EE 344 Project Proposal
Visible Light Communication using LED

Arka Sadhu - 140070011
Sudeep Salgia - 14D070011
Parth Kothari - 14D070019

January 2017

Contents

Abstract

LiFi (Light Fidelity) is the new buzzword in new era of communication. It is often used to describe high speed Visible Light Communication (VLC). VLC dedicates itself to solving the problem of illumination and communication together. The way it is implemented is that the light source is switched on and off at a very high speed, such that it is not discernible to the human eye, but a sensitive photodiode can detect it. This solves the problem of illumination and at the same we can encode information in the switching pattern and hence enabling us to transmit data, and recover it using the photodiode receiver.

In our project, we aim to develop a prototype of Visible Light Based Communication link. The project will consist of a transmitter, a LED in this case, which will transmit the message signal which will be received by the receiver. The Transmitter will transmit a file preloaded on a USB/SD card and this will be captured by receiver.

Project Description

Background and Motivation

Visible Light Communication is the most advanced communication technology using "Visible Light"; the visible light everywhere around our daily life. We are heavily relying on our eyes to gather almost all information for our day-to-day activities. "Visibility" is one of the most important things for human being, and many devices are developed to assist our "Visibility".

For instance, there are many devices including the lightings in our offices, home, the lightings on roads, traffic signals, commercial displays, small lamps on electronic home appliances including TVs, etc.

Recently, LED (Light Emitting Diode) has been used for those devices. LED has a special characteristic to light on and off very fast. The data can be transmitted by lighting LED on and off at ultra high speed. And, the digital camera and the camera on cell phones, which are popular now, are very excellent system to receive the visible light.

By using the visible light for the data transmission, many problems related to radio and infrared communications are solved. The visible light communication has characteristics to be ubiquitous, transmitted at ultra high speed and harmless for human body and electronic devices, compared to those by radio and infrared communications.

We wish to explore the possibilities laid down by VLC. In particular we want to evaluate the capacity of LEDs to transmit data at relatively high speed and over a short range.

Project Goal

Our project aims to achieve the the following objectives in order to make a satisfactory prototype

- Transmission speed should be 1 Mb/s
- Blinking should not be detected by the naked eye
- Link should work over a distance of 50 cm
- Should transmit a file stored in a USB/SD card

Project Specifications

- Customer Specifications: The following specifications will guarantee a finished product for consumer use
  - Efficient, reliable and accurate transmission of the data at desired high speeds.

- Availability of ambient light, along with the simultaneous data transmission from the LEDs. Also, care will be taken that the flickering of the LEDs would be indiscernible, without compromising much on the illumination.

- Technical Specifications:
  - Data Rate : The speed with which data can be transmitted from one device to another. (Transmitter to Receiver in this case). Our initial aim is to achieve a data rate of 1 Kbps and then increase and finally reach the desired speed of 1 Mbps.
  - Bit Error Rate : It is the number of bit errors is the number of received bits of a data stream over a communication channel that have been altered due to noise, interference, distortion or bit synchronization errors. It is given by the formula, in On-Off Keying Modulation Scheme, as
    $$\text{OOK} : \text{BER} = \mathcal{N}(\sqrt{\text{SNR}})$$
    We hope to achieve a BER of 10^{-4} and reduce it further if possible.
  - Distance : We hope to achieve accurate data transmission upto a distance of 50 cm. If we are done with the above objectives, we hope to increase the distance till 100 cm.

Technical Design Description

Possible Solutions and Design Alternatives

When it comes to design, there a lot of choices regarding the LED specifications and modulation techniques. There are small tradeoffs with choices of one over another in terms of speed, illumination in the room, power consumption, range of the link etc. The choice depends on the place of deployment and the kind of data we need to transmit. Hence our design parameters can be changed and tweaked keeping mind the following issues. Our aim, however, will be to build a simple demonstrable prototype of a VLC, without delving into the nuances of the parameters

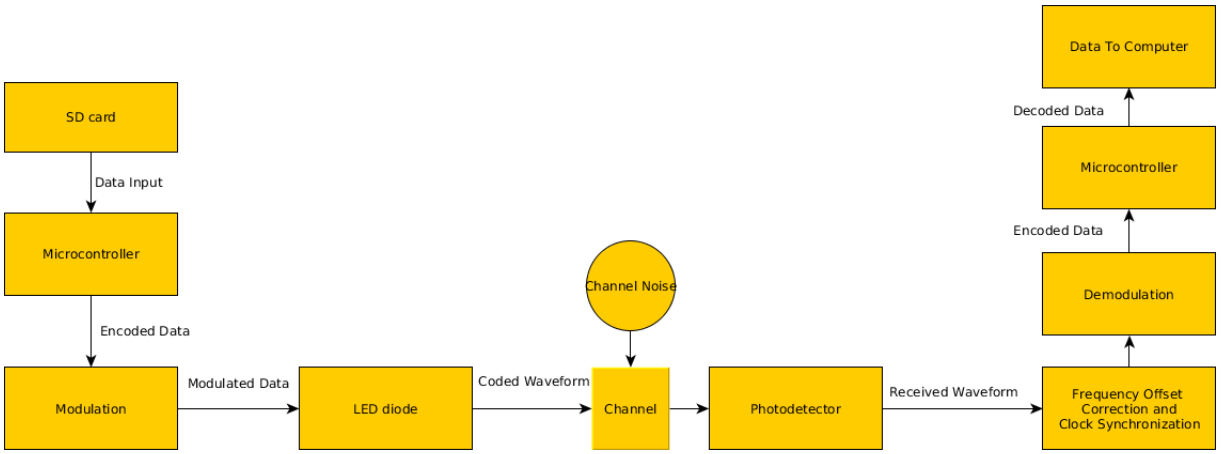
There are a number of issues when it comes to implementing VLC with the lights in the room which are to be used for illumination purposes. One of them being that due to modulation and constant variation in intensity to transmit information. This leads to a reduction in the average DC value of the light and hence in the illumination of the roo. Thus it is often task to maintain a basic level of illumination in the room that does not affect anything else. For this the main idea is to increase the frequency of the ones in the encoding scheme so that the average DC value increases. This is done using very simple coding techniques like giving a preference to 1 over 0 in Huffman encoding, etc. However we aim to tackle this problem and work on it and incorporate it into the plan of action once we have finished doing more fundamental aspects like synchronization and clock offset correction.

System-level overview

- WHAT WILL IT LOOK LIKE:
  The final product will essentially consists of 2 components:
  - The Transmitter: This will consist of a microcontroller (TIVA Board) which will get the data from the USB/SD, encode the data and finally modulate it. The data will then be sent to the LED circuit, driven by the microcontroller, for transmission. The LED circuit as mentioned earlier will essentially be used to drive the LED and ensure proper biasing. If time permits, we wish to make the LED circuitry on a PCB. Thus, the transmitter side consists of a microcontroller and LED circuit.
  - The Receiver : The transmitted signal will be received by the Receiver circuitry. This circuitry will consist of an amplifier to amplify the received signal which will then be sent to the microcontroller. The phase offset and clock synchronisation will either

be done by PLL or by the microcontroller. We will try both alternatives and choose whichever works better. After synchronisation, the microcontroller will demodulate the signal and finally decode it to get the original message. Again, if time permits, we will make a PCB of the receiver circuit also.

- HOW IT WILL WORK:
  The following is the step-by-step description of the entire system right from acquisition of the data to its reception in a file on the computer.
  - Data Input - The data will be first acquired by the microcontroller from the SD card.
  - Modulation - The encoded data will then be modulated and thus converted to a form which can be transmitted through the optical Channel via the LEDs (the Transmitter).
  - Channel - In visible light communication, it is pretty obvious that the data will be transmitted through an optical channel. Errors may arise due to interferences amongst symbols, or addition of noise or multipath fading
  - Frequency Offset Correction and Clock Synchronisation at the Receiver- The receiver will be more complicated in design than the transmitter because of this feature. Appropriate circuitry will be designed to correct the frequency offset and synchronise the clocks
  - Demodulation - Once the point mentioned above, gets implemented correctly, the modulated data will be demodulated to recover the encoded data
  - Decoding - The encoded data will be decoded to retrieve the original data intended to be sent
  - Saving the data - Finally the data which is received will then be saved in a file on the computer
- WHAT IT WILL DO:
  The project on completion will be capable of accomplishing the following tasks:
  - Efficient, reliable and accurate transmission of the data at a speed of 1 Mbps.
  - Transmission of a file stored in a USB or a SD card
  - Accurate transmissions upto a distance of 50 cm
  - Provision for ambient lighting for aesthetic effects along with transmission.
- Functional Diagram:



Performance Validation

The following measures will be noted will be used to values our performance by keeping a distance of 50 cm between the LED and the receiver:

- Time required to transmit given data from the LED to the receiver and thus the Data Rate
- The Bit Error Rate (BER) - By comparing the input file with the received file

Project Plan

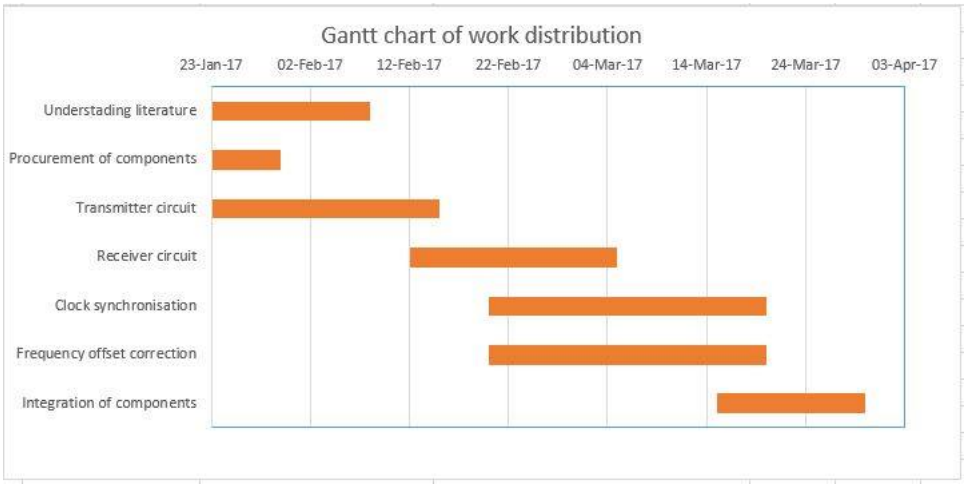
Tasks to be done:

- Reading Literature : We would need to go through a basic survey regarding the basics of visible light communication, corresponding hardware, modulation techniques with pros and cons of each of them, and hence come with a viable solution incorporating the all the factors and the feasibility given the availability of components and time constraints. The sources mainly comprise a number of papers and the few books in the field
- Circuit design : Broadly speaking there would be two main parts to this, the transmitting circuit and the reception circuit. The transmission circuit would mainly involve the LED, a biasing circuit, and a switching circuit to generate the bit pattern amongst other basic elements. The reception circuit, which is relatively more difficult would mainly involve a photodetector,a circuit to nullify the ambient DC value and related basic elements.
- Generation of bit stream : Another task is about taking a file and converting it into a bit stream which can be used to drive or feed the switching circuit. The main part is first to get a serial output of the bit pattern of the file and then modulate the signal according to the modulation scheme chosen initially. There a number of things that can be carried out in addition to the basic process outlined here which have been described later in the possible solutions section.
- Software implementation : This mainly would pertain to optimization of the implementation of the modulation scheme, error rate checking and correction and most importantly clock recovery and frequency offset correction hence synchronisation to improve the performance and the throughput of the system. This would mainly be done using a DSP board.
- PCB design : The design and development of a PCB for circuits of both the ends.
- Integration and debugging: The individual components would need to be debugged at all the stages and the all these components would need to be integrated to form a complete working system involving the debugging of the system after arranging them and finally packaging them.

Work distribution

- Reading Literature : All
- Transmitter Circuit : Parth and Arka
- Reception Circuit : Arka and Sudeep
- Generation of bit stream : Sudeep and Parth
- Software implementation : Sudeep and Arka
- PCB design : Parth and Sudeep
- Integration and debugging: Arka and Parth

Gantt chart



Project Implementation

Components Required:

- Led (white) : Rs 50
- Bias Tee Inductor and Capacitor
- Photodiode (detector) : Rs 50
- OP-Amp (for driver circuit) [TL082/ UA741] : Rs 20
- PLL IC (CD4046B)
- DSP Board
- Microcontroller (Tiva C LaunchPad) : Rs 1800

The testing strategy would be mainly around on sending different bit patterns and seeing and noting the error in each of them. The final aim is to transfer a file using the communication link. We would go about to reach this final aim in small steps of sending different bit patterns of varying length and estimate and establish the fidelity of the link. There is no specific requisites for the same except for the something that can collect and tally the data sent and received which would be done using our laptops. There aren't any specific risks associated with this and does not demand any specific setup as such. In fact that is the challenge of not having a very specific arrangement to use the communication link.

Deliverables

- By first week of February, we hope to get done with
  - Understanding Literature
  - Procurement of Components
  - Finishing the Transmitter Circuit
  - Getting Started with the Receiver
- By second week of March, we hope to accomplish
  - Finish Tackling the Problem of Clock Synchronization and Frequency offset
  - Start integrating the components.

- By first week of April, we hope to accomplish
  - After second evaluation, we get started with testing of the circuit. We will start off with 10 kbps, correct the errors which come in the way and in the end hope to get the desired speed of 1Mbps.