Course5
Transformative intelligence

LIGHT FIDELITY :

A Breakthrough Technological Innovation in Industry 4.0 Transformation

Can the technology disrupt the entire data transfer and connectivity landscape?

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Abstract

Imagine a world where light connects us to the internet. Lights that illuminate our offices, homes, cars and streets, are also connecting us to data and powering our growing demand for connectivity through Li-Fi (Light Fidelity) technology.

29 Billion

Number of connected devices by 2022

6 Billion

Jump from 3.8 billion in 2018 to 6 billion internet users by 2022

The demand for the Internet is driven by huge mobile penetration and digitization happening across industry verticals. To accommodate this rise in usage of internet and industry 4.0 transformation, there is a requirement for technology that can transfer data at high speeds and uninterruptedly. Companies and research organizations are developing new technologies to transfer data faster, in order to match the growing demand and to reach more audience. Technologies such as Loon from Google, Samsung's satellite idea, Amazon's Project Kuiper initiative, Facebook's satellite powered internet-beaming drone are few of the projects working towards this goal.

In this regard, Professor Harald introduced Li-Fi technology, which is gaining importance as one of the hottest new technologies emerging in the wireless communication space. The Li-Fi technology utilizes light from light-emitting diodes (LEDs) as a medium to transmit data instead of radio frequency methods. It is a faster and cheaper version of Wi-Fi (Wireless Fidelity).

This whitepaper provides a deep understanding of how Li-Fi can disrupt the digital communications industry and significantly contribute to digital transformation, the implications of Li-Fi on different stakeholders, and also deliberates on whether Li-Fi will replace Wi-Fi or Bluetooth.

Introduction

Li-Fi refers to visible light communication (VLC) technology that uses light as a medium to deliver high-speed communication in a manner similar to Wi-Fi and complies with the IEEE standard IEEE 802.15.7. Li-Fi was introduced by Professor Harald Haas at a TedGlobal Talk in 2011, where he demonstrated Li-Fi for the first time. He used a table lamp with an LED bulb to transmit the video of a blooming flower, projecting it onto a screen.

Li-Fi is a faster and cheaper version of Wi-Fi and is based on VLC technology. VLC is a data communication technology that uses visible light between 400THz and 800THz as an optical carrier for data transmission. Li-Fi uses LED bulbs to enable data transfer, boasting speeds of up to 224 Gbps.

The first Li-Fi LED luminaire was commercialized in 2016 by Lucibel and pureLiFi. A very high connection density, as well as staggering bandwidth improvements in the lab, in excess of 10 Gbps, hint on a luminous future for Li-Fi as a powerful alternative to Wi-Fi.

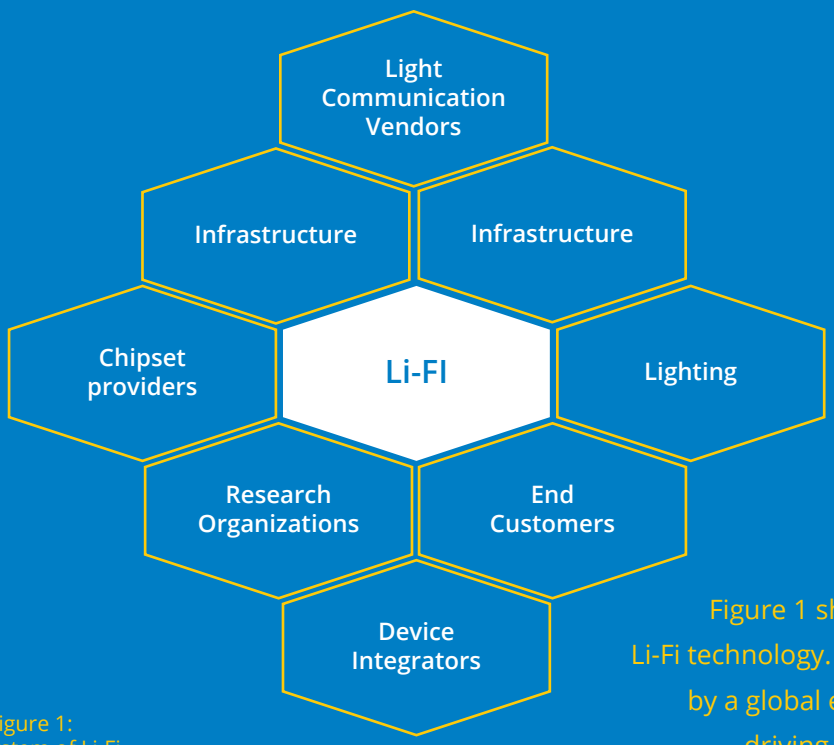


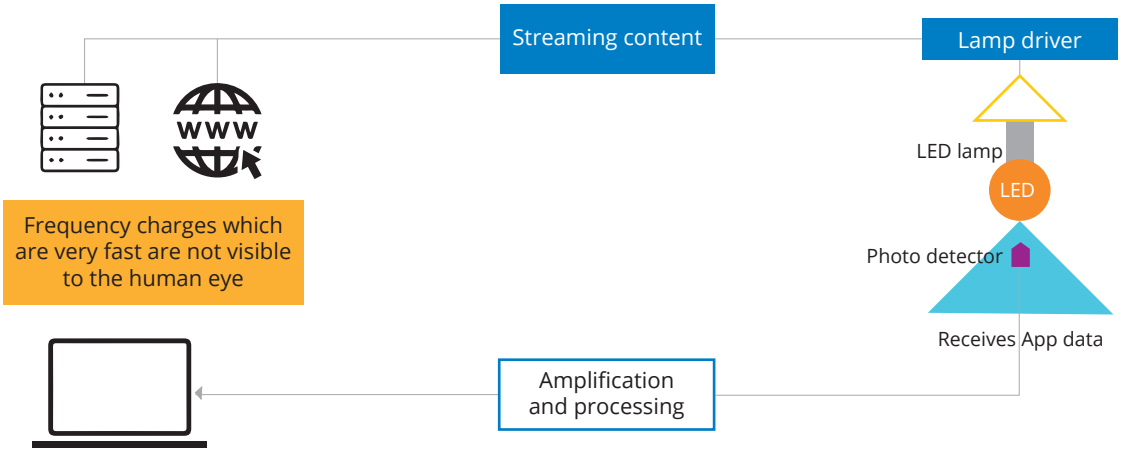
Figure 1:
Ecosystem of Li-Fi

Figure 1 shows the ecosystem of Li-Fi technology. The technology is supported by a global ecosystem of companies driving the adoption of Li-Fi

Li-Fi works on a unique principle of visible light communication technology

Both Wi-Fi and Li-Fi transmit data over the electromagnetic spectrum, but while Wi-Fi utilizes radio waves, Li-Fi uses visible light, Ultraviolet, and Infrared. The visible light spectrum is 10,000 times larger than the entire radio frequency spectrum. Figure 2 shows the block diagram of Li-Fi working. A Li-Fi system consists of a light emitter on one end, i.e., an LED transmitter, and a photo detector (light sensor) on the other. The data input to the LED transmitter is encoded into the light (technically referred to as Visible Light Communication) by varying the flickering rate at which the LEDs flicker 'on' and 'off' to generate different strings of 1s and 0s. The on-off activity of the LED transmitter enables data transmission in the light form, in accordance with the incoming binary codes: switching ON a LED is a logical '1', switching it OFF is a logical '0'. By varying the rate at which the LEDs flicker on and off, information can be encoded in the light to different combinations of 1s and 0s.

In a typical setup, the transmitter (LED) is connected to the data network (Internet through the modem); the receiver (photodetector/light sensor) on the receiving end receives the data as a light signal and decodes the information, which is then displayed on the device connected to the receiver.



Li-Fi will play an important role in the digital world to develop new use cases and to support digital transformation

Digital transformation is happening across industry verticals - smart offices, buildings, homes, automotive and healthcare industries, and governments. Li-Fi has massive potential in today's digital age, as it will add more value and will enable more use cases in this digital era with its unique features of high speed and security.

Li-Fi can add value to the autonomous car industry by enabling vehicles to communicate with each other with the help of this technology. Li-Fi enables marketers to communicate with their customers and create a unique digital customer experience. A few real-world scenarios where Li-Fi technology is being implemented for digital transformation include: the French real estate investment company Icade is piloting Philips Li-Fi-enabled luminaires at its smart office in Paris; as part of Smart City's plans to provide fast and secure internet services, Dubai is planning on implementing Li-Fi technology.

As the market for IoT devices grows and sensors are added to more and more things and places, faster and heavier data transmission will be required. The current infrastructure simply cannot handle the volume of data that will need to be transmitted, if IoT continues to grow at projected rates.

Li-Fi could become a viable solution to encourage Big Data and for IoT technologies to grow. As the existing LED lightbulb technology requires only the addition of a tiny microchip to become a Li-Fi transmitter, more than 14 billion lightbulbs in the world could be converted into 14 billion Li-Fi transmitters.

Li-Fi will create a huge impact on different stakeholders

Li-Fi impact on business: it will result in significant impact in saving infrastructure and power costs

Li-Fi presents a unique opportunity for the business sector to create new business models and to explore new use cases. Li-Fi consumes a fraction of the power that lights consume, providing significant economic savings. In addition, eliminating the power-hungry transmitters and range boosters involved with Wi-Fi, would result in an even more financially efficient office setup. The added security that is inherent to Li-Fi would decrease the strain and stress on IT and networking departments, freeing them up to tackle larger issues.

Marketers and retailers will clearly gain from the immense potential of Li-Fi. It can be used to send promotional notifications, customer guidance to products, and location tracking in a store or shopping mall. For example, a product called the GEOLiFi transmitter from Oledcomm is an indoor positioning system that transforms the lighting system into a map, enabling users to find specific products in a retail environment.

Li-Fi will open new business models in the lighting industry:

Li-Fi has enormous potential to provide innovative services and unlock new revenue streams in the lighting industry. The technology will lead to light-as-a-service (LaaS) in the lighting industry. Philips, one of the l eaders in the lighting industry, has developed a LaaS solution, where the user can pay according to usage with no down payment. Li-Fi technology can unlock the potential of IoT and drive adoption of Industry 4.0 applications.

Li-Fi offers ample number of opportunities and use cases in the areas of smart buildings, smart factories, smart homes, and healthcare and automotive industries.

Li-Fi impact on society: Li-Fi will become an integral part of every home in the coming years

Though Li-Fi is currently not adopted by the public on a large scale, it has the potential to alter society in many interesting ways. Li-Fi could equip over 4.3 billion people who thus far did not have access to Wi-Fi. With Li-Fi, there will be huge energy savings, which can be carried out using the existing infrastructure. Li-Fi has the potential to power up to 50 billion devices with today's infrastructure.

The creator of Li-Fi has said that "It is possible that Li-Fi will be present in every aspect of our lives within the next decade".

Li-Fi impact on government: Can help achieve smart city goals

Many governments have a positive outlook on Li-Fi technology. Governments are conducting pilot projects on Li-Fi technology to connect the remote and terrain areas, hospitals and to improve underwater communication. One of the biggest use cases of Li-Fi could be in upcoming smart cities, whose underlying theme is the internet of things for modern city management. Li-Fi can be implemented in traffic systems to communicate with vehicles and emergency ambulance systems.

The Governments of U.S and U.K are promoting smart LED bulbs in a big way and are developing the infrastructure base to VLC system providers. Governments are also supporting the LED industry by providing OEMs with financial subsidies, incentives, and resources, to improve manufacturing processes to drive the Li-Fi market.

Some governments, such as those of U.S, Germany, Dubai, China, Japan, and India, have a positive outlook towards promoting the LED lighting technologies.

Will Li-Fi replace Wi-Fi and Bluetooth technologies?

Li-Fi is currently attracting a great deal of interest, yet most people are unfamiliar with how it is different from other technologies like Wi-Fi and Bluetooth. Both Li-Fi and Wi-Fi can provide wireless Internet access to users. The difference is that while Wi-Fi technology uses radio waves for transmission, Li-Fi uses light waves. According to Harald Hass, the price would be 10% of a Wi-Fi system. Li-Fi can exchange data incredibly fast, securely, and at a much lower power level compared to Wi-Fi.

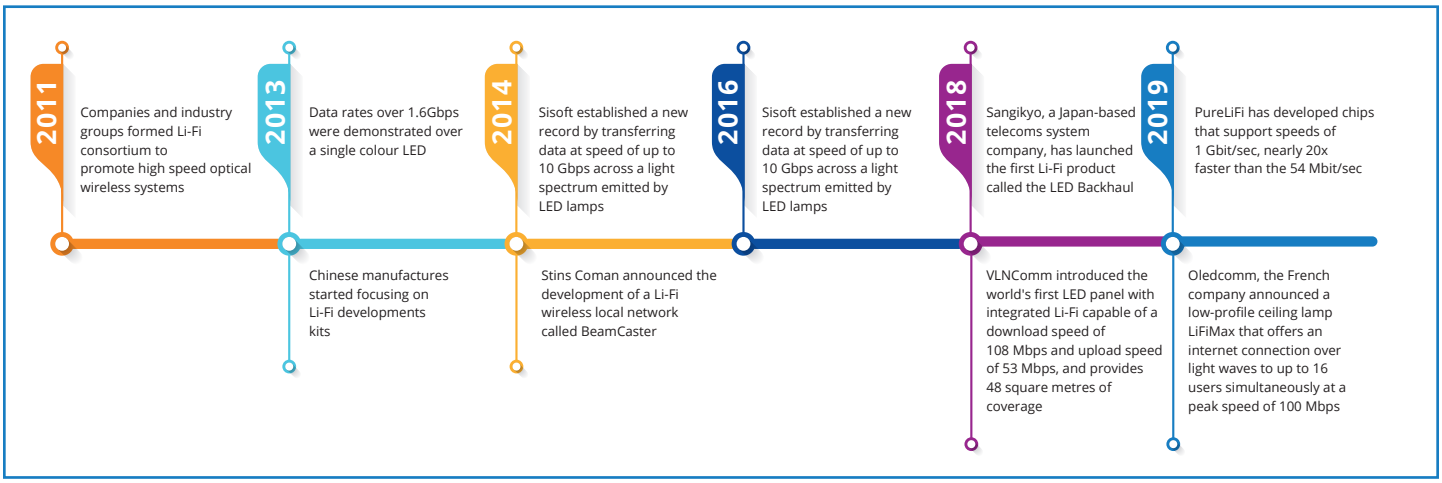
Considering the few similarities and differences between Li-Fi and Wi-Fi usage and principles, there are varied perspectives in the industry about Li-Fi taking over the Wi-Fi landscape. We believe that Li-Fi will not completely replace Wi-Fi but can instead become an incredible companion of Wi-Fi technology. In some use cases where Wi-Fi is not allowed, Li-Fi will be useful and can be an alternative to Wi-Fi.

The table below shows the comparison between Li-Fi, Wi-Fi and Bluetooth:

Parameters	Li-Fi	Wi-Fi	Bluetooth
Medium of communication	Li-Fi uses light as a medium for data communication	Wi-Fi uses radio waves for data communication	Bluetooth transmits data via low-power radio waves
Technology	Li-Fi is optical communication technology	Wi-Fi is radio communication technology	Bluetooth uses ISM Band for communication (2.402 GHz and 2.480 GHz)
Operation	Li-Fi transmits data using light with the help of LED bulbs	Wi-Fi transmits data using radio waves with the help of a Wi-Fi router	Transmits data between 2 Bluetooth devices at least
Application areas	Used in airlines, undersea explorations, hospital operation theatres, smart offices, and smart homes	Used for internet browsing with the help of Wi-Fi kiosks or Wi-Fi hotspots	Used to transmit data over short distances. Used heavily to transfer data between mobile devices and PC peripheral accessories
Level of Interference	Interference is less, can pass through salty seawater, works in dense regions	Interference is more, cannot pass through seawater, works in less dense regions	Bluetooth devices can interfere with other technologies such as microwaves
Components required	LED bulb, LED driver and photodetector	Routers, Modems and access points	Does not require any additional equipment
Data transfer rate	1 Gbps and more	100 Mbps to 1 Gbps	780 kbps
Standard	Li-Fi is present in IrDA (Infrared Data Association compliant) devices. IEEE standard 802.15.7	WLAN 802.11a/b/g/n/ac/ad standard compliant devices	Bluetooth IEEE 802.15.1
Cost	Low	High	Low

Li-Fi technology has witnessed evident developments in its short journey so far

Since the launch of Li-Fi technology by Professor Harald Haas, the technology has attracted noticeable investments and attention from the market, in terms of developing new Li-Fi solution and products



With developments occurring at a rapid pace, LED manufacturers are actively pursuing Li-Fi as a potential business opportunity

Looking at the potential growth and application areas, major companies such as GE Lighting, Oledcomm and Philips have started investing in the development of a Li-Fi ecosystem. A few prominent players and their activities in Li-Fi are:

Provides Li-Fi enabled luminaries:

Philips Lighting, one of the world leaders in lighting, is now offering Li-Fi enabled luminaires from its existing office lighting portfolio. It offers Li-Fi enabled Philips PowerBalance gen2 and Philips LuxSpace downlight luminaires.

Developing Li-Fi hardware:

pureLiFi is a Light communication company that was founded by Prof. Harald Haas and Dr. Mostafa Afgani in 2012. pureLiFi provides Li-Fi hardware systems, optical components, including Li-Fi drivers and receivers. pureLiFi developed the first Li-Fi ASIC chip to allow flexible integration.

Provides Li-Fi hardware and SDK's:

Oledcomm creates complete Li-Fi solutions such as microcontrollers (modem), Li-Fi photo-receivers (dongles and bridges) and a dedicated Li-Fi Cloud SDK, online and offline. Some of Oledcomm products include LiFi Discovery Kit, GEOLiFi Showroom Kit, LiFiMAX, MyLiFi lamps, LiFiNET street lighting, GEOLiFi OEM and MyLiFi Dongle Modem. Oledcomm, in partnership with WISeKey, has developed a solution called MyLiFiPro to provide ultra-fast, wireless internet connection with maximal security.

Smart lights and fixtures:

GE has established its presence in the VLC market with its offerings through the lighting segment. The GE LED lighting fixtures are embedded with indoor location technology. The solution integrates VLC, BLE, and inertial device sensors.

Development kits:

Nakagawa Laboratories is engaged in the R&D and sales of optical wireless communication technology. It is part of the Visible Light Communications Consortium. It aims to speed up and promote the standardization of VLC technology. Its products include Visible Light ID System Development Kit and Underwater Visible Light Communications.

In this effort to develop sustainable Li-Fi solutions, forging partnerships across the value chain will be the key to companies

The preferred strategy for companies has been partnerships and acquisitions in order to strengthen their position in the global Li-Fi market. Some of the noticeable partnerships and acquisitions materialized are:

- Philips Lighting has acquired a French company, Luciom, which is specialized in VLC, to boost its capabilities in Li-Fi
- An industry body was formed at the world's first Li-Fi forum in November 2017, which includes Orange, Nokia, Deutsche Telecom, VLNComm, pureLiFi and the University of Edinburgh, to drive broader commercial awareness of Li-Fi technology
- Another big partnership was forged between pureLiFi and Wipro in 2017, to provide Li-Fi technology for Wipro Lighting, in order to develop applications for the wireless communications and lighting market in Asia

Advantages of Li-Fi can enable numerous use cases in different verticals

Below are the advantages of Li-Fi:

Low cost & Easy deployment	The development and installation of a Li-Fi product require very few components and it can work with negligible additional power from LED lights, which can save power costs. Also, the visible light spectrum is also free to use which can save cost to user.
High speed	The combination of low interference, high bandwidth, and high-intensity output, helps Li-Fi to provide high data rates i.e., 1 Gbps or even beyond. It provides speeds that are around 100 times faster than the currently achievable speeds in Wi-Fi.
Reduction in network congestion	Li-Fi uses light instead of radio waves and the spectrum of Li-Fi is 10,000 times larger than Wi-Fi, which means that Li-Fi will have reduced network congestion.
Immune from Electromagnetic Interferences	Zero electromagnetic interference provides connectivity even in areas where Wi-Fi isn't accepted, such as hospitals, aircraft cabins and nuclear plants.
Offers high security	Li-Fi offers more data security as the light waves cannot pass through opaque structures, making it more secure and impossible to hack.
Availability	Wherever there is a light source, there can be Internet. Light bulbs are present everywhere - in homes, offices, shops, malls and even planes, which can be used as a medium for data transmission.

Unique features of Li-Fi will enable new applications, where internet is under-penetrated

Li-Fi has great potential in many popular applications, such as location-based services, mobile connectivity, smart lighting, and hazardous environments. Applications of Li-Fi can extend to areas where Wi-Fi technology lacks presence like aircrafts, hospitals, operation theatres, and power plants, where electromagnetic interference is a great concern for the safety and security of equipment and people.

Underwater communication:

As visible light can penetrate deep into water, Li-Fi can be used to communicate underwater where Wi-Fi fails, thus opening up endless opportunities for underwater military operations.

Hospitals and Medicares:

Wi-Fi is not allowed in operation theatres due to radiation concerns. In such conditions, Li-Fi can be used in place of Wi-Fi to access the internet and to control medical equipment. This will be beneficial to conduct robotic surgeries and other automated procedures.

Aviation:

Passengers in aircrafts are not provided access to Wi-Fi as it could interfere with the aircraft's navigation systems. In this case, Li-Fi can be used for data transmission. It can provide high-speed Internet via every light source, such as overhead reading bulbs, etc., which are present inside the aircraft.

Traffic management:

Li-Fi can be used in traffic signals to communicate with the vehicles (through the LED lights of cars) which can help in managing the traffic better, resulting in the smooth flow of traffic and reduction in accidents too. Moreover, LED car lights can also alert drivers when other vehicles are too close.

Education systems:

Li-Fi can provide the fastest speed for Internet access and can hence replace Wi-Fi at educational institutions so that students can avail of high-speed Li-Fi.

Safe environment:

As visible light is safer than RF, it can be used in places where RF cannot be used, such as petrochemical plants.

Smart Lighting:

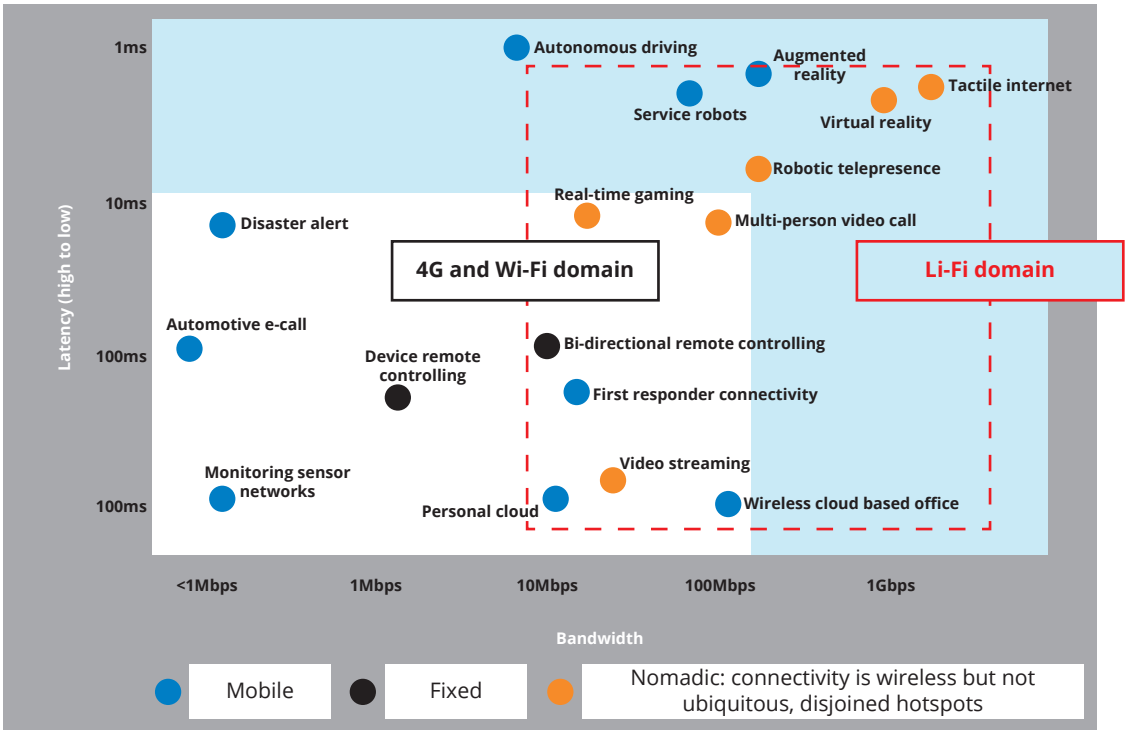
Any private or public lighting, including street lamps, can be used to provide Li-Fi hotspots. This has a two way benefit of lighting, as well as wireless communication and data transfer.

Mapping of Li-Fi, 4G and Wi-Fi application areas:

Intrinsic low latency and the potential for a very large bandwidth make Li-Fi a technology of reference for video streaming and cloud-based office, as well as for emerging use cases such as Virtual Reality and applications of robotics in the industry, in offices or in public spaces.

Commercial deployment in residential spaces relies on further cost reductions, miniaturization, and integration of the receivers' components in consumer electronics devices.

The below figure shows the different application areas of Li-Fi and 4G & Wi-Fi technologies, with respect to latency (y-axis) and bandwidth (x-axis). The applications that require low latency and high bandwidth are falling under the Li-Fi technology zone.



Regardless of the advantages of Li-Fi, standards will be crucial for large-scale Li-Fi deployments

The Li-Fi ecosystem requires standardization across providers, integrators and hardware suppliers. Li-Fi needs a meeting of many companies and two different industries - the connectivity industry and the lighting industry. Standards will help the industries to collaborate with each other in order to develop the standard protocols and working principles for Li-Fi. Standardization of Li-Fi technology helps to establish the foundation for the growth of the market and adoption of the technology on a large scale.

With lighting companies like General Electric, Philips Lighting and Osram expressing interest in Li-Fi technology, VLC standards are expected to be implemented by manufacturers of products such as mobile devices, PCs, VR goggles and VLC dongles. VLC standards also offer valuable support to the Internet of Things, a landscape composed of a very diverse set of solution providers.

Standards bodies such as the Institute of Electrical and Electronics Engineers (IEEE) and International Telecommunication Union-Telecommunication (ITU-T) have announced some standards for Li-Fi. In 2017, the IEEE announced that it is working on standards for visual light communications with the creation of a light communication study group (the IEEE 802.11 Working Group). The Visible Light Communication interest group, certified by the IEEE, with its standards approved in 2011 by IEEE as IEEE 802.15.7, is the most active one. ITU G.9991 by ITU-T details the system architecture, physical layer and data link layer specifications for high-speed indoor VLC transceivers.

The technology still has some bottlenecks that have to be addressed

Limited range	Physical barriers, such as walls and doors, limit the operational scope of a Li-Fi-enabled LED lamp. Data transmitted by a Li-Fi product remains confined within a closed space, because light cannot penetrate opaque objects and has a shorter range.
Light source reliance	In Li-Fi technology, the internet cannot be used without a light source, which could limit the locations and situations where Li-Fi could be used. Moreover, it cannot be used in an outdoor environment, like RF signal.
Unavailability of compatible technologies	It will take a few years for Li-Fi to become more practical than Wi-Fi. The existing devices such as laptops, smartphones, and tablets, are equipped with the hardware for Wi-Fi. These devices would hence not readily work with a Li-Fi network, because they do not have the necessary hardware specifications.
Light interference	There are chances that other sources of light, such as natural light, sunlight, regular electric light, etc., could interfere with the signal and affect the data transmission speeds.

Certain myths about the Li-Fi ecosystem:

Future: Li-Fi will take 5-8 years to be commercialized on a large scale

Overall, Li-Fi is a relatively simple technology that has the potential to reach speeds that are up to 100x faster than Wi-Fi. It offers greater security, reduced power consumption, and statistically significant economic savings for businesses. However, Li-Fi still needs time to grow as a product and is currently too immature a technology to be implemented on a large scale. Most industry insiders are looking beyond 2023. However, many major mobile device manufacturers are already expecting adoption of the technology in the near future.

According to industry estimates, the market size of Li-Fi is forecast to reach $75.5 billion by 2023 (includes hardware, software, and services) and this technology will grab a bit of the market share out of Wi-Fi. Currently, Europe and the United States are posting strong growth in Li-Fi market. In the future, Asia Pacific countries are also expected to show significant growth in Li-Fi adoption.

As Li-Fi becomes more commercialized in the coming years, it will result in an era of incredible business opportunities, such as allowing telecom service providers to reach out to remote areas and expand their customer base. Smartphone manufacturers can enable a wide variety of consumer use cases such as downloading traffic information from traffic lights or a television program guide. In the future, shops will transmit advertisements to smartphones directly as they pass nearby and bus schedule changes will be transmitted to a screen at the stop. Smarter home appliances that talk machine-to-machine are already being extensively researched, where LED lights on electronics, function as Li-Fi access points.

Conclusion

Despite the fact that Li-Fi is an efficient, faster and more cost-effective technology, more research and development is yet to be carried out in this area to prototype a flexible solution. Due to the rise in demand for high-speed data, the IoT market and mobile market growth, the industry has to find methods of transmitting more data and at faster speeds. Therefore, we believe that Li-Fi technology will become the next big thing in the digital communication industry and is likely to see large scale adoption in the next 5-8 years as the technology gets standardized. We are expecting to witness the implications of Li-Fi technology in many digital age application areas and also see how it helps in the widespread reach of internet across untapped geographies.

Progress through Partnership

As Li-Fi is an emerging technology in the data transfer and connectivity landscape, the industry is growing through partnerships and acquisitions. Signify (formerly called Philips Lighting), which for years has been developing alternative broadband technology that transmits Internet data using light waves from LED light fittings, has entered a partnership with one of the world's largest telecommunication firms, Vodafone, to turn the technology into a daily reality.

With this partnership, Vodafone aims to potentially make Li-Fi a part of its Deutschland's 5G network, which the company implemented in several German cities this year. The partnership could help both companies to explore new application areas and implement Li-Fi technology on a larger scale. It will also help Vodafone's 5G initiatives as both 5G and Li-Fi can complement each other in use cases such as communication in driverless vehicles to assist in braking and steering instructions, and also play other roles in machine-to-machine communications.

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