LI-FI: TRANSMIT DATA THROUGH LIGHT

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***Abstract*—Society now relies on data transmission systems. Wireless connections are efficient, but their efficiency decreases when there are many devices connected, and is limited to a fixed bandwidth (radio waves). Li-Fi is a new technology based on the transmission of data through visible light by sending data through a LED bulb, that varies in intensity faster than the human eye can follow. The transmission rates are approximately 1 GB/s. In addition, LiFi systems can maintain a complete wireless network with bidirectional multiuser communication. A primary LiFi system can be used to transmit audio signals using an LED, and a photodiode as a receiver. The variations in light intensity are transformed into current fluctuations that are amplified in the receiver. LiFi can face new challenges in data transmission due to its exciting properties.**

***Index Terms*—component, formatting, style, styling, insert**

I. Introduction

The constant human necessity on transfer data and connect devices is one of the most relevant issues in any environment even more for business or educational purposes. On the latest years the digital transformation have been played an essential role in almost all the fields and wireless networks are not the exception. The technological advance in wireless connections have as predilect actor the Wi-fi technology, which is described as radio comunication technology for wireless local area networking. For Wi-fi the IEEE 802.11 protocol is which establishes the regulations for its performance and devices. At the same time "Wi-Fi is a trademark of the Wi-Fi Alliance, which restricts the use of the term Wi-Fi Certified to products that successfully complete interoperability certification testing" [1]. Thus, although Wi-fi is an effective system to achieve the connection between local areas allowing mainly internet access its weakness appears when there is a massive people concentration. Wi-fi tends to become slower and unstable when a huge amount of users saturates its capacity, for this reason the people in charge of networks and connectivity are always looking for the optimal distribution of the available devices in order to obtain the maximum profit of them. However, the as long at the number of electronic devices which need to be connected increases (IOT) the number of provider devices need to increase to, raising the cost of implementation and maintenance. There is a not widely explored wireless technology which can be the perfect combination of the Wi-fi technology in order to free its crowded system and help it to transfer data in short range and closed locations denominated Li-fi. Then, it have show better features in terms of data density, security, among other characteristics that converts it in the best companion of Wi-fi in order to improve the data transmission between near users and mainly the internet access distribution.

A. Visible Light Communication

The visible light spectrum is also a wireless channel for data, is light-based Wi-Fi with the main difference that it uses light instead of radio waves. Li-fi are the abbreviation of light fidelity and it refers also its capacity of preserve data in an integral way, it uses common fluorescent lamps without any special device. As the spectrum goes from 400 to 800 THz (780–375 nm) it could use all this capacity for for transmit data with high switching speeds (224 Gbps theoretically) able to modulate according to the stream of bits that are sent in a bandwidth 10000 time more bigger. Transmission takes place in a parallel stream for this reason more data is being transmitted simultaneously. [2]. It would be optimal in the data transference in rooms that somehow can be separated of environment natural light, and that the data need not no much range. At the same time is important to know that Li-fi works under Optical Comunication Standar IEEE 802.15.7. By the Optical Comunication Standar IEEE 802.15.7 Li-fi has:

- Access to THz of a spectrum without licence.
- MAC && PHY.
- Stands audio, video, multimedia with 10 000 nm a 190 nm.
- 3 PHY layers.
- Modulations: OOK, VPPM and CSK. [3]

B. Technical Features

Li-Fi project efficient measures this time is based in an experimental work developed in Salesiana Universisty in the 2016 . There they purpose different validations with different metrics taking as reference the baud that goes from 1200 baud to 19200 baud [3]. Then, the important features extracted for these project are the following:

- Speed:1,2 Kbps - 19,2 Kbps
- Frequencies: 389,823 Hz - 4,38500 KHz
- Distance: 0,1 m - 1,2m
- Bandwidth: 1169,469 Hz - 13,155 KHz

C. Wireless Technology for Educational Purposes

This project be aware that there are several communities with lack of access to new technologies or obsolete technologies in poor condition, such as schools in Urcuquí. This technology can provide Urcuqui students with an improvement in Internet distribution without the need to invest a large amount of money, since they will no longer need a large amount of megabytes, since Internet speed will no longer be inversely proportional. to the number of connected users. In addition, authorities could control where and when students can access the Internet. This project purpose the physical representation in a scale model of a classroom in which the roof lamps (LED) transmit two kinds of information to the students desktops serial data and audio. As the project implementation does not requires of an strong investment as social project it could be scalable and replicated in other educational centers in the country.

II. Related Works

Some works have been develop about the topic being a thesis from Salesiana University of Ecuador and an article published in International Journal of Pure and Applied Mathematics the main bibliographical sources of the project. In both works make a review and an experimental design of Li-fi with different approaches and describing useful features for the project purposes. The first work main contribution is the simulation with an oscilloscope in the ranges mentioned before which allows to determine which frecuencies and data types can work better in an experimental design [3]. The second work is focused in the experimental setup and describes in detail the functions (audio signal and text) of Li-fi that this project desire to implement in order to demonstrate the impact in large scale [2].

III. Data Transmission

For data transmission the following setup was purposed and implemented:

- Through arduino microcontroller.
- Using the serial monitor.
- Transmit binary and decimal values.
- Different serial ports.
- PHY II layer.
- Modulation:OOK form 1,25 Mbitps to 96 Mbitps.
- SISO an only receptor.

IV. Sound Transmision

For audio transmission the following setup was purposed and implemented:

- Through Smart-phone or Computer.
- Input audio digital.
- Convert to analog.
- PHY III layer.
- Modulation: CKS from 12 Mbitps to 96 Mbitps.

V. Methods and Materials

This projects is easy to implement but powerful to understand how Li-Fi works. The project is built in two parts. The first part allows to transmit data, in this case a decimal number, between a LED and a LDR. The second part allows to transmit sound from a LED to a solar panel. This solar panel is connected to a speaker which is going to play the sound. For this, it is necessary the following materials:

- 200 ohm resistor (x2),
- White LED high luminosity (x2)
- LDR (Light Depending Resistor) or Fotoresistor,
- Jack PinOut (x2)
- 9 Volt Battery
- 9 Volt Battery Connector
- 6 Volt Solar Panel
- Switch
- Arduino UNO
- Speaker

For the connection we weld the cables using tin. Also, we designed a computer laboratory to simulate how the Li-Fi will work in it. In one table we put the LDR and on another we put the solar panel to receive the signal through the light emitted for the LEDs. The LEDs were placed in the ceiling simulating the bulbs of the laboratory. The arduino, the batteries and the cables with the Jacks PinOut were placed in the back part of the computer laboratory. We add a switch to turn on and off the LEDs. In one side we put the Speaker to be connected to one of the Jack PinOut to listen the sound emitted for one LED. Finally, we left a wall available to open to see the inside of the computer laboratory.

VI. Circuit Scheme and Implementation

The code below is for the first part which allows to transfer a decimal numbers through the light emitted for the LED in OOK modulation. Also, it convert the binary message received for the LDR into decimal number which is the message received.

Code

```
int sensorPin = A0; // select the input pin for ldr
int sensorValue = 0; // variable to store the value coming from the sensor
int i=0;
int d[32];
int temp=1;
int k=0;
int add=0;
int mesg;

void setup()
{
  pinMode(13, OUTPUT); //pin connected to the relay
  Serial.begin(9600);
}

void loop()
{

  if (Serial.available()){
    Serial.println("The message to send is: ");
    mesg=Serial.parseInt();
    Serial.println(mesg);

    // Serial.println(sensorPin);
    int b;
    // Serial.println(Serial.available());
    while(mesg!=0)
    {
```

```
        b=mesg%2; //converts decimal to binary
        mesg=mesg/2;
        // Serial . println (b);
        // Serial . println (mesg);
        if (b==1)
        {
           digitalWrite (13,HIGH);
          delay(500);
          sensorValue=analogRead(sensorPin);
          d[i]=sensorValue;
           Serial . println ("Sending");
           // Serial . println (d[i]);
        }else {
           digitalWrite (13,LOW);
          delay(500);
          sensorValue=analogRead(sensorPin);
          d[i]=sensorValue;
           Serial . println ("Sending");
           // Serial . println (d[i]);
        }
        i++;
      }
      i--;

      Serial . println ("The message was sent");

      // for converting binary to decimal
      while(i>=0)
      {
        if (d[i]>=75 && d[i]<1005)
        {
          k=i;
          while(k!=0)
          {
            temp=temp*2;
            // Serial . println (temp);
            k--;
          }
           Serial . println ("Recieving");
          delay(500);
          add=add+temp;
          // Serial . println (add);
          temp=1;
        }
        i--;
      }
      Serial . println ("The message recieved is:"); // Final recieved value gets printed
      Serial . println (add);
      digitalWrite (13,LOW);
      Serial .end();
      Serial .begin(9600);
      // Serial . println ( Serial . available ());
    }

  }
```

The following scheme represents the connections of the first part which allows transmit data, in this case decimal numbers, to the fotoresistor and read it.

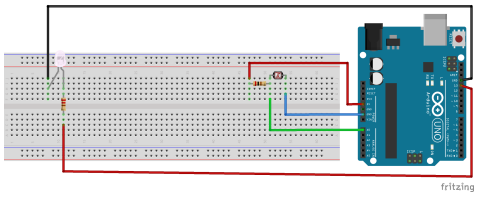

Fig. 1. Scheme of the data transmission between a LED and a LDR

For the second part, we used two schemes. One scheme is for the transmitter part showed in the figure 2, and the another for the receiver part showed in the figure 3.

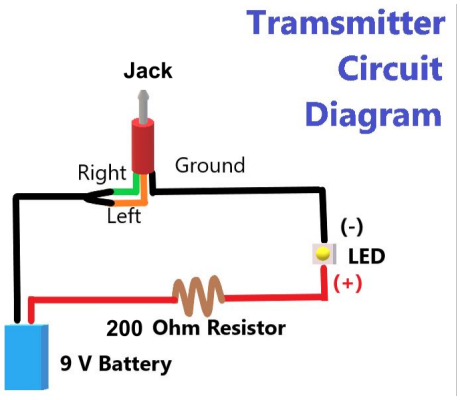

Fig. 2. Scheme of the transmitter of sound transmission through a LED

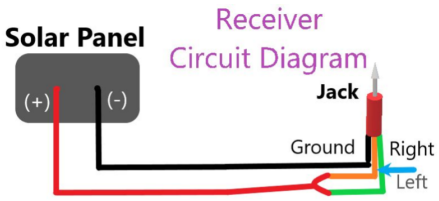

Fig. 3. Scheme of the receiver of sound transmission through a solar panel

VII. Results

The data transmission part through OOK modulation using a LED and a LDR works excellent. It transmits any decimal number through the light. The figure above shows a screenshot of the serial monitor.

Fig. 4. Output result of the data transmission

As the figure 4 shows the message is sending through LED in binary signal (on/off). When the message arrives the LDR make a conversion from binary to decimal to get the correct number. The figures above shows the physical implementation.

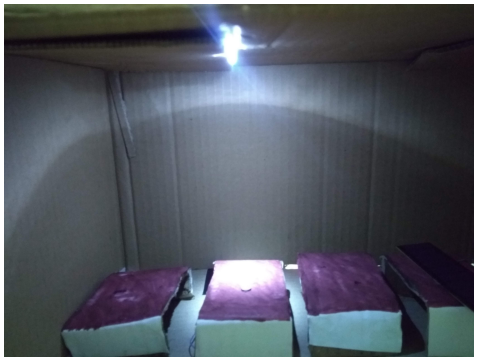

Fig. 5. Data being transmitted to the LDR

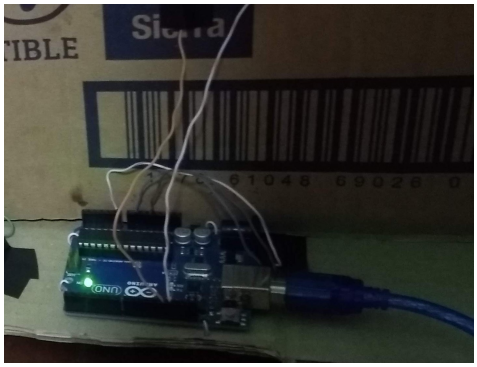

Fig. 6. Arduino connected on the back

The second part also works excellent. The sound is transmitted through the light to the solar panel. The sound is good. The figures above shows the physical implementation of the transmiter and the receiver.

Fig. 7. Data being transmitted to the solar panel

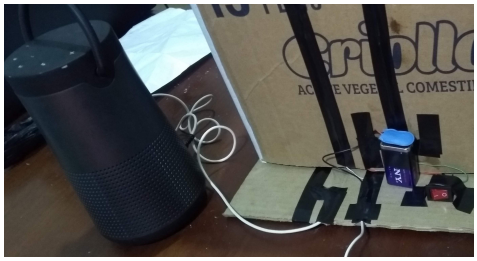

Fig. 8. Connection between the speaker and the battery

VIII. Discussion

The kind of modulation needs to be changed to implement the transmission of data like: files, videos, pictures. Also, if we want to improve the receiver it is necessary to implement a amplifier which improve the received signal. In the same way, if we want to improve the transmitter it is necessary use a powerful bulb which will improve the scope range of the light.

On the other hand, we notice that for data transmission of message as decimal numbers, the LDR works fine but it depends a lot of the quantity of light near. If an external light interferes with the light the LDR changes its received values which alter the conditions to convert from binary to decimal number. Therefore, we consider that a LDR is not a good receptor for the transmission of data through light. In contrast, the solar panel is a good receiver, because in spite of external light the sound is perfect heard. However, the volume of the sound is decreased a little.

IX. Conclusion

It was shown that the project purpose of implement a Li-fi system in schools classroom is really feasible, but it need to have a better diffusion and organization of social projects. At the same time the advantages that this technology aims are related with solve the saturation of Wi-fi and the use the not licence infrastructure and maintenance being low cost. As disadvantages were seen that the environmental conditions are somehow limited, but these conditions are not difficult to implement to improve the fidelity and range of the transmission.

Li-Fi is an emerging technology and has broad application. If this technology can be put to practical use, every bulb can be used as a WiFi hotspot to transmit wireless data. This concept can be used to solve issues such as shortage of radio frequency bandwidth. Thus, this technology provides numerous benefits. By using this technology, we can proceed towards a greener, safer and cleaner future. It is an advanced approach that will make our lives more technology-driven soon.

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