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Infrastructure-less Vehicular Communication System Using Li-Fi Technology

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Abstract

This paper introduces vehicle to vehicle (v2v) communication system using Li-Fi technology. The lightning quick transfer of information between vehicles becomes mandatory when danger is imminent as it can instantly diffuse a potentially hazardous situation. Connected cars will help cities and states cut down on congestion and improve safety. On the road, cars will communicate with each other, automatically transmitting data such as speed, position, and direction, and send alerts to each other if a crash seems imminent. We consider the several scenarios: 1) communication between car and RSU 2) inter vehicular communication 3) communication based network system. The reach ability, delay in transmission and percentage collisions are evaluated with respect to the average distance between cars using pixel oriented visualization. With the help of LEDs fitted in the car, we can transmit data seamlessly using rapid pulse of light over VANET (Vehicular Ad-hoc network) for high speed communications.

Keywords: Li-Fi technology; vehicle to vehicle (v2v) communication system; VANET; Road Side Unit (RSU); On Board Unit; reach ability.

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1. Introduction

These days the developed countries are increasingly characterized by a pervasive and extensive computing environment. People’s living environments have been emerging based on information resource provided by the connections of various communication networks. In the last decade, advances in both software and hardware technologies have resulted in the need for connecting vehicles with each other. In this paper, we present (i) initial designs and results of using light fidelity (Li-Fi) technology, recent technology that was developed in the last couple of years [1], which still needs more procedural inquiry on its sustainability and bear ability for outdoor vehicular networks (ii) the performance of the VLC network system in terms of delay in vehicle to vehicle broadcasting and percentage of packet collisions (iii) examination of the MANET dynamic network for exchanging information without using any previously existing fixed network infrastructure or a centralized administration.

Vehicle to vehicle communication [2] is the most fruitful solution we have used in order to reduce vehicle's accidents. The scenarios of cars in all different situations have been taken into account. [3]The proposed use of LiFi technology comprises of mainly light emitting diode (LED) bulbs as a means of connectivity by sending data via light spectrum as an wireless optical medium for propagation of signal. The design system focuses to ensure a fully reliable communication between a commercial LED based transaction light and a receiver that is mounted on a vehicle. Vehicular Ad hoc Networks (VANET) belong to a subcategory of the traditional Mobile Ad hoc Networks (MANET) [4]. The important feature of VANETs is that mobile nodes are vehicles that are incorporated with sophisticated “on-board” tools and equipments, traveling on a path with constraints (i.e., lanes and roads), and communicating with each other for message exchanges via Vehicle-to-Vehicle (V2V) communication protocols, and also between vehicles and fixed road side Access Points (i.e., cellular and wireless network infrastructure), in case of Vehicle to Infrastructure (V2I) communications. The MANET nodes are equipped with wireless receivers and transmitters using antennas, which may be multi directional (broadcast), highly -directional (point to point), also possibly steerable, or some combination thereof [5]. The ad hoc topology may change with time as the nodes (i.e. vehicles) adjust or move their reception and transmission parameters.

The rest of the paper is presented as follows. The different types of communications between vehicles and Road Side Units are discussed in section 2. A simple design of the working of the infrastructure based communication system is explained in section 3. We introduce different network services that can be incorporated in the infrastructure based communication design in section 4. Reach ability, transmission delay and collision percentages are evaluated in section 5.

2. Types of vehicular communication

2.1. One way communication

Figure 1 represents a Position Based Routing for Wireless Ad hoc Network [11] in a rectangular space. The main components in the figure are: (1) A stationary Road Side Unit (RSU) (2) Solar Harvester and Receiver on the top panel of the car (3) LED Headlights and Taillights. The LED periodically sends out mobile packets with its current velocity and direction which is detected by the passing sensor mote and is added to its routing table. The road side unit gauges the position of the current node and neighboring nodes and sends this data to all the nodes in the network. This data is captured by all the solar panel receivers in range of the sensor mote. Once this information is received by a particular car or multiple cars, it can be used to update information of the cars in vicinity which cannot be reached by any sensor mote as shown in the figure. Such a system would help the cars signal to one another so they can respond quickly to upcoming traffic changes as well as warn drivers of immediate threats.

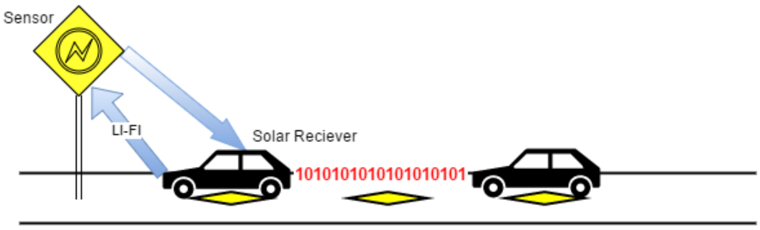

Figure 1: Communication between Road Side Unit and fitted LED

2.2. Bidirectional Communication

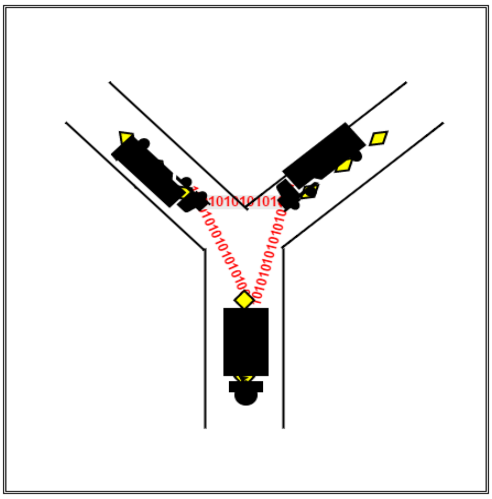

Figure 2: Bidirectional Communication using encrypted LED

Figure 2 represents multiple vehicles communicating with each other in a Y Junction. It should also be taken into consideration a lack of RSU in this scenario which might affect the accuracy for computing traffic flow but can be very useful for alerting drivers and curb potential accidents. While humans can't pick up on fast modulations in light, LEDs can. Hence the headlights and taillights act as transmitters and receivers of data packets [14]. The information of presence of other vehicles is sensed and the speed of the vehicle approaching is estimated with the help of the encrypted LED. This data is updated in the database table after every certain number of hops and thus transmitted further in the ad hoc network keeping a criterion either of distance not being more than 70% or transmission delay being high, whichever one is smaller. This kind of communication can protect drivers from blind spots.

2.3 Infrastructure Based Communication

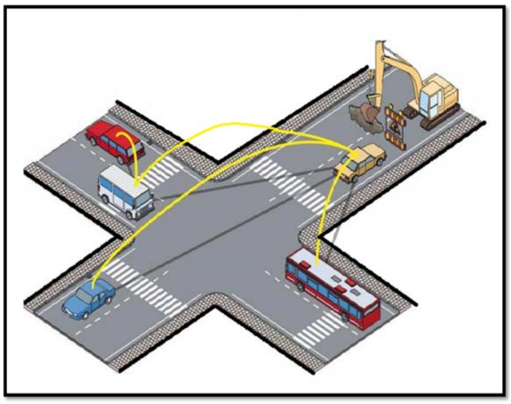

Figure 3: Traffic Control

A network can be formed by incorporating the first two communication techniques. The Li-Fi packets travel short distances from one vehicle to the neighboring vehicle carrying information about their unique ID, speeding information, number of hops and Virtual Path ID. Information is passed from one vehicle to another forming a MANET infrastructure-less network. The local tables of every vehicle are updated through the On Board Unit (OBU) provided for every car. Virtual Path ID and number of hops will alert users about probable accidents. The RSU will be used inform the local user about congested routes. Since each vehicle will be given a unique identity their speeding information can be tracked by the RSU which can be used for traffic control [9].

3. System Design

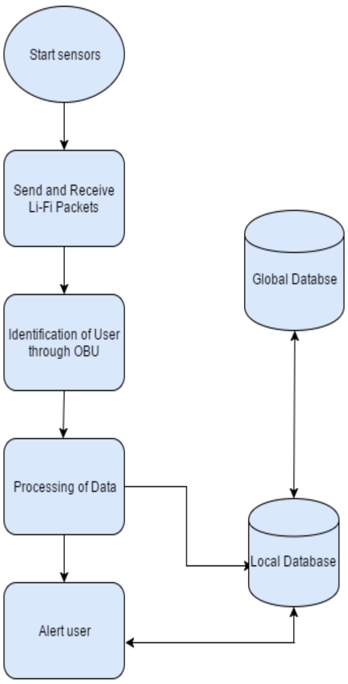

Figure 4: System Flowchart for Infrastructure-less Vehicular Communication System

Infrastructure based communication system will consist of a local and global database. The working of this system is explained further. The LED light installed in every vehicle will broadcast a "START" signal to all sensors in the coverage area [12] .The on-board unit (OBU) is the device, installed in the motor vehicle of the road user. The OBU will allow the system to collect details of the incoming Li-Fi packets for accurate identification of the vehicle and processing of stored data [13].This data is processed .and added to the local database. The local database has will perform two major roles. First it will alert the user about any threat in the near future or provide updates about the traffic and speeding information. Secondly it will help in mapping a global database which can be used for forming a MANET infrastructure-less network [2] used for traffic and congestion control.

4. Infrastructure-less Vehicular Communication Network

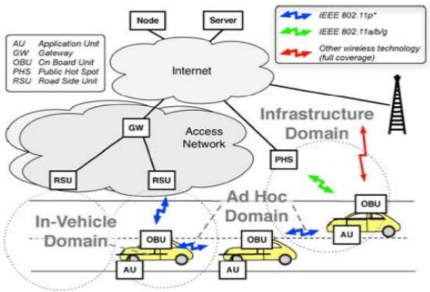

Figure 5: Ad-hoc network for V2V communication

Infrastructure-less communication forms a MANET network. A MANET is a collection of wireless mobile nodes that dynamically make a network for exchange of information without any use of pre-existing fixed network infrastructure or an administration that is centralized [2]. MANET nodes(i.e. vehicles) are equipped with wireless receivers and transmitters using antennas, which are multi-directional (broadcast), highly - directional (point-to-point), possibly a bit steerable, or some combination . At any given point in time depending on the nodes' positions and their receiver and transmitter coverage patterns, the co-channel interference levels and the transmission power levels, wireless connectivity in the form of a multi-hop, random graph or an ad hoc network that formulates between the nodes.

As an example, based on internal timetables and traffic conditions, the suitable and advisable speed limit for that section of the road at the time is determined limit in the broadcasting dynamic velocity. As a result, the roadside unit will sporadically broadcast the velocity limit message and will compare the vehicle data with any geographic or directional limits to make a decision about sending a velocity limit warning to the vehicles in the vicinity. If a vehicle exceeds the posted velocity limit, the vehicle receives a broadcast in the form of a auditory or visual warning asking the driver to limit his speed [3].

Every vehicle that is part of a VANET has been equipped with an On Board Unit (OBU) and a couple of sensors that collect and process information about vehicle's position, road conditions, direction, speed, etc, and then send it as a message to different vehicles or RSU via the wireless medium by using the broadcast communication. The important functions of an OBU are: ad hoc and geographical routing, wireless radio access, network congestion control, reliable message transfer IP mobility and data security .VANETs allow vehicles that are equipped with OBUs to share information via Vehicle-to-Vehicle (v2v) communications and to perform the communications between vehicles and Road Side Units (RSUs) via Vehicle to Infrastructure communications (V2I). RSU is equipped with a network device for a Dedicated Short Range Communication (DSRC) for Wireless Access Technology for Vehicular Environment (DSRC WAVE), which is developed by the IEEE 1609 group, which utilizes IEEE 802.11p, a modified version of IEEE 802.11 (WiFi) standard. The motivation behind the deployment of DSRC is to enable collision prevention application [16].

5. Reach Ability

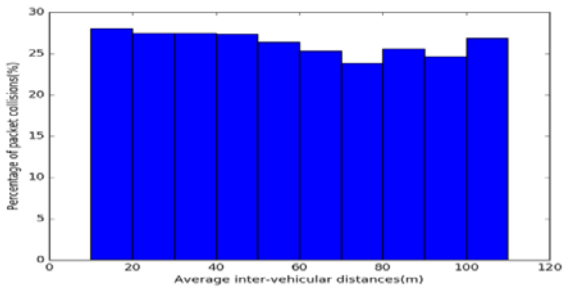

Figure 5: Average % of collisions vs. average inter-vehicle distance

Average percentage of packet collisions, the ratio of the number of collisions to the sum of the number of receptions and the number of collisions averaged over all vehicles, remains between 24% and 30%. However, these collisions affect reach ability drastically for inter-vehicle distance larger than 66 m. The reason for this is that for shorter inter-vehicle distances, multiple paths are available to reach any vehicle. Hence, to decrease reach ability, the collisions would need to occur on all possible free paths, whose probability is less. The larger the inter-vehicle distance becomes, the number of available paths to reach vehicles becomes smaller and the probability of several paths being affected by collisions increments. Hence, there is decreasing trend in reach ability as the average inter-vehicle distance becomes greater. The large variations in reach ability are due to the random movements of the vehicles that randomize the number of possible and available paths as the vehicle cluster expands [4].

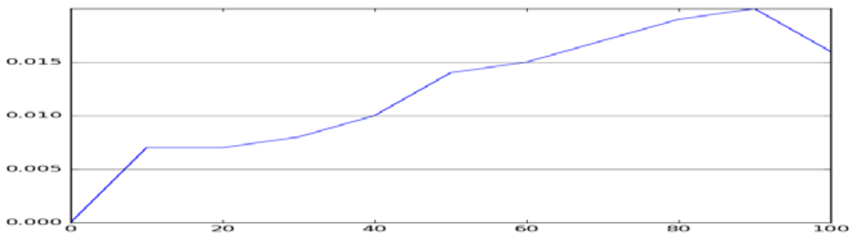

Figure 6: Depicts the average delay for vehicle-to-vehicle broadcasting ,

As a function of the average inter vehicle distance. The delay satisfies the latency requirement (i.e. ≤ 20 ms) that require vehicle to vehicle broadcasting.

6. Conclusion

In this paper we discuss about Li-Fi technology and its application in vehicle to vehicle communication. The types of different vehicular communication are presented. These communication systems can have varied applications such as preventing accidents, traffic and congestion control and protecting drivers from blind spots. The system design for infrastructure based vehicular communication system is proposed and network services required for this system are established. We finally examine the affect of collisions on reach ability and infer that the vehicle-to-vehicle broadcasting delay is within latency requirement by the vehicle safety applications.

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