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Intelligent Multi-homing Switching for Vehicles Connectivity

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***Abstract*— The spread of the internet applications has affected the vehicle connectivity requirements where connected vehicles can communicate with other systems to exchange data outside the vehicles. The continuous connectivity of smart vehicles is becoming very important for supporting various user applications. The challenges arise from the moving nature of vehicles on the road and the ability of providing a stable network connection due to areas where the network coverage is not available. The use of predictive multi-homed switching can eliminate the effect of network coverage holes. A switching decision can be supported by the intelligence of a connectivity gateway that analyzes network connectivity metrics collected from the vehicles such as round time delay and packet loss rate. In this paper we study the use of predictive multi-homed switching and the associated connectivity gateway in order to evaluate the improvement on the service connectivity of the vehicles. The gateway provides information ahead of time to prepare the vehicle to utilize alternative connectivity methods on different areas along the path of the vehicle. The system's reaction to the elimination of network coverage holes is assessed where we show the improvement in the continued connectivity key performance indicators.**

Keywords*— *Multi-homing, Predictive Switching, Service Continuity, Coverage holes

I. INTRODUCTION

A connected vehicle is equipped with Internet access in order to provide connected services to the user. The connected vehicle services may include navigation assistance, emergency services, and maintenance alerts. On one hand, these connected services provide the ability to access real-time sensor-based data from the vehicle gaining continuous access to operational data. On the other hand, connected services allows the user to receive data and gain visibility into road conditions. Connectivity in vehicles is now becoming the norm, and with autonomous vehicles in particular, sustained connectivity is becoming an increasingly important factor for vehicle applications.

The fact that vehicles are normally moving place challenges on providing a stable network connectivity to the vehicle itself. Moreover, vehicle networks have dynamic topology since vehicles (nodes) are continuously moving, and hence, there is a need for the network coverage to be able to adapt to these movement in order to provide continued network coverage and application services.

There are several networking methods that utilize different wireless technologies including but not limited to, IEEE 802 protocols [1] and cellular protocols which are described later in the paper. Ideally, there should be a primary connection using one type of network and then a secondary connection to be utilized when a coverage hole presents itself in the primary network connection. Even though the new generations of wireless networks have advantages of providing better connectivity in terms of throughput and capacity, the continued connectivity can still become a problem in areas with lack of good coverage[2]. The use of vehicle-to-vehicle connectivity can be used as alternative connectivity for vehicles that face trouble connecting to their subscribed networks [3].

In this paper, we study the effect of the Predictive Multi-Homed Switching (PMHS) mechanism on the performance of vehicle connectivity. The PMHS mechanism can be used to predict upcoming network coverage holes and the availability of network alternatives along the path of the moving vehicles [4]. The PMHS can make the decision to switch a current network provider based on certain connectivity metrics including round-trip time and packet loss rate. The PMHS makes use of collected data available on an Intelligent Vehicle Connectivity Analytics (IVCA) gateway.

The rest of the paper is organized as follows. Section 2 presents related and similar work that supports our statement of work. Section 3 provides the evaluation methodology. The simulation results are then presented in Section 4 followed by the conclusion and future work in Section 5.

II. LITERATURE REVIEW

Multi-homing is basically established by connecting a node to more than one network. For example, one node with more than one network interface and multiple IP addresses can receive connectivity from two different networks. Clearly, multi-homing can provide enhanced reliability and service performance. Multi-homing has been explored in research areas and the performance effect of multi-homing on heterogeneous network is addressed in [5] for dual wireless interfaces mobile devices. Multi-homing can also enable mobile devices to access the network using multiple interfaces in order to increase service performance. The work done in [6] enables multi-homing for applications running on mobile devices by providing a middleware layer. The solution was tested by a remote monitoring application.

Multi-homing can bring about some security concerns that needs to be addressed. Reference [7] introduces a secured efficient fast handover multi-homing mobility framework for the continuous connectivity of the nodes. The framework uses a predictive method to handle the handover between heterogeneous networks and it also provides the secure acknowledgement before handover. However, as a result of the security during handover, the latency and packet loss are affected. A new LTE-based architecture is introduced in [8] with a privacy preserving security for vehicle-to-everything (V2X) service. On one hand, the authors indicate that the V2X message delivery requirements can be met by proper resource allocation. On the other hand, they indicate that LTE-based V2X security cannot fully meet the security and privacy requirements. As such, they integrate their proposed security scheme with the system architecture in order to meet the two requirements, namely, the message delivery and the message security.

Communication protocols that enable the seamless integration and operation of the Internet of Vehicles (IoV) are proposed in [9]. While the authors discussed the IoV protocols and the security requirements, they present a seven-layer architecture for IoV covering data acquisition, processing, communication all the way to application development. The authors argue that the integration of automotive and information technology will contribute indirectly to energy efficiency and safety within IoV systems. On the other hand, the special service of healthcare monitoring via small sensors installed in the vehicles is addressed in [10] where remote healthcare centers receive passengers' data. Beside the networking issues, the security of the transmitted information becomes of utmost importance. A secure data dissemination scheme using vehicular relay network is designed with a strong cryptographic solution for communication among vehicles. Also, a cost-effective IoT architecture is introduced in [11] with the focus of improving the safety of road networks. The proposed architecture is tested by a safety-based route planning application using scalable metrics for assessing the road safety.

A new protocol for multi-homing and load-balancing is presented in [12] and tested on bandwidth intensive IoT applications such as vehicular systems with cloud-based video workload. The protocol is implemented for mobile IoT gateway where the IoT objects can connect and load-balance between dual networks. Also, mobile user network switching, and multi-homing techniques are analyzed in [13] where end user network switching provides higher throughput. However, the end user multi-homing in this case depends on radio resource allocation from individual networks.

The issue of handover in wireless networks becomes important for moving nodes as it is essential to transfer ongoing connectivity from one network to another. In [14] the authors propose a new handover management solution based on GPS information and previous values of network parameters. This multi-homed system predicts handovers and improves handover latency. Another grid-based predictive geographical routing protocol for inter-vehicle communication is proposed in [15] to overcome the problem of selecting the node that relays the packets to the destination node. The protocol predicts the movement during selection process and shows improvements in packet delivery rate and link breakage rate. An improved vehicular Wi-Fi access is proposed in [16] through the prediction along frequently used roads, thus improving the connectivity to the access points. The proposed method uses a strategy that reduces the connection establishment latency and increases download speeds.

A model for resource allocation in vehicular cloud computing is presented in [17] while taking in consideration heterogeneous vehicles and roadside units. The paper applies semi Markovian decision processes to find the optimal strategy of resource allocation. The results show that the new resource allocation model improves system parameters such as power consumption. In addition, the suitability of mobile ad-hoc network routing protocols have been assessed in [18] where the performance of topology-based and position-based routing protocols in three dimensional environments is tested. The researchers have found that topology-based protocols achieve acceptable performance in terms of delivery rate and path dilation. The position-based protocols can achieve higher data rates but with larger cost factor.

There is a great interest in new application areas related to vehicles and the use of connectivity protocols. In [19], the authors present a method to associate and discover mobile devices when they are on board a vehicle and obtain location information in order to perform some required action. In [20] the authors present a model to detect different types of malfunctions using a trained model to recognize different sounds produced by cars when they experience certain problems. The collected data can be shared with a cloud data base in order to enhance the system capabilities.

A vehicle-based relay assistance system presented in [21] provides deep analysis of the benefits of crowd-sensing supported by the continuously moving vehicles that can improve the dissemination of road-side information in a timely manner. The work in [22] relies on the mobile devices of a group of users and determines when these devices lose connection to their networks in order to figure out the departure time of their flight. The ideas shed some light on the possibilities of inferring certain information based of connection and disconnection events of mobile users. The same principles could be used to enhance the accuracy of the IVCA by predicting the time at which certain events occur, e.g., predicting the time a number of users lose connection or suffer from a very poor connection due to rush hours.

Many upcoming applications will rely on the continued connectivity to the vehicles whether for safety issues, maintenance issues, monitoring issues, or accidents preventions. To increase safety of drivers, a safety acknowledgment framework is proposed in [23] based on the states of eye, utilizing a camera and an algorithm for determining if the driver needs help using alarms. Many of such ideas, combined with continuous vehicle connectivity can give a rise to additional services to the drives of the vehicles and works on avoiding critical emergency situations.

The vehicle to vehicle communication is becoming essential for many applications as it alleviates the effects of areas with no wireless network accessibility. The standardization of the IEEE 802.11p for wireless vehicular communication consisted of the Cooperative Intelligent Transport Systems (C-ITS) standard in Europe and the Dedicated short-range communications (DSRC) standard in the U.S [24]. The Cellular V2X is basically developed within the Third Generation Partnership Project (3GPP) [25] to replace the DSRC and the C-ITS. The 3GPP completed the standardization of Cellular V2X technology in June 2017 [26]. The standard is designed to connect vehicles to each other, roadside infrastructure, other road-users, and to cloud-based services.

The 5G cellular will provide enhancements for direct communication among devices using the proximity services which can support vehicular communication. The 5G support for multiple radio technologies will allow the integration with the IEEE 802.11p standards. The capabilities inherent in the 5G technology, like low latency and high throughput, will accelerate the realization of V2X communication to improve transportation experience and allow brand new experiences for drivers and road users [27]. The V2X standards support application safety and automation requirements and other enhanced vehicle communication scenarios [28]. The long-term evolution (LTE-V) presented in [29] is an integrated V2X solution with a modified time division LTE physical layer for supporting V2I requirements.

The main objective of our study is to keep the vehicles connected via one of the available network alternatives. For this purpose, our system relies on the interaction between the PMHS on the vehicle and IVCA gateway in order to predict the next hole in network coverage. The system takes the appropriate switching action in due time so as to prevent discontinuity of coverage and thus preserve the user services. However, there are limitations to the capability of taking this course and there must be ways to mitigate these limitations.

III. METHODOLOGY

A. System Overview

In this sub-section we present a description of the system which basically consists of a connectivity database that contains information about the availability of multiple networks with respect to the location of the nodes. The nodes location's data is collected via crowd sensing and used to support the switching decision. The prediction technique is based on the direction of movement of the node. When the node is expected to enter one of the network coverage holes, the node looks for a network alternative that keeps the connection up. In case none of the alternative networks is available then coverage dropout is detected and the packets that the node is attempting to send are counted as lost packets until a connection is re-established.

The network quality of service is measured using performance metrics including, but not limited to, round-trip delay and bandwidth. The availability of the network in the model is determined by registering a set of network "holes" with respect to vehicle location. The connectivity database has two components for registering network holes. A slow-changing component that accounts for coverage holes due to lack of coverage equipment in certain areas. The other component is the fast-changing component that accounts for temporary events such as weather conditions, equipment failure, congestion, etc. Using the information from the connectivity database, the system can bridge network coverage holes by using one of the available alternative networks. Figure 1 shows a conceptual view of the coverage for a particular vehicle.

The predictive approach to switching alleviates the effect of the network coverage holes. We measure this improvement in our model by calculating the average coverage holes duration using the switching approach.

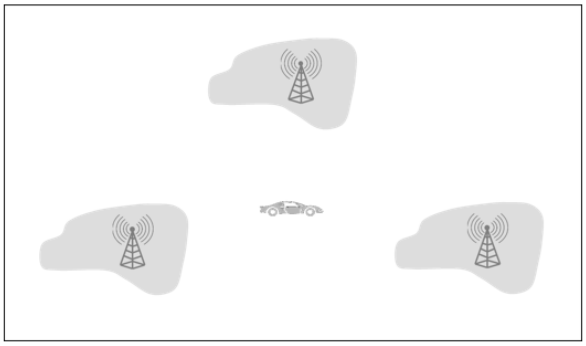

Fig. 1. Conceptual view

B. Evaluation Methodology

In order to test the continued connectivity, we first define the metrics that will aid us in identifying the quality and continuity of the connection. We use the following connectivity metrics.

- Round Trip Time (RTT) which is the time from the start of sending a message to the destination and back to the source vehicle.
- Average coverage holes duration which is the time from losing the network coverage to the point of re-establishing the connectivity again.
- Average number of coverage holes encountered by nodes.
- Packet loss rate which is the number of lost messages to the total number of sent messages.

The first metric measures the quality of the connection, while the other three determine the continuity of the vehicle connection to the base station. Note that the destination base station is a server that is assumed to be always available and is connected to the Internet backbone.

Since our main concern is to measure the continuity and stability of the connection over time, we generate loads on regular intervals in order to identify temporal events such as the dropout of network connectivity. This workload resembles services such as internet calls. In our simulation, we model an area with a number of coverage networks and a number of network coverage holes in order to test the system capabilities.

The simulation starts by configuring a square area and placing random network holes for all three networks. The network holes are areas that are used to simulate loss of connectivity due to coverage problems which in real-world would resemble areas not covered by cell towers. The network holes are uniformly distributed across the simulation area. The diameters of the holes are also drawn from a uniformly distributed random variable.

We run two series of simulations, both with and without predictive multi-homing support in order to evaluate its effect. The simulation was built using NS3 (Network Simulator 3), a widely known network simulation tool, with the addition of custom modules that implement the functionality of the IVCA.

As our aim is to evaluate the effect of multi-homing support on the continuity of the vehicle connection, we assume that the simulation area is covered by two LTE networks and a Low Earth Orbit (LEO) satellite. A full list of the simulation parameters can be found in Table 1. The node movement is randomized over the entire simulated area, both in terms of speed and direction. The speed of the nodes will have greater impact on connection stability as the risk of reaching a network coverage hole becomes greater. The simulation parameters for the moving vehicles connections are used mainly to show the effectiveness of predictive switching systems compared to traditional multi-homing.

Note that the average coverage hole diameter is 70-150m with a uniform distribution. Each node selects a destination and starts moving towards the destination with a random speed between 15 and 25 m/s. Once the node reaches its destination, it pauses for a random time then selects another destination. The node motion follows a random waypoint model between the minimum and maximum velocities. The speed limits are used to avoid any simulation inaccuracy due to the random waypoint model [30]. In our evaluation, we run the simulation with different parameters in order to study the effect of the increased load on the system and how it behaves in response to the changing number of nodes and the changing number of coverage holes.

TABLE I. SIMULATION MODEL PARAMETERS

Simulation Model Parameters	
Parameter	***Value***
Simulation Area	10 Km x 10 Km
Max Number of Active Nodes	500
Movement Speed	15 ~ 25 m/s (uniform distribution)
Load Generation Interval	0.2 Second
Load size	16KB
Simulation Time	24 Hours
Number of Coverage Networks	3

We model a client-server balanced load, such as a phone call. Both the server and the client engage in sending and receiving data at nearly equal bitrates. In our simulation, the base station server, the LTE PGW (Packet Data Network Gateway), and the satellite are all connected to a core networking device that acts as the Internet backbone. Note that the usage of a 5G network can increase throughput rates to the user over LTE networks as it rely on data-only IP network core [31] rather than a hybrid data and voice network. Note also that it is not necessary to rely only on cellular network, it is possible to explore other connectivity methods such as LoRa which can be used for IoT-based public vehicle tracking system [32].

The satellite has a 1 Gbps connection to the core and a delay of 40ms. Both LTE PGW elements and base station server are connected to the core via 100 Gbps link with 0.1ms delay. Each user can be connected to the satellite, via a 4Mbps link, in addition to, the two LTE connections. Each node selects the closest eNB (E-UTRAN NodeB) of each of the two LTE networks. Each LTE network has 3 eNB nodes randomly positioned to cover the simulation area. Figure 2 shows the topology used in our simulation model. Based on the available information, each vehicle selects a connection method.

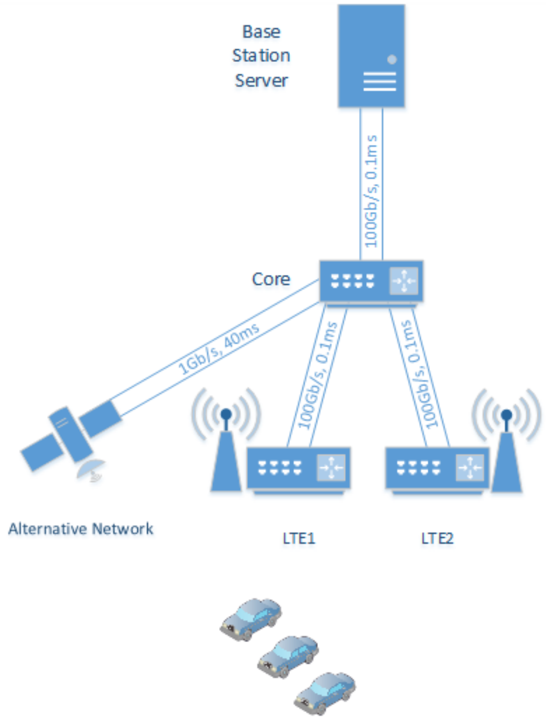

Fig. 2. Simulation topology

IV. RESULTS

In this section, we present the results of the simulation model based on the system parameters presented in section III. We implemented the predictive multi-homed switching method and compared it to the case of non-predictive service provisioning. Under the multi-homed scenario, when a node is about to start suffering from a coverage problem, it is switched to an alternative provider to keep the user in service. We show the comparison based on round- trip time, number of disconnections per node, the disconnect durations, and the number of lost packets per node.

The predictive approach, in which the node selects a network alternative before getting into a coverage hole, shows significant improvement in the packet dropout performance. In the non-predictive simulations, each node picks the serving network at the beginning of the simulation. As the coverage holes visibility prediction is turned off in this case, the node decides to switch networks only after the connection breaks. This results in more packet losses due to coverage holes compared with predictive switching.

The results are based on simulations runs with 3 networks alternatives with nodes varying from 10 to 500.

The number of holes per the main serving network is evaluated with two values, namely, 100 holes and 300 holes. The results of the simulations are more interesting when we take the average over each network prediction type. We group the results by non-predictive versus predictive switching in relation to the values of the hole counts.

Figure 3 shows the average round-trip time. The case of using the alternative network as satellite internet, with inherently higher transmission delays, is different than the case where the alternative network is another cellular network, and this depends on the predictive method network selection. The predictive system, in this case, is set to favor connection continuity, so when it predicts that the current connection will break, it selects the network that is predicted not to break in the near future based on the previously collected key performance indicators.

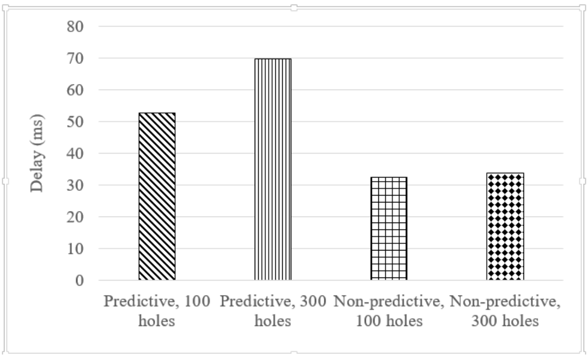

Fig. 3. Average round-trip time comparison

Figure 4 shows the average number of disconnections per node. The average number of disconnections a node has experienced is assessed over 24-hour simulation period. It can be seen that the predictive system decreases the number of disconnections greatly. In the case of the predictive case with 100 coverage holes, there is about 83% improvement over the non-predictive case, while in the case of 300 coverage holes, there is about 43% improvement over the non-predictive case. The increase in the number of disconnections adversely affects the user experience because of the effect on the average durations of disconnections, meaning loss of service.

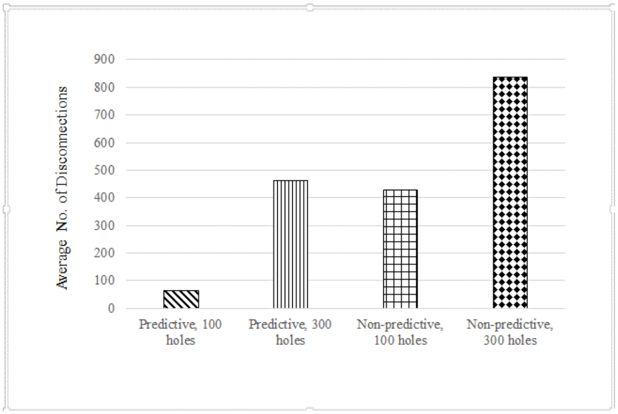

Figure 4 - Average Number of Disconnections per Node

Figure 5 shows the evaluation of the duration of disconnections experienced by each node. In the case of the predictive case with 100 coverage holes, there is about 60% improvement over the non-predictive case, while in the case of 300 coverage holes there is about 65% improvement over the non-predictive case. It is clear from the figures that the system managed to keep the coverage holes duration as small as possible by intelligently choosing the alternative network during the network coverage breaks events. To be selected, the network alternative must be available in the direction of vehicle travel and is not predicted to break shortly after the connection is established.

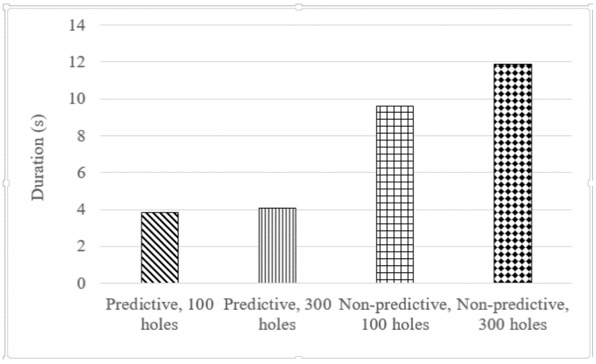

Figure 5 - Average Disconnect Duration

Figure 6 provides the estimates of the average number of lost packets during network breaks. This is done in the simulation by counting the number of packets that would have been otherwise sent if the node was connected. Due to the reduced number of coverage holes and their durations, we can see that the predictive system significantly reduces the average number of lost packets. The loss of packets greatly affects the service continuity of the user applications especially if the user is on an audio or video phone call.

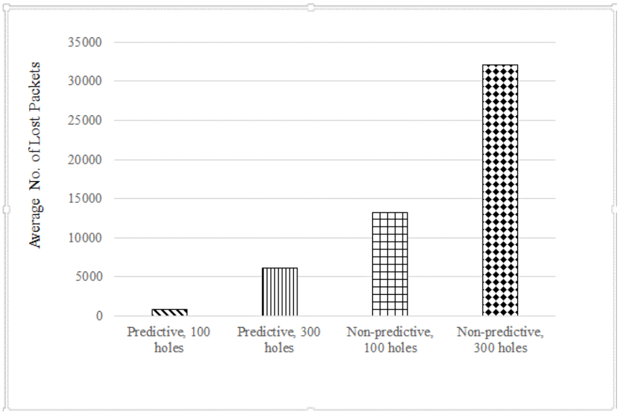

Figure 6 - Average Number of Lost Packets per Node

From the above results, the average coverage holes durations, and number of encountered coverage holes per node, we can see a decline in the continuity of the coverage provided to the user of the node. We believe that this is a direct result of the preemptive switching done by the PMHS in response to the changing nature of the network coverage in different areas as the node moves along its path.

The packet loss rate, which measures the number of lost messages with respect to the total number of sent messages, has sharply declined in the case of predictive switching. The effect of PMHS is clear when compared to a non- predictive approach. Average coverage hole duration, number of encountered coverage holes, and packet loss rate give us solid indications on the continuity of the connection.

To further investigate the predictive switching, we studied the situation where all the network alternatives are equally good in terms of performance parameters. We normalized the RTT values of each node using the average delay of the currently active network interface. We found out that the RTT value in both cases (predictive and non-predictive) are very close which verifies that the system response time isnot adversely affected, while at the same time improving connection continuitywiththe predictiveswitching. In contrast with the case of using satellite internetalternative, the response time was affected whileat the samemaintaining connection continuity with improved average packet loss rates.

V. CONCLUSIONS

In this paper, we studied the effect of network coverage and predictive switching on the continuity of vehicle connectivity and the quality of service. We used of multi-homed predictive switching coupled with the intelligence of supporting gateway that enables predictive decisions and allow the nodes to preemptively switch between available networks.

We evaluated the predictive multi-homed switching mechanism in order to identify the system's merits and its suitability for in-vehicle applications. The results of our evaluation shows improvements in the performance metricsfor thecontinuity of the vehicle connection. The performance improvements isdemonstrated by theaverage coverage hole duration, average number of coverage holes encountered by a node, and the packet loss rate.

Even though the experiments were done on a model that uses two service providers, they can be equally applicable to other means of service provisioning. The main objective is to identify coverage holes with respect to location and try to eliminate their effect on user applications. Hence, the same methodology can be applied to 5G networks as it is applied to LTE coverage, only some parameters will change according to the additional network capacity of the alternative networks. For future work, the evaluation under dynamic conditions such as changing signal attenuation due to weather conditions and other network events will to be examined.

REFERENCES

[1] IEEE 802 Standard, "Local and Metropolitan Area Networks: IEEE Standard: Overview and Architecture," in IEEE Std 802-2014, ISBN: 978-0-7381-9219-2, pp.1-74, June 2014

[2] N. TuanLe, M. Hossain, A. Islam, D. Kim, Y. Choi, and Y. Jang, "Survey of Promising Technologies for 5G Networks", Mobile Information Systems Journal, Vol. 2016, No. 2676589, pp. 1-25, Dec 2016

[3] K.DeyKakan et al., "Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication in a heterogeneous wireless network – Performance evaluation", Transportation Research Part C, pp 168-184, Elsevier, July 2016

[4] S. Bhaskaran, J. Yu, "Predictive Flow Switching and Application Continuity in Connected Vehicle Networks", US Patent Pub. No. US 2018/0302770A1, Oct. 2018

[5] S. Mukherjee, "Network-Assisted Multihoming for Emerging Heterogeneous Wireless Access Scenarios", A thesis submitted to the Graduate School, The State University of New Jersey, New Brunswick, Rutgers, 2014

[6] P. Pawar, B. Beijnum, A. Peddemors, A. Halteren, "Context-Aware Middleware Support for the Nomadic Mobile Services on Multi-homed Handheld Mobile Devices", IEEE Symposium on Computers and Communications, ISCC 2007

[7] M. Sangari, K. Baskaran, "Secured Efficient Fast Handover Multihoming Based NEMO+ (SEFMNEMO+) for Vanets", Circuits and Systems,pp. 239-254, Apr 2016

[8] K. Ahmed, M. Lee, "Secure LTE-Based V2X Service", IEEE Internet of Things Journal, Vol. 5, No. 5, pp. 3724-3732, Oct 2018

[9] J. Contreras-Castillo, S. Zeadally, J. Guerrero-Ibañez, "Internet of Vehicles: Architecture, Protocols, and Security", IEEE Internet of Things Journal, Vol. 5, No. 5, pp. 3701–3709, Oct 2018

[10] P. Singh, R. Bali, N. Kumar, A. Das, A. Vinel, L. Yang, "Secure Healthcare Data Dissemination Using Vehicle Relay Networks", IEEE Internet of Things Journal, Vol. 5, No. 5, Oct 2018

[11] A. Taha, "An IoT Architecture for Assessing Road Safety in Smart Cities", Wireless Communications and Mobile Computing Journal, Vol. 2018, No. 8214989, pp. 1-11, Nov 2018

[12] T. Balan, D. Robu, F. Sandu, "Multihoming for Mobile Internet of Multimedia Things", Mobile Information SystemsJournal, Vol. 2017, No. 6965028, pp. 1-16, Sep 2017

[13] B. Finley, A. Basaure, "Benefits of Mobile End User Network Switching and Multihoming", Computer Communications, Vol. 117, pp. 24-35, Dec 2018

[14] L. Bokor, Z. Mihály, "GPS aided predictive handover management for multihomed NEMO configurations", 9th International on Intelligent Transport Systems Telecommunications, pp. 69-73, Nov 2009

[15] S. Cha, K. Lee, H. Cho, "Grid-Based Predictive Geographical Routing for Inter-Vehicle Communication in Urban Areas", International Journal of Distributed Sensor Networks, Vol. 2012, No. 819497, pp.1 -7, Jan 2012

[16] P. Deshpande, A. Kashyap, C. Sung, S. Das, "Predictive Methods for Improved Vehicular WiFi Access", International Conference on Mobile Systems, Applications, and Services (MobiSys), June 2009

[17] C. Lin, D. Deng, C. Yao, "Resource Allocation in Vehicular Cloud Computing Systems with Heterogeneous Vehicles and Roadside Units", IEEE Internet of Things Journal, Vol. 5, No. 5, pp. 3692 – 3700, Oct 2018

[18] A. Bujari, O. Gaggi, C. Palazzi, D. Ronzani, "Would Current Ad-Hoc Routing Protocols Be Adequate for the Internet of Vehicles? A Comparative Study", IEEE Internet of Things Journal, Vol. 5, No. 5, pp. 3683 – 3691, Oct 2018

[19] G. Levy, Y. Aizenbud, "Associating External Devices to Vehicles and Usage of Said Association", US Patent No. US2018/0310146A1, Oct 2018

[20] L. Ekkizogloy, S. Kolluru, M. Brouwer, Y. Liu, "Automatic Detection of Vehicular Malfunctions Using Audio Signals", US Patent No. US2018/0350167A1, Dec 2018

[21] V. Petrov, A. Samuylov, V. Begishev, D. Moltchanov, S. Andreev, "Vehicle-Based Relay Assistance for Opportunistic Crowdsensing over Narrowband IoT", IEEE Internet of Things Journal, Vol. 5, No. 5, pp. 3710 – 3723, Oct 2018

[22] T. Cohen, "Determining Transportation Status Using Network Connections", US Patent No. US10,127,526B2, Nov. 2018

[23] L. Robinson, S. Manikandan, "Drivers Drowsiness Measurement and the Indication of Eye Movements through Algorithmatic Approach to Avoid Accidents", International Journal of Innovative Technology and Exploring Engineering, Vol. 8, No. 5, March 2019

[24] A. Festag, "Standards for vehicular communication—from IEEE 802.11p to 5G", Elektrotechnik and Informations Technik, Vol. 132, No. 7, pp. 409–416, Springer, Jul 2015

[25] A. Papathanassiou, A. Khoryaev, "Cellular V2X as the Essential Enabler of Superior Global Connected Transportation Services", Next Generation and Standards, Intel Client and Internet of Things Businesses and Systems Architecture Group (CISA), Intel Corporation, IEEE 5G Tech Focus: Vol. 1, No. 2, June 2017

[26] GSMA, Cellular Vehicle-to-everything (C-V2X), Groupe Speciale Mobile Association, London, United Kingdom, https://www.gsma.com/iot, 2018

[27] 5G Americas White Paper, “Cellular V2X Communications Towards 5G”, http://www.5gamericas.org/ files/9615/2096/4441/ 2018_5G_Americas_White_Paper_Cellular_V2X_Communications_Towards_5G__Final_for_Distribution.pdf, 2018

[28] X. Wang, S. Mao, M. Gong, “An Overview of 3GPP Cellular Vehicle-to-Everything Standards”, GetMobile, Vol. 21, No. 3, pp. 19-25, Sep 2017

[29] S. Chen, J. Hu, Y. Shi, L. Zhao, “LTE-V: A TD-LTE-Based V2X Solution for Future Vehicular Network”, IEEE Internet of Things Journal, Vol. 3, No. 6, pp. 997-1005, Dec 2016

[30] X. Yoon, M. Liu, B. Noble, “Random waypoint considered harmful”, IEEE INFOCOM. Twenty-second Annual Joint Conference of the IEEE Computer and Communications Societies, IEEE Xplore, pp. 1312-1321, July 2003

[31] B. Gopal, P Kuppusamy, “A Comparative Study on 4G and 5G Technology for Wireless Applications”, Journal of Electronics and Communication Engineering, International Organization of Scientific Research, Vol. 10, No. 6, pp. 67-72, Nov 2015

[32] R. Salazar-Cabrera, A. Cruz, and J. Molina, “Proof of Concept of an IoT-Based Public Vehicle Tracking System Using LoRa and Intelligent Transportation System Services”, Journal of Computer Networks and Communications, Vol. 2019, No. 9198157, pp. 1-10, Dec 2019