A Location Tracking Protocol Over Visible Light Communication

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ABSTRACT
Visible Light Communication (VLC) is a blooming research area that uses a visible light spectrum as the communication channel. Exponential growth of Light Emitting Diode (LED) deployment as a light source is encouraging its use for communication purposes as well.

With the introduction of VLC, LED can be used for communication while providing the primary function of illumination. In order to prove the strength of this concept, a location tracking protocol which communicate over visible light was developed. This protocol can be used in indoor and outdoor environments. A smart torch application was developed to demonstrate the strength of the protocol. This application can be used by security guards, military or police while they are patrolling indoor as well as outdoor environments during night time.

General Terms
This research belongs to the data communication and information security application area. Visible Light Communication (VLC) is the communication media which explores in this application.

Keywords
Visible Light Communication, Information Security, Location Tracking

1. INTRODUCTION
Visible Light Communication (VLC) is defined as the communication of signals between two locations using the visible region of the electromagnetic spectrum. The process is usually performed using a pair of visible light source and visible light detector as a signal sender and signal receiver respectively [1].

In practical applications, the visible light source can be an incandescent bulb, fluorescent bulb or more recently a Light Emitting Diodes' (LED) bulb. The detectors that can be used are photo-diodes, LDR, LED and Digital Cameras [2].

In recent years with the bloom of the field of solid-state, lighting leads to the replacement of fluorescent lamps by Light Emitting Diodes (LEDs) which further motivates the usage of VLC. It uses LEDs' ability to switch into different intensity levels at a fast rate to transfer data. The characters of modern LED such as low cost, low power consumption, durability than other lamps and features like fast switching capability, Pulse Width Modulation (PWM) support on dimming capability (digital dimming without regulating voltage), direct control by digital circuit than other lamps, has made LED the best candidate for this [3].

VLC to perform location tracking which works both indoor and outdoor areas. VLC technology is used for detecting the device and its location [4]. Through this research, we are proposing a novel protocol for tracking the location of security guards, military person or policemen using VLC.

Our main target is to provide the location of the tracking person while they are patrolling during the night. It also prevents the sleeping of security guards and providing false information to the management.

The technologies such as figure print devices, security cameras can be used for the same purpose. However, it requires manual interaction and addition processes [5]. Using this novel protocol we can automatically trace the indoor or outdoor location without using GPS. The proposed protocol uses the existing infrastructure with minimum changes to achieve its objective.

In order to demonstrate the strength of our protocol, a standard LED torch is improved to provide location tracking facilities.

2. VISIBLE LIGHT COMMUNICATION (VLC) TECHNOLOGIES
Communication through visible light is important due to many reasons [6]. Firstly, mobile data traffic has increased exponentially in the last two decades and it has proved the fact that the RF spectrum is scared to meet the ever-increasing demand.

Compared to that the visible light spectrum is completely untapped for communication and it includes terahertz of unused free bandwidth. Secondly, due to its high frequency, it cannot penetrate through most of the objects and walls. This characteristic allows one to create small cells of LED transmitters with no intercell interference issues beyond the walls and partitions [7].

Thirdly it allows us to use the existing lighting infrastructure for communication as well. Therefore VLC systems can be deployed with less cost and effort. The above reasons motivate us to use VLC for building a location tracking system [8].

In any VLC system, there are two main parts involved, one is the transmitter and the other one is the receiver. The LED luminaire is the transmitter of any VLC system. The most important design aspect of a VLC system is that it should not affect the illumination, which is the primary purpose of the luminaire, due to communication usage.

There are two types of receivers; photodetector and image sensor [9]. The image sensor can allow any mobile device with a camera to receive visible light communication. However, this can provide very limited throughput (few Kbps) due to its low sampling rate. However, stand-alone photodetectors have a significantly higher throughput (hundreds of Mbps) [10].

In this research, we have used the receiver to be the photodetector in the initial prototype design and the target in the future is to replace it with an image sensor, in other words by the CCTV camera or the mobile device.

3. CONFIDENTIALITY OF THE MESSAGES

Sending messages only to the intended recipient is not possible only using VLC technology since any device in the Luminous Intensity Curve of the VLC enabled light source can receive the message. Therefore in this protocol, we are using message encryption. Hence received messages can be processed only by the intended recipient.

As specified in section 5, encryption is done using symmetric cryptographic keys from the charging station to the location tracking server. It uses three keys of the AES symmetric-key algorithm and operates in counter mode (CTR). AES CTR is a block cipher operational mode and it uses a counter value for the encryption instead of a chaining mechanism. All keys are maintained by the location tracking server and that keys never repeat. These keys are also embedded in devices and distributed in the area of interest. The location tracking server generates these keys at the registration of the devices.

4. COMMUNICATION PROTOCOL

Visible light communication is a data communications standard which uses visible light between 400 and 800 Terahertz (THz). VLC is a subset of optical wireless communications technologies.

A simple message format has been designed to share data between the VLC transmitter and receiver. The message format for VLC communication is given in figure 1.

The message format is designed in a way such that it has 800 microseconds (µs) or higher with high voltage "ON" state to start each byte. Within a byte, each bit starts with 40 µs low voltage state followed by high voltage 200 µs for digital zero (0) and 40 µs low voltage state followed by high voltage 400 µs for digital one (1).

When sending a message along with the original message additional information will be concatenated. This would be in the format of an ASCII value. Once this is combined this will be used to terminate a given message string.

The main reason for the voltage variation encoding approach would be the existing encoding approaches were not in a position to illuminate the flickering of the light source with the given hardware specification.

As an example in Manchester encoding, it uses ON to OFF sate as 1 and OFF to ON state as 0 operating in equal time stamps. Hence the flickering occurs.

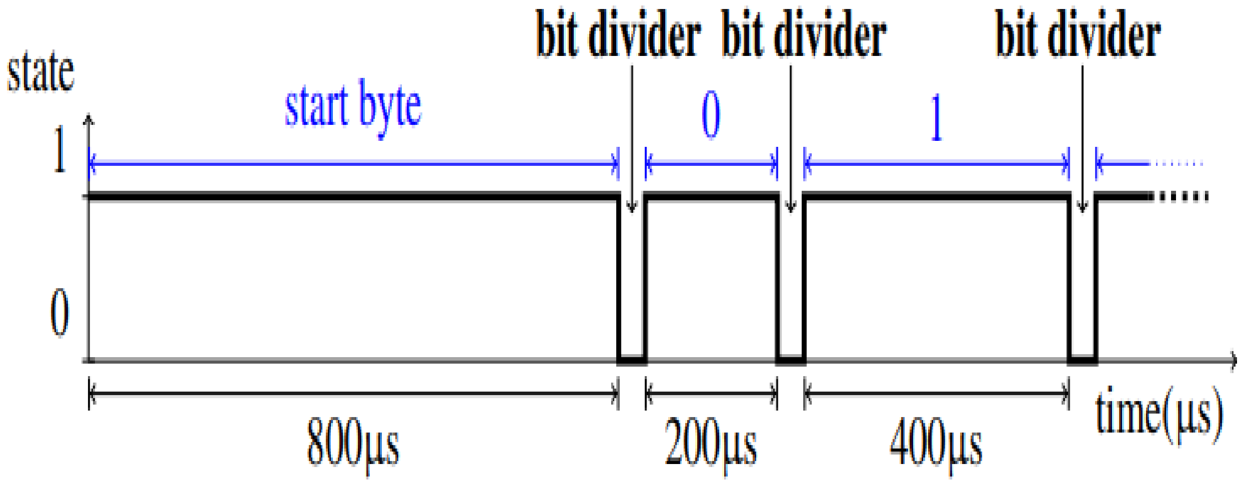

Fig 1: The Message Format

Specially designed electronic devices consist of a photo-diode that receives signals from light sources. The photo-diode sensor module has been attached to Arduino Uno and it is used as the VLC receiver in our application. It is connected to the Internet by using a Wi-Fi network.

5. A LOCATION TRACKING PROTOCOL

The following are the entities participate in the protocol.

1. A Smart Torch (ST): Special LED Torch has a VLC transmitter. It emits the data. It has a unique identification number and an embedded AES key.
2. A Security Guard (SG): A person who uses the Smart Torch (ST). ST transmits data over VLC. He/she has a unique identity number.
3. A Charging Station(CS): Special USB charging point with a keypad, unique identity number and embedded AES key. CS initializes the ST.
4. A Location Sensor (LS): A low-cost VLC receiver connect to the Wi-Fi network. It has a unique identification number and an embedded AES key. These sensors will be deployed in the monitoring area.
5. A Location Tracking Server (LTS): A server handles all registration, authentication, tracking and reporting functions.

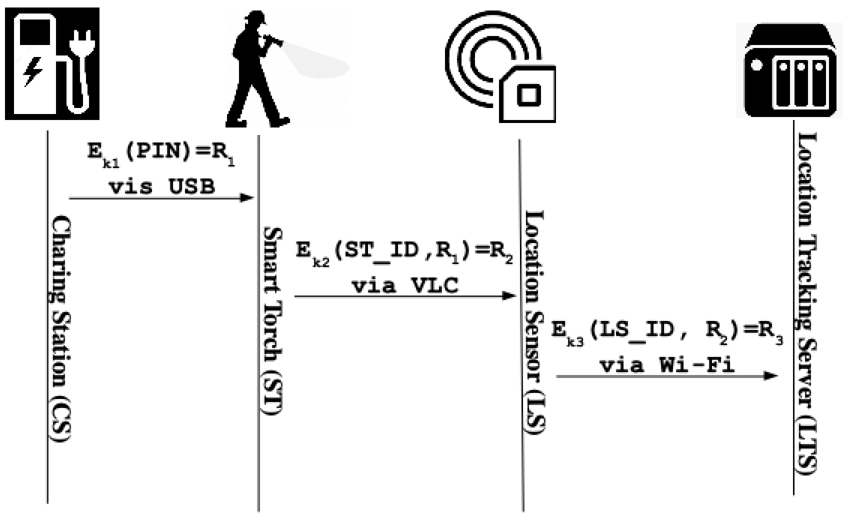

Fig 2: Protocol Message Sequence

The registration process follows the below steps.

1. All security guards are registered at the Location Tracking Server (LTS) with an identity number (PIN).
2. A Charging Station(CS) has an AES key (k1) embedded. The AES key, the CS identity number (CS_ID) and the location of CS are registered at the Location Tracking Server (LTS).
3. A Smart Torch (ST) has an embedded AES key (k2). The AES key and the ST identity number (ST_ID) are registered at the Location Tracking Server (LTS).
4. A Location Sensor (LS) has an embedded AES key (k3). The AES key, the LS identity number (LS_ID) and the location of LS are registered at the Location Tracking Server (LTS).

The tracking process follows the below steps as shown in figure 2.

1. When ST connects to the CS to charge, a security guard should enter his/her PIN. This PIN encrypts with k1 and transmits to ST via USB. Let's assume the encrypted PIN is R1.
2. ST encrypts ST_ID and R1 with its AES key (k2) and saves it. Let's assume the final vale is equal to R2.
3. The security guard takes the ST and moves in the designated area (indoor and outdoor) at random intervals during the night.
4. When he/she uses the smart torch (ST), it emits R2 at random intervals.
5. The LS detects the code (R2) emitting periodically by the ST and reads it using the photo-diode sensor attached to the device.
6. The LS encrypts LS_ID and the code (R2) with its AES key (k3) and transmits to LTS. Let's assume the final vale is equal to R3.
7. When LTS receives R3 from LS node, it decrypts it with the corresponding AES key (k3) to get R2. Then LTS decrypts R2 first with the k2 and then with the k1. It gets the information regarding the security guard (PIN), smart torch id (ST_ID), location sensor id (LS_ID). Finally, LTS records the data with the current time.

6. THE PROOF OF CONCEPT APPLICATION

In order to verify the protocol design, the Smart Torch location tracking application has been developed. VLC enabled light source of the torch is emitting its data from time to time when it wants to send information. These data are encrypted and only LTS can decrypt it. Communication between the LS and the LTS is encrypted which can only be decrypted by the LTS. Relevant smart torch module and its location can be identified by using the ST_ID and LS_ID since location information of LS are given upon registration.

By using the AES algorithm communication security is guaranteed. The R1 transmits by ST can be detected by any intruder device within the luminous intensity curve of the device bulb. However, the same person cannot obtain the device key. In addition to that, without being visible and coming in between the direct LS communication channel, (the intercept area of both the transmitter and receiver) intruder cannot obtain the R1. Thus the man in the middle attack is not possible.

The photo-diode sensor module has been attached to Arduino Uno and it is used as the VLC receiver. It is connected to the Wi-Fi network. In order to make the communication happen, the ST and the LS should be placed in the line of sight.

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7. CONCLUSION

Using the emerging Visible Light-based communication technology, we have developed a location tracking protocol where communication is done through VLC. This application would be to provide a monitoring system for physical security infrastructure. This will make sure the organization will have less overhead in managing physical security.

The Visible Light is incapable of penetrating through walls and that feature has been used here for providing location information. The protocol is implemented using existing LED technologies and the design has been made carefully to avoid the extra cost. The minimum changes have to be made to the typical LED torch to obtain the above-mentioned location tracking advantage.

When considering the receivers, the careful design should be made for placing it in the indoor location. The cell layout of the indoor location should make sure that LS is available in each room.

As future enhancements, several improvements that need to be added to the protocol design have been identified. At present, the VLC transmitter used in the proposed protocol has only one-directional communication. As future work, we could think of using the bi-directional communication of the VLC transmitter and the receiver.

The protocol works while the visual light is in the ON states under full bright mode which is visible to the naked eye. However, we could think of further investigating on making the communication happens while the light in different brightness levels and visual OFF state.

The protocol would be more useful if the receiving end of the VLC can be replaced with existing CCTV cameras.

8. ACKNOWLEDGMENTS

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