



Taxonomy of Intelligent Transportation Systems (VANET): A Survey

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Abstract

For last years, the evolution of new issues has incited a great development of the transportation system. In this paper, we discuss ingredients of ITS (intelligent transportation system) that are inter-vehicle communication (IVC) or what can be called vehicular ad hoc networks (VANET), which are special types of MANET. We will survey the main issues relevant to VANET in detail with providing a conceptual model for the overall taxonomy. Also detail applications comparison, characteristics and properties of vanet projects and applications are given. Mobility models are beneficial as to research area, so their main features are discussed. The consortiums relatives of these systems are introduced. Whole protocol type's classification with their common using protocols is proposed and analysis for the main relative ones provided. Also some suggestions for routing protocols, data diffusion, mobility models, media access control protocols, and security are discussed. The investigation will try to answer the future relative attributes and limitations.

Keywords: VANET, ITS, communication, vehicle, security, mobility

1. Introduction

VANET is one of the challenging categories in mobile ad hoc networks that creates an intelligent space for vehicles communications. One of our main daily requests which comprises road and car safety capability such as traffic, emergency information about accidents and providing our good times (such: using Internet, helping us to follow each other on the road, etc). The goal of an ITS is to enhance security, efficiency, fun and pleasure in road. The goal of customary traffic control systems is based on the concentrated foundations such as sensors and monitors performed along the road for collecting information in congestions and traffic state for relative processing and sending notice messages. Here, we are talking about the architecture based on a distributed and independent system which consists of the vehicles with no relativity to any centralized system, and data routing, especially a VANET [1] as shown in Figure 1.

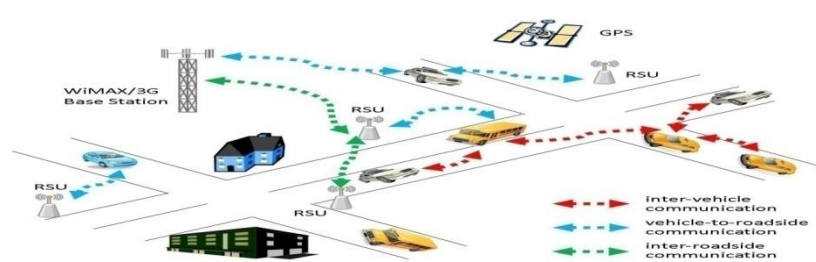


Figure 1. Example of VANET network

In this paper, we study the components in VANET that is an ITS system for inter-vehicle communication (IVC) and its relative provisions (Figure 2).

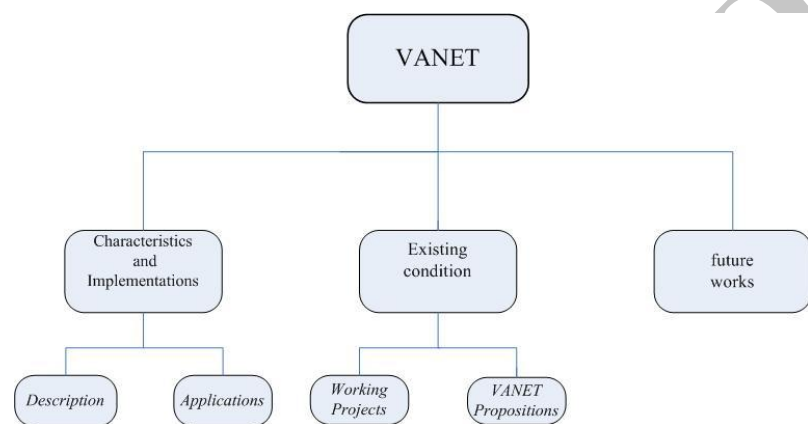


Figure 2. VANET relative provisions

The rest of the paper is organized as follows. Section 2 gives the VANET characteristics, Section 3 reviews the relative history, Section 4 describes the main idea and Section 5 concludes the paper.

2. Characteristics

The capabilities of VANET for intelligently controlling traffic and providing safety, are based on its properties that provide a vast number of relevant applications.

In a VANET, we don't have MANET relevant restrictions. In this network, power device, processing ability and memory facilities are desired in a good condition. The network can adopted for using in real-time WANs based on GPS system.

Because of VANET characteristics and fast topological changes, mainly due to high velocities [2, 3], they can also exhibit limited temporal and functional network redundancy, in addition to frequent fragmentation of the network topology [4]. The VANET itself can modify its own topology, for instance through the way drivers respond to messages sent out by the VANET.

A VANET also involves occasional communication to roadside infrastructure (known as Roadside Units or RSUs [5]). In civilian applications, roadside communication may

be to a roadside network carrying accident or traffic black spot alerts. Because of the accident avoidance and safety, all communications will concentrate on information transmission from a node to other destination nodes. However the vehicle nodes involved in similar transmission, upon their degree of implication in the activated contest, are nodes with one way solution.

The characteristics of VANET, particularly size condition, need making corrections.

There are three major categories: safety and efficiency in road, driver convenience and commercial issues. For improving safety and efficiency in travel and managing road accidents, IVCs suggest the feasibility to avert collisions with monitoring surrounding road, avert all obstacles and atmospheric conditions. Convenience applications make the independency easy and specially help the driver, principally for managing traffic and for case of consuming decreasing. Commercial applications will provide the entertainment such as web access, streaming audio and video, inter-vehicle chat, network games, etc. Here, we identify the description of a few application services of V2V (Vehicle-to-Vehicle) communication system.

- *Abnormally Traffic Signals*

Safety applications would be Slow/Stop Vehicle Advisor (SVA) in which a slow or motionless vehicle will broadcast alert message to its neighborhood. Congested Road Notification (CRN) detects and notifies about road congestions which can be used for route and journey planning [6]. The toll collection without stopping is another use of this type.

- *Environmental Conditions*

Vehicle nodes are intended to send and receive the information about weather, intersection collision warning, parking, obstacles, emergency message etc. In this case the information must be small and transmitted quickly.

- *Driving Assistance*

Providing the information that drivers have missed or might not able to see. Driving cooperative [7] is a case that improves transport safety to decrease injury in accidents. This practice support transmitting between nodes provided with tools such as sensory devices, so detecting environment situation and then forming dynamic clusters. Vision enhancement, information about weather and parking availability information are other applications.

- *Roadside Locations and Entertainment*

Helping to find the shopping centre, hotels, and gas stations and accessing the internet are the example applications. Also people can use games from other place, multimedia files, and so on. According to this description, comparisons between vanet applications are shown in Table 1.

Table 1: comparisons between vanet applications

Application	Categories	Traffic Type	Project Examples
Abnormally Traffic Signals	Category 1	event	C2C-CC
Environmental Conditions	Category 2	periodic	FleetNet
Driving Assistance	Category 2	event	PReVENT
Roadside Locations and Entertainment	Category 3	event	Car Talk

3. History

Based on the previous research papers, in this section we have reviewed fundamental projects and propositions.

Many projects and trials have been invested in the field of V2V communications. In [8] a brief summary of VANET trials supported by consortia in the USA, European Union, and Japan are discussed. Here some of the known activities and relative partnerships are discussed.

- FleetNet (2000–2003): Fleetnet [9] supported by some manufacturers and academic centres in Europe, concentrated on various research areas. The consortium includes exploratory character description of VANETs, suggesting the new routing and MAC protocols, with exploring other technologies in wireless and AdHoc.
- VII (Vehicle Infrastructure Integration) (2004–2009): This consortium provides collaboration between manufactures, IT suppliers and other relative associations. The aim of the VII program is to deploy an enabling communications infrastructure that supports vehicle-to-infrastructure, as well as vehicle-to-vehicle communications, for a variety of vehicle safety applications and transportation operations. In addition, VII will enable deployment of different applications which support encourages interests, involving vehicle manufacturers [10]. Principal applications are under development such as [11] noticing drivers for unsafe situations and collisions they should be around to run off the road, supplying real-time information for congestion concerning operators, weather situations, and other events, also supplying operators the corridor capacity information.
- VSC (Vehicle Safety Communications (2002–2004), (VSC-2) (2006–2009): This consortium [12] has run many experiments over the last four years in coordination with the NHTSA (National Highway Traffic and Safety Administration). In particular its objectives of the trials are to improve past safety scenarios by the use of DSRC(Dedicated Short Range Communication) along with positioning systems, defining requirements and parameters for safety oriented applications, traveler information, on board entertainment, fuel efficiency, pollution control etc.
- IVI (Intelligent Vehicle Initiative) (1998–2004): The IVI goal was to decrease the severity of crashes through avoiding driver mistakes.

- C2C (Car-to-Car Communications Consortium): The Car2Car [13] project started in 2001 and its main objectives are development and release of an open European standard for cooperative ITS and associated validation process with focus on IVC systems, to push the harmonization of Car-2-Car communication standards worldwide, driver assistance with new technologies, development of active safety applications, contributing to the EU standardization bodies.
- NOW (Network-on-Wheels) [14] (2004-2008): A German government supported project, established by vehicle manufactories and academic centres. Its goal was performing optimum protocols for transferring messages (for network and transport layer for IEEE 802.11 and ad hoc) in addition to methods for secure data transfer that used in C2C communication consortium and the EU standardization body ETSI. In addition to a flexible IEEE 802.11a hardware platform, which manages in an efficient way the low level wireless communication interface has been developed and is used by the partners.
- CVIS (Cooperative Vehicles and Infrastructure Systems): An EU project that commenced in 2006 to design, develop and test the technologies to allow cars to communicate with each other (C2C) and with the nearby roadside infrastructure (C2I) with goal of road safety and efficiency [15]. The project also work on traffic and network monitoring, define an architecture and system for applications, and develop common core components to support cooperation models in real-life applications and services for drivers, operators, industry and other key stakeholders, to address other issues relative to user, privacy and security, system openness and interoperability, risk and liability, public policy needs, cost/benefit and business models, and so on. Further, it will develop a mobile router using a wide range of communication media, including mobile cellular and wireless local area networks, short-range microwave (DSRC) or infrared, to link vehicles continuously with roadside equipment and servers.
- EVITA (E-safety vehicle intrusion protected applications) (2008-2011): A project funded by the EU Commission [16] within the 7th framework programme for research and technological development. The main objective of EVITA is to design, verify, and prototype an architecture for automotive networks with security components protecting and sensitive data protecting against compromise when transferred inside a vehicle. In addition, it also focuses on the protection of the intra-vehicle communication EVITA complements, other e-safety related projects that focus on the protection of the vehicle-to-X (V2V, VI, and so on) communication. Based on our considerations from above projects, comparison of main properties is shown in Table 2.

Table 2: main properties of vanet projects

project	Main Objective	commenced	architecture	Type of Communication
FleetNet	driver assistance & security	Germany	Hybrid(cellular/ WLAN and ad hoc)	V2V and V2I
VII	safety applications	USA	Hybrid	V2V and V2I
VSC	safety applications	USA	cellular/ WLAN	V2V and V2I
IVI	driver distraction & crash avoidance	USA	ad hoc	V2V
C2C	driver assistance & safety applications	europ	ad hoc	V2V
NOW	protocols & security	german	ad hoc	V2V
CVIS	standards for V2V and V2I	europ	Hybrid	V2V and V2I
EVITA	security	europ	Hybrid	V2V and V2I

Some of other trials that are based on consortiums and projects include the following projects:

ADASE II, AKTIV, ANEMONE, ARTIC, ATESS2, ASV, CALM, CarTALK 2000, COVER, COOPERS, CONVERGE, COMeSafety, COM2REACT, CODIA, CFVD, CVHS, CVPC, CVTA, CYBERCARS-2, DAIDALOS, Demo 2000, DIVAS, e-FRAME, EcoMove, eIMPACT, EMMA, eSafety Support, FESTA, FIDEUS, , FOT-Net, FRAME, FREILOT, FRICTI@N, GST, GOODROUTE, GeoNET, HeavyRoute, HIGHWAY, I-WAY, i2010, INFONEBBIA, IntelliDriveSM, INTERSAFE 2, INTRO, INVENT, iTETRIS, IVSS, JARI, KAREN, Mediamobile, MITRA, MobiVip, MORYNE, NEARCTIS, OmniAir, OPTIS, P3ITS, PRE-DRIVE C2X, PRECIOSA, PReVENT, PROMETHEUS, REACT, ROADSENSE, RTMS, SAFESPOT, SAFETY TECHNOPRO, SATIN, SeVeCom, SIM-TD, SISCOGA, SISTER, SMARTFREIGHT, PREDIT, SPITS, SUMMITS, TRACE, TRACKSS, Traffimatics, V2X, VAS, WATCH-OVER, XFCD.

4. Idea

In this section we classify and describe some propositions for VANET that still need more investigation.

4.1 Routing

The routing protocols in vehicle networks are based on the principles of routing in mobile ad hoc networks (MANET). There are two categories of MANET routing protocols – the flat and the large-scale protocols. The flat one includes two different subsets: Proactive protocols (DFR, IARP, CGSR, FSLs, OLSR, TBRF, ...), that update network routing information to all nodes at all times even if those paths are not currently being used, Reactive protocols (SENCast, DYMO, RAODV, ACOR, AODV, BSR, DSR, ...), that maintain and update only the routes which are currently in use. Communications between vehicles in VANET only use few numbers of routes; due to vanet characteristics, reactive protocols are suitable for them. The large-scale one includes two subsets: Geographical protocols (AGSG, GGAR, DREAM, LAR, GPSR, GRP, GeoTORA ...) and Hierarchical protocols (HSR, ZRP, CGSR, LANMAR ...).

The vehicles mobility attributes and their replacing topology results in conventional MANET protocols being insufficient for efficiently deal with VANET as intermediate nodes cannot always be found between source and destination nodes and complete connectivity cannot always be performed. This influenced the investigators to find dynamic routing protocols that are strong enough for the common path distributions caused by vehicle mobility [17, 18, 19], new approaches that can deliver enhanced throughput and better packet delivery ratio [20, 21], thereupon protocols investigation, they are classified into two major categories: topology-based and position-based. These routing protocols shown in Figure 3.

• *Position based (Geographic) Protocols*

These protocols [22] use the information regarding physical location of the involved nodes that are available to the straight neighbors in a manner that transmit beacons periodically. Determination of routing in all nodes is based on the destination's location included in their packets and the location of the neighbors of forwarding nodes. Examples of position based protocols include:

A-STAR (Anchor-based Street and Traffic Aware Routing) [23] was a protocol for a urban IVC condition. This protocol is based on buses route for recognizing anchor-based routing for sending or receiving packets.

CAR (Connectivity-Aware Routing) [13], main property of CAR is its capability to maintain a cache of achieved routes between sources and destinations. This property was inspired by supervision of other position-based protocols and their lack for utilizing information gathering about detached routes, after detecting those disconnections.

GSR (Geographic Source Routing) proposed for VANET in city environments [24]. It joins position-based routing protocol with topological information by calculating the junctions arrangement that must be pass overed by packets to reach their destination; then this information is contained in the packets in the form of GSR.

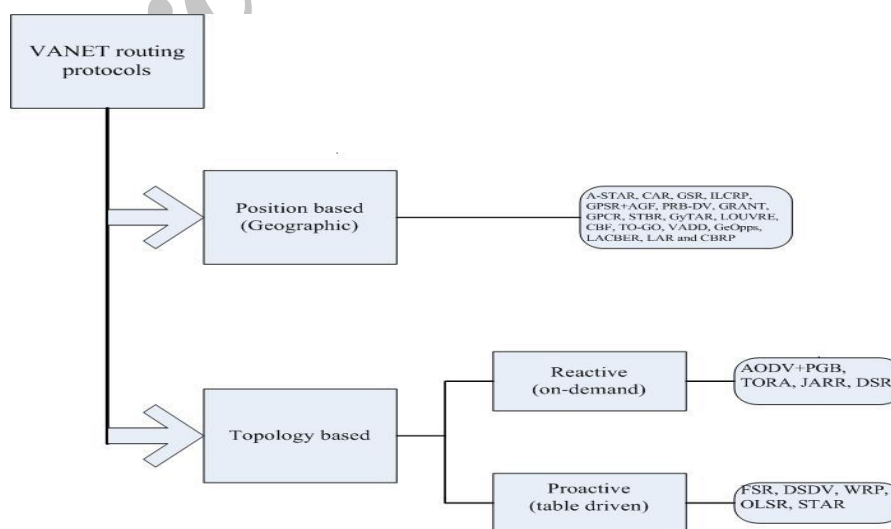


Figure3. Routing Protocols in VANET

ILCRP (Improved Location aided Cluster based Routing Protocol) for GPS enabled MANETs hoped that the geographic routing based clustering scheme presented would form the foundation for the possibility of reliable data sharing and communication between highly mobile vehicles i.e., VANETs for the present and in the future [18].

Many other protocols have been proposed including: GPSR+AGF, PRB-DV, GRANT, GPCR, STBR, GyTAR, LOUVRE, CBF, TO-GO, VADD, GeOpps, LACBER, LAR and CBRP.

- *Topology based Protocols*

These routing protocols use network links data. These protocols categorized in two divisions, the first is Reactive and the second is Proactive. Example of proactive (table driven) routing protocol is FSR (Fisheye State Routing) (Iwata, 1999; Pei, 2000) which is based on link state protocols. Each of network nodes works with a network state diagram and sends this information to their near nodes. Examples of reactive (on-demand) routing protocols are: AODV+PGB (Distance Vector+ Preferred Group Broadcasting) [25]. Its main goal is reducing the network bandwidth consumption in distance vector protocols for discovery manner. Other property is stable routing for vehicle nodes. Drawbacks are the taking longer route discovery and broadcast can discontinue if the group is found to be empty. TORA (Temporally Ordered Routing Algorithm) the main property of protocol is giving route to entire nodes, so the route stability needed for vanet is in desired level and network control packets reach to farthest nodes rapidly.

4.2 Dissemination and Diffusion of data

Information diffusion is data forwarding from a source node to other destination nodes, which guarantee a finite delay, effective reliability and better resource use with regard to Road Safety and Commercial Applications. Receiving nodes in diffusion method may be known with their IP and conditions or other identification. The following are some relative methods.

VADD (Vehicle-Assisted Data Delivery) use predictable traffic model and vehicle mobility to assist the effective data delivery [26]. Its main goal is identifying paths with minimum delay that is essential for wireless disseminations. For rapid packet transmission, high speed road must be selected. The selection may be changed based on intersections condition.

MDDV (Mobility-Centric Data Dissemination Algorithm for Vehicular Networks) [27]. For reflecting relative traffic density and distance, a weight assigned to each connection. This solution uses a forwarding path indicated as the smallest weight route to destination domain in the lead graph.

UMB is an IEEE 802.11 based Urban Multi-hop Broadcast protocol [28] for IVC. The protocol works on two relevant issues, in directions and junctions. In directional dissemination, information sending is based on furthest distance vehicle node. In junction dissemination, information sends to all road sections.

SODAD is a method for scalable information dissemination in highly mobile VANETs [29]. This protocol's main goal is for driver convenience and helping them. In SODAD, information about traffic conditions, weather, accidents and other comfort

related data such as parking lots are stored and disseminated to all neighbors and updated periodically.

TRADE (Track Detection) [30], purpose is promise good reliability and restricted number of rebroadcasts so every vehicle must indicate in relative near nodes which their motions assurance guaranteed.

DDT (Distance Defer Time) [30], uses a delay period for receiving packet previously and meanwhile if it gets that same packet from other node, it doesn't transmit it to others.

IVG (inter- vehicle geocast) [31] is other dissemination method which makes the last methods general (TRADE and DDT) for overcoming network segmentation and trustworthy. Dynamic retransmits are initiated for periodically retransmit alarm notices that are selected according to their distance with source node. The IVG has better performance and reliability than TRADE and DDT.

4.3 Mobility models

The complexity of VANET environment makes it difficult and expensive to implement and evaluate them before any new issues. A mobility model defines the set of rules that defines the movement model of nodes used by network simulators to create random topologies based on nodes position and perform some tasks between them.

The UDel mobility model version 1.0[32] is a simulating tool for urban mesh networks that contains interference in mobile nodes and produces corresponding urban area graph. The behavior of mobile nodes will be observed. Other simulators such as TRANSIM [33], VISIM [34], CORSIM [35] and Vanet MobiSim [36] are able to generate the traces for movement of vehicles and their behaviors traffic in urban.

In the STRAW (STreet Random Waypoint) [38] model, node motion is limited to road areas and specified with true classified information which mobility is restricted to road congestion. MOVE tool on the basis of SUMO (Simulation of Urban Mobility) was developed [37] for producing data files for movability used with NS-2 and Qualnet simulators in [39], GrooveSim simulation tool was improved that merges path models with a set of mobility, communication and traffic. The Features of the major vehicular mobility models are shown in Table 3.

Table 3: mobility models features

mobility model	Input	Output	Graph	Platform	Velocity	Human Patterns
MobiSim	GDF, AWL	ns-2, glomoSim, QualNet	User Defined	java	uniform	IDM
STRAW	TIGER	Swans	Geographical	Swans	smooth	CFM
MOVE	TIGER db	ns-2, QualNet	User Defined, Random	C++	uniform	CFM
SUMO	TIGER db	ns-2, glomoSim, QualNet	Grid Based, UserDefined	C++	Road Dependence, Smooth	CFM
Groove Sim	TIGER db	none	Geographical	C++	uniform	no

4.4 Media Access Control (MAC)

Currently, there are two types of approaches in developing MAC for IVC: contention-based and schedule-based (contention-free) protocols [40]. The main advantage of contention-based approaches is that no reconfiguration is needed during operation however, due to the random access they cannot guarantee a bounded access delay. Thus, the main challenge for this kind of protocols is to find a way that limits the access delay (with high probability). Contrary, schedule-based protocols can provide a bounded access delay. But reconfiguration needed due to time slots, which takes time and needs messages to be exchanged. Now we discuss some propositions which attempt to enhance specific aspects of existing rules:

D-FPAV (Distributed Fair Transmit Power Adjustment for VANET) is a Contention-based protocol [41], the main purpose is limit transmit power of periodic status messages (prioritization), keep overall network load under specific threshold (maximum beaconing load: MBL) always reserve some bandwidth for safety messages.

VeSOMAC (Vehicular Self Organising MAC protocol) is a contention-free protocol [42] using time slots, It is a distributed TDMA approach and it's able to reconfigure it's schedule very fast after topology changes. It uses an in-band network topology information exchange technique, it's necessary for every node to send at least one packet every frame, even if no application data is available for sending.

LCA (Location-based Channel Access) a distributed access protocol on the basis of position information that divides a geographical surface into several cells with an individual channel. Each can use every multiple access protocol such as CSMA or CDMA.

RR-ALOHA (Reliable R-ALOHA) protocol on the basis of UTRA TDD. In this protocol, extra information about the situation of every slot is transmitted to all nodes for avoidance of the similar reservation occurs.

Several other protocols are proposed like: MBCC, adaptive QoS, VMESH MAC, RMAC, clustering based multichannel MAC, CA-CDMA. Although many other protocols recommended, but more work is needed to be performed in this field.

4.5 Security

Security of message content is a big issue for V2V and V2I communication. The research work is concentration on the security system of VANET with following features: Authentication, Data Integrity, Anonymity, Availability, Low Overhead, Privacy, and Real Time Constraints. A brief description of some of these propositions are as follows.

Within the SeVeCom project [43], having developed a security architecture that introduced a range of mechanisms, to handle identity and credential management, and to secure communication while enhancing privacy. In [44], the authors presented the ECPP protocol that characterized by the generation of on-the-fly short-time anonymous keys between On-board Units (OBUs) and Roadside Units (RSUs), which can provide fast anonymous authentication and privacy tracking while minimizing the required storage for short-time anonymous keys. The authors of [45] propose Adaptive Message

Authentication (AMA), a lightweight filtering scheme that reduces the number of cryptographic operations performed by the nodes. The authors of [46] recommended a model for evaluating validity level of data move around in the VANET. The authors of [47] described and analyzed the different attacks in vehicular networks and suggest one security design for describing and evaluating its protocols. Also they present a cryptography public key adapted for VANET networks. The authors of [48] offered the SecCar design for IVCs based on a public key infrastructure to offer security solutions. The authors of [49, 50] have discussed security requirements using digital signatures and public key infrastructure for a VANET environment. In NOW project [51] a construction of attack trees implemented.

5. Conclusions and future works

In this article we have explained several components of VANET. For a comparative survey in characteristics and various applications, projects, consortiums and propositions, a number of contributions are presented. Subsequently a review of previous mobility models was conducted to contribute the researchers for future work. Due to the vast number of routing protocols, we classify them into two major categories. Also there is similarity to MANET, demands and solutions need special investigate with researches. We think that Many researches fields such as special concentration must be given to mobility models for a good overall situation, allocation of a protected frequency and for road safety, possible use of the IEEE 802.11p / WAVE standard(wireless access to vehicular environment), data transport MAC protocols and cross-layer design, realistic approaches for the investigation of routing protocols, joining of wireless technologies, security, control of congestion, resource management, IP mobility and IPv6 deployment in VANET, capacity and mobility connectivity, integration of VANETs with cellular networks and data dissemination are left for future work.

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