Wi-Fi and Li-Fi Towards 5G: Concepts, Opportunities, and Challenges

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I. INTRODUCTION

Fifth generation (5G) access expected to be obtainable after 2020 will be able to satisfy demand for ever increasing data rates and low latency. In comparison to already accessible 4G technologies, 5G targets high throughput using more bandwidth and high frequencies at low cost and reduced power consumption. More bandwidth is needed to be allotted to 5G and available bandwidth is to be used more effectively than the previous generation. As the demand for wireless voice and data services has increased, the number of mobile devices with multimedia capabilities and Internet access is expanding rapidly. The user's main activities utilizing data capacity now and in the coming years are watching HD streaming movies and videos, playing online games, and accessing cloud-based services. In a few years, most of the data traffic is likely to occur from indoor locations and operators are struggling to meet this demand while maintaining adequate service quality. In comparison to outdoor propagation, indoor wireless medium exhibits high demand for video and cloud-based data expected to increase, and it is a major impetus for the adoption of the additional spectrum including the use of optical wireless media, making the design of 5G indoor communication systems even more challenging. In terms of network topology, heterogeneous networks (HetNets) will play a key role in integrating a diversified spectrum to provide high quality-of-service (QoS), particularly in a wide range of wireless coverage zones, such as open outdoor environments, office buildings, homes, and underground places.

Fig. 1. Demonstration of Li-Fi and Wi-Fi

II. ENHANCEMENT OF LI-FI OVER WI-FI

High signal strength in indoor access Wi-Fi networks indicates a fast and reliable Wi-Fi connection, except in dense Wi-Fi networks where the connection is possible using the concept of tree topology (multiplexing) with the collapse of the frequency band from neighboring Wi-Fi routers and shifting the connection from one router to another establishes network disconnection. Light fidelity (Li-Fi) technology solves these problems by using a peer-to-peer network (oneto- one communication) to make connectivity more secure, fast, and simple to use. High interference signals from surrounding Wi-Fi APs and/or several active users sharing a Wi-Fi AP's limited bandwidth can also cause slow connectivity in Wi-Fi, which is resolved in Li-Fi because the property of light is that it travels faster in the air (Refraction of Light) with the same polarization as light is emitted in all directions as series of waves having the same speed for all users in one space using Li-Fi technology with excellent connectivity. Li-Fi is recommended for high-speed connectivity, but it has some drawbacks, it provides the ideal speed for short ranges, especially in indoor facilities. When it comes to long-distance connectivity, Wi-Fi is the better because it uses radio frequency (RF) waves for connectivity, which are generated from towers that are spaced evenly apart, as well as the Wi-Fi technology, which uses a router and modem for its connection, which has (RJ45) Ethernet port that can be easily connected to computers and laptops by a simple Ethernet cable for experiencing high speed.

III. THE STATE OF WIRELESS AND MOBILE COMMUNICATION

Wi-Fi's wavebands have a high absorption rate and are best used in a line-of-sight environment. Higher frequencies and additional spectrum are being considered in the Wi-Fi development to achieve multi-Gb/s peak data speeds (60 GHz) indoors and to serve multiple users concurrently. Many common obstacles, like walls, pillars, and home appliances, can significantly restrict range, but this also helps avoid interference between multiple networks in congested areas. Indoors, an access point (or hotspot) typically has a range of roughly 20 meters (66 feet), but some newer access points claim a range of up to 150 meters (490 feet) outdoors. Hot spot coverage can be as limited as a single room with radio-wave blocking walls, or as vast as many square kilometers (miles) with roaming allowed between overlapping access points. Although line-of-sight is ideal for Wi-Fi signals, they can transmit, absorb, reflect, refract, diffract, and up and down fade through and around man-made and natural structures. Metallic structures (such as rebar in concrete and low-e coatings in windows) and water have a significant impact on Wi-Fi transmissions (such as found in vegetation). Because of the complicated nature of radio propagation at standard Wi-Fi frequencies, especially around trees and buildings, algorithms can only forecast Wi-Fi signal strength for any given location concerning a transmitter to some extent [1].

The IEEE 802 protocol family includes Wi-Fi. At the data link layer, the data is structured into 802.11 frames, which are essentially like Ethernet frames but have additional address fields [2]. For LAN routing, MAC addresses are utilized as network addresses. IEEE 802.11 defines the MAC and physical layer (PHY) specifications for modulating and receiving one or more carrier waves in the infrared and 2.4, 3.6, 5, or 60 GHz frequency bands to transport data. The IEEE LAN/MAN Standards Committee designed and maintains them (IEEE 802). The standard's first version was published in 1997, and it has since undergone numerous revisions. The standard and revisions form the foundation for Wi-Fi-branded wireless network products. While each modification is legally withdrawn when it is included in the most recent version of the standard, the business sector prefers to sell to the revisions since they succinctly express product capabilities [3]. However, defining such a new model of simultaneous transmissions to numerous users that is backward compatible will necessitate a significant standards effort. Furthermore, with a larger number of antennas, there are complexity restrictions. The difficulty of linear MIMO equalizers is generally known to scale with N3, where N is the number of antennas, whereas optimal scheduling difficulties, particularly between the beams of several nearby APs, are NP-hard. A workable solution has recently been developed because of these standardization, scalability, and complexity difficulties, as well as the growing demand for Wi-Fi, scalability is limited, and alternate wireless media should be considered [4].

IV. INCREASING CAPACITY AND DENSITY

Due to the issues, we propose an additional tier in wireless HetNets made up of indoor gigabit SCs to provide additional wireless capacity where it is most needed. In a HetNet, where RF microcells, RF-SCs, and O-SCs comprise a three-layer network, Li-Fi-enabled indoor luminaires (lights) can be depicted as optical SCs (OSCs). The performance of a single Wi-Fi AP or numerous Wi-Fi APs should be improved by offloading traffic to the most localized and directed Li-Fi. Aside from high-speed traffic unloading and seamless connectivity, the proposed Li-Fi Wi-Fi system also has certain novel characteristics, such as improved O-SC security and indoor location [5]. According to operators, 80 percent of mobile traffic happens indoors; thus, the combination of Li-Fi and Wi-Fi has a lot of promise in future HetNets, including next-generation (5G) mobile telecommunications systems [6, 7]. To our knowledge, current research focuses on improving the performance of each of the technologies separately, despite the evident need for reliable Wi-Fi and Li-Fi coexistence solutions [8].

Li-Fi-enabled light fixtures, or luminaires in lighting jargon, give data access to stationary and quasi-stationary mobile users, as shown in Figure 2. This strategy can reduce congestion and free up RF resources to serve users who are more mobile or outside of the Li-Fi coverage region. More highly mobile customers will be able to rely on the Wi-Fi network's expanded coverage. User devices (UDs) in the Li-Fi and Wi-Fi network must be Li-Fi-enabled. The evolution of cellular networks can be used as a benchmark for evaluating the development of Li-Fi-enabled devices.

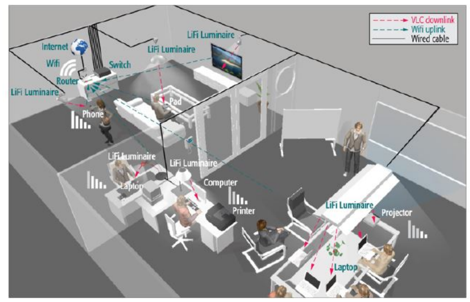

Fig. 2. The proposed Li-Fi and Wi-Fi HetNet

Mobile technologies, which have progressed from 1G to 4G, have paved the way for the marketing of increasingly powerful and pricey consumer devices. Li-Fi-enabled smartphones provide manufacturers with significant economic potential by enabling richer mobile broadband experiences. Most current smartphones support numerous radios and protocols out of the box. Even while the Li-Fi and Wi-Fi network will most likely be asymmetric, with Li-Fi serving as the downlink, this should free up Wi-Fi system capacity to accommodate any future traffic-uploading expansion.

V. MODULATION TECHNIQUES FOR LI-FI

Single carrier and multiple carrier modulation techniques are the most common modulation techniques used in Li-Fi systems. Single carrier modulation approaches include on-off keying (OOK), pulse position modulation, unipolar pulse amplitude modulation (PAM), pulse width modulation, and pulse amplitude modulated discrete multi-tone modulation. These low-speed single carrier modulation schemes are simple to implement. Because of its simplicity, the OOK modulation is more popular for low-medium data rate transmission. A bit ”1” is represented by an optical pulse in OOK, whereas a bit ”0” is represented by the absence of an optical pulse. The most prevalent types of OOK are the return-to-zero (RZ) and non-return-to-zero (NRZ) schemes. The bit duration is equal to the duration of the transmitted pulse to indicate ”1” in the NRZ scheme, but they are not equal in the RZ scheme, i.e., the pulse fills only a portion of the bit ”1”. Single carrier modulation systems are known to be susceptible to inter-symbol interference (ISI). As a result, applying these modulation techniques requires more complicated equalizers at the receiver to counteract the ISI over the dispersive channel as the needed data rate grows. Multi-carrier modulation techniques are more spectrum efficient than single carrier modulation schemes and can provide larger data speeds. The introduced ISI in Li-Fi systems is the result of signal transmission across a dispersive optical channel at high data rates while also using off-the-shelf bandwidth-constrained LEDs. OFDM has several advantages, including 1) efficient use of spectrum, 2) channel robustness against frequency selectivity by splitting it into narrowband flat fading subcarriers, 3) simple channel equalization by using a singletap equalizer (while adaptive equalization techniques are used in single carrier modulation schemes), and 4) computational efficiency by using fast Fourier transform (FFT) and inverse FFT (IFFT) techniques.

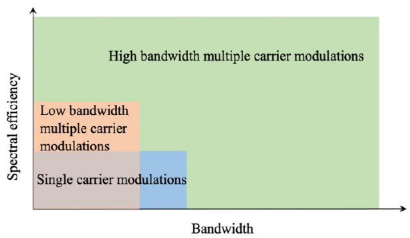

Fig. 3. A comparison of single carrier and multiple carrier modulations in terms of spectral efficiency

The proposed Li-Fi and Wi-Fi HetNet is put to the test utilizing bidirectional high-speed Li-Fi transceiver devices that supply real-time data and meet the OSI protocol stack layers 1 and 2. The gadget, whose principle is depicted in Figure 4, employs a high-power phosphorus-converted LED (PC-LED) that can provide both illumination and data transmission in tandem. An analog modulation bandwidth of up to 180 MHz is achieved using a customized LED driver. A large-area high-speed silicon PIN photodiode is employed in the receiver, along with a trans-impedance amplifier (TIA). Both the LED and the photodiode use a plano-convex 1" lens to focus the beam and increase the receiving area, respectively. A digital baseband unit (BBU) sits behind the analog transmitter and receiver circuitry, converting Ethernet packets into DC-biased orthogonal frequency division multiplexing (OFDM) signals and vice versa. The OFDM signals have a 70 MHz bandwidth. To reconstruct the received symbol constellations, the BBU uses pilot-assisted channel estimation and frequency-domain equalization. The error vector magnitude (EVM) is calculated from the received pilot sequence and sent back to the transmitter. The bit loading is adjusted based on the channel quality as a function of frequency.

VI. CONCEPTUAL EXPERIMENT

A proof-of-concept hybrid Li-Fi and Wi-Fi configuration is constructed [14, 15], using a single Wi-Fi AP and a single Li-Fi AP. Three systems are compared in this article. The Wi-Fi is solely used to connect to the Internet in the first version. The second system, known as a hybrid system, is like the first, but one of the users' downlinks is connected via a Li-Fi link. In the third method, known as an aggregated system, one user is simultaneously connected to both Wi-Fi and Li-Fi. Figure 4 shows the hybrid system (a) and aggregated system (b) designs (b). The unidirectional Li-Fi link is used in the hybrid system to supplement the traditional Wi-Fi downlink, whereas, in the aggregated system, both bi-directional Wi-Fi and Li-Fi links are completely employed to increase possible throughput and offer reliable network connectivity.

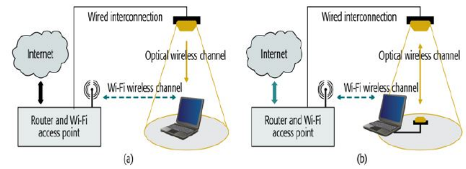

Fig. 4. configurations of the a) hybrid system, and b) the aggregated system

The average throughput of the three systems was tested at various distances between the Wi-Fi and Li-Fi frontends in Figure 4a. The Li-Fi frontends are perfectly aligned in this design (i.e., zero off-axis displacement). The Wi-Fi router's setting is set to "up to 54 Mb/s" to ensure reliable connectivity in a congested environment. Although the Wi-Fi signalling strategy is in principle dependent on the received SNR, the Wi-Fi-only throughput displayed in Figure 6a is nearly constant in the Li-Fi AP's coverage area because Wi-Fi performance degrades when the distance exceeds 25 meters, where VLC connectivity is already absent. Near the Li-Fi AP, the hybrid system more than doubles throughput, but it quickly degrades as distance rises. When the distance is raised to roughly 4.1 m, the throughput of a Wi-Fi-only system exceeds that of a hybrid system, because the downlink capacity of Li-Fi declines with distance, eventually becoming inconsequential. It's worth noting that the hybrid VLC system's throughput statistics are solely dependent on the Li-Fi downlink's capacity.

CONCLUSION

This survey opens several doors for field research on the existence of both Wi-Fi and LIFI, with Li-FI giving an enhanced interior experience by delivering high data speeds and security, and Wi-Fi providing increased off-loading opportunities. HetNets are useful in this situation because they provide additional wireless bandwidth at the required location, resulting in increased indoor connectivity. Li-Fi has evolved into a ubiquitous system technology with unique networking capabilities for universal application, allowing a variety of device platforms to connect over the internet at high rates. The integration of two technologies produces an output that is needed in the field.

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