2015 4th International Conference on Instrumentation, Communications, Information Technology, and Biomedical Engineering (ICICI-BME)
Bandung, November 2-3, 2015

Comparative Performance Evaluation of DSRC and Wi-Fi Direct in VANET

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Abstract-In this paper, we present a comprehensive study on the performance and behavior of AODV and DSDV routing protocols by using two standards which is the conventional DSRC and the latest Wi-Fi Direct. DSRC is a well-known technology being considered as the most promising wireless standard in VANET. On the contrary, as the latest wireless networking standard, the potential of Wi-Fi Direct technology should be concerned. We evaluated these standards using both routing protocols under realistic mobility model in order to analyze the QoS performance by using NS-2 and SUMO simulator. It is demonstrated via simulations that AODV routing protocol produces better results compared to DSDV routing protocol in both standards. It also can be concluded that DSRC is slightly better than Wi-Fi Direct standard. However based on QoS performance that has been obtained by a combination of AODV and Wi-Fi Direct standard, we can defer that Wi-Fi Direct is feasible to be used as an alternative standard since it has been considered as potential competitor of DSRC in VANET.
Keywords: AODV, DSDV, VANET, DSRC, Wi-Fi Direct

I. INTRODUCTION

Vehicle ad-hoc network (VANET) is a type of mobile ad-hoc network (MANET) where it forms small networks which consist of moving vehicles in order to provide security, safety and convenience for passengers [1]. VANET is used for the applications such as to alert the driver about probability of collision, road sign alarms, automatic payment for parking lots, toll collection, and so on so forth [2]. For this time being, VANET is used to establish a Dedicated Short Range Communications (DSRC) among vehicles-to-vehicles and between vehicles-to-infrastructure equipment. Potential application of DSRC is a warning system, where it is a standard that exchange data between vehicles on fast transmission rate such as the location, acceleration and speed in order to avoid accidents [3]. Currently, there are some research focusing on the development of efficient wireless communication systems that depends on available short range communication technology as explained in Section 2.

It is known that DSRC is currently considered as the most promising wireless standard but there are some circumstances that should be addressed. One of the concerns is, DSRC technology is an expensive vehicle enhancement that require additional hardware, software and enabling infrastructure since it does not have a subscription or revenue component. Apart from it is related to exchange all safety and non-safety messages since the data that sent over the DSRC has to be processed with different priorities depending on how critical they are for vehicle safety [4]. The most important one is related to the pedestrians. This is where the difference between DSRC and Wi-Fi Direct technology as DSRC equipped cars do not have the capability to detect pedestrians but Wi-Fi Direct enhanced cars capable. In other words, not only depends on DSRC technology such as vehicle-to-infrastructure and vehicle-to-vehicle system, the mechanism on detecting the pedestrians under development using Wi-Fi Direct which is a peer-to-peer standard that allows Wi-Fi devices [5], can connect directly among each other without the need for a wireless hotspot.

We reviewed several studies which highlight some nuances related to our work, such as Tufail et al. that investigated about the behavior of network connections that are started over an IEEE 802.11g or Wi-Fi channel, where they discussed on the possibility of using IEEE 802.11 protocol in order to establish connection between fast moving vehicles and the impact of vehicle's speed [6]. Marcelo et al. then made an extended study on Tufail's work by reviewed the characteristics of links formed by in-vehicle nodes using IEEE 802.11a and Wi-Fi technologies in ad hoc mode [7]. While in [8], the researchers reviewed about the feasibility study on vehicle-to-infrastructure communication using WiMAX. A quite similar study has been carried out by Msadaa et al. where they evaluated on the performance for different vehicle speed, data rates and network deployments by using DSRC and mobile WiMAX standards [9]. They pointed out that mobile WiMAX recorded higher delay compared to DSRC while the changes on vehicle's speed does not affect the throughput performance. As in [10], Eriksson et al. developed an evaluation of CTP which is a content delivery network for moving vehicles by using IEEE Wi-Fi standard. As the latest study in [4] and [5], the researchers proposed an idea of creating groups for Wi-Fi Direct function, where there will be one group leader that acts as an access point and controls the communication between the nodes within the group. They evaluated on how Wi-Fi Direct can be used in vehicular environment in order to exchange safety-related messages about possible incoming events between smartphones of vehicle drivers. As they made a comparison between Wi-Fi Direct and DSRC standard, the result showed that transmission delay decreased resulting from their proposed broadcasting method.

II. VANET STANDARDS

A. Dedicated Short Range Communication (DSRC)

DSRC is based on the standard IEEE802.11p which also known as Wireless Access in Vehicle Environment (WAVE) [11]. It is one of the most popular technologies in communication between vehicles such as in VANET because it is a wireless technology that is used for exchanging security information between vehicles. Each vehicle broadcasts basic safety information that usually contains the speed, location and heading message [12]. By using all of these information, DSRC device in a car can calculate the probability of colliding occurrence. Although DRSC provides a reliable communication between vehicle-to-vehicle, problem concerning on the cost of DSRC hardware become a constraint. Because of the fact that DSRC requires a dedicated hardware, we can assume that it cannot be considered as the best solution to warn pedestrians or cyclists, since it may require them to carry DSRC equipment all the time. Because of this shortcoming, we use Wi-Fi Direct standard as an alternative for vehicle-to-vehicle communication in order to provide enhanced solutions for the collision avoidance application since it has been considered as potential competitor other than DSRC standard.

B. Wi-Fi Direct

Wi-Fi Direct is based on the IEEE 802.11n standard that has been developed by Wi-Fi alliance in order to ease device-to-device communication through software without using access point. It is known that Wi-Fi Direct was introduced for network-based infrastructure [13], but this research was conducted because we want to analyze the effectiveness of using this standard into vehicle-to-vehicle communication in ad-hoc mode. By replacing the DSRC standard with Wi-Fi Direct standard, safety messages can be provided with the use of Wi-Fi Direct such as speed, location and direction of the vehicle. Usually in vehicular network, the location information is obtained by using the GPS technology. Furthermore, if a mobile application can be programmed to compute necessary calculations in order to predict the collision occurrence and warn the driver, this can be considered as an economical initiative since it has no additional cost compared to DSRC. Table 1 shows the comparison of DSRC and Wi-Fi Direct communications [4]. It can be conclude that Wi-Fi Direct has more advantages especially on faster data rates over two way area coverage and also it can be applied to advanced security protocols for data transmission.

TABLE I
COMPARISON OF DSRC AND WI-FI DIRECT COMMUNICATIONS

Parameters	DSRC	Wi-Fi Direct
Operating band	5.9 GHz	5/2.4 GHz
Channel bandwidth	10 MHz	20 MHz
Data rates	6-27Mbps	Up to 250Mbps
Operating range	100m – 1000m	250m
Coverage	Two way area line of sight	Two way area
Equipment cost	$350	No additional cost

Other than the differences on DSRC and Wi-Fi Direct communication standard, there are several challenges in VANET such as security and privacy, node addressing, routing protocol, connectivity and quality of services (QoS) [14]. Here, we will focus on routing protocol in VANET by evaluating two selected of proactive and reactive routing protocols using NS-2 simulator. Noted that routing protocol has greater challenges in VANET since the features of frequently changes in topology and high mobility makes the design of efficient routing protocol become difficult and challenging. In VANET, routing protocols can be divided into two categories which is topology-based routing protocol and position-based routing protocol. Routing protocols that available in VANET is shown as in Figure 1 [15]. Most of the routing protocols are classified as topology-based routing protocols since it use link information in the network to transmit data packets from source to destination. This protocol has two approaches which is proactive and reactive routing, respectively for table-driven and on-demand [16]. On the contrary, geographic routing is a routing where every node knows its own and neighbor node position by using a service such as GPS where information from GPS devices usually used for routing decisions. This approach does not maintain any routing table or change any link state information with the neighbouring nodes [17]. In reactive routing protocol, it called as demand routing because it begins the route discovery only if a node has to communicate with other nodes. Because of this, we can say that this routing protocol will reduce the network traffic since it only maintains on the routes that are currently in use. To see the difference, we have selected two protocols which are AODV and DSDV for this study.

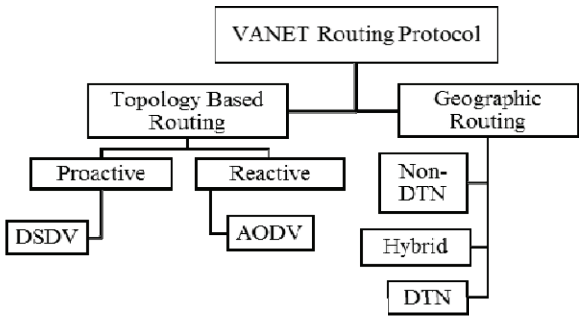

Fig. 1. Routing protocols in VANET

The rest of this paper is divided into the following sections, where Section 2 gives an overview of related work, Section 3 describes on simulation setup, and Section 4 presents on the results and analysis.The conclusion is given in Section 5 while the future work is in Section 6.

III. SIMULATION SETUP

This research is carried out by using NS-2 and SUMO traffic simulator in order to analyze the performance of AODV and DSDV routing protocol for different DSRC and Wi-Fi Direct standard in terms of the following performance metrics:

a) Throughput: The number of data packets that received at destination over simulation time.
b) Delay: Time takes for the first bit to travel from sender to receiver. This is the most significant parameters because one of VANET characteristics is hard delay constraints [18].
c) Packet loss rate: Number of packets that failed to reach the destination.
d) Packet loss rate: Number of packets that failed to reach the destination.

The simulation has evaluated in city road scenario, where the important intersections in Bandung, Indonesia named as Jl. Asia Afrika, Jl. Sunda, Jl. Tamblong, Jl. Sumatera, Jl. Belitung, Jl. Lembong, Jl. Veteran, Jl. Sunda, Jl. Kalimantan, Jl. Sumbawa, Jl. Kosambi, Jl. Naripan, Jl. Braga, Jl. Sumbawa and Jl. Veteran have been chosen as shown in Figure 2. In this scenario, the required map has been downloaded from Java OpenStreetMap Editor and configured to work with SUMO traffic simulator.

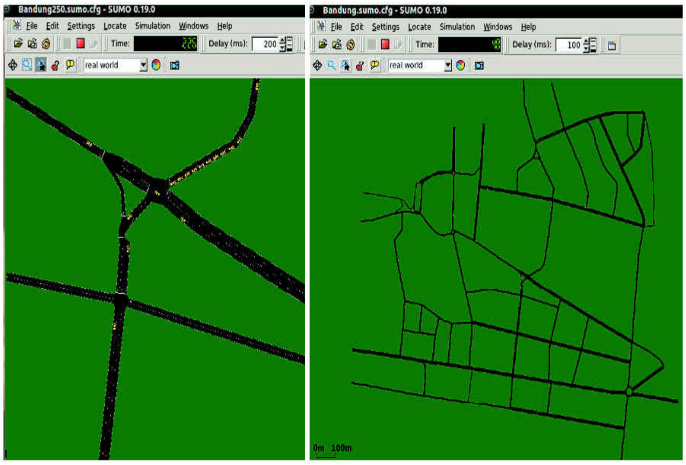

Fig. 2. Road map and vehicles movement at city of Bandung, Indonesia.

Here, we performed a simulation based on two different scenarios; (1) the effect of changes in number of vehicles and (2) the effect of changes in vehicle speed. The selection of these two scenarios are based on the characteristics of VANET which has a very high dynamic topology due to the fast moving and changing in number and speed of vehicles. The evaluation for this scenario is done by using the simulation parameters for DSRC and Wi-Fi Direct as summarized in Table 2.

TABLE 2
SIMULATION PARAMETER

Parameters	DSRC	Wi-Fi Direct
Carrier frequency	5.9 GHz	2.4 GHz
Data rate	6-27 Mbps	Up to 250 Mbps
Operating range	100-1000m	200m
Routing protocol	AODV/DSDV	AODV/DSDV
Transport protocol	TCP	TCP
Traffic type	CBR	CBR
Packet size	512 byte	512 byte
Radio propagation model	Two ray ground	Two way ground
Speed of vehicles (Scenario 1)	Random	Random
Speed of vehicles (Scenario 2)	10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120	10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120
Number of vehicles (Scenario 1)	50, 100, 150, 200, 250, 300	50, 100, 150, 200, 250, 300
Number of vehicles (Scenario 2)	2	2
Simulation area	1500m x 2000m	1500m x 2000m

Noted that in the first scenario, we choose random speed of vehicles because we want to simulate VANET like in real-time traffic conditions thus we can see the effect of changes in number of vehicles. At the beginning of simulation, we use 50 vehicles in an area of 1500m x 2000m. Then we varied the number by adding another 50 vehicles on each simulation, thus the changes will be 100, 150, 200, 250 and 300.

IV. Results and Analysis

In this city road scenario, the AODV and DSDV routing protocols have been evaluated using two standards which is DSRC and Wi-Fi Direct in order to analyze the performance of throughput, delay, packet delivery ratio and packet loss ratio. The analysis will be divided into two parts; (1) the effect of changes in number of vehicles and (2) the effect of changes in vehicle speed.

A. The Effect of Changes in Number of Vehicles

From Figure 3, we can observe that the average throughput of AODV for Wi-Fi Direct is slightly better than AODV for DSRC when the number of vehicles up until 200.

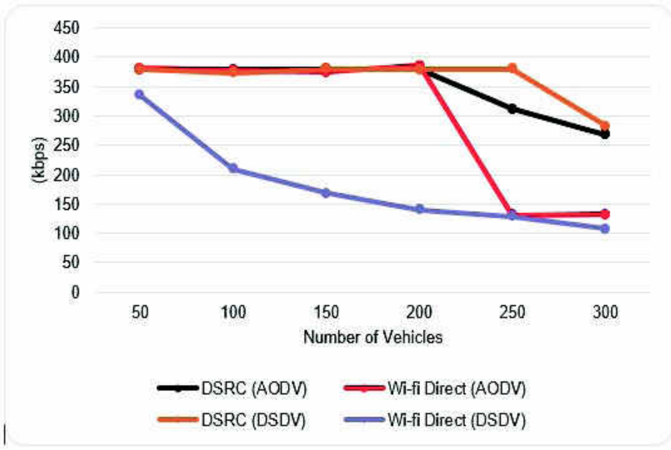

Fig 3. Throughput versus number of vehicles

However when the number of vehicles up to 300, the performance of throughput has been deteriorated. Noted that the operating range of Wi-Fi Direct is shorter than DSRC which can cause the number of hops that been transmitted increase. The changes in number of hops is caused by the rapidly changes in network topology. Due to the high number of changing hops, the greater delay will be produced thus resulting on the decreasing throughput. On the other hand, the throughput of DSDV for DSRC is much better than DSDV for Wi-Fi Direct due to the higher packet loss in Wi-Fi Direct which closely related to the multi-hop retransmission.

As in Figure 4, we can observe that the delay of DSRC for both routing protocols increased along with the increasing of vehicle number. The same goes to Wi-Fi Direct standard except for the scenario that using DSDV routing protocol. Here, the delay decreased due to the packet loss rate that reached 98.5% where almost all of the transmitted packets failed to reach the destination even though having several times of retransmission. Noted that the increasing number of vehicles will lead to the increasing number of data communication on network where there will be a possibility of collision. To avoid this collision, usually a function of back off time is needed where a new time slot that used to determine which vehicle can send the data to the destination will be produced. If the collision occurs, then the network will takes some additional back off time which in turn could lead to delay increasing. We also can conclude that the best combination for having a low delay is obtained by DSRC using AODV and DSDV routing protocol because it follows the minimum delay requirement in VANET for road safety application that should not exceed 100ms [19].

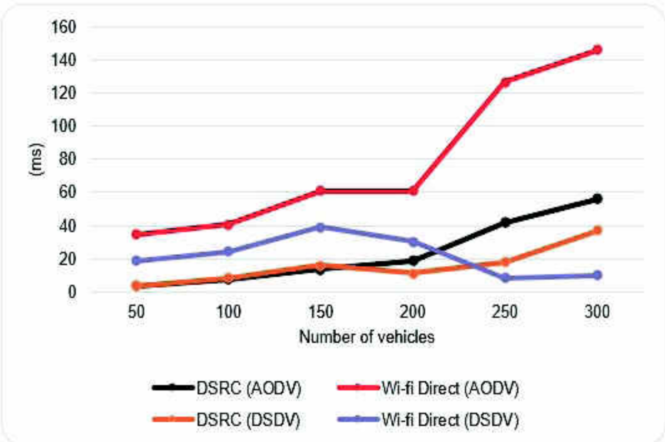

Fig 4. Delay versus number of vehicles

In Figure 5, we can see that the percentage of packet loss ratio of AODV in DSRC and Wi-Fi Direct standards has recorded a good result compared to DSDV routing protocol. In conversely, the percentage of packet loss that using DSDV routing protocol suffered a dramatic rise for both standards especially in Wi-Fi Direct. In this case, we can conclude that because of high mobility, a lot of routes are broken which causes large number of packet drop. As the number of vehicles increase, route discovery will becomes more complicated and large amount of overhead is introduced because of the communication. Then it will leads to more packet drop occurs.

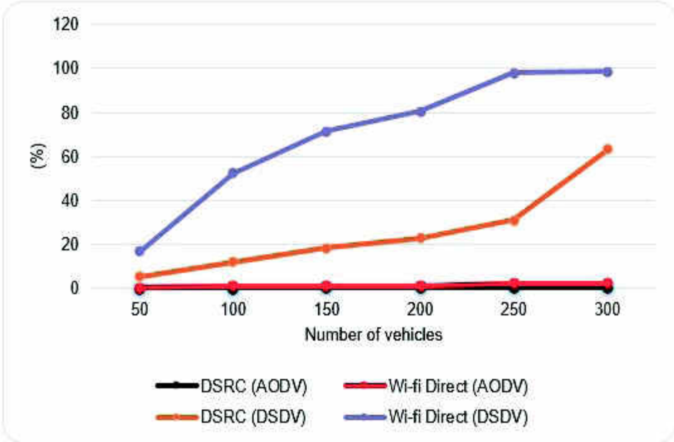

Fig 5. Percentage of packet loss ratio versus number of vehicles

Here, we also found out that the percentage of packet delivery ratio of AODV in DSRC and Wi-Fi Direct standards has recorded a good result which is nearly 100% compared to DSDV routing protocol, due to the characteristics of AODV that will only search a route when there is a demand. If the route already exists and can be used, then the function of AODV will not be executed, so that it will reduce the network load. From graph, we can see that the percentage of packet delivery ratio of DSDV is quite poor. The reason is due to the characteristics of this routing protocol that keeps changing the entire routing table periodically. In addition, whenever there is a topological change that obviously will introduce significant overhead, it will consume more bandwidth. A large amount of bandwidth is used in order to handle these overheads. That is why the packet delivery ratio suffers.

As mentioned by Wellens et al. and Msadaa et al. in their studies [8] [9], QoS performance of vehicle communication by using Wi-Fi standard showed that they achieve higher throughput and lower latency at a shorter distances, in addition they succeed to achieve higher data rate with Wi-Fi standard over longer distances. Their results also showed that larger frame size in Wi-Fi offers better throughput, consequently it will cause higher delay. Thus in this particular scenario, we can say that our simulations are qualitatively acquiescent with previous studies that have been before.

B. The Effect of Changes in Speed of Vehicles

Figure 6 shows that both AODV and DSDV routing protocol in DSRC and Wi-Fi Direct standards produce the same throughput that ranging from 10 km/h to 80 km/h which is 120.39 kbps. In ideal condition where no other vehicles interfere the communication between these two vehicles, either DSRC or Wi-Fi Direct standard will work at the same maximum level. It is proved by the same value of throughput that been produced by both standards despite several changes in speed have been made.

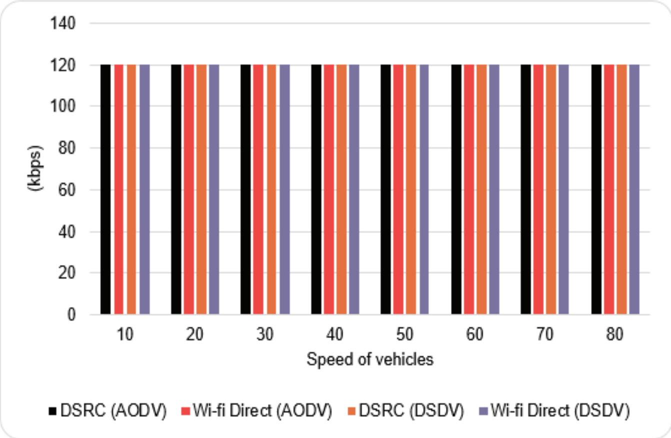

Fig 6. Throughput versus speed of vehicles

Figure 7 shows that the delay of Wi-Fi Direct standard is better than DSRC standard, at least up to a speed of 70 km/h. But when the speed is up to 80 km/h, the delay caused by DSRC standard is better. The increasing delay on Wi-Fi Direct is caused by the occurrence of packet drop retransmission during the communication process. It also shows that DSRC produces lower delay compared to Wi-Fi Direct in high-speed condition, and vice versa.

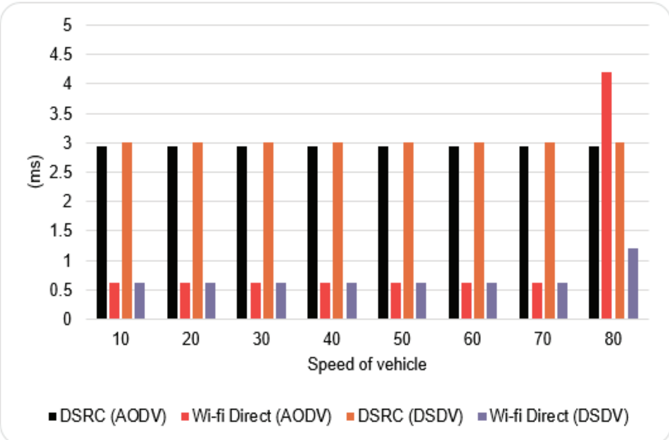

Fig 7. Delay versus speed of vehicles

As in Figure 8, the percentage of packet loss ratio for DSRC and Wi-Fi Direct using AODV routing protocol has recorded similar result, which is 0% for a speed up to 70 km/h. While for a speed of 80 km/h, the packet loss for Wi-Fi Direct using AODV and DSDV routing protocol has increased to 0.14%, respectively. Here, we can conclude that packet loss that been produced by AODV is slightly better than DSDV. This is due to the characteristics of DSDV that keeps updating their routing table periodically, thus it will cause the increasing of network load and packet loss. In this case, we can conclude that packet loss in DSRC is more stable compared to Wi-Fi Direct. In addition, if the network topology does not change, the packet loss ratio for both standards will be very minimal.

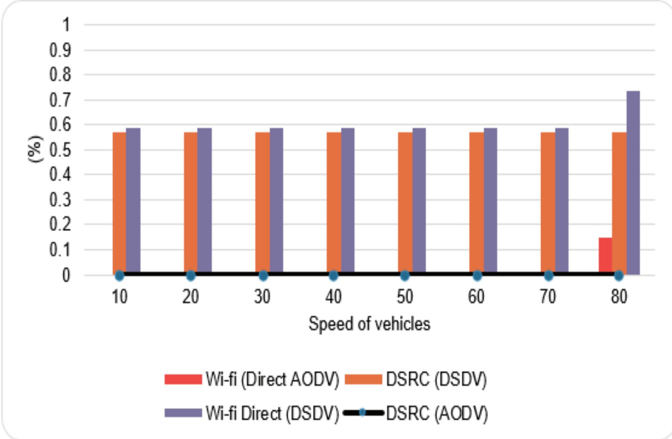

Fig 8. Percentage of packet loss ratio versus speed of vehicles

Here, we also observed that packet delivery rate is contrary to packet loss rate, where up until a speed of 70 km/h, the packet delivery ratio will reach 100% for both DSRC and Wi-Fi Direct standard by using AODV routing protocol. It means there is no packet loss. But when the speed of vehicle is 80 km/h, the packet delivery ratio will decrease to 0.14% in Wi-Fi Direct standard using both routing protocols. We can see that AODV is slightly better than DSDV due to the characteristics of DSDV that keeps updating their routing table periodically, thus it will cause the decreasing in packet delivery rate. To conclude, the changes of vehicle speed does not reduce the packet delivery rate in DSRC. On the other hand, when the vehicle is in higher speed, the packet delivery rate will be decreased slightly in Wi-Fi Direct.

V. CONCLUSION

This paper presented the evaluation of two routing protocols which is AODV and DSDV by using DSRC and Wi-Fi Direct standards in city road scenario which using the simulation environment of NS-2 in two different scenarios; (1) the effect of changes in number of vehicles and (2) the effect of changes in vehicle speed. In a nutshell, the simulation results show that AODV routing protocol outperforms DSDV routing protocol in term of average throughput, delay and packet loss ratio. Noted that the explanation on these results have been presented as in previous section. By looking at DSRC and Wi-Fi Direct standards, we can conclude that the QoS performance of AODV using DSRC is slightly better than Wi-Fi Direct standard. However based on QoS performance that has been obtained by a combination of AODV and Wi-Fi Direct standard, it shows that it has a good achievement.

For a conclusion, we know that DSRC has been considered as the most promising wireless standard but there are several circumstances that should be emphasized [4]. Instead of relying on this conventional standard that has been widely used in VANET, the extra advantage of using Wi-Fi Direct where it is known as a peer-to-peer standard that allows Wi-Fi devices, can connect directly among each other without the need for a wireless hotspot. Thus we can say that Wi-Fi Direct as the latest wireless networking standard can overtake DSRC performance in the near future.

VI. Future Work

The future work will concentrate on modifying the MAC protocol in Wi-Fi Direct standard that usually use a Uniform DCF in order to decrease the end-to-end delay and packet loss ratio while keeping the high throughput and high packet delivery ratio by using AODV routing protocol.

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