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Visible Light Communications for IoT services based on high-power LEDs in Industry 4.0

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I. Introduction

In the framework of Industry 4.0, visible light communications (VLC) are proposed for providing connectivity in those environments where radio-frequency (RF) transmission achieves a poor performance or it is even banned [1]. Specifically, VLC are potentially useful for providing Internet of Things (IoT) services while consuming a small portion of the transmission resources, considering a user-centric approach and subject to a low-cost implementation [2]. Recently, the European Commission warned about the need for employing low-cost and energy-efficient LEDs for future VLC systems to maintain the reduction in the energy consumption [3]. As a consequence, the VLC-IoT hardware implementations must consider commercial LEDs, which are subject to non-linearities, reduced and unknown bandwidth and other impairments for data transmission, while maintaining the energy efficiency for illumination purposes. In this work, a low-cost VLC-IoT implementation is presented based on commercial high-power LEDs. The proposed configuration is focused on providing connectivity in those environments where RF transmission is not efficient so that an external access point (AP) distributes the connectivity through a backhaul link that feeds the set of optical access points (APs).

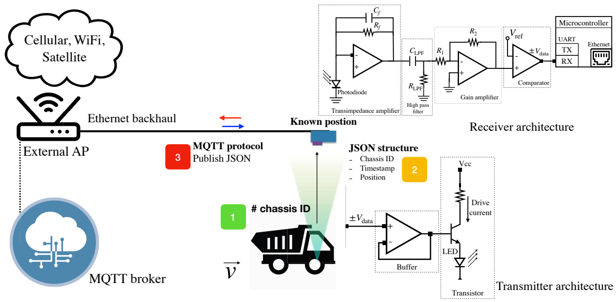

Fig. 1. Architecture of the VLC-IoT system.

II. Measurement Set-up

The transmitter is composed of a microcontroller equipped with a universal asynchronous receiver-transmitter (UART) module that generates and on-off keying (OOK) signal. Thus, the LED is polarized with the current that provides the desired illumination using a transistor as it is shown in Fig. 1. For the proposed demo, the commercial chip on board (CoB) LED CLU038-1208 of Citizen Electronics and the infrared LED OSRAM ILR-IO09-85SL-SC211-WIR200 are considered for visible and infrared transmission, respectively. The data rate of IoT communications allow us to use low/medium bandwidth components, which results in low-cost and easy to implement architectures. The first stage of the receiver corresponds to a transimpedance amplifier. After that, a high pass filter is applied to remove the influence of external illumination sources. The resulting signal is amplified again and, finally, a comparator generates an OOK signal.

The network set-up is composed of an external AP that provides connectivity from outside of the VLC area, a backhaul link deployed along the scenario and the set of optical APs. For this demo, the backhaul link is implemented using Ethernet cable. Transmission of the IoT data is carried out using the MQTT protocol. Basically, the IoT data is published for a specific topic, e.g., temperature, humidity or ID of the user. This information is received by a MQTT server, which is usually denoted by broker. Therefore, the IoT data from the area of interest can be monitored anywhere simply connecting to the broker and subscribing to the topic of interest.

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III. Obtained Results and Conclusions

The proposed VLC-IoT demonstrator allows us to keep track of the IoT parameters measured by the sensors in an industrial environment where RF transmission is not efficient or is even banned. To do that, the user must connect to the MQTT server and subscribe to the topic of interest. The cost of the pair transmitter-receiver for the proposed VLC-IoT system is less that 50$ without considering mass production. Further research will be focused on integrating the VLC-IoT system in industrial elements such as helmets, reflective vests or industrial vehicles.

References

[1] N. Chi, Y. Zhou, Y. Wei, and F. Hu, “Visible light communication in 6G: Advances, challenges, and prospects,” *IEEE Vehicular Technology Magazine*, vol. 15, no. 4, pp. 93–102, 2020.

[2] A. A. Qidan, M. Morales-Céspedes, A. G. Armada, and J. M. H. Elmirghani, “Resource allocation in user-centric optical wireless cellular networks based on blind interference alignment,” *Journal of Lightwave Technology*, vol. 39, no. 21, pp. 6695–6711, 2021.

[3] Z. G, B. P, and R. S. T, “Update on the status of led-lighting world market since 2018,” no. KJ-NA-30500-EN-N (online), 2021.