Evaluation of Performance Enhancement of OFDM Based on Cross Layer Design (CLD) IEEE 802.11$_p$ Standard for Vehicular Ad-hoc Networks (VANETs), City Scenario

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***Abstract*—In recent years, Vehicular Ad hoc Network (VANET) plays an important role in Intelligent Transportation Systems (ITS) due to their impact in reducing traffic jams and increasing safety. Dissemination of emergency safety messages is an important function in VANET to realize safety applications. Therefore, short delay dissemination and reliable delivery are required in between vehicles. In fact, IEEE 802.11p is an IEEE physical and MAC standard which intended specially for vehicular communications. In this VANET standard, different physical layer transmission techniques are defined. The latest researches indicate the great potential of employing OFDM for VANET safety applications. In this paper, the performance of VANET city scenario is evaluated in terms of average throughput, delay and PDR. The proposed routing approach which named by Cross Layer Design (CLD) is based on sharing information between physical (PHY) and MAC layers in order to select the best path (route). From the simulation results, we can show that our proposed approach can achieve short delay and maximum Packet Deliver Ratio (PDR) in city environment by simultaneous transmission. The achieved results confirm the best PDR for our proposed technique when there is no movement of communicating vehicles. In addition, the proposed routing approach minimizes delay and hence maximizes the throughput comparing with other conventional routing protocols. In addition, a stable behaviour of PDR values is achieved by using CLD approach.**

***Index Terms*—VANET, cross-layer, OFDM, DSRC, IEEE 802.11p**

I. Introduction

In the past few years, further developments in Mobile Ad-hoc Networks (MANETs) have led to the emergence of Vehicular Ad hoc Networks (VANETs). The concept is to create an ‘ad-hoc network’ of moving vehicles with ever-present connectivity. Each vehicle acts like a mobile node and moves along predetermined paths (roads). The connectivity is established when a vehicle tries to look for a nearby vehicle or infrastructure within the communication range to establish desired communication [1], [2]. Since vehicles can communicate with each other, it has opened a totally new communication paradigm that can be used to provide new services to stakeholders. Emerging Vehicular networks will provide both driver and passengers with a variety of applications for safety, traffic efficiency, driver assistance, as well as infotainment to be incorporated into modern automobile designs. This emerging area of vehicular networks has several research activities in the Europe, the United States (U.S.), Japan, and Singapore [3]. In recent years, control systems of automobiles have moved from the analog to the digital domain. Adopting wireless communication in vehicles has created unique opportunities for the transportation community.

Indeed, VANET are based on the combination of Ad hoc and cellular technologies to provide two different networks architecture. In order to be part of a VANET, vehicles must be equipped with wireless transceivers and protocol stack to allow them to act as network nodes [4]. Researchers have subdivided VANET scenarios into three categories, namely Urban/City, Rural and Freeway/Highway to make sure that all the needs of inter-networking within the specific environments are covered [5]. This is mainly to cater for the specific challenges that are unique to each environment. Moreover, each environment can be defined according to specific speed. General speed limits are limits that apply on all streets and roads for which there are no specific or local speed limits [6], [7].

Routing issue in VANET is one of a big challenging task due to the dynamic nature VANET environment and high speed of vehicles nodes [8]. Unfortunately and specially for VANET, this becomes even more difficult due to a number of reasons such as lack of permanent infrastructure, high speed and sparse distribution of vehicles, and various interfering obstacles. Thus, a selection of an appropriate type of routing protocols plays a key role in delivery of data between vehicles in efficient form [9], [10]. From the literature, the traditional routing protocols proved poor performance in VANET dynamic environment and cannot improve the QoS which is a critical factor in order to provide high

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level of safety and multimedia applications [11]. This calls for the need to explore new strategies that can adapt with VANET highly dynamic environment.

In fact, IEEE 802.11p or Dedicated Short Range Communication (DSRC) is a standard wireless communication channel for use among VANET nodes [12]. The Federal Communications Commission (FCC) has allocated the frequency spectrum between 5.850 and 5.925 GHz for dedicated short-range communications (DSRC) in vehicular environments. With its nationwide availability, this allocation provides an ideal opportunity for automakers, government agencies, and commercial entities. IEEE 802.11p is an amendment to the IEEE 802.11 standard to add wireless access in vehicular environments (WAVE) [13], [14]. DSRC is a general purpose communications link between the vehicle and the roadside (or between vehicles) using the 802.11p protocol. The MAC layer operation of IEEE 802.11p uses the same CSMA/CA mechanism as used in the legacy IEEE 802.11 systems [15]-[18]. However, IEEE 802.11p allows the use of service classes as defined in the IEEE 802.11e standards to provide service quality differentiation. At the PHY layer, the use of an OFDM system is expected to allow V2V as well as V2I communications for distances of up to 1000m and relative speeds of 200 km/hr. IEEE 802.11p that exploits (OFDM) [12] to exchange information can improve system throughput and support transmission information with high transmission rates over dispersive channels.

In this paper, two different scenarios of VANET environment in term of movement are simulated and compared in terms of PDR, average throughput and delay by using cross layer design (CLD) based on IEEE 802.11p OFDM which has specially been conceived for vehicle ad-hoc networks. The reminder of this paper is organized as follows: Section II reviews several studies the usage of Orthogonal Frequency Division Multiplexing (OFDM) in VANET system. In Section III, the proposed system model is discussed and the simulation environment is explained in details. Section IV presents the results and analysis for different scenarios. Section V concludes the contribution of this paper.

II. Related Works

Many efforts have been done by researchers for finding the best routing protocols in VANET system under the best physical (PHY) and MAC layers techniques. Different physical layer transmission techniques such as Direct Sequence Spread Spectrum (DSSS), Frequency Hopping Spread Spectrum (FHSS) and Orthogonal Frequency Division Multiplexing (OFDM) which all defined by IEEE 802.11p are evaluated in terms of different parameters. All researchers are looking forward to test the VANET performance under OFDM PHY technique. In [19], the authors proposed the cooperative communication system for VANETs. The main objective of this works is to employ multiple transmission of same OFDM signals to disseminate information effectively because same OFDM signals can be demodulated in OFDM when the signals arrive within a GI period. The obtained results indicated that, the proposed system be realizing the short dissemination delay and scalability in urban environment. By simulation, the performance was evaluated for the proposed cooperative communication system in VANETs comparing to a basic flooding mechanism.

Another effort was done in [20] in order to reduce interference in VANET environment. The authors proposed to apply Orthogonal Frequency Division Multiplexing (OFDM) are since it has features like robustness against multipath fading and high data rates. Thus, improves the Signal to Noise ratio in VANET and enhance performance of the VANET is achieved in this work. The model was build using software Lab View on 64 bit Windows operating system in order to analyse Bit Error Rate (BER) in terms of Signal to Noise Ratio (SNR) for various protocols under different modulation scheme.

According to authors in [21], they introduced Diversity Coded Orthogonal Frequency Division Multiplexing (DC-OFDM) approach in order to maximize the probability of successful reception and increase the reliability of OFDM-based systems through diversity coding. In their work, they focused on the application of DC-OFDM to vehicular networks based on IEEE 802.11p. The performance is analysed to study the effect of different parameters, such as: Number of data links, number of coded (protection) links, modulation technique, and DC code rate, to optimize the communication's probability of successful reception of an OFDM symbol at the receiver. The obtained results showed that, DC-OFDM significantly improves the performance of vehicular ad hoc networks in terms of throughput and the expected number of correctly received symbols.

As a summary from the recent works, it is important to evaluate the effect of OFDM PHY technique for VANET environment. For safety applications, different Quality of Service (QoS) metrics can be tested. Many researchers focus for doing their simulation in VANET without using realistic scenarios. It is important to test and evaluate new MAC protocol under specific PHY layer transmission technique via using VANET's simulator. MATLAB is an appropriate choice to analyse the performance of the proposed system model which exploits Cross Layer Design approach for routing decision due to their simplicity and availability.

III. Simulation Environment

A. Radio Propagation Model

Wireless transmission modelling in any communication system is a challenging task due to the dynamic nature of the medium. A key influencing factor for the probability of packet reception is given by the assumed radio wave propagation model. In general speaking, high fading environments lead to high data losses, which seriously affect the communication of safety applications in VANETs. As it is known, line of sight not always exist between transmitter and receiver. To take into the account non line of sight path, a Two-

Ray propagation model was developed [22]. The strength of received power using this model can be calculated based on the value of cross-over distance which is determined from the following equation:

$$d_{cross} = \frac{4\pi h_t h_r}{\lambda} \quad (1)$$

where: h_t = the transmitted antenna height, h_r = the received antenna height, and λ = the wavelength.

The following formula shows the relationship between the strength of received power (Pr) and the distance between two communicating vehicles nodes (d) based on the value of d_{cross}:

$$P_r = \begin{cases} P_t G_t G_r (\frac{\lambda}{4\pi d})^2 & d \le d_{cross} \\ \frac{P_t G_t G_r h_t^2 h_r^2}{d^4} & d > d_{cross} \end{cases} \quad (2)$$

B. The Proposed Cross Layer Design Approach for Routing

Cross Layer Design (CLD) has been proposed in recent works and it refers to a protocol design that exploits the dependency between protocol layers to achieve desirable performance gains. On the other hand, the research and application development in VANETs are driven by the IEEE 802.11p technology which is intended to enhance the IEEE 802.11 to support ITS applications where reliability and low latency are crucial factors. Therefore, it is important to test and evaluate cross layer design (CLD) based on IEEE 802.11p for VANET system by using the actual radio propagation models such as shadowing model. In this paper, the main goal of our cross layer design CLD) is to increase PDR and throughput under log-normal shadowing propagation model for safety and multimedia applications. Cooperation between physical layer and MAC layer is provided in this proposed method. The main feature that is provided by physical layer is the calculations of the received signal strength P_r and then SNR value for each transmitted link (route). The idea is to add modifications to traditional protocol in order to find the most stable route that has a good received signal strength (RSS).

The main flow chart of the proposed approach is presented in Fig. 1. When the source moving node (vehicle) wish to send packets to a destination node (vehicle). The aim is to route this packet from source to destination in such a way that it minimizes the delay in transmission delivery. Hence, the source creates a common neighbourhood of potential vehicles which based on selected routines. These routines establish the criteria for vehicle selection based on different layer attributes unique to each scenario. If the destination vehicle is present in the neighbourhood then the packets are transmitted to the destination. Otherwise, the algorithm selects the next hop vehicle using the defined criteria. The algorithm for sending a packet to the next hop vehicle is repeated until the destination is reached.

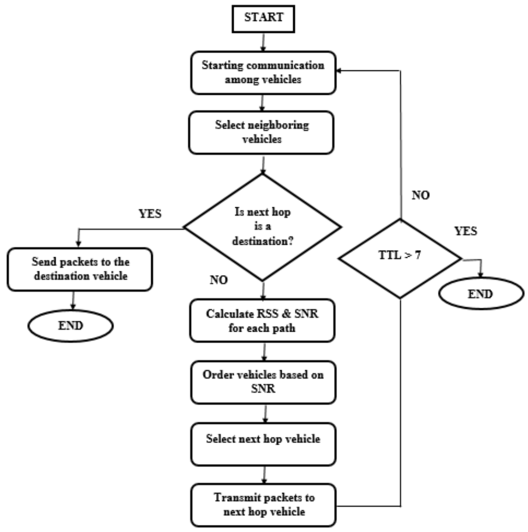

Figure 1. The proposed algorithm flow chart.

C. Simulation Scenarios and Parameters

The proposed system model consists from n communicating vehicles (nodes) in a specific city area topology that defined by a size of $x_{max} \times y_{max}$ and moving with standard velocity that defined for city scenario. The positioning of the vehicles are defined according to the homogeneous Poisson point process. It is assumed that the source vehicle s randomly selects a destination vehicle d to communicate with. Besides, Random Waypoint model was used in order to model the mobility of vehicles.

The main simulation parameters were defined according to the structure of OFDM that are defined according to IEEE 802.11p. Nodes initial topology as presented in Fig. 2 shows the simulated city road topology which defined by an area that has a size equals to $x_{max} \times y_{max}$ (900×500).

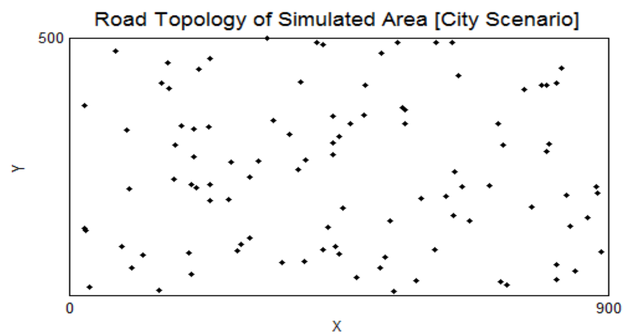

Figure 2. Initial road topology of simulated area in MATLAB (Highway Scenario).

As mentioned before, IEEE 802.11p which was designed specially for vehicular communications is proposed to be used in our simulation model. Hence, the simulation parameters were defined according to the IEEE 802.11p draft. The standard in [23], [24] defined the main parameters as shown in Table I. In this simulation, OFDM as one of the famous PHY layer techniques was used in order to simulate city scenario.

IEEE 802.11p OFDM/PHY characteristics and Physical Layer Convergence Protocol (PLCP) frame formats as shown in Table II were obtained from IEEE standard in [25], [26].

TABLE I. THE SIMULATION PARAMETERS

Parameter	Value
Frequency	5.9 GHz
# of Vehicles	50-200
Speed Limit (Km/h)	40/65
Packet size (Bytes)	18496
Network size (m)	900 x 500
Transmitter Gain Gt	10
Receiver Gain G_r	10
Transmitter Height h_t(m)	1
Receiver Height h_r (m)	1
Physical Layer	IEEE 802.11p
Contention Window Min (CW_{Min})	31 slots
Contention Window Max (CW_{Max})	1023 slots
Mobility	Random Way Point
Propagation Model	Two-ray

TABLE II. OFDM PHY PARAMETERS

Parameter	OFDM
Slot Time [µs]	9
Turnaround Time [µs]	2
Preamble [bits]	20
PLCP header [bits]	4
Data Rate [Mbps]	3
SIFS interval [µs]	16

IV. SIMULATION RESULTS

In this section, the proposed system model of VANET was evaluated for city scenario in terms of average throughput, delay and PDR which define QoS by using MATLAB environment.

A. Packet Delivery Ratio (PDR)

The first evaluation was done in term of PDR for different number of traffic and vehicles (traffic density). This value is calculated by dividing the overall number of packet arrived at destination node (R^p) by the overall packet sent from source nodes (S^p) according to:

$$PDR = \frac{\sum_{1=no.des} R_1^p}{\sum_{1=no.sou} S_1^p} \quad (3)$$

Fig. 3 shows the effect of increasing the number of traffic on PDR for different vehicles traffic density (n=80/150). The maximum values of PDR were achieved for high traffic density due to the availability of more route paths between communicating vehicles. It can be clearly seen that, PDR has a stable behaviour. In the case of low traffic density where the number of vehicles was 80, PDR is increased by increasing the number of traffic that wish to transmit. The maximum value of PDR was equals to 98.27% when number of traffic was 25 packets/s.

In order to study the effect of vehicles movement on PDR, two scenarios were evaluated for different number of vehicles as shown in Fig. 4. In a general view, PDR values show unstable behaviour due to routing process in order to find the best path. It can be clearly realized that, vehicles which communicate with each other without movement have higher PDR than moving communicating vehicles. In case of there no movement; PDR is decreased by increasing number of vehicles. The maximum value of PDR was obtained when number of vehicles nodes was 100 and equals to 99.42%. On the other hand, by increasing number of vehicle nodes the PDR is increased which is a normal situation. However, when number of vehicles becomes more than 160 nodes, the PDR is decreased due to link failure. After that, when number of nodes becomes 200 vehicles the routing path is more stable to deliver information which gives enhancement in PDR.

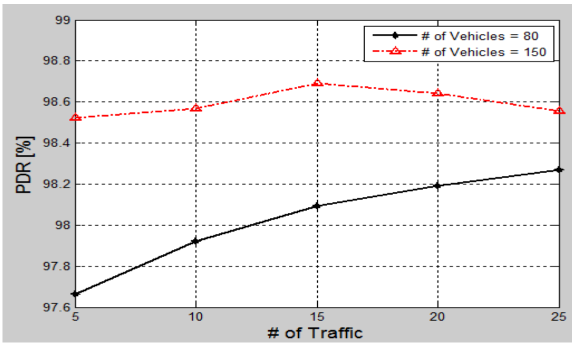

Figure 3. Packet delivery ratio in VANET network with different traffic.

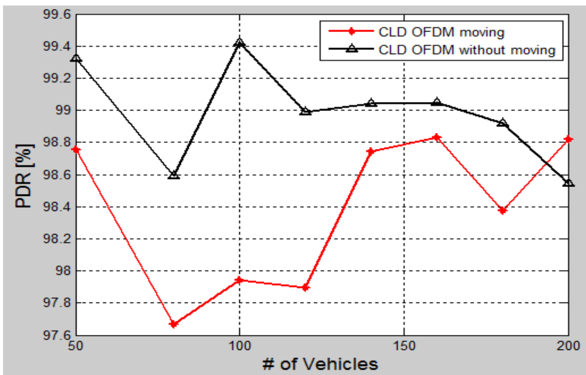

Figure 4. The effect of movement on packet delivery ratio in VANET network.

B. Average Throughput and Delay

This is one of the important and critical parameters that measure the overall network performance. The average throughput $\bar{\gamma}$ in kbps can be calculated as [27]:

$$\bar{\gamma} = \frac{K\sum_{m=1}^{n} R_m^p}{D} \qquad (4)$$

where k is the packet size, R_p no. of received packets and D is the delay. Fig. 5 presents the effect of increasing traffic on average throughput Mbps for different traffic density (n=80/150). The average throughput was decreased rapidly by increasing the number of sending traffic. The maximum values of average throughput were achieved in case of low traffic density in which the number of vehicles is equals to 80. The maximum average throughput was 0.1637 Mbps when traffic was 5 packets/s.

Fig. 6 shows the effect of increasing number of vehicles nodes on average throughput for two different scenario. The first scenario shows the values of system average throughput when vehicles communicate without movement. In this case, the average throughput proved better performance than the second scenario which reflect the behaviour of system when vehicles are moving. In the second scenario, the average throughput is decreased by increasing the number of vehicles which is a normal behaviour.

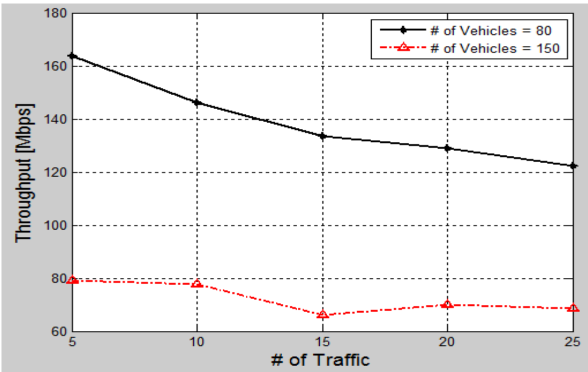

Figure 5. Average throughput $\bar{\gamma}$ in VANET network with different traffic.

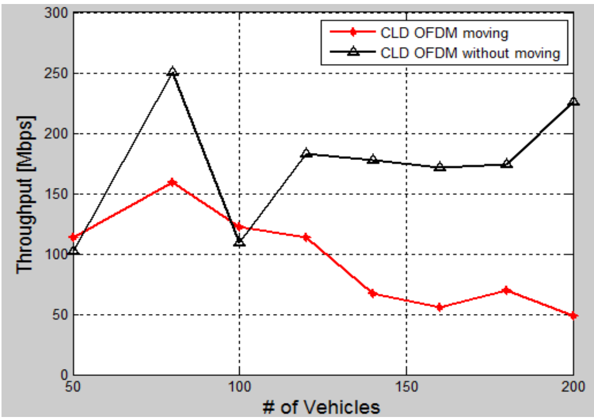

Figure 6. The effect of movement on average throughput in VANET network.

The delay represents the time period that needs to route a packet from the source to the desired destination [28], [29]. The delay can be defined as the packets per unit time interval length which depends on PDR value in the network and can be calculated from equation (4). Fig. 7 which shows poor effect is obtained by increasing number of traffic for city scenario due to the high collision rate. It can be clearly realized that, for low traffic density (n=80) presents low delay values comparing with the case where the number of vehicles was 150. On the other hand, vehicles movement affects the VANET system in term of delay as shown in Fig. 8. More delay was achieved in case of movement vehicles. The maximum value of delay was equals to 249.08 ms when number of vehicles was 180.

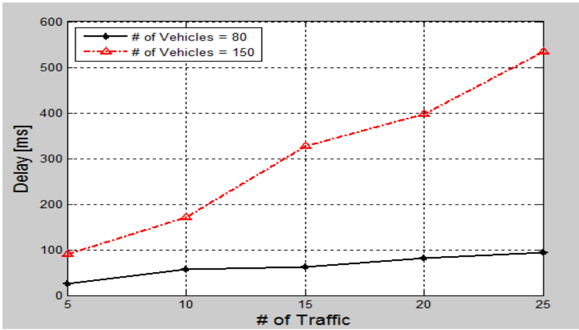

Figure 7. Delay in VANET network with different scenarios.

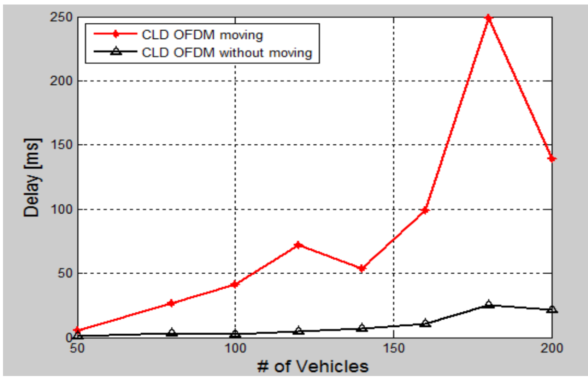

Figure 8. The effect of movement on delay in VANET network.

V. Conclusions

Nowadays, Vehicular Ad hoc Network (VANET) plays an important role in vehicle safety and transportation efficiency. The main aim of VANET system is to ensure vehicle safety for the drivers and passengers as well as to reduce time and fuel consumption, among other services. Several IEEE standards are proposed in order to support efficient working of such a system. Indeed, IEEE 802.11p is a physical and MAC layers draft standard which defined specifically for VANET. In this standard, Orthogonal Frequency Division Multiplexing (OFDM) is defined as a one of physical layer technique that have great interest in vehicles communications. The objective of this paper is to analyse and evaluate the performance of the proposed cross layer design (CLD) based on OFDM which defined in IEEE 802.11p by using MATLAB environment. The performance of city scenario is simulated and evaluated in terms of PDR, average throughput and delay. Our goal is to estimate the performance of cross layer routing model for city scenario by using OFDM PHY layer technique. In our method, the information sharing between physical and MAC protocol layers is improved via cross layer technique. Firstly, the evaluation was done under different number of traffic. By increasing the number of traffic, delay metric was increased and average throughput was decreased. Secondly, the simulation results showed the effect of movement in these QoS metrics. In case of there is no movement of communicating vehicles, minimum delay and maximum average throughput were obtained. Finally, comparing our proposed routing approach with conventional routing schemes, an enhancement of PDR values were achieved as well as minimum delay was obtained from simulation results. As a conclusion, the OFDM based VANET will improve its performance in network.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Mayada and prof. Rashid contributed to the model design and simulation issue of the research, to the analysis of the results and to the writing of the paper. Mayada conceived the study and analysed all graphs in the results section. Prof Rashid was responsible about giving the critical feedback and was in charge of overall direction and planning and approved the final version of this paper.

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