Ad hoc communication between intelligent vehicles

Laurent Bouraoui, Philippe Jacquet, Anis Laouiti, Michel Parent, Laurent Viennot

Ad hoc communications between intelligent vehicles

Laurent Bouraoui, Philippe Jacquet, Anis Laouiti, Michel Parent, Laurent Viennot
INRIA Rocquencourt, BP 105, 78153 Le Chesnay Cedex, France
Email:{philippe.jacquet,anis.laouiti,michel.parent,laurent.Viennot}@inria.fr

Abstract

Wireless ad hoc networks are composed of mobile autonomous nodes, and can work without any fixed infrastructure or centralized entity. Moreover, they are adaptive and self-configurating. These kind of networks are well suited for inter-vehicles communication and information exchange (used for tele-traffic management for example). Depending on the context, some of these information need to be sent to almost all the network, and other information need to be sent to a smaller subset of vehicles. Since the wireless resource is very scarce, this data diffusion should be done in a way to save bandwidth as much as possible. This paper describes two multicast protocols for inter-vehicles communication. MOLSR for dense scenarios, and SMOLSR for localized scenarios.

Keywords:*OLSR, SMOLSR, MOLSR, intelligent vehicles, inter-vehicle communication.*

1 INTRODUCTION

In the recent years mobile wireless communication have progressed with giant laps. The mobile ad hoc networks (MANET) allow highly broadband communications based on high speed radio communications such as Wifi and IEEE 802.11e. Since the radio ranges of such links are in general in inverse function of link capacity, dynamic internal routing is a requirement in order to achieve a permanent connectivity. Routing is the task of the internet protocol and the Internet Engineering Task Force (IETF) has standardized very efficient protocols such as OLSR [1] and AODV [2] in the working group MANET. These protocols enable a wireless mobile networks made of heterogeneous mobile can stay connected by the simple continuity of the various radio ranges. Every topology changes are monitored in real time and the routing protocol updates in real time.

Since the resource of communication is very scarce compared to wired networks, one has to be very careful in the bandwidth waste. For example the topology monitoring is limited to its strict minimum so that the topology changes does not swamp the network with too much control traffic. On the counterpart it is also needed that the traffic of data delivery be optimized in order to save bandwidth. Furthermore when the same information has to be delivered to several destination there is a great potential of useless duplicate transmissions between the mobile nodes, wasting more bandwidth. In this case it is interesting to multicast transmissions (from one node to many nodes) that takes advantage of the inherent broadcast nature of radio transmissions.

Paper introduces the application and implementation of multicast for inter-vehicle communications. The plan of of the paper is the following. In a first part we will briefly presents the various applications that can benefit from inter-vehicle multicast, for example the distributed tele-traffic information. Then we will describe in more detail the routing and multicast protocols based on OLSR protocol, that apply to vehicle communications. We finish the paper by presenting some experiment results, and concluding.

2 MULTICAST APPLICATIONS FOR INTER-VEHICLES COMMUNICATIONS

In this section we present two possible multicast applications: Distributed tele-traffic information (DTI), and Remote vision on highways application.

2.1 Distributed tele-traffic information (DTI)

Centralized tele-traffic management in general provides low updated information about traffic conditions on the roads. Here we propose that an application based on ad hoc networking and peer2peer architecture provides a more updated complement to existing tele-traffic management by sharing updated information.

The cars build information page about their local traffic on the road portions they travel on by comparing density, speed vectors and localization of neighboring cars. The pages are dated in their database. Via a peer2peer application on a mobile ad hoc networks they share and update their information database by updating their information pages in order to keep the most recent. The peer2peer management is done on a per connected component basis. This way the user will get the most updated information about their surrounding road portions. Clearly the closer is the road portion the more updated will be the information. The speed at which the information will propagate is function of car density (on all lanes) and of car speed. If the mobile ad hoc network has a giant connected component, the information will be spread almost instantaneously. Otherwise the information will move at a speed anyhow much faster than car speed (mathematically on rough models the speed is $\frac{e^d+1}{2}v$ where d is the car density, r is the radio range and v is the average car speed).

2.2 Remote vision on highways

.

Cars and especially trucks have video cams which take forward and backward traffic. Maybe lateral traffic for cross roads. The multimedia streams are shared in a p2p way, so that connected cars can access to any real time video streams. This way user can virtually zoom forward the traffic conditions. If the trucks block the view an intelligent video management can display the trucks as if they were half transparent so that the traffic view hidden by truck but anyhow broadcasted by the truck can be seen through the truck. Successive trucks can be made half transparent the same way.

3 PROTOCOLS

3.1 The Optimized Link State Routing (OLSR)

The OLSR protocol is particularly adapted to dense scenarios where nodes are mobile and data traffic is dense and multi-directional. The OLSR protocol is based on a broadcast optimization called MultiPoint Relay (MPR)[3]. Every node elects its MPR set which is a subset of the node's neighborhood that optimally covers the node's two-hop neighborhood(see figure 1). The MPR set is very small compared to the neighbor size. If M_r is the size of the MPR set and M is the size of the neighborhood , one has $M_r \sim M^{1/3}$ in simulations and $M_r \sim \log M$ in some models.

When a node wants to broadcast an information to the entire network, the following happens:

1. the node broadcasts the packet to its neighborhood;
2. The MPRs of the node relay the packet to the two hop neighbors;
3. The MPR of the MPR relay and so forth

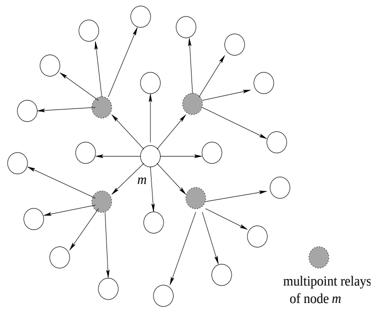

Figure 1: Multipoint relays of node m

In the last statement it must be noted that the relay is done upon the first reception, further reception are discarded. Therefore if a node in the network receives the packet for the first time from a non MPR selector node then it does not relay it.

The number of retransmissions is expected to be reduced by a factor $\frac{M_r}{M}$ compared to the classic flooding where all nodes retransmits the same information.

3.2 Multicast protocols

There are two classes of multicast protocols each of them corresponding to distinct scenarios:

- The uniform scenario
- The localized scenario

In the dense scenario, the multicast group is uniformly dense in the whole network. In this case the SMOLSR (Simple Multicast OLSR) protocol will fit. SMOLSR simply uses the flooding via MPR, node applications filter the incoming packets (section 4).

In the localized scenario, the multicast group is grouped in various locations and are absent in the most other part of the network. In this case the MOLSR (Multicast OLSR) protocol will fit: the multicast group builds a spanning tree based on shortest path and MPRs. The protocol activates a small subset of relays that covers the area of the multicast group. That way the retransmissions for this multicast group don't affect the other parts of the network (section 5).

4 SMOLSR DESCRIPTION

SMOLSR is a transport protocol for multicast communication in mobile ad-hoc networks (MANETs). It is well suited to large and dense mobile networks, as the optimization achieved using the MPRs works well in this context and where multicast groups are not specifically localized. The larger and more dense a network, the more optimization can be achieved as compared to the classic link state algorithm. SMOLSR uses hop-by-hop routing, i.e. each node uses its local information to route packets.

SMOLSR is well suited for networks, where the traffic is random and sporadic between "several" nodes rather than being almost exclusively between a small specific set of nodes.

SMOLSR minimizes the overhead from flooding of broadcast data traffic by using only selected nodes, called MPRs, to retransmit those data. This technique significantly reduces the number of retransmissions required to flood a message to all nodes in the network. Actually, it is the same technique used by OLSR to flood its control messages to the entire network in an optimized manner. Consequently, SMOLSR does not need any additional control message to ensure its functioning.

The simple Multicast protocol based on OLSR (SMOLSR) is supposed to work on all version of OLSR, provided it can access to host symmetric neighborhood and host MPR selector list (i.e the list of neighbors that have chosen the current an an MPR).

5 MOLSR DESCRIPTION

The Multicast Optimized Link State Routing (MOLSR) protocol [4] takes benefit of the topology knowledge gathered by the OLSR protocol with its Topology Control messages exchange to build multicast trees. MOLSR is developed as an extension to OLSR. It can works even when not all nodes are multicast capable provided that multicast nodes offer the minimal connectivity between the sources and the members of the multicast group. A multicast tree is built and maintained for any tuple (source, multicast group) in a distributed manner without any central entity and provides shortest routes from the source to the multicast group members. The trees are updated whenever a topology change is detected.

The multicast optimized link state routing protocol (MOLSR) belongs to the source based family. It maintains one multicast tree per tuple (source, multicast group). Those trees are only composed of multicast capable nodes. Three steps are distinguished: the tree building, the tree maintenance, and the tree detachment. Each step is detailed in a subsection.

5.1 Tree building

Once a source wants to send data to a specific multicast group G, it sends a SOURCE_CLAIM message enabling nodes which are members of this group to detect its presence and to attach themselves to the associated multicast tree.

This message is flooded within the ad hoc network using the optimized flooding technique of OLSR.

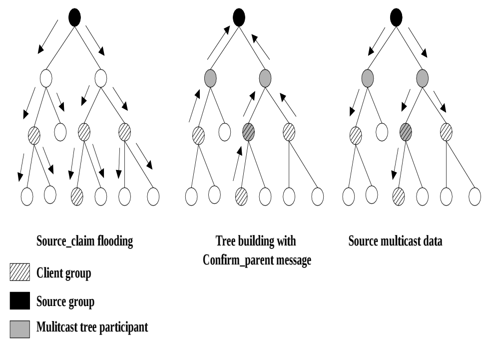

Figure 2: Tree building mechanism

Branches are built in a backward manner: group members which do not know yet about this source try to attach themselves to the corresponding tree (see figure 2).

More specifically, when a group member receives a SOURCE_CLAIM message and it is not already a participant of this (source, multicast group) tree, it attaches itself to the (source, multicast group)tree by proceeding as follows:

- it looks into the OLSR routing table for the next hop (i.e the parent interface address) to reach the source (the OLSR routing table provides shortest routes to all the nodes). This next hop becomes its parent in the multicast tree.
- Then it sends a CONFIRM_PARENT message to its parent node. This message is sent using the corresponding interface to reach this neighbor.
- The parent node receiving this message attaches itself to the (source, multicast group) tree, if it is not already a participant to this tree.

The CONFIRM_PARENT message is handled hop by hop, by intermediate multicast routers which build the corresponding branch.

5.2 Tree maintenance

The trees are periodically refreshed, by means of the SOURCE_CLAIM message and the CONFIRM_PARENT message. Notice that topology and neighbor changes are still detected by the exchange of topology control messages which is done naturally by OLSR. Thus, trees updates are triggered by the detection of topology changes and OLSR routing table re-calculation.

5.3 Tree detachment

If a node wants to leave the multicast tree and it is a leaf, it detaches itself from the tree: it just sends a

LEAVE message to its parent in this multicast tree. If its parent becomes a leaf, and this parent is not a group member, it detaches itself from the tree on its turn.

The LEAVE message is processed hop by hop and unused branches are deleted automatically.

6 EXPERIMENTS

We present now the results of some experiments conducted at INRIA with mobile vehicles. The goal of this experiments is to measure the available throughput between two communicating vehicles while they move towards each other.

6.1 Scenario description

For our experiment we have used two Cycab vehicles (a Cycab is a four wheeled electric vehicle that have robotic abilities, and could be run fully autonomously) and one fixed wireless machine. Each vehicle has a GPS device and a linux box runing OLSR embedded. We have used 802.11b cards for wireless communications.

The wireless machine is placed in the same road as the vehicles at half distance in order to relay the traffic between them. At the begining of the experiment, we ensure that the two vehicles are two hops away from each other in terms of routing hop. Then, they start runing towards each other during 90 seconds. One of the vehicles sends a TCP traffic to the other vehicle while it moves. We use iperf tool for TCP traffic generation and throughput measurements.

6.2 Results

Figure 3 shows the throughput function of distance between the two running vehicles. The distance between the two vehicles is considered as negative before they cross each other, and then it is considered as positive. During the experiment we notice that the throughput is at least 500kbps. This means that we had connectivity during the hole trajectory. The throughput increases where the distance decreases to reach a maximum of 3.5Mbps when the vehicles are one hop away from each other, and then it decreases again while the vehicles move away from each other. Notice that in static scenarios, we obtain better throughput results when the nodes are one hop away each other. We explain this by the lack of external antennas. In fact, the routing boxes were placed inside the vehicles.

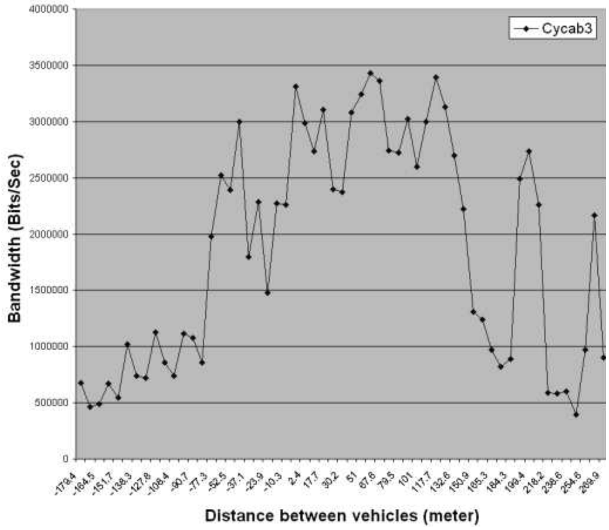

Figure 3: Bandwidth

7 CONLCUSION

We presented two multicast protocols based on OLSR protocol that can be used for inter-vehicles communications. The first one, SMOLSR is well suited for large and dense networks. It adds no extra overhead, and uses only OLSR control information in order to diffuse data packets. MOLSR is the second protocol. It is dedicated to localized scenarios where multicast groups members are situated in a few locations. MOLSR builds multicast trees from sources to group members using the shortest routes provided by OLSR. We have also shown the firt results of throughtput measures in a simple scenario with two mobile vehicles. More intensive tests and measures are planned to study the behaviour of the proposed multicast routing protocol with mobile vehicles.

References

[1] P. Jacquet, P. Muhletaler, P.Minet, A. Qayyum, A. Laouiti, T. Clausen, L. Viennot, *Optimized Link State Routing Protocol*, IETF RFC3626, October 2003.

[2] C.Perkins, E.Belding-Royer, and S.Das, *Ad Hoc On-Demand Distance Vector(AODV) Routing*, IETF RFC3561, July 2003.

[3] A. Qayyum, A. Laouiti, L. Viennot, *Multipoint relaying technique for flooding broadcast messages in mobile wireless networks*, HICSS: Hawai Int. Conference on System Sciences, January 2002, Hawai, USA.

[4] A. Laouiti, P. Minet, C. Adjih, P. Jacquet, L. Viennot, *Multicast OLSR*, Rapport de recherche INRIA RR-4721