

2<sup>nd</sup> **INTERNATIONAL CONFERENCE-**  
On innovations in Computer Science & Software Engineering

December 5-6, 2018

NEDUET  
**iCONICS** 2018  
KARACHI ●●

# Conference Proceedings

**Editor: Dr. Shariq Mahmood Khan**

Assistant Editors: Ms. Simra Najm, Ms. Sidra

In cooperation with the Higher Education Commission Pakistan



A Joint Publication of  
The Department of Computer Science & Information Technology  
The Department of Software Engineering  
NED University of Engineering & Technology  
Karachi, Pakistan

## **PREFACE**

This conference proceedings contains the research articles of contributions submitted in the 2<sup>nd</sup> International Conference on Innovations in Computer Science & Software Engineering (ICONICS'18) held at NED University of Engineering & Technology on December 5 – 6, 2018. The purpose of the conference is to provide a platform for researchers both national and international to exchange novel and contemporary ideas in the emerging fields of computing and to provide a forum for researchers from academia and industry to meet and share cutting-edge development in the field of Computer Science & Software Engineering.

The conference looks to unite a wide range of global specialists to make a helpful situation for coordinated effort and learning exchange. The conference requests huge commitments in every real field of Computer Science and Software Engineering from theoretical and useful viewpoints. Authors are invited to contribute to the conference by submitting articles that illustrate research results, surveying works and industrial experiences that describe significant advances in the field of Computer Science and Software Engineering. It presents new findings on theoretical or practical aspects of computer science and software engineering, share experiences on combining new technologies into products and applications, discuss the work on applying computing and software engineering to real-life problems, describe their development and operations of challenging computing related systems, and highlight open research problems.

We record our gratitude to our kindred individuals from the dedicated organizing committee and distinguished technical program committee for their work in securing a considerable contribution of research articles. We additionally recognize the authors themselves, without their contribution we could not imagine such a successful conference.

# Organising Committee

## Patron-in-Chief

Dr. Sarosh Hashmat Lodi  
Vice Chancellor, NEDUET

## Co-Patron

Prof. Dr. Muhammad Tufail  
Pro-Vice Chancellor, NEDUET

## Vice Patron

Prof. Dr. Noman Ahmed  
Dean (ISH), NEDUET

## Conference Chair

Prof. Dr. Najmi Ghani Haider  
Chairman, Department of CS&IT

## Conference Secretary

Dr. Shariq Mahmood Khan  
Associate Professor, Department of CS&IT

## Sponsors Committee

Dr. Muhammad Mubashir Khan (**Chair**)

- Mr. Muhammad Mustafa Latif
- Mr. Muhammad Faraz Hyder
- Ms. Simra Najm

## Travel & Accommodation Committee

Dr. Najeed Ahmed Khan (**Chair**)

- Mr. Muhammad Umer Farooq
- Mr. Waseemullah

## Website And Printing Committee

Dr. Shariq Mahmood Khan (**Chair**)

- Mr. Muhammad Imran
- Mr. Syed Haroon Ahmed

## Finance Committee

Dr. Sh. M. Wahabuddin Usmani (**Chair**)

- Mr. Kashif Mehboob Khan
- Mr. Waseemullah
- Ms. Asma Khan

## Publicity Committee

Dr. Shehnaila Zardari (**Chair**)

- Ms. Shumaila Ashfaq
- Ms. Maria Andaleeb Siddiqui
- Mr. Muhammad Imran Shaikh

## Program Committee

Dr. Muhammad Mubashir Khan (**Chair**)

- Engr. Amjad Ali
- Mr. Muhammad Faraz Hyder
- Mr. Nadeem Ahmed Khan

## **Paper & Poster Committee**

Dr. Saman Hina (**Chair**)

- Ms. Asma Khan
- Mrs. Nazish Irfan

## **Shield & Certificates Committee**

Mr. Waseemullah (**Chair**)

- Mr. Muhammad Mustafa Latif
- Mr. Syed Haroon Ahmed

## **Publications Committee**

Dr. Shariq Mahmood Khan (**Chair**)

- Ms. Simra Najm
- Ms. Sidra

## **Registration Committee**

Dr. Raheela Asif (**Chair**)

- Ms. Sidra
- Ms. Uzma Zehra

## **Reception Committee**

Ms. Saba Izhar Haque (**Chair**)

- Ms. Shumaila Ashfaq
- Ms. Maria Andaleeb Siddiqui
- Ms. Uzma Zehra

## **Catering Committee**

Dr. Najeed Ahmed Khan (**Chair**)

- Mr. Muhammad Umer Farooq
- Mr. Imdadullah

## **IT Support Committee**

Mr. Muhammad Ejaz Yunus (**Chair**)

- Engr. Amjad Ali
- Ms. Noor Afshan Vasty
- Mrs. Nazish Irfan
- Mr. Muhammad Imran Shaikh

## TECHNICAL PROGRAMME COMMITTEE

<b>Prof. Dr. Junaid Ahmed Zubairi</b>	The State University of New York, US
<b>Prof. Dr. Agathe Merceron</b>	Beuth University of Applied Sciences, Germany
<b>Dr. Rajagopal Nilavalan</b>	Brunel University London, UK
<b>Dr. Junaid Arshad</b>	University of West London, UK
<b>Dr. Sakinah Ali Pitchay</b>	Universiti Sains Islam Malaysia
<b>Dr. Muazzam Siddiqui</b>	King Abdulaziz University, KSA
<b>Dr. Syed Saad Azhar Ali</b>	Universiti Teknologi PETRONAS Malaysia
<b>Dr. Siva Kumar Subramaniam</b>	Universiti Teknikal Malaysia Melaka
<b>Dr. Esra Alzaghool</b>	The University of Jordan
<b>Dr. Ismail Yusuf Panessai</b>	Sultan Idris Education University, Malaysia
<b>Dr. Nadia A. Al-Aboody</b>	Southern Technical University, Iraq
<b>Dr. Hussien Al-Hmood</b>	Thi-Qar University Iraq
<b>Dr. Shahabuddin Muhammad</b>	Prince Mohammad Bin Fahd University, KSA
<b>Dr. Muhamad Syamsu Iqbal</b>	University of Mataram, Indonesia
<b>Dr. Mohamad Zoinol Abidin</b>	Universiti Teknikal Malaysia Melaka
<b>Prof. Dr. Muhammad Atif Tahir</b>	FAST - NUCES , Karachi, PK
<b>Prof. Dr. Shahzad Ahmed Memon</b>	University of Sindh, PK
<b>Dr. Mukhtaj Khan</b>	Abdul Wali Khan University Mardan, PK
<b>Dr. Ghufran Ahmed</b>	COMSATS Islamabad Campus, PK
<b>Dr. Shukat Wasi</b>	Mohammad Ali Jinnah University, PK
<b>Dr. Tahir Syed</b>	FAST - NUCES , Karachi, PK
<b>Dr. Salman A. Khan</b>	PAF-KIET , Karachi, PK
<b>Dr. Izaz ur Rehman</b>	Abdul Wali Khan University Mardan, PK
<b>Dr. Hassan Ali Baig</b>	IGEO, PMAS-AAU , PK
<b>Dr. Naeem Ahmed Mahoto</b>	MUET Jamshoro, PK
<b>Dr. Muhamad Asad Arfeen</b>	NEDUET, PK

## SPONSORS



NEDUET



IFGICT, USA



HEC-PAKISTAN



E-Services & Technologies



# Table of Contents

<b>ICONICS'18 Keynote</b> .....	<b>1</b>
5D Image Processing .....	2
Investigating Typical Learning Behaviors in the Smart Learning Project.....	3
Artificial Intelligence for understanding the Quran and the Bible.....	4
The challenges on a static multi-hop Wireless sensor network .....	5
Trend Detection in Online and Social Media Streams.....	6
The art of Data Curation and its Application.....	7
<b>ICONICS'18 Papers</b> .....	<b>8</b>
Design and Implementation of Single Board Solution- Arduino Graphic Studio.....	9
Multi-Purpose Robot for Marine and Land Based Applications .....	14
Mitigating the energy demand-supply mismatch in Pakistan using intelligent consumption feedback .	18
Water Resource Management and Irrigation Scheduling via Decision Support System .....	28
MUD using GA with variation in Cross over Operator .....	32
Adaptivity of Quiz-based E-Learning using Semantic Web and Ant Colony Optimization .....	36
Node-Wise Monitoring of Power Supply Distribution Network Using Smart Cable & GPS smart monitoring to an anti-theft approach.....	40
Biosensor Interfacing: A Generic Architecture.....	47
Complexity Analysis of Swarm & Evolutionary Based MUD using Synchronous MC-CDMA System .....	50
A Game-Based Strategy To Overcome Stress Using Brain-Computer Interface .....	56
Speech Recognition Based Expert Systems Limitations & Proposed Solutions .....	61
REAL OR FAKE NEWS? Can you guess? .....	66
Exploration to Optimize Network Traffic by Cuckoo Search Algorithm.....	75
QKD Protocols: Comparison & Security Analysis.....	84
Fuzzy Logic enabled Spectrum Access Scheme for Cognitive Radio Applications.....	90
Towards Efficient Vectorization using Polyhedral Compilation .....	96
<b>ICONICS'18 Poster</b> .....	<b>106</b>
Quick Talk Android Application Based on Speech System .....	107
Enhancement in Hybrid Edge Detection for MR Image via Median Filtering Method.....	108

# **ICONICS'18 Keynote**

## **5D Image Processing**

**Dr. Kayyali Mohamed**

CEO / Co-Founder of 4D Business Consulting  
USA

### **ABSTRACT**

When it comes to image or signal processing, we usually do many amounts of computational algorithms for 1D signal processing, 2D and 3D imaging whatever the applications for research dedicated for! But when we think about future concept regarding or disregard 4D and defining 5D, we have to understand the sooner or later 5D image processing would be the leading in all real time applications. Most of future research projects and publications would be relaying on such phenomena. What would be the engineering concept of 5D processing, what would be 5D results looks like in comparing to 3D, what are the sooner applications to adapt such tremendous approach in computer vision era?

### **KEYNOTE SPEAKER'S BIOGRAPHY**

Dr. Kayyali, Innovation Management from Harvard Business School HBS, a PhD & M.Sc from (WCU), he is IEEE Industrial Officer, and BCS (British Computer Society)Chartered Fellow, awarded Chartered Scientist by the Royal Chartered of UK Science Council & Awarded BCS ELITE , his biography listed in Who's Who in Science and Engineering and he has patent theory with many published conferences & journals papers and author of digital image processing book listed by the Library of Congress in USA, invited key note speaker by U.N.& EU's industry foundations ,he was a researcher visitor at the University of California- Santa Barbara UCSB Currently he is:

- 1- CEO / co-founder of 4D Business Consulting 4dbc.net
- 2- President of International Federation of Global & Green ICT , IFGICT.org USA org.
- 3 Founder of KSF Space a U.K International Space Foundation.
- 4- Founder of ANAhost.net an ISP company in the U.S.A

# **Investigating Typical Learning Behaviors in the Smart Learning Project**

**Prof. Dr. Agathe Merceron**

Beuth University of Applied Sciences  
Germany

## **ABSTRACT**

The emergence of Massive Open Online Courses (MOOCs) has enabled new research to analyze typical behaviors of learners. In this preliminary study, we investigate whether this research can offer interesting insights to other courses that are backed by a learning management system (LMS) as MOOCs are, but that are not massive nor open. First, we present the pedagogical approach followed in the smart learning project. Then, we introduce four sets of features to characterize individual learning behaviors taking into account the specificities of the LMS used in the project. We apply clustering techniques to uncover typical behaviors in university (online) courses. It turns out that the different characterizations of individual learning behaviors are consistent with each other. Interestingly, though students have maximum freedom in their time management, in one case, the typical behaviors emerge in the middle of the course. These results inform new developments for our LMS, in particular the design of a gamification module.

## **KEYNOTE SPEAKER'S BIOGRAPHY**

Agathe Merceron is Professor of Computer Science at the Beuth University of Applied Sciences Berlin. She represents subjects such as programming, theoretical foundations of computer science, algorithms and machine learning. She is the head of the Media Informatics Online Bachelor's and Master's degree programs. In the past, she researched formal methods and Petri networks. Currently, she is interested in Technology Enhanced Learning with a focus on Educational Data Mining and Learning Analytics. She is nationally and internationally involved in these areas and is Associate Editor of the Journal of Educational Data Mining. <https://prof.beuth-hochschule.de/merceron/>

# **Artificial Intelligence for understanding the Quran and the Bible**

**Prof. Dr. Eric Atwell**

Professor of Artificial Intelligence for Language  
School of Computing, Faculty of Engineering  
University of Leeds, UK

## **ABSTRACT**

Our AI4L Artificial Intelligence for Language research group in the School of Computing at the University of Leeds has collected, analysed and annotated a variety of Quran corpus resources, and these have been widely used by other researchers in Corpus Linguistics, Computing and Artificial Intelligence, and Religious Studies (Atwell 2018a,b). Classical Arabic texts, in particular the Quran and Hadith, are a specialised genre. The Classical Arabic Quran has been analysed, translated, interpreted and annotated by scholars for over a thousand years, to give us knowledge sources for rich corpus linguistic annotation. AI researchers at Leeds University have collaborated with Arabic linguists to develop a number of Classical Arabic corpus resources: the Quranic Arabic Corpus with several layers of linguistic annotation; the QurAna Quran pronoun anaphoric co-reference corpus; the QurSim Quran verse similarity corpus; the Qurany Quran corpus annotated with English translations and verse topics; the Boundary-Annotated Quran Corpus; the Quran Question and Answer Corpus; the Sunnah Arabic Corpus with detailed morphological tagging; the Multilingual Hadith Corpus; the King Saud University Corpus of Classical Arabic; and the Corpus for teaching about Islam. We have also worked with Quran translations, in English and Malay. We are now extending our work, to develop Bible corpus resources, similarity measures, and question-answer data-sets. Much computational linguistics research focuses on short text snippets from social media, patient records, customer reviews; these might seem to differ markedly from religious texts in language and genre. However, Quran and Bible verses are also short text snippets, analogous to modern tweets or customer reviews. Quran and Bible verses enriched with corpus linguistic analyses can provide rich training data for supervised Machine Learning of language models. So, the language of the Quran and Bible may inform computational linguistics and artificial intelligence research; and in turn, our Quran and Bible language resources can be used for Religious Studies research.

## **KEYNOTE SPEAKER'S BIOGRAPHY**

Eric Atwell graduated from Lancaster University in 1981 with a BA degree in Computing and Linguistics, a unique degree programme at that time; he remained at Lancaster University as a research fellow for three years, then moved to Leeds University, first as a lecturer, then a variety of other roles and secondments, and currently Professor of Artificial Intelligence for Language.

## **The challenges on a static multi-hop Wireless sensor network**

**Dr. Siva Kumar Subramaniam**

Universiti Teknikal Malaysia Melaka  
Malaysia

### **ABSTRACT**

In the recent years, increasing demand on static multi-hop wireless sensor network (WSN) had predominated many remote monitoring applications such as in the oil and gas industry, road networks, railway condition monitoring etc. The research and development of static multi-hop WSN have been carried out by scholars and experts on the aspects that effect the overall performance when full deployment is attempted on a specific application. One of the most common areas of static multi-hop WSN application is in a pipeline network where sensing points are connected through wireless nodes bridging the remotely measured points to a centralized monitoring station. This keynote speech will focus on the deployment of a WSN on a pipeline network and will highlight the crucial factors contributing to the degrading of overall network performance that is proportional to the network density. In general, such geographically unique network architecture has a significant impact on the destabilization of network reliability, throughput unfairness, higher latency and energy consumption. Hence, in a large-scale implementation of a pipeline network contributes to inadequate utilization of network resources due to competitive data transmission that results in data snowballing effect towards the destination node.

### **KEYNOTE SPEAKER'S BIOGRAPHY**

Dr Siva Kumar Subramaniam is a Senior Lecturer at Universiti Teknikal Malaysia Melaka, where he has been since 2006. He completed his Diploma in Electronics Engineering from Politeknik Ungku Omar in 2002. Siva Kumar Subramaniam than received a B.Eng in Electronics Engineering (Industrial Electronics) from Kolej Universiti Teknikal Kebangsaan Malaysia in 2006 and an M.Sc in Electronics Engineering from the same institution in 2009 which is now known as Universiti Teknikal Malaysia Melaka. He received his PhD in Electrical Engineering and Electronic Research from Brunel University London, United Kingdom in 2017. His research interest is in wireless sensor network using IEEE 802.11 and IEEE 802.15.4 standards. He has a particular interest in a wireless sensor network, IoT system, and system integration and consumer electronics system with a good track record of successful industrial collaboration for the past10 years. To date, he has published more than 20 International Journal, 45 proceeding papers, filed 10 patents, 12 copyrights and 1 trademark from his previous research projects. Through his research and product innovation, Siva Kumar was awarded more than 5 special awards, 20 gold medals, 40 cumulative silver and bronze medals in both national as well as international innovation competition in countries like Malaysia, Belgium, Switzerland, Kuwait, South Korea, United Kingdom and Germany. Siva Kumar is an Associate Fellowship of the Higher Education Academy, a member with the Institution of Engineering and Technology (IET), Board of Engineers Malaysia (BEM) and The Institution of Engineers Malaysia (IEM).

# **Trend Detection in Online and Social Media Streams**

**Dr.-Ing Syed Saqib Bukhari**

Research Center for Artificial Intelligence (DFKI)  
Germany

## **ABSTRACT**

Among the vast information available on the web, social media streams capture what people currently pay attention to and how they feel about certain topics. Awareness of such trending topics plays a crucial role in multimedia systems such as trend aware recommendation and automatic vocabulary selection for video concept detection systems. Correctly utilizing trending topics requires a better understanding of their various characteristics in different social media streams. In this talk I will present the comprehensive study done by our colleagues at DFKI across three major online and social media streams, Twitter, Google, and Wikipedia, covering thousands of trending topics during an observation period of an entire year.

## **KEYNOTE SPEAKER'S BIOGRAPHY**

Syed Saqib Bukhari has completed his Ph.D. in late 2012 in Image Understanding and Pattern Recognition (IUPR) Research group in Technical University of Kaiserslautern and German Research Center for Artificial Intelligence (DFKI GmbH) with Professor Thomas M. Breuel and Professor Andreas Dengel. During PhD, he also worked in Fraunhofer-Gesellschaft Germany as a research assistant in the field of microscopic materials image analysis, and he did internship in the area of GIS analysis at NEC Japan. After completing PhD, he worked as a research and development engineer in Insiders Technologies GmbH Germany, which develop digital mailroom processing systems, for more than two years till December 2014. There he was mainly involved in developing research prototypes for business forms, text and emails classification systems as well as development of incremental features in the current digital mailroom processing systems. Currently he is working in German Research Center for Artificial Intelligence (DFKI GmbH) as a senior researcher in the Multimedia Analysis and Data Mining (MADM) group.

# **The art of Data Curation and its Application**

**Dr. Asad Masood Khattak**

Zayed University  
UAE

## **ABSTRACT**

In recent years, the focus of experts and research in the field of Computer Science and Information Technology has shifted towards data driven fields e.g., Data Science, Data Analytics and Data Driven Recommendations. However, to produce desired results in all the above-mentioned fields, we need to accurately curate the data before it is being used to serve the purpose. The initial step of data curation has huge impact on results from accurate results to accurate desired results in a given context. The data curation process is streamlined as an initial step in our research that has facilitated us in achieving encouraging results in the later stages. This talk will initially explore the concept of data curation. Then the use and impact of data curation in various applications and results will be discussed. This talk will also include application scenarios, implemented applications and success stories of data curation.

## **KEYNOTE SPEAKER'S BIOGRAPHY**

Asad Masood Khattak is working as an Associate Professor at the College for Technological Innovation, Zayed University in Abu Dhabi, UAE that he joined in August 2014. He received his M.S. in Information Technology from National University of Sciences and Technology, Islamabad, Pakistan in 2008 and received his Ph.D. degree in Computer Engineering from Kyung Hee University, South Korea in 2012. He worked as Post-Doctoral Fellow at Department of Computer Engineering, Kyung Hee University, South Korea for seven months and then he joined the same college as Assistant Professor. He is currently leading two research projects and collaborating in four research projects in the fields of Data Curation, Context-aware Computing, IoT, and Secure Computing. He is IEEE member and has authored/co-authored more than 80 journal and conference articles in highly reputed venues. He and his team have secured several internal and external awards in different competitions.

# **ICONICS'18 Papers**

# *Design and Implementation of Single Board Solution- Ardui Graphic Studio*

Shiraz Afzal, A.M. Khan, Muhammad Rauf,  
Muhammad Taha  
Electronic engineering department  
Sir Syed University of engineering and technology  
Karachi, Pakistan  
safzal@ssuet.edu.pk

Muhammad Khalid  
Electronic engineering department  
Bahria University  
Karachi, Pakistan

**Abstract**— The nature of experimental tools is greatly related to student performance in electronic experiments. The graduate engineers from various institution lack in the requisite practical knowledge in the field of electronics engineering, consequently this lacking not only enforce the students to source out their final year projects but also they join the industries without having acquired appropriate practical experience. In order to bridge this gap we designed an electronic trainer board using Arduino with graphical studio interface. The motivation behind this task is the Elvis trainer which is available in the market but this trainer is very expensive and can only be interfaced with the dedicated software, moreover, only limited sensors can be interfaced because it only supports the sensors of its own. The idea is to design a trainer that overcomes these limitations. So, we designed this trainer board which is supported with graphical studio software and it's free reliance software to provide the user-friendly interface between Arduino board, input and output. The trainer is capable of checking different sensor output on hardware and graphs on visual studio software. Performing the experiments involving electronic and control system fulfill the requirements of undergraduate projects and can be extend to postgraduate projects.

**Keywords**—Arduino, Graphical user interface, sensor

## I. INTRODUCTION

The engineering technology education outcome is to produce the skilled persons that have the ability to produce the design and application of both software and hardware with a new concept, ability and creativeness [1]. An abundant work has been seen in literature [2]. In general, laboratory work can be classified into three aspects of knowledge [3].

1. Cognitive Domain: Actions like practical modelling, investigation, data scrutiny and design.
2. Psychomotor Domain: Actions like apparatus handling and sensory awareness.
3. Affective Domain: Attitudes erudite from creativity, failure, safety, teamwork, communication and integrity in the laboratory.

Cognitive domain is an art of learning and perceiving and shows that real learning and understanding is well translated through interactive and collaborative techniques. In an era of media, students are aware of multimedia incitements and interactive deeds [4]. Current studies such as [5], [6]

demonstrate that there is a gap between conventional training and technical skills required in the job markets in various fields of engineering and technology. Therefore based on the knowledge, problematic approaches are applied to resolve the problems and make the in-depth analysis of the design. It is therefore required that the technical institute should provide such a platform where a student learns solution-based learning to bridge the gap between industry and academia. Thus, it is necessary to create such laboratory experiments which are equipped with the problem-solving approaches, various skills and awareness acquisitions. So that to encourage learning toward new research in the field of science and technology [7].

## II. CONCEPT DEVELOPMENT

Recent development in electronic field has highlighted the need for the knowledge of implementing various sensors and actuators. Commercial training development kits are used for numerous subjects related to electronics engineering. These kits provide a pragmatic and vigorous solution for learning. However, they have two main problems, kits are limited for the particular area and do not provide the graphical output for the real data. Furthermore, commercial training boards provide user friendly interface, but sometimes do not provide sufficient information so that learner can easily understand the operation. Also, the flexibility of this platform controls the actuators with the sensor inputs. This customization may also become a learning aspect at higher level.

Several attempts have been made to implement the training kits. A number of studies have found that training kits are limited to their dedicated functions. In a recently published paper [8], design of digital logic trainer using emulation technique and using 8955 microcontrollers. Similarly, Daniel Perez proposed training kit for power electronic subject [9], in which he proposed the Digital Signal Processing (DSP) based power electronic training kit for power electronics and motor control applications.

Arduino is a microcontroller based hardware structure with an open source library comprise of ATMEL controller and a software IDE (Integrated development environment) is used to implement the code in order to operate the hardware. There are several types of Arduino hardware available in the market depending upon the requirements. This proposed design project utilized the Arduino Uno platform that provides the hardware environment which is very simple to get set up with. The board

contain fourteen digital I/O pins out of which six can be used as PWM (pulse width modulation) outputs, six analog inputs, a USB connection, 16 MHz oscillator, an ICSP header allowing by passing of the bootloader, a USB connection and a reset button [10].

The technology advancement is now the part of life because of its flexibility that make it fit in easily, so that you don't really even notice it. [11]. A lack of connection between the theory and practical is always a problem for engineering students. The presented work bridges the gap between theory and practical approach so this makes easy for the students and they start learning about the various sensors and outputs by connecting through the trainer kit, Its user friendly interface makes it easy for anyone to understand and work with it. The output can be displayed on the proposed interface which provides the real-time solution. This product comes with 27 portable sensors and actuators which can be easily connected through the trainer board. The user can easily connect and analyze multiple sensors outputs at the real-time through graphical studio application as well as on the built-in actuators on the trainer board. This product also provides sample codes for the sensors so that the user can have an idea of programming the particular sensor.

### III. EMERGENCE

The idea and motivation behind this designed project is the N.I ELVIS, as shown in the following Figure 1. The presented work provides a one lab solution with an infinite learning opportunity and a complete teaching solution for motivating and engaging the learner in hands-on labs in the field of power electronics, digital electronics, controls, communication, instrumentation and measurement. Each laboratory includes complete experiments and lab materials, so the learner can explore theory in the physical laboratory with in-depth knowledge and practical exposure [12]. As compared to the available trainer in the market which is very costly and cannot be afforded because of its multiple specialized areas, only the software requires cost in thousands of dollars. The idea is to make a product affordable and at the same time specialized in the field of electronics. All electronics lab can be performed through this trainer and provide the facility to integrate multiple sensors and actuators with it.

The Arduino Graphical Studio is trainer board designed to have the multiple connecting ports through which the different sensors can be connected. The designed application software makes it more convenient for the user to visualize the real-time operation and also there are multiple actuators built-in on the board on which the user can observe the output readings of the sensors. The advantage of this project is its user friendly interface, this trainer also surmount the drawback for the N.I Elvis that comes with its own sensors which can only be replaced with supported sensors, whereas the Arduino Graphical Studio comes with generic sensors that are easily available in the market.



Fig.1. N.I Elvis Engineering Lab Workstation

### IV. METHODOLOGY AND WORKING

To date, various methods have been introduced for the development of different electronic trainer board to measure various output associated with different electronic devices but here the idea is to develop such a trainer board which provides a platform with the modern integrated application software for simulating the output of different electronic sensors. In order to implement this idea Arduino-Graphical studio, modular hardware and software are designed which helps you to solve conceptual engineering challenges.

The goal is to plan a platform that integrates most commonly used sensors and outputs. This design offers the flexibility which allows the easy measurement acquisition and display. This project is made in three design phases:

- ✓ Designing the hardware.
- ✓ Analyzing data from sensors in arduino.
- ✓ Making a graphical interface for data extraction.

The working flow graph of the proposed designed project is depicted in Figure 2. According to the flowchart the working is defined as follows:

- First of all, the user will select the sensor from the sensors selection window on graphics studio platform.
- After the sensor is selected the Arduino will start reading values from the sensor.
- After the values are taken, those values will be analyzed through the programmed formulas and methods.
- If there is any error found in the calculations, the user will recalibrate the sensor and will start from the first step.
- If there is no error, the values are forwarded for further process.
- The values are converted into digital through the analog to digital converter.
- The values are then displayed on the gauges available on the software interface.

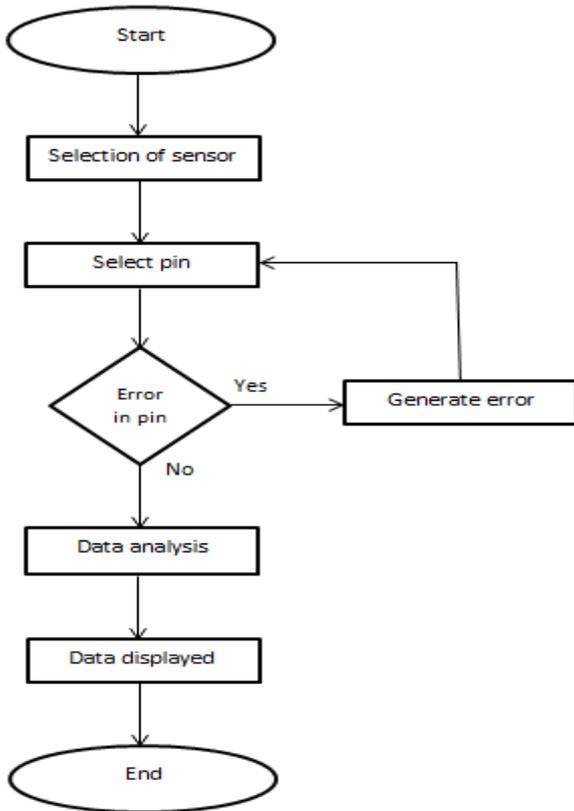


Fig.2. Flowchart of the Proposed Designed Project

A. Visualizing and Analyzing Data

In the serial monitor as shown in following Figure 3, the values are analyzed for errors in the data. If any mistake is found in the data the sensors are then re-calibrated and values are again processed. These analyzed values are then used in formulas for example the temperature sensor represents values in the form of voltage, the voltage values are then converted into temperature using the temperature formulas.

This temperature value can be shown on LCD and it can be used to control output like fan or heater to maintain the temperature.

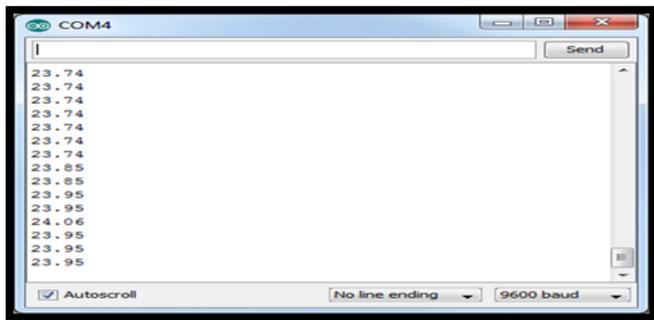


Fig.3. Serial Monitor value display for Temperature Sensors on Arduino IDE.

B. Designing a Graphical User Interface

Graphical Studio is an integrated set of tools that uses dot net frameworks. It includes a user interface controls such as gauge control, waveform graph control, analysis Functionality, Following Figures 4 and 5 show some pictures of the Graphical User Interface of the designed interface.

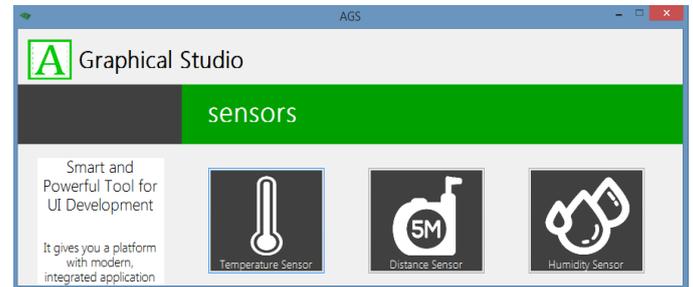


Fig. 4. Graphical Studio Home Window

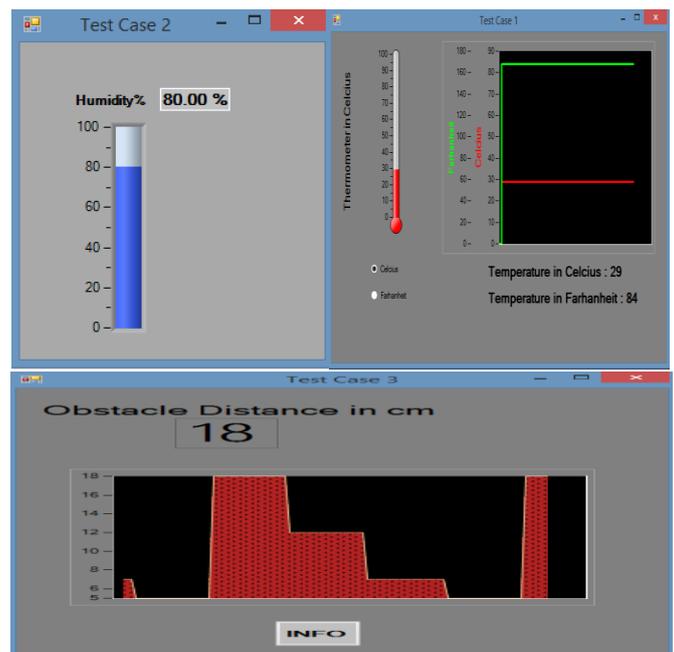


Fig. 5. GUI Based Output Quantities

The GUI is designed in such a way that the user feels comfortable in using the software. The design of this user interface is very easy and the user will get an appropriate learning and hands on experience.

C. Hardware Design

It consists of following blocks as shown in Figure 6

1. Sensor input.
2. Graphical user interface and Arduino controller.
3. Actuator output.

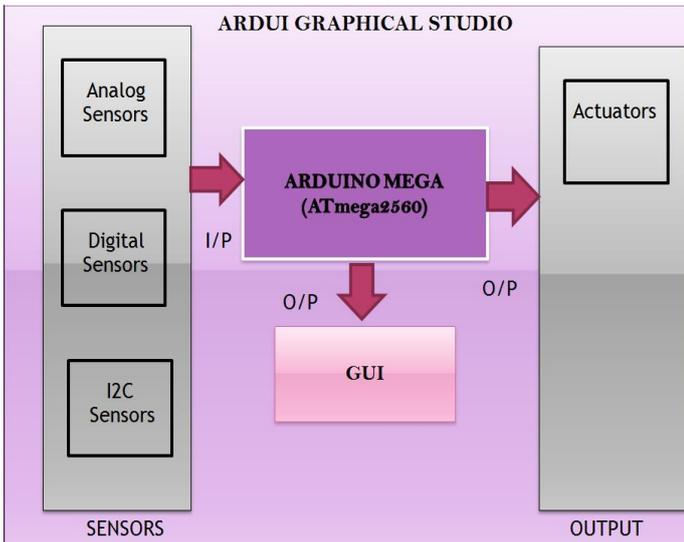


Fig. 6. Block Diagram of the Proposed AGS

The sensors block consists of the sensors which are connected to the connectors on the trainer board as input. The data received from the sensors as input is then forwarded to the Arduino microcontroller. The microcontroller is programmed to analyze and process the data. The processed data is then forwarded to the software interface. The graphical user interface block is designed to select the sensors from the main window. The received data is shown on the specific gauges which are designed in such a way that the real-time monitoring of the data is achieved. The actuator block consists of all the actuators that are used to drive the outputs. The user can also control outputs from the designed graphical user interface. The trainer board design is shown in the following Figure 7.



Fig. 7. Trainer Board

D. Circuit Diagram

The circuit diagram is designed on the Proteus Design Suite as shown in the Figure 8.

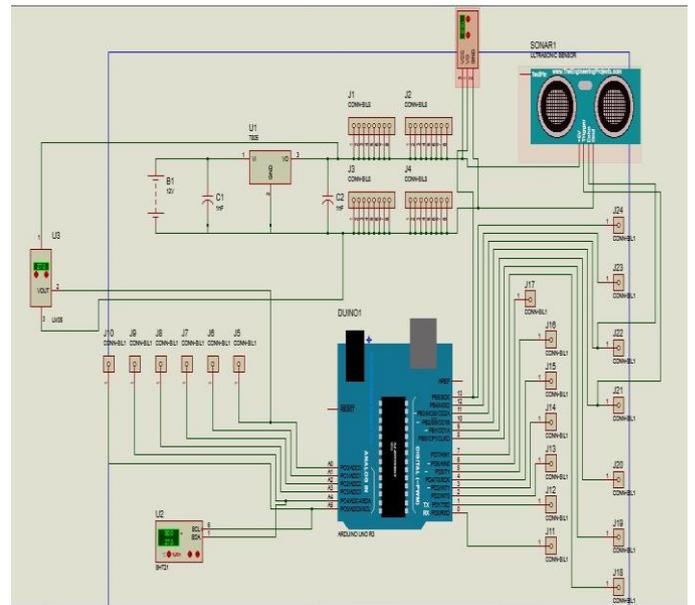


Fig. 8. Circuit Diagram using Proteus Design Suite

V. SENSORS

Following sensors are available for testing

1. Sonar sensor (HC-SR 04)
2. Altitude sensor (BMP-180)
3. Flame Sensor (KY-026)
4. Accelerometer (ADXL-345)
5. Rotary Encoders (KY-040)
6. Tilt Switch Module (KY-020)
7. Line following Sensor (KY-033)
8. Laser sensor module (KY-008)
9. Mini Reed switch (KY-023)
10. Analog Hall
11. Ball Switch Module
12. Small Passive Buzzer (KY-006)
13. Big Sound (KY-038)
14. Photo resistor module (KY-038)
15. Flex sensor
16. Tap module (KY-031)
17. IR emission sensor (KY-005)
18. IR receiver sensor
19. Shock sensor module (KY-002)
20. Temperature sensor (LM35)
21. Heart beat module (KY-039)
22. Humidity Sensor (DHT-11)
23. Smoke sensor (mq-2)
24. Magnetic hall sensor module (KY-003)
25. Obstacle avoidance sensor (KY-032)
26. HMC compass (58831)

VI. RESULT AND DISCUSSION

Ardui-Graphical Studio is a very reliable and efficient product for monitoring the behavior and measuring the values of different analog, digital and I2C sensors. The software shows the real time GUI (Graphical User Interface) in a short period of time. It takes very less time to measure and analyze the values taken from the sensor. It displays real time generation on the gauges of the sensor. Real time generation plays an important role in understanding the behavior of the sensor.

In the start, the main window opens as shown in Figure 8 which allows the user to select any sensor from the available sensors by clicking the icon of that sensor. After selecting the desired sensor as shown in Figure 9, the next window will be open. In that window the real time values which are taken by the sensor are shown on the gauge and real graph is plotted. This window contains the information related to that sensor which is useful for the students.

The software provides the interactive GUI that not only attracts the user but also develops the interest to learn about the sensors used in, through real time simulation of the sensor values in the GUI.

VII. CONCLUSION

This trainer board is an interactive solution that in reach of every person who is eager to learn about the working of electronic sensors according to their real world problems. The user envisages the sensors values through the gauges which show real time data. This product gives an opportunity to the engineering students to start learning about the microcontrollers and their applications.

REFERENCES

- [1] F. Attarzadeh, D. Gurkan and D. Benhaddou, "Innovative Improvements to Engineering Technology Laboratory Education To engage, Retain and Challenge Students of the 21st Century", Proceedings of ASEE Gulf-Southwest Annual Conference, Southern University and A& M College American Society for Engineering education, 2006
- [2] Kim, Bryant Y., and Joon S. Kim. "Hand controller for electronic trainer." U.S. Patent No. 9,642,338. 9 May 2017
- [3] L. D. Feisel, Albert J. Rosa, "The Role of the Laboratory in undergraduate Engineering Education", Journal of engineering Education, pp. 121-130, January 2005.
- [4] R. Bradbeer, "The Effectiveness of Teaching Introductory Electronics in an Integrated Teaching Studio Environment", International Journal of Engg. Education, Vol. 15, No. 5, pp. 344-352, 1999.
- [5] R., Judith A., Haggett, Rosemary R, "Engaged and Engaging Science: A component of a good liberal education", Peer Review, winter.,2005.
- [6] M. F. Kazmierczak, J. James, "Losing the Competitive Advantage? The Challenge for Science and Technology in the United States", aea, pp. 4, February 05. [http://www.Aeanet.org/publications/IDJJ\\_AeA\\_Competitiveness.asp](http://www.Aeanet.org/publications/IDJJ_AeA_Competitiveness.asp) .
- [7] C. C. Bonwell, "Active Learning: Creating Excitement in the classroom", Active Learning Workshops, Green Mountain Falls, CO 80819, [www.active-learning-site.com](http://www.active-learning-site.com).
- [8] O. A. Ogungbenro, G. A. Chukwudebe, F. K. and Opara G. N. Ezeh "Design and emulation of logic gate emulator" IEEE 3rd conference on Electro-technology for national Development 2017.
- [9] D. Pérez, J. Balcells, M. Lamich and N. Berbel, J. Zaragoza, J. Mon "Training kit for power electronic Teaching" IEEE 34th Annual conference on Industrial electronics, IECON 2008.
- [10] L. M. Herger and M. Bodarky "Engaging Students with Open Source Technologies and Arduino" IEEE integrated STEM conference 2015
- [11] "U.S. students recently finished 27th in math and 20th in science in the ranking of 34 countries by the Organization for Economic Cooperation and Development." From: "Increasing the Achievement and presence of Under-Represented Minorities in STEM Fields, National Math and Science Initiative (NMSI), NMSI.org.
- [12] <http://www.ni.com/en-lb/shop/engineering-education/engineering-lab-stations/ni-elvis-engineering-lab-workstation/what-is-ni-elvis.html>

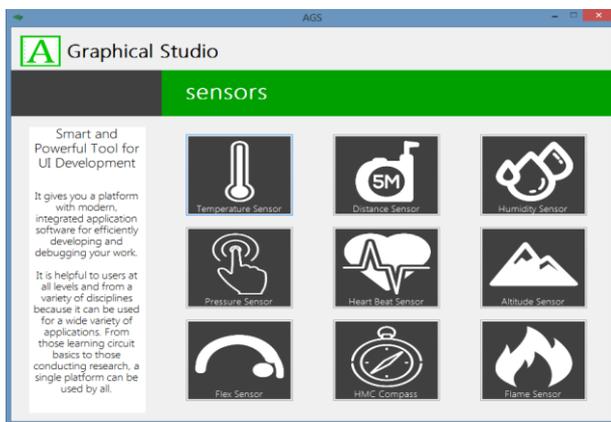


Fig. 8. Sensor selection window

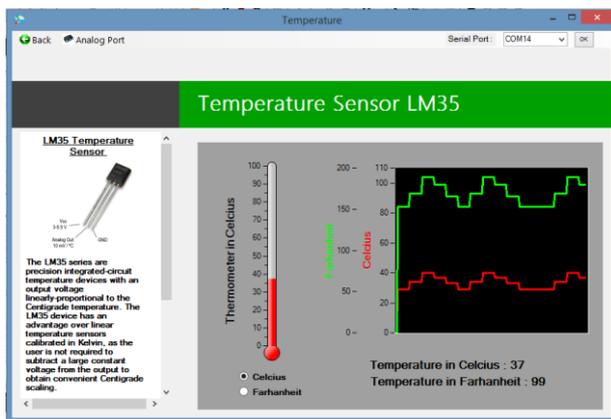


Fig. 9. Window show the selected sensor output

# Multi-Purpose Robot for Marine and Land Based Applications

M.Tahir Qadri

Department of Electronic Engineering,  
Sir Syed University of Engineering & technology  
University Road, Karachi, Pakistan.  
mtahirq@hotmail.com

Ali Akbar Siddique

Department of Telecommunication Engineering  
Sir Syed University of Engineering & technology  
University Road, Karachi, Pakistan.  
ali124k@hotmail.com

**Abstract**— In a past decade, the field of Robotics has made a major contribution in making everyday life a bit easy. Many machines were previously developed and presently manufactured in the particular field to solve the major problems faced by people such as transportation of different object via land or sea. Although, there are certain limitation in robotic work and researchers around the world are more focused on its accuracy. In the proposed work, a design of an amphibious robot is proposed which is also capable of functioning on land as well. It is fully capable to relocate objects from one location to another either on land or marine route. In order to relocate objects, a robotic arm is mounted on the robot that is controlled wirelessly. Robot itself is autonomous with the help of a mounted Global Position system (GPS) through with it tracks its next waypoint coordinates. These coordinates can be provided either by manual feed before launching or wirelessly. A camera is also mounted in order to guide the person controlling the robotic arm and also to avoid any hurdles encountered by the robot.

**Keywords**—*Robotic Arm, Global Positioning System (GPS), Wireless communication*

## I. INTRODUCTION

Over the years, Robots are being used in different areas and applications in industries. Many organizations are using them for coast line operations as well. There has been significant development in Robotics which make them capable enough of performing amphibious tasks. Researchers around the world are focusing on the marine resources and invest their time in development of these resources. It is a well-known fact that marine route may not be best choice due to the major ocean turbulence and the robot build these days are adaptable to tackle such situation.

Many systems have been build based on marine mechanism in past few years [1]. Most applications introduced were based on robotics and utilized for testing and inspection [2-3]. Many researchers also introduce algorithm of path planning for robots either on land or sea [4-5]. Mounted gripper for robots are also utilized to underwater applications with embedded sensors for movement [6-9]. Usually a robot face a lot of obstacles while reaching to the specified location and Schmitt, Silke, et al introduced such system that is capable of performing the task [10].

In this paper, a multi-purpose robot is proposed capable of performing tasks on land and sea. It contain a robotic arm to

relocate objects from one location to another via land or sea route. GPS mounted on the robot will help it to reach its next waypoint. It can also be controlled wirelessly if need arises. It also possess amphibious traits, such as relocating objects via sea route as well. Rover is designed in such way that it produces an up thrust or buoyancy force while submerged. Many tasks can be easily performed utilizing multi-purpose robot, not just relocating objects. It is also capable of balancing itself while performing tasks.

## II. HARDWARE BLOCK MODEL

Fig.1 represents the complete system block diagram. ARDUINO is used as an onboard processing unit. It is interfaced with the Global Positioning System (GPS) to provide information about its current location and track the next waypoint. These waypoint can be preprogramed or transmitted wirelessly from base station via RF transceiver. Base of the robot is composed of a floating material through which it can easily follow buoyancy force and float rather than sink. This principle works on the objects like ships where most part of it is sunk underwater and the rest floats due to the up thrust produced by the water itself. Density of an objects also plays a vital role for an object to stay on the top of the water. The buoyancy force always points upwards as the pressure of the water increases the deep an object goes.

Mounted Robotic arm has a 6 DOF to move around freely in all directions, it also has a gripper to grab objects. Arm is controlled using emote controller RC, a wireless camera is also mounted on the robot to help a person controlling it more control. Basically the robot is autonomous due to the mounted GPS, and the arm is controlled from the base station.

Fig.2 represents the block diagram of an on-board Robotic Arm. They are controlled by ARDUINO through motor driver IC (H-Bridge). Four motors are interfaced to provide complete 6 DOF movement for the ARM. Arm can move toward object with the help of remote controller (RC) from the base station.

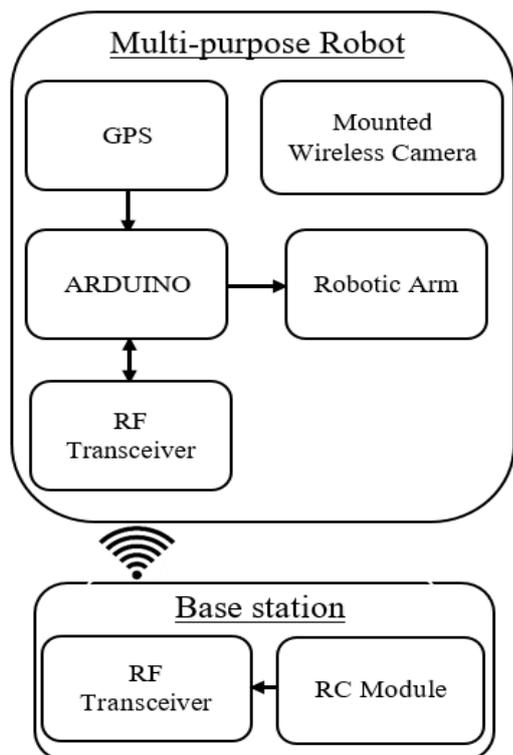


Fig.1. Hardware Block Diagram

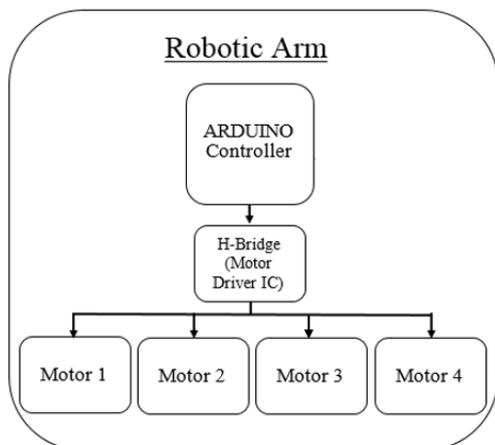


Fig.2. Block Diagram of an On-board Robotic Arm

III. SOFTWARE FLOW CONTROL

Fig.3 represents the system software model. After system initialization, robot will acquire new set of co-ordinates to follow from the base station wirelessly. It may be loaded with the co-ordinates before activation. The Robot will acquire co-ordinates of its present location via GPS in order to identify and follow the next waypoint. ARDUINO controller will track the error response generated and guide the robot to follow correct trajectory. Error response is basically the subtracted value for the co-ordinates of the rover in its present location and the co-ordinates acquired wirelessly from the base station.

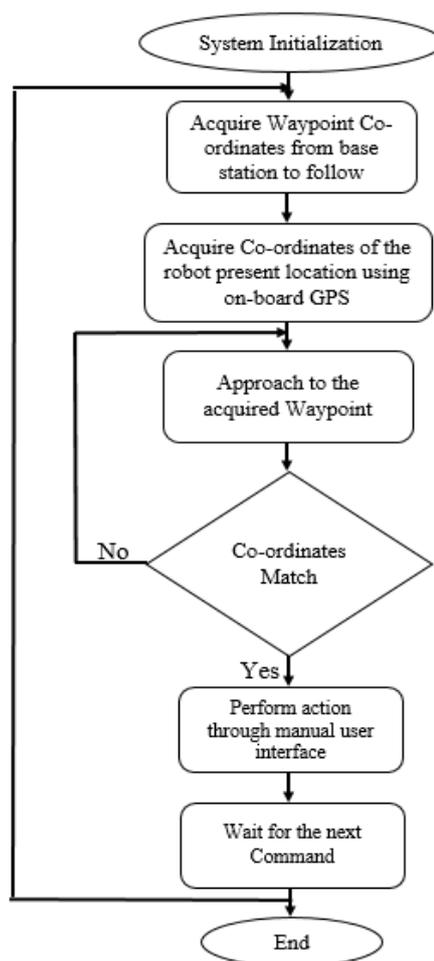


Fig.3. System Software model

Robot will try to approach the desired destination provided by the base station. If the co-ordinates are not same, then that means an error and the robot will keep on approaching toward the co-ordinate. This mismatch in co-ordinates is termed as error. If the error increases, it means that the robot is moving further away from the desired co-ordinates and if it decreases, that mean robot is heading in the right direction. Onboard ARDUINO receives the co-ordinates from GPS every 60 sec to determine whether the robot is going in the right direction. As the robot moves its co-ordinates also vary and as soon as the error between the desired co-ordinate and present co-ordinates matches, then the robot reached its destination. Now the robot stops and the person in the base station controls the onboard robotic arm wirelessly. Then it will wait until the next set of co-ordinates are received from the base station. As soon as it receives the next waypoint, this whole process repeats or the next waypoint.

IV. RESULTS

Fig.4 is basically a waypoint trajectory and the co-ordinates were provided to the robot by the base station wirelessly. Robot was feed with three designated waypoint to follow. Co-ordinates in fig.4 are land based. Robot started it

journey from its present location displaying as 24.957332 Latitude and 67.108028 Longitude. It follow the given two waypoints and reach its final destination with accurate precision.

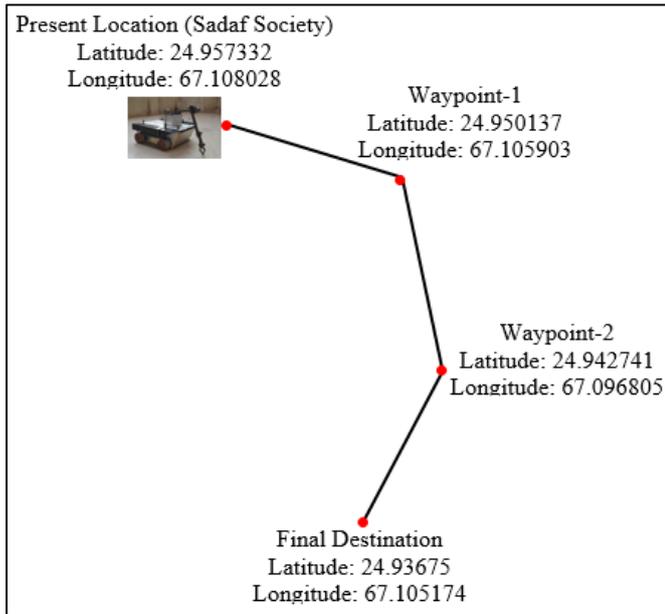


Fig.4. Land Based Waypoint Trajectory

Fig.6 represents the co-ordinates of marine route for the robot to follow. First waypoint was from the land and the following were of marine route. Fig.6 represent the hardware model of the multi-purpose robot with the robotic arm mounted on it.



Fig.6. Multi-purpose Robot Image

Table.1 represents the accuracy of the robot in terms of the distance. It was found that the further the robot travel from the base station, the more sequence delay it generated, in turn delays the processing time required by the ARDUNIO controller. At 150 meters distance from base station it has about 36ms sequence delay with the accuracy of 87.01%, and as it move further away from the base station its sequence delay increases but there is no change in its accuracy. The reason there is no change in its accuracy because it's working on a simple principle of error minimization and will always reach to its destination by reducing it. In such case it is more appropriate to preload the desired co-ordinates to avoid the sequence delay. In that condition robot will not stop at any location in order to receive the next set of co-ordinates but keep performing its task.

TABLE I. ROBOT DISTANCE FROM BASE STATION AND TIME DELAY ACCURACY

No	Robot distance vs. Accuracy		
	Distance from Base Station (meters)	Delay (sec)	Accuracy (%)
1	150	0.036	87.01
2	250	0.0811	86.71
3	500	0.194	86.9
4	1000	0.8226	86.88

V. CONCLUSION

It can be concluded that all the experiments conducted yield satisfactory results. These experiments were conducted in the controlled environment. The mechanical design can be further enhanced for much better performance. Robot successfully received the co-ordinates from the base station wirelessly and approached its destination as well. The proposed robot can be used for military operations on land or at sea. It can also be used transport objects to the desired location if need arises. It is cheap and can greatly reduce the human risk factor in critical situation where it may not be possible for a human to perform his given task.

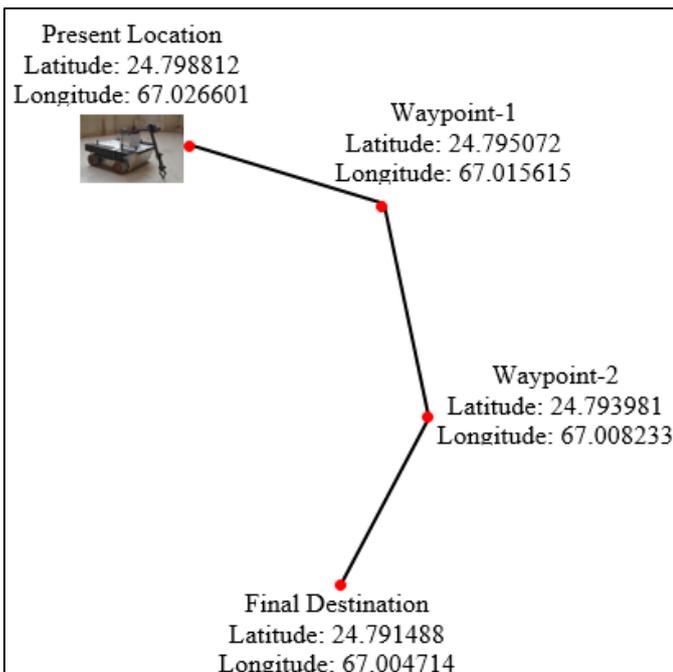


Fig.5. Marine Based Waypoint Trajectory

## ACKNOWLEDGMENT

The completion of this research could not have been possible with the help of Dr. M. Tahir Qadri. His help and guidance meant a world and really helped in the progression of research smoothly.

## REFERENCES

- [1] Shi, Yang, et al. "Advanced control in marine mechatronic systems: A survey." *IEEE/ASME Transactions on Mechatronics* 22.3 (2017): 1121-1131.
- [2] Moe, Signe. "Guidance and Control of Robot Manipulators and Autonomous Marine Robots." (2016).
- [3] Bogue, Robert. "Applications of robotics in test and inspection." *Industrial Robot: An International Journal* 45.2 (2018): 169-174.
- [4] Singh, Yogang, et al. "Path Planning of an Autonomous Surface Vehicle based on Artificial Potential Fields in a Real Time Marine Environment." (2017).
- [5] Manjanna, Sandeep, et al. "Collaborative sampling using heterogeneous marine robots driven by visual cues." *Computer and Robot Vision (CRV), 2017 14th Conference on.* IEEE, 2017.
- [6] Palli, Gianluca, et al. "An Underwater Robotic Gripper with Embedded Force/Torque Wrist Sensor." *IFAC-PapersOnLine* 50.1 (2017): 11209-11214.
- [7] Zhang, Fumin, et al. "Future trends in marine robotics [TC Spotlight]." *IEEE Robotics & Automation Magazine* 22.1 (2015): 14-122.
- [8] Abreu, Pedro Caldeira, et al. "The MEDUSA class of autonomous marine vehicles and their role in EU projects." *OCEANS 2016-Shanghai.* IEEE, 2016.
- [9] Jones, Matt, Paul Wheller, and Mike Allen. "Vehicle based system for managing personal items." U.S. Patent No. 9,881,483. 30 Jan. 2018.
- [10] Schmitt, Silke, et al. "Obstacle avoidance for an autonomous marine Robot—A vector field approach." *Quantitative monitoring of the underwater environment.* Springer, Cham, 2016. 119-131

# Mitigating the energy demand-supply mismatch in Pakistan using intelligent consumption feedback

Arzam Muzaffar Kotriwala\*  
*Electrical Engineering and Computer Science*  
*KTH Royal Institute of Technology*  
 Stockholm, Sweden  
 amkot@kth.se

**Abstract**—The dominant narrative is that the energy demand-supply mismatch in Pakistan can be met only if the government takes the necessary medium- and long-term steps to resolve internal problems and install more capacity. Whilst such changes are absolutely required, there is also a dire need for short-term solutions. Previous research has shown that conservation plays an essential role in lowering resource demands. However, taking personal responsibility by individuals to pro-actively conserve resources is not discussed much. This paper provides an overview of intelligent solutions for feedback of energy consumption, new in the market, that are enabled by recent advances in the Internet of Things and Machine Learning. These solutions provide transparency of energy usage by breaking down overall consumption into smaller individual consumers, thereby making consumption easier to understand, track and control. A survey was conducted to understand the awareness and attitude of individuals towards energy conservation. Most identified themselves as having positive attitudes towards energy conservation and agreed that transparency of energy consumption would help them reduce demand. However, the results highlighted a lack of awareness and understanding of everyday energy consumption.

**Index Terms**—machine learning, internet of things, non-intrusive load monitoring, energy demand, sustainability.

## I. INTRODUCTION

A continuous growth in energy demands makes energy conservation and sustainability one of the biggest challenges of our time [1], [2]. Owing to the non-renewable nature of our current major energy resources and their adverse environmental impact, any effort to minimize energy wastage will have a direct positive impact on our lives, both economically and environmentally [2].

### A. Background

The first commercial oil well was struck over a hundred and fifty years ago, which led to the inception of a huge industry that has since provided power to the world. However, with the increasing unpleasant concerns of climate change and diminishing non-renewable fuels, the industry is undergoing disruptive change. Entrepreneurs are quickly pushing new business models forward which are ‘putting power - literally and metaphorically - into the hands of us all’ [3].

Many problems arising in the energy and sustainability space can be addressed using techniques from Data Mining and Machine Learning [1]. With the rise of advanced metering

infrastructures in recent times, the energy consumption data being collected today is greater and at a higher resolution than ever before. This enables data-driven solutions to yield valuable insights into power consumption patterns, both at the micro- and macro-level, allowing greater control over the energy demand-supply system [4].

### B. Problem

A scarcity of essential resources such as energy and water in Pakistan greatly hinders growth, prosperity, and peace. Pakistan’s severe energy imbalance is the greatest single drain on its weak economy and unstable national security situation [5]. The crisis arises from a mismatch of supply and demand of energy, which dates back to about two decades from now and has ever since remained a largely unresolved matter [6]. Pakistan’s energy shortage issues are ‘deep and complex’ [7], and are contributing to a shut-down of businesses, unemployment, and unrest [8], [9]. Over the years, the government has attempted to increase capacity of the power grid to mitigate the persistent deficit but such measures are expected to take time to realize [8].

### C. Scope

To solve the persistent energy crisis in Pakistan, the bulk of existing literature has focused on bringing about medium term and long term changes to step up the supply of electricity to meet the demand. On the contrary, this research aims to investigate whether or not business models based on energy monitoring and feedback can mitigate the energy crisis in Pakistan.

The goal of this study is directly in line with goal #12 of United Nation’s 17 sustainable development goals i.e to ‘ensure sustainable consumption and production patterns’ [10]. This includes (but not limited to) ‘promoting resource and energy efficiency’, ‘reducing resource use’. Additionally, this research work can also be considered to complement goal #9 of United Nation’s sustainable development goals i.e. to ‘build resilient infrastructure, promote sustainable industrialization and foster innovation’. This encompasses investments in information and communication technology amongst other domains and considers all these domains as being crucial to achieving sustainable development and empowering communities in many countries [10].

\*Now at ABB Corporate Research Center in Ladenburg, Germany.

## II. UNDERSTANDING THE ENERGY CRISIS

Pakistan's power sector is faced with several chronic problems - it is in one of the worst states in its history [9]. An overview of the well-documented energy crisis in Pakistan is given here.

### A. Energy Demand, Capacity and Supply

Since 2007, Pakistan has been suffering from a serious energy shortage that is costing both households and industry. In particular, the electricity supply is substantially short of requirements, at times by as much as 32% (7,000 MW) of total demand [11]. Pakistan's nominal installed capacity as of January 2015 totalled 24,663 MW, inclusive of various Independent Private Producers (IPPs). However, only 14,000-14,500 MW is available for generation on a typical summer day and about 11,500-12,000 MW in winter. The peak demand is 22,500 MW in summer and 14,500 MW in winter [11]. In fact, the installed capacity exceeds the peak demand, implying that the mismatch occurs during supply of energy.

### B. Causes of the Crisis

The energy crisis emerged gradually - it has resulted from incautious energy policies over a long period of time. These have staggered the production of abundant and inexpensive domestic sources of energy. Such policies have also yielded very inefficient fuel-mix variety, weakening energy and economic security. Pakistan's energy mismatch is essentially a result of huge institutional and governance failure [12]. Next, various factors responsible for the energy crisis are summarized.

1) *Demand Side Factors*: These factors refer to the increasing consumption and efficiency of energy, which may lead to pressures on the entire system [11]. In the power sector, over the last four decades, household energy consumption has risen at an mean annual rate of 10 per cent per annum. The past two decades have seen an surge in the usage of electrical appliances across the country and many of these appliances contribute to the crisis via inefficient consumption [13].

2) *Supply Side Factors*: These factors receive a greater degree of attention - they refer to issues in production infrastructure, tariff and financial management, and overall governance. A decrease in investment in the power sector in the last decade has deprived the sector of incentives to improve its efficiency [11].

3) *Energy Mix and Infrastructure*: The fuel mix policies initiated two decades ago resulted in power generation relying excessively on thermal power plants, primarily using furnace oil than hydropower [5]. Two factors greatly led to the emergence of this situation: Pakistan's inability to finish a hydroelectric project over the years, and the lenders changing from the public to private sector [9]. Currently, most of the electricity supply is provided by hydroelectric

plants and IPPs. The output of the hydro plants is dependent on the water available in the dams, and can fall to as low as 40% when water levels drop considerably. As for the IPP output, it is often limited by financial problems [9]. Despite having sufficient capacity, the actual power supply remains insufficient. This is partly as a result of obsolete and inefficient power plants and partly due to a cash flow problem, which often does not allow power plants to operate at their optimal capacity (because of being unable to purchase the needed furnace oil) [9].

4) *Financial Issues*: For many of Pakistan's problems, experts put the blame on 'circular debt' which mainly emerges due to the poor recovery of receivables by the power distribution companies. It is estimated that the distribution companies only get paid for about 30% of the power they generate, with 40% being being stolen, and the remaining 30% go to long-term receivables [9]. Consequently, the government has to provide nearly US\$ 2 billion per year from already scarce financial resources in order to bridge the production cost and revenue mismatch [11]. To make matters worse, Pakistan is simultaneously facing a tax crisis - only about 12.5% (of a potential 4 million) Pakistanis pay tax [14].

5) *Overstaffing*: After privatization of KESC, the IPP of the largest and most populous city in Pakistan, its new management attempted to correctly size the organization. However, this move was countered by its employees, who enjoy noteworthy political support [9].

### C. Impact of the Crisis

The energy crisis has severe consequences for Pakistan and it is the largest single drain on its economy [5]. In what follows, the various implications of the energy crisis are summarized.

1) *Power Outages (Load Shedding)*: As a direct cause of the inability of generated power to cater to the peak demand in both, summer and winter, more than 140 million Pakistanis either have no connection to the power grid or experience more than 12 hours of load shedding on a daily basis [8]. Power outages are also impacting manufacturing and commercial activity which harms Pakistan's economic growth. The national cost of load shedding is as much as Rs 1.4 trillion [14]. Consequently, Pakistan's energy crisis accounts up to 4 percent of GDP annually in recent years as per some estimates [15] and about 7% according to other estimates [11].

2) *Temporary Backup Power Solutions*: To counter everyday power outages, the public has been and continues to increasingly resort to using temporary backup power solutions. These commonly entail generators and Uninterrupted Power Supply (UPS) batteries. With power outages persisting, imports and sales of generators skyrocketed during fiscal year 2015-16. The opening of generator workshops in almost all

localities over the past five to six years also indicates that a large number of households depended on generators in their daily lives [16]. The issue with this private solution of UPS and generators is that they are often inefficient compared to the national power grid - making the situation worse [17].

3) *Industries and Unemployment*: Primarily owing to power outages and the economic turbulence that comes with it, many international investors have relocated their businesses, and a large number of manufacturing business have been shut down. Capacity utilization in some important industries has drastically reduced to nearly 50%. The fertilizer industry is perhaps the worst affected as it suffers interruptions to its gas supply and forced closures [9]. This has resulted in an increase in the already high levels of unemployment. Besides the distress and difficult conditions that arise owing to power outages, it is estimated that nearly 500,000 households directly experienced lay-offs due to energy-related downsizing and closures [11].

4) *Violence and Terrorism*: Over the past eight years, long outages and frequent breakdowns have contributed to law and order problems, with protests turning violent in a number of cities in the country [11]. With sluggish economic growth and inadequate job creation, the risk of destabilising elements capitalising on the cynicism and hopelessness amongst a young population is quite high [11].

### III. TACKLING THE ENERGY CRISIS

The energy demand-supply mismatch weakens the economy and contributes to unrest 'but the country has options' [9]. Next, some of the solutions mentioned in relevant research as well as steps already taken are mentioned.

#### A. Policies and Reforms

Pakistan needs to devise policies for the short, medium and long terms to overcome its energy crisis, [9].

1) *Short-Term Policies*: Firstly, Pakistan must try to bring about direly needed order to its inhibited energy sector. A better coordinated and integrated energy sector can best be achieved by consolidating Pakistan's many energy-related institutions into a single common ministry. A tighter institutional set-up could allow Pakistan's energy sector to enjoy better coordination of planning, decision-making, and implementation [7]. There is also a great need to resolve investment and financial issues at the earliest by perhaps taking another loan from International Monetary Fund (IMF) whilst bearing in mind that such a measure could impose politically delicate conditions and thus not be beneficial in the long run.

2) *Medium-Term Policies*: After implementing short-term policies, supporting policies must be devised and implemented to prevent circular debt from reappearing. This would necessitate controlling theft and improving recovery. An increase in the energy tariff could augment cash flow at power distribution companies but opponents pose that a higher tariff in fact gives an incentive to steal energy so the government should rather necessarily provide an uninterrupted supply of electricity at affordable cost [9]. A medium-term policy could be to refurbish and revamp all power plants operating in the public sector to improve efficiency - this would help reduce the generation costs. In fact, the primary focus should be on attaining the highest possible output from hydro power, where the generation cost is cheaper compared to the bulk power purchase tariff being paid to IPPs, mostly consuming furnace oil. At the same time, efforts should be made to switch the running of power plants from furnace oil to coal and gas should be avoided [9].

3) *Long-Term Policies*: In the long run, the challenge for policymakers is to implement reforms that move towards sustainable and renewable resources, move away from expensive generation inputs, and ensure that a competitive market in energy is able to function without political interference and hindrance [11]. A long-term measure could entail the government prioritizing the completion of the Thar Power Plant. The Thar area has more than 185 billion tons of lignite coal, suitable for mine-mouth power plants [9]. Experts say Pakistan should focus on hydro generation as the country has potential to produce great amount of energy by constructing small and medium sized dams and run-of-the-river projects. Two of the latter type (Ghazi-Broth and Laraib) are already in operation [9].

#### B. Green Initiatives

The country urgently needs to make strategic decisions to change the national energy mix [9]. Furthermore, there is a need to make the public aware of energy efficient products and practices and to promote them.

1) *Generation from Renewable Sources*: This could reduce the country's vulnerability to unforeseen circumstances such as a sharp increase in international oil prices [11]. In fact, wind generation has sufficient potential to supply all of Pakistan's energy needs. There are approximately 1.2 million irrigation pumps installed in Pakistan, with about 90% of them using diesel either directly or indirectly. Consequently, the use of solar irrigation pumps for agricultural purposes instead of diesel-powered or tractor driven pumps could mean a 27% saving in consumption of diesel fuel for irrigation pumping [8].

The increasing use of off-grid solar energy solutions is an encouraging trend, and one that should be prioritised and further facilitated by the government. The rapid growth in the adoption of conservation practices and renewables is

evident via both, market-based purchase and government-sponsored projects such as for wind and solar electricity generation. A number of existing initiatives include rooftop solar photovoltaics and wind resources. In addition to these initiatives, a number of government policies, laws and activities that support energy conservation already exist [11].

2) *Generation from Sugar Mills:* Pakistan also has the prospective to get energy from sugar plants located all over the country, particularly in rural areas. This option is very cost-effective since sugar mills will mostly use very low-cost bagasse to heat the boilers, using furnace oil only as a supplement. In fact, another benefit of sugar mills is that they have the capacity to produce ethanol, which can be added to motor gasoline to produce E-10 (petrol comprising 10% ethanol). This would reduce oil imports and conserve compressed natural gas [9].

3) *Transition to Energy-Efficient Appliances:* An even more swift solution to the crisis is the conservation and efficient use of energy, as about 67% of domestic energy consumption stems from inefficient appliances such as lights and fans. It is expected that energy efficient fans and energy efficient lighting can reduce power outages by 39% and 47% respectively [8]. Encouragingly, both consumers and the government are increasingly welcoming the use of energy-efficient appliances such as LED lights and inverter-type air conditioners. There is therefore an opportunity to assist this positive behavior through government and voluntary initiatives that can contribute to reducing the gap between energy demand and supply. Initiatives such as 'lighting conversion', 'solar irrigation pumps', and 'solar gas water heaters' provide the potential to reduce the existing shortage by up to 40% [11].

#### IV. REDUCING THE ENERGY DEMAND

In this section, an overview of intelligent solutions for feedback of energy consumption, new in the market, that are enabled by recent advances in the Internet of Things and Machine Learning is given.

##### A. Taking Personal Responsibility

Whilst most of the steps needed to be taken to resolve the energy crisis have to do with improving the supply of energy, there is not much talk about reducing the demand of energy to bridge the gap between supply and demand. Only very recently, the Research and Advocacy for the Advancement of Allied Reforms (also known as RAFTAAR) has begun to call for responsible use of energy to reduce the demand and for the public to also be a key part of the solution to the energy crisis. They refer to citizen-led initiatives for energy saving as low-hanging fruit with significant potential gains to help alleviate the crisis in a durable and sustainable manner [17].

Despite being poorly served by electricity, the energy saving potential in Pakistan is substantial - it is estimated that about 17% of the total electricity demand can be reduced [18]. Another study found tremendous opportunity for industrial

players to implement cost-effective methods to reduce their energy consumption. It asserted that data on energy and corresponding cost savings, as well as payback periods on investments, must be gathered to help inform decision-makers [15]. RAFTAAR provides statistics of energy wastage in households from letting appliances run when not needed, showing that more than 25% of it is wasted. The notion is a simple one - if people consume less electricity, the government has to provide less electricity, and can thus reduce power outages. Additionally, the usage of older appliances is also leading to inefficient energy use. In this regard, the government has to run campaigns encouraging conservation, promoting energy efficient lighting and fans [17].

##### B. Intelligent Consumption Feedback

Most energy use is largely not visible to the vast majority of consumers and this is a key cause of much wastage. Most people have only a rough idea of how much energy they are using for various purposes and what kind of difference they could make by changing day-to-day behavior or investing in efficiency measures. Thus, it is important to monitor energy and provide feedback in making energy usage more transparent and easier to understanding and control [19]. Energy monitoring solutions offer consumers with feedback information on their energy consumption and costs. As a result, a once aggregate and static electric bill is turned into a real-time transparent, dynamic, and controllable process. Energy monitoring solutions can induce changes in customer behavior even if they are not incentivized by a change in prices or rebates for purchasing efficient equipment [20].

Whilst feedback on energy consumption is necessary for cost reductions, it is not always sufficient - other factors, together with feedback from energy monitoring also play a vital role, such as condition of housing, personal contact with a trustworthy advisor (when needed), and the support from utilities and government which can provide the technical, training and social infrastructure to make learning and change possible [21]. A study performed to empirically investigate the effective on energy monitoring and feedback revealed that it encourages consumers to make more efficient use of energy. In particular, consumers who actively use such solutions can reduce their consumption of electricity on average by about 7 % when prepayment of electricity is not involved. When consumers both use an electricity prepayment system as well, they can reduce their electricity consumption by about twice that amount [20].

##### C. Players in the Market

RAFTAAR admits that this severe energy deficit and inefficient usage provides a 'major opportunity for private and public sector investment'. The good news is that there is a worldwide energy revolution underway primarily led by startups. In response to global energy issues and climate change, innovative minds are rushing to find solutions [3].

Among these startups are several that aim to democratise information about energy usage - to make transparent how much

energy they use information that previously was exclusively owned by big energy firms. Machine Learning and the Internet of Things are being used to give the common public the chance to track (and change) their energy usage and, potentially, even help stop global warming [3].

Several startups have emerged with business models based on energy monitoring and feedback in different parts of the world. For instance, Watty [22], Bidgely [23] and Sense Labs [24], each located in a different continent, amongst several others use minimal and easy-to-install hardware typically connected to energy distribution points or the fusebox in homes to provide real-time feedback on energy usage. In particular, these startups are leveraging Machine Learning to break down the overall energy consumption of buildings into appliance-level energy consumption.

Watt-Now [25] uses similar technology to monitor overall energy consumption but provides a different offering. They target sites which require energy for a short period of time, typically powered by generators. Consequently, they propose actionable insights such as choosing the correct size of generator for optimal power provisioning, which not only lowers the carbon footprint of power generation but also reduces the respective fuel costs incurred.

V. SURVEY: ENERGY CRISIS AND ENERGY CONSERVATION

For the purpose of this research, a survey was conducted with the objective of gathering primary data to better understand the following:

- 1) The impact of the energy crisis in Pakistan;
- 2) People’s understanding and perception of the energy crisis in Pakistan;
- 3) People’s attitude towards energy conservation;
- 4) People’s awareness of residential energy consumption.

This section highlights the choices that were made in designing the questionnaire, the results obtained as well as an analysis of the responses.

A. Questionnaire Design

The online questionnaire was divided into 2 parts of closed-ended questions. Part 1 comprised questions 1-6 and addressed objectives (1) and (2). Part 2 comprised questions 7-15 and addressed objectives (3) and (4). These questions and their respective answer choices are mentioned in Section V-C. All questions were multiple choice questions whereby a single answer had to be chosen with the exception of question 6, which allowed and encouraged participants to choose as many checkboxes as they deemed necessary.

In order to keep the questionnaire interesting and easy to fill, care was taken to keep it short and straightforward. In doing so, where applicable, the answer choices presented were mostly simplified versions of the Likert-Type Scale Response Anchors [26]. To begin developing the questionnaire, the web was searched for existing similar questionnaires using two search queries with the following keywords:

- 1) ‘Energy consumption awareness’
- 2) ‘Energy crisis pakistan questionnaire’



Fig. 1. Map highlighting different countries other than Pakistan where responses are received from.

Query (1) returned several relevant search results. For instance, two very comprehensive reports based on conducted survey questionnaires and focus groups were obtained [27], [28] as well as questionnaires only [29], [30]. Query (2) returned one relevant questionnaire [31] but most other search results pointed to not questionnaires but presentations on the energy crisis in Pakistan. No questionnaire was found which addressed all 4 objectives needed to be addressed to answer the research question. For instance, [31] primarily addressed objectives (1) and (2) whilst [29] addressed objective (3) only. Consequently, relevant questionnaires were used as a starting point to develop a new questionnaire, which addressed all 4 objectives. In particular, 4 of the 20 questions from [30] were adapted and used in the questionnaire.

B. Data Collection

The online questionnaire was circulated primarily by individually messaging personal ‘friends’ or ‘connections’ on social media. The questionnaire was available online for about 3 weeks and attracted a total of 367 respondents. Whilst requests were made to also ask their respective family members to also fill the questionnaire, it is likely that most of the respondents were either university students or working professionals, living in different cities of the world.

C. Results and Analysis

In what follows, each question asked in the questionnaire is mentioned along with the available answer choices and results obtained.

1) *Which country have you lived in for most of your life?:* Two options were provided - ‘Pakistan’ and ‘Other’. If the latter was chosen, the country name had to be typed in the field provided. Of the 367 respondents, 65.9% indicated to have lived in Pakistan for most of their lives. The remaining 34.1% belonged to 33 different countries, with 50% of them belonging to 4 countries only. These countries with the respective number of respondents (indicated by the relative sizes of the coloured circles) are shown in Figure 1.

For further analysis, the 33 countries other than Pakistan have been assigned to geographical regions, based on the categorization done by the International Telecommunication Union [32]. Though Pakistan also belongs to the ‘Asia & Pacific’ region, for the purposes of this analysis, Pakistan is treated as a separate entity. This is because other countries in

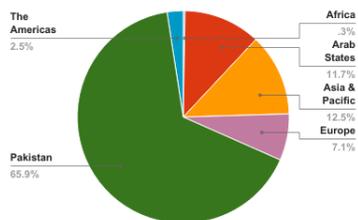


Fig. 2. Distribution of respondents grouped by where they lived in for most of their life.

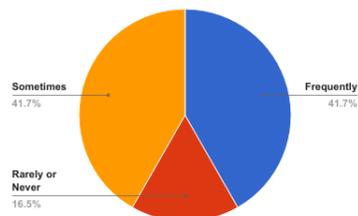


Fig. 3. Load shedding frequency in Pakistan

the same region may or may not experience similar energy problems and thus, it is meaningful to treat this region in the same way as other regions are treated when making comparisons and drawing insights.

Figure 2 shows the distribution of respondents grouped by the continent in which they lived in for most of their life. Since only a single response was received from Africa, it is omitted from further analysis.

2) 'Load shedding' refers to power outages (or temporary interruptions in power supply). How often do you experience load shedding at home?: Three options were provided - 'Frequently', 'Sometimes' and 'Rarely or Never'. Figure 3 shows that 83.4% of the people living in Pakistan experience load shedding either frequently or sometimes. Figure 4 shows the number of respondents who selected 'Rarely or Never' shown as a percentage of the number of respondents from the respective region. It is interesting to see that the least percentage of respondents who selected this option belong to Pakistan followed by Asia & Pacific.

3) Irrespective of whether you experience load shedding or not, how do you feel about it?: Four options were provided -

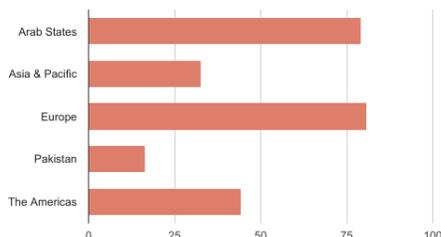


Fig. 4. Number of respondents who selected 'Rarely or Never' shown as a percentage of the number of respondents from the respective region.

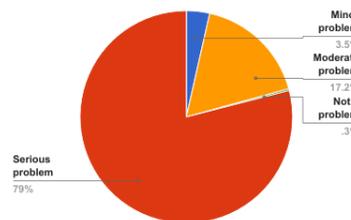


Fig. 5. The severity of load shedding as perceived by the respondents

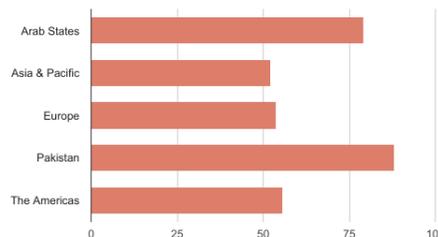


Fig. 6. Number of respondents who selected 'Serious problem' shown as a percentage of the number of respondents from the respective region.

'Serious problem', 'Moderate problem', 'Minor problem' and 'Not a problem'. Figure 5 shows that 79% and 17.2% of all respondents feel that load shedding is a serious problem and a moderate problem respectively. Figure 6 shows the number of respondents who selected 'Serious problem' shown as a percentage of the number of respondents from the respective region. Respondents representing the majority from each continent consider the problem of load shedding to be a serious one.

4) For access to power during load shedding, do you have a backup generator or UPS (Uninterrupted Power Supply) battery at home?: Four options were provided - 'Yes, I have a generator', 'Yes, I have a UPS', 'Yes, I have both, generator and UPS' and 'No, I don't have either'. Figure 7 shows that only about less than 10% of the households represented by the respondents from Pakistan do not have any backup power supply.

5) For years on end, Pakistan has persistently been unable to meet its energy demands. In your opinion, which of the following can help solve this energy crisis? (You may select multiple options and/or give your own suggestions as well!):

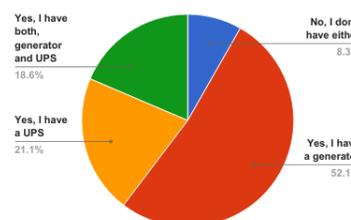


Fig. 7. Distribution of backup power sources in households in Pakistan

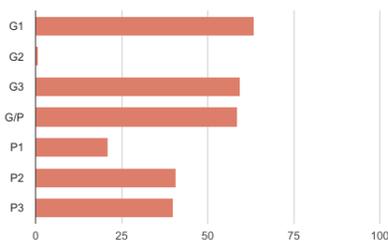


Fig. 8. Number of respondents from Pakistan who selected different checkboxes as a percentage of the number of respondents from Pakistan.

This is the only question where more than a single answer could be chosen i.e. several check-boxes could be checked. The first available answer offered a chance to move to the next question by choosing ‘I really don’t know - I’m proceeding to the next question!’ Seven other carefully tailored answers were also provided. The first three addressed the government:

- 1) The government should invest more in building new infrastructure (dams, transmission lines, etc);
- 2) The government should increase electricity rates;
- 3) The government should quickly transition to renewable sources from depleting, unreliable and inefficient energy sources.

The last three addressed individuals:

- 1) People need to reduce their energy consumption;
- 2) People need to replace their lights and other appliances with energy-efficient ones;
- 3) The majority of people do not pay all taxes - this needs to change.

Sandwiched between these answers was a statement which could be applied to both, the government as well as individuals i.e. ‘There is too much corruption at all levels - this needs to change’.

Figure 8 shows the number of respondents from Pakistan who selected different checkboxes as a percentage of the number of respondents from Pakistan. The answers mentioned above pertaining to the government are labeled G1 - G3 respectively, those pertaining to individuals or people are labeled P1 - P3 respectively and the answer which could apply to both is labeled G/P. This reveals very interesting insights - it is easy to see that the public does not want any further increase in electricity rates and in fact, the answers addressing more work to be done by the government received the most votes. Whilst less than a fourth of the respondents think people need to reduce their consumption, a little more than a third of the respondents think that adopting energy efficient practices and paying taxes can help mitigate the energy crisis.

6) *Do you ever suspect that your monthly electricity bills are strangely inconsistent and unreliable?:* Two options were provided - ‘Yes’ and ‘No’. Figure 9 shows that 64% of the respondents from Pakistan suspect that their monthly

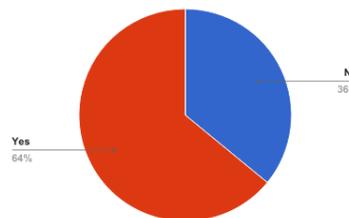


Fig. 9. Speculation of respondents from Pakistan about whether their electricity bills could be erroneous or not.

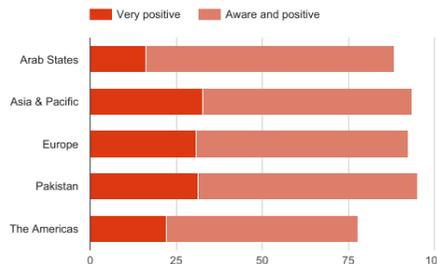


Fig. 10. Number of respondents who selected ‘Very positive’ and ‘Aware and positive’ shown as a percentage of the number of respondents from the respective region.

electricity bills could be erroneous.

7) *What is your general attitude toward energy saving/conservation?:* Four options were provided:

- 1) Very positive — I actively save energy and believe I can make a difference
- 2) Aware and positive — I think it is important and try to save energy when possible
- 3) Indifferent — Its not something I worry about
- 4) Negative — I don’t think my actions at home can make any difference to the energy crisis

Figure 10 shows that across all continents, the vast majority of respondents consider energy conservation to be important.

8) *What is your level of awareness of energy consumption of typical household appliances?:* Three options were provided - ‘Well aware’, ‘Somewhat aware’ and ‘Unaware’. Figure 11 shows that shows that across all continents, the vast majority of respondents are either ‘Well aware’ or ‘Somewhat aware’.

9) *Would it help you to save more energy if you could know the appliances consuming most of the power in your home and how much it costs you to use each of them?:* Three options were provided - ‘Yes’, ‘No’ and ‘Maybe’. Figure 12 reveals that across all continents, respondents believe that energy monitoring and feedback solutions could help them save energy.

10) *Which of the following appliances typically has the highest power rating?:* Three options were provided - ‘Television’, ‘Refrigerator’ and ‘Air conditioner’. The correct

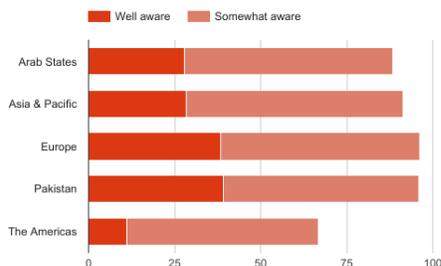


Fig. 11. Number of respondents who selected 'Well aware' and 'Somewhat aware' shown as a percentage of the number of respondents from the respective region.

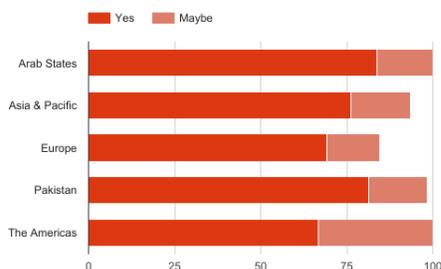


Fig. 12. Number of respondents who selected 'Yes' and 'Maybe' shown as a percentage of the number of respondents from the respective region.

answer is Air conditioner and 'Television' is the least likely answer. 79.6% got this question right. Figure 13 shows the number of respondents who selected the wrong answer i.e. 'Refrigerator' or 'Television'.

11) 'Inverter air conditioners' are known to consume significantly less energy (amongst other benefits) than the more common standard air conditioners. However, they are typically far more expensive to buy. Would you be willing to pay the high initial price for the inverter air conditioner to save on your energy bill?: Two options were provided - 'Yes' and 'No'. Figure 14 shows that across all continents, the vast majority of respondents would be willing to pay the high initial price for the inverter air conditioner to save on your energy bill.

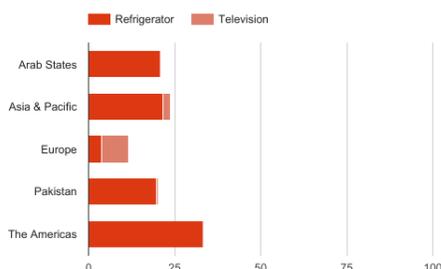


Fig. 13. Number of respondents who selected 'Refrigerator' and 'Television' shown as a percentage of the number of respondents from the respective region.

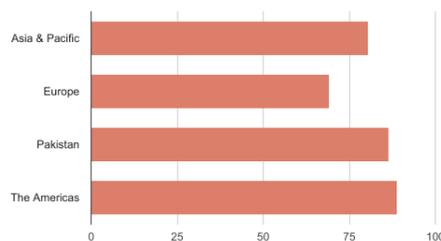


Fig. 14. Number of respondents who selected 'Yes' shown as a percentage of the number of respondents from the respective region.

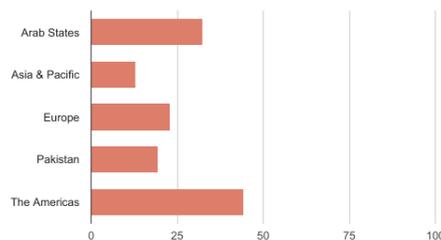


Fig. 15. Number of respondents who selected 'True' shown as a percentage of the number of respondents from the respective region.

12) True or False? Hair dryers and clothing irons typically consume low power compared to other household appliances.: Two options were provided - 'Yes' and 'No'. 79% chose False, the correct answer. Figure 15 shows the distribution of the wrong answers across the continents from the 21% of all respondents that chose True, the incorrect answer. It should be mentioned that two people voiced an error in the question i.e. the term 'energy' should have been used instead of 'power'. However, this question is not excluded from the analysis since most people use these terms interchangeably in non-technical conversations.

13) True or False? Assume the room temperature is 29C. For a typical air conditioner, setting the thermostat at a lower temperature (e.g. 16C) will cool the room faster than setting it at a higher temperature (e.g. 21C).: Two options were provided - 'Yes' and 'No'. 57.2% chose False, the correct answer. Figure 16 shows the distribution of the wrong answers across the continents from the 42.8% of all respondents that chose True, the incorrect answer.

14) True or False? A typical refrigerator will consume more energy if hot food is put in it as opposed to colder food.: Two options were provided - 'Yes' and 'No'. 46.6% chose True, the correct answer. Figure 17 shows the distribution of the wrong answers across the continents from the 53.4% of all respondents that chose False, the incorrect answer.

15) True or False? As long as appliances such as TVs, phone chargers and microwaves are OFF, they do not use any power. It doesn't matter if they are plugged into a socket or not.: Two options were provided - 'Yes' and 'No'.

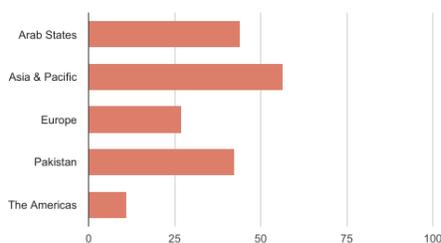


Fig. 16. Number of respondents who selected 'True' shown as a percentage of the number of respondents from the respective region.

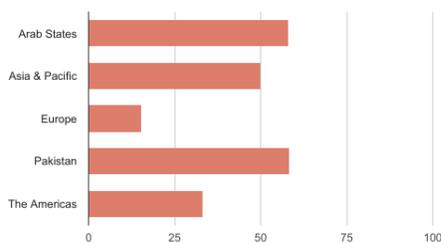


Fig. 17. Number of respondents who selected 'False' shown as a percentage of the number of respondents from the respective region.

65.7% chose False, the correct answer. Figure 18 shows the distribution of the wrong answers across the continents from the 34.3% of all respondents that chose True, the incorrect answer.

## VI. DISCUSSION

The end goal of energy monitoring and feedback is to help reduce energy consumption i.e. to reduce the energy demand. Thus, theoretically, it is easy to see that by reducing the demand, the problem of the mismatch between demand and supply can surely be alleviated. This research entailed testing this hypothesis and has revealed that surely there is great potential in reducing the energy demand.

The conclusions of this research also resonate with the apt statement made in a news article titled, 'The Other Solution' calling for a shift in paradigm - "...we dont have to rely just on the state if we start making private efforts. If we want to leave a country where our children and grandchildren can survive climate change and water scarcity, our needs and wants have to move away from wasteful consumerism to a holistic ethos of environmental conservatism" [17].

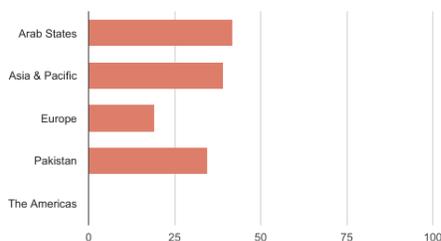


Fig. 18. Number of respondents who selected 'True' shown as a percentage of the number of respondents from the respective region.

### A. Implications of Survey Results

In particular, the survey conducted revealed that the people of Pakistan are severely affected by power outages. 83.4% of the respondents admitted that they experience power outages either 'frequently' or 'sometimes', 88% of the respondents feel that it is a 'serious' problem and 91.7% of the respondents either have a personal generator or UPS or both for backup power.

Question 5 in particular revealed very interesting insights. It can be seen that the majority of respondents identify the government as not effectively solving the energy crisis with the least number of people (after the most unpopular choice of increasing electricity rates) thinking that they should reduce their consumption. Surely there is a lot of work that needs to be done at the government level as explained in Section II and Section III but this also highlights the potential of empowering the public to reduce their energy usage.

The answers to questions 6, 8 and 9 particularly highlight that consumers need energy monitoring and feedback solutions. 64% of the respondents from Pakistan indicated that they do not trust their electricity bills and only 3% of the respondents from Pakistan and all over the world do not believe that transparency of energy consumption would help them save energy - 79.8% are certain that it would help and 17.2% think 'maybe' it would help.

Question 7 revealed that most people all over the world are aware and positive about energy conservation - this is a good sign and it shows that they would likely be interested in having more access to know-how of reducing their energy consumption. This positive attitude is also reflected in the overwhelming majority of respondents from around the world to be willing to pay the extra initial costs to purchase energy-efficient appliances.

The last four 'true or false' questions of the questionnaire tested the awareness of the respondents. Whilst question 12 was answered correctly by 79% of all respondents, only 57.2%, 46.6% and 65.7% answered question 13, question 14 and question 15 correctly respectively. This shows that it would indeed be fruitful to increase transparency in energy consumption.

### B. Innovations in the Energy Sector in Pakistan

At this point, there are no companies operating in Pakistan using similar business models to provide transparency in energy consumption. The closest offering that exists is energy auditing, which entails a site visit to investigate possibilities for energy savings. Such services are indeed useful too and need to be promoted and made more accessible. Most energy companies in Pakistan are pushing for a shift towards adopting solar energy solutions in particular. Again, this is much needed but these offerings do not address reducing the energy consumption footprint.

It is interesting to see that initiatives to introduce smart meters in Pakistan are also materialising. As part of Pakistans Vision 2025 programme, a first phase of smart meter rollout projects is set to begin by June 2017 and will cover selected

areas. This decision has been primarily motivated by an increase in revenue loss as a result of inaccurate power billing, power theft and technical losses [3].

Whilst this is positive news and such an initiative would improve energy demand management and generation and curb energy disruptions, it is not hard to imagine that top-down change from governments is slow. In fact, a ‘bottom-up change’ can be triggered far more quickly and swiftly - even the smallest lifestyle changes, when added up across great numbers in the population, can indeed make a great difference [3].

## VII. CONCLUSION

The discussions and actions in regards to solving the energy crisis have focused on fixing the various problems the energy sector is plagued with. This paper highlights that there is also a dire need to identify and implement immediate solutions to mitigate the crisis. The survey results show that awareness of everyday energy consumption must be raised and individuals should be encouraged to pro-actively make conscious efforts to reduce the energy demand. To this end, introducing intelligent solutions providing feedback of energy consumption in Pakistan could greatly help reduce consumption.

It is concluded that whilst intelligent solutions for consumption feedback will likely not diminish the energy crisis completely and immediately, they have great potential to help citizens use energy more responsibly, thereby mitigating the crisis. In fact, reducing the energy consumption would also be a milestone towards reducing the carbon footprint of the country and fighting climate change globally.

## REFERENCES

- [1] J. Z. Kolter and M. J. Johnson, "Redd: A public data set for energy disaggregation research," in *Workshop on Data Mining Applications in Sustainability (SIGKDD)*, San Diego, CA, vol. 25, 2011, pp. 59–62.
- [2] A. Hemmatifar and M. Mogadali, "Household energy disaggregation based on difference hidden markov model."
- [3] C. Stokel-Walker, "An energy revolution is coming. meet the startups leading the charge," <http://www.wired.co.uk/article/big-oil-startups-future-of-energy-access>, 2016, Accessed: April 2017.
- [4] D. Vercaemer, B. Steurtewagen, D. Van den Poel, and F. Vermeulen, "Predicting consumer load profiles using commercial and open data," *IEEE Transactions on Power Systems*, vol. 31, no. 5, pp. 3693–3701, 2016.
- [5] S. Aftab, "Pakistan's energy crisis: causes, consequences and possible remedies," *Norwegian Peace Building Resource Center*, 2014.
- [6] B. Energy, "Pakistan energy sector — buksh energy," <http://bukshenergy.com/pakistan-energy-sector/>, Accessed: April 2017.
- [7] M. Kugelman, "Pakistan's energy crisis - from conundrum to catastrophe?" 2013.
- [8] Dawn, "7 facts about pakistan's energy crisis and how you can help end it," <https://www.dawn.com/news/1275116>, 2016, Accessed: April 2017.
- [9] S. H. Kazmi, "Pakistan's energy crisis," <http://thediplomat.com/2013/08/pakistan-energy-crisis/>, 2013, Accessed: April 2017.
- [10] U. Nations, "Sustainable development goals," <https://www.un.org/sustainabledevelopment/sustainable-development-goals/>, 2015, Accessed: December 2016.
- [11] RAFTAAR, "Energy in pakistan: Chronic shortages, concrete solutions," 2016.
- [12] I. N. Kessides, "Chaos in power: Pakistan's electricity crisis," *Energy policy*, vol. 55, pp. 271–285, 2013.
- [13] J. A. Ghani, "The emerging middle class in pakistan: how it consumes, earns, and saves," in *International conference on marketing*. Citeseer, 2014.
- [14] RAFTAAR, "Research and advocacy for the advancement of allied reforms," <http://www.raftaar.pk/>, Accessed: April 2017.
- [15] N. P. Organization, "Sustaining growth: Cleaner production in pakistan," 2016.
- [16] T. E. Tribune, "Import of generators in pakistan surges 38billion," <https://tribune.com.pk/story/1147985/power-outages-import-generators-surges-38-rs192-billion/>, 2016, Accessed: May 2017.
- [17] T. Nation, "The other solution," <http://nation.com.pk/editorials/30-Jul-2016/the-other-solution>, 2016, Accessed: May 2017.
- [18] O. I. C. of Commerce and I. (OICCI), "A roadmap for energy efficiency and conservation in pakistan," 2012.
- [19] S. Darby *et al.*, "The effectiveness of feedback on energy consumption," *A Review for DEFRA of the Literature on Metering, Billing and direct Displays*, vol. 486, no. 2006, 2006.
- [20] A. Faruqui, S. Sergici, and A. Sharif, "The impact of informational feedback on energy consumption: a survey of the experimental evidence," *Energy*, vol. 35, no. 4, pp. 1598–1608, 2010.
- [21] S. Darby, "Making it obvious: designing feedback into energy consumption," in *Energy efficiency in household appliances and lighting*. Springer, 2001, pp. 685–696.
- [22] Watty, "Watty," <http://watty.io>, 2017, Accessed: May 2017.
- [23] Bidgey, "Bidgey," <https://www.bidgey.com/>, 2017, Accessed: May 2017.
- [24] Sense, "Sense," <https://sense.com/>, 2017, Accessed: May 2017.
- [25] Watt-Now, "Watt now," <http://watt-now.nl/>, 2017, Accessed: May 2017.
- [26] W. M. Vagias, "Likert-type scale response anchors," 2006, Accessed: April 2017.
- [27] M. Ekonomijic, "Survey on public opinion on the level of awareness of energy efficiency," <http://www.energetska-efikasnost.me>, 2011, Accessed: May 2017.
- [28] M. of the Environment and W. Resources, "Household energy efficiency study," 2013.
- [29] T. U. of York, "Energy awareness questionnaire," <https://www.york.ac.uk/biology/energy/BaseQuestionnaireResponse.pdf>, Accessed: May 2017.
- [30] E. K. U. (EKU), "Energy awareness survey," <http://energyeducation.eku.edu/>, 2011, Accessed: April 2017.
- [31] Mehroshi, "Questionnaire of energy crisis in pakistan," <https://www.scribd.com/doc/75306441/Questionnaire-of-Energy-Crisis-in-Pakistan>, Accessed: May 2017.
- [32] I. T. Union, "Country classifications by region and development status," <http://www.itu.int/ITU-D/ict/definitions/regions/index.html>, Accessed: May 2017.
- [33] M. . S. Energy, "Pakistan prepares for smart meter deployment," <https://www.metering.com/news/smart-meters-pakistan-adb-iesco-lesco/>, 2016, Accessed: May 2017.

# Water Resource Management and Irrigation Scheduling via Decision Support System

Yusra Shahid, Basit Ali Khan, Ahsan Rehman,  
Muhammad Zunair Ahmed Khan, Muhammad  
Khurram

Dept. of Computer Information Systems Engineering  
NED University of Engineering and Technology  
Karachi, Pakistan

yusra\_shahid95@hotmail.com, engr.basit@rcai.pk,  
ahsanrehman@rcai.pk, mzunair11@gmail.com,  
mkhurram@neduet.edu.pk

Syed Saqib Bukhari

Knowledge Management Group  
German Research Centre for Artificial Intelligence  
Kaiserslautern, Germany Country  
saqib.bukhari@dfki.de

**Abstract**— This paper presents a Decision Support System (DSS) for irrigation scheduling. The system was designed to address the issue of water wastage due to inadequate farming practices and old irrigation methods. This improper use of water for agricultural purposes can be a critical problem with the present growing rate of population. Hence, the aim is to opt a method that helps in producing the same amount of crop yield with less amount of water. The DSS determines the time of irrigation and the actual amount of water required for the crop. A wireless sensing node is used to sense ambient temperature, humidity, water flow and soil moisture that are used as inputs. The system is crop specific therefore it also takes crop type, location and plantation date as input. The wireless sensing nodes are deployed on the field in a bitter gourd crop and the scheduling is being done by the DSS.

**Keywords**—Irrigation scheduling, Decision Support System, Python, Wireless Sensor Network

## I. INTRODUCTION

Water scarcity is a major issue prevailing worldwide. Agriculture consumes 85% of the total water resource all over the world and study shows that only 45% of the supplied water is used by the crop. It is for sure that due to population growth the consumption is not going to decrease. Therefore, solutions are needed to make sure that water supplied is equal to the water required with minimum wastage. The main reasons behind water wastage are bad farming practices and old methods of irrigation. Different areas of Pakistan were chosen for case study and it was observed that water resource is wasted not only because of lack of modern machines and methods but also because of improper irrigation schedules. The crop water needs mainly depend upon the climate, crop type and growth stage of the crop. After the study presented in this paper, it was observed that farmers supply more water to the crop than that is needed by the crop. For instance, generally, farmers at Gadap farms in Pakistan water their crops after every two or three days for the whole crop cycle. On the contrary, agricultural experts suggest that a crop needs less amount of water in its initial stage and during middle stage (i.e during flowering) it needs more amount of water [4].

## II. RELATED WORK

There has been significant work done for irrigation scheduling, different approaches focused on different aspects. For instance, the method derived by (M. H. Pham, 2013) focused more on maximizing the crop yield. Models have been developed that use optimization algorithms to calculate an irrigation sequence for maximizing crop yield [2]. Moreover, as soil moisture is one of the major parameters in determining the irrigation schedule [1], many methods have been developed over the years that monitor the soil moisture status and based on it give the irrigation trigger (time for irrigation and volume of water to be applied). However, there is a lack of systems that remotely monitor fields, send data to decision-making machines and provide user-friendly solutions to the farmers.

The aim of the project is to make an intelligent and automated irrigation system that remotely monitors and gives an efficient and user-friendly solution to the farmer. A Wireless Sensing Network developed by RCAI (Research Centre for Artificial Intelligence), NEDUET is installed at a farm in Gadap Town, Karachi, Pakistan. It is being used to obtain real-time data of a bitter gourd crop from the field. The field is divided into sections and one wall is used to monitor each section, to achieve uniformity in water application drip irrigation is being used [6]. The sensing node records temperature, humidity, soil moisture, water flow and heat index and sends it to the thingspeak cloud. This data is retrieved by a decision support system built in Python that determines when to water the crop and how much water should be supplied. The goal of the project is to model the best farming practices.

## III. SYSTEM ARCHITECTURE

### A. Wireless Sensing Network

The wireless sensing network consists of a coordinator node and multiple sensing nodes, both having same hardware design as shown in Fig. 1. Coordinator and sensing nodes have sensors mounted on them to record ambient temperature, humidity, heat index and soil moisture. There are two types of communications taking place in this network; local

communication in which the coordinator sends a request to all sensing nodes and receive the data from each at a time through RF communication, other is the global communication in which the coordinator sends the accumulated data to cloud using a GSM/GPRS module (Sim800). Fig. 2 shows bitter gourd crop’s humidity being displayed on a thingspeak channel.

**B. Decision Support System**

To determine the amount of water required and it’s time of application, a decision support system or a rule-based system was developed using Python’s metelib libraries available to cater the agricultural data accumulated from the field. For DSS does following things;

1) *Calculate Evapotranspiration:* The daily crop water loss is calculated by evapotranspiration. Evapotranspiration is a process by which water is lost from soil to the atmosphere in two ways; by evaporation from the soil surface and by transpiration by the planted crop.

There are various methods available for calculating crop evapotranspiration such as Blaney-criddle method, a pan evaporation method, Penman-Monteith method [5]. Here Penman-Monteith has been used as it inputs comparatively more parameters (that is parameters specific to location as well as those from the atmosphere) and gives more accurate results [6].

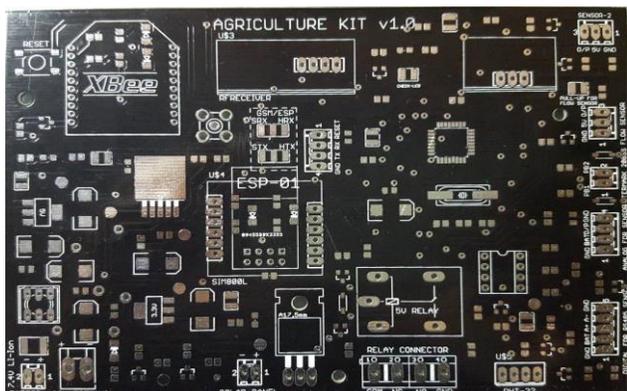


Figure. 1. Shows the PCB layout of front section of the agricultural kit designed by RCAI, NEDUET.

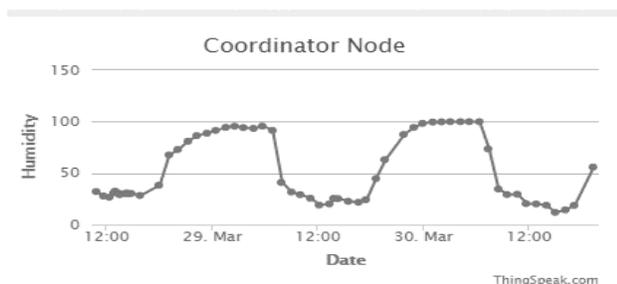


Fig. 2. Visualization of humidity data sent by wireless sensor node to thingspeak’s channel (channel link: [www.thingspeak/channels/218606](http://www.thingspeak/channels/218606)). The node is deployed at Gadap Town in Karachi.

$$ET_o = \frac{0.408\Delta(Rn - G) + y \frac{900}{T + 273} u_2(e_s - e_a)}{\Delta + y(1 + 0.34u_2)} \tag{1}$$

Equation (1) represent the Penman-Monteith equation as given by FAO in 1990. Where  $ET_o$  is the reference evapotranspiration,  $\Delta$  is slope vapor pressure,  $Rn$  is net radiation at crop surface,  $G$  is soil heat flux density,  $T$  is ambient temperature,  $u_2$  is wind speed,  $e_s$  is saturation vapor pressure,  $e_a$  is actual vapor pressure and  $y$  is psychrometric constant [5].

Penman-Monteith method calculates reference evapotranspiration ( $ET_o$ ) which is multiplied by crop coefficient to get crop evapotranspiration ( $ET_c$ ).

2) *Calculate Time and Amount of Water Needed by Crop / Water For Irrigation:* For this purpose Water budget approach with little changes has been acquired. In the Water budget approach, one can assume that there is a reservoir in which soil moisture is the available water and irrigation water is deposited while the source of withdrawal is water used by the crop (indicated by crop evapotranspiration). The DSS gives a decision on daily basis (see Fig. 3), after irrigation application on day one, on day two the evapotranspiration calculated using Penman equation is subtracted from initial water content (from soil moisture sensor).

3) *Send a Trigger*

Two records are being maintained after the above calculations; one is for the Readily Available Water (RAW) and the other is for net water deficiency/depletion of the crop. Readily Available Water is the amount of water that a crop can easily extract from the root zone. As soon as the water deficiency/depletion exceeds RAW the crop should be supplied with water. In this way, DSS sends a trigger whenever the crop needs to be watered

Since every crop has its own specific characteristics, development stages, root length and a crop coefficient therefore although the system built is generic but would require this prior information. Also, along with the crop type, location and date of the plantation are also fed to the system.

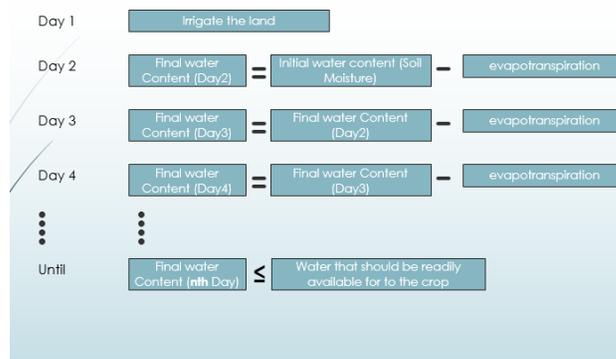


Fig. 3. This figure shows the working of DSS. Note that evapotranspiration is computed every day and subtracted from water content of previous day to get final water content.

IV. WORKING OF THE SYSTEM

Step 1: The nodes deployed on the field send data to the cloud after every fifty minutes.

Step 2: For day one of calculation let us assume that farmer irrigated the land a day before, the Decision Support System imports last 100 values from the cloud, inputs it to the system and gives water deficiency based on soil moisture and evapotranspiration.

Step 3: The Decision support system uploads this water deficiency and RAW on the cloud.

Step 4: On day two the system calculates evapotranspiration again and adds it to the water deficiency of last day.

Step 5: The same process is repeated till water deficiency is greater than RAW and then the farmer is told to irrigate the land with the amount of water shown as RAW. Fig. 4 shows the GUI of Decision Support System and Fig. 5(a) shows graphs of water deficiency and Fig. 5(b) shows RAW for bitter gourd crop.

VI. COMPONENTS REQUIRED

Fig. 6 shows the arrangement of these components.

A. Agricultural Kit components

1. Atmega328 (Arduino)
2. RF module
3. GSM/GPRS Module (Sim800)
4. DHT11 (temperature and humidity sensor)

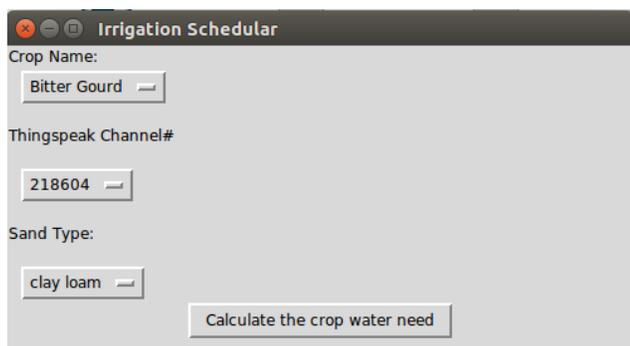


Figure. 4. The scheduler takes crop name, sand type and thingspeak channel as input.

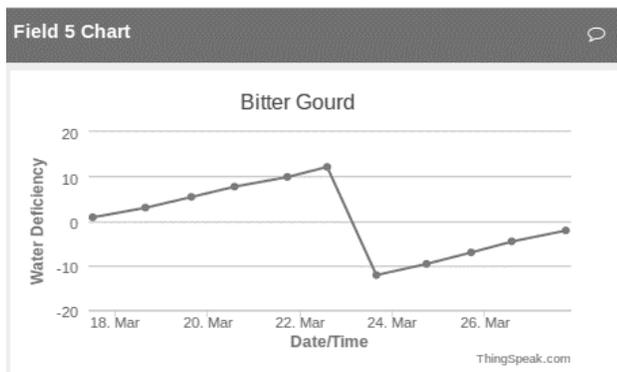


Figure. 5(a). The water deficiency chart is updated every day to see if the current water depletion/deficiency exceeds RAW as explained in figure 3.

5. Soil Moisture Sensor
6. Flow sensor

B. Software Packages used

1. Python Meteolib package
2. Thingspeak IOT Application/API

VII. SUMMARY AND CONCLUSION

The crop cycle of a bitter gourd plant is about 100 days long, till now we have an irrigation sequence for 40 days. A comparative study is being done between two sections; in one section farmer was asked to follow his old irrigation schedule and in other section, the irrigation sequence given by DSS is being followed. So far the system is showing positive results i.e less water consumed by the section governed by DSS and the crop health is similar in both sections as shown in Fig. 7.

In future, on completion of the whole crop cycle, an expert system can be built based on this knowledge and future crop cycles can be made better with anomaly triggers whenever there is a deviation in irrigation scheduling. Moreover, to make the system more stable a proper web server will be integrated with the WSN. The server will receive the data from the coordinator node, run DSS scripts and present results to clients. Hence, the whole system will go online and generate alerts accordingly.

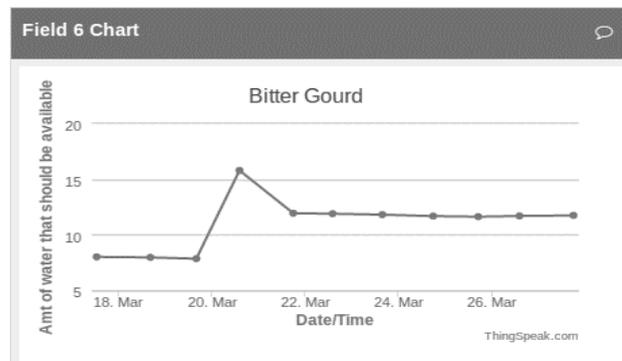


Figure. 5(b). RAW at an instant depends upon crop evapotranspiration (ETc), depletion factor (p) and root length.

ACKNOWLEDGMENT

The authors of this paper are thankful to Research Center for Artificial Intelligence (RCAI) at NEDUET, Knowledge management group of German Center for Artificial Intelligence (DFKI).

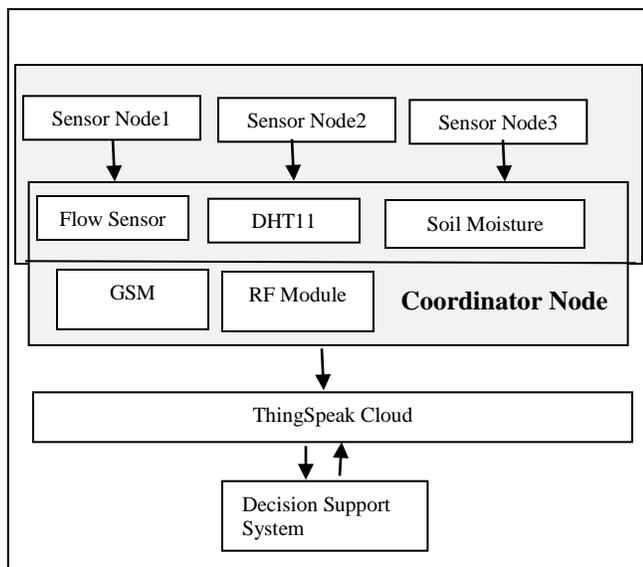


Figure. 6. Wireless Sensor Network and its communication with cloud and DSS

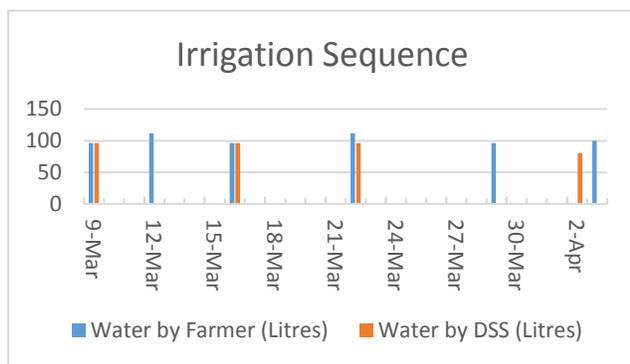


Figure. 7. The figure shows that the triggers by DSS are less than those of farmers. This shows that although the quantity supplied at each event is same but number of events in each sequence differs.

REFERENCES

- [1] Abubaker, J. (n.d.). Irrigation scheduling for efficient water use in dry climates. Sweden.
- [2] M. H. Pham, S. K. (2013). Real-Time Optimization of Irrigation Scheduling in Agriculture. 25th Chinese Control and Decision Conference. IEEE.
- [3] Natural Resources Management and Environment Department. (n.d.). Retrieved from FAO Corporate Document Repository: <http://www.fao.org/docrep/x0490e/x0490e07.htm#TopOfPage>
- [4] Natural Resources Management and Environment Department. (n.d.). Retrieved from FAO Corporate Document Repository: <http://www.fao.org/docrep/X0490E/x0490e08.htm#TopOfPage>
- [5] Natural Resources Management and Environment Department. (n.d.). Retrieved from FAO Corporate Document Repository: <http://www.fao.org/docrep/s2022e/s2022e02.htm>
- [6] Yuan-feng Qiu, G. M. (2012). The Effect of Water Saving and Production Increment by Drip Irrigation. 2013 Third International Conference on Intelligent System Design and

# MUD using GA with variation in Cross Over Operator

Muhammad Nadeem Ali  
*Department of Computer Science,  
 Lahore Garrison University,  
 Lahore, Pakistan*  
 mnadeemali@lgu.edu.pk

Muhammad Adnan Khan, Umer Farooq and Muhammad Sajid Farooq  
*Department of Computer Science,  
 National College of Business Administration & Economics,  
 Lahore, Pakistan*  
 madnankhan@ncbae.edu.pk, umerfarooq@lgu.edu.pk,  
 sajid\_farooq149@yahoo.com

**Abstract**— Optimization of the communication system is always remaining a big issue for the scientist and engineers. Multiple parameters are responsible for the optimal performance of any system. With the rapid growth of research in the field of communication technology, Multi Input Multi Output (MIMO) systems are much favorable as compared to Single Input Single Output (SISO). MIMO is employed using Alamouti scheme using Space Time Block Codes (STBC). In this paper, Genetic Algorithm (GA) is implemented on the receiver side to estimate the weights coefficient of the adaptive receiver. The performance of system is evaluated on the basis of Bit Error Rate (BER.) Further the variation in crossover operator of genetic algorithm is also observed. With the change in crossover operator the performance of the system is changed. The results are verified by simulations on MATLAB 2012.

**Keywords**— MIMO, SISO, BER, STBC, GA.

## I. INTRODUCTION

A big opposition for researchers in radio mobile is to acquire high data rates. Many advanced approaches were initiated to acquire high data rate communication between transmitter and receiver. Effective use of bandwidth is significance factor in mobile trans-mission. Many systems were developed to consume the available bandwidth efficiently. These systems involve Multi Carrier Code Division Multiple Access (MC-CDMA), Multi-Tone Code Division Multiple Access (MT-CDMA), Multi Carrier Direct Sequence Code Division Multiple Access (MC-DS-CDMA) and Orthogonal Frequency Division Multiple Access (OFDMA) [1]. For Multi User Detection (MUD) these mixing methodologies that are being used. But multiuser reach generates a problem which is called Inter Symbol Interference (ISI). Orthogonal signals can be used to eliminate this intrusion problem. Hadamard signals can be used in the creation of orthogonal signals. To accomplish the request of high data rate communication and also to accomplish the requirement of the next generation networks in future MC-CDMA and OFDMA systems are used.

Space time block codes (STBC) are used in order to acquire peak antenna range, [2]. In this system data is transmitted through orthogonal carrier signal. Orthogonal carrier signals are not only used to reduce the ISI between the carrier signals

but also give in-crease to multiuser detection. Multiple antennas are used in MUD at receiver and transmitter side [3]. Although use of multiple antennas at base station or transmitter side is more exemplary. And at receiver side only one receiver antenna is used. The reason behind this is that, with the evolution in the technology small receiver sets are preferred. A big opposition is Multi User Interference (MUI) in MC-CDMA. There are different types of Multiuser receiver. Suboptimal receiver and optimal receiver are two types among those [4]. Optimal receivers are not realistic and is too complex. Where suboptimal receiver is used in this paper and it is less complex along with the batch processing. That's the difference between these two types.

For DS-CDMA and MC-CDMA the batch processing system is implemented with STBC effectively [5]. Inverse calculation of auto correlation of matrix is not suitable in batch processing. Change in channel parameter or user setting may be the reason behind this. Larger the filter tap length causes the system too complex. Receiver is implemented adaptively to solve this problem. Conventional algorithms like Least Mean Square (LMS) or Recursive Least Square (RLS) can be used for such adaptive receiver [6,7,10]. But in order to accomplish Bit Error Rate (BER) and optimized convergence rate these algorithms are not much helpful [8,9,10].

In this paper to obtain the optimal value of weights adaptive receiver genetic algorithm is proposed. Furthermore, the variation in the mutation operator of Genetic Algorithm (GA) is also observed. The change in the convergence rate of MC-CDMA system is cause by the variation in the cross over operator.

Defacing any bit of the data is responsibility of Mutation operator. Many times, the use of cross over operation is more useful as compare to mutation operator. Randomness of the system is also in-creased by cross over ratio. In this article, different cross over techniques are studied. The cross over techniques being used are Single Point (SP), Two Point (TP), Intermediate, Arithmetic and Heuristic cross over.

## II. SYSTEM MODEL

Transmitter and receiver are important components of system model. In this article, two transmit antennas U1 and U2 and one receive antenna is used.

In first interval  $V_m(2i-1)$  and  $V_m(2i)$  are the symbols transmitted by both antennas. In next interval, the antennas transmit symbols  $-V^*m(2i)$  and  $V^*m(2i-1)$ .

In vector form the receiver signal can be written as [5,6,8]:

$$z(i) = [z_{(1)}, z_{(2)} \dots \dots \dots z_{2k}] \quad (1)$$

Where  $z(i)$  is represented as:

$$z(i) = \sum_{k=1}^K \{d_{k,1}U_k(2i-1) + d_{k,1}U_k(2i)\} + v(i) \quad (2)$$

K represents number of users and

$$d_{k,1} = [c_{k,1}^T \quad c_k^T] \quad d_{k,2} = [c_{k,2}^T \quad -c_k^T] \quad (3)$$

Where

$$c_{k,m} = Q_{k,m}B_{k,m} \quad (4)$$

$Q_{k,m}$  is channel frequency response matrix.

It can be defined as:

$$Q_{k,m} = \text{diag}(Q_{k,m,0}, Q_{k,m,1} \dots \dots \dots Q_{k,m,1}) \quad (5)$$

Gaussian noise of zero mean is  $V(i)$  and covariance of  $\delta 2I2k$  with  $2N \times 2N$  identity matrix.

Now filter weight vector for  $V_k(2i-1)$  and  $V_k(2i)$  is detection is determined.  $2N \times 1$  is the size of weight vector  $w_1$  and  $w_2$ . Equation below gives minimum mean square error (MMSE) of filter [6,8].

$$J(w_1, w_2) = [w_1^H z(i) - v(2i-1)]^2 + E[|w_2^H z(i) - v(2i)|^2] \quad (6)$$

$$J(w_1, w_2) = J(w_1) + J(w_2) \quad (7)$$

MMSE receiver for STBS MC-CDMA will be calculated by reducing the cost function given in Eq. (6)

$$[w_{1,opt}, w_{2,opt}] = \underset{\min}{\text{arg}}(w_1, w_2) \quad (8)$$

$$[w_{1,opt}, w_{2,opt}] = \underset{\min}{\text{arg}} J_1(w_1) + J_2(w_2) \quad (9)$$

## III. IMPROVED COST FUNCTION

A new relationship between filter weights is formed by employing STBC technique. This reduces the system's computational complexity and improves the cost function of system. This section describes derivation of special relation among weights of filters.

R defines correlation matrix. Size of matrix is  $N \times N$ . Correlation matrix  $R_y$  is given by:

$$R_y = \Sigma \{gk, 1gk, 1H + gk, 2gk, 2H\} + \delta v 2I2N \quad (10)$$

Following relation is derived from above equations of  $R_y$ .

$$R_{2,2} = R_{1,1} \quad R_{2,1} = -R_{1,2} \quad (11)$$

Using this relationship, sub vectors of weights can be defined as:

$$w_{1,o} = [w_{1,1,opt}, w_{1,2,opt}] \quad (12)$$

$$w_{2,o} = [w_{2,1,opt}, w_{2,2,opt}] \quad (13)$$

sub vector also fulfils the property

$$w_{1,2,opt} = w_{2,1,opt} \quad \& \quad w_{2,2,opt} = -w_{1,1,opt} \quad (14)$$

Complexity of the system is reduced by using Eq. (14). Using algorithm half weights are determined. Remaining weights can be determined by any mathematical operation as conjugate and transpose. This will also reduce the computational cost of system.

## IV. PROPOSED GA BASED ADAPTIVE RECEIVER WITH VARIATION IN MUTATION OPERATOR

Genetic algorithm is proposed to estimate the weights of adaptive receiver [8] [9] in this paper. In table 1 the working of genetic algorithm is given. To determine the optimal value of adaptive receiver weights the genetic algorithm use the cross over, mutation and selection operator. In this paper the cross over used is scattered cross over. The selection operator is stochastic uniform. The variation in the mutation operator is observed. To observe the change in performance of the system using Single Point (SP), Two Point (TP), Intermediate, Arithmetic and Heuristic cross over techniques.

TABLE 1: GENETIC ALGORITHM

Step	Genetic Algorithm
1	Generate initial population
2	Find their fitness
3	Select best parents and generate new offspring's
4	Find the fitness of new offspring's
5	Perform cross over, mutation and selection function
6	Find the fitness
7	If fitness achieved Yes Go to step 8 Else Go to step 3
8	Stop

## V. RESULTS AND SIMULATIONS

The simulations are performed to observe the Bit Error Rate (BER) versus Number of Cycles (NoC)/ages. The quantity of subcarriers is equivalent to spreading code length. The spreading code genuine and nonexistent parts are chosen utilizing the Walsh-Hamard like codes from 1 and - 1 autonomously. In this article, Rayleigh Flat fading is utilized. The channel coefficients are settled along spreading codes and

K in all cycles. The fig 3 to 7 speaks to execution of GA with different cross over techniques for information estimation of MC-CDMA receiver as far as BER.

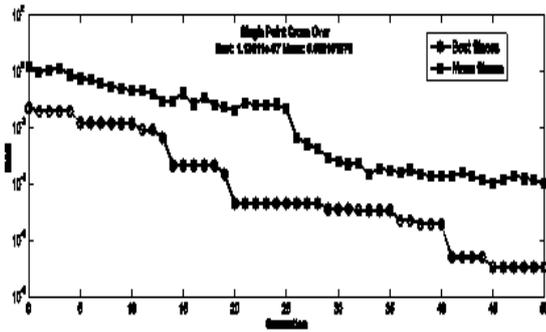


Fig 3. GA based MC-CDMA System with SPCO

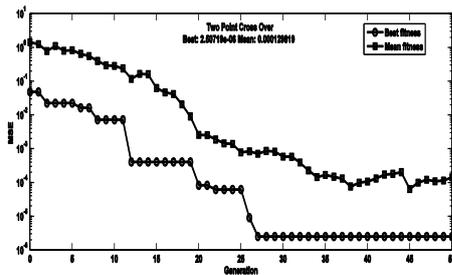


Fig 4. GA based MC-CDMA System with TPCO

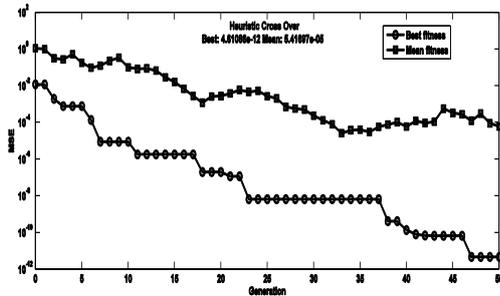


Fig 5. GA based MC-CDMA System with HCO

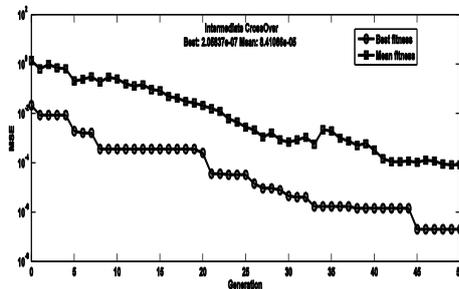


Fig 6. GA based MC-CDMA System with ICO

Fig 3 shows the NoC vs BER of GA based MC-CDMA system with SPCO. The top most curve shows the mean fitness and bottom curve shows the best fitness results. It also observed that mean value is 0.00010878 & best value is 0.113011e-08 achieved by Single Point cross over operator.

Fig 4 shows the NoC vs BER of GA based MC-CDMA system with TPCO. The best & mean value achieved are 0.250719e-07 & 0.000129819 respectively by using Two Point Cross Over.

Fig 5 shows the NoC vs BER of GA based MC-CDMA system with HCO. The number of iteration or generation taken from this result is 50. The best & Fig 7. GA based MC-CDMA System with ACO Mean values are achieved 2.05837e-07 & 8.41058e-05 respectively.

Fig 6 shows the NoC vs BER of GA based MC-CDMA system with ICO. The top most curve shows the mean fitness mean value which is 0.841058e-06 and bottom most curve shows the best fitness value which is 0.205837e-08.

Fig 7 shows the NoC vs BER of GA based MC-CDMA system with ACO. The top most curve shows the mean fitness mean value which is 0.000149481 and bottom most curve shows the best fitness value which is 0.183532e-14.

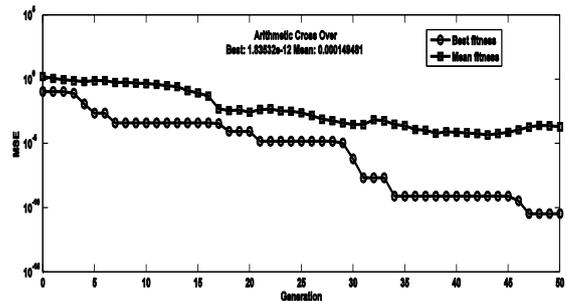


Fig 7. GA based MC-CDMA System with ACO

Table 2. Comparison of GA based MC-CDMA System with different COO

S.NO	Cross Over Technique	Mean Value / NoC	Best Value (MSE) / NoC are fixed at 50
1	SPCO	1.01878e-04 / 50	1.13011 e-07
2	TPCO	1.29819e-04 / 47	2.50719 e-06
3	ICO	8.41058e-05 / 45	2.05837 e-07
4	HCO	5.41697e-05 /47	4.61086 e-12

VI. CONCLUSION

Table2 clearly shown that the arithmetic cross over is accomplishing best wellness esteem 0.182e-13 and on account of mean esteem heuristic cross over is accomplishing 0.54e-06. All the cross over operators are utilizing same number of age to accomplish operation optimal point. Anyway,

arithmetic cross over operator is more appropriate because of its better ideal esteem.

#### REFERENCES

- [1] S. Hara and R. Prasad, "Overview of the multicarrier CDMA," *IEEE Communication Magazine* (1997), 126-133.
- [2] S. M. Alamouti, "A Simple Transmit Diversity Technique for Wireless Communication," *IEEE Journal on select areas in communication*, (1998), 16, 8,1451-1458.
- [3] L. Hongbin, L. Xuguang and B. Georgios, "Capon Multiuser Receiver for CDMA Systems with Space-Time Coding," *IEEE TRANSACTIONS ON SIGNAL PROCESSING*, (2002),1193-1204.
- [4] H. J. R. C. Vahid Tarokh, "Space-Time Block Codes from Orthogonal Designs," *IEEE TRANSACTIONS ON INFORMATION THEORY*, (1999),45,5,5-10.
- [5] M. Umair, M. A. KHAN. M. A. Saleem. "GA backing to STBC Based MC-CDMA Systems," in *IEEE 4th International Conference on Intelligent Systems*, Bangkok, Thailand, 2013.
- [6] B. Seo, W. G. Ahn, C. Jeong, & H. M. Kim, H. M. "Fast convergent LMS adaptive receiver for MC-CDMA systems with space-time block coding", *IEEE Communications Letters*, (2010), 14(8), 737-739.
- [7] R. C. Lammare and R. Sampaio-Neto, "Blind adaptive MIMO receivers for space-time block-coded DS-SS systems in multipath channels using the constant modulus criterion," *IEEE Trans. Commun.*, (2010),58,1, 21-27.
- [8] M.A. KHAN, M. UMAIR, M. A. Saleem, "GA based adaptive receiver for MC-CDMA system," *TURKISH JOURNAL OF ELECTRICAL ENGINEERING & COMPUTER SCIENCES*, (2015), 23, 2267 - 2277.
- [9] M.A.Khan, Umair, M., and Saleem, M.A. (2012). "Accelerated assistant to Sub-optimum receiver for multi carrier code division multiple access systems", *International Conference on Future Trends in Computing and Communication Technologies (FTCom)*, P. 26-29.
- [10] M.A Khan, (2016), *Multi user detection using computational intelligence in multi-carrier communication systems*, ISRA University, Islamabad campus, Pakistan.

# Adaptivity of Quiz-based E-Learning using Semantic Web and Ant Colony Optimization

Asad Ali, Carmine, University of Salerno

**Abstract-Universities around the globe have invested a lot in the area of e-learning, in order to allow their students to learn in their own place and pace. Various studies have shown that the traditional “fit for all” learning materials are not so effective and have failed to improve the student’s performance, so the demand to organize and structure the course contents that adapt itself according to the user’s needs, capabilities and preferences, have raised a lot in the past one decade. In this work, we presented an idea of how to use naturally inspired algorithm, called Ant Colony Optimization with the Semantic Web technologies to provide an adaptive e-learning system to the group of learners. We used the quiz-based learning materials for the users in order to allow them to learn their course contents with motivation and fun.**

**Keywords: Ontology, Semantic we, Ant Colony Optimization**

## 1. INTRODUCTION

Electronic learning, also called as e-learning, is an ongoing research area which utilizes electronic technologies to get access to the educational curriculum outside traditional the classrooms [8]. E-Learning is basically the use of Information Communication Technology (ICT) tools and technologies where (1) learners learn to utilize some use cases and (2) teachers use these technologies to teach learning materials. From past one and half decade, organizations and academics have started to use e-learning technologies to educate their employees and students respectively [2]. While new tools and technologies have been developed, e-learning have adapted itself and thus formed into a new shape [7].

Adaptive e-learning allow users or students to learn according to their understanding by adjusting the system’s navigation [12], presentation and contents according to their knowledge and preference. This is one of the main advantage of e-learning system that it adapts itself unlike traditional class rooms learning which does not care much about learner’s background and behaviour. Also, the content-based learning, which involve huge and boring text, does not motivate users to learn their educational materials [5] and thus, we provided here in this work a quiz-based e-learning system so that the users of the system learn the materials quickly and easily.

Although there are Semantic Web based quiz systems and there are learning system which used the ACO algorithm, but to the best of our knowledge none of the e-learning system

exist in the literature which combined both Semantic Web technologies and ACO for adapting a learning path.

## 2. PROPOSED WORK

In this work, we used the approach of personalized and adaptive learning for group of learners using Semantic Web technologies and Ant Colony Optimization (ACO). The learning materials are quiz-based which are taken from the courses of Natural Computation and Semantic Web. The Figure 1 shows the system architecture.

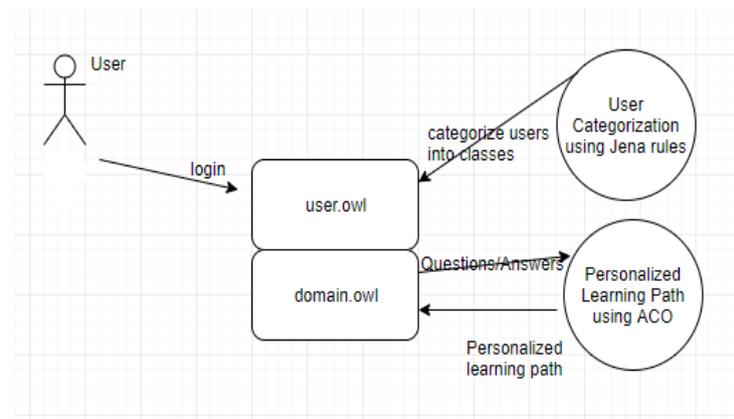


Figure 1: System Architecture

### a. Ontologies

We used two Ontologies: (1) domain.owl, contains all the quiz-based learning materials from the above two courses. We have several classes of domain Ontology like Questions, Answers, Score, etc and object properties like has Answer (each question has an answer ), hasQuestion (each answer has a question ), hasScore (each user has a total score in each course). (2) In user.owl, we divide the users into different classes based on their scores of the quiz when they first appear for it. In user Ontology, we have one main class called User and subclasses SW\_Diligent, NC\_Diligent, SW\_Average and NC\_Average. For instance, if a user appears for Semantic Web quiz and he/she scores more than 60% score, we assign that user to SW\_Diligent class and if the score is less than 60%, we put them into SW\_Average class. Similarly, we assign users when they appear for Natural Computation course. We used Jena rules to divide the users into different classes. The Figure 2 shows the (a) classes (b) object properties and (c) data properties. The Figure 3 shows the user Ontology of our system.

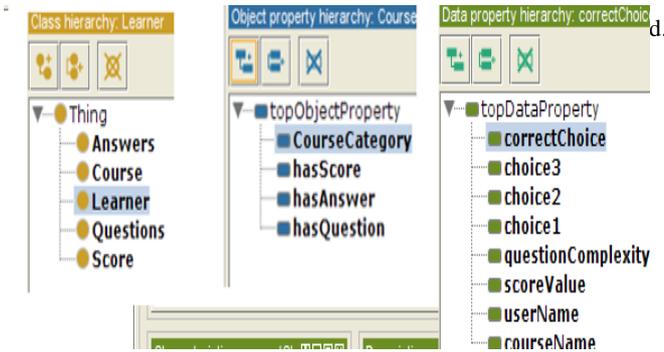


Fig 2(a) Domain Ontology Classes (b) Object Properties (c) Data Properties

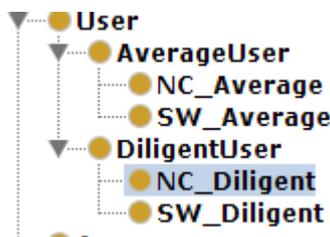


Fig 2. User Ontology

**b. Jena Rules**

We have used the Semantic Web (Jena) rules to classify and categorize users to different classes according to their performance of the quiz. For instance, to assign users to SW\_Diligent class, we used the rule in Fig 3:

**Rule1:** (?x rdf:type ont:User) + (?x ont:score ?scorevalue) + greaterThan(?scorevalue, 50) → (?x rdf:type SW\_Diligent)

**Figure 3: Jena rules to assign users to Semantic Web Diligent class**

For Natural Computation average users, we used the following rules:

**Rule2:** (?x rdf:type ont:User) + (?x ont:score ?scorevalue) + lessThan(?scorevalue, 50) → (?x rdf:type NC\_Average).

**Figure 4: Jena rules to assign users to Natural Computation Average class**

**c. Questions Complexity**

We have fifty different questions for both the courses, with different complexity. The questions are marked with number from 1-10, with 1 the easiest questions and 10 the most difficult questions (the questions are marked by the course tutors). We want to personalize the questions for different

users i.e average users will see the easy level questions first and then gradually it goes difficult while difficult questions will be presented first to the diligent users and the most easy questions in the last.

**Ant Colony Optimization:**

ACO is a type of swarm intelligence approach, which subsequently is a part of natural computation[8]. ACO is used in recent past frequently in the optimization problems and especially in adapting the learning concepts in the e-learning systems. This algorithm is inspired from the traditional ants searching for food from their nests and make arrangements for the shortest path so that the other members of the colony reach there in short time. To do this, the ants drop a special chemical, called pheromone, which the other ants follow to reach the food [8][9]. However, the pheromone evaporates with the passage of time and thus the longer path loses their pheromone amount quickly and thus the ant follows the shortest path (where still the pheromone exists) to reach the destination.

ACO algorithms can be applied to the problems where the information are represented as graph [9][10], and since the e-learning questions are used as Ontology (which represents data as graphs), ACO algorithms can be applied in this case. A question represents a node and the edges represent the moving from one question to the other. The nodes are connected with each other and the idea is to find the optimal learning path which is suitable for individual users according to their knowledge and capabilities in the quiz game.

**Solution Construction:** Initially a learner/ant starts and randomly questions (easy level, difficult level) appear to him/her. At each step, each learner/ant constructs a solution and share the provide the feedback to the entire colony by updating the pheromone trail in the form of a matrix. Each entry of the matrix shows the suitability of each question. When the iteration comes to an end, the pheromone associated with each solution component is reinforced based on the quality of the solution that comprises the particular solution component. In subsequent iterations, the learners/ants uses the intensities of the pheromone to construct the whole solution.

Pheromone trails and heuristic information: The probability of an ant k to move from question I to j at time t is described in the equation 1.

$$P_{ij}^{k,t} = \frac{[\tau_{ij}(t)]^\alpha \cdot [\eta_{ij}]^\beta}{\sum_{k \in allowed_k} [\tau_{ik}(t)]^\alpha \cdot [\eta_{ij}]^\beta} \quad \text{if } j \in allowed_k \quad (1)$$

$\tau$  shows the pheromone trail and  $\eta$  is the visibility or distance from one question to another. The value of  $\eta$  is decided by the course teacher. In our case, the value of  $\eta$  is the complexity of the question and we implement it as a data property, which can be retrieved using SPARQL ORDER BY query.

After a learner completed the visit of all questions, the amount of pheromone deposited on the edges are decreased because of evaporation,

$$\tau_{ij}(t) \leftarrow (1-p) \cdot \tau_{ij}(t) \quad (2)$$

where  $p$  is the evaporation factor.

Finally, we use the following SPARQL query to load the quiz to the users. The questions are re-ordered, in this case, for diligent users.

```

SELECT *
WHERE { ?Qs ont:Question ?QsDesc.
?QS ont:hasAnswers ?AnsQ.
AnsQ ont:hasQuestion ?Qs.
?AnsQ ont:ChoiceOne ?ANSONE.
?AnsQ ont:ChoiceTwo ?ANSWTWO.
?AnsQ ont:ChoiceThree ?ANSWTHREE.
?AnsQ ont:CorrChoice ?ANSCORR.
?Qs ont:hasCategory ?Cat.
?Cat ont:category ?CatName.
?Qs ont:hasScore ?point.
?point ont:score ?Score.
?Qs ont:hasComplexity ?complexity.
        FILTER ( ?CatName = "+ctg+" ).
} ORDER BY desc (?complexity) //?complexity is the value
of  $\eta$ 
    
```

Figure 5. SPARQL Query to Load the Quiz for Diligent Users (Re-Ordering Questions)

The following Figure shows the desired learning path that the ACO produces for diligent users (first difficult questions will be displayed). The values C10, C8 etc shows the complexity level of all questions.

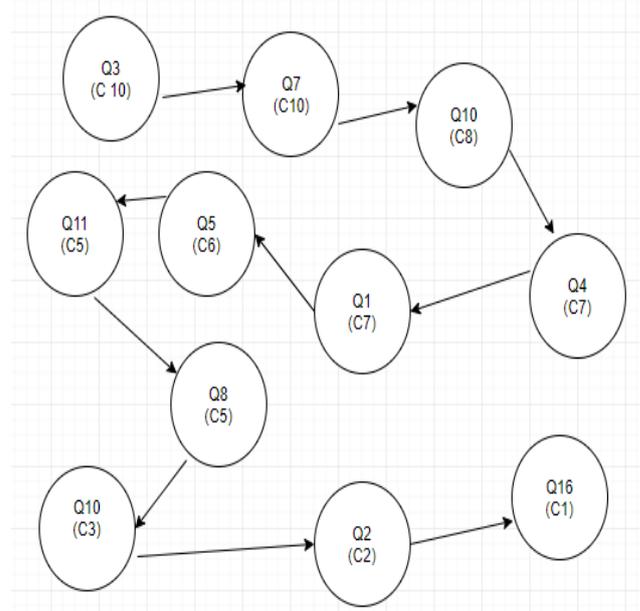


Fig 6: Personalized learning path for diligent users

The pseudo code of our ACO algorithm is shown below.

Input for ACO algorithm: the number of ants/users and ACO's parameters ( $\alpha$ ,  $\beta$ ,  $p$ )

Output of the algorithm: Adaptive/personalized learning path for group of users

1. Do user grouping in user Ontology (via Jena rules)
2. Do (for each group of users) {
3. Set the same value of  $t$  (Tau) and  $\eta$  (eta)
4. % Ant generate
5. Assign questions to ants/users randomly
6. Do (for each Ant) {
7. Calculate equation 2
8. Choose next question according to step 7
9. If the questions with complexity value not reaches (1 for diligent users and 10 for average users)
10. Continue;
11. }
12. Return the adaptive path (for each group of users)
13. Update the pheromone level of all ants (according to eq 1 & 2)
14. Go to step 6 and continue
15. }

### 3. ADVANTAGES OF USING SEMANTIC WEB TECHNOLOGIES IN E-LEARNING

- ✓ Semantic Web enables intelligent searching and navigation of the interface with complex SPARQL queries and can be easily used to adapt the e-learning systems.
- ✓ Since the adaptivity is provided by Jena rules, the e-learning system can be personalized easily.
- ✓ The use of Jena rules and user ontology allows us to separate the adaptivity from code (Java) since the rules only update the ontology and not the code, thus allowing the re-usability.
- ✓ The use of ontologies increases the reusability in our e-learning system. Such as, if we create a quiz-game for another

domain i.e. medical, all we need to do is to change the knowledge base of the domain and update the Jena rules.

#### 4. CONCLUSION AND FUTURE WORK

In this work, we have managed to present an idea of providing a personalized learning path using the Semantic Web technologies and natural inspired algorithm, Ant Colony Optimization (ACO). The learning materials are quiz-based questions of various complexities, which are presented to different users according to their performance in the quiz. We have combined both the strengths of Semantic Web technologies (understand the meaning of the contents and sharing and re-used of Ontologies) and ACO (optimization capabilities) which is a novel work in that case.

In future, we will be able to provide more adaptivity to the system so that the users performance increases each time they appear for the quiz. In that case, we will provide a short explanation of the questions, when the users wrongly answer a particular question. Also we will be able to keep track of user's progress such as what is the user favourite category (Semantic Web or Natural Computation), what is the user's high score category (the course where users score highest marks) etc.

#### References

- [1] Al-Yahya M, George R, Alfaries A. Ontologies in E-learning: review of the literature. *International Journal of Software Engineering and Its Applications*. 2015;9(2):67-84.
- [2] Arkorful V, Abaidoo N. "The role of e-learning, advantages and disadvantages of its adoption in higher education". *International Journal of Instructional Technology and Distance Learning*. 2015 Jan;12(1):29-42.
- [3] Baylari A, Montazer GA. "Design a personalized e-learning system based on item response theory and artificial neural network approach" *Expert Systems with Applications*. 2009 May 31;36(4):8013-21.
- [4] Bizer C, Lehmann J, Kobilarov G, Auer S, Becker C, Cyganiak R, Hellmann S. "DBpedia-A crystallization point for the Web of Data". *Web Semantics: science, services and agents on the world wide web*. 2009 Sep 30;7(3):154-65.
- [5] Bratsas C, Chrysou DE, Eftychiadou A, Kontokostas D, Bamidis P, Antoniou I. "Semantic web game based learning: An i18n approach with greek dbpedia". In 2nd International Workshop on Learning and Education with the Web of Data (LiLe-2012 at WWW-2012), Lyon, France 2012 Apr 17.
- [6] Calvanese D, De Giacomo G, Lembo D, Lenzerini M, Rosati R. "Data complexity of query answering in description logics" *Artificial Intelligence*. 2013 Feb 1;195:335-60.
- [7] Chen CM. "Intelligent web-based learning system with personalized learning path guidance". *Computers & Education*. 2008 Sep 30;51(2):787-814
- [8] Maryam Bahojb Imani, "A new Personalized Learning Path Generation Method: Aco-Map", *Indian Journal of Scientific Research* · January 2014.
- [9] Souvik Sengupta et al, "Construction of Learning Path Using Ant Colony Optimization from a Frequent Pattern Graph", *IJCSI International Journal of Computer Science Issues*, Vol. 8, Issue 6, No 1, November 2011
- [10] Pushpa. M , "ACO in e-Learning: Towards an adaptive learning path", *International Journal on Computer Science and Engineering (IJCSE)*

# Node-Wise Monitoring of Power Supply Distribution Network Using Smart Cable & GPS

smart monitoring to an anti-theft approach

Rehan R. Khan

College of Engineering, PAF-KIET University,  
Karachi, Pakistan  
rehan.khan@pafkiet.edu.pk

Jibran R. Khan\*

Department of Computer Science – UBIT,  
University of Karachi,  
Karachi, Pakistan  
jibran\_rasheed@hotmail.com

Farhan A. Siddiqui

Department of Computer Science – UBIT, University of Karachi,  
Karachi, Pakistan  
farhan@uok.edu.pk

**Abstract:** Electronic devices have become an essential part of daily life routine irrespective of home, industries or business sectors appliances that depend on electricity. The existing electrical power transmission distribution system seems to be incapable to accommodate the rising supply-demand gap and also fail to resist supply theft in many countries that cause the energy crisis. The existing system is also unable to detect electricity mugging and fault location or cable breakdown, which require manual inspection or user complain to rectify the issue. This paper proposed the Smart Cable design and the communication scheme which ensure smooth power transmission distribution and its own security. The proposed system detects fault location, identify external interference, damage, illegal connection and supply theft in a transmission line. The solution is designed to identify exact or nearest incident point and prevalent electricity hocking between poles, meter, and building unit via GPS, without utilizing any artificial intelligence mechanism, extensive data mining and prior data processing techniques. Paper also discuss different practical scenarios to determine its behavior and the expected outcome has been achieved successfully.

**Keywords:** *Electric Fault Detection; NTL Detection; Electric Hocking; Illegal Connection; Fault Diagnosis; Fault Location; GPS; Monitoring; Simulation.*

## I. INTRODUCTION

The Flexible printed electronics also known as Flex Circuits. It allows mounting electronic circuits and assembling on the flexible plastic substrates which can be produced in desirable shaped that can either be fold, bent or stretch. Printed electronics related to plastic electronics and organic electronics, it is a printing technology used to print electronic circuits, components, and devices on plastic material by using the set of methods.

Integration of flexible and printed electronics opening the new door for promising commercial and industrial solutions. The existence of flexible electronics or organic plastic changing future electronics; from hardware components to plastic sheet. Some dominating characteristics such as; low manufacturing & printing cost, printable, foldable, stretchable circuits and disposable devices[1], transparency and zinc proof get the attention of the world. The significant improvement in flexible electronics technology, make the possible organic transistor, sensors, displays, communication and small devices with very low power consumption for data, signals, and power transmission[2]. Nowadays, flexible electronics or organic plastic technology widely used in energy generation and storage, medical & healthcare devices, computation, e-textile, foldable display devices, wearable touch devices, education and human interactive system[3]–[5].

The need for energy rapidly growing by the time as demand rises and the limited availability of resources alarming the authorities. The need for an efficient solution for NTL or electricity fraud detection always been the interest of power sector companies and government. During the past few years, this also become an active research area for industry. Every year, developed and underdeveloped countries spending millions of dollars for two kinds of projects; 1) advance energy sources or renewable energy technology, and 2) supply theft prevalent system to protect and detect any sort of illegal activities in a distribution chain of supply transmission. Because, among all sources of energy, electricity is the first & primarily a requirement for machines, equipment, and devices to operate. By virtue, it is the only energy source that can produce, conserve and consume as per need. Still, industries facing challenges of its safety, performance, and availability[6].

This paper introduces the Smart Cable (SC) concept for an end to end energy transmission and monitoring as a

promising solution. The following section presents the conceptual design of Smart Cable using printed electronics technology, the communicational model and the simulated results of a proposed solution in various scenarios.

The research work and study of existing solutions, no such solutions or application in this domain are found which is entirely based electronics or whose work is independent of Artificial Intelligence, Data Mining or Load Balancing techniques to detect the non-technical loss in electricity supply transmission and distribution are not found.

The existing solutions are heavily based on artificial intelligence, knowledge extraction or data mining and user profiling which are extensively dependent on large data and require continues computational process. The results of such systems can be altered, manipulated and well possessing physical and cyber challenges. Also, it has been noticed that the results get varied by the set of attributes and other factors[7]. The prior study of this work has been conducted in [7], [8] and from the survey of prevailing solutions for NTL detection, and techniques they used are summarized in the following Table 1.

The broad study has been done on a large number of NTL solutions available that all cannot be listed here, but the following Table 2 categories the studied solutions into four broad branches and their ratio of appearance during research are shows as.

TABLE I. EXISTING NTL SOLUTION; TOOLS AND TECHNIQUES USED

Ref	Technique	Year	Special Purpose ICs	FE PE
[9]	SVM	2010	N/A*	X
[10]	Load Balancing	2015	Y	X
[11]	ZigBee	2016	Y	X
[12]	GSM	2014	Y	X
[13]	HPC & SVM	2012	N/A*	X
[14]	Load Balancing	2015	Y	X
[15]	ELM, SVM,	2014	N/A*	X
[16]	Load Balancing	2011	N/A*	X
[17]	Load Balancing	2016	Y	X
[18]	AI, DM	2016	N/A*	X
[19]	Genetic SVM	2009	N/A*	X
[20]	Load Balancing	2015	Y	X
[21]	SOM & DM	2009	N/A*	X
[22]	Bool Rules, Fuzzy & SVM	2016	N/A*	X
[23]	DM & (GRI) model	2014	N/A*	X
[24]	Load Balancing	2014	Y	X
[25]	Neuro-Fuzzy	2009	N/A*	X
[26]	SVM, NN, KNN	2012	N/A*	X
[27]	Regression	2015	N/A*	X
[28]	OPF	2009	N/A*	X

1. Flexible Electronics or Printed Electronics

\*No hardware use in proposed software or framework solution.

TABLE II. EXISTING SOLUTION CATEGORIZATION AND THEIR PROPORTION

Category	%	Description	Technology
Conceptual Idea	23	Ideas without any practical implementation that can be followed to build solutions	-
Theory	24	Consists of surveys and case studies of prevailing solutions. These can aid in improving solutions and addressing their weakness/threats.	Load Balancing with the support of special purpose ICs/devices and Wireless Communication Medium
Hardware	17	Proposed electrical, electronic, and interface based solution for Smart Grid system (AMI, a smart meter).	AI, DM & Combination of them
Software	36	It contains APIs, Tools, software-based management system, desktop and web applications with the incorporation of the smart grid system. Mainly and mostly working on AI and machine learning algorithms.	

II. MATERIAL AND METHODOLOGY

A. Smart Cable Design

Smart Cable (SC), is a modern technological integration with an electrical transmission line. This allows real-time monitoring of illegal activities and disturbance in transmission and distribution chain. Smart Cable is comprising of six (6) layers. These layers are distributed into two groups; Insulation Layers and Conductive layers. Where, layer 1, 3, 5 are the outer most, inner and innermost insulation of conductive wires respectively. The layer 2, 4, 6 are the flexible printed plastic substrates, transmission wire bundle and feedback wire as shown in the Fig. 1.

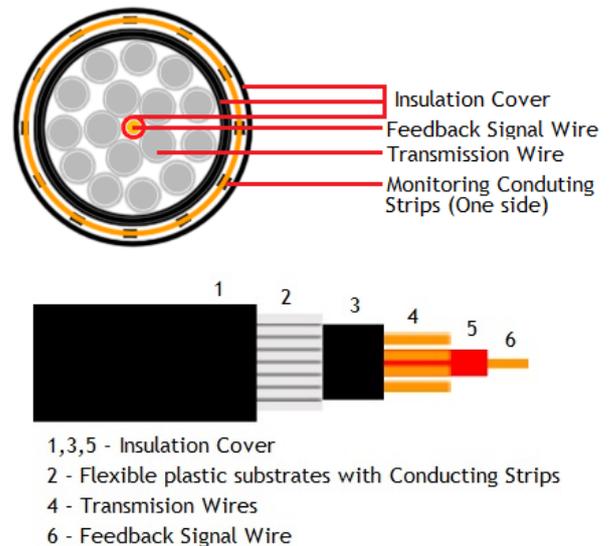


Fig. 1. Smart Cable Design - Top & Left View

The flexible printed plastic substrate uses one side printed wires for monitoring purpose. The number of printed wires are according to the radius of the cable. If this layer is violating or breach by any means the voltage drop occurs and identify at a communication model. The transmission wire layer is solely for electricity transmission purpose. The

innermost or the central single wire plays an important role, it uses as feedback and verification purpose.

**B. Communication Model**

The model has four key components; the monitoring wire connector point, Monitoring Circuit (MC), Control Unit (CU) and GPS device. As the transmission started monitoring circuit start receiving the signals from monitoring wires. The computed result is then passed to the control unit as its input, where it determines whether it is normal or disturb signal. If the signal from monitoring units seem to be disturbed, the control unit then checks the GPS device status either it working or not, and at the same time, it pushes the status in feedback line where it will notify the previous electric pole device as well. Each GPS device has the unique identifier (location coordinates) which is treated as a location identifier. The following Figure 2, shows the communication model.

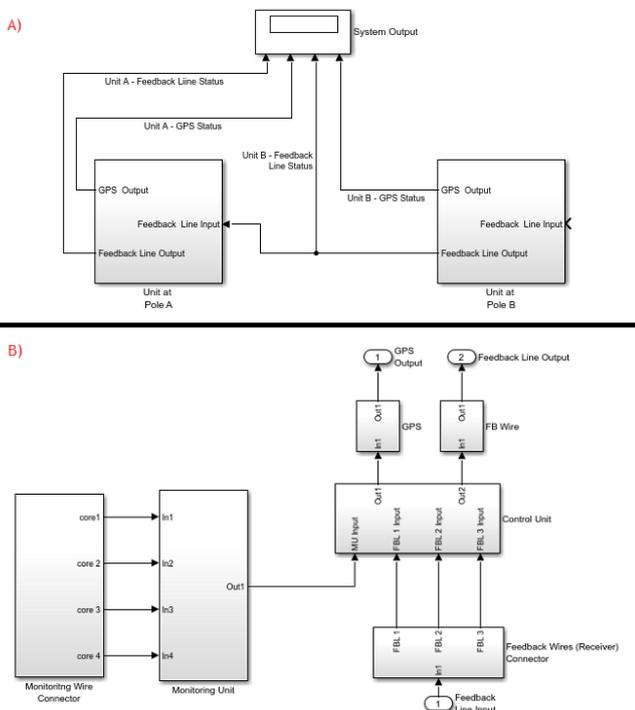


Fig. 2. Matlab Simulink diagram, (A) – Unit level simulation model, (B) – Controller level simulation view

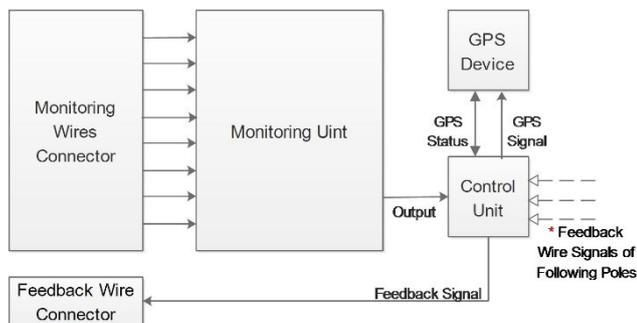


Fig. 3. Communication model block diagram

The control unit has two main functions; forwarding and receiving. The forwarding section will push the signals to its GPS device and in feedback wire and the receiver section will receive the signals from the following pole feedback signal. Both GPS devices will transmit a notification to the operation center, it will help in reaching the accurate incident location.

This scheme is equally applicable in the electric meter to encounter meter tempering or bypassing techniques. In similar fashion, if the cable is a breach between meter and building monitoring unit then the both will transmit the signals to the operation center which specifically prompt which user conducting the crime.

**C. Feasibility Study of SC**

The worth of implementation of the proposed new smart cable concept along with the communication model, a feasibility study is carried out. The study has distributed over several factors such as manufacturing possibility, availability of technology, integration, ease of implementation, security, theft tolerance, security measures, communication required, active time of the device and its component, battery usage, location identification, and some other essential factors. The experimental study also conducted under several and common electrical supply distribution problem, which is discussed in detail in the simulation & results section.

**D. Technological feasibility**

The printed electronics are richly in the market since and promptly is used in advance tool and devices such as a foldable keyboard, flexible wrist mobile, foldable cell phone, thin and curved TVs, and many other IoT devices and sensors. This is not limited to these devices, as discussed above PE plays an important role in almost every dominating fields[29], [30]. Therefore, the technological possibility and some remarkable work also have been done in past few years. Technology is available and can be embedded in the proposed design to enhance the system protection.

**E. Manufacturing Possibility of SC**

It is studied that the overhead distribution cables carry out less than 1kv and the consumer-end received the range from 250-500v. Whereas 220-250v is required in the residential area and 300-500v is installed in an industrial area or as per their need[31]–[33]. It found that many local and international companies, providing and manufacturing the multi-core and multi-insulated power cable for overhead distribution and consumer power cable. Some of them are ELAND Cables[34], Newage Cables[35], JIANGYANG Cable[36], and Southwire[37]. Showed that multi-core/insulated cables which are similar to the SC structure and few are more complex than SC design are widely and commercially available. Hence, the SC production is feasible and will have high business and commercial value.

**F. Integration & Ease of Implementation.**

SC, as by its design and simplicity of work, it does not require any special purpose equipment to work with except the proposed model. Which means, SC flexible enough in the term of integrity with the existing aged electricity system or any new advance infrastructure system in the future. SC does

TABLE III. PARAMETRIC COMPARISON OF SC WITH OTHER SOLUTIONS

	Theft TLRNC	Threat	Security Type	Identify	Fault Location	Identifier	Technique	Data Comm.	Power Req.	Device Components Works	Battery Usage
Non-ABC	X	High	Physical	Manually	X	M	X	X	X	X	X
ABC	X	Med	Physical.	Manually	X	M	X	X	X	X	X
ABC-MC	X	Low	Physical	Manually	X	M	X	X	X	X	X
S/W Sol.	5-20%	High	Physical Cyber	Auto	Nearby	Wifi, GPS	AI, DM, LB	Continues	Always	Always	Max
H/W Sol.	5-20%	High	Physical Cyber	Auto	Nearby	Wifi, GPS	LB	Continues	Always	Always	Max
SG	5-10%	High	Physical Cyber	Auto	Nearby	Wifi, GPS	AI, DM, LB	Continues	Always	Always	Max
SC	0%	Low	Physical	Auto	Exact or Nearby	GPS	Voltage Drop	On Event	Always	On Event	Min

not concern with how much power is supplied, how much load is experiencing due to consumption at user-end and regardless any technique to measure the supply and load factor, but deals with the security of supply, monitoring and instantaneous identification of any illegal or natural interruption. Thus, SC works seamlessly with both kind of infrastructure, also can aid in to enhance the Smart Grid (SG) transmission and distribution security.

*G. Supply Distribution To End-Users' Meter Monitoring.*

SC can be installed as overhead distribution cable and the low voltage supply cable to monitor any sort of illegal interference between the house/building unit and consumer meter which helps in identifying specific customer behavior and charge a penalty to concern user only instead of distributing the penalty among all users of the area. For example, the local electricity distribution authorities, every year, lots of cases appeared of false billing, overcharged bills and charged a penalty to the wrong consumer. By implementing the SC, it prevents the false billing error; people who do not have electricity supply connection never be a charge overcharged bills; the user cannot refute consumption as is only charged as much the user utilized and implies penalty to the only specific user.

*H. Parametric Comparison With Other Existing Solutions*

The worth of SC implementation also compared with the other standing solutions in terms of their physical and cyber security, illegal and irregular behavior identification techniques, battery utilization, etc. This comparative study involved the bare aluminum/copper cable (non-ABC), Ariel Bunded Cable (ABC), ABC Multicore or multi-insulated cables, hardware and software based solution, Smart Grid (SG).

The following Table 3, presents the parametric comparison. Where, it is clearly seen that the theft tolerance level of all other solutions ranges from minimum 5% to 20% or maximum to 25% supply theft, SC does not tolerate any supply theft in transmission. Security, the most considerable

factor of the proposed solution, as Table 3 shows other solutions have to experience both (physical and cyber) threats which cannot be easily or instantaneously identified on breaching security unless it reaches the tolerance threshold while the SC has only possessing physical threats which are also promptly identified the physical damage or disruption to prevent the loss of electricity supply. Similarly, while other solutions using artificial intelligence (AI), data mining (DM), load balancing (LB), user profiling (UP), etc which must require to exceed the threshold limit to respond. SC uses the simplest computational logic which continuously monitors signals to determine that either is high or low. At any instance and by any mean, if the signal is low, it will respond to the operation center for irregular behavior. Another critical factor is battery utilization, where every solution keeps alive all time and consumes maximum battery life which minimizes the operation time, while the proposed model requires minimal power and keeps its other components off to save a battery depletion.

*I. Advantages and Features*

- Based on modern advance technology
- Lightweight electronics
- Low energy consumption electronics and sensors
- Reduced manufacturing & low finishing costs
- Reduce the extensive or less material usage
- Bent without breaking
- Adjustable printing to meet requirements
- More security to the transmission line
- Comparatively hard to hack
- End to End communication, iff on an event occurs
- Independent of AI, DM, load balancing and other techniques
- Almost no computational power requires

J. Application

- Detecting NTL in electricity transmission lines
- Ease in Prevent of supply loss and illegal connection
- Detecting cable damage or breaking point
- Detecting faulty device
- Fault location identification.
- Node-wise monitoring and
- Instantaneous notification.

III. RESULT & DISCUSSION

The proposed communication model is simulated and tested between two points/locations; Unit A and Unit B, on following several scenarios and their output shown in Table 4 and 5, while the network diagram of supply distribution is illustrated in following Fig 4. The following two assumptions have been taken and consider that

- The communication or transmission supply is smooth before the point A and after Point B
- There is no voltage drop or weak signals issue in monitoring wires.

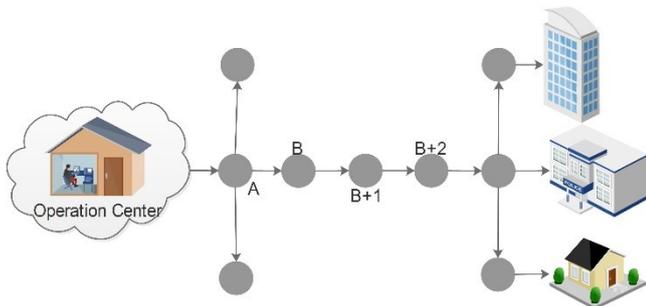


Fig. 4. Distribution network diagram

A. CASE 1 – Normal Transmission

It is a normal case, assume that smart cable is not damaged or the monitoring layer not breached. The GPS device on both sides are not faulty and respond appropriately. So, the high signal of Feedback wire at point/Location B assures that the monitoring layer is not violated. Therefore, supply is consumed legally, no GPS notification or transmission is generated. Whereas, the feedback line status at point A verifies the smooth transmission between point A and its prior points.

B. CASE 2 – External Interference With Both-End Working Device

Fig. 5 is a condition when the monitoring layer of smart cable breached and GPS device on both sides are not faulty and respond appropriately. At Point B, it will receive low signal in its Feedback wire which determines that monitoring layer is damaged. Therefore, illegal activity noticed in supply

transmission or electricity consumption has illegal user connections. GPS notification or transmission is generated at both locations, such as Point A and B.

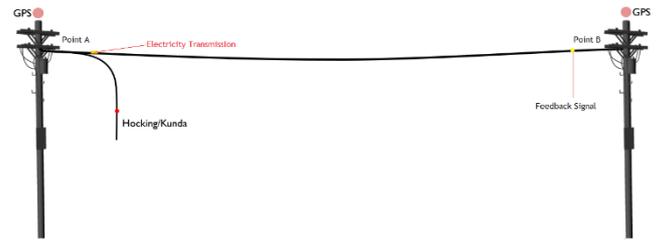


Fig. 5. Electric hocking between any two points

C. CASE 3 – External Interference at The B-End Faulty Device

Fig. 6 depicts the situation when the monitoring layer breached and GPS device at Point B is faulty and not responding. The low signal of Feedback wire at Point B confirms that the monitoring layer is damaged also the non-working GPS device identified near point A. Therefore, illegal activity or damage cable identified in supply transmission. There is no electricity or consumption has illegal user connections. GPS notification or transmission is generated only at point/location A.

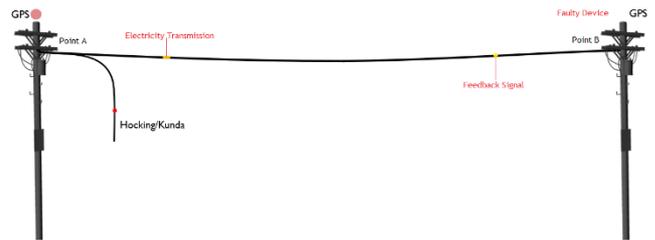


Fig. 6. Identify electric hocking with either hand faulty unit

D. CASE 4 - Faulty Devices Between Hocking Point

Fig. 7 represents the scenario when the monitoring layer breached between the point B and B+1 and found a faulty GPS device at both ends Point B and B+1. The point B+1 will get the low signal upon breaching the monitoring layer that sent the signal to at FBW of point B. As soon unit B identified that its GPS not working. It will send low sing to its previous pole that is point A. Where the FW signal of point A assure that transmission prior to A has no fault but the GPS signal shows that there is a fault in following unit device.

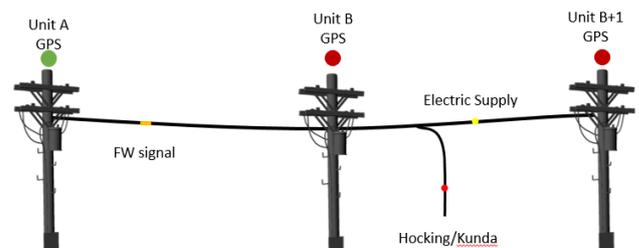


Fig. 7. Identify supply theft when both-ends has a faulty unit

E. CASE 5 – Disaster/External Interference Broken Cable

It is a disaster or a natural incident situation, in which cable accidentally broke. Let's say, cable is broken between the point A and B and the GPS device at point B is not working. As soon as the cable breaks, point B will immediately get no signal which transmits Low signal at FBW to point A and due to the faulty device, GPS signal will not generate. On the other hand, point A will receive no or low signal from point B which identified irregular behavior between A and B and its turn on the GPS that shows the incident location. Whereas, the high FBW signals of the following units of B indicate that cable is secure while the chain has to experience the supply cut off.

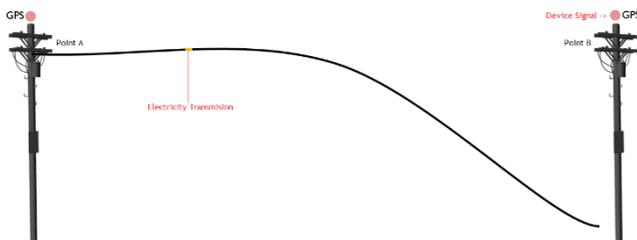


Fig. 8. Identify disaster location in the distribution chain

TABLE IV. SC SIMULATION RESULT IN VARIOUS SCENARIOS

	Unit A		Unit B		Description
	FW	GPS	FW	GPS	
Case 1	1	0	1	0	Legal/Normal supply transmission.
Case 2	1	1	0	1	Fault detected between A & B
Case 3	1	1	0	0	Fault between A, B and faulty GPS detect at point B
Case 4	1	1	0	0	Fault b/w B, B+1 with faulty GPS at both ends, see Table 5
Case 5	1	1	0	0	Broken cord b/w A, B & no faulty GPS, see Table 5

TABLE V. EXPANDED RESULT OF CASE 4 & 5

	Unit A		Unit B		Unit B+1		Unit B+2	
	FW	GPS	FW	GPS	FW	GPS	FW	GPS
Case 4	1	1	0	0	0	0	1	0
Des.	Breaching layer between B & B+1 Where faulty GPS detected at B & B+1. Following chain indicate cut of supply							
Case 5	1	1	0	1	1	0	1	0
Des.	The broken cord between units' A & B While no faulty GPS device detected Following chain indicate cut of supply							

IV. FUTURE WORK

The article presented the initial design and communication model under a couple of assumptions. The model tested in several conditions and a very promising outcome has been achieved. In future, the following topics will be covered as part of the Smart Cable project.

- Testing a smart cable and communication system with all possible conditions and in complex scenarios to determine the system behavior and effect on outcomes.
- Developing smart cable to check its performance with electric supply transmission.
- Selecting suitable printed conductive material for the required distance between two poles.
- Piloting the smart cable test at large or industrial scale.

V. CONCLUSION

This paper proposed the smart cable design and designed the communication model, which does not require any special purpose integrated device, memory or calculating units to identify the supply theft in overhead power distribution lines or a consumer's site. Within the limited resources, we performed the feasibility study to analyze the worth of smart cable. The proposed circuit, then simulated in Matlab Simulink under various practical circumstances, and expected results successfully have been achieved. Also, it has been observed that SC facilitates in identifying exact or the nearest fault location and saving battery power by keeping all unnecessary components powered off. Paper also presents the parametric comparison of SC with standing hardware and software solution, including smart grid. The proposed cable and circuit model, get an advantage over the previous and exiting solutions as it is working independently of Artificial Intelligence, Data Mining, Load Balancing and any prior techniques to identify electricity theft.

REFERENCES

- [1] J. Daniel, "Printed Electronics: Technologies, Challenges, and Applications," Palo Alto Res. Cent., no. Iwfp10, pp. 1–73, 2011.
- [2] K. Ishida et al., "Improvement and applications of large-area flexible electronics with organic transistors," VLSI Circuits Emerg. Appl., no. 2, pp. 95–109, 2014.
- [3] A. E. Ostfeld, A. M. Gaikwad, Y. Khan, and A. C. Arias, "High-performance flexible energy storage and harvesting system for wearable electronics," Nature Publishing Group, 2016.
- [4] B. A. Nathan et al., "Flexible Electronics: The Next Ubiquitous Platform," Proceeding IEEE, vol. 100, pp. 1487–1506, 2012.
- [5] S. Limbu, S. Year, and A. S. Sir, "Applications Of Conducting Polymer In Electronics & Electrochemical Devices."
- [6] DuPont, "DuPont NHFR Polymers for Electrical and Electronic Applications (White Paper)," 2016.
- [7] J. Rasheed Khan, F. Ahmed Siddiqui, and R. Rasheed Khan, "Survey: NTL Detection in Electricity Energy Supply," Int. J. Comput. Appl., vol. 155, no. 9, pp. 975–8887, 2016.
- [8] R. R. Khan, J. R. Khan, and F. A. Siddiqui, "Comprehensive Analysis of Electric Power System: State, Vulnerabilities, Limitations, Consequences and Challenges," Int. J. Eng. Trends Technol., vol. 50, no. 1, pp. 17–25, Aug. 2017.
- [9] J. Nagi, K. S. Yap, S. K. Tiong, S. K. Ahmed, and M. Mohamad, "Nontechnical loss detection for metered customers in power utility using support vector machines," IEEE Trans. Power Deliv., vol. 25, no. 2, pp. 1162–1171, 2010.
- [10] P. Shikalgar, "Power Theft Identification Using Smart Grid Technology," Int. J. Recent Innov. Trends Comput. Commun., no. January, pp. 259–263, 2015.
- [11] P. N. S. Labhde, P. Sunil, B. Gajanan, and V. Ananta, "D

- etection of Power Theft Using ZigBee Technology,” *Detect. Power Th. Using ZigBee Technol.*, vol. 2, no. 1, pp. 121–124, 2016.
- [12] R. Kalaivani, M. Gowthami, S. Savitha, N. Karthick, and S. Mohanvel, “GSM Based Electricity Theft Identification in Distribution Systems,” *Int. J. Eng. Trends Technol.* – Vol. 8 Number, vol. 8, no. 10, pp. 512–516, 2014.
- [13] S. S. S. R. Depuru, L. Wang, V. Devabhaktuni, and R. C. Green, “High performance computing for detection of electricity theft,” *Int. J. Electr. Power Energy Syst.*, vol. 47, no. 1, pp. 21–30, 2013.
- [14] Prachal Jadeja, “Detection and Instantaneous Prevention of Power Theft,” *IOSR J. Electr. Electron. Eng.*, vol. 10, no. 1, pp. 01–03, 2015.
- [15] D. Dangar and S. K. Joshi, “Electricity Theft Detection Techniques for Distribution System in GUVNL,” *Int. J. Eng. Dev. Res.*, no. January, pp. 11–18, 2014.
- [16] S. S. S. R. Depuru, L. Wang, and V. Devabhaktuni, “Electricity theft: Overview, issues, prevention and a smart meter based approach to control theft,” *Energy Policy*, vol. 39, no. 2, pp. 1007–1015, 2011.
- [17] A. Khan et al., “WIRELESS ELECTRICITY THEFT DETECTION,” *Int. J. Adv. Res. Electron. Commun. Eng.*, vol. 5, no. 4, pp. 994–998, 2016.
- [18] P. Jumale, A. Khaire, H. Jadhawar, and S. Awathare, “Survey: Electricity Theft Detection Technique,” *Int. J. Comput. Eng. Inf. Technol.*, vol. 8, no. 2, pp. 30–35, 2016.
- [19] J. Nagi, K. S. Yap, S. K. Tiong, S. K. Ahmed, and A. M. Mohammad, “Detection of abnormalities and electricity theft using genetic support vector machines,” *IEEE Reg. 10 Annu. Int. Conf. Proceedings/TENCON*, no. October 2016, 2008.
- [20] A. Komajwar, D. Singh, and M. Singh, “Wireless Power Theft Monitoring System In Energy Meter,” *Int. J. Sci. Res.*, no. April, pp. 10–11, 2015.
- [21] J. E. Cabral, J. Pinto, and A. M. A. C. Pinto, “Fraud Detection System for High and Low Voltage Electricity Consumers Based on Data Mining,” in *General Meeting of the IEEE Power and Energy Society*, 2009.
- [22] P. Glauner, A. Boechat, L. Dolberg, R. State, F. Bettinger, and Y. Rangoni, “Large-Scale Detection of Non-Technical Losses in Imbalanced Data Sets Large-Scale Detection of Non-Technical Losses in Imbalanced Data Sets,” no. September, 2016.
- [23] J. I. Guerrero, Í. Monedero, F. Biscarri, J. Biscarri, R. Millán, and C. León, “Detection of non-technical losses: The project Advances in Secure Computing, Internet Services, and Applications,” in *Advances in Information Security, Privacy, and Ethics (AISPE)*, no. December, Information Science Reference (an imprint of IGI Global), 2013, pp. 140–164.
- [24] A. Barbero et al., “Development of Adapted Ammeter for Fraud Detection in Low-Voltage Installations,” *Measurement*, vol. 56, pp. 1–7, 2014.
- [25] C. Muniz, M. Vellasco, R. Tanscheit, and K. Figueiredo, “A neuro-fuzzy system for fraud detection in electricity distribution,” 2009 *Int. Fuzzy Syst. Assoc. World Congr. 2009 Eur. Soc. Fuzzy Log. Technol. Conf. IFSA-EUSFLAT 2009 - Proc.*, no. February 2016, pp. 1096–1101, 2009.
- [26] C. C. O. Ramos, A. N. de Souza, D. S. Gastaldello, and J. P. Papa, “Identification and feature selection of non-technical losses for industrial consumers using the software WEKA,” in *2012 10th IEEE/IAS International Conference on Industry Applications*, 2012, pp. 1–6.
- [27] S. Sahoo, D. Nikovski, T. Muso, and K. Tsuru, “Electricity theft detection using smart meter data,” in *2015 IEEE Power & Energy Society Innovative Smart Grid Technologies Conference (ISGT)*, 2015, pp. 1–5.
- [28] C. C. O. Ramos, A. N. Souza, J. P. Papa, and A. X. Falcão, “Fast non-technical losses identification through Optimum-Path Forest,” 2009 *15th Int. Conf. Intell. Syst. Appl. to Power Syst. ISAP '09*, no. July 2015, 2009.
- [29] W. S. Wong and A. Salleo, *Flexible Electronics: Materials and Applications*. Springer, 2009.
- [30] N. D. Sankir, “FLEXIBLE ELECTRONICS: MATERIALS and DEVICE,” *Spectroscopy*, p. 157, 2005.
- [31] T. Thyagarajan, *Engineering Basics: Electrical, Electronics and Computer Engineering*, 3rd ed. New Age International, 2007.
- [32] “Voltage Classification - LV, MV and EHV.” [Online]. Available: <http://www.electrotechnik.net/2011/03/voltage-classification-lv-mv-and-ehv.html>. [Accessed: 20-Jun-2017].
- [33] “Cables Classification According to Operating Voltage - Electrical Engineering Updates.” [Online]. Available: <http://electricalupdates1.blogspot.com/2017/05/cables-classification-according-to.html>. [Accessed: 20-Jun-2017].
- [34] “Power Distribution Cable – DNO Power Network Cable | Eland Cables.” [Online]. Available: <http://www.elandcables.com/electrical-cable-and-accessories/cables-by-type/power-network-local-distribution-cable>. [Accessed: 17-Jun-2017].
- [35] “Products | Newage Cables.” [Online]. Available: <http://www.newagecables.com/main-page/products/>. [Accessed: 17-Jun-2017].
- [36] “JIANGYANG Cable | Power Cable, China Cable Manufacturer.” [Online]. Available: <http://jiangyangcables.com/>. [Accessed: 17-Jun-2017].
- [37] “Distribution.” [Online]. Available: <http://www.southwire.com/Distribution.htm>. [Accessed: 17-Jun-2017].

# Biosensor Interfacing: A Generic Architecture

Tariq Javid, Abdul Basit, Hina Iftikhar and Tayyaba Khalid  
*Department of Biomedical Engineering*  
*Hamdard University*  
 Karachi, Pakistan  
 {tariq.javid,m.basit,hina.iftikhar,  
 tayyaba.khalid}@hamdard.edu.pk

Syma Ghyas  
*Faculty of Eastern Medicine*  
*Hamdard University*  
 Karachi, Pakistan  
 symaghayas@gmail.com

**Abstract**— The discipline of sensing and measuring vital signs of human body with the help of biosensors has a great impact on emerging technologies in biological sciences and biomedical engineering. This paper introduces a generic sensor data acquisition, computational, and visualization architecture for biosensor interfacing. The components of proposed generic architecture are biosensors, adjustable signal conditioning block, microcontroller-based data acquisition unit, Raspberry Pi based computational platform, and visualization device. Through our generic architecture, engineers and medical professionals can easily monitor the vital signs and in some cases, can diagnose the condition of the patient in real-time. Biosensor interfacing establishes a connection between the real-world subject that is human body and the sensor in order to provide important information about vital signs including body temperature, pulse rate, respiration rate or rate of breathing, and in some cases blood pressure.

**Keywords**—Architecture, biosensor, microcontrollers, vital signs.

## I. INTRODUCTION

In the modern technology era of biomedical engineering and medical sciences, numerous innovations are emerging as the result of efforts by scientists and researchers. These inventions are life changer for the human society. Vital signs of human body are important signs of life that should remain within normal ranges to enjoy healthier and happier life. If these vital signs show any symptoms of irregularity for example in heart rhythm, breathing rate, blood pressure or human body temperature, then these minor symptoms can develop as life threatening situation. Therefore, for check-and balance mechanism, many biosensors-based vital sign monitoring devices are available, and many are still in experimental and research phases for more advancement and with more features. These biosensors-based devices may be quantitative based or qualitative based. Biosensors are the transducers that convert biological responses and biological signals into electrical signals or electrical voltages. The purpose of the proposed generic architecture in this project is to interface biosensors with a microcontroller-based Data Acquisition Unit (DAU) in order to acquire and subsequently visualize the information by a computational platform.

The generic architecture developed in this work relates to assistive technology for Eastern Medicine practitioners for diagnosis of diseases through human wrist palpation. In this work, the proposed generic biosensor interface architecture is implemented using human body temperature biosensor. Usually, a signal conditioning stage is introduced between sensor and the digitization platform to filter noise and adjust input electric signal levels. Since the temperature sensor is a

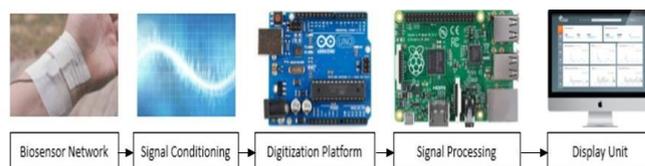


Fig. 1. Block diagram of proposed generic biosensor interface architecture.

specialized biosensor designed for the measurement of human body and the output of this sensor does not need to pass through signal conditioning block. So, after passing through the digitization platform it passes to signal processing unit and finally, the information is passed to the display unit. The layout of this paper is as follows. A brief review on related research is presented in Section II. Sections III and IV describe the proposed generic biosensor interface architecture and its implementation as a computer simulation, respectively. The paper concludes in Section V with future work directions.

## II. BRIEF LITERATURE REVIEW

Biosensors are specialized sensors that record biological responses in the form of electrical signals. These sensors are especially designed with improve specifications and accuracies that can easily measure and observe the desired biological signals.

Biosensors are described in detail with applications in biomedical engineering and material sciences in [1]. These biosensors are highly specific to use cases. They should be independent of other parameters to avoid interfere in measuring signals. The field of biosensors was started by the efforts of Leland C. Clarkin 1962 when he utilized platinum anode to test a sample in order to distinguish O<sub>2</sub> [2], [3]. With the passage of time, different types of biosensors are used in the medical domain. Examples of biosensors include enzyme-based, DNA, piezoelectric and thermal, tissue-based, and immuno sensors. The factors that help us to understand the importance of biosensors in our daily lives and engineering fields are described in detail in [3]. These factors include biosensor design, advantages, detection method, application, types, and advancements. Due to the importance of biosensors, many research groups have made remarkable achievements in making biosensor-based gadgets [4].

Biosensor-based gadgets are expository gadgets that change organic reactions to electrical voltages or signals. Some biosensor gadgets have receptor-transducer incorporated that give or provide quantitative or semi-quantitative diagnostic data by utilizing its highly specific component [5]. Recent and quick developments in

biomaterials, biosensors are also playing an important role in utilization and accessibility of polymers and copolymers [6]. Late advances in small-scale sensors and nanosensors have promoted nanotechnology that posed challenges to researchers and inventors to interface these sensors in order to solve many problems in the Biomedical Engineering discipline.

In [7], a generic architecture of biomedical embedded system was developed by using magnetoresistive sensors. Piezoelectric transducers were used to detect human wrist palpation in [8]. A pulse based sensor using board mount pressure was developed in [9]. The architecture developed in this work is used for Eastern Medicine Practitioners and also it has flexibility to implement different algorithms for data analysis. Biosensors like Melexis MLX90614 single and dual zone infrared thermometer and CM-01B contact microphone [10], [11] specify typical interfaces in line with the applications and do not specify any generic interface circuitry. Our work develops a generic interface architecture for these types of biosensors.

### III. SUBSYSTEMS OF BIOSENSORS INTERFACING ARCHITECTURE

The work in this project mainly consists of two subsections. First, we explain the general block diagram of our proposed architecture and then we present simulation of the proposed architecture with the help of a temperature sensor.

#### A. General Block Diagram Section of Proposed Work

In this study, the sensor used for demonstration purpose is Melexis MLX90614, which is a temperature sensor. This sensor is used to sense the human body temperature without touching the body surface. After the further processing the output of this temperature will be displayed on visualization device. The temperature results are displayed in both Celsius and Fahrenheit scales. The block diagram of the proposed work is shown in Fig. 1. This diagram represents the general overview of proposed biosensor interfacing architecture which contains a biosensor, a sophisticated signal conditioning block, data acquisition unit, flexible computational unit and a visualization device.

1) *Sensor*: A sensor is used to measure the systems function, study its characteristics, then collects information and stores it in the desirable form. A sensor is a term generally used to sense the input which is usually a physical quantity, and then convert it into a suitable signal for processing. There are many wide varieties of the sensor that are performing different functions. But the sensor we are using in this paper is the Melexis MLX90614.

The Melexis MLX90614 is an infrared thermometer for measuring the human body temperature. This temperature sensor uses the infrared light which strikes out to the target objects and reflects back containing the desired information about the body temperature. This shows that the sensor can sense the temperature without touching the subject. The sensor internally comprises of 17-bit ADC, and in order to achieve a high accuracy and resolution, a custom digital signal processing (DSP) chip is incorporated in the sensor. The sensor consists of four pins configuration which are serial clock (SCL), serial data (SDA), power supply (VSS) and ground (GND). The SCL pin is a digital input pin which

serves as a clock for communication with Arduino, whereas DA has digital input and output pins that measure the temperature and send it to the SDA pin of Arduino.

2) *Signal conditioning block*: Most of the measurements such as temperature which are recorded from the sensor also require some signal processing. For accuracy and efficiency of these signals, it is necessary to carry out the signal processing for reliable data acquisition. The signal conditioning block consists of the following components which include, signal amplification, filtering, interfacing with microcontroller etc.

3) *Digitization Platform*: In our work, we have used Arduino UNO to convert the analog signal being received from the sensor into digital signal. The digitized signal is then sent to Raspberry Pi for signal processing to get controlled and accurate result.

4) *Signal Processing*: In order to implement advanced signal processing algorithms and perform statistical analysis, Raspberry Pi 3 is used as signal processing unit. Raspberry Pi 3 takes preprocessed signal from digitization unit and sends information to visual display after performing desired mathematical operations.

5) *Visualization Device*: The visualization device helps in viewing the results on the computer screen in the form of graph or table.

### IV. IMPLEMENTATION OF BIOSENSOR INTERFACING

The temperature sensor MLX-90614, being an infrared temperature sensor transmits the IR light to the subject (human body) and receives the backscattered light to measure the temperature. Since the sensor has built-in chip for conditioning the signal that processes the output of IR sensor. Hence, a separate signal conditioning unit is not required, and a direct connection is established between the biosensor and Arduino through inter-integrated circuit (I<sup>2</sup>C). This takes place through the serial pins i.e. SDA and SCL pins. Whenever I<sup>2</sup>C is used, the devices act as a master or a slave. Arduino is used as master which starts the transfer, i.e., clock synchronization. The sensor is working as a slave, so whenever the master (Arduino) wants to know the temperature the clock of master device (SCL) synchronizes with the clock of the slave (sensor). The sensor receives the commands as well as sends information to master through its SDA pin. When the master sends command to the slave device, it starts receiving the temperature from required object. As the output signal of temperature sensor is in analog form therefore we converted that signal into digital form by using Arduino. Once the signal is converted into digital signal, it has to pass through different signal processing techniques. For this, the digitized signal is forwarded to Raspberry Pi for signal processing through serial communication. After performing serial to parallel conversion and storing of biosensor data, multiple advanced level mathematical operations can be performed. These results can be visualized with the help of a visualization device as shown in Fig. 2.

### V. CONCLUSION

In this paper, a generic biosensor interfacing architecture has been developed and implemented successfully through the simulation software. The initial implementation focused

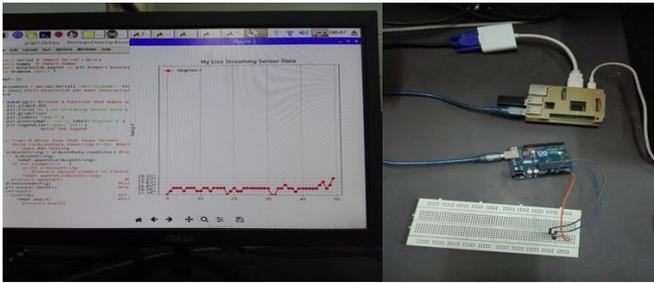


Fig. 2. Complete setup of biosensor interfacing architecture.

on biosensor interfacing for human body temperature measurements. The developed architecture is capable of displaying both basic and advanced results flexible computational unit. The future direction of our work is to use more biosensors such as piezoelectric-based for the measurement of pressure force developed by the blood flow in the human body.

#### REFERENCES

- [1] P. Mehrotra, "Biosensors and their applications—a review," *Journal of oral biology and craniofacial research*, vol. 6, no. 2, pp. 153–159, 2016.
- [2] S. Robertson, "What are biosensors?" 2014. [Online]. Available: <https://www.news-medical.net/health/What-are-Biosensors.aspx>
- [3] A. K. S., "Biosensors," *American Journal of Biomedical Engineering*, vol. 6, no. 6, pp. 170–179, 2016.
- [4] K. E. Mohanty, S. P., "Biosensors: a tutorial review," *IEEE Potentials*, pp. 35–40, 2006.
- [5] H. N. S. M. C. D.-M. J.G. Pacheco, M.F. Barroso, "Biosensors, in current developments in biotechnology and bioengineering," pp. 627–648, 2017.
- [6] W. G. Y. Y. Zhang, S., "Materials and techniques for electrochemical biosensor design and construction," vol. 15, no. 56, pp. 273–282, 2000.
- [7] L. Sousa, M. Piedade, J. Germano, T. Almeida, P. Lopes, F. Cardoso, and P. Freitas, "Generic architecture designed for biomedical embedded systems," pp. 353–362, 2007.
- [8] A. Kalange and S. Gangal, "Piezoelectric sensor for human pulse detection," *Defence science journal*, vol. 57, no. 1, p. 109, 2007.
- [9] K. Goyal and R. Agarwal, "Pulse based sensor design for wrist pulse signal analysis and health diagnosis," 2017.
- [10] (2014) Melexis mlx90614 non-contact sensors data manual.
- [11] (2017) Contact microphone cm-01b data manual.

**Complexity Analysis of Swarm & Evolutionary Based MUD using Synchronous MC-CDMA System**

<sup>1</sup>Faryal Batool, <sup>2</sup>Muhammad Adnan Khan, <sup>3</sup>Sagheer Abbas, <sup>4</sup>Muhammad Saleem, <sup>5</sup>Zohair Durrani

<sup>1,2,3,4,5</sup>Department of Computer Science

National College Business Administration & Economics

Lahore, Pakistan

<sup>1</sup>[faryalb@hotmail.com](mailto:faryalb@hotmail.com), <sup>2</sup>[madnankhan@ncbae.edu.pk](mailto:madnankhan@ncbae.edu.pk), <sup>3</sup>[dr.sagheer@ncbae.edu.pk](mailto:dr.sagheer@ncbae.edu.pk),

<sup>4</sup>[saleemakhtar7369@gmail.com](mailto:saleemakhtar7369@gmail.com), <sup>5</sup>[zohair\\_16@hotmail.com](mailto:zohair_16@hotmail.com)

**Abstract— High data rate is now days, mostly the main requirement of upcoming era in networks. Multi Carrier techniques like (MC-CDMA) Multi-Carrier Code Division Multiple Access, has one of the candidate solutions which can fulfil the requirements of high data rate. Multi User Detection (MUD) is core factor of wireless communication system. Evolutionary and Swarm techniques are preferable to be used for MUD to improve the system performance like Bit Error Rate (BER) and Minimum Mean Square Error (MMSE). When both techniques give same performance in terms of BER/MMSE after the fix number of cycles, then the Complexity plays a vital role for the selection of the best solution. In this article, Complexity analysis of Genetic Algorithm (GA) & Particle Swarm Optimization (PSO) are used for (MUD) which is Multi User Detection for Synchronous MC-CDMA technique. It is observed that in case of Bounded BER and MMSE Time Complexity of the Swarm (PSO) based MUD is better than Evolutionary (GA) based MUD for MC-CDMA synchronous procedure. But in case of memory complexity of Evolutionary based solution is more efficient as compared to Swarm based solution. It also observed that Complexity (time & memory) are directly proportional to number of users. This is verified mathematically as well as via simulation using MATLAB 2017.**

**Keywords—MUD; MC-CDMA; Synchronous Time Complexity; Synchronous Memory Complexity; MMSE; Drift Analysis**

### **Introduction**

Code division multiple access (CDMA) is an intense balance procedure which has the upsides of high recurrence proficiency, little back-offs in the transmitter intensifier and capability of hostile to meddle et al, so it is ending up increasingly critical for current remote interchanges. Be that as it may, the multiple access interference (MAI) is the constraining component of CDMA frameworks, which may cause the close far impact, so multiuser detection (MUD) have been proposed to wipe out the issue of MAI. The ideal MUD proposed in can expel the MAI and in addition the close far impact totally and augment the framework's ability, yet the computational unpredictability of the ideal MUD develops exponentially with the quantity of clients which prompts the impracticability. At that point, numerous imperfect and substitute MUDs are

delivered going for accomplishing the best execution to many-sided quality tradeoff.

Step by step number of clients is expanding with the request of high information rates. Multicarrier systems like Multicarrier-Direct Sequence-Code Division Multiple Access, alternately checking the Orthogonal Frequency Division Multiple Access (OFDMA), along with the MC-CDMA and so forth are utilized to suit a substantial number of clients. Each client needs high information rates MIMO frameworks with MC-CDMA framework are considered to be the proposed applicant answers for satisfy the requirement for high information rates [1,2]. In MIMO the framework differs from transmission radio wires and different synchronous recipient receiving wires are utilization [3,4,5].

Evolutionary and swarm techniques are the types of GA and PSO Based MUD using Synchronous MC-CDMA System. PSO is by and large new formative enlisting procedure proposed in 1995. Starting now and into the foreseeable future, it has been a domain of amazing enthusiasm for the authorities. One can see the amount of varieties proposed up until this point. MUD for MC-CDMA system has been performed using PSO [6,7,8,9]. At to begin with, the response for the multi-client issue was given by Verdu, who proposed the perfect finder [6]. In any case, its computational need to raise arithmetically with the quantity of customers in the system and is excessively immense, making it impossible to ever be used in every practical sense. A while later, different imperfect plans were given to reduce the computational cost. Among various tricky game plans, PSO has a place with the gathering of transformative figuring. In this paper, PSO and its proposed variety have been used for MUD. The issue has been tended to for both synchronous and non-concurrent condition over Rayleigh level obscuring channel. The proposed variety, named as delicate PSO, has given results far better than that of the parallel PSO [10,11]. Extended commence limits (RBF) ought to be amazing for configuration gathering. Another point of view of MUD could be a case portrayal issue. Along these lines the other duty of work is the PSO helped Radial Basis limits which have been utilized for MUD of synchronous Direct Sequence CDMA (DS-SS-CDMA) structure over through (AWGN) Additive White Gaussian Noise channel. Over again, combined and delicate PSO have been utilized and their execution relationship is given in the reproductions.

(BER) Bit Error Rate (MSE) Mean Squared Error & same, complexity plays an important role. Time and space Complexity assumes an imperative part in the assessment of the impact connection. There are distinctive unpredictability examination frameworks, where Swarm based algorithm is. In this article, Complexity Analysis of Swarm & Evolutionary Based MUD using Synchronous MC-CDMA System is performed with different number of users & number of cycles

I. SYSTEM MODEL

$n_k \in \{1, -1\}$  is spreading in parallel on A spreading the signature, which is represented by  $\pi_k^{(a)}(h)$   $a=1,2,\dots,k$ . Whereas  $h$  represents the chip interval. The subcarrier is given

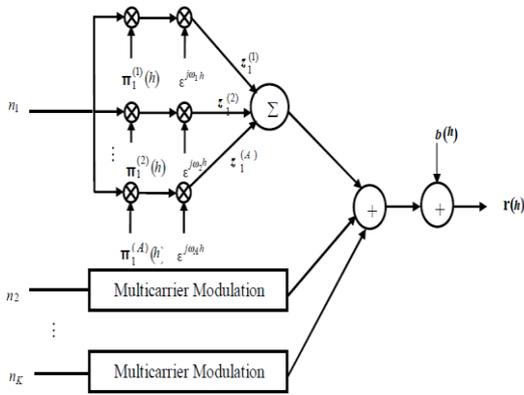


Fig.1: MC-CDMA Transmitter

Fig.1: MC-CDMA Transmitter

as  $\epsilon^{j\omega_a t}$ .

In here  $z_k^{(a)}$  receiver signal of the  $a^{th}$  user and it can be narrated as

$$z_k^{(a)}(h) = \alpha_k \pi_k^{(a)}(h) n_k \epsilon^{j\omega_a h} \quad (1)$$

$$z^{(a)}(h) = \sum_{k=1}^k \alpha_k \pi_k^{(a)}(h) n_k \epsilon^{j\omega_a h} \quad (2)$$

the Rayleigh distribution channel  $\phi_a$  has smooth circulation over pause. The sub-carrier is given as below

$$s_a(h) = \sum_{k=1}^k \alpha_k \pi_k^{(a)}(h) n_k c^{(a)} \epsilon^{j(\omega_a t + \phi_a)} + b^{(a)}(h) \quad (3)$$

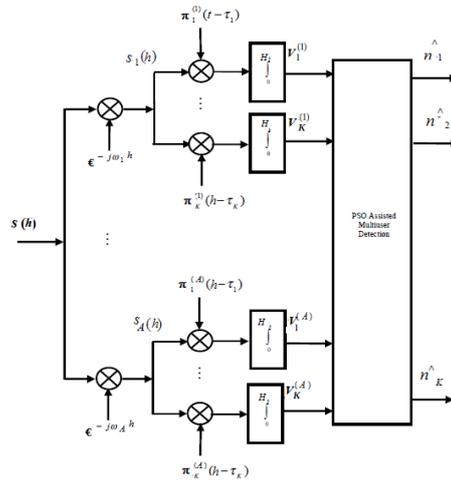


Fig.2: MC-CDMA Receiver

The receptionist standard is shown in the Fig 1 above. The greater motion treats the shipper base at the receiver's end.

Filtering  $f_g^{(a)}(h)$  we get the following

$$v_i^{(a)} = \int_0^A s_{(a)}'(h) \pi_i^{(a)} dh = \sum_{k=1}^k \alpha_k n_k p_{ik}^{(a)} c^{(a)} \epsilon^{i\phi_{(a)}} + s_i^{(a)} \quad (4)$$

Where  $s_{(a)}$  is de-modulation of  $s_a(h)$ . We can write it in matrix form as follows.

$$v^{(a)}(j) = [v_1^{(a)}(j) v_2^{(a)}(j) \dots v_k^{(a)}(j)] \quad (5)$$

$$v_{(a)} = R^{(a)} D^{(a)} \alpha_n + s_a \quad (6)$$

Where

$$D^{(a)} = c_a \epsilon^{i\phi_{(a)}} \quad (7)$$

For the optimum MUD in MC-CDMA, the independent task is greater and is shown

Thus, there are  $2^k$  is the maximum combination of "c" through which the user has to be chosen

$$\sum_{a=1}^a \{ R_e [ \alpha_n^h D^{(a)} v^{(a)} ] - \alpha_n^h D^{(a)} R^{(a)} D^{(a)} \alpha_n \} \quad (8)$$

$$C_{opt} = \text{agr} \{ \text{top}_c [ Y(C) ] \} \quad (9)$$

in here to we want to maximize the above equation. In this article PSO and GA is used for MUD. The complexity analysis is performed in synchronous MC-CDMA.

**Complexity Analysis of Evolutionary based MUD using Synchronous. MC-CDMA:**

GA is the Evolutionary Technique and in this article, the Complexity analysis of GA based MUD using MC-CDMA with detailed flow chart is given in fig 3.

**Time complexity of GA synchronous. MUD using MC-CDMA:**

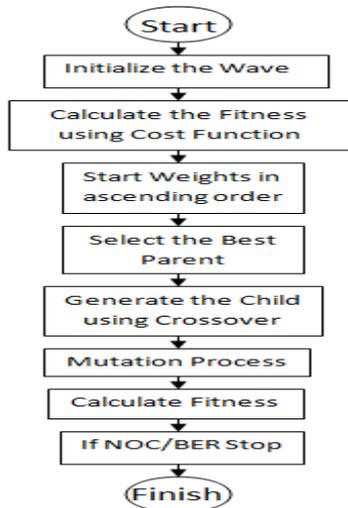


Fig.3: Flowchart of Genetic Algorithm

In this section Time & memory complexity of the GA based Mc-CDMA is calculated in different steps

**Time Complexity of GA based Solution**

Step 2:

Initialize the wave

$$A_1 = \sum_{x=1}^U \sum_{y=1}^V (1) = \sum_{x=1}^U V = UV(10)$$

Step:3:

Calculate the fitness using cost function

$$A_2 = \sum_{y=1}^V (1) = V(11)$$

Step:4:

Merge Sort: In step 4 population fitness is calculated and sorted using merge sort.

$$P_{(U, V)} = read(); (12)$$

$$A_{(V)} = 2 A \left( \frac{V}{2} \right) + V(13)$$

Putting the value of  $U = \frac{U}{2}$

$$4 A \left( \frac{V}{2} \right) + 2 V(14)$$

Similarly,

$$8 A \left( \frac{V}{8} \right) + 3 V(15)$$

$$2^3 A \left( \frac{V}{2^3} \right) + 3 V(16)$$

$$A_4 = 2^q (A) \left( \frac{V}{2^q} \right) + \ln(17)$$

Assume

$$2^q = V(18)$$

Taking log on both sides

$$\log 2^q = \log V(19)$$

$$V + V \log_2^V(20)$$

Here  $V = U$

$$A_4(V, U) = VU + VU \log_2^U(21)$$

Step 5

$$A_5 = C$$

Step 6:

$$A_6 = BU$$

Step 7

$$A_7 = C$$

Step 8

$$A_8 = B$$

Overall complexity:

$$A_{(U, V, B, C)} = UV + V + UV + UV \log_2^U + C + BU + C + B(22)$$

$$A_{(U, V, B, C)} = (UV(1 + \log_2^U + V + B(1 + U) + 2C))Nc(23)$$

above eq. 23 shows the total time complexity of GA based MUD Synchronous using MC-CDMA Technique.

**Memory Complexity of Evolutionary Based MC-CDMA System:**

$$Mc = 2UV + C$$

above equation shows the memory complexity of the Evolutionary (GA) synchronous MUD using MC-CDMA. It is clearly shown that memory complexity depends upon the number of users' u and v.

**Complexity Particle Swarm Optimization Assisted MUD for Synchronous MC-CDMA**

PSO accept that every conceivable result is particle in the swarm. The  $j^i$  particle or solution is written as

$$a_i = [a_{i1} a_{i2} \dots a_{ip} \dots a_{jq}]$$

Where  $Q$  is the amount of client and  $a_{jp}$  is the location where  $p^j$  user on  $j$  particle. Each particle position  $a_{jp}$  has a corresponding velocity  $V_{\zeta}$ .

**Time complexity of PSO synchronous. MUD using MC-CDMA:**

PSO is the Swarm Analysis Technique and in this article, the Complexity analysis of PSO based MUD using MC-CDMA with detailed flow chart is given in fig 4.

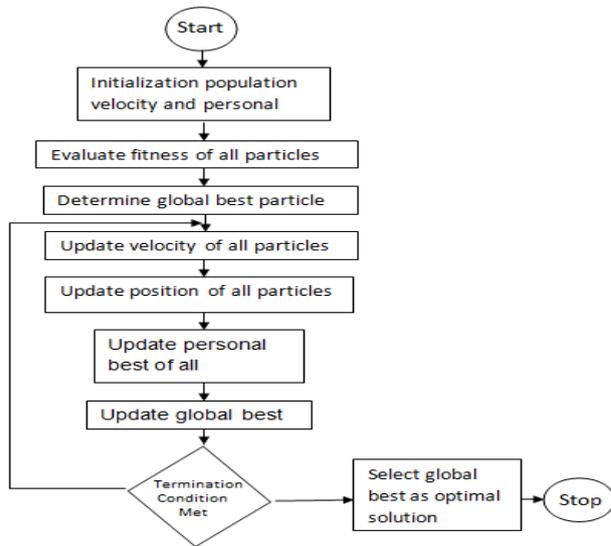


Fig.4 Flowchart of PSO Algorithm

**Complexity Analysis of PSO Algorithm:**

In this section, Complexity of both solutions is calculated regarding time and memory.

**Time Complexity of PSO Based MC-CDMA System:**

Step 1:

Here Complexity of initialization of data population:

$$A_1 = \sum_{x=1}^R 1 = R$$

$$A_2 = \sum_{y=1}^S A_1 = \zeta \sum_{y=1}^R R = \zeta RS \zeta$$

Complexity of initialization of data velocity will be same as that of initialization of data population as above

$$A_3 = RS$$

Step 2:

In step 2 population fitness is calculated and sorted using merge sort as above.

$$A_4(V, U) = g + V \log V$$

Step 3:

As total particle size is  $a$ , so the complexity to find global best particle for data population is  $a$ .

$$A_5 = C$$

Step 4:

Apprise the speed of all particles.

$$A_6 = R\zeta$$

Step 5:

Renew the location of particles.

$$A_7 = R\zeta$$

Step 6:

Update personal best for all particles

$$A_8 = C$$

Step 7:

Update global best for all particles

$$A_9 = C$$

Total Complexity:

$$TC_A = A_1 + A_2 + A_3 + A_4 + A_5 + A_6 + A_7 + A_8 + A_9$$

$$TC_A = R + RS + RS + g + V \log V + C + RS + RS + C + \zeta C$$

$$TC_A = (R + 4RS + g + V \log V + 3C) * Nc$$

**Memory Complexity of Swarm Based MC-CDMA System:**

$$MC = 2RS + C$$

**Simulation AND Results**

The Complexity of the PSO-GA based MC-CDMA system is implemented with, number of users ( $U/R$ ), and number of cycles (Ncc). Here, we have taken  $U$  for GA user and  $R$  for PSO users.

In Fig 5&6 shows Time Complexity (TC) of swarm and evolutionary based MUD MC-CDMA System regarding NoC,  $U/R$ . And Figure 5&6 represents the Memory Complexity (MC) of PSO-GA based synchronous MC-CDMA System

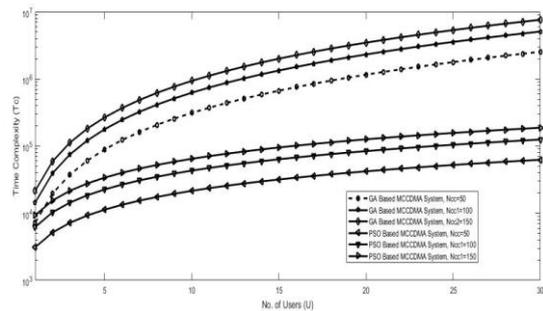
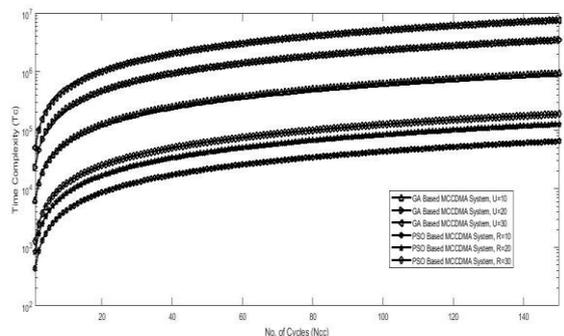


Fig 5 Time Complexity of PSO & GA based MC-CDMA

Fig 5 shows the time complexity of PSO-GA based MC-CDMA relation with respect to different number of clients. It is clearly shown that when the number of consumers and number of cycles (NoC) are improved, then time complexity also increases. It further indicates that time



complexity in proposed PSO based MC-CDMA is less as compared to GA based MC-CDMA system

Fig. 6 Time Complexity vs Users (U/R) with different Number of Cycles (NoC)

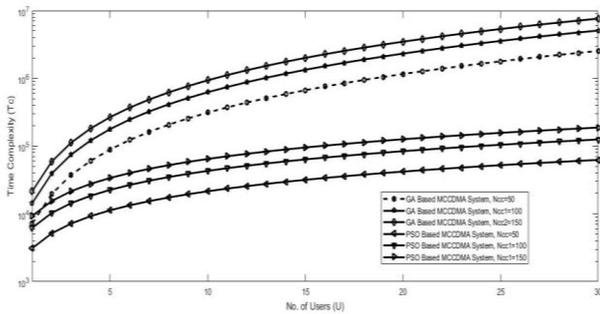


Fig. 7 Time Complexity vs Number of Cycles (NoC) with different Users (U/R)

Fig 7 shows the time complexity of PSO based MUD MC-CDMA system relation with regard to different Number of Cycles (Ncc). It is clearly shown that when the client's number and number of series are increased, with it time complexity is also increased. It further indicates that time complexity of the proposed PSO established MC-CDMA is less as compared to GA based MC-CDMA system.

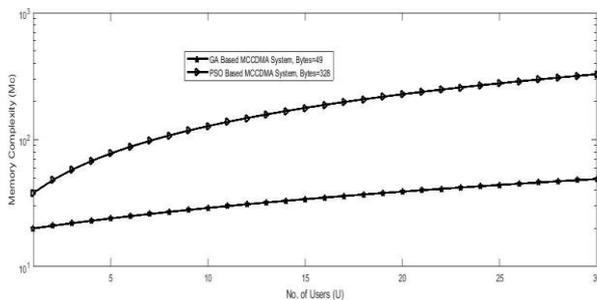


Fig. 8 Memory Complexity (Mc) vs number of users

Fig 8 shows the memory complexity vs Number of Users. It's clearly shows that memory complexity of Evolutionary with different number of users is less as compared to Swarm based MC-CDMA system.

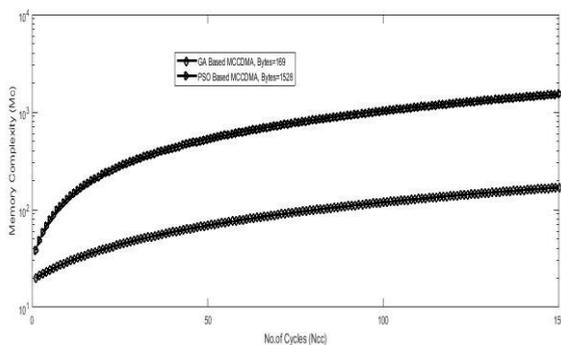


Fig. 9 Memory Complexity (Mc) vs Number of Cycles (NoC)

Fig 9 shows the memory complexity vs Number of Cycles (NoC). It's clearly shows that memory complexity of GA with different number of cycles is less as compared to PSO based MC-CDMA system.

**Conclusion**

Population based Drift Analysis is used to calculate the Time Complexity of the swarm as well as evolutionary based MUD for synchronous MC-CDMA. It is observed that in case of Bounded BER and MMSE, the time complexity of swarm (PSO) is less as compared to GA based MC-CDMA synchronous receiver. It also observed that, memory complexity of GA based MC-CDMA system is less as compared to Swarm based PSO system.

**REFERENCES**

1. Kristem, V., Molisch, A. F., & Christen, L. (2018). Jammer Sensing and Performance Analysis of MC-CDMA Ultrawideband Systems in the Presence of a Wideband Jammer. *IEEE Transactions on Wireless Communications*.
2. Khan, M.A., "Multiuser detection using computational intelligence in multicarrier communication system", PhD thesis, ISRA University, Islamabad Campus, Pakistan, 2017.
3. Kapucu, N., M. Bilim, and I. Develi. "Outage performance of cooperative DS-CDMA systems with best path selection over  $\alpha$ - $\eta$ - $\mu$  fading channels." *Electronics Letters* 53, no. 11 (2017): 752-754.
4. Peixoto, Antonio Augusto Teixeira, and Carlos Alexandre Rolim Fernandes. "Tensor-Based Multiuser Detection for Uplink DS-CDMA Systems with Cooperative Diversity." *XXXV Simpósio Brasileiro de Telecomunicações e Processamento de Sinais (SBrT 2017), (São Pedro, Brazil)* (2017).
5. Khan. M. A, Umair. M, and Choudry. M.A.S, "Island differential evolution based adaptive receiver for MC-CDMA system." *Information and Communication Technologies (ICICT), 2015 International Conference on. IEEE, 2015.*
6. Zubair, Muhammad, Muhammad Aamer Saleem Choudhry, and Ijaz Mansoor Qureshi. "Multiuser detection using soft particle swarm optimization along with radial basis function." *Turkish Journal of Electrical Engineering & Computer Sciences* 22, no. 6 (2014): 1476-1483.

7. Zubair, M., Saleem, A. M., & Qureshi, M. Q., "Multi-user Detection using Soft Particle Swarm Optimization for Asynchronous MC-CDMA." *International Information Institute (Tokyo) Information* 16, no. 3 (2013): 2093.
8. Zubair, M., Choudhry, M. A., Naveed, A., & Qureshi, I. M. (2008). Particle swarm with soft decision for multiuser detection of synchronous multicarrier CDMA. *IEICE transactions on communications*, 91(5), 1640-1643.
9. Palanki, Ravi. "Frequency hopping design for single carrier FDMA systems." U.S. Patent 8,917,654, issued December 23, 2014.
10. L. Shi and G. Xu., "Self-adaptive evolutionary programming and its application to multi-objective optimal operation of power systems", *International Journal of Electric Power Systems Research*, vol. 57, no.3, pp. 181-187, April 2001.
11. S. Kondo & Milstein, L. B., "Performance of multicarrier CDMA systems," *IEEE Trans. Commun.*, vol. 44, no. 2, pp. 238-246, Feb. 1996.
12. S. Verdu, "Multiuser Detection," *Cambridge Press* 1998.
13. Salz, "Digital transmission over cross-coupled linear channels," *AT&T Tech. J.*, vol. 64, no. 6, pp. 1147-1159, July/Aug. 1985.
14. Ahmed, I & Majunder, SP 2008, "Adaptive resource allocation based on modified genetic algorithm and particle swarm optimization for multiuser OFDM systems", *Proceedings of the international Conference on Electrical and Computer Engineering*, pp. 211-216.
15. J. Namgoong, T. F. Wong, and J. S. Lehnert, "Subspace multiuser detection for multicarrier DS-CDMA," *IEEE Trans. Commun.*, vol. 48, no. 11, pp. 1897-1908, Nov. 2000.
16. S. L. Miller and B. J. Rainbolt, "MMSE Detection of Multicarrier CDMA," *IEEE Journal on Selected Areas in Communications*, vol. 18, pp.2356-2362, November 2000.
17. Gao, L & Cui, S 2008, "Efficient Subcarrier, Power, and Rate Allocation with Equality Consideration for OFDMA synchronous" *IEEE Transactions on Wireless Communications*, vol. 7, no. 5, pp.1507-1511.
18. Sharma. N and Analgen. A., "Joint subcarrier and power allocation in downlink OFDMA systems A multi-objective approach", *Transactions on Emerging Telecommunications Technologies*, vol. 10, pp. 993-1008, 2014.
19. 17. Deb, K., "Multi-objective optimization". In *Search methodologies*. Springer, Boston, MA, pp. 403-449, 2014.

# A Game-Based Strategy To Overcome Stress Using Brain-Computer Interface

Kapil Kumar

Department of Computer Science  
Shaheed Zulfikar Ali Bhutto Institute of  
Science and Technology  
Hyderabad, Pakistan  
kapilsonii666@gmail.com

Sumbul Ghulamani

Department of Computer Science  
Shaheed Zulfikar Ali Bhutto Institute of  
Science and Technology  
Hyderabad, Pakistan  
sumbul.ghulamani@hyd.szabist.edu.pk

Muhammad Ali Qureshi

Department of Computer Science  
Shaheed Zulfikar Ali Bhutto Institute of  
Science and Technology  
Hyderabad, Pakistan  
aliqureshi373@gmail.com

**Abstract**—This research proposes a smartphone game, which targets the students, who become stressed or getting depressed, it helps them to overcome their stress by playing it with mental commands and also helps to rehabilitate them from getting stressed. However, this game is a proposal idea for a smartphone game based on the existing work, which has been described in the paper. A preliminary survey taken in this research showed that 90% of students prefer to play smartphone games than computer games, that's why this research focused on smartphone games. The game intends to be played when the player will be in a relaxed mode or imagining nothing. The results have shown that by playing such game with the help of electroencephalogram (EEG) will decrease their stress level up to 15% and increase the focus level up to 8.25% and students got engaged up to 10.25% more than those students, who play with the keyboards. Concerned towards the limitations, the eyebrow and eye movements can be the factor in terms of the noise, or even the wrong placement of the electrodes can also be the factor affecting the game commands.

**Keywords**— *BCI game therapies; Brain-Computer Interface games; EEG Stress Measurement; EMOTIV games; Smartphone games; Stress Rehabilitation.*

## I. INTRODUCTION

With the advancement of this modern era, the technology known as Brain-Computer Interaction (BCI) is a successive innovation and implementation as used for the humans, where Humans do not require any physical activity to do a particular task. Recent researches over BCI have been covered the electroencephalogram (EEG), where it is found that EEG is reliable sources and helpful in terms of BCI interactions. In terms of mental health conditions, BCI is marking its way towards generating the most effective signal processing techniques, which become able to detect and understand the various conditions like stress and anxiety, which is a way most common to this age of a generation. Although, the stress of an individual is always detected by another type of signals like skin conductivity or heart signal rates [1].

The scope of BCI research expanded into so many fields like medical and non-medical as well. Early studies and experimentations of BCI mostly targeted the mobility and disability of an individual, but later on, it emerged out as important in the fields of emotional intelligence or the emotional response of a person. It no longer has been limited up to controlling of any object, apart from that, the target of the brain signals has widened up to the emotional and cognitive intents of a person's responses, where the brain itself learns to have the control over emotional intelligence [2].

Brain-Computer Interaction now resides to a game development community, where different games are in interaction with the BCI, in order to improve the game community as different communities and researchers have taken BCI as the game controller through which they can develop the interactive game environment [3].

Concerned towards so many of medical or technical terminologies, we will now direct to the background for such terms. After that, the literature and related work of this field will be shown in section III. In section IV, we will figure out the proposed methodology related to the research consisting of all the factors involved. Section V will present us the limitations regarding this research and along with this, section VI will show the results based on the research and by concluding the work with the future directions in section VII.

## II. BACKGROUND

### A. Brain-Computer Interface (BCI)

Brain-Computer Interface is a technology, which helps the human mind to be connected with the machine or any system. Humans can be able to provide commands to a machine without any of their physical support. Instead of that, they can provide commands just with their brain signals, which are been processed through a particular mechanism like converting of analog to digital signals and vice versa, then the signals can be understandable by the machines and so the commands will become executed. Brain-Computer Interface is a communication medium for the human mind and the machine to communicate each other with an active or passive mode, whereas, in active mode, the human mind give commands to a machine and in passive mode, the machine gives a command that is been processed by the human mind [1].

### B. Electroencephalogram (EEG)

Electroencephalogram known as EEG is a device used to measure the brain's electrical signal's fluctuation activities. It consists of electrode plates attached with the device, which are placed on the head to specific positions, where the neurotransmission activities can be read carefully and accurately. EEG is apparently inexpensive and known to be best for the commercial use. However, it has certain limitations to its signal to noise ration [1].

### C. Emotiv EPOC+

This is an EEG based, 14 channel wireless system designed by EMOTIV Inc., which is used for the research purposes regarding the brain-computer interface technology.

This system helps to collect the raw data from the brain by means of an open source software.



Fig. 1. Commercial Emotiv EPOC+ device with electrodes.

### III. LITERATURE REVIEW

Form this section, related work done so far in this field will be discussed regarding EEG stress signal detection as well as EEG based cognitive games. Limitations of related work will also be discussed here with our contribution as well.

#### A. Stress Signal Detection Through EEG

As explained and depicted by Y. Tran and Thuraisingham in [1], individuals act the same in both situations whether in a state of stress or in the fatigue, the chances are same such as; change in cardiac rates, the conductivity of the skin, the volume of blood, etc. Concerned with the related researches, they are focusing on using the EEG for finding the different bands of frequency. Studies have always given their assumptions that during the change in state of being fatigued or stressed, the bands of frequency regarding EEG spectral signals produces the increment in decrease of alpha, beta and delta signals. While the EEG alpha signals increase during the most increasing relaxation, while it decreases where the stress will be found. BCI systems measure the level of mental loads and stresses with the help of EEG and alert any individual depending on its response time and type.

It has also successfully conducted researches on the transportation side, where the driver can most of the times feel fatigue while driving for hours and hours or maybe some other mental stress can be there for a driver and he loses the alertness and attentiveness, hence producing a major cause for the accidental scenarios. So, signals of EEG can be used in detecting the distraction and fatigue-ness and so by alerting the driver [2].

Another profound research has been shown in [5], where a signal got for the processing to the computer system, it passes from the filter that works in three states as normal, stresses and overstressed states. Here, an acquired rate is fixed, where, if the coming pulse is greater than that acquired pulse rate, then the person is in a stressed condition and if the coming pulse rate is less than the acquired rate, then the person is in a normal state. The range defined for acquired pulse is based on the frequency of the Beta signals as fluctuating with the range defined for 14Hz to 30Hz. In this system, if the threshold will become crossed, the message will be sent to the person that he is in stressed mode and can apply the yoga or music to overcome the stress.

A group of rats was under a severe experimental research, where rats were divided into groups, one of them is a controlled group, another group was treated under the BCI and rest of group was targeted of the stress of cold water for the 10 minutes daily up to 1 or 2 months. The study shows that after 1 – 2 months, the BCI treatment made the hippocampus neurons activated and the group of rats learned the task after that with the normal addition [9].

#### B. EEG Based Cognitive Games

Tan and Nijholt have depicted Brain ball game [2], which expects to drop the feeling of anxiety. The clients can just move the ball by relaxation, therefore, the more relaxed player will probably be the champ and along these lines they would figure out how to control their anxiety while being entertained.

In [4], five different games were introduced, which are BCI controlled games, where the Users have to play the game with the input as their emotions. The game detects the user's emotions as the game's intent and the positive emotions will lead to the next level whether the negative emotions will lead to the same level to be completed. This approach can help in rehabilitating the user's emotional intelligence and rip off from the negative thoughts at a great instinct.

Moreover, in [8], it is explained that as we concern towards the BCI gamer, we don't assume that it will wear a heavy headset of Magnetic Resonance Imaging (MRI) for the measurement of brain pulses in order to play the game. Not even a gamer is supposed to have a surgery for pertaining the strong brain signals measurements for the brain games. Rather, EEG headset is a very light-weight device containing electrodes on the head reading and measuring the brain pulses which serves as the source of input for the BCI games by sending those activities of brain pulses as the information to the game engine.

Alaa Eddin Alchalabi et. al. proposed a serious game in [11] based on unity engine. The game is for the patients of Attention Deficit Disorder (ADD). In this game, the avatar will run by the mental capability to think of running to collect the yellow cubes and have to be relaxed to stop the avatar. The gyroscope of the emotive device will be used for the changing the directions as left and right

#### C. Limitations and Our Contribution

In [2], BCI concerned towards EEG also have certain limitations and challenges as well. Level of concentration and fatigue are the main source of and challenges for any individual. Another important constraint is the noise factor, which can be caused through several parameters like blinking of an eye, movement of eyes or pulses generated by skeletal muscles or the wrong placement of electrodes where incorrect readings with the great number of noise can be the great cause. Training is necessary for an individual's up to one or more times is also a challenge for the BCI community.

Whereas, in [10]. Analysis of EEG signal has been covered, where most importantly described that the movements of eyes, blinking of eyes or the movement of muscles are a source of noise to the data and given system,

which has to be ignored by setting the threshold values through EEG headset to diminish the noisy artifacts.

Our contribution to this field is that, in this research, we are proposing a serious game based on a smartphone. As none of the above work has researched over smartphones so far in terms of serious games with the help of BCI Community. This research contains the motivation of serious games to be played on smartphones as they are the handheld devices used among the individuals. In this way, it can be easily beneficial for them to practice the game their daily routines in order to overcome the stress level.

#### IV. METHODOLOGY

This proposed game is a smartphone game. The game consists of an avatar, which will only move only if the person will be in a relaxing mode. In this game, the avatar will have to collect the maximum coins in a given time. If no relaxation feeling or idle feeling is found, the avatar's speed lowers down.

Considering the work of Alaa Eddin Alchalabi et al. proposed in [11], this research focuses towards such a game but based on a smartphone. Smartphone game has been selected here because, in the world of smartphones, most of the games are being played on it. Here, we have targeted the students. For that purpose:

A preliminary survey was conducted in this research from 120 students across different institutes, and it had been asked from them that whether they like to play games on the computer or on the smartphones. Following are the survey questions, which had been asked:

- How often do you play games?
- Where do you most likely prefer to play games, on PC or Smartphones?
- If Smart Phones, then why use them?
- Does playing games on smartphone help you to lower down your stress or anxiety?

According to this survey, 90% of the students preferred to play smartphone games than PC games, because they said that they can play smartphone games anytime and anywhere and it will increase their engagement and even helps to lower their stress most of the times due to increasing attention towards games. That's why the suggestion for the smartphone game has been proposed using the brain-computer interface.

By considering the game from [11], several gaming aspects have been taken from it in terms of applying those same features for that smartphone game in order to enhance the research for the betterment of the community.

##### A. Surrounding Environment of Game

The surrounding environment of the game is full of nature, which is a greater means of finding relaxation and calmness as shown in Fig. 2. The background music will also be added in the game, and the music represents the relaxing environment with null noise. The avatar in this game will be attractive to the player as well as the

surrounding nature-like environment will also change the player's mood and switch that to become relax.



Fig. 2. Showing the nature-like the environment of the game.

##### B. Game Setup

The game implemented with the unity game engine along with the EMOTIV open source SDK [11]. All the readings of brain signals will be gathered by the 14 electrodes and sent to the smartphone by means of Bluetooth. Before the starting of the game, it will be checked whether the EEG EMOTIV headset kit is well installed and the connection of the sensor is good or bad. By means of the headset control panel, it will also be checked, whether all the electrodes are providing the excellent strength or not, by showing the green color of electrodes plates means that the signal strength is good, otherwise the red signal shows a bad signal and weaker connection of the electrode as illustrated from Fig. 3.

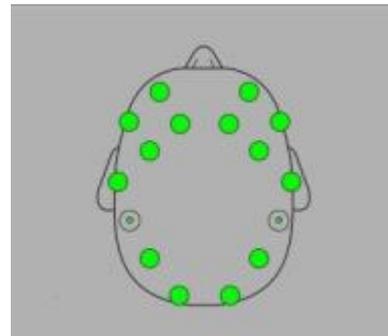


Fig. 3. All the electrode plates are connected showing green spots.

##### C. Training And Game-Play

Before playing the game, training is very essential in terms of how to play the game by using this EMOTIV headset. From [11], it is explained that how the training of different game states can be achieved, where the eye or muscle movements should not take place.

Whereas the gameplay is concerned, this research also considered the work from [11], the change has been done here with the game, which is consisting of an avatar along nature like surrounding with the background light music to make a calm and relaxed surrounding atmosphere to the user. The open source SDK library for the headset is used, where the Neutral state has been provided to the player. In the neutral state, the player has to remain calm and relaxed and nothing to do with anything, by performing such state, the avatar will start moving imagining that the player is doing nothing and is relaxed, that's why the avatar will speed up and collect the coins in the time required.

As the player will think of anything of imagining the avatar to stop, the avatar will stop by that. This will also be done by using that open source library. In this manner, the player will be calm and relax in order to move the avatar to collect the coins in the required time. Each time the player will play the game, he/she will compete to its own best time. The player has to only give the mental commands of making himself in a relaxed and calm situation.

#### D. Training And Game-Play

As far as the stress is concerned, playing of the game, practicing, and training the mental commands of this game habitually will help the player automatically rehabilitating him/herself of being stressed. Apart from that, the game's psychology of its surrounding environment along with the background music will even help him to play calmly. By keeping practicing the game, the player will know about how to remain idle and think of nothing, this would be the key that will help him to manage or overcome the stress and also by playing again will rehabilitate the player from being stressed. Limitation

This suggested game will have certain limitations like movements of eyes and eyebrows and the movements of muscles will be a source of noise to this game and the respond regarding the game's command will be attenuated. However, the wrong placement of electrodes will also be unable to sense the readings of brain signals, whereas, the EEG headset also has a certain level of quality, which is not better than the MEG. But we use EEG because it is widely used in terms of commercial purpose and provided the low cost with ease of use.

#### V. RESULTS

From the tests and experiments as depicted in [11], the players were asking to play through the keyboard instead of playing along with the mental commands. On the other side, the second group of players will be asked to play the game by means of mental commands. The results have shown that:

The players, who played with the keyboard have found to be the focus level with the fewer fluctuations. And the players, who played with the mental commands, have the focus level with the high fluctuations. Which results in the higher engagement level and focus level along with the lower level of stress found in the players who played with the mental commands.

Therefore, from [11], we can depict the results of playing the game with EMOTIV and keyboard based, where the players with EMOTIV has found to be more interested and relaxed than playing with the keyboard.

Results related to [11] are shown in Fig. 4, elaborating that the players playing with EMOTIV headset have reduced their stress rate up to 15% than the players playing using the keyboard. Similarly, the engagement and focus levels of those players have increased up to 10.25% and 8.25% other than the players using keyboards.

In this way, results have shown the success rate of reducing the stress level of players. Proposing a smartphone

game seems to be more beneficial in this way because the majority of audience prefer smartphones to play games than computers. Smartphones are the handheld devices for each personnel that is why there will be a greater probability for reducing the stress.

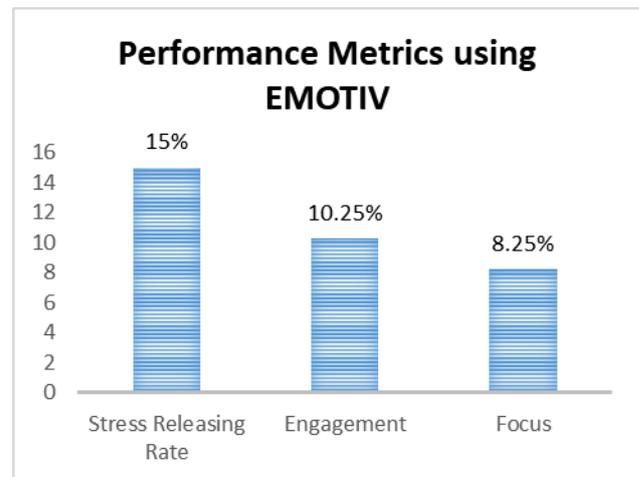


Fig. 4. Showing the results related to Reducing stress, Engagement, and the Focus.

#### VI. CONCLUSION

Concluding all, this research is considering the work of a previous research based on EMOTIV EPOC+ based game, from which, this research has proposed that the game can be developed for the smartphones, as the smartphone games have been targeted more than PC games. Therefore, it will fill the gap in the previous work. Survey taken from students also showed the enhanced response for the future purpose, as they wish to have such serious games for the smartphones, in order to easily access the game anytime and anywhere just from their phones. The results have also been shown with a positive response; in that case, it will be more beneficial for the BCI researchers to look more frequently on serious games based on smartphones.

Such BCI related serious games are growing more with the game development industry. This will induce the life of cognitive or mentally disturbed and stressed students or the patients. In future, the multiplayer levels could be added to such games, where interaction levels of the players will increase a positive response. Hence, the community will be able to tackle the stress and anxiety with a lot more interactive ways.

#### ACKNOWLEDGMENT

For this research, all the authors delightfully thank to all those participants (students) from Mehran University of Engineering and Technology (MUET), Sindh University (SU) Jamshoro, HIAST College Hyderabad and from Shaheed Zulfiqar Ali Bhutto Institute of Science and Technology (SZABIST) Hyderabad campus, who have interactively helped in terms of conducting the research survey successfully from all of these institutes as well as helped in facilitating us in order to get results more accurately and precisely.

## REFERENCES

- [1] Y. Tran, R. A. Thuraisingham, N. Wijesuriya, H. T. Nguyen, and A. Craig, "Detecting neural changes during stress and fatigue effectively: A comparison of spectral analysis and sample entropy," *Proc. 3rd Int. IEEE EMBS Conf. Neural Eng.*, pp. 350–353, 2007.
- [2] S. N. Abdulkader, A. Atia, and M. S. M. Mostafa, "Brain computer interfacing: Applications and challenges," *Egypt. Informatics J.*, vol. 16, no. 2, pp. 213–230, 2015.
- [3] H. Gürkök, A. Nijholt, and M. Poel, "Brain-computer interface games: Towards a framework," in *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 2012, vol. 7522 LNCS, pp. 373–380.
- [4] "Brain-Computer Interface Games based on Experiments Gabriel Alves Vasiljevic Mendes Gabriel Alves Vasiljevic Mendes Brain-Computer Interface Games based on Consumer-Grade Electroencephalography Devices: Systematic Review and Controlled Experiments," no. July, 2017.
- [5] A. Tiwari and R. Tiwari, "Design and Implementation of a Brain Computer Interface for Stress Management Using LabVIEW," pp. 152–157, 2017.
- [6] A. Nijholt, "Multi-Brain BCI Games: Where to Go from Here?," in *Proceedings of Measuring Behavior 2016, 10th International Conference on Methods and Techniques in Behavioral Research*, 2016, p. 5.
- [7] M. Joselli, F. Binder, E. Clua, and E. Soluri, "Mindninja: Concept, Development and Evaluation of a Mind Action Game Based on EEGs," in *Brazilian Symposium on Games and Digital Entertainment, SBGAMES*, 2014, vol. 2014–Decem, no. December, pp. 123–132.
- [8] A. Nijholt, B. Reuderink, and D. O. Bos, "Turning shortcomings into challenges: Brain-computer interfaces for games," *Lect. Notes Inst. Comput. Sci. Soc. Telecommun. Eng.*, vol. 9 LNICST, no. 2, pp. 153–168, 2009.
- [9] S. Ramar, A. Bose, J. Smida, A. Vaiyapuri, A. Prof, and S. Arabia, "Effect of Brain Computer Interface ( BCI ) in stress induced loss of cognition in hippocampus of wistar albino rats," vol. 5, no. 3, pp. 152–162, 2016.
- [10] N. Sulaiman, M. Taib, S. Lias, Z. Murat, S. Aris, and N. Hamid, "Novel Methods for Stress Features Identification using EEG Signals," *Ijssst*, vol. 12, pp. 27–33, 2011.
- [11] A. E. Alchalabi, A. N. Eddin, and S. Shirmohammadi, "More attention, less deficit: Wearable EEG-based serious game for focus improvement," *2017 IEEE 5th Int. Conf. Serious Games Appl. Heal. SeGAH 2017*, 2017.
- [12] EMOTIV, "EMOTIV - Brainwear® Wireless EEG Technology," EMOTiV. [Online]. Available: <https://www.emotiv.com/>.
- [13] Alchalabi, Alaa Eddin and Elsharnouby, "Feasibility of detecting ADHD Patients' attention level by classifying their EEG Signals" *2017 IEEE International Symposium on Medical Measurements and Applications, MeMeA 2017 - Proceedings*, 2017.

# SPEECH RECOGNITION BASED EXPERT SYSTEMS LIMITATIONS & PROPOSED SOLUTION

Sallar Khan

Department of Computer Science  
Sir Syed University of Engineering & Technology  
Karachi, Pakistan

Jawaria Hafeez

Department of Computer Science  
Sir Syed University of Engineering & Technology  
Karachi, Pakistan

Jahanzaib Ali

Department of Computer Science  
Sir Syed University of Engineering & Technology  
Karachi, Pakistan

**Abstract**— Experts systems are rapidly changing the face of new technological era. Speech Recognition Based Expert Systems (SRBES) are also a part of expert systems; however there are few limitations such as: uncontrolled environments, random-dialects and long sentences which are unattended. This paper focuses on long sentences issue and proposes an expert system which could lead an end user to interact using long-sentences with a machine. Data Processing unit will accept long voice commands by our system to perform user tasks. Hence we are trying to investigate, how can a user convey long-sentences to a machine? Moreover, how the proposed expert system helps the physically impaired persons? A prototype has been designed to address these types of queries.

**Keywords**— *Speech Recognition, Expert Systems, Artificial Intelligence.*

## I. INTRODUCTION

With the rapidly growing digital world, speech recognition is gaining widespread acceptance; it is the ability of a machine to analyze the vocabulary and phrases spoken by a person and converts those phrases in machine readable format [1][11][12]. Speech recognition is concerned with the field of science and artificial intelligence which interacts natural language (spoken by human) with a computer system[2]. Recent research highlights the presence of noise and proposes a method to remove it that makes one step closer to achieve robustness in speech recognition [2] but still long sentences issue remains in SRBES. To fill this gap, the proposed system executes long sentences spoken by the user which provides more ease of access to accomplish any task using his/her voice. Furthermore, the proposed system would be very helpful for the physically impaired people. These could be blind people or people who are unable to use their hands effectively or having some kind of hearing impairment.

The rest of paper is organized as follows. In the next section we discuss different types of speech recognition systems and various limitations in different speech recognition-

based systems [3].In third section, we have proposed our method. In the fourth section we will briefly discuss the usage of speech synthesizer and speech [4].Further in section fifth, we have evaluated our proposed system. The results collected for physically impaired people are shown in subsequent section. In the seventh section we have compared our proposed system with existing expert systems.

## II. LITERATURE REVIEW

The term speech recognition is generally used by many expert systems and by the usage of this technology; a user can accomplish his/her task effectively and easily without using any type of hardware (physical) medium. However, from the implementation point of view, it still lacks user-friendliness.

In literature review, different types of speech recognition are discussed. Subsequently, all possible limitations will be discussed which can occur in a SRBES.

### A. Types of Speech Recognition

Speech recognition systems can be divided into a number of classes. This division is based on their ability to recognize the words and list of words. A few classes of speech recognition are isolated speech, connected speech, continuous speech and spontaneous speech. Isolated speech consists of words having a pause between two utterances; it not only acquires a single word but rather it requires one utterance at a time. Then we consider connected speech, which accepts separate utterances with minimal lapse between them while continuous speech allows the user to speak almost naturally; it is also called the computer dictation. In the end, we will discuss spontaneous speech, which is capable of handling a range of natural speech features such as words being run together, "ums" and "ahs", and even minor stutters.

### B. Limitations of Speech Recognition Systems

Presented Literature contains limitations faced by SRBES users [5-8][13-15].Those works suggest that, currently 'long-

sentences limitation' is the main challenge faced by every expert system.

Extant literature discussed four types of limitations as shown in Fig. 1:

Uncontrolled environment limitation [2][9][10] points to all those environments which can distract the recognitions ability of any speech recognition system like exceptionally noisy environment.

Long vocabulary limitation [9] points to those words which are hard to recognize or they are difficult to verbalize by a speech recognition system, for example like nascent, milieu, flummox.

Random-dialects [1] means random languages, it is difficult for a system to be multi-language SRBES.

Long-sentences limitation refers to a task which contains a long sentenced voice input by a user to do multiple and simultaneous tasks.

Graph in Fig.1 illustrates the higher frequency of long-sentences barrier by the average of 90%, while random-dialects appear 50% in the average. On the other hand, frequency of occurring long-vocabulary issue is 30% and, controlled and noisy environments also affect the quality of an expert system with 20%.

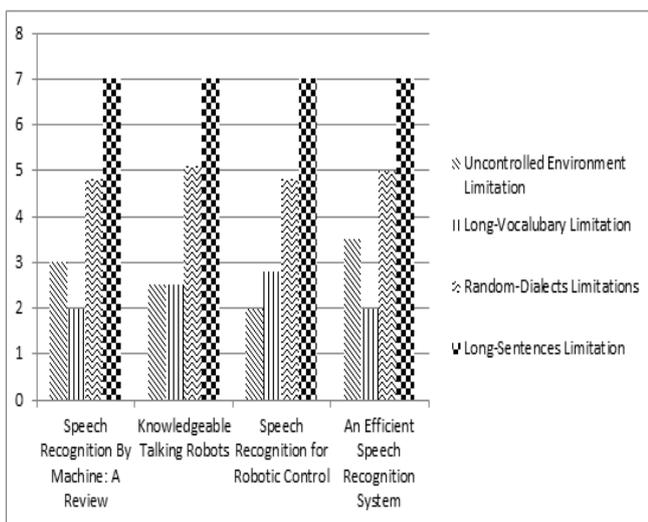


Fig.1. Analysis of limitations in different speech recognition based systems [5-7]

### III. PROPOSED METHODOLOGY

The main objective behind this method is to facilitate the system to perform multiple tasks on receiving long-sentences-based voice commands. In this modern world of technology, using of voice commands is much efficient and convenient way to operate any device or system instead of using mouse [2].

As mentioned in Fig. 2, first of all we took long sentences-based audio from the microphone which must be natural language and that also involves environmental noises. In the second setup, we use speech synthesizer which provides access to the functionality of an installed speech synthesis

engine. In the third step, we have implemented the speech recognition engine which recognizes the given input voice of user. In the fourth step, we created a list of predefined phrases within the program and parse it by the grammar provided by the speech recognition engine. In the fifth step, we break long sentences into small. In the sixth step, we start to recognize the spoken words. In the 7th step, we concatenate the broken words with each other. In the 8th step we start to compare the phrases with already predefined list of phrases in system. Finally, in the last step, system executes the user task and in result, an acknowledgement will be sent to the user by a voice command alongside with that user can also see the resulted output on the screen:

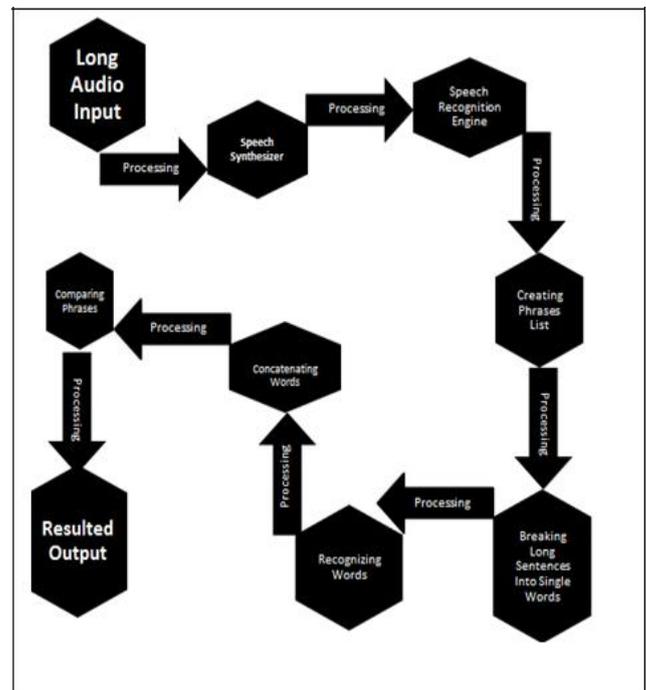


Fig.2. AstroBot framework of proposed method

### IV. LANGUAGE AND SPEECH

In this section, we will describe the two essential classes which are very useful for the speech recognition process. They both are interconnected with each other and by the help of these we can develop any speech recognition based system.

#### A. Speech Synthesizer

'Speech Synthesizer' is a Microsoft platform-based class that provides the access to the functionality that belongs to the speech synthesis engine. We can also control following aspects of speech synthesis by the help of this class.

- It can generate speech.
- It can produce speech from text
- It can utilize one or more lexicons to guide its pronunciations of words
- It can also change the delivery of speech output.

*B. Speech Recognition Engine*

Similarly, the speech recognition engine is also a class which is based on Microsoft platform. By the help of this class we can use any installed recognizer (a run time language for recognition). It can also help us to achieve following tasks by using the functionalities provided by the speech recognition engine:

- By creating the instance of this class, we can specify the installed run time language for recognition.
- Can configure the input to the speech recognition engine.
- Can manage the grammar for speech recognition.
- Can set parameter for speech recognition tasks.
- Can monitor the input to the speech recognition engine.
- Also can test the effectiveness of grammar using the emulated recognition.

**V. PROPOSED SYSTEM EVALUATED**

The motivation behind our proposed system is to overcome all the obstacles and challenges which a user faces while using a basic speech recognition system. Alongside with the execution of long sentences we tried to focus a few other features too which we will discuss later, which can make our system efficient and useful. Furthermore, we made our system to interact with the web using user's voice command.

By following our study, long-sentences remain a main query which should be solved and must be cleared. For example if a user wants to access 'my computer' as in the Windows operating systems, he can access it by any simple speech recognition based software, but if a user wants to access a file 'xyz' and wants to delete that file by his voice command which is placed inside so many other folders how could a user do that. Hence, this is our system's fundamental goal to overcome this limitation in any speech recognition based software's and systems.

Besides this limitation, we tried to put other features in our proposed system. According to our experiments over different tools and software, we found a basic limitation that makes different SRBES dependent of internet. Hence, we overcame this issue and made our system non-dependent of internet, a user can do his tasks without having the access to internet.

As shown in *Fig. 3*, websites can also be accessed through the voice command spoken by user. This feature is dependent on internet connectivity due to interaction with web.

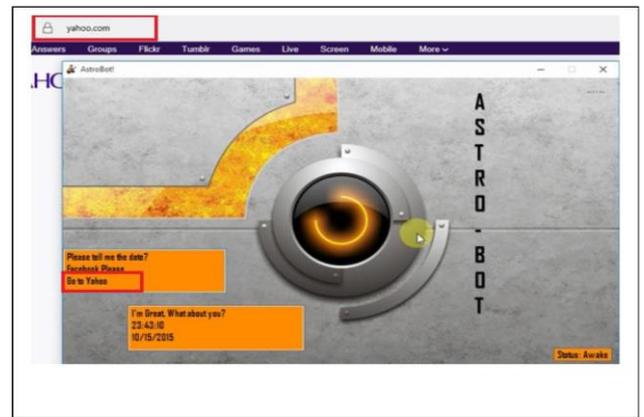


Fig.3. Proposed system interacting with internet

**VI. SYSTEM RESULTS FOR PHYSICALLY IMPAIRED PERSONS**

There are various disabilities described below which have been used to convey long instructions to the machine, which can be very helpful for physically impaired people. We mentioned earlier about focusing the people with blind and hearing deficiencies or for those who are unable to use their hands.

*Fig. 4* exhibits the initial user interface of our proposed system; which shows, we are having two sections on which texts are displaying, one section is containing the input voice commands spoken by user and displaying it accordingly while the other section is containing the output responded by the system.

We can tackle all three disabilities which we mentioned earlier, following are the examples demonstrating the usage of the system:

- For those people who are unable to use their hands, our proposed system will be very useful as they can accomplish any task just by voicing their task to the system.
- All Speech recognition systems are already very efficient and effective for the blind people; hence our proposed system is also can be very useful due to speech interaction of user with system.
- While hearing impaired people can also use it to accomplish their tasks by just watching the resulted output on screen.



Fig.4. Proposed User Interface of SRBES

VII. DISCUSSIONS

As we mentioned earlier about a few limitations in SRBES, long sentences remains a considerable point of discussion. According to our experiments after using different speech recognition software we concluded a few essential findings, as shown in Table 1. We took a total of two systems alongside with our proposed system; ‘Cortana’ is a Microsoft platform-based expert system and ‘Voice recognition’ is a Google platform based expert system.

First we will talk about the random dialects issue which is present in all 3 systems due to its complexity. There are very rare chances for a system to support random dialects functionality in its speech recognition structure, as more dialects you will create the more complex your system will become.

Second point is based on a very fundamental limitation which occurs in SRBES, the dependency of internet. As shown below in Table 1, both two systems are dependent of internet. For example if you want to know the current time which is a non-web connected task, these systems will need internet connectivity for that, as shown in Fig.4. While we have overcome this limitation successfully, our system will only be dependent on internet if the user task is related to web for example to open any website, otherwise it is not dependent on internet and can execute all types of tasks which are non-web connected. As shown in Fig. 5, the primary researcher is doing the same task which is asking the current time, and our system responds it well without having any internet connectivity.

Third point is our main point of discussion, which is long sentences limitation. This issue is critical for all SRBES and it prevails in every system. Our research will overcome this limitation through the methodology we provided earlier in Fig.2.

TABLE I. Comparison of different speech recognition based expert systems with our proposed system

(SRBES)	Limitations in different SRBES		
	Random Dialects	Internet Dependent	Long Sentences
CORTANA	✓	✓	✓
GOOGLE CHROME	✓	✓	✓

ASTRO-BOT	✓	✗	✗
-----------	---	---	---

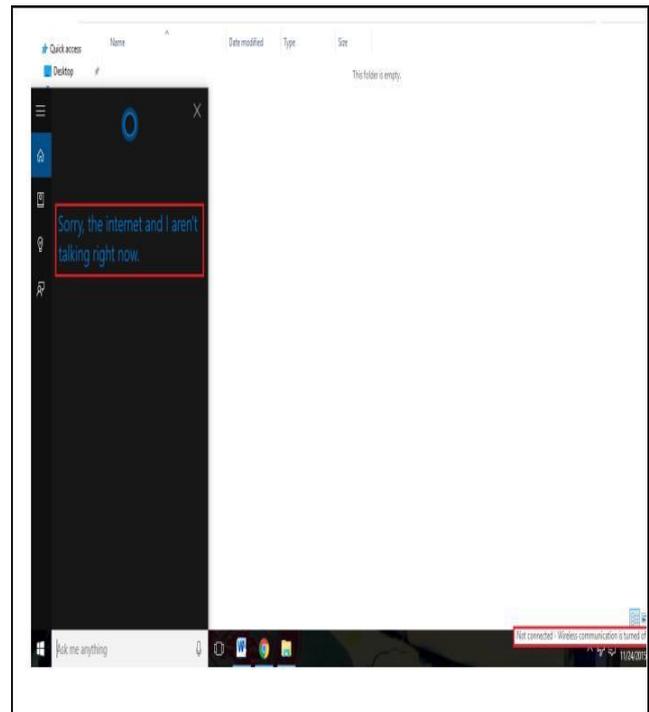


Fig.5.Cortana expert system's dependency on internet



Fig.6. Proposed system's non-dependency on internet

VIII. CONCLUSION

Expert systems are being widely used around the globe these days. The majority of them are speech recognition based software. Technology is changing and people are giving preference to operate their systems and devices smartly by using their voices instead of their hands. In this regard, we have proposed speech recognition based expert system capable of performing advance recognition with the execution

of long sentences. This could lead an end-user to surpass the pipelines regarding long-sentences which they usually face while using an SRBES.

Our main target was to remove the limitation associated with long sentences around any environmental barrier like: noisy and unclear environment and random-dialects environments. During the implementation of our system, we covered all basic aspects of an SRBES. One of the limitations, however, is that our system only supports the English language. Our future work will focus to improve our system and make it more efficient and user friendly, also we want to make it a multi-language SRBES which will omit the random-dialects issues.

#### REFERENCES

- [1] H. Sobey, "LiteratureSurvey -AutomaticSpeechRecognition," 2009. [Online]. Available: [http://shenzi.cs.uct.ac.za/~honsproj/cgi-bin/view/2009/katz\\_mathai\\_sobey.zip/Speech\\_Katz\\_Mathai\\_Sobey/Downloads/LiteratureSurvey\\_HeatherSobey\\_SBYHEA001.pdf](http://shenzi.cs.uct.ac.za/~honsproj/cgi-bin/view/2009/katz_mathai_sobey.zip/Speech_Katz_Mathai_Sobey/Downloads/LiteratureSurvey_HeatherSobey_SBYHEA001.pdf).
- [2] A. Gupta, N. Patel, and S. Khan, "Automatic Speech Recognition Technique For Voice Command," pp. 1–5, 2014.
- [3] S. K. Gaikwad, B. W. Gawali, and P. Yannawar, "A Review on Speech Recognition Technique," *Int. J. Comput. Appl.*, vol. 10, no. 3, pp. 16–24, 2010.
- [4] "SpeechRecognitionEngine." [Online]. Available: <https://msdn.microsoft.com/en-us/library/microsoft.speech.recognition.speechrecognitionengine.aspx>.
- [5] M. Anusuya and S. Katti, "Speech recognition by machine: A review," *Int. J. Comput. Sci. Inf. Secur.*, vol. 6, no. 3, pp. 181–205, 2009.
- [6] L. C. Aiello, E. Bastianelli, L. Iocchi, D. Nardi, V. Perera, and G. Randelli, "Knowledgeable Talking Robots," pp. 182–191, 2013.
- [7] S. D. Gosavi, U. P. Khot, and S. Shah, "Speech Recognition for Robotic Control," vol. 3, no. 5, pp. 408–413, 2013.
- [8] S. Swamy and K. V Ramakrishnan, "An Efficient Speech Recognition," vol. 3, no. 4, pp. 21–27, 2013.
- [9] A. Choudhary and R. Kshirsagar, "Process Speech Recognition System using Artificial Intelligence Technique," no. 5, pp. 239–242, 2012.
- [10] W. Ghai and N. Singh, "Literature Review on Automatic Speech Recognition," *Int. J. Comput. Appl.*, vol. 41, no. 8, pp. 42–50, 2012.
- [11] "Speech Recognition," 2009. [Online]. Available: <http://searchcrm.techtarget.com/definition/speech-recognition>.
- [12] "How Speech Recognition Works," 2006. [Online]. Available: <http://electronics.howstuffworks.com/speech-recognition.htm>.
- [13] S. Furui, "50 Years of Progress in Speech and Speaker Recognition Research," vol. 1, no. 2, pp. 64–74, 2005.
- [14] A. Katz and R. S. Editor, "That lacks the cachet of 'Open the pod bay doors, Hal,' but unlike the fictional computer in '2001: A Space Odyssey,' Hermes is quite real. He — it, really — lives in operating room 2 at Yale-New Haven Hospital.," 2001.
- [15] Pinola, M (2011). Speech Recognition Through the Decades: How We Ended up with Siri. Retrieved from [http://www.pcworld.com/article/243060/speech\\_recognition\\_through\\_the\\_decades\\_how\\_we\\_ended\\_up\\_with\\_siri.html](http://www.pcworld.com/article/243060/speech_recognition_through_the_decades_how_we_ended_up_with_siri.html)

# ***REAL OR FAKE NEWS? Can you guess?***

## ***A new era technology to fight the war against fake news***

*Dr. Saman Hina, Dr. Muhammad Mubashir Khan, Ushna Shaheen, Hafsa Ali, Samrah Syed*

*saman.hina@gmail.com, mmubashirkhan@gmail.com, ushnaa12@gmail.com, hafsa6137@gmail.com, samrah727@gmail.com*

*Department of Computer Science and Software Engineering*

*NED University of Engineering and Technology,*

*Karachi, Pakistan*

**Abstract-** The evolution of social media coupled with the rise of socio-political factors has been a double edged sword in spreading false information. On one hand, social media has made it possible for news to be in fast circulation, be easily accessed while socio-political factors has given a rise to difference of opinions leading to various propagandas misleading people with negative intent. Overtime this has resulted in the rise of fake news by 29% as compared to a decade ago. Fake news, i.e low quality news intentionally made to deviate the people, has the potential to impact a society negatively. This paper is focused on providing an optimal solution using machine learning techniques and proposes a functional concept of detecting fake news in actual time, thus working to reduce such circumstances.

In this paper, we present machine patterns to verify the authenticity of published news. The basic concept is to train the machine to distinguish and identify between genuine and false news. The preprocessed dataset is run through various classification algorithms, and we found the F1 scores of each. The F1 scores help to identify which algorithm is potentially the best. Depending on the two datasets we worked on, we got Naive Bayes and Support Vector Machines as the more accurate algorithms to apply for detecting fake news.

**Keywords—***fake; machine learning; authenticity; distinguish;*

### I. INTRODUCTION

Fake news is the product of social propaganda and to mislead people with negative intent, in order to gain some advantage and create an uprising, or change of opinions. It has become increasingly difficult to identify the trustworthy news sources due to two reasons: (1) Due to the proliferation of misleading information in everyday access media outlets such as social media feeds, news blogs, and online newspapers (2) The former leading to the human incapability to go through these millions of articles to verify their authenticity or good causes. Thus there's a increased need for computational tools able to provide insights into the reliability of online content. In recent history, a false tweet by the Israeli

Ministry of Defense, Avigdor Lieberman, resulted in threatening to destroy Israel by the Pakistani Ministry of Defence, may have caused severe political relationships within the countries had this news been evaluated of its authenticity beforehand.

In this article, we present an overview of fake news detection and discuss promising research directions. The key motivations of this survey are summarized as follows:

- The main goal is to contribute our small achievements in this global fight against fake news and to eradicate it completely in order to promote the truth and stop people from getting deceived by what is fact and what is fiction.
- That is a very vast issue and therefore our objective at the current moment works on finding the best combination of a Classification algorithm applied along with different NLP techniques.
- This paper summarizes the development of a logical predictive model and scrutinizes the results emerged and the overall performance and effectiveness of the model based on real time textual data.

Fake news problem is not as simple as it seems, a simple fact-checker is not a reliable solution rather computer software has to be trained to detect the reliability of the news, which is not an easy task. In order to combat this challenge of fake news, innovating ventures like artificial intelligence (AI) and the fields of machine learning are being tested and applied. Amazingly these are producing much accurate results than expected. However, there is still a lot of development work to be done in order to achieve 100% results.

According to a webservice, *Explore*, Fake news is an emerging problem and it is only sought to increase. Along enough evidence of the problem existing, several published articles suggested the use of machine learning to solve such a problem, as it deals with distinguishing what we want- true news and what we do not want- false news. Nevertheless, there are countless machine learning algorithms at the moment, but getting it narrowed down to just classification algorithms, was assisted by a thorough analysis during literary review of 10 published research papers to learn datasets, analyze techniques incorporated and the path taken to derive to results. This was followed by preprocessing of data i.e extraction of features from statements in the training data using NLP techniques i.e Stemming and Tokenization. This was then preceded by implementing these features in classification techniques on each of these set of preprocessed data with the following algorithms:

- Logistic Regression
- SVM
- Naive Bayes
- SGD
- Random Forest
- Passive Aggressive classifier

To select a classifier among these that has the best performance and accurately detects reliability of news- a performance and accuracy test was conducted using regularization parameters (GridSearchCV method) to check the validity of the generated model and the F1 score was found. The Project- a research based product aims to find the most suited Algorithm to create an API to be integrated for detection of fake news.

## II. THE DETECTION PROCESS

In this part of the paper we will be focusing on the brief overview of the whole process that led to the development of our prediction model. As mentioned above, we are using machine learning techniques in order to create the model. Firstly we are going to use structured and benchmark datasets to create the model for providing more credibility. Moreover, we will be applying several natural language processing techniques as well as different classification algorithms, due to the supervised nature of problem domain. Lastly, we will evaluate the performance and accuracy of these models to select the best predictive model by their f1 scores. A brief summary of the whole process can be seen in fig 1.

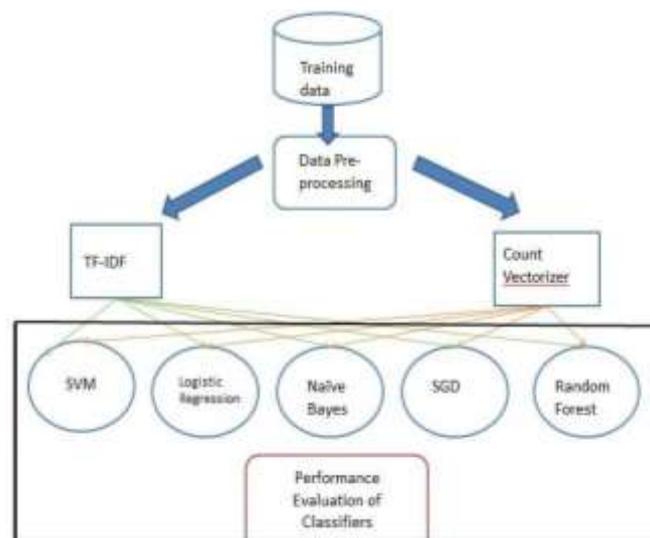


Figure1. Design and Methodologies we selected in terms of predicting fake news

Furthermore, we will be using Python3 as our programming language and using the Anaconda environment to develop the model. We selected python as it provides a very powerful framework to create machine learning models and consists of innumerable packages and libraries to implement the various statistical algorithms and functions required to create the model. We have conducted the whole source code on the Jupyter Ipython notebook which provides a browser based environment and visualization of data is also help made easier.

The following techniques and analysis have been placed in chronological order and provide implementation details:

### A. Methodology for fact checking and creating the dataset

The datasets that we used, i.e from Politifact and Datacamp, are looked over from over ten thousand articles and those claims are fact checked on with respect to personal analysis, such as does it sound wrong, does it have the tendency to spread, is it going to put you in a dilemma if this is fake? These ‘doubted’ claims were then double checked with other published documents online. And categorized to different facts -ranging from different ranges of true to different ranges of false. Overtime, as errors come over, they are either archived, updated, or deleted. All of it taking a good amount of time to build the dataset. This information becomes significant as it tells the reliability of datasets, and tells upon which basis is the dataset for false news created. Therefore, in case there is a need to create a dataset for a different domain in false and true news, a similar methodology can be adopted.

### B. Datasets

#### I. LIAR Benchmark Dataset

For the model generation we have selected the infamous “LIAR” dataset produced by William Yang Wang. This dataset has been used previously by other research scholars and has produced interesting results.

The dataset consists of three excel files consisting of train, test and valid datasets. Each file consists of a total of 14 columns and have been carefully and expertly gathered by the Pulitzer prize winning website POLITIFACT.COM.

The train file consists of around 5k true and 4k false articles, while test and valid consist of 1k false and 1k true articles each.

TABLE I

<i>true</i>	<i>true</i>
<i>Mostly-true</i>	<i>true</i>
<i>Half-true</i>	<i>true</i>
<i>Barely-true</i>	<i>false</i>
<i>Pants-on-fire</i>	<i>false</i>
<i>False</i>	<i>false</i>

Table1: To further simplify our problem, we have reduced the columns to two and have considered the ratings as either TRUE or FALSE and decreased the original six classes to two.

Moreover, for our model we have only used the Training and testing datasets. Dataset is available at <https://arxiv.org/abs/1705.00648>

## II. Datacamp Dataset

This dataset is produced by datacamp, which aims to provide the basic understanding in terms of using Natural Language processing(NLP) and machine learning classification algorithms to predict authenticity of news for learning purposes. This data set comprises of training dataset having four columns(ID, title, Text, Label) with almost 8k samples of news including real and fake one. In order to simplify our problem we trained our model using two columns(text, label). This data set is available at [https://s3.amazonaws.com/assets.datacamp.com/blog\\_assets/fake\\_or\\_real\\_news.csv](https://s3.amazonaws.com/assets.datacamp.com/blog_assets/fake_or_real_news.csv)

### A. Pre-Processing of Data

After observation of our data in graphical form, we discovered few outliers and null values. Hence, we discarded those statements and organized our data. Furthermore, we prepared our data by applying

normalization techniques such as removing punctuation, stopwords, numerical data etc. We also applied stemming and tokenization techniques to clean data all of which functionalities were part of Python’s Sci-Kit Learn package which includes many such natural language processing tools and embedded functions such as NLTK, word2vec, bag of words, Sci-py etc.

### B. Feature Selection Techniques

Our features are textual in nature and hence for the machine to understand them and feed it to the classification algorithms which are statistical and mathematical in nature, it is necessary to convert them into numbers. This is easily done by using the TF-IDF and Countvectorizer libraries which were embedded in the Sci-Kit Learn package of python.

#### 1. Term frequency- inverse document frequency

It is one of the many information retrieval techniques used for both search engine optimization and in machine learning. It’s basic working is that it counts the frequency or how much a word occurs in a context and calculates its weight (TF). This algorithm also calculates the inverse document frequency (IDF) of the terms, which is the downscaling of those terms that appear most in the dataset. Finally, it multiplies the TF and IDF scores of a word which is also known as the tf-idf of that term.

$$tfidf(t, d, D) = tf(t, d) \cdot idf(t, D)$$

Equation 1: Shows the relationship between TF and IDF weights to calculate the overall TF-IDF of a term.

The essence of this whole process is that it is used to weigh a term in any content and assigns its value according to its occurrence in the document. Hence, depicting how important that term is overall. The smaller the weight of the term shows that it is more commonly occurring. To sum up, it is a ranking function which ranks the words in a document according to how commonly they occur.

#### 2. CountVectorizer

It is a text feature selection technique in which the words are tokenized and then these words help build the dictionary. It also encodes this vocabulary into new documents meaning that this vocabulary can also be used for new datasets. Moreover, we can increase our list of words by adding in this dictionary.

This in turn, creates a matrix of the words which have been converted to numeric form during tokenization.

C. Classification Algorithms

Prediction models are mostly supervised machine learning problems in nature and use classification algorithms to create the model. Classification algorithms can identify to which class a set of data variables belong. They usually use a mathematical function in their operation. The following classifiers were used in order to create several models:

- Logistic Regression
- Naive Bayes
- Stochastic Gradient
- Support Vector Machine
- Random Forest Classifier
- Convolutional Neural Networks
- Stochastic Gradient classifier

1. Logistic Regression

This algorithm is by far one of the most simplest and finds the probability of the train data to be of a linear outcome out of two dependent variables which can be labelled as '0' or '1'. It uses a sigmoid function to estimate the output. Moreover, it also uses an optimization function to improve the fitness of model and produce more accurate results. The Beta values in the equation is set to reduce overfitting of the model.

$$p(x) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 x)}}$$

Equation 2: Denotes the sigmoid function used by Logistic regression to calculate its output.

2. Naive Bayes

Naive Bayes classification algorithm is the adequate proof of simplest and the powerful one in terms of its speed, accuracy and reliability. It comprises of 'Probabilistic Algorithm', drive from applying 'Bayes' Theorem' in order to predict the label of text (like news headlines). They are probabilistic, which indicates that they evaluate the probability of each and every tag of a given text, and then return the tag with the highest one. They evaluate these probabilities by 'Bayes' Theorem', which relate probability of a feature, based on foregoing conditions that might be ground on that feature.

$$P(A | B) = \frac{P(B | A) P(A)}{P(B)}$$

Equation 3: Shows the mathematical notation of the Naive Bayes Equation.

3. Stochastic Gradient Descent(SGD)

Stochastic Gradient classifier is used when evaluating the parameters is expensive and the dataset is immense. Least square criteria is used in linear regression which lacks in accuracy as a result of least square error, in order to minimize least square error, 'Gradient Descent' is used but it is very expensive to calculate parameters when data is immense. stochastic gradient descent allow us to scale algorithm to much bigger datasets. In 'SGD', a representative of training set or single training set is involved to evaluate the parameters instead of using the entire training sample space on each and every iteration like 'Gradient Descent', so its faster, reliable and less expensive.

$$\theta_j := \theta_j - \alpha \frac{\partial}{\partial \theta_j} J(\theta_0, \theta_1) \quad (\text{for } j = 0 \text{ and } j = 1)$$

Equation 4: Shows the cost function used by the stochastic gradient algorithm in order to prevent overfitting of model.

4. Support Vector Machine(SVM)

Support vector Machine (SVM) is supervised learning algorithm which can be utilized for both, classification and regression problems. SVM is often used for classification problems.

SVM gives an idea in terms of hyper plane that perfectly divides dataset into two classes. It is composed of support vectors (critical elements) which are the data points nearest to the hyper plane. The greater the distance of support vectors to the hyper plane the more accurate our data is classified. The main goal is to find the best hyper plane having the larger margin between the data points (support vectors) and hyper plane shown in fig 2

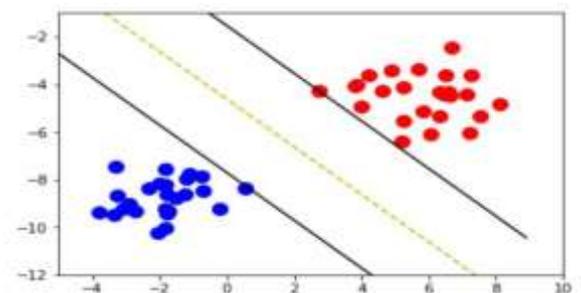


Figure 2: Classification results of SVM

5. Passive Aggressive Classifier

Passive Aggressive Classifier holds family of different learning algorithms for both classification and regression complications, their accuracy level is verified to be greater than many other alternative algorithms. It can learn from huge streams of data. It is simpler to implement and very fast.

6. *Random Forest Classifier*

It is a combinational learning method which is used by both linear and regression problems and works by building multiple decision trees during training process and hence identifies the output variable class using the mean prediction values generated by the decision trees. Although they show high bias but overall produce boost to the efficiency of the model.

$$\sigma = \sqrt{\frac{\sum_{b=1}^B (f_b(x') - \hat{f})^2}{B - 1}}$$

Equation 5: Displays the mathematical equation to calculate the value of theta, in order to generate decision trees.

7. *Convolutional Neural*

This is a complex machine learning technique rather it is a deep learning technique which is derived from the concepts of neural network system inspired by the human body's actual nervous system. Although, mostly used for image processing, this technique can also be applied to classification problems as well. The essence of this phenomenon is that it uses a layered system through which multiple inputs are sent through and output is produced.

$$F_1 = \frac{2}{\frac{1}{\text{recall}} + \frac{1}{\text{precision}}} = 2 \cdot \frac{\text{precision} \cdot \text{recall}}{\text{precision} + \text{recall}}$$

neuron can consist of multiple hidden layers and a single input and output layer each. The overall performance of this technique is to increase the number of training samples, so that the model can learn more efficiently.

In the case of a convolutional neural network (CNN), the input layer is always a convolutional layer meaning that the input matrix is filtered by a neuron over a specific region and iterates to cover the whole region of the matrix. Simultaneously, this filter multiplies with the input layer region to calculate weights which are features. All of these features are

then collectively called as activation map. The first layer of the hidden layer is highly perspective and is used to identify the unique details of the features. There are several different hidden layers which improve the robustness of the model and help prevent over fitting to produce a smoother and less rigid model.

The final layer then compares the input with the high level features produced by the hidden layers and predicts the class which is most accurate with the input, this layer is also known as the fully connected layer. Moreover, back propagation and forward feed networks are applied to adjust the filters in the convolutional layer to calculate weights more precisely.

For our CNN model, we have used pre-trained word embedding's courtesy of Stanford NLP GloVe which consists of 6B tokens and 400k vocabulary words. We have used a batch size of 50 and dense layer size of 100. Channel size is two, total number of CNN layers is two with one dense layer. Loss used is binary entropy loss and activation value of sigmoid is used to build the model.

D. *Performance Measures*

1. *F1 Scores:*

We have selected f1 scores as one of the metrics that will highlight the accuracy of the model for its evaluation. F1 scores are the harmonic average of precision and recall values. Precision is the mathematical ratio of how many observations were predicted correctly against the total positively predicted observations, while Recall is the mathematical ratio of positive observations predicted correctly against the total observations. It takes both false positives and false negatives into account while determining the performance of model. The equation below shows the mathematical relationship between precision and recall to calculate the f1 score.

2. *Classification Reports:*

It is another unit of performance that evaluates the model and consists of a miniature report with precision, recall, f1 scores and accuracy values of the model. This accuracy metric is an embedded function in Sci-Kit Learn package which is only available in the Python programming language. It provides a brief description of the model's performance.

	precision	recall	f1-score	support
False	0.61	0.47	0.53	1169
True	0.62	0.74	0.68	1382
avg / total	0.62	0.62	0.61	2551

Figure 3: miniature report with precision, recall, f1 scores and accuracy values of the model.

A sample classification report of our LIAR dataset SVM model is shown in fig 3.

3. *Confusion Matrices:*

An essential performance metric that highlights the True Positive (TP), True Negative (TN), False Positive (FP) and False Negative (FN) values in matrix form, be it graphical or in mathematical form.

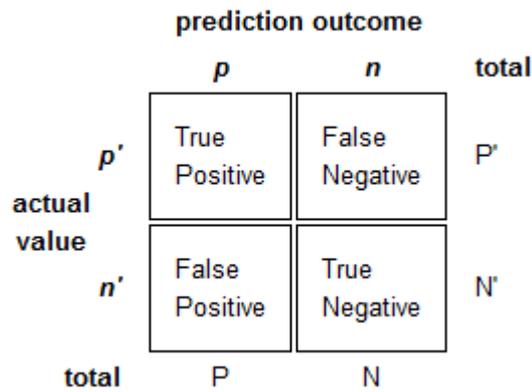


Figure 3. A Confusion Matrix format

The TP shows the correctly predicted positive values, the TN the correctly predicted negative values, the FP the incorrectly predicted positive values and the FN the incorrectly predicted negative values.

```
[[2016 2472]
 [1524 4228]]
```

Figure 4: A sample confusion matrix from our LIAR dataset SVM model.

learning algorithm and got most accurate results which are shown below.

After applying the selected classification algorithms on our training dataset and evaluating our model through performance and accuracy metrics as well as applying grid search cross validation technique to enhance it, we have compiled our results in tabular form of both Tf-idf and Countvectorizer shown in TABLE 1, TABLE 2, TABLE 3, TABLE 4 respectively.

We will analyze our results based on the accuracies and f1 scores of each separate algorithm. Finally, we will choose a final model which will be converted into an API format that can be integrated with both desktop as well as mobile phone applications.

1. *Liar Benchmark Dataset*

Sno	Results(Countvectorizer)		
	Classifier	f1 score	accuracy
1	Logistic Regression	0.704	0.614
2	Naive Bayes	0.722	0.598
3	Stochastic gradient	0.719	0.562
4	SVM	0.679	0.610
5	CNN (at 50 epochs)	0.606	0.606
6	Random Forest	0.662	0.610

Table 2: Results of CountVectorizer

Sno	Results(TF-IDF)		
	Classifier	f1 score	accuracy
1	Logistic Regression	0.647	0.593
2	Naive Bayes	0.670	0.610
3	Stochastic gradient	0.676	0.600
4	SVM	0.610	0.563
5	Random Forest	0.700	0.620

Table 3: Results of TF-IDF

E. *Results*

We figured out the best predicted classifier for both datasets, for the purpose of model selection. After that, we made the prediction model of best selected supervised

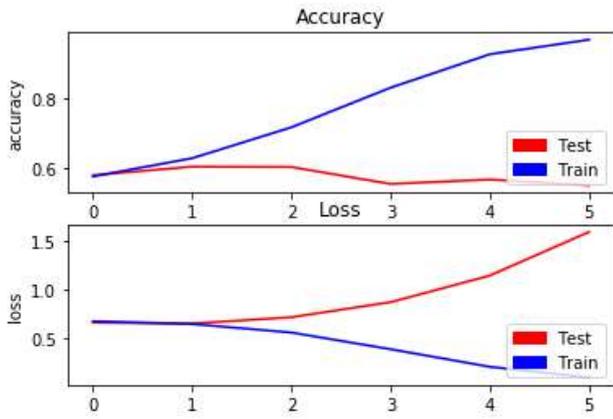


Figure 5: Depict the accuracy of our CNN model at 5 epochs and 50 epochs respectively.

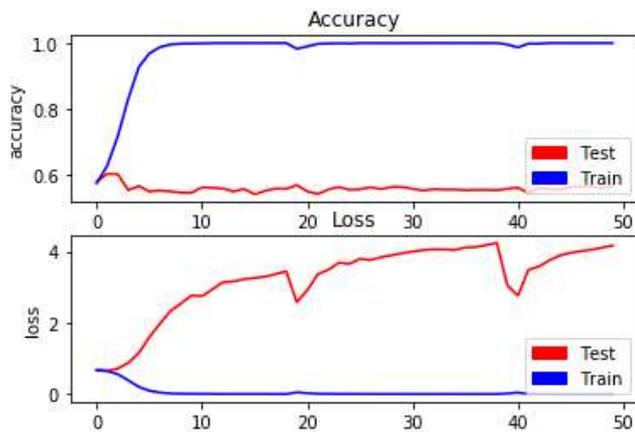


Figure 6: : Depict the accuracy of our CNN model at 50 epochs respectively.

The first graph in figures 5 and 6 shows the accuracy of the model against the number of iterations or epochs. The test and train datasets are highlighted. Both accuracy graphs at 50 epochs show that training of dataset is very accurate while testing dataset has stabilized to 0.6. Similarly; the second graph shows the loss of the training and testing datasets. A steep graph shows an excellent rate of training while the descending graph depicts a good learning rate which is clearly observed in fig 7.

2.DataCamp Dataset

Sno	Results(TF-IDF)	
	Classifier	accuracy
1	Logistic Regression	0.914
2	Multinomial Naive Bayes	0.898
3	Stochastic gradient	0.936
4	SVM	0.936
6	Passive aggressive classifier	0.933

Table 4: Results of TF-IDF

TABLE 1.

Sno	Results(Countvectorizer)	
	Classifier	accuracy
1	Logistic Regression	0.910
2	Multinomial Naive Bayes	0.893
3	Stochastic gradient	0.908
4	SVM	0.879
6	Passive aggressive classifier	0.896

Table 5: Results of CountVectorizer

H. Final Model Selection

1. LIAR Benchmark Dataset

The tabular results clearly show that Naive Bayes algorithm applied with tf-idf is the most accurate model according to its f1 scores; this can be depicted by fig 8.

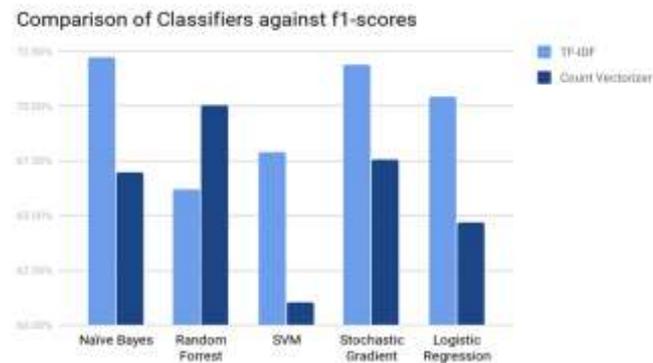


Figure 7: Comparison of classifiers we used in liar benchmark dataset against f1 score

Furthermore, we plot the learning curve to observe the model’s characteristics and learning progress against the training dataset values. Figure 9 displays the learning curve of the selected model.

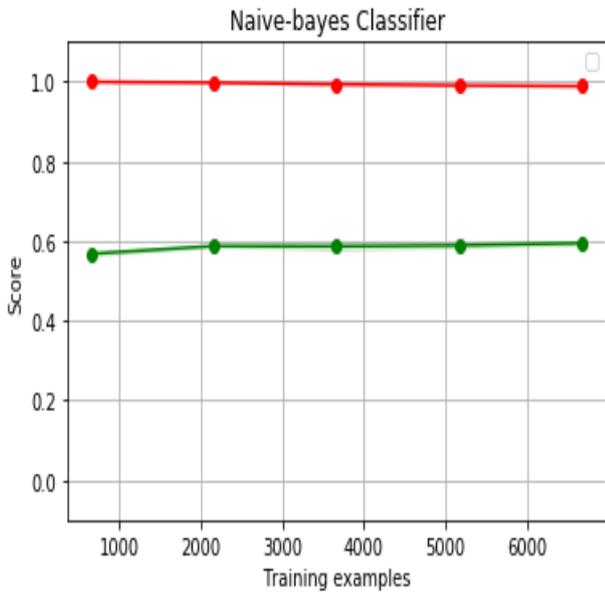


Figure 8: learning curve of naive-bayes classifiers

Hence, we select Naive Bayes algorithm as our final model.

2. DataCamp Dataset

Here we selected 'Support Vector Machine' in terms of model selection which has proven its high accuracy.

a) Performance measures of SVM

- Accuracy: 0.936
- Confusion matrix: (shown in fig 10)

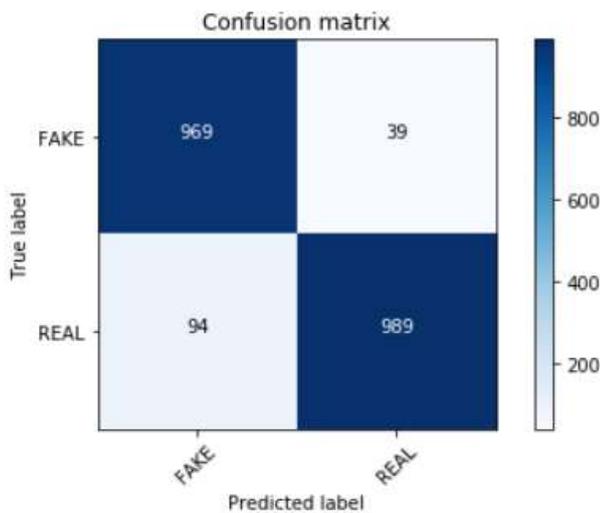


Figure 9: confusion matrix of SVM

Moreover, we also plot the learning curve which shows training error verses the sample size. Figure 11 shows the learning curve of SVM.

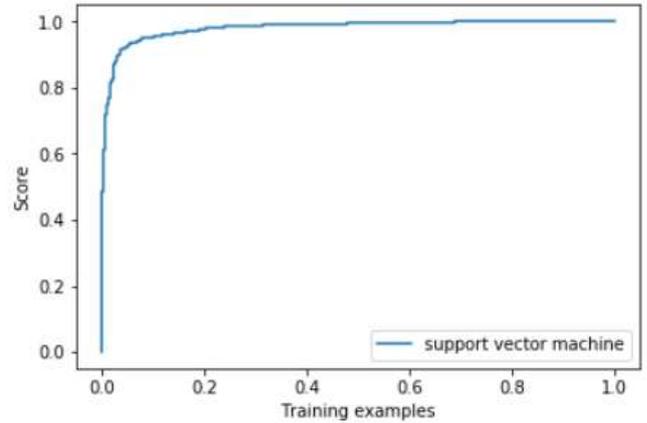


Figure 10: learning curve of SVM

With the use of learning curve we can determine whether our selected model has high parameter estimators.

- Bias: Difference between the expected value and true value of the parameter being estimated
- Variance: It shows, how long the values can be estimated, far from its expected value of the parameter being estimated.

The lower the bias, the higher the variance and vice versa.

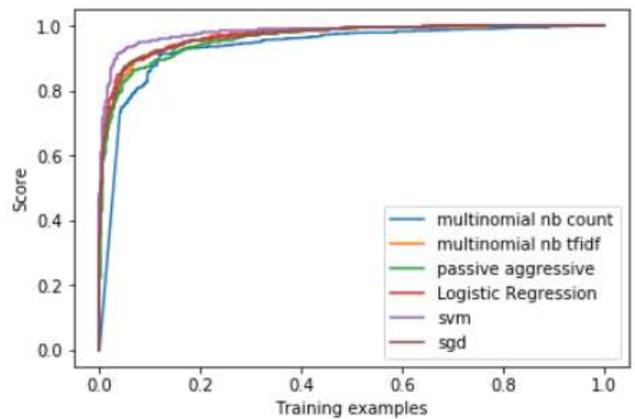


Figure 11. Illustrates the learning curves of all the applied classifiers.

III. FUTURE WORK

- We are moving towards the goal of improving the performance of our model by increasing the number of features or by increasing the training dataset size. NLP techniques such as POS word tagging, unigrams and bigrams can be used to increase the number of features, thereby, enhancing our model's accuracy.
- Moreover, we intend to make an Application Program Interface (API) for which we are going to acquire 'RESTful' web services using 'Python' and the 'Flask' framework that will be portable and easily integrated with a desktop website application. Moving ahead, even a mobile phone application development by using Kivy, which is cross platform software development kit, it contributes in the development of GUI application with python.
- We have worked on figuring out the methodology behind the dataset. Understanding the underlying methodology will give us an edge to working from scratch in different area false news has affected society. Such as, false claims circulating the economic industry can take huge help from this entire project. But the work on the entire project needs to start from scratch where we will be looking into working on a proper dataset, solving bigger issues.
- Working on different domains looking to verify false news, will be on an edge as we have filled the essential steps of machine learning as presented in

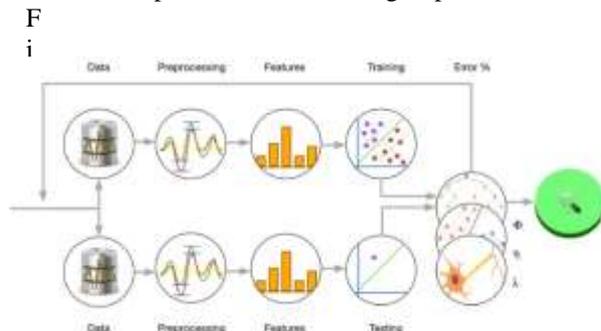


Figure 12: illustrates the steps we have gone through to come to our predictions.

IV. CONCLUSION

With advances in new technology, there are several ways that information can be twisted. So it's important to question what we see, especially things that seem pretty unbelievable. We must use technology like machine learning instead of human fact-checkers because humans might be not well equipped to determine fact from fiction. Moreover fake news can also cause a lot of violence, for instance publication of single pseudo-scientific paper arguing that routine vaccination of

children causes autism inspired an entire anti vaccination movement despite of the fact that original paper was already disregarded by scientific community. So we can't believe what we read without proper justification from viable sources and this can be achieved by making the proper use of Artificial Intelligence (AI) technology.

V. ACKNOWLEDGMENT

This research would not have been possible without our mentors and advisors Dr. Saman Hina and Dr. M. Mubashir Khan who gave us both technical and mental support. They have guided us throughout our journey and at all circumstances encouraged us to go beyond our goals and to accept new challenges and face them with our whole spirit.

We thank you for being a positive inspiration for us and helping us in succeeding towards our goal.

REFERENCES

- [1] "Does Fake News Matter?" *Explore | Are Humans | Ruining the Earth?*, explore.org/question-detail/does-fake-news-matter#1122.
- [2] "Detecting Fake News with Scikit-Learn." *DataCamp Community*, www.datacamp.com/community/tutorials/scikit-learn-fake-news.
- [3] Wang, and William Yang. "'Liar, Liar Pants on Fire': A New Benchmark Dataset for Fake News Detection." [1402.1128] *Long Short-Term Memory Based Recurrent Neural Network Architectures for Large Vocabulary Speech Recognition*, 1 May 2017, arxiv.org/abs/1705.00648.
- [4] *Stanfordnlp*. "Stanfordnlp/GloVe." *GitHub*, 24 June 2018, github.com/stanfordnlp/GloVe.
- [5] "Scikit-Learn." 1.4. *Support Vector Machines - Scikit-Learn 0.19.1 Documentation*, scikit-learn.org/stable/index.html.
- [6] nishitpatel01. "nishitpatel01/Fake\_News\_Detection." *GitHub*, 30 June 2018, github.com/nishitpatel01/Fake\_News\_Detection.
- [7] "Python :: Anaconda Cloud." :: *Anaconda Cloud*, anaconda.org/anaconda/python.
- [8] harsh19. "harsh19/CNN-Text-Classification." *GitHub*, 20 Jan. 2017, github.com/harsh19/CNN-Text-Classification.
- [9] "KDnuggets." *KDnuggets Analytics Big Data Data Mining and Data Science*, www.kdnuggets.com/2018/03/text-data-preprocessing-walkthrough-python.html.
- [10] Deshpande, Adit. "A Beginner's Guide To Understanding Convolutional Neural Networks." *A Beginner's Guide To Understanding Convolutional Neural Networks - Adit Deshpande - CS Undergrad at UCLA ('19)*, adeshpande3.github.io/A-Beginner's-Guide-To-Understanding-Convolutional-Neural-Networks/.
- [11] "Accuracy, Precision, Recall & F1 Score: Interpretation of Performance Measures." *Exsilio Blog*, 11 Nov. 2016, blog.exsilio.com/all/accuracy-precision-recall-f1-score-interpretation-of-performance-measures/.

# Exploration to Optimize Network Traffic by Cuckoo Search Algorithm

Talha Akhtar<sup>1\*</sup>

Department of Computer  
Science & IT  
NED University of Engineering  
& Technology,  
University Road,  
Karachi-75270, Pakistan  
[talhaakhtar@nbp.com.pk](mailto:talhaakhtar@nbp.com.pk)

Najmi Ghani Haider<sup>2</sup>

Department of Computer  
Science & IT  
NED University of Engineering  
& Technology,  
University Road,  
Karachi-75270, Pakistan  
[najmi@neduet.edu.pk](mailto:najmi@neduet.edu.pk)

Shariq Mahmood Khan<sup>3</sup>

Department of Computer  
Science & IT  
NED University of Engineering  
& Technology,  
University Road,  
Karachi-75270, Pakistan  
[shariq@neduet.edu.pk](mailto:shariq@neduet.edu.pk)

**Abstract-** Cuckoo Search (CS) contains innovative method enthused from Meta heuristic approach produced by Yang and Deb in the year 2009. It is established on the offspring parasitism of certain eccentric type of cuckoo species. In the recent study the CS IS hypothetically more effective than Particle swarm Optimization, Genetic Algorithm and its variants. Cuckoos species are charming, because of the attractive sounds in addition they can make also because of their antagonistic duplicate approach. Selected kind such as Ani a Guira cuckoos species placing their spawns in collective Nets; they can remove others' eggs to maximize the generating chance of their particular eggs. Somewhat a quantity of kind involves the force offspring parasitism by placing their offspring in the nests of other congregation birds (often new sorts). The problem definition is load balancing and the aim to examine load burden on overloaded node and optimize traffic burden into under and normal loaded node during rush day's hours by using Cuckoo Search. The respective approach is producing much effective result to heighten the traffic as compare to Particle Swarm Optimization.

**Keyword Search:** - Optimization, Load Balancing, Cuckoo Search, Levy Flights

## I. INTRODUCTION

Optimization produces a significant role for resolving different engineering problems. The objective to find either minimum or maximum value of the problem being solved called objective function [1]. The problem is not only containing to system design, electric generation, wireless communication, network operation and minimization of energy damages during the energy transmission. The appropriate validations of optimization algorithm need valuation of computational interval and conjunction rate in accumulation for defining minimum and maximum values produce by a system [3].

Some investigators have originated optimization algorithm belongs to nature observations, these algorithms called nature-inspired algorithms. Ant and bees move in chronological order collect food from

jungle and accumulated into the nest by using a chemical substance pheromone contain the smell of scents, so movement like a trail of bridge [4] this is known as Ant Colony Optimization (ACO), it is very effective to enhance load burden on computer networks. Particle swarm optimization (PSO) innovated by the inspiration from flocks of birds and school of fish [5]. A Bat nature inspired procedure was created to establish on echolocation to intelligence space among a bat and its adjoining edge [6]. The idea of Differential evolution (DE) process was produced by Storm and Prince [7] consists of population approximation by means of mutation, crossover and selection operators.

Simulated annealing process is a mechanism to construct on the properties of the metal strengthening method [8].

Cuckoo Search (CS) Procedure is enthused from offspring reproductive tactic of cuckoo bird to increase their population [9]. It is very operative form other algorithm like PSO, DE and SA in terms of merging quickness and touch best result. CS is computationally more efficient than PSO [10].

The Cuckoo Search (CS) algorithms to reduce the traffic jamming by maximizing the routine of passage on road networks. The objective function was distinct as entire period and spent cost of 16 connection magnitude extensions [2]. The Cuckoo Search is generated best and optimum result as compare to other past algorithms. CS Algorithm is a mechanism was used to conserve the fault level of voltage variability inside tolerable side by side, thus lessen actual energy damages in smooth network [11].

The goal of this paper of load balancing to maximize the throughput of computer network with minimizes the response time as well as decreasing queue length. The number of active connection must be necessary to optimize the performance of a system. The load burden must be shift on normal loaded and under loaded nodes.

The section 1 describes the Load Balancing and its parameters, section 2 consist of Cuckoo Algorithm and its breeding behaviors. The section 3 describes the Levy Flight mechanism of Cuckoos. The section 4 defines Cuckoo Search Algorithms. The section 5 consists of Experiment and section 6 consists of

Comparison of PSO and CS and Section 7 is improvement in CS Algorithm section 8 consist of Graphical representation by using PRTG Monitoring Tool. The last section is conclusion.

Figure 1 Load Balancing Using Cuckoo Search Load Balancer

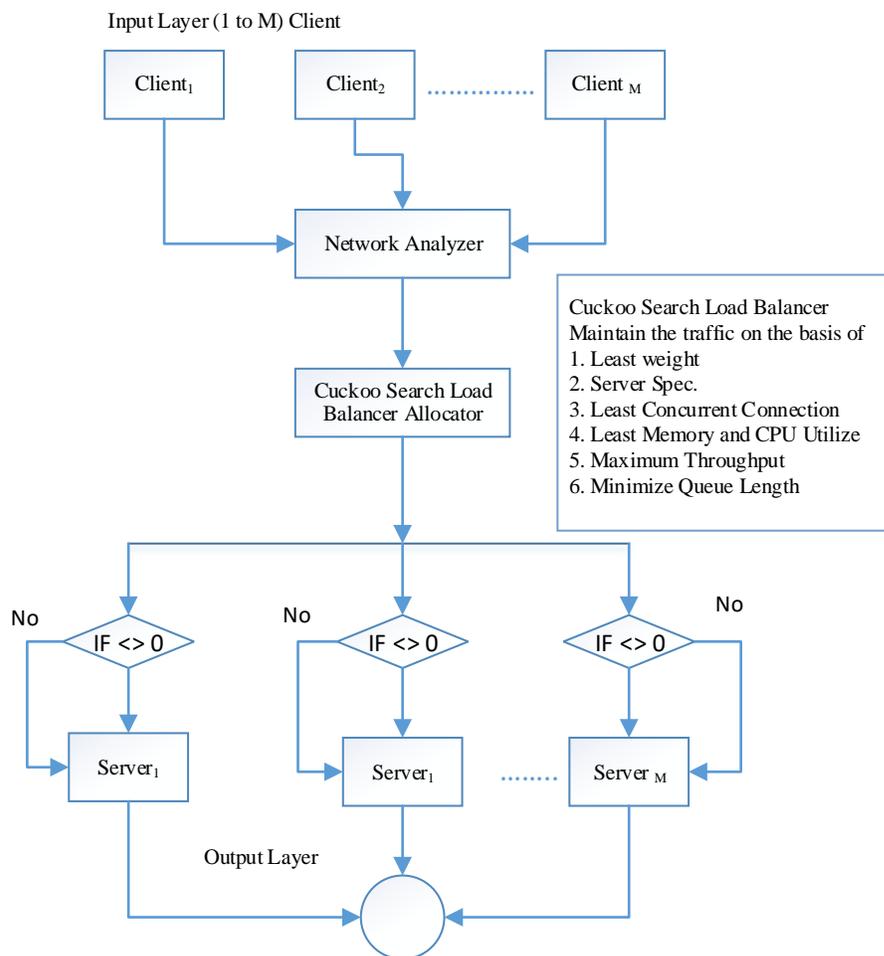


Fig 1 Load Balancing using Cuckoo Search Algorithm

## II. LOAD BALACING PARAMETERS

Load Balancing is a mechanism to optimize the network traffic on computer network and shift the traffic on less loaded or under loaded nodes. There are following parameter are considering optimizing the traffic on peak hours, days and maintaining its stability which is under as:

1) **Throughput:** - The quantity of task has been executed. It must greater to maximize the enactment

of the network system. If the response time is decrease definitely the throughput is maximize.

2) **Overhead Associated:** - this one is making of upstairs due to transfer of jobs, inter-procedure and inter- process message transfer. It can be minimize to increase the performance of the system and work efficiency

3) **Fault Tolerance:** - The Facility of process to achieve constant load burden in spite of random node

or linkage down. The load burden is necessary for best fault tolerance procedures.

**4) Migration Time:** - Time requires transferring of job from on node to another node. It should be minimize to maximize the strength of computer network system.

**5) Response Time:** - the quantity of interval to reply a specific weight burden process in distributed scheme. It must be minimize to overcome milestone.

**6) Scalability:** - the facility of a procedure to achieve weight burden for a computer network system with limited number of nodes. This size would be better-quality.

**7) Performance:** - it is used to find productivity of the computer network system. This must be better at a sensible rate e.g. to lessen response time span though observance tolerable delay time [13].

**8) Queue Length:** - 1. If  $Q(m)$  ( $1 \leq m \leq M$ ) is the existing queue length of certain computer server machine  $m$ , the predictable queue length after interval  $T$ , [equivalent to the predictable period between two consecutive] can be estimated by-

$$Q(m) = Q(m) + L(m) - T \mu / f_s(m) \quad \dots \quad 1$$

Here  $L(m)$  predictable amount of requests allocated to server  $m$ ,  $T$  interval, is the service rate, is the Mean of the new arrival request in this time interval.

2.  $T \mu / f_s(m)$  is predictable amount of call processing  $T$  supposing that the server is continuously in busy state. The queue length minimizes to overcome best performance.

### III. CUCKOO BREEDING SCHEME

The Cuckoo Search is motivated by the need parasitism of certain cuckoo species class via placing their offspring spawns into the shell of individual animals. Nearly cuckoos species have elaborated so that female parasitic cuckoo's species can reproduce various shades and pattern of the egg of slight nominated host kinds. This minimizes the chance of the eggs being plentiful so re-production is maximized. It is to mention that various swarm birds engage nonstop battle with interrupting cuckoo species. If the congregation birdie determines the egg is not their belonging to the family, they will either toss them out or simply abandon their shell and form fresh ones. Parasitic cuckoo's species frequently select a shell where the congregation bird just placed its eggs belong to its own family. In common, the cuckoo eggs entrance slightly previous than their host eggs. Once the first cuckoo chick is entrance, his first nature action is to remove the host eggs by blindly pushing the eggs out of the nest. This achievement results in growing the cuckoo chick's share food provided by its host bird [12]. The breeding behavior of the cuckoos can be applied in engineering

optimization problem specially load balancing of computer network in peak days, hours and slightly shift on lighted loaded nodes. The Levy Flights mechanism is used instead of simple random walk tom improve the performance of Cuckoo Search.

### IV. LEVY FLIGHTS MECHANISM

The Different types of species having a characteristic to forage the food in a haphazard way in environment. The searching way of species is efficiently a haphazard movement because the subsequent change is depending upon the present place of species position and conversion chance to next location. The selection of direction to foraging food modelled mathematically. Compare to normal walk the levy flights are additional well-organized in discovering big scale of search zones. In some animal it is followed by 90° degree turn compare to normal walk. The variance of levy flights much quicker than that of usual random walk [9].

### V. CUCKOOO SEARCH OPERATION

The main purpose of Cuckoo Search nature inspired algorithm to reproduce of cuckoos birds. The cuckoo normally places their fertilized eggs in other cuckoos species shell with anticipation of their off-spring having higher by substitution maternities. It is time decide that the eggs is not belong to their family. In this position the foraging eggs are also terrified out of shell or whole nest are uncontrolled. There are three types of rules based on relative algorithm:

- Each Cuckoo chooses one eggs randomly form the nest and place the egg to the nest to other species.
- The best shell with the great value of eggs will be passed for the next group.
- The amount of current congregation shell is established, and host can catch an alien egg with probability  $P_a \sum [0, 1]$ . In that condition congregation cuckoo species either toss the egg away or abandon the shell and build a new one someplace else.

VI. EXPERIMENT

A. Parameters

int npar = 100;	quantity of enhancement
double varLo = -5.0;	minimum value of band
double varHi = 5.0;	maximum value of band
int numCuckooS = 5;	initial quantity
double numNewCuckooS = 0.0;	New quantity
int minNumberOfEggs = 2;	least quantity of eggs
int maxNumberOfEggs = 4;	extreme quantity of eggs
int maxIter = 100;	highest repetitions
int knnClusterNum = 1;	quantity of clusters
int motionCoeff = 9;	Lambda variable in COA paper, default=2

B. Initialize number of eggs for each cuckoo

```
for (a = 0; a < numCuckooS; a++)
{
  numberOfEggs[a] = ((maxNumberOfEggs -
  minNumberOfEggs) * rnd.Next() +
  minNumberOfEggs);
}
```

C. Get total number of available eggs between all cuckoos

```
for (a = 0; a < numCuckooS; a++)
{
  summ = summ + numberOfEggs[a];
}
```

D. Calculate egg laying radius for each Cuckoo, considering problem

```
eggLayingRadiuses[c] = eggLayingRadiuses[c] +
rnd.Next(1, aa);
}
```

```
for (a = 0 ; a < numCuckooS; a++ )
{
  params1[a] = cuckooPop1[a];
  tmpRadiuses[a] = eggLayingRadiuses[a];
}
```

E. Get total number of available eggs between all cuckoos

```
for (a = 0; a < numCuckooS; a++)
{
  eggLayingRadius[a] = numberOfEggs[a] / summ *
  (radiusCoeff * (varHi - varLo));
}
```

F. Now we evaluate egg positions

```
for (a = 0 ; a < numCuckooS; a++)
{
  allPositions[a] = allPositions[a] + cuckooPop1[a] +
  newPosition4Egg[a];
}
```

G. Cuckoo Search Process flow

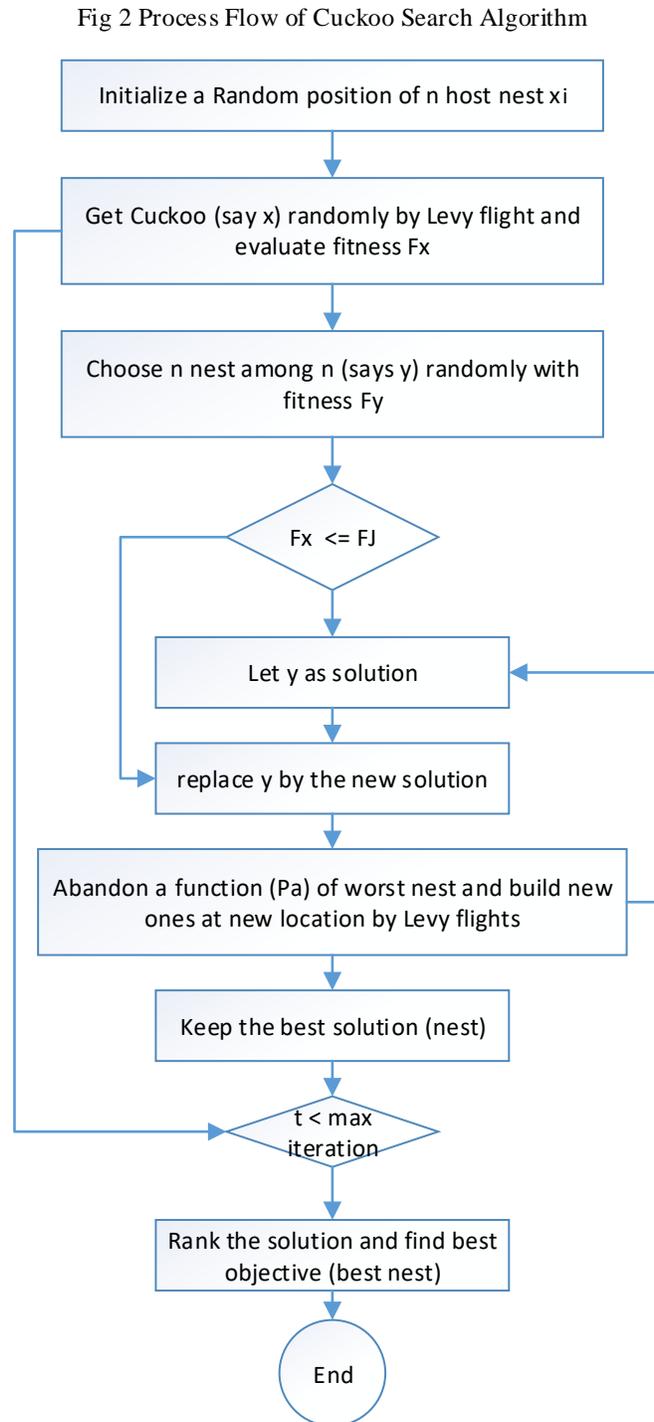


Fig 2 Process Flow of Cuckoo Search Algorithm

VII. COMPARISON OF PARTICLE SWARM OPTIMIZATION (PSO) AND CUCKOO SEARCH ALGORITHM (CK)

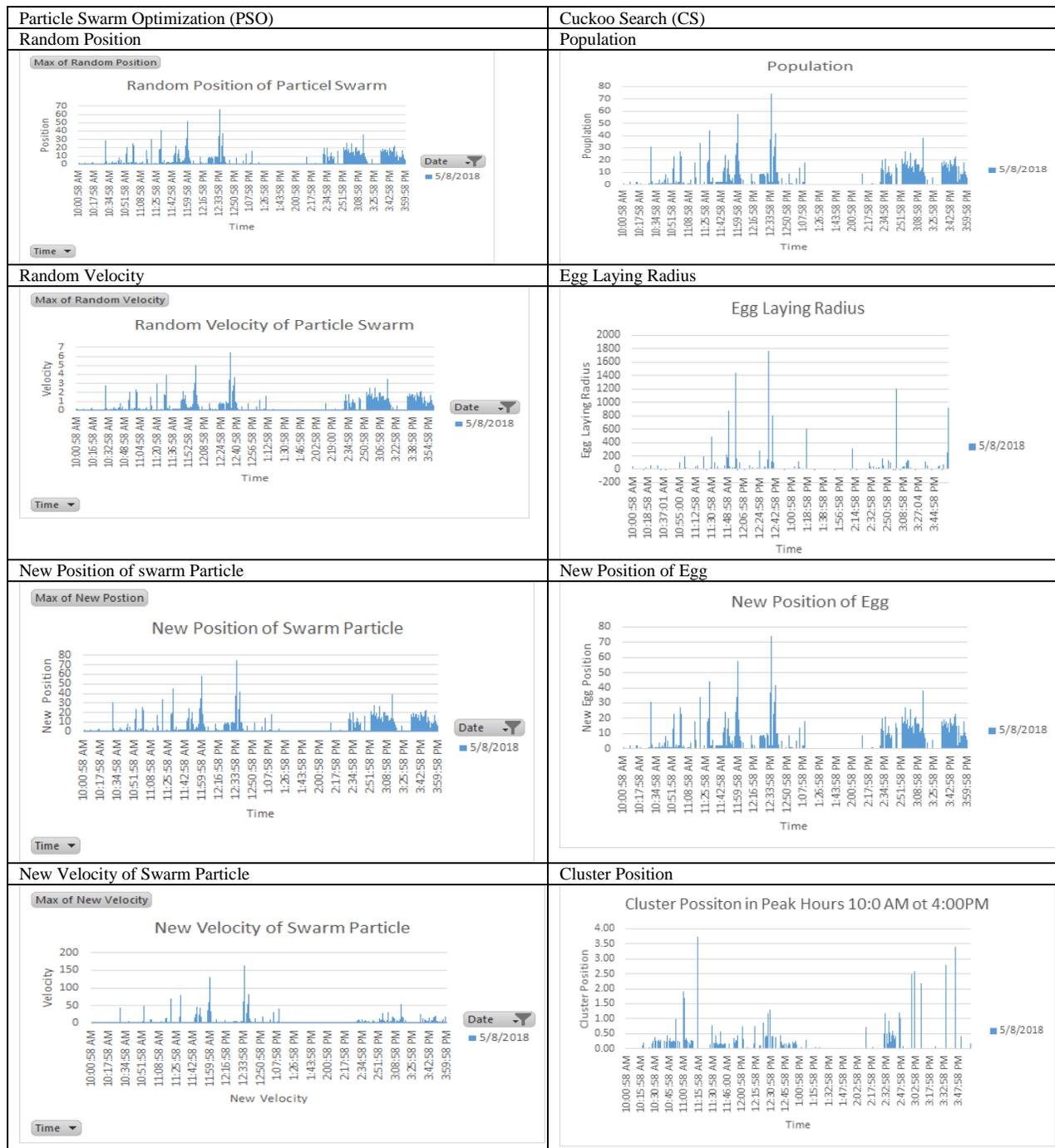


Fig 3 Comparison of CSA and PSO

VIII. IMPROVEMENT IN EXPERIMENTAL RESULT OF CUCKOO SEARCH ALGORITHMS (CK)

A. Parameters

int npar = 100;	quantity of enhancement
double varLo = -5.0;	minimum value of band
double varHi = 5.0;	maximum value of band
int numCuckooS = 5;	initial quantity
double numNewCuckooS = 0.0;	New quantity
int minNumberOfEggs = 2;	least quantity of eggs
int maxNumberOfEggs = 4;	extreme quantity of eggs
int maxIter = 100;	highest repetitions
int knnClusterNum = 1;	quantity of clusters
int motionCoeff = 9;	Lambda variable in COA paper, default=2

We can improve the result by changing the parameter to get optimum result. The Value is change dynamically according to the condition of network burden. How to improve the response time as well as minimize queue length of process execute on the machine and how to shift on neighboring and under loaded and normal loaded node. If we receive maximum throughput so the performance become maximize as well as task scheduling is perform on equal no of load on existing nodes or task will be execute depends upon hardware spec or number of active concurrent connection. The improvement can be possible in optimization of local optimum and global optimum because if an egg through so it can change position from random position to global position. The purpose of research to increase or decrease the value of parameter between the local and global random walk as well as number epoch. The

purpose to increase decrease the CPU usage, memory management, number of active concurrent connection on neighboring edges or node. We can improve by changing switching parameter as well as changing in exponential parameters. We can optimize the quantity of eggs, variation in eggs laying radius, new egg position and cluster position of cuckoos.

B. Traffic Load in Peak Hours

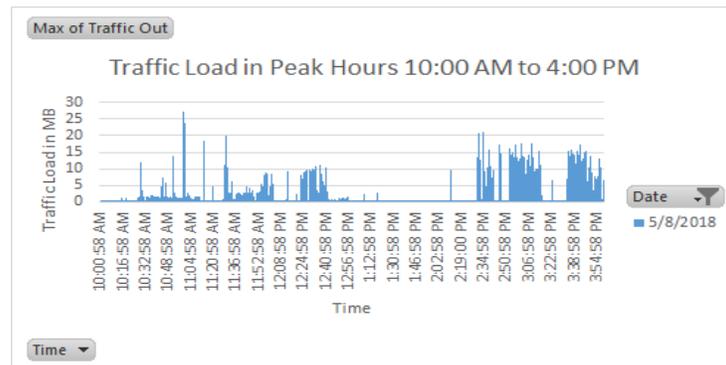


Fig 4 Load Burden in rush hours

C. Traffic Load Optimize

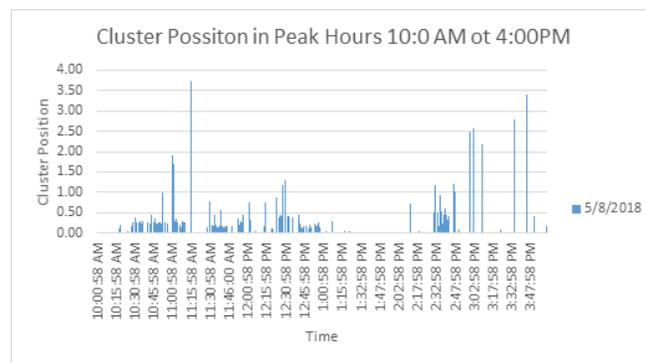


Fig 5 Traffic Optimize

IX. GRAPHICAL REPRESENTATION OF CUCKOO SEARCH BY USING PRTG NETWORK MONITORING TOOL

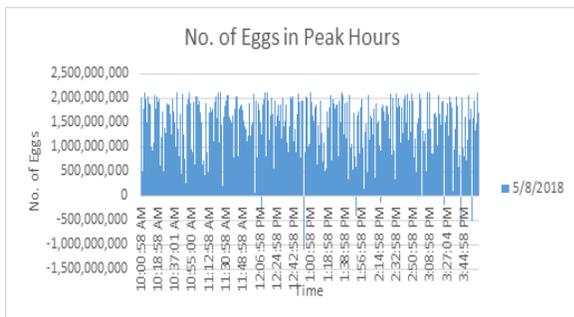


Fig 6 No. of Eggs in Peak Hours

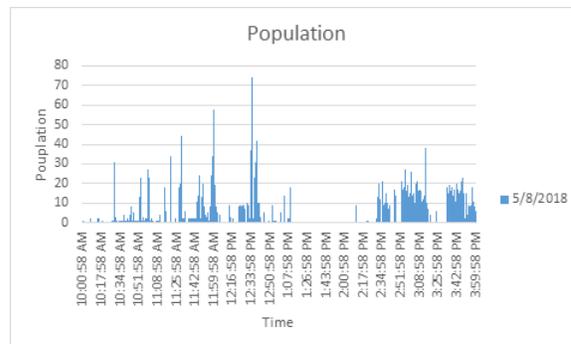


Fig 9 No. of Population

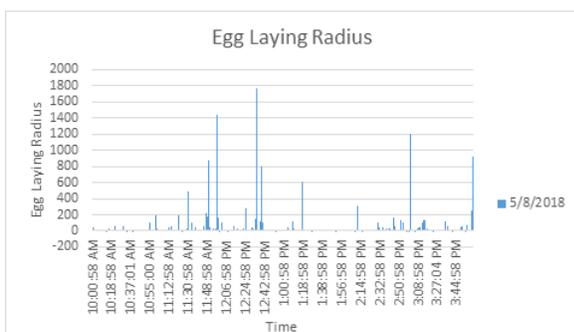


Fig 7 No. of Eggs Laying Radius through by cuckoo of alien egg

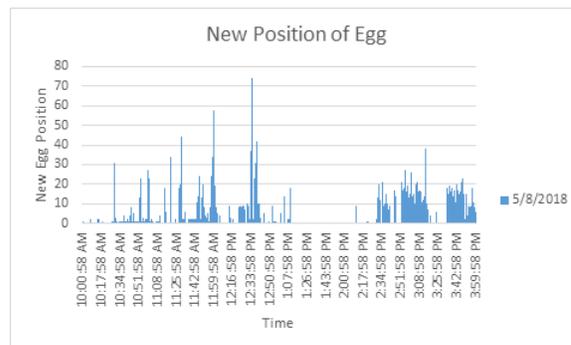


Fig 10 New Position of Egg

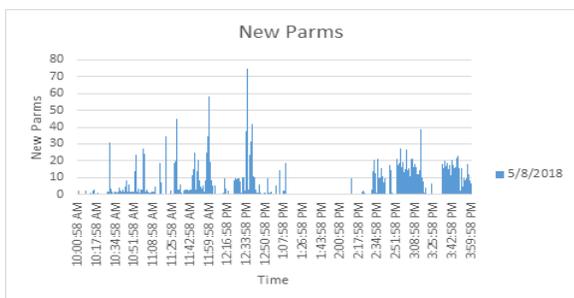


Fig 8 New Parameters

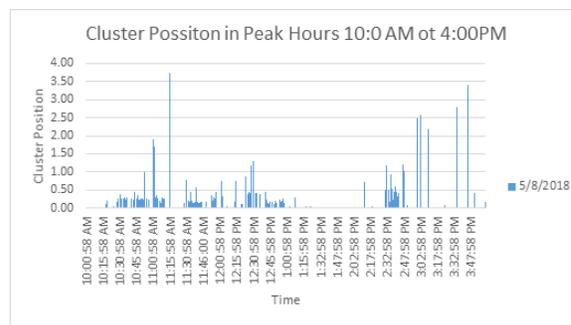


Fig 11 Cluster Position or reduce load burden

CONCLUSION

The load burden is minimizing by using Cuckoo Search Algorithm in peak hour or days by updating current position into new position. It is helpful in greater number of nodes burden and it is shift to lighter nodes. The response time in minimize and throughput is maximized. The memory usage is also

minimized and shifts the traffic on least number of active connection nodes. The queue length is minimize is also a big achievement. The traffic is equally divided or depends upon the specification of node. If a server has more spec. then the quantity of traffic is divert to those nodes is maximize.

## REFERENCES

- [1] S. Nouredine, An Optimization approach for the satisfiability problem. *Appl. Comput. Inform.* 11 (1) (2015) 47-56
- [2] O. Baskan. Determining optimal link capacity expansions in road networks using Cuckoo search algorithm with Levy flights, *J. Appl Math.* 2013 (2013) 1-11
- [3] A. Platonov. Information theory and optimization of analog feedback communication systems, in 2016 IEEE International Black Sea Conference on communication and Networking 2016.
- [4] Gao R. and Juebo W., "Dynamic Load Balancing Strategy for Cloud Computing with Ant Colony Optimization", *ICI 2007, 3rd IEEE/IFIP International Conference in Central Asia on Internet*, pg 1–7, Sept. 2007.
- [5] D.P. Rini. S.M. Shamsuddin. S.S. Huhani, Particle Swarm Optimization: technique, system and challenges. *Int. J. Comput. Appl.* 14(1) (2011) 19-27.
- [6] X.S. Yang A new metaheuristic bat-inspired algorithm, in J.R Gonzalez D.A. Pelta. C, Curz G. Terrazas N. Krasogor (Eds.). *Nature inspired Cooperative Strategies for Optimization (NICSO 2010)* vol. 284. Springer, Berlin, 2010. Pp. 65-84.
- [7] R. Storm, K Prince. Differential evaluation – a simple and efficient heuristic for global optimization over continuous spaces. *J. Global Optim.* 11 (4) (1997) 341-359.
- [8] S. Kirkpatrick, C.D. Gelatt. M.P Vecchi. Optimization by simulated annealing *Science* 220 (4598) 1983 670-680.
- [9] X.S Yang, *Nature-inspired Optimization Algorithms*, first ed. Elsevier. London. 2014.
- [10] M.A. Adnan, M.A. Razzaque, A Comparative study of particle optimization and Cuckoo search technique through problem - specific distance function, in 2013 International and communication Technology (ICoICT). Bandung Indonesia. 2013.
- [11] W. Buaklee. K Hongesombut. Optimal DB Allocation in smart distribution grid using Cuckoo Search algorithm. *ECTI Trans. Electr. Engr. Electron. Commun.* 11 (2) (2013) 16-22.
- [12] X. S. Yang. S. Deb, Engineering optimization by Cuckoo search, *int. j. Math. Modell. Numeric Opt.* 1 (4) (2013) 16-22.
- [13] Nada. M. Sallami, Al., Sarmad A., Load Balancing with Neural Network, *IJACSA* (4) 2014, 138-144

# QKD Protocols: Comparison & Security Analysis

A Comprehensive Theoretical and Simulation Analysis of QKD Protocols

Ehtesham Khan

Department of Computer Science & Information Technology  
 NED University of Engineering & Technology  
 Karachi, Pakistan  
 ehtesham\_khan@live.com

Muhammad Mubashir Khan

Department of Computer Science & Information Technology  
 NED University of Engineering & Technology  
 Karachi, Pakistan  
 mmkhan@neduet.edu.pk

**Abstract**—The inception of quantum key distribution (QKD) empowered the communication networks with unconditional security because of the unique characteristics of quantum mechanics. Since QKD genesis, various protocols have been proposed to augment the feasibility of its real-world implementation and to overcome the inherent vulnerabilities of communication channel. In the past several years’ studies emphasize the significance of QKD in the field of secure communication because it can counter critical attacks quite effectively. In this paper, we present in-depth security analysis of the notable QKD protocols which encompasses from their theoretical assertions to their practical implementation factors and simulation outcomes.

**Keywords**—QKD; Quantum Key Distribution; Quantum Cryptography; QKD Protocols; Comparison; Security Analysis; Simulation; Network Implementation;

## I. INTRODUCTION

In the cryptosystem the secure key exchange between the two legitimate parties over the public channel was one of the crucial issue. In the classical cryptography, the fundamental architecture of security schemes depends upon mathematical complexity like Public-Key Infrastructure (PKI) which is eventually based upon computational power, that is a handicap as per “Moore’s Law” [1] and will not remain secure ultimately once quantum computers are readily available to the users [2].

Due to this limitation of classical cryptography, it is never considered to be unconditionally secure but more as a reasonably secure. Otherwise, the encryption technique like “One-Time-Pad (OTP) or Vernam Cipher” [3] comprises the guaranteed security for the operational requirements of an ideally secure communication. In contrast, quantum cryptography opens new horizons in the field of secure communication that motivated and aided researchers to evolve the novel key distribution methodology, which could offer the absolute security.

“Quantum cryptography differs from conventional cryptography in that the data are kept secret by the properties of quantum mechanics, rather than the conjectured difficulty of computing certain functions.” [4]

This paper is organized in four major sections. In section II, significance of QKD and the elementary methodology about its protocols that are in practice, is discussed. In section III, the theoretical analysis of selected QKD protocols based upon factors of their real-world network implementation and simulation analysis based upon their efficiency against eavesdropping detection is evaluated. In section IV, the conclusion about security analysis of the selected QKD protocols is presented.

## II. QKD CRYPTOGRAPHY & ITS PROTOCOLS

The methodology of transferring a secret key between the two legitimate parties through quantum channel (QC) by using laws of physics for quantum mechanics such as “No-cloning theorem” [5], termed as Quantum Key Distribution (QKD).

Besides of “No-cloning theorem”, the information can be encoded by using properties like superposition states, electron spins or photon polarization of quantum particles. QKD focuses upon distribution of the secret key, not the complete data. Since QKD beginning, several protocols have been introduced and investigated to address the numerous challenges of communication field.

The subsequent sub-sections briefly explains the prominent QKD protocols (chronologically) with their core functional methodologies, that are compared in later section of this study based on their network implementation factors.

### A. BB84 Protocol

The first QKD Protocol is acclaimed for its simplicity and novelty, named after C. H. Bennett and G. Brassard [4] introduced in 1984. This protocol is based on Uncertainty Principle [6] contributed by German physicist, Werner Heisenberg in 1927. Alice and Bob can transfer the key, using mutually unbiased bases (i.e.  $e$  or  $f$ ) and encoding scheme (i.e.  $|e_1\rangle$  or  $|f_1\rangle = 0$  and  $|e_2\rangle$  or  $|f_2\rangle = 1$ ) with the efficiency of 25%. The core methodology of this novel scheme is elaborated as follows:

- First, Alice generates stream of random bases and random bits.
- Alice measures these bits as per its stream of bases into the qubits, then sends them to Bob over the quantum channel (QC).
- Bob generates stream random bases and measures the each of the qubit received from Alice.
- Once the measurement by Bob is completed, Alice announce its stream of bases over the classical channel (CC).
- Measured bits where Bob’s bases and the Alice’s bases is same, that bit will be selected for a key.

TABLE I. BB84 MEASUREMENT MECHANISM

Bases Announced by Alice	Bob’s Measurement Result			
	$ e_1\rangle$	$ e_2\rangle$	$ f_1\rangle$	$ f_2\rangle$
$E$	0	1	×	×
$F$	×	×	0	1

*B. E91 Protocol or EPR Paradox*

In 1991, A. K. Ekert designed a peculiar protocol [7] whose foundation based upon EPR Paradox. The EPR Paradox is one of the brilliant mistakes of history that eventually becomes the remarkable contribution by scientists A. Einstein, B. Podolsky and N. Rosen in 1935, named as Einstein-Podolsky-Rosen (EPR) which endorses the prospects of Quantum Entanglement [8]. The mechanism of this unique scheme is as follows:

- One of the entangled pair must be transferrable between Alice and Bob over QC.
- The entangled pair must be perfectly correlated in a way; they must get the exact outcome with 100% probability from each photon of that entangled pair.
- Then, Alice and Bob will receive the stream of random qubits for measurement with random bases over QC.
- When the measurements are completed one of them publicly announced their used stream of bases over CC.
- In a similar fashion like BB84, Alice and Bob will consider the result of measured qubits for the key construction, where only their respective basis matches with each other.

According to the Bell's inequality experiment [9], perfectly entangled (correlated) photons can result maximum  $S = 2\sqrt{2}$ . So, if Evan attempts to intercept key transmission, it will destroy the correlation between the photons of entangled pairs, through which Alice and Bob can easily find out the presence of eavesdropping.

*C. B92 Protocol*

This protocol presented in 1992 by one of the original author of BB84 protocol, C. H. Bennett [10]. It's a simplified version of BB84 protocol. The only variation is using two non-orthogonal states (i.e.  $|e_2\rangle = 0$  and  $|f_1\rangle = 1$ ) instead of two orthogonal states. This protocol behaves in a similar way as BB84 as follows:

- First, Alice initiates stream of random bases and random bits.
- Alice measures these bits as per its stream of bases into the qubits using two non-orthogonal states, then sends them to Bob over the QC.
- Bob generates stream random bases and measures the qubits received from Alice.
- Once the measurement is completed, Bob announce its stream of bases over CC.
- Measured bits where Bob's bases and the Alice's bases is same, that bit will be selected for a key.

TABLE II. B92 MEASUREMENT MECHANISM

Bases Used by Alice	Bob's Measurement Result	
	$ e_2\rangle$	$ f_1\rangle$
$e$	0	×
$f$	×	1

*D. Differential Phase-Shift (DPS) Protocol*

This protocol introduced in 2002 by K. Inoue, E. Waks and Y. Yamamoto [11]. The algorithm of scheme is as follows:

- Alice splits single-photon into three pulses with equal ratio & recombines using beam splitter (BS).
- $T$  are time delays between two sequential pulses.
- Two sequential probability amplitudes are randomly modulated by  $0$  or  $\pi$ , then sends to Bob over QC.
- Bob splits the incoming photons into two equal paths and recombines by BS such as time delay remains  $T$ .
- Bob measures recombined output using photon detectors  $D_1$  &  $D_2$  and prepares key such as (i.e.  $D_1 = 0$  &  $D_2 = 1$ ).

DPS protocol claims greater robustness against PNS attack when single-photon source is used in ideal conditions.

*E. SARG04 Protocol*

In 2004, V. Scarani, A. Acin, G. Ribordy and N. Gisin presented this protocol [12]. It's identical to BB84, except the difference in reconciliation phase, with encoding scheme (i.e.  $|e_1\rangle$  or  $|e_2\rangle = 0$  and  $|f_1\rangle$  or  $|f_2\rangle = 1$ ), as follows:

- SARG04 performs same as BB84, for initial phase.
- For later phase, when Alice and Bob determine for which bits their bases matched.
- Alice declares its non-orthogonal states instead of declaring its basis, in which one is used in encoding.
- If Bob selected the right basis, measurement will give the correct result.
- If Bob selected the wrong basis, measurement will give either Alice's initial bit or unable to find out bit.

SARG04 protocol seems quite robust in scenario of PNS attack due to its novelty of its reconciliation phase.

*F. Coherent One Way (COW) Protocol*

To countermeasure the challenge of commercial readiness of single-photon sources, this protocol was introduced by N. Gisin, et al., in 2004 [13] based on weak coherent pulses (WCP) using time slots. Later augmented by A. I. Khaleel in 2012 [14]. This scheme are as follows:

- Alice will encode bit stream with time slots and sends to Bob. The probability of decoy bits will be  $f$  and leftover will be shared into original bits as  $(1 - f)/2$ .
- Bob utilize data detector ( $DB$ ) to measure raw key and time monitoring detector ( $DM_2$ ) for security.
- Bob announces the number of measured bits by  $DB$  and time of detections by  $DM_2$ .
- Alice verifies the sequence of bits & decoy bits and time of detections by interferometer. When Evan intercepts, the coherence will be broken so can be detected easily.
- Then, Alice announce bits of raw key on which Evan intercepted, and it will not be included in final key.

G. KMB09 Protocol

In 2009, this protocol was proposed and named after the authors; M. M. Khan, M. Murphy and A. Beige [15]. It's an advancement of the original BB84 protocol that enhances the efficiency rapidly to detect eavesdropper with the higher dimensions of its implementation.

The minimum ITER for KMB09 (2-dim) is same as BB84 i.e. 25% but for KMB09 (4-dim) it increases up to 50% analytically. Alice and Bob can transfer the key even in the presence of Evan, using mutually unbiased bases (i.e.  $e$  or  $f$ ), encoding scheme (i.e.  $|e_i\rangle = 0$  and  $|f_i\rangle = 1$ ) and an index of each qubit (i.e.  $i = 1, 2 \dots N$ ). The underlying idea of the protocol stated as follows:

- First, Alice generates stream of random bases and random bits.
- Alice measure these bits as per its stream of bases into the qubits, then sends them to Bob over the QC.
- Bob generates stream random bases and measure the qubits received from Alice.
- Once the measurement is completed, Alice announce its stream of indices of qubits over the CC.
- Measured bits where Bob's index and the Alice's index is not same, that bit will be selected for a key.

TABLE III. KMB09 (2-DIM) MEASUREMENT MECHANISM

Index Announced by Alice	Bob's Measurement Result			
	$ e_1\rangle$	$ e_2\rangle$	$ f_1\rangle$	$ f_2\rangle$
1	×	1	×	0
2	1	×	0	×

H. S13 Protocol

This protocol was elaborated by E. H. Serna in 2013 [16]. The premise of this protocol not to lose of any bit during the key exchange, to get the final key as equal length of the plain text for usage in OTP. It's an augmented version of BB84 and identical in its initial phases, but have novelty of usage of private reconciliations, random seed and asymmetric cryptography. The core phenomenon of this model as follows:

- For quantum part, initial phases remain identical as BB84, except Alice or Bob will announce a random binary string  $x_1 x_2 \dots x_N$ , that is named as Random Seed.
- In classical part, asymmetric cryptography is used in which mainly Alice sums  $i_k \oplus j_k$ , (i.e.  $k = 1, 2 \dots N$ ) to acquire the  $y_1 y_2 \dots y_N$  that forwarded to Bob.
- In private reconciliation phase, Alice compares strings  $s_1 s_2 \dots s_N$  &  $m_1 m_2 \dots m_N$  and sends to Bob  $s_k \oplus m_k$ .
- In ideal scenario, Alice and Bob exchange four secret keys of length  $N$  i.e.  $m_1 m_2 \dots m_N$ ,  $s_1 s_2 \dots s_N$ ,  $i_1 i_2 \dots i_N$  &  $j_1 j_2 \dots j_N$ .

This scheme claims the zero information losses because the probability of the reconciled key against the size of the raw key is 100% comparatively to 50% probability in BB84.

I. AK15 Protocol

In 2015, A. Abushgra and K. Elleithy introduced this protocol [17]. This protocol consists four phases *Authentication, Transformation, Exchanging* and *Reconciliation* by using *EPR, Quantum* and *Public* channels. It is based on both Heisenberg Uncertainty and Quantum Entanglement principles. The protocol as follows:

- Alice establishes a link and shares authentication key ( $a_c$ ) with Bob through various steps on EPR channel (EC).
- While encoding of  $a_c$  including dimensions of matrix, sorting rows and initiation time done through QC.
- Alice places data bits in the lower-triangle and random qubits in the upper-triangle and diagonal with parity bit (i.e. 0 or 1), then sorts as per the  $a_c$ .
- Alice then transmits the rows of matrix with the selected time, length and indices, that seems random to Evan.
- Bob then measures the sent stream of qubits as per the decided size of matrix and verifies that there are any interruptions or not through parity cell.
- After comparing the measurement results with the original bits sent by Alice and can decide to reject the attempt and restart again, if the QBER is above 90%.

This protocol claims that it is more robust than the original BB84 protocol and designed in such a way that it can detect eavesdropping even in weak scenarios.

J. LZWW16 Protocol

This protocol is proposed in 2016 by H. Li, L.X. Zhu, K. Wang, K.B. Wang and claimed to be the improved version of BB84 in transmission efficiency rate [18]. The algorithm of the improved scheme as follows:

- Firstly, Alice and Bob agree upon the polarization of basis either it will be rectilinear or diagonal and assured by advance signature.
- Alice generates stream of random bits and encodes as a single photon polarization, and sends over the QC.
- Bob decodes the upcoming single photon with a selected polarization basis and notes the results and time slots.
- In case of eavesdropping, Bob will send time slots in which the qubits have not been received.
- Then Alice and Bob perform the reconciliation of original bits with measurement results and decides which qubits needs to be discarded.
- Error correcting code has been introduced to resolve stream in case of minor errors.
- After error correction, the bit sequence by Alice and Bob is component of encryption, so Evan have as minor as possible to obtain key knowledge.

Major benefit of this scheme is that it removes the step of extracting original key, but also resolves the authentication issue of communication and offers double efficiency than BB84.

### III. COMPARATIVE ANALYSIS OF QKD PROTOCOLS

In this section, we elaborated the in-depth theoretical and simulation analysis of the prominent QKD protocols (chronologically) based on different network implementation factors.

In sub-section A, we focus to accumulate the theoretical characteristics of the QKD protocols about the practical implementation on the common network topologies as well as the robustness against the critical Man-in-the-Middle (MITM) attacks.

In sub-section B, we have developed and simulated the BB84 & KMB09 (2-dim) protocols with an open-source python framework; named as Quantum Toolbox in Python (QuTiP) [19], [20] for various scenarios through which we replicated, evaluated and verified the significant results of eavesdropping detection, claimed by the respective authors.

#### A. Theoretical Analysis

We comprise the analysis of selected QKD protocols as per the theoretical knowledge acquired from the original literature, conference proceedings, journals or their recent advancements. It mainly encompasses the contrast among the selected QKD protocols in terms of the following features:

- *Robustness*: against critical MITM attacks i.e. Photon-Number-Splitting (PNS) attack & Intercept-and-Resend (I&R) Attack
- *Efficiency*: due to impact Eavesdropping on Quantum Bit Error-Rate (QBER), Bell's Inequality (BI), Phase Error (PE) & Index Transmission Error-Rate (ITER)
- *Reliability*: in terms of eavesdropping detection in the presence of native transmission losses of communication channel in real-world implementation

TABLE IV. THEORETICAL ANALYSIS OF QKD PROTOCOLS

QKD Protocols	Comparison Factors					
	Encoding Scheme	Number of States	Safety against PNS Attack	Safety against I&R Attack	Minimum Error due to I&R Attack	Core Principle
<b>BB84</b>	$\uparrow$ or $\nearrow = 0$ $\rightarrow$ or $\searrow = 1$	4 states	Low	Low	QBER $\geq 25\%$ [14]	Uncertainty
<b>E91 / EPR</b>	$Z_{0^\circ}$ or $Z_{45^\circ}$	2 entangled photons	Low	High	BI $< 2\sqrt{2}$ [20]	Entanglement
<b>B92</b>	$\nearrow = 0$ $\rightarrow = 1$	2 states	Low	Low	QBER $< 5\%$ [21]	Uncertainty
<b>DPS</b>	N/A	4 states	High	High	PE $> 2\%$ [22]	Entanglement
<b>SARG04</b>	$\uparrow$ or $\rightarrow = 0$ $\nearrow$ or $\searrow = 1$	4 states	Medium	High	QBER $\approx 11.5\%$ [23]	Uncertainty
<b>COW</b>	N/A	Time intervals	High	High	PE $< 2\%$ [22]	Entanglement
<b>KMB09 (2-dim)</b>	$\uparrow$ or $\rightarrow = 0$ $\nearrow$ or $\searrow = 1$	4 states	High	High	QBER $\geq 25\%$ ITER $\geq 25\%$ [14]	Uncertainty
<b>KMB09 (4-dim)</b>	$\{\{e_i\}: i = 1 \dots 4\} = 0$ $\{\{f_i\}: i = 1 \dots 4\} = 1$	8 states	High	High	QBER $\geq 37.5\%$ ITER $\geq 37.5\%$ [14]	Uncertainty
<b>SI3</b>	$\rightarrow$ or $\searrow = 0$ $\uparrow$ or $\nearrow = 1$	4 states	N/A	High	QBER = 100% with Random Seed [15]	Uncertainty
<b>AK15</b>	$\uparrow$ or $\nearrow = 0$ $\rightarrow$ or $\searrow = 1$	$n$ states	High	High	QBER $\approx 90\%$ with Parity Cell [16]	Uncertainty
<b>LZWW16</b>	$\rightarrow$ or $\nearrow = 0$ $\uparrow$ or $\searrow = 1$	4 states	N/A	High	QBER $\approx 100\%$ with Parity Cell [17]	Uncertainty

<sup>a</sup>Details gathered from original literature, conference proceedings, journals or their recent advancements

#### B. Simulation Analysis

We developed the BB84 & KMB09 (2-dim) protocols to measure the possible outcomes and examine the contrast between the QBER theoretical results claimed by the respective authors.

We considered the real-world scenario of quantum cryptosystem [25], in which Evan passively attempts to intercept each qubit of communication between Alice and Bob over quantum channel (QC) and calculate the effect of

this interception on the detection of its presence in terms of QBER.

To ensure the accuracy of developed protocols, we further performed reliability testing of each protocol using following selected configuration denoted by  $\eta$  (1):

$$\eta = 500 \text{ Sequences} * 50000 \text{ Cycles} * 10 \text{ Qubits} \quad (1)$$

1) *BB84 Protocol Simulation*

We simulate the BB84 protocol using pseudo-random bits (i.e. 0 or 1), pseudo-random bases (i.e. rectilinear: + or diagonal: ×) and the original encoding scheme (i.e. ↑ or ↗ = 0 and → or ↘ = 1). We observe that the simulation outcomes are comparatively identical to the results theoretically calculated by the authors i.e. average QBER for BB84 protocol i.e. 25.26% (≈ 25%).

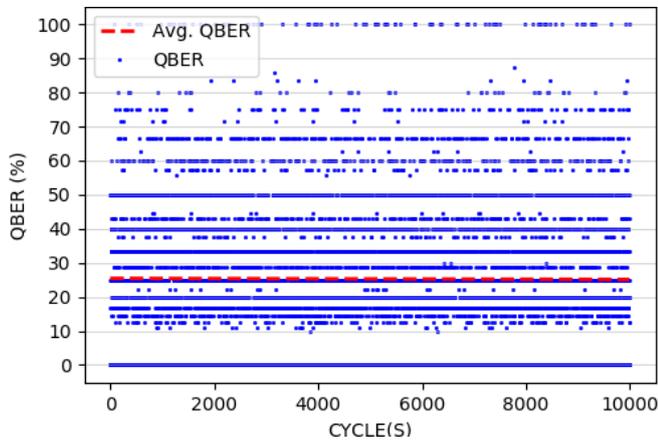


Fig. 1. Numerical calculation of the quantum bit error-rates for BB84 protocol introduced by Evan for  $10^4$  (10 thousand) randomly generated qubit transactions. We observe that the calculated rates 25.26% (red dashed-line) are equal to theoretical minimum of 25%.

After carrying out a reliability testing of simulation for this protocol using selected configuration  $\eta$  (1), we have further measured the accuracy of the simulation results. The measurement of average QBER for BB84 protocol throughout the reliability testing remains around 25% (Min: 24.98% & Max: 25.03%).

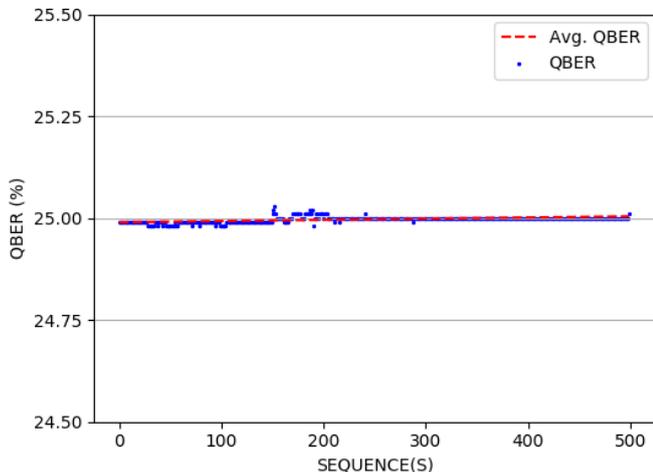


Fig. 2. Reliability testing outcomes of averages of quantum bit error-rates for BB84 protocol for  $2.5 \times 10^8$  (250 million) randomly generated qubit transactions simulated on two different PCs. We observe that the calculated rates 25.01% (red dashed-line) remains around theoretical minimum with tolerance  $\pm 0.03$ .

2) *KMB09 (2-dim) Protocol Simulation*

We simulate the KMB09 (2-dim) protocol using pseudo-random bits (i.e. 0 or 1), pseudo-random bases (i.e. rectilinear: + or diagonal: ×) and the original encoding scheme (i.e. ↑ or → = 0 and ↗ or ↘ = 1). We observe that the simulation outcomes are comparatively identical to the results theoretically calculated by the authors average QBER for KMB09 (2-dim) protocol i.e. 25.22% (≈ 25%).

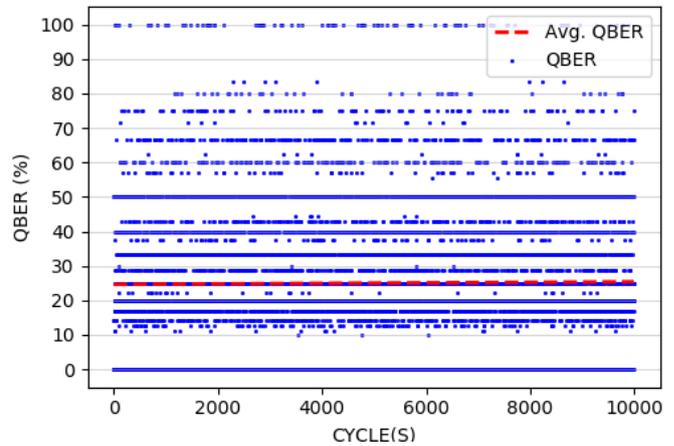


Fig. 3. Numerical calculation of the quantum bit error-rates for KMB09 (2-dimensional) protocol introduced by Evan for  $10^4$  (10 thousand) randomly generated qubit transactions. We observe that the calculated rates 25.22% (red dashed-line) are equal to theoretical minimum of 25%.

Similarly, after carrying out a reliability testing of simulation for this protocol using selected configuration  $\eta$  (1), we have further measured the accuracy of the simulation results. The measurement of average QBER for KMB09 (2-dim) protocol throughout the reliability testing remains around 25% (Min: 24.93% & Max: 25.08%).

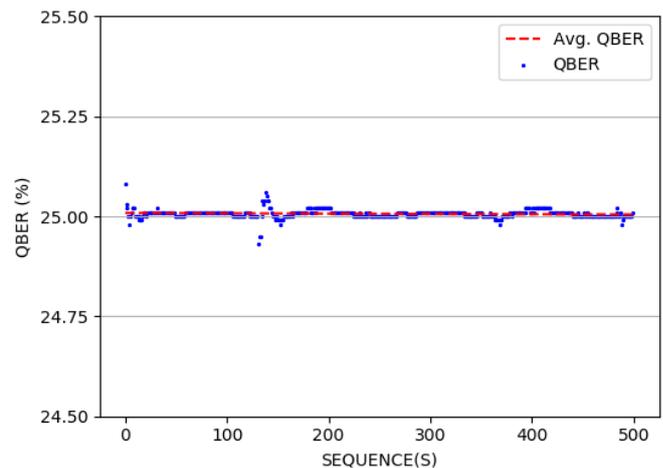


Fig. 4. Reliability testing outcomes of averages of quantum bit error-rates for KMB09 (2-dim) protocol for  $2.5 \times 10^8$  (250 million) randomly generated qubit transactions simulated on two different PCs. We observe that the calculated rates 25.05% (red dashed-line) remains around theoretical minimum with tolerance  $\pm 0.08$ .

IV. CONCLUSION

This paper is outlined to highlight the comparative analysis of QKD protocols including some of the extensively used protocols till date or their latest improvements with some recently introduced protocols. The foremost motivation behind this comparative study to assist the future researchers and implementers of QKD in terms of their network implementation. Through this study we found the efficiency, robustness and reliability of selected QKD protocols with the various challenges of their real-world implementation respectively.

Also, we measure and validate the efficiency results of BB84 and KMB09 (2-dim) protocols claimed by the authors through their respective simulation outcomes. From Fig. 1 and Fig. 3, the result depicts that for KMB09 (2-dim) protocol is equally well as BB84 protocol in terms of their quantum bit-error rates (QBERs), but KMB09 can be more robust because of its one additional eavesdropping detection parameter i.e. index transmission error-rate (ITER). While for higher dimensions i.e. KMB09 (n-dim) the authors claim the much efficient results of eavesdropping detection i.e. up to 50%.

TABLE V. COMPARISON OF QBER OF BB84 & KMB09 (2-DIM)

QKD Protocols	QBERs	
	Theoretical	Simulation
BB84	25%	25.01% ( $\approx 25\%$ )
KMB09 (2-dim)	25%	25.05% ( $\approx 25\%$ )

Some of the protocols are still unable to test in the practical environment due to the unavailability of their measurement devices. In view of Moore’s Law, we are nearly approaching towards the quantum limit, so it’s better to take the quantum effects into account now [26]. So far QKD achieves to bridge the huge gap between the reasonable security and the absolute security of the communication channel by the help of revolutionary quantum mechanics. But still an evident gap exists regarding its feasible usage like classical cryptography mechanisms.

ADDITIONAL INFORMATION

For the academic and research purposes, we have published source code of our simulations based on QuTiP framework, online on Github repository. If you find this simulation code useful in your research, please consider citing this paper.

Repository: [www.github.com/ekehtesham/qkd](http://www.github.com/ekehtesham/qkd) [27].

REFERENCES

[1] R. R. Schaller, “Moore’s Law: Past, Present, and Future,” *IEEE Spectr.*, vol. 34, no. 6, pp. 52–59, Jun. 1997.

[2] G. Brassard, “Quantum Computing: The End of Classical Cryptography?,” *SIGACT News*, vol. 25, no. 4, pp. 15–21, Dec. 1994.

[3] Pro-technix.com, “The only unbreakable cryptosystem known—the Vernam cipher.” [Online]. Available: [http://pro-technix.com/information/crypto/pages/vernam\\_base.html](http://pro-technix.com/information/crypto/pages/vernam_base.html). [Accessed: 09-Jul-2017].

[4] C. H. Bennett and G. Brassard, “Quantum Cryptography: Public key distribution and coin tossing,” in *IEEE International Conference on*

*Computers, Systems and Signal Processing, Bangalore, India*, 1984, p. 175.

[5] W. K. Wootters and W. H. Zurek, “A single quantum cannot be cloned,” *Nature*, vol. 299, p. 802, Oct. 1982.

[6] W. Heisenberg, “The actual content of quantum theoretical kinematics and mechanics,” *Zeitschrift für Phys.*, vol. 43, pp. 172–198, 1927.

[7] N. S. Yanofsky and M. A. Mannucci, *Quantum computing for computer scientists*, 20th ed. Cambridge University Press Cambridge, 2008.

[8] Stanford.edu, “Quantum Entanglement and Information.” [Online]. Available: <https://plato.stanford.edu/entries/qt-entangle/>. [Accessed: 09-Jul-2017].

[9] J. S. Bell, “On the Einstein-Podolsky-Rosen paradox,” *Phys. Phys. Fiz.*, vol. 1, pp. 195–200, 1964.

[10] C. H. Bennett, “Quantum cryptography using any two nonorthogonal states,” *Phys. Rev. Lett.*, vol. 68, no. 21, pp. 3121–3124, May 1992.

[11] K. Inoue, E. Waks, and Y. Yamamoto, “Differential Phase Shift Quantum Key Distribution,” *Phys. Rev. Lett.*, vol. 89, no. 3, p. 37902, Jun. 2002.

[12] V. Scarani, A. Acín, G. Ribordy, and N. Gisin, “Quantum Cryptography Protocols Robust against Photon Number Splitting Attacks for Weak Laser Pulse Implementations,” *Phys. Rev. Lett.*, vol. 92, no. 5, p. 57901, Feb. 2004.

[13] N. Gisin, G. Ribordy, H. Zbinden, D. Stucki, N. Brunner, and V. Scarani, “Towards practical and fast quantum cryptography,” *arXiv Prepr. quant-ph/0411022*, 2004.

[14] A. I. Khaleel, “Coherent one-way protocol: Design and simulation,” in *International Conference of Future Communication Networks (ICFCN)*, 2012, pp. 170–174.

[15] M. M. Khan, M. Murphy, and A. Beige, “High error-rate quantum key distribution for long-distance communication,” *New J. Phys.*, vol. 11, no. 6, p. 63043, 2009.

[16] E. H Serna, “Quantum Key Distribution From A Random Seed,” *arXiv Prepr. arXiv1311.1582*, Nov. 2013.

[17] K. Elleithy and A. Abushgra, “Initiated decoy States in Quantum Key Distribution Protocol by 3 ways channel,” *2015 IEEE Long Isl. Syst. Appl. Technol. Conf. LISAT 2015*, May 2015.

[18] H.-F. Li, L.-X. Zhu, K. Wang, and K.-B. Wang, “The Improvement of QKD Scheme Based on BB84 Protocol,” in *International Conference on Information System and Artificial Intelligence (ISAI)*, 2016, pp. 314–317.

[19] J. R. Johansson, P. D. Nation, and F. Nori, “QuTiP: An open-source Python framework for the dynamics of open quantum systems,” *Comput. Phys. Commun.*, vol. 183, no. 8, pp. 1760–1772, 2012.

[20] J. R. Johansson, P. D. Nation, and F. Nori, “QuTiP 2: A Python framework for the dynamics of open quantum systems,” *Comput. Phys. Commun.*, vol. 184, no. 4, pp. 1234–1240, 2013.

[21] T. Honjo *et al.*, “Long-distance entanglement-based quantum key distribution over optical fiber,” *Opt. Express*, vol. 16, no. 23, pp. 19118–19126, 2008.

[22] H. Takenaka, A. Carrasco-Casado, M. Fujiwara, M. Kitamura, M. Sasaki, and M. Toyoshima, “Satellite-to-ground quantum-limited communication using a 50-kg-class microsatellite,” *Nat. Photonics*, vol. 11, p. 502, Jul. 2017.

[23] B. Korzh, N. Walenta, R. Houlmann, and H. Zbinden, “A high-speed multi-protocol quantum key distribution transmitter based on a dual-drive modulator,” *Opt. Express*, vol. 21, no. 17, pp. 19579–19592, 2013.

[24] Y.-C. J. and Y.-S. K. and Y.-H. Kim, “An experimental comparison of BB84 and SARG04 quantum key distribution protocols,” *Laser Phys. Lett.*, vol. 11, no. 9, p. 95201, 2014.

[25] A. Amerimehr and M. H. Dehkordi, “Quantum Symmetric Cryptosystem Based on Algebraic Codes,” *IEEE Commun. Lett.*, vol. 22, no. 9, pp. 1746–1749, 2018.

[26] T. Zhou, J. Shen, X. Li, C. Wang, and J. Shen, “Quantum Cryptography for the Future Internet and the Security Analysis,” *Secur. Commun. Networks*, vol. 2018, pp. 1–7, 2018.

[27] E. Khan, “QKD Protocols Simulations on QuTiP,” 2018. [Online]. Available: <https://github.com/ekehtesham/qkd>. [Accessed: 05-Jul-2018].

# Fuzzy Logic enabled Spectrum Access Scheme for Cognitive Radio Applications

Shabbir Ahmed

Department of Electronic Engineering  
NED University of Engineering & Technology  
Karachi, Pakistan  
shabbir\_umrani@yahoo.com

Aamir Zeb Shaikh

Department of Electronic Engineering  
NED University of Engineering & Technology  
Karachi, Pakistan  
aamirzeb@neduet.edu.pk

**Abstract**— Cognitive Radio (CR) is an evolutionary idea to exploit unused spectral bands i.e. white spaces. However, due to dynamic wireless channel behavior, received SNR is not uniform and does not follow a consistent probability density function hence; the spectrum decision making process is usually a complicated one. In such uncertain operating environments, decision making process is highly important. This paper presents a fuzzy logic enabled spectrum decision making is devised that could deal with uncertain environments and make a suitable decision regarding secondary access of RF spectrum. Input parameters for the proposed decision making spectrum access scheme are assumed SNR, priority of the secondary user and detection probability while the output is assumed to be the spectrum access functionality. The results of the proposed scheme show that the presented scheme will find useful application especially when the input information is uncertain.

**Keywords**—cognitive radio, fuzzy logic, spectrum access

## I. INTRODUCTION

Cognitive Radio provides an attractive and economical option to exploit unused spectral bands for secondary access. The bandwidth requirement of wireless users shows an exponential increase day by day. Additionally, the evolving technologies such as internet of things (IoT) also requires huge amount of bandwidth [1]. These sensors will provide useful applications in the domain of smart home, smart retail, smart grid and smart healthcare. Additionally, internet of vehicles (IoV) is another evolving technology that corresponds to the vehicular communications. This technology aims to provide smart transportation by involving vehicles to communicate using machine to machine communications. This will result in improving traffic congestion and providing smart transportation facilities that will also yield better fuel consumption[2]. Cisco estimates the number of connected devices to reach 25 billion by 2019 with 10 billion machine to machine connected devices. Furthermore, Bell Labs estimates an increase of six times into bandwidth requirement from 2015 to 2025. The statistics suggest for novel methods of exploiting frequency bands. Cognitive Radio is one of the technologies that aim to achieve the proposed task by providing dynamic

spectrum access to the wireless users in place of fixed spectrum access.

Cognitive Radio is an intelligent wireless device that transmits on unused spectrum bands by exploiting RF information[3]. The RF information can be exploited by the local spectrum sensor by using spectrum sensing techniques or through sing database driven spectrum manager [4]. In the local spectrum sensing radios, the sensor collects RF information from environment using sensing techniques such as matched filter detector, cyclostationary feature detector and energy detector [5]. Additionally, in some cases, the cognitive users may also combine their sensing information at a fusion center to come up with better accumulated information. This technique is known as cooperative spectrum sensing mechanism. In the database driven radios, cognitive users download the information about white spaces from an opportunistic engine and exploit those bands. This technique is viable for a specific geographical area. The complete process of shifting transmissions from one spectrum band to another spectrum band is achieved through the use of cognitive cycle [6]. The cognitive cycle incorporates various actions to exploit RF bands in opportunistic style, these include radio environment analysis, identification of RF channels, transmit-power control and dynamic spectrum management. The spectrum management is the key step towards successful utilization of RF spectrum in opportunistic fashion. This module analyzes the available white spaces and connects the bands to the most appropriate user (for secondary access). However, due to dynamic wireless channel conditions accurate decision making is a difficult process. It is due to the inaccurate input information. To address this issue, Fuzzy Logic provides a possible option to make decisions on the basis of incomplete information.

Fuzzy Logic is an excellent method of modeling a real time system where the input information is incomplete or vague. In some cases, especially real wireless environments, the input and output relations between various factors is nonlinear and time variant [7], in such cases, linear modeling process is not applicable. Linear modeling procedure can be implemented through a condition that is IF then ELSE. In linear modeling equations, an additional input creates a completely new

viewpoint of the whole system, whereas in Fuzzy Logic based systems, an additional input simply creates a new membership function and the newly developed system can easily be modeled. Fuzzy logic is used to solve many critical problems of wireless communications from 1990. It has also been used extensively in the area of cognitive radio technology to model various decision making processes in the opportunistic communications [8-11]

In this paper, a fuzzy logic system is incorporated to improve decision making process on the spectrum access of the system. The input of the system is assumed to be SNR received from the RF sensor, the detection probability of the white spaces and the priority of the secondary wireless user. The output is achieved in the form of decisions on the basis of spectrum accessibility.

This paper contains various sections. Section II presents the related work. This section presents various researchers' work that incorporate fuzzy logic into the domain of cognitive radio networks for making decisions on the basis of vague information. Section III presents the proposed fuzzy logic based spectrum access scheme. This scheme consists of three inputs and a single output. Section IV presents the results of the simulation of proposed model. Section V concludes the paper.

## II. RELATED WORK

Fuzzy Logic System is used by various researchers to model incomplete input information and producing reasonable output results in the domain of cognitive radios.

In [12], authors use various information parameters of the primary and secondary users to decide giving the accessibility to the secondary radio. The information exploited for decision making include spectrum utilization efficiency of the unlicensed user, degree of mobility of unlicensed user and its distance to the licensed. The resultant output regarding the permission of using RF spectrum in secondary fashion is better modeled through the Fuzzy Logic System (FLS).

In [13], researchers model a FLS for improved management of spectrum access. In this scheme, the assumed inputs are efficiency of spectrum utilization for unlicensed users, mobility, distance of the licensed user, and signal strengths of the unlicensed users. Based on these descriptors, 81 fuzzy logic rules are devised. These rules are based on the linguistic knowledge of the opportunistic radio designer.

In [14], researchers design the FLS system for decision making process to infer knowledge about the availability of spectrum access from the cognitive network. The researchers developed the system by incorporating the knowledge of realistic wireless channels and conditions into the model. It is also assumed that the bands will be shared with primary users. And it is also considered to develop such a system that could be protected from the use of harmful interference of the secondary users of the communication system. FLS is involved to make useful decision regarding the use of a

specific spectrum sensing algorithm such as coherent detection techniques such as matched filter, correlation, cyclic feature detection, energy detection and cooperative spectrum sensing. The system is further elaborated to make useful decisions on the basis of working environment of the wireless environment.

In [15], authors design and present a two level FLS for providing adaptive bandwidth to the cognitive users of the opportunistic network. One system uses analytical model to evaluate access latency of the system while the second system allocates the bandwidth to the opportunistic users based on the pre-assigned priorities. These priorities are assigned on the basis of the traffic type of the opportunistic users.

In this paper, a novel spectrum access scheme is introduced for making the task of opportunistic access block more effective in future intelligent wireless networks. The proposed system three factors as input, these include SNR, detection rate and the priority of the secondary user and decides about giving access to a secondary user based on the available data.

## III. PROPOSED SYSTEM

A cognitive radio system is proposed and designed that incorporates a FLS enabled decision block to make useful decisions on spectrum access unit using incomplete and vague information. The FLS is implemented using three step procedure. These include fuzzification, inference and defuzzification. The first step associates the logic 0 and 1 to the various linguistic values. The second step involves various conditions that depend on IF then ELSE rules to associate different inputs based on the requirements. This functionality is achieved through the use of inference engine. The third step towards realization of FLS is the use of defuzzification. In this step, the fuzzified values are again converted into crisp values i.e. 0 and 1. The inputs for the proposed system are assumed as SNR, detection probability of the white band and the priority of the secondary user. The output is assumed as the spectrum access of the wireless network. The inputs and output is shown in figure 1.

**Input Function 1: SNR.** It consists of three membership functions i.e. Low, Medium, and High

**Input function 2: Detection Probability.** It consists of three levels i.e. Low, Medium, and High

**Input Function 3: Priority of the Secondary User.** It consists of two values Low and High.

These three input functions are used to produce a final decision output i.e. **Spectrum Access** of RF spectrum.

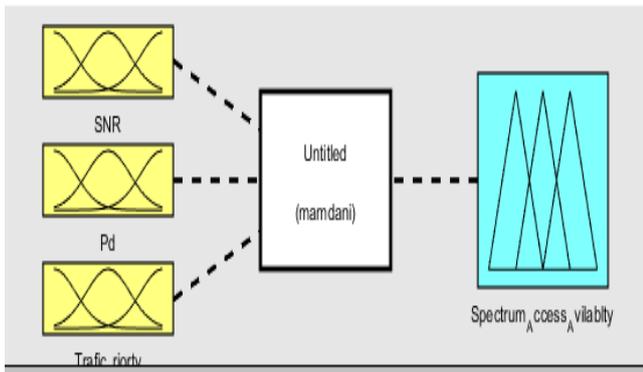


Figure 1. Showing input-output variables of the proposed system.

Figure 2 depicts membership functions for received signal to noise ratio. The possible values for the input consist of low, medium and high. Figure 3 describes the membership functions for detection probability. The available options for the input are low, medium and high.

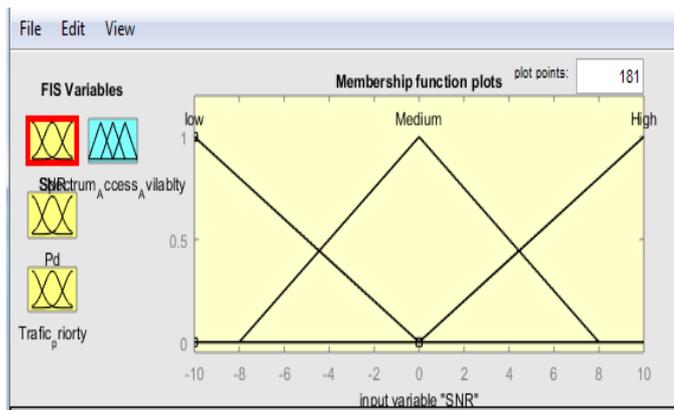


Figure 2. Showing membership function plot for SNR

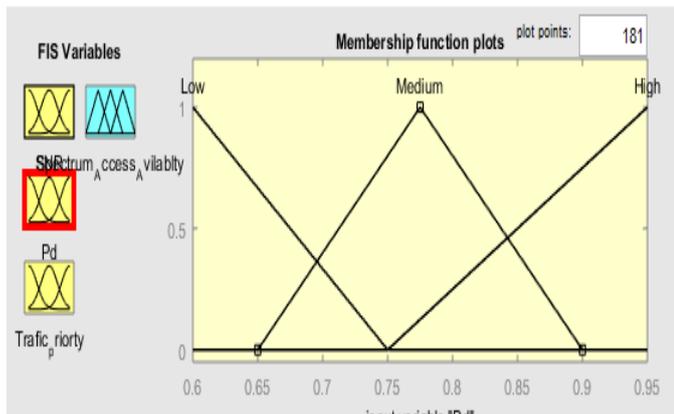


Figure3. Showing membership function plot for Probability of Detection

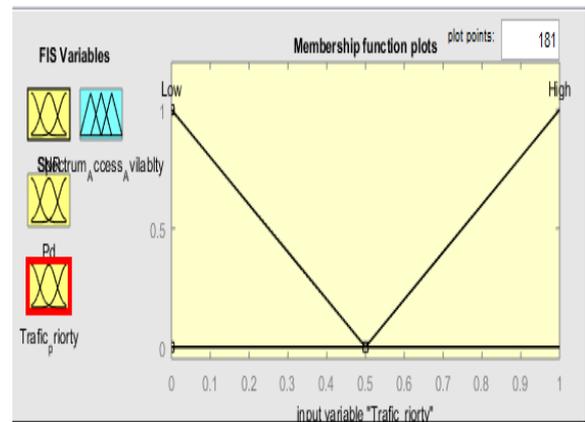


Figure4. Showing membership function plot for Traffic Priority of Secondary User

Figure5 describes the input-output membership functions for the proposed dynamic secondary network. Figure 6 describes the relationships between input and output linguistic values.

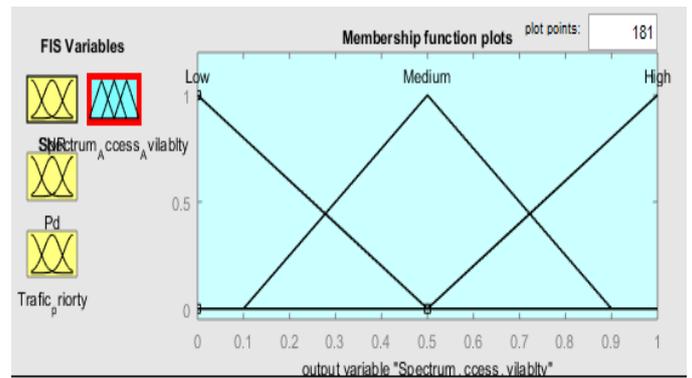


Figure5. Showing membership function plot for Output of the System

If				and				and				Then			
SNR is				Pd is				Traffic_priorty is				Spectrum_Acces			
low	Medium	High	none	Low	Medium	High	none	Low	Medium	High	none	Low	Medium	High	none

- If (SNR is low) and (Pd is Low) and (Traffic\_priorty is High) then (Spectrum\_Access\_Availability is High) (1)
- If (SNR is High) and (Pd is High) and (Traffic\_priorty is Low) then (Spectrum\_Access\_Availability is High) (1)
- If (SNR is low) and (Pd is Low) and (Traffic\_priorty is Low) then (Spectrum\_Access\_Availability is Low) (1)
- If (SNR is High) and (Pd is High) and (Traffic\_priorty is High) then (Spectrum\_Access\_Availability is High) (1)
- If (SNR is low) and (Pd is Medium) and (Traffic\_priorty is Low) then (Spectrum\_Access\_Availability is Medium)
- If (SNR is low) and (Pd is High) and (Traffic\_priorty is Low) then (Spectrum\_Access\_Availability is Medium)
- If (SNR is Medium) and (Pd is Low) and (Traffic\_priorty is Low) then (Spectrum\_Access\_Availability is Medium)
- If (SNR is Medium) and (Pd is Medium) and (Traffic\_priorty is Low) then (Spectrum\_Access\_Availability is Medium)
- If (SNR is High) and (Pd is High) and (Traffic\_priorty is High) then (Spectrum\_Access\_Availability is Medium)

Figure6. Showing the relations between various input values and output linguistic values

IV. NUMERICAL AND SIMULATION RESULTS

In this section, the simulation results of the FLS based proposed communication network is presented. Table 1 describes the membership function rules for the proposed system with three inputs and one output i.e. spectrum access. Table 2 presents the composite rules for the proposed system and Table 3 presents fuzzy rules.

M F	SNR Range	PD Range	traffic priority Range	SAA Range=
MF1	Low = -10 to 0	Low = 0.6 to 0.75	Low = 0 to 0.5	Low = 0 to 0.5
MF2	Medium = -8 to +8	Medium = 0.65 to 0.9		Medium = 0.1 to 0.9
MF3	High = 0 to 10	High = 0.75 to 0.95	High = 0.5 to 1	High = 0 to 1

Table 1 describes Rules for the proposed System

For  $f_1 = (\text{Max range of SNR} - \text{SNR selected}) / \text{max SNR}$   
 $\text{SNR} = 10 - 0.723 / 10$

$f_1 = 0.927$

$f_2 = 1 - f_1 = 0.0723$

For  $f_3$  and  $f_4$  of Detection Probabilities

$f_3 = (\text{Max range of P D} - \text{PD obtained}) / \text{Max PD}$   
 $= 0.95 - 0.712 / 0.95$

$f_3 = 0.250$

$f_4 = 1 - f_3 = 1 - 0.250 = 0.75$

For  $f_5$  and  $f_6$

$f_5 = (\text{max priority} - \text{obtained priority}) / \text{max priority}$

$f_5 = (1 - 0.151) / 1 = 0.849$

$f_6 = 1 - f_5 = 1 - 0.849 = 0.151$

Results of the scheme are computed as follows:

$R_0 = F_1 \wedge F_3 = 0.927 \wedge 0.250 = 0.250$

$R_1 = F_1 \wedge F_4 = 0.927 \wedge 0.749 = 0.749$

$R_2 = F_1 \wedge F_5 = 0.927 \wedge 0.849 = 0.849$

$R_3 = F_1 \wedge F_6 = 0.927 \wedge 0.150 = 0.150$

$R_4 = F_2 \wedge F_3 = 0.072 \wedge 0.250 = 0.250$

$R_5 = F_2 \wedge F_4 = 0.072 \wedge 0.749 = 0.749$

$R_6 = F_2 \wedge F_5 = 0.072 \wedge 0.849 = 0.849$

$R_7 = F_2 \wedge F_6 = 0.072 \wedge 0.150 = 0.150$

Rules	SNR	PD	Traffic priority	SAA	Output
R1	high	high	high	high	1
R2	low	low	high	high	1
R3	high	high	low	high	1
R4	low	low	low	low	0
R5	Medium	Medium	Low	Medium	0.5
R6	Medium	High	Low	Medium	0.5

Table 2 shows Composite Rules

If				then
Rules	SNR	PD	Traffic priority	
R0	High	High	High	High
R1	Low	Low	High	high
R2	High	High	Low	high
R3	Low	Low	Low	Low
R4	Medium	Medium	Low	Medium
R5	Medium	High	Low	Medium
R6	Medium	Low	Low	Medium
R7	Medium	Low	High	Medium
R8	Medium	Medium	High	Medium
R9	Low	Medium	High	Low
R10	Low	Medium	Low	Low
R11	Low	Medium	Low	Low
R12	Low	High	Low	Medium
R13	Medium	High	High	Medium
R14	High	Low	Low	Medium
R15	High	Low	High	Low
R16	High	Medium	Low	Low
R17	High	Medium	High	Low

Table 3 shows Fuzzy Rules

Mamdani model  $= (\text{sum of } R_i * S_i / \text{sum of } R_i) * 100$

$R_i = 0.250 + 0.749 + 0.849 + 0.150 + 0.250 + 0.749 + 0.849 + 0.150 = 3.999$

Sum of

$R_i * S_i = 0.250 * 1 + 0.749 * 1 + 0.849 * 1 + 0.150 * 0 + 0.250 * 0.5 + 0.749 * 0.5 = 2.212$

$2.212 / 3.999 * 100 = 55.31$

Matlab simulated value :  $0.487 * 100 = 48.7$

Mathematically Calculated value- Matlab values =  $= 55.31 - 48.7 = 6.61$

Error =  $6.61 / 48.7 * 100 = 13.5\%$

Figure 7 shows the output spectrum access availability value is 0.4 for the selected value of SNR= 0.723, PD= 0.71 and Traffic priority of 0.151.

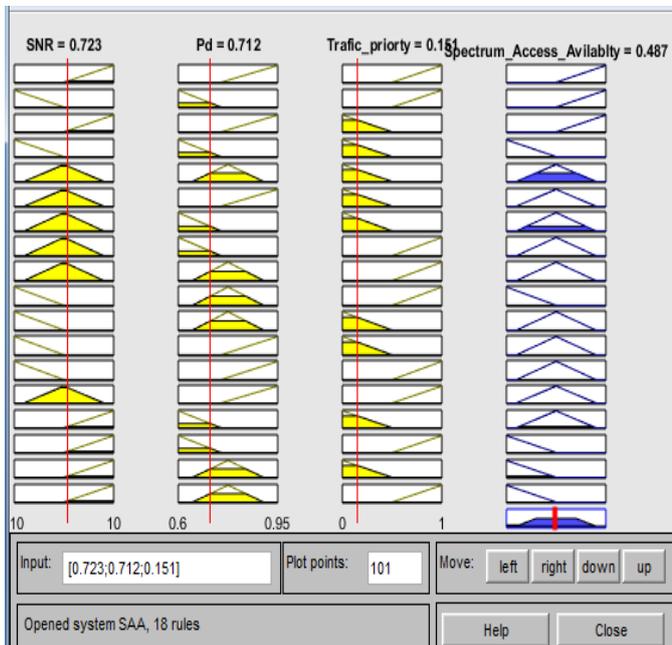


Figure 7. Showing the outputs for various selected inputs

Figure 8 depicts the 3D view of the spectrum access availability for the proposed system.

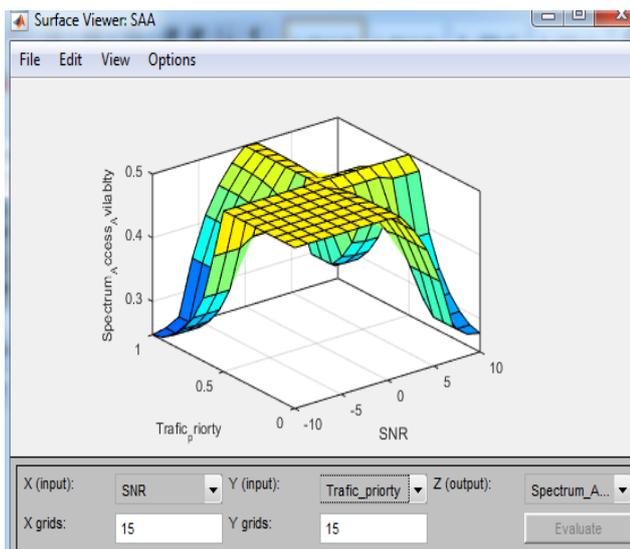


FIGURE 8 SHOWS THE 3D VIEW OF SPECTRUM ACCESS AVAILABILITY

### Conclusion

A Mamdani type fuzzy Logic enabled decision making block is implemented to provide better decisions under uncertain values of SNR, detection probability and the traffic priority. The results show the system performs better than the crisp composite system, carrying accurate values of inputs.

- [1] W.-C. Tsai, *et al.*, "An implementation of IoT gateway for narrow bandwidth and massive

### ACKNOWLEDGMENT

The authors thank the university administration of NED University, Karachi that provided required facilities, without those the research work could not be completed.

### REFERENCES

- machine-type communications over B4G cellular network," in *Advanced Computational Intelligence*

- (ICACI), 2018 Tenth International Conference on, 2018, pp. 273-278.
- [2] G. Stefansson and K. Lumsden, "Performance issues of smart transportation management systems," *International Journal of Productivity and Performance Management*, vol. 58, pp. 55-70, 2008.
- [3] J. Mitola, "Cognitive radio---an integrated agent architecture for software defined radio," 2000.
- [4] H. Arslan, *Cognitive radio, software defined radio, and adaptive wireless systems*: Springer, 2007.
- [5] H. Arslan and T. Yücek, "Spectrum sensing for cognitive radio applications," in *Cognitive radio, software defined radio, and adaptive wireless systems*, ed: Springer, 2007, pp. 263-289.
- [6] S. Haykin, "Cognitive radio: brain-empowered wireless communications," *IEEE Journal on Selected Areas in Communications*, vol. 23, pp. 201-220, 2005.
- [7] K. Self, "Designing with fuzzy logic," *IEEE spectrum*, vol. 27, pp. 42-44, 1990.
- [8] E. Ahmed, *et al.*, "Fuzzy-based spectrum handoff and channel selection for cognitive radio networks," in *Computer, Control, Informatics and Its Applications (IC3INA), 2013 International Conference on*, 2013, pp. 23-28.
- [9] W. Ejaz, *et al.*, "Fuzzy logic based spectrum sensing for cognitive radio networks," in *Next Generation Mobile Applications, Services and Technologies (NGMAST), 2011 5th International Conference on*, 2011, pp. 185-189.
- [10] R. Kaniezhil and C. Chandrasekar, "An efficient spectrum utilization via cognitive radio using fuzzy logic system for heterogeneous wireless networks," in *Emerging Trends in Science, Engineering and Technology (INCOSET), 2012 International Conference on*, 2012, pp. 300-307.
- [11] M. J. Kaur, *et al.*, "Analysis of decision making operation in cognitive radio using fuzzy logic system," *International Journal of Computer Applications*, vol. 4, 2010.
- [12] H.-S. T. Le and H. D. Ly, "Opportunistic spectrum access using fuzzy logic for cognitive radio networks," in *Communications and Electronics, 2008. ICCE 2008. Second International Conference on*, 2008, pp. 240-245.
- [13] I. Sharma and G. Singh, "A Novel Approach for Spectrum Access Using Fuzzy Logic in Cognitive Radio," *International Journal of Information Technology and Computer Science*, vol. 4, pp. 1-9, 2012.
- [14] M. Matinmikko, *et al.*, "Fuzzy-logic based framework for spectrum availability assessment in cognitive radio systems," *IEEE Journal on Selected Areas in Communications*, vol. 31, pp. 2173-2184, 2013.
- [15] P. Kaur, *et al.*, "Fuzzy based adaptive bandwidth allocation scheme in cognitive radio networks," in *Knowledge Engineering, 2010 8th International Conference on ICT and*, 2010, pp. 41-45.

# Towards Efficient Vectorization using Polyhedral Compilation

Hameeza Ahmed<sup>1</sup>, Muhammad Ali Ismail<sup>2</sup>

High Performance Computing Centre (HPCC)

Department of Computer & Information Systems Engineering, NED University of Engineering & Technology  
University Road, Karachi-75270, Pakistan<sup>12</sup>

Email: <sup>1</sup>[hameeza@neduet.edu.pk](mailto:hameeza@neduet.edu.pk), <sup>2</sup>[maismail@neduet.edu.pk](mailto:maismail@neduet.edu.pk)

**Abstract**—Modern General Purpose Processors (GPPs) have provision of vector instructions. However, the existing compilers are unable to automatically exploit Data Level Parallelism (DLP) due to inefficient vectorization techniques. Hence, a wide degree of advancements is needed in this area. One way of improving the auto vectorization is polyhedral model which can vectorise complex loops by modeling and transformations. This paper shows the comparison between compiler default and polyhedral based vectorization. It is done using Low Level Virtual Machine (LLVM) compiler's Polly framework and Polybench benchmark suite. The performance is evaluated by varying kernel, compiler vectorization flags, Polly techniques and data size. The compiler vectorization flags include O3 and Ofast, while Polly techniques are polly+vector, polly+stripmine, and polly+unroll. The results depict how Polly achieves greater speedup relative to default vectorization. Also, the speedup is increased by increasing the data sizes. Besides, this paper proposes an effective combination of polly+vector(Ofast). By employing Ofast flag with polly+vector, the speedup is increased to about 223x relative to simple Ofast. Further, polly+vector(Ofast) shows maximum of 3.7x speedup than polly+vector(O3). Therefore, polly(Ofast) is more scalable than polly(O3).

**Keywords**—Vectorization, Compiler, LLVM, Polyhedral model, Polly, O3 flag, Ofast flag.

## I. INTRODUCTION

The recent emerging applications such as multimedia, graphics, Internet of Things (IOT) and big data involve larger size data. The exploitation of Data Level Parallelism (DLP) appears to be a relevant solution for dealing with these wider applications [1]. In DLP, the parallelism is obtained by performing same operations across large set of data. DLP can be achieved by Graphics Processing Units (GPUs) and vector Instruction Set Architecture (ISA) extensions. These options provide the advantage of easier programmability, greater performance and lesser energy consumption. These can handle large amount of data by exploiting DLP to the maximum capability [2]. Presently, the vector instructions have been included in the ISA of major General Purpose Processors (GPPs) which appears to be a feasible approach towards exploitation of DLP in common GPPs. Obviously, it is impractical for a programmer to write these vector assembly instructions manually, hence the responsibility of vector code emission is shifted on compiler. This process of vector instruction emission is also known as vectorization [3]. There are numerous ways of vectorization such as vector intrinsics, directives, and auto vectorization [4]. Amongst these, auto vectorization appears to be the automated solution with minimal programmer intervention. The compiler is responsible to first detect the portion of code and then perform vectorization in an automatic way. The vectorization is performed either on loop or basic blocks [5].

There have been significant growth in auto vectorization technique. However, still the existing compiler based solutions are inefficient in fully exploiting available vector processing units in automatic manner [6]. Commercial compilers like GNU GCC [7], LLVM [8], and Intel ICC [9] provide vectorization flags (O2, O3 & Ofast) to allow automatic vectorization but these can still miss numerous vectorization opportunities. Hence, a wide scope of improvements is needed in these techniques. Recently, one relevant technique to improve vector codes is polyhedral compilation which is based on the polyhedral model. This model provides a powerful abstraction for analyzing and transforming regular codes [10]. Polyhedral compilation is used for a range of applications, including data locality optimizations, memory management optimizations, automatic parallelization, vectorization, program verification, communication optimizations, high-level synthesis, code generation for hardware accelerators, etc [11].

Low Level Virtual Machine (LLVM) is an open source compiler infrastructure [8]. Despite the presence of well-known compilers like GNU GCC [7], Intel ICC [9], LLVM occupies a prominent position in the community. There are several reasons for LLVM wide adaptability such as open source code, modular and reusable components, and faster learning curve. Due to these properties compiler development is much easier in LLVM. LLVM compiler has three passes namely clang front end, opt middle end, and llc backend. Optimizer opt is the core of LLVM compiler. It is responsible to optimize the obtained Intermediate Representation (IR) code. Several automatic optimizations can be performed such as dead code elimination, basic-block vectorization, loop vectorization, loop fission, simple constant propagation, global variable optimizer, and many others [8], [12], [13]. In order to achieve specialized tasks, LLVM has numerous sub projects available. Polly is one such project which is based on polyhedral model [14]. In this way, Polly can be used along with LLVM default optimizer to further optimize the solutions. In literature, it is claimed that Polly is able to exploit even those vectorization opportunities that are missed by default LLVM vectorizer, hence enhancing the performance to a larger extent [15].

This paper presents a comparison between number of auto vectorization techniques employed by compiler. The experiment is done by compiling Polybench benchmark codes [16] using LLVM vectorization flags alone and LLVM flags+Polly vectorization techniques. The two flags O3 and Ofast are used for LLVM default vectorization. Whereas, Polly vectorization techniques include polly+stripmine, polly+vector and polly+unroll. Further, the applications are compiled by varying input data sizes as well. The data sizes include four sets namely small, medium, large and extra large. The performance is measured by means of vector operation count and speedup of polly+Ofast relative to

polly+O3 and LLVM vectorization flags alone. To the best of our knowledge, this paper gives a novel contribution by studying the impact of Ofast flag on Polly vectorization. The applications are executed on Intel x86 Haswell microarchitecture with AVX-2 vector processing units available, which can deal with up to 8 single or 4 double precision elements at one time [17], [18].

The results depict how the vectorization is maximized when kernels are compiled using Polly. All three Polly techniques namely stripmine, vector and unroll show greater speedup as compared to the default LLVM vectorizer for all the data sizes. Moreover, it is observed that the Polly speedups are increased with larger input sizes. Also, Polly vectorizer shows the optimal vector operation count and greater speedup as compared to stripmine and unroll. Besides, stripmine performs better than unroll. Further, comparison is done on the basis of LLVM vectorization flags O3 and Ofast. It is observed that Polly(Ofast) shows lesser speedup than Polly(O3) for stripmine and unroll. However, when the compilation is performed using Ofast with polly+vector, the speedup is higher as compared to O3 and polly+vector. The maximum speedup achieved by O3 and polly+vector is 60x whereas the speedup with Ofast and polly+vector is reached to 223x. It happens because Ofast is the highest optimization level and it enables all O3 along with additional mathematical optimizations.

Rest of the paper is organized as follows: Section 2 discusses related work. A brief background is given in section 3. Section 4 discusses the methodology. A detailed comparison of performance results is covered in Section 5. The final conclusion is presented in section 6.

## II. RELATED WORK

In this paper, the focus is performance comparison using LLVM vectorization flags and techniques of Polly. In this regard, the most relevant work found is reported in [15]. It shows the speedup of Polly stripmine, vector and unroll for matrix multiplication kernel of standard data size. It uses Polly techniques with LLVM O3 flag only. Moreover, the paper [15] reports the speedup of fvector flag relative to O3 for Polybench suite but for small size data only. Besides, the results reported in [15] uses an older version of LLVM and Polly. In comparison to [15], our paper presents a more detailed comparison of Polly with LLVM vectorizer (Ofast & O3) considering various factors at the same time such as Polly vectorization techniques, data set sizes and application kernels. As per our knowledge, this paper is the first one to discover that the compilation using polly+vector and Ofast flag is most effective. It means greater performance is achieved by using Ofast flag with polly+vector technique. Further, the results reported in this paper are generated using higher version of LLVM and Polly.

## III. BACKGROUND

Several important terminologies and concepts associated in this paper are discussed in this section. It includes vectorization, LLVM compiler, and Polly Framework.

### A. Vectorization

Compiler can be defined as a program which is responsible to translate the given high level language code into architecture specific assembly code. Due to huge

technological advancements, the compilers are no more just the translators rather they enable some imperative optimizations in order to automatically exploit the hardware resources to their maximum capability. It is true that the hardware resources cannot be utilized to fullest if the generated assembly is not efficient. This implies that despite the presence of powerful hardware design, still the performance goals are not meet due to lack of competent software solutions. There exists a large number of optimization opportunities in compiler which if exploited can easily utilize the modern hardware to its maximum capabilities. Moreover, these optimizations can help developers to achieve their overall design objectives by taking advantage of both application specific and architecture-specific information. There has been large number of compiler optimizations such as profile driven optimizations, loop optimizations, data-flow optimizations, SSA-based optimizations, code generator optimizations, interprocedural optimizations, dead code elimination, basicblock vectorization, loop vectorization, loop fission, simple constant propagation, global variable optimizer, and many others [19], [20], [21].

Vectorization is the process of vector instruction emission through a compiler [3]. There are three ways of performing vectorization including vector intrinsics, directives, and auto vectorization. Vector intrinsics is the manual technique which appears to be the most difficult among three. In this case, the programmer is expected to perform vectorization by writing intrinsics directly. This level has the higher performance portability with a loss of code portability. Similarly, semiautomatic vectorization can be done by using compiler directives. Instead of writing vector instructions, programmer is expected to write compiler directives to advise the compiler about vectorization decisions. This approach is less difficult as compared to intrinsics but still the programmer is assisting the compiler in vectorization process [4]. Auto vectorization appears to be the easiest of the three techniques. In this case, compiler is able to perform vectorization of code in an automatic manner with minimal user intervention [5]. However, this technique is less efficient as compared to the other two because still the compilers are not intelligent enough to exploit the vectorization opportunities automatically [6]. In case of auto vectorization compilers are intended to generate vector assembly instructions for specific target processors. These processors are expected to possess vector extensions in their respective ISAs. These vector operations are performed in hardware by using vector processing units. For example, there are several vector instruction set extension to the Intel x86 architecture including SSE, AVX, AVX2 and AVX512 [22].

- Streaming SIMD Extensions (SSE):- The vector registers are 128 bits in size. SSE capable processors can perform four 32 bit float operations for every vector instruction, or two 64 bit double operations at same time. XMM vector register is used for handling 128 bit data operations.
- Advanced Vector eXtensions (AVX):- In this, the size of the vector register is doubled from 128 bits to 256 bits. AVX capable processors can perform eight single precision or four double precision operations at same time. It allows 256-bit floating-point vector instructions, but it doesn't include 256-bit integer



Fig. 1. Compilation Flow of LLVM

SIMD instructions. YMM vector register is used for handling 256 bit data operations.

- AVX2:- It is an extension of AVX. AVX2 capable processors allows to operate with the AVX 256-bit wide YMM register for integer data types as well.
- AVX-512:- In this, the size of the vector register is doubled from 256 bits to 512 bits. AVX-512 capable processors can perform sixteen single precision or four eight precision operations at same time. ZMM vector register is used for handling 512 bit data operations.

### B. LLVM Compiler

Low Level Virtual Machine (LLVM) is an open source compiler infrastructure which is designed as a set of reusable compiler and toolchain technologies with well-defined interfaces. LLVM enables the development of compiler front ends and backends along with provision of large number of optimization opportunities at compile time, run time, link time and idle time. Also, it provides the support for both the static and run time compilation. The three main components of LLVM compiler include frontend, middle end (optimizer), and backend. Figure 1 shows the compilation flow of LLVM. It can be seen that the frontend (clang tool) is responsible to translate high level language programs into LLVM Intermediate Representation (IR) which is target independent. This phase includes multiple tools such as lexical analyzer, syntax parser, semantic analyzer, and the LLVM IR code generator. Then the target independent IR is passed through optimizer (opt tool) where most part of optimizations is applied on the IR. Finally, the optimized IR is lowered to target specific assembly code through the backend phase (llc tool) of LLVM. The code translation at the backend is comprised of different phases including instruction selection, instruction scheduling, register allocation, and code emission. Moreover, the backend is responsible to perform all those optimizations that are target specific [8], [12], [13].

Besides, the most significant feature of LLVM is its middle end known as optimizer. This layer uses opt tool to optimize the IR code. At this stage, there are opportunities for large number of optimizations such as dead code elimination, basic-block vectorization, loop vectorization, loop fission, simple constant propagation, global variable optimizer, function integration/ inlining, loop invariant code motion, loop strength reduction, unroll loops, promote memory to register, tail call elimination and many others. All these optimizations are automatic in the manner that they can be enabled by specifying an appropriate flag input while performing compilation. In terms of auto vectorization, LLVM offers two optimizers namely loop vectorizer and SLP vectorizer. Both the vectorizers employ

different techniques and different optimization opportunities. The loop vectorizer extends instructions in order to enable the loops to operate on multiple consecutive iterations. While, the SLP vectorizer is responsible to combine multiple scalars into vectors. In order to take benefit of vector ISA in target architecture, it is required to optimize the obtained IR through respective vectorizer using optimization phase of LLVM. Finally, in the backend these IR vector instructions are matched with architecture specific vector instructions using some appropriate pattern. After this, the required vector assembly or binary code is emitted appropriately [8], [12], [13].

Therefore, it can be said that even if the vectorization instructions are supported in backend then also the compiler is unable to perform the vector operations if the IR is not optimized through respective optimizer. In LLVM the optimizer is able to generate larger vector length. However, usually this large size of vector is not supported by the existing architectures. The x86 AVX-512 backend supports vector width of maximum <16xi32> due to the presence of 512 bit registers. Hence, no matter how much the IR code is optimized, still the generated assembly can process maximum 16 single precision elements at a time. The greater the vector length, greater the number of elements processed by a single vector instruction. This results in the increase of overall Data Level Parallelism (DLP) and reduction in the execution time. The details of LLVM compilation can be seen through Table I. In this, a vecsum kernel is considered which is first passed through clang front end which generates the IR. Then, the obtained IR is passed through opt which vectorizes the IR for Knight Landing (KNL) microarchitecture having AVX-512 vector processing units. Hence, the vectorized IR shows single load, add and store instructions for 16 single precision elements i.e <16xi32>. In the end, the vectorized IR is passed through llc which generates KNL microarchitecture vector instructions. The correctness is verified through generated assembly instructions where 512 bit ZMM registers are used.

Vectorization is not always possible due to reasons like dependence, unknown loop counts, remainder loops etc. Hence, certain applications are more favorable to get vectorized than others. However, still the compiler can play important role because mostly loops can be vectorized by incorporating certain transformations at the compiler level. It means the compilers are required to be intelligent enough such that it can utilize maximum vectorization opportunities.

### C. Polly Framework

Polly is an LLVM subproject intended for loop and data locality optimizations. Besides, it can exploit parallelism and vectorization in an automatic manner. Polly uses

mathematical representation which is based on integer polyhedra. The polyhedral technique performs modelling and transformations of loops. In this way, it can vectorize many complex loops that could not be easily vectorized. Polly functions in series of steps such as detection, translation, analysis, optimization and code generation. Initially, the code parts are detected which are intended for optimization. Then, these parts of program are translated to polyhedral representation. It is followed by analysis and optimization of polyhedral representation. Finally, the optimized program code is emitted. These steps are implemented by a set of LLVM IR passes. These passes are used in front end, middle end and backend of LLVM compiler [14], [10], [11].

IV. METHODOLOGY

This paper shows a comparative study of vectorization on General Purpose Processors (GPPs). The study shows how the present compilers can automatically exploit the vector processing units in an optimal way. The comparison is performed between auto-vectorization of LLVM open source compiler and the vectorization done by Polly framework. In order to do so, a set of application kernels are considered which are compiled by specifying different optimization flags. Then, the respective performance is measured by relevant metrics. The performance is evaluated based on two LLVM vectorization flags and four Polly vectorization techniques. LLVM vectorization flags are O3 and Ofast. Whereas, Polly techniques includes polly+stripmine, polly+vector and polly+unroll. Polly vectorization is an extension to the existing LLVM vectorization, it means each Polly technique requires the use of LLVM vectorization flag. Hence, this work exploits Polly vectorization techniques with respect to both O3 and Ofast LLVM flags. Also, the same set of experiment is repeated by varying input data sizes in order to measure the impact of data sizes on the kernel performance. The experiment is conducted using LLVM Polly version 4.0 on Linux Ubuntu Operating System. Two sets of readings are obtained one is LLVM IR code which is generated for Knight Landing (KNL) and the other is executable code which is generated for Hasewell backend. The metric vector operation count is measured by LLVM IR whereas execution time is computed by executing codes on hasewell machine. Further, the details regarding experimental setup are shown in Table II. It includes machine configurations, software settings and

compiler flags. The compiler flags are specified as clang command line arguments.

A. Factors Affecting Vectorization

1) *Vectorization Technique*: There exist numerous options to vectorize loops. Some of these are listed below.

a) *LLVM O3*: It is based on O2 and it enables several optimizations. In terms of vectorization, it enables loop and SLP vectorization [8].

b) *LLVM Ofast*: The highest level of optimization possible. It is based on O3, here some additional optimizations are enabled for mathematical calculations. These include fno-signed-zeros, freciprocal-math, ffp-contract=fast, menableunsafe- fp-math, menable-no-nans, and menable-no-infs [8].

c) *Polly Stripmining*: Strip mining is the generation of code such that each vector operation is done for a size less than or equal to the maximum vector length. It deals with breaking loop into pieces such that they are able to fit into vector registers. Polly stripmining exposes vectorizable loop and improves data locality by changing the loop structure. It is achieved by using polly-vectorizer=stripmine flag. Moreover, it prepares instructions into vector-sized chunks but does not generate vector instructions itself. The LoopVectorizer can generate vector instructions from it [14].

d) *Polly Vector*: The created vectorizable loop is replaced with vector instructions. Also, it is recognized that the innermost loop is parallel and necessary optimizations are performed automatically. It is done by using flag polly-vectorizer=polly. It is similar to Polly stripmine, but it generates vector instructions itself [14].

e) *Polly Unroll*: In this optimization, multiple copies of loop body are created and loop counter is adjusted accordingly. It is done by flag force-vector-interleave=32. Here, unroll factor is kept 32 [14].

2) *Data Size*: The performance is evaluated also on the basis of data size. There are four data sizes namely small, medium, large and extra-large used. The values of data size is different for different applications. The actual sizes are shown in Table II.

TABLE I. LLVM VECSUM COMPILATION

Vecsum kernel	Default IR	Vectorized IR (Vector-width=16)	Vector Assembly (GPP)
<pre>for(int i=0;i&lt;N;i++) { c[i] = a[i] + b[i]; }</pre>	<pre>%136 = getelementptr inbounds [8192 x i32], [8192 x i32]* @a, i64 0, i64 %135 %137 = load i32, i32* %136 %140 = getelementptr inbounds [8192 x i32], [8192 x i32]* @b, i64 0, i64 %139 %141 = load i32, i32* %140 %142 = add nsw i32 %137, %141 %145 = getelementptr inbounds [8192 x i32], [8192 x i32]* @c, i64 0, i64 %144 store i32 %142, i32* %145</pre>	<pre>%wide.load = load &lt;16 x i32&gt;, &lt;16 x i32&gt;* bitcast ([8192 x i32]* @a to &lt;16 x i32&gt;*) %wide.load107 = load &lt;16 x i32&gt;, &lt;16 x i32&gt;* bitcast ([8192 x i32]* @b to &lt;16 x i32&gt;*) %0 = add nsw &lt;16 x i32&gt; %wide.load107, %wide.load store &lt;16 x i32&gt; %0, &lt;16 x i32&gt;* bitcast ([8192 x i32]* @c to &lt;16 x i32&gt;*)</pre>	<pre>vmovdq32 zmm0, zmmword ptr [rip + b+64] vpaddq zmm0, zmm0, zmmword ptr [rip + a+64] vmovdq32 zmmword ptr [rip + c+64], zmm0</pre>

B. Polybench Benchmark Suite

It is a C code benchmark suite consisting of 30 numerical computations, representing various application domains such as linear algebra computations, image processing, physics simulation, dynamic programming, statistics, etc. The codes are divided into various categories like data mining, linear algebra, medley and stencils [16]. Some of the application codes used in this work are as follows;

- Correlation: It belongs to data mining category and it performs correlation computation.
- Covariance: It belongs to data mining category and it performs covariance computation.
- 2mm: It belongs to linear algebra category and it performs matrix multiplications (D=A.B; E=C.D).
- 3mm : It belongs to linear algebra category and it performs matrix multiplications (E=A.B; F=C.D; G=E.F).
- Doitgen: It belongs to linear algebra category and it is a multi resolution analysis kernel.
- Gemm: It belongs to linear algebra category and it does matrix-multiply  $C=\alpha.A.B+\beta.C$ .
- Syr2k: It belongs to linear algebra category and it performs symmetric rank-2k operations.
- Syrk: It belongs to linear algebra category and it performs symmetric rank-k operations.

C. Performance Metrics

The performance is measured on the basis of two metrics namely number of vector operations and speedup. The count of vector operations specifies whether the computation is done using scalar or vector instructions. It is obvious that greater vector operations are required to achieve higher performance. The vector operations are measured through different vector sizes in generated code. These vector sizes include v16if32, v8if64, v8if32, v4if64, v4if32, and v2if64. Here v16if32 means 16 single precision integer or float elements. The width of vector operation is translated to the

application execution time. The greater the vector operations, lesser time it takes to execute in most cases. Besides, more vector operations can add extra overhead resulting into extra penalty. In order to distinguish between performance of base line settings and optimized settings speedup is used. Speedup is the ratio of baseline and optimized execution times.

V. RESULT ANALYSIS

In order to conduct the experiment, eight kernels of Polybench benchmark suite are used. Initially the Knight Landing (KNL) Intermediate Representation (IR) of each kernel is generated. The codes are generated for same kernel by varying LLVM vectorization flags and Polly techniques. The IR are generated for clang(O3) and clang(Ofast), polly+stripmine(O3),polly+vectorize(O3), polly+unroll(O3), polly+stripmine(Ofast), polly+vectorize(Ofast), and polly+unroll(Ofast). After this, number of vector operations are counted. These include <v16xi32>, <v16xf32>, <v8xi64>, <v8xf64>, <v8xi32>, <v8xf32>, <v4xi64>, <v4xf64>, <v4xi32>, <v4xf32>, <v2xi64>, and <v2xf64>. Similarly, the metric speedup of eight kernels is measured with respect to default clang(O3) and clang(Ofast) for each specific Polly vectorization technique like polly+stripmine, polly+vector, and polly+unroll. In this case, the data size of each kernel is also varied. The speedup of polly+stripmine, polly+vector, and polly+unroll are measured for small, medium, large and extra large data sizes. Finally, speedup of polly(Ofast) is measured relative to polly(O3).

A. Number of Vector Operations

As shown in Figure 2, there are four categories clang(O3), polly+stripmine(O3), polly+vector(O3) and polly+unroll(O3). Vectorization is dependent on selected kernel in the manner that certain kernels have more vectorizable loops as compared to others. For example through Figure 2, it can be seen kernel 2mm and 3mm have more vectorization potential as compared to gemm. Without

TABLE II. EXPERIMENTAL SETUP

<b>Machine Configuration</b>	Architecture = x86_64, Model = Intel(R) Core(TM) i7-4790 CPU @ 3.60GHz (Haswell Microarchitecture), RAM = 32GiB, Disk Partition = 477GiB
<b>Vector ISA Extensions</b>	Haswell = AVX2 (256 bits/yymm) <8xf32> <4xf64>, AVX (256 bits/yymm) <8xf32> <4xf64>, SSE (128 bits/xmm) <4xf32> <2xf64>, KNL = AVX-512 (512 bits/zmm) <16xf32> <8xf64>
<b>Software Version</b>	Linux Ubuntu 16.04.4 LTS (Kernal 4.4.0-130-generic) LLVM 4.0.0 Polly 4.0.0
<b>clang Vectorization Flag</b>	-O3, -Ofast
<b>Polly Vectorization Flag</b>	-O3 -mllvm -polly -mllvm -polly-vectorizer=stripmine -O3 -mllvm -polly -mllvm -polly-vectorizer=polly -O3 -mllvm -polly -mllvm -force-vector-interleave=32 -Ofast -mllvm -polly -mllvm -polly-vectorizer=stripmine -Ofast -mllvm -polly -mllvm -polly-vectorizer=polly -Ofast -mllvm -polly -mllvm -force-vector-interleave=32
<b>Backend Flag</b>	-march=haswell, -march=knl
<b>Polybench Benchmark</b>	Version = 3.2 Kernels (covariance, correlation, 2mm, 3mm, doitgen, gemm, syr2k, syrk) covariance & correlation {Small N,M=500, Medium N,M=1000, Large N,M=2000, Extra large N,M=4000} 2mm & 3mm {Small NI,NJ,NK,NL=128, Medium NI,NJ,NK,NL=1024, Large NI,NJ,NK,NL=2000, Extralarge NI,NJ,NK,NL=4000} doitgen {Small NQ,NR,NP=32, Medium NQ,NR,NP=128, Large NQ,NR,NP=256, Extralarge NQ,NR,NP=1000} gemm {Small NI,NJ,NK=128, Medium NI,NJ,NK=1024, Large NI,NJ,NK=2000, Extralarge NI,NJ,NK=4000} syr2k & syrk {Small NI,NJ=128, Medium NI,NJ=1024, Large NI,NJ=2000, Extralarge NI,NJ=4000} N,M,NI,NJ,NK,NL,NQ,NR,NP are loop iteration count

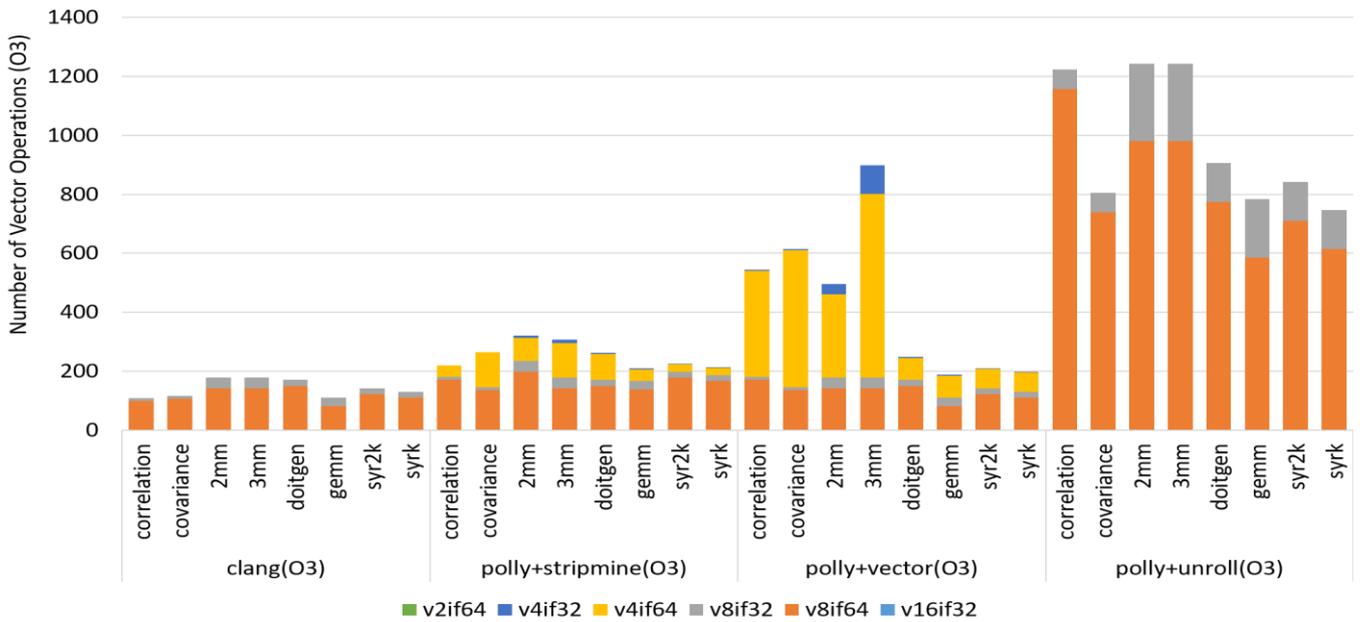


Fig. 2. Number of Operations with O3

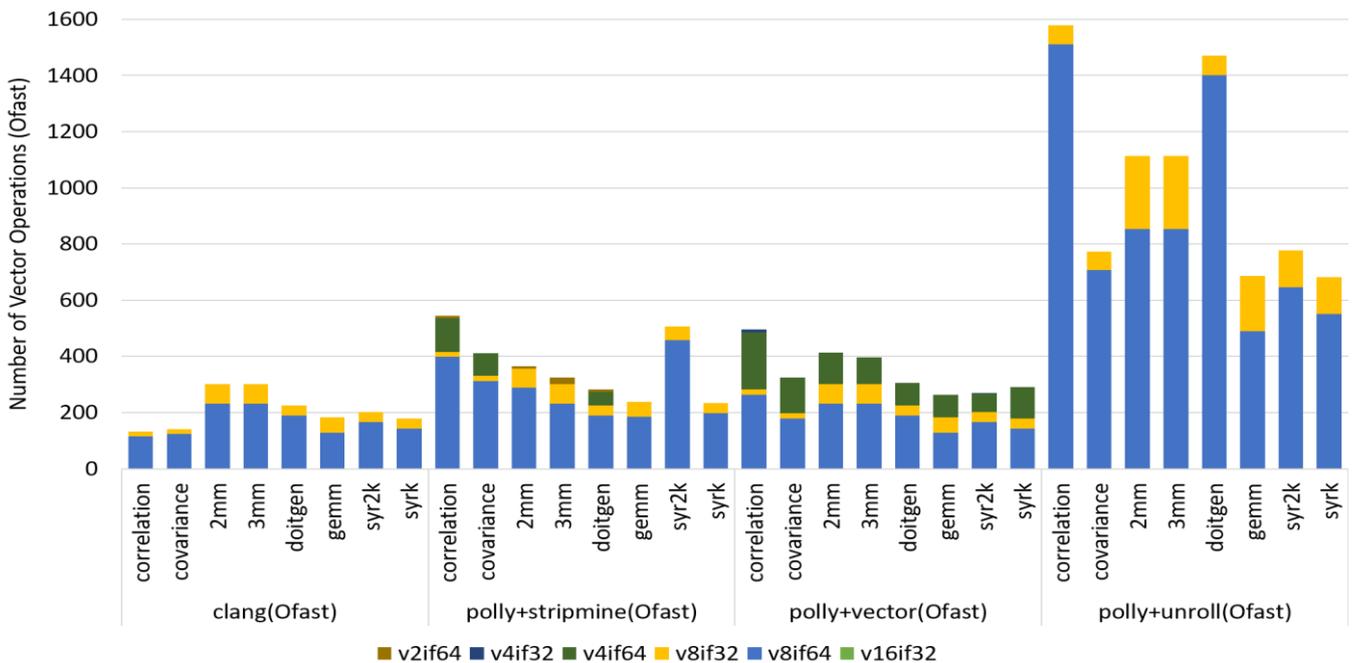


Fig. 3. Number of Operations with Ofast

Polly, clang(O3) shows less number of vector operations. Only two vector sizes are used i.e v8if64 and v8if32 for all the kernels. It means the default LLVM vectorizer misses number of opportunities. Besides, there involves no vector mixes although in most cases smaller vector operations can easily be utilized here. However, polly+stripmine and polly+vector shows different picture. In both of these Polly optimizations, the number of vector operations are increased as well as mix of vector sizes is shown. For example, polly+stripmine emits v8if64, v8if32, v4if64, and less v4if32 operations which is better than clang(O3) as Polly is able to emit vector operations for smaller size loop count by utilizing smaller size vector operations. But still polly+stripmine emits lesser vector operations as compared to polly+vector. Polly+vector shows improved number of v8if64, v8if32, v4if64, and v4if32 operations. In this case

v8if64 and v8if32 are almost same as polly+stripmine, but v4if64 is much larger as compared to polly+stripmine. Additionally, in polly+vector v4if32 is greater in number as compared to polly+stripmine. Finally, in case of polly+unroll maximum number of vector operations v8if64, v8if32 are generated. This is expected because unroll factor 32 generates greater vector operations. However, this large number of vector operations is not always translated into improved performance as there is greater overhead associated with high unroll factor. Moreover, there are no vector mixes observed like v4if64 and v4if32 which can be a disadvantage because remaining small iterations are more favoured to be handled through smaller size vector operations. Also, for all vectorization techniques it can be seen that no v16if32 operations are generated because the considered applications have double precision datatypes

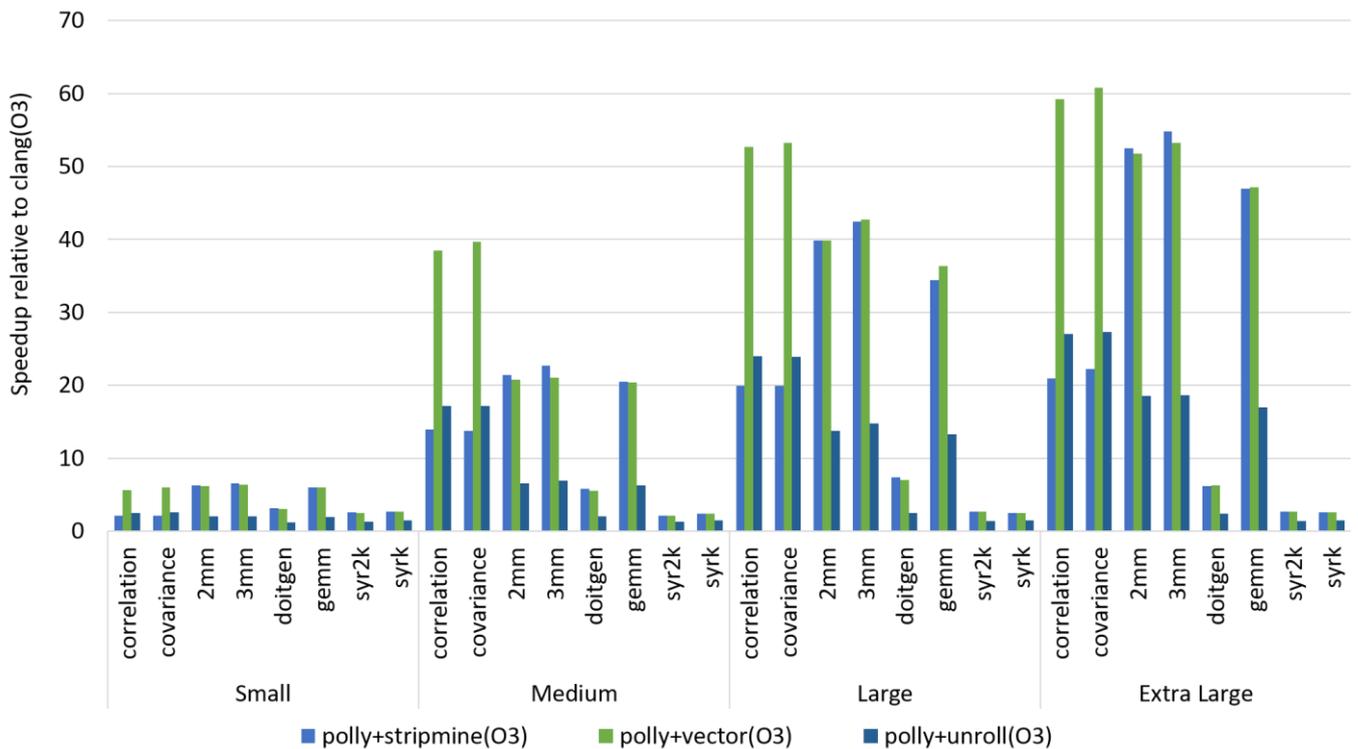


Fig. 4. Speedup of polly(O3) relative to clang(O3)

hence v8if64 is observed.

Similarly, the number of operations with respect to flag Ofast can be observed through Figure 3. In this scenario, vectorization operation count is not same as O3 as Ofast involves more optimizations beyond O3 resulting into modified vectorization than before. It can be seen through Figure 2, kernel correlation, 2mm and 3mm have more vectorization potential as compared to gemm. It can be seen simple clang(Ofast) shows less number of vector operations without Polly. However, polly+stripmine(Ofast) and polly+vector(Ofast) shows different picture. In both of these, the number of vector operations are increased as well as mix of vector sizes is shown. For example, polly+stripmine emits v8if64, v8if32, v4if64, and less v2if64 operations. But, still polly+stripmine emits lesser vector operations as compared to polly+vector. Polly+vector shows improved number of v8if64, v8if32, v4if64, and v4if32 operations. Finally, in case of polly+unroll(Ofast) maximum number of vector operations v8if64, v8if32 are generated.

### B. Speedup

The same set of eight benchmark codes are executed on Haswell machine to measure the execution time by varying both vectorization techniques and data sizes. Besides this, the performance is also dependent on employed kernel code because certain codes have more vectorization opportunities than others. But, still those vectorization opportunities remain unexploited if the employed technique is not efficient. The speedup is measured with respect to clang(O3) and clang(Ofast). Figure 4 shows the speedup results with respect to clang(O3). It can be seen through Figure 4, when the data size is small the maximum speedup

is 6.5x and it is achieved for 3mm application through polly+stripmine optimization. In the same case, polly+vector achieves speedup of 6.3x. However, for the other remaining applications in small category except doitgen and 2mm, polly+vector performs either better or same as polly+stripmine. It can be observed for application syr2k and syr both polly stripmine and vector show almost same speedup. For application correlation polly+vector shows speedup of 5.6x, whereas polly+stripmine gives speedup of 2.0x. Similarly, for covariance polly+vector has speedup of 6.0x whereas polly+stripmine has speedup of 2.0x which is a large difference. In case of kernel gemm the speedup of vector is greater than stripmine but the difference is very less. Finally, for kernel doitgen stripmine shows slightly better performance by speedup of 3.1x and polly+vector speedup is 3.0x. In case of polly+unroll the speedup is less as compared to polly+vector for all application codes. However, in comparison to polly+stripmine, polly+unroll has lesser speedups for all codes except for correlation and covariance kernels. In case of both kernels, polly+unroll speedup is 2.5x whereas stripmine speedup is 2.0x.

When the data size of benchmark codes is increased to medium, further increase in speedup is observed. In this case the maximum speedup reported is 39.6x. This much speedup is achieved through polly+vector for covariance kernel. Whereas, for the same application stripmine gives the speedup of 13.7x and unroll gives speedup of 17.1x which are again higher than the speedups achieved with small dataset. Similarly for application correlation, polly+vector performs better than stripmine and unroll. However in case of 2mm, 3mm, doitgen, gemm, syr2k, and syr stripmine shows better results than other two. In only correlation and covariance kernels, polly+unroll shows better performance than polly+stripmine.

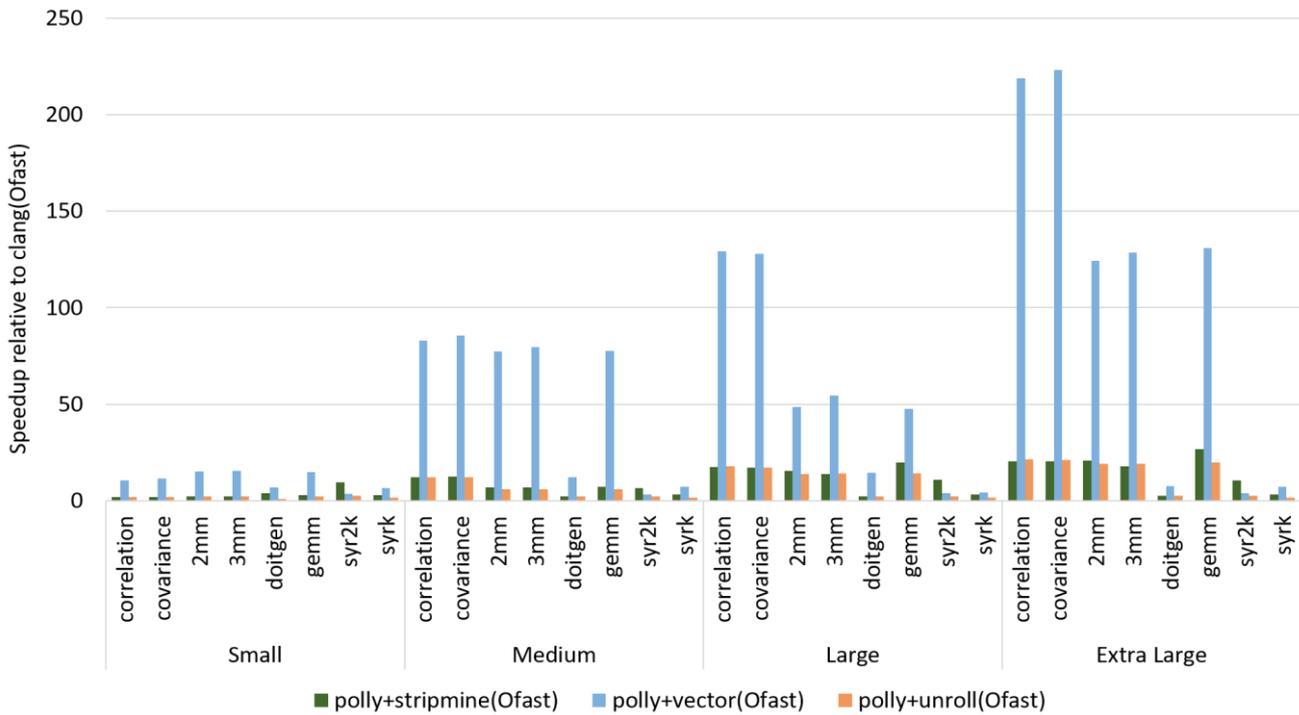


Fig. 5. Speedup of polly(Ofast) relative to clang(ofast)

Furthermore, when the data size is increased to large the maximum speedup is reached to 53.2x. But, still the application behaves in a similar manner as the past two cases of small and medium sizes. Again, the covariance kernel with polly+vector shows highest speedup of 53.2x. It is greater than both the polly+stripmine and polly+unroll. In case of applications 2mm and doitgen, polly+stripmine leads polly+vector with minor difference. Besides, vector+unroll shows lesser performance than other two for all applications except correlation and covariance. In both of these applications, vector+unroll shows greater speedup than polly+stripmine but lesser than polly+vector.

Finally, when the data size is increased to extra large again the speedups are increased but application behavior is almost the same. In this case, the maximum achieved speedup is 60.7x again for covariance benchmark using polly+vector optimization. It is greater than speedup of polly+stripmine and polly+unroll. For applications syr2k and syrk the attained speedup is less in all 3 techniques. In fact, the speedup in these applications is almost the same for all the data sizes. It means these kernels are less affected by data size variation. For kernels 2mm and 3mm stripmine shows slight improvement in speedup as compared to polly+vector. Still, the polly+unroll has less speedup as compared to other two except for kernels covariance and correlation where it shows better result as compared to polly+stripmine.

Similarly, speedup is measured relative to optimization Ofast as shown in Figure 5. It can be seen, when the data size is small the maximum speedup is 15.6x and it is achieved for 3mm application through polly+vector(Ofast) optimization. Also, for the other remaining applications except syr2k in small category polly+vector(Ofast) performs better than other two. In case of syr2k, polly+stripmine(Ofast) is better than both vector and unroll. Further, polly+stripmine(Ofast) is better than polly+unroll(Ofast) for all applications in small category.

When the data size of benchmark codes is increased to medium, further increase in speedup is observed for certain applications. The maximum speedup reported is 85.6x which is achieved through polly+vector(Ofast) for covariance kernel. Polly+vector(Ofast) outperforms other two for all codes except syr2k which is best optimized by Polly+stripmine(Ofast). Also, polly+stripmine(Ofast) is better than polly+unroll(Ofast) for all applications. Besides with medium size, syr2k and doitgen do not show an increase in speedup. In comparison to syr2k small, the speedup is reduced to 6.4x in polly+stripmine(Ofast), 3.3x in polly+vector(Ofast) and 2.3x in polly+unroll(Ofast). Similarly, the speedup is lowered to 2.1x in case of doitgen. It is known that Ofast enables some aggressive optimizations along with O3 which might result in violation of strict compliance with language standards. In this way, by using these aggressive optimizations the performance is lowered for certain applications. It means with the increase in data size, the impact is more evident in terms of reduced speedup.

Furthermore, when the data size is increased to large the maximum speedup is reached to 129.1x for covariance kernel with polly+vector. Here as well, Polly+vector leads other two for all applications except syr2k where polly+stripmine is dominant. Also, polly+stripmine leads polly+unroll for all applications except correlation and covariance. Moreover, when the data size is increased to large 2mm, 3mm, gemm and syrk polly+vector(Ofast) show fall in speedup. In comparison to medium, the speedup is reduced to 48.6x in 2mm, 54.3x in 3mm, 47.6x in gemm, and 4.3x in syrk. The reason of reduction is possibly the use of some aggressive optimizations in Ofast. With the increase in data size, the impact is clearly evident in terms of reduced speedup.

Finally, when the data size is increased to extra large, the maximum achieved speedup is 223.2x for covariance benchmark using polly+vector optimization. Here, again

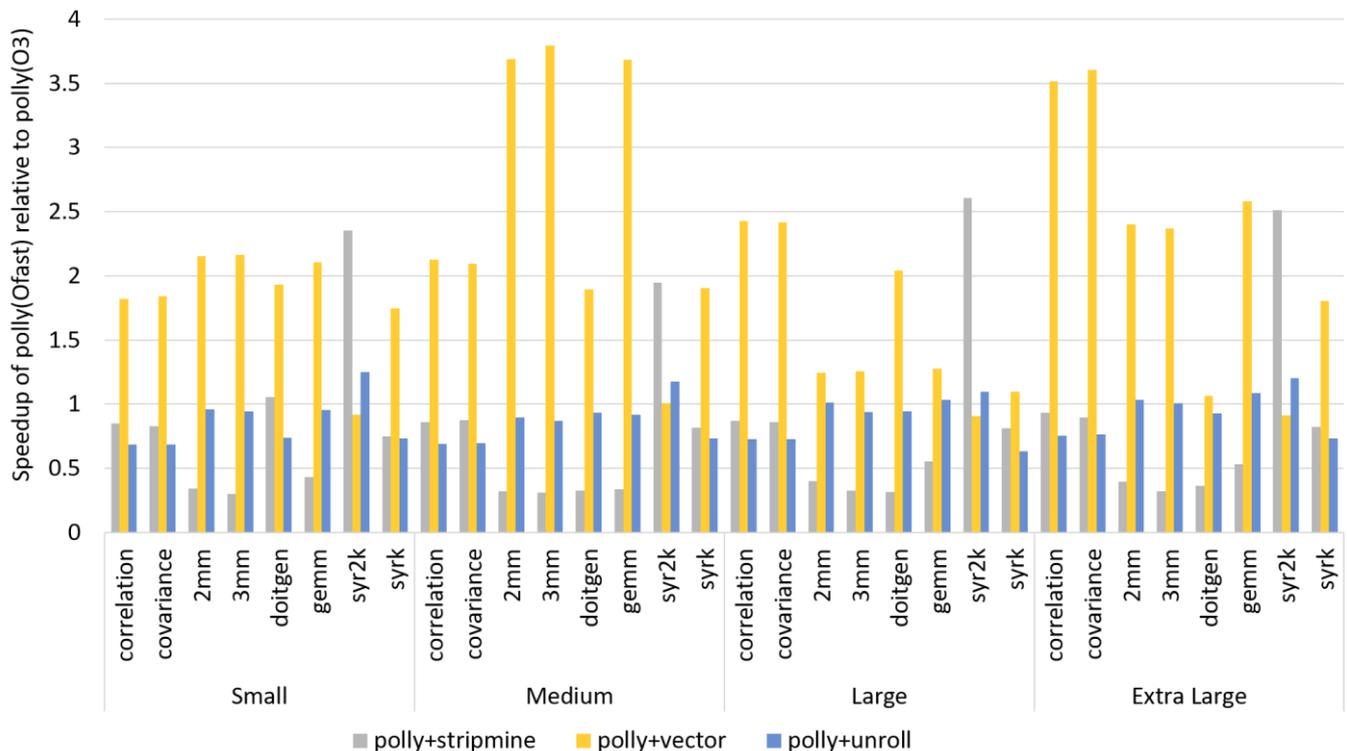


Fig. 6. Speedup of polly(Ofast) relative to polly(O3)

polly+vector lead other for all applications except syr2k. In case of syr2k, polly+stripmine(Ofast) is better than other two. Further, polly+stripmine(Ofast) is better than polly+unroll(Ofast) for all applications except correlation, covariance, and 3mm. It can be seen that polly+vector(Ofast) shows the speedup even greater than polly(O3) for all applications except syr2k. Further, when the data size is increased to extra large doitgen polly+vector(Ofast), and syr2k polly+stripmine(Ofast), polly+vector(Ofast) show decline in speedup. In comparison to large, the speedup is reduced to 7.434x in doitgen, 10.5x in syr2k polly+stripmine(Ofast), 3.8x in syr2k polly+vector(Ofast). The possible reason of reduction is the use of some aggressive optimizations in Ofast. The increase in data size depicts the impact in performance in terms of reduced speedup.

By analyzing the performance of polly(O3) and polly(Ofast) it can be seen in both the cases the application behavior is almost the same. Also, in both cases performance is enhanced by varying data sizes. However, different speedups are reported by using different flags O3 and Ofast. In certain cases, O3 performs better and in other Ofast is better. Hence, the performance of polly Ofast can be analyzed with respect to polly O3 through Figure 6. It can be seen that polly(Ofast) is slower as compared to polly(O3) for stripmine and unroll as the speedup is less than 1. However, for syr2k kernel both polly+stripmine(Ofast) and polly+unroll(Ofast) are slightly faster than O3. Besides, the outcome is different in case of polly+vector(Ofast) as this option shows the faster execution as compared to O3 resulting into higher speedup. The maximum speedup of polly+vector(Ofast) with respect to polly+vector(O3) reported here is 3.6x which is huge in terms of performance. This 3.6x is translated to 223x with respect to simple LLVM Ofast and 218.8x with respect to O3 flag. This shows the

effectiveness of our proposed combination i.e vectorization with polly+vector(Ofast).

Furthermore, it can be observed how the default LLVM vectorization is ineffective for larger data size applications. These optimizations are static thus emitting the similar behaviour even with varying data sizes. It implies that conventional clang vectorization is not scalable as the performance is heavily reduced by increasing the data size. However, Polly vectorization shows scalable behavior as the performance is improved or even maintained if the data size is increased. It implies that Polly performs more optimizations with an increase in data size, hence it is adaptable in nature. In addition to this, the vectorization proportion is bounded by the nature of application kernel. For example, if application possess dependencies, unknown loop counts, remainder loops, conditional codes etc then the vectorization is not straightforward. In such cases, Polly can enable certain transformations and can improve performance in comparison to default vectorizer but still there are cases where Polly is also unable to vectorize and the speedup is limited.

## VI. CONCLUSION

In this paper, a comprehensive vectorization analysis is done using Polybench benchmark suite. The performance is evaluated on the basis of LLVM and Polly vectorization techniques with varying data sizes. The techniques include O3, Ofast, polly+stripmine, polly+vector and polly+unroll. It can be seen how polly vectorization is able to show better results both for vector operations and speedup. Specifically polly+vector when used with Ofast flag, shows better outcomes as compared to other combinations. It can be seen that the number of mix size vector operations are greater for polly+vector which is translated to greater speedup. Further, polly+stripmine shows better performance than

polly+unroll. Polly+unroll shows improved performance than default, but still lesser as compared to polly+vector and polly+stripmine. In polly+Ofast, speedup is raised with increase in data size for certain applications only, due to aggressive optimizations. Polly+O3 shows scalable vectorization because the speedups are improved with increasing data sizes for all applications with the three techniques. It implies that the existing default vectorization (O3 & Ofast) is not adaptable to larger size problems. Hence, in order to maximize vector processing in General Purpose Processors (GPPs) it is recommended to compile the codes using combination of Polly's vector technique and LLVM Ofast flag.

## REFERENCES

- [1] Y. Zhang, T. Cao, S. Li, X. Tian, L. Yuan, H. Jia, and A. V. Vasilakos, "Parallel processing systems for big data: a survey," *Proceedings of the IEEE*, vol. 104, no. 11, pp. 2114–2136, 2016.
- [2] J. L. Hennessy and D. A. Patterson, *Computer Architecture, Sixth Edition: A Quantitative Approach*, 6th ed. San Francisco, CA, USA: Morgan Kaufmann Publishers Inc., 2017.
- [3] X. Tian, H. Saito, S. V. Preis, E. N. Garcia, S. S. Kozhukhov, M. Masten, A. G. Cherkasov, and N. Panchenko, "Effective simd vectorization for intel xeon phi coprocessors," *Scientific Programming*, vol. 2015, p. 1, 2015.
- [4] J. Lee, F. Petrogalli, G. Hunter, and M. Sato, "Extending openmp simd support for target specific code and application to arm sve," in *International Workshop on OpenMP*. Springer, 2017, pp. 62–74.
- [5] H. Wang, P. Wu, I. G. Tanase, M. J. Serrano, and J. E. Moreira, "Simple, portable and fast simd intrinsic programming: generic simd library," in *Proceedings of the 2014 Workshop on Programming models for SIMD/Vector processing*. ACM, 2014, pp. 9–16.
- [6] S. Maleki, Y. Gao, M. J. Garzar, T. Wong, D. A. Padua et al., "An evaluation of vectorizing compilers," in *Parallel Architectures and Compilation Techniques (PACT), 2011 International Conference on*. IEEE, 2011, pp. 372–382.
- [7] G. Team, *GCC, the GNU Compiler Collection*, 2018-01-30 (accessed July 8, 2018). [Online]. Available: <https://gcc.gnu.org/>.
- [8] L. A. Team, *The LLVM Compiler Infrastructure*, 2018-03-08 (accessed July 8, 2018). [Online]. Available: <https://llvm.org/>.
- [9] I. Team, *Intel C++ Compiler*, 2018 (accessed July 8, 2018). [Online]. Available: <https://software.intel.com/en-us/c-compilers>.
- [10] K. Trifunovic, D. Nuzman, A. Cohen, A. Zaks, and I. Rosen, "Polyhedralmodel guided loop-nest auto-vectorization," in *Parallel Architectures and Compilation Techniques, 2009. PACT'09. 18th International Conference on*. IEEE, 2009, pp. 327–337.
- [11] P. Team, *Polyhedral Compilation*, 2018 (accessed July 8, 2018). [Online]. Available: <https://polyhedral.info/>.
- [12] M. Pandey and S. Sarda, *LLVM cookbook*. Packt Publishing Ltd, 2015.
- [13] B. C. Lopes and R. Auler, *Getting started with LLVM core libraries*. Packt Publishing Ltd, 2014.
- [14] L. Polly, "Polyhedral optimizations for llvm." (accessed July 8, 2018). [Online]. Available: <https://polly.llvm.org/>.
- [15] T. Grosser, A. Groesslinger, and C. Lengauer, "Polly-performing polyhedral optimizations on a low-level intermediate representation," *Parallel Processing Letters*, vol. 22, no. 04, p. 1250010, 2012.
- [16] L.-N. Pouchet, "Polybench: The polyhedral benchmark suite," *URL: http://www.cs.ucla.edu/pouchet/software/polybench*, 2012.
- [17] D. Molka, D. Hackenberg, R. Schöne, and W. E. Nagel, "Cache coherence protocol and memory performance of the intel haswell-ep architecture," in *Parallel Processing (ICPP), 2015 44th International Conference on*. IEEE, 2015, pp. 739–748.
- [18] D. Hackenberg, R. Schöne, T. Ilsche, D. Molka, J. Schuchart, and R. Geyer, "An energy efficiency feature survey of the intel haswell processor," in *Parallel and Distributed Processing Symposium Workshop (IPDPSW), 2015 IEEE International*. IEEE, 2015, pp. 896–904.
- [19] M. Hall, D. Padua, and K. Pingali, "Compiler research: the next 50 years," *Communications of the ACM*, vol. 52, no. 2, pp. 60–67, 2009.
- [20] S. Triantafyllis, M. Vachharajani, N. Vachharajani, and D. I. August, "Compiler optimization-space exploration," in *Proceedings of the international symposium on Code generation and optimization: feedback-directed and runtime optimization*. IEEE Computer Society, 2003, pp. 204–215.
- [21] K. Hoste and L. Eeckhout, "Cole: compiler optimization level exploration," in *Proceedings of the 6th annual IEEE/ACM international symposium on Code generation and optimization*. ACM, 2008, pp. 165–174.
- [22] C. C. Chi, M. Alvarez-Mesa, B. Bross, B. Juurlink, and T. Schierl, "Simd acceleration for hevc decoding," *IEEE Transactions on circuits and systems for video technology*, vol. 25, no. 5, pp. 841–855, 2015.

# ICONICS'18 Poster

## Quick Talk Android Application Based on Speech System

Hira Farman<sup>1</sup>, Aisha Jamil<sup>2</sup>, Mariam Jamil<sup>3</sup>, Nisha Kumari<sup>4</sup>, and Mazin Zunoon<sup>5</sup>

Computer Science Department  
Mohammad Ali Jinnah University  
Karachi, Pakistan

<sup>1</sup>hira.farman@jinnah.edu, <sup>2</sup>ajamil.here@gmail.com, <sup>3</sup>mariam.jamil789@gmail.com  
<sup>4</sup>nisha.sitani@gmail.com, <sup>5</sup>mazin.zunnoon95@gmail.com

**Abstract** — The rapid advancements in the mobile and communications technologies are providing immense opportunities for the betterment of human life. It also provides wider scope for developers to build useful mobile applications for key daily life activities such as banking, healthcare and transportation among others. Speech recognition innovation is one of the fast growing engineering technologies. Nearly 20% people of the world's population are suffering from various disabilities; many of them are blind or unable to use their hands effectively. This can limit their activities in many ways; for example, while sharing any information/content with other people through mobile device or performing any required tasks. Therefore, this work presents a voice SMS and calling application, which is developed using Android SDK platform to enable the client to send SMS and dial the phone numbers through voice. Users can send messages and call the entered telephone number from the phonebook. This work is capable to recognize the speech and convert it into text for certain functions mentioned in this paper.

# Enhancement in Hybrid Edge Detection for MR Image via Median Filtering Method

Muhammad Faris<sup>1</sup>, Kashaf Fatima, Maliha Azhar, Rohana Kamran

Department of Biomedical Engineering  
Faculty of Engineering, Science and Technology  
Hamdard University

<sup>1</sup>m.faris@hamdard.edu.pk

**Abstract** —In MR images, edges of all the entities present in the image are played fundamental role for the identification and indication of the abnormality in the human body. This paper represents a hybrid technique to obtain high quality MR images in which edges of objects present in the image are preserved. Hybrid edge detector is the combination of canny and Sobel operators. For effective and efficient edge detection in MR images filtration is the fundamental part because of the high level of noise. This proposed approach is the combination of two stages one of them is filtration and the other one is edge detection. In MR images 'salt and pepper' noise is one of the most important problem faced by physicians and surgeons during the identification and surgeries of different body parts just like brain tumor. In our technique median filter is applied in order to remove noise from MR image. This filter worked efficiently with the different levels of noise in comparison with gaussian filter. After the elimination of noise MR image is subjected to proposed hybrid edge detector. Hybrid edge detector showed proper and comprehensive detection of edges, especially for the borders. After the qualitative and quantitative analysis of results, it has found that proposed technique reflects more appropriate results in terms of image quality measured on the basis of some significant parameters like PSNR and MSE.