Performance Analysis of DDM Method to Reduce The Doppler Effect on Vehicular

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Abstract. VANET is an innovation that supports vehicle to vehicle and vehicle to infrastructure communication. The main application of VANET technology is to realize better and safer traffic management. However, due to the high mobility of the vehicle, this technology causes the Doppler effect, when the spectral signal enlarges in the OFDM system. The Doppler effect occurs due to the influence of the use of Rayleigh fading vehicle-to-vehicle channels on the VANET environment and the effect of changing channel movement conditions causing time-varying channels. It also triggers the spread of Doppler to be larger than the symbol duration. This certainly can disrupt the orthogonality of the OFDM system which is the basis of VANET communication. The effect is the occurrence of ICI (inter-carrier-interference) causing the performance of OFDM to decrease. This research proposes the Direct Development Method (DDM) scheme, a technique to compensate for the Doppler effect which is different from the general scheme. In this study, the scheme used is to focus the corrector on the data frame before sending it. The simulation is carried out by testing the modulation which refers to the IEEE 802.11p standard with 4 different vehicle speed conditions namely 24, 64, 144, and 294 km/h. Analysis of the performance of the application of the DDM scheme on modulation based on the effect of the speed provided gives better results compared to the modulation performance without the compensation of the Doppler (Non-DDM) or conventional effects on the SNR requirement side to achieve the BER $10^{-3}$ target.

1. Introduction

Vehicular ad-hoc network (VANET) is part of the development of ITS technology (Intelligent Transport System) which is presented to improve safety and comfort in driving. Until now, the development of communication quality between vehicles continues to be considered and formed a standard of wireless communication in a vehicle or standard environment Wireless Access for Vehicular Environment (WAVE) to support vehicle to vehicle (V-to-V) and vehicle to infrastructure (V-to-I) communications that work at a frequency of 5.885 GHz as the basis of an Intelligent Transport System (ITS) [1]. The WAVE standard consists of two standards, IEEE 1609 and IEEE 802.11p. IEEE 1609 relates to standardization at the top layer and IEEE 802.11p explains all operations at the Medium Access Control (MAC) and physical (PHY) layers. The machinery used at the base layer for VANET communication is Orthogonal Frequency Division Multiplexing (OFDM) [2].
Until now, VANET has constraints on the performance side, namely when two or more vehicles communicate with each other with high mobility, with the condition of the vehicles moving away from or near each other resulting in a Doppler or Doppler Shift (DS) frequency shift. It has an impact on the transmitted signal in the receiver side that will shift or cause the orthogonality of the OFDM system to decrease. This causes many errors so that the system performance decreases [3]. The Doppler frequency shift can affect carrier frequency, subcarrier frequency, and symbol duration on OFDM systems, resulting in decreased data performance received [4].

Based on some researches on techniques or models of Doppler effect compensation as a challenge to reduce problems in VANET, the Doppler effect compensation can refer to schemes in three domains, namely the time, frequency, and space domain [5]. One of the Doppler frequency shift coverage in the frequency domain is the bandpass modulation scheme and the coding of the baseband used.

Albarazi et al., (2011) analyzed the compensation of the Doppler effect on VANET by proposing adaptive modulation schemes with variations in channel codes in various baseband modulations by allocating power and selecting appropriate rainy modulation to overcome the fading of signals that have deteriorated when arriving at the receiver's side. So if a system needs a particular BER, the power sent has to be estimated based on channel conditions or designated to each subcarrier considering the channel circumstances. For instance, BPSK and QPSK, which are categorized as low-order modulation, are more resistant to noise but smaller in sending the amount of data. In contrast to 16-QAM high order modulation, the data transmission rate is large but susceptible to noise [6].

Novfitri, (2014) [9] mentioned that the adaptive modulation used power allocation counterfeited on the OFDM system. As a result, adaptive modulation methods provide excellent performance for several small symbols. It performs an adaptive transmission scheme on V-to-V with a calculation of three-channel circumstances [10]. In this study, variations speed is used in those three conditions. Thus, variations in V-to-V conditions with higher speeds are required to examine the adaptive modulation performance. V-to-V communication reproduction with a correlated double-ring channel model has been conducted in the presence of Rayleigh and Rician fading at various speeds and a different amount of scatterer. The channel response results show the correlated double-ring channel model that can be used in the high-speed environment in-vehicle communication [11].

The study describes the Direct Derivation Method (DDM) method to solve Doppler shifts on VANET. Here, the Doppler shift was exposed up to 1400 Hz by modulation scheme choice. Doppler shifts can be overcome by choosing the best modulation scheme outcome. Each of them then correlated to a compensation arrangement without a Doppler shift.

This research will analyze the implementation of the Direct Development Method (DDM) with the OFDM system in the VANET environment with V-to-V Rayleigh fading channel conditions. This method is used as compensation for Doppler shift conditions before the data is transmitted. Direct Development Method (DDM) is a Doppler shift compensation technique with SymMax values established based on the amount of coherence time generated in each channel and given variable corrector to avoid the Doppler effect of the transmitted data, so the value of the Doppler shift can be corrected. Usage testing of this method is carried out by applying modulation in accordance with the rules of IEEE 802.11p as seen from BER on the SNR of several conditions that indicate the performance of the proposed system.

This paper is divided into several sections. Section II explains the planned model system and the derivation of the mathematical representation of channel models. Elaboration of DDM simulation outcome arrangement in OFDM system over V-to-V Rayleigh fading channel is presented in Section III. Ultimately, Section IV concludes this research.

2. Model System

2.1. OFDM for VANET Model System
VANET technology has been used in this research, OFDM which supports IEEE 1609 and 802.11p which is made specifically for DSRC message types. Figure 1 shows the DSRC channel design consisting of SSH and CCH channels [7]. In this figure, the SSH allocation channel is divided into two requesting inter-vehicle communication applications (V-to-V) set on channel 172. Meanwhile, communication between vehicles and telecommunications infrastructure (V-to-I) is established on channel 184 so that it can be moved between V-to-I and V-to-V communication. The V-to-V service places two distribution blocks on channels 174 and 176. Furthermore, channels 180 and 182 are for the placement of the V-to-I service channel. Each service channel is provided by the control. Channel 178 is trying to improve safety and for parameters of the 802.11p standard as shown in table 1.

The carrier frequency used is 5.885 GHz with a bandwidth of 10 MB. The CCH and SCH channels have periods with intervals of less than 100ms. Where the division of time in the CCH and SCH intervals is divided based on Guard Interval (GI) of 4ms, so 27 Mbps is the maximum data speed that can be relayed through this innovation. The concept of time division in the CCH and SCH interval can be seen in Figure 2.

| Parameters            | DSRC 802.11p         |
|-----------------------|----------------------|
| Information Data Rate | 3 – 27 Mbps          |
| Bit rate (Mb/s)       | 3, 4, 5, 6, 9, 12, 18, 24, 27 |
| Modulation mode       | BPSK, QPSK, 16QAM, 64QAM |
| Code rate             | 1/2, 2/3, 3/4        |
| Number of subcarriers | 52                   |
| OFDM Symbol duration  | 8μs                  |
| Guard time            | 1.6μs                |
Based on the outline of this research, the system modeling shown in Figure 3, about the OFDM system for suppliers, is implemented with the application of DDM. The transceiver block is based on IEEE 802.11p which uses OFDM waves at a carrier frequency of 5.885 GHz. The wireless channel adapts the condition of the cellular channel to cellular using a correlated double ring from changes in the speed of both automobiles adjusted by Doppler.

The use of the Rayleigh fading V-to-V channel is added to the channel to see the performance resistance of the proposed system. Additionally, AWGN noise jamming is added after passing through the channel because at that time the signal condition is weak. Channel Estimator block containing channel state information (CSI) which functions as a switch modulator as a form of automation response to the effects of the Doppler shift experienced. Channel estimation is considered perfectly calculated at the receiver before going through the system block. On the receiver OFDM side, the process occurred in contrast to the previous process, the data signal that has passed through the channel will be converted again into parallel data according to the specified subcarrier value. Next, the CP data is separated by the original data and through the demodulator, the FFT process. Then bandpass demodulation works according to the input of the channel estimator. The results obtained by demapping then become serial data in the form of bits which are then compared with the input data on the transmitter to see the value of the bit error rate (BER).

2.2. Doppler Frequency Shift

Channel condition in vehicular communications is dynamic or time-varying [7]. In the planned system can experience the Doppler shift to conduct the modulation degradation in OFDM. The amount of the Doppler shift is related to relative motion between the transmitter, receiver, and vehicle speed [8]. The Doppler shift ($f_d$) can be computed by this formula:

$$f_d = f_c \frac{v}{c} \cos \alpha$$

(1)

where $f_c$ is source frequency of DSRC at 5.885 GHz, $v$ is the difference of acceleration between vehicles, $c$ indicates a speed of light $3 \times 10^8 m/s$, and $\alpha \in [0, \pi]$ denotes the angle of the velocity vector. To ensure the maximal Doppler shift achievement, it should happen when $\alpha=0$. Doppler shift
is expressed by normalized maximum Doppler shift \( \left( f_d \right) \) in the MATLAB simulation process. It can be calculated by comparing the division of the Doppler shift value with the subcarrier spacing \( \left( F_s \right) \)

\[
V(t) = \sum_{i=1}^{N_c} A_i \cos \left( \omega_i t + \phi_i \right)
\]  

(2)

\( A_i \) is the value of the amplitude of the signal \( V \), \( \omega_i \) represent the angular frequency \( \phi_i \) is the phase of the \( i \)-th subcarrier, \( N_c \) shows the number of subcarriers used in OFDM, then each subcarrier must be orthogonal to one another. This can be obtained in the condition of \( f_i = \omega_i 2\pi \), which is the integer multiplication of \( 1/2T \), with \( T \) (the period of the data) and \( f_i \) (the frequency range with a value of \( R_s = 1/T \)).

If we proceed to equation (2) with processing at up converter side to produce 5.8 GHz frequency, then the formula should be

\[
V_i = A_i \cos \left( \omega_i t + \phi_i \right) e^{-j(2\pi f_s)e^{2\pi \alpha}}
\]

(3)

if the value of \( A_i \cos \left( \omega_i t + \phi(t) \right) = S_i \) then

\[
V_i = S_i e^{-j(2\pi f_s)e^{2\pi \alpha}} \]

(4)

with the value of \( e^{-j(2\pi f_e)c^2} \) and \( \tau_i \) is frequency carrier and \( \tau_i \) represent the carrier frequency and delay to the \( t_i \) component of the received signal. If the vehicle moves at a constant velocity \( v \), and each vehicle moves straight with \( \alpha \) then the value of the transmitted signal is affected by the value of \( \frac{V}{c} \cos \alpha \) that the equation (4) becomes:

\[
V_i = S_i e^{-j(2\pi f_s)c^2 \cos \alpha}
\]

(5)

By replacing equation (1) to (6), it becomes,

\[
V_i = S_i e^{-j(2\pi f_s)c^2 \cos \alpha}
\]

(6)

with \( j2\pi ft \) is a value from phase changing at the transmitted signal. if the value of \( t = \frac{1}{4} \Delta f \), then the equation becomes

\[
V_i = S_i e^{-j(2\pi f_s)c^2 \cos \alpha}
\]

(7)

with \( j2\pi \Delta ft \) is a value from phase changing at the transmitted signal. if the value of \( t = \frac{1}{4} \Delta f \), then the equation becomes

\[
V_i = S_i e^{-j(2\pi f_s)c^2 \cos \alpha}
\]

(8a)

\[
V_i = S_i e^{-j(2\pi f_s)c^2 \cos \alpha}
\]

(8b)

With \( e^{j\pi /2} = j \) (Euler equation) the equation becomes

\[
V_i = jS_i e^{-j(2\pi f_s)c^2 \cos \alpha}
\]

(9)

From the derivation, assumption the period is \( 1/4 \) of the Doppler shift, consider of coherence time then the equation becomes :

\[
T_c = \frac{1}{4\Delta f}
\]

(10)

During the delivery process of OFDM symbol, a discrete time channel impulse is defined as,
\[ h(n, t) = \sum_{i=1}^{L} h_i(n) \delta(\tau - \tau_i) \] (11)

2.3. DDM (Direct Development Method) Scheme
Direct Development Method (DDM) is a technique to reduce Doppler impact which refers to [3]. DDM uses the concepts of equations (3) to (10). This technique uses a correction system (system corrector) which will later offset the data affected by the Doppler shift on the wireless channel when transmitted steps in generating a DDM system.

From these steps, can be determined based on DSRC, the frequency used is 5.855 GHz and the maximum speed of each vehicle is 250 km/hour. And SymMax value refers to equation (12).

\[ SymMax = \frac{Transmission\ time\ duration - GI}{Interval\ Symbol} \] (12)

The key to this method is the correction of DS in frames that have been divided according to the SymMax Sub Period before the data transmitted results from SymMax even given the variable \( j \). After giving corrector \( j \), the data is transmitted on the wireless channel determined later on the wireless media, SymMax will even meet the factor \( j \) derived from the Doppler effect. After the correlation \( j \) is multiplied by the \( j \) factor of the Doppler effect, the DS can be ignored and the data matches the transmitted signal.

2.4. Channel Model
The channel model used in this study is the Rayleigh fading V-to-V channel which was adapted from the application of the concept of mobile to mobile channel ring [12] as shown in Figure 4. The part of the sum of sinusoid (SoS), can be written mathematically in the following equation [13]:

\[
\begin{align*}
\psi_n & = 2n\pi - \pi + \theta_n \\
\psi_m & = 2(2m\pi - \pi + \psi_m) \\
M \text{ and } N \text{ are the values of the specified scatterer } M = N = 8. \ & \alpha_n \text{ and } \beta_m \text{ are the initial angles of departure of each scatterer part of } \theta_n \text{ and the angle of arrival of each scatterer part of } \psi_m.
\end{align*}
\] (13)

\[
\begin{align*}
\alpha_n & = \frac{2n\pi - \pi + \theta_n}{4N} \\
\beta_m & = \frac{2(2m\pi - \pi + \psi_m)}{4M}
\end{align*}
\] (14)

\( M \) and \( N \) are the values of the specified scatterer \( M = N = 8. \ \alpha_n \) and \( \beta_m \) are the initial angles of departure of each scatterer part of \( \theta_n \) and the angle of arrival of each scatterer part of \( \psi_m \).

\( \theta_n, \psi_m, \theta_{\text{min}} \) are random variables that are independent of each other in the range \(-\pi \) to \( \pi \). In this simulation, because channel modeling is an SoS iteration, will be carried out 50 times to get the
appropriate results. $f_1$ and $f_2$ are normalized Doppler frequencies generated from each vehicle. For this reason, the relationship between Doppler frequency and the velocity of each vehicle can be presented in equation (13).

$f_c$ is the carrier frequency (5.885 GHz), $v$ is the relative speed of each vehicle, and $c$ the speed of light ($3 \times 10^8$). The value of the normalized Doppler frequency is obtained by applying the following equation

$$f_{dnorm} = \frac{f_d}{\Delta f}$$

where $\Delta f$ is the change in frequency that has been obtained at the receiver.

3. Simulation Result

In this section explains the influence of the Doppler shift in the V-to-V communication system can affect the phase of the signal being sent but with the application of the DDM scheme the effect of the shift can be suppressed, to show this, the scheme of the DDM is compared to the system without applying the DDM scheme as seen in Figure 5 below shows the graph of the comparison between DDM and Non-DDM scheme with testing on BPSK modulation with predetermined speed variations. Table 2 shows the need for the SNR value of each test which shows that the implementation of the DDM scheme still provides better performance when compared to Non-DDM modulation.

![Figure 5](image)

**Figure 5.** Comparison of BER and SNR functions in DDM and Non-DDM schemes with BPSK Modulation.

| fd norm | BER Improvement |
|---------|----------------|
| 0.0008  | 0.95            |
| 0.0022  | 0.93            |
| 0.005   | 0.94            |
| 0.01    | 0.92            |

**Table 2.** DDM vs Non-DDM Response With BPSK Modulation Using V-to-V Channel

| Mode Transmisi BPSK | SNR [dB] |
|---------------------|----------|
|                     |          |

7
Furthermore, in Figure 6 below shows the graph of the comparison between the DDM and Non-DDM schemes with testing on QPSK modulation with a predetermined speed variation. Table 3 shows the SNR value of each test which shows that the implementation of the DDM scheme still provides better performance when compared to Non-DDM modulation.

| $f_d$ norm | speed   | DDM   | Non DDM |
|------------|---------|-------|---------|
| 0.0008     | 24 km/h | 25.69 | 27.81   |
| 0.0022     | 64 km/h | 27.6  | 31.02   |
| 0.0051     | 144 km/h| 27.5  | 31.68   |
| 0.01       | 294 km/h| 28.09 | 32.25   |

**Figure 6.** Comparison of BER and SNR functions in DDM and Non-DDM schemes with QPSK Modulation.

**Table 3.** DDM vs Non-DDM Response With QPSK Modulation Using V-to-V Channel

| Mode Transmisi QPSK | SNR [dB] |
|---------------------|----------|
|                     | $f_d$ norm | speed   | DDM   | Non DDM |
| QPSK                | 0.0008     | 24 km/h | 25.52 | 30.8    |
|                     | 0.0022     | 64 km/h | 27.6  | 34.13   |
|                     | 0.0051     | 144 km/h| 28.89 | 34.59   |
|                     | 0.01       | 294 km/h| 28.75 | 34.81   |

And the final test results of the comparison between the DDM and Non-DDM schemes can be seen in Figure 7 below, the results graph with 16QAM modulation still provides better performance when compared with Non-DDM modulation can be seen in table 4 for the SNR value of each test.
Figure 7. Comparison of BER and SNR functions in DDM and Non-DDM schemes with 16QAM Modulation.

Table 4. DDM vs Non-DDM Response With 16QAM Modulation Using V-to-V Channel

| $fd_{norm}$ | speed | SNR [dB] | DDM | Non DDM |
|-------------|-------|----------|-----|---------|
| 0.0008      | 24 km/h | 26.63    | 37.37 |
| 0.0022      | 64 km/h | 28.83    | 39.78 |
| 0.0051      | 144 km/h | 29.33    | 39.79 |

4. Conclusion
The application of the DDM scheme is based on channel achievement allocation for V-to-V communication which is affected by Doppler frequency. The final results of the performance analysis of the three modulations with the application of the DDM scheme compared to Non-DDM on the fourth value of the speed conditions tested on the DDM scheme provide better performance when compared to the Non-DDM modulation. It gives more efficient results in terms of SNR for this communication system.

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