Literature Study of Visible Light Communication Techniques

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Abstract-Optical wireless communication (OWC) is trending in today's world where there is an ever increasing need of bandwidth and fast speed of communication. Visible light communication (VLC) is a subset of OWC. VLC makes use of available visible light spectrum which is present in ample amount and can be used for future needs. Source (transmitters) used in VLC is light emitting diode or any other light source and photo diode is used as a detector (receiver). As there are many advantages and future scope for VLC, it is a hot research topic. This paper studies recent techniques and development in the VLC along with the applications of VLC. Existing techniques for VLC are discussed and intelligent traffic system using VLC is presented. Two of the research areas of VLC- indoor VLC and Intelligent Traffic System are discussed.

Keywords – VLC, optical, wireless, communication, smart communication.

I. INTRODUCTION

Visible light communication is a very good alternative to radio frequency communication. It finds a wide range of applications in indoor communication. Instead of wired communication, VLC is a better alternative which is a wireless technique. Nowadays radio waves are in trend which is also a wireless technique of communication. Radio Waves produce radio frequency interference. This interference causes disturbances in electrical appliances. So, radio waves are prohibited in the areas where electronic devices need to be operated with a great efficiency. On the other hand, VLC are preferred in such situations because they do not produce any such interference. Transmitter in case of VLC is a light source. White LEDs are mostly preferred because they are power-efficient, already installed in various places, ample light energy, cost-efficient and heat radiation is also low. Receiver in case of VLC is a photo diode. These devices are cheaper than Radio Frequency equipment. [1]

In most of the cases radio frequency (RF) is used. There are certain limitations of radio frequency communication. These limitations can be overcome by VLC. Advantages of VLC are listed below:

- Safety - VLC is safe for humans as compared to RF because if RF is used above a certain limit then it can be cause harmful effects.
- Security - Signal transmitted by RF can be easily intercepted by a third party. But in case of VLC the signal is not able to be penetrated outside the opaque object which results in secure communication.
- Cost-effective - LEDs which are already used as a lighting source in several areas can be used for VLC. So, same hardware is used for illumination which is used for data transmission. Wiring present indoor areas can be used to transmit data through them to the LEDs and to interconnect them.
- Bandwidth – Available bandwidth in case of visible light is free, license and charges are not required. [2-4]

In this paper, we have presented the concept of indoor visible communication system and modulation techniques. Indoor VLC is discussed in the section 2 along with the modulation techniques and applications of VLC. Section 3 presents open problems and their solutions. Research done in the field of intelligent traffic system is presented. The paper is concluded in section 4.

II. INDOOR VISIBLE LIGHT COMMUNICATION SYSTEM

Devices like laptops, personal computers, tablets and mobile phones have been used increasingly by people. When number of devices is being used in a particular specific area, then it is more appropriate to use a technique like VLC to serve the purpose of communication. Wired communication can result into lots of expenses and a complex network of wires. Use of radio frequency communication comes with a limited bandwidth and use of infrared frequency comes with a harmful effect on eyes above a certain range. [5-8]

A. Overview

A basic indoor wireless communication system consists of a transmitter, a transmission medium and a receiver. Modulated electrical signals are transmitted to the light source. A light source can be used as a transmitter in VLC. White LEDs serve as a very good option as a transmitter. They are already installed at different places like offices, home, airplanes, and malls. Also they provide illumination with lesser power consumption as compared to other light sources. LEDs are basically of two types- trichromatic and blue-chip. [9] [10] Both of them provide data rates up to few hundreds megabits per second. Air is used as a transmission medium. Receiver in case of VLC is a photo diode which filters out the noise first and then amplification of photo current is done. Figure 1 represents the block diagram of indoor visible light communication system.

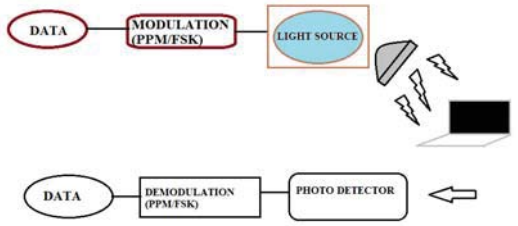

Figure-1 Indoor VLC System

B. Modulation Techniques

Generally four modulation techniques are present for VLC namely ON-OFF keying (OOK), Color shift keying (CSK), Orthogonal frequency division multiplexing (OFDM) and Variable pulse-position modulation (VPPM). A single light source is supported by PHY1 and PHY2, so OOK and VPPM are being supported by them. Multiple light sources is supported by PHY3, that is various colors, so CSK is being supported by it. These techniques can prevail together and can complement each other in VLC. [11]

OOK is the most customary of the above mentioned modulation technique. It is simple as there are two levels 0 and 1 for LED. Levels 0 and 1 decide the intensity of light. [12] Different coding techniques can be combined with it like NRZ and Manchester coding. CSK [13] technique uses bit coding respective to colors of light, so the LED must be of RGB type. Intensity of colors changes and a white light is given as the output. With the help of OFDM, data can be transmitted at high speeds by using sub carriers. Conventional OFDM system needs modification to be used in VLC. In VPPM signals are characterized by their pulse position and this pulse width is changed in accordance to the response of dimming level.

C. Applications

Indoor visible light communication can be used in several scenarios in which RF communication cannot be used because it causes interference with other electronic appliances. Most common usage of VLC is in the following areas:

- Airplanes: During a flight passengers are asked to switch off their mobile phones because that causes hindrance in proper functioning of airplane equipment. Mobile phones use radio frequency which is not well suited with installed devices on an airplane.

- Mines: Hazards can take place if a RF technology is used in mines. Only VLC is suitable in such critical conditions.

- Intelligent traffic system: Vehicles on the roads can communicate with each other and get to know the speed and distance of other vehicles around them. Traffic lights and headlights of cars are made of LED and they make VLC possible.
- Shopping malls: any person who wants to get the information of whereabouts of various shops, products and restaurants in a mall can use an application provided by the mall. They can use the visible light spectrum to get such information.
- Hospitals: Equipments installed in a hospital are not able to work properly due to the interference caused by the RF equipment like mobile phones. So use of reading lamps is a way better option to transmit data.
- Diving: In case of underwater diving, one can use VLC to contact with other divers, ships and submarines. None of the other communication technique can be used in this situation.

II. Related Research Work

With some benefits and applications in special case, there are some issues as well. VLC has a great future but some problems need to be resolved. Research work done in resolving these problems is discussed in this section.

A. Open Problems and Solutions

There are several challenging problems associated with VLC which need to be investigated. It has to account for the mobile users. It should be considered that what happens if the user is not under the direct light lo LED. As VLC systems use LEDs the problem of change in illumination can occur. This change in illumination due to LED can affect the performance of data transmission. This problem is known as dimming problem. Down link is easier in VLC but efficient techniques related to Up link are yet to be designed.

Indoor users can move from one location to another. This means that they can move from one LED to another LED. This can result in loss of connection. So there is a requirement of efficient handover techniques to deal with it, similar to the handover concept of wireless phones from one base station to another base station. Another problem is of dimming of LED, that is the illumination brightness has to be set depending on the requirements. The whole concept is to maintain the quality and performance of the data transmission and link maintenance. It can be achieved by PWM (pulse width modulation). [14] The dimming problem can also be resolved if LEDs are handled and maintained on one by one basis instead of tackling with them in a group or array. [15] Issue of shadowing can be combat if we use a TDD (time division duplexing). In [16] radio frequency has been used to serve the purpose of uplink. LEDs used in VLC are well suited for Downlink but in case of Uplink the research scope is still available. WDD technique used in [17] can be seen as one of the potential solution to this problem. In [18], it is demonstrated that a white LED can be used to serve the task of uplink and downlink. But data rate needs to be increased.

Table 1: Issues and Solutions for VLC

Issues	Solutions
Mobility of Users	Handover Mechanisms
Dimming	PWM [14]
Shadowing	TDD [16]
Up Link	WDD [17]

B. Intelligent Traffic Systems Using VLC

Traffic systems can be made smart by using VLC techniques and can help to tackle the situations that arise while driving. Vehicles, obstacles and pedestrians can be detected with the help of such systems which results in control of traffic and avoidance of accidents. Red light is used as a transmitter in such systems. [19] An intelligent traffic system using the concept of VLC is shown in Figure 2. Cars can receive data with the help of high speed cameras installed on them. [20] Research is being done in this field. Technique presented in [21] uses a detection technique for transmitter. Vehicle is made to move at a speed of 30 km/h and a high speed camera is used to receive the data. The technique proposed in the respective paper needs improvement so that speed of vehicle can be increased and real-world weather conditions are also need to be considered. SEVECOM [22] presents different modules which are categorized on the basis of security levels and handles different tasks. A flexible security system is required.

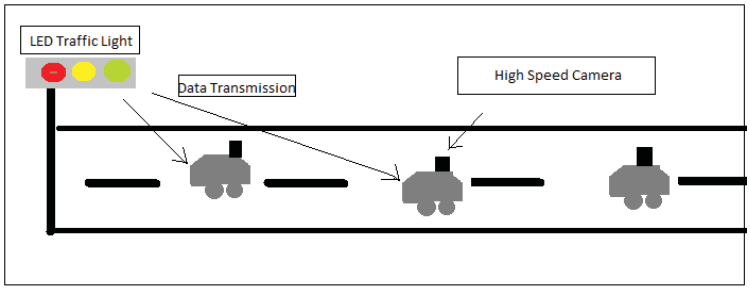

Figure-2 Intelligent Traffic System (ITS)

Each LED is modulated at an individual level and hierarchical coding is used to provide an intelligent traffic system in [23]. Data communication is done in a parallel fashion. Existing technique of ON-OFF keying is outperformed by the proposed technique. A few 100 kbps data is transmitted using this technique with in a distance of few meters. Instead of using a single LED an array of LEDs is used in [24]. Overlay coding technique is proposed which makes it possible for a transmitter to receive the data at large distances from an array of LEDs. The decoding of received signal is done on the basis of priority of the received data. High priority data is firstly decoded. Data rate is low in the proposed scheme. So in [25], data rate is improved by the authors by transmitting inverted and original signals at alternate intervals, for the long range data. But for short range data only original signal is transmitted. Receiver ads up these different range signals and track down the LED. Spatial division of LED is done in [26] using the concept of parallel wireless communication. Speed of transmission is dependent upon the partitions of LED.

Since existing techniques for traffic management have not proved their effectiveness, VLC is considered as a promising alternative to the problem. In [27] an analog circuit is being designed with the requirements of traffic management system and it is carefully integrated with the computer data so that data can be transmitted with the help of LEDs used in traffic lights and car headlights. The simulation results prove that the technique helps to effectively manage the traffic and also prevents logjams. The jams are avoided by giving information in advance to the vehicles before they reach to the point of logjams. This technique can be proved very beneficial if used in metro cities where traffic is growing day by day. Integration of two systems is done in the technique proposed in [28], using the traffic lights which are LED based to transmit data along with the ITS architecture. Different modulation techniques like OOK and PPM are used to study different results of the proposed system to inspect its efficiency in real time environment. Different scenarios are considered: night time, no interference from any other light source and day time.

For better traffic management system, the range of data transmission should be high so that the vehicles can get the information about other vehicles with in an ample amount of time in order to take decision of driving. This driving assistance with a long range of transmission up to 100 m is provided by the algorithm proposed in [29]. Receiver in this case shows high flexibility in case of changes in packet size and number of packets and the system is called VIDAS which is a modification of ADAS. N. Rajagopal et. al. in [30] presents a hybrid VLC especially for the devices which have limited power. The proposed technique is so developed that it can be used with the present IR systems as well, thus providing no changes to the design of existing systems. High speed data as well as low speed data can be transmitted. The power is efficiently used, energy consumption and simulation time are lesser than RF devices. BFSK and Manchester coding is used for high speed data's modulation in order to be useful for low-speed receiver like cameras used on the vehicles. Table 2 provides the summary of Intelligent Traffic Systems (ITS).

Table-2 Summary of ITS

Proposed Schemes	Year	Results
Transmitter detection algorithm [21]	2008	Camera installed on vehicles moving at 30 kmph in real environment.
Hierarchical transmission scheme [23]	2007	Data which is of high priority is guaranteed transmission.
Overlay coding [24]	2011	Data receiving distance is being increased.
Overlay coding [25]	2012	Overlaying of long and short range data
Parallel optical wireless communication [26]	2005	Data transmission rate is 2.78 kbps.
Intelligent traffic management [27]	2015	Prevent traffic logjams
Integrated RSUs and ITS [28]	2014	DSSS SIK modulation technique performed better

		among other modulation technique.
VIDAS [29]	2006	Receiver is made adaptable.
Hybrid communication protocol [30]	2014	Low-speed and high-speed data is being transmitted at 1.3 and 104 Bps respectively.

IV. CONCLUSION

VLC is an interesting area of research with a very good future scope. Numbers of devices which are used in indoor communication are increasing with advancement in technology. VLC is a better option for indoor communication than Radio Frequency Communication (RFC). There are some special scenarios where RFC cannot be used. VLC is found out to be promising in those cases. In this paper, a brief survey is presented on recent research work done in this field. We presented various applications of VLC and existing problems are also discussed. Traffic systems using VLC are discussed describing the future demands and problems.

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