Estimation of System Operating Margin for Different Modulation Schemes in Vehicular Ad-Hoc Networks

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***Abstract*— In this paper, system operating margin (SOM) is estimated for vehicular ad-hoc networks in absence and presence of Rayleigh fading. The Ad-hoc IEEE 802.11 model is considered for estimating the signal strength and system operating margin. Rayleigh fading was then simulated and system operating margin are estimated in Rayleigh fading environment for different standard modulation schemes.**

Keyword-Vehicular Ad-hoc network; IEEE 802.11 model; system operating margin; Rayleigh fading; modulation schemes

I. INTRODUCTION

Vehicular communication is the communication in which the information is directly exchanged among the vehicles [1]. Vehicular Ad-hoc Network (VANET) is an off-shoot of Mobile Ad-hoc Network (MANET). Ad-Hoc means a system of network elements that combine to form a network requiring little or no planning for communication between vehicle to vehicle and vehicle to infrastructure. In VANET, vehicles act as transmitter and receiver which are able to send, receive and forward the information at the same time. VANET involves relatively short radio multi hops, low cost antennas deployed in each car and low transmitter power [2]. It has a lot of applications that increase traveller safety, improve traveller mobility, decline travelling time, preserve energy and protect the environment, enlarge transportation system efficiency and boost on-board luxury [3]. In vehicular ad-hoc networks, there is no restriction in communicating with neighbouring vehicles travelling within a specific transmission range. In VANET system multi-hop communication takes place [4]. Ad-hoc networks are beneficial for deploying these networks in the areas where it is not practicable to install the needed infrastructure [5].

A typical VANET scenario is shown below in figure 1. It shows the inter-vehicle communication, vehicle to road side communication and inter road side communication [6].

This type of networks are self-configuring networks having a collection of vehicles and elements of roadside infrastructure connected with each other without requiring an underlying infrastructure, sending and receiving information and warnings about the current traffic situation [7]. VANET integrates on multiple ad-hoc networking technologies for easy, accurate, effective and simple communication between vehicles on dynamic mobility [3]. VANET needs high cost and great effort for its deployment. VANETs would support life-critical safety applications, safety warning applications, electronic toll collection, internet access, automatic parking, roadside service finder, etc. An important property is the absence of infrastructure; connection is there as soon as two or more vehicles are within communication distance. Because no infrastructure is involved, VANETs rely heavily on distributed measures to regulate access to the wireless channel [8].

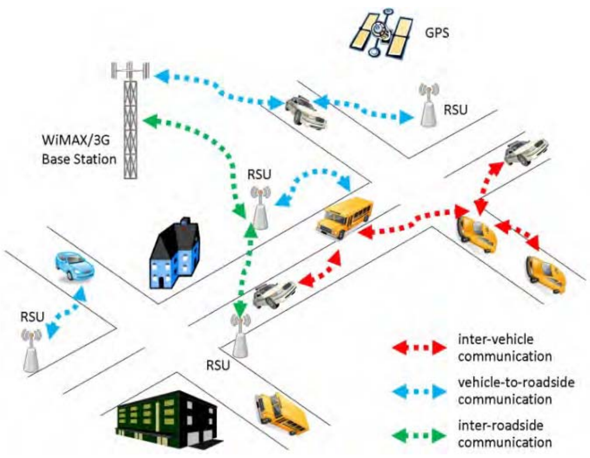

Fig 1. Typical VANET Scenario

II. Signal Strength estimation for VANET

A. *IEEE 802.11 Model for Ad-Hoc Network*

An Ad-Hoc network is classified as decentralized type of wireless network. Due to this the scalability of the network is improved. It does not rely on pre-existing infrastructure such as access points as in managed wireless networks [9]. The path loss equation is quite accurate for mobile wireless local area network system which operates typically with antennas that are between two meters above the ground. Basically this model is the extension to the free space model and can be analyzed as follows [4]. The model can be used for path loss estimation in VANET.

$$P_{loss} = 10*n*\log_{10}(d) + 20*\log_{10}(f) - 20*\log_{10}(h_t\, h_r) \quad (1)$$

where, f is the frequency in GHz, h_t is the transmitter antenna height in meters, h_r is the receiver antenna height, d is the distance and n is the path loss exponent. Equation (1) can also be simplified for free space propagation at 2.4 GHz frequency band.

$$P_{loss} = 7.6 + 20*\log_{10}(d) - 20*\log_{10}(h_t\, h_r) \quad (2)$$

B. *Rayleigh Fading*

Fading is deviation of the signal strength that affects the signal over a certain transmission medium. The fading may vary with time, environmental location or radio frequency. In wireless systems, fading may either be due to multipath propagation, or due to shadowing from obstacles affecting the wave propagation. The presence of reflectors in the environment which are surrounding a transmitter and receiver create multiple paths that a transmitted signal can traverse [10].

Rayleigh fading is caused by multipath reception. The mobile antenna receives a large number of reflected and scattered waves. Rayleigh fading is a geometric model for the effect of a propagation situation on a radio signal. Rayleigh fading is described as a realistic model [9].

Rayleigh fading is a practical model when there are various objects that spread the radio signal in the environment before it comes at the receiver. If there is no dominant component to the scatter, then such a process will have zero mean and phase evenly distributed between 0 and 2π radians. This random variable has a probability density function as follows:

$$P(r) = r / \sigma^2 \exp(-r^2 / 2\sigma^2); \qquad (0 \le r \le \infty) \qquad (3)$$

where, σ is the rms received voltage signal before envelope detection and σ^2 is the time average power of the received signal before envelope detection [5].

To estimate the signal strength in vehicular ad-hoc network using IEEE 802.11 model, the following parameters are considered -

Frequency = 2.450 GHz

Distance = upto 1 Km

Path loss exponent (n) = 2 to 6

Transmitter antenna height = 2 meters

Receiver antenna height = 2 meter

Transmitted power = 15 dBm

Antenna gain = 5 dBi

Cable and connector loss = 1.2 dB

On the basis of these parameters the signal strength is estimated [9] and shown in figure 2.

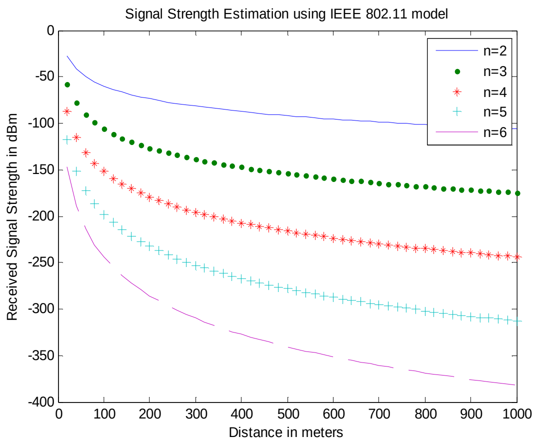

Fig 2. Signal Strength Estimation for VANET

Rayleigh fading was then simulated using MATLAB. The following parameters were considered during simulation –

Number of multipath = 5

Carrier frequency = 2.45 GHz

Sampling frequency = 9.8 GHz

Sampling time = 102.04 microseconds

Average vehicular speed = 40km/hr in Indian scenario

Signal strength was then estimated incorporating Rayleigh fading [9] and shown in figure 3.

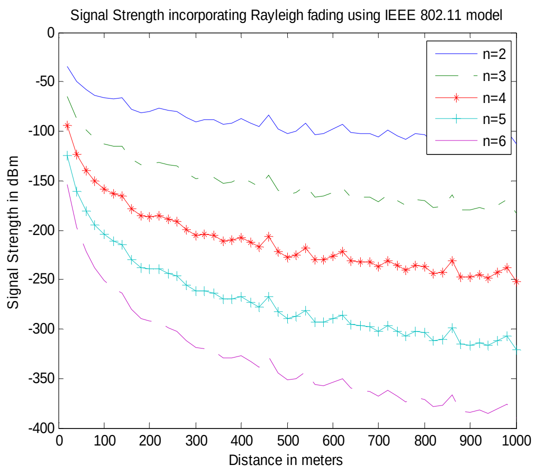

Fig 3. Signal Strength Estimation under Rayleigh fading for VANET

III. Estimation of SOM

On the basis of the signal strength estimated in the last section, SOM is then calculated. System Operating Margin (SOM) is defined as the difference between the received signal level and the receiver sensitivity. SOM is the difference between the signals which a radio actually receives and the signal quality required for adequate data recovery (receiver sensitivity). SOM can be defined as

$$SOM = P_r - S_r \qquad (4)$$

where, P_r is the received power in dBm, S_r is the receiver sensitivity in dBm and SOM is the system operating margin [11].

The System Operating Margin predicts the area of optimal reception between the transmitter and receiver. An ideal System Operating Margin would be 20dBm or more than that for optimum operation. However these values are not always attainable but a value lower than 10dBm is usually considered unacceptable [4].

The data which is modulated into signals and transmitted over the air is defined by a sub-layer of IEEE 802.11. Table 1 lists the specified modulation techniques, their data rates, coding rate and receiver sensitivity. The available data rates range from 3 to 27 MBit/sec.

TABLE I

Data rates, modulations, receiver sensitivity as specified by IEEE 802.11

Data Rate	Modulation	Coding Rate	Sensitivity (dBm)
3	BPSK	½	-85
4.5	BPSK	¾	-84
6	QPSK	½	-82
9	QPSK	¾	-80
12	16-QAM	½	-77
18	16-QAM	¾	-73
24	64-QAM	2/3	-69
27	64-QAM	¾	-68

The most vigorous modulation scheme BPSK has the lowest data rate and lowest coding rate is fixed to be achieved with at least -85 dBm received signal strength. The demand for signal strength increases with increasing data rate. -68 dBm received power is required for 27 MBit/sec data rate [1]. The receiver sensitivity is given for the different modulation schemes namely BPSK, QPSK and QAM for different data rates and coding rate. On increasing the data rate, the receiver sensitivity also increases.

For calculating SOM, path loss exponent (n) is chosen to be 4, considering a suburban area. In figure 4, the variation of system operating margin against distance is shown for BPSK (data rates 3 Mbps and 4.5 Mbps) and QPSK (data rates 6 Mbps and 9 Mbps) modulation schemes without considering Rayleigh fading. Same is shown in figure 5 for 16-QAM (12 Mbps, 18 Mbps) and 64-QAM (24 Mbps, 27 Mbps).

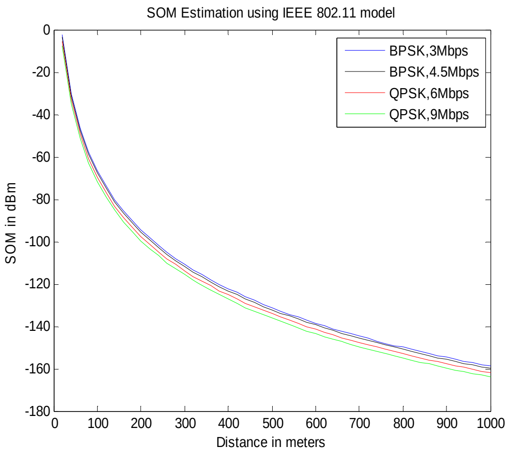

Fig 4. SOM Estimation for VANET

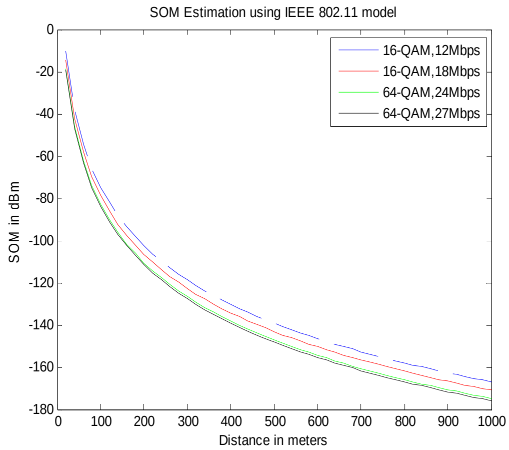

Fig 5. SOM Estimation for VANET

It is seen from figures that highest system operating margin is obtained for 3 Mbps BPSK modulation scheme and the lowest system operating margin is obtained at 27 Mbps 64-QAM modulation technique.

SOM is then calculated considering Rayleigh fading for the same modulation schemes and data rates and plotted in figures 6 and 7. Similar kinds of results are obtained in Rayleigh fading condition also except the fluctuations due to multipath environment.

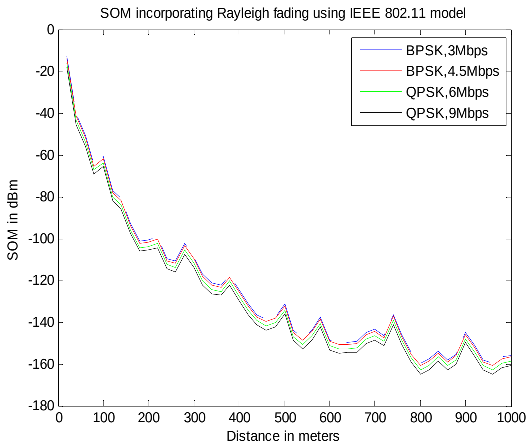

Fig 6. SOM Estimation under Rayleigh Fading Environment

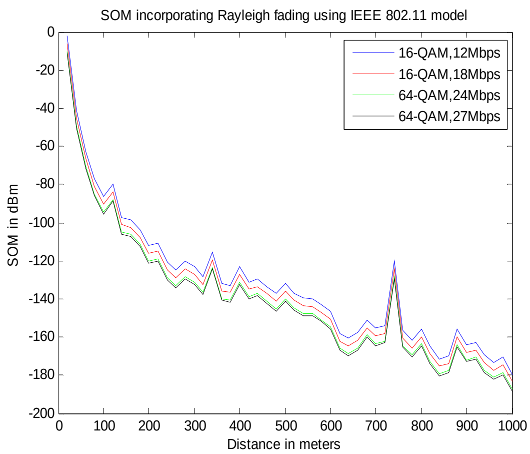

Fig 7. SOM Estimation under Rayleigh Fading Environment

IV. CONCLUSION

The system operating margin is calculated based on the signal strength estimation with and without Rayleigh fading for a typical vehicular ad-hoc network using IEEE 802.11 model. From the estimated results, it may be concluded that the system operating margin decreases with increasing distance. Highest system operating margin is obtained for 3 Mbps BPSK modulation scheme and the lowest system operating margin is obtained at 27 Mbps 64-QAM modulation technique. In Rayleigh fading environment, the SOM show fluctuations. The results will help designing an energy efficient VANET

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