Applicability of Li-Fi Technology for Industrial Automation Systems

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***Abstract*—Light Fidelity (Li-Fi) is a new technology for wireless communication. In this article, Li-Fi technology will be analyzed in details. Its applications, challenges and limitations will be mentioned. Li-Fi will be compared with Wireless Fidelity (Wi-Fi). In industrial automation systems, production process should be fast and safely. Unlike Wi-Fi, high-speed internet connection is provided using Li-Fi technology. Therefore, applicability of industrial automation systems of Li-Fi technology will be examined.**

***Index Terms*—Light Fidelity (Li-Fi), Wireless Fidelity (Wi-Fi), industrial automation system, visible light communication**

I. Introduction

Wireless communication system has become an indispensable part of everyday lives with the help of the technological devices (e.g. smartphones, tablets). NCR corporation/AT&T invented Wireless Fidelity (Wi-Fi) in 1991 [1]. Wi-Fi technology, which enables to exchange data between two or more devices, utilizes radio waves to send data without using wires or cables [1]. Thus, the Internet access can easily be provided in both private and public places. Radio signals, router and antenna are fundamental elements in wireless communications. Antennas and routers transmit data using radio waves and Wi-Fi receivers collect that signals [2]. Nowadays, four different types of Wi-Fi access technologies, which are Wi-Fi-802.11 a/b/g/n, are used in local area [3].

The amount of data that send through wireless network usage rises 10-fold within four years according to estimation [4]. However, Radio Frequency (RF) bandwidth is narrow and limited to allocate. In near future, a potential spectrum crisis is expected according to The US Federal Communication Commission due to limited RF spectrum range [5].

A variety of wireless solutions have been recommended to provide more data traffic [6]. In 2011, Harald Haas announced a new wireless technology that is called Light Fidelity (Li-Fi) [7]. Although Wi-Fi uses radio waves, Li-Fi uses visible light spectrum. The radiofrequency spectrum is 10,000 times shorter than the visible light spectrum as shown in Fig. 1 [5], [7].

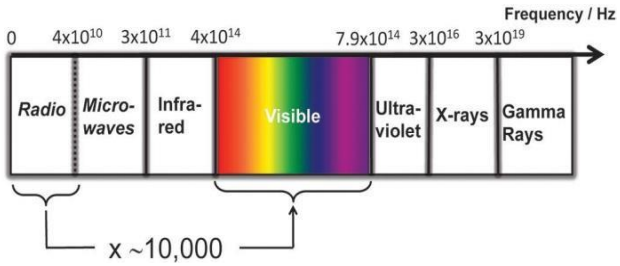

Figure 1. The electromagnetic spectrum [5]

Infrared rays can be used only low power due to eye safety regulation. Gama rays and ultraviolet light can be dangerous for human body. However, visible rays are safe for human body. Therefore, visible light is used for Li-Fi technology.

Although Wi-Fi uses modems, Li-Fi uses transceiver-fitted LED lamps that can transmit and receive information. Li-Fi can transmit more data in a very short amount of time than Wi- Fi seeing as a higher aggregate data rate is possible.

II. The Operation Principle of Li-Fi

In data transmission, Li-Fi utilizes light waves instead of radio waves so visible light spectrum is used Li-Fi technology. As mentioned previously, visible light spectrum is 10,000 times larger than radio spectrum. Therefore, Li-Fi technology offers unlimited capacity in wireless network system [8]. Although the transmission speed of fluorescents light source is 10Mb/s, LED (light emitter diode) light transmission speed is 500Mb/s. Therefore, LED light source is preferred in Li-Fi systems [9]. Essentially, Li-Fi is a Visible Light Communication system (VLC) that uses high brightness white LED lights to transmit data without wires. In other words, not only Li-Fi transfers data wirelessly but it also receives data wirelessly [7], [9].

In principle, LED lamps can be turn on and off very quickly and this situation cannot be realized in human eye. If light is on state, a digital 1 is transmitted. If light is off state, a digital 0 is transmitted. LED can be switched on

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and off within nanoseconds, which gives good possibility for transmitting data [9]. A photo detector, which is p-i-n photodiode or avalanche photodiode, receives transmitted data from the light source and decodes the data [5], [9]. Parallel data transmission can be produced using LED arrays so data transmission speed is increased.

The operation principle of Li-Fi is similar with TV remote system. These two systems are shown in Fig. 2 [10].

Figure 2. The operation principle of Li-Fi and TV remote control system [10] (*bits per second)

Intensity modulation and direct detection is used to encode data because LED light generates incoherent light, which is oscillating different directions. Therefore, data communication cannot use the signal phase as used in laser diodes [5].

A block diagram of the Li-Fi system is shown in Fig. 3. Power supply produces constant power for lamp driver. Lamp driver connect to the internet connection. Switch and LED lamp is connected lamp driver with fibre optics cables. LED lamp acts as a communication source. Microchip, which is located in LED lamp, converts the data into light. High-speed data is transmitted using light beam from LED lamp to photo detector. Receiver detects changing in intensity of the light beam and converts the data into electrical signal [9]. These converted data are transmitted to the technological devices [8], [9].

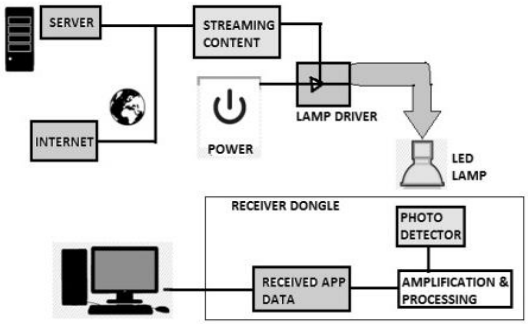

Figure 3. A block diagram of Li-Fi system [9]

Li-Fi has a variety of applications due to providing fast speed Internet access and using visible light. Wi-Fi uses radio waves for communication. However, Wi-Fi connection cannot permit in some places (hospitals, airplanes, etc.) because of radiation concerns and interfering with other radio signals [7]. Unlike Wi-Fi, signals of monitoring equipment cannot be blocked using visible light. Thus, Li-Fi can be used in hospitals to access Internet and control the medical equipment. Additionally, it may be used for robotic surgery in near future [11].

Li-Fi can provide cheaper and high speed Internet in airplane using every light source [7], [12]. In addition, Li-Fi can be used for location specific information services which are navigation and advertising. Stores use LED lights to brighten their showcases. At the same time, they can advertise their products using Li-Fi technology [12]. Museums and art galleries use specific light to illuminate exhibits. Li-Fi technology can be used to get further information about the object using that specific light.

RF that cannot use in intrinsically safe environments such as petrochemical plants and mine generate antenna sparks but Li- Fi can be used due to safer than radiofrequency communication [12]. Petrochemical plants need fast interconnected data systems to monitoring core temperature and grid integrity. Li-Fi technology provides cheap and fast internet connection to data transmission [7], [12].

Strong signals are absorbed in water so Wi-Fi fails in underwater communication. However, light can pass through water so Li-Fi can be used in underwater communication [12].

In outdoor environment, between two radios base station distance is about 200-250 meters. In current communication system, radio base station should be positioned in every 250 meters. However, streetlights can be utilized as free access point for high speed Internet along the street using Li-Fi technology [7]. Thus, street lights provide fast and cheap internet connection along the street. Another application is vehicle-to-vehicle or vehicle-to-roadside communication using Li-Fi technology [7] [11]. Traffic lights, street lights and car lights are LED-based. Cars not only can communicate each other but also can communicate traffic light using Li-Fi technology as shown in Fig. 4. Roadside infrastructures, location, direction of travel and each vehicle's speed can be exchanged using Li-Fi [7], [12]. Thus, traffic can be managed and accidents can be reduced.

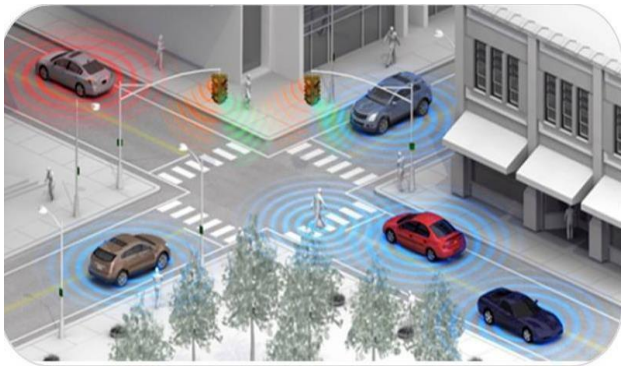

Figure 4. Vehicle-to-Vehicle communication [13]

Li-Fi technology is used different usage models. Li-Fi consortium defined Giga-speed technologies for different usage purpose. Giga Docks, Giga-Shower, Giga-Beam, Giga- MIMO and Giga-Spot models are different type of Giga-speed technologies [14]. These models address various user scenarios for wireless indoor-like and indoor data transfer. Giga-Docks models including wireless charging for technological devices, which are

smartphones, notebooks or tablets, with speed up 10Gb/s [14]. Unidirectional data services are provided using Giga-Shower. This model enables several channels to multiple users gigabit-class communication speed [14]. Giga-Beam models are used a point-to-point data link for applications or portable-to-portable data exchanges. That means, full HDTV movie can be transferred one device to another device within seconds. Giga-MIMO is an optical wireless multi-channel hot-spot solution which offers bidirectional gigabit-class communication in room [14]. Giga- Spot is an optical single-channel hot-spotsolution.

III. Comparison of Li-Fi with Wi-Fi

Current wireless technology, which is called Wi-Fi, has various problems. These problems can be divided into three main groups that are capacity, efficiency and security [8]. Radiofrequency spectrum is narrow so Wi-Fi technology offers limited bandwidth. In addition, 3G and 4G technologies run out of this limited radio spectrum [15]. However, visible light spectrum is 10,000 times wider than radiofrequency spectrum so Li-Fi technology offers unlimited capacity for communication systems. According to Haas, Li-Fi technology is ready for IoT and 5G [15].

On the one hand, Wi-Fi technology uses base station or cellular radio masts to transmit data using radio waves. 1.4 million base stations consume remarkable energy especially to cooling stations. The efficiency of these stations is only at about 5% [15]. On the other hand, Li-Fi uses light waves to transmit data using LEDs. LEDs consume less energy as compared base stations. It can be seen clearly, wireless communication can be cheaper and more efficient using Li-Fi technology.

Energy efficiency graph is shown in Fig. 5. In this graph, Li-Fi and Wi-Fi technology is compared. Energy efficiency of Wi-Fi network declines rapidly while users increasing. However, the energy efficiency of Li-Fi network remains constant along a large number of users. The green curve represents the ratio between Li-Fi and Wi-Fi. As can be seen in this graph, Li-Fi is more energy efficient network technology than Wi-Fi.

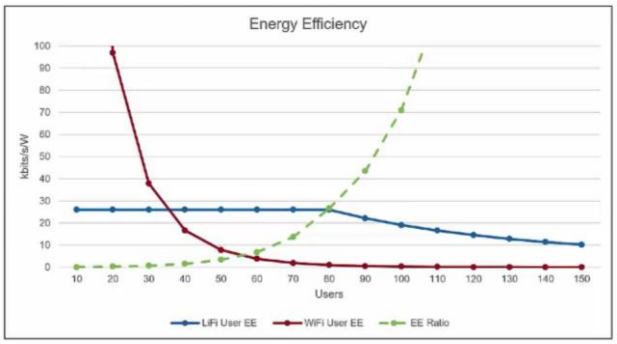

Figure 5. Energy efficiency of wireless technologies [15]

Radio waves can pass through walls and any objects in environment so private networks can be used by someone else [7]. This situation increases security problem in Wi-Fi communication. Light cannot pass through any objects and walls so private network cannot be used someone else for any negative purpose. Therefore, Li-Fi provides secure and private environment. Radio frequencies penetrate human body and can cause cell mutation but light are not harmful for human body. Unlike Wi-Fi, Li-Fi offers safe and green communication environment [7].

Another issue is speed of Internet that is around 11 Mb/s for Wi-Fi connection is 1Gb/s for Li-Fi connection. It can be clearly seen that Li-Fi is a high-speed wireless technology [15]. Data transmission rate of different LEDs is shown in Fig. 6. Different type of LED light source can affect data transmission rate as shown in below graph. 100Gb/s transmission rate are achieved in laboratory environment using laser LEDs [16].

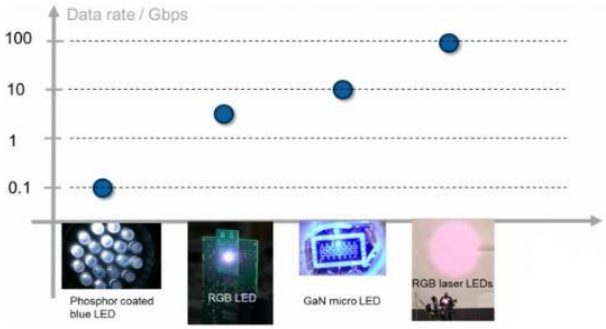

Figure 6. Different LED light transmission rates [16]

Wi-Fi Internet connection area is around 100 meters. However, Li-Fi Internet connection area is based on LED lights. That means Internet connection area can be widening using LED lamps as shown in Fig. 7. This characteristic feature is a great advantage for places that need large Internet access area (e.g. factories, industrial places).

Figure 7. Widening Li-Fi internet connection using LEDs

All these differences are shown in below Table I.

TABLE I. Comparison Table of Li-Fi with Wi-Fi

Characteristic	Wi-Fi	Li-Fi
Frequency	5 GHz	No frequency for light
Standard	IEEE 802.11	IEEE 802.15
Range	100 meters	Base on LED light
Primary application	Wireless local area networking Cost Low Medium high	Wireless local area networking
Data transfer rate	800 Kbps - 11 Mbps	>1Gbps
Power consumption	Medium	Low
Cost	Medium	High
Security	Its medium secure	Its high secure

Li-Fi has limitation and challenges despite all these advantages. Light cannot pass through walls and solid objects. On the one hand, this situation provides more secure communication environment. On the other hand, solid objects on light pathways can affect data transmission. Researchers try to solve line-of-sight problems for Li-Fi technology. In these days, they work on hybrid model. Hybrid model will include both Wi-Fi and Li-Fi technology. The working principle of hybrid system will be simple. When Li-Fi connection is interrupted for some reasons, Wi-Fi connection will be activated. Therefore, Internet connection will continue without any interruption. However, hybrid model has not been implemented yet.

Sunlight, natural light and electric light are different light sources. These different light sources can affect data transmission speed. In Li-Fi technology, receiver and light source should be placed a perfect position to reach high-speed transmission rate [7]. Li-Fi has a high installation cost because it is a new technology.

IV. Applicability of Industrial Automation Systems of Li-Fi Technology

In industrial manufacturing process, it is extremely important that process should be completed fast and safely besides product quality. Therefore, the communications between units are developing day by day in nowadays- industrial automation systems. These developments that mostly depending on usage of protocol are shown data transmission rate and security.

In industrial applications, while monitoring and control are being done in real time benefiting various network topologies. The efficiency of network is an important factor while this topology is chosen. However, it will be useful to take into consideration; the using network topology is used to recognize devices besides data transmission speed may vary depending on the distance between units. Under these criteria, many industrial automation companies are trying to provide with different communication protocols. It offers significant advantages in terms of both cost and speed if data transmission is done wirelessly. Wireless monitoring and control systems are provided a major contribution to the development of the SCADA systems. Wireless communication systems, especially applications are made with web-based or smartphones, has been used successfully. As compared with Wi-Fi, Li-Fi technologies should be preferred because of having high-speed data transmission rate and more secure in wireless communication systems.

In current wireless communication system have a security gap because radio waves can pass through the walls. Security gap is a big disadvantage for industrial automation systems that are working in higher-up security level. Light waves cannot pass through the walls. Therefore, these industrial automation systems are protected using Li-Fi technology.

As mentioned previous chapter, line-of-sight is a big challenge for Li-Fi systems. Some people claim that Wi-Fi is an over light based communication technologies and is not much affected from line-of-sight problem as compared with Li-Fi in a factory environment that includes lots of moving obstacles. Therefore, Wi-Fi systems are more useful than Li-Fi for industrial areas. However, when considering a factory, Wi- Fi connection receivers are positioned in specific locations. The internet connection is delivered to the robotic arms via Ethernet cables. When Wi-Fi systems are replaced with Li-Fi, still receivers are positioned in specific locations and nothing can interrupt light. Therefore, internet connection can be provided without any interruption to the robotic arms or any other devices. Thus, line-of-sight problem are solved. In addition, it can be clearly seen that production process will be faster with using Li-Fi, which is provided high-speed data transmission rate. This system model is shown in Fig. 8.

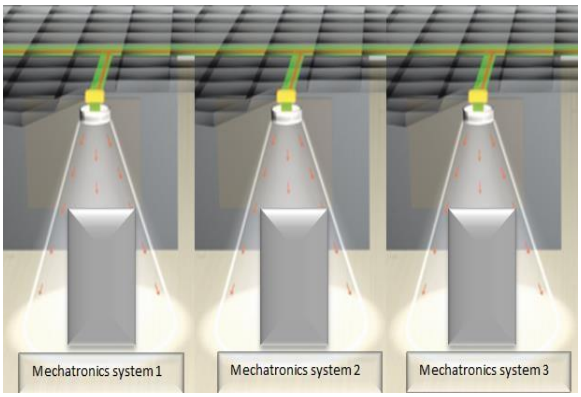

Figure 8. Li-Fi connection system in a factory

V. Conclusion and Future Work

In this article, the new wireless communication technology, which is called Li-Fi, was examined in details. Li-Fi internet connection area can be extendable using LEDs, which is located sequentially. In other words, internet connection can be provided for large areas without disconnection.

In industrial automation systems, safe and high-speed internet connection is an important two factors for production process. Considering the fact that a Li-Fi connection is limited with the area of LED lights, the outside reach to the network is not possible. That leads to a very secure connection. Thus, the Li-Fi technology brings safety connection. This fact might lead to more application fields for future work. For example, the Li-Fi can be used in military networking systems. The control of military devices through Li-Fi may be investigated in future studies. Additionally, the finance departments of companies or banks may use Li-Fi in order to obtain more secure networks.

In addition, all of these, if hybrid model is implemented for real life, this model will be more suitable for industrial automation systems to include Li-Fi and Wi-Fi systems' advantages.

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