DATA TRANSMISSION ANALYSIS USING LIGHT FIDELITY TECHNOLOGY

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Abstract— Handling data transmission for radio signals became one of the most important concerns, giving birth to Light as a significant alternative. Visible Light Communication (VLC) arose as an effective option for data communication. Light Fidelity (Li-Fi) is one of VLC technologies and represents a new technique operating with light signals in order to transmit data a source to a destination. It guarantees several benefits and can overcome different limitations of Wi-Fi technologies including security issues, media obstacles, and radio interference. Li-Fi technologies are adopted for experimental usage and does not extensively arise in industry. The adoption of Li-Fi technology in industry, it is necessary to measure the performance of data transmission several data types requiring to be supported. The purpose of this paper is to investigate the performance of data communication using VLC. This work will be based on an implementation for different types of data transmission through Li-Fi. The methodology that has been adopted for this study consists on a simulation topology by NS-3 which has been built to study the performance TCP and UDP protocols in Li-Fi environment for VLC communication. Various types of data have been transmitted through an appropriate designed model. The simulation results show the differences between the two common algorithms. The implementation explained the needs for Li-Fi data transmission. Indeed, this work show a successful audio, text, and images transfer through VLC technology.

Keywords—Li-Fi, Data Transmission, VLC, NS-3, TCP, UDP.

I. INTRODUCTION

Light Fidelity (Li-Fi) is a new wireless communication mechanism for data transmission through a LED light. It is one the major Visible Light Communication (VLC) technologies. Visible Light Communication is new technique of wireless technology developed to answer the requirement of green technology [1]. Light Emitting Diodes are nowadays more present in VLC technology such as verifying the user location information [2]. Li-Fi technology principally depends on the ability of a solid state lighting architecture to generate a binary code of 0 and 1s with a flickering LED, invisible for human vision [3]. In order to receive data within the light visibility area, electronic devices implanted with photodiode may be used [4]. In other words, wherever LEDs are used, the LED bulbs not only provide lightening, but also a wireless connection to ensure a data exchange over those lights [5].

Due to the high demand of wireless data transmission in different areas and radio spectrum shortage, numerous problems with hazardous electromagnetic waves have seen the light. Li-Fi is considered as a green and cheap alternative to conventional Wi-Fi technology [6].

Li-Fi became a promising data transmission technology. Although it is the most frequently used wireless technology, Wi-Fi is subjected to a huge number of limitations. Wi-Fi works with radio waves in order to transmit data, making it extremely vulnerable to high interferences, limited frequency ranges. Moreover, the noise from other radio transmission stations lead to a degradation of the Wi-Fi devices performance [7].

Unlike Wi-Fi which uses electro-magnetic waves at radio frequencies, Li-Fi uses light to transmit data. However, the low interference experienced by light, compared to radio frequency waves, Li-Fi is preferred in case of more dense environments. The Wi-Fi spectrum is limited to an area near 5 GHz. However, Li-Fi consists of a transmission on beams of light, with a huge amount of the electromagnetic spectrum, regrouped around 500,000 GHz, leading to a virtual limitless range of frequencies required for data transmission [8]. Li-Fi operates as illustrated in Figure 1.

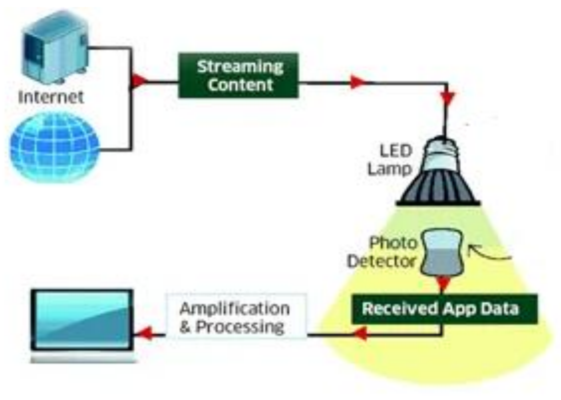

Fig. 1. Li-Fi Data Transmission

Another advantage of this new technology is security. In fact, light is opposed by the walls which will ensure a higher secured data transfer. Li-Fi implementation requires various managing mechanism of channel waves and data representation. Several researches have been conducted about Li-Fi data transmission, but with limited data types.

Equivalent data types including audio may be easily transmitted excluding any possible processing. Some other types of data need a more complicated processing and management [9]. TCP and UDP are two significant underlying protocols serving for the exchange of data between two wireless networks whose performance may be evaluated based on chosen evaluation metrics [10]. These two protocols are the mostly used in data transmission area and contributed in many evaluation, analysis, and measurement studies such as the online traffic measurement and the analysis of big data [11].

This paper focuses on the evaluation of the data transmission performance using Li-Fi through a simulation, using evaluation metrics. TCP and UDP protocols performance have also been explored.

II. METHODOLOGY

The procedure followed in this study consists of an implementation for the transmission of encoded and non-encoded data. The purpose is to investigate the performance of Li-Fi following various performance metrics including packet delivery ratio and network throughput. A reliable simulator meeting Li-Fi requirements is used in this process and a simulation scenario was designed. NS-3 simulator [12] is used for this scenario implementation.

A. Network Simulator NS-3

NS-3 represents a discrete-event network simulator and consists of a C++ implementation of the simulation core and models. It is represented as a library either statically or dynamically linked to a C++ main program defining the simulation topology and starting the simulator. It also exports almost all of its API to Python and enabling Python programs to import "NS-3" module similarly as the NS-3 library is regrouped by executables in C++. The architecture of this simulator is explained in Figure 2.

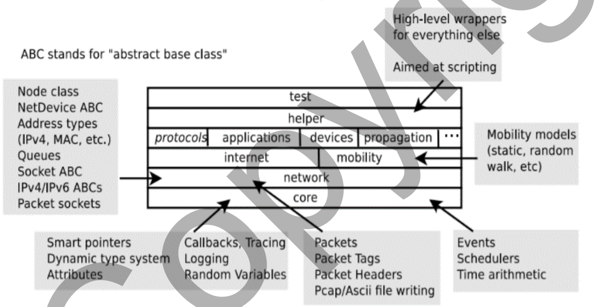

Fig. 2. NS-3 Simulator Architecture

The simulator core comprises several components used by the hardware, the protocol, and the environmental models. The core is implemented in src/core folder. The principal components of the network simulator including Packets are implemented in src/network folder. The generic simulation core used for this study is composed of two simulation modules which are used by numerous types of networks besides Internet-based networks. Two other modules that complement core C++-based API are also included. API's may be accessed by NS-3 programs directly or may require the use of the helper API. It guarantees encapsulation of low-level or convenient wrappers API calls.

Li-Fi not being implemented in NS-3 by default, the new module, "VLC-M," which represents an extension of the NS-3 core libraries is proposed in [13]. This module comprises several examples and classes to explore VLC-based networks. The module is composed of VLC helpers, VLC channel model, VLC mobility model, and example scripts. The large-scale VLC networks are managed by helpers where VLC mobility models and channel integrate diverse VLC specificities.

B. Simulation Topology

The simulation topology of this study is presented in Figure 3. It is composed of a Li-Fi Access point connected to the wired local area network (LAN) composed of 4 servers to ensure services for Li-Fi clients. The network topology includes three Li-Fi Clients which connect to the LAN servers using the Li-Fi communication with the Li-Fi Access point.

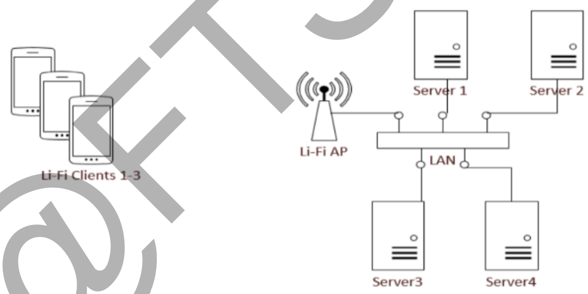

Fig. 3. The Simulation Topology

C. Simulation Parameters

Various parameters were set based on Li-Fi characteristics in order to adapt data transmission with a photodetector view filed, an Azimuth receiver representing the photodetector elevation angles. The simulation parameters indicate the transmitter's data rate and the FET channel noise factor which characterizes the fixed capacitance of a photo detector per unit area as explained in Table I. The photo detector permitted zone is distinguished by the Photodetector Area Parameters. However, for the simulation time, it is divided into four various simulation times in order to explore the performance of the data transmission process. Three Li-Fi devices send data to a unique Li-Fi access point and then forwarding traffic to LAN servers. Packet size was set to 1024 byte and two transport layer protocols were simulated.

TABLE I. SIMULATION PARAMETERS

Parameters	Value
photodetector field of view	70 degree
Receiver Azimuth	180
Receiver Gain	70
transmitter data rate	5 Mbps
FET channel noise factor	1.5
Photo Detector Area	1.0e-4
Simulation time	10,20,30,40 seconds
Packet Size	1024
Transport protocols	TCP, UDP
Number of Li-Fi nodes	3
Li-Fi Access point	1

D. Evaluation Metrics

To study the performance of TCP and UDP protocols used in Li- Fi networks, two evaluation metrics have been defined. These metrics are network throughput and packet delivery ration.

- Network Throughput: It is represented by the number of packets successfully received from source device at a specific duration of simulation. The obtained value increases when the density of sending devices increases as well. It may be represented by the size of data delivered per a second bit/s or bps.

$$Throughput = \frac{\text{No. of pkts} * \text{Pkt Size} * 8}{\text{Simulation Time}}$$

- Packet Delivery Ratio: The reliability of the network was measured following the Packet Delivery ratio concept (PDR). It represents the ratio of the effectively packets delivered to the destination node versus the total number of packets which has been sent. As PDR increases, it signifies that a lower number of packets of drops, leading to a higher network performance.

$$PDR = \frac{\text{Successfully received packets}}{\text{Total packets sent}} * 100$$

III. Results and Discussion

This section consists of reporting the results of the network simulation and a performance comparison for both TCP and UDP Protocols.

A. TCP Protocol Performance

PDR and network throughput simulation showed a significant increase in the number of delivered packets along with the time as explained in Table II. The network throughput was constant during the simulation period. However, the packet delivery time decreased as the simulation time was increasing.

TABLE II. TCP Protocol Simulation Results

Simulation time	10	20	30	40
Send TCP	5189	11600	17939	24309
Received Packets	3184	6357	9587	12831
Network Throughput (Kbps)	2608.333	2603.827	2617.89	2627.789
PDR	61.36057	54.80172	53.44222	52.78292

B. UDP Protocol performance

Packet delivery ratio and network throughput were constant and stale at different simulation times, leading to the conclusion that the network performance remains the same when the simulation time increases. Table III summarises the results obtained for UDP protocol.

TABLE III UDP PROTOCOL SIMULATION RESULTS

Simulation Time	10	20	30	40
Send Packets	4647	9367	14163	19056
Received Packets	4642	9361	14157	19050
Network Throughput (Kbps)	3802.72	3834.266	3865.80	3901.44
PDR	99.89	99.93	99.95	99.96851

C. Performance Conmparison in Simulation

The purpose of this work is to evaluate the performance of TCP and UDP in terms of PDR and network throughput. Figure 4 and 5 show the comparison of the results obtained for the two protocols for each metric.

UDP protocol has higher PDR than TCP with an increase going up to 40% as illustrate in figure 4. However, PDR of TCP protocols decreased when with the increase of simulation time since a retransmission attempt is considered when packet loss occurs.

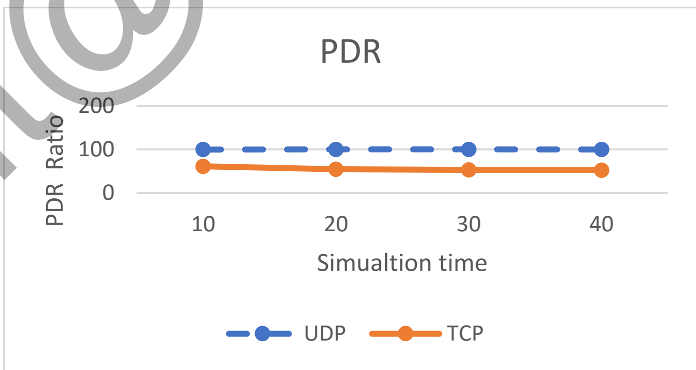

Fig. 4. The PDR Ratio of TCP Protocol Against UDP Protocol For Li-Fi Simulation

Network throughput of TCP is significantly lower than the UDP traffic because of the increase in the number of dropped packets. For both TCP and UDP, the network throughput is not affected by the increase of the simulation time as shown if figure 5.

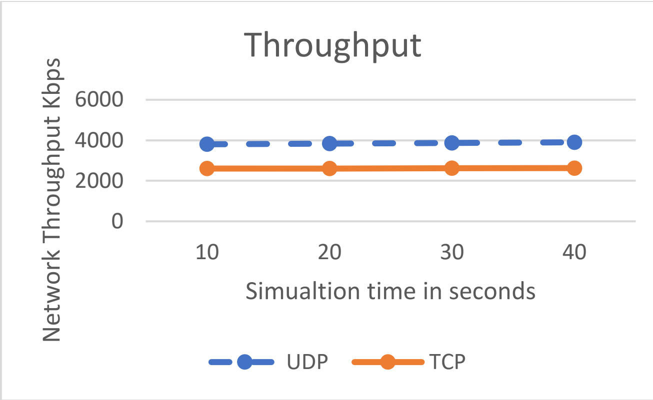

Fig. 5. The Network Throughput Of TCP Against UDP For Li-Fi Simulation

IV. Conclusion

This research project consisted of a data transmission implementation through Li-Fi with light signal propagation circuits and Arduino Uno kits. The circuit is composed of two Arduinos, a LED, a photodiode and a software developed with Arduino Ide and C#. Data communication was implemented through an Arduino board for data encoding and decoding. The LED and the photodiode were used to send and receive data signals. Two distinguished types of data were transmitted including text and images data. The performance of TCP and UDP protocols was evaluated in order to measure the reliability of Li-Fi technology in data transmission. The network protocols were simulated, and the performance was evaluated following two principal evaluation metrics which are network throughput and packet delivery ratio. The results concluded that the two protocols differ in behaviour as the simulation time increases.

The next step in this research work will consist on a testbed implementation, and a comparison analysis of the performance. It will primarily focus on two types of data transmission including voice and text testbed implementation. The purpose of this step being mainly to strengthen and support the results obtained above and ensure a better understanding of Li-Fi technology functioning.

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