An Overview of V2V Communication Channel Modeling

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ABSTRACT
The principal objective of this work is to show that ubiquitous communication, in a vehicular communication environment, is possible by exploring the existing radio access networks. Proper channel modeling is essential to utilize current network infrastructure. An overview of basic channel propagation models and fading models are presented here. Then vehicle-to-vehicle (V2V) channels are compared with cellular channels. Performance of three existing radio access networks, viz., 3G, WLAN and WiMax , in V2V communication environment is evaluated through simulation and results are shown. MALAB 7.5 is used as simulation platform.

Keywords
Intelligent Transportation System (ITS), vehicle-to-vehicle (V2V) channels, Ubiquitous communication, Doppler.

1. INTRODUCTION
Frequent traffic accidents causing enormous number of deaths and injuries have become a serious health and social issue. Intelligent Transportation System (ITS) is a method of converging remote sensing, communication and information technologies and other advanced methods with transportation engineering to address transportation problems involving a complex interplay between technology; human perception; cognition and behavior; and social, economic, and political systems [1]. Vehicle-to-vehicle (V2V) communication is a subset of ITS. Besides safety applications, new vehicular communication technologies are also desirable to improve the efficiency of transportation systems and to improve the comfort of drivers/passengers (e.g., internet access, satellite TV, etc., in the vehicle). Initiatives to create safer and more efficient and comfortable driving conditions have therefore drawn strong support from both governments and car manufacturers. V2V communications, also known as inter-vehicular communications, play a central role in these efforts, enabling a variety of applications for safety, traffic efficiency, and infotainment.
Different countries are using different standards for ITS. Thus, International Telecom Union (ITU) and International Organization for Standardization (ISO) in 2003, and promoted by the more recently created industry association – The CALM Forum – to develop a new family of ITS standards with the overall branding of "Continuous Air-interface for Long and Medium range(CALM)"[2]- [4]. The aim of CALM is to provide wide area communications to support ITS applications that work equally well on a variety of different network platforms. The decision on which platform to use in a particular country or for a given application would then be based on logical selection of pre-set criteria to make the best use of resources. Thus, CALM is intended to be platform independent, and therefore to avoid the battles over regional standards that have dogged existing ITS standards like DSRC. For instance, the basic CALM system architecture (ISO 21217) foresees support for 10 main categories of network [4], and 22 different sub-categories each of which would need a different Service Access Protocol (SAP). Digital video and audio broadcasting (DVB and DAB) are included in CALM.
In order to support non-safety applications, the V2V system needs to support at least one wireless local area network technology, e.g., IEEE 802.11a/b/g. In contrast to non-safety applications, safety applications are usually of broadcast nature. Safety applications are directly supported by specific V2V network and transport protocols, and are normally based on IEEE 802.11p [5]. The IEEE 802.11p radio technology is directly derived from IEEE 802.11a with some modifications to adapt to vehicular environments. It occupies 75 MHz of the licensed spectrum, from 5.85 to 5.925 GHz, as part of the intelligent transportation system for dedicated short range communications (DSRC) in the USA [5]. The IEEE 802.11p, Wireless Access in Vehicular Environment (WAVE) standardization process originates from the allocation of the Dedicated Short Range Communications (DSRC) spectrum band in the United States and the effort to define the technology for usage in the DSRC band [6].
Although V2V communication technologies are very promising, many research challenges have to be addressed before their wide deployment. The nature of the radio access network throughout the journey is heterogeneous. Thus seamless connectivity for ubiquitous communication is a great challenge. Proper vertical handover [7-9] algorithm is required for the seamless access in heterogeneous network scenario. Another major challenge is the V2V channel modeling. The VTV propagation channel has strong impact on the coverage, reliability, and real-time capabilities of VTV networks. Wrong assumptions about fading lead to erroneous conclusions on the dependability of inter vehicle warning systems. On the contrary, reliable knowledge of the propagation channel and a corresponding realistic channel model serve as the enabling foundation for flexible and practical design and testing of V2V systems. Thus, it is vital to use well characterized measurement based models of VTV communications channels. This underlines the importance of developing physically meaningful yet easy-to-use methods to mimic V2V channels. Therefore, much research attention has been attracted to V2V channel modeling and measurements. Section 2 focuses on the background of this work. A detailed literature survey on V2V channels is given in section 3. Pathloss models and the fading models are described in section 4 and 5 respectively. A comparison between cellular channels and the V2V channels is provided in section 6. Simulation work of V2V channel is explained in section 7. Discussion on this work is presented in section 8 and Finally the paper is concluded in section 9.

2. BACKGROUND OF THE WORK

Authors are involved for a multi-channel solution of ITS challenges. Remote sensing is used in ITS for safety applications. Authors have shown in [10, 11], how digital radar is effective to avoid collision. Ubiquitous communication is another major requirement for both safety and non safety applications. Authors have taken an initiative to design a robust vertical handover algorithm to provide seamless connectivity in heterogeneous radio access network scenario [7-9]. Convergence of both remote sensing and communication is presented in [12].

This work is an extension to the work presented in [7-12]. Here, survey on the necessity of V2V communication channel modeling is presented with the help of a detailed literature survey and simulation. Also the cellular channel models are compared with the V2V channels.

3. LITERATURE SURVEY ON V2V CHANNELS

The term channel characterization is used to describe the models, theory, and experimental data that constitute one's knowledge of a wireless channel in a specific type of environment, typically a function of channel bandwidth and center frequency [16]. One can define the channel as the complete set of parameters for all paths that transmitted electromagnetic waves in the frequency band of interest take from transmitter to receiver over the spatial region of interest. For engineering purposes, the characterization must be quantitative and as thorough as possible.

Matolak et. al., [13-17] are involved in V2V channel modeling and measurement in 5GHz band for some time. They have developed models for several V2V settings: urban, with antennas outside the cars (UOC); urban, with antennas inside the cars (UIC); small cities (S); and open areas (highways) with either high or low traffic densities (OHT and OLT). These models were designed for multiple values of bandwidth, including 5 MHz, 10 MHz, and 20 MHz. Molisch et. al., [18-21] have presented the effect of scatters on V2V channel modeling and measurements. Generalizing this approach to VTV channels, [22] considered a situation where both TX and RX are moving, the angles of incidence are independent at transmitter and receiver, and the angular power spectrum and antenna pattern at TX and RX are uniform. Few V2V measurement campaigns [23,24], have investigated channel characteristics when the Tx and Rx are moving in opposite directions.

The Rayleigh model is almost universally used as a worst case model. Matolak [16] has termed this "worse than Rayleigh" fading severe fading, such severe fading has been reported in multiple environments at multiple frequency bands, but has only recently gained much attention in the research community. Physical mechanisms used to explain this severe fading include multiple scattering, rapid transitions of multipath components, and in some cases a generalized Ricean model that allows for two dominant components plus the diffuse (scattered) components, in contrast to the conventional single-dominant-component Ricean case. Our models incorporate both statistical nonstationarity and severe fading to model the V2V channel as realistically as possible.

4. PATH LOSS MODELS

If there is a clear unobstructed line-of-sight path between the transmitter and receiver, then we resort to the free-space propagation model. Satellite communication systems and microwave line-of-sight radio links undergo free-space propagation. In this model, the power is presumed to decay with distance from the transmitter according to some power law, usually as square of the distance from the transmitter. The free-space power received by an antenna at a distance *d* from the transmitter is given by (1),

$$P_r(d) = \frac{P_t G_1 G_2 \lambda^2}{(4\pi)^2 d^2 L} \quad \ldots\ldots\ldots\ldots(1)$$

Where

P_t is the transmitted power,

P_r (d) is the received power as a function of the separation distance d in meters,

G_1 is the transmit antenna gain,

G_1 is the receive antenna gain,

L is the system loss not related to propagation ($L \geq 1$), and

λ is the wavelength in meters.

Free-space propagation is rarely encountered in real-life situations. In reality, we need to take into account the terrain profile in a particular area for estimating path loss. The terrain may vary from a simple curved earth profile to a highly mountainous profile. The presence of trees, buildings, and other obstacles must be taken into account. A number of propagation models are available to predict path loss over irregular terrain. These models differ in their ability to predict signal strength at a particular receiving point or in a specific local area. Since their approach is different, their results vary in terms of accuracy and complexity.

4.1 Okumura Model

This is a widely used model for signal prediction in an urban area. It is applicable for frequencies in the range of 150 to 1,920 MHz and can be extrapolated up to 3 GHz and distances of 1 to 100 Km. It can be used for base station antenna heights ranging from 30 to 1,000m.

Okumura [25] developed a set of curves giving the median attenuation relative to free space (A_{mu}) in an urban area over a quasi-smooth terrain with a base station effective antenna height (h_{te}) of 200m and a mobile antenna height (h_{re}) of 3m. These curves were developed from extensive measurements using vertical omni-directional antennas at both base and mobile and are plotted as a function of frequency in the range 100 to 1,920 MHz and as a function of distance from the base station in the range of 1 to 100 Km. To use these curves, we first determine the free-space path loss between the points of interest and then the value of $A_{mu}(f, d)$ is added to it along with correction factors to account for the type of terrain. The model is expressed as

$$L_{50}(dB) = A_{mu}(f,d) - G(h_{te}) - G(h_{re}) - G_{AREA} \quad \ldots\ldots(2)$$

Where,

L_{50} is the 50th percentile (i.e., median) value of propagation path loss,

L_F is the free-space propagation loss,

A_{mu} is the median attenuation relative to free space,

$G(h_{te})$ is the base station antenna height gain factor,

$G(h_{re})$ is the mobile antenna height gain factor, and

G_{AREA} is the gain due to the type of environment.

The antenna height gains are strictly a function of height and have nothing to do with the antenna patterns.

Okumura's model is completely based on measured data and there is no analysis to justify it. All extrapolations to these curves for other conditions are highly subjective. Yet it is considered the simplest and best in terms of accuracy in path loss prediction for cellular systems in a cluttered environment. It has become a standard in Japan. The major disadvantage is its slow response to rapid changes in terrain. Hence, it is not so good in rural areas. Common standard deviations between predicted and measured path loss values are around 10 dB to 14 dB.

4.2 Hata Model

The Hata model [26]is an empirical formulation of the graphical path loss data provided by Okumura and is valid from 150 to 1,500 MHz. Hata presented the loss as a standard formula and supplied correction equations for application to other situations. The standard formula for median path loss in urban areas is given by,

$$L_{50(Urban)}(dB) = 69.55 + 26.16\log f_c - 13.82\log h_{te} - a(h_{re}) + (44.9 - 6.55\log h_{te})\log d \text{......(3)}$$

Where

fc is the frequency in MHz from 150 to 1,500 MHz,

h_{te} is the effective transmitter (base station) antenna height (in meters) ranging from 30 to 200m,

h_{re} is the effective receiver (mobile) antenna height (in meters) ranging from 1 to 10m,

d is the T-R separation distance (in Km), and

$a(h_{re})$ is the correction factor for effective mobile antenna height, which is a function of the size of the coverage area.

For a small to medium-sized city, the correction factor is given by

$$a(h_{re}) = (1.1 \log fc - 0.7)\, h_{re} - (1.56 \log fc - 0.8) \text{ dB} \quad \text{------------(4)}$$

and for a large city,

$$a(h_{re}) = 8.29(\log 1.54\, h_{re})^2 - 1.1 \text{ dB for } fc \le 300 \text{ MHz} \quad \text{----------(5)}$$

$$a(h_{re}) = 3.2(\log 11.75\, h_{re})^2 - 4.97 \text{ dB for } fc \ge 300 \text{ MHz} \quad \text{--------(6)}$$

To obtain the path loss in a suburban area, the standard Hata formula in (3) is modified as

$$L_{50}(dB) = L_{50(Urban)} - 2[\log\left(\frac{f_c}{28}\right)]^2 - 5.4 \text{.......... ....(7)}$$

and for path loss in open rural areas, the formula is modified as

$$L_{50}(dB) = L_{50(Urban)} - 4.78(\log f_c)^2 + 18.33\log f_c - 40.94 \text{.......(8)}$$

The predictions of Hata's model compare very closely with the original Okumura model, if d exceeds 1 Km. this model is well-suited to large cell mobile systems.

4.3 Stanford University Interim (SUI) Model

The Stanford University has developed a channel model for the frequency bands bellow 11GHz, named the SUI model. The SUI models are defined for the Multipoint Microwave Distribution System (MMDS) frequency band which is from 2.5 GHz to 2.7 GHz. Their applicability to the 3.5 GHz frequency band that is in use in the UK has so far not been clearly established [28]. The SUI models are defined for three types of terrains, namely A (hilly terrain), B (flat terrains with moderate to heavy tree densities or hilly terrains with light tree densities) and C (flat terrain with light tree densities). Type A is associated with maximum path loss and is appropriate for hilly terrain with moderate to heavy foliage densities. Type C is associated with minimum path loss and applies to flat terrain with light tree densities. The basic path loss equation with correction factors is presented in [29,30].

$$P_L = A + 10\gamma\log_{10}[\frac{d}{d_0}] + X_f + X_b + s \quad for \quad d > d_0 \quad \text{------------- (9)}$$

Where,

d is the distance between the Access Points (AP) and the Customer Premises Equipment (CPE) antennas in meters,

d_0 = 100 m and

s is a log normally distributed factor that is used to account for the shadow fading owing to trees and other clutter and has a value between 8.2 dB and 10.6 dB.

The other parameters are defined as,

$$A = 20\log_{10}(\frac{4\pi d_0}{\lambda}) \quad and \quad \gamma = a - bh_0 + \frac{c}{h_b} \quad \text{-- (10)}$$

where,

h_b is the base station height above ground in meters and should be between 10 m and 80 m.

The constants used for a, b and c are given in Table 1. The parameter γ in (10) is equal to the path loss exponent. For a given terrain type the path loss exponent is determined by h_b.

Table 1. The parameters of SUI model in different types of environments [32]

Model Parameter	Terrain A	Terrain B	Terrain C
a	4.6	4.0	3.6
b(m^{-1})	0.0075	0.0065	0.005
c(m)	12.6	17.1	20

The correction factors for the operating frequency and for the CPE antenna height for the model are,

$$X_f = 6.0\log_{10}\left(\frac{f}{2000}\right) \text{...............................(11)}$$

$$X_h = 10.8\log_{10}\left(\frac{h_r}{2000}\right) \text{.............................(12)}$$

$$= 20.01\log_{10}\left(\frac{h_r}{2000}\right) \text{ for Terrain type C......(13)}$$

Where, f is the frequency in MHz and hr is the CPE antenna height above ground in meters. The SUI model is used to predict the path loss in all three environments, namely rural suburban and urban.

4.4 COST 231

This is the model that is widely used for predicting path loss in mobile wireless system [27,28]. The COST-231 Hata model is designed to be used in the frequency band from 500 MHz to 2000 MHz. It also contains corrections for urban, suburban and rural (flat) environments. Although its frequency range is outside that of the measurements, its simplicity and the availability of correction factors has seen it widely used for path loss prediction at this frequency band. The basic equation for path loss in dB is ,

$$P_L = 16.3 + 33.9\log_{10}(f) - 13.82\log_{10}(h_b) - ah_m$$
$$+ (44.9 - 6.55\log_{10}(h_b))\log_{10} d + c_m \ldots\ldots\ldots(14)$$

Where,
f is the frequency in MHz,
d is the distance between AP and CPE antennas in km, and
h_b is the AP antenna height above ground level in metres.
c_m is defined as 0 dB for suburban or open environments and 3 dB for urban environments.
ah_m is defined for urban environments as,

$$ah_m = 3.20(\log_{10}(11.75h_r))^2 - 4.97,$$
$$\text{for } f > 400MHz \ldots(15)$$

For suburban or rural (flat) environments,

$$ah_m = (1.1\log_{10} f - 0.7)h_r - (1.56\log_{10} f - 0.8)\ldots(16)$$

Where,
h_r is the CPE antenna height above ground level.
Observation of (14) to (16) reveals that the path loss exponent of the predictions made by COST-231 Hata model is given by,

$$n_{\cos t} = (44.9 - 6.55\log_{10}(h_b)) / 10 \ldots\ldots\ldots\ldots\ldots(17)$$

To evaluate the applicability of the COST-231 model for the 3.5 GHz band, the model predictions are compared against measurements for three different environments namely, rural (flat), suburban and urban.

4.5 ECC-33 model

The ECC 33 path loss model, which is developed by Electronic Communication Committee (ECC), is extrapolated from original measurements by Okumura and modified its assumptions so that it more closely represents a fixed wireless access (FWA) system. The path loss model is defined as [28],

$$PL(dB) = Af_s + Ab_m - G_t - G_r \ldots\ldots\ldots\ldots\ldots\ldots(18)$$

Where,
Af_s is free space attenuation,
Ab_m is basic median path loss,
G_t is BS height gain factor and
G_r is receivedantenna height gain factor.
They are individually defined as,

$$Af_s = 92.4 + 20\log(d) + 20\log f$$

$$A_{bm} = 20.41 + 9.83\log(d) + 7.894\log(f) + 9.56[\log(f)]^2$$

$$G_t = \log\left(\frac{h_b}{200}\right)[13.98 + 5.8(\log(d))^2]\ldots\ldots\ldots(23)$$

for medium city environments,

$$G_r = [42.57 + 13.7\log(f)][\log(h_m) - 0.585]\ldots\ldots(24)$$

Where, f is frequency in GHz,
The performance analysis is based on the calculation of received signal strength, path loss between the base station and mobile from the propagation model. The GSM based cellular d is distance between base station and mobile (km) h_b is BS antenna height in meters and h_m is mobile antenna height in meters.

5. FADING MODELS

Small-scale fading or simply *fading* is used to describe the rapid fluctuations of the amplitude, phases, or multipath delays of a radio signal over a short period of time or travel distance, *so that large-scale path loss effects may be ignored.* Fading is caused by a number of signals (two or more) arriving at the reception point through different paths, giving rise to constructive (strengthening) vectorial summing of the signal or destructive (weakening) vectorial subtraction of the signals, depending on their phase and amplitude values. These different signals other than the main signal are called *multipath* waves. Multipath in a radio channel creates small-scale fading effects. These effects are commonly characterized as causing:

1) Rapid changes in signal strength over a small travel distance or time interval.
2) Random frequency modulation due to varying Doppler shifts on different multipaths.
3) Time dispersion (echoes) caused by multipath propagation delays.

Even when a line-of-sight exists, multipath still occurs due to reflections from the ground or surrounding structures. Assume that there is no moving object in the channel. In such a case, fading is purely a spatial phenomenon. The signals add or subtract, creating standing waves in the area where the mobile is located. In such a case, as the mobile moves, it encounters temporal fading as it moves through the multipath field. In a more serious case, the mobile may stop at a particular point at which the received signal is in deep fade. Maintaining good communication in that case becomes very difficult. Two basic fading models are discussed here.

5.1 General Description of Rice and Rayleigh Process

The sum of all scattered components of the received signal is — when transmitting an unmodulated carrier over a frequency-nonselective mobile radio channel — in the equivalent complex baseband often described by a zero-mean complex Gaussian random process [31]

$$\mu(t) = \mu_1(t) + j\mu_2(t)\ldots\ldots\ldots\ldots\ldots\ldots(25)$$

Usually, it is assumed that the real-valued Gaussian random processes $\mu_1(t)$ and $\mu_2(t)$ are statistically uncorrelated. Let the variance of the processes $\mu_i(t)$ be equal to $\text{Var}\{\mu_i(t)\}=\sigma_0^2$ for i = 1, 2, then the variance of $\mu(t)$is given by $\text{Var}\{\mu(t)\} = 2\sigma_0^2$
The line-of-sight component of the received signal will in the following be described by a general time-variant part

$$m(t) = m_1(t) + jm_2(t) = \rho e^{(2\pi f_\rho t + \theta_\rho)}\ldots\ldots\ldots(26)$$

Where, ρ, f_ρ, and θ_ρ denote the amplitude, the Doppler frequency, and the phase of the line-of-sight component respectively.
At the receiver antenna, we have the superposition of the sum of the scattered components with the line-of-sight component. In the model chosen here, this superposition is equal to the addition of (25) and (26). For this reason, we introduce a further complex Gaussian random process with time-variant mean value $m(t)$.

$$\mu_\rho(t) = \mu_{\rho 1}(t) + j\mu_{\rho 2}(t) = \mu(t) + m(t)\ldots\ldots\ldots\ldots(27)$$

Forming the absolute values of (25) and (27) leads to Rayleigh and Rice processes, respectively. In order to distinguish these processes clearly from each other, we will in the following denote Rayleigh processes by

$$\zeta(t) = |\mu(t)| = |\mu_1(t) + j\mu_2(t)| ....(28)$$

And, Rice processes by

$$\xi(t) = |\mu_\rho(t)| = |\mu(t) + m(t)|......................(29)$$

The shape of the power spectral density of the complex Gaussian random process (27) is identical to the Doppler power spectral density, which is obtained from both the power of all electromagnetic waves arriving at the receiver antenna and the distribution of the angles of arrival. In addition to that, the antenna radiation pattern of the receiving antenna has a decisive influence on the shape of the Doppler power spectral density.

By modelling mobile radio channels, one frequently simplifies matters by assuming that the propagation of electromagnetic waves occurs in the two-dimensional plane, hence, horizontally. Furthermore, mostly the idealized assumption is made that the angles of incidence of the waves arriving at the antenna of the mobile participant (receiver) are uniformly distributed from 0 to 2π. For omni directional antennas, we can then easily calculate the (Doppler) power spectral density $S_{\mu\mu}(f)$ of the scattered component $\mu(t)=\mu_1(t)+\mu_2(t)$. For $S_{\mu\mu}(f)$, one finds the following expression,

$$S_{\mu\mu}(f) = S_{\mu_1\mu_1}(f) + S_{\mu_2\mu_2}(f)..............(30)$$

Where

$$S_{\mu_1\mu_1}(f) = \begin{cases} \dfrac{\sigma^2}{\pi f_{\max}\sqrt{1-(f/f_{\max})^2}}, & |f| \le f_{\max}, \\ 0, & |f| > f_{\max} \end{cases};.........(31)$$

holds for $i = 1; 2$ and f_{max} denotes the maximum Doppler frequency. In the literature, (31) is often called *Jakes power spectral density* (*Jakes PSD).*

6. COMPARISON OF V2V AND CELLULAR CHANNELS

The characteristics of V2V channels, such as pathloss or power delay profile (PDP), differ from those of mobile cellular communications channels. These differences can be summarized as follows:

1) In V2V communications described in literature are peer-to-peer communications, thus the transmitter (TX) and receiver (RX) are at the same height, and in similar environments. One the contrary, in cellular communications, link is established between a base station that is high above street level and a mobile station at street level. Thus the dominant propagation mechanisms of the multipath components are different.
2) For a V2V channel, scattering can occur around both the TX and the RX, while for cellular channels, the area around the base station is usually free of scatterers.
3) The distance over which communications can take place is much smaller in V2V channels (< 100 m) than in typical cellular scenarios (~ 1 km).
4) In cellular channels, only one of the TX or RX is moving, and moving scatterers have less relative importance; whereas in a V2V channel, both the TX and RX as well as many of the important scatterers are moving which has a severe impact. This implies that the channel fluctuations in V2V channels are faster compared to cellular channels.
5) V2V systems operate mostly at 5.8-5.9 GHz carrier frequency, while cellular communications, including WiFi and WiMax, occurs mostly at 700–2400 MHz. Due to their high operating frequency, V2V channels have higher signal attenuation, and specific propagation processes like diffraction are less efficient than in cellular radio.

7. SIMULATION OF V2V CHANNELS

Since the vehicle movement is the principal concern for V2V communication, we have developed a model for utilizing the existing radio networks for this purpose. The simulation for V2V channel is done following the steps described bellow.

Step1. First we consider, number of sample points as N ($N=2^n$ where, n=number of carriers)

Step2. Now, taking Maximum Doppler Frequency Shift as F_m=600MHz.

Step3. For estimating carrier receiver speed(denotes the velocity of the vehicle), $v= (F_m*c_0)/f_0$

Where, F_m- Maximum Doppler Frequency,
f_0- carrier frequency,
c_0- speed of light.

Step4. Considering some variables as,

f_s = Sampling Frequency.
Mean =Mean of Gaussian random variables.
Variance =Variance of Gaussian random variables.

Step5. Now based on above parameters, we are calculating the standard deviation.

Step6. Calculating independent Gaussian random variables for in-phase & quadrature phase noise component separately and calculating circular symmetric complex Gaussian random variable as C.

Step7. Defining Spectral characteristics of the Doppler effect in frequency domain from the mathematics of doppler shift and taking output as F_k = Doppler Filter output.

Step8. Now, Multiplying Doppler filter output with C as, $U= C*F_k$.

Step9. Taking Inverse Fourier transform of U and storing the output in "u".

Step10. Finding absolute value of above found output.

Step11. Now finally, plotting graph between elapsed time and Rayleigh fading envelope (in dB) and observing the output.

In the two-dimensional horizontal plane, the Doppler shift (Doppler frequency) of an elementary wave is equal to $f = F_{max}.\cos(y)$, where y is the angle of arrival, and $F_{max} = v. f_0/c_0$ denotes the maximum Doppler frequency (v: velocity of the vehicle, f_0: carrier frequency, c_0: speed of light).

This model is tested for three different available networks, viz., 3G cellular network, WLAN and WiMax. The results are shown below.

7.1 Results:

7.1.1 3G Cellular Network

The 3G cellular networks are mainly working in the frequency ranges from 1800MHz to 2100MHz.

The parameters considered for the simulation, are listed bellow,

$V=F_{max}.c_0/f_0$;
Now, F_{max}= 600 Mhz;
f_0=2100 Mhz
v=(600*3*10^8)/2100
v=85.7143km/hr.

The simulation shows that the 3g cellular network is suitable up to 85.7kmph vehicular speed. Fig.1 is showing the power delay profile (PDP) obtained from the simulation results.

7.1.2 WLAN

Wireless LAN which is used for ITS, is mainly working in the range of 5-5.9 GHz. The parameters considered for the simulation, are listed bellow,

$V=F_{max}.c_0/f_0$;

Now, F_{max}=600 Mhz;

f_0=5GHz

v=(600*3*10^8)/5000

v=36km/hr.

The simulation shows that the WLAN is suitable up to 36 kmph vehicular speed. Fig.2 is showing the power delay profile (PDP) obtained from the simulation results.

7.1.3 WiMax:

WiMax which is used for ITS, is mainly working in the range of 2.4-2.5 GHz. The parameters considered for the simulation, are listed bellow,

$V=F_{max}.c_0/f_0$;

Now, F_{max}=600 Mhz;

f_0=2500 Mhz;

v=(600*3*10^8)/2500;

v=72km/hr.

The simulation shows that the WiMax is suitable up to 72 kmph vehicular speed. Fig.3 is showing the power delay profile (PDP) obtained from the simulation results.

8. DISCUSSION

The above results obtained in different networks i.e. 3G, WLAN, WiMax was associated with Doppler shift which is the major concern in a V2V communication system. Let us compare the above obtained results of V2V communication channel with that of the standard graph obtained in the case of Rayleigh fading without Doppler (Fig. 4). Here, we see that in case of ideal channel, there is no distortion which is due to stationary nature of the receiver but in case of Doppler shift there is much distortion which is due to continuous change in motion of the receiver with time. Here, we have considered an ideal case where θ=0o ,for maximum Doppler shift where, θ=Relative angle between the moving object and the point of reception of the Doppler's signal.

The graph obtained in the fig:1 is in 3G environment where Doppler has been incorporated by keeping receiver in motion and we obtain the maximum velocity of the receiver which it can support. In this case we get v=85.7km/hr.

In this work we have implemented Rayleigh fading process with Doppler. A further modification of Rayleigh process was done by incorporating carrier receiver speed. Here we have determined the carrier receiver speed, i.e., vehicular speed, for three existing networks which can be explored for vehicular communication.

9. CONCLUSIONS

In this paper we describe the importance of accurately modeling communication channel for ITS applications. After a review of important channel parameters, we show how the V2V channel differs from the channel in other settings, and can exhibit severe fading and statistical non-stationarity. Both these features should be taken into account when modeling the channel. In this work, we explored the efficiency of the existing radio access networks which can be used for V2V communication. On comparing the performance of three networks, we can conclude that WLAN supports less Doppler in comparison to 3G and WiMAX. If we compare 3G and WiMAX we see that it supports Doppler with speed in similar range but then also 3G is supporting more velocity of receiver.

Thus by changing the radio network in proper instant (vertical handoff), it is possible achieve ubiquitous communication using the existing network infrastructure.

9. REFERENCES

[1] Henry Leung, Nour-Eddin El Faouzi and Ajeesh Kurian, "Intelligent Transportation System (ITS)", Information Fusion 12 (2011) 2–3, ELSEVIER.

[3] International Telecommunication Union, available at http://www.itu.int/ITU-T / newslog / Intelligent + Transport + Systems + Rely+ On + CALM.aspx

[4] International Telecommunication Union, available at http://www.itu.int/ITU-T/techwatch/index.phtml

[5] IEEE P802.11p/D2.01, "Standard for Wireless Local AreaNetworks Providing Wireless Communications while in Vehicular Environment," Mar. 2007.

[6] Daniel Jiang, Luca Delgrossi, "IEEE 802.11p: Towards an International Standard for Wireless Access in Vehicular Environments", IEEE Vehicular Technology Conference, Singapore, 11-14 May, 2008. DOI:10.1109/VETECS.2008.458

[7] S.Dhar, R.Bera, A. Ray, "Design and Simulation of Vertical Handover Algorithm for Vehicular Communication", International J. of Engineering Science and Technology, vol 2,no 10, October,2010

[8] Sourav Dhar, A. Ray, R.Bera, "Design, Simulation and Sensitivity Analysis of Vertical Handover Algorithm for Vehicular Communication", International J. of Computer Science and Software Technology, Vol 3, no.2. July-dec 2010

[9] Sourav Dhar, A. Ray, R.Bera, S.N.Sur, D.Ghosh, "A Complete Simulation Of Intra Vehicle Link Through Best Possible Wireless Network ", International J. of Computer and Electrical engineering, vol 2,no 4, August,2010

[10] Rabindranath Bera, Sourav Dhar, Debdatta Kandar, "Digital Radar for Collision Avoidance and Automatic Cruise Control in Transportation", published in IEEE ISM 08, 3-6 Dec'08, Bangalore,India.

[11] Sourav Dhar, Sanjib Sil , Samarendra Nath Sur , Debasish Bhaskar , Debdatta Kandar and Subir kr. Sarkar, "Vehicular Communication and Safety in Realization of Intelligent Transport System", Rabindranath Bera ,Dipak Mondal, , published in IEEE CODEC 2009, December 14-16, 2009, Kolkata, India.

[12] Rabindranath Bera, Sourav Dhar , D. Kandar, N.B. Sinha, Manojit Mitra.," Modeling and Implementation Of Wireless Embedded System For Intelligent Transport System Application ", published in 2008 IEEE Region 10 Colloquium and the Third International Conference on

Industrial and Information Systems, December 8 -10, 2008, Kharagpur, INDIA.

[13] D. Matolak, I. Sen, W. Xiong, and N. Yaskoff, "5 GHz wireless channel characterization for vehicle to vehicle communications," in MILCOM 2005, pp. 1–7, 2005. [14] D. W. Matolak, I. Sen, and W. Xiong, "Channel Modeling for V2V Communications," (invited paper) Proc. 2nd Int'l. Wksp. Vehicle-to-Vehicle Communications 2006, San Jose, CA, 21 July 2006.

[15] I. Sen and D. W. Matolak, "V2V Channels and Performance of Multi-User Spread Spectrum Modulation," Proc. IEEE 1st Int'l. Symp. Wireless Vehic. Commun., Baltimore, MD, 30 Sept.–1 Oct. 2007.

[16] D.W. Matolak , "Channel Modeling for Vehicle-to-Vehicle Communications", IEEE Communications Magazine, May 2008

[17] B. Wang, I. Sen, and D. W. Matolak, "Performance Evaluation of 802.16e in Vehicle to Vehicle Channels," Proc. IEEE VTC-Fall, Baltimore, MD, 1–3 Oct. 2007.

[18] A. F. Molisch and M. Steinbauer, "Condensed parameters for characterizing wideband mobile radio channels," Int. J. Wireless Information Networks, vol. 6, p. 133-154, 1999.

[19] A. F. Molisch and F. Tufvesson, "Multipath propagation models for broadband wireless systems," in CRC Handbook of signal processing for wireless commmunications (M. Ibnkahla, ed.), 2004.

[20] A. F. Molisch, F. Tufvesson, J.Karedal and C.F. MECKLENBRÄUKER, "A Survey on Vehicle-to Vehicle Propagation Channels", IEEE Wireless Communications, December 2009.

[21] J. Karedal, F. Tufvesson, N. Czink, A. Paier, C. Dumard, T. Zemen,C. F. Mecklenbraeuker, and A. F. Molisch, "A geometry-based stochastic MIMO model for vehicle-to-vehicle communications," IEEE Trans.

Wireless Comm., submitted, 2008.

[22] A. Akki and F. Haber, "A Statistical Model of Mobileto-Mobile Land Communication Channel," IEEE Trans. Vehic. Tech., vol. 35, 1986, pp. 2–7.

[23] A. Paier et al., "Characterization of Vehicle-to-Vehicle Radio Channels from Measurements at 5.2 GHz," Wireless Personal Commun., June 2008;

[24] G. Acosta and M. A. Ingram, "Six Time-and Frequency-Selective Empirical Channel Models for Vehicular Wireless LANs," IEEE Vehic. Tech. Mag., vol. 2, no. 4, Dec. 2007, pp. 4–11.

[25] T. Okumura, E. Ohmori, and K. Fukuda, "Field strength and its variability in VHF and UHF land mobile service," Review Electrical Communication Laboratory, Vol. 16, No. 9-10, pp. 825–873, Sept.-Oct. 1968.

[26] M. Hata, "Empirical formula for propagation loss in land mobile radio services," IEEE Trans. Vehic. Technol., Vol VT-29, No. 3, pp. 317–325, Aug. 1980.

[27] COST Action 231, "Digital mobile radio towards future generation systems, final report," tech. rep., European Communities, EUR 18957, 1999.

[28] V.S. Abhayawardhana, I.J. Wassell, D. Crosby, M.P. Sellars, M.G. Brown"Comparison of empirical propagation path loss models for fixed wireless access systems" Vehicular Technology Conference, 2005. IEEE Date: 30 May-1 June 2005 Volume: 1, On page(s): 73- 77 Vol. 1

[29] V.Erceg, K V S Hari, et al., "Channel models for fixed wireless applications," tech. rep., IEEE 802.16 Broadband wireless access working group, jan-2001

[30] V. Erceg, L. J. Greenstein, et al., "An empirically based path loss model for wireless channels in suburban environments," IEEE Journal on Selected Areas of Communications, vol. 17, pp. 1205–1211, July 1999.

[31] Matthias Pätzold, " Mobile fading channels", John Wiley & Sons Ltd, 2002.

[32] P.K. Sharma, R.K. Singh, "Comparative Analysis of Propagation Path loss Models with Field Measured Data", IJEST, Vol. 2(6), 2010, 2008-2013

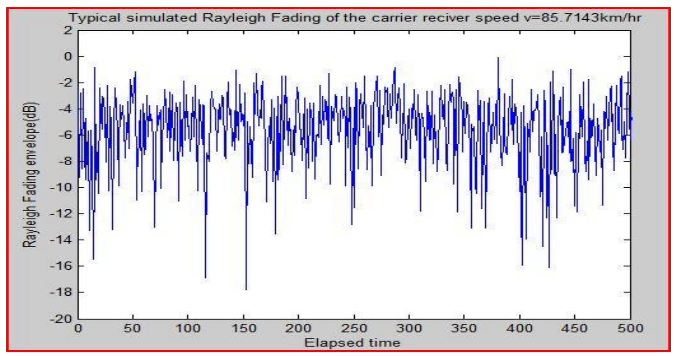

Fig.1: PDP for 3G cellular network at 85.7143kmph vehicular speed.

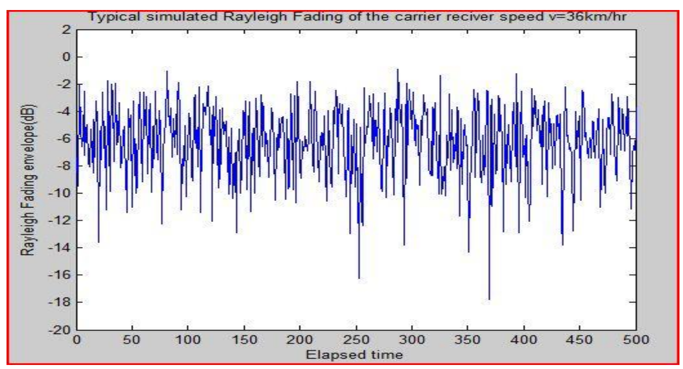

Fig.2: PDP for WLAN at 36kmph vehicular speed.

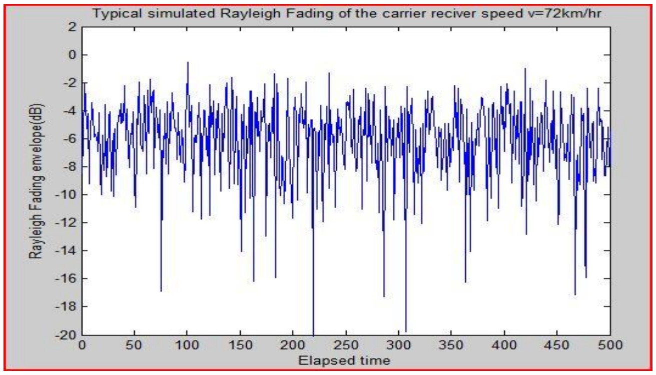

Fig.3: PDP for WiMax at 72kmph vehicular speed.

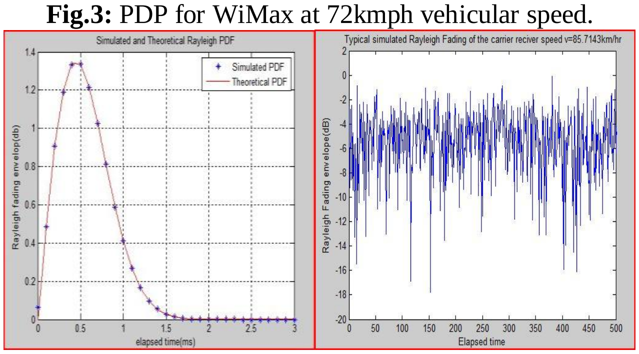

Fig. 4: Ideal channel (without doppler) PDF and V2V Channel PDP