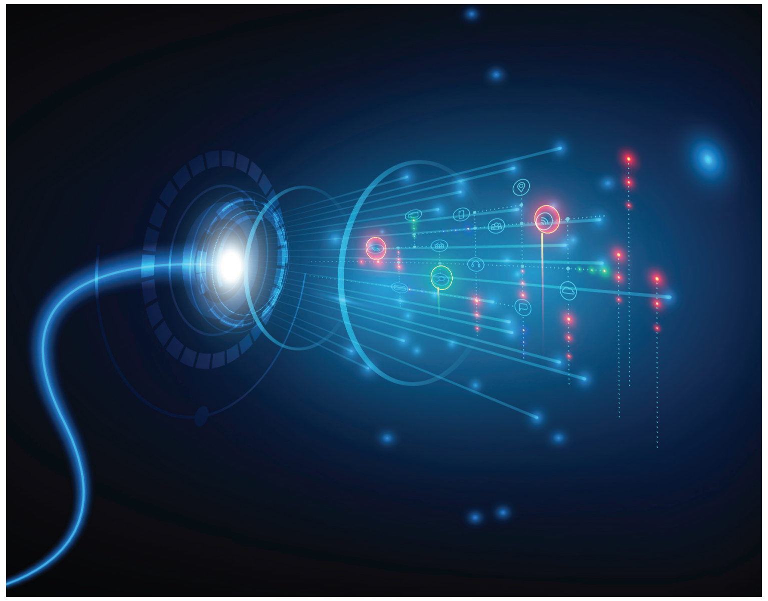


WHAT IS LiFi?

Imagine getting your Internet through beams of light instead of radio waves. The pros, cons, current progress and future potential of LiFi

By Randy Reid

Readers may only be vaguely familiar with LiFi, but the technology's expected market growth demonstrates its increasing importance in our industry. Today, connectivity across the world continues to rise. Cisco estimates the number of connected devices will reach 50 billion by 2020, and traffic over Wi-Fi will increase 640% by 2021. Simultaneously, the global market for LiFi technology—a potential solution for Wi-Fi's throughput and bandwidth limitations—is expected to reach $35.82 billion by 2028, representing a 71% increase from 2018. Here's an overview of how LiFi works, where it's being used and what's on the horizon.

LiFi enables wireless data transmission featuring optical networking technology using light-emitting diodes (LEDs). Think of getting your Internet through beams of light instead of radio waves, as with Wi-Fi. With LiFi, for example, a user would choose a 4K movie from Netflix and that specific movie would download to the user's laptop in a few seconds using beams of light.

There are two types of LiFi: bi-directional (also known as omni-directional or two-way LiFi) and mono-directional (also known as one-way LiFi). Bi-directional LiFi allows users to send and receive data through the light spectrum. Mono-directional LiFi only allows users to receive data through the light spectrum. Bi-directional LiFi typically uses high-speed photodetectors to provide gigabit per second connection speed, while mono-directional LiFi usually uses cameras for data reception at speeds lower than 1 megabit-per-second (Mbps).

First, let's look at the better-known bi-directional LiFi. Imagine a LiFi-enabled downlight, connected to a CAT 6A cable. The luminaire features Power over Ethernet (PoE), so the only connection required is the CAT 6A cable going back to a router. The luminaire will send data in binary code. Unfortunately, laptops, tablets and smartphones are not designed to receive LiFi signals, so those devices have to be equipped with a decoder, or dongle, to convert the 0s and 1s into meaningful data. The actual transmission uses the light spectrum, which offers many advantages over the radio spectrum that we currently use with Wi-Fi.

LiFi uses the optical bandwidth, which includes both visible light (400-700 nanometers) and also can include infrared light (700 nanometers to 1 millimeter). It is important to emphasize that the optical bandwidth is about 2,600 times greater than the radio frequency bandwidth. Most product manufacturers use Visible Light Communication or VLC, as LiFi was originally conceived, providing both high-quality light and high-speed data.

The advantages of bi-directional LiFi over Wi-Fi are many, but the two most important benefits today are security and speed. In terms of security, LiFi technology is essentially line-of-sight. The word "essentially" is important here because the decoder must be in the presence of the light to receive the signal, but it does not have to be directly under the light, as LiFi can be transmitted using reflected light. Wi-Fi, on the other hand, penetrates walls and buildings, so a hacker could capture a Wi-Fi signal and break into a system while sitting in a car outside of an office. LiFi is more secure because the bad actor would have to actually break into the building and sit under the light to steal the signal.

This is why the U.S. Army is one of first users of LiFi. When I was president of IES, and on active duty during Operation Iraqi Freedom, there were buildings where we were not allowed to bring phones or laptops because of sensitivity to hacking. LiFi can almost eliminate the risk of signals being stolen outside of designated areas. Also, the U.S. Army likes the dongle because it is another security point. Soldiers are required to turn in their dongles at the end of the day.

Speed is probably the best-known benefit. At LIGHTFAIR in 2018, my company, LumEfficient, won an Innovation Award for our LiFi downlight, which measured 32 Mbps download speed. At CES in Las Vegas and at LEDucation earlier this year, we displayed LiFi at 100 Mbps using an infrared version of LiFi. At the Mobile World Congress 2019 in Barcelona, PureLiFi demonstrated 1 gigabit-per-second (Gbps), so the speed continues to increase. The theoretical limit is 224 Gbps.

There are, however, some drawbacks to bi-directional LiFi. For one, the industry has not agreed on a standard for bi-directional LiFi. In addition, a LiFi module has to be added between the driver and the LEDs in the luminaire and an infrared receiver must be installed enabling the fixture to receive the upload data. Thus, retrofit applications are not very practical. However, it is relatively simple for the OEM to add LiFi in the factory.

One of the greatest drawbacks to bi-directional LiFi is the need for the dongle to send and receive data. iPads and smartphones don't have USB ports, so an adapter is required. In 2019, no one wants to use a dongle, much less an adapter and a dongle. This is where mono-directional LiFi is useful.

Mono-directional LiFi uses the camera on smartphones or tablets to capture data. It is important to note that the camera is capturing data rather than images, as receiving images would dramatically deplete battery life. Receiving data does not.

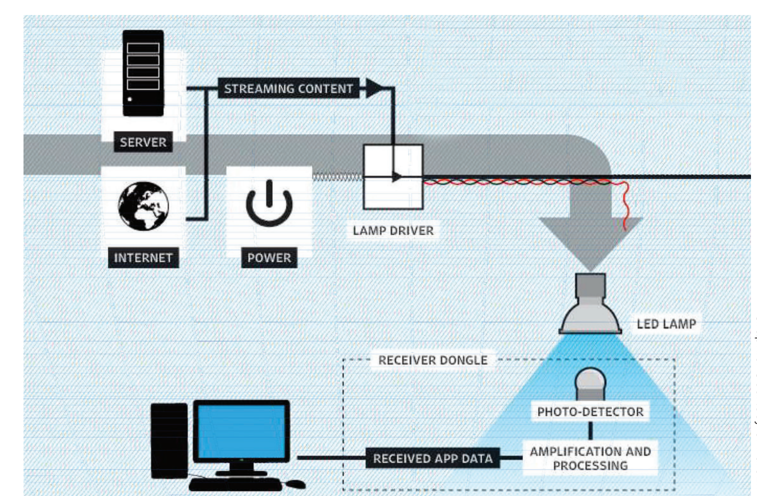
With mono-directional LiFi, one can only receive, but not send, data. In this case, Netflix could download a movie to the phone, but the user could not tell Netflix which movie to download. Because mono-directional is one way, users cannot surf the Internet.

However, there are areas where one-way communication is practical, such as in museums. In a museum setting, a patron would simply scan an opt-in QR code upon arrival. Individual lights would be matched to individual exhibits and the patron would receive specific information about that exhibit on their smartphone when standing under the light associated with that exhibit. The transmitted information can be in the form of a text file, a PDF, an audio file or a video file. It doesn't matter.

The problem is that the Optical Camera Communications (OCC) in smartphones and tablets is relatively slow to receive data—too slow to be practical for museums—which is why the industry developed three solutions for mono-directional LiFi.

1. *Store-on-the-phone.* When the patron scans the opt-in QR code, the software and individual files for specific exhibits are downloaded. Upon arriving under a mono-LiFi enabled luminaire, the luminaire would simply transmit the address of the fixture and that address would queue a specific file associated with that address, which has already been installed on the smartphone. In this case, the only data being transmitted is the address, not the actual video file. Store-on-the-phone LiFi is great for small galleries with a limited number of exhibits, but it is impractical for large museums, as there would not be enough space on the phone or tablet to download these files. Thus, a second type of mono-directional LiFi was developed, store-on-the-cloud.

2. *Store-on-the-cloud* works the same way, except when the patron scans the opt-in QR code, only the software and opt-in agreement is loaded, but not the individual files. Upon receiving a signal from an individual light at an exhibit, the smartphone would queue the appropriate file from the cloud, either using Wi-Fi or mobile to receive that



Graphic: Courtesy of PureLiFi

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

LiFi is more secure because the bad actor would have to actually break into the building and sit under the light to steal the signal

file. Again, the only data being transmitted from the light is the address of the fixture.

3. *OCC*. Imagine downloading flight information at the airport by pointing your phone at the flight status screen. Because the user is not downloading pictures, the camera in the phone would be fast enough to capture this flight information.

Carrefour and Orange are two of the largest European companies experimenting with mono-directional LiFi. In the U.S., Hartsfield International Airport in Atlanta has installed LiFi as well as beacon technology but, as of this writing, it is not being utilized.

The price of bi-directional luminaires is decreasing; however, until the dongle is built into devices, LiFi will not reach mainstream. The good news is that Apple began installing LiFi drivers (but not receivers) into their iOS systems beginning in 2016. The bad news is we haven't seen any public information from Apple on LiFi since then.

Mono-directional modules sell for about $50 and can easily be adapted to installed fixtures or to new fixtures at the OEM factory level. No CAT 6A cable is required. Today, mono-directional LiFi is practical and economically viable. While bi-directional LiFi is perfect for operations security (OpSec) areas such as the military or banking industry, and is also well suited for early adopters, it is still a few years away from being mainstream. ◎

This article is based on the author's presentations at the 2018 IES Annual Conference and the 2019 LEDucation Conference.

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