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# Fuzzy Logic-based Intelligent Scheme for Enhancing QoS of Vertical Handover Decision in Vehicular Ad-hoc Networks

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**Abstract.** The design of next generation networks in various technologies under the “Anywhere, Anytime” paradigm offers seamless connectivity across different coverage. A conventional algorithm such as RSSThreshold algorithm, that only uses the received strength signal (RSS) as a metric, will decrease handover performance regarding handover latency, delay, packet loss, and handover failure probability. Moreover, the RSS-based algorithm is only suitable for horizontal handover decision to examine the quality of service (QoS) compared to the vertical handover decision in advanced technologies. In the next generation network, vertical handover can be started based on the user’s convenience or choice rather than connectivity reasons. This study proposes a vertical handover decision algorithm that uses a Fuzzy Logic (FL) algorithm, to increase QoS performance in heterogeneous vehicular ad-hoc networks (VANET). The study uses network simulator 2.29 (NS 2.29) along with the mobility traffic network and generator to implement simulation scenarios and topologies. This helps the simulation to achieve a realistic VANET mobility scenario. The required analysis on the performance of QoS in the vertical handover can thus be conducted. The proposed Fuzzy Logic algorithm shows improvement over the conventional algorithm (RSSThreshold) in the average percentage of handover QoS whereby it achieves 20%, 21% and 13% improvement on handover latency, delay, and packet loss respectively. This is achieved through triggering a process in layer two and three that enhances the handover performance.

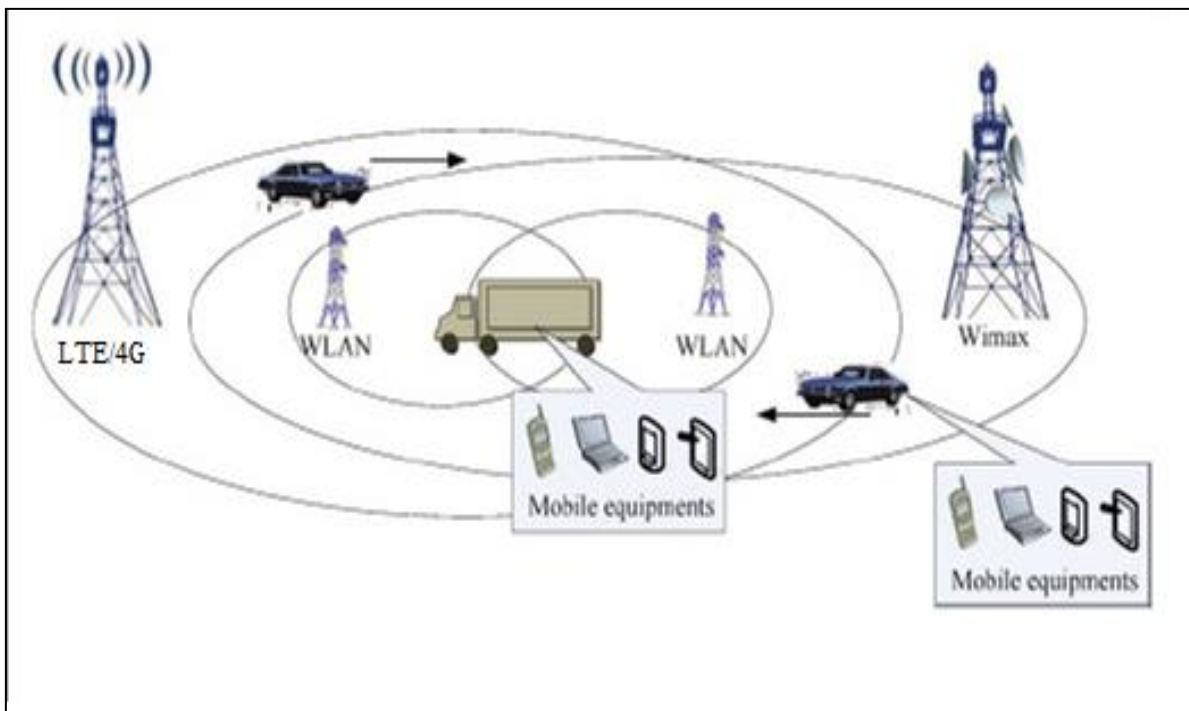
## 1. Introduction

Users’ demand for mobile Internet access is increasing every day. Several types of radio access technologies are available and implemented with their own properties such as bandwidth, response time and coverage area. These properties are essential due to the development of applications and services that require large bandwidths, low latency, anywhere and anytime connection alive without disconnection and so on. However, to accommodate these needs, new and better networks are being specified and developed. For example, popular applications among mobile users nowadays include those used for video conferencing, email, messaging and even live TV. Most of these applications necessitate that the connection be maintained as the device move from one access point (AP) to another. Sometimes a mobile user needs to change the connection to another type of network. Vertical handover mechanisms can be used for seamless mobility and better service quality in networks.

The main problems with current handover mechanism are a lot of unnecessary handovers and dropped calls [1]. The unnecessary handovers and dropped calls occur due to low signal, and the long distance between the device and the AP or Base Station. Furthermore, these problems can also occur in overlapping areas where mobile users travel quickly back and forth between one cell and the next cell in the network. The conventional handover algorithm (e.g. RSS-based algorithm) is more suitable



for horizontal handover networks that use only the received signal strength (RSS) as a single metric. However, in vertical handover decision-making, the received signal strength (RSS) is not sufficient to make an optimal handover decision [2]. Therefore, to make an optimal decision, parameters such as cost of service, available bandwidth, power requirements, QoS and user preferences, should be implemented as multi-metrics in the vertical handover. However, it is a challenge to develop a vertical handover decision algorithm for optimal radio resource utilization that requires several QoS criteria. Figure 1 shows the problems that occur in different radio access technologies that use RSS-based algorithm. The problems are increased handover latency, higher packet loss, and higher handover delay in real-time application and so on.



**Figure 1.** Vertical handover in vehicular ad-hoc network

Other issues that cause instability in the link quality in a wireless access network are natural interference, multi-path fading, and increase in signal-to-noise ratio. These problems affect the growing users' demand for entertainment applications such as high-speed Voice-over-IP (VoIP) and Internet Protocol TV (IPTV) services during traveling [3].

## 2. Vertical handover

Handover management (HM) is a mechanism that allows mobile users to be connected to their service network and continue to use the mobile terminal while moving from a single Point of Attachment (PoA) to another PoA network coverage. HM has two categories: horizontal handover and vertical handover. The horizontal handover (known as intra-system handoff or homogeneous) involves PoAs of different cells but in the same networks, whereas the vertical handover (VHO) (known as inter-system handoff or heterogeneous) involves PoAs in different network access technologies. In a homogeneous network, it typically requires horizontal handover when a mobile terminal (MT) moves into an area where the coverage of an AP or BS is not available due to the movement of the MT. For instance, the changes in MT's signal transmission from an AP with IEEE 802.11 to a neighboring AP with IEEE 802.11 is considered as two horizontal transformation processes. However, in

heterogeneous networks, the changeover of radio signal transmission between WLAN AP and BS that overlay a cellular network is called vertical handoff process.

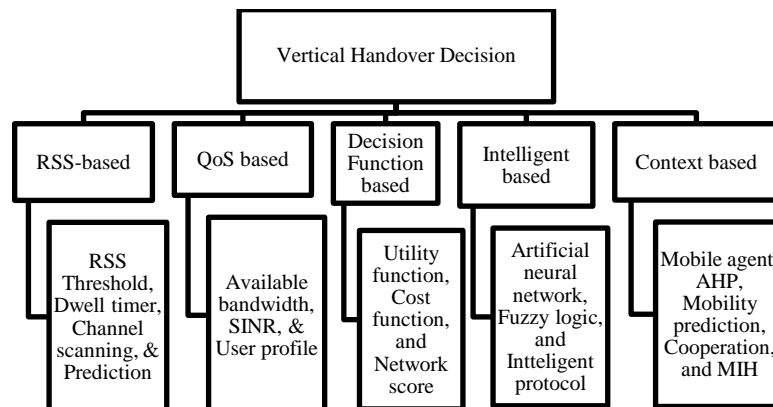
Seamlessness and network switching are two important characteristics in vertical handover management that require further investigation. Vertical handover is the key for future wireless communication to prepare for advanced technological change from the superseded horizontal handover. This is due to the multi-technology integrated network grouping, that offers broadband access to mobile users [4]. However, horizontal handover occurs only when the receiver signal strength (RSS) becomes weak in its coverage, whereas vertical handover depends on users' assessment and experience.

There are three stages in the vertical handover process which include handover information gathering, handover decision, and handover execution [7, 8]. The foremost concern of vertical handover is to sustain running services even with the IP address adjustments, and change of network interfaces and quality of service (QoS) characteristics in the multi-different networks. Discussion on handover topics must involve three main phases [9, 10]. The first stage is handover information gathering, where the mobile node identifies particular information required to determine the necessity for a handover process [9]. Normally, the information initiation, as shown in Table 1, is prepared.

**Table 1.** Data collection in handover information gathering.

Information Collection	Parameters
Network detection in neighbors network	<ul style="list-style-type: none"> <li>Throughput, handover rate, cost, packet loss ratio, Received Signal Strength (RSS), Noise Signal Ratio (NSR), Signal to Interference Ratio (SIR), Carrier to Interference Ratio (CIR), Bit Error Ratio (BER), distance, location, and QoS parameters.</li> </ul>
Mobile node status	<ul style="list-style-type: none"> <li>Battery status, speed, resources, and service category.</li> </ul>
User preferences	<ul style="list-style-type: none"> <li>Budget, monetary cost, and services</li> </ul>

The next stage is handover decision process where the most suitable network access will be identified and determined as an MT moves into the handover area. This stage will also be associated with communicating instructions to the execution stage, which is known as system selection. In literature, numerous studies discuss the categorization of vertical handover (VHO) decision schemes as mentioned in [10][11][12][13][14][15]. The last stage is the handover execution process, where a mobile terminal moves from its current network to the new network coverage. A seamless network connection will be achieved if the handover decision algorithm is intelligent enough to decide the best candidate network by considering several parameters related to the complexity of current network architecture and technological advancement [16][17][18][19]. Based on the existing work, VHO decision-making schemes can be categorized into five classes. The schemes and the methodologies to process the handover decisions are shown in Figure 2.



**Figure 2.** Category of Vertical Handover Decision Schemes [7]

In addition, a summary of the comparison of vertical handover decision schemes is presented in Table 2.

**Table 2.** Comparison of vertical handover decision schemes

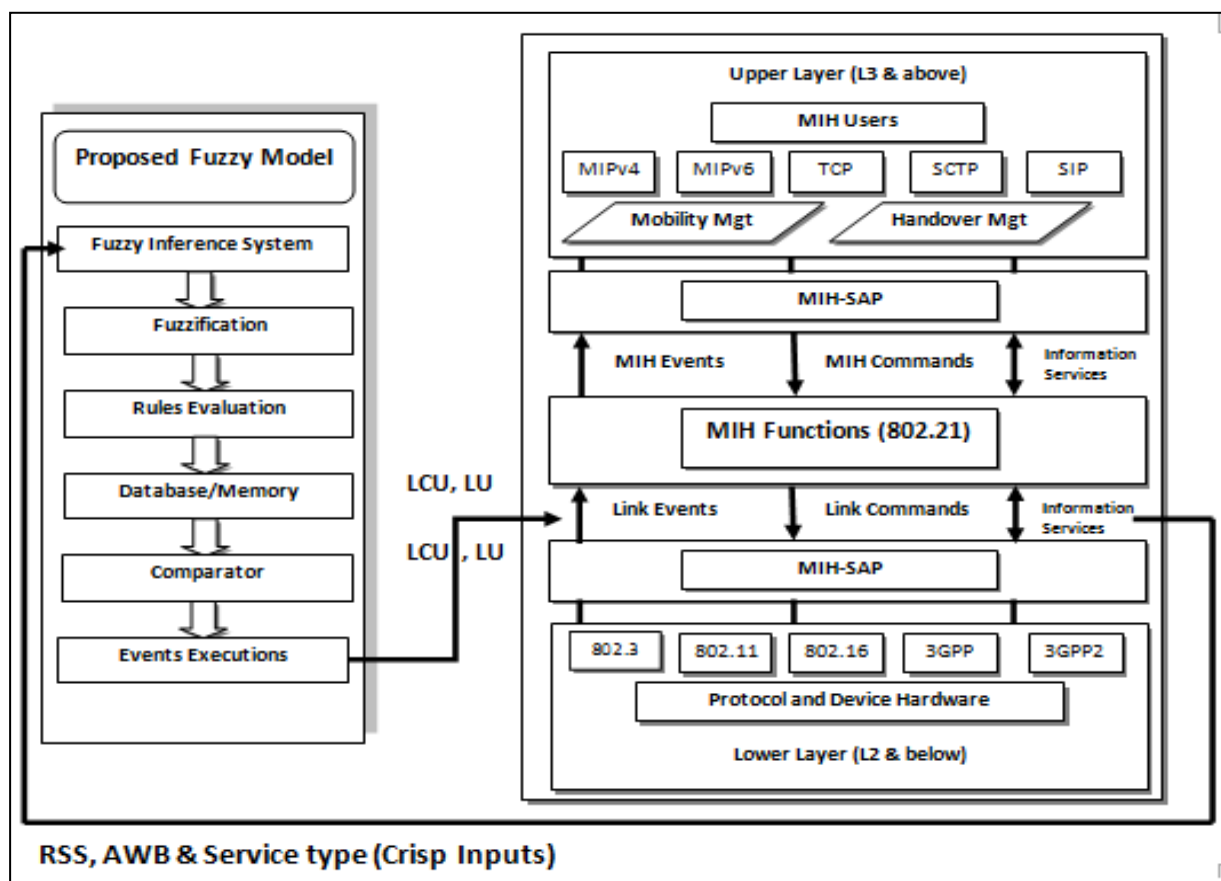
Category of VHD Scheme	Description	Advantages	Drawbacks	Author
RSS-based Scheme	The decision of handover only based on RSS value and another metric assist for handover procedures but not directly involved in the handover decision making.	Reduced handover delay, reduced handover failure, reduced Ping-Pong effect.	Increased packet loss, increased signaling, higher handover delay in real time application, increased handover latency.	[12], [20], [21], [22], [23], [24], [25], [26]
QoS based Scheme	To maximize the QoS using the metrics of available bandwidth, user preferences and Signal-to-Interference and Noise Ratio (SINR) for making an optimal handover decision.	High throughput, decreased handover latency, less packet loss, reduced handover delay.	High Ping-Pong effect, not applicable for high speeds, higher resource consumption, inefficient bandwidth calculation.	[27], [28], [29], [30],[31]
Decision Function based Scheme	This handover decision making in order to select the best available networks becomes multi-criteria decision making (MCDM). The MCDM has included the cost, utility, score, and policy-based functions.	Cost effective, low handover blocking rate, reduced Ping-Pong effect, rank network selection.	Increased handover latency, unsuitable real-time application, high communication delay.	[32], [33], [13], [34], [16], [35], [11], [36]
Intelligent based Scheme	This scheme is used to overcome the issues of handover performance that irreversible in real-time data delivery in terms of handover latency, throughput, and unnecessary handovers.	Reduced handover delay, reduced latency, lower packet loss, successful handover, intelligent network selection, users satisfaction	High complexity, higher decision processing delays, high signaling overhead	[17], [18], [37], [38], [39], [40]
Context-based Scheme	The context is defined within any information that is relevant to the situation of an entity (person, place or object.). In other words, it is the distribution of correct and accurate information to the end users for making a decision.	Optimal network selection, reduced packet loss, high throughput,	Higher resource consumption, increased communication overhead, high signaling cost, security provision.	[41],[42],[43], [44],[45]

### 3. Experiment

This section has two subsections, the integrated Fuzzy Logic (FL) with Media independent handover (MIH), and simulations and parameters. The simulation was performed using VanetMobiSim and the simulator NS2.29, with add-on modules, which integrated multiple packages including the MIH or IEEE 802.21 standard library. The modules were developed by the National Institute of Standards and Technology (NIST).

### 3.1 Integrating Fuzzy Logic and IEEE 802.21 Media independent handover (MIH)

This subsection explains the experiment and simulation scenario of the proposed Fuzzy Logic VHO with MIH mechanism. The MIH protocol represents IEEE 802.21 standard deployed information exchange between peers for triggering handover. In addition, it allowed common information payload through the various media technologies such as 802.3, 802.11, 802.16, and Cellular/UMTS/LTE [46]. In general, MIH prediction algorithm had four services which included link up (LU), link down (LD), a link going down (LGD), and link coming up (LCU) that determined the events in MIH. The parameters such as received signal strength (RSS), available bandwidth (ABW) and service type (assume as available) were utilized for decision-making. After that, it used the information to acquire the link status from the MIH event service manager as shown in Figure 3. The proposed Fuzzy Logic algorithm was designed to select the best candidate networks that solved handover delay and packet loss handover problems. The MIH prepared significant crisp input (e.g. RSS, ABW, and service types) through the Information Service (IS), which gathered data from available networks such as Wi-Fi, WiMAX, and LTE networks. The prediction method used crisp input from the MIH IS and fed them into Fuzzy Logic scheme to overcome connection quality issues. The event execution process in the Fuzzy Logic model transmitted label information to the MIH event service that managed the degree of link trigger.



**Figure 3.** Fuzzy Logic model with MIH process

The process began when the fuzzy inference system (FIS) received the crisp inputs (e.g. AWB, RSS, and service type) from the MIH and then evaluated the inputs and referred it to a specification of regulation. Fuzzifier with the rule assessment was adjusted to fulfill the user's interest. According to FIS, the fuzzification process consisted of a series of steps to transform the value into membership

function (MF) grading for the linguistic supply of fuzzy sets and delineated MFs to all parameters, as listed in Table 3 and Table 4. The MFs utilized the procedures to estimate the link status of MIH process. The result was then passed to the defuzzification process inside the comparator. Event Executions received the results from the comparator, then produced crisp output for MIH link event.

**Table 3.** Values of the membership functions

Membership Functions (mfs)	Weak	Medium	Strong	Available	Unavailable
Value	1	2	3	4	5

**Table 4.** Variables of the membership functions

	Weak	Medium	Strong
RSS (- db)	RSS<60	60 <=RSS <90db	RSS =>90
ABW( Mbps)	ABW< 0.2	0.2 < ABW < 0.37	ABW => 0.37
Service type	Unavailable (U)		Available (A) In our case assume all service is available

### 3.2 Simulation and Parameters

The simulation used handover scenario as shown in Figure 4, where there were three different radio technologies such as Wi-Fi, WiMAX, and LTE in the vehicular ad-hoc network (VANET) traffic light. The simulation was implemented in NS2.29 which was integrated with VanetMobiSim simulator. To get the real vehicles' movements in the traffic light scenario, the simulation used several vehicular mobility models such as VanetMobiSim, SUMO, CityMob, and FreeSim. This study also used the CanuMobisim Spatial Model traffic data provided by University of Stuttgart Informatik which was generated in VanetMobiSim simulator. The model had the features of macroscopic and microscopic models that include road topology, road characteristics (multiples lane or directional traffic flow, speed constraint, and intersection crossing rules), and patterns movement selection. The data traffic was transformed into XML format, and then it was integrated into the NS2.29 simulation to evaluate the QoS performance.

Table 5 shows the set-up of the simulation parameters in NS2.29. For mobility, the Mobility Internet Protocol version 6 (MIPv6) was used in the simulation. The effectiveness of MIH mechanism with a Fuzzy Logic algorithm for handover prediction was evaluated based on the simulation scenario (Figure 4). The Fuzzy Logic algorithm was developed in C++ and was interfaced with MIH library in the NS2.29. For the simulation scenario, the vehicles were configured to utilize multiple radio access technologies such as Wi-Fi, WiMAX, and LTE networks. Hundreds of vehicles were made available to access the different network coverage in the simulation. For the simulation time, vehicles were assumed to travel across the traffic light in the heterogeneous network for 300 seconds. The mobile was using an interactive application type of traffic classes. At the beginning of the simulation, traffic transmission started with LTE and Wi-Fi interfaces and then continued to connect to WiMAX interface. The traffic light was set up in three lanes to imitate the real traffic light situation. The vehicle movement started from the first lane of the road at the traffic light then crossed the traffic light and left the traffic light during which it was connected to the nearest access point of access networks coverage (e.g. LTE, Wi-Fi, and WiMAX). After that, the vehicle in the second lane crossed and left the traffic light. Later, the vehicle in the third lane did the same as the second vehicle but in the third lane. The maximum interval time was set up for 5 seconds.

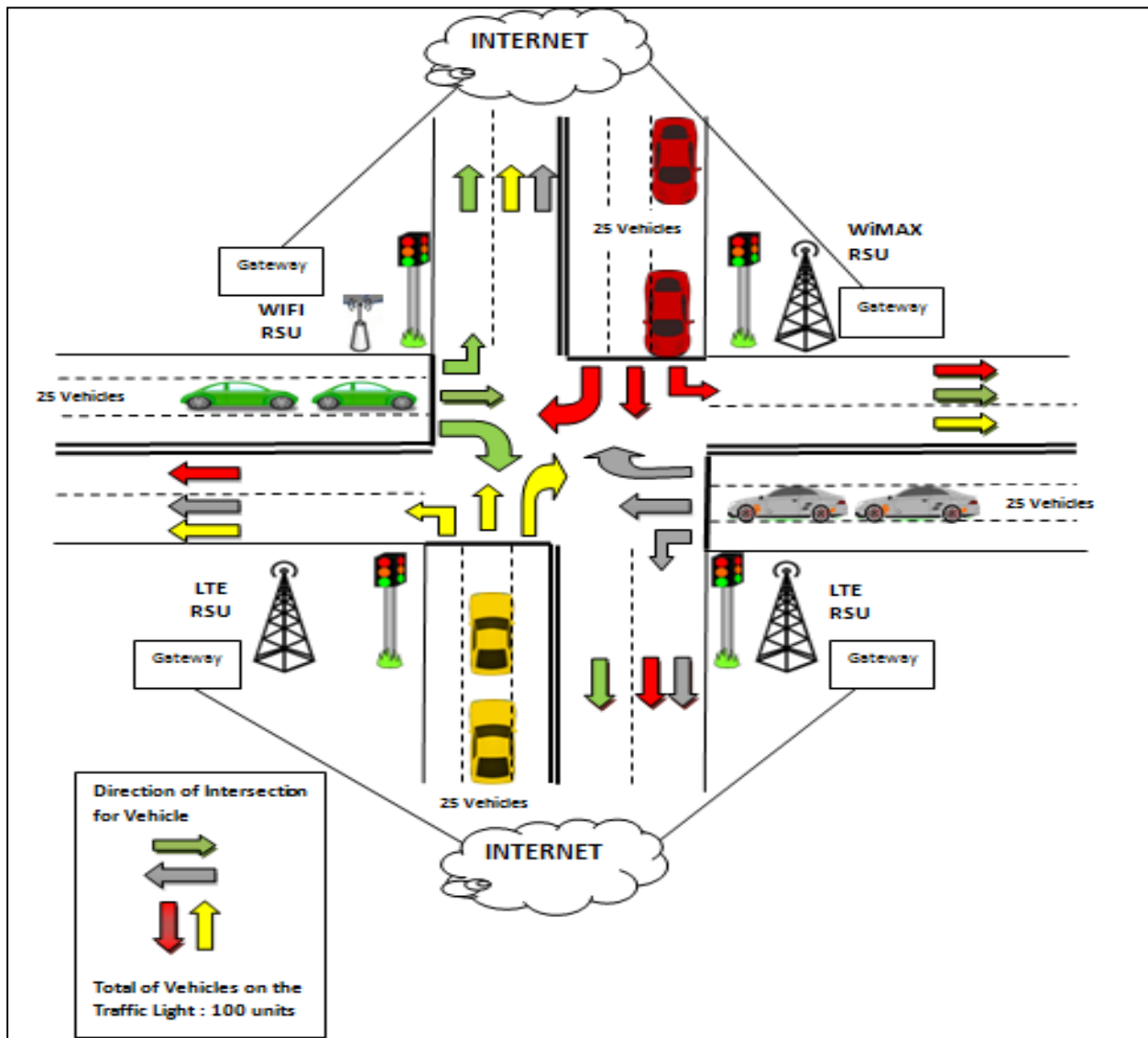


Figure 4. Simulation scenario

Table 5. Simulation Parameters

SIMULATION PARAMETERS	VALUES
Simulation range	2000m x 2000m
Simulation duration	300 s
Frequency bandwidth of 802.11	2.4 GHZ
Transmission radiuses of 802.11	20 m
Data rate of 802.11	11 Mbps
Propagation Model	TwoRayGround
Antenna	Omni antenna
Routing Protocol 802.11	DSDV
Max packet in if queue length 802.11	50
Frequency bandwidth of 802.16	3.5 GHZ
Transmission radiuses of IEEE 802.16	500m
802.16 channel bandwidth	10 MHz
Propagation Model	TwoRayGround
802.16 modulation and coding	OFDM 16QAM 3/4
MAC/802.16 UCD (uplink channel) interval	5 s
MAC/802.16 DCD (downlink channel) interval	5 s
UMTS/LTE uplink bandwidth	384 kbps
UMTS/LTE downlink bandwidth	384 kbps
Link data rate	100 Mb/s



UDP Max packet size (byte)	1,024
UDP header size (bytes)	8
Mobility protocol	MIPv6
Vehicle speed	1~100 / kmph

#### 4. Result and Discussion

This section discusses the QoS performance of the vertical handover in the vehicular ad-hoc network that used the proposed Fuzzy Logic algorithm. It then compares the performance with the RSSThreshold-based algorithm in terms of handover latency, end-to-end delay, and packet loss using the different speeds of the vehicles e.g. 20, 40, 60, 80, and 100 km/h.

##### 4.1 Handover Latency

Handover latency is the time taken for a data packet to be transmitted from the sender node to the receiver node. It also represents the total of the network latency, and the handover latency of a packet travels from one node to another node. In Figure 5, it can clearly be seen that the handover latency of the Fuzzy Logic is less than the handover latency of the RSS-based algorithm. The average latencies for the Fuzzy Logic and the RSS-based algorithm are 10.6 and 13.2 seconds respectively. The improvement is about 20 percent reduction of handover latency when the speed increased from 20 km/h to 100 km/h.

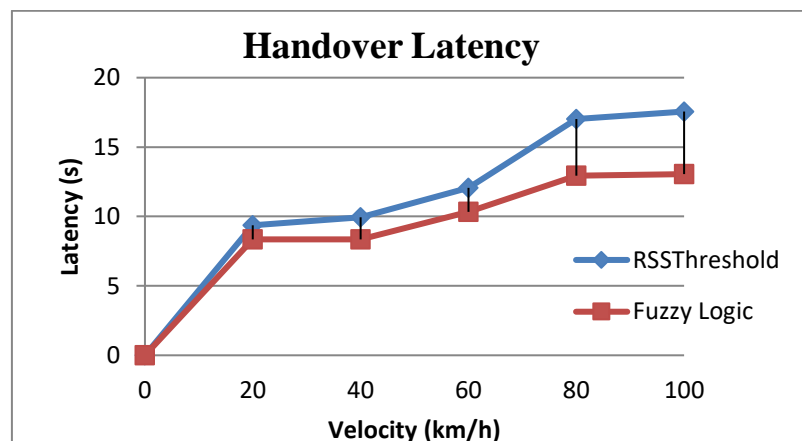


Figure 5. Handover Latency vs Velocity

##### 4.2 End-to-end Delay

The end-to-end delay is the time taken for a packet to be transmitted across a network from the source to the destination. It is also known as a one-way delay. It is measured in milliseconds to several hundred milliseconds in units. Figure 6 shows the end-to-end delays obtained from the simulation. The Fuzzy Logic algorithm was much better than the RSSThreshold algorithm, which has a lower average of end-to-end delay of about 21 percent. It also rapidly decreased the end-to-end delay by up to 29 seconds when the speed of vehicles increased from 20 km/h to 100 km/h.

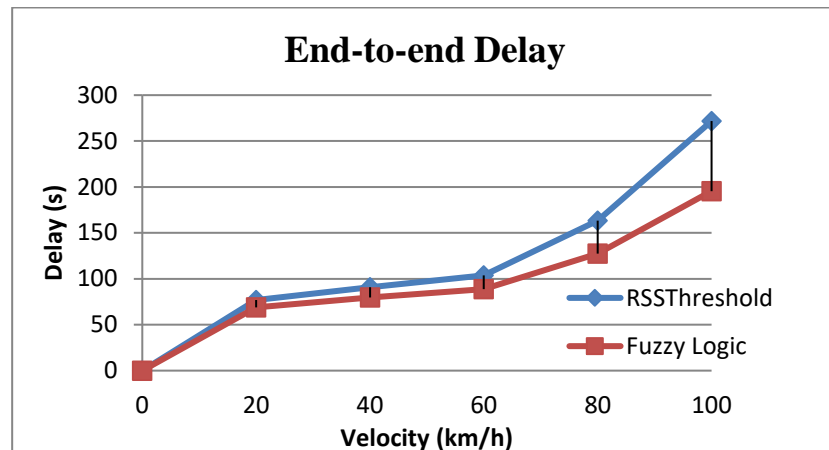


Figure 6. End-to-end vs Velocity

#### 4.3 Packet Loss

Packet loss is the total number of packets that failed to reach their destination during the handover process. It was measured only during the handover triggering operation under several access networks coverage. Figure 7 shows the graph of packet loss versus velocity obtained from the simulation. Generally, packet loss will decrease as handover latency decreases. As a result, the Fuzzy Logic reduced the average packet loss to approximately 13 percent lower than the RSSThreshold algorithm.

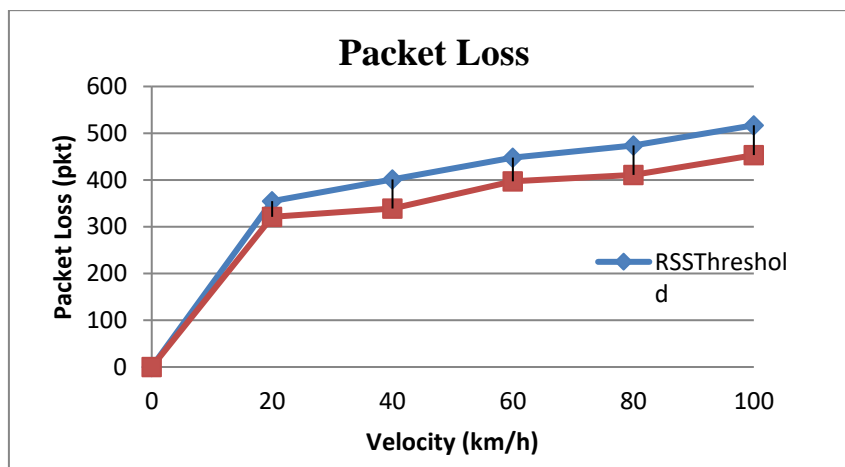


Figure 7. Packet Loss vs Velocity

### 5. Conclusion

Nowadays, multi-technology enabled terminals are becoming popular. In future, vehicular heterogeneous wireless networks, network detection, and handover decision procedures will play a significant role in attaining efficient mobility solutions for Internet connection. However, accomplishing seamless service using vertical handover between vehicular ad-hoc heterogeneous networks is complicated. Therefore, this study proposes Fuzzy Logic algorithm to address this problem. The analysis of the results shows QoS enhancement in vertical handover between Wi-Fi, WiMAX, and LTE networks. The simulation results indicate the proposed Fuzzy Logic algorithm achieved better QoS performance than the RSSThreshold algorithm in heterogeneous VANET by reducing the handover latency, end-to-end delay, and packet loss. The Fuzzy Logic algorithm can be considered as uncertain, ambiguous and vague systems but with accurate mathematical methods to handle complexity or somewhat irrelevant decision-making process which comprehends the vertical handover problem.

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