Handover Decision for V2V Communication in VANET Based on Moving Average Slope of RSS

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Abstract —In a vehicular ad hoc network (VANET), the nodes have very high mobility and hence, it is an important challenge to maintain the quality of communication. Due to the mobility, the vehicle nodes should perform handover from one infrastructure to another. Thus, the better quality of signal can be obtained. In vehicle to vehicle (V2V) communication, the nodes may experience more frequent handover than in vehicle to infrastructure (V2I) communication. Frequent handover can aggravate the networks especially in routing process, since the network topology is also changed when a handover occurred. Moreover, the network resources are also used for handover process and hence the communication overhead increases. In this paper, a handover decision method is proposed to reduce the handover rate in V2V communication while maintaining the quality of signal. The proposed method utilizes the moving average slope of received signal strength (MAS-RSS) and signal to noise ratio (SNR) threshold in handover decision process. The MAS-RSS technique is used to observe the trend of RSS fluctuation and hence the handover can be decided adaptively with the change of the network condition. As the result, the handover rate can be reduced without causing the significant decrease of SNR average compared to the ordinary RSS based handover decision method.

Index Terms—Handover decision, mobile infrastructure, moving average slope, received signal strength, vehicular ad hoc network, vehicle to vehicle

I. Introduction

The future of transportation technology envisioned the communication ability between vehicles. In intelligent transportation system, the ability of communication between vehicles will become the key part of the framework. This necessity can be attained by the emergence of vehicular ad hoc network (VANET). By installing a device called on board unit (OBU) in each vehicle, the communication network between vehicles can be established through VANET. The communication link between vehicles enables several applications such as transportation safety, traffic management, and on board entertainment. Many potential applications of VANET have been presented in [1]. Despite the hefty potential of VANET, the implementation on real world still has many challenges to overcome such as connectivity, routing [2], and security [3]. The difficulties are mainly due to the mobility of vehicles and the dynamic environment in VANET.

The high mobility causes the vehicles to change the connection from one infrastructure to another more frequently. In other words, the vehicles should perform more frequent handover. This is a detriment to the quality of communication. The frequent handover can disrupt the data transfer that leads into several problems such as delay and packet loss. The problems become more serious if the handover is decided inappropriately, e.g. handover is performed too late, too early, or to the infrastructure that eventually has a poorer signal quality. Therefore, handover decision is essential and must be performed properly.

A handover is basically a connection change from one infrastructure to another. In vehicle to infrastructure (V2I) communication, handover is performed from a road side unit (RSU) to another RSU. Meanwhile, in vehicle to vehicle (V2V) communication, handover is performed from a mobile infrastructure (MI) to another MI. Compared to an RSU which is placed in a fixed location, an MI is placed in particular vehicle such as a bus [4]. In addition, it is possible that the coverage area of an MI is overlapped with other MIs.

There is a prominent different between a V2I connection and V2V connection in term of distance change between the vehicle node and the infrastructure. In V2I connection, the distance between a vehicle node and an RSU gradually shrinks as the vehicle approaches the RSU. Afterward, the distance between vehicle and RSU gradually increases as the vehicle passes by the RSU and continues to move forward. Meanwhile, in V2V connection, the distance between the vehicle and MI can change dynamically since both are mobile. The distance change is affected by the behavior of the drivers and the traffic condition. Thus, the distance can be increased, decreased, or unchanged accordingly.

Since the distance change in V2I is easily predictable, the value of received signal strength (RSS) is also predictable and the trend is straightforward as illustrated in Fig. 1. As the vehicle approaches the RSU-1, the value of RSS increases to the maximum value i.e. when the vehicle is at the nearest distance to RSU-1. Afterwards, the value of RSS decreases as the vehicle moves away from RSU-1 and meantime, the value of RSS from RSU-2 increases. Meanwhile, in V2V connection, since the distance change is affected by the driver's behavior and

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traffic condition, predicting the value of RSS can be difficult and the trend is dynamic. For example, Fig. 2 illustrates the fluctuation of RSS measured at a vehicle node related to MI-1 and MI-2. Assume that the vehicle node follows the movement of MI-1. Thus, the distance between vehicle node and MI-1 can increase and decrease with the dynamic value of change in distance. At the same time, the vehicle node moves and passes by MI-2, as MI-2 moves at a constant speed and slower compared to the vehicle node or in another condition, MI-2 is stopping. As the result, the RSS value has a trend as in V2I connection. In this case, it can be assumed as if the vehicle node passes by a static node.

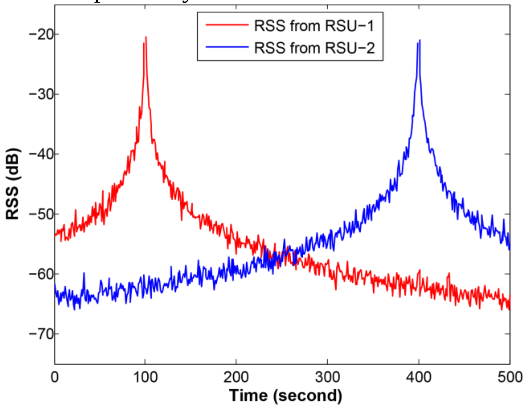

Fig. 1. RSS fluctuation in V2I connection.

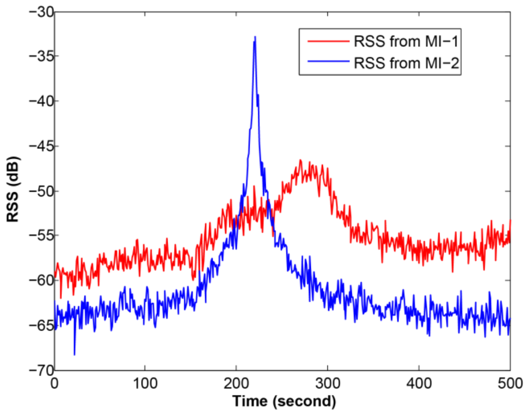

Fig. 2. RSS fluctuation in V2V connection.

In wireless networks, the common method used for handover decision is by comparing the value of RSS of currently serving cell with another nearby cell. If the value of RSS from another cell is higher than RSS of currently serving cell, then handover will be performed. In VANET, a cell can be regarded as an RSU or an MI. It can be noticed that handover decision in V2I connection is straightforward since the trend of RSS value can be predicted. However, in V2V connection, handover decision is more complicated since the trend of RSS value is dynamic. If the common handover decision method is applied in V2V connection, the vehicle can suffer the frequent handover. Therefore, handover decision in V2V connection requires a special approach. Hence, this paper proposes a handover decision method for V2V communication which aims to reduce the handover rate while maintaining the link quality i.e. the average of signal to noise ratio (SNR). Basically, the proposed method is also RSS based since RSS is the easiest metric that can be measured or obtained by the vehicle. However, we use different approach to use RSS in handover decision i.e. by employing the moving average slope of the RSS.

Moving average is a method to analyze a time series data by generating a series of averages of the time series data. Furthermore, the slope of moving average represents the steepness of moving average line, either increase or decrease. The slope of moving average is used to predict the trend of time series data. Thus, it was implemented in economics to study the market trends such as in [5]. In handover decision, the moving average slope of RSS is used to predict the trend of RSS value in spite of the rapid fluctuation. The proposed handover decision is based on the prediction result i.e. the slope of moving average. This paper is expected to give some contribution as follows.

- To reveal the handover problem in highly dynamic environment of VANET, especially in V2V communication. Furthermore, an analysis related with the appropriateness of currently existing handover decision method in wireless network for implementation in V2V communication is given.
- To propose more appropriate handover decision method for V2V communication in VANET. The proposed method utilizes the moving average slope of RSS for handover decision. Thus, this method only uses one measurement for convenience i.e. RSS, but equipped with data processing i.e. the moving average slope to decide the handover adaptively with the change of the network condition.
- To reduce the handover rate in V2V communication using the proposed method and maintain the quality of communication at the same time.

The remaining presentation of this paper is organized as follows. The review of several previous works related with handover in VANET and wireless network in general is given in section II. The presentation of the proposed handover decision method namely moving average slope of received signal strength (MAS-RSS) is given in section III. The description of system model used for simulation and the results of simulations are given in section IV. Afterwards, section V presents the conclusions of the paper.

II. Related Works

Several handover decision methods in VANET have been proposed in previous works. The parameters considered for handover decision in those previous works are various. The proposed methods to decide handover are also various. The summary of handover decision methods in previous works is presented in Table I. Not only in VANET, RSS is the parameter commonly used for handover decision in wireless networks as reported in some review papers [6], [7], and [8]. The other parameters commonly used for handover decision in

VANET are the crossing time, vehicle mobility, available bandwidth, quality of service, and monetary cost [9]. However, those parameters are more appropriate for V2I handover decision. Crossing time is very useful to estimate the connection lifetime before next handover will be performed again. Thus, selecting node with higher crossing time is the right decision in order handover rate can be reduced and the throughput can be maximized. However, crossing time estimation is possible for V2I connection since the infrastructure is not moving. Meanwhile, it is very difficult for V2V connection to estimate crossing time due to the dynamic mobility of the two connected nodes. Vehicle mobility seems to be the reasonable parameter for handover decision in V2V connection. However, it requires additional information and it can increase the communication overhead. Moreover, the utilization of GPS is not recommended due to the accuracy problem in real time application, especially for moving nodes with high speed. Network resource related parameters such as available bandwidth, network load or occupancy are important for handover decision to obtain the sufficient quality of service. However, the parameters related with network resource need the existence of infrastructure to manage the resource and provide the information to the nodes. Therefore, those parameters become less appropriate for the implementation in V2V communication where handover decision is performed in distributed manner. V2V connection is designed to be established even though without the existence of infrastructures. The other parameter, monetary cost, is irrelevant to be considered in V2V communication, since monetary cost is considered when the handover is performed between two different network technologies (vertical handover) such as WiFi and cellular. Thus, network service cost becomes the consideration of the user to select the network candidate. In V2I communication, the problem of dynamic environment is not too severe. Therefore, most of the researches related to handover in V2I connection aim to achieve seamless and low latency handover [10].

Since most of the parameters used in handover decision for V2I communication are less appropriate for the implementation in V2V communication, then this work consider RSS as the parameter for handover decision in V2V communication. The reason is that RSS can be measured directly by the nodes from the received signal from transmitter and it also represents the quality of communication link. Therefore, it is expected that in handover decision process, the communication overhead does not increase since no additional information is required. Furthermore, the problem left is how to design a specialized handover decision method to deal with the dynamic environment in V2V communication where both nodes (the node performing handover and the serving node) are mobile. Especially, in VANET environment, the vehicle nodes move at high speed and the speed difference between vehicles can vary depending on the type of vehicle and the driver's preference.

TABLE I: HANDOVER DECISION METHODS FOR VANET IN PREVIOUS WORKS

Authors	Mode	Parameters considered	Decision method
[11]	V2I	- Crossing time - Accumulative jitter	- Crossing time estimation
[12]	V2I	- Data rate - Load balance across AP	- Optimization
[13]	V2I	- Vehicle speed - Monetary cost of network - Cost of handover - Quality of service	- Markov decision optimization
[14]	V2I	- Vehicle speed - RSS	- Time thresholding - Traveling time
[15]	V2I	- SNR - Data rate - Number of users - Throughput - Packet loss - Packet Delay	- Handover initiate process - Neighbor network information container
[16]	V2I	- RSS - Type of traffic - Vehicle speed - Network occupancy	- Multiple attribute decision making
[17]	V2I	- RSS - Available bandwidth - Service type	- Fuzzy logic
[18]	V2I	- Monetary cost - Available bandwidth - Data transfer delay	- Optimal stopping approach
[19]	V2I	- Vehicle speed - Bandwidth	- Crossing time estimation

III. PROPOSED HANDOVER DECISION METHOD

The most prominent handover decision method in wireless network is based on the value of RSS [6]. In RSS based decision method, a node will perform handover if the RSS of currently serving cell is lower than another nearby cell [8]. Specifically, handover will be initiated if the RSS difference of the nearby cell (S_n) and the serving cell (S_s) is higher than hysteresis value as denoted by the following equation.

$$S_n - S_s > Hys_s \quad (1)$$

In VANET, more specific in V2V communication, the handover from an MI to another is performed by a vehicle node if the RSS from the currently connected MI is lower than RSS from another MI.

The problem in VANET is that the network environment is very dynamic and hence, the fluctuation of RSS can be severe. Moreover, the characteristic of path loss is different in every distinct environment such as urban, suburban, rural, and highway. For example, the path loss model in highway environment according to [20] is defined as follows.

$$PL = 54.02 + 16.6 \log_{10} d + \sigma_S + Y \quad (2)$$

where PL is path loss in decibel and d is the distance between a vehicle node with the MI, and σ_S is the large scale fading which is modeled using random variable with normal distribution. For highway environment, since the dedicated short range communication (DSRC) technology is assumed in this research, then the random variable to represent large scale fading has standard deviation of 3.68 dB for transmission at 5.9 GHz and with line of sight. Y is the small scale fading which is modeled using Nakagami distribution with the probability density function as follows.

$$f(x;\mu,\omega) = \frac{2\mu^{\mu}}{\Gamma(\mu)\omega^{\mu}} x^{2\mu-1} \exp\left(\frac{-\mu x^2}{\omega}\right) \quad (3)$$

where μ and ω respectively denotes the shape parameter and the average power. In this paper, the value of μ is estimated based on the transmission distance and it is defined using distance bin as presented in [21]. Furthermore, the RSS value measured at the receiver vehicle subject to PL in (2) is given by

$$S = p10^{(PL/10)} \quad (4)$$

where p is the transmission power at the transmitter vehicle. Both p and S are measured in watt.

The fluctuation of RSS can lead into frequent handover and this is detrimental especially for routing and transmission with longer duration such as streaming, call, or downloading large data. Therefore in this paper, the concept of moving average of RSS is proposed to overcome this problem. Moving average is utilized to provide another perspective of RSS with smoother fluctuation. In time series data, it is common to use moving average to smooth out the fluctuations in data. The purpose of smoothing the fluctuation is to provide the vision about the long term trend of the time series data.

Moving average is calculated based on the average of previous n data. The value of moving average at time t is the average of time series data from $(t-n)$ to t, where n is the number of discrete time series data. Based on this definition, the moving average of RSS at time t ($\overline{S}_t$) is formulated as follows.

$$\overline{S}_t = \frac{1}{n}\sum_{i=0}^{n-1} S_{t-i} \quad (5)$$

Therefore, as t moves forward, the n series of data being averaged is modified by including the newest value and excluding the oldest value. For example, the calculation of RSS moving average using RSS time series data as in Fig. 2 is depicted in Fig. 3. It can be noted that the moving average line is smoother than the RSS line. Moreover, a very high instantaneous deviation of RSS can be dampened by the means of moving average.

Based on the curve of RSS moving average, a parameter for handover decision is formulated i.e. the curve slope. The slope of RSS moving average curve represents the trend of curve in recent time. The increasing trend of RSS is denoted by the positive value of slope and the decreasing trend of RSS is denoted by the negative value of slope. The value of slope can also represent the steepness of the curve, i.e. the change rate of RSS value (either increasing or decreasing). The slope (m) of RSS moving average is calculated as follows.

$$m = \frac{\overline{S}_t - \overline{S}_{t-i}}{i} \quad (6)$$

where i is time interval which is represented by two points in RSS moving average curve. The first point denotes the value of RSS moving average at current time ($\overline{S}_t$) and the second point denotes the value of RSS moving average at previous time with interval i ($\overline{S}_{t-i}$).

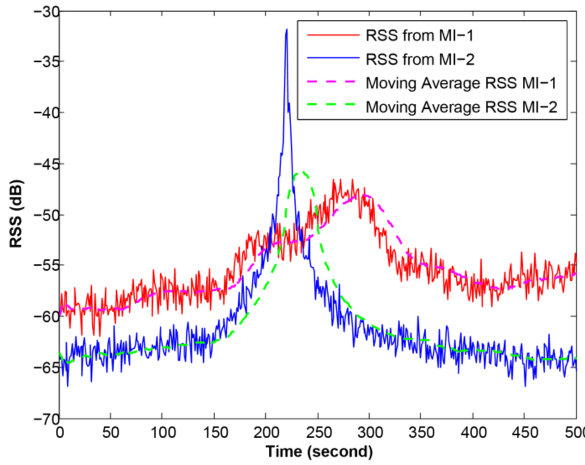

Fig. 3. Moving average of RSS in V2V connection.

The three categories of moving average slope value are depicted in Fig. 4. The positive value of slope (m>0) is more intended since it implies the increasing RSS value. Furthermore, if the curve is horizontal, then the value of m is zero or very close to zero. In this case, the trend of RSS value is constant or stable. Meanwhile, if the value of slope is negative (m<0), then the trend of RSS value is decreasing. The more negative the slope, then the decrement of RSS value is larger or faster. Thus, the negative value of m at certain level should trigger the handover. When the value of m is lower (more negative) than the threshold, the handover procedure will be initiated. However, the value of threshold must be determined appropriately. If the value of threshold is too small (more negative), the connection can be more stable and can be maintained for longer duration. However, the average of RSS will be very low and the handover may be too late to be performed. On the contrary, if the value of threshold is too high (approaching zero), the small decreasing of RSS moving average could trigger handover and hence the handover will be executed more frequently. This is unfavorable even though the average of RSS may be higher.

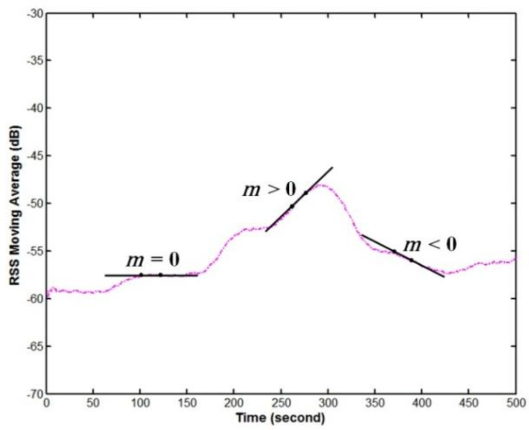

Fig. 4. The slope of RSS moving average.

If only the slope of RSS moving average is used to determine handover decision, it is possible that the connection with current MI is still maintained even though the value of RSS is very low. That is when the value of m remains negative for certain duration but it is still higher than the threshold. Thus, handover will not be performed although the RSS has dropped to very low value. Therefore, in addition to the slope of RSS moving average, another parameter is included in handover decision process i.e. the minimum value of SNR. This parameter is needed to trigger handover when the value of SNR is too low so that the transmission quality becomes poor and hence it is better to perform handover to another MI with higher RSS. The relation of RSS with SNR is as follows.

$$\Gamma_t = 10 \log_{10} \left(\frac{S_t}{BN_0} \right) \tag{7}$$

where Γ_t denotes the SNR value at current time. Γ_t is in decibel, while S_t is in watt. B and N_0 respectively represent the bandwidth of channel and the intensity of white noise.

The procedure of handover using RSS moving average slope is summarized in Algorithm 1. Since the proposed method utilizes time series data, thus RSS measurement is done periodically. In this case, probe interval (*PI*) represents the time interval between two RSS measurements. The example of *PI* value is 0.5 seconds, hence the measurement is done every 0.5 second or twice in one second. In Algorithm 1, *retain_MI* denotes an indicator that will be used in later part of algorithm to decide whether the handover will be performed or not.

Algorithm 1 – RSS moving average slope based V2V handover decision procedure

1: **for** every PI
2: $retain\_MI \leftarrow 0$;
3: measure RSS at current time (S_t) ;
4: calculate Γ_t as in (7);
5: **if** $\Gamma_t \geq \Gamma_{THD}$
6: **if** $t < n$
7: calculate $\overline{S}_t$ using t previous data;
8: **else**
9: calculate $\overline{S}_t$ using n previous data as in (5);
10: **end if**
11: calculate slope of $\overline{S}_t$ (m) as in (6);
12: **if** $m \geq m_{THD}$
13: $retain\_MI \leftarrow 1$;
14: **end if**
15: **end if**
16: **if** $retain\_MI = 0$
17: **for** $MI = 1,2,\dots,n_{MI}$
18: measure S_{MI} ;
19: **end for**
20: $MI_{selected} \leftarrow \max_{MI} S_{MI}$;
21: **else**
22: $MI_{selected} \leftarrow MI_{current}$;
23: **end if**
24: **end for**

After the RSS from current MI is measured, the value of SNR is calculated. If the value of SNR is higher than the threshold of SNR (Γ_{THD}), then the moving average of RSS at current time ($\overline{S}_t$) is calculated. Furthermore, the slope of RSS moving average (m) is calculated. If m is higher than the threshold (m_{THD}), then the connection with current MI will be maintained or in other words, handover is not performed. It can be noted that the connection with current MI will be maintained as long as both the value of SNR and the slope of moving average are equal or above the threshold. If both or one of those parameters are not satisfied, then the vehicle will perform handover i.e. by selecting nearby MI with the highest RSS as in Algorithm 1 line 20. However, it is possible that current MI still has the highest RSS among nearby MI. If so, the vehicle will maintain the connection with current MI (Algorithm 1 line 22), since it is the best choice after all.

IV. Simulation Results and Discussion

A. Simulation Setup

Simulations in this research are constituted from simulation of vehicle mobility and simulation of V2V handover. The mobility of vehicles is simulated using simulation of urban mobility (SUMO) [22]. SUMO is an open source simulator for traffic simulation with microscopic mobility of vehicles. SUMO has many features that enable flexibility of simulation such as arranging the road network, type and characteristics of vehicles, vehicles route, and visualization of simulation. Moreover, the results of simulation in SUMO can be saved in an XML file which consists of information about vehicle's ID, coordinate position, speed, angle, etc. The results of vehicle mobility simulation in SUMO are then used for simulation of V2V handover in MATLAB. For this purpose, a dedicated program is built in MATLAB which covers the signal propagation model and handover decision method.

The simulation of vehicle mobility in SUMO uses the following model. The road environment is assumed as in highway. The road network consists of a straight road with the length of 3 kilometers. There is a road junction in every 1 kilometer as illustrated in Fig. 5(a). The main road has two opposite directions, and each direction has three lanes. The vehicles are deployed at the edges of the main road and the edges of the road junctions. Furthermore, the vehicles can leave the road network through the edges of the main road or the road junctions. The types of vehicle used in simulation are car, coach, and truck. Each type of vehicle has different characteristics in terms of average speed, acceleration, and the dimension or size of the vehicle. The average speed of vehicle is defined by the maximum lane speed and the speed factor of vehicle. For example, if the maximum lane speed is 20 m/s and the speed factor of vehicle is 0.9 then the vehicle has average speed of 18 m/s. In this research, the simulations use several scenario by altering maximum lane speed from 20 m/s to 30 m/s with interval 2 m/s. Meanwhile the speed factor of car, coach, and truck are 0.9, 0.6, and 0.7 respectively. Furthermore, the dimension of vehicle, acceleration, and mobility model (such as car following model) have been defined by SUMO. The observed vehicle i.e. a car performing handover (later is called vHO) is deployed in the main road from left edge and then moves to the right edge. The speed factor of vHO is 1.2 and since it is faster than other vehicles, then vHO will perform several handover depending on the mobility of the neighbor vehicles and the handover decision method assumed.

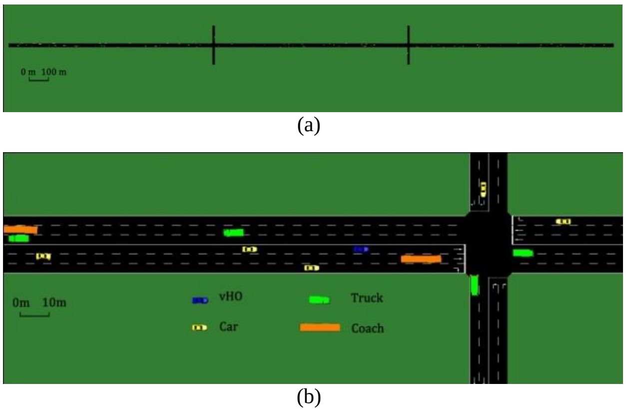

Fig. 5. Road network in SUMO for simulating the mobility of vehicles.

Handover in V2V communication is performed by vHO when it changes the connection from one MI to another. MI is a designated vehicle equipped with a device and the function is similar to an RSU. In this simulation, the coaches are assumed as the MIs. It is possible that the coverage of an MI is overlapped with the coverage of other MIs, including MIs from the opposite direction.

For the purpose of performance evaluation, the handover decision method proposed in this paper is compared with other handover decision methods based on RSS as in (1) and time average of RSS (TA-RSS) as proposed in [23]. TA-RSS based handover decision method selects the new MI with the highest value of time average of RSS which is calculated as follows.

$$\hat{S}_t^j = \hat{S}_{(t-1)}^j \cdot \left(\frac{S_t^j}{\hat{S}_{(t-1)}^j} \right)^{\gamma} \tag{8}$$

where $\hat{S}_t^j$ and $\hat{S}_{(t-1)}^j$ denote time average of RSS from MI j at current time (t) and previous time $(t-1)$ respectively. S_t^j represents the value of RSS from MI j at current time and γ is the rate which denotes the impact of current value of RSS to the calculation of time average of RSS. In TA-RSS based method, vHO always monitors RSS from all MIs and hence, the value of TA-RSS is always updated. The handover will be performed if RSS from currently connected MI is below the predefined RSS threshold.

B. *Results and Discussion*

The simulation results of V2V handover using the proposed method with maximum lane speed 20 m/s are shown in Fig. 6 and Fig. 7. When the value of SNR threshold is increased, the average of SNR increases too as in Fig 6. However, the handover rate also increases when SNR threshold is increased as indicated in Fig 7. This can be explained as follows. When the SNR threshold is higher, more handovers will be triggered. In handover decision, the proposed method selects one of the MIs with the highest RSS. The purpose is so that the gap between current SNR value and the SNR threshold is higher and hence the newly established connection can be maintained for longer duration. As the result, the average SNR becomes greater while the handover rate is also higher. On the contrary, when the SNR threshold is lower, the proposed method has more tolerance of SNR and thus the longer connection can be established. Hence, handover rate can be reduced. However, the SNR average becomes lower as the consequence of maintaining connection for the longer time.

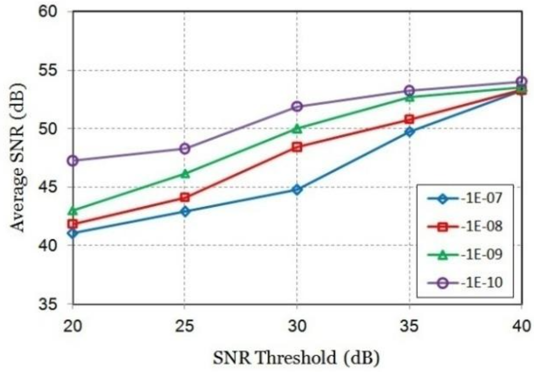

Fig. 6. Average SNR of simulation using MAS-RSS with MLS 20 m/s.

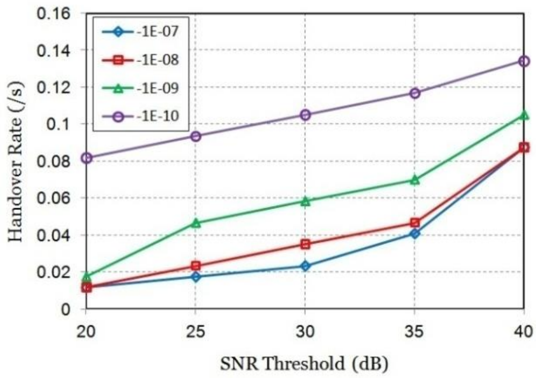

Fig. 7. Handover rate of simulation using MAS-RSS with MLS 20 m/s.

In addition to the variation of SNR threshold, the simulations were also performed by varying the slope threshold (m_{THD}) of RSS moving average. When m_{THD} is more negative, e.g. -10^{-7}, the handover rate is lower but the average of SNR is also lower. This can be explained as follows. The more negative m_{THD} means that it is more tolerant of the negative slope. In other words, it is more tolerant of the decreasing of RSS moving average. Therefore, the connection with current MI can be maintained for longer duration even though the SNR average is lower as a consequence. On the contrary, when m_{THD} is closer to zero, e.g. -10^{-10}, the handover rate is higher although the SNR average is also higher. At $m_{THD} = -10^{-10}$, vHO experienced frequent handover due to the slope drops below the threshold. Every time handover was performed, the MI with higher RSS was selected and hence the average of SNR was higher than if more negative m_{THD} was used.

The results of handover simulation using original RSS-based method are presented in Fig. 8 and Fig. 9. The highest average of SNR is obtained when the RSS hysteresis (Hys_S) is the lowest. However, the handover rate is also highest when Hys_S is at the lowest value. This is due to the lower Hys_S can trigger more handovers since the small difference of RSS between current MI and other nearby MIs is sufficient to cause handover. More handovers means higher handover rate. However, when handover is performed, the node selects an MI with higher RSS. Thus, the average SNR becomes higher. On the contrary, when Hys_S becomes higher, the handover rate and the average of SNR will decrease.

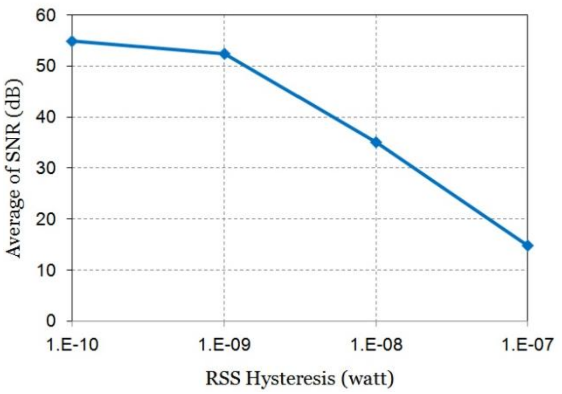

Fig. 8. Average SNR of simulation using RSS-based with MLS 20 m/s.

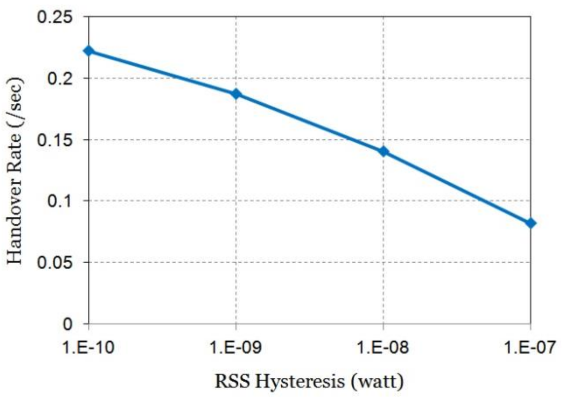

Fig. 9. Handover rate of simulation using RSS-based with MLS 20 m/s.

From Fig. 8 and Fig. 9, it can be seen that RSS-based handover decision method is straightforward i.e. by adjusting Hys_S, the average SNR and handover rate can be increased or decreased. Therefore, let us observe the effectiveness by comparing RSS-based method with the proposed method. Fig. 10 and Fig. 11 are the simulation results at lane speed 20 m/s. The results of MAS-RSS handover are taken from simulation by varying m_{THD} and using $\Gamma_{THD} = 35$ dB, meanwhile the results of RSS-based handover are taken from simulation by varying Hys_S. From these two figures, it can be noted that the reduction of handover rate during simulation using RSS-based method is less significant. However, this causes the significant decrease of SNR average. Meanwhile, MAS-RSS can reduce handover rate by adjusting the slope threshold while the decrease of SNR average is not significant.

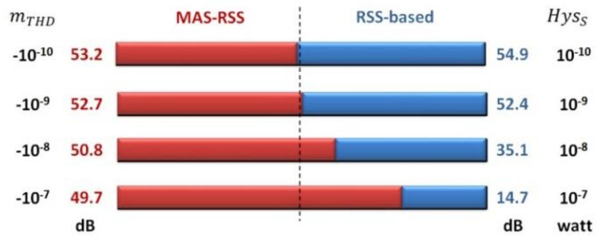

Fig. 10. Comparison of SNR average change between MAS-RSS and RSS-based handover.

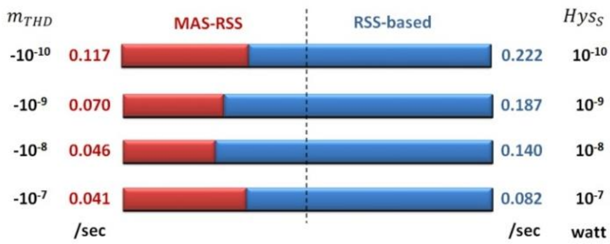

Fig. 11. Comparison of handover rate between MAS-RSS and RSS-based handover.

Furthermore, the simulation was extended by varying the lane speed from 20 m/s to 30 m/s. The results of simulation are presented in Fig. 12 and Fig. 13. Here, the purpose of varying the lane speed is to observe the relation between SNR average and handover rate. Meanwhile, the effect of lane speed toward the performance of handover decision methods cannot be concluded from these results. The more specific purpose is to compare the handover stability between the proposed method (MAS-RSS), the mainstream method (RSS-based), and another RSS-based method namely TA-RSS. Therefore, in simulations, all of the methods have the same target of SNR average. As can be seen in Fig. 12, all methods have almost same value of SNR average. Furthermore, let the handover rate distinguish the performance of the three methods. Fig. 13 shows that the handover rate of MAS-RSS method is prominently lower than RSS-based and TA-RSS method regardless the lane speed. TA-RSS method can also obtain the lower handover rate than conventional RSS-based method, since the selection of new MI is based on the time average of RSS. TA-RSS can provide the prediction of MI candidates' potential through time averaging method. Thus, the expected MI candidate should have more stable RSS value and the new connection can be maintained longer. However, the reduction of handover rate is less significant. This is because the handover is triggered if RSS of current connection drops below the predefined RSS threshold. It becomes ineffective for reducing handover rate since the fluctuation of RSS in V2V connection can be very high and frequent. Therefore, if RSS threshold is set too high, SNR average can be higher but the handover rate is also higher. The proposed MAS-RSS also applies SNR threshold to trigger handover. However, the purpose is to prevent the connection to be maintained while SNR drops too low. This is because in MAS-RSS method, the connection will be hold as long as the slope of moving average of RSS is above the threshold even though the SNR is constantly decreasing. Thus, to maintain the quality of communication, handover should be performed if SNR has dropped below the defined threshold.

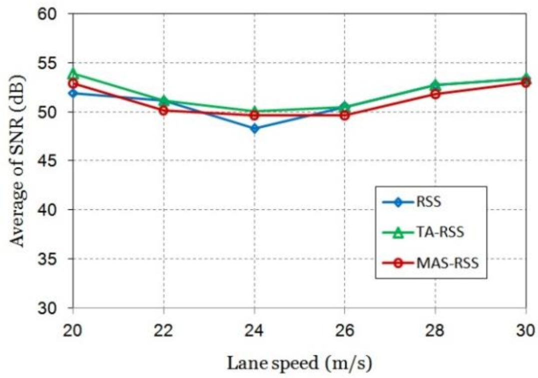

Fig. 12. Average SNR of simulations with various lane speed.

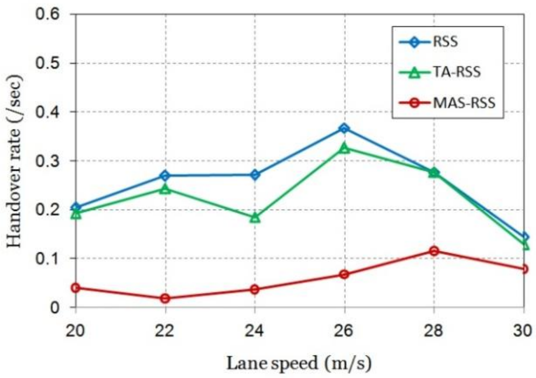

Fig. 13. Handover rate of simulations with various lane speed.

V. Conclusion

The network condition in VANET is characterized by the high mobility of the nodes and the dynamic environment. In this condition, the fluctuation of RSS can trigger a frequent handover in V2V communication. The proposed handover decision in this paper employs the moving average slope technique. The moving average of RSS is used to observe the trend of RSS fluctuation based on the previous value of RSS time series data. Afterwards, the slope of moving average is calculated to be used in handover decision process. The vehicle node will initiate a handover if the slope of moving average and the SNR value are below the thresholds. Otherwise, the node will maintain current connection regardless the RSS value from the other MIs. When a handover is performed, the vehicle node will select the MI with the highest RSS. Therefore, the proposed method can reduce handover rate without reducing the average SNR significantly. The performance of the proposed method is evaluated through simulation and compared with other handover decision methods based on RSS with hysteresis and RSS with time averaging. The results of simulations show that the same target of SNR average, the proposed method can reduce handover rate significantly than other RSS based handover decision methods.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

SA formulated the method, conducted the comprehensive simulations and wrote the paper. SS and IWM defined the problem formulation, validated and analyzed the results. RA observed the related works and conducted the vehicle mobility simulations. All authors had approved the final version.

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