MOKSLAS – LIETUVOS ATEITIS
SCIENCE – FUTURE OF LITHUANIA

2010, 2 tomas, Nr. 1
2010, Vol. 2, No 1

Elektronika ir elektrotechnika
Electronics and electrical engineering

Telecommunication Engineering T 180

INTERVEHICLE COMMUNICATION RESEARCH – COMMUNICATION SCENARIOS

Šarūnas Stanaitis
Vilnius Gediminas technical university
E-mail: sarunas.stanaitis@gmail.com

Abstract. Recently intervehicle communications are attracting much attention from industry and academia. Upcoming standard for intervehicle communication IEEE 802.11p, known as Wireless Access in Vehicular Environments (WAVE), is still in its draft stage, but already coming into final standardization phase. Problematic, regarding mobile WAVE nodes, are described in several articles, simulations prepared and experiments done. But most of these works do not consider possible maximal communication load. This paper presents intervehicle communication scenario in respect to radio communications, mobility and other aspects of vehicular environments.

Keywords: WAVE, IEEE 802.11p, intervehicle communication scenario, vehicle to vehicle.

Introduction

Each year in Europe and all over the world millions of people die or are seriously injured during car accidents. Most of the accidents happen because of human factor and majority of these accidents can be avoided knowing in advance about dangerous objects on the path, nearby cars, or prepare for unavoidable accidents optimizing usage of actuators such as air bags, motorized seat belt pre-tensioners and extendable bumpers.

Traffic jams are one of the biggest problems in medium and big cities. If traffic management organizations could get detailed information about vehicles and their destinations it would be possible to better manage the traffic in the cities and to advice each driver which path is better to take to get faster to the destination. Also it is very important for special transport, like police, ambulance, etc., to come to their destinations as soon as possible having green light tunnel in the city.

To reduce car accidents and to increase traffic efficiency intervehicle communication – Wireless Access in Vehicular Environments (WAVE) is presented. Recently topics from WAVE field are getting much attention from industry and academia. The base for WAVE is draft standard IEEE P802.11p/D5.0 (2008), which together with a set of IEEE standards 1609.1/2/3/4 (IEEE Std. 1609.1-2006; IEEE Std. 1609.2-2006; IEEE Std. 1609.3-2007; IEEE Std. 1609.4-2006) describes intervehicle communication. IEEE 802.11p differs from 802.11a/b/g, because it is intended for highly mobile vehicular environments with fast moving nodes. Communication mode is also different from usual Wi-Fi. In IEEE 802.11p are defined not just different radio channels, but there is also time division into two time channel slots: control channel and service channel. Synchronization of control channel and service channel is done using GPS receiver's universal time clock signals.

Most of WAVE experiments and simulation are using simple scenarios, not considering real life situation. But to correctly interpret simulation results, quantity of communication nodes, speed and communication obstacles should be estimated. This paper presents WAVE communication scenario, which can be used as reference for simulations and experiments. It shows vehicle count in one hop for 500 m and 1000 m communication range and distribution of the vehicle count in respect to different velocities.

Related work

Highway scenario is given in (Bilstrup *et al.* 2008) and more in detail described in (Bilstrup *et al.* 2009). Here highway has 5 lines in each direction. The vehicles are entering each lane of the highway according to the Poisson process with a mean interarrival time of 3 s (the 3 s are chosen in accordance with the Swedish 3-second rule, where vehicles should maintain a 3 s space to the vehicle in front). Car speed is different for all lanes and is the value of the Gaussian random variable with mean values of 23 m/s (~83 km/h), 30 m/s (~108 km/h) and 37 m/s (~133 km/h) and a standard deviation of 1 m/s. Communication range of one hop is 500 m and 1000 m. Given highway scenario describes the real life situation very accurately, but is not always applicable, because of fast changing number of vehicles in one hop.

Several communication scenarios are used in experiment, described in (Jerbi *et al*. 2008). Though described experiments are done using real cars and IEEE 802.11b communication equipment, they are not presenting real life simulation, because maximum of six cars are used.

Stibor *et al*. (2007) chooses highway scenario with two lanes in each direction with 40 vehicles – relative speed between 60 km/h and 180 km/h. This scenario represents just one possible highway condition, and there is no reasonable explanation of chosen scenario values.

Intervehicle communication scenarios

Communication scenarios are briefly described in (Car-to-Car Communication Consortium 2007). This chapter gives a short overview of the possible use cases according to C2C-CC manifest.

There are three use cases for intervehicle communication distinguished:

- Safety.
- Traffic efficiency.
- Infotainment and others.

All use cases are shown in Fig. 1.

Safety. Safety use cases are such, where the safety of the cars is increased entering safety zone. There are three safety use cases defined:

- *Cooperative forward collision warning* – provides assistance to the driver primarily to avoid rear-end collisions with other vehicles.
- *Pre-crash sensing/warning* – here, the assumption is, that a crash is unavoidable and will take place and this information can be used to prepare the car for the impact.
- *Hazardous location vehicle to vehicle notification* – utilizes the network of vehicles to share information that relates to dangerous locations on the roadway, as for instance slippery roadways or potholes.

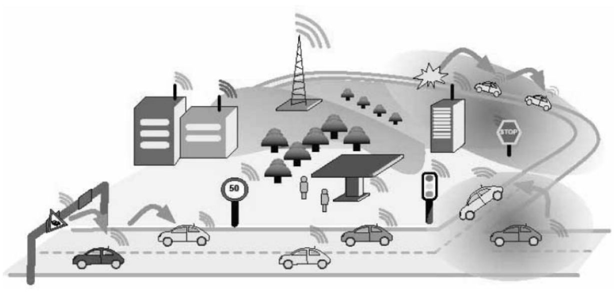

Fig. 1. Communication scenarios (Car-to-Car Communication Consortium 2007)

Traffic efficiency. These uses cases are meant to increase traffic performance by providing information to the owners of the transportation network or to the drivers in the network. Traffic efficiency cases are following:

- Enhanced route guidance and navigation – uses information collected by an infrastructure owner to deliver route guidance information to a driver.
- Green light optimal speed advisory – provides information to the driver in an effort to make their driving smoother and avoid stopping.
- vehicle to vehicle merging assistance – allows merging vehicles to join flowing traffic without disrupting the flow of the traffic.

Infotainment and others. These cases should include all other communication cases, which are not directly related to traffic safety or traffic efficiency. Infotainments can be:

- *Internet access in vehicle* – allows a connection to the Internet.
- *Point of interest notification* – allows local businesses, tourist attractions, or other points of interest to advertise their availability to nearby vehicles.
- *Remote diagnostics* – allows a service station to assess the state of a vehicle without making a physical connection to the vehicle.

Each of these use cases has different requirements to the communication system.

Intervehicle system architecture

Intervehicle communication architecture, shown in Fig. 2, consists of three domains:

- *In-vehicle domain* has on board unit (OBU) and application unit (AU) domains. OBU communicates with other cars and infra-structure. AU is a device, which executes applications and uses OBU for communicating.
- *Ad hoc domain* or vehicular ad hoc network (VANET), consists of vehicles equipped with OBUs and road side units (RSU). RSU increases the coverage of VANET and connects OBU with infrastructure.
- *Infra-structure domain* builds VANET independent internet access. It can use hot spot (HS) or other radio network types (GSM, GPRS, UMTS, HSDPA, WiMax, 4G) to access internet.

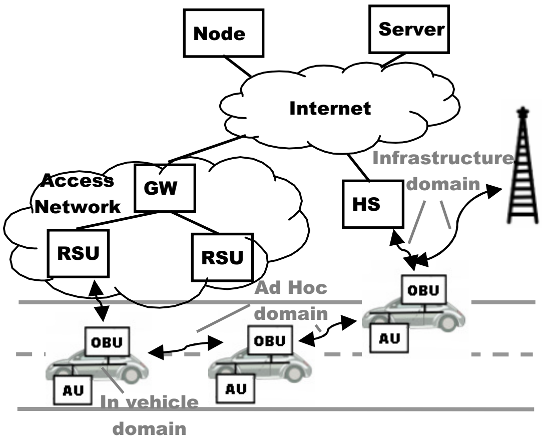

Fig. 2. Intervehicle system communication architecture

Communication scenario conditions

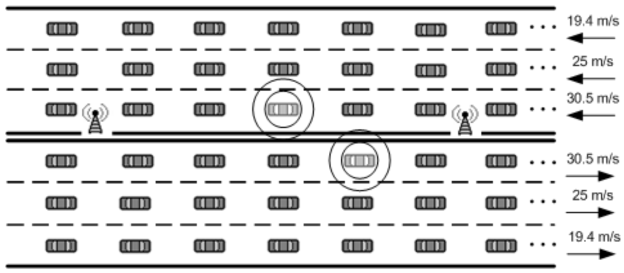

Fig. 3. Highway scenario with 3 lines in each direction

For intervehicle communication scenario several values are important. These are number of nodes (cars), velocity of the nodes, communication range of one hop, transferred packet size, data rate, etc.

Distance between vehicles. According to the Lithuanian recommendations to the drivers, recommended distance from the front car is same in meters as half of the cars speed in km/h:

$$d \approx \frac{v}{2}, \tag{1}$$

here: d, m – distance between vehicle centers (though recommendation sais, that distance should be between end and front of two cars, but it is more reasonable to take distance between centers, because of different length of the cars); v, km/h – velocity of the car.

Communication range. According to the requirements of (Car-to-Car Communication Consortium 2007) communication range r should be between 300 m and 1000 m. (Bilstrup *et al.* 2008, 2009) are spreading simulation into two parts for 500 m and for 1000 m communication range. In this paper both 500 m and 1000 m communication ranges are used.

Velocity. As shown in Fig. 3, vehicle velocity v is different in different lanes. Usually vehicles in the middle lanes are moving faster than in the outer lanes. The cars in Fig. 3 are traveling in three lanes in each direction with velocities 19.4 m/s (70 km/h), 25 m/s (90 km/h) and 30.5 m/s (110 km/h). These values are used for three lanes in each direction highway calculation. For five lanes highway following velocities are used: 19.4 m/s (70 km/h), 25 m/s (90 km/h), 30.5 m/s (110 km/h), 36.1 m/s (130 km/h) and 41.6 m/s (150 km/h).

Vehicle count. Vehicle count in one lane is calculated using following formula:

$$n = \frac{2 \cdot r}{d} \approx \frac{4 \cdot r}{v}, \tag{2}$$

here: n – vehicle count.

Vehicle count, calculated using (2), for three and five lanes highway given in Table 1.

Distribution of the vehicle count in different lanes with different velocities is shown in Table 2.

Note, that given vehicle count values are true for one hop, that means, that for the 500 m range this number is in lane length of 500 m, but for this communication range each vehicle can reach 500 m to both sides from itself, so the value of reachable vehicle will be double.

Results in Table 2 can be used for building up the suburban scenario. If communication range is 500 m and vehicle speed in all lanes is 50 km/h and there are two lanes in each direction, then there are 80 vehicles in one hop.

Table 2 can be used also for the city scenario with traffic jam, which means vehicle velocity is 5 km/h, and there are three lanes in each direction there will be 1200 vehicles in one hop.

Table 1. Vehicle count in three and five lanes highway

Range, m / Lanes	500	1000
Three	68	138
Five	98	194

Table 2. Vehicle count distribution in different lanes with different velocities

Range, m / Velocity, km/h	500	1000
5	200	400
20	50	100
50	20	40
70	14	29
90	11	22
110	9	18
130	8	15
150	7	13

Presented highway, sub urban and city scenarios are calculated for perfect communication conditions, which means, that all cars are reachable in one hop. In real world there will be no such case, especially in the city, there many obstacles for the communication exists. But this means, that there will be less communicating nodes in one hop and the communication load will be smaller. So given numbers represent maximal number of communicating nodes and builds up the edge task for communication system to support.

Permissible delay time. The most important task for emergency warning system is to deliver warning messages on time. There can be several warning messages types, but sudden brake or crash in front warning messages have to be delivered soonest. According to the Lithuanian rule to keep distance from front car same as half of the cars speed brings time between vehicles positions 1.8 s. That means that after the crash in 1.8 s the following car should stop. 1.8 s is the average reaction time of the drivers to accidents on the road. Warning messages should deliver destinations faster than 1.8 s (how much faster should be answered by doing investigation on driver reaction to emergency warnings in the car).

Data rate and packet size. Important parameter for modeling is data rate and packet size, which are influencing performance of the communication system. Data rates are defined in IEEE Std. 1609.3-2007 (2007). They are: 3, 4.5, 6, 9, 12, 18, 24, 27, 36, 48 and 54 Mbps. For worst case simulation lowest data rate should be used. Packet length is variable number of octets and can be from 1 to *WsmMaxLength*, which default value is 1400.

Conclusion

1. This paper summarizes the intervehicle communication use cases, which should give clear understanding of what is the intervehicle communication meant for and to help by building up simulation models.

2. Given calculations of the vehicle count in one hop for 500 m and 1000 m can be directly used by simulating highway scenario. Suburban and city scenarios are also mentioned and calculations of the cars in one lane are given, that helps to build up simulations.

3. Number of vehicles in one hop at the same radio conditions is dependent of the vehicle velocity. Choosing the correct vehicle velocity should be noticed by building up the simulations, because it will influence the number of nodes in one hop, which affects communication performance.

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TARPAUTOMOBILINIO RYŠIO TYRIMAS – KOMUNIKACIJOS SCENARIJAI

Š. Stanaitis

Santrauka

Pastaruoju metu ryšys tarp automobilių sulaukia vis didesnio dėmesio iš pramonės ir akademinės bendruomenės. Ruošiamas tarpautomobilinio ryšio standartas IEEE 802.11p, žinomas kaip WAVE, yra dar standartizavimo stadijoje. Mobiliųjų WAVE komunikacijos taškų problemos yra aprašytos keliuose straipsniuose, yra atlikti modeliavimai ir eksperimentai. Dauguma iš šių darbų neatsižvelgia į maksimalią komunikacijos sistemos apkrovą. Šiame straipsnyje išnagrinėti tarpautomobilinio ryšio scenarijai modeliavimams remiantis IEEE 802.11p standartu atsižvelgiant į radijo ryšį, mobilumą ir kitus automobilių aplinkos aspektus.

Reikšminiai žodžiai: WAVE, IEEE 802.11p, tarpautomobilinio ryšio scenarijai.