A Pmipv6-Fog Scheme for Vehicular Mobility Support

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Abstract: *Vehicular Ad-hoc Networks (VANETs) and the rapid development of communicationand computation technologies are one of the main next generation wireless networks which are envisaged to be an integration of homogeneous and heterogeneous wireless networks. Although VANETs are deployed in reality offering several services, a seamless handover mechanism with negligible handover delay is required to maintain active connections during roaming across these networks. Cloud computing as a solution has been deployed with special requirements of mobility, location awareness, and low latency. However, the handover delay remains high and unacceptable for delay-sensitive services such as real-time and multimedia services. This paper, therefore, proposes a PMIPv6-Fog model for VANET mobility management framework utilizing the merging of VANETs with fog computing, and the recently emerged network-based localized mobility management protocol, Proxy Mobile IPv6, to further reduce handover delay.*
<u>*Keywords:*</u> *VANET, MIIS, fog computing, Cloud Computing, Proxy Mobile IPv6, Vehicular Cloud Computing.*

I. Introduction

Vehicular Ad-hoc Networks (VANETs) are set of moving vehicles in a wireless network that apply Information Communication Technology (ICT) to provide state-of-the-art services of transport and traffic management. Presently, vehicles inVANETs are being equipped with processing, embedded sensors and wireless communication capabilities opening a myriad of possibilities for powerful applications, such as mobility vehicular cloud services, intelligent transportation systems (ITS), traffic efficiency and vehicle road safety [1]. With the interchange of data among entities in VANETs, it provides safety and comfort for drivers. The exact prospective of connected vehicles will be comprehended only when vehicles are interconnected to each other. Cloud computing is the hottest technology within recent years. With the growth of VANETs, cloud computing platform provides vastly manageable and scalable virtual servers, virtual networks, computing resources, storage resources, and network resources. Moreover, data can be accessed far and wide devoid of the trouble of keeping large storage and computing devices. With cloud computing, large amount of content can be shared and collaborated easily. It offers a solution to process distributed content. Vehicular cloud computing (VCC) is a new concept, which takes advantage of cloud computing to serve the drivers of VANETs with a pay as you go model [1]. But, it cannot meet all the requirements of mobility and quality of service (QoS) in VANETs, so new technologies and architectures are needed.

Fog computing is a paradigm (archetype) that extends the services of cloud computing to the edge of the network. As opposed to the cloud, which is more centralized, fog computing is aimed at services with widely distributed deployments. With one of the attributes localized, low latency communication and more context awareness in fog computing is possible. Similar to cloud, fog provides application services, compute, data, andstorage to end-users [2]. Fog computing as a new architecture is a suitable candidate for VANETs to meet the requirements, such as quick reaction to underlying device, reduce the burden on cloud, analysis real-time data stream with cloud and etc. Any device with computing, storage, and network connectivity can be a fog node, including mobile vehicles and infrastructure by the roads [3]. In VANETs, fog nodes closest to the network edge ingest the data from different types of devices, and developers decide how to use them. Compared with VCC, it is hard to resist the temptation to choose solutions based on fog computing which do better in real-time reaction issues.

The key objective of this paper is to extend Fog computing concept integrating it with the Proxy Mobile IPv6 (PMIPv6) protocol. The PMIPv6-based Fog approach we envision consists of two parts: (i) a PMIPv6-based inter-domain mobility management support based on inter-domain PMIPv6 based Vehicle Mobility Support (ii) a Logical handover block (L-Hanover block) based on MIIS /Hard Ware Flow, which exploits the mobility information delivered by the PMIPv6 inter-domain mobility management approach to decide on triggering the migration of services/sessions within the Fog. Integrating MIIS/HW Flow rules with PMIPv6 permits removing the complexity and workload associated with tunneling in mobility management. The remainder of this paper is organized as follows. Section II discusses the background and related work. In Section III, we present our PMIPv6-Fog scheme. In section IV the network model is presented. Finally, the paper concludes in Section V.

II. Background And Related Work

In this section, we briefly introduce the basic idea and architecture of Fog Computing based VANET. Several researches related to VANET Mobility and VANET-Fog architecture in wireless environment are also mentioned to steer the research line.

2.1 Fog Computing

Fog Computing, incorporated by Cisco in 2012, recently turn out to be an active research in cloud-related area. It is the paradigm that extends Cloud computing in which data, services and processing are concentrated at the edge of the network instead of entirely in the cloud. Fog Computing places the traditional cloud services closer to the end-users offering various benefits such as low latency, location awareness and mobility support. It integrates Core Cloud services, turns conventional data center into distributed, heterogeneous platforms. Fog Computing, thus, supports Internet of Thing (IoT) applications in VANETs, sensor/actors network sand industrial automation which require context-aware processing and sensitive-delay [4, 5]. To deploy Fog Computing, an orchestration is required to manage resources and services across edge devices. Fog services are provisioned, managed and tracked among such devices. Software Defined Network (SDN) was applied to Fog to support vehicle mobility, in [6] the authors proposed a SDN-based VANET architecture by introducing a SDN controller to the system. They also considered some operational modes and fallback mechanism to adapt SDN to VANET scenarios. They simulated and compared some routing protocols in the proposed architecture with traditional MANET/VANET ones, showing the benefits in using SDN. A further step was made by [7] by applying SDN to RSU Cloud. A new component to VANET architecture called RSU micro-data center which supports virtualization and SDN Controller capability was introduced. The traditional RSUs and specialized RSUs are forming RSUs cloud. The cloud controller, SDN controller and resource manager models are also proposed; implemented in one or more RSU micro-data center for cloud services. They also considered the reconfiguration overhead and proposed a heuristic algorithm to minimize the cost. In [8] a VANET Fog architecture was proposed by applying SDN-based to VANET Fog architecture, VANET Fog architecture was leveraged to support both safety and non-safety services. Figure 1 shows VANET Fog architecture using SDN
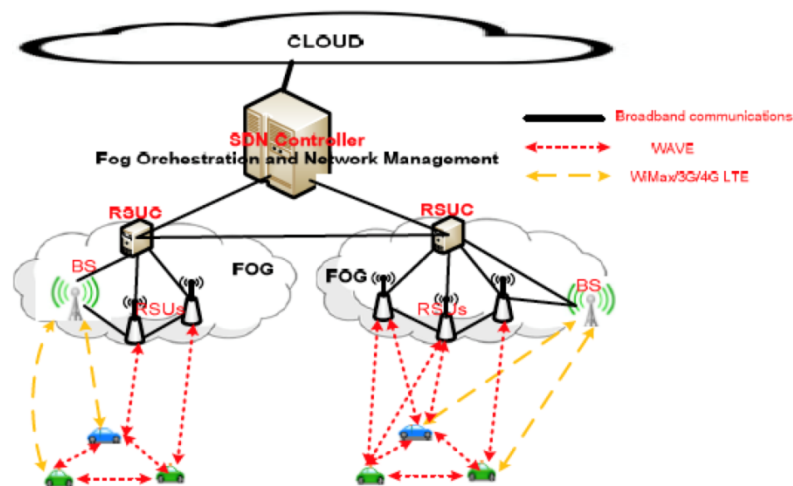

Figure 1 SDN-based VANET Fog Computing architecture

2.2 Mobility Management

Several research studies have been conducted to manage users' mobility [7]. In [8], the authors consider the usage of PMIPv6 for the intra-domain mobility management while MIPv6 is used for inter-domain mobility. This method incurs additional complexity to mobile clients as they must support two protocol stacks, host-based and network-based. In [9], an extension for PMIPv6, called Inter-domain PMIP (I-PMIP) was proposed to support inter-domain mobility reusing the Local Mobility Anchor (LMA) as a global mobility manager for mobile users outside their home networks. The main drawback of the proposed extension is that it is user-based, which is always applied even for services that do not require mobility support (e.g., sub-optimal routing, tunneling load problems). In [10], a Distributed Mobility Management (DMM-based approach (called D-PMIP)) is proposed to support inter-domain PMIPv6 mobility. Two methods were considered: partially distributed (DP-PMIP) with an Inter-Domain Central Mobility Database (ICMD) used to record inter-domains mobility information, and fully distributed (DF-PMIP) without ICMD. The solution allows bringing the mobility anchors closer to MNs and dynamically provides a per-session mobility support.

To support seamless inter-domain handover among heterogeneous wireless networks, Media Independent Handover (MIH) is defined as a common function framework in IEEE 802.21 standard. In the case of Multi-Mode Terminal (MMT) supporting Network Access Interface which has more than 2 features and MIH makes a range of handover between IEEE 802 series like WiMAX (Worldwide Interoperability for Microwave Access) and WiFi and non-IEEE 802 series like 3GPP and 3GPP. Figure 2 defines equipment which include MIH Function (MIHF) as a MIH entity which is classified as locations of equipment [11].
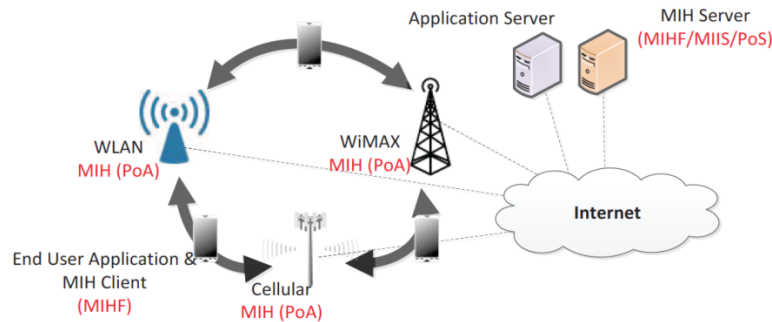

Figure 2 MIH Scenario for supporting handover among heterogeneous wireless networks.

MIH Point of Service (PoS) is an entity that is located in network that transmit MIHF service directly to terminal. It is located in the Data-Link-Layer (layer 2) devices like Point of Access (PoA) or the Network-Layer (layer 3) devices like IP router or remote network server. On the other hand, MIH Information Server (MIIS) supervises the information about AN, PoA, vendor and so on through database for offering information as to various Heterogeneous Wireless Network.

III. PMIPv6-Fog VANET Mobility Scheme

This section describes the proposed PMIPv6-Fog mobility scheme, role and operation for each component. Fog Computing framework, which takes advantage of MIIS concept, is also discussed to show the benefits in offering services. The design of PMIPv6-Fog mobility scheme is motivated by the following factors:

- Reduced handover latency and packet loss: Handover latency and packet loss in the proposed PMIPv6-Fog mobility scheme should be in the range where they do not disrupt seamless handover to support real time applications.
- Reduced control signaling cost on MAG: In the proposed PMIPv6-Fog mobility scheme, MAG should not be overburdened by extensive control signaling with LMA or any other entity inPMIPv6 domain.
- Extensibility: Different schemes for reducing handover latency and packet loss should be easily added and removed as per-requirement
- Scalability: In the proposed PMIPv6-Fog mobility scheme, addition and removal of different network elements should be easy
- Compatibility: Proposed PMIPv6-Fog mobility scheme should be backward compatible with standard PMIPv6 [10]

In order to support vehicle mobility for vehicles roaming between intra/inter-domain networks we propose the PMIPv6-Fog scheme, we assume that each MAG is a Fog device. Furthermore, each LMA is also assumed to be a Cloud-Fog device [3] which are capable of storing all the information needed for processing the handover for the vehicles roaming within different networks. We propose two methods to support seamless handover, 1) LMA control block, and 2) L-Handover Block. Applying these methods, it is assumed that both control signaling and data communication in PMIPv6 between mobile access gateway (MAG) and local mobility anchor (LMA) takes place over the same path. The LMA controller block and L-Hanover block extensions solve the long handover latency by separating the control signaling information from the data communication information. Logically, the LMA controller block and L-Hanover block controller in PMIPv6-Fog manages multiple LMAs and MAGs as one single LMA domain and performs the control signaling with the LMA on behalf of multiple LMA domains. The logical separation is where the L-Hanover block controller performs the PMIPv6 control signaling with LMA and MAG on behalf of MAG. As control signaling has been offloaded from the MAGs therefore they are only responsible for establishing Data Link Layer (L2) connection with the vehicle. In PMIPv6-Fog scheme, MAGs are assumed to be connected with the L-Hanover block controller trough the LMA controller. Table1 shows the information stored using fog and MIIS. LMA resides in the home network of the vehicle node. L-Hanover block controller communicates with LMA through Network Layer (L3) messages. Same as the traditional PMIPv6 this communication travels through the network. Depending on the access technology

of the MAGs, network can be Internet or it can be LTE network of mobile operator or any other network. IP data tunnel is created between LMA and Fog-MAG for the transmission of data packets from to Fog-MAG and vice-versa. Figure 3 presents the overall signaling flow of the PMIPv6-Fog scheme.

Table 1 LMA Controller information

	HW/Flow Rules using MIIS	Actions
1	Vehicle IP= signal strength, incoming MAG	MAG sends PBU to LMA, LMA registers and store vehicle info
2	LMA starts packet encapsulation to MAG. Destination= vehicle	LMA sends encapsulated packets through MAG
3	Packet encapsulated from MAG to LMA	LMA send encapsulated Packets trough next MAG
4	Vehicle IP= signal strength going down	LMA Buffers packets/establish connection with next LMA, sends encapsulated packets from LMA trough next LMA

Table 1 depicts a simple example of the rule table used by LMA controller based L-handover block in PMIPv6-Fog scheme to support vehicle mobility roaming within the network. If a vehicle arrives from outside of the LMM domain, it will be registered with the LMA domain. And the vehicle will start receiving packets within the network.
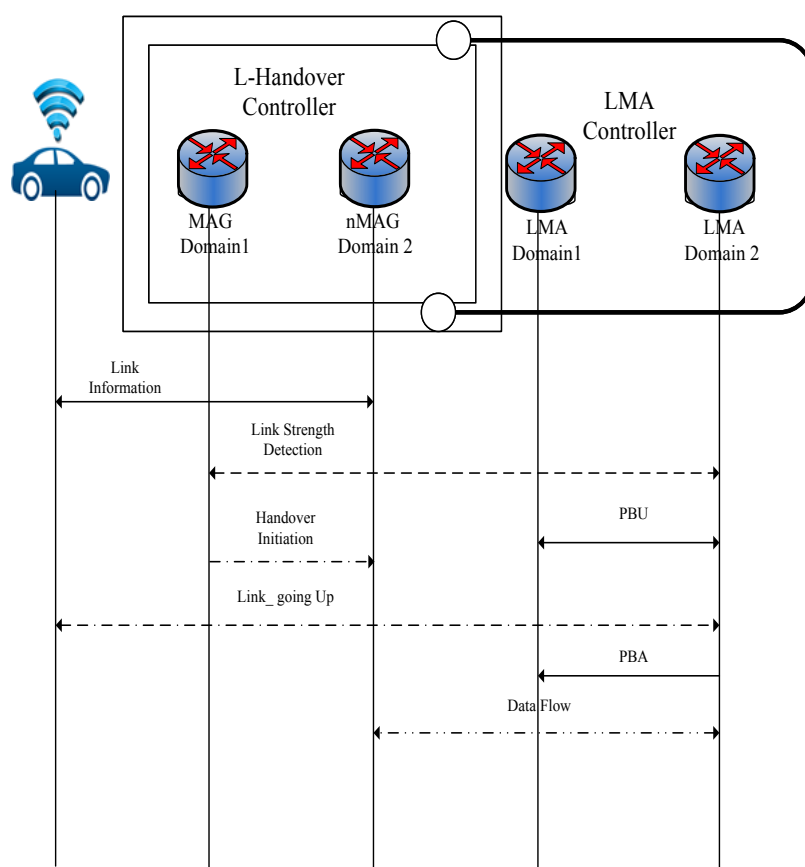

Figure 3 Proposed PMIPv6-Fogsignaling flow

The proposed PMIPv6-Fogscheme exploits the services of the MIIS information contained in the L-Handover block to reduce handover delay, e.g., inter-domain handover delay which can cause significant delay. The L-Handover Block enables some operations to be performed prior to the handover process while the vehicle is still connected to the old MAG's link in the First LMA domain. Thus, when the handover is eventually performed, there will be less delay causing procedures executed. For example, the handover delay is dealt with by enabling the new LMA to begin the handover procedure ahead of time by making use of the LMA controller Block information. Utilizing the information stored LMA controller block, the vehicle and MAGs (pMAG and nMAG) get to know of their neighboring networks' characteristics by requesting from information elements at a centralized information or MIIS server. The information server is assumed to be collocated within the LMA. The L-Handover Block information elements provides information that is essential for making handover estimation, such as, general information and accesses network specific information (e.g. network cost, service level

agreements, QoS capabilities, etc.), point of attachment specific information (e.g. proxy care-of-address, data rates, MAC addresses, etc.), and other access network specific information.

IV. Network Model

In this part, we discuss the proposed PMIPv6-Fog VANET Network architecture shown in Figure 4. The below components are needed to incorporate for deploying the system.

- Road-Side-Unit Controller (RSUC): A cluster of RSUs (e.g. BS) are connected to a RSUC through broadband connections before accessing to the Controller. RSUC is Hardware Flow-enabled and controlled by L-Hanover block Controller. Besides the responsibility of forwarding data, RSUCs also store local road system information and perform emergency services. RSUCs are fog devices. Furthermore, cellular Base Station (BS) in our proposed network is not simply carrying voice calls and conveying data, it is more sophisticated. The BS is under the L-Hanover block controller, capable of delivering fog services. Similar to RSUC, BS is also local intelligence.
- MAG is the mainly evolved component in PMIPv6-Fog scheme in comparison with PMIPv6. The two major changes in MAG comparing to MAG in PMIPv6 are: 1) It supports the Hardware (HW) flow table, MIIS 2) PMIPv6 control signaling functionalities of MAG have been offloaded to the L-Hanover block controller. The main functionalities of MAG are briefly described as below.

Link State Monitoring:

MAG monitors the link state of the vehicle attached to it, by monitoring the HW flow table, MIIS information value of the received frames/packets. These link state values are maintained as an exponential moving average, and when signal drops below a threshold MAG reports this event to the L-Hanover block controller by sending the vehicle-ID and link state value. The MAG also snap shots the link state of vehicles which are in its vicinity but are not attached to it, by utilizing the monitor mode of the IEEE 802 standard. If the link state of any such vehicle is above a certain threshold, then it is reported to the L-Hanover block controller by sending the vehicle-ID and snap shot link state value. It also plays as Fog Orchestration and Resource Management for the Fog.

Tunnel Management:

From PMIPv6 perspective, the main responsibility of MAG is to maintain the information table for tunnels between MAG and LMA. In MAG, the tunnel can have two status values.

- Provisional: When the tunnel status is provisional, MAG buffers the data packets received from this tunnel, without forwarding them to the vehicle
- Conclusive: When the tunnel status is conclusive, MAG will forward the data packets received from this tunnel to the destination vehicle.
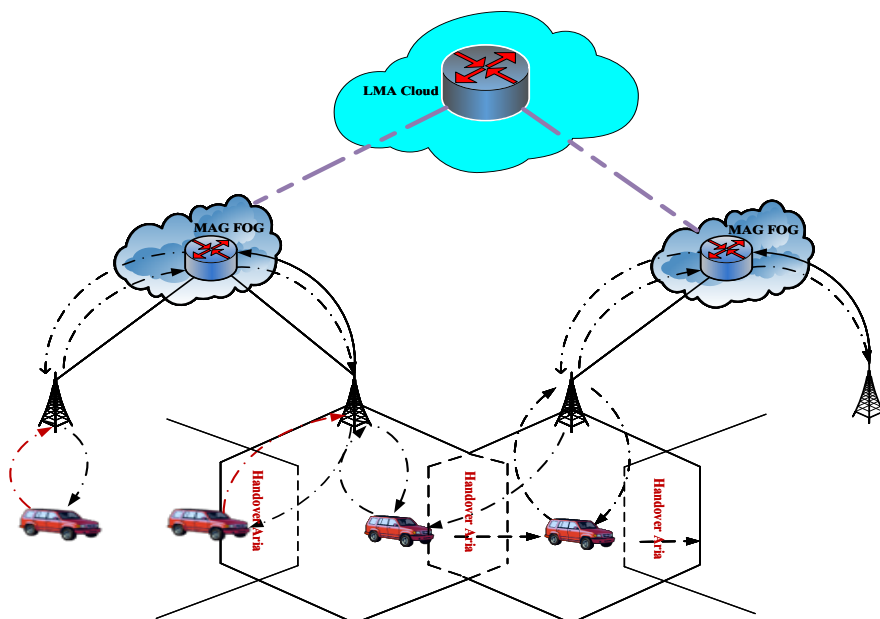

Figure 4 PMIPv6-Fog Network Model

V. Conclusion

In this paper, we proposed a PMIPv6-Fog scheme for VANET Mobility model environment to support continues roaming between (WiMax, LTE) LMA domains The proposed PMIPv6 scheme is based on LCO Block information function. Using the MIH services (MIIS), the MAG can obtain information without rout discovery or RtSolPr/PrRtAd messages. Thus, the handover latency time due to concurrent start of Data link layer and Network layer handover process is reduced. In this way, our scheme is suitable for a cost-effective network compared with PMIPv6 scheme. The PMIPv6-Fog scheme is proposed to solve the high mobility of the vehicle while roaming between (WiMax, LTE) LMA domains by using Fog/HW-flow to support continuance communication within the new PMIPv6 LMA domain after completing the handover process. Our future direction consists of plans to develop a mathematical model to evaluate the PMIPv6-Fog technique in different environments for both inter-domain and intra-domain schemes and compare the technique to other related research studies. In addition, we will propose a new handover estimation technique. Further investigation of the PMIPv6-Fog will be tested on a highway vehicular scenario. The impact of the intra-domain and inter-domain scheme on seamless connection support for vehicles roaming in PMIPv6 domains will be analytically analyzed.

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