Qualitative analysis of Spectrum Utilization in Vehicular Communication Networks

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Abstract: Actually the rapid growth of wireless traffic demands in vehicular networks, spectrum scarcity is becoming urgent in the Dedicated Short Range and long range Communication. Vehicular Communication networks (VCNETs) are created by applying the principles of mobile ad hoc networks (MANETs). The spontaneous creation of a wireless network for Vehicle-to-vehicle (V2V) data exchange to the domain of vehicles. Recently, vehicular networks (VCNETs), has become the key technology of the next-generation intelligent transportation systems. Prior to the implementation of VCNETs on the roads, realistic computer simulations of VCNETs using a combination of Urban Mobility simulation and Network simulation are necessary. V2V is under threat from cable television and other tech firms that want to take away a big chunk of the radio spectrum currently reserved for it and use those frequencies for high-speed internet service. With the development of mobile Internet, people want to enjoy the Internet access in vehicles just as anywhere else. The auto industry is trying to retain all it can saying that it desperately needs the spectrum for V2V. The main motivations for V2V are road safety, traffic efficiency, and energy savings. There are two types of V2V communication technology depending on the underlying technology WLAN & cellular based.

Keywords: VCNET, Road Safety, Electromagnetic Spectrum, Traffic Efficiency, Cellular, WLAN

I. Introduction

V2V is currently in active development by General Motors, which demonstrated the system in Cadillac vehicles. It is a variation of MANET (Mobile ad hoc network), with the emphasis being now the node is the vehicle. VCNETs support a wide range of applications – from simple one hop information dissemination of, e.g., cooperative awareness messages to multi-hop dissemination of messages over vast distances. Most of the concerns of interest to mobile ad hoc networks (MANETs) are of interest in VCNETs, but the details differ. Rather than moving at random, vehicles tend to move in an organized fashion[1]. The interactions with roadside equipment can likewise be characterized fairly accurately. By incorporating wireless communication and networking capabilities into automobiles, information can be efficiently and reliably disseminated among vehicles, road side units, and infrastructure, which enables a number of novel applications enhancing the road safety and providing the drivers/passengers with an information-rich environment. And finally, most vehicles are restricted in their range of motion, for example by being constrained to follow a paved highway.

- **Electronic brake lights,** which allow a driver (or an autonomous car or truck) to react to vehicles braking even though they might be obscured[2] (e.g., by other vehicles).
- **Platooning,** which allows vehicles to closely (down to a few inches) follow a leading vehicle by wirelessly receiving acceleration and steering information, thus forming electronically coupled "road trains".

Standardization of WLAN based V2V supersedes that of cellular based V2V system. IEEE first published the specification of WLAN based V2V (IEEE 802.11p) in 2012. It supports direct communication between vehicles (V2V) and between vehicle and infrastructure (V2I). DSRC uses the underlying radio communication provided by 802.11p. In 2016, 3GPP published V2V specifications based on LTE as the underlying technology. It is generally referred to as "cellular V2V" (C-V2X) to differentiate itself from the 802.11p based V2X technology. In addition to the direct communication (V2V, V2I), C-V2V also supports wide area communication over cellular network (V2N)[3]. This additional mode of communication and native migration path to 5G are two main advantages over 802.11p based V2V system.

II. The Architecture of the Electromagnetic Spectrum utilization in VC Networks:

The infrastructure also participates in such systems, then referred to as V2V (vehicle-to-Vehicle). Over the years, there have been considerable research and projects in this area, applying VANETs for a variety of applications, ranging from safety to navigation and law enforcement. Electromagnetic radiation, as you may recall from a previous chemistry or physics class, is composed of electrical and magnetic waves which oscillate on perpendicular planes. Visible light is electromagnetic radiation. So are the gamma rays that are emitted by spent nuclear fuel, the x-rays that a doctor uses to visualize your bones[4], the ultraviolet light that causes a painful sunburn when you forget to apply sun block, the infrared light that the army uses in night-vision goggles, the microwaves that you use to heat up your frozen burritos, and the radio-frequency waves that bring music to anybody who is old-fashioned enough to still listen to FM or AM radio.

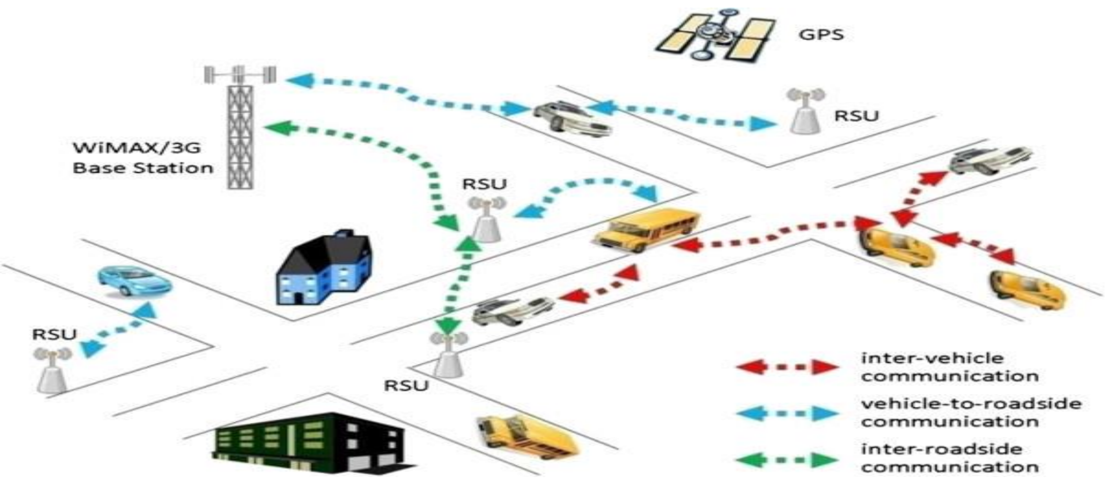
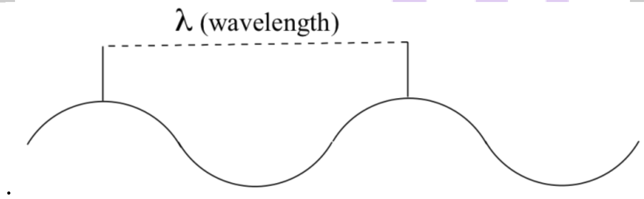


Fig.1. Architecture of vehicular communication system using EM Spectrum.

As shown in Fig.1 it is a vehicular communication system that incorporates other more specific types of communication as V2I (Vehicle-to-Infrastructure), V2N (Vehicle-to-network), V2V (Vehicle-to-vehicle), V2P (Vehicle-to-Pedestrian), V2D (Vehicle-to-device) and V2G (Vehicle-to-grid).Just like ocean waves, electromagnetic waves travel in a defined direction. While the speed of ocean waves can vary, however, the speed of electromagnetic waves – commonly referred to as the speed of light – is essentially a constant, approximately 300 million meters per second. This is true whether we are talking about gamma radiation or visible light[5]. Obviously, there is a big difference between these two types of waves – we are surrounded by the latter for more than half of our time on earth, whereas we hopefully never become exposed to the former to any significant degree. The different properties of the various types of electromagnetic radiation are due to differences in their wavelengths, and the corresponding differences in their energies: shorter wavelengths correspond to higher energy.



High-energy radiation (such as gamma- and x-rays) is composed of very short waves – as short as 10-16 meter from crest to crest. Longer waves are far less energetic, and thus are less dangerous to living things. Visible light waves are in the range of 400 – 700 nm (nanometers, or 10-9 m), while radio waves can be several hundred meters in length.

III. Modules in VC Networks:

A. **Traffic information systems,** which use VANET communication to provide up-to-the minute obstacle reports to a vehicle's satellite navigation system
B. **Road Transportation Emergency Services** – where VANET communications, VANET networks, and road safety warning and status information dissemination are used to reduce delays and speed up emergency rescue operations to save the lives of those injured.
C. **On-The-Road Services** – it is also envisioned that the future transportation highway would be "information-driven" or "wirelessly-enabled". VANETs can help advertise services (shops, gas stations, restaurants, etc.) to the driver, and even send notifications of any sale going on at that moment[6].

The notion that electromagnetic radiation contains a quantifiable amount of energy can perhaps be better understood if we talk about light as a stream of particles, called photons, rather than as a wave. (Recall the concept known as 'wave-particle duality': at the quantum level, wave behavior and particle behavior become indistinguishable, and very small particles have an observable 'wavelength'). If we describe light as a stream of photons, the energy of a particular wavelength can be expressed as: $E=hc/\lambda$
where E is energy in kJ/mol, λ (the Greek letter lambda) is wavelength in meters, c is 3.00 x 10^8 m/s (the speed of light), and h is 3.99 x 10^{-13} kJ·s·mol^{-1}, a number known as Planck's constant. Because electromagnetic radiation travels at a constant speed, each wavelength corresponds to a given frequency, which is the number of times per second that a crest passes a given point. Longer waves have lower frequencies, and shorter waves have higher frequencies. Frequency is commonly reported in hertz (Hz), meaning 'cycles per second', or 'waves per second'. The standard unit for frequency is s^{-1}.When talking about electromagnetic waves, we can refer either to wavelength or to frequency - the two values are inter converted using the simple expression: $\lambda\nu=c$

Unlike cellular technologies, DSRC is ready for V2V deployment today, and addresses the most challenging V2V use-cases. The direct communication between vehicle and other devices (V2V, V2I) uses so-called PC5 interface. The motivation of the mission critical communication was to allow law enforcement agencies or emergency rescue to use the LTE communication even when the infrastructure is not available, such as natural disaster scenario. In Release 14 onwards, the use of PC5 interface has been expanded to meet various market needs, such as communication involving wearable devices such as smart watch. In C-V2V, PC5 interface is re-applied to the direct communication in V2V and V2I. In addition to the direct communication over PC5, C-V2V also allows the C-V2V device to use the cellular network connection in the traditional manner over Uu interface. Uu refers to the logical interface between the UE and the base station[7]. This is generally referred to as vehicle-to-network (V2N). V2N is a unique use case to C-V2V and does not exist in 802.11p based V2V given that the latter supports direct communication only. Combination of the direction communication over PC5 and traditional cellular communication over Uu interface allows wider and more diverse C-ITS usages.

3.1.WLAN(802.11p):

The original V2V communication uses WLAN technology and works directly between vehicles, which form a vehicular ad-hoc network as two V2V senders come within each other’s range as shown in Fig.2. Hence it does not require any infrastructure for vehicles to communicate, which is key to assure safety in remote or little developed areas[8].

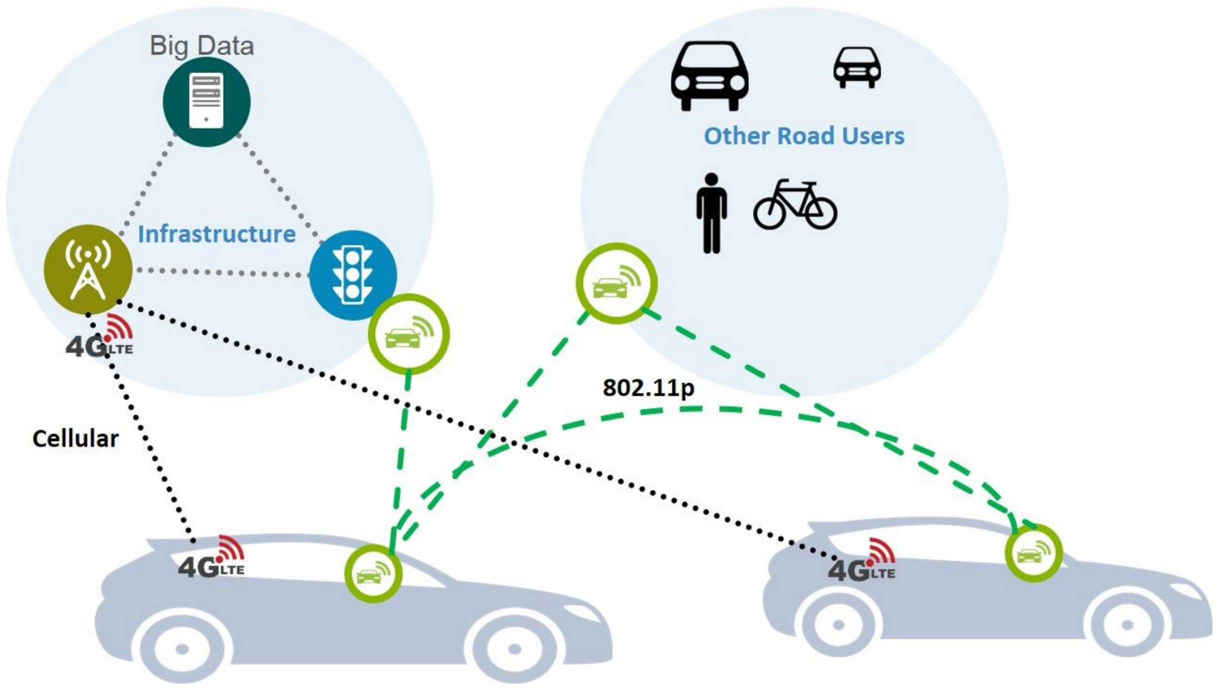


Fig.2. IEEE 802.11p and Cellular for VC networks

WLAN is particularly well-suited for V2V communication, due to its low latency. It transmits messages known as Cooperative Awareness Messages (CAM) and Decentralised Environmental Notification Messages (DENM) or Basic Safety Message (BSM). The data volume of these messages is very low.

3.2. Cellular based 3GPP (C-V2X) Network:

Despite many industrial applications requiring customized solutions, not all applications require the utilization of sophisticated and expensive spectroscopic techniques. Therefore, for particular applications low cost solutions are sufficient. More recent V2V communication uses Cellular network and is called Cellular V2V(or C-V2V) to differentiate it from the WLAN based V2V. There has been multiple industry organizations, such as 5G Automotive Association (5GAA) promoting C-V2V due to its advantages over WLAN based V2V. C-V2V is initially defined as LTE in 3GPP Release 14 and is designed to operate in several modes: 1) Device-to-device (V2V), 2) Device-to-cell-tower (V2I), and 3) Device-to-network (V2N). In 3GPP Release 15, the V2V functionalities are expanded to support 5G. The main advantage of C-V2V includes support of both direct communication between vehicles (V2V) and traditional cellular-network based communication. Also, C-V2V provides migration path to 5G based systems and services. Due to our long-term experience with optical components (sources, optics, detectors), we are qualified in providing assistance for customer specific problems. An example is the use of the existing pyrometer-technology to investigate the capabilities of this technique in an industrial environment.

IV. Conclusion:

V2x communication, which involves vehicles exchanging data with each other and the infrastructure, has proven to improve traffic safety and increase the efficiency of transportation systems. PC5 refers to a reference point where the User Equipment

(UE), i.e. mobile handset, directly communicates with another UE over the direct channel. In this case, the communication with the base station is not required. In system architectural level, proximity service (ProSe) is the feature that specifies the architecture of the direct communication between UEs. In 3GPP RAN specifications, "sidelink" is the terminology to refer to the direct communication over PC5. PC5 interface was originally defined to address the needs of mission critical communication for public safety community (Public Safety-LTE, or PS-LTE). Direct Short Range Communication (DSRC), which is based on IEEE 802.11p, has been the subject of extensive standardization, product development and field trials by all stakeholders, proving its benefit for V2V.

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