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Li-Fi the future of Vehicular Ad hoc Networks

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ABSTRACT

VANET is a set of vehicles moving on the road, equipped with communication capabilities among one to another and with Road Side Units using wireless technologies such as Wi-Fi or WiMAX. The number of possible applications of VANETs is expanding. In addition to safety applications, vehicles are foreseen to support entertainment applications such as peer-to peer applications and Internet connectivity applications. For all this, most mobile data traffic is consumed. Light fidelity (Li-Fi) which is related to visible light communication (VLC) offers many key advantages, and effective solutions. This paper presents some advantages that can improve performance of VANETs by using Li-Fi which is interesting to reach high speed data communication between vehicles.

Keywords: VANETs Vehicular ad hoc networks, Li-Fi Light Fidelity, VLC Visible light communication.

1 Introduction

Nowadays, the need of users to access Internet anywhere at any time is increasingly becoming a necessity. The exponential increase in mobile data traffic has led to the massive deployment of wireless systems. As a consequence, the limited available RF spectrum is subject to an aggressive spatial reuse and co-channel interference has become a major capacity limiting factor. Therefore, there have been many independent warnings of a looming “RF spectrum crisis” as the mobile data demands continue to increase while the network spectral efficiency saturates despite newly-introduced standards and great technological advancements in the field. It is estimated that by 2017, more than 11 exabytes of data traffic will have to be transferred through mobile networks every month [7]. Most recently, VLC has been identified as a potential solution.

Unlike other wireless environments that are mostly stationary or with low mobility, data transmission in VANETs poses more challenges to be resolved. Since the topology is constantly changing, vehicles could move away from their home network and cause connectivity breakage. In order to cope with this problem, a vehicle connected to the wireless network should be able to move using different access points available along the road. These access points could belong to different networks or wireless technologies like Wi-Fi, WiMAX or 3G. The performances are not enough good with the traditional RF technologies. In this paper we will show how in VANETs networks a Li-Fi wireless network would complement existing heterogeneous RF wireless networks, and would provide significant spectrum relief by allowing cellular and wireless-fidelity (Wi-Fi) systems to off-load a significant portion of wireless data traffic.

The reminder of this paper is organized as follows. We start in section 2 with describing VANETs architecture, characteristics, applications and their challenging issues. In section 3, we introduce Li-Fi: the networked, mobile, high-speed VLC solution for wireless communication. In section 4, we focus

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on how Li-Fi can improve QoS and Security requirements for VANETs. Then, we conclude the paper in section 5.

2 Vehicular Ad hoc Networks

Vehicular communication networks have emerged as a key technology for next-generation wireless networking. The main goal of these wireless networks consists in providing safety and comfort for passengers by preventing vehicles crashes and traffic jam. In [1], the authors described vehicular Ad Hoc Networks: (VANETs) can be defined as a form of ad hoc networks to provide communications among nearby vehicles and between vehicles and nearby fixed equipments. VANET is a technology that uses moving vehicles as nodes in a network to create a mobile network. Vehicles which are members of a VANET share information about road conditions via Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) wireless communications.

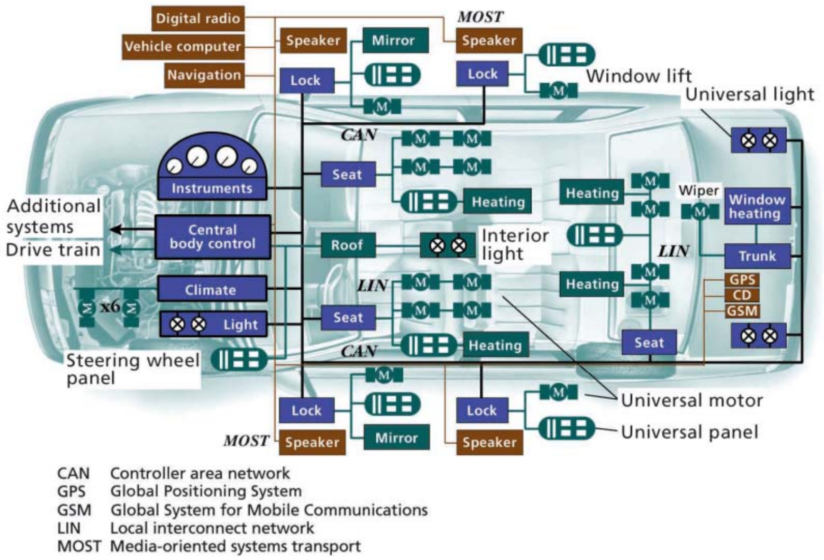

Figure.1 Design of a modern vehicle's network architecture, [4].

2.1 Architecture

This category of wireless networks does not rely on any central control unit and enables vehicles to intelligently communicate with each other and with roadside infrastructure. Each vehicle that is part of a VANET is equipped with an On Board Unit(OBU) and a set of sensors to collect and process information about road conditions, vehicle's position, speed, direction, etc, then send it as a message to other vehicles or RSU through the wireless medium using broadcast communication. The main functions of an OBU are: wireless radio access, ad hoc and geographical routing, network congestion control, IP mobility, reliable message transfer and data security [2].VANETs allow vehicles equipped with OBUs to share information through Vehicle to Vehicle communications (V2V) and to perform communications between vehicles and Road Side Units (RSUs) through Vehicle to Infrastructure communications (V2I). The RSUis equipped with one network device for a Dedicated Short Range Communication for Wireless Access Technology for Vehicular Environment(DSRC//WAVE),developed by the IEEE 1609 Group, which utilizes IEEE 802.11p, a modified version of IEEE 802.11 (Wi-Fi) standard.The motivation behind deployment of DSRC is to enable collision prevention applications (Figure.2).

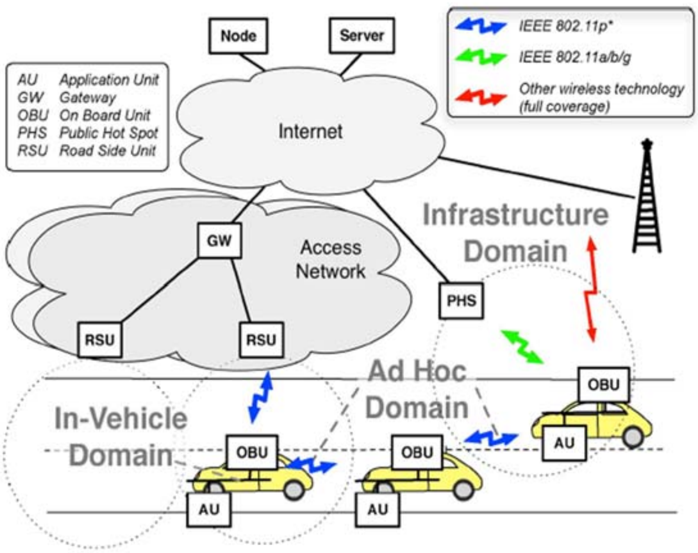

Figure 2. System architecture, currently assumed by the V2V Communication Consortium (C2C-CC) [2]

These applications depend on frequent data exchanges among vehicles, and between vehicles and roadside infrastructure [3].RSU is responsible about extending the communication range of the ad hoc network by re-distributing the information to other OBUs and by sending the information to other RSUs in order to forward it to other OBUs, running safety applications such as a low bridge warning, accident warning or work zone, using Infrastructure to Vehicle communication (I2V) and acting as a source of information and providing Internet connectivity to OBUs [2]. The OBU is connected to other OBUs or RSUs trough a wireless link based on IEEE 802.11p radiofrequency channel. OBU can also communicate with other hosts for non-safety applications, using the communication of cellular radio networks (GSM, GPRS, UMTS, HSDPA, WiMAX and 3G or 4G).

Characteristics

VANETs have individual characteristics that are decisive in the design of the communication system. These include: dynamic topology, large scale network, high computational capability, impredictiblemobility, infinite energy supply in order to provide real time message dissemination platform to share data between vehicles and guarantee reliable exchange of information.

Infinite energy supply: vehicles in VANETs are not energy constrained like are nodes in a MANET. The vehicle can provide energy to the OBU continuously via the long life battery.

Rapid changes in the network topology:due to the high speed of vehicles, the topology of the network is very dynamic. VANETs will not have constant connectivity because of the high-speed movement between vehicles. In low-density vehicles, the link is highly likely to be disconnected.

Predictable mobility: unlike MANET where nodes move in a random way, VANET topology is not absolutely random. VANET movement restrictions are defined by road layout, topology, traffic rules, and the reaction to messages sent by other vehicles.

High computational capability: Because the nodes in VANET are vehicles, they can be equipped with a sufficient number of sensors and computational resources; such as processors, a large memory capacity, advanced antenna technology and global position system (GPS).

2.2 Applications

The three major classes of VANETs applications are safety applications, convenience applications and commercial applications [13, 14, 15]. For example, applications like collision alert, weather conditions, road surrounding warning are classified under safety applications. They use the message broadcast feature of VANETs to inform nearby vehicles about critical alerts. Convenience applications would detect road congestion, help tool booths to collect toll without stopping vehicles. These applications are classified as safety applications which aim to ameliorate traffic conditions and prevent road accidents and save peoples' lives.

Commercial and entertainment applications become an attractive tendency. They include a wide range of future multimedia and data applications, such as audio/video as well as e-maps and roads vehicle related services. Road side businesses such as hotels and restaurants can use content rich video streams to broadcast advertisements to drivers on the road. Peer-to-peer applications are another category of non-safety VANET applications. Passengers in nearby cars can set up a video conversation by using the inter vehicle streaming technology, exchange music, instant messages, stream music or movies from special servers. Travelers could play games in order to alleviate boredom. Vehicles are envisaged to become a part of internet in the near future, either as mobile endpoints, as mobile backbone routers or as mobile sensors.

2.3 Challenges

VANETs inherit from the wireless network shortcomings since they use radio frequency channel to exchange information between the different entities composing the network. These shortcomings consist on signal fading and bandwidth limitations [22].

Signal fading: This phenomenon is mainly frequent in urban regions. Buildings or other vehicles may constitute obstacles for nodes communications. These objects may cause transmitted signal fading or prevent it from reaching its destination.

Bandwidth limitations: as mentioned before, VANETs do not rely on any central administration. Consequently, this brings out problems about the management of nodes communication and contention control. In order to optimize vehicular communications, it is necessary to use the available bandwidth efficiently. The high density of vehicles in urban regions may increase the probability of channel contention. An efficient utilization of the available bandwidth influences the time delay of message dissemination. Channel contention increases data transmission latency. This has very negative impacts, especially for warning messages delivery in safety applications. For entertainment applications, channel contention and the non-optimal use of bandwidth causes degradation of QoS requirement of users.

In addition there are some challenges which are specific for VANETs. Some of these challenges are time constraints, large scale of the network, and high mobility of nodes [20].

Time constraints: Safety messages are critical information which should be delivered with respect to time limitations. Warning messages are very time sensitive, so they must be delivered in a short interval of time beyond which they are useless. A driver must have enough time to react to a received warning message in order to prevent a crash.

Large scale network: the growing number of vehicles on the road will become, in the near future, one on the main constraints facing VANETs. A global authority must be set to manage information about users and others related to security. Since the security and privacy rules differ from a region to another in the world, their standardization will be complicated.

High mobility of nodes: VANETs are characterized by high topology changes due to the high speed of vehicles. These changes cause frequent link failures. To alleviate this problem it is necessary to elongate link life by increasing the transmission power. But this solution can cause throughput degradation[9]. The vehicles high speed may cause handoff and cause packets loss which can reduce the throughput of the network. Since vehicles frequently change their point of network attachment when they access Internet services, they need mobility management schemes that provide seamless communication. This mobility management meets requirements such as seamless mobility, support IPV6, scalable overheads and low handoff latency. One approach for mobility management recently proposed NEMO Basic Support. VANETs differ from MANETs in the highly mobile nodes, the probability of network partition which is higher and end-to-end connectivity which is not guaranteed.

Privacy and security: VANETs are very constrained in terms of security and privacy. Making a balance between security and privacy to protect, users and data, in the same time, is a key challenge which must be solved. While registration to the network, vehicles provide some credentials because users require trustworthy information. However, this may violate source privacy.

3 Li-Fi

Visible light communication (VLC), which uses a vast unregulated and free light spectrum, has emerged to be a viable solution to overcome the spectrum crisis of radio frequency. Light fidelity (Li-Fi) is an optical networked communication in the subset of VLC to offload the mobile data traffics.

During the last ten years, there have been continuous reports of improved point-to-point link data rates using off-the-shelf white LEDs under experimental lab conditions. Recently, data rates in excess of 1 Gbps has been reported using off-the-shelf phosphor-coated white LEDs,4 and 3.4 Gbps has been demonstrated with an off-the-shelf red-green-blue (RGB) LED. To the best of the authors' knowledge, the highest speed that has ever been reported from a single color incoherent LED is 3.5 Gbps. The experiment was led by researchers of the University of Edinburgh. VLC, and the Li-Fi Consortium was formed in Oslo, Norway in 2011 with the purpose of providing a high speed and wireless optical network [11,12].The vision is that a Li-Fi wireless network would complement existing heterogenous RF wireless networks, and would provide significant spectrum relief byallowing cellularand wireless-fidelity (Wi-Fi) systems to off-load a significant portion of wireless data traffic.

Unlike RF modulation methods, VLC adopts the intensity modulation to carry binary data by turning LED on and off quickly, in which the amplitude and phase information are lost. For providing both illumination and seamless communication coverage, attocell architecture has been proposed, which is referred from cellular network as the cell sizes are smaller than in a typical RF femtocell network. Every LED light bulb in attocell Li-Fi network is treated as an access point and an illumination source for covering a limited region. In this context, Li-Fi is shown potentially to provide at least an order of magnitude improvement in the area spectral efficiency (ASE) as compared to the femtocell system [8].

In attocell Li-Fi architecture like RF cellular network, inter-cell and intra-cell interference mitigation techniques are indispensable. The most common method is to assign different sub-bands for neighboring cells in order to avoid co-channel interference (CCI). A combined wavelength division and code division scheme is proposed in [10].

4 Li-Fi & VANETs

In this section we propose our VANET architecture based on Li-Fi. Based on the attocell architecture, users must be associated with one or some cars LED lamps for accessing and downlink transmission. The enhanced bandwidth-based (BB) lamp selection scheme [6] access scheme is used.

Enabling communications in mobile outdoor systems, particularly in dense, fast moving safety-critical automotive environments is one of the main benefits of VLC for VANETs. In vehicular applications, mobile communications are particularly suitable for adoption of directional communications using Line Of Sight LOS links. Applications such as safety and emergency messaging require very high reliability, and this can be provided through short-range inter-vehicular communications. As an instance, vehicles can be equipped with optical transceivers, such that they can communicate with other similarly equipped vehicles. Together with adaptive cruise control assisted by V2V communications, the problem of vehicle crashes due to human error can be alleviated.

Figure 3. Li-Fi for V2V communications

Our attention will be focused on the use of Visible Lighting Communications (VLC) Li-Fi and how it can provide a valid technology for communication purposes in VANETs. The use of the visible spectrum provides service in densities exceeding femtocells for wireless access. It represents a viable alternative that can achieve high data rates, while also providing illumination. This configuration minimizes packet collisions due to Line Of Sight (LOS) property of light and promises to alleviate the wireless bottleneck that exists when there is a high density of rich-media devices seeking to receive data from the wired network.

We present in figures 4 and 5 the results of our experiments using Matlab [23]. For all experiments, we consider two cars which start at the same time and with the same speed. We evaluate the latency and the average packet loss ratio using three velocities 50 km/h, 70 km/h and 90 km/h and with different distances between cars. We consider UDP traffic between nodes with 2048 kbps. In figures 4 and 5 we can see the latency and the packet loss ratio.

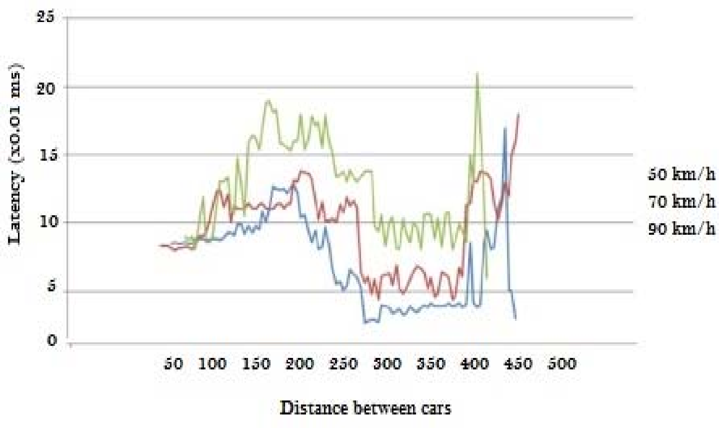

Figure 4. Latency for 2 cars

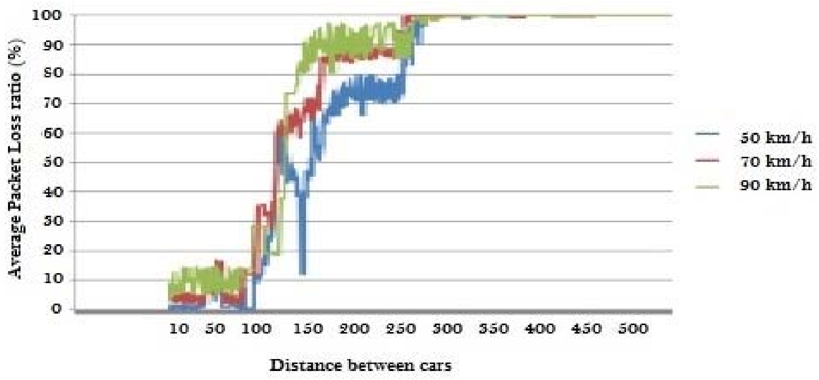

Figure 5. Packet Loss ratio for 2 cars

Based on the results we can that the latency using Li-fi communication between cars is around 0.02 ms which is better than the latency using the standard IEEE802.11p [24]. For the packet loss ratio, we have the confirmation that when the distance between cars increases the packet loss ratio increases till 100% when the cars are very far one from the other.

5 Conclusion

In this paper we investigated main aspects of vehicular ad hoc networks. We discussed the state of art research on Li-Fi and its potential advantages that can make it supplement RF communications and improve wireless network performance wherever short range links are used such as vanets for high speed and secure data transmission. However, there are still many problems that need additional study. The cooperative techniques and protocols between Li-Fi and the existing RF network need further study. RF networks are widely used and gradually to be indispensable in our lives. Integrating Li-Fi into RF communications will not only accelerate the marketization of Li-Fi, but also offload traffic from the extremely crowded cellular networks. However, a large number of feedback packets and considerable delay may exist when performing handover between Li-Fi and RF network, which need to be investigated.

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