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Inter-Vehicle Wireless Communications Technologies, Issues and Challenges

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Abstract: Wireless communication technologies have emerged vehicular networks in the forms of Intra-Vehicle (InV), Vehicle-to-Vehicle (V2V) and Vehicle-to- Infrastructure (V2I) communications. These technologies enable a variety of applications for driver and passenger needs, such as safety, convenience and entertainment facilities incorporated into modern automobile designs. The researchers exploit the different services that will enable to exchange useful information with-inside and with-outside vehicle via vehicular networks. Vehicles exchange information about their state, view of current road, navigation information and other general information about weather report and digital map update. A key for exchanging information in timely manner is an opportunity to access the medium for longer life with low power consumption in various ranges. They provide high reliability without experiencing long and uncertain delay. Thus, widespread adoption of vehicular networks is fast becoming a reality, where additional functions will be provide by the car electronics and the passengers will be able to access the Internet and other core network resources. This study presents an overview of the potential wireless technologies for data exchange in a various ranges, its current research activities, issues and challenges that exist in each wireless technology.

Key words: Intra-vehicle, vehicle-to-vehicle, vehicle-to-infrastructure, issues and challenges

INTRODUCTION

Wireless communications is a fast-growing technology to provide the flexibility and mobility. These technologies in recent years allows different communications systems in vehicles, to fulfill the needs of drivers and passengers (Wewetzer *et al*., 2007). There are a number of technologies which makes it possible to transmit real-time video/audio in mobile and pervasive environments (Willke *et al*., 2009). The benefits of these technologies include the dynamic network formation inside and outside of the vehicle, low cost and easy deployment. A very important role should be played by these technologies to ensure security and driving safety in real-time emergency situation due to fog, car accidents and so on (Li and Wang, 2007). Nevertheless, these services are the most difficult to provide due to the stringent requirements of the application; especially in case of emergency warning services which should be based on the possibility of informing all vehicles in the neighborhood of a dangerous situation within a short amount of time from its occurrence which requires a prompt system response (Misra *et al*., 2008). Therefore, the introduction of such services is still seen as a long-term goal; nevertheless, this study focuses on the suitability of wireless communication technologies for various vehicular network applications along with challenges.

These technologies are categorized according to their range i.e., Long range, Medium Range and Short range as shown in Fig. 1. Long-range communication technologies could be use for data exchange among those vehicles which locate out of the radio range (Dressler *et al*., 2008). Medium range communication technologies could be use within the radio range where short range could only be use in line of sight. From result of these communication technologies, information gathered through vehicular

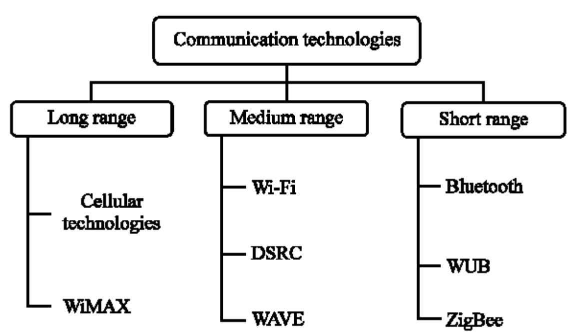

Fig. 1: Vehicular communication technologies

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Table 1: Long range wireless technologies for V2V and V2I communication

Features	Cellular Technologies	WiMAX
Standard	Based on 3G cellular technology standard, ETSI, 3GPP	Based on the IEEE 802.16 standard. Broadband technology in 2007
Coverage	Up to 15 km	5 km
Network	Full mobile	P2M, full mobile
Modulation technique	FDD, TDD, CDMA	OFDMA, QAM-16, QAM -64 (BPSK-1/2, QPSK-1/2)
Advantages	Already available, large coverage, high data rates specially in case of LTE	High data rates, large coverage
Disadvantages	Very high deployment costs, scalability (backhaul)	High deployment costs, scalability (backhaul)
Bit Rate	<2 to 100 Mbps	75 Mbps
Applications	Between high speed vehicle and mobile phone communication	Internet access, e-mail, VoIP (Voice over IP)
References	Willke *et al*. (2009), Hannan *et al*. (2010a) and Wang *et al*. (2008)	Jerbi and Senouci (2008) Fazel and Kaiser (2008) and Chien *et al*. (2009)

Table 2: Medium range wireless technologies for V2V and V2I communication

Features	Wi-Fi(Wi-Fi a/b/g/n)	DSRC[802.11p]	WAVE
Standard	IEEE802.11/New Wi-Fi technology with MIMO standard 802.11n standard in 2009	IEEE, ASTM ISO; A short to medium range Communications based on IEEE 802.11p./ High-speed High bandwidth based on IEEE802.11a	IEEE 1609 based on MAC and Network Layer
Coverage	100 m to 1 km	1000 m, 305 m	1 km
Network	Point to point	Point to point	Point to multipoint
Modulation techniques	OFDM or DSSS with CCK BPSK, QPSK, 16-QAM, 64-QAM	BPSK, QPSK, 16-QAM, 64-QAM, PHY of WAVE using OFDM, MAC of WAVE using CSMA/CA	BPSK, QPSK, 16QAM and 64QAM
Advantages	Dominating WLAN tech Replace Ethernet cables	Low deployment costs distributed	Efficient, secure, low latency broadcast service
Disadvantages	Traditionally consume high power; Suitability for mobility is low; short to medium range Interference due to shared spectrum	With low penetration rate, the vehicular ad-hoc network suffers from fragmented network problem	Routing becomes a challenging in *ad hoc* network
Bit rate	600 Mbps using MIMO	IEEE 802.11p 3 to 27 Mbps IEEE 802.11a 6 to 27 Mbps	Up to 27 Mb sec^{-1}
Applications	Roadside to vehicle and V2V communication, Office and home networks. WLAN Replace ethernet cables	Roadside to vehicle and V2V communication. Communication for remote applications, located outside of the vehicular environment	Wireless and cooperative local danger warning; Traffic information dissemination
References	Liu (2012), Minhas *et al*. (2011) and Shimizu *et al*. (2007)	Hassan *et al*. (2011), Hannan *et al*. (2010a) and Morgan (2010)	Campbell *et al*. (2011), Banchs and Vollero (2006) and Hannan *et al*. (2010b)

Table 3: Short range wireless technologies for In-vehicle communication systems

Features	ZigBee	UWB	Bluetooth
Standard	Defined in IEEE 802.15.4, Ratified in December 2004	IEEE 802.15.3a	IEEE 802.15.1 First launched (1998)
Coverage	10 to 75 m	<60 cm for a 500 MHz wide pulse, <23 cm for a 1.3 GHz bandwidth pulse	1, 10 and 100 m
Network	Mesh	Point to point	Point to point
Modulation	DSSS	OFDM or DSUWB	FHSS
Advantages	Secure communications transport cryptographic keys, controlling devices, static network and Low power consumption	Easy and cheap to build, low power consumption, provides high bandwidth, Broad spectrum frequencies	In vehicles today. Easy synchronization of mobile devices, frequency hopping tolerant to harsh environments, eliminating short-distance cabling
Disadvantages	Low bandwidth	Short range, interference	Interference with Wi-Fi, Consume medium power
Bit rate	20-250 kbit sec^{-1} per channel	extremely high data rates 1000+ Mbps	12 Mbps (ver 2.0) 53-480 Mbps; WiMedia Alliance (proposed)
Applications	Entertainment, smart lighting control/ Remote control, advanced temperature control, safety and security, sensors, etc.	Multimedia applications; healthcare applications	Used in voice applications; connect and exchange information between mobile phones, laptops, personal computers, video game consoles, etc.
References	Park and Rappaport (2007), Sugiura and Dermawan (2005) and Pokharel *et al*. (2005)	Hu *et al*. (2010), Richardson *et al*. (2006) and Park and Rappaport (2007)	Hannan *et al*. (2010a), Corral *et al*. (2012) and Richardson *et al*. (2006)

communication can improve the road traffic safety and efficiency (Ravichandiran and Vaithiyanathan, 2009). This survey focused on the discussion of communication technologies used for vehicle communication system. These communication technologies are summarized in Table 1-3.

LONG-RANGE COMMUNICATION TECHNOLOGIES

Long-range communication technologies can deliver data in miles distance. They may be used as a back-haul between two sites or to deliver data services to individual mobile devices, such as smart phones and laptop computers. Therefore, these technologies may also be useful for Vehicles to communicate directly with each other (V2V) and with the fixed infrastructure (V2I) in the form of vehicular *ad hoc* network (VANET). The standard, coverage, bit rate and explanation of the long-range communication technologies are shown in Table 1 explained as follows: The comparison between WiMAX and cellular technologies of the long-range communication are shown in Fig. 2.

Cellular technologies (3G, LTE, UMTS, HSPA): GSM (Global System for Mobile Communication), consider as 2G (2nd Generation) and 3G (3rd Generation) wireless networks are both mobile communication technologies that have been evolved over the time. One of the most important goals of evolving from GSM to 3G is the powerful and efficient mobile access to the internet. 3G cellular systems are being designed to support wideband and faster communication services. services provide by wideband are high speed internet access, video and high quality image transmission with the same quality as the fixed networks Where fast communication services include Voice, Fax and internet with seamless global roaming. GPRS is a good service example of both 2G and 3G cellular communication systems, data rates of 56-114 kbps provides the capability to users to connect Internet. 3G wireless networks support 2.05 Mbps data rate for stationary devices, 384 kbps for slowly moving devices and 128 kbps for fast moving devices (Wang *et al*., 2008).

3G Cellular networks cover large areas and may be a good solution for IVC systems when vehicles are outside major cities and highways. However, cellular systems were not designed and provisioned for simultaneous utilization by a large number of users for long periods at high traffic volumes. Also 128 kbps data rate clearly indicates that 3G networks are unsuitable for providing IPTV (Internet Protocol Television) and VoD (Video on Demand) services to fast moving vehicles on highways. Furthermore, as 3G is basically designed for cellular network which is inherently centralized and in case of V2V communication there is no centralized infrastructure, therefore it is impossible to directly apply 3G technologies. Therefore most of the proposed Vehicle Communication System (VCS) uses 3G wireless networks in combination with other wireless LAN technologies

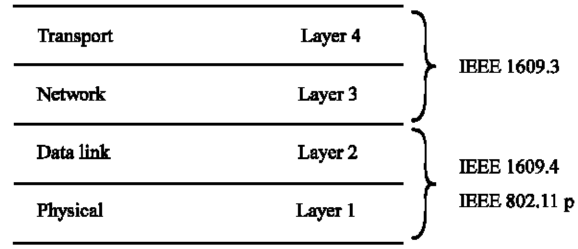

Fig. 2: Wave location in OSI model

(Willke *et al*., 2009) or proposed new 3rd Generation Partnership Project (3GPP) and the 3GPP Long Term Evolution (LTE) technologies.

The 3GPP project operates under the trademark to be nominated by one of the associations in the partnership, the European Telecommunications Standards Institute (ETSI). LTE is a step towards the Fourth Generation (4G) and is a new radio technology to increase capacity and speed of mobile networks. It is a set of enhancements to the UMTS (Universal Mobile Telecommunications System) which was introduced in the 3GPP Release 8. Much of 3GPP Release 8 focuses on adopting 4G mobile communications technology, including an all-IP flat networking architecture (Hannan *et al*., 2010a). The LTE specification provides downlink peak rates of at least 100 Mbps, an uplink of at least 50 Mbps and RAN (Radio Access Network) round-trip times of less than 10 msec. LTE supports scalable carrier bandwidths, from 20 MHz down to 1.4 MHz and supports both Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD). The main advantages are high throughput, low latency, plug and play, FDD and TDD in the same platform, an improved end-user experience and a simple architecture resulting in low operating costs. LTE also support seamless passing to cell towers with older network technology such as GSM (Global System for Mobile Communications) CDMA One, CDMA (Code division multiple access) and 2000 W-CDMA (UMTS), therefore, it has advantage of almost 80% trail customers around the world (Hannan *et al*., 2011).

UMTS (Universal Mobile Telecommunications System) is one of the 3G cell phone technologies which are also being developed into a 4G technology. The system does not provide means for ad-hoc communication because data is not directly exchanged among nodes. It routed through the backbone network and then transmitted from the base station to the receiver. Therefore, UMTS can expect higher latency compared to wireless *ad hoc* communication. UMTS is based on Code Division Multiple Access (CDMA) since Mobile nodes have guaranteed communication slots. Simultaneous communication among multiple nodes uses same frequency by assigning orthogonal channel codes to each node. The UMTS downlink original bandwidth of 384 kbp has been increased by the High-Speed Downlink Packet Access (HSDPA) which allows data rates up to 7.2 Mbits sec^{-1}. similarly, uplink bandwidth is 64 kbits sec^{-1} but will be extended by High-Speed Uplink Packet Access (HSUPA). With HSUPA, up to 5.8 Mbits sec^{-1} are achievable in theory (Wischhof *et al*., 2005). Both HSDPA and HSUPA are considering as HSPA.

UMTS is beneficial in Vehicular applications, such as, the traffic jam warning, the bad road condition warning and employing a point-to-multi-point communication. With UMTS, traffic warnings achieve an average transmission delay of about 300 msec. Furthermore, employing Multimedia Broadcast Multicast Service (MBMS) for message dissemination leads to vehicle-to-vehicle delays of about 500 msec. In Europe UMTS, with the UMTS Terrestrial Radio Access Network (UTRAN) are used for 3G cellular radio system. For duplex communications two implementations UTRA-TDD and UTRA-FDD are defined using time division duplex and frequency-division duplex, respectively. In the Fleet net project an ad hoc mode of UTRA-TDD was proposed for VCS (Hannan *et al*., 2008).

WiMAX: WiMAX (Worldwide Interoperability for Microwave Access) is a part of 4G telecommunications technology aimed to provide wireless data over long distances in a variety of ways, from point-to-point links to full mobile cellular type access. It was a major revision of the 802.16 standard which allows data rates of 40 Mbps in 3 km cell for both fixed and mobile type access. With the 2011 update providing up to 1 Gbit sec^{-1} for fixed stations (Fazel and Kaiser, 2008). WiMAX far surpasses the 30 m wireless range of a conventional Wi-Fi Local Area Network (LAN), offering a MAN (metropolitan area network) with a signal radius of about 50 km. Mobile WiMAX (802.16e) was originally designed to provide high-speed internet access for mobile devices in rural areas. Besides the original task of mobile WiMAX, it also allows variety of different applications: such as, connection of smart electric meter as well as command and control of miniature unmanned aerial vehicles Due to the potential relevance of WiMAX technologies for vehicle applications, recent research considered it as a possible candidate technology for the support of this type of applications. Mobile WiMAX data rate is 40 Mbps which is a sufficient bandwidth for supporting different services in vehicular communication (Chien *et al*., 2009).

Mobile WiMAX networks are usually made of indoor (CPE) (customer premises equipment) such as desktop modems, laptops with integrated Mobile WiMAX or other Mobile WiMAX devices. Mobile WiMAX devices typically have an omni-directional antenna that is of lower gain compared to directional antennas but are more portable. In practice, this means that in a line-of-sight environment with a portable Mobile WiMAX CPE, speeds of 10 Mbit sec^{-1} at 10 km sec^{-1} could be delivered. However, in urban environments they may not have line-of-sight and therefore, users may only receive 10 Mbit sec^{-1} over 2 km sec^{-1}. Higher-gain directional antennas can be used with a Mobile WiMAX network with range and throughput benefits but the obvious loss of practical mobility. To cope with such type of issues WiMAX requires a new network to be built for vehicle communication, whereas a new technology LTE don't have such requirement, as it is an evolution of existing W-CDMA/High Speed Packet Access (HSPA) networks (Jerbi and Senouci, 2008).

MEDIUM-RANGE COMMUNICATION TECHNOLOGIES

Medium-range also referred to as "Wireless Local Area Network," or WLAN. Medium range technologies can be used within the radio range and measured in tens or hundreds of feet. The range of technologies may also be helpful for V2V and V2I communication. The standard, coverage, bit rate and application of the medium range communication technologies are shown in Table 2. The comparison between WAVE, DSRC and Wi-Fi technologies of the medium-range communication are shown in Fig. 3. The detail of medium range communication technologies are explained as follows.

Wi-Fi: Wireless Fidelity (Wi-Fi) includes IEEE 802.11a/b/g/n standards for (WLAN) based on a cellular architecture. The aim of the IEEE 802.11 standard (Liu, 2012) is to provide wireless connectivity to devices that require quick installation, such as portable

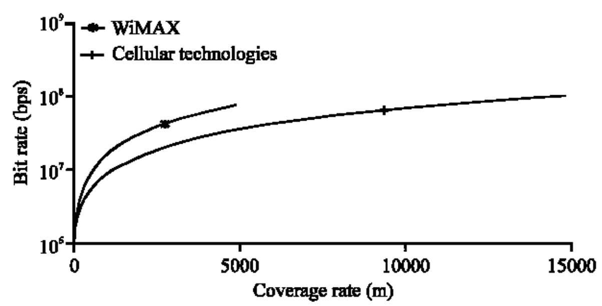

Fig. 3: Comparison parameters of the long-range technologies

computers, PDAs, or generally mobile devices inside a Wireless Local Area Network (WLAN). Legacy Wi-Fi has two ratified variants, 802.11a and 802.11b were defines at physical layer for the operation in unlicensed 5 GHz bands. 802.11 g is a backward compatible extension of 802.11b, operates in the 2.4 GHz frequency bands and provides raw data rate up to 54 Mbps. The improved performance of Wi-Fi 802.11 n introduced Multiple Input Multiple Output technique with maximum data rate 248 Mbps and radio frequency band is from 2.4 to 5 GHz. The standard use OFDM, CCk and DSSS modulations techniques Wi-Fi was used for inter-vehicle communications by, e.g., the Car2Car Consortium (Minhas *et al*., 2011), a non-profit organization initiated by European vehicle manufacturers. Applications here are advanced drive assistance reducing the number of accidents, decentralized floating car data improving local traffic flow and efficiency and user communications and information services for comfort and business applications to driver and passengers. The European Network-on-Wheels (NoW) project is one of the research projects working in this area (Jung and Kim, 2008).

In VANETs, the Wi-Fi has limitations in degree of covering, capacity and interference of the channel, the high mobility of the nodes, frequent topology changes and network fragmentation. Thus, a great deal of effort is dedicated to offer new MAC access strategies and to design efficient routing protocols, adjacent devices use same channel for accessing medium cause interference. Thus, 802.11 Mac protocol uses a contention-based access mechanism to regulate the medium access, but this can greatly limit network throughput. Different routing strategies have been defined based on prior ad hoc network architectures by targeting the specific VANET needs of scenarios and applications (Shimizu *et al*., 2007).

DSRC: The Dedicated Short-Range Communications (DSRC) standards suite is based on multiple cooperating standards mainly developed by the IEEE. It is a multi-channel wireless standard operates in 75 MHz licensed spectrum at 5.850 to 5.925 GHz band range allocated by US Federal Communications Commission USFCC. DSRC's physical layer based on the IEEE 802.11a is originally designed for indoor low-mobility WLAN applications. Whereas, DSRC MAC is meant for outdoor applications e.g., for high-speed vehicle (up to 200 km h^{-1}). DSRC MAC Layer, the DSRC band plan consists of seven channels of 10 MHz bandwidth which include one control channel to support high priority safety messages and six service channels to support non-safety applications (Kiokes *et al*., 2009). DSRC is capable of delivering 27 Mbps data-rate in 1 km range by using a two way line-of-sight short-range radio which is significantly lower cost compared to cellular, WiMAX or satellite communications.

DSRC is currently considered the most promising wireless standard in vehicular networks. The DSRC workgroup, that adopting Wi-Fi standards facilitates operations in infrastructure and ad hoc modes which map to V2I and V2V communications, respectively. Relevant application layer consortiums like Vehicle-Infrastructure Integration (IntelliDrive), Cooperative Intersection Collision Avoidance Systems (CICAS) and others have developed their architect with DSRC services in mind (Hannan *et al*., 2010a). DSRC is specifically design for both public safety and private operations for vehicular communication environment. The 802.11-p based DSRC is being seriously considered as a promising wireless technology for enhancing transportation safety and highway efficiency. It operates in stringent environment which requires; fast communications to maintain the connection with speeding vehicles at all times, strict QoS committed to predefined threshold delays for safety messages, minimal use of transmission power and maintaining privacy and anonymity of roaming users in addition to many other environmental challenges. Potential applications of DSRC are Electronic toll collection, Intersection collision avoidance, Automatic vehicle safety inspection, Transit or emergency vehicle signal priority and many more (Hassan *et al*., 2011).

DSRC is currently widely used for V2I application. Where V2V applications will not be fully functional until a significant percentage of cars on the road are equipped with DSRC systems For vehicle safety applications at road intersections, DSRC reception is likely to be problematic due to Non-line-of-sight reception conditions. Alternatively, it required a system with better coverage for information exchange, such as cellular system. DSRC is not expected to replace other wireless technologies, nor is it expected to uniquely serve all vehicular communication needs, rather DSRC is seen as the main candidate for safety, short-range applications, subscription free services, road toll services and other similar localized applications (Morgan, 2010).

WAVE: The combination of IEEE 802.11p and the IEEE 1609 protocol suite is denoted as WAVE (Wireless Access in Vehicular Environments) as shown in Fig. 4. The IEEE 802.11p is the modified version of IEEE802.11a and IEEE 1609 is complete set of protocol family. The Physical (PHY) layer and the basic Medium Access Control (MAC) layer are specified in IEEE 802.11p standard, where, MAC and network protocol layers are described by the IEEE 1609 standard family (Uzcategui and Acosta, 2009).

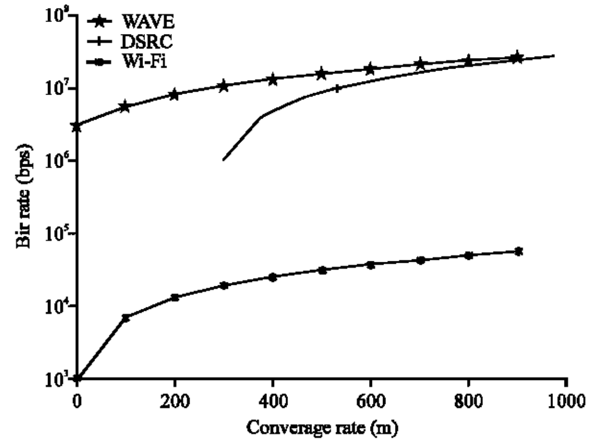

Fig. 4: Comparison parameters of the medium range technologies

There are six standards under 1609 family named as 1609,1,2,3,4,5,6. Each one handles different issues at different layers. Such as Application layer (IEEE 1609.1) details the management activities required for the proper operation of application. Security (IEEE 1609.2) defines security, secure message formatting, processing and message exchange. Networking (IEEE 1609.3) defines routing and transport services. It provides an alternative to IPv6. It also defines the management information base for the protocol stack. MAC (IEEE 1609.4) deals mainly with specification of the multiple channels in the DSRC standard. 1609.5 deals with layer Management while 1609.6 offers an additional transport and application layer, for handling of additional facilities at the application layer (Hannan *et al*., 2010b).

The FCC of the US Department of transportation (USDOT) has allocated 75 MHz bandwidth at 5.855-5.925 GHz for the Intelligent Transportation System (ITS). This bandwidth is divided into seven 10 MHz channels i.e., one Control Channel (CCH) and Six Service Channels (SCH). IEEE 802.11p, in the US also called DSRC, has been adopted as a technique to offer ITS services on this frequency band. After investigations in Europe, a 30 MHz channel is recommended for road safety applications (5875-5905 MHz) and further 20 MHz (5905-5925 MHz) are suggested to be considered for future ITS expansion (Morgan, 2010). The 30 MHz channel is divided into the SCH and CCH. The PHY of WAVE using OFDM technology with a frequency channel spacing of 10 MHz can support a data rate up to 27 Mb sec^{-1} with maximum radio output power is 760 mW. OFDM system provides both V2V and V2I wireless communications over distances up to 1 km while taking into account the environment, that is, high absolute and relative velocities (up to 200 km h^{-1}), fast multipath fading and different scenarios (rural, highway and urban). By using the optional 20 MHz channels, it allows data payload capabilities up to 54 Mb sec^{-1}. The basic MAC protocol of WAVE uses IEEE 802.11 Distributed Coordination Function (DCF) that is based on the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) scheme. The WAVE MAC extension layer, specified in IEEE 1609.4, adopts the Enhanced Distributed Channel Access (EDCA) of 802.11e which is meant for the distributed QoS support in IEEE 802.11 WLAN. Together these standards provide the foundation for a broad range of applications in the transportation environment, including vehicle safety, automated tolling, enhanced navigation, traffic management and many others (Banchs and Vollero, 2006).

WAVE is able to provide broadband local communications with low latency which is mandatory for realizing vehicular active safety applications, such as wireless local hazard warnings, vehicle maneuvering assistance and cooperative automatic cruise control. in the presents of infrastructure WAVE can satisfy the communication requirements of safety and non-safety applications in most cases, such as on the highway and in a city, under over-crowded and sparse traffic conditions (Wisitpongphan *et al*., 2007). However, crucial number of RSU (Road side units) is a prerequisite for the successful introduction of the service.

WAVE communication services provide data communications over two protocol stacks, namely; IPv6 and WAVE Short Message Protocol (WSMP). For safety applications which usually require a point to multi-point communication, the networking issue is copped with the novel WAVE Short Message Protocol (WSMP) introduced by IEEE 1609.3 standard (Campbell *et al*., 2011). WSMP (Wireless short message protocol) provides efficient broadcast service with low latency. As far as multi-hop communication is concerned, routing becomes a challenging issue because of the dynamically changing network topology of (VANET). As surveyed (Li and Wang, 2007), location and geographic information based routing algorithms, known as position based routing and geo-cast routing, are usually used in VANET.

Another major issue here with WAVE is security. Abdalla *et al.* (2007) authors mentioned that In the IEEE WAVE standard vehicles can change their IP addresses and use random MAC addresses to achieve security, IPv6 has been proposed for use in vehicular networks. Vehicles should be able to change their IP addresses so that, they are not traceable, however it is not clear how this will be achieved. Moreover this can cause inefficiency in address usage since when a new address is assigned the old address cannot be reused immediately. Delayed packets will be dropped when the car changes its IP address which causes unnecessary retransmissions.

SHORT-RANGE COMMUNICATION TECHNOLOGIES

Short-range also referred to as Wireless Personal Area Networks or WPAN and generally less than 10 feet. Short range technologies could be only used in Line of sight therefore may be helpful in InV communications. WPAN protocols operate at lower frequencies between devices that are usually only a few feet apart. Currently Bluetooth, ultra-wideband (UWB), ZigBee is protocol standards for short- range wireless communications with low power consumption (Park and Rappaport, 2007). The standard coverage, bit rate and application of the long range communication technologies are shown in Table 3. The comparison between Bluetooth, UWB and ZigBee technologies of the short-range communication are shown in Fig. 5. The detail long-range communication technologies are explained as follows.

Bluetooth: Bluetooth is currently the most widely used automotive wireless technology in many vehicles. In a Bluetooth-enabled vehicle, the car audio system takes over the phone function. In addition, other Bluetooth devices can easily interconnect within a Bluetooth enabled car: for example, portable devices, such as DVD, CD, MP3 players, can be connected to speakers. Table 4 reports the data transfer speeds required by some audio systems. Beyond entertainment and phone calls there are other emerging possibilities, including remote starting to warm-up the car in the winter or start the air conditioning in summer, a remote parking garage or home garage door controller and payment for gas at the pump and toll road payments (Sugiura and Dermawan, 2005).

However, Bluetooth has several drawbacks in an IVC context. Perhaps the most important drawback is that Bluetooth imposes a Piconet structure which is difficult to maintain in IVC systems that are much more dynamic than the stationary systems Bluetooth targets. It was shown, using accurate Bluetooth simulations which Piconet and Scatternet formation may take as long as 7 and 45 sec, respectively. Furthermore, new nodes joining existing Piconets encounter significant delays (Pokharel *et al*., 2005). Finally while the specifications allows for transmission ranges of up to 100 m, almost all current chipsets only allow for ranges of up to 10 m (the lowest specified in the standard). Even the 100 m range is considerably smaller than that of DSRC.

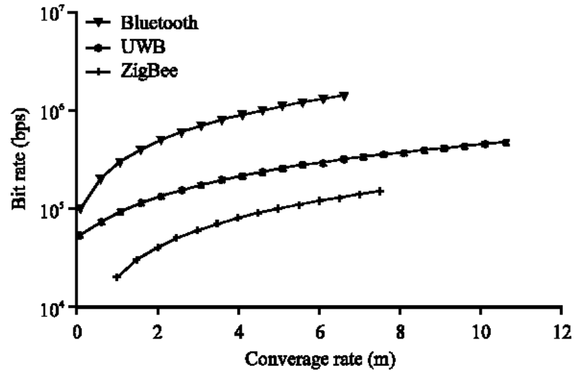

Fig. 5: Comparison parameters of the short range technologies

Table 4: Data transfer speeds needed by some audio systems.

Audio system	Quality	Data rate (kb sec^{-1})
CD audio	16 bit stereo, 44.1 kHz sampling	1411.20
MP3 audio	Close to CD audio	128.00
POTS (telephone)	8 bit mono, 8 kHz sampling	64.00
GSM audio	Close to POTS (telephone)	13.42

UWB: An alternative to Bluetooth is a new radio frequency technique called UWB. UWB has recently attracted much attention as an indoor short-range high-speed wireless communication. One of the most exciting characteristics of UWB is that its bandwidth is over 110 Mbps (up to 480 Mbps) which can satisfy most of the multimedia applications such as audio and video delivery in home networking and it can also act as a wireless cable replacement of high speed serial bus such as USB 2.0 and IEEE 1394. UWB uses very short pulses, so that the spectrum of the emitted signals spread over several GHz, because of the wideband nature of the signal, UWB has been used in radar applications (Hu *et al*., 2010).

UWB is the newcomer in the area of vehicle communication system. The main advantages of UWB technology are its high data rate, low cost and immunity to interference. It is applicable for vehicular collision-detection systems and suspension systems that respond to road conditions (Richardson *et al*., 2006). But due to the fact that UWB could potentially interfere with communication sources, is a technical problem that must be solved before it could be used in IVC systems. In addition, there is a concern that UWB's radio coverage could extend to uninvolved vehicles which could generate false or irrelevant information.

ZigBee: ZigBee is a recently developed wireless technology, Build upon PHY and MAC layer and used in many commercial and research applications. Based on the IEEE 802.15.4 specification, it has become a very attractive wireless connectivity solution due to its open standard, low cost and low power characteristics (Richardson *et al*., 2006). ZigBee is suitable for low data rate WPAN (LR-WPAN) for supporting simple devices that consume minimal power and typically operate in the Personal Operating Space (POS) of 10 m. ZigBee provides self-organized, multi-hop and reliable mesh networking with long battery lifetime ZigBee fills a gap not provided by the other technologies, namely the interconnection of wireless sensors for control applications (Hannan *et al*., 2010a). ZigBee operates in the industrial, scientific and medical (ISM) radio bands; 868 MHz in Europe, 915 MHz in countries such as USA and Australia and 2.4 GHz in most jurisdictions worldwide.

ZigBee is expected to be used in monitoring and control applications, related to temperature and humidity measurement as well as heating, ventilation, air-conditioning and lighting control. There are also quite novel and original ways of using ZigBee for the driver's benefit. One of them is rental car monitoring. A ZigBee-enabled monitoring system could allow customers to quickly drop off a rental car without waiting for the attendant to check gas or mileage. Other interesting automotive applications are tire-pressure monitoring and remote keyless entry. Further proposals involve attaching a ZigBee device to anything which should not be lost (e.g., car keys), so that, whenever the device goes out of range, an alert signal is generated from a ZigBee-equipped phone (Corral *et al*., 2012). Due to the low transmission rate and small area coverage, ZigBee manufactures slow to make an appearance on the market.

CURRENT ISSUES AND CHALLENGES

In order to establish communication in vehicular network, many technical issues and challenges must be addressed. All Communication technologies come with their own set of requirements, especially in the aspects of quality of service, speed and link establishment etc.

Selection of communication technology: Selection of proper technologies required support of high data rate and high mobility in dense Vehicle communication network (Jerbi *et al*., 2010).

Interference issues in short range communication: When communication interference appears, wireless transmitters in the immediate vicinity operating in the same frequency band invariably cause (Misra *et al*., 2008). The high radio density can result in substantial delays in time to transmit and even data losses.

Mobility and handover: Due to high mobility, a VANET is extremely dynamic in nature and requires extreme configurations, high-speed movement of vehicles cause frequent topology changing (Park *et al*., 2003). In the worst case, if two cars with high speeds drive in opposite directions, the link will last only a very short amount of time. Further, Handover becomes a challenging task in high mobile environment, where high-speed nodes frequently handoff between Access Points (APs) along the road.

Frame error rate: A high velocity of vehicles causes a large and fast variation of the channel conditions which may increase Frame Error Rate (FER) e.g. Vehicle moving at speed 60 km h^{-1} caused variation of the channel conditions and may increase FER dramatically due to the flat fading Rayleigh channel (Afonso *et al*., 2011).

Quality of service: IVC system requires fast association and low communication latency between communicating vehicles in order to guarantee: (1) service's reliability for safety-related applications while taking into consideration the time-sensitivity during messages transfer and (2) the quality and continuity of service for passenger's oriented applications (Li *et al*., 2006).

Radio channel characteristics: In real time wireless communication, multiple objects could degrade the strength and quality of receiving signal and, therefore, have a negative impact on messages reception rates (Sun *et al*., 2006). Moreover, due to mobile nature of vehicles, fading effects have to be taken in account. Because of fast fading phenomena, a transmitter can experience a different multipath environment each time when it sends a packet.

Hidden nodes: Due to the low strength radio wave in far apart nodes or if there are some barriers between these nodes, they cannot detect the traffic status of each other (Toor *et al*., 2008). This is so called Hidden Nodes problem which may cause a high possibility of collision.

Security: Security becomes more challenging in *ad hoc* network due high-speed mobility in extremely large network. In particular, it is essential to make sure that "life-critical safety" information cannot be inserted or modified by an attacker; likewise, the system should be able to help establishing the liability of drivers and privacy of passengers (Dressler *et al*., 2008). It is obvious that any malicious behavior of users, such as a modification and replay attack with respect to the disseminated messages, could be fatal to other users.

Bootstrap: At this moment only few number of cars will be have the equipment required for the DSRC radios, so, if we make a communication we have to assume that there is a limited number of cars that will receive the communication, in the future we must concentrate on getting the number higher, to get a financial benefit that will courage the commercial firms to invest in this technology (Javadi *et al*., 2012).

The technologies used for vehicular networks are still not mature and will probably not be implemented in the immediate future. The opportunities that a VANET presents are unlimited. The future introduction vehicular networks offer a tremendous opportunity to increase the safety of the transportation system and reduce traffic fatalities.

DISCUSSION

This study presents the review of the wireless communications technologies used for data exchange in vehicular networks in the forms of InV, V2V and V2I communications and the issues that are being facing problems (Dressler *et al*., 2008; Li and Wang, 2007). The most recent technologies have been considered based on their range. The characteristics of them have been investigated through vehicular network to achieve related applications in data communication (Toor *et al*., 2008). Within different ranges, a comprehensive study is provided to employ the most suitable technology by considering the advantages and drawbacks of every single technology (Willke *et al*., 2009; Misra *et al*., 2008). However, on this way there are number of challenges and issues due to the nature of vehicular networks such as mobility and hardware, frame error rate, hidden nodes, network scalability, etc., which should be considered (Abdalla *et al*., 2007; Hussain *et al*., 2006; Wewetzer *et al*., 2007; Ravichandiran and Vaithiyanathan, 2009). In comparison with other surveys in this field which focused on a specific technology, this study has discussed a wide range of technologies and compared them to each other to achieve a comprehensive vision to apply them for IVC systems. As the emerging area of vehicular networks has attracted a number of researchers in the world, this review then introduces the consortiums and initiatives working on advanced automotive technologies. In the future, vehicular networks certainly play a vital role in enhancing the automotive industry for safety, security and entertainment.

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