Vehicle-To-Vehicle Data Broadcasting Through Visible Light Communication

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Abstract: Visible Light Communication (VLC) is a fast-growing technology to provide data communication using low-cost through LED-LASER and photodiodes. Which the transmitter and receiver of visible light communication have been designed and realized. In the experiment, the illumination of the receiving surface in different distance between LED-LASER and photodiode receiver has been tested, and the effect of background light has been considered, data transmit bit rate can be achieved at 111.607 kbit/s when the average illumination is 40 lx, with the communication distance of our visible light system at 1.1 cm to 1.5 km. We first develop a custom V3LC (vehicle-to-vehicle visible light communication) research platform using Microcontroller (Arduino interface) on which we experimentally evaluate the feasibility of a V3LC system under working conditions in relation to link resilience to visible light noise and interference. Our experiments show that a receiver's narrow field-of-view angle makes V3LC resilient to visible light noise from sunlight and legacy lighting sources as well as to interference from active VLC transmitters. Our main objective keys findings include: (i) in dense vehicular traffic conditions (e.g., urban highway during peak hours), of packet collisions; (ii) traffic blockage control. In this paper our main motto have to design low cost communication device which have high range and high accuracy so that we outline same basic design of transmission and receiver through microcontroller arduino mega board. Finally, evaluation of our prototype provides evidence that the system can indeed detect potential risks in advance and provide early warnings to the driver in real-world scenarios, lowering the probability of traffic accidents.

Keywords: Broadcasting, VVLC, Arduino, Control design, Filter.

I. Introduction

Currently there is rapid development in the field of lighting and illumination. Concerns about energy consumption are leading to the phasing out of incandescent sources. LED has many advantages such as long life, small volume, low power consumption and low heat radiation. Visible Light Communications (VLC) originated in Japan, where the Visible Light Communications Consortium (VLCC) [1] has been in existence for several years. Interest is now growing rapidly, both in Asia and Europe, where the Wireless World Research Forum [2] has worked in this area. This paper introduces the principles of VLC, and outlines some of its major challenges. Some potential solutions and future applications are also described.[12][13]

First we identify and classify a set of required V2LC services, namely, vehicle-to-vehicle broadcasting, limited vehicle-to-vehicle broadcasting, infrastructure-to-vehicle broadcasting, vehicle- to-infrastructure any casting, and vehicle-to/from infrastructure unicasting. Furthermore, we develop a V2LC prototype research platform employing three principles. First, we use optical and analog techniques to increase the prototype's robustness to noise. Second, we use off-the-shelf components and achieve a feasible form factor for a vehicular environment. Third, we provide a flexible programming environment for algorithm -Implementation.

Second, we evaluate the feasibility of V2LC networks to operate in working conditions via experiments with the prototype. We find that V2LC is resilient against diurnal noise sources (i.e., sunlight) with the exception of direct exposure to the sun. This exception can only occur when vehicles have unobstructed direct line-of-sight to the sun during sunrise and sunset (i.e., when the sun makes a small angle to the horizon and falls into the VLC receiver’s -120 field-of-view angle). Additionally, we find that V2LC is robust to nocturnal noise generated by idle VLC transmitters as well as legacy lights with no data transmission abilities. When evaluating V2LC’s performance under interference from other active VLC transmitters, we determine that the VLC receiver’s field-of-view angle yields a spatial binary property on the probability of successfully receiving signals. Last, we evaluate the ability of V2LC to operate in full-duplex mode. We characterize the feasibility of full-duplex mode in relation to multipath effects created by reflective and scattering surfaces in vehicular environments and experimentally show that such effects exist only in very short distances, e.g., within 1.5 m. Third, we examine the ability of a V2LC system to provide the necessary network services to satisfy vehicular applications' requirements. To this end, we perform a large-scale simulation to paths results from V2LC’s high spatial reuse, and it overcomes the effects of packet collisions. Second, in the presence of a visible light blockage in vehicular traffic, V3LC can opportunistic enable successful transmission using the inter-vehicle gaps that are caused by the dynamic vehicular movements.
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II. Overview

VLC has potential applications in a number of areas. Each of these is briefly described in the following sections, together with the motivation for using this means of communication.

2.1 Visual Signaling and communication

Colored signal lights are widely used in marine, automotive and other applications. In this case the color provides a signal to the observer, such as ‘red for danger’, and augmenting this with data communications might improve safety and other aspects of traffic management. Due to their reliability, LEDs are widely used in these applications, and there have been several demonstrations of data transmission by modulation of these sources. In [3] data is transmitted from a traffic signal to a car, and in [4] a scheme for parallel communication is presented. An EU research project [5] examined car-to-car communication using white-light headlights. V2V can warn you of potential danger by alerting you to the presence of cars in your blind spots or around a bend, and it can also use data such as speed, direction, and acceleration to determine whether or not you’re going to smack that Scimitar in front of you.

Figure 1. Real time VVLC communication system

2.2 Information display and communications

Displays, such as signboards and indicator boards, are often fabricated from arrays of LEDs, and these can be modulated to broadcast the signboard information to a PDA or handheld terminal. In [6] an example of a signboard used to transmit data is described. This might find application in airports, museums and other environments where location dependent broadcast of data is required. Such location dependence and indoor positioning is an area of interest, particularly within the VLCC. In this case a locally generated signal can be transmitted to a terminal, thus determining its location by its proximity to a particular lighting fixture.

2.3 Communications

Point-to-point links between handheld terminals rely on there being ‘sufficient’ alignment between the two ends of the link. Using visible light allows the user to be involved in this, allowing smaller beam divergence, and therefore lower path loss. Communication between two peripherals is described in [7], and it may be possible to create very high bandwidth links for secure media downloading using similar techniques.

2.4 Illumination and communications

White LEDs can be used for both illumination and communications, so that information can be broadcast within a room [8, 9], or transmitted via a car headlight [5], with the necessary illumination provided at the same time. Several examples of music broadcast demonstrators [7] have also been reported. This may be a wide area of application, and there is considerable interest in building systems that do this.

2.5 Positioning and communications

Obtaining the position of a mobile user indoors is challenging, and VLC allows the transmission of positioning information from a lighting fixture, so that a user knows their location in a building. There have been a number of schemes proposed [11-13] that use either triangulation or proximity to a beacon, or a combination to provide position estimation. It can be seen that there are a number of different types of VLC link, but in most cases the communications is a secondary function. This makes it distinct from most other wireless standards, as VLC must be compatible with any standards for the primary function. This introduces a number of constraints, and also the necessity for co-development of standards with the primary body. In the next section applications using white LEDs for illumination and communication are described in more detail.
III. Challenging

3.1 Increasing light intensity

Light intensity modulation is used to differentiate and detect symbols ON and OFF. At the receiver side, the ability of detecting and differentiating symbols ON or OFF is affected by the attenuation of the transmitted light from the source VLC device and the intensity of the ambient light. Assuming that transmitters and receivers are synchronized, an ideal detection threshold is helpful to reliably decode the received bits by distinguishing the ON and OFF symbols. Such a threshold is difficult to determine because the level of ambient light changes over time. When the two devices are placed close to each other with the LEDs pointing towards each other’s field of view, they try to synchronize. After the VLC devices achieve synchronization, the devices emit and receive light at the same time.

3.2 Increasing data rate

The low bandwidth of the transmitter is to block the phosphor component at the receiver by using a blue filter. In [8] it is shown that this can increase the bandwidth substantially, albeit at the penalty of a small reduction in received power due to filter losses. It is also possible to improve the response by transmitter and/or receiver equalization, or the use of bandwidth-efficient modulation schemes that take advantage of the high available signal to noise ratio. In addition, for higher data rates it may be possible to use parallel data transmission from a number of LEDs. Each of these techniques is discussed in more detail below.

3.3 Transmitter equalization

Analogue equalization techniques can be used to compensate for the rapid fall-off in response of the white LEDs at high frequencies. It is possible to use an array of LEDs, each driven using a resonant technique with a particular peak output frequency to achieve this. Careful choice of a number of different frequencies allows the overall response to be ‘tuned’ to that desired. In [14] a 16 LED array is modified to have a bandwidth of 25MHz (without blue filtering) offering a data-rate of 40Mb/s for Non-Return to Zero (NRZ) On-Off Keying (OOK). More complex equalization can also be used for single devices, and data rates of 80Mb/s (NRZ OOK) [18] have been demonstrated.

3.4 Receiver equalization

Transmitter equalization has the disadvantage that the drive circuits for the LED (which often involve currents of several hundred milliamps) need modification, and in a typical coverage area there may be a number of sources, making the modifications potentially costly. In addition some of the signal energy used is not converted into light, thus reducing the energy efficiency of the emitter. Equalisation at the receiver allows complexity to be at the receiver only. A simple first-order analogue equalizer is modelled in [15], and this shows there is substantial improvement in data-rates. More complex approaches are likely to yield higher data rates.

3.5 Noise Control

Discrete and extended background sources are the main two sources for the daylight noise. The first source is corresponding to the sun optical beam and it is considered as the main challenge in any optical receiver design, based on the fact that this noise may or may not be in the LOS of the receiver, and considering as small as 2 meters of inter-vehicle distance in a platoon, we assume that the receiver is not directly exposed to the discrete noise. The extended background source assumed to have isotropic behaviour and equally effect to the entire received spectrum since the source of this noise is the skylight [13], and can be detected in any optical receiver FOV. Following the analysis in [14], most background sources are described by a Blackbody radiation model, in which the spectral irradiance is as follows:

\[
W(\lambda) = \frac{2\pi bpC^4}{\lambda^5} \left[ \frac{1}{\exp(kTB/\lambda) - 1} \right] \]  

Here bp is the Planck’s constant, C is the speed of light, \(\lambda\) is the desired wavelength, \(k\) and \(TB\) are the Boltzmann’s constant and the average temperature of the sun surface, respectively. Based on this analysis, the irradiance that falls within the spectral range of the receiver optical filter is

\[
E_{det} = \int_{\lambda_1}^{\lambda_2} W(\lambda) \, d\lambda 
\]

There for noise power detected by the optical receiver physical area is given by

\[
P_{\text{background}} = E_{det} T e A_{ph} n^2 
\]  

Total noise variance \(N\) is the sum of the both shot and thermal noise by combining both (5) and (6) which yields in
Here $\partial s$ and $\partial th$ Shot noise real light and sun light

Shot noise represents the shot noise contributions from both LED vehicle rear light and the intense ambient light during the day time as the following;

$$\partial s = 2qP_{signal}B + 2qP_{bg}I^2$$

(5)

Where $q$ is the electronic charge, $B$ is the equivalent noise rectangular transmitter pulse shape [18]. The background noise power $P_{bg}$ determined using (9) is a time variable reaches its peak at 02:00 pm [15]. Thermal noise is uniformly distributed across the frequency spectrum and can be given by:

$$\partial th = \frac{8nkT_{a}}{G} \eta I^2 B^2$$

(6)

Where $T_{a}$ is the environment temperature, $G$ is the open-loop voltage gain, $\eta$ is the channel noise factor and $I^2$ is the noise bandwidth factor.

3.6 Longitudinal and lateral control

In order to maintain a constant inter-distance reference $d_{ref}$, we use a classical proportional integral controller to control the velocity $V_F(t)$ at time $t$ of the follower vehicle. For a measured inter-distance $d(t)$ at time $t$, the velocity of the follower vehicle is given by the following formula:

$$V_F(t) = K_p e(t) + K_i \int e(\tau) \, d\tau$$

(7)

Where the error $e(t)$ is given by:

$$e(t) = d_{ref} - d(t)$$

(8)

Figure 2 mathematical curve calculation

IV. Modulation Model

BER performance is related to the both coding and the chosen modulation techniques. In this study and because of its excellent compromise between the peak power and the receiver bandwidth requirements, as well as the simplicity of implementation, we consider for the studied model a binary level modulation scheme consisting of two equally likely symbols On-Off-Keying (OOK).

$$BFB = Q(\sqrt{SNR})$$

(9)

We know that

$$SNR = \frac{S}{N}$$

(10)

Where $S$ is signal and $N$ is total background noise

V. Implementation

5.1 Test-tool

The test consists of Atmel ATmega328P evaluation board (Arduino board) [3] connected to a computer. The computer generates the traffic for board and collects the measurement results. Evaluation board operates one transceiver LED to mimic one VLC device. The VLC devices operate the Python and JAVA software language. A 5mm red LED, type Kingbright L-7113SEC-J3, with transparent case. This LED has a peak wavelength of 640 nm, a 20° field of view (radiation angle), and a brightness of 12000mcd. This type was selected because it is common and widely available. Board connects an LED to the microcontroller. We are interested in counting successful frame transmissions and measuring the time it takes to deliver them (including waiting time and retransmission time, if any). The tests were performed in an Lab indoor space with windows but no direct sunlight, during the day, and with normal lab artificial lighting.
VI. System Model And Architecture

6.1 System model

![System design layout model](image)

Figure 4 real time hardware design using Arduino board

Led for transmission and photo detectors for reception. A photo detector efficiently converts light photons into electrical current. Already with one LED and one photo detector, it is possible to build a one-way VLC system in which frames are transmitted from the LED to the photo detector, but this kind of VLC system does not provide a feedback channel back to the LED. To build a two-way VLC system that allows feedback, two components per device would be required: an LED to transmit, and a photo detector to receive. It is possible to use the LED as a photo detector to receive optical messages using the same LED that is used for transmission [6], a setup that reduces the complexity per device.

VII. Conclusions

LED is a promising candidate of the future lighting system. In this paper, a visible light communication based on white LED has been proposed. We designed the circuitry diagram by using Arduino /python as the coding and decoding devices. In our experiment, the illumination of the receiving surface in different distance between LED and photodiode receiver has been tested and the indoor illumination has been considered. The BER vs. communication distance also had been tested experimentally. And the results show that our system has a good performance that the communication distance can be get 1.5 m with bit rate upto 111.607 kbit/s.

References


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