American Journal of Engineering Research (AJER) 2015
American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-4, Issue-9, pp-63-71
www.ajer.org
Research Paper Open Access

Evaluation and Critical Technical Study of Li-Fi Compared with Wi-Fi and WiMax Technology

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Abstract: *Modern life becomes easier and wireless communications play an important role to do so. In computer networking, wireless technology is a modern alternative to networks that use cables. Li-Fi is a wireless communication system in which light is used as a carrier signal instead of traditional radio frequency as in Wi-Fi. Li-Fi is a technology that uses light emitting diodes to transmit data wirelessly. Li-Fi is a form of Visible Light Communication (VLC). VLC uses rapid pulses of light to transmit information wirelessly that cannot be detected by the human eye. In modern age everyone wants to use wireless data but capacity is drying up. Wireless radio frequencies are getting higher, complexities are increasing and RF interferences continue to grow. In order to overcome this problem in future, light –fidelity (Li-Fi) become a better technology. This new wireless technology can save a large amount of electricity by transmitting data through the light bulbs. Li-Fi is a better alternative to Wi-Fi and WiMAX in wireless communication. Li-Fi has thousand times greater speed than Wi-Fi and provides security as the visible light is unable to penetrate through the walls, which propose a new era of wireless communication. Such technology has brought not only greener but safer and cheaper future of communication. Despite of numerous advantages of Li-Fi technology, there exist some drawbacks also. Line of sight propagation problem is one of them. So we proposed a new method that not only reduces this problem buy also increase the performance of this technology.*

Keywords**:** *Wi-Fi (Wireless Fidelity), WiMax, Li-Fi (Light Fidelity), VLC, LED, Photo detector, LoS*

I. Introduction

There are many factors which have been considered for the need to converge IEEE 802.x wireless network technologies. These factors range from device interoperability, cost effectiveness, manageability, service scalability and availability, and bandwidth usage. Due to their flexibility wireless networks, are becoming the preferred form of communicating data, voice and video, which were traditionally being transferred using separate networks [1], [5]. As number of user increases in wireless network, their requirement increases that leads to decreases in speed proportionally. It is still in shortage for accommodating huge requirements of users [3]. To rectify this limitation of Wi-Fi in small coverage area, WiMax has been introduced. WiMAX is a wireless communications standard designed to provide 30 to 40 megabit-per-second data rates, with the 2011 update providing up to 1 Gbit/s for fixed stations. Due to the technological development, A new era in wireless communication is soon going to hit the word, A German physicist, Herald Hass who evolve a method to transfer data through illumination which he called it as D-light (or LI-FI). LI-FI which is a very advanced version of WI-FI is basically light fidelity which uses visible light communication instead of radio wave communication as in WI-FI. As speed of light is way faster than radio waves hence it can be used with a speed of around 250 times more than any high speed broadband and its speed is above the 1 Gbps[4].

II. Wi-Fi (Wireless Fidelity)

Wi-Fi is a local area wireless computer networking technology that allows electronic devices to network, mainly using the 2.5 gigahertz (12 cm) UHF and 5 gigahertz (6 cm) SHF bands and it is based on the Institute of Electrical and Electronics Engineers (IEEE) 802.11 standards [2]. The computers and handsets enabled with this technology use radio wave to send and receive data anywhere within the range of a base station. Wi-Fi typically provides local network access for around a few hundred feet which works up to 54 Mbps in 20 MHz channel. To

connect to a Wi-Fi LAN, a computer has to be equipped with a wireless network interface controller. All stations share a single radio frequency channel. Transmissions on this channel are received by all stations within range. A typical wireless access point using 802.11b or 802.11g with a stock antenna might have a range of 35 m (115 ft) indoors and 100 m (330 ft) outdoors. IEEE 802.11n, however, can more than double the range also varies with frequency band.

Advantages of Wi-Fi

- Wi-Fi allows cheaper deployment of local area networks
- Wi-Fi Protected Access encryption (WPA2) is considered secure, provided a strong passphrase
- Wi-Fi is a core technology in GPS Industries Applications.
- Wi-Fi technology available in hotels, airports, etc., will be more inclined to bring laptop with us
- Frees network devices from cables, allows for a more dynamic network to be grown.
- Changes the way people live, communicate, work and play

Disadvantages of Wi-Fi

- Spectrum assignments and operational limitations are not consistent worldwide
- The 802.11b and 802.11g use the 2.4 GHz spectrum which is crowded with other devices.
- Power consumption is high compared to other standards, making battery life and heat a concern.
- It is not always configured properly by users[2]

III. WiMax

WiMAX (Worldwide Interoperability for Microwave Access) is a wireless communications standard designed to provide 30 to 40 Mbps data rates, with the 2011 update providing up to 1 Gbps for fixed stations.[wiki] WiMAX is a technology standard for long-range wireless networking. WiMAX equipment exists in two basic forms base stations, installed by service providers to deploy the technology in a coverage area, and receivers, installed in clients. It is also known as the IEEE 802.16 wireless metropolitan area network, along with the development of mobile communication and broadband technology and it has become a hot spot for global telecom operators and manufacturers [1],[5]. WiMAX is gaining popularity as a technology which delivers carrier-class, high speed wireless broadband at a much lower cost while covering large distance than Wi-Fi[7]

IV. Li-Fi (Light Fidelity)

Advantages

- Single station can serve hundreds of users.
- Much faster deployment of new users comparing to wired netw
- Speed of 10 Mbps at 10 kilometers with line-of-site.
- It is standardized and same frequency equipment should work together.

Disadvantages

- Line of site is needed for longer connections
- Weather conditions like rain could interrupt the signal.
- Other wireless equipment could cause interference.
- WiMAX is very power intensive technology
- It requires strong electrical support
- Big installation and operational cost

Visible Light Communications Project in which several universities together has achieved 3.5GBps of the three primary colors from a small LED. Combined of this makes a total in excess of 10GBps of what is known as Li-Fi [4].

Li-Fi (Light Fidelity) as coined by Prof. Harald Haas during his TED Global talk is bidirectional, high speed and fully networked wireless communications, like Wi-Fi, using visible light [6]. As the speed of light is faster than radio waves hence it can be used with a speed of around 250 times more than any high speed broadband. Recently the use of internet is increasing and hence traffic is also increasing. Due to the disadvantage of Wi-Fi such as it covers Small distance, more traffic slower speed, costly. These limitations are overcome by Li-Fi which can be used for large coverage of area, traffic handling capacity, cheaper. It transmits data through LED which changes its intensity faster than human eye and that intensity is captured by a detector. Estimated transmission of data is around 10GBps. A recent project in foreign universities proved that, Ultra-Parallel Visible Light Communications Project in which several universities together has achieved 3.5GBps of the three primary colors from a small LED. Combined of this makes a total in excess of 10GBps of what is known as Li-Fi [4].

A. Working Principle of Li-Fi and Proposed Method

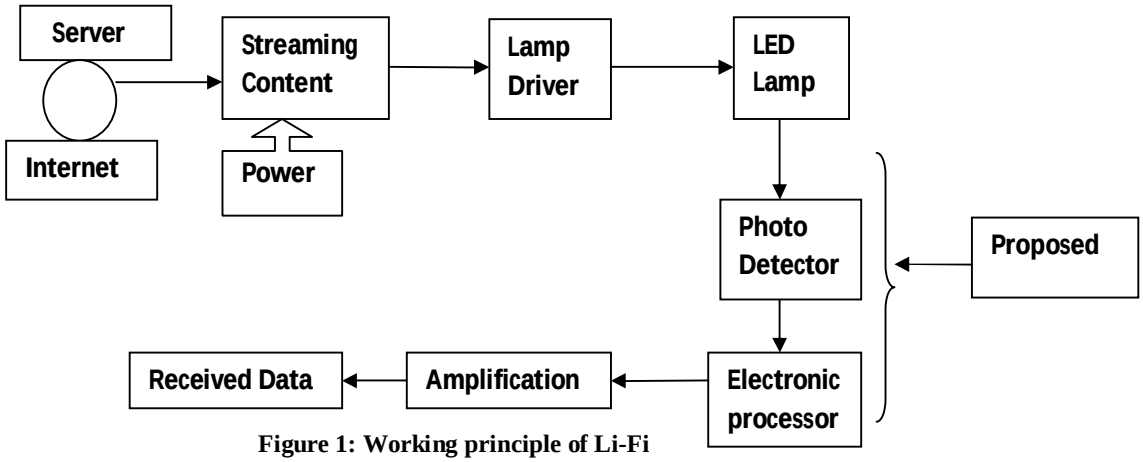

Figure 1: Working principle of Li-Fi

B. Working procedure[8]

The following factors are essential for the proper function of Li-Fi technology. These are:

1. Server

A server is a system (software and suitable computer hardware) that responds to requests across a computer network to provide, or help to provide, a network service. Internet and server run parallel. When we type a site for example-google.com, it sends request to various servers and finally sending request to the server of Google in USA. Finally after analyzing the request Google server sends us the required information in various packets. All this happens in a few seconds.

2. Lamp Driver

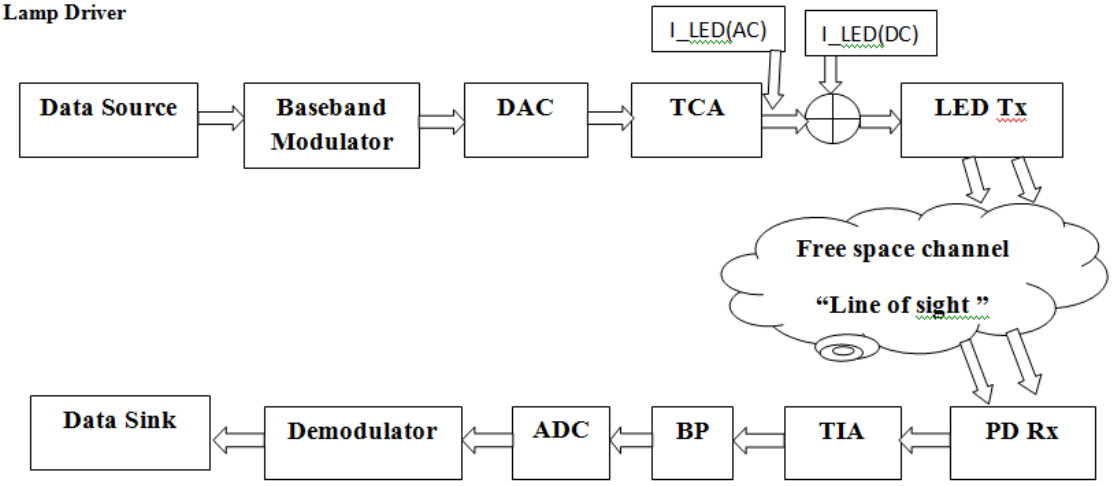

Figure 2: Working of lamp driver

Components of Light driver

i. Baseband modulator: Baseband modulation and demodulation techniques are fundamental to communication systems. Baseband is actual frequency band of signal (e.g. voice, video). If we consider the voice signal then voice signal band is approximately 4 kHz. That means voice signal contains frequencies ranging from 0-4kHz.Modulation is basically increasing signal frequency. This means voice base band of 4 kHz can be uplifted to let's say, 1900 kHz.

ii. DAC: In electronics, a digital-to-analog converter (DAC, D/A, D2A or D-to-A) is a function that converts digital data (usually binary) into analog signal (current, voltage, or electric charge).

iii. TCA: A trans-conductance amplifier (gm amplifier) puts out a current proportional to its input voltage. In network analysis, the trans-conductance amplifier is defined as a voltage controlled current source (VCCS). It is common to see these amplifiers installed in a cascade configuration, which improves the frequency response.
iv. ADDER: It simply adds a dc current to the TCA output.

3. LED lamp

An overhead lamp fitted with an LED with signal processing technology streams data embedded in its beam at ultra-high speeds to the photo-detector.

4. Receiver

A receiver dongle then converts the tiny changes in amplitude into an electrical signal, which is then converted back into a data stream and transmitted to a computer or mobile device.

C. Proposed method

Li-Fi technology has higher potential and it is highly possible to transmit data via light by changing the flicker rate that provides different strings of 1 and 0, and its intensity is modulated so quickly that the human eyes cannot notice its intensity. The functioning of Li-Fi is simple, we just needs two thing, first is LED (which acts as a light source) and other is photo detector (a light sensor for capturing light). When light source starts to emit light, light sensor on other end will detects it and gets a binary 1 otherwise binary 0. LED flashes certain time and builds up a message. Light Sensor detects the light flashing of light and receives the message. But A major problem which has introduced for Li-Fi is the line of sight propagation. To solve the line of sight propagation problem of Li-Fi , we have proposed that the combination of photo detector and electronic processor by which we can get radio wave data at the receiver end. As a result we will find the data speed of Li-Fi at the receiver end and solve the problem of line of sight propagation that will increase the performance of Li-Fi technology.

1. Line of sight propagation

Line of sight (LoS) is a type of propagation that can transmit and receive data only where transmit and receive stations are in view of each other without any sort of an obstacle between them. FM radio, microwave and satellite transmission are examples of line-of-sight communication. Line-of-sight propagation is a characteristic of electromagnetic radiation or acoustic wave propagation. Electromagnetic transmission includes light emissions traveling in a straight line. The rays or waves may be diffracted, refracted, reflected, or absorbed by atmosphere and obstructions with material and generally cannot travel over the horizon or behind obstacles. At low frequency (below approximately 3 MHz) radio signals travel as ground waves, However, at higher frequencies any obstruction between the transmitting antenna (transmitter) and the receiving antenna (receiver) will block the signal, just like the light that the eye may sense. Therefore, since the ability to visually see a transmitting antenna (disregarding the limitations of the eye's resolution) roughly corresponds to the ability to receive a radio signal from it, the propagation characteristic of high-frequency radio is called "line-of-sight".
There are three mechanisms which may cause the path loss due to line of sight-

- Refraction in the earth's atmosphere, which alters the trajectory of radio waves, and which can change with time.
- Diffraction effects resulting from objects near the direct path.
- Reflections from objects, which may be either near or far from the direct path.

2. Photo detector

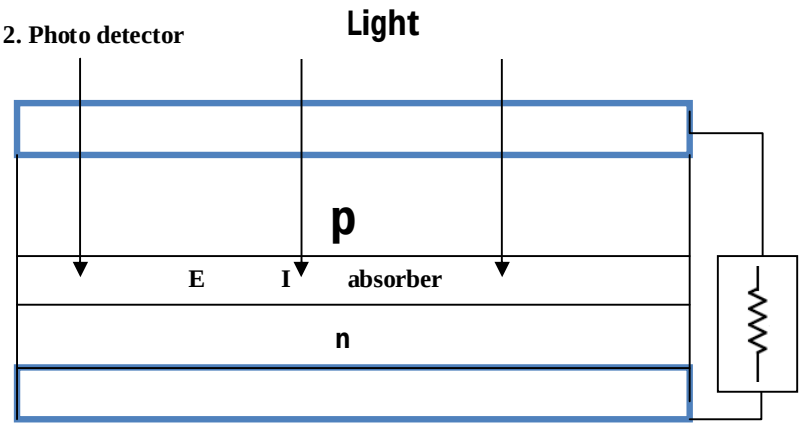

Figure 3: Photo detector

A photo detector operates by converting light signals that hit the junction .The junction uses an illumination window with an anti-reflect coating to absorb the light photons. The result of the absorption of photons is the creation of electron-hole pairs in the depletion region.PIN photodiode includes an intrinsic layer in between the P and N type materials. The PIN must be reverse bias due to the high resistivity of the intrinsic layer; the PIN has a larger depletion region which allows more electron-hole pairs to develop at a lower capacitance. The illumination window for a PIN is on the P-side of the diode because the mobility of electrons greater than holes which results in better frequency response. By another way, PIN junction diode has heavily doped p-type and n-type regions separated by an intrinsic region, which is a major absorption layer. When reverse biased, it acts like a constant capacitance and when forward biased it behaves as a resistor. Light is absorbed by intrinsic region. The result of the absorption of photons is the creation of electron-hole pairs in the depletion region which then produce electrical signal.

3. Converter/Transducer

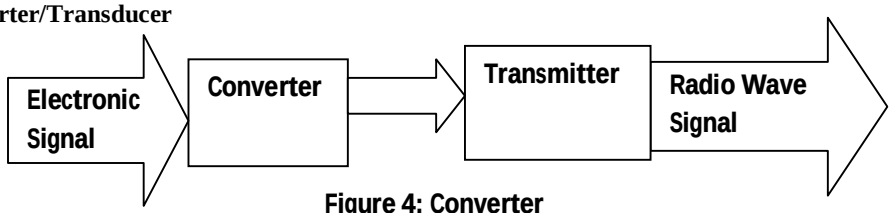

Figure 4: Converter

After taking the electrical signal from the photo detector, the electrical signal is converted by converter/transducer to get the radio wave signal .This signal is then transmitted by the transmitter and signal is thrown by means of radio wave.

D. Advantages of Li-Fi

- Capacity: Visible light spectrum is 10000 times bigger than RF spectrum.
- Security: Light cannot penetrate walls, but radio waves can, thus security is higher in using Li-Fi.
- Efficiency: The 1 million radio masts base stations consume a lot of energy, which indeed is used to cool the base stations and not to transmit radio waves.
- Transmission of data: Wi-Fi transmits data serially and Li-Fi transmits thousands of data streams parallel thus offering higher speed as high as above 1 Gbps.
- Li- Fi uses light rather than radio frequency signals
- Li-Fi may solve issues such as the shortage of radio frequency bandwidth
- Security is another benefit, since light does not penetrate through walls.

E. Disadvantages of Li-Fi

- The main problem is that light can't pass through objects
- Interference from external light sources like sun light, normal bulbs; and opaque materials in the path of transmission will cause interruption in the communication.
- High installation cost of the VLC systems can be complemented by large-scale implementation of VLC though Adopting VLC technology will reduce further operating costs like electricity charges, maintenance charges etc.
- .We can't have a light bulb that provides data to a high-speed moving object or to provide data in a remote area where there are trees and walls and obstacles behind.[7],[9]

Still there are some backdrops like it can only transmit when in the line of sight. Due to this problem we propose the integrated circuit which helps to solve the propagation problem of Li-Fi

F. Applications of Li-Fi [18]

- Intelligent Transport System: LED equipped headlight and backlights where cars can talk to each other.
- Indoor Navigation: Li-Fi can be used to navigate through any hospital.
- Oil and gas wells: Testing and maintaining of gas wells can be performed with greater ease and efficiency. This can be obtained by placing the Li-Fi transmitter at the bottom of the well and the receiver at the surface, for real-time continuous monitoring.
- Intrinsically safe environments: This can be used in petroleum and chemical industries and other environments where the usage of radio waves or other transmission frequencies can be hazardous.
- Boon for Hospitals: Operating rooms in hospitals do not allow Wi-Fi over radiation concerns, and also there is lack of dedicated spectrum.
- Bulbs: There are around 19 billion bulbs worldwide, they just need to be replaced with LED ones that transmit data. We reckon VLC is at a factor of ten, cheaper than WI-FI.
- Traffic control: In streets for traffic control, Cars have LED based headlights, LED based backlights, and Car can communicate each other and prevent accidents in the way that they exchange Information.

Traffic light can communicate to the car and so on. Education systems: As with the advancement of science the latest technology is the LIFI which is the fastest speed internet access service.[111]

- Significantly Lower Power Consumption: Radio masts are very inefficient and require vast sums of power in order to broadcast and in some cases keep them cool enough to operate.
- Airlines: Airline Wi-Fi Nothing says captive audience like having to pay for the service of dial-up speed Wi-Fi on the plane. The best I have heard so far is that passengers will be offered a high-speed**.**

G. Modulation techniques used in Li-Fi [15]

In order to actually send out data via LED, like any multimedia data, it is necessary to modulate these into a carrier signal. This carrier signal consists of light pulses sent out in short intervals. Li-Fi technology uses the following modulation techniques:

1. Pulse-position modulation (PPM)

Sub-Carrier Inverse PPM (SCIPPM), method whose structure is divided into two parts (1) sub-carrier part and (2) DC part. The DC part is only for lighting or indicating. When there is no need of lighting or indicating SCPPM (Sub-Carrier PPM) is used for VLC to save energy.

2. Frequency Shift Keying (FSK)

In frequency shift keying (FSK) data is represented by varying frequencies of the carrier wave. Before transmitting two distinct values (0 and 1), there need to be two distinct frequencies. This is also the normal form of frequency {shift keying, called binary frequency shift keying (BFSK).

3. SIM-OFDM Technique (Sub-Carrier Index Modulation OFDM)

Traditional OFDM depicted in the SIM-OFDM technique splits the serial bit-stream B into two bit-sub streams of the same length. Unlike traditional OFDM depicted in the SIM-OFDM technique splits the serial bit-stream B into two bit-sub streams of the same length. . The next step is to select two different modulation alphabets MH and ML (i.e. 4-QAM and BPSK) to be assigned to the first and the second subsets of the first bit-sub stream.

V. Comparison among Wi-Fi ,WiMax and Li-Fi

Although Wi-Fi, WiMAX and LiFi all are the wireless communication technology, there is a lot of difference among them.

A. Comparison between Wi-Fi and WiMAX

Features	Wi-Fi	WiMAX
IEEE Standards	based on IEEE 802.11	based on IEEE 802.16
Range	a few hundred feet	up to 40 miles
Bit rate	Works at 2.7 bps/Hz and can peak up to 54 Mbps in 20 MHz channel.	Works at 5 bps/Hz and can peak up to 100 Mbps in a 20 MHz channel.
Primary Application	Wireless LAN	Broadband Wireless Access
Frequency Band	2.4 GHz ISM	Licensed/Unlicensed 2 G to 11 GHz
Channel Bandwidth	20-25 MHZ	Adjustable
Half/Full Duplex	Half	Full
Radio Technology	OFDM (64-channels)	OFDM (256-channels)
Bandwidth Efficiency	<=2.7 bps/Hz	<=5 bps/Hz
Modulation	BPSK, QPSK, 16-, 64-QAM	BPSK,QPSK,16-, 64-, 256-QAM
Encryption	Optional-RC4 (AES in 802.11i)	Mandatory-3DES Optional- AES
Mobility	In development	Mobile-WiMax (802.16e)
Access Protocol	CSMA/CA	Request/Grant
Quality of service	does not guarantee any QoS	several level of QoS

Table 1: Comparison between Wi-Fi and WiMAX [11], [12], [13]

Features	**Wi-Fi**	**Li-Fi**
Speed	Uncontrolled speed	Controlled Speed due to intensity of light
Connection	Wireless- EMF	Wireless- Light
Security	Less secure due to transparency	More secure due to non penetration of light through walls
Reach	Excellent	Excellent
Impact	unknown	None
Cost	Expensive in comparison to Li-Fi Because its uses radio spectrum.	Cheaper than Wi-Fi because free band doesn't need license and it uses light.
Bandwidth Expansion	Limited	Exceptional
Operating frequency	2.4 GHz	Hundreds of Tera Hz
Data transfer medium	Used Radio spectrum	Used Light as a carrier
Spectrum Range	Radio frequency spectrum range is less than visible light spectrum.	Visible light spectrum has 10,000 time broad spectrum in comparison to radio frequency
Data Density	Transfer rate is less	transfer rate is more
Transmitter/Receiver power	Less	More

Table 2: Comparison between Wi-Fi and Li-Fi [14], [15], [16]
Comparison among Wi-Fi, Li-Fi and WiMAX

Features	**Wi-Fi**	**Li-Fi**	**Wi-Max**
Speed	54 Mbps	>1 Gbps	70-100 Mbps
Connection	Wireless- EMF	Wireless- Light	Wireless- EMF
Security	Good	Excellent	Better
Reach	Excellent	Excellent	Excellent
Impact	unknown	None	unknown
Cost	Good	Low	Good
Bandwidth	Limited	Exceptional	Dynamic [ijrtt]

IV. Simulation and result

Table 3: Comparison among Wi-Fi, Li-Fi and WiMAX [17]

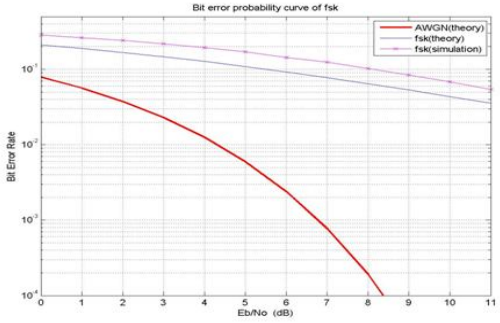

Figure 5: Bit Error Rate vs EB/No curve of FSK

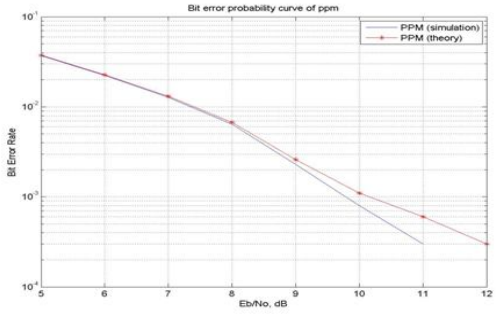

Figure 6: Bit Error Rate vs EB/No curve of PPM modulation

In figure 5: the red color for the Additive White Gaussian Noise (AWGN), the blue for theoretical BER and magenta for simulation BER of FSK modulation. If we observe we will see the AWGN is much smaller than BER. On the other hand the simulated magenta color signal is slightly higher than theoretical blue color signal, which is negligible. From the observation of figure 6:,it is clear that the theoretical red color signal of PPM modulation is mostly overlapped by the simulated blue color signal and slightly change in the last portion which is negligible.

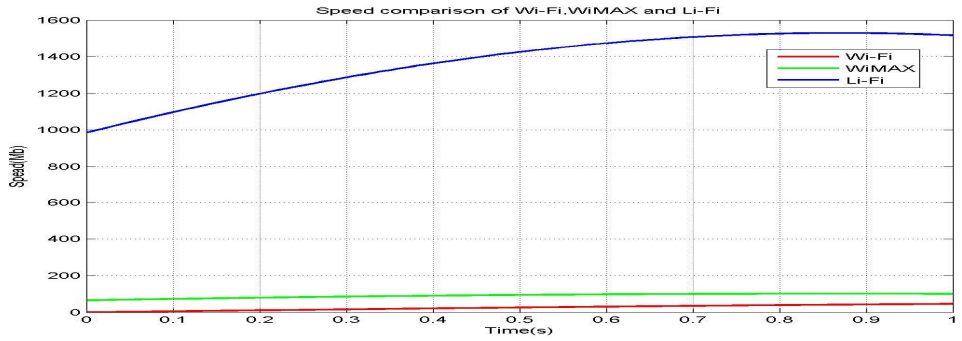

Figure 7: speed comparison curve of Wi-Fi, WiMAX and Li-Fi

From figure 8: we see, the Li-Fi technology has highest speed compare to Wi-Fi and WiMAX technologies. It also clear that Wi-Fi has a speed of 0-around 50 Mbps, WiMAX has 70-100 Mbps but Li-Fi started from greater than 1 Gbps(1024 Mbps) .

Future scope of Li-Fi

Existing spectrum becomes narrow and causes interference, so broad spectrum is required to accommodate wireless signals without any effect. In hospitals where radio waves can't be used due to harmful effect on body visible light can be used for wireless communication. In airplanes where radio waves can affect the equipments li-fi can be used without any distortion. In the depth of water where radio waves can't travel more visible light communication can be more beneficial. So li-fi has higher advantages than other wireless technologies and can be seen as a future technology [9].

V. Conclusion

As much as the wireless networks (Wi-Fi, WiMax and Li-Fi) have decreased the installation and deployment costs, increased productivity and better convenience through its flexibility compared to wired networks. WiMax has a superior and predominant technical position and influence in the history of wireless communication then Wi-Fi .The only solution to this is a high-speed bidirectional fully mobile wireless network is Li-Fi system. Currently, the LI-FI concept is attracting a great deal of interest, because it provides an authentic and very efficient alternative to wireless device which used radio spectrum. It is very advantageous and implementable in various fields that can't be done with the Wi-Fi and other technologies. Hence the future applications of the Li-Fi can be predicted and extended to different plat-forms like education fields, medical field, industrial areas and many others fields.

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[2] Md. Selim Hossain is studying B. Sc in Telecommunication and Electronic Engineering (Level-4 Semester-II) in Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh. His main working interest is based on Software Engineering, Database Management system, Web development, Digital Signal Processing, Network Security and Optical fiber Communication. He also completed a thesis on "Performance Analysis of Orthogonal Frequency Division Multiplexing (OFDM) System by using Peak to Average Power Ratio (PAPR) Algorithm".

[3] Md. Mahasin Ali is studying (Level-4 Semester-II) in B. Sc in Telecommunication and Electronic Engineering in Hajee Mohammad Danesh Science and Technology University Dinajpur-5200, Bangladesh in 2015. His main interest is based on Teletraffic Engineering , Digital Signal Processing ,Software Engineering and Networking security . He likes natural beauty. " Believe Is an Art."

[4] At the last stage of completion for the degree, Bachelor of Science in Telecommunication and Electronic Engineering, decided to make himself as a researcher. He has strong interest in wireless network specifically Ad Hoc network and wireless sensor network. But he has the capability to take challenge in new era of sciences and this thesis is the reflection of his youthful spirit.

[5] Rupam Chandro is studying B. Sc in Telecommunication and Electronic Engineering (Level-4 Semester-II) in Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200 Bangladesh. His main working interest is based on Software Engineering, Database Management system, android developer, Web development, Digital Signal Processing and Networking.

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[7] Md. Dulal Haque completed both B. Sc and M. Sc degree in Applied Physics and Electronic Engineering from Rajshahi University, Bangladesh. At present, He is serving as an assistant professor in the department of Telecommunication and Electronic Engineering in Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh. His research interest is on electronic device fabrication and wireless communication.