Using Visible Light as a Truly Green Way of Communication

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I. INTRODUCTION

According to an Ericcson report, by 2030, the number of Internet of Things (IoT) devices around the world could reach 125 billion, which can produce an extraordinary growth in wireless traffic demand. At that point, wireless communication is expected to be responsible for 20% of all global electricity consumption and 14% of worldwide greenhouse gas emissions [1]. In 2016, ustainability development goals (SDG) have been developed by the United Nations (UN) for the 2030 Agenda. Thus, to achieve the UN SDG, it is critical to design high energy efficient wireless communication systems, which should fulfill the requirements of the next generation (6G) wireless networks such as massive device connectivity, high Quality of Service (QoS), high system capacity, low latency, no bad effects on the environment and human health, more security, and digital inclusion.

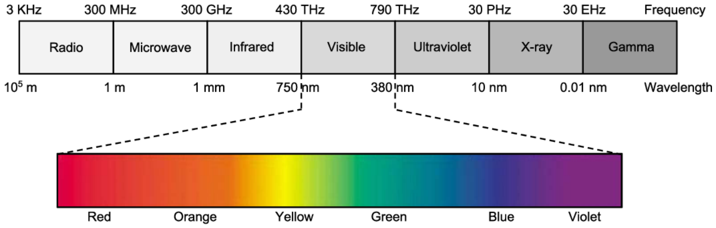

Fig. 1: Spectrum allocations according to their frequencies and wavelengths.

Unfortunately, traditional radio frequency (RF) communication systems are becoming unable to provide the exponentially increasing wireless traffic demand for high-data-rate IoT devices due to limited spectrum resources. For example, in order to achieve a higher data rate in 5G technology, the RF spectrum was extended by utilizing a higher frequency band, i.e., millimeter-wave (mm-Wave) (24GHz to 47GHz) band. However, the major challenge of extending the RF spectrum is that the higher carrier frequency you use, the higher propagation loss you get. Therefore, mm-Wave can travel only a short distance. Because of that, in 5G technology, the number of access points is increased and placed close to each other to ensure comprehensive coverage. Thus, extending the RF spectrum further will result in a dramatic increase in energy consumption, which goes against the UN SDG.

The recent advancement in light emitting diode (LED) technology has resulted in the ability of LEDs to be switched between different levels of luminous intensity at an extremely high rate. Thus, it has enabled the emergence of visible light communication (VLC) as a new high-speed wireless communication method that uses LEDs for lighting and communication. VLC utilizes the license-free visible spectrum (380–750 nm, i.e., 400–789 THz) for data transmission, offering a colossal 400 THz bandwidth, as seen in Fig. 1. Therefore, VLC can solve the RF spectrum scarcity and congestion issues. In addition, VLC systems have many unique advantages:

- Safety and health: Wavelengths of visible light (VL) spectrum are safe to the human body, enabling transmission with a higher power in some applications, while there are power constraints for eye and body safety in RF.
- QoS and security: In VLC, mainly a Line-of-Sight (LOS) is required for communication; thus, the communication system is protected from potential eavesdroppers. Moreover, the VL cannot penetrate walls, providing small cells with high spatial reuse and high QoS.
- Augmentation of the existing technologies: VLC is intended to complement RF rather than to replace it. VLC networks can offer an extra data layer with a higher rate.
- Green technology: By exploiting the ubiquity of LEDs lighting infrastructure, VLC is a truly green and energy-efficient technology that combines illumination and data transmission functions.

In addition, VLC potentially will play a significant role in the development of 6th-generation (6G) technology because it can provide massive, dense, and high-speed connectivity while satisfying the UN SDG.

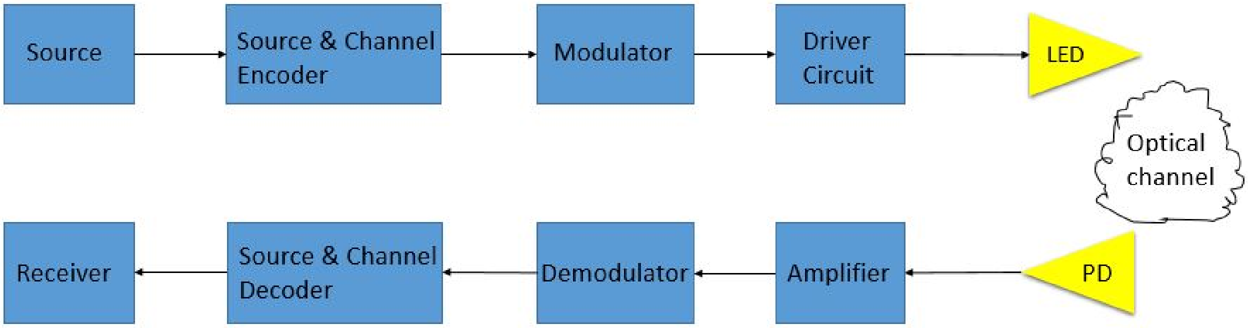

Fig. 2: VLC system model.

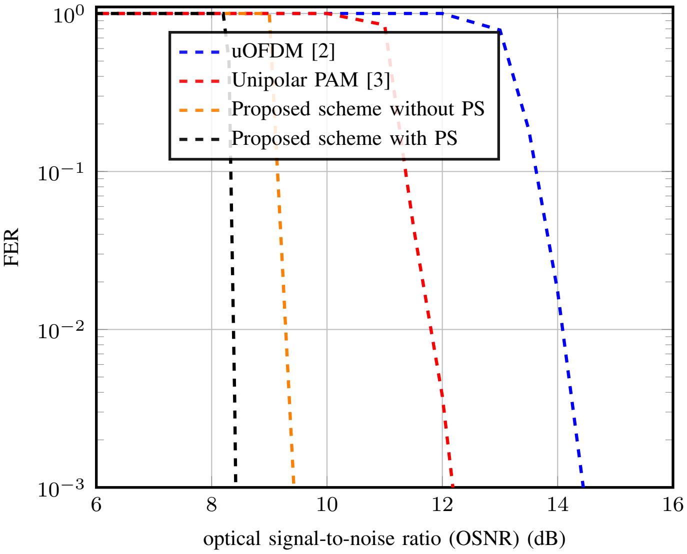

Fig. 3: Comparison of different schemes in terms of FER for normalized data rate, $\mathrm{R} = 2$ b/cu/sc.

II. VLC SYSTEM OVERVIEW

In typical VLC systems, off-the-shelf LEDs and photo-detectors (PDs) are used as transmitters and receivers, respectively. Fig. 2 illustrates the block diagram of the typical end-to-end VLC system. In a process called intensity modulation (IM), the LEDs send information by varying the light intensity at a very high speed, so that the human eye cannot observe these intensity variations. At the receiver, in a process known as direct detection (DD), PDs detect information by generating an electrical current proportional to the variation in the received optical power.

III. CONTRIBUTIONS

Despite tremendous unlicensed bandwidth in VLC, the narrow modulation bandwidth of LED limits the development of VLC systems with high achievable data rates. Therefore, in order to improve spectral efficiency (SE) in VLC channels with intensity modulation and direct detection (IM/DD), our work proposes novel adaptive coded forward error correction (FEC) based color-shift keying (CSK) modulation scheme with probabilistic shaping (PS), where the probability of the CSK input symbols is optimized. The proposed scheme outperforms unipolar pulse amplitude modulation (PAM) and orthogonal frequency-division multiplexing (OFDM) based schemes in terms of SE and/or frame error rate (FER). For example, as can be seen from Fig. 3, at FER$= 10^{-3}$ and for normalized data rate $\mathrm{R} = 2$ bits per channel use per sub-carrier (b/cu/sc), the proposed scheme outperforms the unipolar PAM and unipolar orthogonal frequency-division multiplexing (uOFDM) by around 4 dB and 5.9 dB, respectively. Currently, we are at the stage of experimentally validating the simulation results.

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