2017 IEEE/ACS 14th International Conference on Computer Systems and Applications

A Seamless Mobility Mechanism for V2V Communications

Amina Gharsallah, Nouri Omheni, Khouloud Ghanmi, Faouzi Zarai
NTS'Com Research Unit, ENET'COM
University of Sfax, Tunisia
gharsallahamina@gmail.com

Mahmoud Neji
MIRACL Laboratory, University of Sfax, Tunisia
mahmoud.neji@gmail.com

***Abstract*— The wireless Internet of Things (IoT) is the future of Internet technologies in which every object around us will be connected using some kind of network to every other object, and they will have the capability to send and receive data from them. IoT will trigger a large range of use cases. One interesting and prominent use case is Vehicle-to-Everything (V2X) communications, which aim at revolutionizing the travelling experience especially within a smart city. The connected vehicles enable the exchange of information between the vehicle and its surroundings via the IoT. V2X communications face great challenges due to the special features in mobility, such as high mobility, frequent topology changes. Hence, as vehicles move in and out of the coverage areas of other vehicles, Wi-Fi and cellular base stations, and change their communication Point of Attachment (PoA), mobility management aims to provide a seamless communication by efficient handover strategies and Radio Access Technology (RAT) selection schemes. In this paper, we present a novel multi-criteria handover algorithm to select the best RAT for V2X communications. Fuzzy logic system is used to decide whether a target candidate is suitable for handover. The efficiency of our mechanism is evaluated through appropriate simulation by using OMNET++, SUMO and VeinsLTE framework. The properties of our mechanism satisfy the service continuity requirements while decreasing the V2V handover failure rate and the handover failure rate mode switch.**

Keywords*— Internet of Things (IoT), V2X Communications, LTE-A, Handover, RAT selection, Fuzzy logic, VeinsLTE.

I. INTRODUCTION

Mobile communications have instrumentally transformed our contemporary societies to smart societies. Currently, we are at the era of digitally connected world, also called Internet of Things (IoT) or Internet of Everything (IoE). IoT is a paradigm envisioned as a global network of all kinds of physical, mechanical, electrical, and electronic objects capable of interacting with each other. IoT should have the capability to connect and transfer data among billions of devices in 2020 [1].

IoT will trigger a large range of use cases, such as tactile internet, virtual reality, augmented reality, eHealth services, remote computing, collaborative robots, smart wearable like sports and fitness, industrial control, smart agriculture, automotive driving /Internet of vehicles and so on.

The arrival of this innovative paradigm (IoT) foretells a variety of applications for the envisioned smarter planet, such as rich connectivity and interactions among vehicles (V2V) as recently defined by the 3rd Generation Partnership Project (3GPP) group [2]. Connected vehicles or V2V connectivity is the real-time exchange of information among vehicles. Such dynamic information exchange offers many opportunities for significant improvements especially on the vehicle safety aspect. In addition, connected vehicles enable a wide range of applications for safety, traffic efficiency and infotainment, and in the future facilitate connected autonomous vehicles. Examples of such applications include cooperative collision warning, traffic hazard warnings, collision risk warning, intersection collision avoidance, vehicle software/data provisioning and update, in-vehicle internet access, point-of-interest notification, and remote vehicle diagnostics [3].

There are two potential solutions to support V2X communications: IEEE 802.11p, a synonym of Dedicated Short Range Communications (DSRC) and Long Term Evolution (LTE) cellular network technology. DSRC generally refers to a wireless technology used for automotive and Intelligent Transportation System (ITS) applications via short-range exchange of information. Among DSRC devices : a) on-board units (OBUs) located inside the vehicles, b) road-side units (RSUs) placed on the side of the road, or c) hand-held devices carried by pedestrians [4]. In the other hand, earlier 3GPP defined in release 14 [5] new uses cases of LTE technology such as LTE Vehicle-to-Everything (V2X). LTE V2X communications as defined in 3GPP consists of four types: V2V, V2I, V2N and V2P. Fig.1 illustrates these examples.

- Vehicle-to-Vehicle (V2V) Communications: covering LTE-based communication between vehicles via a new V2V interface (designated as PC5, also known as sidelink at the physical layer).
- Vehicle-to-Network (V2N) Communications: covering LTE-based communication between a vehicle and a network.
- Vehicle-to-Infrastructure (V2I) Communications: covering LTE-based communication between a vehicle and a roadside unit.

2161-5330/17 $31.00 © 2017 IEEE
DOI 10.1109/AICCSA.2017.109

- Vehicle-to-Pedestrian (V2P) Communications: covering LTE-based communication between a vehicle and a device carried by an individual (e.g. handheld terminal carried by a pedestrian, cyclist, driver or passenger).

While IEEE 802.11p communication is suitable for applications such as active road safety and traffic efficiency, which require timely dissemination of warnings and awareness messages, it presents challenges inherent in spectrum availability and fading. IEEE 802.11p is not expected to meet the high data traffic demand for vehicle Internet access. LTE-based V2V communications is more favorable to bandwidth-greedy applications, which require higher throughput and reliable network connection linking vehicles. Indeed, hybrid solutions that exploit the benefits of both IEEE 802.11p and LTE technologies is proposed for V2X communications.

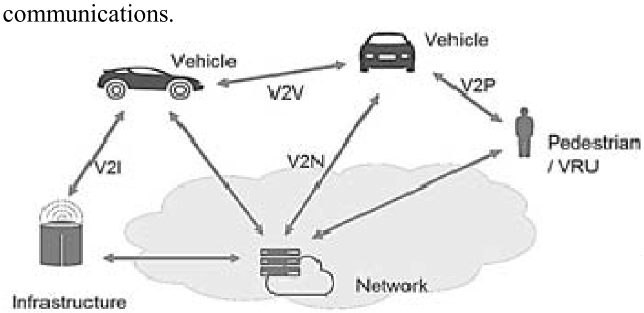

Fig. 1. V2X Types

In mobile networks, handover refers to the process of transferring an ongoing call or the ongoing session from one channel connected to core network to another one. Handovers are classified into two strategies such as horizontal handover and vertical handover.

a) Horizontal handover: when a data transmission session is transferred from one PoA to another on the same network (using the same access technology).

b) Vertical handover: when a data transmission session is transferred from one PoA to another on a different network (using a different access technology).

In this paper, we focus on proposing an algorithm that selects the best available communication technology for handover mechanism.

The remainder of this paper is organized as follows: In section II, we discuss related works, while in Section III the proposed access technology selection mechanism is described. In section IV, simulation results are discussed to evaluate the performance of the proposed mechanism. Section V concludes the article.

II. RELATED WORK

In this section, we review previous research on vertical handover and radio access network selection in 5G and V2X communications.

Authors in [2] proposed a context-aware heterogeneous Vehicle-to-Infrastructure (V2I) scheme where vehicles dynamically select the most appropriate access network using context information and the assistance of the infrastructure. The network selection algorithm is based on performance and cost estimations obtained using context-based models.

In [4], authors review potential DSRC and cellular interworking solutions for efficient V2X communications. They present the limitations of each technology in supporting V2X applications. Furthermore, they study potential DSRC-cellular hybrid architectures and the main interworking challenges such as vertical handover and network selection issues.

In [6], authors provided a comprehensive survey on next generation 5G wireless networks. They presented a review of cellular evolution towards 5G networks. They discussed the new architectural changes associated with the RAT design, such as smart antennas, cloud and heterogeneous networks. In addition, they presented the novel emerging applications, like Device-to-Device (D2D) and Machine-to-Machine (M2M) communications, Internet of Things (IoT), Vehicular communications and Healthcare applications.

Authors in [7] proposed a network selection scheme in V2I communication over heterogeneous network environment consisting of LTE macro and Wi-Fi small cells. Their goal was to reduce the overall handover delay by performing network selection in advance, and to avoid unsuccessful handovers resulting in Ping-Pong effects. Fuzzy logic system was used to decide whether a target candidate is suitable for handover.

Authors in [8] proposed an intelligent interface selection scheme for the multi-interface terminal that is providing two of the most viable communication standards for vehicular environment - LTE and IEEE 802.11p.

Authors in [9] presented the scenarios for operating LTE-based V2X services. In addition, they addressed the main challenges of high mobility and densely vehicle environments in designing V2X technical solutions, like the spectral-efficient air interface and the cost-effective network deployment.

In [10], authors proposed a Context-Aware RAT Selection mechanism (COmpAsS) in 5G ultra-dense network environments. The contextual information items used in this scheme are: the traffic load of the RATs (in terms of available bandwidth), the backhaul load of the available RATs, the mobility characteristics of the user equipment (UE) (speed), the type of the traffic flow, the RSS of the available RATs. Authors used Fuzzy Logic Controllers (FLC) to evaluate the available RATs and identified the best one.

Authors in [11] proposed An Exemplary Handover Scheme during D2D communication based on Decentralization of SDN (EHSD). In the proposed EHSD, framework authors combined both Device-to-Device communication and handover mechanism in 5G heterogeneous network. The vertical handover mechanism is performed in Content Delivery Network (CDN) by applying fuzzy logic.

A hybrid communication approach based on 4G/LTE and IEEE 802.11p technologies to support a V2X video streaming application was proposed in [12]. The proposed approach includes a procedure for selecting the best RAT. Handover decision and RAT selection are made based on a number of factors such as application quality of service (QoS) requirements, network resources availability and cost, etc.

Other recent schemes on IoT, V2X, vertical handover, and network selection are considered in [13, 14, 15, 16, 18, and 19].

III. PROPOSED RAT SELECTION MECHANISM

A. System Model

The system model is based on a heterogeneous vehicular network composed of different types of base stations serving different coverage areas. As shown in Fig.2, there is one macro cell and multiple small cells contain several competent communication technologies such as IEEE 802.11p/DSRC, Wi-Fi and LTE.

LTE Advanced enhanced Node B (eNB) is connected via S1 interface to the core network, i.e. Evolved Packet Core (EPC). Access Network Discovery and Selection Function (ANDSF) existing within the EPC [17]. ANDSF helps a device to automatically discover and select the most suitable underlying RAT (non-3GPP access networks such as Wi-Fi and 3GPP access networks such as LTE), based on certain priorities and policies predetermined by the network operators.

Vehicles are equipped with multi-interface such us LTE Uu interface, LTE PC5 interface, and IEEE 802.11p/DSRC interface. Each vehicle can use its IEEE 802.11p or PC5 interfaces to communicate with its neighboring vehicles. Also vehicles are equipped with a Global Navigation Satellite System (GNSS) to determine the speed, direction and position of the vehicle with high precision.

The heterogeneous vehicular network consists of multiple groups, referred to as clusters. Each cluster is coordinated by one of the vehicles, referred to as the Cluster Head (CH) which downloads data from the eNB and serves the rest of vehicles which are referred to as the Ordinary Vehicles (OVs) through V2V connectivity.

The eNB can determine how clusters are formed by taking into account the context information provided by incoming vehicles (e.g. location, direction, speed and final destination). Furthermore, the eNB is in charge of assisting a vehicle joining an already formed cluster by considering the context information delivered by the vehicle: when a vehicle is approaching an eNB it can, indeed, advertise its position, resource and service capabilities, application and user interests and availability to join V2V clusters. Depend on this information, the eNB can select the active clusters that best match the context information and extend these V2V clusters accordingly.

Clustering method is useful and effective for avoiding network congestion by reducing the number of connections vehicle-eNB, reducing effective network size, minimizing latency within each cluster. Clustering method aims to find opportunities to minimize the consumption of radio resources and to minimize the interference in the system, by integrating information, working as one station, reusing radio resources and controlling interference in different clusters.

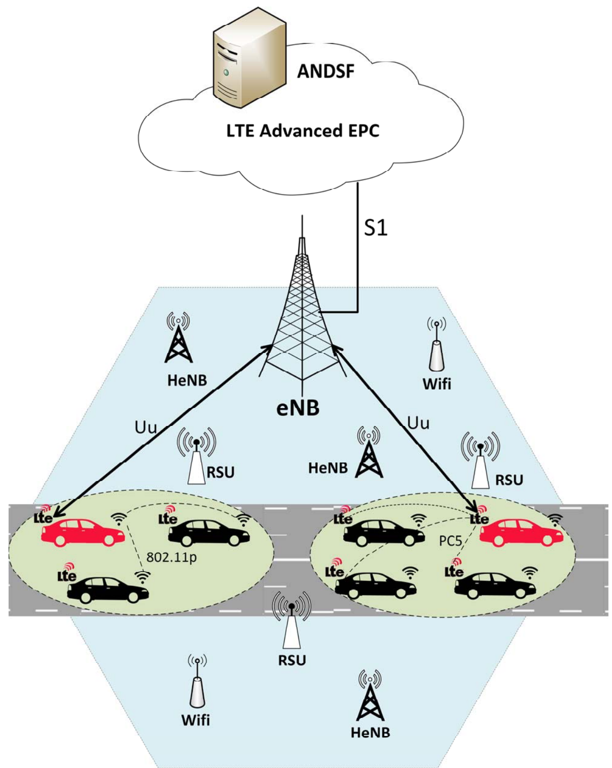

Fig. 2. System Model

B. RAT selection mechanism

Fig.3 presents our proposed algorithm designed for selecting the most appropriate RAT. We assume that an ordinary vehicle (OV) and the cluster head (CH) are in V2V communication via LTE PC5 interface. A handover is triggered when the triggering condition, Eq. (1) is satisfied.

$$V2V\ signal < V2V_{Th} \tag{1}$$

V2V signal is the radio signal strength between vehicles. $V2V_{Th}$ is a constant variable that represents whether the cluster-head vehicle can provide services to the ordinary vehicle. If the V2V signal from the CH is greater than $V2V_{Th}$, the CH can provide the services to the OV.

When a handover is required, the RAT selection process is activated. The OV sends its context information to the eNB for availability to join new V2V clusters. Context information contains: location, direction, speed and final destination. Based on this information, the eNB can select the active cluster that best match the context information and extend this V2V cluster accordingly. If there is no active cluster, the eNB communicates to the OV information about available access networks in its vicinity. The eNB can gather this information through the ANDSF entity in the core network. The vehicle sends an ANDSF query to ANDSF server (which may be accessed via eNB) inquiring the coordinates of available candidate RATs in its vicinity. The ANDSF query also contains the vehicle context information (location, speed, direction, etc.) so that the ANDSF server response contains available RATs in the vicinity of the vehicle.

In the proposed mechanism, we propose to extend the ANDSF concept by assuming that it may provide information about the load for every RAT in the area.

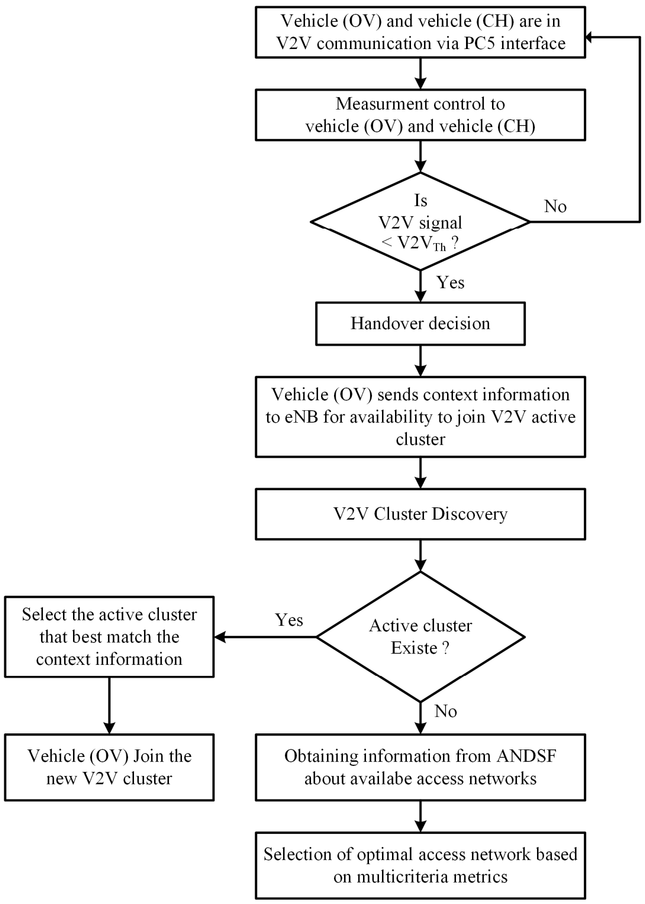

Fig. 3. RAT selection algorithm

The vehicle needs to select only the potential candidate based on multi-criteria metrics. The considered criteria are as the follow:

- Network conditions: these refer to the characteristics of each RAT such as RSS and load.

a) The RSS for non-3GPP networks or RSRP for 3GPP networks of the available RATs: is a measurement used for evaluating the signal quality of the neighbor base stations.

b) The traffic load of the network: the traffic load of the cellular base stations and/or Wi-Fi Access Points (APs) (in terms of available bandwidth). It is the ratio between the number of resources used in the network and the total number of resources in the network for a period of time t.

- Vehicle conditions: The speed of the vehicle is a crucial decision parameter. Fast moving vehicle may cross over a WLAN coverage rapidly. Thus, handing it over from a cellular network to a WLAN could cause quick successive handovers which may result in high signaling overheads and delays.

To identify the most suitable access network, the vehicle uses a fuzzy logic scheme, which is presented in the next sub-section.

C. Fuzzy logic modeling

For efficient RAT selection, we adopt fuzzy logic algorithm in our scheme. Fuzzy logic is an ideal tool for dealing with uncertainty cases, when the inputs are rough estimated values [11]. The fuzzy logic controller is composed of four elements. These are fuzzification, rule base, inference mechanism and defuzzification. A block diagram of a fuzzy logic control system is shown in Fig.4. The fuzzifier undertakes the transformation (fuzzification) of the input values to the degree that these values belong to a specific state (e.g., low, medium, high, etc.). After that, the inference mechanism correlates the inputs and the outputs using simple "IF…THEN…" rules. Then, the output degrees for all the rules of the inference phase are being aggregated. The output of the decision making process, comes from the defuzzification procedure.

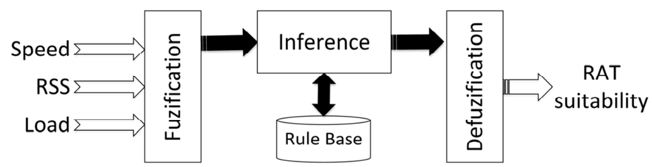

Fig. 4. Block diagram of a fuzzy logic control system

In the proposed scheme, fuzzy logic controller is applied on the following criteria: speed, RSS and load. We assume three types of networks such as LTE macro cell, LTE micro cell and Wi-Fi. Every time that the algorithm is triggered, all the available eNB, Home eNB (HeNB) and APs are evaluated.

The process starts from the fuzzifier where the input parameters are fed up, there by which gets transformed to fuzzy sets of values (low, medium, and high). Next the inputs are being combined in the interference engine, by a set of rules; at this case for each of the three fuzzy reasoners (eNB, HeNB and Wi-Fi) we have defined 27 rules to cover all the potential input combinations.

Examples of fuzzy inference system (FIS) rules:

a) IF (RSS_{RAT1} = = high) AND ($Load_{RAT1}$ = = medium) THEN RAT1 selection probability is high.
b) IF (RSS_{RAT1} = = low) AND ($Load_{RAT1}$ = = medium) THEN RAT1 selection probability is low.

The strategy of the rules is the following. The RAT, which is characterized by high RSRP and low load, is advantageous for the vehicle choice. On the other hand, high mobility vehicles are preferably placed in larger cells and small cells are avoided to minimize the unnecessary handover and Ping-Pong effect.

Finally, the defuzzification process aggregates all the outcomes of all the rules and ends up to a certain degree of the output value, i.e., RAT suitability. The network with the highest RAT suitability will be selected; in case of a rejection the second in the list is being selected, etc. The Suitability value ranges from 0, 0 to 1, 0 (0 to 100% respectively).

IV. PERFORMANCES EVALUATION

A. Simulation methodology

In this section, we investigate the performances of our proposed multi-criteria RAT selection algorithm for heterogeneous vehicular networks via simulation analysis.

We use Veins LTE [20] (Vehicles in Network Simulation) framework for running heterogeneous vehicular network simulation, where vehicles are equipped with both IEEE 802.11p and LTE network interface cards. Veins LTE integrates OMNeT++ [21] (Objective Modular Network Tested in C++) an event-based network simulator, SUMO [22] (Simulation of Urban Mobility) a road traffic simulator, Veins for IEEE 802.11p model and SimuLTE for LTE model. Veins LTE makes a TCP connection between SUMO and OMNET++ and simulates traffic and network in parallel.

The main system parameters are summarized in Table I.

TABLE I. SIMULATION PARAMETERS

Parameters	Values
Simulation area	3 km × 3 km
Simulation time	180 s
Number of vehicles	440
Vehicles speed	20 Km/h ~ 140 km/h
Propagation model	COST 231,Simple Obstacle Shadowing
IEEE 802.11p frequency	5.89 GHz
IEEE 802.11p BW	10MHz
IEEE 802.11p coverage	250 m
IEEE 802.11p Tx power	26 dBm
IEEE 802.11p range of RSS	From -90 dBm to -30 dBm
LTE frequency	2.1 GHz
LTE BW	20 MHz
LTE coverage	1 Km
eNodeB TxPower	45 dBm
LTE range of RSRP	From -140 dBm to -44 dBm
V2V transmission power	23 dBm
Vehicle (UE) TxPower	20dBm
Resource blocks (RBs)	100 RBs and 180kHz per RB
No.of subcarriers per RB	12
Minimum association RSRP for D2D communication	-112 dBm
Mobility model	SUMO

The vehicles are generated in SUMO and are randomly and uniformly placed on roads. We select the vehicles, which are above the minimum association RSRP, to form V2V clusters.

In order to evaluate the performances of the proposed multi-criteria RAT selection algorithm, we use, as performances evaluation metrics:

- Handover failure rate mode V2V which is the ratio between the number of V2V handover failures and the total number of V2V handovers. V2V handover failure occurs when the signal quality in the V2V pair or the RSRP to source eNB is so poor.
- Handover failure rate mode switch which is the ratio between the number of V2I handover failures and the total number of V2I handovers.

We compare our work to schemes in [7] and [8].

B. Simulation results

The proposed multi-criteria handover algorithm to select the best RAT maintains service continuity while reducing the handover failure rate mode V2V and the handover failure rate mode switch.

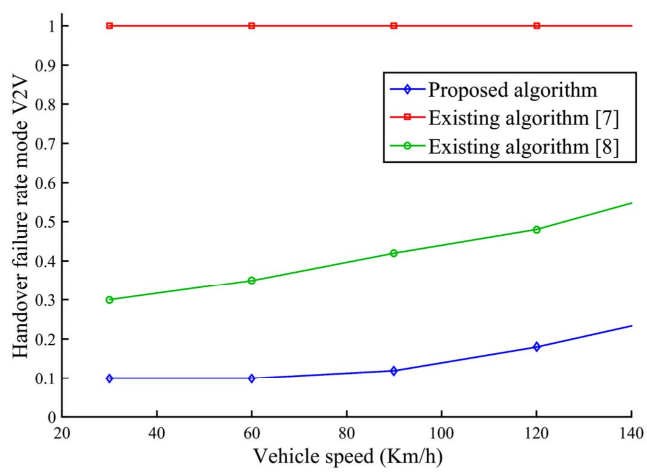

Fig. 5. Handover failure rate mode V2V

Fig.5 presents the performance comparison of the handover failure rate mode V2V according to the variation of vehicle speed values. It can be seen from the curves that in case of using our proposed algorithm, the V2V handover failure rate increases slowly with the increment of vehicle speed values. This is because the vehicle move away from the relay vehicle.

By comparing the curves in Fig.5, we note that the proposed handover algorithm, gives a slight increase in V2V handover failure rate and this rate can reach the order of 2% when the vehicle speed value equal to 140Km/h. While the V2V handover failure rate in the case of using the scheme of reference [8] equals to 58% and this rate equals to 100% in the case of using the scheme of reference [7] when the vehicle speed value equal to 140Km/h. These best results can be explained by the fact that our proposed RAT selection algorithm enable vehicle to stay in the V2V transmission mode for a long time, so that is maintains better service continuity.

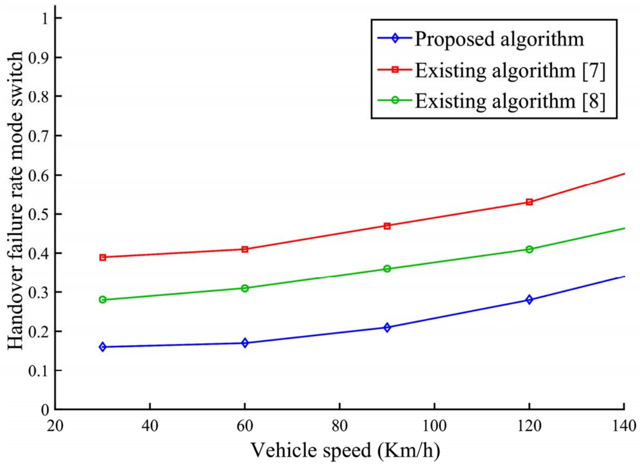

Fig. 6. Handover failure rate mode switch

Fig.6 presents the performance comparison of the handover failure rate mode switch according to the variation of vehicle speed. It can be notice from the curves that our proposed algorithm outperforms the algorithms in [7] and [8].

From the Fig.6, in case of using our proposed algorithm we can observe that the growth of handover failure rate starts when vehicle speed value equal to 30Km/h, and the handover failure rate begins to grow slowly and reaches a value of 2.2% for vehicle speed value equal to 140Km/h.

Whereas, for the other solutions, the rate of handover failure begins to grow rapidly and can reach about 5% for algorithm in [7] and 6 % for the algorithm in [8] for vehicle speed value equal to 140Km/h. The reason for this best results is due to the lower V2V handover failure rate. In addition, when the speed of the vehicle increases, then, time duration for vehicle to stay in V2V mode is short, so the number of V2V handover triggers decreases and vehicle can perform handover to the most suitable underlying RAT that offer enough time to complete the handover when vehicle is crossing them.

V. CONCLUSION

This paper presents a novel multi-criteria handover scheme to select the best access technology for V2V communications. The architecture is based on a heterogeneous vehicular network composed of several competent communication technologies such as IEEE 802.11p/DSRC, LTE macro cell and LTE micro cell. Vehicles with multi-interface enabled V2V communication via IEEE 802.11p/DSRC radio technology and LTE PC5 interface are provided to ensure reliable data exchange and a quality of service for applications. Simulation results show that proposed handover mechanism performs better than other existing scheme. It significantly reduces the V2V handover failure rate and the handover failure rate mode switch.

In future research plan, we will interest to radio resource management in vehicular communication in advanced 5G network.

APPENDIX A: ACRONYM LIST

Abbreviation	Meaning
ANDSF	Access Network Discovery and Selection Function
CDN	Content Delivery Network
CH	Cluster Head
CN	Core Network
D2D	Device-to-Device
DSRC	Dedicated Short Range Communications
eNodeB	enhanced NodeB
EPS	Enhanced Packet System
FIS	Fuzzy Inference System
FLC	Fuzzy Logic Controllers
GNSS	Global Navigation Satellite System
HeNB	Home eNB
IoE	Internet of Everything
IoT	Internet of Things
ITS	Intelligent Transportation System
LTE	Long Term Evolution
LTE-A	LTE-Advanced
MIMO	Multiple-Input Multiple-Output
OBU	on-board unit
OMNET	Objective Modular Network Tested in C++
OV	Ordinary Vehicle
PoA	Point of Attachment
QoS	Quality of Service
RAT	Radio Access Technology
RSRP	Reference Signal Received Power
RSS	Received Signal Strength
RSU	road-side unit
SUMO	Simulation of Urban Mobility
UE	User Equipment
V2I	Vehicle to Infrastructure
V2P	Vehicle to Pedestrian
V2V	Vehicle to Vehicle
V2X	Vehicle to Everything

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