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Routing with QoS in Vehicular Ad Hoc Networks (VANETs)

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Résumé VANETs (Vehicular Ad Hoc Network) represent a subclass of MANETs in which the transmitters and receivers are vehicles. This kind of networks form the core of an Intelligent Transport System (ITS) whose main objective is to improve road safety and road transport by taking advantage of the emergence of communication technologies and the low cost of wireless devices.
To allow this communication between vehicle-to-vehicle, vehicule-to-infrastructure or infrastructure-to-vehicule of the network, routing protocols are necessary. We are interested in this work in geographic routing protocols because they are considered to be the most robust to support rapid changes in topology and high vehicule mobility.
Keywords : Vanets, routing, protocol, IEEE802.11p.

2.1 Introduction

Mobile ad hoc network (MANET) is formed by mobile nodes that are connected in a self-organized way without an underlying hierarchical infrastructure. The MANET is called a vehicular ad hoc network (VANET) in the special case where the mobile nodes are embedded in vehicles. This kind of networks form the core of an Intelligent Transport System (ITS) whose main objective is to improve road safety by taking advantage of the emergence of communication technology and the decreasing cost of wireless devices. Indeed, thanks to sensors installed in vehicles, or at the board of roads, communications vehicular allow drivers to be aware early enough of potential dangers and situations that they cannot see. In addition, these networks no longer be satisfied to improve road safety only, but will also offer new services to road users making the road more enjoyable.

2.2 Architecture, Characteristics and Standards of VANETs

2.2.1 Architecture

There are two types of communications in VANETs : V2V and V2I

- Vehicle-to-Vehicle (V2V), in which vehicles transport data between each other. It can be used to provide information about traffic conditions and/or vehicle accidents based on wireless inter-vehicle communication. In V2V communication environments, vehicles are wirelessly connected using multi-hop communication without access to any fixed infrastructure.

- Vehicle-to-Infrastructure (V2I), in which vehicles send and receive data to/from Road Side Unit (RSU) that is a fixed wired network with access points. It can provide real-time information on road traffic conditions, weather, and basic Internet service via communication with backbone networks.

2.2.2 Characteristics

- *High Dynamic Topology :* Since vehicles are moving at high speed, topology formed by a VANET is always changing.
- *Frequently disconnected network :* The highly dynamic topology results in frequently disconnected network. This problem is also caused by changing node density.
- *Potential support from infrastructure :* Unlike common MANETs, VANETs can actually take advantage of infrastructure. This property has to be considered to improve protocols and schemes for VANETs.
- *Abundant energy and storage :* The VANET nodes have abundant energy and computation resources, since nodes are vehicles instead of small handheld devices.
- *Mobility Modeling :* The mobility pattern of vehicles depends on traffic environment, roads structure, the speed of vehicles, driver's driving behavior and so on.

2.2.3 Standards

DSRC – WAVE – IEEE 802.11p

DSRC : Dedicated Short Range Communication
- 75 MHz spectrum set aside for Vehicular Communication (VC)

WAVE : Wireless Access in Vehicular Environments
- Set of standards (incl. 802.11p) for VC

IEEE 802.11p : 802.11a modification for VC
- V2V : Vehicle-to-Vehicle Communication
- V2I : Vehicle-to-Infrastructure Communication

The WAVE standard (Wireless Access in Vehicular Environment) describes the set of standards IEEE 1609.x (.1/.2/.3/.4) deployed at the MAC layer (Layer 2) and network layer (level 3) of the OSI model. At the physical layer (level 1), the IEEE 802.11p standard is used. The set WAVE and IEEE 802.11p, form DSRC standard (Dedicated Short Range Communication).

DSRC is actually considered as the most appropriate standard for wireless communications in vehicular ad hoc networks. With the DSRC standard, it is possible to establish a vehicle-to-vehicle (V2V) communication and a vehicle-to-infrastructure (V2I) communication.

DSRC characteristics are :
(i) it supports a vehicle speed exceeding 200 km / h,
(ii) it offers a wireless range between 300 and 1000 meters,
(iii) it provides a theoretical throughput (bandwidth) up to 6 Mbps.

2.3 Application categories

We classify these applications into two main categories :

• **Safety Related :** Applications like collision alert, road conditions warning, merge assistance, deceleration warning, etc. will be classified under safety related applications where the main emphasis is on timely dissemintation of safety critical alerts to nearby vehicles.

• **Internet Connectivity Related (User) :** Accessing emails, web browsing, audio and video streaming are some of the connectivity related applications where the emphasis is on the availability of high bandwidth stable internet connectivity.

Each application has its own QoS requirement. QoS is defined as a set of service requirements that needs to be met by the network while transporting a packet stream from a source to its destination. For example safety warning applications should have minimum End to End (E2E) delay, because if a warning message receives at destination with high delay, that message could not be helpful for preventing an accident. Accordingly, packet loss and throughput are two other QoS factors that are very important in active safety applications.

2.4 Routing protocols classification

Routing is the core of the vehicular ad hoc networks and several routing protocols have been proposed to compete with sudden changes that may arise due to the nature of VANET. We have two main classes of routing protocols :

Topology-based routing - the IP addresses are used to identify the nodes and setup the routes, using the information about the links that exist in the network to identify the best path to forward data. This kind are grouped into three categories of proactive, reactive and hybrid routing.

Position-based routing - instead of using the IP addresses, position-based routing relies on the knowledge of the geographical position of the nodes to select the best path to forward data to a destination. Thus, when using position-based routing each node must be able to determine its own location and a source node must be aware of the location of the destination node.

In the last years many routing protocols proposals have been made considering the particular VANET characteristics. From the many proposals that came up, the protocols based on the vehicles positions were found to be the most adequate to VANETs due to their resilience to handling the nodes position variation. For these reason we have emphasis on position-based (geographic) routing. Geographical forwarding is one of the best solutions for VANET routing because it maintains only local information of neighbors rather than per-destination routing entries.

2.4.1 Position-based routing

The functionality of a position-based routing protocol may be split in three different aspects :

1. Path selection
2. Forwarding
3. Recovery

1. Path selection

In position-based routing it is not mandatory to use a path selection, but one can use a path selection algorithm if it brings an advantage to the routing protocol. Two of the most commonly used path selection strategies are :

Full path using Dijkstra

Based on the well known Dijkstra algorithm, in which a path between a pair of nodes (source, destination) is computed at the source node. When using this strategy, each packet carries the position of all junctions to be traversed. Different metrics can be used to compute the cost of the paths. Some routing solutions consider that the cost of each road is the distance (GSR, 2003), whilst others use more attributes to weight the cost, this is the case of the protocol A-STAR.(2004), that uses the information of the number of bus lines to weight the paths.

It has two main problems : overhead and reduced availability. It has a big overhead since each packet needs to carry information about the entire path (the various junctions it traverse). It also has reduced availability due to many disconnection problems that might happen, since the vehicles have a high mobility.

Next junction selection

Select at each junction, which road to follow next (GPCR, 2005 ; GyTAR, 2007). Thus, each time a packet arrives at a junction the node who carries it selects which of the surrounding roads is the best to follow and selects a node that uses that road. This can be done using different metrics, the most commonly used is a combination between the progress toward the destination and the vehicle density of that road. Each of the metrics can have a different weight as suggested in (GyTAR, 2007). The weight of each metric can be set depending on what is more important.

At each moment the packet would only carry two positions : the position of the destination and the position of the next junction. This solution does not increases the overhead as much as the full path using Dijkstra since only one location (the next junction) is needed beside the position of the destination.

2. Forwarding

In spite of having a path selected or not, every position-based routing protocol needs a forwarding strategy either to forward to the destination or to forward between junctions in the selected path. Some of the most used approaches are :

A. The greedy forwarding
Which is used by Karp and Kung (GPSR, 2000). In this approach the sending node sends the packet to the neighbour that is closer to the destination.

B. Greedy along the path
As the name suggests, is the greedy approach but considering only the nodes that are on the selected path or road to next junction. This is the approach used by Jerbi and al. (GyTAR, 2007). In this protocol no path from source to destination is constructed. In each junction the forwarding node calculates which is the best next junction taking into account the number of vehicles between them and the progress towards the destination in terms of distance.

C. Restricted greedy
There are also a couple of greedy approaches with some restrictions (GPCR, 2005).

3. Recovery

In order to escape from a local optimum a repair strategy may be used. The general aim of a repair strategy is to forward the packet to a node which is closer to the destination than the node where the packet encountered the local optimum.

One of the recovery-mode strategies widely used is the right-hand rule (GPSR, GPCR,...) to traverse graphs. The rule says that if node n receives the packet from edge E1, it sends the packet through its next edge counter clockwise about n. The routing protocols switches back to forwarding mode once the forwarding node is closer to the destination than the node that triggers the recovery strategy.

Other approach used is the carry-and-forward (VADD, 2008). As the name suggests, when the local maximum occurs the node carries the packet until a eligible neighbour appears.

Instead of using a recovery strategy, some algorithms recalculate the path when the local maximum occur (A-STAR, 2004).

2.5 Conclusion

We have presented the Vehicular Ad Hoc Network which is a subclass of ad hoc network , we have been focusing on routing problem especially on geographic routing protocole classe considering the most robuste for supporting a high changement in the topologie and high mobility of the nodes.