Organic Visible Light Communication

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ABSTRACT
Since the increment of internet final consumers for digital television, streaming, social networks, Internet-of-Things (IoTs), the demand of a secure and fast data transfer connection "any-where/time" requires new approaches. Visible Light Communication (VLC) is one of the most promising new wireless communication technology, thanks to the possibility of use environmental lights as data transfer channel in free-space. VLC offers unique benefits not present in radio communication, such as inherent security and license free operation. In this wide field, organic visible light communication (O-VLC) is rapidly gaining interest in the research community as a standalone technology in optical wireless communication, since organic light-emitting diodes and photonic devices possess fascinating characteristics, such as mechanical flexibility and extremely low cost solution-based processing. Such a technology is extremely interesting for application in network devices for "Smart City".

Keywords: visible light communication, photo-detector, light-emitting diode, organic devices, 5G, smart city.

The 5th generation mobile (5G) network is not merely a boost of actual radio interface (LTE), providing faster speeds to meet business and consumer demands [1]. Instead, 5G represents the concept of a new evolved network, in which all the elements are internet connected devices (IoTs), communicating each other, thus expanding the network potential. Indeed, 5G network is closely related to the broader concept of "Smart City" [2], in which all the "urbanistic" elements (traffic lights, buildings, banners, road signs, etc.) have an "electrical mind" capable to communicate.

Indeed, the expansion and growth of a smart city lead to an obvious increment of "internet connectable" devices, thus the useful bandwidth has become a concrete issue. Modern wireless local area networks have made it possible to stream high speed information to users' devices wirelessly from the internet; however, in a restricted and confined space (like home), a single final user could have at the same moment more devices that requires the use of internet, such as smart TV, smartphone, tablet, notebook, and (forerunning) IoT-like household appliances. This increase of data demand results in the so-called "last-meter" bottleneck [3].

There is an alternate implementation of the WiFi concept, based on data communications via artificial illumination in the visible range (LiFi, Light Fidelity), through the use of light emitting diodes (LEDs), concept better known as Visible Light Communication [4]. VLC is envisaged as an alternative to radio frequency (RF) based communication technologies due to over-allocated and therefore expensive spectrum availability. VLC offers advantages such as inherent security, license free operation and dual solid state lighting and data communications functionality.

The main concept of VLC working is the use of environmental light as channel of a data communication system (Figure 1). Solid-state lighting (white-light and other visible LEDs) are becoming more efficient, have high reliability and can be incorporated into many lighting applications. Recent examples include car head-lights based on white LEDs, and LED illumination as an architectural feature. The prediction that general illumination will use white LEDs in the future has been made, due to the increased energy efficiency that such an approach may have. Such sources can also be modulated at high-speed, offering the possibility of using sources for simultaneous illumination (will appear always switched on at human eye) and data communications [5].

Another interesting feature of visible light communication is the "safety" of the data-transport medium. In a sensible ambient like an hospital (Figure 2), RF technology could affect or interfere both medical diagnostic and life-saver devices; instead, environmental illumination is harmless, necessary (it's obviously yet present in the rooms!) and will connect directly several monitoring devices, for example during a check-up of a patient [6].

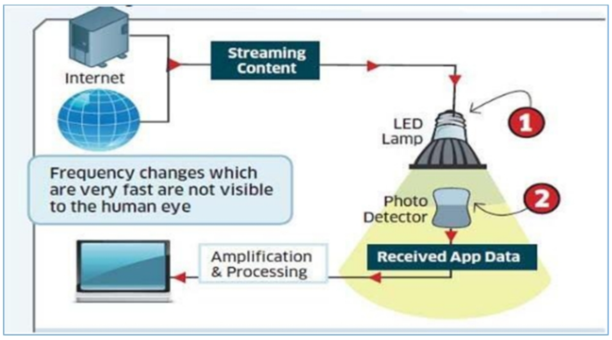

Figure 1. Visible Light Communication concept [5].

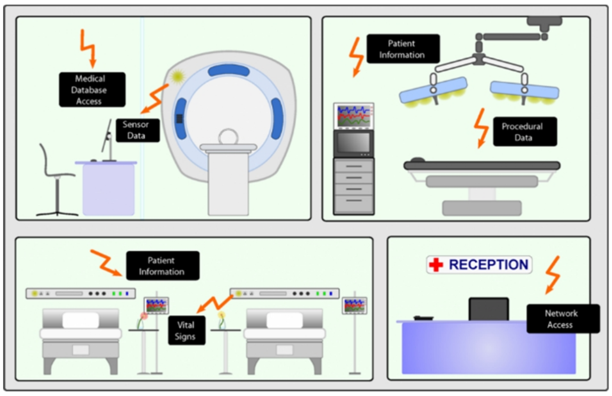

Figure 2. Schematic of VLC applied in a hospital.

Besides, the core of a VLC system is both a LED, as transmitter of the light signal, and a photo-voltaic device (detector), as receiver. In the huge amount of different realizable configurations, an interesting option is a VLC system containing both transmitter and receiver realized with organic devices (OLED, organic light-emitting diode, and OPD, organic photo-detector, see Figure 3). OLEDs are already an industrial and commercially available reality, since their established application in Smart TV, phones, tablets, and now also in building integration, particularly as refined indoor light source for interior design [7]. On the other side, organic photo-voltaic devices have achieved high visibility in the field of Renewable Energy (OSCs, organic solar cells) thanks to attractive characteristics [8], like mechanical flexibility (flexible devices), extremely low-costs of production, device realization via solution processing techniques commonly used in printing industry, possible tailoring of the optical and electrical attributes of the raw materials. Therefore, the wide know-how could be transferred for the realization of organic photo-detectors for visible light communication systems. Moreover, OPD are intrinsically more suitable for the detection of light in the visible range (Figure 3).

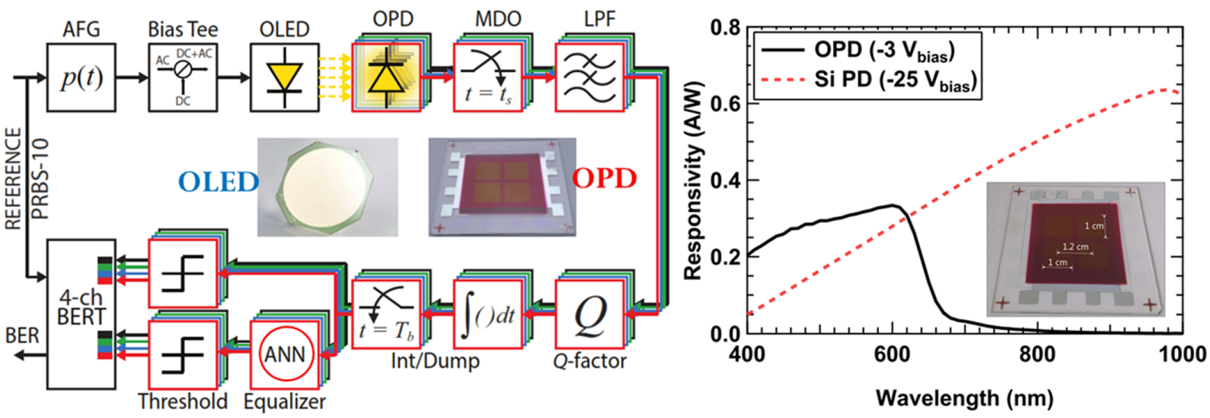

Figure 3. (left) A prototype (schematic) of an organic visible light communication (O-VLC) system, with a commercial available OLED and lab-realized OPD [9]; (right) comparison between responsivity of an OPD and a typical silicon-based photo-detector [10].

We work on the realization and characterization of OPDs for VLC application. We study the combination of device architecture, physical parameters, and organic compounds to optimized the bandwidth and optical-to-electrical response of the organic photo-detector with respect to light source (white or combination of single-color LEDs). Furthermore, due to the need of an "artificial intelligence" for de-modulation processing of data signal, we will interface the OPD to a Raspberry Pi module, realizing a low-cost IoT system [11].
VLC can be used as a communications medium for ubiquitous computing, because light-producing devices (such as indoor/outdoor lamps, TVs, traffic signs, commercial displays, car headlights/taillights, etc.) are used everywhere. Thanks to all such features, VLC is an excellent candidate as data transfer system to catch the "smart city" idea of unique network to improve citizens' quality of life (Figure 4).

Figure 4. Possible final applications for Visible Light Communication technology [12].

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