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Comparative Study of IEEE 802.11, 802.15, 802.16, 802.20 Standards for Distributed VANET

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Abstract – This paper investigates the simulation time and real time use of IEEE wireless standards for distributed VANET. Inter vehicle communication in VANET requires the appropriate use of wireless standard which support high data rate along with better communication range in sparse as well as in dense situation. This paper study different wireless standards supported by VANET and compare their parameters (range, data rate, and frequency band). It finally concludes the best suitable standard for real time and simulation time environment.

***Keywords** - VANET, wireless, IEEE 802.11, IEEE 802.15, IEEE 802.16, IEEE 802.20, Distributed VANET.*

I. INTRODUCTION

VANET is an enhancement in ad-hoc wireless network toward the application of vehicular system. In VANET different types of vehicles communicate with each other to share the speed, location and different parameters. The size of information shared and message to be sent at distance is varying according to the density of vehicles. As this information is shared wirelessly, the appropriate wireless standard should be chosen. There is mainly IEEE 802.11, 802.15, 802.16, 802.20 wireless standards are available. In this paper we are just comparing the different parameters for these standards and conclude, which is the best standard for distributed VANET at simulation time and real time implementation.

In today's life traffic congestions are unavoidable part. Drivers waste their most of time in traffic congestion. Intelligent transportation systems are accepted to avoid road accidents, to find nearest road segment, and traffic free movement of vehicles.

There are basically two approaches for intelligent transportation system (ITS). Centralised system in which vehicles communicate with road side unit and in Distributed system there is a vehicle to vehicle communication. In centralised system road side units are placed near road side at a density of 2 or 3 per kilometre. In distributed system vehicles are at any distance from each other. So the communication range in distributed should be large as compared to centralised approach.

At a dense situation in distributed VANET the media should carry maximum data. Consider if the average size of data of vehicles in 100 meters are 1K bytes, and 1M bytes in a range of 250 meters. So the media should carry that amount of data at a time. As a density increases the size of the data to be carried increased, so maximum bandwidth should be required.

II. WIRELESS STANDARDS

There are many standards available for wireless Network. In this paper we consider only comparative wireless standard for distributed VANET. So these are not the complete set of standards. And this comparison is not exhaustive until the new arrivals of wireless standards.

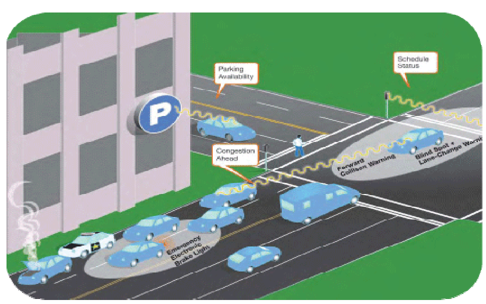

Fig.1: Intelligent Transportation System

A. *IEEE 802.11-WLAN/Wi-Fi*

In 1997, the Institute of Electrical and Electronics Engineers (IEEE) created the first WLAN standard. They called it 802.11 after the name of the group formed to oversee its development. Unfortunately, 802.11 only supported a maximum network bandwidth of 2 Mbps - too slow for most applications.

For this reason, ordinary 802.11wireless products are no longer manufactured.

802.11 Standard	Freq. (GHz)	Bandwidth (MHz)	Data Rate (Mbps)	Approximate Range (m)
a	5	20	54	120
b	2.4	20	11	140
g	2.4	20	54	140
n	2.4/5	20	100	250

Table 1: Comparison of 802.11 Wi-Fi Standards

The most popular are those defined by the 802.11b and 802.11g protocols, which are amendments to the original standard followed by 802.11g and 802.11n. 802.11n is a new multi-streaming modulation technique. Other standards in the family (c–f, h, j) are service amendments and extensions or corrections to the previous specifications [1]. The WLAN standard operates on the 2.4 GHz and 5 GHz Industrial, Science and Medical (ISM) frequency bands. The table 1 shows the comparison of 802.11 standard.

B. *IEEE 802.15-PAN*

IEEE 802.15 is a working group of the Institute of Electrical and Electronics Engineers (IEEE) IEEE 802 standards committee which specifies wireless personal area network (PAN) standards. It basically divides into 3 groups IEEE 802.15.1, 802.15.3, and 802.15.4.

IEEE 802.15.1 i.e. Bluetooth is a proprietary open wireless technology standard for exchanging data over short distances (using short wavelength radio transmissions in the ISM band from 2400-2480 MHz) from fixed and mobile devices, creating personal area networks (PANs) with high levels of security. Created by telecoms vendor Ericsson in 1994, it was originally conceived as a wireless alternative to RS-232 data cables. It can connect several devices, overcoming problems of synchronization. Bluetooth uses a radio technology called frequency-hopping spread spectrum, which chops up the data being sent and transmits chunks of it on up to 79 bands (1 MHz each; centered from 2402 to 2480 MHz) in the range 2,400-2,483.5 MHz (allowing for guard bands). This range is in the globally unlicensed Industrial, Scientific and Medical (ISM) 2.4 GHz short-range radio frequency band.

802.15 Standard	Freq. (GHz)	Data Rate	Approximate Range (m)
802.15.1	2.4	3Mbps	100
802.15.3	2.4	110Mbits	10
802.15.4	2.4	250Kbps	75

Table 2: Comparison of 802.15 PAN Standards

IEEE 802.15.4 was designed to address the need for a low-cost and low-power wireless solution and has become a solid foundation for monitoring and controlling networks, including ZigBee technology, RF4CE industry consortium, WirelessHART technology as well as numerous other proprietary network stacks. Freescale's one-stop-shop is complete with hardware and software, which includes development tools and reference designs, all designed to help ease 802.15.4 wireless development and speed time to market. IEEE standard 802.15.4 intends to offer the fundamental lower network layers of a type of wireless personal area network (WPAN) which focuses on low-cost, low-speed ubiquitous communication between devices (in contrast with other, more end-user oriented approaches, such as Wi-Fi).

The emphasis is on very low cost communication of nearby devices with little to no underlying infrastructure, intending to exploit this to lower power consumption even more. The basic framework conceives a 75-meter communications range with a transfer rate of 250 Kbit/s. Tradeoffs are possible to favour more radically embedded devices with even lower power requirements, through the definition of not one, but several physical layers. Lower transfer rates of 20 and 40 Kbit/s were initially defined, with the 100 Kbit/s rates being added in the current revision.

Ultra wideband will not replace Bluetooth for short-range communications, because Bluetooth is a complete, end-to-end communications standard, whereas UWB is merely a radio technology that can be used as part of an overall standard. Bluetooth defines how data is managed, formatted and physically carried over a wireless personal-area network (WPAN). However, designers expect that future Bluetooth implementations will be built on top of UWB signals.

802.15.3 is the IEEE standard for a high-data-rate WPAN designed to provide sufficient quality of service for the real-time distribution of content such as video and music. It is ideally suited for a home multimedia wireless network. The original standard uses a traditional carrier-based 2.4-GHz radio as the physical transmission layer.

802.15.3a, a follow-on standard still in the formative stages, will define an alternative physical layer. Current proposals based on UWB will provide more than 110Mbit/sec. at a distance of 10 meters and 480Mbit/sec. at 2 meters. This will allow the streaming of high-definition video between media servers and high-definition monitors, as well as the extremely fast transfer of files between servers and portable devices [2].

Table 2 shows the comparison between different 802.15 standards.

C. IEEE 802.16-WiMax

IEEE 802.16 stands for WiMAX (Worldwide Interoperability for Microwave Access) is a trademark for a family of telecommunications protocols that provide fixed and mobile Internet access. The 2005 WiMAX revision provided bit rates up to 40 Mbit/s with the 2011 update up to 1 Gbit/s for fixed stations. It supports the frequency bands in the range between 2 GHz and 11 GHz, specifies a metropolitan area networking protocol that will enable a wireless alternative for cable, DSL and T1 level services for last mile broadband access, as well as providing backhaul for 801.11 hotspots. Fig. 2 shows WiMAX as broad band wireless access.

It can provide broadband wireless access (BWA) up to 50 km for fixed stations (e.g., desktop PCs), and 5 - 15 km for mobile stations (e.g., notebooks, computers, mobile phones, personal media players, and PDAs). The newest version of the IEEE 802.16 standard, dubbed 802.16m or Mobile WiMAX 2.0, could drive mobility up to 350 km/hr and push the data transfer speed up to 1 Gbps. Draft one of 802.16m is expected to deliver performance of over 300 Mbps in 4x4 MIMO configurations using 20-MHz channels and will likely be finalized in 2011.

WiMAX allows for infrastructure growth in underserved markets and is today considered the most cost-effective means of delivering secure and reliable bandwidth capable of supporting business critical, real-time applications to the enterprise, institutions and municipalities. It has proven itself on the global stage as a very effective last mile solution. In the United States though, licensed spectrum availability and equipment limitations have held up early WiMAX adoption. In fact, while there are currently 1.2+ million WiMAX subscribers worldwide, only about 11,000 of those are from the United States. Future growth in this market will be driven by wireless ISPs like Clear wire who intends to cover 120-million covered POPs in 80 markets with WiMAX by the end of 2010. Growth will also be driven by the availability of the 3.65-GHz spectrum that the FCC opened up this past year [3] [4].

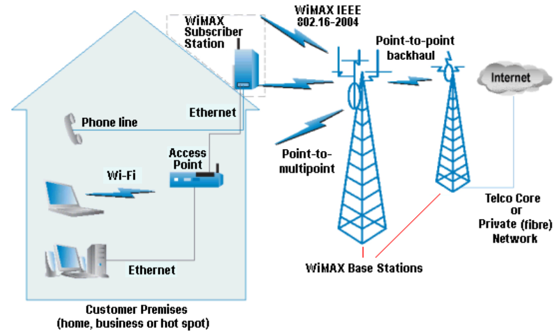

Fig 2: IEEE 802.16 (BWA)

The table 3 shows comparative 802.16 standards.

	Mobile WiMAX2.0	Mobile WiMAX	Fixed WiMAX
Standard	802.16m	802.16e	802.16d(802.16-2004)
Usage	WMAN Portable	WMAN Portable	WMAN Fixed
Throughput	Over 300 Mbps(100 MHz BW)	Up to 30Mbps(10 MHz BW)	Up to 75Mbps(20MHz BW)
Range	Typical 1-3 miles	Typical 1-3 miles	Typical 4-6 miles
Frequency	Sub 6 GHz	2-6 GHz	Sub 11GHz

Table 3: Comparison of IEEE 802.16 Standards

D. IEEE 802.20-MBWA

IEEE 802.20 i.e. mobile broadband wireless access operates at frequency below 3.5GHz.The actual data rate it supports is 1Mbps and it supports vehicular mobility classes up to 250Km/h [5].

Since July 1999, the IEEE 802.16 Working Group on Broadband Wireless Access has been openly developing voluntary consensus standards for Wireless Metropolitan Area Networks with global applicability. Addressing the demand for broadband access to buildings, IEEE 802.16 provides solutions that are more economical than wired-line alternatives. The standards set the stage for a revolution in reliable, high-speed network access in the “last mile” of Internet by homes and enterprises [6]. On December 11th, 2002, the IEEE Standards Board approved the establishment of IEEE 802.20 Mobile Broadband Wireless Access (MBWA) Working Group. It described the scope of IEEE 802.20 as:

Specification of physical and medium access control layers of an air interface for interoperable mobile broadband wireless access systems, operating in licensed bands below 3.5 GHz, optimized for IP-data transport, with peak data rates per user in excess of 1 Mbps. It supports various vehicular mobility classes up to 250 Km/h in a MAN environment and targets spectral efficiencies, sustained user data rates and numbers of active users that are all significantly higher than achieved by existing mobile systems [6].

According to the MBWA announcement, IEEE 802.20 is aimed at mobile communication, and its data rate can reach more than 2Mbps in high speed mobile application. IEEE 802.20 is the first real broadband wireless network standard that dedicatedly supports the mobility of network. A comparison between IEEE 802.20 and others mobile techniques for traditional RCS are shown in Table 4 [7][8][9].

III. OPERATION MODES

We have seen four wireless standards with their different classes. They have different modes of operation: Ad-hoc, infrastructure [10], with this we check one more mode i.e. VANET. Infrastructure wireless networks usually have some kind of base station1 which acts as a central node which connects the wireless terminals. The base station is usually provided in order to enable access to the Internet, an intranet or other wireless networks. Most of the time the base stations have a fixed location, but certain mobile base stations also exist. The disadvantage over ad hoc networks is that the base station is a central point of failure. If it stops working none of the wireless terminals can communicate with each other.

Ad hoc networks can be formed “on the fly” without the help of a base station. Self organization is the key to forming an ad hoc network because initially there is no central node to talk to. In ad hoc networks the wireless terminals may communicate directly with each other while terminals in infrastructure networks have to use the base station to relay their messages [10].

The application of mobile communication technology to support road traffic constitutes a challenging, [11] but at the same time very promising working area for research and development. A whole community has formed around the questions that vehicular communications and, in particular, vehicular ad hoc networks (VANETs) pose. Consisting of public authorities, academia, and car manufacturers [12, 13, 14], this community fosters the use of communication technology to enhance driving security and comfort. Proposed applications reach from the reduction of road casualties by avoidance systems [15] to offering guidance to available parking lots [16], discovering the traffic situation on a planned route [17], and coordinating car flow and traffic lights [18, 14].

Characteristics	GSM-R	TETRA version 2	GT800 (3G)	IEEE 802.20
Data Rate	2.4-28.8Kbps	96-384Kbps	2Mbps, < 144Kbps in high speed	16Mbps, > 2Mbps at the speed of 250mk/h
Latency	About 1000ms	About 500ms	About 250ms	About 30ms
Spectral Efficie-ncy	200KHz/8 channel	25KHz/4channel	About 0.2b/s/Hz/cell	> 1b/s/Hz/cell
Cell radius	5~10 Km	10~15 Km	2~5 Km	> 15 Km
Spectrum	Licensed bands 876 -880/921-925MHz	Licensed bands 806 -821/851-866Mhz	Licensed bands below 2.7GHz	Licensed bands below 3.5GHz
Switch-ing Method	Circuit	Circuit	Circuit/Packet	Packet

Table 4：IEEE 802.20 Vs. Other Mobile Techniques used by Traditional RCS

The different standard support different mode of operation. We see in table 5 which standard support which mode.

Standard	Ad hoc	Infrastructure	VANET
802.11a/b /g/n	Yes	Yes	Yes
802.15.1/ 4/3	Yes	No	Yes
802.16 m/e/d	Yes	Yes	Yes
802.20	Yes	Yes	Yes

Table 5: Modes of Operation for Different Wireless Standard

IV. INTELLIGENT TRANSPORTATION SYSTEM

Figures 3 and 4 depict the possible distributed communication configurations in intelligent transportation systems. These include inter-vehicle and routing-based communications. Inter-vehicular and routing-based communications rely on very accurate and up-to-date information about the surrounding environment, which, in turn, requires the use of accurate positioning systems and smart communication protocols for exchanging information. In a network environment in which the communication medium is shared, highly unreliable, and with limited bandwidth [16], smart communication protocols must guarantee fast and reliable delivery of information to all vehicles in the vicinity. It is worth mentioning that Intra-vehicle communication uses technologies such as IEEE 802.15.1 (Bluetooth), IEEE 802.15.3 (Ultra-wide Band) and IEEE 802.15.4 (Zigbee) that can be used to support wireless communication inside a vehicle but this is outside. [20]

A. Inter vehicular communication

The inter-vehicle communication configuration (Fig. 3) uses multi-hop multicast/broadcast to transmit traffic related information over multiple hops to a group of receivers. In intelligent transportation systems, vehicles need only be concerned with activity on the road ahead and not behind (an example of this would be for emergency message dissemination about an imminent collision or dynamic route scheduling). There are two types of message forwarding in inter-vehicle communications: *naive broadcasting* and *intelligent broadcasting*. In *naive broadcasting*, vehicles send broadcast messages periodically and at regular intervals. Upon receipt of the message, the vehicle ignores the message if it has come from a vehicle behind it. If the message comes from a vehicle in front, the receiving vehicle sends its own broadcast message to vehicles behind it. This ensures that all enabled vehicles moving in the forward direction get all broadcast messages.

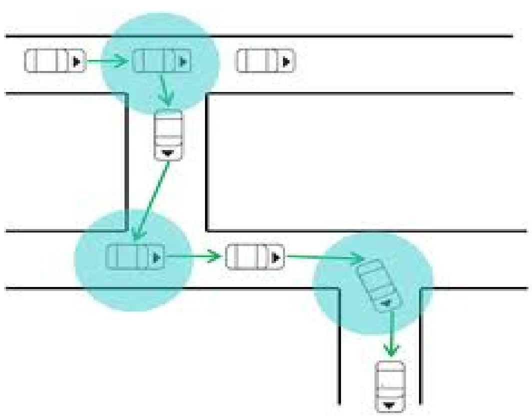

Fig. 3: Inter Vehicular Communication

The limitations of the broadcasting method is that large numbers of broadcast messages are generated, therefore, increasing the risk of message collision resulting in lower message delivery rates and increased delivery times [21]. *Intelligent broadcasting* with implicit acknowledgement addresses the problems inherent in naïve broadcasting by limiting the number of messages broadcast for a given emergency event. If the event-detecting vehicle receives the same message from behind, it assumes that at least one vehicle in the back has received it and ceases broadcasting. The assumption is that the vehicle in the back will be responsible for moving the message along to the rest of the vehicles. If a vehicle receives a message from more than one source it will act on the first message only [22].

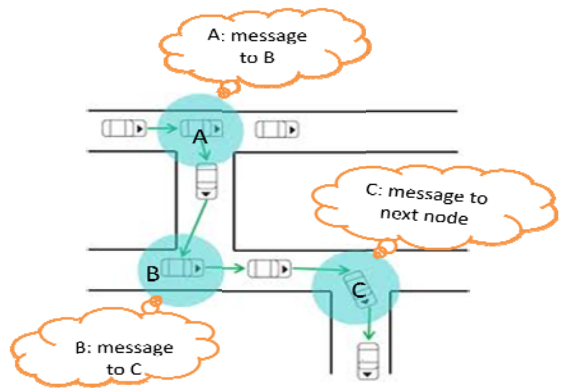

Fig 4: Routing Based Communication

V. DISCUSSION

There are many standards that relate to wireless access in vehicular environments. These standards range from protocols that apply to transponder equipment and communication protocols through to security specification, routing, addressing services, and interoperability protocols.

Depending upon the development of VANET i.e. simulation based development and real time development, inter vehicle communication and intra vehicle communication we face certain challenges. The challenges faced are given in table 6.

Standard	License/ Un - licensed	Lower Range		Higher Range	
		Data rate	Range	Data rate	Range
802.11a/b /g/n	Unlicensed	11-100 Mbps	120-250m	11-100 Mbps	120-250m
802.15.1/ 4/6	Unlicensed	250Kbps-1Gbps	2-100m	250Kbps-1Gbps	10-100
802.16 m/e/d	Unlicensed	1Gbps	1km	30Mbps	5-15km
802.20	Licensed	80 Mbps	15Km	80 Mbps	15Km

Table 6: Comparison of IEEE Standards according to Range, Data Rate, and License.

A. WiMAX

[23] 802.16 WiMAX cannot deliver 70 Mbit/s over 15 kilometers (31 miles). Like all wireless technologies, WiMAX can operate at higher bitrates or over longer distances but not both. Operating at the maximum range of 15 km increases bit error rate and thus results in a much lower bit rate. Conversely, reducing the range (to less than 1 km) allows a device to operate at higher bitrates.

A city-wide deployment of WiMAX in Perth, Australia demonstrated that customers at the cell-edge with an indoor Customer-premises equipment (CPE) typically obtain speeds of around 1–4 Mbit/s, with users closer to the cell tower obtaining speeds of up to 30 Mbit/s]

Like all wireless systems, available bandwidth is shared between users in a given radio sector, so performance could deteriorate in the case of many active users in a single sector. However, with adequate capacity planning and the use of WiMAX's Quality of Service, a minimum guaranteed throughput for each subscriber can be put in place. In practice, most users will have a range of 4-8 Mbit/s services and additional radio cards will be added to the base station to increase the number of users that may be served as required.

B. MBWA

Mobile Broadband Wireless Access have higher data rate with maximum range up to 15Km. It has license frequency bands below 3.5 GHz.

C. PAN

Private area network has unlicensed frequency band with data rate up to 250Kbps and limited range which is suitable for intra vehicular and not for inter vehicular.

D. Wi-Fi

In Wi-Fi 802.11b/g has data rate up to 11 Mbps in practical scenario and communication range of 250m which better than 802.11 a/n and it has unlicensed frequency bands

VI. COMPARISON

From above discussion we can see that private area network (PAN) has very low data rate where as for distributed VANET communication the minimum requirement of data rate in dense situation is 1-2 Mbps.

Mobile Broadband Wireless Access (MBWA) has a maximum range and data rate sufficient for distributed VANET communication. But as it has licensed frequency band we cannot used it for real time communication.

So, now we proceed for comparative study of Wi-Fi and WiMAX which has unlicensed frequency, maximum data rate and greater communication range.

A. WiMAX and Wi-Fi

Comparisons and confusion between WiMAX and Wi-Fi are frequent because both are related to wireless connectivity and Internet access.

- WiMAX is a long range system, covering many kilometres, which uses licensed or unlicensed spectrum to deliver connection to a network, in most cases the Internet.
- Wi-Fi uses unlicensed spectrum to provide access to a local network.
- Wi-Fi is more popular in end user devices.
- Wi-Fi runs on the Media Access Control's CSMA/CA protocol, which is connectionless and contention based, whereas WiMAX runs a connection-oriented MAC.
- WiMAX and Wi-Fi have quite different quality of service (QoS) mechanisms:
  - ✓ WiMAX uses a QoS mechanism based on connections between the base station and the user device. Each connection is based on specific scheduling algorithms.
  - ✓ Wi-Fi uses contention access - all subscriber stations that wish to pass data through a wireless access point (AP) are competing for the AP's attention on a random interrupt basis. This can cause subscriber stations distant from the AP to be repeatedly interrupted by closer stations, greatly reducing their throughput.
- Both 802.11 (which includes Wi-Fi) and 802.16 (which includes WiMAX) define Peer-to-Peer (P2P) and ad hoc networks, where an end user communicates to users or servers on another Local Area Network (LAN) using its access point or base station. However, 802.11 supports also direct ad hoc or peer to peer networking between end user devices without an access point while 802.16 end user devices must be in range of the base station [3][23].

VII. CONCLUSION

In distributed vehicular network different vehicles communicate with each to share messages for road status, speed of vehicle, location status and many parameters. In highly dense situation the standard should carry very large amount of data at a time for different vehicles. In distributed communication environment we cannot predict the distance between vehicles, so to remain in communication range at sparse environment the standard should have maximum range.

At simulation environment we require wireless standard which support maximum range with high data rate along with licensed free frequency bands.

Considering above factors and from comparison we can conclude that Private Area Network cannot support the required data rate to carry data. WiMAX cannot support greater communication range and high data rate at a time, so it is unreliable in case of distributed VANET.

Mobile Broadband Wireless Access has better data rate with greater communication range, but as it has licensed frequency band we cannot used at simulation time but we can used at real time communication.

IEEE 802.11b standard supports most of the requirement of VANET i.e. communication range, data rate and as it has licensed free frequency band we can used this wireless standard at distributed VANET simulation time environment.

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