

Review of Li Fi Technology: Scope of Next Generation Communication System for Home Area Network

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Abstract: This paper discusses about the implementation possibility of li Fi technology within 21st century electric grid communication technology with more efficient and robust capabilities of smart grid. With increasing demand of large capacity, band width and speed, 5th and 6th generation power grid seeking for more valuable communication technologies for various Internet of Things (IoT) as the available and used centimetre (cm) radio wave communication become insufficient to fulfil the requirement of new era cellular systems. As establishment of smart Advanced Metering Communication Infrastructure (AMI) is a challenge to the researchers to considering the radio spectrum of millimetre wave communication. Till now we have radio spectrum based wireless communication system but now is time to switch to visible light spectrum. Li Fi can be the most suitable communication technology for 5G and beyond. This paper will review the power metering infrastructure for home area networks in smart grid. This paper will also review the current research work of Li-Fi application in IOT, characteristic of Wi-Fi, Zig-Bee and implementation possibilities of Li-Fi in Home Area Network (HAN) within a Smart Grid as a best communication technology in future.

Key words: Wi-Fi, HAN (Home area network), Li-Fi, Internet of Things, Smart Grid.

1. INTRODUCTION

Now a day with the grown-up infrastructure of a power grid and wireless communication infrastructure, the requirement of new, more suitable and advantageous wireless communication technologies is essential for implementation of Smart metering infrastructure in Home area networks for Internet of Things. Internet of Things is a self-configuring wireless network between people and everyday objects

through RFID sensors. In Home Area Network, all home objects are connected to internet through wireless communication, a imperative research is required in order to establish a supporting infrastructure using Li-Fi technology in place of existing infrastructure (Wi-Fi and Zig-Bee). Li-Fi works on concept of line of sight (LOS) designed by using LED for very high speed using very small nanometre(nm) cells based on the concept of visible light communication (VLC) with enormous advantages with very few ill effects.

Li-Fi is more useful in HAN as other light like sunlight; daylight can affect speed of transmission. In Home Area Network, various equipment can be connected to smart meter via various wireless communication technologies. Although there are so many choices for communication and network standard for smart grid but not all are suited for smart grid communication in HAN between utility and entities in a smart metre infrastructure.

Smart Grid is being abstracted, established and governed by various established Government and private organizations all around the world such as National Institute of Standards and Technology (NIST), Institute of Electrical and Electronics Engineers (IEEE), Electric Power Research Institute (EPRI), European Technology Platform (ETP), International Electrotechnical Commission (IEC) etc. Smart Grid, the new era electric grid is based on digital technology having one of the most important components called Advanced Metering Infrastructure (AMI).

AMI system, the most important segment of SG that has been developed to perform automated meter reading to support reliable information transfer between the various equipment's and meter and then utility or entities in a smart meter infrastructure. The major fundamental components of AMI system are

Smart Meters, Management System (MDMS) Communication infrastructure, Head End System (HES), Meter Data etc. Communication Meter shall have capability to communicate with DCU/Access Point/HES on any one of the technologies mentioned in IS16444 in a protected manner, as per the spot situation and as per design necessity of AMI Implementing organization. establishment, development and implementation of Smart Meters and communication infrastructure for different networks like HAN, NAN and WAN networks requires suitable regional, national and international standards and communication technology. Zig-bee protocol based on IEEE 802.15.4 standard. There are many challenges towards achieving a suitable communication infrastructure and technology for integration of Home Area Network with Smart Meter. Next-generation visualization is on its way to achieve a new intelligent, automated electric grid that will completely remove the shortcoming of ill structured old electric grid. According to a novel report from Navigant shipment of Smart meter will peak at 131 million units annually by 2018 and by 2022, 114 million units per year.

2. Home Area Network (HAN)

An automated, user friendly, intelligent Home area network connected with a central regulator or

Smart meter characterized by a two-way communication & information infrastructure, capable of monitoring and controlling the whole lot from meter to customer preferences to individual electronic appliances to deliver real-time information and enable the near instantaneous sense of balance of supply and demand at the device level. HAN-enabled smart home is a essential step to enable the exchange of information and interoperability among several smart domestic appliances and Devices. All the devices and appliances within HANs are connected via various communication technologies but most used and suitable technologies based on, IEEE 802.15.4(Zig-Bee) and IEEE 802.11 (Wi-Fi). Zig-bee Smart Energy is the global wireless standards (open standard 2.4 GHz) that link the widest range of devices within the home area enabling them to interact together wisely and provide controlling capabilities to its users as shown in figure1. Figure 1 shows a picture of a smart home where a verity of smart devices like smart watch, washing machine ,microwave, smart TV, ,laptop etc are interacting and communicating wirelessly along with a smart meter using some communication technologies suitable for home network such as Zig-Bee, LoRa ,WLAN etc Now a day's LoRa "Long Range communication" is also a good substitute for bidirectional communication for integrated

appliances and machine to machine communication within home area netw

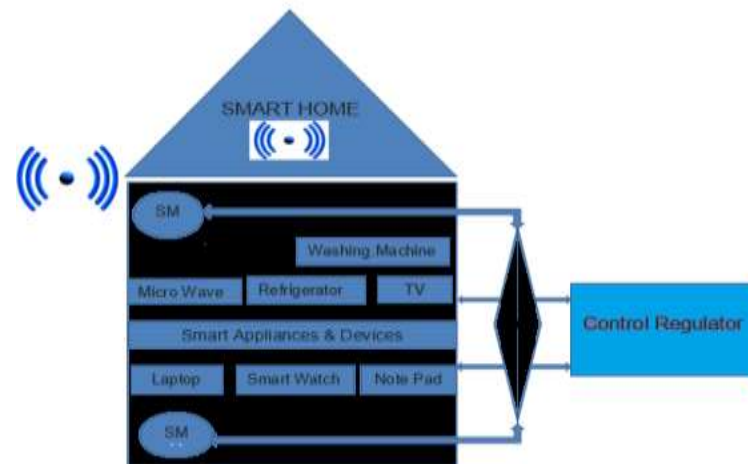


Figure1: Wireless Smart Home area network

A search indicates that the installed base of smart home networks worldwide is expected to increase from 1.5 million homes in 2009 to around 15 million in 2014. Installation of smart meters with an in-home display is the latest application of Home Area Networks to monitor and manage the power consumption within the networked area. According to a report from pike research the total no of HAN households to reach 57.5 million by 2020 and the Global revenue from HAN power will rise from \$127 million in 2012 to \$1.1 billion in 2020 and then HAN technology premise saving of will become from 10 to 20%.

2.1 INTERNET OF THINGS (IOT)

Networked interconnection of everyday devices or appliances described as a self-configuring wireless network or phenomenon called IOT. To interconnect all the devices IOT required communication between all the devices, smart meter and people. IOT has four basic elements information collection, two-way transmission of power and information, treatment and feedback control. IOT within HAN has capability that devices will automatic alarm if something goes wrong or power exceeds your limit. Each smart device like washing machine, refrigerator, air conditioner, notepad, smart watch etc in IOT network will communicate each other and meter. It will also give and takes command and inform about the utilization of power and gives real time consumption information. In short, every device becomes intelligent power device to develop a super smart network that can dramatically change the world of power and energy.

2.2 COMMUNICATION TECHNOLOGIES FOR HANs

2.2.1 Zig-Bee: Zig-Bee(IEEE 802.15.4) is a low power wireless communication

technology ,has been realized as an ideal technology for communication between smart meter and appliances in home area network providing good coverage due to ease of setting up. Now a days it is the most used wireless technology within range of 10 meters suitable for home area network because of Low data rate (20-250 Kbps) working with 2.4 GHz, 868MHz, and 928 MHz under IEEE802.15.4 standard. it can be used among various home appliances such as washer dryers, ac, water heater, smart watch ,PHEV etc.

2.2.2 Sub-GHz: In India 890-960 MHz frequency band is allocated for cellular services and 585-806 MHz for broadcasting services and 2.4GHz is for Zig-Bee technology is intensely marketed and used broadly in the present markets. With the shortage of GHz band for wireless applications, Sub-GHz technology is a principle substitute for smart consumption, lower deployment and operating costs., Sub-GHz wireless systems is a simple wireless technology and offer several advantages for home security/automation and smart metering with battery power on your own for up to 20 years.

2.2.3 LoRa: LoRa technology transmits in the Sub GHz Spectrum (109MHz, 433MHz, 866MHz and 915MHz. It is a low power, long range wide area wireless technology, targeted key requirement of Internet of Things (IoT). LoRa “Long Range “communication” is more suitable for bidirectional communication, mobility and

localization services ,integrated into home appliances for M2M(machine to machine) communication. LoRa has several key features such as long range up to 15km -20 km, millions of nodes, low cost and long battery life in excess of ten years supporting Smart Metering applications.

2.2.4 Wi-Fi: IEEE 802.11 a/b/g/n/ac/ series standardize PHY and MAC layers ranges from 2.4 and 5.8 GHz propose the basis for wireless network products using the famous Wi-Fi trade name. Wi-Fi is a very admired wireless communication technology basically used in home area networks, mobile phones, video games, and other electronic devices and appliances. Speed and flexibility are the main features of Wi-Fi.

2.2.5 Bluetooth: Bluetooth(IEEE 802.15.1) technology fit for wireless connectivity between individual devices such as headphones, medical, sport & fitness, mobile phones ,wireless key board or laptops within the range of 10 meters. it is a standard wished-for a secured and economical way of connecting and transferring data amongst supported devices, providing a Personal Area network. Presently, various versions of Bluetooth are available for short-range wireless transmission such as Bluetooth Low Energy (BLE), that's a less complex, low-cost, communication utilizing frequency radio bands from 2.4 to 2.485 GHz.

In spite of all above mentioned communication technologies ,several other kind of ISM protocols that are based on IEEE standard are Wireless HART Over IEEE 802.15.4 , Mi-Wi Over IEEE 802.15.4, Isa100.11Over IEEE 802.15.4 functioning on ranges 2.4 GHz/915 MHz (USA)/868 MHz (EU)) and the protocols and standards that are not based on any IEEE standardized like SimpliciTI {2.4 GHz and Sub 1 GHz } I, Z-

Wave {2.4 GHz : 908.4 MHz (USA): 868.4 MHz (EU)}, EnOcean {315 MHz (USA) 902.875 (USA) 868 MHz (EU) }, Insteon{915 MHz (USA) },Wavenis{433 MHz 868 MHz (EU) 915 MHz (USA) 2.4 GHz },WM-Bus {169 MHz 433 MHz 868 MHz} etc.

3. Challenges of existing communication technologies based HAN

HANs are designed to operate at a much shorter assortment indoors applications. Home Plug Power line Alliance, Z-Wave, and the Zig-Bee Alliance are well-known alliances related to the utility industry in the Home Area Network market that have worked towards technology standardisation. Other coverage area of few meters is IEEE 802.15.1(Bluetooth), IEEE 802.15.4(Zig-Bee), IEEE 802.11(WLAN/ Wi-Fi) and IEEE 802.3 (Ethernet). Now a day in smart home network, variety of products like, control, appliances, lighting safety, and other products based on different standards like Zig-Bee, Lora,Sub GHz, Z-Wave, Wi-Fi. Globally .Zig-Bee and Wi-Fi devices are primary choice of various vendors such as Atmel,Digi International, Freescale Semiconductor, Green Peak Technologies, Renesas Electronics, Silicon Laboratories, and STMicroelectronics, Texas Instruments etc. for smart home automation or **IoT** solutions.

In order to new development in smart home network one of the major challenges is to integrate more superior communication technology resolutions, so that smart meter services such as automation, security, energy management can be offered seamlessly. Some basic concern among the technology like bandwidth, speed, security and range etc needs to be resolved and reinvestigate in order to be cope by 5th or 6th generation grid. 5G and further generation will show a picture where we wake up and tap to our smart phone to switch on our

coffee machine as it prepared it will send a text. On other hand, our fridge sends us a message that it is out of bread. just imagine? is it possible? Yes, it is possible with the integration of an optical communication technology Li- Fi technology, known as a 5th generation visible light communication (VLC). Visible light communication (VLC) is a class of wireless technologies for transmitting and receiving data using infrared, visible light spectrum of about 400 THz to 800 THz. The concept of VLC originated in Japan's Nakagawa Laboratories in 2003. In 2010 the IEEE published the 802.15.7 standard for short-ranges Wireless Optical Communication up to 96 Mbps by fast modulation of optical light sources.

Uses of wireless communication achieved maximum utility as the existing technology Zig-Bee and other can't meet them very good because of nonstop decreasing capacity, speed and security issues. The research on Li-Fi based wireless network is a spatial requirement of some applications for smart grid communication infrastructure as based on HANs to the development of IOT.

4. Li-Fi



We know that radio spectrum become congested day by day with great exact of users but demand for wireless data doubled every year. Figure 2 shows an animated image of Wi-Fi traffic taken by US on 7th June 2017 that shows severe state of traffic globally. During year 2017 there are 4 million base stations and 5 billion mobile stations serving wireless communication services, this tend to a very big issue regarding radio spectrum. For short range and low power devices within a home area network Zig-Bee and

Wi-Fi are the most widely used IEEE standard wireless technology but with the increasing demand of capacity and RF band these technologies suffers with its own limitations .

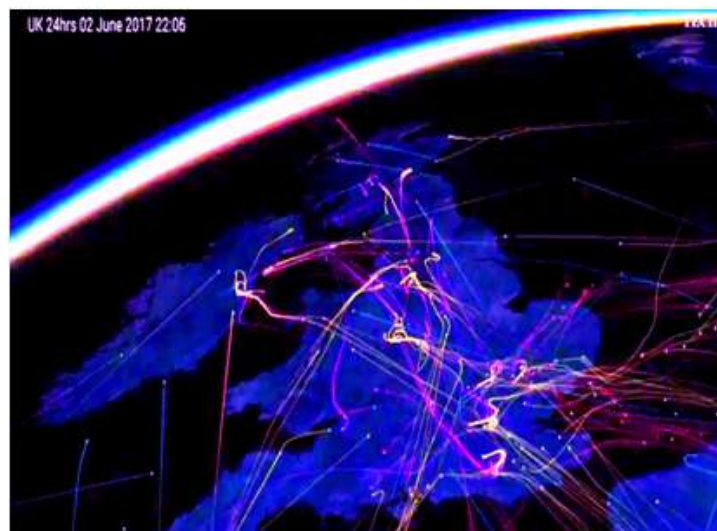


Figure2: Animated image of Wi-Fi traffic by US on 2 June 2017

To handle the crises of radio spectrum for new generation devices it is the right time to switch IEEE 802.15.7 from 802.11 where any type of light device can be turned into a Wi-Fi spot with superior characteristics. Li-Fi network is more suitable and essential to built new generation automated meter reading system facing to internet of things within a home area network.

Now the question is that who can replace radio wave for wireless communication? Answer may be Li-Fi as a possible substitute for future communication. Li-Fi (Light Fidelity) is a potential substitute for Wi-Fi and refers as new class of high intensity of light source of solid state design for the transmission of data with illumination for IoT applications with clean, safe and bright future of communication technology. By 2018, the Li-Fi Centre at the University of Edinburgh hopes to “fully harness the commercial

and innovative potential of Li-Fi, and to help establish a major new \$8.5 billion Li-Fi industry. If comparing with Wi-Fi, Li-Fi has large variety of significant advantages such as Enormous Band width, very fast ,Easy Installation and Extension, Long Life, Very Secure, Cost Effective, No Interference and Disturbance, More Efficient, Availability, Less Complex Circuit etc.

In spite of all these advantages there are some challenges of Li-Fi as it works on only Line Of Sight transmission and unable to penetrate walls and other opaque materials. Besides these drawbacks it won't be long at this time before Li-Fi becomes an everyday, every time and everywhere communication technology as also stated by the company Pure Li-Fi founded by Professor Hass *"PureLi-Fi seeks to resolve the global struggle for diminishing wireless capacity by developing and delivering technology for secure, reliable, high speed communication networks that seamlessly integrate data and lighting utility infrastructure and significantly reduce energy consumption"*

4.1 Some Research in area of Li-Fi

In 2003 the modern wireless Li-Fi or VLC came into picture. It is first originated in Japan's Nakagawa Laboratories

In late 2010 the IEEE published the 802.15.7 standard for Short-Range Wireless Optical Communication Using Visible Light, and LVX System launched a commercial product.

In 2011, Professor Harald Hass at University of Edinburgh introduced a VLC protocol, "Li-Fi," and compare it with Wi-Fi to aware of the concept blowout. Professor Harald Hass introduced a Li-Fi protocol at a Ted Talk, the awareness for it, spread far and wide.

Same year, in 2011 the European Union's Omega Project covered up, VLC platforms Byte Light and Outstanding Technology launched and Disney Research showed off simple VLC applications in children's toys and clothing using light-emitting diode (LED) lighting.

In 18 October, 2011 a Li-Fi Consortium grouped by some companies and industries formed an international platform focusing on optical wireless technologies to foster the development and distribution of (Li-Fi). It was founded by four technology-based organizations.

Then in 2012 the *Li-Fi Consortium* a roadmap is outlined for different optical communication such as gigabit-class communication wireless infrared and visible light communication etc.

After that Estonian Velmenni's "Jugnu" Li-Fi demonstrated data transfer at 1 Gbps, or about 100 times faster than Wi-Fi.

During2016, Indian researchers developed Triplet Li-Fi (T-Li-Fi) using three colours, each carrying different data streams, thus tripling conventional Li-Fi capacity-Li-Fi concept is similar to Li-Fi uses the concept of RGB multiplexing scheme to produce white light spectrum. Each colour carries different data, so the speed is three times better than conventional Li-Fi.

University of Oxford Li-Fi researchers hits the possibility of speed 224 Gbps in certain lab conditions fast enough that it could download around 10 movies of 1Gb each, all within a time frame of 30 seconds.

4.2 Construction of Li-Fi Technology

Li-Fi (light-Fidelity) is arriving wireless technology using a bidirectional mode of communication, where the data can be transmitted through high brightness LED light with varying intensity faster than human eyes. It works on the very fast on-off phenomenon of LED, if LED is on then considered as 1 whereas if LED is off then 0. So by producing on-off state of LEDs binary digital sequence or stream of 1s and 0s can be obtained that can be encoded and processed with the help of electronic circuitry. LED can be switched on and off very quickly to transmit data require controller. For the transmission of parallel data we can use array of LEDs and LEDs also can be red, blue and green so that light frequency can be altered in order to use as different data channels using concept of wavelength division multiplexing (WDM). Li-Fi communication worked under association of Li-Fi communication physical layer, modulation format, and Frequency Spectrum standard. IEEE802.15.7 standard define physical layer and Media Access Control (MAC) layer having capability to transmit or delivering data rates of audio, video and multimedia services. Some characteristics of VLC and the main components of Li-Fi system are as follows

- Optical carrier that uses visible light between 400THz (780nm) to 800THz (375 nm).
- High Brightness LED(doubled micro-LED or micron sized LED) or Array of LEDs are used as source of communication boosting speed up to 224 Gbps.
- Silicon Photodiode having good response to visible light falling on it.
- Electronic circuitry for modulation and encoding of LED with the data signal and flickering of light. Flickering rate be like that we should be able to see light but can't see the data

- The light used to transmit data called D-light. This name is given by Herald Hass organizer of Li-Fi in TED talk.

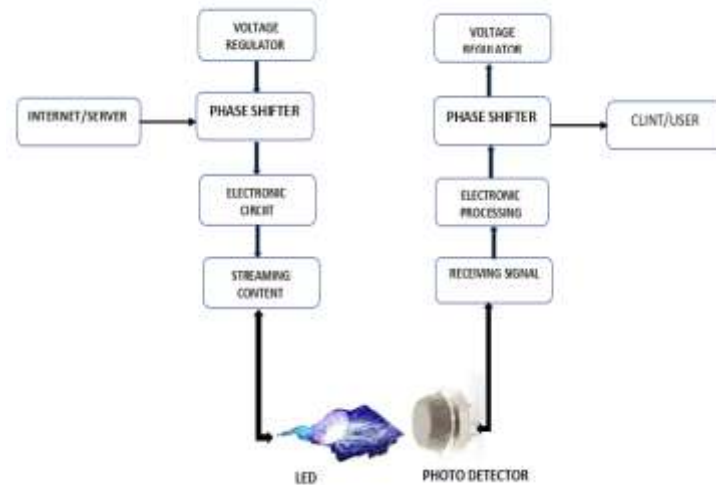


Figure no3: System Architecture of Li-Fi

4.3 Working of Li-Fi

The principle of working of Li-Fi is very simple and easy. On one end of system there is a light emitter as a transmitter and a photo detector (light sensor) as receiver on the other end of system. The input data to the LED transmitter is encoded by varying the flickering rate at which the LEDs flicker 'on' and 'off' to generate different strings of 1s and 0s as a digital encoder. The on-off action of the LED light is so rapid that a human eye is unable to notice the change, and the light of the LED appears steady to the user and enables data transmission in light form done by LED intensity modulation which seems to be invisible as the modulation is so in accordance with the incoming binary codes in form of logical '1' and logical '0'. with reference to the home area network every device and appliances communicate with each other along with smart

meter as shown in figure no 4.Using an array of LEDs covering the whole room area.

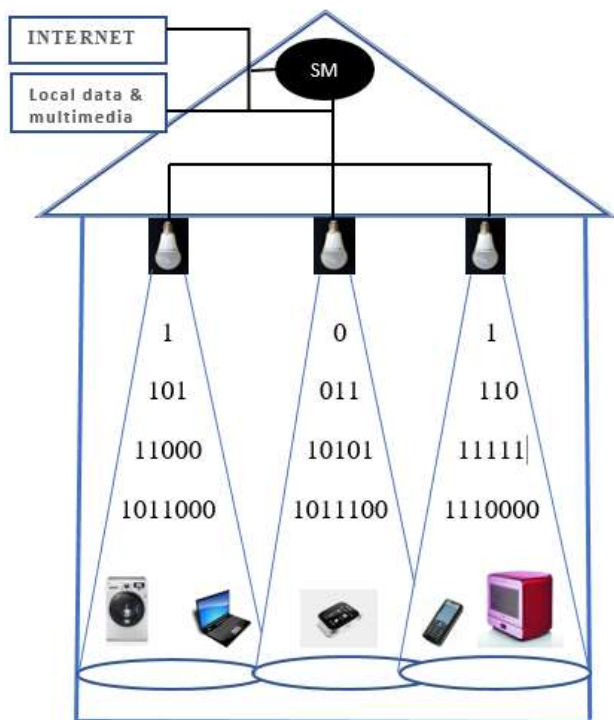


Figure 4: Li-Fi Based Home Area Network

The selection of LEDs also plays a critical role, like LEDs size can affect data rate of the communication system. The data rate is inversely proportional to the Size of LEDs, which means smaller the size of LED more will be data rate. hence the development of Double micro LED or micron-sized LED for Li-FI is thousand time smaller then the commercial LEDs it means LED can flicker 1000 times more than commercial LEDs.

LED works on principle of electro luminescence ,when an appropriate voltage passes through LED (Diode) , electrons are able to recombine with electron holes with in a device and releasing energy in form of photons (light),The luminance expresses the brightness of device that depends on applied voltage and two basic properties of LED i.e. luminous intensity

(i.e. energy flux per solid angle) shown in equation1 and 2 and by transmitted optical power (i.e. total energy radiated from optical source)shown inn equation no 3

$$I(\phi) = I(0)\text{Cos}^m(\phi) \dots\dots\dots 1$$

A horizontal luminance E_{ho} at a point (x,y) is given by

$$E_{ho} = I(0)\text{Cos}^m(\phi)d^2 \text{Cos}(\theta) \dots\dots\dots 2$$

where $I(0)$ shows centre luminous intensity of an LED , θ is the angle of incidence and Θ is the angle of irradiance, and d is the distance between an LED and a detector's surface.

We use led with high luminous intensity typically have narrow apex angle and the three dimensional angular spam for an apex angle Ω is

$$\Omega=2\pi \left(1 - \text{cos} \frac{2\theta}{2}\right) \dots\dots\dots 3$$

When we build a wireless home area with Li-Fi like figure 4 we must consider above parameters so that maximum area with proper luminance can be achieved for correct communication among devices and Smart meter.

5. CONCLUSION

In our near future All the objects and devices in our premises can be connected into IoTs with a new kind of emerging technology that has vast potential and large amount of available bandwidth. Soon we have, everywhere a light bulb is available something a kind of Wi-Fi spot will be available. In this paper we have introduced 5th generation communication technology known as Li-Fi. Now a day this technology explores especially for smart cities and smart homes but as light is the main source of transmission, being everywhere the future possibilities of Li-Fi can be extended to various areas and applications like Medical areas,

education field, military areas, Airlines, traffic, industrial areas etc. In future it will be possible to achieve a data rate of more than one billion bits per second called Gi-Fi refers as wireless Li-Fi . At the end Li-Fi is the shortly coming alternate of Wi-Fi technology on day to day basis in the field of wireless communication.

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