# Wireless Access Network Final Project Vehicular Communication Systems

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***Abstract*—Along with the development of wireless communication in modern life, the vehicle to vehicle(V2V) communication has appeared with various application for better road safety and traffic efficiency. New standards like IEEE 802.11p, IEEE 1609.4, DSRC, WAVE and VANET focus on this topic with various improvements or enhancements. In this paper, we analyze the performance of 802.11p standards with the prevalent NS3 simulator to see how the mechanism like Qos feature, or the traffic pattern like packet size effect the performance, which is measure by throughput or average time delay here. Besides, we layout a simple traffic scenario to simulation a real life traffic roads. As a result, we can better understand how 802.11p works and why some configuration matters.**

## I. Introduction

Vehicular communication systems are a type of network in which vehicles and roadside units are the communicating nodes, providing each other with information, such as safety warnings and traffic information. As a cooperative approach, vehicular communication systems can be more effective in avoiding accidents and traffic congestions than if each vehicle tries to solve these problems individually [1].

Generally, vehicular networks are considered to contain two types of nodes: vehicles and roadside stations. Both are dedicated short-range communications (DSRC) devices. DSRC works in 5.9 GHz band with bandwidth of 75 MHz and approximate range of 1000 m as shown in Fig 1. The network should support both private data communications and public (mainly safety) communications but higher priority is given to public communications.

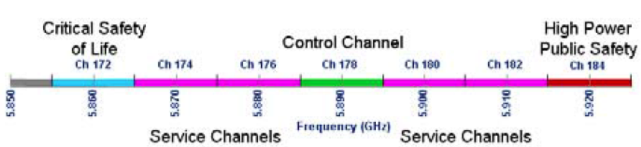


Fig. 1. DSRC spectrum and channels in the U.S.

Two categories of draft standards provide outlines for vehicular networks. These standards constitute a category of IEEE standards for a special mode of operation of IEEE 802.11 for vehicular networks called Wireless Access in Vehicular Environments (WAVE). 802.11p is an extension to 802.11 Wireless LAN medium access layer (MAC) and physical layer (PHY) specification, and it aims to provide specifications needed for MAC and PHY layers for specific needs of vehicular networks. On the other hand, IEEE 1609 is a family of standards which deals with issues such as management and security of the network as shown in Fig. 2 1609.1 focuses on Resource Manager, it provides a resource manager for WAVE, allowing communication between remote applications and vehicles, 1609.2 focuses on Security Services for Applications and Management Messages, 1609.3 foucuses on Networking Services, this standard addresses network layer issues in WAVE, and 1609.4 talks bout Multi-channel Operation, aims to deals with communications through multiple channels.

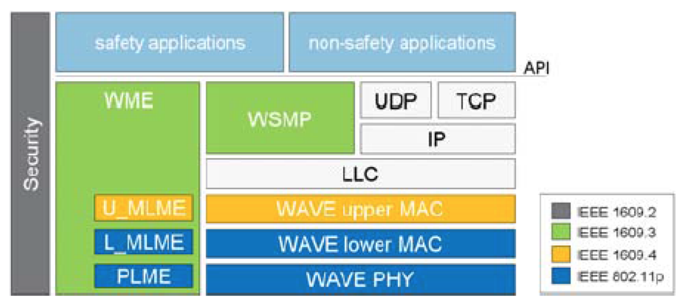


Fig. 2. DSRC standards and communication stack

There is a control channel (CCH), which is the default channel for common safety communications. The two channels at the ends of the spectrum band are reserved for special uses. The rest are service channels (SCH) available for both safety and non-safety use. Advertisement messages broadcast over the CCH to provide information on which services are currently available on which service channels, so that radios can tune to a service channel if desired.

Time here is divided into alternating Control Channel (CCH) and Service Channel (SCH) intervals both 50ms long as shown in Fig. 3, each pair forms a Sync interval, and the start of a CCH interval is aligned with the start of a Coordinated Universal Time (UTC) second or multiples of 100ms thereafter.

A DSRC onboard unit tunes to the CCH to send and receive safety messages continuously, and the DSRC radio is used for safety communications during CCH intervals and used for other applications during SCH intervals. Each DSRC radio,

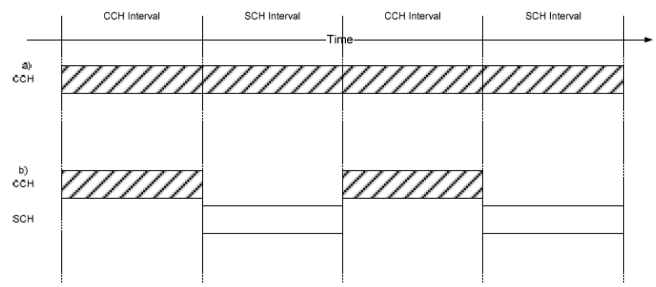


Fig. 3. Channel intervals and continuous/alternating channel access

even if in continuous access on the CCH, is expected to track the start and end of CCH and SCH intervals at all times.

It also defines a Guard interval at the start of each channel interval as shown in Fig. 4, which is meant to account for radio switching and timing inaccuracies among different devices. so the Guard interval is defined as the sum of the SyncTolerance and MaxChannelSwitchTime parameters. SyncTolerance describes the expected precision of a devices internal clock in aligning to the UTC time. MaxChannelSwitchTime is the time overhead for a radio tobe tuned to and made available in another channel.

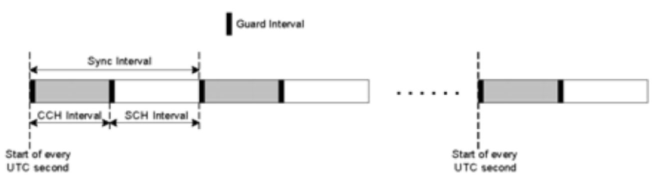


Fig. 4. CCH, SCH, Guard and Sync intervals

Due to the common unreliability of 802.11 DCF mechanism, more and more seek to find a alternative method to replace or offload the vehicle information traffic when necessary. The the author [2] argue the possibility of LTE in VANET. Its known that 802.11p has drawbacks such as scalability issues, unbounded delay, no deterministic quality of service (QoS) guarantees, limited radio range lack of pervasive roadside communication infrastructure thus results in only offering intermittent and short-lived V2I connectivity, while LTE performance a much better service that particularly fits the high-bandwidth demands and QoS-sensitive requirements of a category of vehicular applications, as shown in Fig. 5.

As shown in Fig. 6, there are two kinds of messages in vehicle communication with different requirements.

CAMs (a.k.a. beacons or heartbeat messages) are short messages periodically broadcast from each vehicle to its neighbors to provide information of presence, position, kinematics, and basic status. DENMs are event-triggered short messages broadcast to alert road users of a hazardous event. Both CAM and DENM messages are delivered to vehicles in a particular geographic region: the immediate neighborhood (awareness range) for CAMs, and the area (relevance area) potentially affected by the notified event (congestion, hazard warning, etc.)

| Feature | Wi-Fi | 802.11p | UMTS | LTE | LTE-A |
|---|---|---|---|---|---|
| Channel width | 20 MHz | 10 MHz | 5 MHz | 1.4, 3, 5, 10, 15, 20 MHz | Up to 100 MHz |
| Frequency band(s) | 2.4 GHz, 5.2 GHz | 5.86–5.92 GHz | 700–2600 MHz | 700–2690 MHz | 450 MHz–4.99 GHz |
| Bit rate | 6-54 Mb/s | 3–27 Mb/s | 2 Mb/s | Up to 300 Mb/s | Up to 1 Gb/s |
| Range | Up to 100 m | Up to 1 km | Up to 10 km | Up to 30 km | Up to 30 km |
| Capacity | Medium | Medium | Low | High | Very High |
| Coverage | Intermittent | Intermittent | Ubiquitous | Ubiquitous | Ubiquitous |
| Mobility support | Low | Medium | High | Very high (up to 350 km/h) | Very high (up to 350 km/h) |
| QoS support | Enhanced Distributed Channel Access (EDCA) | Enhanced Distributed Channel Access (EDCA) | QoS classes and bearer selection | QCI and bearer selection | QCI and bearer selection |
| Broadcast/multicast support | Native broadcast | Native broadcast | Through MBMS | Through eMBMS | Through eMBMS |
| V2I support | Yes | Yes | Yes | Yes | Yes |
| V2V support | Native (ad hoc) | Native (ad hoc) | No | No | Potentially, through D2D |
| Market penetration | High | Low | High | Potentially high | Potentially high |

Fig. 5. Main candidate wireless technologies for on-the-road communications

| | | |
|---|---|---|
| **Cooperative awareness message (CAM)** | **Periodic time-triggered position messages**<br>–Frequency: 1–10 Hz<br>–Max latency: 100 ms<br>–Length: up to 800 bytes (security overhead included) depending on the type of application | **Use cases**<br>–Emergency vehicle warning<br>–Slow vehicle indication<br>–Intersection collision warning<br>–Motorcycle approaching indication<br>–Collision risk warning<br>–Speed limits notification<br>–Traffic light optimal speed advisory |
| **Decentralized environmental notification message (DENM)** | **Event-driven hazard warnings**<br>–Max latency: 100 ms<br>–Length: typically shorter than CAMs | **Use cases:**<br>–Emergency electronic brake light<br>–Wrong way driving warning<br>–Stationary vehicle accident<br>–Stationary vehicle-vehicle problem<br>–Traffic condition warning<br>–Signal violation warning<br>–Road-work warning<br>–Collision risk warning<br>–Hazardous location<br>–Precipitation, wind<br>–Road adhesion<br>–Visibility |

Fig. 6. Safety message requirements and use cases

Besides, there are some more open issues like Coverage and mobility, Market penetration, Capacity, Centralized architecture, Channels and transport modes, Status mode of the device left to be solve We organize the paper as followed, firstly we layout a scenario to set up the roads and vehicles traffic pattern we need and define the vehicles communication behavior, then we analyze the effect of different Qos mechanism or communication configuration like package size to the overall performance, finally we sum up our thinking in conclusion part.

## II. Related Work

Simulation of Urban MObility (SUMO) is a traffic simulator which can help us simulate the traffic in our map and we can use come tools to modify its output format so that we can get the cars roads and lanes information. Moreover, we make the NS-3 can process roads and lanes information.

Early, we build a SUMO scenario as the Fig. 7 shown and we want to import it into the NS-3. However, we encounter a problem while we want to send packets to some nodes which are not exist on the NS-3 map so that the error will come up. The error reason is that we need to set total the numbers of nodes and net devices in the simulation, however, the vehicles routes and time are setting so we will encounter troubles that the destinations of net devices which the vehicles are finishing their routes and not exist in the NS-3 map that means no location information can be gotten. We set the nodes by *MobilityHelper* in NS-3 instaed of SUMO. Adn we want to simulate the vehicle traffic as that in SUMO so we construct a model which vehicle spacing is 40 meters and uniformly distribute over the map as the SUMO. Channel model in the simulation, we refer to two channel models for LOS and NLOS as the following shown.

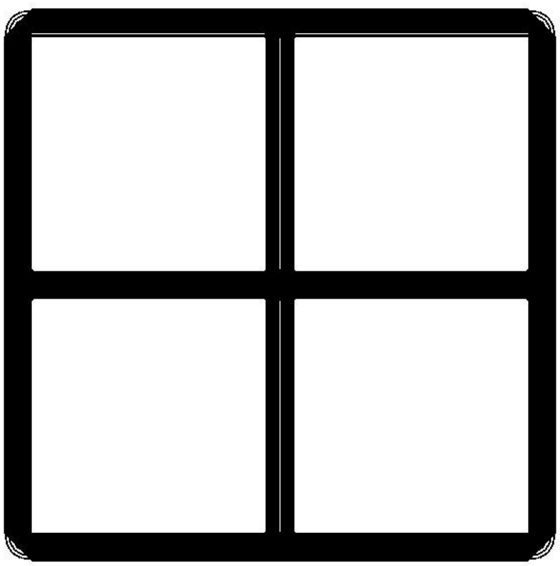

Fig. 7. The SUMO scenario

### A. LOS Propagation Model

We can distinguish the relation between two cars with the roads and lanes information. When cars are on the same road, we set the propagation loss models among the transmitter and receivers as:

$$PL(d) = PL_0 + 10nlog_{10}(\frac{d}{d_0}) + X_{\sigma_2} + \zeta PL_c, d > d_0, \quad (1)$$

where $PL$ is the path loss, $PL_0$ is the path loss at reference distance (dB), $n$ is the path loss exponent, $d$ is the propagation (Tx-Rx) distance, $d_0$ is the reference distance (m), $X_{\sigma_2}$ is a zero-mean normally distributed random variable with standard deviation $\sigma_2$, $PL_c$ is a correction term that accounts for the offset between forward and reverse path loss, and $\zeta$ is defined as:

$$\zeta = \begin{cases} 1, & \text{for reverse path loss} \\ -1, & \text{for forward path loss} \\ 0, & \text{for convoy path loss.} \end{cases}$$

### B. NLOS Propagation Model

Conversely, when cars are not on the same road, we set the propagation loss models as:

$$PL(d) = PL_0 + 10nlog_{10}(\frac{d}{d_0}),$$

where the parameters as the above description. Unfortunately, both the channel models lead to the delay cant accepted by the NS-3 determining conditions so we adopt the default channel model in our simulation.

We use the LOS propagation model to simulate the urban area, and the parameters are shown in the following:

TABLE I
LOS PROPAGATION MODEL

| Parameter | Value |
|---|---|
| $PL_0$ | 62 |
| $n$ | 1.68 |
| $d_0$ | 10 |
| $\sigma_2$ | 1.7 |
| $PL_c$ | 1.5 |

Also, we simulate the same situation with the NLOS propagation model, and the parameters are shown in the following:

TABLE II
NLOS PROPAGATION MODEL

| Parameter | Value |
|---|---|
| $PL_0$ | 47.8649 |
| $n$ | 2 |
| $d_0$ | 1 |

## III. SCENARIO OF NS-3 MODEL

We consider the video streaming in the vehicle-to-vehicle system so that we set 544 nodes uniformly distribute in our simulation on the map as the Fig. 7 shown and consider different channel model which are LOS and NLOS refer to different distances. Generally, the vehicles at different roads have much larger distances and we set the transmitting radius of 100 meters. Moreover, the data rates set at 2.8Mbps and 6.22Mbps that are refer to video resolution at 1920*1080 and 1280*720 both at 30 frames per second(FPS).

## IV. SIMULATION

In this project, we refer to two example files in the NS-3 which are *wave-simple-device.cc* and *wave-simple-80211p.cc*. Firstly, we adopted the two different *MacHelper* which are *QosWaveMacHelper* and *NqosWaveMacHelper*, we set different *PhyHelper* and *Wifi80211pHelper* for NQoS and *WaveHelper* for QoS. We adapt the NqoS and QoS for our simulation successfully and have not enough time to debug for adapting Sch and Vsa in QoS. The results in different data rates as the Fig. 8 and Fig. 9 shown, we can compare data rate at 2.8Mbps with 6.22Mbps, it is more alleviative that the data rate is more less than physical layer supporting rate compares with 6.22Mbps more higher than physical rate. To explain that the concussions in average delay, we think that short length of packets directly transmit is more efficiently in Nqos than QoS, however, the results are not exist consistency because we only consider the receiving packets and ignore the lost packets so we may get the lower average delay but higher lost ratio which the phenomenon in the figure will be interpreted.

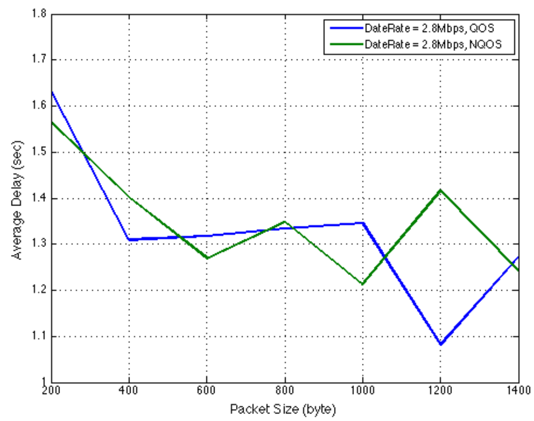


Fig. 8. Packet size to average delay at data rate = 2.8Mbps

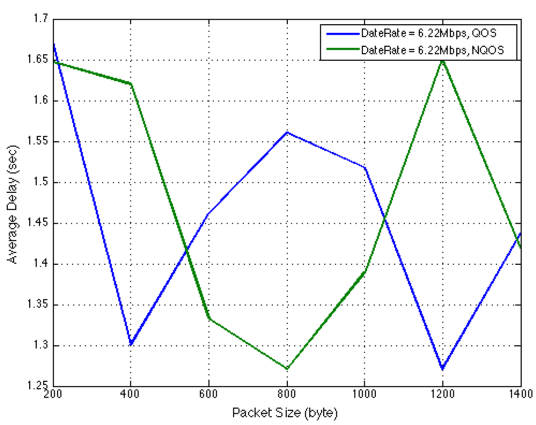


Fig. 9. Packet size to average delay at data rate = 6.22Mbps

## V. Conclusion

As the above description, we spend many times debugging the codes. And we have found some solutions to our problems. Though the code in NS-3 and simulation result are not good as our expectation, we learn a lot when we trial and error and survey on the related paper. There are many interesting idea such as difference between Markov chain model in the VANET and the model in the class. In the end, we have direction of the SCH and VSA frames in QoS part so that it can help us for future research.

## References

[1] Q. Chen, D. Jiang, and L. Delgrossi, “Ieee 1609.4 dsrc multi-channel operations and its implications on vehicle safety communications,” in *Vehicular Networking Conference (VNC), 2009 IEEE*. IEEE, 2009, pp. 1–8.

[2] G. Araniti, C. Campolo, M. Condoluci, A. Iera, and A. Molinaro, “LTE for vehicular networking: a survey,” *Communications Magazine, IEEE*, vol. 51, no. 5, pp. 148–157, 2013.