A Comparative Study of IEEE 802.11 Standards for Non-Safety Applications on Vehicular Ad Hoc Networks: A Congestion Control Perspective

Shamsul Jamel Elias, Mohd Nazri Bin Mohd Warip, R Badlishah Ahmad, Aznor Hanah Abdul Halim

***Abstract* — Vehicular Ad Hoc Networks (VANETs) is an important component within the intelligent transportation systems (ITS) that have been part of global strategy and advanced applications. The aim is to provide innovative services relating to various modes of transportation and traffic management. These systems enable users to reach their destinations better, safer and more coordinated. In order to make the system workable, several radio access technologies (RAT) such as UMTS, WiFi, WiMAX and radio spectrum at 5.9 GHz have been proposed for next generation ITS. In this survey, we investigate the IEEE wireless standards for non-safety applications in a distributed VANET. Furthermore, Inter vehicle communication requires the use of wireless standard which support high data rate along with better communication range in sparse as well as in dense situation. The paper provides study of different wireless standards supported by VANET and compare their parameters (range, data rate, and frequency band). Finally, the survey recommends the best suitable wireless standards for non-safety applications both real time and simulation time environment.**

***Index Terms* — Intelligent transportation systems (ITS), non-safety applications, radio access technologies (RAT).**

I. INTRODUCTION

The Vehicular Ad Hoc Networks (VANET) is a progressively indispensable area in Mobile Ad Hoc Networks (MANETs). Recently, researchers have shown an increased interest in Vehicular communications. According to definition provided by authors in [1] , the VANETs comprise vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communications based on wireless local area network technologies.

Manuscript received July 20, 2014; revised August 16, 2014.

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The distinctive set of ITS application (e.g., collision triggering and traffic and road condition for drivers, internet resources (wifi, licensed spectrum), and the traffic environment (e.g., vehicular traffic flow patterns, traffic topology concerns) make the VANET a unique area of wireless communication.

Three main categories of applications have been focused by [2] as in Table 1.

TABLE I. INTELLIGENT TRANSPORT SYSTEMS (ITS) APPLICATION CATEGORIES

Application category	Latency tolerance	Range	Example (delay requirement)
Road safety	Low	Local	Pre-crash sensing (50 ms) Collision risk warning (100 ms)
Traffic efficiency	Medium	Medium	Traffic information (500 ms)
Value-added services	Low	Medium	Map download update/Point of interest notification (500 ms)

In Table 1 value-added applications could be categories as on-demand services related to infotainment or non-safety applications where the author going to focus on. Notification from point of interest such as parking lot, list of available restaurants or e-map downloading may save time and thus reduce the fuel consumption.

Several ITS architectures have been proposed by vehicular communications directives and standardization bodies. The intelligent transport system consists of internet vehicles communication, traffic surveillance information and real-time traffic control. Three system features can communicate with existing on-road vehicle surveillance network to form a ITS architecture. In the Figure 1, the wireless communication unit inside car (on board unit or OBU) exchange data with the roadside unit (road side unit or RSU) to get road condition and traffic information ahead of it.

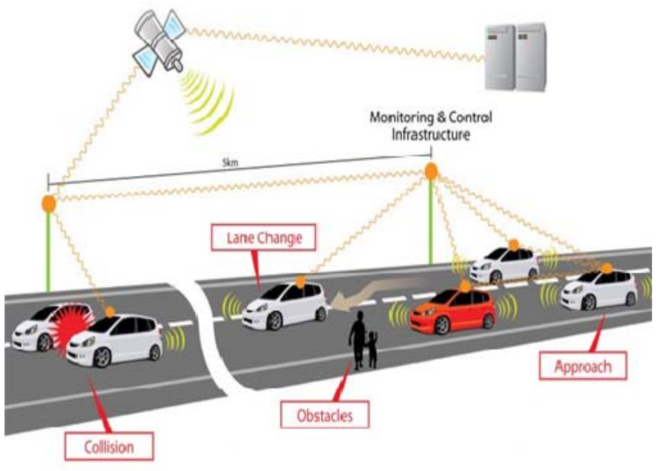

Fig. 1. An overview of Intelligent Transport System (ITS)

These traffic congestion and road safety information can be published through service center to different RSU clusters for broadcasting. Every vehicle participate in sensing and updating latest road information.

Internet of Vehicle - Communication. The data exchange amonge OBU in vehicles are through RSU or road-side assistance system, which is based on wireless networking technology. There three wireless radio technology standards set for the vehicle communication [3]:

a. IEEE 802.11 - WiFi,
b. IEEE 802.15.3 - UltraWideband, high data rate
c. IEEE 802.15.4 - ZigBee, low data rate.

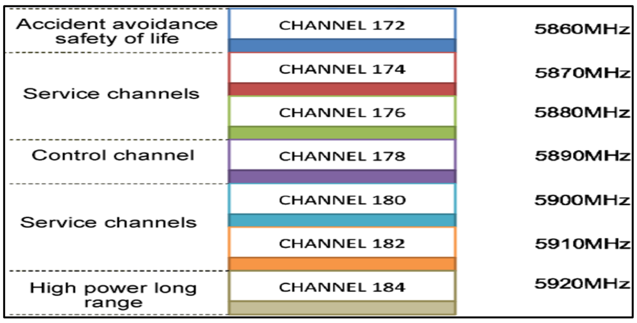

Fig. 2. The seven channels of Dedicated Short Range Communication (DSRC)

In order to communicate using VANETs, the IEEE is working on the IEEE 802.11p (WAVE – Vehicular Environments Wireless Access) and 802.11 protocols standard for Dedicated Short Range Communication (DSRC). The DSRC was designed using a multi-channel system. The FCC divided the spectrum into seven channels, each with 10 to 20 MHz, in which six were identified as Service Channels (SCHs), and one as a Control Channel (CCH).

Figure 2 explained the channel allocation for DSRC. The CCH channel is used for safety messages while non-safety services (WAVE-mode short messages) are expected to go through the other six service channels available [4],[5]

The remainder of this paper is structured as follows. Section II presents the overview of WLAN related work. It summarizes and distinguishes each access technology and evaluates them based on several criteria. Section III provides congestion control algorithm design and others researcher works. . In Section V concludes the paper by defining the main obtained results and providing future work directions.

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II WLAN STANDARDS

The foundation for wireless local area networks (WLANs) products began with the original 802.11 standard developed in 1997 by the Institute of Electrical and Electronics Engineers (IEEE). That base standard was formulated by a letter following the 802.11 name, such as 802.11b, 802.11a, or 802.11g. The letter suffix represents the task group that defines the extension to the standard. These additional enhancements increase the data rate and its functionality. The following TABLE II briefly summarizes the comparison of 802.11 standard and the enhancements related to data rate (the WLAN physical layer).

TABLE II. IEEE 802.11 SPECIFICATIONS

	802.11a	**802.11b**	**802.11g**	**802.11n**	**802.11p**
Standard approved	July 1999	July 1999	June 2003	Oct 2009	July 2010
Maximum data rate	54 Mbps	11 Mbps	54 Mbps	100 Mbps	≥100 Mbps
Modulation	OFDM	DSSS	OFDM & DSSS	OFDM	OFDM
Data rates	6, 9, 12, 18, 24, 36, 48, 54 Mbps	1, 2, 5.5, 11 Mbps	DSSS: 1, 2, 5.5, 11 OFDM: 6, 9, 12, 18, 24, 36, 48, 54 Mbps	15, 30, 45, 60, 90, 120, 135, 150, up to 600 Mbps	≥600 Mbps
Frequencies	5.15–5.35 GHz 5.425–5.675 GHz 5.725–5.875 GHz	2.4–2.497 GHz	2.4–2.497 GHz	2.4–5 GHz	5.470-5.925 GHz
Approximate Range (m)	120	140	140	250	≥ 250

ISBN: 978-988-19253-7-4
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

The most popular are those defined by the 802.11b and 802.11g protocols, which are amendments to the original standard followed by 802.11n and 802.11p. 802.11p is a new multi-streaming modulation technique. The WLAN standard works on the 2.4 GHz and 5 GHz Industrial, Science and Medical (ISM) frequency bands.

TABLE III. WLAN MOFES OF OPERATION[3]

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

The above table shown the different standard support in term of functionality and operation of wireless local area network (WLAN).

TABLE IV. COMPARISON OF IEEE STANDARD[3]

Standard	**License/Un licensed**	**Lower Range**		**Higher Range**	
		Data rate	**Range**	**Data rate**	**Rang e**
802.11 a/b/g/n/p	Unlicensed	11-100 Mbps	120-250m	11-100 Mbps	120-250m
802.15.1/4 /3	Unlicensed	250Kbps-1 Gbps	2-100m	250Kbps-1 Gbps	10-100m
802.16 m/e/d	Unlicensed	1Gbps	1 km	30Mbps	5-15km
802.20	License	80 Mbps	15 km	80 Mbps	15km

From Table III and Table IV we can conclude there are many standards related to wireless local area network (WLAN) accessibility in vehicular ad hoc network (VANETs) environments. There are also the different functionality and operations among all the standards. These standards range from protocols that apply to RSU equipment and OBU communication protocols through security specification, routing, addressing services, and interoperability.

For future development of VANETs i.e. simulation based development and real time development, inter vehicle communication and intra vehicle communication will face certain challenges that described in TABLE IV.

III. CONGESTION CONTROL ALGORITHM DESIGN CRITERIA

The foundation challenges in designing for congestion control algorithm can be adopted from the process proposed by authors in [6]. Some modification has been suggested by author in carrying out this research. As illustrated in the flowchart of Figure 4, the congestion control algorithm process can be break into measurement-based detection and queue freezing techniques in which case to monitor all the data go through the SCH channel.

The researchers in [7] proposed the novel VMESH MAC protocol for enhancing the performance of non-safety applications in vehicular environments based on the WAVE infrastructure. The proposed MAC protocol generates a distributed beaconing scheme and a reservation based channel access (DRP) on SCH to increase the channel access efficiency. They also investigated the performance of the VMESH MAC protocol in more realistic scenarios with stochastic simulations and more realistic mobility, channel and traffic models.

The literature in [8] introduced CRaSCH, a cooperative scheme in 802.11p/WAVE-based vehicular networks in for service channels reservation. The proposed scheme targets vehicle-to-infrastructure and vehicle-to-vehicle communications, in which nodes, either roadside or on-board units, and acting as WAVE providers choose a service channel for their initialized WBSS.

CRaSCH (Cooperative Reservation of SCH), a gossip-based reservation mechanism that relies on cooperation among nearby providers. Specifically, they proposed two approaches:

a. Proactive Gossiping: every provider advertises its own SCH and SCHs are reserved by nearby users or providers
b. Reactive Gossiping: every provider spreads out the perceived SCH status information to nearby users or providers

Furthermore, research efforts are required to investigate the additional countermeasures taken by providers or users to protect data transmissions in the SCH interval against collisions due to the hidden nodes.

The authors in [9] have considered a set of simple and easy-to-deploy data rate adaptation policies that rely on position information during the SCH interval in order to select the data rate for packet transmission. As a future work, the researchers plan to enhance the proposed solution to work in urban scenarios in which time-varying multipath channel conditions and higher vehicle density could affect performance. Moreover, the researchers have enhanced the solution with functionalities that are already partially available in the literature, to differentiate the causes of frame losses and failures due to collisions from failures caused by channel errors/weak signals, in order to avoid performance degradation due to rate under selection when the link conditions are good and not saturated.

The work in [10] studies a novel MAC and SCH allocation scheme to guarantee the QoS of non-safety services and the reliability of safety services in the RSU-assisted VANETs. We anticipate vehicle density for improving the non-safety service time. Accordingly, in Figure 4 explained the research methodology accomplished by previous scholars on SCH. The studies shown the improved in QoS performance for non-safety services by applying a MAC dedicated multi-channel allocation scheme based on channel throughput analysis for centralized RSU in VANETs.

ISBN: 978-988-19253-7-4
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

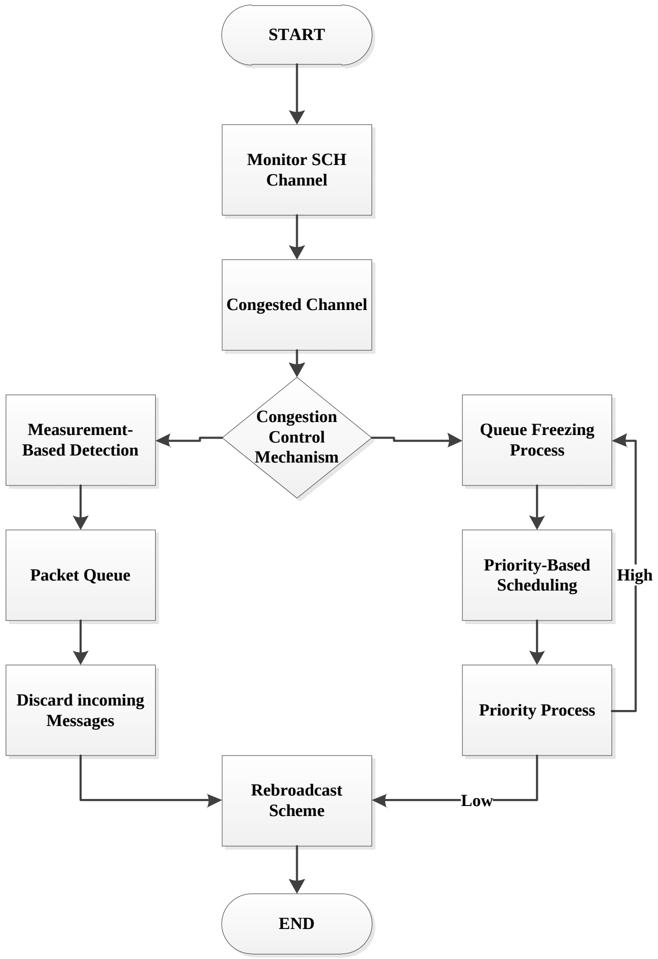

Fig. 3. VANETs flow chart algorithm derived from[6]

A recent work in [11] have addressed a variable CCH interval (VCI) multichannel medium access control (MAC) scheme, in which can adjust the length ratio between the CCH and SCHs. In addition, the scheme introduces a multichannel coordination mechanism to provide contention-free access of SCHs. Markov modeling is applied in optimizing the intervals range based on the traffic condition. The proposed scheme shown in IEEE 1609.4 MAC significantly enhanced the throughput of SCHs and reduced the transmission delay of the service packets.

The proposed taxonomy in Table V was derived from the characteristic of congestion control algorithms and functionality of each algorithm in VANETs. The researchers in [12] concluded a proactive algorithm, was one of the best congestion control algorithm for VANETs which used transmission power and packet generation rate control at the same time, based on dynamic carrier sense threshold thus differentiate the priorities of the packets types.

The literature in [13] studies the use of multiple channels in vehicular networks. The analysis commences with the design challenges unique to the vehicular environment that need to be addressed in order to make decisions concerning the adoption, adaptation, and improvement of the multichannel architecture proposed by the standardization bodies. Provisioning the safety-critical and commercial services on the road are crucial to vehicular ad hoc networks. Multiple channels are assigned in the 5 GHz spectrum to support these services.

TABLE V. SUMMARY OF VANETS CONGESTION CONTROL TECHNIQUES[12]

Class	Approach	Packet rate	Utility function	Power control	Access priority	Carrier sense	Smart rebroadcast
Proactive	Vehicle-To-Vehicle for Cooperative Collision Warning	Y	N	N	N	N	N
	Utility-Based Packet Forwarding and Congestion Control	N	Y	N	Y	N	N
	Dynamic Priority-Based Scheduling	N	Y	Y	N	N	N
	Cross-layer Congestion Control	N	N	Y	Y	N	Y
	Broadcast Reception Rates and Effects of Priority Access	N	N	Y	Y	N	N
	Application-Based Congestion Control	Y	N	Y	N	N	N
	D-FPAV - a fully distributed and localized algorithm	N	N	Y	Y	Y	N
Reactive	Power or Rate based Congestion Control	Y	N	Y	N	Y	N
Hybrid	Power & Rate combined Congestion Control	Y	N	Y	N	Y	N
	Concepts and Framework for Congestion Control	N	N	N	N	N	Y
	Adaptive Inter-vehicle Communication Control	Y	N	Y	N	N	N

Y = Yes N = No

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In [14], through the dynamic service-channels allocation (DSCA) method, the throughput could be maximized assigning different service channels to the users. The solution for multiple service-channels assignment is based on some vehicular environments variables that include BERs, access categories and traffic and road conditions applying a single transceiver. The realistic parameters have been used from CISCO traffic analysis in NS-3 simulation. The average throughput is extensively evaluated under various channel conditions and vehicle densities. However, non-safety applications can affect the network efficiency by exchanging traffic information using four different access categories as mentioned earlier.

A recent contribution in [15] proposed the enhanced multi-channel MAC for VANETs, where exchange of non-safety messages is possible during CCH and SCH interval. The simulation result done by this researcher has shown that the VEMMAC protocol outperforms the IEEE 1609.4 in terms of aggregate throughput and average delay.

IV. CONCLUSION AND FUTURE WORKS

In this paper we have presented a literature survey on congestion control of VANETs. The research contributions that we have reviewed in this paper exhibit the potential and limitations of congestion control implemented in service control channel (SCH) for vehicular ad hoc networks. We first compared each of IEEE standards. Then we investigated technologies and methods realized by various researchers and proposed a framework for congestion control for SCH applications mainly for non-safety applications. The congestion control approach is one of the solid solutions to minimize the congestion in wireless communications channel. We have highlighted the algorithm for the non-safety messages queues and mechanism to monitor the channel communications based on defined threshold.

In VANETs communication each vehicles share messages in term of road status, speed of the vehicles, location status and many variables. In higly dense traffic the IEEE standard should anticipate the large amount of data at a time for different vehicles and RSUs. In a distributed network environment we cannot foresee the distance for both V2V and V2I thus the communication range at sparse environments and should increase up to the maximum range.

Based on the above discussion WiMAX cannot support greater communcation range and high data rate at a time for the non-safety applications in VANET environments. IEEE 802.11p standard supports most of the requirement of non-safety applications in VANET i.e. communication range, data rate and it has free lisenced frequency band thus we can applied this wireless standard at VANET simulation time environment.

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