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Definition and Implementation of a Simulation Model for the Physical Layer and the Radio Channel in Dedicated Short Range Communication Systems

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***Abstract*—**This paper proposes a vehicle-to-vehicle propagation model implemented with SDL. To estimate the channel characteristics for Inter-Vehicle communication, we first define a predicted propagation pathloss between the moving vehicles under three typical scenarios. A Ray-tracing method is used for the simple gamma model performance.

***Keywords*—**Inter-vehicle communication (IVC), propagation model, road traffic, road vicinity, pathloss.

I. Introduction

RECENTLY, many research group have concentrated their work on new generation systems in vehicular environments like DSRC system [4] , the FleetNet project [5], CarNet project [6], etc.. Disseminating warning messages through the vehicular network, providing traffic information services and connecting vehicles to the internet are the main goals of the development of such systems. The most effective method to exchange this information is through inter-vehicle communication (IVC).

Vehicle-to-vehicle communications demonstrate properties of two network types: Peer-to-Peer network and Ad Hoc network. In so-called inter-vehicle communication, vehicles are equipped with computer controlled radio modems allowing them to contact other equipped vehicles in their vicinity. By exchanging information, vehicles build knowledge about the local traffic situation which can improve comfort and safety in driving [3].

Given the mobility of vehicles on the road, the network topology changes constantly so as the received power. This involves that there is a relation between the received power and the environment which surrounds the communicating nodes (road traffic {density of traffic and velocity of vehicles} and road surrounding {urban, sub-urban, rural environment}).

II. Description of Scenarios

Taking the inspiration from the starting points [1] and [2], we defined three typical scenarios under different road types, different traffic density and different vehicular mobility.

A. Scenario 1

We imagine this scenario as a freeway, as depicted in figure1, an open environment with a low traffic density. As only few vehicles are travelling on the highway, vehicles are travelling at high speeds and there is no obstacle between transmitter and receiver.

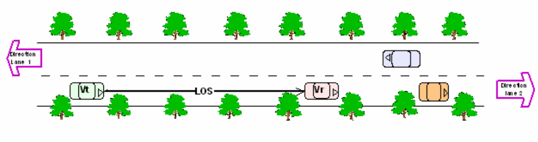

Fig. 1 A freeway with low traffic density

We postulate that the received signal in this scenario is a sum of two components: line-of-sight and ground-reflected (two-ray model). Using the formula of the two-ray from [7], the total received power field P_r is expressed as

$$P_r = P_t.G_r.G_t.(H_t.H_r)^2 / r^4 \tag{1}$$

Thus, the path loss, expressed in dB, is given by the following equation

$$L_p = 40\log r - 10.(\log P_t + \log G_r + \log G_t + 2.\log(H_t.H_r)) \tag{2}$$

Where

H_t and H_r are the heights of transmitter and receiver antenna,

r is the ground distance between transmitter and receiver, and

G_t and G_r are transmitter and receiver antenna power gains.

B. Scenario 2

Unlike in scenario 1, we assume that there is no direct path

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between transmitter and receiver (highway with high traffic density). In this scenario, we propose to calculate the reflected waves on vehicles in beside lanes. The number of reflected paths varies with the number of vehicles which travel between transmitter and receiver (see Fig. 2).

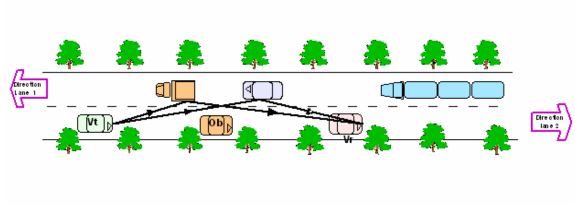

Fig. 2 A highway with high traffic density

So, the corresponding total received power is given as

$$P_r = \frac{A_e}{\eta}\sum_{i=1}^{N}\left|30.P_t.G_r.G_t.\left(\frac{R_v}{d_i}\right)^2\right| \quad (3)$$

Where

A_e is the effective aperture of the receiver antenna (for omnidirectional antenna ($A_e = \dfrac{\lambda}{4\pi}$),

η is the intrinsic impedance of the propagation medium in ohms,

λ is the wavelength ($\lambda = 50.85$ mm for a frequency band of $f = 5.9$ GHz),

N is the number of vehicles,

d_i is the path length of the ith ray,

G_t and G_r are transmitter and receiver antenna power gains, and

R_v is the reflection of beside vehicle coefficient ($R_v = 0.9$ set by [1]).

Refer to (5) of [2], we can calculate the corresponding path gain as

$$L_p = 10.\log\left(\frac{P_r}{P_t}\right) \quad (4)$$

C. Scenario 3

We envision this scenario as a typical street in an urban environment. There are large buildings in the vicinity of the vehicles on one or both sides of the street. For this scenario, we calculate only a reflected ray on the buildings in adjacent to the road as shown in Fig. 3.

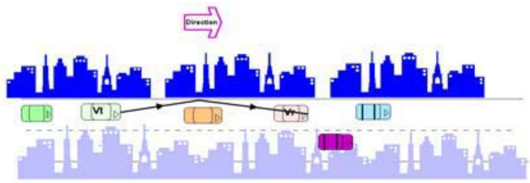

Fig. 3 A Roadway with buildings on the sides

The received signal power for a wall reflected path is given by $P_r = \dfrac{\lambda^2}{16\pi}.\dfrac{P_t.R_w{}^2.G_t.G_r}{d_{wr}{}^2}$ (5)

Where

G_t and G_r are transmitter and receiver antenna power gains,

R_w is the reflection coefficient, and

d_{wr} is the absolute path length.

Finally, using (5) of [2], the path loss is expressed as

$$L_p = 10\log\left(\frac{P_r}{P_t}\right) = 20\log\left(\frac{\lambda R_w}{4\pi d_{wr}}\right) + 10\log G_t G_r \quad (6)$$

III. Simulation Setting

As basis for the simulations, the Medium Access Control (MAC) Layer of the FleetNet system was implemented in SDL. The MAC for the ad-hoc extension of UTRA TDD foresees that the available TDD frame comprising 14 slots is divided into a first part for high priority services and into a second part for on-demand dynamic reservations [9].

Four TDD frames together form a superframe structure and each station is able to reserve one fixed slot per superframe, which is used for the Circuit Switched Broadcast Channel (CSBC). The CSBC is reserved in every following superframe by means of reservation (R)-ALOHA and is basically used for signaling purposes, esp. for reservation of additional capacity by means of in-band signaling. Reserved slots are sensed and will be respected by the neighboring stations.

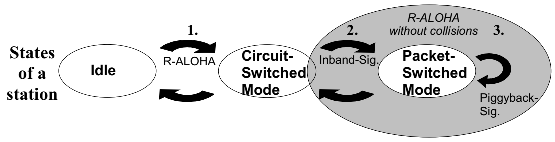

Fig. 4 States of the MAC protocol

TABLE I
SIMULATION CONDITION

Simulation time	30 s
Number of devices	8 and 20
Transmission range	1000 m
Simulation size	1000 m × 20 m
Distribution of the nodes	Uniformly
Rate	0.1 kb/s to 4.5 kb/s
Number of lanes per direction	1
Transmitter power	37 dBm
Data Traffic	Poisson
Packet size	26 bytes

IV. Simulation Results

Several parameters are measured during the simulation like average delay, collision rate, average capacity, total transmitted packets per node, total dropped packets per node, etc.. In this paper, we will be interested only in average delay and collision curves for different path models which are simple_gamma model, two_ray model and inter_vehicle model.

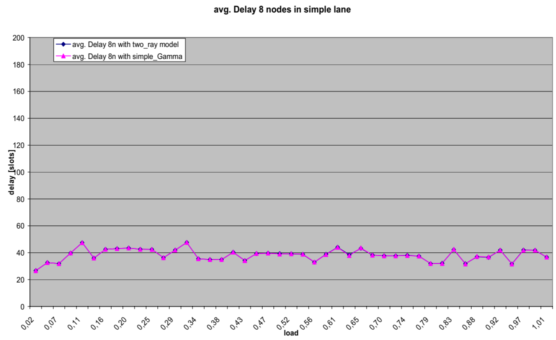

Fig. 5 The average delay in single lane scenario with Simple Gamma path model and two_ray model for 8 nodes

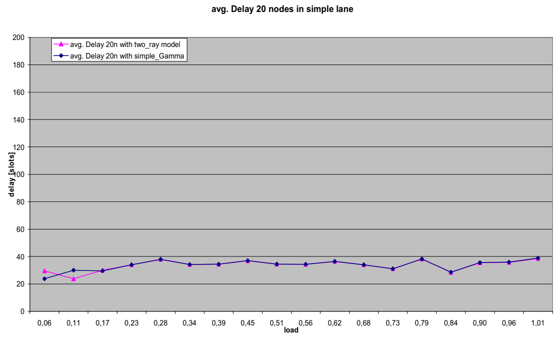

Fig. 6 The average delay in single lane scenario with Simple Gamma path model and two_ray model for 20 nodes

The presented results show some interesting points. First, in all of these average delay curves, we only count successfully transmitted packets. The delay of those packets is nearly constant, that is why the delay curves are almost flat as depicted in figures 5, 6, 7 and 8.

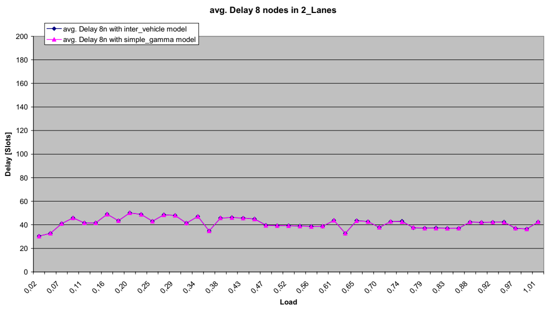

Fig. 7 The average delay in 2_lanes scenario with Simple Gamma path model and inter_vehicle model for 8 nodes

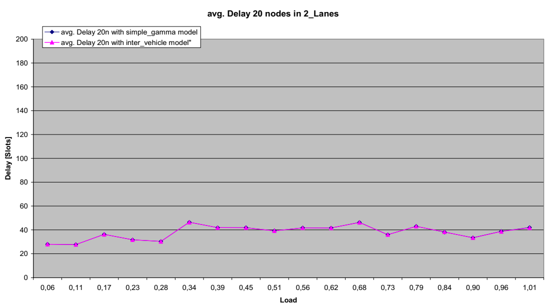

Fig. 8 The average delay in 2_lanes scenario with Simple Gamma path model and inter_vehicle model for 20 nodes

In addition, we note that there is no difference in delay for different path models. This is due to the low number of vehicles, involving a low number of reflected paths. Additionally, with more vehicles uniformly distributed on a road, the distance between vehicles is shorter. That is why the delay is smaller in the case of 20 nodes.

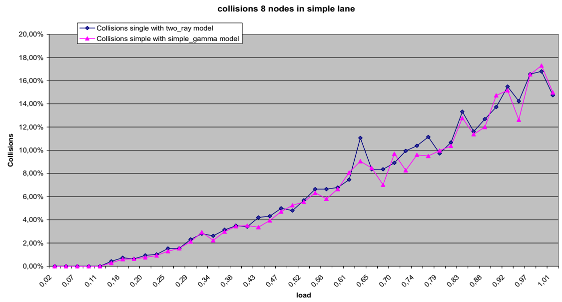

Fig. 9 The collision in single lane scenario with Simple Gamma path model and two_ray model for 8 nodes

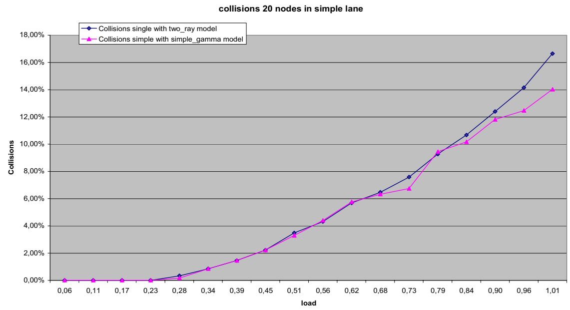

Fig. 10 The collision in single lane scenario with Simple Gamma path model and two_ray model for 20 nodes

On the other hand, we encounter slight differences in number of collisions (cf. figures 9, 10, 11 and 12). These results can be explained as follows. Having a fully meshed network, the MAC layer works collision free (see figures 7 and 8), because all nodes overhear the reservation messages of all other nodes and can respect them. If the simulation area is larger (larger than 1000 m * 1000 m), nodes can not hear reservations of nodes farther away than communication range (these nodes are so-called hidden nodes). Packet collisions can occur, if more than one node is transmitting using the same time slot.

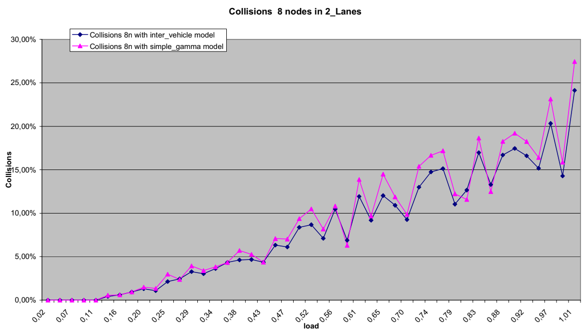

Fig. 11 The collision in 2_lanes scenario with Simple Gamma path model and inter_vehicle model for 8 nodes

To conclude, the different path models have an effect on the collisions, because the effective transmission range changes with the path-model. With a smaller range, less hidden nodes should cause interference. In addition, we show that with fewer vehicles, we have fewer collisions, because fewer vehicles are competing for the available resources.

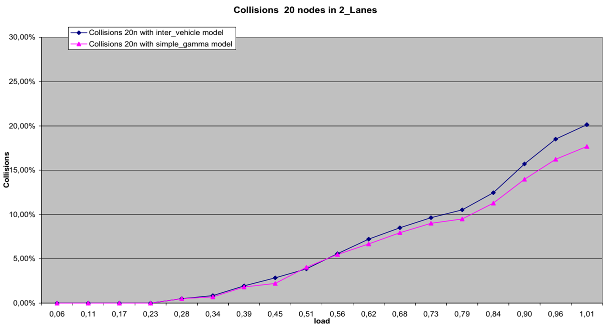

Fig. 12 The collision in 2_lanes scenario with Simple Gamma path model and inter_vehicle model for 20 nodes

V. Conclusion

In this paper, we have proposed a new propagation model for the inter-vehicle communication system based on ray-tracing approach which takes into account all signal paths between transmitter and receiver vehicles. Then, we have defined three basic scenarios for roadways. After simulation run, the simulation results were analysed and compared to the simple gamma model.

In the future, we plan to expand this paper by considering more complex scenarios such as scenarios with vehicles at intersection or in a curved road and taking into account an other propagation phenomena, (diffractions on the edge of roofs or corners of buildings or diffusions on the vegetation or the phenomena of penetration through obstacles such as walls of buildings).

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