LIGHT FIDELITY

WHERE LIGHT BECOMES DATA

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Where Light becomes Data

Executive Summary

Being at the center of work, education, and communication today, internet and its stable connectivity 24/7 are of utmost importance for well-functioning of global economies.

Wi-Fi is a wireless technology that utilizes radio frequencies to transmit internet data to our phones and laptops. The radio spectrum, however, isn't infinite. With the ever-evolving need for high-speed internet and the overwhelming demand for data, we stand amidst a massive spectrum crunch. The spectrum crunch refers to the lack of sufficient wireless frequency spectrum needed to support the growing demand for high-speed internet and data transmission.

Thus, there is a need for an alternative form of wireless technology that can share the load of Wi-Fi. Light Fidelity, or Li-Fi, is a visible light communication (VLC) system that transfers digital signals through light. It combines wireless connectivity with usual overhead lighting or desk lamps, allowing users to go online all around the room. This technology, with infinite spectrum, is independent of radio frequencies. Li-Fi technology holds the potential to revolutionize the internet usage by providing access to places that Wi-Fi's radio frequencies cannot reach and transform industries through its compelling future possibilities.

Li-Fi and the science behind it

Li-Fi is a VLC system that transmits wireless internet communications at very high speeds. The technology uses emitted pulses of LED light bulb, undetectable to the human eye, to transmit data to and from receivers. Data is captured in modulated light frequencies of a solid-state LED light source and is then transmitted and received by Li-Fi-enabled devices. A photosensitive detector demodulates the light frequency signal, converts it back into an electronic data stream, thus enabling a high-speed, bi-directional, fully networked wireless communication.[1]

When on a Li-Fi network, a device, such as a laptop or a smartphone, would use its receiver to pick up the light signals and its transmitter to send the light signals back to the bulb using either visible light or infrared light. The varying intensity of the light from the LED lamps at billion times per second transforms it into a digital signal that transmits data to a user and back. A single network can contain multiple lights, allowing one to go from light to light without losing internet connectivity. Li-Fi can be used without being directly under an LED bulb since the digital signal can be carried by light reflected off walls and other surfaces. Li-Fi would still depend on a regular internet service provider to supply internet to homes or offices.

Market at a Glance

The Li-Fi market is expected to reach $4.15 billion by 2026, up from $295 million in 2020 with a CAGR of 69.7% over the forecast period 2021–2026. Li-Fi is an innovative technology that is set to disrupt many industries. The technology can increase the potential of Internet of Things (IoT), drive Industry 4.0 applications, and lead to the upcoming Light as a Service (LaaS) in the lighting industry. North America is currently the largest market, however, due to a catch-up effect, Asia-Pacific is the fastest-growing market.[2]

With increasing research on Li-Fi networking techniques, such as multiuser access, interference mitigation, and the development of Li-Fi products, there have been more instances of wireless networking with light over the last few years. Moreover, as energy efficiency via smart homes and smart cities increase, Li-Fi technology can penetrate these applications to benefit from the growth in the smart home and smart city markets.

1. LiFi.co
2. Mordor Intelligence report, 2021

Wireless Technology Landscape

Comparison between Li-Fi and Wi-Fi

Data requirements and usage are growing exponentially with the amount of data on the internet likely to double with the rise of smart cities, Industry 4.0, connected vehicles, and other disruptive technologies. As we are advancing from 4G to 5G networks, the radio frequency spectrum (a scarce natural resource) is getting congested, limiting the availability of bandwidth as well as the indoor and rural reach required by new technologies, applications, and solutions on the horizon. This oversaturation of the radio frequency spectrum is what we know as the 'Spectrum Crunch'. This puts constraints on the increasing demand for ubiquitous connectivity with varied bandwidth capability. Wi-Fi is the legacy incumbent of indoor wireless networking but will very soon suffer from spectrum crowding.

However, Li-Fi technology does not use radio frequency. It uses the light spectrum, which can open up 1000 times more spectrum than radio frequency.

Telecom operators are looking for more and more ways to tackle the problem of spectrum overcrowding and making efficient use of the limited allotted spectrum (along with increasing numbers of other users of the same scarce unlicensed spectrum). Emerging technology like Li-Fi offers a much better performance fit, augmenting the existing wireless technologies like Wi-Fi, 5G, and Bluetooth.

Table 1: Comparison between Li-Fi and Wi-Fi[1]

Parameters	Li-Fi	Wi-Fi
Operation	Li-Fi transmits data using light with the help of LED bulbs	Wi-Fi transmits data using radio waves with the help of Wi-Fi router
Interference	Does not have any interference issues that are present in radio frequency waves	Will have interference issues from nearby access points (routers)
Technology	Present IrDA compliant devices	WLAN 802.11a/b/g/n/ac/ad standard compliant devices
Applications	Used in airlines, undersea explorations, operation theatres in the hospitals, office and home premises for data transfer and internet browsing	Used for internet browsing with the help of Wi-Fi kiosks or hotspots
Advantages	Interference is less, can pass through salty sea water, and work in a dense region	Prone to interference, can't pass through sea water, only work in less dense regions
Privacy	Light is blocked by the walls, therefore more secured on data transfer	For RF signals, dry walls are transparent, requiring techniques for secure data transfer
Frequency of Operation	10,000 times frequency spectrum of the radio (In the Tera Hz range)	2.4GHz, 4.9GHz and 5GHz
Data Density	Can work in a high dense environment	Can only work in less dense environment due to interference issues
Coverage Distance	About 10 meters	About 32 meters (WLAN 802.11b/11g), vary based on transmit power and antenna type
System Components	Lamp driver, LED bulb and photo detector	Routers, subscriber devices referred to as stations
Data Transfer Speed	About 1 Gbps	WLAN-11n offers 150Mbps, About 1-2 Gbps can be achieved using WiGig/Giga-IR

1. Government of India study paper on LiFi

Challenges with Li-Fi

Limited Range

Wi-Fi has a range of 32 metres in open environments, while Li-Fi has a range of 10 meters, limiting the use of Li-Fi in open environments.

Limited Compatibility

Most of the electronic devices currently do not have the Li-Fi compatible hardware and software systems. However, a few smartphone companies are developing technologies to integrate Li-Fi into their next generation telecom devices.

Interference from other light sources

Sunlight and light from other sources can interfere with the Li-Fi from an LED, disrupting the data transmission. One possible solution would be to use infrared light for transmission, but long exposure to infrared is not suitable for humans.

High initial cost to deploy

Most LED bulbs today do not support Li-Fi technology as they need special adaptors or complete replacement with the Li-Fi compatible ones. Also, as LED bulbs are needed at all corners for robust Li-Fi signals, this would imply higher implementation costs. Still, as Li-Fi adoption rate improves, such costs are expected to reduce.

Use Cases

Li-Fi is a powerful technology that holds the potential to revolutionize the world of wireless communication by providing a secure, faster, and safer medium that will fill the gaps in current wireless data transmission by Wi-Fi.

A few key characteristics of Li-Fi technology - directional lighting, intrinsic security, energy efficiency, signal blocking by walls, and high data transmission speed capabilities - open pathways for its diverse applications. The following are a few examples of real-life use cases of Li-Fi.

Dense Urban Environments

Artificial lighting infrastructure in closed environments like exhibitions, conferences, airports gives users access to high-speed internet where they can download, receive, and send data at high speeds. As the light waves won’t propagate through walls, the wireless communication is interference-free and secure.

Underwater Communication

Traditional Wi-Fi cannot be used underwater as radio waves get absorbed by water . On the other hand, Li-fi technology uses visible light to penetrate deep into water, improving the way underwater vehicles and drivers communicate.

Augmented Reality (AR), Virtual Reality (VR) and Mixed Reality (VR)

Wi-Fi technology is used on these platforms, but the experience can be slow and sluggish when the number of devices connected to a Wi-Fi network rises. With the influx of Li-Fi technology, the speed and latency will improve, thereby improving the AR/VR/ MR experiences for users.

Aviation Industry

Li-Fi technology can be used in airline cabins and aircraft interiors, enabling people to enjoy seamless and safe data streaming, downloading and communication without creating electromagnetic interference (EMI) with sensitive radio equipment on the flight deck.

Hazardous environments/ Sensitive areas

The use of Li-Fi can simplify network configuration in hazardous environments or sensitive areas, as radio communication interference is considered dangerous for such environments or their products. For example, the use of cell phones are prohibited in dangerous explosive environments like [1]nuclear power plants and laboratories. Similarly, petrochemical industries have products that are sensitive to radio frequencies.

Intelligent Transportation Systems

With car headlights and tail lights being replaced with LED bulbs, opportunities open up for connected vehicle communication over Li-Fi. This allows for the development of anti-collision systems and information exchange systems on driving conditions between vehicles. This can also be extended to road elements for smart traffic control. Traffic management systems can be deployed over Li-Fi using the LED lighting of traffic light infrastructure. This would enable car systems to download real-time information from the network and have real-time information on routes, road conditions, and traffic.

Industry 4.0 trend, Artificial Intelligence, Big Data, Machine Learning, and Industrial IOT

Wi-Fi systems in industries currently face limitations due to poor coverage in all areas of factories, and hence, ethernet is used to transmit the instructions to the robotic arms. But this if replaced by Li-Fi, light receivers can be put in positions where nothing can disrupt the light signals, allowing the internet connection to be transmitted to the robotic arms in a more efficient and faster way, ensuring maximum data security.

Data Centers and Cybersecurity

The nature of visible light is that it cannot penetrate opaque walls and therefore connection is confined within the space in which it is shone. This prevents unauthorized access to the Li-Fi connection, adding another layer of security to the network.[1]

Li-Fi and The Future Ahead

As light and LEDs are ubiquitous, Li-Fi technology has tremendous potential in various fields. With the potential to supplement and support the telecom industry and position itself as a catalyst in the autonomous vehicle ecosystem, there are a few examples of possible future use cases where this technology can add high value.

1. LiFi.co

5G and Li-Fi, A Match made in Connections

As the world leaves behind 4G to embrace 5G, it looks forward to a much faster and robust network that has the lowest latency and greater capacity.

However, 5G's frequency range is short, potentially reducing its effectiveness in its market wide implementation. This is where Li-Fi, with its data transfer rate of greater that 1 Gb/s, can be a complementary technology to 5G that ensures no data is lost during the transmission and the latency is matched. With Li-Fi systems based on LED bulbs and being cheaper compared to Wi Fi, we can see higher adoption of 5G with Li-Fi in various industries.

To test this hypothesis, Signify, a leading lighting company, and Vodafone Deutschland have collaborated to integrate the two communication technologies, 5G and Li-Fi, and develop applications and solutions to deliver a secure and reliable two-way wireless communication at higher speeds. [1]

Disruptions in radio frequencies in industrial settings due to reflections off of large objects, or doppler effects, or shadowing from solid objects, or diffraction from sharp objects, or scattering due to small objects can lower its data transmission ability. The combination of 5G and Li-Fi offers advantages for industrial customers, and in their use of IoT devices by enabling reliable and secure high-speed wireless communication with low latency in areas where certain radio frequencies perform poorly or where wireless communications are not allowed.

Connecting the world with Connected Cars

Vehicle to Vehicle Communication (V2V System)

Segula Technologies along with Ascia Technologies has designed a system that uses Li-Fi technology to transmit data between vehicles via the front and rear lights of the vehicles. This system can be used to maintain suitable distances between two vehicles, and in the future, could be used to create convoys of autonomous vehicles.[2]

The use of Li-Fi for vehicle-to-vehicle communication would help in instant sharing of information that includes the vehicle's speed, braking distance, objects in front of the lead vehicle, or other details, such as loss in stability of a vehicle, which improves the situational awareness of the vehicles nearby. Road accidents can be reduced with enhanced vehicle communication and seamless data transfer. For example, if the car ahead brakes suddenly, the information can be transmitted in real-time to the trailing vehicle and the artificial intelligence system in that vehicle can lower its speed accordingly. Thus, Li-Fi in vehicle-to-vehicle communication can enable faster data transmission and prevent possible road mishaps.

Vehicle to Infrastructure (V2I systems)

Along with establishing vehicle communication networks, road infrastructure needs to be transformed by making road surfaces, signs, traffic, and street lighting smart to ensure the safety of autonomous cars. Bi-directional connection between cars and road elements needs to be considered as a major use case of Li-Fi for smart traffic control for vehicle-to-infrastructure communication.

1. Signify.com
2. Segulatechnologies.com

V2I communication with Li-Fi, like V2V communication, will add to road safety by allowing rapid exchange of data between vehicles and infrastructure. For example, under low visibility conditions like heavy rain or fog, Li-Fi technology can readily relay pavement markings and signpost information to vehicles. A vehicle's dashboard and automatic audio tracks can incorporate Li-Fi transmission sources to display comprehensive information on possible speed restrictions, sharp bends, and work zones on the travel routes. This can reduce accidents due to unanticipated road and weather conditions.

Conclusion

Li-Fi provides a significant increase in speed, bandwidth, and latency when compared to Wi-Fi which makes it a worthwhile upgrade. When you add in cheaper infrastructure costs, increased data security, and access to locations where radio frequencies aren't available, Li-Fi becomes an even more compelling technology to complement today's wireless infrastructure. The extensive growth in the use of LED lighting infrastructure for illumination provides a huge opportunity to integrate the Li-Fi technology into a plethora of environments and applications. With this integration, we can chase 10x the speed of current-day data transmission. Li-Fi perfectly addresses the issues with spectrum crunch and has opened a new door for several use cases. However, Li-Fi does have implementation challenges and the technology is yet to be adopted fully on a commercial scale. Nevertheless, with companies such as Signify, Segula, and Vodafone experimenting in the Li-Fi landscape, this technology can soon be the way forward to migrate to cleaner, greener, and safer communication networks.

Glossary

- Li Fi - Light Fidelity
- VLC - Visible Light Communication
- LED - Light Emitting Diode
- CAGR - Compounded Annual Growth Rate
- LaaS - Light as a Service
- IrDA - Infrared Data Association
- WLAN - Wireless Local Area Network
- RF - Radio Frequency
- EMI - Electromagnetic Interference
- IoT - Internet of Things
- V2V - Vehicle to Vehicle
- V2I - Vehicle to Infrastructure

Sources

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