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Mobility Management in Vehicular Adhoc Networks: A Review

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Abstract: *Vehicular Adhoc Networks (VANET) are gaining importance in vehicular networks and attracting an increasing attraction from both industry and research communities. Mobility Management is one of the most important and challenging research issue in vehicular networks which support various applications of Intelligent Transportation System (ITS). A specific mobility management solution is required for Vehicular Adhoc networks, because traditional mobility management schemes for mobile Adhoc networks (MANET) cannot meet the requirements of vehicular Adhoc networks (VANET) due to its unique characteristic (i.e. high mobility). In this paper, an overview of mobility management techniques in VANET is reviewed in three vehicular communication modes, i.e., Vehicle to Infrastructure (V2I) communication, Vehicle to Vehicle (V2V) communication and Hybrid Vehicle (HV) communication. Finally, the related open research issues are discussed.*
Keywords: *VANETs, Mobility Management, V2I, V2V, HV, ITS, RSUs, RVs.*

I. Introduction

In Intelligent Transportation Systems (ITS), each vehicle plays an important role of sender, receiver, and router to broadcast information to vehicular network. This information is used to ensure safe and free flow of traffic by vehicular network. Due to the recent developments of wireless communication technologies and computing devices, a novel infrastructure has been grown out known as Vehicular Adhoc Network or (VANET) which also supports to various applications in intelligent transportation systems. Vehicular Adhoc Networks represent a rapidly growing and a special class of Mobile Adhoc Network (MANET) providing communications among vehicles (V2V) and between vehicles and nearby fixed infrastructure of road side units (V2I) and hybrid vehicles (HV). Vehicular Adhoc network (VANET) has recently received considerable attention both from industry and academia [1-3]. VANET is a self organizing and decentralized network with moving vehicles being network nodes similar as mobile Adhoc network (MANET) [4]. Vehicular Adhoc Networks are distinguished from other kinds of Adhoc networks by their node movement characteristics, hybrid network architecture and new application scenarios. Standard organization (e.g. IETF) and Different Consortia (e.g. Car-to-Car Communications Consortium (C2C-CC) [5]) have been working on various issues in vehicular Adhoc networks. IEEE working group provided an IEEE 802.11p or dedicated short range communications (DSRC) for inter vehicle communication, which is an extension of 802.11 standards. For the support of network mobility in Vehicular Adhoc Network, IETF has standardized Network mobility Support (NEMO BS) [6].

For communication to occur between vehicles and nearby fixed infrastructure of road side units (RSUs), vehicles must be equipped with some kind of radio interface or OnBoard Unit (OBU) which enables to form a short range wireless Adhoc network [7]. An example of system model is shown in Fig. 1. In VANET, there are three communication modes, i.e., vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) and hybrid vehicle (HV). In V2V communication vehicles communicate with each other through Adhoc manner. V2V communication configuration is a multi-hop unicast where a message is propagated through multi-hop fashion until desired data is reached by vehicle. Due to short range bandwidth, V2V communication is efficient and cost effective. In vehicle-to-infrastructure (V2I) communication, road side units broadcast message to all equipped vehicles in a single-hop manner. A high bandwidth link is required between vehicles and road side units in V2I communication so that vehicles may access infrastructure such as BS or AP for information interactive. The road side units may be placed every kilometer or less so that a high data rate may be achieved and maintained in heavy traffic.

Hybrid vehicle (HV) communication refers to a configuration in which communication occurs among vehicles as well as between vehicle and nearby fixed infrastructure of RSUs. Because there is no available infrastructure around, vehicles may connect BS or AP through multi-hop routing with RSUs or other vehicles serving as fixed or mobile gateways. VANET is a special class of mobile Adhoc networks (MANETs) [8] with unique characteristics. There are certain factors which differentiates VANET from MANETs i.e., the density of VANET varies dramatically, topologies of VANET are highly dynamic due to high mobility of vehicles, there is no major concern of power consumption in VANET and using of different mobility models and routing protocols for VANET.

To support seamless communication, mobility management has been a challenging and important issue in VANET. Since MNs change their points of attachment frequently leading to changing in topology abruptly in VANET, mobility management is essential for providing seamless and high speed services for vehicular networks.

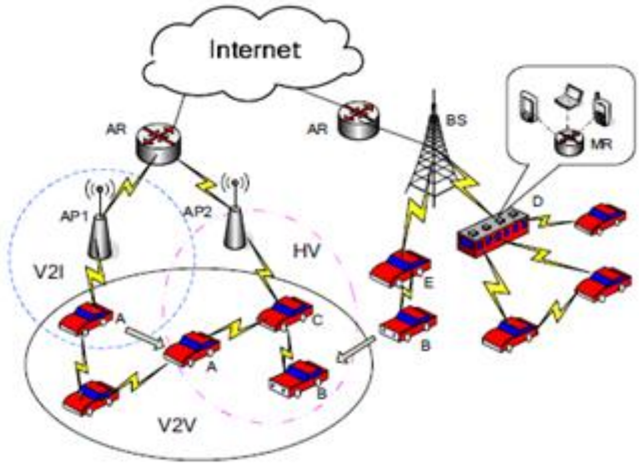

Figure 1. Three communication modes in VANETs [10]

To achieve optimal performance in V2V, V2I and HV communications, different mobility management schemes can be designed for respective modes since communication in all three modes are different. For V2V communication, mobility management focuses on route discovery, maintenance and recovery which are similar to those of MANETs [9]. For V2I communication, most mobility management solutions focuses on internet mobility management protocols, such as MIPv6 or FMIPv6, since data is exchanged between vehicles and nearby infrastructure of RSUs. Different types of mobility management solutions have been designed for compatibility and interoperability for the V2I communication. Due to the unavailability of RSUs infrastructure around, in HV communication, different mobility management schemes are adopted which are compatible to both V2V and V2I communication because the data is exchanged between vehicle-to-vehicle as well as vehicle-to-infrastructure of road side units. In this paper the current, state of art on mobility management for V2V, V2I and HV-based VANET will be provided.

The rest of this paper is organized as follows. In section II, an overview of mobility and mobility management in vehicular communication with its requirements and challenges in VANET is provided. Mobility management schemes for V2V, V2I and HV communication are detailed in section III. The mobility management solutions for heterogeneous wireless networks are discussed in section IV. In section V, open research issues in mobility management for VANET are discussed. Finally, the conclusion is outlined in section VI.

II. Mobility And Mobility Management in VANETs

In vehicular communications, an internet gateway or an infrastructure is required through which some applications of ITS may access internet [11]. In VANET, bidirectional internet connectivity and global addressability can be provided by internet gateway to the mobile nodes in VANET [12]. Since mobile nodes in VANET are far away from the fixed infrastructure providing internet, so communication may be relayed through intermediate mobile nodes leading to multi-hop communication. MIPv6 based mobility management solutions can not be applied in these scenarios directly due to unavailability of direct connection between internet gateway and mobile nodes. To apply MIPv6 based mobility management in vehicular networks certain issues are arised such as: handoff decision and movement detection. To provide handoff support for VANET, many traditional mobility management protocols, such as mobile internet protocol version 4 (MIPv4) [13], mobile internet protocol version 6 (MIPv6) [14] and NEMO basic protocol [15] have been proposed. In VANET, vehicular area network (VAN) can be established for various applications which are supported by ITS. To enable high speed seamless connection in vehicular network another network are provided in which different technologies can be integrated in to one known as heterogeneous network [16]. In this section, we discuss the types of mobility in vehicular Adhoc network in V2I and HV communication modes. Mobility management issues and its technical challenges in vehicular networks are also discussed.

2.1 Mobility in VANETs

Vehicle communicates with RSUs directly or through other relay vehicles (RVs) in V2I and HV communication modes. When a vehicle leaves its current coverage area of associated RSU/RV and enters in new area of RSU/RV, it is required to establish a new connection to maintain its connectivity or point of attachment. To achieve the goal of seamless handoff and to conduct these operations between new RSU/RV and previous one, the mobility management of the moving vehicle is required. In VANET, individual vehicle or group of vehicles may need to perform handoff when they move as a unit and accordingly mobility is categorized as group mobility and individual mobility [10]. Fig. 2 shows taxonomy of mobility scenario in VANET [10].

- Typical Mobility scenarios in VANET
  - Groupmobility
    - Cluster based Mobility
    - Mobility in VAN
  - Individual mobility
    - Mobility in V2I
    - Mobility in HV

Fig. 2 Mobility scenarios in VANETs [10]

2.1.1 Group Mobility

There are certain applications in VANET in which a group of vehicles or mobile terminals (MTs) move together as a unit e.g. moving vehicles in a cluster or in vehicular area network (VAN). Mobility in VAN and cluster based mobility is discussed in following [10].

2.1.1.1 Mobility in VAN

In VAN, vehicles equipped with electronic units such as: entertainment systems, vehicle sensors, navigation system or mobile devices, move as a network and communicate other vehicles via IEEE 802.15.4 WPN or IEEE 802.11 WLAN technology. The improvement in communication performance and the saving of handoff signaling cost can be achieved in VAN due to fix relative location of vehicles, movement at same velocity of mobile gateways and equipments of vehicles and no additional handoff process is required for internal equipments. For equipments inside the vehicles, the handoff process of mobile relay is also transparent. In fig. 1, vehicle D shows as an example of VAN.

2.1.1.2 Cluster based mobility

To achieve efficient and fast message transmission basis on the certain metrics of network or vehicles such as moving directions of vehicles, geographical locations and the link characteristics between vehicles and RSUs or between vehicles, a cluster-based mobility management scheme is proposed and may be applied for VANET in which a vehicle is chosen among vehicles as a cluster head based on certain criterions. This cluster head is responsible for various cluster topological management in VANET. In VANET, if there are multiple clusters then management in entire vehicular Adhoc network is done through co-operation or coordination among cluster heads. In VANET, two types of mobility scenarios may occur, i.e., ordinary vehicle handoffs and cluster head handoffs. In ordinary vehicle handoffs, handoff is performed by vehicles inside a one cluster with vehicles of another cluster resulting through either from relative movement of vehicles or reselection of cluster head in the same cluster. On the other hand in cluster head handoff, the whole cluster needs to perform handoff with target RSU after moving out of previous cluster due to the mobility of vehicles.

2.1.2 Individual Mobility

In this subsection, the individual mobility employed for both V2I and HV communication has been subscribed [10].

2.1.2.1 Individual mobility in V2I

In V2I communication, vehicles connect with IP-based backbone through accessing the relating RSUs. When the received signal strength (RSS) from current related RSU drops below predefined threshold, then the vehicle searches new RSU with which the link quality is good enough to support communication services and performs handoff to the target RSU. In fig. 1, when vehicle A moves out from the coverage area of AP1and enters in coverage area of AP2, its RSS decreases from AP1 and increases with AP2. Thus, handoff from AP1 to AP2 is required and it is an example of individual mobility in V2I.

2.1.2.2 Individual mobility in HV

In HV communication, RSUs are accessed by vehicles through RVs. Due to movement of source vehicles or RVs, the handoff of source vehicles or RVs is required. The hand off of source vehicles and RVs or wireless channel characteristics is given below.

(i) RV handoff

When a RV moves out of its current coverage area of current RSU, it has to connect to new RSU for accessing and if new RSU is not available around then it may connect to RV for continuing external network communication. In fig. 1, a RV hand off is required for vehicle E when it moves out of coverage area of BS to that of AP2.

(ii) Source vehicle hand off

Similar to RV handing off, a source vehicle may also needs to perform hand off with adjacent RV when the target RSU or RV is not available, after moving out of coverage area of its current RV. In fig. 1, vehicle B is connecting to BS via RV E originally, if the link between vehicle B and vehicle E is not available due to mobility of vehicles, then vehicle B may perform hand off from vehicle E to its adjacent vehicle *i.e.* vehicle C, which is able to give relay function for accessing network via AP2, to continue communication with BS.

2.2 Mobility Management & its Requirements

There are various criterions on the basis of which mobility management can be categariosed in traditional infrastructure based mobile networks discussed in following.

2.2.1 Micro mobility and Macro mobility management

Micro mobility and macro mobility management solutions can be classified according to the user's roaming area. Micro mobility and macro mobility management provide local and global mobility management respectively. Performance of mobile users can be improved by a hierarchal designing of local and global management. For both micro and macro mobility management various mobility management schemes have been proposed. Hierarchical MIPv6 (HMIPv6) [17], Fast handover mobile IPv6 [18], Proxy MIPv6 [19], HAWAII [20] and Cellular IP [21] were proposed for micro mobility management. For macro mobility management, MIPv4 [22] and MIPv6 [14] were proposed.

2.2.2 Host mobility and Network mobility management

Host mobility and network mobility management are mobility management depending upon the mobile host signaling. There is a direct involvement of mobile host in signaling in host mobility management whereas in network mobility management there is no direct involvement of mobile host in signaling.

2.2.3 Homogeneous and Heterogeneous mobility management

These are the mobility management depending upon their network structure. Homogeneous mobility management can be classified for homogeneous networks [23] and heterogeneous mobility management for heterogeneous networks [24].

2.2.4 OSI layers dependent mobility management

There are certain mobility management schemes which can be identified by OSI layers. Various mobility management schemes are proposed which can be implemented in network layer, data link layer, transport layer, application layer and cross layer fashion.

In VANET, mobility management should give best connectivity of mobile nodes with correspondent nodes (CN) or in the internet or global connectivity for mobile nodes in vehicular Adhoc networks. In [10], [25] and [26], the requirements are given for mobility management in VANET.

2.2.5 Multi-hop communication support

Multihop communication is a considerable requirement for mobility management schemes in VANET since it increases the reachability of mobile nodes to destination by extending transmission range. So, this requirement may be considered by mobility management schemes an optimized accordingly.

2.2.6 VANET characteristics

High mobility is a dynamic characteristic of VANET and using IPv6-based multihop support, a large address space can be availed for each sensor or mobile vehicles or mobile nodes in vehicular Adhoc network.

Besides, the advantage of large address space, IPv6 also supports the essential requirements of ITS applications such as: quality of service (QoS) and security.

2.2.7 Seamless mobility

A frequent handover occurs in VANET due to high mobility of vehicles resulting discontinue of services and accessibility which should be guaranteed regardless of wireless technology and vehicles' location. So, seamless mobility is important challenge that has to meet by mobility management in vehicular network.

2.2.8 Scalability and efficiency

In VANET, the number of vehicles or mobile nodes may be large and so the connected sensors or devices to each vehicles also very large. Mobility management schemes must be efficient and scalable due to frequent changing of point of attachment to support different types of traffic in vehicular network.

2.2.9 Vertical and Fast handover

There are safety related delay-sensitive ITS applications in which fast handover is required. Since, vehicle spends a very short period of time at point of attachments due to high mobility, so fast handover is a crucial requirement for wireless network having small coverage area. In heterogeneous wireless networks different wireless technologies are integrated into one. To achieve seamless service, vertical handover of mobile nodes connections is essential to support different wireless technologies in heterogeneous wireless network.

III. Mobility Management Scenarios in VANETs

3.1 Mobility Management in V2V Communications in VANETs

For vehicular ad-hoc networks (VANETs), mobility is managed through recovery, maintenance and route discovery [9]. Mobility management in vehicle to vehicle communications contains several contents which have been described below. A vehicle to vehicle communication has been shown in fig. 2.

Figure 3. Vehicle to Vehicle communication

3.1.1 Location Based Management in VANETs

Due to large latency and overhead, basic Adhoc routing protocols can not be directly applied to VANETs having unique mobility characteristics [27]. However, geographic routing was shown to be effective and efficient for VANETs. Communicating nodes are required to have the location information of each other using geographic routing such as: Geographical Routing Algorithm (GRA) [29] and Greedy Perimeter Stateless Routing (GPSR) [28]). In VANETs, a location management scheme is needed, which deals with the storage, maintenance, and retrieval of mobile node location information [30].

In VANET, Location management can be categorized in to rendezvous-based and flooding based approaches [31]. Location servers are responsible in rendezvous-based approach. Nodes query the location of destination and update their location from location servers. On the other hand, the source floods the location query to the entire network which incurs huge overhead in a flooding-based approach. In VANETs, various schemes were proposed for location management. In [32], a quorum-based approach is capitalized to achieve efficient location service management by means of message aggregation and node clustering. Thus in one control message, the updates and the queries of nearby nodes are aggregated. In [33], region based location service management protocol was proposed which supports both locality awareness and scalability. In RLSMP, for both locations updating and querying to improve scalability, message aggregation with the enhancement from geographical clustering was used. To locate the destination node, local search was used for locality awareness.

3.1.2 Topology Based Management in VANETs

In Topology Management, there are certain schemes which can be proactive and reactive. In proactive schemes, signaling messages are sent periodically to explore the topology information. On the other hand, in reactive schemes, signaling messages are sent when it is needed. VANETs may be very large so, purely host-based topology control does not suit in vehicular Adhoc networks. This limitation of VANETs is solved by cluster-based topology control. Vehicles are grouped into multiple clusters and head of each cluster is responsible for communication by coordinating among each other in this cluster-based topology control management. However, due to constrained mobility and high speed of vehicles in VANET scenario the optimal performance cannot be achieved. In [34], clustering for open inter vehicle communication (IVC) networks (COIN) was proposed in which the cluster head selection is done on the basis of driver intentions and mobility information in addition with accommodating the oscillatory nature of inter-vehicle distances. To reduce the periodic beaconing process and to increase the topology maintenance interval by mobility prediction, a prediction-based reactive topology control was proposed [35]. In this topology, to support the use of standard Adhoc protocols a location-aware framework, i.e. kinetic graph was introduced and described that the standard Adhoc protocols can perform efficiently with kinetic graph in VANETs.

3.1.3 MAC Based Protocol Management in VANETs

A co-operative scheme for medium access control is proposed in [36], which is referred to as Co-operative Adhoc MAC (CAH-MAC). In CAH-MAC, the packets are retransmitted which were failed to reach at destination node due to poor channel condition, by utilizing the unreserved time slots of neighboring nodes. Thus, transmission reliability is increased by cooperation of neighboring nodes leading to increases network throughput in various network scenarios. But a cooperation collision occurs by introducing a time slot reservation which degrades the system performance. This problem is studied in [37] and an enhanced CAH-MAC (eCAH-MAC) is proposed. In eCAH-MAC cooperation collision is avoided by efficiently utilizing time slot. To avoid cooperation collision and to reserve time slots efficiently, the cooperative relay transmission phase is delayed. In [38], the reliability of CAH-MAC is studied in terms of packet dropping rate (PDR) and packet transmission delay (PTD). Through simulation it is shown that the PDR and PTD of CAH-MAC is decreased. Further on comparing with existing approaches, CAH-MAC provides reliable communication. Medium access control (MAC) protocol plays an important role for an efficient broadcast service to support high priority safety applications in vehicular Adhoc networks (VANET). In [39], a novel multichannel TDMA MAC protocol proposed specifically for a VANET scenario which supports efficient one-hop and multi-hop broadcast services by using implicit acknowledgments on control channel and eliminating the hidden terminal problem. By assigning disjoint sets of time slots to vehicles moving in opposite directions and to the roadside units, this protocol reduces transmission collision due to node mobility on the control channel.

3.1.4 Handoff Management in VANETs

Handoff management in vehicular Adhoc networks is very important aspect which is performed by rerouting to construct a new path to the destination. Due to high speed and constrained mobility of vehicles in VANETs, the routing protocols developed for the MANETs are not applicable for VANETs. So, various routing protocols have been proposed for VANET scenarios to construct a new path to the destination. In VANETs, a group of neighbor's changes when a mobile node moves, hence a new connection must be established quickly to transfer data to the destination node for better handover performance. Handoff management can also be categorized as proactive and reactive. In [40], a review of various routing schemes in VANETs can be found.

3.1.5 Data Access Management in VANETs

In VANETs, unreliable wireless communication and high mobility of vehicles significantly degrade the data access performance among vehicles. A novel vehicle- platoon aware data access (V-PADA) solution is proposed to address this problem [41]. In V-PADA, data is shared after replicating by buffers of vehicles in same platoon. After leaving the platoon, vehicle prefetches interested data and transfers its buffered data to other vehicles in advance so that they can still access the data after it leaves. To achieve this goal, a vehicle-platooning protocol and data management component are designed to identify platoon formation, predict platoon splits and to guide platoon members to replicate and prefetch the most suitable data. In [42], an efficient destination-based data management policy is proposed which considers road-side criterion, mobility of vehicles and context of the messages criteria through a context-aware service based on the geographic location of the vehicles and the data. A destination-based cluster algorithm to disseminate the data is implemented in this policy.

3.1.6 Message Dissemination Management in VANETs

Message dissemination in VANETs leads to give the solutions of various issues like security, safety and traffic management. In [43], the performance of message dissemination in VANETs with two priority classes of traffic is studied. Firstly, the probability distribution of low-priority transmissions in the system is derived through birth-death process. Secondly, to study performance measures of high–priority messages, the percentage of destination node population are determined which are not getting error free messages due to interference. The cooperative active safety system (CASS) is proposed as an inter-vehicle communication framework, whose operation is based on the message disseminations having information of surrounding vehicles state, such as: position and motion of vehicles, through a wireless network [44]. A time/location-critical (TLC) framework for EM dissemination and scalable modulation and coding (SMC) scheme is used to achieve the goal. In specific, vehicles near the accident site (or the point-of-interest location) receive guaranteed, detailed messages to take proper reaction immediately (e.g., slow down or change lanes), and vehicles further away have a high probability to be informed and make location-aware decisions accordingly (e.g., detour or reroute), with the assistance of reverse traffic when possible and necessary. The TLC framework and the use of the SMC scheme are shown to be able to disseminate EMs effectively and efficiently by taking both the time and location criticality into account, while simplifying the design of radio transceivers and access control protocols for VANET [45].

3.1.7 Data Aggregation in VANETs

Data aggregation is important area in which researches have keen interest of doing work. In [46], it has been focused that how to exploit data exchanged among vehicles to get information to be used for the drivers later on. In existing systems information is exchanged only when it is needed and then data is assumed obsolete and deleted. In this paper a technique is proposed in which data is aggregated when it is obsolete and produce additional knowledge for drivers when no relevant data is has been communicated among vehicles. A cluster based data aggregation in VANET technique is proposed which is based on autonomous clustering and a combination of functional equation based information fusion. In this work, vehicles are divided into autonomous clusters and one vehicle considered as cluster head [47]. All information is aggregated by cluster head and dissimulates it in to network among vehicles. The size of data is reduced before disseminate in vehicular networks.

3.2 Mobility Management in V2I Communications in VANETs

V2I communications may be used for the internet access and various important information which facilitates driver of vehicle for various applications in traffic management system as shown in figure 4. In V2I communication mode all the information is gathered in roadside infrastructure i.e. Traffic Management Centre (TMC) and forwarded to vehicles.

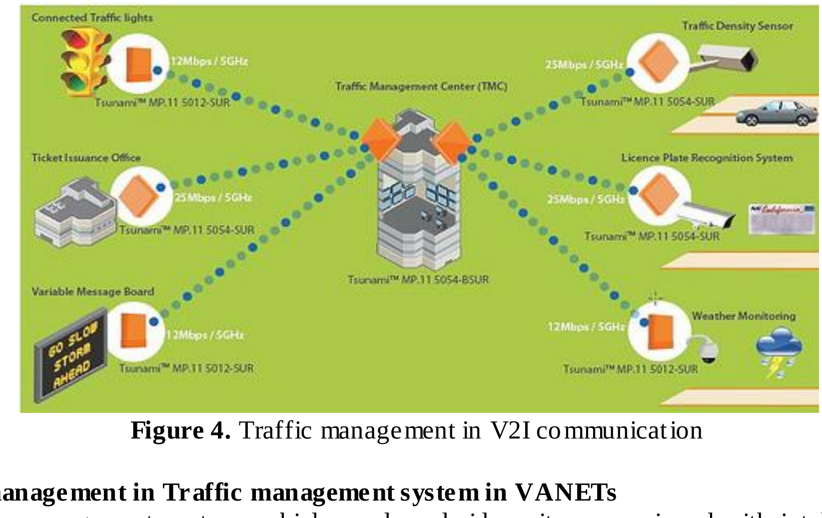

Figure 4. Traffic management in V2I communication

3.2.1 Mobility management in Traffic management system in VANETs

In traffic management system, vehicles and road side units are equipped with intelligent systems. In [48], an intelligent V2I based traffic management system is described which proposed a solution to the problem of regulating traffic flow and to avoid accidents by alerting the driver of traffic conditions. To determine the driving state on the basis of vehicle's direction, location, the road lay out and the speed, a control station is responsible. In this paper a fuzzy-based control algorithm is designed in which a traffic management solution, the reference speed and distance and the driving state is designed to evaluate the traffic situation. In vehicle infrastructure integration (VII) systems, two artificial intelligence (AI) paradigms, i.e., artificial neural networks

(ANNs) and support vector regression (SVR), are used to determine future travel time based on such information as the current travel time and VII-enabled vehicles' flow and density [49].

3.2.2 Dynamic data regulation for fixed vehicle detector in VANETs

In [50], a novel methodology regarding dynamic data regulation for vehicle passage detectors is proposed. A vehicle detector is generally fixed at a specific location, but this location may not, at all times, be the optimal place for efficient data collection. If the detector is occupied by queues during a specific period, it will produce irregular data for traffic control and management. Therefore, the optimal location should be dynamic. This paper develops a regulator to track the optimal vehicle-detector location in a variety of traffic conditions and an algorithm to adjust the detected data from the original fixed detector as if they were detected by the detector at its time-dependent optimal location. Without moving the fixed detectors from time to time, this method allows vehicle detectors to issue more reliable data that reflect the actual traffic demand and are not corrupted by traffic signals or queues.

3.2.3 Efficient Vehicular Content Distribution in VANETs

For better road safety and driving experience, content distribution for vehicle users through roadside Access Points (APs) becomes an important and promising complement to 3G and other cellular networks. In [51], a Cooperative Content Distribution System for Vehicles (CCDSV) is proposed which operates upon a network of infrastructure APs to collaboratively distribute contents to moving vehicles. CCDSV solves several important issues in a practical system, like the robustness to mobility prediction errors, limited resources of APs and the shared content distribution. This system organizes the cooperative APs into a novel structure, namely, the contact map which is based on the vehicular contact patterns observed by APs. To fully utilize the wireless bandwidth provided by APs, they proposed a representative-based prefetching mechanism, in which a set of representative APs are carefully selected and then share their prefetched data with others [51].

3.3 Mobility management in Hybrid Vehicle communication (HVC) in VANETs

HVC systems are proposed for extending the range of V2I communication systems. In HVC systems vehicles communicate with roadside infrastructure even when they are not in direct wireless range by using other vehicles as mobile routers. An HVC system enables the same applications as a V2I communication system with a larger transmission range. Here are some algorithms or schemes which have been proposed for mobility management in HV communication.

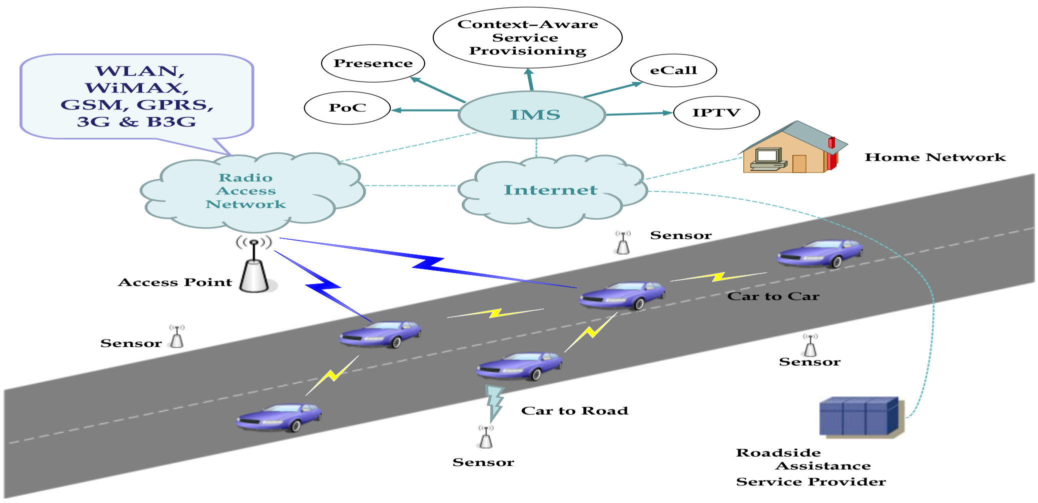

Figure 5. Hybrid vehicle communication

3.3.1 Utility Optimization Based Management in HV communication in VANETs

A utility-based RV selection algorithm is proposed in which multiple metrics from various protocol layers are jointly considered, including the characteristics of, the link status, the delay, physical channel and the bandwidth characteristics of RVs and user service requirement [52, 53]. By choosing the metrics, i.e., collision probability, available RV bandwidth, stability and link capacity as utility factors the utility functions of both RVs and SVs are modeled.

3.3.2 Game Theory Based Management in HV communication in VANETs

In [54], a Game theory-based RV selection algorithm, which jointly considers multiple metrics from various protocol layers, including the characteristics of physical channel, the link status, the bandwidth and delay characteristics of RVs and user service requirement. The payoff functions of both SVs and RVs are modeled. In order to optimize the overall system performance, a joint SV and RV cooperative Game model is established. The optimization problem is formulated and solved based on bipartite matching algorithm. Numerical results demonstrate that compared to previous algorithm, the proposed algorithm offers better performance in terms of throughput, transmission delay and successful transmission rate [54].

3.3.3 Access Gateway Discovery and Selection Management in HV communication in VANETs

Vehicular Adhoc network protocol with hybrid relay architecture is proposed for improving the success ratio. Access gateway estimation and a probability table based on the routing information are developed and applied in the backhaul-connected infrastructure network in order to estimate the access gateway region where the destination node locates and reduce the transmission flooding in wireless and wired network [55]. In [55], the Access Gateway Discovery mechanisms and Access Gateway Selection scheme have been shown effective by the significant improvement of success ratio in NS-2 simulation based on realistic vehicular mobility models.

3.3.4 Relay Vehicle Based Access Network Selection Scheme for VANETs

The selection for specific access technology is of particular importance in VANET for it may affect both system performance and user Quality of Service (QoS) significantly. In this paper, authors propose an accessing selection scheme for VANET application scenario with RV-based communication be accessible. A three-dimensional Markov chain is modeled to characterize the proposed network access scheme. Detail performance analysis for the network selection scheme is conducted and the numerical results shows that the proposed scheme offers better blocking probability and dropping rate of vertical handoff calls comparing to the traditional access method [56].

IV. Mobility Management For Hetrogeneous Wireless Access

In vehicles, mobile routers or current mobile nodes can be equipped with multiple radio access interfaces for different wireless networks (e.g. 3G, WiFi, and WiMAX). This is known as heterogeneous access. Seamless vertical handoff (i.e. handoff among different wireless technologies) should be performed for better wireless access performance and session continuity. In addition with, mobile vehicular nodes should be able to access multiple networks simultaneously for load balancing purpose. In heterogeneous wireless access environment, efficient mobility management schemes are required for vehicular networks to achieve the optimal performance. For the last few years researchers have paid attention on multihoming in which, to perform vertical handoff, a mobile node is able to use multiple access networks simultaneously. [57] proposed an analysis of multihoming in network mobility support in which mobile networks were classified in to a taxonomy which comprises of eight possible multihomed configurations.

In heterogeneous wireless network many works were done for host mobility while a little attention has been paid on network mobility due to heterogeneity of access scenario in mobile networks. In a mobile network, heterogeneity may arise due to several mobile routers each with a different access interface. In [58], the solution of multiple mobile routers was proposed in which the mobile network architecture provides IPv6 addressing, heterogeneous network accessibility and mobility management by using DHCPv6 and handoff management center (HMC). Forward loss recovery and location management are implemented by HMC based on mobility anticipation. Cooperative mobile router based handover (CoMoRoHo) was proposed in [59]. In this scheme different mobile routers are enabling during handover to access different subnets and cooperatively receive packets destined for each other. The packet loss and handoff latency are reduced by using multihoming techniques in CoMoRoHo. Further it is shown that CoMoRoHo outperforms FMIPv6 by reducing the packet loss as well as signaling overhead by 50%. A mobility management architecture based on mobile IP was proposed in [60] aiming at efficient network selection and timely handling of horizontal and vertical handovers. In this proposed paper, calculations of a metrics combining delay and delay jitters are used for hand-over decisions taken and depending on speed and variations in the metrics the frequency of binding updates is dynamically controlled.

There may be a frequent occurrence of simultaneous handover in vehicles due to its high mobility rate. A proxy-aided simultaneous handover (PASH) mechanism for the mobile networks in vehicles was proposed in [61] which aim of capable of reestablishing the session and reconstructing the optimized routing path as fast as possible. A FREE algorithm is designed for this purpose. In addition with this PASH mechanism also solve the addressing problem resulting from simultaneous handover in SIP-NEMO. On comparing the PASH mechanism with HASH mechanism, it has been shown that handover delay is reduced in PASH mechanism leading to probability of communication is high in vehicles. The problem of simultaneous mobility and its solutions are discussed in [62]. This paper presents a new ways for MIPv6, MIP-LR and SIPMM to handle simultaneous mobility problems and its solutions.

V. Open Research Issues

Despite the existing research efforts in recent years many research work have been conducted in mobility management in VANET, but there are still many open issues in vehicular networking.

5.1 Quality of Service (QoS) Issues:

Guaranteed QoS is challenging issue to design mobility management in VANET having mobile vehicles carrying diverse applications. Although some works have been proposed on QoS related with schemes and architecture for VANET but still, during the process of user handoff, there is need to give guarantee user QoS. Safety application should be given higher priority even if handoff is performed in vehicular network. Handoff latency should be minimized for multimedia communication. For achieving optimum resource utilization and seamless handoff, user mobility management may be combined with network resource management. Resource utilization, scalability, QoS negotiation during handoff, safety related application and user location management for efficient access and timely delivery are important factors while designing resource allocation mechanism.

5.2 Adoc routing issues

In Adhoc routing protocols mobility was not considered. With the increasing number of hops and mobility scenarios in V2V and V2I communication, the handoff performance degrades severely. To facilitate fast handoff there is a requirement of mobility aware vehicular Adhoc routing protocol.

5.3 Mobility model related issues

Traditional mobility model used for MANET cannot meet the requirements of vehicular networks due its unique characteristics (e.g. high mobility). Random way point (RWP) is the most commonly employed mobility model in MANET, however, existing literature of VANET suggested that RWP mobility model would be very poor approximation of real vehicular mobility in VANET. So, there is requirement of extension of existing protocols and accurate mobility model for performance evaluation of vehicular networks.

5.4 Access selection issues

In heterogeneous environment, mobile vehicles facing multiple access interfaces are required to perform access selection. An efficient load balancing scheme is highly desired, if mobile vehicles select multiple access networks simultaneously. The factors accounted for selection for multiple access networks are bandwidth, cost and delay which are to be defined. In addition with multiple internet gateways are also required when VANETs are integrated with internet i.e., an indirect internet gateway and a direct internet gateway. Further, to select optimum internet gateway is also a critical issue.

5.5 Relay vehicle selection issues

To increase coverage area and network capacity and to improve user QoS in vehicular Adhoc network, RVs may be applied as mobile gateways. Although a lot work have been done for HV communication in choosing RV in VANET, but still there are some open issues in which work has to be carried out such as: gateway selection schemes, how to design optimal handoff schemes depending upon characteristics accessing network, source vehicle and application requirements. In HV communication, the factors of computation complexity and hardware cost are worth investigation.

5.6 Issues related to transport and application layer performance

In VANET, it is expected that performance of transport and application layer protocols need to be optimized. There is need for investigation on the effect of mobility management schemes on transport and application layer such as: TCP, UDP. Various mobility management schemes are proposed for medium access control (MAC) layer, so compatibility of MAC layer with vehicular communication is an important issue for research in VANET.

5.7 Handoff management in VANET

In vehicular Adhoc network, handoff management is performed by rerouting to create a new path to the destination vehicle. Many mobility management schemes are proposed in VANET on the basis of handoff management. Although various researches have been carried out to enhance handoff performance for VANET, still the performance evaluation under network topology and application scenario is highly desired.

VI. Conclusion & Future Directions

In this paper, we have presented mobility scenarios and some technical challenges in mobility management for VANET. Existing works on mobility management techniques for V2V, V2I and HV communication modes in VANET is reviewed. Mobility management for heterogeneous wireless access network is discussed. Finally open issues of mobility management in VANET are also discussed.

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