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Challenges of Routing In Vehicular Ad Hoc Networks : A Survey

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Abstract **- The advancement in WLAN technologies and introduction of WAVE standards, motivated researchers in the area of Vehicular ad hoc networks (VANETs). VANETs are special kind of ad hoc networks having the characteristics of fast topology changes and high node mobility. Commitment of various governments to allocate dedicated wireless frequency spectrum for VANETs and sensitivity towards safety in road navigation, further accelerated the interest in vehicle to vehicle communication (V2V) and vehicle to infrastructure communication (V2I). A vehicular ad-hoc network is the cooperative engagement of a collection of mobile nodes without the required intervention of any existing infrastructure. The successful delivery of radio packets within stipulated time period, is very challenging in this constrained situation. In this article, we discuss various types of routing strategies and survey the various routing protocols and associated mobility models for VANETS.**

I. INTRODUCTION

In the past few years, we have witnessed many developments in vehicular ad hoc network area. One of the major development was wide adoption of 802.11 technologies due to its affordable price. The other milestone was the standards of Federal Communication committee USA (FCC), which came into force in 1999. A dedicated frequency spectrum of 75 MHz (5.850-5.925 GHz) of DSRC (Dedicated Short Range Communication) was allocated to V2V and V2I communication. Consistent growth in automobile industry and increasing demand of safety and comfort factors led the research community to investigate the issue of vehicular communication deeply. VANETs are comprised of sensors and onboard units installed in vehicles and road side units. These devices enable the vehicles to communicate directly with other vehicles and roadside infrastructure. VANET and MANET are characterized by high node mobility, fast changing topology and self organization of node without any access point. But they are different in some ways like mobility patterns, scalability issue, efficient channel utilization, and security and privacy issues. From the above mentioned characteristics, it is evident that conventional MANET routing Protocols are not suitable in VANET environments. Therefore, more and more researchers have concentrated on proposing suitable routing protocols to deal with the highly dynamic nature of VANET. The routing Protocols in VANET are categorized into various types like Topology based, Position based, Geocast based, Cluster based, broadcast Based and Infrastructure based[12].

II. APPLICATIONS

Vehicular networking applications can be classified as road safety applications, traffic management applications and entertainment applications. Road safety applications reduce the probability of accidents on the road. These applications include head on collision warning, Emergency brake warning, Intersection collision warning, Violation of speed limit warning, Lane change assistance, Wrong way driving indicator and traffic condition warning etc. The main motive of traffic management applications are to focus on improving the vehicle traffic flow, traffic coordination and traffic assistance and provide updated local information, messages of relevance bounded in space and/or time. Speed management and Co-operative navigation are two typical groups of this type of applications. Entertainment applications consist of quite a diverse set. Tolling, point of interest notification, game playing, fuel station information, commercial advertisement and internet access are some examples to mention.

In past few years many research projects have been initiated around the globe. Here we consider standards, protocols and applications that came into existence with the collaborative effort of industry, government and academia in Europe, USA and Japan.

A. USA

Since inception in 2002, vehicle **Safety communication Consortium(VSC) [22]** has been busy in developing DSRC standards, protocols and applications for vehicle to vehicle and vehicle to infrastructure communications. Industrial, governmental and university research efforts have created significant opportunities in projects such as US **IntelliDrive (sm) [23], CAMP/VSC-2; CICAS, SafeTrip21, California PATH**. The vehicular networking protocol standards used in such projects, except the SafeTrip21, are the WAVE protocol standards that are standardized by the IEEE in the IEEE 802.11p and IEEE 1609 protocol set. The SafeTrip21 project does not use wireless technologies, but rely on other technologies such as cellular technologies.

B. Japan

In July 1996, five related government bodies jointly finalized a “Comprehensive Plan for ITS in Japan” [24], [25]. These government bodies are the National Police Agency (NPA), Ministry of International Trade and Industry (MITI), Ministry of Transport, Ministry of Posts and Telecommunications (MPT), and Ministry of Construction. This ITS plan has been based on the "Basic Guidelines for the Promotion of an advanced Information and telecommunication Society", which was determined by the Advanced information and telecommunication Society Promotion Headquarters in February 1996. The five government bodies listed above, recognized the need to develop a design that could respond to changes in social needs and development in technology in the future. In August 1999, these five government bodies jointly released a first draft of the "System Architecture for ITS". The draft was released so as to collect opinions from the industrial and academic sectors and to actively address the information worldwide. In November 1999, the "System Architecture for ITS" has been finalized. Currently, the main public and private organizations that influence the initialization, research, realization, and standardization of ITS in Japan are the following organizations:

• **ITS Info-communications Forum, Japan**

• **Public and Private sectors Joint Research**: MIC (Ministry of Internal Affairs and Communications), MLIT (Ministry of Land Infrastructure and Transport), and NILIM (National Institute for Land and infrastructure Management)

• **DSRC Forum Japan**: HIDO (Highway Industry Development Organization), ARIB (Association for Radio Industry and Businesses), JARI (Japan Automobile Research Institute), JSAE (Society of Automotive Engineers Japan), Private corporations and organizations.

• **Others**: ITS Japan, AHSRA (Advanced Cruise-Assist Highway System research Association), JAMA (Japan Automobile Manufacturers Association) ASV (Advanced Safety Vehicle), JEITA (Japan Electronics and Information Technology Industries Association)

Smartway: It supports vehicle to infrastructure communication at 5.8 GHz, e-payment services and VICS traffic information and warning in a single OBU. Smartway driver information and warning service became operational in 2006.

ASV (Advanced Safety Vehicle) program is divided into four phases:

ASV-1(1991-1995)
ASV-2(1996-2000)
ASV-3(2001-2005)
ASV-4(2006-2010)

ASV-1 and ASV-2 support traffic safety and efficiency applications for vehicle to infrastructure communications. ASV-3 and ASV-4 demonstrates the direct communication between vehicles and the infrastructure. **ITS-Safety 2010** defines the frequency band of 700 MHz for V2V safety applications.

C. Europe **C2C-CC (Car 2 Car Communication Consortium)** is a non-profit organization [26] initiated in 2002 by the European vehicle manufacturers, which cooperates closely with ETSI TC ITS and the ISO/TC 204 on the specification of the ITS European and ISO standards.

HTAS (High Tech Automotive Systems) [27] is a Dutch organization. It works jointly with cooperation of Industry, Knowledge Centers and Government.

EUCAR (European Association for Collaborative Automotive Research) [28], established in 1994, evolved from the previous Joint Research Committee (JRC) of the European motor vehicle manufacturers. EUCAR supports strategic cooperation in research and development activities.

eSafety, can be considered to be a joint initiative of the European Commission, industry and other stakeholders. It aims to accelerate the development, deployment and use of Intelligent Vehicle Safety Systems.

Major ITS projects in Europe are **SAFESPOT** by France, Germany, Italy, Netherlands, Spain and Sweden, **CVIS** technologies and applications are being tested in seven European countries, i.e., France, Germany, Italy, Netherlands, Belgium, Sweden and the UK.

III. Mobility Models

Due to huge cost of deploying and implementing VANET in real world, most researchers rely on simulations for evaluation of VANETs. Mobility model determines the position of nodes in the selected topology at any given time, which affects network connectivity and throughput [1]. Analysis of related literature reveals that the results of performance studies of ad hoc networks depend heavily on the chosen mobility model [2]-[5]. Mobility models need to consider many aspects like speed variation in presence of neighbouring vehicles, maintaining the minimum inter vehicle distance, queue at a crossing, traffic light at a crossroad, lane changing information scheme, traffic burst caused by retransmission, simulation period, network density, traffic congestion etc, so that the mobility model emulates the actual traffic behavior. One realistic modeling approach would be to use traces. Unfortunately traces are not available for vehicles which are roaming in cities randomly. As a result, the mobility of vehicles is often approximated by variety of mobility models equipped with various control parameters.

Random Way Point (RWP) Mobility model [30], is widely used in ad hoc network simulations. Nodes randomly choose a destination and approach towards that destination at a uniform speed. After reaching the destination, nodes randomly select another destination and so forth. RWP does not attempt to model any real mobility situation. Modified RWP model [31] considers road length, average speed, number of lanes, and average inter-vehicle gap as parameters. Saha and Johnson [32] proposed a realistic street mobility model based on the road information from the TIGER (*Topologically*

Integrated Geographic Encoding and Referencing) [33] US road map by US Census Bureau. In their model, they convert the map into a graph. In this model starting and destination points are randomly chosen on a road and movement follows shortest path algorithm. (STRAW) [29] is also based on the road information from the US road map by US Census Bureau. Manhattan mobility model Manhattan mobility model [34] is widely used in urban street scenario. It is also called City Street mobility model.

IV. WAVE Standards and Protocols

IEEE standards IEEE P1609.1, P1609.2, P1609.3 and P1609.4 are prepared for vehicular networks (Fig. 1). P1609.1 is the standard for Wireless Access for Vehicular Environment (WAVE) Resource Manager. It acts as the interfaces of the WAVE resource manager applications. P1609.2 defines security aspect. It deals with secure data delivery, message formatting, and message exchange. Routing and transport services are covered in 1609.3. P1609.4 deals with the usage of multiple channels specified in the DSRC standard. The WAVE stack uses IEEE 802.11p for its Medium Access Control (MAC). On the MAC layer, WAVE refers to carrier sense multiple access with collision avoidance (CSMA/CA) with request/clear to send (RTS/CTS), a mechanism in IEEE 802.11, to deal with the hidden and exposed terminal problems.

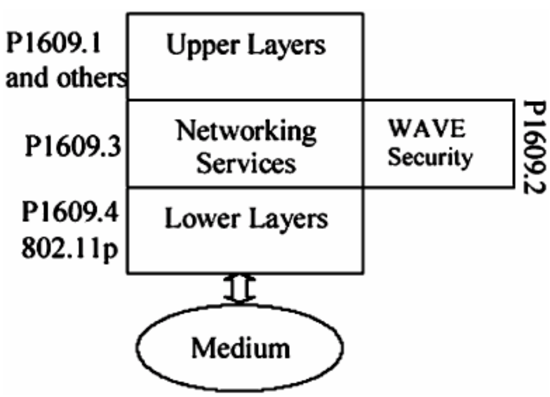

Fig. 1 WAVE Standards

V. Routing Protocols

The dynamic topology of vehicles makes packet routing very challenging. In this section, we classify routing protocols in IVC into four categories:

- Ad hoc routing
- Cluster based routing
- Position based routing
- Broadcast routing

A. Ad Hoc Routing Protocols

Most routing techniques which are very useful in MANETs can be used in vehicular ad hoc networks also due to common characteristics of self organized, self managed, less radio transmission range and frequent change in topology. These characteristics tempted researchers to utilize existing ad hoc routing techniques in VANETs also. AODV[6] and DSR[7] are a reactive protocol. The reactive routing protocols update the routing table only when there is demand to send data. AODV starts route discovery process through flooding. The aim of these protocols is to maintain a route from source to destination. They send flooded route request (RREQ) and wait for route reply (RREP). Route maintenance process is initiated upon route break. DSR maintains a route sequence from source to destination and AODV maintains only the previous Hop and next Hop of a node. DSR maintains alternative paths. These reactive routing protocols suffer from the initial latency incurred in the route discovery process. Although these protocols are suited for routing due to their reduced routing overhead and low bandwidth usage, they are less suitable in highway scenario which is highly portioned. Due to highly dynamic node movement these protocols suffer from poor route convergence. In this situation it becomes very difficult for a TCP connection to complete three way handshake due to high mobility.

Namboodiri et al. [8] presented that AODV algorithm resulted in frequent link break owing to dynamic nature of node's mobility. Two predictions are added to AODV for the improvement of algorithm.

In first, geographic position and speed information are added in AODV to predict link life time before route is set. This is referred as PR-AODV. It selects a new link before the expiry of estimated link lifetime (In AODV, the link is created only after the connectivity failure).

In the second algorithm (PRAOVD-M), it computes the maximum predicted life time route among various route options (PRAODV or AODV selects the shortest path). The simulation showed improved packet delivery ratio. However, the success of this algorithm largely depends on the authenticity and precision of node position and mobility.

B. Cluster Based Protocol

This kind of routing is used to provide scalability despite the dynamic topology due to fast speed of nodes (vehicles). A virtual network is created through partitioning the nodes in different clusters. Each cluster is having a cluster head. All the member nodes of a cluster perform direct communication with the other members of same cluster. Inter-cluster communication is performed through cluster heads. Studies show that many MANET based routing strategies are not suitable for VANET due to constraint on mobility, high speed and driver behavior.

They are unstable because clusters are having too short life to provide scalability.

Blum et al. [35] proposed an algorithm for routing called COIN (Clustering for Open IVC Network). In this proposal the cluster head is elected on the statistics of node mobility (speed and direction) and drivers' intention. It is also accountable for the oscillatory nature of inter-vehicle distances. Simulation results show that this routing technique produces more stable structure. It increases average cluster life time and reduces the cluster membership changes. It introduces little more communication overhead due to dynamic cluster management.

LORA_CBF [13] is a location based reactive protocol. All the nodes may fall in one of three categories namely ordinary node (member of a cluster), cluster head or gateway. The cluster head keeps information of its member clusters and gateways. Those nodes which are connected to more than one cluster are called gateways. Packets are forwarded from source to one of the intermediate nodes in the direction of destination, which is nearest to the destination (greedy routing). If location of a node is not available then route discovery phase is started. Route discovery is done in the similar fashion as adapted in AODV and DSR but only cluster heads and gateway nodes participate in this phase. Simulation results show that from the scalability point of view LORA_CBF is better than AODV and DSR but a great problem for this protocol is the delay and overhead involvement in the formation and maintenance of these clusters.

C. Position Based Protocol

Unlike MANETs, movement in VANETs is bidirectional contained along the roads and streets. Frequent change in direction is normally not experienced in VANETs. In this category of protocols, the routing schemes use geographical position information (from the on-board GPS receiver), traffic models and navigation system on-board vehicle. Studies show that position based routing is more promising than ad hoc routing.

GPSR (Greedy Perimeter Stateless Routing) [9] is a greedy routing protocol. It forwards the packet to the node which is at a minimum distance from the destination. GPSR includes face routing also to handle the situation of local minimum where greedy fails. This algorithm works well in the case of highway where less obstacles are present. This protocol is suitable for open area with evenly distributed nodes. But in urban street scenario tall buildings and trees may obstruct direct communication among nodes. If planarized graph is used to build the routing topology then more overhead will result in performance degradation. GPSR also suffers from routing loop in face routing and high speed of vehicles may lead packets in wrong direction sometimes which incurs more delay.

Lochert et al. proposed Geographic Source Routing (GSR) [14]. This protocol takes help of digital map to decide the preferred route in urban streets. It uses Reactive Service Location (RLS) to find the position of destination node. Sender determines the junctions through which packets are to be forwarded by using street digital map. Once junctions are decided, forwarding of packets among the junctions takes place with the help of geographic positions.

GPCR (Greedy Perimeter Coordinator Routing) [10] is another solution given by Lochert et al. It does not use digital map or source routing. It exploits the fact that nodes follow a natural planar graph at a junction in the street. Greedy algorithm works as long as nodes are in the street. Actual routing takes place at the junctions. These junctions are called coordinators. Routing always take place through junction nodes rather than across the junction nodes. IT uses repair strategy to get out of local minimum. The authors show that GPCR always gives better packet delivery rate in comparison to GPSR, but it faces the problem of larger average number of hops and initial latency.

Another algorithm suited for city environment is A-STAR (Anchor based Street and Traffic Aware Routing). It uses digital maps to compute the sequence of junctions (Anchors) through which data packets make their communication to reach the destination. It computes the anchor routes which possesses higher connectivity on the basis of traffic awareness. A-STAR solves the local minimum problem by selecting alternate anchor path and marking the old path as out of service path temporarily. A-STAR improves the packet delivery ratio by 40% in comparison with GSR and GPCR due to awareness of highly connected path selection.

GYTAR [11] is an improved greedy traffic aware routing strategy in urban streets environment. Packet delivery is performed through junctions. Junction selection is done by comparing current junction with the next candidate junctions on the basis of traffic density and trajectory distance to the destination. Each node (vehicle) maintains a routing table containing position, velocity, and direction of all the neighbouring nodes. This routing table changes periodically. After receiving a packet, a node can guess the next forwarding hop (which is closer to the destination) more precisely due to most recently updated routing table. The local minimum problem is solved by carry and forward scheme. Drawback of this protocol is loop problem and forwarding of nodes in wrong direction.

DREAM (Distance Routing Effect Algorithm for Mobility) [15] is another position based routing protocol. Each node maintains the routing table containing geographical information of every other node in the network. Data packets are broadcasted to only nodes lying in the direction of destination node. It provides loop freedom because every forwarding decision takes the packet away from the source. While nodes are stationary, routing tables are not updated and no overhead occurs.

Due to small size of control packet which contains only the position of nodes, more mobility also does not consume much bandwidth. Rate of change of table depends on node movement and the distance between source and destination.

Vertex-Based predictive Greedy Routing (VGPR) [16] is a vehicle-to-infrastructure routing protocol for high density traffic. It transmits message from source vehicle to the fixed infrastructure via sequence of junctions. It uses position, velocity and direction parameters for estimation of sequence of valid junctions. It uses greedy forwarding for message dissemination. The sequence of valid junctions is formed by estimating shortest path between node and nearest fixed infrastructure with the help of navigation system. Each vehicle maintains a table, containing id, position, velocity and direction of its two-hop neighbors. The source node calculates the weighted score of its own node, packet carrier node and its two-hop neighbors. The scores of these three kinds of nodes are compared to decide the winner. The ultimate winner will take the responsibility to forward the packet further. VGPR have less control overhead compared to its predecessors. Due to fair path selection, lesser packets are to be retransmitted and reliability and packet delivery ratio are improved.

MIBR [17] is a location based reactive routing protocol. Node uses GPS system to find the geographical information of the destination node. It uses buses in route estimation and packet dissemination process. Each bus contains two heterogeneous wireless interfaces and other vehicles have single. This protocol considers transmission quality of all road segment and transmission capabilities of various vehicles on the road. It also keeps the density information of every road segment using bus line information. The next road segment is selected only when the packet is close to a junction. It maintains a route table to store id of next road segment and hop count. This process consumes less bandwidth. MIBR is only suitable in urban scenarios.

D. Broadcast Routing

There are numerous applications in VANETs that need broadcast routing. Path discovery is an essential component of ad-hoc routing which is performed by flooding. Road safety applications can not function without emergency alarm which is again a broadcast routing. The easiest way to implement broadcast is flooding in which every vehicle transmits or retransmits the message to all its neighbours except the one from where the message was received. Flooding guarantees the successful communication. It is suitable for small scale networks.

V-TRADE (Vector based Tracking Detection) [18] is a position based message broadcasting protocol. The basic mechanism is similar to ZRP (Zone Routing Protocol) [19]. The speed and location information of vehicle is utilized to divide the neighbours in different segments. Only few vehicles (border vehicles) from each segment is selected for further rebroadcast. In this protocol there is improvement in bandwidth usage but routes are broken sometimes because fewer vehicles are chosen for rebroadcast as the route discovery progresses.

Urban Multi-Hop Broadcast protocol (UMB) [20] is proposed to tackle packet collisions, and hidden node problems during message delivery in multi hop broadcast. Sender transmits the message to the furthest node in the direction of destination. In this manner flooding is restricted to avoid collisions. Simulations show that UMB performs in higher traffic load and vehicle densities. *Broadcomm [21]* protocol is useful for simple highway network. The highway is partitioned into virtual cells. These cells also move with movement of vehicle nodes. Nodes are categorized in two levels of hierarchy. All the nodes in a cell belong to first level of hierarchy. The nodes located in close proximity of cell centres are called cell reflectors and these are members of second level hierarchy. All the flooding now takes place through these reflectors only. This protocol outperforms similar flooding based routing protocols in the message broadcasting delay and routing overhead.

VI. CONCLUSION

This article surveys various routing protocol for VANETs. Ad-hoc routing protocols are still useful for successful dissemination of data packets with controlled flooding, but these protocols are less scalable due to dynamic mobility. Cluster based protocols are the right choice for scalability problem in VANETs. In this scheme intra-cluster routing is performed proactively and inter-cluster routing is done through reactive protocol. In this paper we have also surveyed position based routing protocol. The comparison (Table-I) shows that position based protocols provide the good alternative for efficient routing in the urban traffic conditions. Greedy forwarding is still an effective method for geographic routing in dense networks. The discovery of efficient greedy strategies has led to cost-efficient methods under realistic physical layer assumptions for reactive message routing. Greedy strategies have been evolved towards practical applicability. However, most of them suffer from the local minimum problem. The solution to this problem lies with recovery strategy. The development of robust recovery strategies is still subject of ongoing research. Position based routing protocols aided with digital map, show good performance in urban streets also where many obstacles are present. In the last, some broadcast routing techniques are discussed ant it is found that broadcast plays an important role in the message transfer for the real time safety applications. From the survey we can conclude that position based and cluster based protocols are more reliable for most of the applications in VANETs.

Protocol	Category	Path Metric	Forwarding Strategy	Scenario	Digital Map	Network Type	Objective
AODV	Ad hoc	Least delay	Multi hop	Urban	no	V2V	Improve control overhead of proactive
DSR	Ad hoc	Least delay	Multi hop	Urban	no	V2V	Improve control overhead of proactive
PR-AODV	Ad hoc	Least delay(path life time)	Multi-hop	Urban	no	V2V	Select new route before link break
COIN	cluster	Least delay(cluster head)	Reactive	Urban	no	V2V	Decrease control overhead
LORA_CBF	cluster	Greedy/cluster head/gateway	Reactive	Urban	no	V2V	Improve packet delivery ratio
GPSR	cluster	Shortest distance	Greedy	Highway	no	V2V	Improve latency
GSR	position	Shortest distance	Greedy	Urban	yes	V2V	Improve delivery rate and latency
GPCR	Position	Greedy/directional	Greedy	Urban	no	V2V	Improve delivery rate of GSR
A-STAR	Position	Greedy	Greedy	Urban	Yes	V2V	Improve delivery rate of GPCR
GYTAR	Position	Least delay/greedy	Greedy	Urban	Yes	V2V	Solve local minima problem by carry and forward
DREAM	Position	Greedy/directional	Greedy	Urban	No	V2V	Less control overhead, Loop freedom
VGPR	Position	Greedy forwarding	Multi hop	Urban/rural	no	V2I	Improve reliability of packet delivery
MIBR	Position	Least delay	Reactive	Urban	No	V2V	Consumes less bandwidth
V-TRADE	Broadcast	--	Directional/position based	Urban	No	V2V	Improve bandwidth utilization
UMB	Broadcast	--	Directional/position based	Urban	no	V2V,V2I	Improve packet loss, Solves hidden node problem
Broadcomm	Broadcast	--	Position based	Highway	no	V2V	Improve message broadcast delay

TABLE-I Comparison of Routing Protocols

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