Bi-Directional Visible Light Communication for Internet-of-Things devices

Harsh P. Gandhi[1]
[1] E&TC Department
[1] SCoE

Abstract- *Traditional methods of wireless communications are saturating in terms of data rate, frequency spectrum and reliability. Visible light communications has attracted interests in many fields due to widespread commercial availability of LED lights and partly due to limited bandwidth available on the radio communication. It is even more effective for Internet-of-Things(IoT) devices which require very little bandwidth but still need to remain connected all the time. In this paper, I propose a method for implementing a bi-directional visible light communication system using commercially available LED lights and at the same time, try to achieve flicker free illumination. In this paper, I also go through the range of communication currently achieved with my developed setup with respect to the distance between transmitter and receiver.*

Keywords- Bidirectional Visible light communication, IoT communication, Visible light communication, VLC on micro-controllers, VLC for embedded devices

I. INTRODUCTION

Visible Light Communication(VLC) as the name suggests is a mode of communication that uses visible part of the electromagnetic spectrum to transmit data. VLC is a subset of optical wireless communications technologies with its frequency range lying in 400-800THz. Information is transferred by modulating emitted light characteristics such as amplitude and using it as a carrier to transmit the underlying data. LEDs can be switched on-off easily hence has attracted a lot of attention to use LED bulbs in communication. Most of the IoT devices require Low-Medium data rate for communication and hence, regular LEDs can be used for home automation such as light, temperature, humidity sensing and controlling. Moreover, the microcontroller present in these devices will be able to decode the signals without requiring separate co-processor.

Although LED-to-LED communication has been implemented in various research projects, LEDs have very selective frequencies. Moreover, to attain decent transfer rates, coloured LEDs such as Red, Blue, Green must be used at a time which is annoying to the regular user. Hence, in my research, I have used regular White LEDs for transmission and a photodiode as a receiver.

Transmitter and receiver devices are made up of ATMEGA168 due to relatively good clock frequency as well as enough memory to implement software based physical layer control and medium access control.

II. SOFTWARE DEFINED PHYSICAL LAYER

The physical layer is responsible for the data transmission via light, synchronization, switching modes from reception to transmission based on various parameters. The Li-Fi system consists of micro-controller system which is used to process data for transmission and reception of the data including frame formation.

In the setup, LiFi devices use LEDs to transmit data and use Photo Resistors for sensing. The communication is performed by using time slots of duration T=5000microSeconds. The system could reach even higher data rate by making this duration shorter.

However, this value is chosen for stability during testing phase. Two slots work together simultaneously sending data in standard Manchester encoding. This can also be changed with no change to the data throughput or bit error rate.

III. FRAME FORMAT

To synchronize receiver with the emitter, data is sent in a frame. This frame is composed of a synchronization preamble (0x55) that helps to compute the binarization threshold. A 0x5D then breaks the synchronization and STX (0x02) indicates the start of the frame. A sequence of maximum 32 bytes then follow (this can be changed by changing the buffer length to hold more characters) and then ETX(0x03) ends the transmission.

IV. ADAPTIVE BIT DETECTION THRESHOLD

Light intensity modulation is used to transmit symbols ON and OFF. At the receiver side, the ability to detect and differentiate symbols is affected by the attenuation of the transmitted light due to transmission medium and ambient light. Optimal detection threshold can be considered as the average of the amount of light while transmitter LEDs are off and amount of light when transmitter LEDs are ON. This threshold value is currently hardcoded into the program but can be setup to be automatically calculated.

V. EXPERIMENTAL SETUP

Testbed: To test out the bidirectional VLC and its effectiveness, following setup was used:

- 2 – ATMEGA168 acting as a modem for transmission as well as reception
- 2 – Photo-resistors for sensors
- 2 – IRFZ44N for high current switching
- 4 – BC547 for Darlington pair to switch IRFZ44N
- LED strip lights as transmitter
- Few resistors for current limiting and voltage divisions.

Procedure:

ATMEGA168 ICs are mounted on the communication board. ICs are then connected to a computer via a USB to Serial device. This will provide serial data path as well as power to our communication boards. Both LEDs and Photo-resistors are kept in line of sight. Serial console is opened for both ICs. Send some characters to one of the serial console. There will be a slight flicker on the transmitter LEDs (due to using low bitrate) and the data sent via one serial console will appear on the other console. The waveforms look as follows.

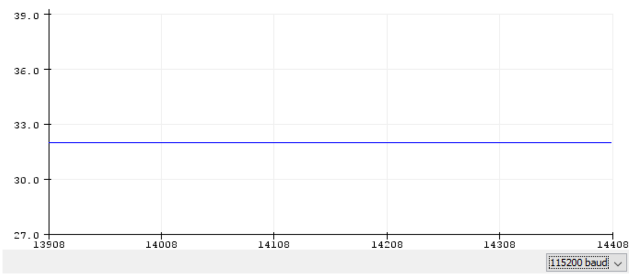

Figure 1. Photo Resistor voltage output when no data is being transmitted

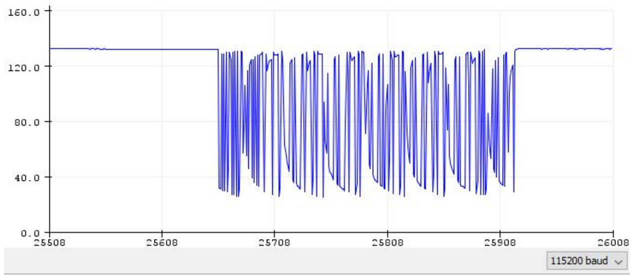

Figure 2. Photo Resistor output when data is being transmitted and light falls on it

Power Consumption:

- ATMEGA168 uses the least power of about 50mW at its peak load.
- Majority of the power is consumed by the LED series which depends upon the number of LEDs connected.

Accuracy of the received data WRT the distance between Tx and Rx:

Table 1.

Distance between Tx & Rx	% accuracy of reception
5cm	100
10cm	100
20cm	98
50cm	70
100cm	50
500cm	0

As it can be seen from the table above, with the current setup, I have been able to achieve about 50cm gap between transmitter and receiver before the data received is no longer of any value.

It should be noted here that, the receiver used is a photo-resistor which does not give the best sensitivity. It can be replaced by photodiode or phototransistor to get better results. The software also does not anticipate or correct the incoming errors that may occur due to ambient light. Improving software to perform error detection and correction will also result in a higher range with better bit accuracy rate.

VI. CONCLUSION

This work considered the effectiveness of Bi-directional Visible Light communication based on a simple 8-bit micro-controller and software implementation of the physical layer and a part of the MAC layer. An experimental setup was created to test out the efficacy of the proposed system using readily available components. The results showed that provided adequately high powered LEDs, it is possible to communicate with devices across an entire room.

The simplicity of this approach lies in the re-use of existing components. The LED-based VLC adhoc network obscures the communication within the visible light and hides the communication in the illumination. Such an LED-based VLC adhoc network, in which VLC devices communicate with each other via free-space optics, might in the future achieve a performance so that this approach will be useful for combining smart illumination with low-cost networking, to eventually become a candidate technology for the Internet-of-Things.

VII. FUTURE SCOPE

There are many fronts on which more development can be achieved. First of all, the sensor used in this project had very less sensitivity which is good for removing ambient fluctuations but bad for bit rate and range. Another important development can be made in the software front where error detection and correction codes can be implemented. Since ATMEGA168 does not have such computation capability, it can be offloaded to a coprocessor or an ASIC.

Advancement of VLC has lead to the explosion of possibilities of communication and control that was never thought of before. Indoor positioning systems based on VLC can be used in places such as hospitals, elder-care, homes, warehouses and large, open offices to locate people and to control indoor robotic vehicles. Outdoor applications include Infrastructure to Vehicle and Vehicle to Vehicle communication.

VIII. ACKNOWLEDGEMENT

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