Visible light communication for smart cities

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Abstract

Objectives
This paper presents the results of Hybrid-VLC/IR-RF project that can be applied for secure communication using optical spectrum in smart cities. Experiments using this novel communication system is presented inside buildings and applicability for inter-building smart city applications is evaluated

Prior work
Some previous work has focused on integrating new hardware components specific to the VLC/IR-RF hybrid communications system and a brief description of the architecture of the communications system has been presented in a paper at CYSEC conference.

Approach
The paper presents the case study about new ways of implementing the communication interfaces following the improvements that have been made to the VLC/IR-RF laboratory test bench from the hardware and software point of view. Also, performance evaluations in various environmental conditions are presented.

Results
The experiments present integration at prototype level as a test bench for the hybrid VLC communications system. As such, sensor configuration is performed on IoT (Internet of Things) devices and a mobile application is developed for receiving data over MQTT (Message Queuing Telemetry Transport) protocol.

Implications
The practitioners can use this solution for communication beyond WiFi/5G radio spectrum where secure communication is needed in harsh

environments, for example underground metro, electromagnetic shielded/smogged spaces.
Value
The paper presents original work for next generation communication solutions beyond existing wireless communications such as 5G. The attention is focused on the intensive testing of the optical communication system within buildings where SMEs operate, as well as on the evaluation of its functionality for smart cities telemetry.

Keywords: *IoT, security, VLC, optical communication, sensors.*

1. Introduction

The scope of this project is to obtain an intelligent mechanism comprised of an integrated, multifunctional module with IR (infrared) sensor as compact as possible named microbolometer [1]. We target increased performances, reduced costs of implementation and energy [2]. In this paper it is presented the Hybrid VLC/IR-RF project which focuses on these requirements. The micro-bolometer [1] integrated in the VLC device has the function to measure a thermal map. It presents increased sensitivity and reduced energy consumption. In this way, VLC IR RF will be capable of multifunctional detection regarding monitoring of energy usage and ambience control [3].

The structure of the paper is as follows: Section 2 presents the architecture of the system, Section 3 the structure of the Hybrid VLC/IR-RF system, Section 4 presents the The contribution of the hybrid VLC / IR-RF communication system from the point of view of the SmartCity concept, whilst Section 5 concludes the article.

2. Architecture

VLC IR RF's function is to monitor energy consumption and to control ambiental parameters in homes, buildings, offices. This device will be able to run a processing algorithm based on artificial intelligence, therefore it needs computation power and reduced energy consumption, for example to count people or objects, to make difference between more objects, detect energy leakage [4]. Through this project, Beia Consult International contributed to developing, testing and implementation at a large scale of a hybrid system based on VLC-IR/RF communication. This system is compatible with video cameras and embedded devices which function with reduced energy. The hybrid system will be further improved, so in a few years will support building-to-building optical communications [1].

Fig. 1 presents the architecture of the system, which comprises: LED matrix, TX Unit and RX Unit development boards, VLC communication channel.

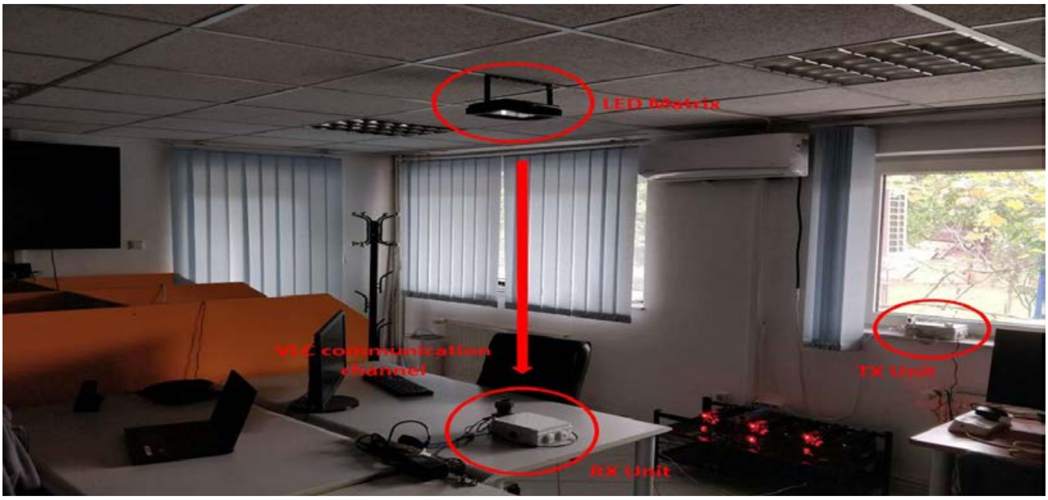

Fig. 1. VLC/IR RF System Architecture

To answer requirements from more business areas, we focused to reach a testbench level in developing the VLC/IR-RF system, to understand the principle of VLC operation, to analyze the effects and if they cause disturbances. The research team involved in this testbed had focused on the number of data packets not received when testing a connection based on an error-correction-free coding method (Fig.2) [2].

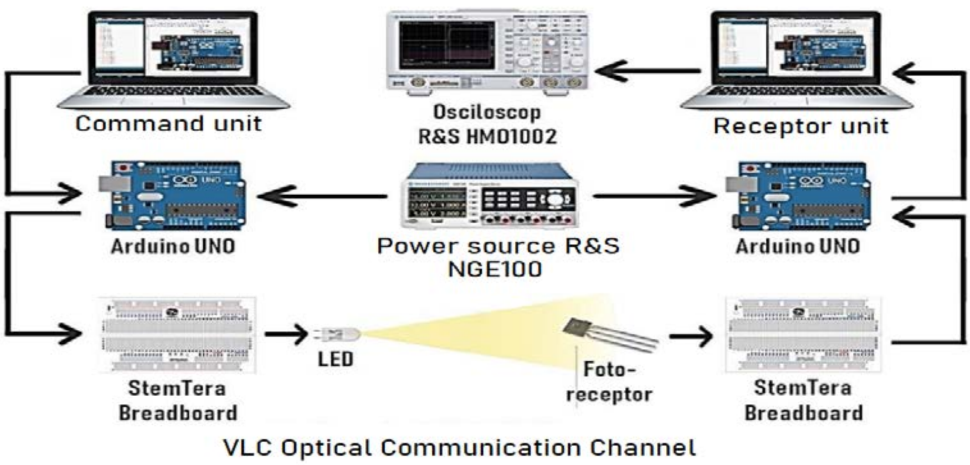

Fig. 2. VLC IR RF TestBench

The focus is to obtain superior transfer rates. Beia Consult International partnered with the National Center NanoFab, Korea, to develop a communication system VLC-IR/RF for answering specific business requirements. Developing and testing the intelligent control system took place at Beia Consult International.

3. Structure

As shown in the picture, the hybrid system VLC IR RF is made up of the following components:

- VLC/IR-RF transmission unit;
- High power LED matrix;
- VLC/IR-RF reception unit;
- Micro-bolometer sensory unit. The micro-bolometer sensory unit was brought to this project by Korean NanoFab National Center. The micro-bolometer acquires thermic images.

3.1. Transmission Unit

The transmission unit can be seen in Fig. 3. Each sensory component used for the transmission unit is described as following:

- LM35 temperature sensor module is used for detecting the moment when the ambient temperature does not fit in the value range declared.
- TSL235R professional light sensor does continuous supervising of light intensity in a certain area. The main scope of this sensory module is the guarantee of a high level of safety of the employees which stay in this area.
- PIR HC-SR501 movement sensor module supervises working areas after termination of work.
- GP2Y1014AU0F dust particle sensor monitors dust concentration inside the testing lab of the communication system;
- Noise detector sensor module which functions after termination of working hours aims for high level of safety in the laboratory.
- Micro-bolometer sensor module which detects detects movement and ambient temperature. In the research laboratory is needed movement monitoring [2].

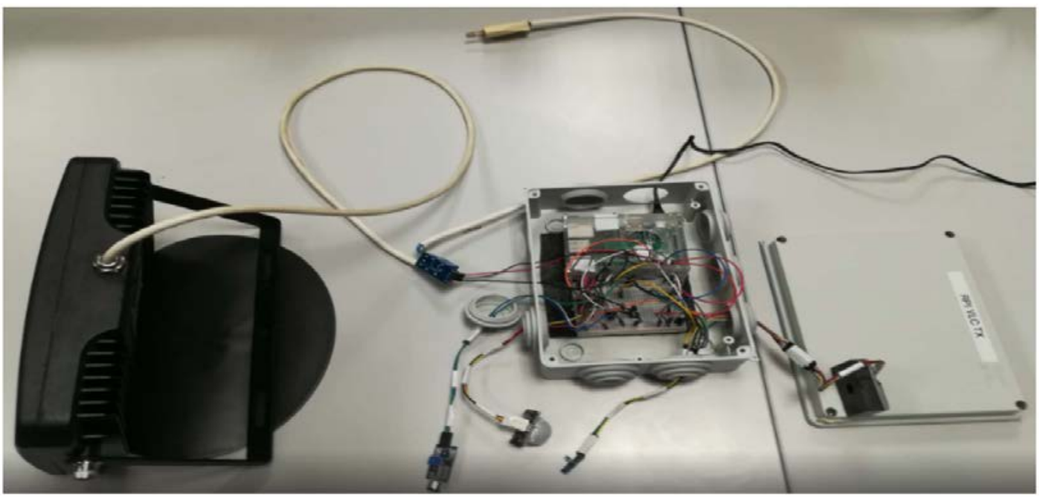

Fig. 3. Transmission unit

The hybrid system VLC has dedicated modules (developed by Beia Consult International Bucharest) that make possible installation of the sensors mentioned in the minicomputer Raspberry Pi 3B+.

3.2. Reception Unit

The photo-detector ThorLabs PDA10A (see Fig. 4) can detect a large range of light radiation values even values close to femtowatts. This photo-detector is embedded in the Receiver module.

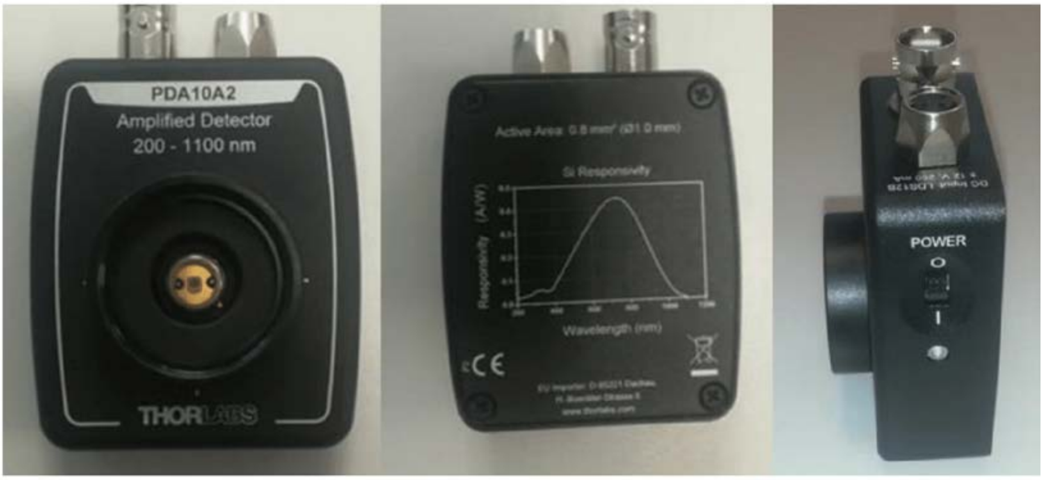

Fig. 4. ThorLabs PDA10A

Because the light received from the LED matrix must fall directly on PDA10A’s photo-sensible surface, photographic type optical lenses will redirect the matrix light to it. They can be seen in the Fig. 5, integrated to the Receiver TX.

Fig. 5. Receiver TX

The camera objective was installed successfully to the Thorlabs VLC photo-receptor. The optical communication channel is functioning. Micro-bolometer sensor (Fig. 6) is provided by NanoFab, Korea within this project. Micro-bolometer is placed in a vacuum and thermic isolated from the exterior medium. The size of the vacuum depends on the structure of the pixels from the thermal image results. The infrared radiation is captured by the absorbing material found over the suspension bridge. At the time of absorption of IR radiation the bridge temperature increases. This increase in temperature is noticed by the electronic components in the ultra-low noise reading circuit under the micro-bolometer [1].

Following the acquisition of thermal images by the micro-bolometer, in order for them to reach a processing unit, the camera can be accessed via its IP address. The partners also designed a graphical interface that allows access to the camera and image processing (Fig. 7). This allows real-time viewing of images from the thermal camera; the viewing method can be set for both black and white images and color images depending on the temperature of the viewed elements [1].

Fig. 6 shows the use of micro-bolometer cameras in an office (in order to prevent fires and detect unauthorized personnel), within the hybrid VLC/IR-RF communications system.

Fig. 6. Micro-bolometer unit

Fig. 7. User Interface

4. The contribution of the hybrid VLC / IR-RF communication system from the point of view of the SmartCity concept

An important aspect worth mentioning below is the contribution that this hybrid VLC/IR-RF communication system can have on the SmartCity concept, if we want to implement it in the near future within the infrastructure specific to outdoor environments, such as road infrastructure (traffic lights, street lighting sources, etc.), but also in the one specific to B2B (Building-to-Building) wireless communication networks (wireless effectively understanding the absence of the data cable-based transmission environment). In order to validate this statement, an additional test of the final system was performed in an outdoor environment, under the direct influence of sunlight, which is for VLC technology one of the largest sources of communication channel disruption. The purpose being to observe the level of performance of the system in circumstances different from those specific to the indoor environment of the research laboratory, was chosen for outdoor testing a day when weather conditions are favorable in terms of BER (Bit Error Rate), which involved the presence of a cloudy character and the absence of precipitation. The results obtained from this test are presented in Fig. 8. The monitoring process was performed within 2 hours, the transmission of the parameters being done once every 10 minutes.

No.	Date/Time	Sent strings	Received strings	Corrected strings	Validation
1	20.10.2020/ 13:48	[illegible]	[illegible]	[illegible]	Yes
2	20.10.2020/ 13:58	[illegible]	[illegible]	[illegible]	Yes
3	20.10.2020/ 14:08	[illegible]	[illegible]	[illegible]	No
4	20.10.2020/ 14:18	[illegible]	[illegible]	[illegible]	Yes
5	20.10.2020/ 14:28	[illegible]	[illegible]	[illegible]	Yes
6	20.10.2020/ 14:38	[illegible]	[illegible]	[illegible]	Yes
7	20.10.2020/ 14:48	[illegible]	[illegible]	[illegible]	Yes
8	20.10.2020/ 14:58	[illegible]	[illegible]	[illegible]	No
9	20.10.2020/ 15:08	[illegible]	[illegible]	[illegible]	No
10	20.10.2020/ 16:18	[illegible]	[illegible]	[illegible]	Yes
11	20.10.2020/ 16:28	[illegible]	[illegible]	[illegible]	No
12	20.10.2020/ 16:38	[illegible]	[illegible]	[illegible]	Yes
13	20.10.2020/ 16:48	[illegible]	[illegible]	[illegible]	Yes

Fig. 8. System monitoring process in outdoor environment

As can be seen, the optical emission source, as well as the reception component, showed an adequate operation of the communication channel, the performance of the system being lower compared to the results obtained indoors. Therefore, this feature demonstrates the potential of this system in terms of improving the existing communication infrastructure at local / national level. By replacing the LED emission source within the VLC transmitter with LED sources with a longer lifespan, the integration into the communication system of optical filters with the role of minimizing the specific disturbance of sunlight, as well as by using advanced methods of modulation, the hybrid VLC / IR-RF communication system developed by BEIA Consult International, Bucharest, is able to contribute to the modernization trend of Bucharest, from a technological point of view, being able to provide a high level of performance.

Of course, the adoption of such technology at regional / national level will include new challenges in terms of penetration of major industries, the reference being made to the interface with the automotive industry and that of street warning lights (traffic lights, flashing lights, etc.). These technical challenges will be the target of further research, if such an approach proves to be of widespread interest.

6. Conclusion

The emphasis of the paper was on the evaluation of the new system developed by the company BEIA Consult International, from the point of view of the SmartCity concept, with direct reference to the modernization trend of the city of Bucharest. To properly understand this concept, the work was started by analyzing the current state of knowledge about the capabilities that VLC technology has in this regard. Once this approach was completed, the contribution that the final hybrid VLC / IR-RF communications system that had been obtained could have in this direction was presented. To validate this statement, an additional test of the VLC / IR-RF system was performed in an outdoor environment, under the direct influence of sunlight, which is for VLC technology one of the largest sources of communication channel disruption. The results of the outdoor testing were also made available in this activity.

The Hybrid VLC/IR-RF project addresses the active actors on the electronic component development market by developing a device that uses more sensors for smart home and smart grid purposes. It brings increased sensitivity and reduced energy consumption. The device will be capable of multifunctional detection regarding monitoring of energy usage and ambience control in houses, buildings and offices.

Through this project, the technical expertise of Beia Consult International will contribute to the successful development, testing and large-scale implementation of a hybrid VLC-IR / RF communications system specially designed for embedded cameras and devices that require low energy consumption. The aim of the current research activity is to improve current technologies for intelligent control of personal homes and business buildings.

In the future, after the development and testing of the intelligent control system, which will be carried out at the headquarters of Beia Consult International, activities will start to improve the hybrid system so that it will be able in a few years to cope with the establishment of B2B optical communications (Building-to-Building).

The emphasis of the paper was on the evaluation of the new system developed by the company BEIA Consult International, from the point of view of the SmartCity concept, with direct reference to the modernization trend of the city of Bucharest. To properly understand this concept, the work was started by analyzing the current state of knowledge about the capabilities that VLC technology has in this regard. Once this approach was completed, the contribution that the final hybrid VLC / IR-RF communications system that had been obtained could have in this direction was presented. To validate this statement, an additional test of the VLC / IR-RF system was performed in an outdoor environment, under the direct influence of sunlight, which is for VLC technology one of the largest sources of communication channel disruption. The results of the outdoor testing were also made available in this activity.

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