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# Visible Light Communication via 5G Networking

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**ABSTRACT:** Visible Light Communication [VLC] is a potential way of data communication in which information is transferred via visible light frequency ranging between  $4.3 \times 10^{14}$  to  $7.5 \times 10^{14}$ . 5G Networking is currently the fastest wireless technology used for data communication. In this article we aim to provide latest advancement in Visible Light Communication [VLC] and 5<sup>th</sup> generation technologies. This work spotlight the robustness of Visible Light Communication [VLC] in 5G networking. This work also specifies why Visible Light Communication [VLC] is more preferable over Radio Frequency [RF]. It reviews the literature work in Visible Light Communication and 5G Networking. This paper covers the aspects of Physical Layer Security (PLS) for VLC, including different channel models, input distributions, network configurations, precoding/signalling strategies, and secrecy capacity and information rates. The widespread deployment of Internet of Things (IoT), more and more devices are involved in wireless networks, and the fifth generation (5G) network requires to support the massive connectivity and diverse services for the huge number of IoT devices. Visible light communications (VLC) and visible light positioning (VLP) are two promising supplementary technologies to assist 5G networks to support the massive connectivity, high reliability, high data rate, high positioning accuracy, low latency, low power consumption and improved security of IoT. Integration of VLC and VLP within 5G networks to support massive connectivity and meet the diverse service requirements of IoT devices (integrating VLC and VLP within 5G networks) with the objective to address the challenges.

**KEYWORDS:** Visible Light Communication, Physical Layer Security, Internet of Things, Visible Light Positioning.

## I. INTRODUCTION

Fifth generation (5G) wireless systems represent the next phase of mobile telecommunications beyond the current 4G standards. The next generation technology is not very clear, but could be focused on higher system spectral efficiency, data rates, network capacity, scalability and reliability of communications, as well as lower battery consumption, cost, and so on[1]. In telecommunications, 5G is the fifth generation technology standard for broadband cellular networks, which cellular phone companies began deploying worldwide in 2019, and is the planned successor to the 4G networks which provide connectivity to most current cell phones. 5G networks are predicted to have more than 1.7 billion subscribers worldwide by 2025, according to the GSM Association.

Traditional radio frequency (RF)-based wireless communication has arrived at a bottleneck to meet these needs. First, there is a shortage of RF spectra: most of them have been allocated. The bandwidth of each allocation is somehow limited. Second, various exploitations of RF frequency utilization have been studied for decades, and the potential to exploit more is limited[1]. Densely deployed light emitting diodes (LEDs) points can be employed into access points (APs) to support the high density of indoor IoT devices and satisfy the diverse services, since many studies have reported that wireless devices will spend about 80 percent of their time indoors[2].

## II. OVERVIEW OF VLC

Due to its numerous advantages such as wide unregulated bandwidth, high-speed, high security, reliable transmission, high energy efficiency and comparatively low-cost to build, VLC is considered as favourable complement to most indoor communication systems such as infrared (IR) and mmWave communication in 5G networks. Moreover, VLC can offer illumination, communication, and localization simultaneously[3]. License-free spectrum, practically unlimited



channel bandwidth, high capacity links and energy efficiency are the main features of light fidelity (Li-Fi) networks. Li-Fi is a subset of the VLC domain, which refers to broadcasting access networks with multiple users[4].

Some specific designs of systems and components have even been demonstrated in practice. From this experience, the concept of VLC has been proved to be feasible for indoor fixed applications. However, the problem of how to provide mobile applications over VLC is still quite open. Currently, many research groups focus on the design of VLC mobile communications. This section presents a summary of both fixed and mobile VLC communication[1]. VLC offers several advantages over RF, which are summarized in the bottom Table 1. First, it has unregulated spectrum, specifically from 428 to 750 THz, which provides huge communication bandwidth to deliver license-free extremely high data rate services such as large files and super high definition video transfer[1].

| Advantage                 | Challenge          |
|---------------------------|--------------------|
| Wide unregulated spectrum | Low mobility       |
| High spatial reuse        | Light interference |
| Security Eye safety       | Eye safety         |
| High energy efficient     |                    |

Table 1. Advantages and challenges of VLC [1].

### III. HYBRID VLC/RF SYSTEMS

In indoor environments, the light diffused from LED sources is naturally confined to a small area. In addition, the light beams are susceptible to indoor blockages, such as the human body, which may cause severe fluctuations in the received SNR. Consequently, the hybrid integration of VLC and RF

systems were envisioned to significantly improve the user experience, since VLC systems can support very high data rates in specific areas and RF systems can provide greater coverage area to support mobility. LiFi is a fully networked optical communication system that includes both uplink and downlink transmissions. The uplink operates over the infrared (IR) spectrum while

the downlink operates over the visible light spectrum. The second alternative consists of deploying hybrid wireless fidelity (Wi-Fi)/LiFi. Both technologies are bidirectional and can jointly provide high coverage and high data rates. Fig 1

presents an illustration of the hybrid Wi-Fi/LiFi architecture, where the RF AP is a Wi-Fi node and the VLC AP is an array of LEDs. Since hybrid VLC/RF systems encompass VLC components and RF components jointly, security for hybrid

VLC/RF systems should be attentively investigated due to the broadcast nature of both communication systems, which is the focus of this section[5].

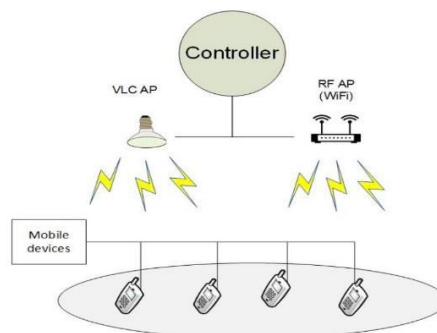


Fig. 1: Illustration of the heterogeneous LiFi-Wi-Fi system[5].

### IV. SUPPORT OF IOT IN VLC

As the massive number of IoT devices are involved in wireless networks, 5G wireless networks will support various connectivity and diverse services of IoT devices. This section describes the main types of IoT devices and analyses the challenges in support of IoT. In wireless networks, different IoT devices have different service requirements, traffic

characteristics and resource constraints. Generally, these IoT devices can be classified into the following five groups based on their required services as illustrated in Table 2[2].

| Types of IoT devices | Service characteristics  | Applications  |
|----------------------|--|---|
| Massive IoT          | Delay-tolerant and low data rates, but energy-constraint.                                    | Smart city, smart grid, and smart home.                           |
| URLLC-IoT            | Needs strict low latency, high reliability and stable connectivity, but with low data rates. | Industrial automation, emergency response, and real-time control. |
| HAP-IoT              | Requires high-accuracy positioning and real-time tracking services.                          | Shopping mall localization and robot navigation.                  |
| HSR-IoT              | Needs high data rates, even has latency constraints.   | Video surveillance, software downloading, and webpage surfing.    |
| S-IoT                | Requires communication security and privacy protection.                                      | Industrial manufacturing and automatic payment.                   |

TABLE 2. Types of IoT devices[2].

- Massive IoT: This class of IoT refers to serve a large number of low-cost, long range and low-energy consumption devices. They are less latency sensitive and require relatively low data rates
- IoT with ultra-reliable and low latency communications (URLLC-IoT): This kind of IoT devices have strict low latency, high reliability and stable connectivity requirements, but do not need the high data rates
- IoT with high-accuracy positioning (HAP-IoT): These IoT devices require high positioning accuracy, and they are used for indoor tracking and navigation.
- IoT with high-speed data rates (HSR-IoT): These devices have high data rate requirements but are less interested in strict latency constraints
- IoT with security (S-IoT): This class of IoT devices requires high communication security. Examples of devices are those envisioned for industrial manufacturing and automatic payment[2].

### V. INTEGRATION OF VLC AND VLP (VLCP) WITHIN 5G NETWORKS FOR IOT

The presented multi-layer network architecture is shown Fig. 2, which mainly consists of three layers: macrocell layer, picocell layer and optical attocell layer, which are classified by their coverage ranges. The macrocell layer is associated with macrocell base stations (BSs) operating in low RF frequencies, which supports seamless coverage. The picocell layer is associated with picocell access points (APs) with smaller coverage areas (e.g., factory, home or building). The optical attocell layer is the lowest layer which is composed of VLC APs (refer to femtocells), and it is mainly employed for indoor services[2].

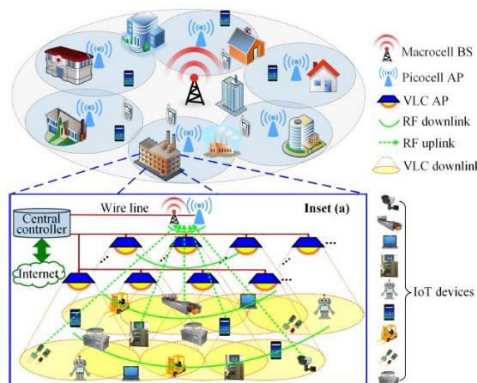


Fig 2. The architecture of integrating VLC and VLP within 5G networks for IoT [2]



The former two layers operate in the RF spectrum while the bottom layer is on the visible light spectrum. The objective of the presented multi-layer network is to increase data rate and improve indoor positioning accuracy via VLC APs while the larger cells (macrocells and picocells) support the better coverage and reliability. We take one unit of the multi-layer network to show the working principle. As illustrated in Fig.2 (inset (a)), a number of VLC APs are uniformly equipped on the room ceiling, while the RF BSs/APs also support communication services for IoT devices. Each VLC AP has a LED lamp to support the lighting requirements, communication and positioning services, and each VLC AP covers a small area to generate an optical cell [2].

## VI. CONCLUSION

The 5G technology promises significantly high data rate, massive device connectivity, much lower latency, high carrier frequencies and improved overall wireless coverage for the future mobile networks and IoT systems. Although, the realization of the future 5G networks require a lot of efforts among both academic researchers and communication companies, recent research works has shown the potential and benefits of OWC technologies such as VLC and LiFi for 5G and beyond communication systems. A multi-layer network architecture by integrating VLC and VLP into 5G networks for IoT, in order to support massive IoT connectivity and satisfy diverse service requirements of devices. The multi-layer network, different IoT devices may have different QoS requirements, ranging from high reliability and low-latency, high positioning accuracy to high transmission data rates.

An investigation of modern research progress on VLC for future 5G communications. These literature works are categorized into two portions: VLC-based fixed and mobile communications. For VLC-based fixed communications, we summarize the current VLC indoor applications and ISI mitigation technologies. RF has wide beamwidth, receivers have a wide range of angles of view that enable them to receive the signal in the mobile environment. A comprehensive and comparative review of all PLS techniques reported in the literature that aim to enhance the security of VLC systems.

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