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STUDY AND ANALYSIS OF A ROUTING IN VEHICULAR AD HOC NETWORKS

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ABSTRACT

In this article, we introduce the new emerging technology to achieve smart communications and the efficiency of the inter-vehicle throughput. These characteristics can be achieved only by the special network technology that is Vehicular Ad Hoc Network(VANET). It is the Integrated ad hoc network for Wireless LAN (WLAN) and Cellular Technology. These type of VANETs are developed in Hybrid Network type and hence, it is different from other networks architectures and characteristic features. This technology became popular and varies in working research challenges and designs in efficient routing protocol. Here, we describe the routing technology of VANETs and recent surveyed routing protocols and also the related models.

INTRODUCTION

Vehicular Ad Hoc Networks (VANETs) integrates the wireless networks and provides the ability to make use of the Network in the mobile users. It provides the connective communications between the users in vehicles and other networking users. It also provides the high efficient communications which enables the ITS (*Intelligent Transportation Systems).* ITS is one of the major applications in developing the communications in the vehicular Network protocols. Due to the parallel strong connectivity existence between the vehicles and the users of same and as well as in different networks, these networks are named as Inter-vehicle communications (IVC) and Vehicle-to-Vehicle (V2V) Communications. ITS type networks includes the applications like traffic flow control, cooperative traffic monitoring, collisions prevention, blind crossing, information services and Real-time detour routes computation.

VANETs also facilitates the vehicular users by providing the Web connectivity network protocol within the vehicles. Hence these network protocols increased the usability of Web to the mobile users and the transmission rates gradually grown to the high end. As the usability increased, the many other features like downloading and uploading different official documents from the WEB are fulfilled. Users can also engaged with other entertainment applications like music, games etc. With the rapid development of wireless technologies since 2002, various workshops emerged to address the research issues such as *ACM International Workshop on Vehicular Ad Hoc Networks* and *International Workshop on Intelligent Transportation.* Other major manufacturing workshops also adopted to invest the IVC type networks. By means of IVCs, many companies like Audi, BMW, DaimlerChrysler, Fiat, Renault and Volkswagen joined to develop the non-profitable organization as *Car2Car Communication Consortium* (C2CCC) [4] which is further useful in increasing the safety and efficiency of the vehicular network systems. IEEE also formed the new IEEE 802.11p task group which focuses on providing wireless access for the vehicular environment. According to the official IEEE 802.11 work plan predictions, the formal 802.11p standard is scheduled to be published in April 2009.

VANET has its unique characteristics in many challenging research issues, such as data dissemination, data sharing, and security issues. This article mainly focuses on routing protocols for VANETs. The main requirement is to achieve minimal communication time with less consumption of network resources. Many routing protocols have been developed for *Mobile Ad Hoc Networks* (MANETs), and some of them can be applied directly to VANETs. The simulation results shows the poor performance because of the characteristics of fast vehicles movement, dynamic information exchange and relative high speed of mobile nodes are different from those of MANETs. So finding and maintaining routes is a very challenging task in VANETs. In addition, a realistic mobility model is very important for both design and evaluation of routing protocols in VANETs. In this article, we will survey the most recent research progress of routing protocols and mobility models in VANETs.

NETWORK ARCHITECTURES AND CHARACTERISTICS

In this section, we describe the two different types of Architectures : VANETs and MANETs.
MANETs are independent networks on the fixed stream of infrastructure communications and are also disseminating the information. VANETs has the same functionality and principles and are applicable only to the dynamic environments of surface transportation. The following Figure shows three categories of VANETs architecture such as Pure Cellular, Wireless LAN, and the Hybrid.

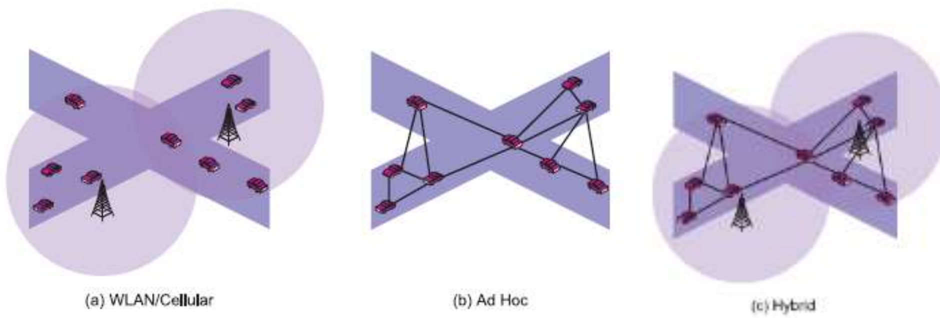

Figure 1: Three possible Network Architectures of VANETs.

These VANETs also use the special cellular gateways with fixed measures and access points of WLANs at traffic intersections which connects to the Web, and gather all the routing information for easy traffic. Figure 1(a) gives an idea of network architecture of cellular/WLAN network. VANET is a combinational network that combines the cellular/WLAN Network systems where the WLAN is used as the major access point that is available and also as the 3G connecting service. Considering the costs of the infrastructure, these gateways provides the unfeasible connectivity to the mobile nodes that are around the sides of the roads. In such cases, all these wireless devices and the vehicles forms a huge network known to be as Mobile Ad Hoc Network as shown in the Figure 1 (b). This type of Network performs a vehicle-to-vehicle communications such as Blind crossing (crossing without light control). A hybrid architecture (Figure 1(c)) of combining cellular, WLAN and the Ad hoc networks also has been a possible solution for VANETs. Namboodiri *et al.* [5] proposed such type of hybrid architecture in some vehicles having both the cellular and WLAN gateway capabilities and the Routers so that the vehicles with WLAN gateway networks are capable to communicate with them through multi-hop links to remain connected to the Web.

VANETs has a special feature of comprising the radio enabled mobile nodes as well as Routers which acts as the other nodes. In addition to the similarities with ad hoc networks, such as the short radio transmission range, self-organization and self-management, low bandwidth, VANETs make a big difference from the other ad hoc networks with the following characteristics:

High dynamic topology

The topology of VANETs is always changes due to the high speed between the mobile nodes or vehicles.
Let us assume that the transmission range of a vehicle is 250m, then the link exists between the two vehicles if that distance is less than the transmission range mentioned(250m). In worst-case scenario, if the vehicles has the opposite directions with the with the transmission range 60mph (25 m/sec), then the link between these vehicles will last for only 10 sec.

Frequent network disconnection

With the same reason, the connectivity of the VANETs also changes frequently. Especially the network failures depends on the density variations of the vehicles. For example, if the density of the vehicle is low, then it has higher probability for the network failures. In some applications, like ubiquitous Internet access, this is more frequent to the disconnection , and hence the problem must be solved in such cases. However, the only possible solution is to pre deploy the access points around the mobile nodes in the network area to establish the long last connectivity.

Sufficient power and storage

There is one common characteristic in the VANETs network nodes is that they have the ample energy and computational power which includes both the storage capacity and the processing, since the network is of mobile nodes instead of less power consuming devices.

Geographical type of communication

VANETs have a special type of communication with addressing the geographical areas where the packets has to be forwarded. Comparing to the other types of networks, the geographical communication includes the end points in the link that are defined by the ID or Group IDs.

Mobility modeling and predication

As for the high speed mobility of the network nodes and the dynamic topology, this character plays an important role in VANETs network design protocol. In more often cases, these vehicular nodes are constrained by pre-built networks on the highways, roads and streets providing with the navigation maps and transmission speed, further vehicle conditions are predicated.

Various communicating environments

VANETs generally operates in two types of typical communicating environments. One is the simple and straightforward environment and the other is complex environmental conditions. In the simple environments like highway traffic zones, it is said to be as one-dimensional movement. In the later type, there may not be always a direct line of communication in the same direction as there involves many other obstacles such as buildings, trees and power consumption.

Hard delay constraints

In some of the VANETs network design applications, the network requires only less data rates, but has the hard delay constraints. Let us assume that, in an automatic highway network system, when the brake event is organized, the protocol must transfer the message and reach at certain time slot to avoid the crashes. This kind of applications, the maximum delay is crucial instead of the average delay constraints.

Interacting with on-board sensors

Assume, if the mobile nodes are equipped with the on-board sensors, they provide the information that is used to form the links and routing the communicating networks. Since the GPS receiving systems are common in the vehicles which provides the geographical information and mapping the locations, the nodes with these on-board sensors provides the facility of knowing the routing network locations with communication links.

ROUTING PROTOCOLS

Due to the dynamic topology feature in the mobile node networks, it became a big challenge in finding the routes and maintaining the links in the VANETs. Routing protocols in the VANETs has been classified into five categories. They are: 1. Ad Hoc, 2. Position Based, 3. Cluster Based, 4. Broadcast, 5. Geo Cast Routing.

Ad Hoc Routing

As mentioned before, VANET and MANET share the same principle that they do not rely on fixed infrastructure for communication, and with many similarities, like independent organization, self management, low bandwidth and short radio transmission range. Due to these characteristic features, most of the ad hoc protocols are now applicable. Some of these are *Ad-hoc On-demand Distance Vector(*AODV) [6] and *Dynamic Source Routing(DSR*) [7]. These routing protocols,(*AODV* and DSR) are designed for the general purpose ad hoc networks for mobile nodes and they do not maintain the routes unless in necessary conditions. Hence, these protocols can reduce overhead, in some scenarios like the less network flow counts.

Moreover, VANET differs from MANET by its dynamic topology. It has gone through many studies to simulate and compare the performance of the Routing protocol networks in different traffic conditions in VANETs [5], [8]-[11]. The results of the simulation shows the most of the routing protocols like AODV and DSR, suffers from high dynamic nature of the nodes mobility because they have the poor routing convergence and low communication throughput. As mentioned in [11], AODV is explained with six sedan vehicles. In this scenario, the AODV is unable to find, maintain and update the long routes in VANETs quickly. In the real world experiment, under AODV, most of the packets are excessively lost with the network failures. It almost became impossible even to the TCP connection to establish the connection to finish its three way handshake environment. Thus, modifications to the existing ad hoc routing protocols deals with the high dynamic mobility and also need to develop the new routing protocol network systems.

The Namboodiri *et al.* [5], has routing exists from vehicle to a gateway vehicle, and is expected to be in only a few hops away. This highway scenario divides into more partitions and the probability is very small in forming long paths. Thus the scalability is not a big issue and the traditional reactive routing protocol like AODV is still considerable in small networks with few hop path lengths. However, the routes are no longer lasts due to the dynamic nature of the AODV. To reduce the frequent breakages of the routes, there are two prediction based AODV protocols to avoid the ill effects and thus increases the performance. These are PRAODV and PRAODVM. Namboodiri *et al*. uses the speed and location information to predict the routes life times. The simulations shows the some improvements of the packet delivery ratio. The PRAODV develops the alternate route before it ends the targeted lifetime but in PRAODV-M selects the maximum lifetime among the multiple routes. However, these methods depends highly on the accuracy point of the prediction method.

In [12], AODV is modified only to forward the routing requests within the *Zone of Relevance* (ZOR). The basic idea is same as *location aided routing* (LAR) [13]. ZOR is specified as a rectangular or circular range, and is determined by particular application [14]. In the road model of the highway, the ZOR covers the region behind the accident on the side of the highway where the accident happens.

Position-Based Routing

Mobility of Nodes in VANETs is restricted in bidirectional movements constrained along the roads and streets. So it make sense that the routing strategies of geographical location information obtained from street maps, traffic models or even more prevalent navigational systems on board. This fact receives more support from a number of studies that compare the performance of the topology based routing (such as AODV and DSR) against the position based routing strategies in high way traffic scenarios [8], [9]. Therefore, geographic routing (position based routing) has been identified as the best routing paradigm for VANETs.

Most of the routing algorithms are based on forwarding decisions on location information. For example, greedy routing always forwards the packet to the node which is closest locations to its target. *Greedy Perimeter Stateless Routing(GPSR*) [15] is one of the best position-based protocols. It combines greedy routing with face routing to get rid from the local minimum where the greedy fails. It works greatly in the open spaces with evenly distributed nodes. GPSR is used to perform the simulations in [9] and its results were compared to DSR in a highway scenarios. In the city scenarios for VANETs [8],[9],16], the usage of GPSR has many disadvantages. Greedy forwarding is restricted because the direct communications does not exist due to the obstacles like building and trees. Secondly, the routing performance degradation. i,e. packets must travel a longer path with higher delays. The Figure 2 describes the disconnected VANET due to the first phase of planarization. Thirdly, the mobility also induce the routing loops in face routing, sometimes the packets may lead to the higher delays or network partitions.

Lochert *et al*. [16] proposed a routing solution called *Geographic Source Routing* (GSR) assumes the aid of a street map in city environments. GSR uses *Reactive Location Service* (RLS) to obtain the target position. The algorithm needs the global knowledge of city topology as it is provided by the static street map. The sender determines the node points that has to be traversed using the Dijkstra’s algorithm. Forwarding between the nodes(junctions) is made in a position-based technology. By combining the geographic routing and topological knowledge, GSR proposes a routing strategy for VANETs in city locations. The simulation demonstrates the results, that GSR has average delivery rate, less bandwidth consumption, similar latency of first delivered packet with DSR and AODV.

Later Lochert *et al*. [19] also proposed another solution GPCR (*Greedy Perimeter Coordinator Routing*) without the use of routing and availability of street maps. The nodes at a junction in the street follows a natural planar graph. Hence a restricted greedy algorithm may be followed as long as the nodes are in the estimated location. Node points(Junctions) are the only places where the actual routing decisions are made. Thus the packets are always to be forwarded to the node on the Junction(called *Coordinator*) than being forwarded.

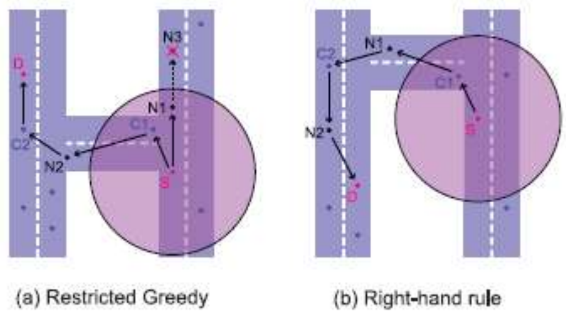

Figure 2: (a) Greedy Routing vs. Restricted Greedy Routing in the area of a junction. (b) Right-hand rule is used to decide which street the packet should follow in the repair strategy of GPCR.

Figure 2(a) illustrates the same. GPCR uses a *repair strategy* to get out from the local minimum, *i.e.*, no neighbor exists which is closer to the destination than the node itself. The repair strategy (1) targets, on each junction, which the packet should follow the next (by right-hand rule) and (2) applies greedy routing, in between the junctions, to reach the next junction. Figure 2(b) is the best example of using the right-hand rule to decide which packet should follow the repair strategy of GPCR. The simulation is made in NS-2 simulator with a real-time city topology (which is a part of Berlin, Germany). GPCR has high delivery rate than GPSR with large average number of hops and slightly increase in the latency. Position-based routing for VANETs has great challenge in city environments. Mostly, vehicles are more unevenly distributed to concentrate on some high built obstacles roads may lead VANETs unconnected.

A new routing technique called A-STAR (Anchor-*based Street and Traffic Aware Routing*) [8] has evolved for such city environments. This Technique uses the street map to compute the sequence of junctions (anchors) through which a packet has to pass to reach its target location. But unlike GSR, A-STAR computes the anchor paths with traffic awareness. A-STAR technique differs from GSR and GPSR in two aspects. Firstly, it incorporates the traffic awareness by using statistical data rated maps (counts the no of bus routes on each street to identify the anchor paths of maximum connectivity) or dynamic rated maps (dynamically monitoring the latest traffic conditions to identify the anchor paths) to identify an anchor path with high connectivity of packet delivery. Secondly, A-STAR employs a new local recovery scenario for packets which are routed to a local minimum that is more suit-able for a city environment than the greedy approach of GSR and the perimeter mode of GPSR.

In local recovery state, the packet is salvaged by traversing the new anchor path. To prevent the traversing of other packets from through the same location, the street at which local minimum occurred is marked temporarily as "out-of-Service". In this mark assumption, streets are not used in anchor computation or re-computation and they resume "operational" after the time-out scope. With traffic awareness, A-STAR the best performance that is compared to GSR and GPSR, selecting the paths with higher connectivity for packet delivery. As much as 40% of packets are delivered by A-STAR comparing to GSR.

Cluster-Based Routing

In cluster-based routing network protocol, a virtual network infrastructure has to be created through the cluster nodes in order to provide scalability. Figure 3 shows that illustration in VANETs. Each cluster have a cluster head, that is responsible for both inter and intra cluster coordination in the network management functions. These cluster nodes, communicate through direct links and the inter cluster communication is performed through the cluster heads. The creation of a virtual network infrastructure is crucial for scalability of media access protocols, routing protocols, and the security infrastructure. The stable cluster node is the only key to create the infrastructure. VANETs are organized in different ways than the models that predominate in MANETs, due to driver behavior, mobility constraints, and high speeds. Consequently, the current MANETs clustering techniques are not stable in vehicular network models. The cluster nodes which are created by these techniques have short lifetime to provide scalability with low communications overhead.

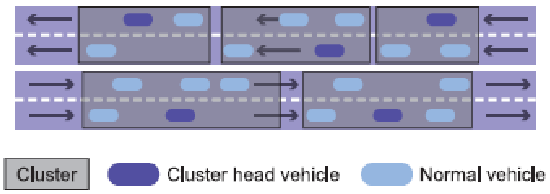

Figure 3: Vehicles form multiple clusters in cluster-based routing.

Blum *et al*. [23] proposed a *Clustering for Open IVC Net-works* (COIN) algorithm. This algorithm accommodates the oscillatory nature of inter vehicle distances. They shows COIN stable structures in VANETs including additional overhead. This COIN algorithm increases the lifetime of the cluster by minimum 192% and reduce the number of cluster membership changes by minimum 46%.

Santos *et al*. [10] introduced a reactive location-based routing algorithm, uses the cluster-based called LORACBF. Each node is the cluster head, the gateway or a cluster member. Each of the cluster has exactly one cluster head. If a node is connected to other than one cluster, it is called a gateway. The cluster head maintains all the information about its node members and its gateways. Packets are forwarded from the source to its destination which is similar to greedy routing. If the location is unavailable, then the source sends the *location request* (LREQ) packets. This is similar to the route discovery phase in AODV network system, and the cluster heads and gateways disseminates LREQ and LREP (*Location Reply*) messages. The performance (of LORACBF, AODV and DSR) is then evaluated in typical urban and the highway traffic scenarios. Simulation results demonstrates that the network mobility and size affects the performance of AODV and DSR more significantly than LORA_CBF.

Cluster-based method is also used in the data dissemination and information propagation, such as in [24].In summary, cluster-based routing protocols can achieve good scalability for large networks, but a significant hurdle for them in fast-changing VANET systems is the delay and overhead involved in forming and maintaining these clusters.

Broadcast Routing
Broadcast is a frequently used routing method in VANETs, such as sharing traffic, weather, emergency, road condition among vehicles, and delivering advertisements and announcements. Broadcast is also used in unicast routing protocols (routing discovery phase) to find an efficient route to the destination. When the message needs to be disseminated to the vehicles beyond the transmission range, multi hop is used.

The simplest way to implement a broadcast service is flooding in which each node re broadcasts messages to all of its neighbors except the one it got this message from. Flooding guarantees the message will eventually reach all nodes in the network. Flooding performs relatively well for a limited small number of nodes and is easy to be implemented. But when the number of nodes in the network increases, the performance drops quickly. The bandwidth requested for one broadcast message transmission can increase exponentially. As each node receives and broadcasts the message almost at the same time, this causes contentions and collisions, broadcast storms and high bandwidth consumption. Flooding may have a very significant overhead and selective forwarding can be used to avoid network congestion.

Durresi *et al*. [25] presented an emergency broadcast protocol, BROADCOMM, based on a hierarchical structure for a highway network. In BROADCOMM, the highway is divided into virtual cells, which moves as the vehicles move. The nodes in the highway are organized into two level of hierarchy: the first level includes all the nodes in a cell; the second level is represented by the *cell reflectors*, which are a few nodes usually located closed to the geographical center of the cell. Cell reflector behaves for a certain time intervals as a base station (cluster head) that handles the emergency messages coming from members of the same cell, or close members from neighbor cells. The cell reflector serves as an

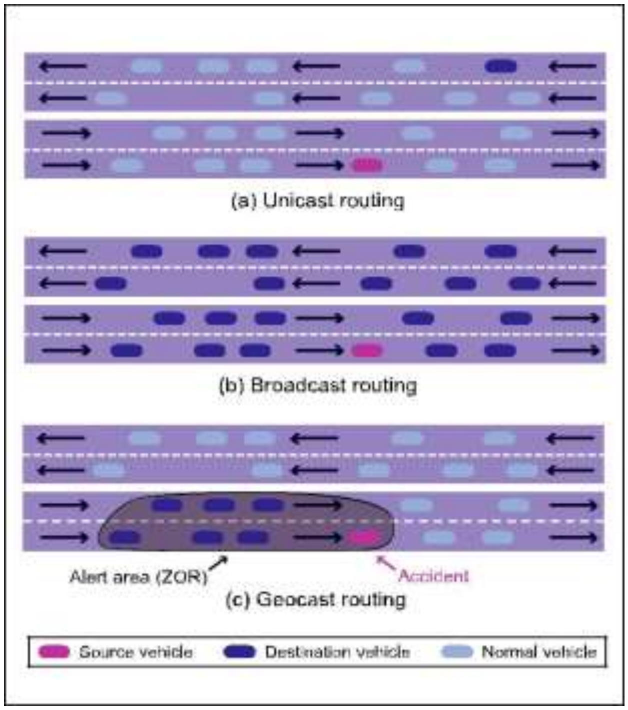

Figure 4 Different communication scenarios in VANETs.

intermediate node in the routing of emergency messages coming from its neighbor cell reflectors and decides which will be the first to be forwarded. This protocol outperforms similar flooding based routing protocols in the message broadcasting delay and routing overhead. However, it is very simple and only works with simple highway networks.

Urban Multi-Hop Broadcast protocol (UMB) [26] is designed to overcome interference, packet collisions, and hidden nodes problems during message dissemination in multi hop broadcast. In UMB, the sender nodes try to select the furthest node in the broadcast direction to assign the duty of forwarding and acknowledging the packet without any a priori topology information. At the intersection, repeaters are installed to forward the packets to all road segments. UMB protocol has much higher success percentage at high packet loads and vehicle traffic densities than 802.11-distance and 802.11-random protocols, which are flooding based modified IEEE 802.11 standards to avoid collisions among rebroadcast packets by forcing vehicles to wait before forwarding the packets.

Vector-based TRAcking DEtection (V-TRADE) and *History-enhanced* V-TRADE (HV-TRADE) [27] are GPS based message broadcasting protocols. The basic idea is similar to the unicast routing protocol *Zone Routing Protocol* (ZRP) [28]. Based on position and movement information, their methods classify the neighbors into different forwarding groups. For each group, only a small subset of vehicles (called border vehicles) is selected to rebroadcast the message. They show significant improvement of bandwidth utilization with slightly loss of reachability, because the new protocols pick fewer vehicles to re broadcast the messages. But they still have routing overhead as long as the forwarding nodes are selected in every hop.

Geo cast Routing

Geo cast routing [29] is basically a location-based multi-cast routing. The objective of a geo cast routing is to deliver the packet from a source node to all other nodes with a specified geographical region (*Zone of Relevance*, ZOR). Many VANET applications will benefit from geo cast routing. For example, a vehicle identifies itself as crashed by vehicular sensors that detect events like airbag ignition, then it can report the accident instantly to nearby vehicles. Vehicles outside the ZOR are not alerted to avoid unnecessary and hasty reactions. In this kind of scenarios, the source node usually inside the ZOR. See Figure 5 for an illustration of difference among unicast, broadcast and geo cast in VANETs.

Geo cast can be implemented with a multicast service by simply defining the multicast group to be the certain geographic region. Most geo cast routing methods are based on directed flooding, which tries to limit the message overhead and network congestion of simple flooding by defining a forwarding zone and restricting the flooding inside it. Non flooding approaches (based on unicast routing) are also proposed, but inside the destination region, regional flooding may still be used even for protocols characterized as non flooding.

In [14], a simple geo cast scheme is proposed to avoid packet collisions and reduce the number of rebroadcasts. When a node receives a packet, it does not rebroadcast it immediately but has to wait some waiting time to make a decision about rebroadcast. The waiting time depends on the distance of this node to the sender. The waiting time is shorter for more distant receiver. Thus mainly nodes at the border of the reception area take part in forwarding the packet quickly. When this waiting time expires, if it does not receive the same message from another node then it will rebroadcast this message. By this way, a broadcast storm is avoided and the forwarding is optimized around the initiating vehicle. The scheme also uses a maximal hop-number threshold to limit the scope of the flooding. Bachir and Benslimane [30] proposed a *Inter-Vehicles Geo cast* protocol, called IVG, to broadcast an alarm message to all the vehicles being in risk area based on defer time algorithm in a high way. The main idea is very similar to [14].

Maihöfer and Eberhardt [31] concerned with cache scheme and distance aware neighborhood selection scheme to deal with the situation of high velocities in VANET compared to regular geo cast protocols. The main idea of their cached greedy geo cast inside the ZOR is to add a small cache to the routing layer that holds those packets that a node cannot forward instantly due to a local minimum. When a new neighbor comes into reach or known neighbors change their positions, the cached message can be possibly forwarded to the newly discovered node. Their distance aware neighborhood strategy takes frequent neighborhood changes into account. It chooses the closest node to destination which is inside the range *r* (smaller than the transmission range) instead of the node transmission range in the general greedy routing mode. Notice that in greedy routing, the intermediate node always select next hop node that lies close to the relaying nodes' transmission range border, so the selected next hop node has high possibility to leave the transmission range because of the high speed node movement. Simulation results show that a cache for presently unforwardable messages caused by network partitioning or unfavorable neighbors can significantly improve the geo cast delivery success ratio. The improved neighborhood selection taking frequent neighborhood changes into account significantly decreases network load and decreased end-to-end delivery delay.

Beside of the classical geo cast routing, recently, Maihöfer *et al*. [32] also studied a special geo cast, called abiding geo cast, where the packets need to delivered to all nodes that are sometime during the geo cast lifetime (a certain period of time) inside the geo cast destination region. Services and applications like position based advertising, publish and subscribe, and many others profits from abiding geo cast. In [32], the authors provided three solutions:

(1) a server is used to store the geo cast messages; (2) an elected node inside the geo cast region stores the messages; (3) each node stores all geo cast packets destined for its location and keeps the neighbor information.

MOBILITY MODEL

A realistic mobility model is not only important in obtaining the accurate results in routing performance evaluation but also predicts the next positions of vehicles and make smart routing decisions in many VANET protocols. Choffnes *et al*. [33] introduces the special protocol that shows the performance variations with the mobility models and traffic scenarios. Realistic mobility models for VANETs need to consider the street conditions, urban conditions, traffic speeds, vehicle density, and obstacles.

One of the simplest and the earliest mobility models is *Random WayPoint* (RWP) Mobility model [34], where the target destinations are chosen randomly with uniform speed. When the nodes reach the destination, it repeats the process of choosing randomly. RWP is widely used in ad hoc network simulations (such as NS-2), but it does not attempt to model any real mobility situation since street-bound vehicles follows a completely different movement pattern. At this point of view, Nadeem *et al*. [35] modified this RWP model by including the necessary parameters like road length, average speed, number of lanes, and average gap between vehicles.

Firstly, Saha and Johnson [36] subjected to realistic street mobility model using road information from the TIGER (*Topologically Integrated Geo-graphic Encoding and Referencing*) [37] US road map by US Census Bureau. In this model, the topology converts the map into a graph and then assumes each node starting at some random point on a road segment and moves toward a random destination following shortest path algorithm.

The speed is uniformly distributed within 5mph above and below to its limit. Another realistic mobility model, *STreet RAndom Waypoint* (STRAW) [33] is also based on the same road information particulars from the US road map. STRAW uses a simple schema to simulate realistic traffic congestion in an urban environments. Compared to the model described in [36], STRAW considers the interaction among vehicles, traffic congestion and traffic controls. Both AODV and DSR are used to compare performances of STRAW against RWP under varying traffic conditions in geographical locations and is concluded with different results by using such a realistic mobility model.

The new trend is arrived in building mobility model is the realistic vehicular trace data. Fübler *et al*. [38] introduced the set of movement traces driven from typical situations to simulate the traffic movement on a highway scenarios. The vehicular mobility is defined as tuples of one-dimensional position and a lane on the highway for discrete time steps of 0:5 seconds. They cut those movement trace data into valid partitions and combine them into movement scenarios. Jetcheva *et al*. [39] recorded the movement traces of the buses of the public transportation system in Seattle, Washington. However, these traces describes the movement of the buses; they represents a fraction of total number of road traffic participants. Recently, Naumov *et al*. [40] introduced a new source of realistic mobility traces for simulating inter-vehicle network systems. These traces are obtained from a *Multi-agent Microscopic Traffic Simulator* (MMTS) [41], which is capable to simulating public and private traffic over real regional road maps of Switzerland with a high level of realism.

APPLICATIONS AND INTEGRATIONS

As more researches has been done on vehicular ad hoc communication networks, newer applications emerged from this technology. Most VANETs applications can be categorized into two groups: 1.intelligent transportation applications, 2.comfort applications.

Intelligent transportation applications.

These are the major applications of VANETs and ITS that includes a variety of applications such as on-board navigation, co-operative traffic monitoring, traffic flow control, analysis of traffic congestion on the (fly and detour) routes computation based on traffic conditions and the destination. For example, the existing road side sensors monitors the traffic density and vehicular frequencies and sending them to a central authority which uses to compute traffic flow controls and optimal traffic light schedules. This extended "feedback" loop can be reduced by VANETs where the vehicular nodes share the road conditions among themselves. In case of road accidental issues, the mobile nodes relay on the road side sensors for the information which then warn the oncoming traffic about congestion or contacting the emergency response teams. VANETs are also used for the implementation of blind crossing on highway entries to prevent collisions, and provides the information query services of nearby points of interest on a given route by interacting with fixed road side gateways, like in, upcoming gas stations or motels. These kind of applications are used broadcast or geo cast routing strategies to exchange and distribute the information quickly.

Comfort applications

These type of applications allow the users to communicate with other vehicles or Internet hosts to improve the users usability of this technology with comfort. VANETs provides the Internet connectivity to vehicular mobile nodes so the user can download music or games. Usually, some fixed or dynamic networks are added to the Internet networks to deliver the messages between the VANET and the Web. These applications use uni-cast routing protocols as primary communication method.

We mainly focus on routing protocols of VANETs with ad hoc architectures. However, other kinds of technologies are also integrated to support vehicle to vehicle communications. Integrating the new cellular networks enhances the coverage and also the connectivity in some rural areas. Ultra wide band communication systems can also integrated with VANETs to provide the high data rates. The vision for the future intelligent transport system supports the existence and interoperability of wireless technology with varying in requirements.

CONCLUSION

This article describes the challenges in designing the routing protocols in VANETs and surveys on several routing protocols which are recently adopted for VANETs. Table 1 summarizes the characteristic features of routing protocols (*i.e.*, routing types, use of position information, and existence of hierarchical structures) and evaluating processes (*i.e.*, simulators and simulation scenarios). Because of their geographical constrains, the position-based routing and the Geo casting are more popular than other routing protocols in VANETs. However, the performance depends on the mobility model, the driving scales, the vehicular density, and the other facts. Therefore, having a universal routing solution for all the VANETs application scenarios or a standard evaluation criterion for routing protocols in VANETs is extremely hard. For certain VANETs applications, we need to design a specific routing protocol and mobility model to fulfill the requirements.

Even though routing in VANETs has received more attention in the wireless network community as a relatively new area, there are a few challenges that has to be met. Like security, is an important issue for routing in VANETs, because many applications will affect decisions and illicit tampering can have devastating consequences. The characteristics of VANETs makes the secure routing problem more challenging and novel than in other communication networks. Recently, there are some initial efforts on this case [42], [43]. Another challenge is efficient data dissemination and data sharing in VANETs. There are several approaches evolved [44]–[47]. Other related topics includes the research on network fragmentation, delay constrain routings, and delay-tolerant networks.

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