Fuzzy Adaptive Hysteresis of RSS for Handover Decision in V2V VANET

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Abstract: A communication technology which enables the information exchanges between vehicles to support intelligent transportation system is the characteristic of vehicular ad hoc network (VANET). The vast applications of VANET including transportation safety, traffic management, and passenger amenities are also followed by some technical challenges. The rapid topology changes and high nodes mobility are the main source of the challenges. One of the prominent challenges is the handover decision, especially in vehicle to vehicle (V2V) communication. In this paper, handover decision method for V2V VANET is proposed using fuzzy system. The proposed method adjusts the value of received signal strength (RSS) hysteresis adaptively using fuzzy system so that the proposed handover decision method is called fuzzy adaptive hysteresis (FAH). To adjust the value of hysteresis, fuzzy system utilizes RSS value, speed difference, and connected time as the input. Based on the simulation results, the proposed method can reduce handover rate as well as maintaining the higher value of signal to noise ratio (SNR) average.

Keywords: RSS hysteresis, fuzzy system, handover decision, vehicle-to-vehicle, vehicular ad hoc network.

1. Introduction

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In the concept of intelligent transport systems (ITS), one of the principal constituents is the vehicular ad hoc network (VANET). Enabling the intercommunication between vehicles and vehicles with the infrastructures can be the major feature of VANET that will hold the important role in ITS. The intercommunication is attained by installing the required device known as the on board unit (OBU) in a vehicle. The infrastructures to support communication in VANET are deployed on the streets and thus they are called as road side units (RSUs). There are considerable diversities in the network environment of VANET. The network condition in urban roads, highways, and rural areas are naturally different, such as in terms of vehicles speed, network density, and path loss characteristics.

There are two major categories of applications in VANET. Those are safety and non-safety applications [1]. Safety applications, such as in the concept of ITS, are aimed to improve the safety of transportation by providing the crucial information to the drivers. The information related to nearby events such as sudden braking, lane changing, and pedestrian crossing is beneficial for accident prevention. Meanwhile, non-safety applications are proposed to improve the driving convenience and passenger comfort. Such examples of non-safety applications are traffic management system and congestion control [2]. The other applications are navigation system, nearby facilities information e.g. gasoline station, hospital, ATM, hotel, and so on. Furthermore, with the internet access provided by the infrastructures, other applications such as web browsing, email, online gaming, and video streaming are also enabled.

To support the various applications of VANET, a reliable communication link is required. However, it is not easy matter particularly in VANET environment where the nodes are certainly vehicles with high mobility. Hence, the topology of the network could change swiftly and the fluctuation of the signal is also strenuous [3]. Therefore, several challenges are still encountered during the implementation of VANET [4]. One of the challenges is experienced during the connection change process or known as the handover.

Based on the connection type, the link of communication in VANET can be vehicle to infrastructure (V2I) or vehicle to vehicle (V2V). Thus, the handover process in VANET is indicated by the connection change from one RSU to another RSU in V2I or connection change form one vehicle to another vehicle in V2V. The challenge rising during handover process in VANET is mainly because of the high mobility of the nodes which results the strenuous fluctuation of the signal. This problem becomes more prominent in V2V connection since the both nodes establishing the connection are mobile. This makes handover decision in VANET become more challenging. The common handover decision methods in wireless communication will be insufficient to handle handover decision in VANET.

Both V2V and V2I communications have advantages and disadvantages. However, according to [5], V2V communications will be more favorable than V2I communication, especially for the regions with rare availability of infrastructures. Several ideas have been proposed to make the infrastructure become more efficient such as the utilization of Wi-Fi instead of the dedicated hardware to support the dedicated short range communication (DSRC) [6]. However, V2I communications still demand high cost for infrastructures installation, while V2V communications just need the OBU in each vehicle to establish the connection. Based on this reason, the research of handover decision in this paper is directed to tackle the problem in V2V communications.

The remaining of this paper is organized as follows. The review of related research, highlight of the V2V handover decision problem and contribution of this paper are presented in section 2. The proposed handover decision method utilizing fuzzy system is presented in section 3. The setup, results and analysis of simulations are given in section 4. Finally, the conclusion and further research are given in section 5.

2. Literature Review

The handover problem in VANET has been investigated in several previous works. However, the number of research related with V2V handover in VANET is still limited since most of the existing works deal with the V2I handover. In

[7], a handover prediction method is proposed to improve handover performance between an access point (AP) to another AP. Handover prediction is based on the vehicle's movement. By using the prediction, the handover latency is expected to be reduced. In [8], a network mobility for VANET which supports handover between infrastructures (RSU) is proposed by extending N-PMIPv6 protocol. In [9], a handover scheme for V2I communication called FHP is proposed. In FHP, the RSU currently connected with the vehicle provides the information related with the next RSU that the vehicle will be connected in the future, and hence the handover process can be optimized. In [10], an investigation of the beaconing effect on network dwell time was conducted to attempt a smooth handover in VANET. However, the handover scenario is limited to V2I connection. More studies related to handover in VANET discuss about vertical handover, i.e. the handover between different wireless network technologies such as WiFi and cellular network. The research in [11] proposes a handover mechanism between IEEE 802.11g and 3G along with IEEE 802.11p. The research in [12] proposes a vertical handover decision algorithm which consider several parameters such as velocity, position, density, and jitter. The research in [13] proposes an optimization of handover decision algorithm. The handover scenario is between VANET and cellular networks.

The previous work that investigate the handover in V2V VANET is reported in [14]. The research in [14] studies the handover procedure of a vehicle node and the relay vehicles (RVs). A relay vehicle is a selected vehicle node that is responsible for relaying the messages and managing the communication between vehicle nodes. Thus, the concept of RVs is almost similar with the cluster head in the concept of clustering. However, only bus or other large vehicles are proposed to be the RVs. Meanwhile, the most of clustering methods use different criteria to select the cluster head such as vehicle position, speed difference, travel destination and so on. There is a difference between the work in [14] and our work. The work in [14] propose a handover procedure for VANET by employing the RVs. Meanwhile, work in this paper pays particular attention to the handover decision. A handover should be decided properly so that the quality of communication can be maintained. Here, the quality of communication is not only defined by the signal quality or known as signal to noise ratio (SNR), but also the handover rate. The higher SNR and the lower handover rate are better.

Handover decision in V2V communication is more complex compared to handover decision in V2I [15]. This is because in V2V communication, both nodes are mobile. Consequently, the pattern of signal strength becomes various. To describe this case, handover decision in V2I and V2V communication will be compared. In V2V communication, the vehicle nodes are moving from the coverage of an RSU to another as illustrated in Figure 1. When the vehicle is moving to the direction of RSU1 the signal strength from RSU1 is increasing. Afterwards, when the vehicle is leaving behind RSU1, the signal strength from RSU1 is decreasing. At the same time, the signal strength from RSU2 is increasing. When the received signal strength (RSS) from RSU2 is higher than RSS from RSU1 and the difference is higher than the hysteresis, then handover is performed. In this case, the vehicle changes the connection from RSU1 to RSU2. This method for handover decision is the common method used in wireless network generally [16].

It can be seen that the pattern of signal strength in V2I communication is straightforward. Meanwhile, in V2V communication, since both nodes are mobile, the pattern of signal strength is intricate. For example, consider the scenario as illustrated in Figure 2. Let VHO be the observed vehicle that performs handover in this scenario. VHO is moving with the average speed similar to Vtx1. In addition, VHO is significantly faster than Vtx2. Therefore, the signal strength from Vtx1 fluctuates in accordance with the distance between VHO and Vtx1. At the same time, signal strength from Vtx2 has a pattern as in V2I communication. This is because VHO moves faster than Vtx2 and eventually passes by Vtx2 as if VHO passes an RSU. From this one example of scenario, it can be imagined that many other scenarios are possible in V2V communication. Therefore, in order to adapt to this condition, a particular handover decision devised for V2V communication is required.

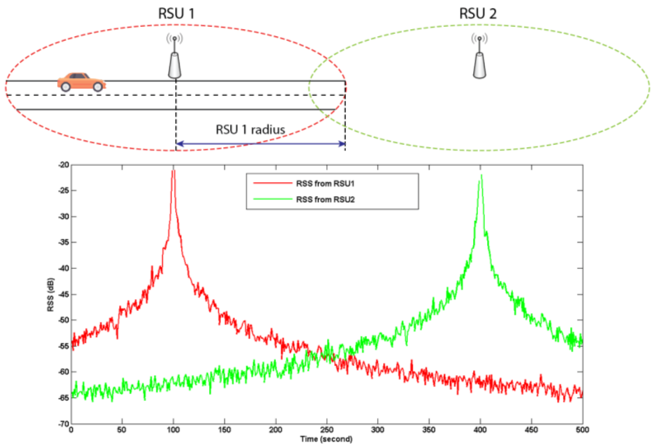

Figure 1. Signal strength in V2I connection

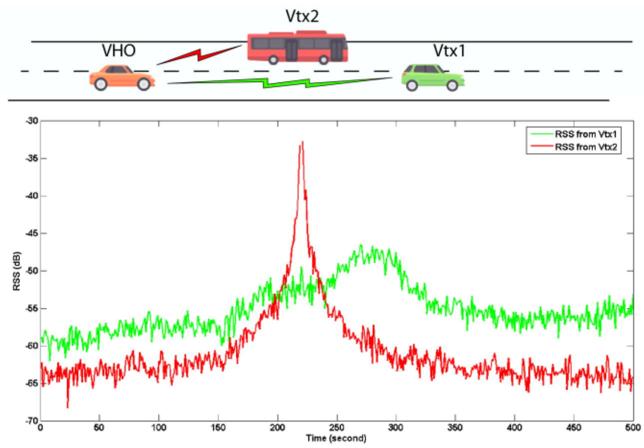

Figure 2. Signal strength in V2V connection

In handover decision, there should be metrics used as the consideration in decision making. There have been many researches about handover decision in wireless networks. The dominant metric used in those researches is the RSS as reported in some review papers [17], [18], and [16]. Some of the works also employ the RSS threshold in handover decision. However in those works, the case of handover is between a mobile node and the static serving nodes or base stations (BSs) such as in WiMAX [19], WLANs [20], and other heterogeneous networks [21]. Therefore, a specialized handover decision method with the appropriate metrics is needed for implementation 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. Therefore, this research aims to contribute as follows:

- To propose fuzzy system as a handover decision method in V2V VANET,
- To propose speed difference, received signal strength, and connected time as the metrics used in V2V handover decision,
- To reduce handover rate in V2V communication while maintaining the higher average of SNR.

3. Proposed Method

The main problem in V2V handover is the very dynamic condition in VANET environment, hence the RSS can fluctuate rapidly and the frequent handover can occur. The proposed method is devised to deal with this problem. Normally, handover will be executed if the RSS value of current Tx node (RSS_C) is lower than RSS value of other nearby Tx node (RSS_N) with the difference higher than hysteresis (Hys) as follows.

$$RSS_N - RSS_C > Hys \tag{1}$$

Then, the key idea is to adjust the hysteresis of RSS adaptively according to the environment condition. With the adaptive RSS hysteresis, the handover decision can be done more appropriately to reduce the handover rate while maintaining the average of SNR. To accomplish this goal, the fuzzy system is employed in RSS hysteresis adjustment. Fuzzy system is projected as the potential approach to solve this problem mainly due to the high computational speed so that the process of decision making can be executed very quickly. Fuzzy system is capable to do that since the decision making uses the set of fuzzy rules devised based on the expert knowledge. When the fuzzy rules have been defined, fuzzy system can process the inputs and give the result for decision making in an instant. This is because the fuzzy system can generate the output directly based on the fuzzy rules, unlike the other approaches such as artificial neural networks, metaheuristic algorithms, and other methods which need iteration to obtain the results. For the implementation in V2V handover decision, the proposed fuzzy system uses three parameters as the inputs, i.e. the speed difference between the vehicle node and the cluster head; the RSS measured by the vehicle node; and the time elapsed since the vehicle node connected with current cluster head. Meanwhile, the output of the fuzzy system is the value of RSS hysteresis which further is used for handover decision. The block diagram of the proposed fuzzy system is depicted by Figure 3.

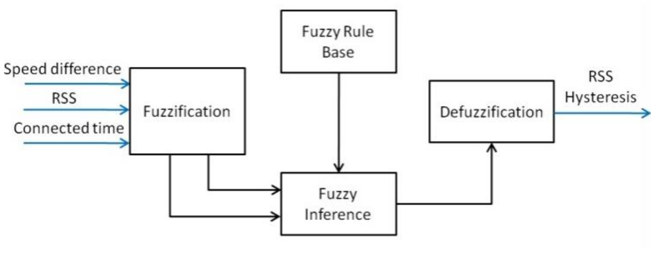

Figure 3. Block diagram of the proposed fuzzy system for V2V handover decision

The three parameters used by the proposed fuzzy system are measured by using the following methods and assumptions.

- Speed difference between cluster head and vehicle node is calculated using the assumption that the cluster head gives the information about its speed at a time to the vehicle node. Thus, the speed difference with the cluster head can be calculated by the vehicle node. Speed difference is selected as one of the input for the fuzzy system because it is related with the estimation of connection lifetime. The higher speed difference will result a shorter connection lifetime, since one vehicle will leave behind the other vehicle sooner. Meanwhile the lower speed difference will result a longer connection duration, since the two vehicles can move along together for a longer duration unless they split the direction. Therefore, speed difference is closely related with the handover decision.
- Received signal strength (RSS) is the signal strength from the cluster head and received by the vehicle node. Thus, RSS is measured at the vehicle node device. In simulation, RSS is calculated using the following formula.

$$RSS = p10^{(PL/10)} \tag{2}$$

where p denotes the transmit power at the cluster head in watt and PL is the path loss of the transmission in decibel. Path loss is the signal attenuation due to the propagation from the transmitter to the receiver. The amount of attenuation can be different in various environment such as rural, urban, or highway. Based on the experiment in [22], in highway environment, VANET's signal transmission at 5.9 GHz spectrum will suffer path loss that can be modeled as follows.

$$PL = 54.02 + 16.6 \log_{10} d + \sigma_S \tag{3}$$

In (3), d represents the distance traveled by the signal from the transmitter to the receiver and σ_S denotes a random variable to represent the large scale fading. Fading is the variation or fluctuation of signal due to the surrounding environment. During propagation, the signal can be reflected by the environment and hence creating multi path of the signal transmission to the receiver. As the result, the instantaneous signal level can be amplified or attenuated. Fading is modeled using random variable and in this case, normal distribution is used with the standard deviation 3.68 dB in highway environment.

RSS is also used as the input of fuzzy system as it is directly related with the quality of data transmission. Therefore, the handover decision should include RSS as one of the considered factors.

- Connected time represents the duration counted since the vehicle node established a connection with current cluster head. The consideration to include connected time as one of the inputs for fuzzy system is motivated by the ping pong effect. To reduce the handover frequency, the vehicle node that has just performed handover must be obstructed to perform handover again. The obstruction is equivalent with the connected time, i.e. by defining the higher value of RSS hysteresis when the vehicle node has just established a connection with the cluster head and then gradually reducing the hysteresis as long as the vehicle node is still maintaining the connection with current cluster head.

In handover decision process, the above three parameters must be considered simultaneously to acquire the appropriate RSS hysteresis for handover decision. Therefore, there are many conditions that can be created by the combination of those three parameters. In this case, an intelligent system capable of considering those three parameters for decision making is needed and fuzzy system is regarded as the proper method, especially when the light computation is preferable. To process the inputs and give the result i.e. the adaptive value of RSS hysteresis, the fuzzy system has several blocks of process as illustrated in Figure 3. The more detailed explanations of the process in each block are given as follows.

i) Fuzzification

In fuzzification, the value of each input is mapped onto membership function of its respective parameter. The membership functions for speed difference, RSS, and connected time are given in Figure 4, Figure 5, and Figure 6 consecutively. In this proposed fuzzy system, the three inputs use the same fuzzy set, i.e. low (L), medium (M), and high (H). However, the range of value and the membership function are different for each input. For convenience, the value of speed difference for fuzzy input uses the absolute value. Therefore, the value range of speed difference in Figure 4 is above zero. The value range of RSS in Figure 5 is defined based on the data from the result of handover simulation using RSS-based method with fixed hysteresis as shown in Figure 7. Meanwhile, the value range of connected time is defined empirically. The value range of the inputs is adjusted in accordance with the simulation of V2V handover in highway environment. However, the value range can be modified to work better with the condition in real world.

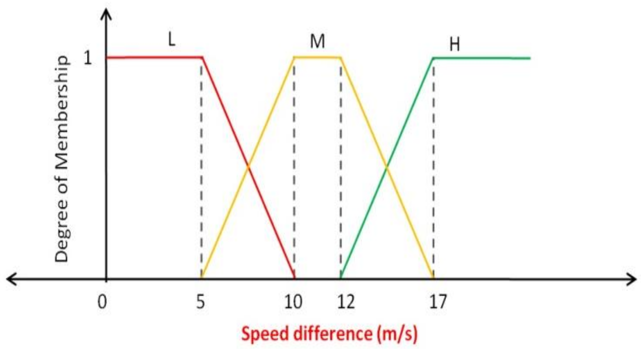

Figure 4. Membership function related to speed difference

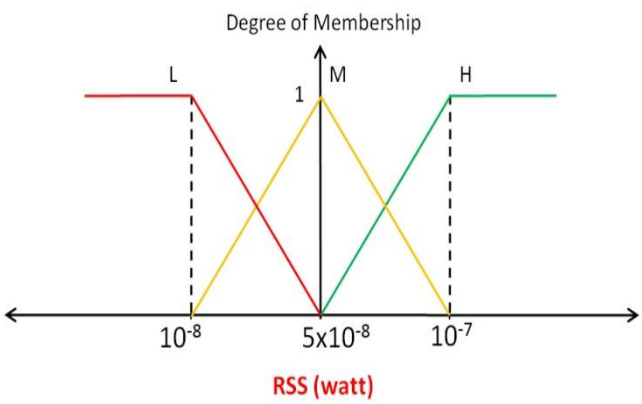

Figure 5. Membership function related to RSS value

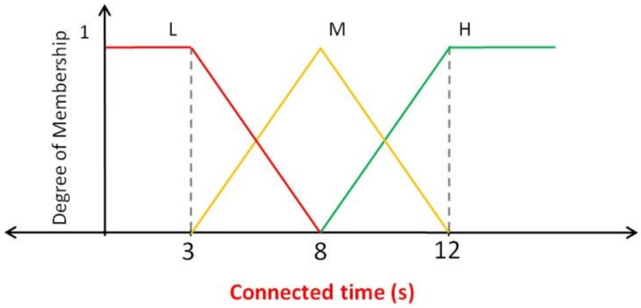

Figure 6. Membership function related to connected time

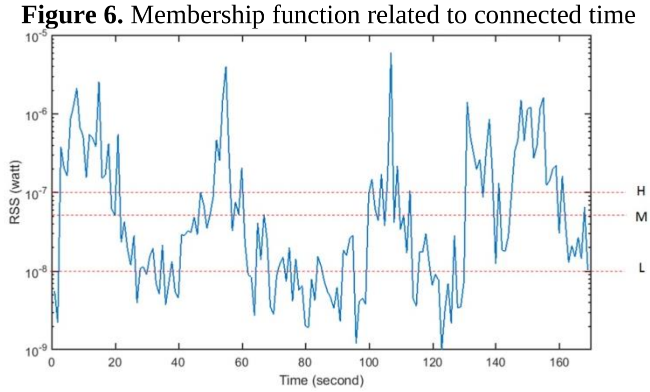

Figure 7. Value range of RSS for estimating the membership function related to RSS

The result of fuzzification is the membership value of input fuzzy set (μ_{x_1} and μ_{x_2}). The conversion of the inputs value into membership value of input fuzzy set according to the membership function is given as follows.

- Input 1 (speed difference = x_1)

$$\mu_{x_{1(L)}} = \begin{cases} 1, & x_1 \leq 5 \\ \frac{10-x_1}{5}, & 5 < x_1 < 10 \\ 0, & x_1 \geq 10 \end{cases} \tag{4}$$

$$\mu_{x_{1(M)}} = \begin{cases} 0, & x_1 \leq 5 \text{ or } x_1 \geq 17 \\ 1-\frac{10-x_1}{5}, & 5 < x_1 < 10 \\ 1, & 10 \leq x_1 \leq 12 \\ 1-\frac{17-x_1}{5}, & 12 < x_1 < 17 \end{cases} \tag{5}$$

$$\mu_{x_{1(H)}} = \begin{cases} 0, & x_1 \leq 12 \\ \frac{17-x_1}{5}, & 12 < x_1 < 17 \\ 1, & x_1 \geq 17 \end{cases} \tag{6}$$

- Input 2 (RSS = x_2)

$$\mu_{x_{2(L)}} = \begin{cases} 1, & x_2 \leq 10^{-8} \\ \frac{(5\times10^{-8})-x_2}{4\times10^{-8}}, & 10^{-8} < x_2 < 5\times10^{-8} \\ 0, & x_2 \geq 5\times10^{-8} \end{cases} \tag{7}$$

$$\mu_{x_{2(M)}} = \begin{cases} 0, & x_2 \leq 10^{-8} \text{ or } x_2 \geq 10^{-7} \\ 1-\frac{(5\times10^{-8})-x_2}{4\times10^{-8}}, & 10^{-8} < x_2 \leq 5\times10^{-8} \\ \frac{10^{-7}-x_2}{5\times10^{-8}}, & 5\times10^{-8} < x_2 < 10^{-7} \end{cases} \tag{8}$$

$$\mu_{x_{2(H)}} = \begin{cases} 0, & x_2 \leq 5\times10^{-8} \\ 1-\frac{10^{-7}-x_2}{5\times10^{-8}}, & 5\times10^{-8} < x_2 < 10^{-7} \\ 1, & x_2 \geq 10^{-7} \end{cases} \tag{9}$$

- Input 3 (connected time = x_3)

$$\mu_{x_{3(L)}} = \begin{cases} 1, & 0 < x_3 \leq 3 \\ \frac{8-x_3}{5}, & 3 < x_3 < 8 \\ 0, & x_3 \geq 8 \end{cases} \quad (10)$$

$$\mu_{x_{3(M)}} = \begin{cases} 0, & x_3 \leq 3 \text{ or } x_3 \geq 12 \\ 1 - \frac{8-x_3}{5}, & 3 < x_3 < 8 \\ \frac{12-x_3}{4}, & 8 \leq x_3 < 12 \end{cases} \quad (11)$$

$$\mu_{x_{3(H)}} = \begin{cases} 0, & x_3 \leq 8 \\ 1 - \frac{12-x_3}{4}, & 8 < x_3 < 12 \\ 1, & x_3 \geq 12 \end{cases} \quad (12)$$

ii) Fuzzy Rules

The rules in this fuzzy system are aimed to define the value of RSS hysteresis based on the value of the inputs. To determine the value of RSS hysteresis, the fuzzy set for RSS hysteresis is staged into very low (VL), low (L), medium (M), high (H), and very high (VH). The membership values of input fuzzy sets are used to determine the membership value of output fuzzy set based on the fuzzy rules as given in Table I. The fuzzy rules in Table I are defined by the user based on experience and hence the rules can be modified to work better in real world implementation.

Table 1. Fuzzy Rules for Adaptive RSS Hysteresis

		RSS		
Speed Difference	Connected Time	L	M	H
L	L	H_1	VH_1	VH_2
L	M	M_1	H_3	H_5
L	H	L_1	M_3	H_6
M	L	H_2	H_4	VH_3
M	M	M_2	M_4	H_7
M	H	L_2	M_5	M_7
H	L	L_3	M_6	H_8
H	M	VL_1	L_4	H_9
H	H	VL_2	VL_3	M_8

From Table 1, it can be seen that one fuzzy output can be resulted by several different combination of fuzzy input. For example, high speed-difference, medium connected-time, and low RSS will result a very low RSS-hysteresis as well as high speed-difference, high connected-time, and medium RSS. Therefore, the output fuzzy set is attached with an index such as in VL_1, VL_2, VL_3, and so on. In the implementation of fuzzy rules, min operator is used to define the value of output fuzzy set based on the respective input fuzzy set. The value of output fuzzy sets (μ_y) according to the fuzzy rules in Table I are given as follows.

$$\mu_{y_{(\mathrm{VL1})}} = \min\left(\mu_{x_{1(H)}}, \mu_{x_{2(L)}}, \mu_{x_{3(M)}}\right) \quad (13)$$

$$\mu_{y_{(\mathrm{VL2})}} = \min\left(\mu_{x_{1(H)}}, \mu_{x_{2(L)}}, \mu_{x_{3(H)}}\right) \quad (14)$$

$$\mu_{y_{(\mathrm{VL3})}} = \min\left(\mu_{x_{1(H)}}, \mu_{x_{2(M)}}, \mu_{x_{3(H)}}\right) \quad (15)$$

$$\mu_{y_{(\mathrm{L1})}} = \min\left(\mu_{x_{1(L)}}, \mu_{x_{2(L)}}, \mu_{x_{3(H)}}\right) \quad (16)$$

$$\mu_{y_{(\mathrm{L2})}} = \min\left(\mu_{x_{1(M)}}, \mu_{x_{2(L)}}, \mu_{x_{3(H)}}\right) \quad (17)$$

$$\mu_{y_{(\mathrm{L3})}} = \min\left(\mu_{x_{1(H)}}, \mu_{x_{2(L)}}, \mu_{x_{3(L)}}\right) \quad (18)$$

$$\mu_{y_{(\mathrm{L4})}} = \min\left(\mu_{x_{1(H)}}, \mu_{x_{2(M)}}, \mu_{x_{3(M)}}\right) \quad (19)$$

$$\mu_{y_{(\mathrm{M1})}} = \min\left(\mu_{x_{1(L)}}, \mu_{x_{2(L)}}, \mu_{x_{3(M)}}\right) \quad (20)$$

$$\mu_{y_{(\mathrm{M2})}} = \min\left(\mu_{x_{1(M)}}, \mu_{x_{2(L)}}, \mu_{x_{3(M)}}\right) \quad (21)$$

$$\mu_{y_{(\mathrm{M3})}} = \min\left(\mu_{x_{1(L)}}, \mu_{x_{2(M)}}, \mu_{x_{3(H)}}\right) \quad (22)$$

$$\mu_{y_{(\mathrm{M4})}} = \min\left(\mu_{x_{1(M)}}, \mu_{x_{2(M)}}, \mu_{x_{3(M)}}\right) \quad (23)$$

$$\mu_{y_{(\mathrm{M5})}} = \min\left(\mu_{x_{1(M)}}, \mu_{x_{2(M)}}, \mu_{x_{3(H)}}\right) \quad (24)$$

$$\mu_{y_{(\mathrm{M6})}} = \min\left(\mu_{x_{1(H)}}, \mu_{x_{2(M)}}, \mu_{x_{3(L)}}\right) \quad (25)$$

$$\mu_{y_{(\mathrm{M7})}} = \min\left(\mu_{x_{1(M)}}, \mu_{x_{2(H)}}, \mu_{x_{3(H)}}\right) \quad (26)$$

$$\mu_{y_{(\mathrm{M8})}} = \min\left(\mu_{x_{1(H)}}, \mu_{x_{2(H)}}, \mu_{x_{3(H)}}\right) \quad (27)$$

$$\mu_{y_{(\mathrm{H1})}} = \min\left(\mu_{x_{1(L)}}, \mu_{x_{2(L)}}, \mu_{x_{3(L)}}\right) \quad (28)$$

$$\mu_{y_{(\mathrm{H2})}} = \min\left(\mu_{x_{1(M)}}, \mu_{x_{2(L)}}, \mu_{x_{3(L)}}\right) \quad (29)$$

$$\mu_{y_{(\mathrm{H3})}} = \min\left(\mu_{x_{1(L)}}, \mu_{x_{2(M)}}, \mu_{x_{3(M)}}\right) \quad (30)$$

$$\mu_{y_{(\mathrm{H4})}} = \min\left(\mu_{x_{1(M)}}, \mu_{x_{2(M)}}, \mu_{x_{3(L)}}\right) \quad (31)$$

$$\mu_{y_{(\mathrm{H5})}} = \min\left(\mu_{x_{1(L)}}, \mu_{x_{2(H)}}, \mu_{x_{3(M)}}\right) \quad (32)$$

$$\mu_{y_{(\mathrm{H6})}} = \min\left(\mu_{x_{1(L)}}, \mu_{x_{2(H)}}, \mu_{x_{3(H)}}\right) \quad (33)$$

$$\mu_{y_{(\mathrm{H7})}} = \min\left(\mu_{x_{1(M)}}, \mu_{x_{2(H)}}, \mu_{x_{3(M)}}\right) \quad (34)$$

$$\mu_{y_{(\mathrm{H8})}} = \min\left(\mu_{x_{1(H)}}, \mu_{x_{2(H)}}, \mu_{x_{3(L)}}\right) \quad (35)$$

$$\mu_{y_{(\mathrm{H9})}} = \min\left(\mu_{x_{1(H)}}, \mu_{x_{2(H)}}, \mu_{x_{3(M)}}\right) \quad (36)$$

$$\mu_{y_{(\mathrm{VH1})}} = \min\left(\mu_{x_{1(L)}}, \mu_{x_{2(M)}}, \mu_{x_{3(L)}}\right) \quad (37)$$

$$\mu_{y_{(\mathrm{VH2})}} = \min\left(\mu_{x_{1(L)}}, \mu_{x_{2(H)}}, \mu_{x_{3(L)}}\right) \quad (38)$$

$$\mu_{y_{(\mathrm{VH3})}} = \min\left(\mu_{x_{1(M)}}, \mu_{x_{2(H)}}, \mu_{x_{3(L)}}\right) \quad (39)$$

iii) Fuzzy Inference

Fuzzy inference aims to summarize the output fuzzy set after the fuzzy rules have been implemented. Thus, after fuzzy inference process, the membership value of output fuzzy set can be obtained. The inference of fuzzy output uses max operator as given by the following equations.

$$\mu_{y_{(\mathrm{VL})}} = \max\left(\mu_{y_{(VL1)}}, \mu_{y_{(VL2)}}, \mu_{y_{(VL3)}}\right) \quad (40)$$

$$\mu_{y_{(\mathrm{L})}} = \max\left(\mu_{y_{(L1)}}, \mu_{y_{(L2)}}, \mu_{y_{(L3)}}, \mu_{y_{(L4)}}\right) \quad (41)$$

$$\mu_{y_{(\mathrm{M})}} = \max\left(\mu_{y_{(M1)}}, \mu_{y_{(M2)}}, \dots, \mu_{y_{(M8)}}\right) \quad (42)$$

$$\mu_{y_{(H)}} = \max\left(\mu_{y_{(H1)}}, \mu_{y_{(H2)}}, \dots, \mu_{y_{(M9)}}\right) \quad (43)$$

$$\mu_{y_{(\mathrm{VH})}} = \max\left(\mu_{y_{(VH1)}}, \mu_{y_{(VH2)}}, \mu_{y_{(VH3)}}\right) \quad (44)$$

iv) Defuzzification

The final output of fuzzy system namely the value of RSS hysteresis will be obtained after defuzzification process. The value of RSS hysteresis is divided into five levels, i.e. VL, L, M, H, and VH with the membership function as presented in Figure 8. To calculate the fuzzy output (y^*), center of average is utilized as expressed in (45).

$$y^* = \frac{\sum_i^N \mu_i y_i}{\sum_i^N \mu_i} \quad (45)$$

where i and N respectively denote the index and the total number of fuzzy output set. μ_i is the membership value toward fuzzy output set i; while y_i is the RSS hysteresis value of fuzzy output set i. Furthermore, based on the center average formula in (45) and membership function as in Figure 8, the crisp value of fuzzy output (RSS hysteresis) is defined by

$$y^* = \left[\left(\mu_{y_{(\mathrm{VL})}}\right)(10^{-10}) + \left(\mu_{y_{(\mathrm{L})}}\right)(5\times10^{-10}) + \left(\mu_{y_{(\mathrm{M})}}\right)(10^{-9}) + \left(\mu_{y_{(H)}}\right)(5\times10^{-9}) + \left(\mu_{y_{(\mathrm{VH})}}\right)(10^{-8})\right] / \left(\mu_{y_{(\mathrm{VL})}} + \mu_{y_{(\mathrm{L})}} + \mu_{y_{(\mathrm{M})}} + \mu_{y_{(H)}} + \mu_{y_{(\mathrm{VH})}}\right) \quad (46)$$

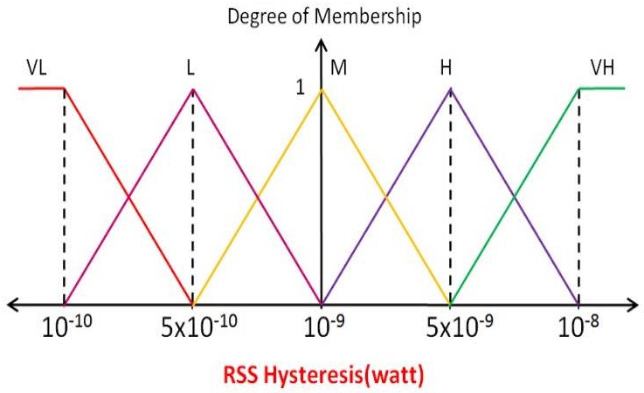

Figure 8. Membership function related to RSS Hysteresis

4. Simulation Results and Discussion

4.1 Setup of Simulation

In this research, the simulation of vehicle mobility is carried out using a simulator namely simulation of urban mobility (SUMO). In this simulator, user can define several parameters such as road length, number of lanes, maximum lane speed, type of vehicles, vehicle's speed factor, vehicle density, and so on. Parameters that determine the average speed of vehicle is the vehicle's speed factor and maximum lane speed. Speed factor is the multiplier of maximum lane speed that defines the average speed of vehicle. In this research, the values of parameters used in the simulation of vehicle mobility in SUMO are given in Table 2.

In mobility simulation, VHO is the observed vehicle performing handover during simulation. Handover is performed from one mobile infrastructure to another. The concept of mobile infrastructure as presented in [23] is similar to RSU but mobile. This is enabled by installing infrastructure equipment to the buses or coaches. To ensure VHO performing handover several times during simulation, the speed factor of VHO is set higher than other vehicles.

Table 2. Parameters Value for Moblity Simulation

Parameters	Value
Road length	3 kilometers
Number of lanes	3 lanes each direction
Number of road junctions	2 (every 1 km)
Maximum lane speed	20-30 m/s
Truck speed factor	0.7
Coach speed factor	0.6
Car speed factor	0.9
VHO speed factor	1.2

The results of simulation from SUMO are the vehicle mobility data consisting of vehicle position, speed, and direction each second. The data of vehicle mobility is used for handover decision simulation in MATLAB. For the purpose of performance evaluation, the handover decision method proposed in this paper is compared with RSS based handover decision as in (1) with several values of hysteresis ranging from 10^{-7} to 10^{-10}.

The metrics used for performance evaluation are the average of SNR and handover rate. SNR determines the quality of communication, thus it is normally used to evaluate the performance of handover decision. Another metric widely used to evaluate the performance of handover decision is the handover rate which the lower value of handover rate means the better performance. In this research, handover rate is presented in per second which means the total number of handover occurred during simulation is divided by the duration of simulation. The duration of simulation is the time needed by VHO to pass 3 kilometers road with the defined speed factor.

4.2 Results and Discussion

The simulation results of V2V handover using the proposed method (FAH) and RSS based method are presented in Figure 10 and Figure 11. In Figure 10, it can be seen that FAH and RSS based method using hysteresis value 10^{-9} and 10^{-10} can obtain high value of SNR average. Meanwhile, RSS based method using hysteresis value 10^{-8} and 10^{-7}has lower SNR average. It can be noted that the higher SNR average can be obtained by setting the hysteresis into the lower value. This is because the lower value of hysteresis allows handover to be performed sooner. Hence, the new connection with higher SNR can be established sooner. Meanwhile, the higher value of hysteresis will give more restriction so that the current connection will be maintained for the longer duration. Therefore, in term of handover rate, the higher hysteresis value has the lower handover rate.

Although FAH and RSS based method with hysteresis value 10^{-9} and 10^{-10} can obtain high value of SNR average, in term of handover rate, FAH has lower handover rate as can be seen in Figure 11. Based on the simulation results RSS based handover decision has a certain characteristic. When the hysteresis value is lower, the average of SNR can be higher but the handover rate increases. On the contrary, when the hysteresis value is higher, the average of SNR is lower but the handover rate decreases. However, the proposed handover decision method (FAH) can adjust the hysteresis value of RSS adaptively so that the lower handover rate can be obtained while maintaining the higher value of SNR average.

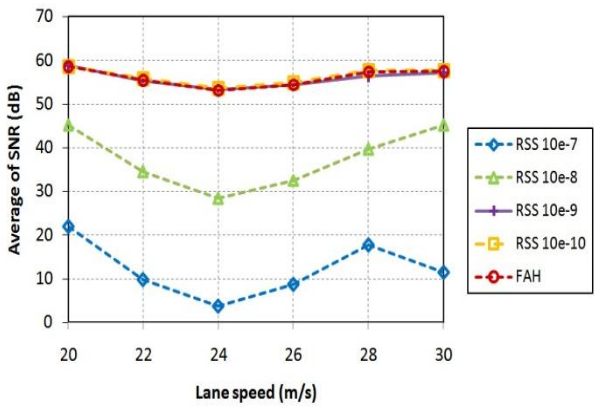

Figure 9. Average of SNR from handover simulation

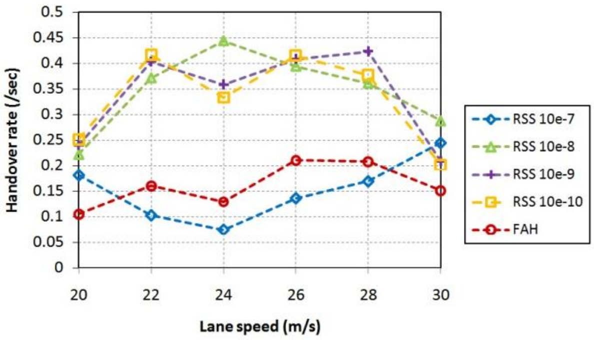

Figure 10. Handover rate from handover simulation

5. Conclusion

A handover decision method for V2V VANET utilizing fuzzy system is proposed in this paper. In order to adapt with the frequent change of topology and high mobility of the nodes, fuzzy system is used to adjust the hysteresis of RSS adaptively. Here, the inputs of fuzzy system are comprised of RSS value, speed difference, and connected time. By adjusting the hysteresis of RSS appropriately, the proposed method can reduce handover rate as well as maintaining the higher value of SNR average. Further research related to this work is the optimization of membership function in fuzzification. Since V2V VANET is highly dynamic, the fixed membership function is less appropriate for implementation in real world. Therefore, membership function should be adjusted according to the actual condition. An optimization method can be proposed to solve this problem.

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