An Indoor Wireless Visual Sensor Network basing on Light-Fidelity Communication

MOSAIF Afaf
Applied Mathematics and Computer science Laboratory (LAMAI)
Cadi Ayyad University
Marrakech, Morocco
afaf.mosaif@edu.uca.ac.ma

RAKRAK Said
Applied Mathematics and Computer science Laboratory (LAMAI)
Cadi Ayyad University
Marrakech, Morocco
s.rakrak@uca.ac.ma

***Abstract*—Wireless Visual Sensor Network is a collective network of nodes equipped by cameras and powered by batteries. These nodes are capable of collecting, processing, and transmitting a large amount of image/video data to each other and to the Sink. In order to increase the lifetime of such a network, it is essential to decrease the energy used in both processing and transmission tasks. This paper proposes an indoor Wireless Visual Sensor Network that uses Light-Fidelity technology to transmit and receive data. The proposed system ensures a high level of security, high speed of data transmission, low energy consumption and a good visual quality of the multimedia. In addition, it can be used for surveillance even in Radio Frequency restricted and hypersensitivity areas/environments.**

Keywords—Wireless Visual Sensor Networks; Visible Light Communication; Light-Fidelity; Wireless communication; Multimedia transmission;

I. INTRODUCTION

Wireless Visual Sensor Networks (WVSNs) are an emerging form of wireless sensor networks (WSNs) where low-cost, low-power visual nodes can capture a large amount of image/video information from a monitored site, process them in a distributed and collaborative way and then transmit the extracted data to each other and to the Sink (the base station) for further analysis. Fig.1 presents WSNs types.

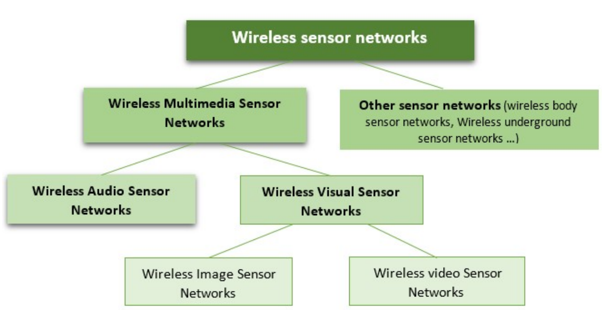

Fig. 1. Wireless Sensor Networks types

For a very long time, camera-based networks have been used for surveillance and monitoring, R. Cucchiara [1] presented several advantages of WVSNs over traditional monitoring and surveillance systems which include:

1) Enlarging the view of an event by providing a close-up view.

2) Enhancing the view of an event by providing a larger field of view (FOV) or by using cameras with different capabilities [2].

3) Exploring multi-resolution views and multiple viewpoints for the same event.

Due to the availability of low-cost CMOS camera and miniaturization of hardware, WVSNs become an important and active research area and many applications for these networks have been envisaged[3]:

- *Surveillance* such in public places, traffic avoidance, parking lots and remote areas;
- *Environmental Monitoring* such as in hazardous areas, animal habitats and buildings;
- *Smart homes* such as in elderly care and kindergarten;
- *Smart meeting rooms* such as teleconferencing and virtual studios;
- *Virtual reality* such as telepresence systems and telereality systems;
- *Industrial Process Control*.

As compared to the traditional wireless sensor networks that can only transmit scalar information (e.g., temperature), WVSNs are more complicated and challenging and require a large bandwidth for data transmission and more energy for both processing and transmitting image/video data.

In WVSNs, standard of communication such as Bluetooth, Zigbee, WiFi, UWB [4] have been used. However, for high data rate applications such as multimedia streaming over WVSNs and for guaranteeing application-specific QoS, ZigBee standard is not suitable; UWB is an ideal choice but is still not very mature [5]. While WiFi and Bluetooth consume more energy which can drain quickly the battery of the node. Other wireless communication technologies have been developed, such as the optical wireless communication (OWC) systems including visible light communication (VLC).

In this paper, we propose an indoor WVSN system that uses Li-Fi technology, which stands for Light-Fidelity as a form of high speed VLC, to transmit and receive image/video data collected from the node source to the Sink.

The remainder of this paper will be organized as follows. The section 2 presents a review of Li-Fi technology and some related works, the section 3 describes our proposed scheme then conclusion and future work are presented in section 4.

II. Li-Fi Review And Related Work

Proposed by the German physicist Harald Haas, Li-Fi is a high speed bi-directional fully connected technology that provides transmission of data through illumination using LED light bulb where the visible light is in between 380 nm and 750 nm corresponding to a frequency spectrum of 430 THz to 790 THz [6] as shown in Fig.2. The LEDs require low power for their operation and have very high switching ON and OFF speeds that cannot be tracked by the human eye.

As a medium of wireless communication, Li-Fi offers several advantages over traditional radio frequency (RF)[7] [8] [9]:

- *Efficiency*: The energy cost for data transmission of Li-Fi is considerably lower than that of RF, because it uses LED light that has a long lifetime, consumes less energy and is highly efficient. Therefore, Li-Fi becomes a promising candidate for green communication.

- *High Speed*: The higher bandwidth of Li-Fi is exploited for high-speed data transmissions boasting speeds of more than 10 gigabits per second that make it more than sufficient for downloading movies, games, music and all in very less time.

- *Safety*: Li-Fi do not have any interference issues similar to radio frequency waves that interfere with airplanes' instruments and equipment in hospitals, and is potentially dangerous in hazardous operations, such as power/nuclear generation or oil and gas drilling. It uses also LED light that is more suitable for indoor applications because it is safer for eyes compared to conventional laser-based VLC.

- *Security*: Since visible light waves cannot penetrate through walls, Li-Fi signals in adjacent rooms or apartment units would not interfere with each other, which enhance communication security by preventing eavesdropping on in-room or in-building communications.

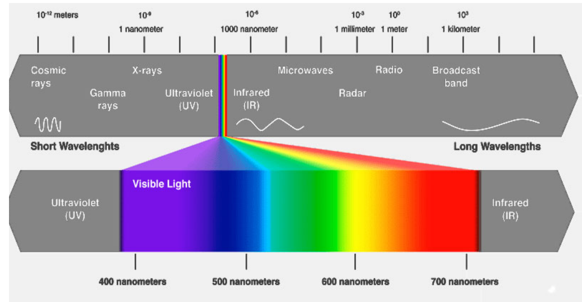

Fig. 2. Li-Fi frequency spectrum

- *Free Band*: Li-Fi makes use of free band that is unlicensed and currently largely unused for communication.

- *Cheaper*: The front-end components of both transmitters and receivers are relatively simple and cheap devices and do not require frequency mixers or sophisticated algorithms.

On the other hand Li-Fi is facing a few challenges which need to be overcome[7]. The main downside is that the visible light cannot penetrate through obstacles; somebody simply walking in front of LED source can easily block it. In addition, we have to deal with changing weather conditions because Li-Fi link data rates are degraded by shot noise if the photodiode receiver is exposed to direct sun-light for example, which leads to limit high data rate Li-Fi communication mostly to indoor environments[8]. Furthermore, the achievable data rate falls sharply with increasing distance and the line of sight is preferred because the signal will be stronger on direct light even if Li-Fi is perfectly capable of data communications from reflected light.

For these reasons, Li-Fi will not replace high-speed RF communication, which will always be used in situations where long-range, non-line-of-sight and/or outdoor links are required [8].

Indeed, Li-Fi and RF communication are complementary technologies. Authors in [10] demonstrated a practical framework for Li-Fi and WiFi to efficiently collaborate. This framework enables off-loading opportunities for the WiFi network allowing to free resources for more mobile users because stationary users will preferably be served by Li-Fi. A real-time indoor hybrid WiFi-VLC system for realizing Internet surfing is proposed in [11] where downstream data flow is transmitted by light emitting diodes (LED), whereas the upstream data flow is forwarded through WiFi connectivity, which not only decreases congestion caused by WiFi access contention, but also resolves the potential problems of uplink transmission in VLC networking.

The use of visible light communication to transmit multimedia data has been investigated in many researches. Authors in [12] proposed a design of a visible light system suitable for transmitting encrypted video files at a baud rate up to 2 Mb/s, this structure allows also audio or raw data transmission without loss of generality. In [13] authors presented a visible light communication system for transmission of audio and video signals where a DVD player is used to generate both the audio and video signals, the white and red LED light sources are used for the transmission. At the receiver side, LCD TV and speakers are used to monitor the quality of the video and audio signals following post-photodetection processing. A 2D image transmission using Li-Fi technology has been introduced in [14] where PCs have been used to transmit and receive data employing visible LEDs and using Matlab software to provide the operation of image processing.

III. Our Proposed Solution

In this section, we will present our proposed indoor WVSN system that uses Li-Fi technology for communication, then the process of this communication.

Our proposed system concept is shown in Fig.3. We propose an indoor wireless communication which use Li-Fi to transmit and receive image/video data collected from the node source (camera) to the Sink (Final user).

As the disadvantage of Li-Fi is that could be blocked by any obstacle in front of the source node, we suggest to use camera nodes that could be hung in a ceiling as shown in Fig.4. Each camera is equipped by a Li-Fi transceiver that allows communication with other nodes of the network. We propose also to use a double ceiling to allow the light passage without any obstacle and to use optique fibres to transmit data across the walls.

The double ceiling could be transparent if we need light for illumination or it could be opaque, to avoid disturbing the user by the light during night for example.

By using visible light waves, our camera nodes can power themselves, they are equipped by transceivers that allow charging their batteries and transmit/receive Li-Fi data, such as the Wysips Connect receivers [15] that transform any screen into a solar panel that can generate its own electric energy and send and/or receive data using light.

Since this research focus on the transmission of image/video information in WVSNs where the amount of visual data collected by sensors is huge. Sensors have to use compression to reduce the amount of data in order to effectively save storage memory, spare the energy and to fit the data on the available network bandwidth[16].

For that, many video compression standards such as MPEG 1, MPEG 2, H.261, H.263, H.264/MPEG4, HEVC has been developed. H.264 [17] is one of the lossy video compression methods for removing spatial and temporal redundancy. It provides a modest file size for longer recording, typically consists of the intra- and inter-mode and it is less complex than HEVC. Thus, H.264 has been chosen in this article as a video coding standard to compress the visual data collected by the nodes.

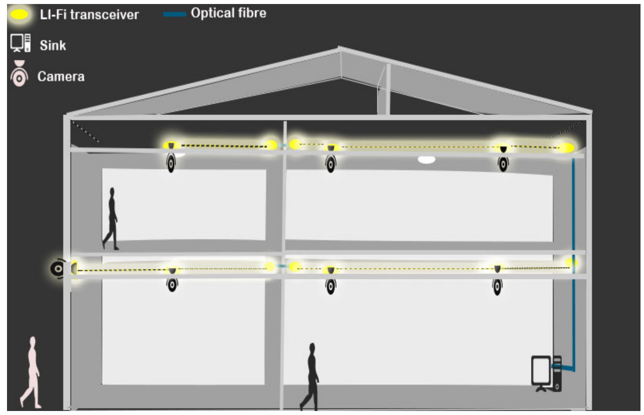

Fig. 3. Light-Fidelity Wireless Visual Sensor Network

Fig. 4. Camera model

Fig.5. describes our proposed process of multimedia data transmission in WVSN via Li-Fi technology by using H.264 video encoding standard.

In this process, the input multimedia (image/ video) signal is passed through the H.264 encoder to generate a compressed video file. Then, modulation (such as ON–OFF keying, PWM and PPM, etc.) is performed and the data is fed to the transceiver to transmit it through visible light. The received data is decoded at the receiver side to have finally a recovered multimedia signal.

To have less power consumption with better visual quality of the multimedia, the H.264 encoder can be used with the parameters in TABLE I based on optimal H.264 encoder parameter values presented in[18].

Using Li-Fi in our system can solve the problem of electromagnetic interference caused by the radio waves of RF technologies such as WiFi, which makes our proposed system ideal for Indoor monitoring and surveillance in RF restricted and hypersensitivity areas/environments such as Hospitals and Medical Laboratories.

Furthermore, due to Li-Fi advantages presented in section 2, our system will provide cheap, secure, energy efficient and fast wireless indoor communication with a wide bandwidth. In addition, the use of H.264 with an optimal configuration will provide a high video quality.

TABLE I. H.264 Encoder configuration

H.264 parameter	Value
Motion estimation	–me Dia
Quantization parameter	--qp 28
Group Of Picture	--keyint 15
CABAC	--no-cabac
Deblock filter	–no-deblock; --nf
Rate Distortion Optimization	--subme 5
Chroma Motion Estimation	--no-chroma-me
Frame rate	--fps 15

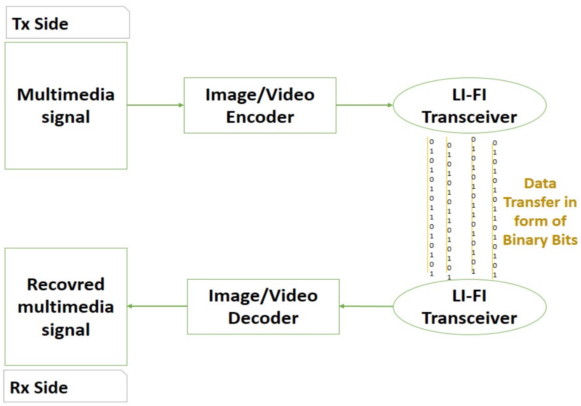

Fig. 5. Process of Li-Fi multimedia transmission

IV. CONCLUSION AND FUTURE WORK

This paper presents an indoor Wireless Visual Sensor Network that uses Li-Fi technology as a cheap, secure, high bit rate and energy efficient medium of wireless communication , which is not achieved by Radio frequency technologies such as WiFi.

The future work of this research will focus on the simulation and the tests of this system.

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