(IJNCAA)

ISSN 2220-9085(ONLINE)
ISSN 2412-3587(PRINT)

INTERNATIONAL JOURNAL OF

New Computer Architectures and their Applications

Volume 6, Issue 3
2016

SDIWC

www.sdiwc.net

International Journal of
NEW COMPUTER ARCHITECTURES AND THEIR APPLICATIONS

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Publisher

The Society of Digital Information and Wireless Communications
Kowloon Centre, 33 Ashley Road, Tsimshatsui, Kowloon, Hong Kong

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The issue date is October 2016.

IJNCAA

ISSN 2220-9085 (Online)
ISSN 2412-3587 (Print)

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Design and Simulation of an X-band Solid State Power Amplifier

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Abstract— **In this paper design and simulation of an X-band Power Amplifier (9.3-9.9 GHz) has been carried out. This kind of amplifiers are used in various types of radars like weather warning radars, vehicle detection radars, frequency hopping radars and phased array radars. Different types of semiconductor devices are studied/ analyzed during solid state device selection phase; however both Gallium Nitride (GaN) and Gallium Arsenide (GaAs) devices are considered appropriate for this type of design. GaAs pseudomorphic induced high electron mobility transistor (pHEMT) has been used for our design. The amplifier has been optimized for low noise, moderate power output, small return loss (input & output) and low cost. The optimization has been carried out with Advance System Design software (ADS) by Agilent. Measured results at the design frequency show overall noise figure around 2.8 dB, a linear gain of 42 dB, input and output return loss over -12 dB with an associated power at 1dB gain compression point is in excess of 29-30 dBm. Using mixed elements (discrete and distributed) design technique it has been confirmed that such amplifiers are easy to build and provide cost effective solution.**

Keywords— **HEMTs, GaAs MMICs, Solid State Power Amplifier, Cascade, Radar applications**

1. INTRODUCTION

GaAs Monolithic Microwave Integrated Circuit (MMIC) technology has matured over the years. It is used for both microwave and millimeter wave applications [1][2]. The high power achievement at X-band frequencies is neither cheap nor easy to design. Design of input/output matching circuits and device stability used to be a critical issue but with advancements in semiconductor industry, amplifier designers today prefer to use MMIC devices [3]. This has not only made circuit design simple and less time consuming but also a lot of miniaturization is being achieved. Low noise amplifiers are vital part of almost all the receivers and can be used as driver amplifier in the transmitters. These are used in highly sensitive systems including Radars, Satellite communication systems and Radio communication systems. Travelling wave tubes are used as main power amplifiers in most of the Radars and Communication systems. These high power amplifiers are driven by medium power amplifiers like the one designed in this paper.

GaAs has dominated the world of wireless communication, military applications and space applications at high frequency since long. Late 1990's and early 2000 saw replacement of the GaAs MESFETS with improved higher performance GaAs HEMTS, which are building block of GaAs MMICs [4]. MMICs are packaged devices that have integrated radio frequency (RF) power devices with matching, coupling/decoupling elements like on chip capacitors, inductors, resistors and transmission lines etc. Due to refinement in semiconductor device manufacturing techniques, these discrete elements can be very easily and conveniently implemented by skillful manipulation of impurities and bulk (GaAs in this case). These discrete elements are placed in close proximity of the power device and packaged, so that the Input, Output and inter-device matching can be achieved.

Power aided efficiency and output power levels are identified as key specifications for amplifiers. However, using MMICs these may not be achieved at the same time. So for an optimum electrical performance following considerations are of paramount importance [5]:-

a. Heating sinking techniques
b. Power device grounding techniques
c. DC blocking techniques
d. Dc bias network design
e. Addition of microwave absorber blocks
f. Isolation blocks

ADS has been utilized for control of critical design parameters like noise figure , input/output return loss and available gain etc. More and more semiconductor device manufacturers have started manufacturing internally matched high power devices at X-band for RF/microwave design in order to reduce the amplifiers development time/cost. However, even if the power devices used are internally matched, ignoring above mentioned considerations may lead to the device breakdown or oscillations. The basic things that can result in degradations are insufficient device grounding and RF signal leakage to bias network.

2. CIRCUIT DESIGN

A. *Circuit Layout / Component Scheme*

This Power Amplifier circuit comprises of three GaAs devices, a microstrip coupled line band-pass filter and a microstrip isolator as shown in figure 1. The substrate is Rogers RO RO4003C, with a thickness 0.508mm, dielectric loss tangent 0.0027 and relative permittivity (ϵ_r) 5.5. First two low noise amplifiers (LNA) are low power/low noise, pHEMTS MMICs internally matched to 50Ω having noise figure of 2.5dB and gain of 13 dB and P1dB output power 14.5 dBm @ 10 GHz. These two devices are self-biased at VDD=5 volts & IDD=66mA. In this biased condition; these two devices are unconditionally stable over the full X-band. The third power amplifier device is the high power device MMIC (FET) having gain of 26 dB and power output of 33 dBm at 9.5-13.3 GHz and it is also used to control the gain amplitude and output return loss. It is a distributed three staged amplifier which gives the cascade a final high gain at the frequency between 9.5-13.3GHz. The biasing has been done at VDD=10 Volts, VGG = -3 Volts and IDD = 1500mA.

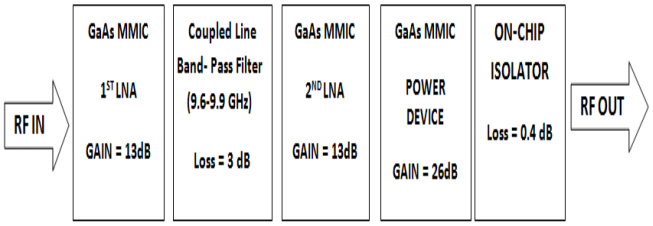


Figure 1. Block diagram of three stage X-Band amplifier showing gain/loss of each element in the cascade.

B. *Stability and Gain analysis*

Stability and Gain analysis has been carried out for this circuit at designed frequency (9.3-9.9 GHz), utilizing ADS from Agilent. The snap shot of layout in ADS is shown in Figure 2.

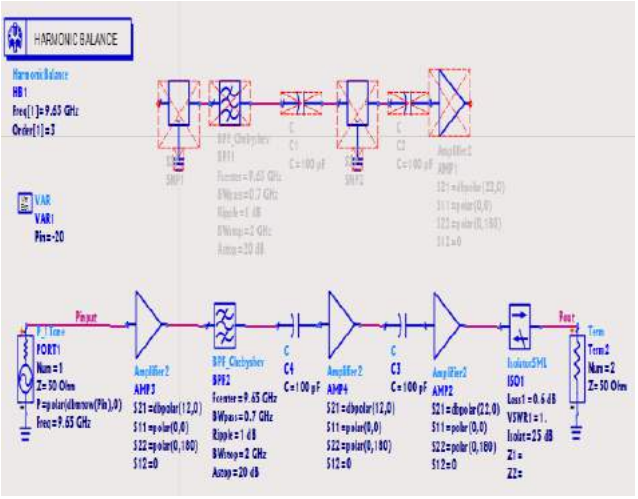


Figure 2. Amplifier Cascade Layout in ADS

C. *Stability Considerations*

The amplifier of our design is unconditionally stable if it passes K-Δ test (Rollet's condition) [6], defined as

$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{12}S_{21}|} > 1$$

And its auxiliary condition is

$$|\Delta| = |S_{11}S_{22} - S_{12}S_{21}| < 1$$

The above two conditions can be combined to a new parameter, $\boldsymbol{\mu}$

$$\mu = \frac{1-|S_{11}|^2}{|S_{22}-\Delta S_{11}^*| + |S_{12}S_{21}|} > 1$$

So if $\boldsymbol{\mu > 1}$, the amplifier is unconditionally stable over the desired frequency range. The S-Parameters at the frequency (9.3-9.9 GHz) for the third and main power device are given in Table.1 (These values have been taken from manufacturer data sheet). At all the frequencies K and $\boldsymbol{\mu}$ values are greater than one and **Δ** values are less than unity, showing the unconditional stability of device at all frequencies of interest.

Table 1. S-Parameters from Device Data sheet (Power Device)

Freq (GHz)	*S11*		*S21*		*S12*		*S22*	
	MAG	*ANG*	*MAG*	*ANG*	*MAG*	*ANG*	*MAG*	*ANG*
9.3	*.299*	*-75.9*	22.37	-37.1	.001	-159.0	*.293*	*-24.1*
9.4	*.286*	*-79.8*	22.23	-51.7	.001	-171.2	*.296*	*-29*
9.5	*.272*	*-83.1*	22.10	-66.1	.001	-166.0	*.297*	*-33.3*
9.6	*.258*	*-86.8*	21.90	-80.0	.001	-174.2	*.300*	*-37.5*
9.7	*.243*	*-90.2*	21.78	-93.7	.000	-174.7	*.304*	*-40.9*
9.8	*.229*	*-93.7*	21.61	-107.1	.001	-162.9	*.305*	*-44.2*
9.9	*.217*	*-97.2*	21.47	-120.1	.001	-166.4	*.307*	*-47.4*
10	*.203*	*-99.4*	21.38	-133.1	.001	-170.5	*.308*	*-50.2*

D. *Cascade Noise Figure Calculations*

The noise figure of the cascade can be calculated by the formula [7]

$$F_{cas} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \ldots$$

The noise figure and gain of individual elements of the cascade are appended in table 2.The Noise Figure of the Cascade comes out to be around 2.85 dB using above mentioned formula.

Table 2. Noise Figure and gain details for different elements

s/no	Element name	Noise Figure dB	Gain dB
1	First LNA	2.5	13
2	Band pass filter	2	-2.3
3	Second LNA	2.5	13
4	Power Amplifier	2.5	26
5	Isolator	1	-0.4

E. Microstrip coupled line filter Implementation

After the first stage LNA, a microstrip coupled line band-pass filter is implemented. It is a 6 element bandpass filter with an insertion loss of 2.3 dB. The centre frequency of filter is 9.65 GHz. It allows frequencies between 9.6-9.96 GHz to pass without attenuation. The filter response is shown in Figure 3.

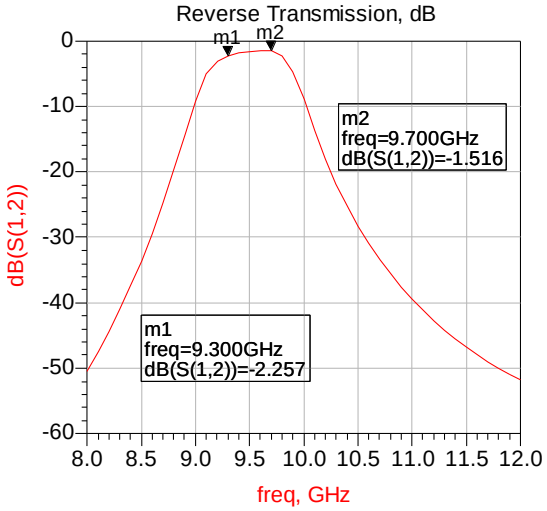


Figure 3. Filter response at 9.6-9.96 GHz

3. CIRCUIT DETAILS

The circuit details including biasing scheme are shown in Figure 4 and Figure 5. The power supply requirement of different devices has been met by utilizing DC-DC converter and voltage converter inverter.

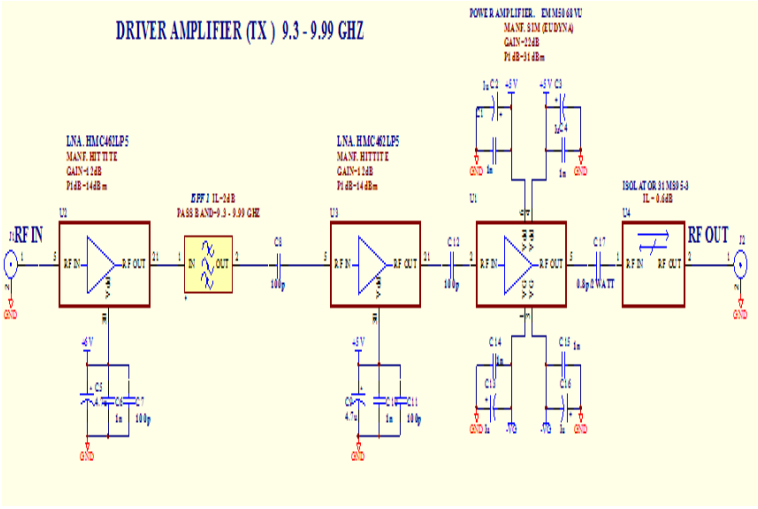


Figure 4. Circuit details including DC blocking and biasing circuit detail

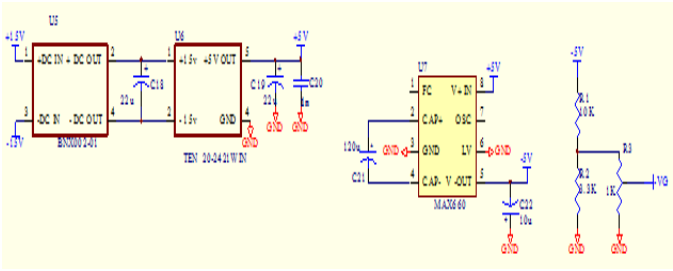


Figure 5. Power supply scheme

4. SIMULATION RESULTS

A. Amplifier Output

The amplifier provides power output between 30.8-31.9 dBm for an input power between -20 to -6 dBm. The simulation results are shown in Figure 6. This graph shows that at a given input of -11 to -6 dbm , corresponding output is around 30-31 dBm which is our desired goal in this design.

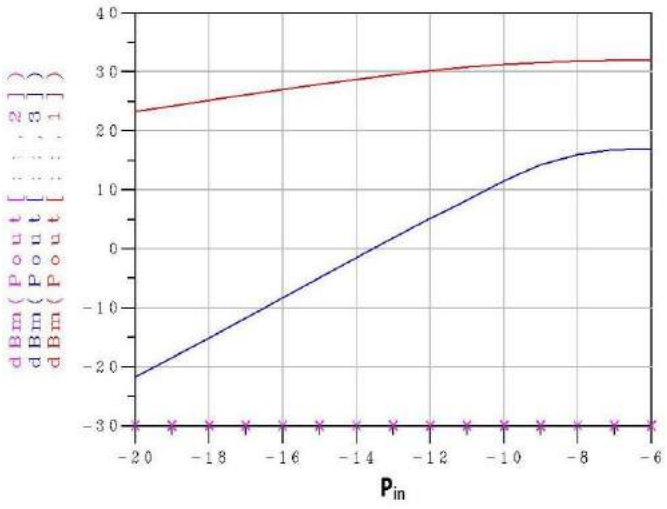


Figure 6. Power Output at desired Input (-11 to -6 dBm)

B. S-Parameters analysis

The S-Parameters at the designed frequency show a flat gain of approximately 42 dB as shown in Figure 7. This gain is kept as flat as possible to meet the specific requirement of application in which it is to be used [8][9].

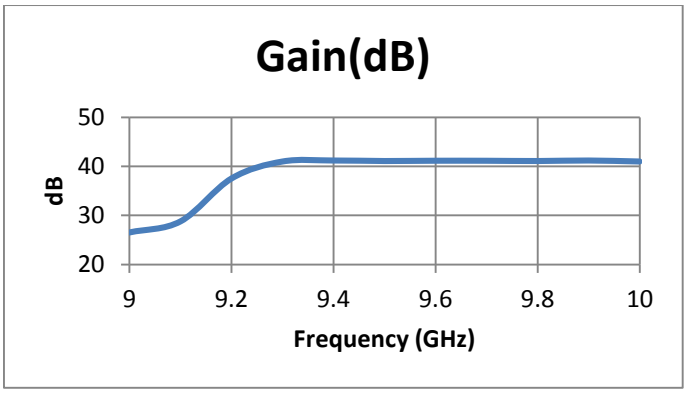


Figure 7. Simulation of S-Parameters at the frequency band between (9-10GHz) of amplifier in momentum (ADS)

C. Power Aided Efficiency (PAE) of the Amplifier

The power aided efficiency (PAE) of the amplifier at the desired frequency band (9.3-9.9 GHz) is simulated as shown in Figure 8. Simulated PAE comes out around 12%, due to linear nature of the amplifier (operated in class-A configuration).

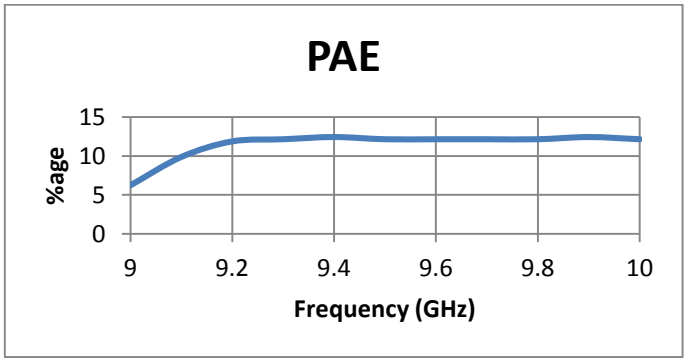


Figure 8. PAE of the amplifier

D. Simulated Noise figure of Amplifier

Snap shot of the simulated noise figure of the amplifier from ADS is shown in Figure 9. This reflects that the overall noise figure of the cascade is governed by noise figure of first stage and comes out around 2.85 dB.

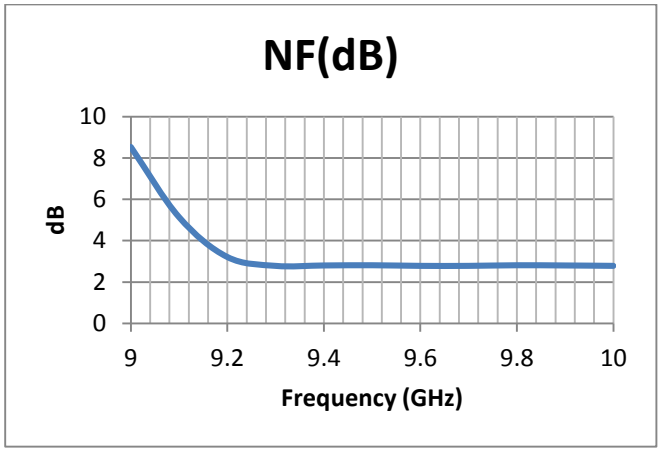


Figure 9. Simulated Noise figure of Cascade

E. Simulated μ parameter of Amplifier

Simulated μ parameter of the amplifier at the designed frequency is shown in Figure 10. It is pertinent to mention that at all the frequencies $\boldsymbol{\mu}$ is greater than one, guaranteeing the unconditional stability throughout the frequency band.

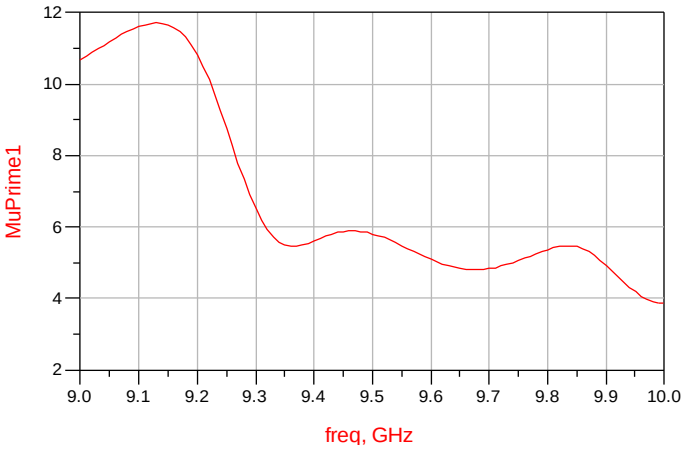
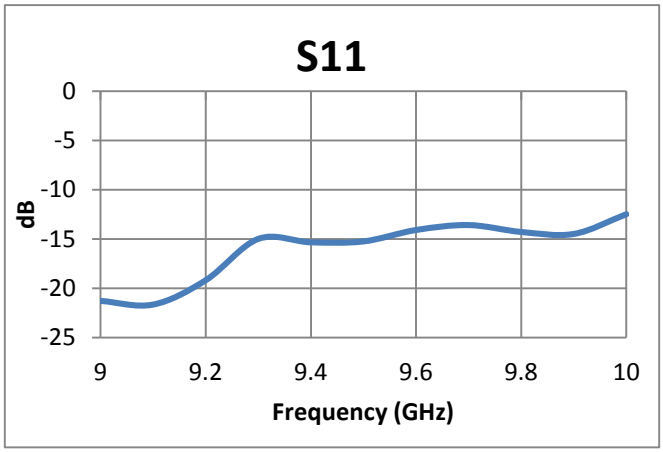


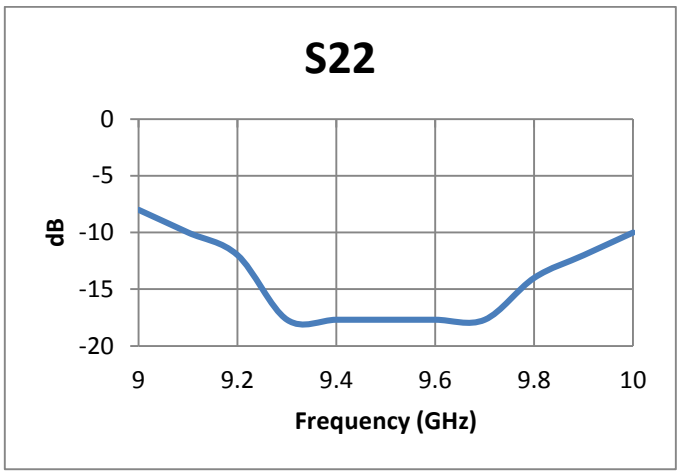
Figure 10. Snap shot of $\boldsymbol{\mu}$ parameter

F. Input and output reflection co-efficient

The input/output reflection coefficient at the two ports of the cascade is shown in Figure 11(a&b). These plots show that due to good matching at both the ports, reflections have been minimized.



(a)



(b)

Figure 11. (a) Input Return loss (reflected power) (b) Output return loss (reflected power)

5. CONCLUSION

In this paper design and simulation of GaAs MMIC's based, 3 staged X-band power amplifier has been demonstrated. The amplifier is operated in class "A" configuration. The simulated results have confirmed the validity of our design and meet our targeted values. The X-band amplifier has achieved an overall linear gain of around 42 dB, a power output of around 29-31 dBm and a PAE (power aided efficiency) of the amplifier is around 12%. This low efficiency is due to excellent gain flatness, which was a prime requirement of our system. The use of GaAs MMIC's matched to 50Ω has provided us with cost effective design.

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International Journal of New Computer Architectures and their Applications (IJNCAA) 6(3): 78-85
The Society of Digital Information and Wireless Communications, 2016 ISSN 2220-9085 (Online); ISSN 2412-3587 (Print)

Medicine Organizer Drawers Using IOS Application and Arduino Board

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Abstract

As people age and engage with life, a lot of people drop the commitments in things which become as a routine that they go on with There are many patients forget to take their treatment on time, while some of them take the treatment but in irregular schedules, which reduces the effectiveness of the treatment. The method of reminding patients their schedules by the nurse for the elderly and sitter kids is not considered successful solution in some cases. Because it relies on another person, who may probably omits or forgets the exact time. With the proliferation of smartphones, it requires a technology solution to help patients in determining medication schedules properly and make them more controlling on taking their medication.

This paper proposed an application running on the IPhone connecting with smart drawers through Arduino Board. The main purpose of this application is to organize and remind patients to take their medicines in an accurate time. Drawers can be opened and closed through the application.

Keywords

Smart drawers, IPhone operating system (IOS), Arduino, WI-Fi shield, Micro Servo

1. INTRODUCTION

No one can deny that technology has a great influence in our daily lives. We may disagree in determining whether this effects in a negative or a positive way, but we agree that technology has affected our lives widely and extensively. In recent years we have seen a revolution in smart phones, tablets and the succession of innovations that have a strong impact in the pattern of our daily lives changes.

One of the most successful treatments of any disease factors, is taking medication specific punctual prescribed by a specialist doctor, it is possible to forget taking the dose due to preoccupation with the concerns of life and circumstances. Forgetting any doses of medication reduces the effectiveness of treatment and limiting access to the desired results. For this reason, innovation stimuli electronic reminder of the date to take the drug in an innovative way. Opirate these stimuli to recall adjust the time according to the time required for the alarm clock which work acoustically or optically or through the application of a mobile phone to send notifications to the users. Thus, ensures eating their medicine regularly without forgetting any dose of doses. These stimuli is also ideal for patients with Alzheimer's disease or patients who suffer from weakness in the memory. For this, the best of these stimuli have been set to help patients in taking their medicines easily without fuss thinking about the timing[1].

There are many types of operating systems of smartphones. IOS is system runs on Apple's IPhone. It was appeared at the beginning of 2007 as the operating system created by Apple for the IPhone. Then the system included IPad tablet devices and IPod Touch.

It was a quantum leap in the world of smart phones. Also it is the best known system and that because of the beauty and simplicity of it's design and it is also different from other mobile systems. The IOS system is a worthwhile system, it has continuous improvements and updates at each period of time.

2. PROBLEM STATEMENTS

Everyone have a lot of things that concern them with their time, every day. By adding new task to their full day. People may forget some of the important things that must be done, such as taking the medications in time. Remembering medications, prescribed and non-prescribed vitamins, is not an easy thing to schedule. This paper presents an effective solution that helps patients to remember their medications daily schedules.

Many of patients think that it is okay to forget taking a few grains of their medications, but this is not the truth. All medicines have the so-called "half-life" by which time their bodies need to get rid of half the dose addressed. When the patients take medication regularly, the medicine in the body up to a state of "stability", which means that the amount of drug absorbed by the body is equal to the amount of medicine they get it out.

Usually the medication needs of five to six "half-life" to reach stability condition. For example: If the medicine that the patient take, has a "half-life" equivalent to twelve hours as a "Lisinopril" (Prescription medication frequently to treat high blood pressure), the drug level stability in the blood case will starts to downward gradually in half within sixty to seventy-two hours or a few days. In this case, blood pressure begins to rise as they have a negative impact on heart health. [1]

A recent medical study has revealed that patients reminder text messages and dates medication can reduce the proportion of the deaths of thousands of patients, following a stroke or heart attack, as well as providing thousands of pounds. The study indicates that the omission of a lot of patients for their medications cause loss of more than 500 million pounds, the value of the drugs provided by the National Health Service in Britain. It explained the new study, conducted by the University, "Queen Mary" in London, that the reminder text messages work to improve medication and absorption by 64%, and not only works to maintain without wasting millions on prescription drugs not covered by the patients, but also prevents the death of many patients who need to take control of cholesterol drugs. The results obtained indicate that the patients text messages to remind the dates of taking their medication is the most effective means of Statistics and the most effective way[8].

The medicine drawers to organize patient's medications which easily founds in private pharmacies and strongly helps if patient forget to eat their medications on a daily basis as they help patients who take more than one medication per day at different times.

Applicants age patients gain the most benefit from these drawers so that it is divided into several sections including covers a full week of medication (or more) as they are today divided into more than one period. These drawers can be carried easily in handbags while travelling, but patients have to be careful not to leave them in a hot place (in the car, for example)[7].

There are many applications on smartphones, which help patients to remember pills time. For example, some free applications for smartphones, user can enter the dates of all the medicines that need to be addressed, the time and date. The Application will remind the user of the entire drugs, it will also remind them of the date of their next visit to the doctor. It also saves all drugs covered or not covered. Patients can browse this information easily and refer to it at any time [6].

users can also add their personal feedback and can read more information about the medicine they take (such as: side effects, different dosages, degree of safety for use during pregnancy and interactions with drugs or different foods). In some Aapplications, users can also add pictures of their medicines if this method suits them best to remember their medication. All the information which users add to the application, is stored on their phone only. This applications are safe and guarantee user's privacy.

3. RELATED WORKS

Janckulik, D.; Martinovic, J.17-19 March 2009 an ad hoc system to monitor the ECG belted with a mobile phone in order to track the status of the patient from the beginning where the connection is through the Internet[2]

Shaosheng Dai 2006 is a system that follows up the heart ICG planning connection Wireless directly with the patient in order to measure pressure, diabetes , heart rate and allows doctors to enter the application and the withdrawal of recorded data of the application to the patient's medical file and allows the application to conduct examination during daily life through the application[4].

Sultan, S. 13-16 July 2009 is a system that works on mobile telephony delivers via Bluetooth, is working to develop some medical advice to patients. In addition patients was directly connected with medical care center and interesting application primarily diabetes and blood pressuree [5].

Shieh, S.C.; Lin, C.C. ; Yang, T.F. ; Tu, G.H. 8-11 Dec. 2008 infrared technology in pharmacy: It is a system based on the connection between the patients' PDA with compartments to organize the drug to be opened and closed using the contact

infrared system RFID so as to prevent people from reaching the non-stating them medicine [6]
Suzuki, T. 26-30 Aug. 2014 A smartphone mediated portable intelligent medicine case for medication management support is a system that works on smartphones that organizes taking medication schedules, such as birth control pills for women as well as he captures images of the medicine to be closets definition for each class of drug items in the application. The application calculates the daily doses as described by the doctor to the patient [7].
Ermisoglu, E. 25-28 Aug. 2013 Simulation of Mobile Treatment Monitoring System , it shows that 50 to 75 of the patients forget the deadline for taking medication , so a system is developed that works on a mobile phone to organize appointments to make it easier for the users to take their medications on time from where they are connected with the Drawer for treatment. It directly helps the patient to know the medication required it was taken at the same moment. It is also useful for the elderly patients [8].
Samir V. 11-12 December 2015 (IOT) internet of things network is considered as a health care system and as a home medicine reminder. It is a distant monitoring system, which gives real appointments of patient and health professionals. It is very important in connecting two technologies, which are: the use of messaging standard by Bluetooth or ZigBee and the use of communication reports. (IOT) stores sensors information and it is very important for a quick reaction in case of emergencies. It is effective for people who have serious conditions and who need to take their pills on time, so it is recommended to use. RFID is an option for personal identification and for detecting objects [9].
Abu-Dalbouh, Hussain 95-101 September a mobile reminder system is created to serve two necessary categories which are elderly and people who are diagnosed with Alzheimer. Both of these categories tend to forget things easily. This system can be used as their own memories. It can very helpful to them because it reminds them to take their medications on time and due to that, they can take care of themselves. It also can be used as a food reminder. It provides a real time monitoring of direct provision of care and patient vital signs by using mobile telemedicine [10].
Mobile-Health services and applications have become more popular these days. These services could save a lot of money because it can take care of the patients without going to the hospital every time. M-health applications are easy to use, which does not need any physical connection between patient and physicians. It is an effective way to enhance patient lives such as elderly, chronically ills, and disables. These health applications are not used for patients only, but important for hospitals, care center. The basic role of these applications is to be used as reminder tools to improve medication adherence [11].

4. HARDWARE EQUIPMENT

Arduino is a great open source project that aims to provide free software and colouring of the development of an interactive open source Development Board used in the construction of electronic circuits smart and able to interact with humans and easily pleased. Anyone can use it to work legitimately own without the need for prior knowledge with the knowledge of electronics and without studying the intricacies of electronic circuits, and the painting is made up from the circle email with a microcontroller programmable through the Arduino IDE and software which can be downloaded free of charge for all operating systems. As shown in figure.1

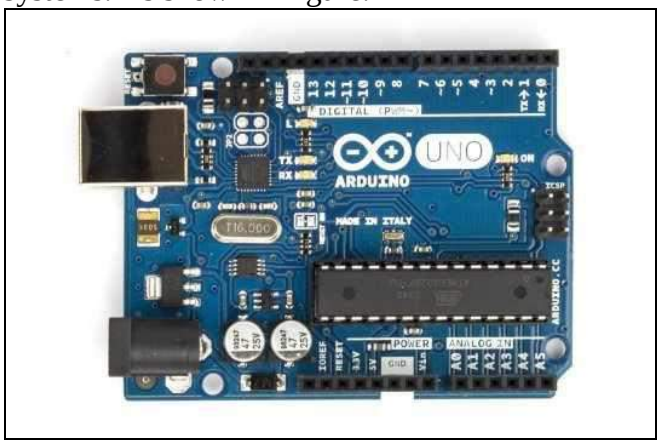

Figure 1 UNO arduino

Breadboard especially to facilitate connectivity and installation of electronic circuits without the need for soldering process, where can accommodate many circuits, that can connect the electricity regulator to electrical connections are not affected to conduct experiments and test electronic circuits. They offer a lot of efforts and time where user can install circuit parts without soldering. There are many points that can be installed where the electronic circuit parts its divided so that each five points theoretically and practically one point. The

breadboard used plate experiments to make temporary Electric circuits either to test the validity of connections or to experience the idea without the need to wild copper wires or components. Panel tests contain metal ports that allow the user to change any connections or the removal of any components easily, which allows using it over and over again.

Figure 2, shows the Wi-Fi Arduino Shield. Wi-Fi shield its device to make a wireless connection between the IPhone and the Arduino board using 802.11 wireless specification which contains the pills drawers by using the static IP address as 192.168.0.200 by using long wire-wrap headers which extend through the shield.

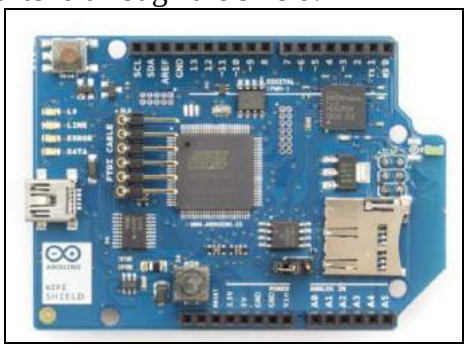

Figure 2 Wi-Fi Arduino Shield

Micro Servo is a small motor used to open and shut Drawer medications. It is linked through Board Arduino. In this project, the Board Arduino has been linked with the application via Wi-Fi.

Pills organizer is a small plastic box with different sizes can be carried. It usually contains seven drawers, according to the number of days of the week (divided from Saturday to the last day in the week, Friday). In addition, the drawer has a brief to the days of labels, so as to facilitate the identification of the day and to identify the medication that must be addressed in this day. There are several designs of the drawers, this form that appears in the project has been chosen, for the ease of dealing with electronically, in addition it can be used to add some labels to let the user to be more awareness to realize appointments.

5. APPLICATION AND SYSTEM DESIGN

The Application provides the user to set timer to take the medicine from the smart drawers. These drawers connect to the application wirelessly so; the application needs to connect to internet network to run the features and it only works in IOS devices. The application asks the user to be allowed to send the notification. Then, to make the communication between them, user should click the "OK" button. If the user click "OK", the communication will start but if the user click "Don't allow" the application will block the communication so user will not send nor receive the notifications. In case the user would like to receive notification, the user can set and configure in the mobile settings. The home screen, which displays the list of the drawers in the application, the user can set the time for each drawer separately by click on the "set timer" button. To set timer for the medicine, user should open the pills drawer through the application to put the medicine by clicking "Open" button. After taking the medicine, user can also close the drawer through the application by clicking "Close" button. As shown in figure 8. Then, user will be moved to the "set timer" screen as shown in figure 3.

In this screen (Figure3), user can scroll the time of the drawer to set the reminder. The application use 12 hour time format and the user is allowed to set between AM and PM. After setting the time, user must click the "Done" button to save changes then, click back.

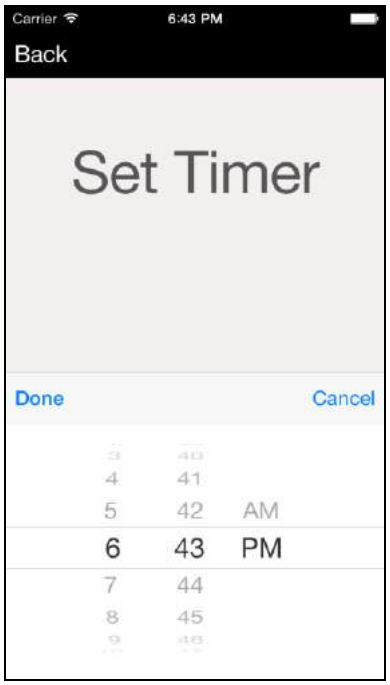

Figure 3 setting reminder time by the user

Figure 4 shows the home screen after setting the timer for two drawers. The home screen contains "settings" button that looks like the washer gear. After clicking the setting button in the upper right

side, user will be moved to the setting screen; to enter the settings of the application.

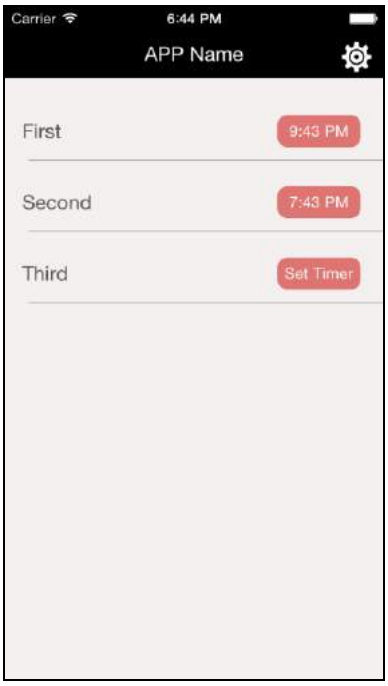

Figure 4 after setting the timer for two drawers.

In "setting" screen, user can add the IP address to connect between Mobile app and the device by manual adding or automatic.

Figure 5 shows the setting screen after adding the IP address. The User adds the IP 192.168.0.200 manually to connect the Smart Drawer.

Figure 5 adding IP address manually

6. IMPLEMENTATION

The Aapplication, the Doses Organizer Application is one of the most important applications that increases a large number of users of IOS devices to regulate taking their medication schedules and remind them through the alarm so as to enable them to take their medication on time. The application's interface is clear and easy to use. It has an eexquisite design and shows the user the types of medicine that is addressed. The application sends notifications when the medicine time come. The application needs to connect to the internet network. One of the application's benefits is that user can open the daily Pharmaceuticals Drawer through the application and close it through either the application or the manual way, and that for the safety of children of tampering with drugs and addressed.

6.1 Application features:

1. Regulates daily doses so that it appears on the screen the amount of medicine or the number of disks, user will not be able to find difficulty in understanding the information.
2. Application alerts in a timely manner that user take the medicine according to the timing of the pre-set or pre-defined intervals.
3. user can specify a certain hour of taking the medication.
4. In case the user wants to determine the alarm clock to take medication at specific intervals, he can just set the starting hour and the length of time between the alarm and the next alarm.
5. The application removes the doses that have been dealt with automatically, and will not treading anymore whether the drug is covered or not.
6. In addition of the drug and the dose name, the user can enter, any information associated with this medication as prescribed by the doctor.
7. Application can regulate eating more than one type of drugs at the same time.
8. The application maintains the confidentiality of the user, and does not allow any one tamper with the medicine which is in the drawers without accessing the application.

9. Application codifies what passed doses were taken from each of medicines is an important record for those dealing drugs.

6.2 Application limits:

Limitations of any system or application is considered out of the question, each system or application in the first time has a few things missing, and that will be developed and fix it in the future.

in this system, limitations can be summed in some of the following things:

1. The application supports only English language.
2. The application supports only 3 drawers, user must repack it again.
3. The application requires internet connection.
4. The application works on IPhone devices only.

7. DATA FLOW DIAGRAM DFD

The system allows communication between the application and the user through the interface of the application to use, where the user can choose all the parts through the buttons on the application. User is able to open drawers and shut down by the caller application completely connected through the Internet with smart drawers to conserve medications. That is easy to use in order to be a friend to all of the elderly who cannot cope with the complexities techs. Figure 6, shows the connection between the application and the smart drawer. This connection needs an internet network. When the IPhone send signals to the Arduino Microcontroller while the IPhone is connecting to the internet, the user can open or close the smart drawer by clicking open/close buttons through the application.

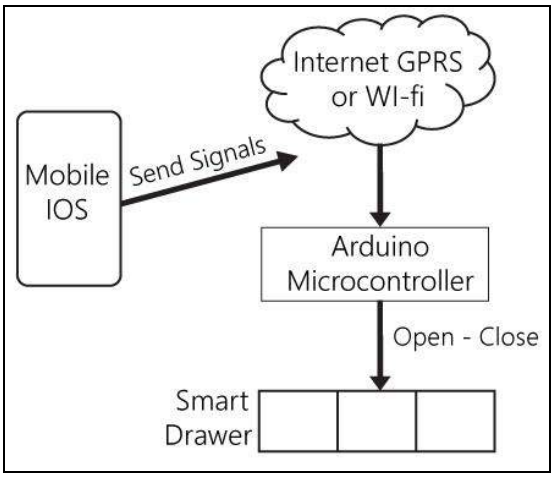

Figure 6 connection between application and smart drawers3

Figure 7 displays a data flow diagram (DFD) shows how the system works. After installing the application and connecting the IPhone to the internet network so as to be contact between the IPhone and pills drawer of the medicine, user should allow the application to send notification (user can set that on the IPhone settings). Then, user starts setting timer for each pills drawer, which is connecting to the application.

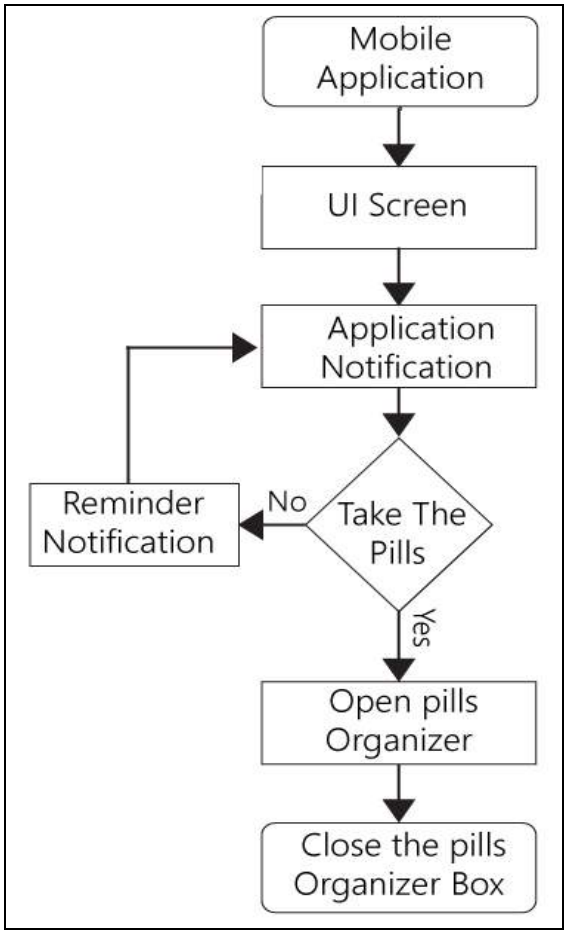

Figure 7 how the system is work

When the user clicks the set timer button for any drawer, user will be moved to a screen that provides the user to open the drawer by clicking the “Open” button. Therefore, user can put the medicine on the drawer and then the user can close the drawer through the application also by clicking “Close” button. After that, user set the timer by scrolling the time and then clicks the “done” button.

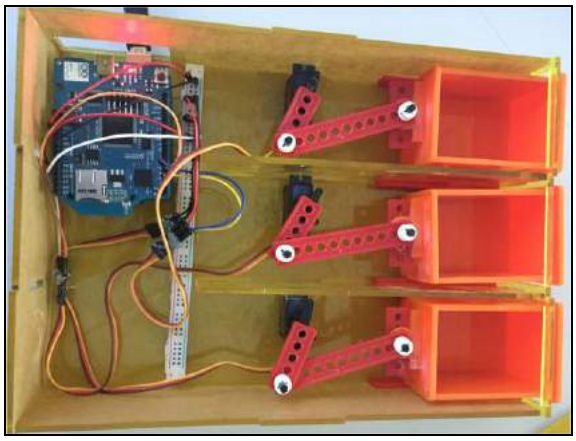

Figure 8 the hardware of pills drawer

The connection between the mobile and the Arduino Shield Wi-Fi, the Wi-Fi is connected to the Arduino board then it processes signals sent to it as shown in figure 8. When the medicine time comes as the user set it, the application will send notification to the user. In this case, the application will display a screen contains two buttons (open and close buttons).

User clicks the "Open" button to open the drawer and take the medicine. Then the application sends orders to Micro servo via the copper wires connected with breadboard, the micro servo push out the drawer the user to take the medicine as shown in figure 9.

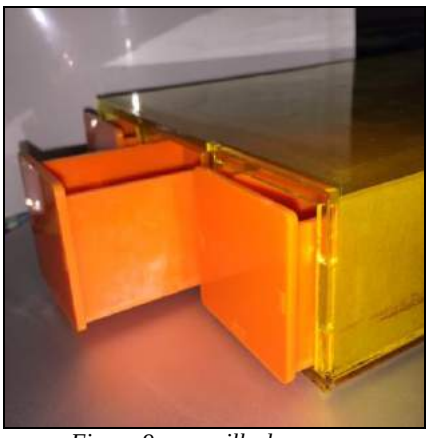

Figure 9 open pills drawer

To close the drawer after taking the medicine, user should click "close" button. Also user can close the pills drawer either through the application (by “close” button) or manually.

8. RESULTS

The application has a distinctive and simple interface allowed the user to add a medication that is being addressed in simple and easy way. Therefore, the application is easy to use especially for the old patients and those that are not associated with technology. In addition, it provided user to add 3 timers of the medicine with three drawers to store the pills with possibility of opening and closing drawers through the application. That helped to remind patients to take their medicine in a timely manner and organizing medicines in smart drawers. User needs to refill drawers if the user needs to. In addition, the application maintains the confidentiality and privacy of the user by disallowing anyone to tamper with the medicine, which is in the drawers without using the application. .

9. CONCLUSION AND FUTURE WORK

This paper presented IPhone application that helps patients to organize and remember their medicine time. In addition, it provided hardware system to connect application with three smart drawers to store medicine with the ability to open and close these drawers by the application.

The application is easy to use, the screens are simple and clear to use. Users can set timer for their medicine easily. However, user may face a problem when the application was deleted, in this case, users have to return and enter all the data again. In addition, to change the language of the application, user needs to change device language. Medical applications in this quality may be in the foreign store, but it is not available in the Arab Store.

In the future, many of the privileges will be added and that will make a wide use for this application. Also, Drawer will be provided and the Arabic will be reinforced.

In addition, the group look forward develops the application by calling the custom number when the user does not respond to the notification. As it will contain protection system, using high quality thumbs to enter the application.

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International Journal of New Computer Architectures and their Applications (IJNCAA) 6(3): 86-91
The Society of Digital Information and Wireless Communications, 2016 ISSN 2220-9085 (Online); ISSN 2412-3587 (Print)

Blood Bank Smart Phone Application for Managing and Organizing the Blood Donation

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ABSTRACT

With the revolution of communications nowadays, people needs technologies developments in all domains, especially in health domains. This paper presented an application with a system designed to provide all of the information available for the blood group or clique that is always demand on an ongoing basis. This system is characterized by ease of use and contact with other donors and the needy for different blood groups. The application is installed on smart devices to ensure the arrival of the largest possible number of blood donors in the country. It works on the smartphones with IOS system by the blood bank employee. It linked the blood bank with the donors by sending messages to the donor who could donate only blood types which enables the patient to take advantage of them.

KEYWORDS

Blood Bank, Smartphone, blood bank system, Health System, IOS system, IPhone application.

1 INTRODUCTION

"We make a living by what we get. We make a life by what we give." Winston Churchill. [1]

There is no doubt that mankind achieved many great things in medicine in the 20th and 21st century. One the most important achievement was blood transfer and blood banks. However, without technology the medicine will not be developed. It is even impossible to imagine medicine without technology.

One of the high achievements in medicine was blood transfer. In 1901, blood types were discovered by Karl Landsteiner [2]. Moreover, Ludvig Hektoen an American pathologist suggested that the blood transfer should be done among the same blood group [3]. However, in 1940, the U.S government tried to organize blood donation by establishing the national blood collection program. In 1941, Shocking from Peril Harbour attacks, The Red Cross started a blood donation program for the U.S military figure [4]. Since then, the need for blood donation has not changed. Wars, accidents, natural calamities and chronic disease are the entire major factor in developing blood banks and their systems.

In the past years, people have also witnessed a revolution in communications. Social networks have become part of the daily life. People are spending most of their time communicating with their friends and it is so easy to get addicted to it. Nevertheless, Social network is a market of ideas where people share their experience, and seeking help. One of the most common use of social network is looking for a blood donor. It is very difficult because it is not easy to find someone who is willing to donate his blood and has the appropriate type of blood. Many people find it very annoying and time wasting.

However, no one can deny the development in communication in the last years, which are, can only be described as a revolution. People are spending more time in social networking chatting, arguing discussing and seeking help. Many people who need blood donor are using social networking to find one. For example, if

someone has an accident and he needs blood, his family and friends will directly post in the social networks asking for blood donors. Nevertheless, it is not that easy to find a blood donor who is willing to donate his blood and has the needed blood type.

Nevertheless, one problem is still disturbing blood banks, which is how to reach people with the required blood type and who are willing to donate.

That is how the idea of this project "The Blood Bank application" came out. This project is designed to make finding a blood donor who has an appropriate type of blood and willing to donate easier and time saving by using smartphones with IOS system. This project is an application that can only be used by the blood bank employee, and its idea is very simple. Instead of randomly looking for a donor, this program is linked to the blood bank database will send messages to people who are registered in the blood bank as a constant donor and have the required blood types. It will save time and effort for both the people who are working in the blood bank and those who need blood. Moreover, since this program is linked to the blood bank database, it will directly send messages to the donors as soon as there is a shortage in the blood supply informing them with the type if blood is needed.

2 RELATED WORK

Haneen Tanni, Alaa Sarhan, Raya Khwayreh and Razan Assaf in their paper have explained a Blood Bank application on Android system, which was operated in Palestine, which is a merge between the Website and the application on the mobile phone. The project aims to communicate with donors and the needy through SMS messages [5]

Mohammed Almalki and others demonstrated that the program of Blood Bank-mail, which the Saudi Ministry of Health adopted it, is the provision of a huge database for donors of blood. The project aims to communicate through the presentation of the figure for the donor and is an online database and no on-site communication mechanism and donate by sending text messages to the site and make an appointment to make a blood donation [6].

Seighali, Fariba, and others, have described that the Blood Bank of Azerbaijan project is a project in collaboration with the Blood Bank Department of the UNDP and the Ministry of Health. The idea goes back to the provision of a database to facilitate the process of communication with others as well as the work of counting the number of communicable diseases [7].

In the Egyptian Study "Journal of Infectious Diseases and Therapy", the Blood Bank charity has been mentioned, which is works for the Blood Bank Charity evidence base contains the largest amount of data and blood groups in the possession of bodies and charities and collected in a centralized database. To get the biggest benefit for patients within the governors of Egypt. Limited to patients with chronic diseases who need blood transfusions on a regular basis for patients with diseases of the blood and kidneys, and other donors and provide them on a regular basis. [8]

Ibrahim and others have tackled in their paper to the Electronic system for blood banks, which are connected to a database of donors, and then it is communicating with these donors in the case of a lack of certain species through the application or mobile short messaging. Service based on two criteria: first, the platoon type of course, second, nearness the platoon's owner from the hospital. [9]

3 IMPLEMENTATION

Apache, MYSQL, Sublime text2, C-Objective x code, File PHP and Kuwait SMS were used in blood bank system

The following lines describe the blood bank system methods and pages:

Login to the system: At the beginning the user "administrator of blood bank" start the application then enter the user name and password, if the username and password

invalid, the application will notify the user to try again, else the user can use the application and start modification. That shown in figure 1.

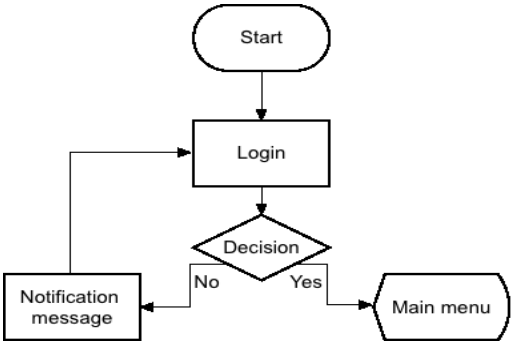


Figure 1. Login processes flowchart

After the valid login processes the main menu will be shown, Main menu contain sex option: Blood inventory, Blood consumption, New blood donation, Add new donor, Blood donation campaign and the logout.

Each option had sub process that the user can use. As shown in figure 2.

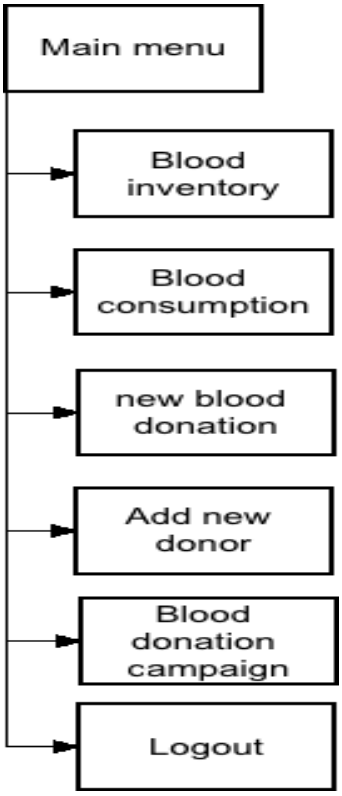


Figure 2. Main menu flow chart.

The first option in the main menu is the blood inventory. That display the amount of each blood type also the amount of the palates. If the user press on blood inventory choice a notification message will appear, the user can editing the amount by clicking the blood type row, After editing the amount the user can save the modification and return to the main menu. (Figure 3)

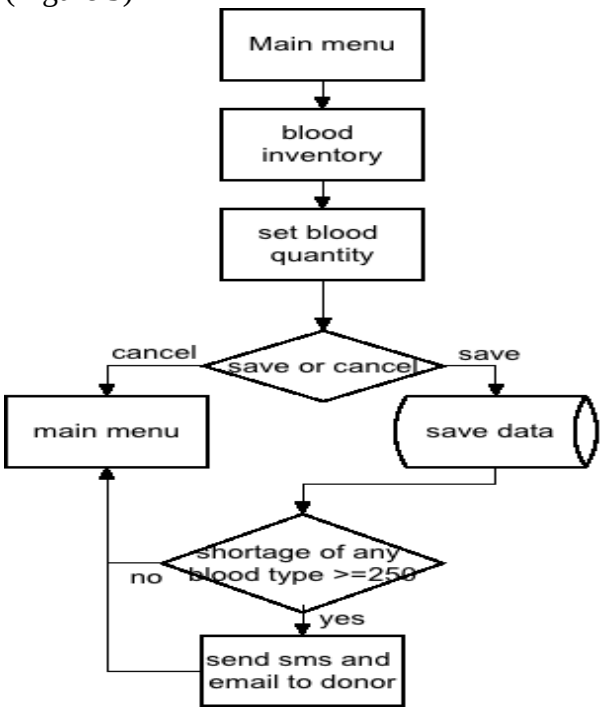


Figure 3. Blood inventory flowchart.

The second option in the main menu is blood consumption, which is used if there are needs for donating, that consuming the needy amount from the blood inventory.

The third option in the main menu, which is new blood donation. It is used when there is new donation of blood type or palates blood to add it on the quantity in the blood inventory.

Figure 4 shows the flowchart of these two options: blood consumption and new blood donation.

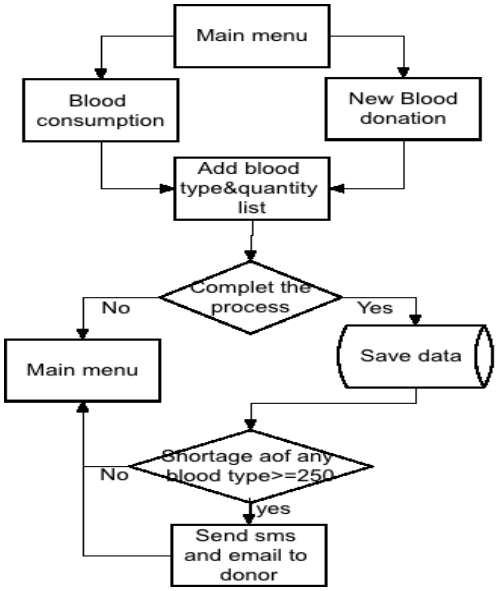


Figure 4. Blood consumption & donation processes.

The fourth option in the main menu is add new donor. It is used when the user want to add a new donor information in the database. (Figure 5).

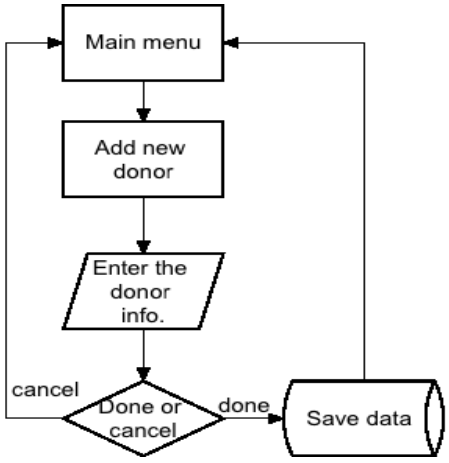


Figure 5. Adding new donor process.

Figure 6 shows a flowchart of the fifth option in the main menu, which is the blood donation campaign. The purpose from this process is to inform the donors about the existence of blood donation campaign in date and time specified, In order to encourage them to donate.

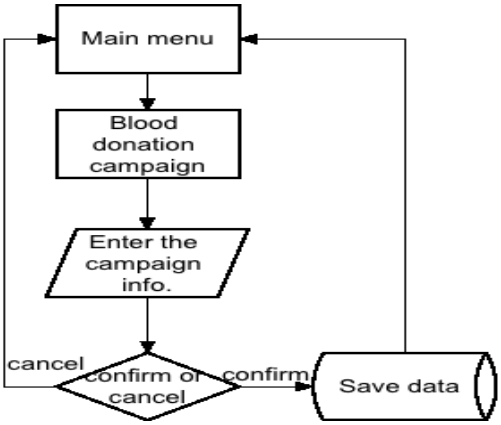


Figure 6. Donation campaign Flowchart.

Figure 7 shows a flowchart of the last option in the main menu, which is the logout. It is used to end the application system.

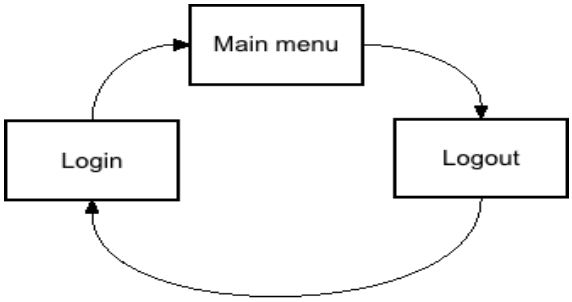


Figure 7. Logout Processes flowchart.

4 RESULT AND DISCUSSION

Bank system has been tested to the blood bank donors who have been storing their data in the database: "name, blood type, mobile phone number, email "optional".

The first implementation was with the consumption in blood type o+. Note that there was no shortage in blood inventory of any blood type. As shown in figure 8.

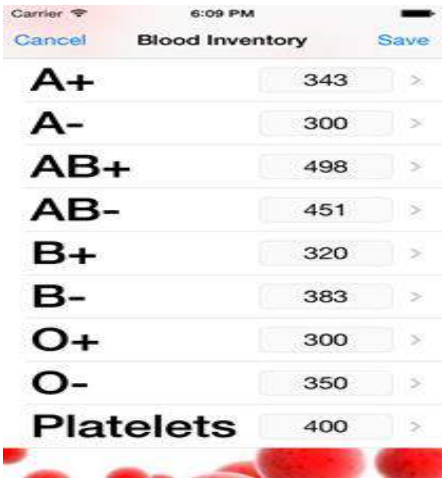


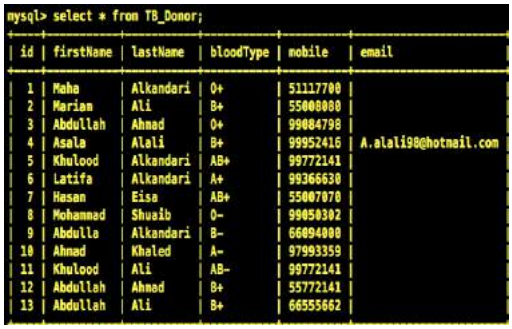
Figure 8. Blood inventory

Figure 9 shows the consumption of blood type "o+" and the amount "50".

When the user confirms the process , there will be an automatically shortage in "O+" blood type in the blood inventory, according to that process the system will send SMS message to the donor whom their blood type are "O+."

Figure 9. The consumption of blood type "o+"

Figure 10 shows the data table of the blood bank donor that include "first name, last name, blood type, mobile and email" which stored in the database.



```
mysql> select * from TB_Donor;
+----+-----------+-----------+-----------+----------+-----------------------+
| id | firstName | lastName  | bloodType | mobile   | email                 |
+----+-----------+-----------+-----------+----------+-----------------------+
|  1 | Maha      | Alkandari | O+        | 51117700 |                       |
|  2 | Mariam    | Ali       | B+        | 55008080 |                       |
|  3 | Abdullah  | Ahmad     | O+        | 99084798 |                       |
|  4 | Asala     | Alali     | B+        | 99952416 | A.alali98@hotmail.com |
|  5 | Khulood   | Alkandari | AB+       | 99772141 |                       |
|  6 | Latifa    | Alkandari | A+        | 99366630 |                       |
|  7 | Hasan     | Eisa      | AB+       | 55007070 |                       |
|  8 | Mohammad  | Shuaib    | O-        | 99050302 |                       |
|  9 | Abdulla   | Alkandari | B-        | 66094000 |                       |
| 10 | Ahmad     | Khaled    | A-        | 97993359 |                       |
| 11 | Khulood   | Ali       | AB-       | 99772141 |                       |
| 12 | Abdullah  | Ahmad     | B+        | 55772141 |                       |
| 13 | Abdullah  | Ali       | B+        | 66555662 |                       |
+----+-----------+-----------+-----------+----------+-----------------------+
```

Figure 10. Data table of blood bank donor

When the blood bank faces a shortage of any blood type, the application will send a message to the donor to informing them with the shortage in blood inventory.

The figure 11 displays the message has received by "Maha" and "Abdullah Ahmad" only because they carry an "O+" blood type.

Figure 11. The message sent to donors.

The second test was on the platelets, figure 8 shows that there is no shortage of platelets inventory. Figure 12 shows the consumption with the platelets with amount 20.

Figure 12. Adding platelets and the quantity.

The third application test was through the work of blood donation campaign on 05/27/2014 at 10:00 by aftermarket up to all donors of all blood types and let them know

this. To encourage them to donate blood. As shown in figure 13.

Figure 13. Informing all donor with the blood campaign.

5 CONCLUSION

This paper explained the proposed Blood bank system, which is linked the blood bank with the donors by sending messages to the donor who registered in the blood bank as a constant donor. To inform them of a shortfall in one of the blood groups both by his platoon. The application used by the blood bank employee through smartphones with IOS system. It characterized by ease of use in organizing the blood donation.

The benefits of blood bank system represented in:

1 New Donors.
2 Increased sharing.
3 Speed in knowing the shortage of blood inventory.
4 Saving the humanity and facilitating the process of finding a donor faster and in lower costs and losses.
5 Update data faster.

6 FUTURE WORK

In the future, there will be development for the system by adding several extra features such as the Donated able to communicate and interact with the system by sending some queries that are answered by one of the staff working in the blood bank. It also possible to add another service that asking the blood bank to send a medical team to the place where the donor in. especially for the old men and disabled people who cannot go out of their home easily have a chance to donate.

In addition, future expectations concerning that this application will be available for the donor to activate the communication by both parties.

Moreover, future expectations concerning that this application will be available for the donor to activate the communication by both parties.

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International Journal of New Computer Architectures and their Applications (IJNCAA) 6(3): 92-102
The Society of Digital Information and Wireless Communications, 2016 ISSN 2220-9085 (Online); ISSN 2412-3587 (Print)

Potentials and Challenges of Light Fidelity Based Indoor Communication System

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ABSTRACT

In this era of modern devices and high speed communication the issue of spectral overloading is increasing with time and becoming more serious. With the advancement in LED industry, light fidelity (Li-Fi) based indoor network is an attractive substitute for the existing radio frequency (RF) based communication networks. Because of its capability to perform dual function of lighting as well as high speed communication, Li-Fi is attracting both industrial as well as academic researchers. The Li-Fi networking paradigm offers performance enhancements which can make it an attractive backup option to be used for networking setup in Internet of things (IOT) and its indoor capabilities make it an attractive choice for large scale indoor communication in next generation wireless networking environment. This paper discusses key potentials of Li-Fi based indoor communication system and point out the challenges which indoor based Li-Fi network is facing under the knowledge of existing research work in the field of Li-Fi.

KEYWORDS

Li-Fi, Optical wireless communication, Indoor communications, Hybrid Wi-Fi and Li-Fi network .

1 INTRODUCTION

Light fidelity (Li-Fi) is one of the new and emergent field of optical wireless communication (OWC) that provides an opportunity to move forward toward higher frequencies in EM spectrum by using a visible light spectrum. The rapid increase in the usage of LEDs and its ability to perform dual function of illumination as well as communication has provided a unique opportunity for indoor lighting and wireless communication system to go through a revolution. LEDs have an ability to switch from different intensity of light at a rapid rate, this capability can be utilize for sending information using visible light spectrum.

Apart from rapid blinking rate at different intensity of light LEDs also have high lifespan. They are energy efficient and a good option to be used for indoor because of lower generation of heat. These benefits let the LEDs to be a perfect choice for a new technology called Li-Fi which can be useful for indoor communication and can also provide a backup for wireless fidelity (Wi-Fi) technology. Li-Fi could be classified as nm-wave communication [1] because it uses higher band of frequencies in the electromagnetic spectrum for high speed data communication. Li-Fi is a complete multi user wireless network that could operate user wireless network that could

operate simultaneously alongside with Wi-Fi and long term evolution (LTE) [2]. It is a green communication method because it reuses the existing lightning infrastructure.

Li-Fi can be consider as more advance networking system as compare to VLC because it can provide point to multipoint communication. This point to multipoint based communication characteristics of Li-Fi system make them different from VLC based systems because VLC only supports point to point communication system [1]. Li-Fi is a continuation of VLC technology using LEDs that can provide a proper networked based wireless system with high speed communication. It is a bi-directional multiuser communication system which can enables full user mobility because of its multiple access point formation. The fact that LEDs are natural beam formers, enables local containment of Li-Fi signals and because of the blockage of the signals by opaque walls, Co-channel interference can effectively be managed and physical layer security can be enhanced. Li-Fi can decrease the traffic bottlenecks caused due to large number of users in RF based indoor networks. Li-Fi can act as a green wireless network based technology for 5G networks [3] because it operates in the unlicensed and safe visible light frequency spectrum which can be helpful for the proper reuse of bandwidth and provides an efficient wireless solution by minimizing the capacity drainage problem of frequency spectrum.

This paper will explain in detail about Indoor implementation of Li-Fi based communication system and emphases on the research conducted by researchers on indoor based Li-Fi systems. The multiple section of this paper are organized as follows, section II consists of the elements which affect the functionality of Li-Fi based indoor network. Section III reviews the key potentials of Li-Fi based network and Section IV emphases on main challenges, weaknesses and issues of Li-Fi network at its current stage.

2 ELEMENTS WHICH AFFECT PERFORMANCE OF INDOOR BASED LI-FI NETWORK

Indoor based Li-Fi network has certain elements which plays an important role in the performance and efficiency of this system. In this section we will explain then one by one

2.1 Modulation Technique

In Li-Fi based system, multiple types of modulation schemes [4] can be useful but because of communication channel having frequency response in non-flat nature , most of the modulation techniques suffer from an undesired channel response called inter symbol interference (ISI). As most of the commonly used modulation methods such as pulse width modulation [5], pulse position modulation, ON-OFF keying, unipolar pulse amplitude modulation suffer from ISI therefore there is a need of such a scheme for Li-Fi which correlates the energy and organize itself adaptivity according to the properties of communication channel. Multicarrier modulation can provide higher data rate and it can also be useful to decrease the effect of interference and distortion but these modulation techniques are less energy efficient. OFDM [6] is most commonly used modulation technique. In OFDM signal is bipolar and its value is

complex in nature. Unipolar signal can be obtained by applying a positive DC bias voltage which can vary the amplitude of the OFDM signal. This modulation scheme is given a name DC biased optical orthogonal frequency division multiplexing (DCO-OFDM) [7]. Such schemes can be useful to implement in scenarios when a system is used to perform dual function of communication as well as illumination. This DC bias method has a drawback that it can considerably compromise efficiency of energy in whole modulation scheme. That is the reason why researchers have dedicated noteworthy efforts in designing a pure unipolar based OFDM modulation schemes. Asymmetrically clipped optical orthogonal frequency division multiplexing (ACO OFDM) can provide a solution to decrease the effects of this issue [8]. Some of the other solutions are flip OFDM and discrete multi-tone modulation (PAM-DMT) along with modulation technique based on pulse amplitude.

2.2 LED's Selection

Basic aim of indoor based Li-Fi wireless network is to achieve high data rates. In Li-Fi network, the selection of LEDs can plays an important role because LEDs blinking rate can affect the overall data rate of entire network. LED's parameters such as its size, ON-OFF speed and color rendering ability are also very valuable attributes. Rate of data transmission is inversely proportional to the dimension of LED's bulb. ON-OFF blinking speed of LED can also control the data rate. Faster the rate of LED blinking higher will be the rate of data transmission. Number of LED's in a system is another factor which increases the data rate. The speed of data transmission can also be enhanced with more coverage area and better ability to accommodate more number of users. The low cost of incoherent solid state LED lighting make them suitable for deployment in indoor based Li-Fi network [9]. In Li-Fi data is encoded according to the intensity of the light emitted from light source. The data is transmitted in the sequence of 0's and 1's without modulating the amplitude and actual phase of the light wave.

LED color can also affect the data rate [10]. White color LEDs coated with phosphor can provide data rate of 1 Giga bits per second [11], similarly combination of red, green and blue color LEDs (RGB) can boost the data rate up to 3.4 Giga bits per second [12]. Incoherent LEDs of single color has reported a rate of approximately 3.5 Giga bits per second.

2.3 Indoor Environment model

LED's based transmitter configuration on ceiling is shown in figure 1. In section A of the figure we can see 4 different section of LED's are deployed with the ceiling of the room while Section B show us Layout model of uniform configuration. Section A layout is useful when we have small number of users using Li-Fi facility. Those users will accommodate at the place where the Li-Fi transmitter are deployed. Section B layout is useful if number of user in indoor unit are large and have to move everywhere [13].

2.4 LED Source Panel (LSP)

LSP is a light source which contains LED bulbs. These LED bulbs can accomplish both roles of illumination and as well as data communication. LED's bulb in a LSP can be circular or rectangular in shape. Both LED's shapes have its own advantages. Circular shaped LED's are used in Li-Fi system when we have to apply light at a fixed place

while rectangular shaped chip like LED's are used when we have to disperse light at a wider area. Number of LED's in a LSP depends upon the size of LSP. If LSP has to cover Indoor environment of large specific area then it size may be large as a result it most of more number of LED's.

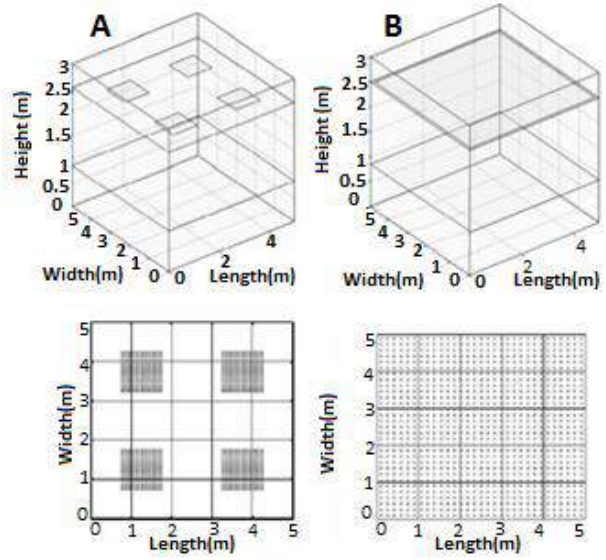

Figure 1. Indoor Environment Model

Total number of LSP in a room is depending upon:

1) A maximum numbers of Li-Fi user needs to accommodate in a system.

2) Total area of room.

2.5 LSP Placement Design

In Li-Fi, the placement of light source panel (LSP) plays an important role. LSP can set the limit of data rate because the intensity of light from LED can be controlled by using LSP. The quality of service can be managed by introducing a threshold value for indoor communication system. For every user, light intensity need to be managed in such an order that everyone can reach that threshold value for efficient communication. We propose a fixed LSP design as shown in figure 2. The covering area of LSP is adjusted in two ways [14]. Section A of figure 2 consists of fixed LSP which cover two users. In Section B we provide an approach of separate LSP for two users which is called dedicated LSP approach. In Section C we have shown dedicated LSP approach for 3 users at single place.

Fixed Single LSP approach [14] can accommodate multiple users at a time. This approach can provide a cost effective solution by providing service to multiple users in a single time slot. Dedicated LSP approach can ensure high data rate and high speed transmission of information along with a secure environment. So all these scenario based approaches can provide a tradeoff between cost and high speed.

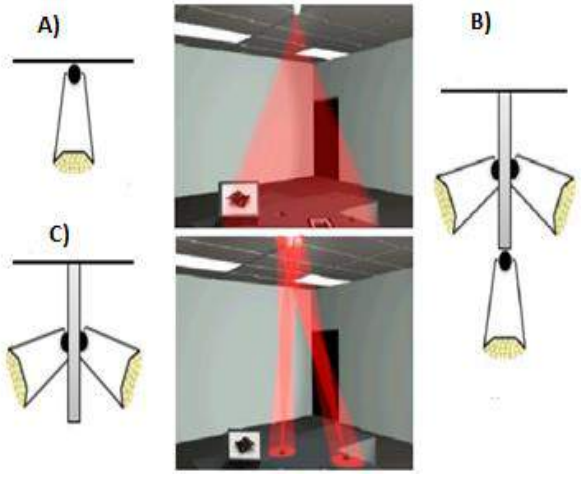

Figure 2. LSP in term of Covering Area

2.6 Li-Fi channel model

Li-Fi channel contains diffuse components as well as line of sight (LOS) components as

shown in figure 3. The LOS component can be explained as [15]:

$$_L = \begin{cases} \frac{(m+1)A_P}{2\pi(z^2+h^2)} g(\theta) T_s(\theta) cos^m(\emptyset) \cos(\theta), & \theta < \Phi_F \\ 0, & \theta \geq \Phi_F \end{cases}$$

where m is the lambertian index which can be describe as a function of radiation angle having half-intensity. A_P represents the coverage area of the optical photo detector, z shows the horizontal distance between access point and optical photo detector .

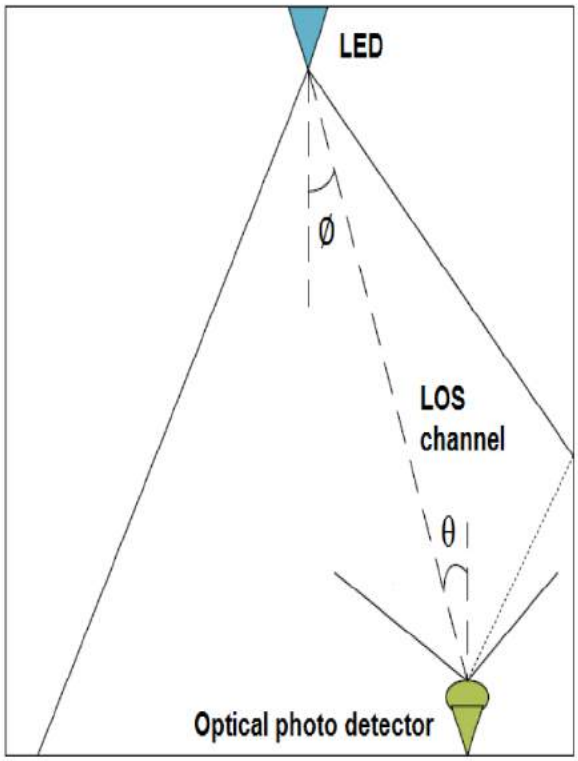

Figure 3. Li-Fi channel model

Here h, ∅, θ, Φ is the height of the room, angle of irradiation, incidence and half angle of the field of view (FOV) regarding optical photo detector respectively while $T_s(\theta)$ is the gain of the optical filter and $g(\theta)$ is the concentrator gain.

3 KEY POTENTIALS OF LI-FI BASED NETWORK

Some of the key potentials of Li-Fi based network are given below

3.1 Multiple access in Li-Fi

Li-Fi can accommodate multiple users with simultaneous network access [16]. Optical space division multiple access (SDMA) can be useful which use an angle diversity transmitter. When compared with the optical time division multiple access (TDMA) technique, it has been shown that optical SDMA can achieve more throughput with in a Li-Fi network. However, such performance enhancement requires careful design of the angle diversity transmitter and time-consuming user-grouping algorithms based on exhaustive search. OFDMA provides a straight forward method for multiuser access [17] where users are served and separated by a number of orthogonal subcarriers but subcarriers with lower frequencies generally provide users with high SNR statistics. Therefore it is important in OFDMA to use appropriate user-scheduling techniques to ensure that fairness in the allocation of resources (subcarriers) is maintained. In order to enhance the throughput, non-orthogonal multiple access (NOMA) was proposed which utilize the broadcasting nature of LEDs, the performance of a Li-Fi network can be efficiently enhanced with the application of NOMA. NOMA is unique as compare to orthodox multiple access technologies because it can serve an increased number of

users by using its unique resource allocation method which is non-orthogonal in nature.

3.2 Li-Fi based internet AP

In an indoor Li-Fi based network [18], every lighting place in a room can act as an optical access point (AP). If the distance between APs is small then the interference between them is unavoidable. This issue can considerably affect the performance of a network. To solve this issue, angle diversity based optical photo detector is proposed to mitigate the LOS interference. This optical photo detector is consists of narrow FOV along with multiple number of directional photodiode. The indoor based Li-Fi network is comprises of two parts, Li-Fi Access Point (AP) and the Li-Fi terminal.

The Local Area Network (LAN) of Li-Fi is consists of two layers, MAC layer and PHY layer. The PHY layer guarantees the efficiency of data stream whereas the MAC layer is used to manage the flow between transmitter and optical receiver. It also ensures that the data is properly transmitted and received in to the form of frames. The MAC layer uses an RJ45 port to connect with the switch. The digital module of PHY layer is used to process the transmitted data stream and LED received an encoded digital signal which is transmitted using an LED light. An optical photo detector is used to receive the beam of a light at receiver end. This optical photo detector transform optical signal back to original data signal.

3.3 Hybrid indoor system based on Li-Fi and Wi-Fi

Li-Fi networks can achieve high throughput by deploying large number of APs [19]. But the spatial distribution of the data rates fluctuates due to the CCI. In order to augment the system performance and to guarantee equally high Quality of Service (QoS) among users, Wireless-Fidelity (Wi-Fi) overlay can be deployed. As Li-Fi is using a different band of frequency spectrum as compare to Wi-Fi so there is no interference among these systems. Therefore, a hybrid system consists of Wi-Fi and Li-Fi network is capable of achieving the desirable throughput. Wireless Gigabit Alliance (WiGig) is one of the latest member of Wi-Fi family can be considered for hybrid network. This latest protocol can operate on three bands of frequency and also consists of some modern advance features. By considering a hybrid network between Wi-Fi and Li-Fi, user's at all possible locations within an enlarged coverage area can benefit from significantly enhanced user throughput and QoS. This hybrid system can provide benefits of reduction of contention as a result losses of spectrum efficiency will reduce. Li-Fi system can provide offload to the present Wi-Fi system and additional benefit of coverage at dead spots can be achieve.

3.4 Li-Fi as Intelligent Lighting

Li-Fi system can act a smart system by giving an advance feature of power saving. The brightness level of lighting system can be controlled according to the number of users and their requirement to save power by using sensors. These sensors can be deployed to monitor multiple parameters such as intensity of light, blinking level of

LED and its color. The coverage area of a LED transmitter can also be controlled by using dimming level of a LED transmitter. This intelligent lighting system can provide a smart solution to control the power consumption of LEDs. These networks can be used in smart home systems [20] where LED based lighting can provide illumination and data communication at the same time. In these smart homes devices which are used for data communication such as laptop, cellphone, and other smart devices can also perform short distance communication at high speed using visible light spectrum.

4 MAIN CHALLENGES FOR LI-FI BASED COMMUNICATION SYSTEM

The Li-Fi based communication system faced different kinds of challenges. These challenges limit its performance and can decrease the overall efficiency of the network. Some of the main challenges are given below:

4.1 LED related issues

Some of the LED related issues are

4.1.1 LED light ON-OFF mode

Indoor Li-Fi based communication system aims to provide illumination with communication, so ON-OFF speed of a LED plays a vital role. For a Li-Fi based system it is always compulsory to have a Light source in ON condition but it initiates main problem of how data transmission will occur when the LEDs are turned OFF. A data transmission can still be possible if brightness level of a LED transmitter is very low. The dimming level of LED bulb can be organized in such a way that a desired data rate can be achieved using light intensity. In hybrid setup, RF or infrared can be useful to provide communication in LED OFF mode but in Li-Fi based communication it is still a challenge to find a suitable solution of how communication will be possible in any undesirable situation when LEDs are in its OFF mode.

4.1.2 LED Junction Temperature

The management of thermal temperature is a critical design issue of high power LEDs. High junction temperature can affects spectral efficiency. Junction temperature of LED can be increase due to variation in drive current, self-heating and ambient temperature. This high junction temperature could cause degradation in power of a single with respect to time which reduces the signal to noise ratio (SNR) and degrades the lifespan of LEDs [21]. The effect could cause serious problems if array of hundreds of LEDs are connected closer to each other in a lighting system at large scale.

4.2 Indoor modeling issues

Some of the indoor modeling issues are

4.2.1 FOV Alignment

In Li-Fi network an assumption is consider before communication that transmitter and receiver have a LOS connection. The LOS connection can provide high data rates because the transmitter and receiver are aligned their FOV to maximize the channel response. Nevertheless, in real life practical scenarios, a receiver FOV can be changed

and it can also move from one place to another. The change in orientation of a receiver and its mobility suggest that receiver's FOV cannot always be aligned with the transmitter. Therefore it is essential to design such techniques which can handle the scenario of FOV misalignment and provides desirable data rates. This needs modification in schemes and development of new approaches to handle this problem but designing such schemes and methods is extremely challenging and it is an important direction of future research.

4.2.2 Shadowing

The data rate in Li-Fi network will decline if an obstacle blocks the LOS channel as a result overall performance of the network will degrades. Not enough research is done until now to understand the indoor model and effect of shadowing on Li-Fi [22]. Shadowing could be one of the reasons of LOS channel blockage and it can produce variations in received signals therefore it is necessary to have a mechanism to provide an alternative wireless connection in a typical blockage event. It is also possible that the blockage event is of very short duration caused by the passing of obstacles or humans so it necessary to propose such a schemes and mechanisms that can provide a solution of problems such as FOV misalignment and shadowing.

4.2.3 Interference

In Li-Fi system light from any other energy source except of LED such as sun light or free ordinary electric light source can cause interference because it can interrupt the LOS channel between transmitter and receiver. The interruption in path of transmission will affect the data communication therefore for indoor communication new techniques are required to find solutions regarding this condition.

4.3 Receiver Design issues in the case of mobility

Li-Fi receivers can consist of an optical photo detector or an imaging sensor for receiving the beam of light. The photodiode is more beneficial for stationary users because in this case receiver FOV can be aligned easily to the LED. The imaging sensor has comparatively larger FOV so they can be useful for devices which support mobility but imaging sensors are less energy efficient and also produce delays in data reception as a result can decrease the overall achievable data rate. Therefore it is challenging to design such an optical receiver that can control FOV misalignment and increase robustness. Hence for both static and mobility cases, an enhancement in optical receiver design is needed to ensure high data rates along with power efficiency.

4.4 Li-Fi internet connectivity issues

For Li-Fi based broadband access network, it is essential that LEDs driving circuit is connected with internet [23]. The cost of internet deployment for Li-Fi and the interference of wireless connections is a limiting factor which can reduce the achievable data rate using internet. Efficient designing techniques are required to provide desirable internet connectivity speed using

LEDs at affordable deployment cost. Therefore it becomes a challenging task to propose a model which can provide internet using Li-Fi for large scale communication.

4.5 Up link transmission issues

A Wireless communication network is incomplete without the facility of uplink communication. In Li-Fi uplink requires that transmitter and receiver maintains a directional link during transmission. It can significantly reduce the overall throughput of the network if both devices are constantly moving. So in Li-Fi it is also a challenge that how the uplink traffic in a network will be operate. The radio frequency and infrared can be considered for transmitting uplink data in Li-Fi network but still more innovative ideas are require for solving the uplink issues in Li-Fi networks.

4.6 Connectivity and Coverage area issues

It is necessary for a Li-Fi system to maintain continuous and high speed connectivity within a coverage area of a Li-Fi cell and between the Li-Fi cells. So advance schemes for link layer are require which can maintain rate adaptation and frame aggregation to cope up with connectivity issues. In a Li-Fi based network it is essential that smooth handover of devices as well as handover of technology will occur for efficient communication in advanced Li-Fi based system.

4.7 Security threats

In recent research [24] it is proposed by the researchers that Li-Fi network can also suffer from security threats. An attacker may be present inside or outside a room can perform eavesdropping using the light signals. These signals can be obtained from gap between floor and door, cracks inside flooring or from partially shielded windows. This threat indicates that more research is required to understand and resolve the security issues and privacy concerns of Li-Fi network.

5 CONCLUSION

The vision behind Li-Fi technology is to provide a high speed data communication using visible light spectrum and its future looks bright for indoor implementation because of rapid increase of LEDs for indoor lighting. With LEDs expected to slowly replace the traditional lighting system, Li-Fi is foreseen to be gradually implemented into general lighting infrastructures which will give rise to several beneficial applications. Broadband internet can also be accessible using same lighting system which provides us illumination in our daily life. Li-Fi has a potential of large scale implementation and this technology can be improve with time which attracts many companies , designers and researchers to keep working for the practical implementation of Li-Fi network for indoor communication. Indeed, research teams are working on multiple schemes, algorithms, indoor models and new techniques to compensate for the limitation of Li-Fi network. System load balancing can be achieved from Hybrid Li-Fi and Wi-Fi based networks. The limitation of Li-Fi system such as sensitivity to the line of sight

connection and non-uniform spatial distribution of data rates due to co-channel interference (CCI) need to be controlled in order to attain high speed communication with desirable data rate. As a result of this technology every LED bulb can act as a hotspot to transmit wireless data and the world will move toward the cleaner, greener, safer and brighter future.

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International Journal of New Computer Architectures and their Applications (IJNCAA) 6(3): 103-113
The Society of Digital Information and Wireless Communications, 2016 ISSN 2220-9085 (Online); ISSN 2412-3587 (Print)

An Easier Way to Understand the Undecidability of Halting Problem of Turing Machines

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ABSTRACT

This paper provides us an easier way to understand the undecidability of the halting problem of Turing machines. Our way is easier because author moves forward by discussing some past concepts in an easier way. The concept of Cantor's diagonal argument has been discussed in an easier and simpler way that then helps us in understanding the undecidability of the halting problem of Turing machines.

KEYWORDS

Uncountable, counting numbers, one-to-one correspondence

1 INTRODUCTION

This paper has been written to understand the undecidability of turing machines in an easier way. Our way is easier because author proceeds forward by discussing some past concepts in an easier way. The cantor's diagonal argument has been explained pictorially in an easier way using the fruit sequences. Cantor's diagonal argument has been used to show that the set of infinite fruit sequences of infinite lengths is uncountable. To further improve our understanding of cantor's diagonal argument and uncountable sets, the cantor's diagonal argument has been used to show that Russel's paradox of barber also produces an uncountable set. Afterward, the halting problem has been discussed in general and at the last, the halting problem of Turing machines and its undecidability has been explained in a formal.

Organization of this paper as follows. In section II, the author will mention some previous work, as well as how the author has used the previous work to get into our topic. In section III, the author will try to understand the Cantor's diagonal argument by using the infinite fruit sequences of infinite length. In section IV, the author will show, by applying the cantor's diagonal argument, that Russel's paradox of barber produces and uncountable set. In section V, the author will discuss the halting problem and its undecidability in general. In section VI, the author will discuss the undecidability of the halting problem of Turing machines in a formal way. In section VI, the author will conclude the discussion.

2 REVIEWS AND RELATED WORK

James V. Rauff has given an easy approach to understanding the Cantor's diagonal argument in [1]. The author will revise it in section III with little improvement. The author is also familiar with famous barber paradox proposed by Russell. The author will present the barber

paradox in a new way such that this presentation with the application of cantor's diagonal argument will give us an interesting uncountable set. This presentation will further increase our understanding of cantor's diagonal argument and its application. Afterward, the author will give a sketch of halting problem and its undecidability. Then author will correlate all the developed concepts to understand the undecidability of the halting problem of Turing machines in a formal way.

3 CANTOR'S DIAGONAL ARGUMENT AND UNCOUNTABLE SETS

An easy approach to understanding the cantor's diagonal argument has been given in [1]. Here author will review it with a little improvement and show that the set of infinite sequences of infinite lengths is uncountable. To construct, infinite sequences of infinite lengths author will use the three fruits shown in figure 1.

Fig.1 Fruits

Let us use the fruits to create some infinite length sequences of fruits as shown in figure 2.

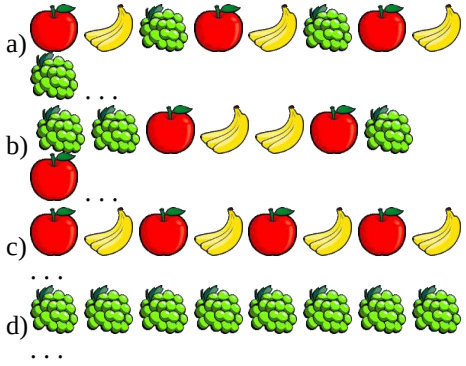

Fig.2 some infinite length sequences of fruits

It is to be noted that a sequence may have a repeating pattern as in Fig.2 (a) or may not have a repeating pattern as in Fig.2 (b). It is also to be noted that it is not necessary for a sequence to contain all the three fruits as in Fig.2 (c) and Fig.2 (d). Here it has become clear to us that any arrangement of these fruits is an acceptable sequence. So, the author can say that a set having an infinite number of such sequences can be created.

Now the fun starts "Can this set of an infinite number of infinite length sequences be mapped with natural numbers as a one-to-one correspondence?" In other words, "Is this set of an infinite number of infinite length sequences countable?" "Yes, this set can be mapped with natural numbers as one-to-one correspondence, hence it is countable", our answer may be like

this, up to now. Let us SUPPOSE that our answer is TRUE. So our set can be mapped one-to-one with natural numbers as:

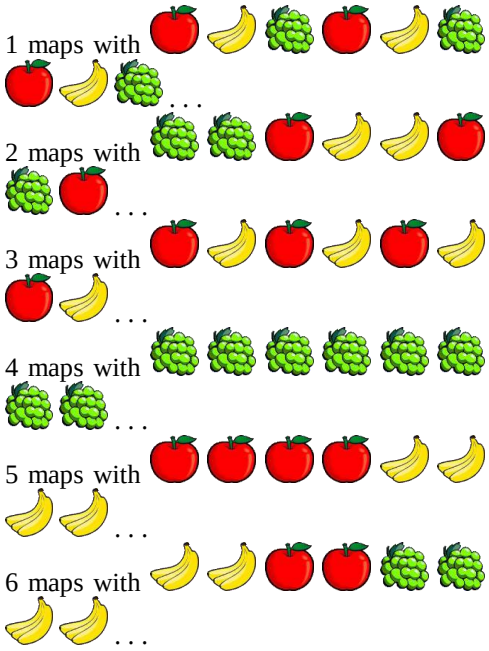

Fig.3 One-to-one mapping of natural numbers with the set of an infinite number of fruit sequences of infinite length.

Fig.3 shows that the set of infinite fruit's sequences of infinite lengths has been successfully mapped with natural numbers, so, the set is countable. Now this is the right time to understand the Cantor's diagonal argument and its application to prove that this set is uncountable i.e. the set cannot be mapped one-to-one with natural numbers. Amazing!!!!!!!

Let us see what a "diagonal item" in each sequence is. 1_{st} item of a 1_{st} sequence is a diagonal item which is an apple. 2_{nd} item of a 2_{nd} sequence is another diagonal item which is grapes. Similarly, a 5_{th} item of a 5_{th} sequence is also a diagonal item which is a banana. The author can also think of any i_{th} item of the i_{th} sequence to be one of three fruits. Furthermore, the author can also think of an interesting diagonal item at the infinite location of an infinite sequence, to be one of three fruits.

Now author is going to create a new sequence called "Cantor's Diagonal Sequence" by taking every diagonal item of every sequence and applying the following two rules:

1. If the diagonal item of any sequence is not an apple (i.e. it is banana or grapes), then it would be an apple in Cantor's diagonal sequence.
2. If the diagonal item of any sequence is apple, then it would be a banana in Cantor's diagonal sequence.

Now if, by applying these two rules, author create a Cantor's diagonal sequence from all infinite sequence in Fig.3, it will look like as in fig.4.

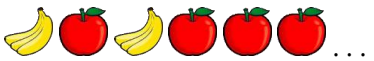

Fig.4 Cantor's diagonal sequence created from the sequences of Fig.3

Fun again starts. Author has created a new Cantor's diagonal sequence using all the infinite fruits' sequences of Fig.3. This new sequence is different from all those infinite fruits' sequences. It differs from all other sequences at the diagonal item. In Fig.3authorhave supposed that all possible sequences of any arrangement of fruits have been mapped with countable numbers, but the author can see here, that Cantor's diagonal sequence was not in those infinite fruits' sequences because it has just been created now and it is different from all those infinite sequences at the diagonal item. So the author can conclude that our supposition was WRONG, and this is a "CONTRADICTION". Therefore, the author can also conclude here that the set of infinite fruit's sequences of infinite lengths cannot be mapped to countable numbers hence the set is uncountable.

Let us discuss another approach. Let us take our supposition again that author has mapped all possible arrangements of fruits in some sequence in Fig.3. Cantor's diagonal sequence is also an arrangement of these fruits, so it is matching to one of those sequences, and, hence, it is already present in those sequences. If it is present in those sequences, then, at which location is it present??? Well, it could be at any location. Okay, let us suppose it is present on K_{th} location. Can the author tell, then, about its K_{th} item to be an apple or banana?

Let us try to answer it. The author knows that the K_{th} sequence is now also the Cantor's diagonal sequence. So by recalling the two rules described earlier, author can say:

1. If the K_{th} item in the K_{th} sequence is not an apple (i.e. it is banana or grapes), then the K_{th} item in the Cantor's diagonal sequence is and apple. But here author know the K_{th} item in both sequences is referring to the same item because the K_{th} sequence and Cantor's diagonal sequence are the names of the same sequence. It means that an item is not an apple, and at the same time, the same item is an apple. A "CONTRADICTION"
2. If the K_{th} item in the K_{th} sequence is an apple, then the K_{th} item in the Cantor's diagonal sequence is a banana. Here again, author

are saying that an item is an apple and a banana at the same. This is again a "CONTRADICTION"

Tracing back, the author can see that our supposition i.e. author has mapped all possible arrangements of fruits in some sequence in Fig.3 is again "WRONG". So our set of infinite fruits' sequences of infinite length is uncountable. That is all author wanted to show in section III.

3 RUSSEL'S PARADOX AND UNCOUNTABLE SET

In this section, author will improve our understanding of uncountable sets and cantor's diagonal argument. The author will see here that an uncountable set can be produced by applying cantor's diagonal argument on Russel's barber paradox.

Without disturbing the logics, Russel's paradox can be restated as: "Suppose that there are 5 people (Mustafa, Zain, Fahad, Ali, and Tahir) living in a village under a condition that one of them is always a barber. A set can be defined as, 'A set of all those people in the village who do not shave themselves are shaved by the barber.'"

The set author has just defined above is an uncountable set. Let us show, by applying Cantor's diagonal argument, that the set is uncountable. Consider the arrangements of people in rows and columns of Table I. Left most header column shows that one of the five people is a barber. The top most row names all the five people. The author put an 'X' in a cell if a person shaves himself and not shaved by the barber. The author put a '√' in a cell if a person doesn't shave himself and shaved by the barber.

An 'X' in the Mustafa (barber) vs. Zain cell shows that Zain shaves himself and not shaved by Mustafa (barber). A '√' in the Tahir (barber) vs. Ali cell show that Ali doesn't shave himself and shaved by Tahir (barber). What symbol will be written in the diagonal cells of the table i.e. Mustafa (barber) vs. Mustafa, Zain (barber) vs. Zain, Fahad (barber) vs. Fahad, Ali (barber) vs. Ali, and Tahir (barber) vs. Tahir; a '√' or an 'X'??????

TABLE I BARBER VS. PEOPLE

	Mustafa	Zain	Fahad	Ali	Tahir
Mustafa (barber)	**?**	X	√	√	X
Zain (barber)	X	**?**	√	√	X
Fahad (barber)	X	X	**?**	√	X
Ali (barber)	X	X	√	**?**	X

Tahir (barber)	X	X	√	√	**?**

Let us consider a Mustafa (barber) vs. Mustafa cell. It is, in fact, a Mustafa (barber) vs. Mustafa (barber) cell. The author cannot say that Mustafa (barber) shaves himself and not shaved by Mustafa (barber), or Mustafa (barber) doesn't shave himself and shaved by Mustafa (barber). It is a "CONTRADICTION" in both cases. A similar contradiction is there for all diagonal cells. This, indeed, is the application of cantor's diagonal argument on the diagonal cells of Table I.

So the author can conclude that only four people can be mapped with countable numbers but not the fifth one. Hence our defined set is uncountable.

4 UNDECIDABILITY OF HALTING PROBLEM

In this section, author will see that what the halting problem in general is, and why it is undecidable. Let us start now.

4.1 Halting Problem

The author might have noticed that the problems involving loops are sometimes interesting. Consider the following three code segments of JavaScript.

TABLE II SEGMENTS OF JAVASCRIPT

```
For (count = 1; count < = 5;
count++)
      Alert ("Hello to
person" + count);
```

```
num = prompt ("Maximum
number", "");
For (count = 1; count < =
num; count++)
      Alert ("Hello to
person" + num);
```

```
While (TRUE) {
      Alert ("Hello World.")
```

The first program will clearly terminate after printing an alert message 5 times. The second program will also terminate after printing an alert message up to the time's author input a number. The third program will remain running forever.

Computer programs have algorithms of some kinds. Algorithms may contain infinite or finite loops, nested or in a sequence. The amount of work done by an algorithm also depends on amount of data input to the algorithm. The halting problem, in actual, is asking a question:

"Given a program and an input, determine whether the program will eventually stop (halt) when the program is run on the input."

Let us consider some trial solution cases. Just run the program on the given input, if the program stops author can say that the program stops. But if the program doesn't stop in a reasonable amount of time, the author cannot conclude that the program will not stop. May be the program stops after taking a long time and the author did not wait enough for that time.

4.2 Undecidability of Halting Problem

The author will discuss only a sketch proof of the undecidability of halting problem here. The Proper proof will be given in Section VI.

Suppose author have succeeded in finding a solution to halting problem, called H. H takes two inputs; a program P and an input I. The solution H when run on the two inputs produces an output "halt" if it determines the program P stops on input I, or it produces an output "loop' if it determines the program P doesn't stop on input I. H takes an acceptable amount of time in this decision. Sketch of H is given in fig. 5.

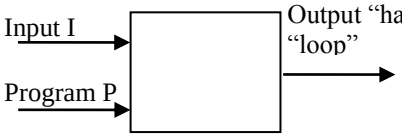

Fig.5 Sketch of solution H

The author knows that every computer program or its input is eventually encoded as strings of 0s and 1s. So program P can also be encoded as a string of 0s and 1s. Furthermore, the author can use the encoding of P as both the program and input to H.

Now let us construct another program D such that it takes as input the solution H and outputs opposite to H. It means that when H outputs "loop", D outputs "halt" and when H outputs "halt" D outputs "loop". Sketch of D has been shown in fig. 6.

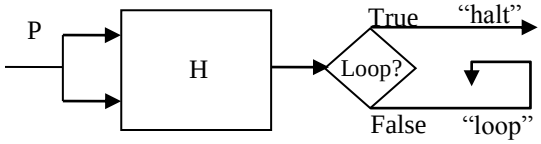

Fig.6 Sketch of program D

Now it is the time to prove the undecidability of the halting problem. As D is a program, so D can also be used as an input of D. Its sketch is shown in figure 7.

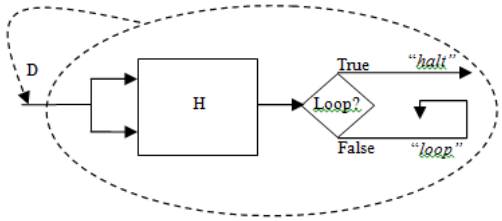

Fig.6 Sketch of program D with input D

Now let us consider the working of D with input D. If H determines "halt" when running on D (D as a program and input), then D will itself say "loop". Similarly, if H determines "loop" when running on D, then D will itself say "halts". In both the cases H determines the wrong answer for D. So author can say that H cannot answer correctly in all the cases. In other words, author has proved that H is not a correct solution and, therefore, Halting problem is undecidable.

5 UNDECIDABILITY OF HALTING PROBLEM OF TURING MACHINES

Author has learned about the cantor's diagonal argument. Author has also learned how to apply cantor's diagonal argument.author have also seen what the halting problem and its undecidability in general is. Now author can use our developed knowledge in understanding of the halting problem and its undecidability in a formal way. Let us start now.

Let A_{TM} be a language such that A_{TM} = {<M, w> | where M is a Turing machine that accepts string w}. M will accept w if M, after running on w, reaches its accepting state. M will reject w if M, after running on w, reaches its rejecting state. But there is a third case; what will happen if M starts looping on w? Will M accept w or reject w in the case of the loop? How M will guess that the loop will eventually end or continue? So here a question arises that "Is A_{TM} Decidable?", in other words, is there any way for M to correctly decide, in an acceptable amount of time, whether M accepts w, reject w, or loop on w? This question is known as the halting problem of Turing machines.

In fact, A_{TM} is undecidable i.e. there is no way for M to halt on each and every input w and provide a correct decision of accept, reject or loop. The author will prove this in a moment by using the Proof by Contradiction technique. Before authors tart our proof let us see Table III. This table shows the behavior of Turing Machine M on <M>. Here <M> is the encoding of M and it is same as w. actually, the definition of ATM is now something like ATM = {<M, <M>> | where M is a Turing machine that accepts string <M>}. Table III shows the results in its intersecting cells when author run some Turing machines M_I on some description of Turing machines $<M_I>$. If Turing machine MI accepts the string $<M_I>$ then the intersecting cell shows 'accept', and if Turing machine M_I rejects the string $<M_I>$

then the intersecting cell shows 'reject', and if Turing machine M_I loops on $<M_I>$ then the intersecting cell shows nothing because M_I cannot tell that M_I will eventually stop.

TABLE IIII M_I RUNNING ON $<M_I>$

	$<M_1>$	$<M_2>$	$<M_3>$	$<M_4>$	$<M_5>$
M_1	Accept	Reject		Accept	
M_2			Reject		Accept
M_3	Accept	Accept		Reject	
M_4		Reject	Accept		Accept
M_5	Reject	Accept	Accept	Reject	

Now let us start our proof. Let us suppose that author has a Turing machine H that decides A_{TM}. H runs on inputs $<M_i, <M_i>>$ such that it accepts the input when the Turing machine M_i accepts the string $<M_i>$. H rejects the input when the Turing machine M_i rejects the string $<M_i>$. And at the last, the most important; H somehow has the power of detecting endless loops, and in the case of a loop, rejects its input when the Turing machine M_i loops on string $<M_i>$. Now let us run H on $<M_i, <M_i>>$ and see the results in table IV.

TABLE IIIV: H RUNNING ON $<M_i, <M_i>>$

	$<M_1>$	$<M_2>$	$<M_3>$	$<M_4>$	$<M_5>$
M_1	Accept	Reject	**Reject**	Accept	**Reject**
M_2	**Reject**	**Reject**	Reject	**Reject**	Accept
M_3	Accept	Accept	**Reject**	Reject	**Reject**
M_4	**Reject**	Reject	Accept	**Reject**	Accept
M_5	Reject	Accept	Accept	Reject	**Reject**

In Table IV author can see that H halts on each and every input. This shows that the A_{TM} is decidable. But it is looking so only up to this point. Now if authors are successful in creating an input such that the behavior of Turing machine H gives a wrong decision at the output, the author will be able to prove that no Turing machine H exists that halts on each and every input by giving a correct decision.

Here author will create such interesting input by applying Cantor's Diagonal Argument. Let us design a Turing machine D such that it does opposite to Turing machine H i.e. reject the input if H accepts it, and accept the input if H rejects it. Such a D is very easy to create. The author knows that D is also a Turing machine and author can get a string from its encoding <D>. Let us now make a new table "Table V" from

Table IV such that some of the inputs of H are D (in place of M). See it in Table V.

TABLE V: H RUNNING ON $<M_i, <M_i>>$ AND $<D_i, <D_i>>$

	$<M_1>$	$<M_2>$	$<D_1>$	$<M_4>$	$<D_2>$
M_1	Accept	Reject	**Reject**	Accept	**Reject**
M_2	**Reject**	**Reject**	Reject	**Reject**	Accept
D_1	Accept	Accept	**?**	Reject	**Reject**
M_4	**Reject**	Reject	Accept	**Reject**	Accept
D_2	Reject	Accept	Accept	Reject	**?**

The author have run Turing machine H on the inputs in Table V and shown the corresponding decisions of H in each cell. The author can see that all the $<D_i, <D_i>>$ intersecting cells are showing a '**?**'. Why these cells are showing a '**?**'; because H cannot decide what it will have; 'accept' or 'reject'. By definitions of D and H, author knows that whenever D_i accepts $<D_i>$, the H should show reject; and conversely, whenever D_i rejects $<D_i>$, the H should show accept. These are the contradictions in both cases. H cannot decide anything on all diagonal cell entries whenever the inputs are D_i and $<D_i>$ (Here, in fact, the author has applied the Cantor's Diagonal Argument). It means no such H can exist that halts and decides on each and every input and hence A_{TM} is undecidable. So author has learned the proof for statement "*Halting problem of Turing machines is undecidable*"

6 Conclusions

Author has learned the undecidability of the halting problem of Turing machines in an easier way. Our way was easier because author has learned the cantor's diagonal argument in an easier way. By applying cantor's diagonal argument, the author has shown that the set of an infinite number of infinite length sequences of fruits is uncountable. To further improve our understanding of cantor's diagonal argument and its applications author used the barber paradox of Russel. Up to that point, author was having enough knowledge about cantor's diagonal argument to use it to show that some problems were unsolvable. Author has discussed the halting problem and its undecidability through easy sketches. Then author correlated our knowledge of cantor's diagonal argument and undecidability of halting problem sketches to formally prove that the halting problem of Turing machines is undecidable. This paper can be

very useful for the student of the theory of computation.

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