Poster: Integration between Home Automation and Visible Light Communications

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Abstract

In the near future, the Internet of Things (IoT) will take a predominant role in home automation and a reliable technology must satisfy the high demand on data traffic, energy consumption and reliability. This poster reveals a novel solution for home automation that relies on visible light communication.

1 Introduction

Home automation is a topic of great interest for the research community and large firms dedicated to offering products to the end user at home. Many products are currently in the market that offer home automation functionalities: assistance managed by voice commands, lighting and temperature control, smart TV and electrical appliances control, energy consumption monitoring, smart locks, etc. These devices mostly relay on Bluetooth or Wireless Fidelity (WiFi) connectivity. On top of that, the ever-increasing wireless services and especially the Internet of Things (IoT) services are saturating the Radio Frequency (RF) spectrum. Thus, the research community is looking for new alternatives that are able to satisfy such a demand.

Visible light communication (VLC) appears as a solution to provide wireless services at home by leveraging the light-emitting diode (LED)-based luminaries deployment [4]. VLC may illuminate and provide Internet connection simultaneously by making use of the optical frequencies. In this way, VLC does not interfere with traditional RF services and both can operate in parallel.

Going forward, we propose to integrate VLC as an enabling technology for expanding the home automation. The lighting infrastructure is leveraged for communication purposes and a fully networked system, called Light-Fidelity (LiFi), may be deployed. Light fixtures are connected either with power line communication (PLC), Ethernet-based communication or optical fiber. Currently, user can interact with the illumination system by changing the hue and brightness as he/she desires, for instance to optimize the blue color in the room [2]. Or hue and brightness could be optimized for providing better illumination to plants in the living room and balcony. However, these action can affect severely the communication and light-based positioning services deployed with LiFi networks.

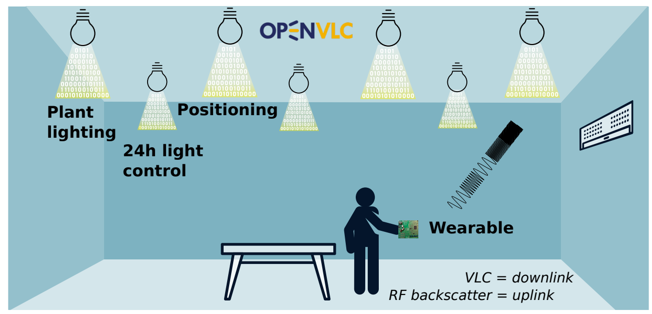

Figure 1. Example of VLC-based IoT scenario for home automation.

This work presents the key actions that are going to be undertaken in order to optimize the communication services under the constraints of multiple services. In addition, a first approach of home automation and VLC integration is detailed and the key technologies and applications that are considered to address this paradigm are presented.

2 Technologies

LiFi can be integrated in the booming home automation field as an enabling technology for wireless communication services. In these regards, OpenVLC is a renowned and stable platform to carry out further developments in the VLC area of expertise [1]. OpenVLC is built around the low-cost BeagleBone Black platform that is provided with general purpose inputs/outputs and external sensors can be connected. As such, this platform combines all the requirements for experimentation in new VLC-based home automation developments with focal point in IoT services, as Fig. 1 shows. As an example, temperature, ventilation and movement detecting sensors can all be integrated in the same board for home automation purposes.

OpenVLC is currently in its third version and offers the following functionalities: transmitter and receiver integrated in the same board, a maximum UDP throughput of 400 kbps and a maximum achievable distance between transmitter and receiver of 6 m, among others. The work here presented will contribute to the development of the next OpenVLC version that will provide the platform with new features for addressing the home automation paradigm. To this end, the following technologies will be integrated:

Red-green-blue (RGB) technology: the current OpenVLC transmitter will be changed by a tri-chromatic LED in order to have a better control of the colour scheme, brightness and dimming mode. This will allow to adapt OpenVLC to the current trend in home automation, and up-to-date developments and research can be carried out in a realistic platform. The impact of changing the light parameters in communication services will be studied.

Bi-directional communication for battery-free devices [3]: The uplink (UL) in LiFi deployments is a challenge that must be further studied and integrated in the set up. The UL design is sometimes dramatic due to the difficulty of having a line-of-sight (LoS) link between transmitter and receiver when using lighting as communication technology. Furthermore, a VLC-based UL is annoying to the human eyes and, then, either active infrared (IR) or RF can be employed instead. Battery-free devices are of great importance for IoT devices where few data are transmitted and an extreme low energy consumption is required. Thus, a novel design for bi-directional communication using battery-free devices will be considered for fostering home automation services. These passive devices will be able to receive and transmit data by means of VLC and RF, respectively. They may be small tags composed of an energy harvester to energize the circuitry with the received light power in the downlink (DL), and a backscatter for passively transmitting data through the UL with a RF signal [3]. The RF carrier that is modulated by the backscatter after impinging on it can be emitted by any radio carrier generator located at the room. A solar panel can be used as receiver and energy harvester to collect light power and convert it into an electrical signal to charge a capacitor. To save energy, a wake-up radio system can be utilized in order to notify the tag when it must deactivate the idle mode and transmit sensed data. This proposal is feasible in an IoT scenario where few data are transmitted and, in this way, only one active RF transmitter is required, which saves a considerable amount of energy. This proposal, which is shown in Fig. 1, makes possible an integration between VLC and RF devices leading to a whole solution whose foundations are the low-energy consumption.

3 Applications

New services are envisaged that merit their study: thanks to the photodiode integrated in OpenVLC, environment conditions can be measured and then lighting features can be automatically controlled according to it. Additionally, communication parameters such as the bandwidth, dimming level or colour scheme can be optimized to minimize the outage produced in communication services; depending on the service, a trade-off between energy saving and achievable data rate can be found; it is necessary to minimize the effect over the communication performance produced by lighting parameters modifications under user demand. Signalling data must be transmitted through the DL in order to inform the receiver about the communication parameters that are used at the transmitter; sensors can be either connected to the OpenVLC platform or distributed around the room in order to identify automatically the activity that is being carried out in place.

To this end, machine learning algorithms will be investigated that can solve a multi-objective optimization, such that lighting and communication parameters can be automatically adapted according to the services; finally, if multiple LED-based access points are deployed, a seamless coverage can be guaranteed as long as MAC layer protocols to enable handover are developed.

Not only user-based services can be studied, but also this solution is useful for organic farming. For example, lighting can also be automatically adapted according to environment conditions in order to favour the growth of the plants. Furthermore, depending on the plant conditions that are measured by sensors and sent through the UL, the lighting can be modified for optimizing its development.

This study is going to be tested in commercial solutions thanks to collaborations with two large companies in the lighting industry: Tridonic and Velmenni Ltd. For the work conducted at Tridonic, the research will concentrate in studying the feasibility of adapting these techniques to professional lighting, considering new constraints identified and denser lighting deployments (scalability) such as production floors where the height can increase up to 15 m. Differently, the work at Velmenni will focus on exploring the integration of the MAC layer developed by the company for smooth handover between multiple light access points. The energy-efficient high bandwidth (DC-50 MHz) receiver with linear response will be also explored for applications with less stringent power requirements and, for IoT applications, the Velmenni's receiver with 120° of field of view will be explored to improve the system performance for non-line-of-sight communication.

4 Conclusions

In this work we introduced a new approach for VLC-based home automation. Two new technologies were presented and proposed to be incorporated in indoor IoT scenarios: RGB lighting and bi-directional communication for battery-free devices. This work paves the way for new developments in the home automation where the focus is communication reliability and energy consumption.

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6 References

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