On Mac and Routing Protocols Cooperation for Inter-Vehicle Communications

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Abstract: *Inter-Vehicle Communications (IVC) are part of a very exciting application area for wireless technologies. However, adapting the actual wireless technologies for IVC is mandatory in order to achieve efficiency and reliability of the communications. In this work, we focus on how the cooperation between MAC and routing layers could be enhanced. The target is a new MAC/Routing framework that takes also into account the inherent characteristics of moving vehicles. We propose a cross-layer architecture and we add future research and implementation directions.*

Keywords: inter-vehicle communications, car-to-car communications, cross-layer design, routing protocols, MANET.

1 INTRODUCTION

Enhancements in transportation technologies will consider, besides traditional aspects such as security and driving conditions, the ability of vehicles to communicate, including the connection of vehicle equipments to the Internet. However, in order to provide Internet-access capability in an efficient way, it would be needed to resolve several technical challenges, from gateways optimal placement in the roads to handover management between gateways; this is out of scope in this work. On the other hand, several applications may be provided for Inter-Vehicle or Car-to-Car Communications (IVC or C2CC). Indeed, vehicles can exchange real-time information, drivers can be automatically assisted, or passengers play distributed games, etc. In this paper we jointly address routing and Medium Access Control (MAC) issues for IVC. Our target is to optimize the lower OSI layers for vehicular environments. Mobile Ad-hoc NETwork (MANET) topology-based routing protocols are not suitable (as they are) for IVC due to the high mobility and fast topology changes [2], [3]. It's obvious that whatever the used routing protocol, if the node mobility is high applications may suffer from service interruption even in presence of strong handover mechanisms which will be in this case called more frequently.

IVC are a special case of MANET communications. One of the most important difference is the high mobility of the nodes, which are indeed vehicles and not simple laptops or PDAs. Furthermore, we don't have constraints on power resources, but we do on fast topology changing. Having more resources for IVC is an important advantage, since these networks provide larger capacities (in terms of both storage and power) on the nodes, which can then have long transmission ranges and virtually unlimited lifetimes [1], In vehicular networks, the nodes can be equipped with a positioning system, such as GPS, that can be used continuously, without power constraints. Another advantage in such networks is the non-random mobility of the nodes (vehicles); generally it is limited by roads which can be represented by a digital maps. Also, the vehicle movements are limited by the road rules which again may be digitally mapped.

An efficient support of access and routing protocols in vehicular environment is then facing issues like: available bandwidth, hidden and exposed nodes, high mobility, heterogeneity, node movement, fast speed, obstacles and fast handover.

In this work, we propose a movement prediction-based routing protocol for vehicle wireless networks. Basically, it predicts the future nodes' positions in order to avoid link ruptures so that frames loss rate is reduced while improving the network efficiency.

The remainder of this paper is organized as follows: Section 2 recalls the principles of cross-layer paradigm with regard to wireless networks. Our proposed routing algorithm is detailed in Section 3 which also points out some ideas for further development and possible extensions. Section 4 concludes this paper and outlines future work.

2 CROSS-LAYER PARADIGM IN WIRELESS NETWORKS

Cross-layer paradigm enables layers to request and use some measured parameters from each other and not only to send/receive their PDUs (Packet Data Unit) [4]. These parameters include signal level, neighbor addresses, available bandwidth, etc. The cross-layer approach could be applied among all layers even if they are not adjacent. In this paper, our focus is limited to the lower OSI layers, i.e. the physical, the access and the network layers. The measures can not, in general, be provided by the layered approach. Therefore, a measurement module has to be developed, interfacing inter-working layers.

Some of the PHY parameters that can improve the routing efficiency are:

- Channel quality: this parameter is important for QoS routing. For example, an application that tolerates losses can be sent even when channel conditions are relatively bad.

- Position, direction and speed: we suppose that these parameters are locally provided by a positioning system.

Some of the MAC parameters that can improve the routing efficiency are:

- Neighborhood: the MAC layer receives broadcast beacons and is able to maintain and process the list of its neighbors MAC addresses. On the other hand, the two-hop neighbors information is useful to optimize the broadcasting mechanism used by the routing protocol for control purposes.

- Speed and direction: to improve the data routing in a vehicle network, we propose to use these information coming from intermediate node MAC layers in order to choose, among existing routes, the better one.

3 MOVEMENT PREDICTION-BASED ROUTING (MOPR) ALGORITHM

3.1 Preliminaries and short overview

Supposing that we have several established multi-hop routes between a source vehicle and a destination vehicle, we propose to choose the route which is more stable when considering the movement conditions of the intermediate nodes with respect to the source and the destination nodes. The intermediate nodes can be either other vehicles or stationary nodes (gateways) along the roads.

This MOvement Prediction based Routing algorithm (MOPR), by knowing speeds and directions of intermediate nodes, can roughly predict their positions in the near future; eventually, by knowing the size of the data to send, the algorithm can know how long the transmission of each data frame will take. Therefore, the optimal route selection for data transmission will provide the route composed by intermediate nodes that are not likely to cause a rupture of the transmission in the near future because of their mobility. This approach should help as well in minimizing the risk of broken links and in reducing data loss and link-layer and transport retransmissions.

An example illustrating the operations of MOPR is given in Figure 1, where a *node A* wants to send a data information to *node B*. Two routes are available to route these data, namely "Route 1" and "Route 2". Node A should choose one of the tow available routes; if it chooses the first one (A, 1, 2, B), then, in the near future, as shown in Figure 1, the link between *node 1* and *node 2* will be cut because of their movement in opposite directions. Our algorithm will instead use the movement information of nodes to choose the best available route; in our example the route (A, 3, 4, 5, B) is selected, so that we can avoid the link break until the end of data transmission. This decision is made despite that *node 4* has not the same direction of nodes *A* and *B*. Hence, it's possible to have intermediate nodes with different directions when this situation does not cause route break during the time needed for transmitting a given frame.

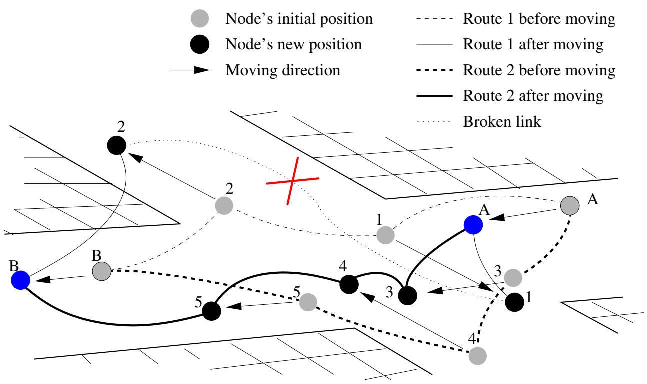

Figure 1: An example showing MOPR basic operations.

We suppose that each vehicle has a specific equipment that allows it to discover its current position, speed, and direction information, and if possible the number of the street it is running along.

Figure 2 shows the diagram used for describing the direction of a node. For position encoding facility, we associate to each direction a specific number: 1 to North, 2 to East, 3 to South, and 4 to West. These numbers will be used by vehicles to precise their directions. For example, the direction of a vehicle moving toward North/East with an angle of 30 degree w.r.t. North is encoded as [1.2.30].

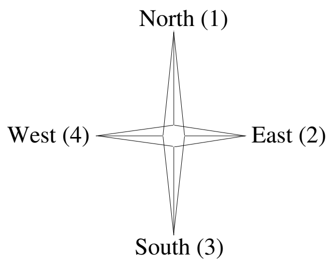

Figure 2: Direction diagram.

3.2 MOPR algorithm description

In our proposal, when a vehicle A has data to send to a vehicle B, it should first look at all available routing routes provided by a classical multi-route routing protocol. Then, among these routing routes, it selects the more stable one. A stable route is the one composed by stable nodes. The questions that we are going to answer hereafter are: *what is a stable node?* and *how to know which nodes are stable?*

A stable node is the one whose mobility (relatively to the movement of the source and the destination) will not cause broken links in the routing route during the time needed to the data transmission which depends on the size of the data to send and on the sender rate.

In our contribution, a stable intermediate node should therefore move in a similar direction and run with a similar speed compared to the source and the destination vehicle directions and speeds. We propose that the stable node speed should be in the range between the speed of A and the speed of B, while its direction should be in between the directions of A and the one of B. Thus, a source node A, having multiple routes available to destination node B provided by a classical routing protocol, should proceed with the following algorithm steps in order to find the more stable route to deliver its data:

```
// R: maximum communication range
// n:  number of available routes to destination
// m:  number of nodes in a route

// The "pos" function estimates the position of
a vehicle after a defined time.
// Time:  the time needed to transmit a data.

procedure pos (id, Time);
  Position:=Position(id)+(speed_node(id)*Time);
  Return position;
end;
```

We can also improve the estimation of the future vehicle's positions using a digital map, and all vehicles can be also positioned on. The advantage of this proposal is that the predicted positions will be more realistic, like the one illustrated in Figure 3 where the vehicle position at $t_0 + t$ estimated without the help of a digital map is not the true one (unless an accident is happened).

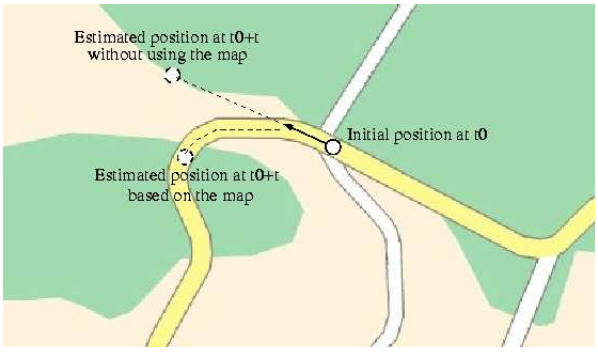

Figure 3: Position estimation based on map.

Supposing that transmission should start at t_0 and the time needed to transmit data is T, the algorithm at first estimates the position of the nodes at time $t_0 + T$ (end of transmission), then it estimates the distances at time $t_0 + T$ between each node and its neighbors in the route, looking if these distances are bigger than the communication radio range, which means that that route is not to be considered stable. Only if those distances are still smaller than the radio communication range that node is a stable node for that transmission.

```
// ε:  guard distance (processing time)
j := 0;
for l := 1 to n do
  Break := False;
  for i = 1 to m-1 do
    if Distance(pos(i-1,T),pos(i,T)) ≥ R-ε and
    Distance(pos(i,T),pos(i+1,T)) ≥ R-ε then
      Break := True;
    end if;
  end;
  if Break = False then
    Select[j] := l;
    j := j + 1;
  end if;
end;
```

The above procedure is executed for each available route provided by a multi-route routing protocol, and, if at the end of the procedure the *Break* value is *False* (i.e. all the intermediate links in this route will not be cut during the time (T) needed to send all the packets), then the concerned route (Route l) will be selected and added to *Select* table.

Now, the following code is executed and we select among the routes saved in *Select* table, the ones where most of the intermediate nodes are moving in a similar direction and with a similar speed compared to both source A and destination B.

```
// A: source vehicle
// B: destination vehicle
// "Dir" function gives a node direction
// "speed" function gives a node speed

Select_Route := Select[0];
Better := m;
for l = 0 to j do
  Nbr := 0;
  for i = 1 to m-1 do
    if speed(A) ≥ speed(B) then
      if (Dir(i) ∉ range(Dir(A),Dir(B))) or
      (speed(i) ≤ speed(B) and
      (speed(i) ≥ speed (A)) then
        Nbr := Nbr + 1;
      end if;
    else
      if (Dir(i) ∉ range(Dir(A),Dir(B))) or
      (speed(i) ≥ speed(B) and
      (speed(i) ≤ speed (A)) then
        Nbr := Nbr + 1;
      end if;
    end if;
  end;
  if Nbr < Better then
    Select_Route := Select[l];
    Better := Nbr;
  end if;
end;
```

Above we mentioned the possibility to use the number of the street associated to the running node in order to improve movement prediction. In this case, the route selection process could be better, for example by taking into account the number of intermediate vehicles driving on the same road of the source and/or the destination.

3.3 A potential "reactive" implementation of MOPR and possible extensions

Previously, we said that an existing multi-route routing protocol is needed to provide us all available routing routes between a source and the destination vehicles, among which our algorithm will choose the best one to transmit. In a future work, we will try to include a similar algorithm in a reactive routing protocol, such as AODV

[AODV]. This process can improve the quality of these protocols.

Generally, when a reactive routing protocol is working, it obtains a route (or some routes) by choosing intermediate nodes one by one until the destination. Our idea is to add in this selection the moving information criteria.

We suppose, as shown in Figure 4, that for every entry in the routing table each node adds the following three information: Position, Direction, and Speed.

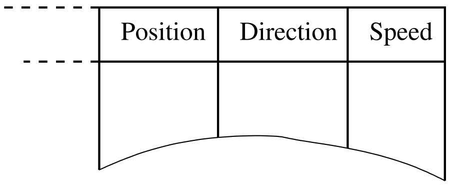

Figure 4: Routing table extension.

A simple example of our future proposal process is depicted in Figure 5, where a node "A" wants to send some data to node "B". Initially, "A" broadcasts a request message to all its neighbors in order to reach the destination node "B". Each intermediate node receives that route request message, fits in it its identifier and all its moving information. Then, as shown in Figure 5, "B" receives several request messages, each one proposing a possible route from "A". Now, using the moving information of all intermediate nodes, provided in the request messages, node "B" could choose the best route using MOPR. In the example shown in Figure 5, even if nodes' directions are not shown, [A.0.2.5.B] can be selected as the best route. Finally, "B" replies to "A" through the selected route.

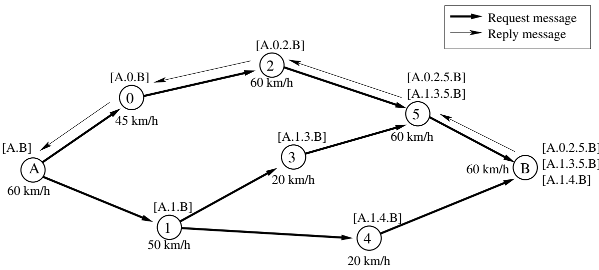

Figure 5: First sight of our future work: simple example showing the integration of MOPR in a reactive routing protocol.

What has been presented above are an initial proposal and some ideas for a cross-layer routing architecture; it is part of our future work to optimize them and to perform comparisons by simulations; finally, our target would be to have working prototypes.

Another alternative approach is to design a joint MAC/Routing scheme, meaning that the routing is done at the MAC layer. More precisely, the routing will not be based on the IP destination address as the case of IP routing but on a link layer label. Similar to MPLS [6], a trivial advantage of this scheme is the fast switching given that packets do not go through the IP layer to be sent to the destination. In [7], the authors propose a label-switching scheme for multi-hop wireless networks. We believe that a similar approach will be efficient for IVC because there is a need for fast switching due to the high topology change frequency. This approach will be a subject of further investigations.

4 CONCLUSION AND FUTURE WORKS

Because of the fast moving characteristics of vehicles and the difficulty to predict the traffic variations, it is very hard to efficiently cope with these problems while deploying methods for data routing in vehicular networks.

In this paper, we presented a part of our work, that focused on designSelect_1ing an algorithm that allows routing protocols to avoid links potentially broken by the node mobility during data transmission, therefore to avoid data loss and network overload caused by retransmissions. Basically, the proposed algorithm uses the moving information of vehicles to choose the best routing route.

Future works include the development of a complete cross-layer architecture (and possibly a joint MAC/Routing architecture as well) including not only information about vehicles speed and direction but also channel quality. Also, as said in above sections, in the future we will implement our algorithm in an existing reactive routing protocol. Some simulations and comparisons should be provided too.

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