Emerging Technologies for the Future IoT: An experimental analysis of LIFI Networks

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***Abstract*—The future Internet of Things (IoT) will evolve into highly dynamic and intelligent ecosystems capable of supporting billions of interconnected devices powered by next-generation wireless technologies, such as 6G, Wi-Fi 7, LiFi, and Bluetooth 6.0. These technologies will provide ultra-low latency, high reliability, high throughput, and massive device connectivity. In this paper, we focus on LiFi, a new and promising technology for wireless communication. Using visible light to transmit data, instead of RF-based signals (as in WiFi), LiFi provides higher data rates, as well as improved privacy, security, and reliability. We present some results obtained through experimental measurements in a real testbed. We measured bit rates of up to 250 Mbps in an ordinary office room. However, we also observed that this technology is very sensitive to line-of-sight and obstacles, which can severely impact performance in certain environments.**

***Index Terms*—6G, WiFi7, Bluetooth 6.0, LiFi, IEEE 802.11bb, Experimental Testbed, Bit Rate.**

I. Introduction

The future Internet of Things (IoT) will evolve into highly dynamic and intelligent ecosystems capable of supporting billions of interconnected devices, powered by next-generation wireless technologies, such as 6G, WiFi7, LiFi, and Bluetooth 6.0, that will provide ultra-low latency, high reliability, high throughput, and massive device connectivity. This will enable real-time communication between smart devices, from autonomous vehicles and industrial robots to wearable health monitors and connected home appliances. Advanced edge computing will play a key role by processing data closer to the source, reducing latency and bandwidth usage, while ensuring faster decision-making and improved responsiveness. Artificial intelligence and machine learning will be deeply embedded in future IoT infrastructures, allowing devices to analyze data, learn user behavior, and adapt autonomously. These technologies will form the foundation of future smart cities, smart energy systems, precision agriculture, and smart healthcare, ultimately improving quality of life and operational efficiency.

To support this trend, new wireless technologies are emerging, such as 6G cellular networks, WiFi7 wireless LANS, LiFi wireless networks, and Bluetooth 6 for short range communication. In this paper, we focus on LiFi (Light Fidelity) [1], a very promising wireless technology that uses visible light to transmit data. Compared to traditional WiFi networks, based on radio frequency (RF) communication, LiFi presents a unique potential to improve the efficiency, security, and sustainability of communication [2]. In terms of speed, LiFi promises to offer a data rate at least 10 times higher than WiFi. Furthermore, the light spectrum is much wider than the Wi-Fi spectrum, offering the necessary infrastructure for the development of IoT applications in many domains and allowing more than 50 objects to be connected in a room, without interference. Regarding security, LiFi does not pass through walls; therefore, anyone who wants to access the network must be in the same room, and the signal can be blocked on windows using filters. This allows improved protection in terms of privacy and makes unfeasible attacks from the outside, such as eavesdropping. Sustainability is another important aspect of LiFi networks: the power required to light up a signal is smaller than the radio counterpart. In addition, all the risks related to the emission of radio waves are avoided, making LiFi a greener communication technology.

Despite that, LiFi is not yet a popular technology. Not only is the number of LiFi networks deployed still very limited, but users and even technologists are still largely unaware of this technology and its potential benefits. On the academic side, many studies have been conducted to consider the utilization of this technology in application domains, such as e-health, working environments (i.e. homes, offices, and industrial settings), navigation systems, and voice/audio transmission. Other works have investigated the integration of LiFi with WiFi and 5G/6G.

In this paper, we investigate the performance of LiFi from the point of view of a user who wants to connect to the Internet with her/his personal device. To this end, we set up an experimental testbed in an ordinary office and measured the maximum bit rate under different lighting conditions, with and without obstructions. We also investigated the effects of distance, orientation, and possible obstacles. For brevity, we show below only a subset of the results obtained. The complete analysis is described in [3]

II. LiFi Experimental Setup and Results

Fig. 1 shows the architecture of a LiFi network. The operating environment (e.g., an office) is covered by a certain number of Access Points (APs) connected to a high-speed backbone network. Each AP is connected to a number of transceivers (TRs) that can transmit/receive infrared light signals to/from the End Point (EP) attached to the user device. With an appropriate deployment of APs and TRs, it is possible to cover

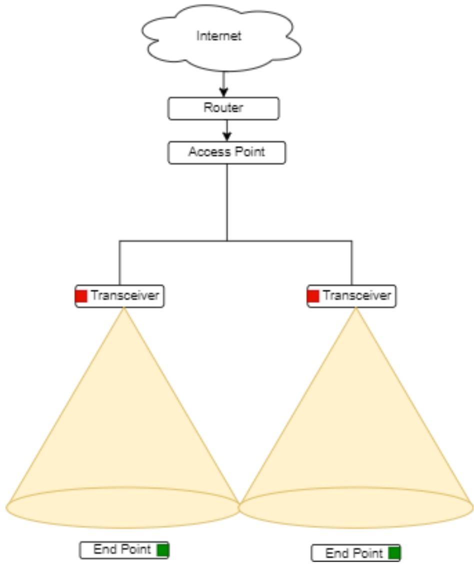

Fig. 1: Architecture of a LiFi Network

even very large environments, avoiding black zones, i.e., areas where the light signal cannot be received.

In our testbed, we used a single TR connected to the AP, which is then connected to the wired (Ethernet) infrastructure of the building. Depending on the specific experiments, we used one or more EPs, each connected to a notebook through a USB port. The AP and related TR were located on the roof of a $3m{*}3m$ office room. For the EP attached to the notebook, we considered three different positions that reflect typical operating modes of a user. We assumed that the notebook can be (i) *handheld* by the user, at a distance of approximately 1 m from the TR; (ii) *on the desk*, at a rough distance of 1.5 m from the TR; (iii) *on the floor*, at a distance of 2.5 m from the TR.

Fig. 2 shows the upstream and downstream bit rate experienced by the user when the EP moves along the x axis (the trend is similar for the z axis). The bit rate is strongly dependent on the vertical distance between EP and TR. When the shift on the x axis is limited, the bit rate increases with the EP closer to the transceiver due to the higher power of the incoming signal. We observe that, at the distances considered, the maximum bit rate is in the range [170–250] Mbps and [110–160] Mbps for donwlink and uplink flows, respectively. When the shift on the x axis increases, the behavior drastically changes and higher rates are experienced at larger vertical distances. This is because the radius of the light cone emitted by the photodiode on the transceiver increases with the vertical distance (see Figure 1). Consequently, the maximum distance at which it is possible to transmit/receive data, increases with the vertical distance. In our setup, when the notebook (EP) is held in hand by the user (vertical distance of approximately 1.0 m), the maximum transmission distance is about 1.1 m. The same increases to approximately 1.7 m, when the notebook is located on the floor (distance equal to 2.5 m).

As a final remark, we can observe that even when the EP is located at the maximum vertical distance from the transceiver (that is, at the floor), the area covered by the cone of light is limited, approximately a circle with a radius lower than $2m$. This means that in a typical working environment (e.g., an office) many TRs are required to adequately cover the entire area. In addition, the location of different TRs must be considered accurately to avoid possible shadow zones.

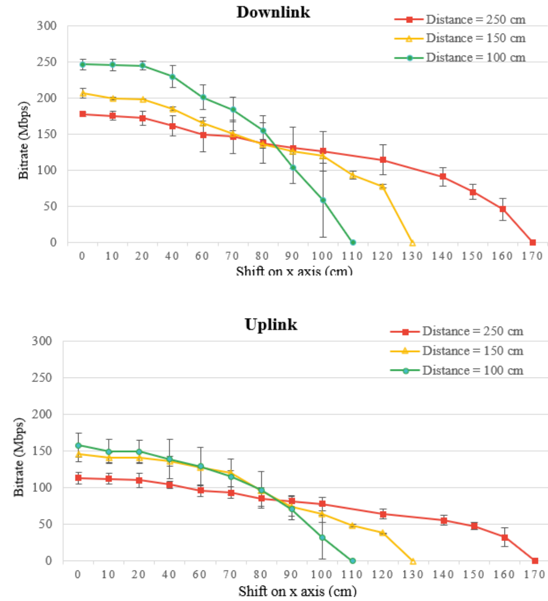

Fig. 2: Impact of the shift along the x axis on the bit rate, in downstream (top) and upstream (bottom)

III. Conclusions

We can draw some important lessons from our experimental measurements. The cone of light emitted by each transceiver is limited to a few meters; therefore, many transceivers are required to cover a certain area. Each TR location must be selected carefully to avoid shadow areas. The maximum bit rate is in the order of hundreds of Mbps, higher than that provided by Wi-Fi. However, it decreases significantly with distance from the TR, especially if line-of-sight is not guaranteed. Obstacles can partially or completely obstruct the light signal, making communication impossible in certain areas. In conclusion, this technology has a number of interesting properties that make it appealing in specific contexts. Conversely, it may not be suitable for scenarios where uninterrupted service is essential.

References

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