Vehicular Network Integration of VANET with NEMO Consideration

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Abstract

Today many people spend a lot of time in the vehicles. Meanwhile, along with technologies of wireless communication, it is possible to install wireless network equipment in vehicles for people to use them to make network connections. However, some technologies such as NEMO, VANET are popular for vehicular network and have its own specific purposes. In this paper, we argue that these two technologies should be integrated to provide a better solution for vehicular network. Therefore, we develop a mechanism which mainly utilizes Network Mobility to enable the automobile to transmit data through fixed infrastructure. When automobiles are near enough, the network traffic can be switched to Vehicular ad hoc network or VANET. Consequently, this mechanism can get a better tradeoff between network stability and bandwidth optimization.

Keywords: Vehicular Network, VANET, NEMO

1. Introduction

Today's society many people spend a lot of time in the car. Up to now, most of vehicular communications use cellular communication networks. Enabling broader communication facilities in cars is an important contribution to the global trend towards ubiquitous communications [1]. Vehicular communications should be able to offer Internet and direct treatment of communication between vehicles, and support more service and application.

Our architectural assumption is that mobile routers[2] deployed in cars provides nodes with network and external communication access. A mobile router, as it will be described later, not only provides connectivity to the network deployed in the car, but also manages transparently the mobility of the whole network, without putting any additional requirements on the devices attached to the mobile network. Since it is expected that in forthcoming 4G networks multiple access technologies will be available, mobile routers will benefit from this heterogeneity by having more than one network interface, allowing the mobile router to forward the traffic through the most appropriate interface. As an example, in vehicular environments, the use of additional WLAN interfaces may allow the creation of multi-hop ad hoc networks by several vehicles, to optimize local (car-to-car) communications.

Besides the Internet access, there are several applications which involve a vehicle-to-vehicle communication. This kind of scenario may be supported by using network mobility solutions, so cars can communicate through the fixed infrastructure but, in this case, when the cars are close enough namely to communicate directly using an ad hoc network. In this way, better bandwidth than the one in the communication through the infrastructure can be achieved. The reason is that, although the number of hops can be similar, the communication with the infrastructure will typically use a technology with lower bandwidth than the ad hoc network. Also, the ad hoc route will probably result in lower costs. VANET routing[2] used in the paper can increase route duration time and throughput, and reduce control overhead.

2. Related works

2.1 Network mobility

In the case of mobile IP and NEMO Basic Support protocol, all the packets forwarded by Mobile Node/Mobile Router in the outbound direction have to go through HA firstly. NEMO Basic Support has become IETF proposed standard in Jan. 2005. This protocol allows for session continuity for every node in the mobile network as the network moves. Every node in the mobile network reachable while mobbing around.

NEMO Basic Support protocol is backward compatible with Mobile IPv6. Home Agent can operate as a Mobile IPv6 Home Agent as well. NEMO Basic Support protocol defines required operations and messages for basic group IP mobility support, and let terminal devices could access multiple networks transparently though the Mobile Router (MR). A MR is located at the edge of the mobile network and connects the mobile network to the backbone of Internet. We may treat a MR as a default gateway for the mobile network, which can include both fixed and mobile node behind the MR. The internal network topology of MR keeps relatively stable when the mobile network is migrating. In NEMO Basic Support, only the MR and the HA are NEMO-enabled. There are four basic elements in NEMO: ”Mobile Router (MR)” that conducts communication while in move, “Mobile Network Node (MNN) get internet accessing through mobile router”, “Home Agent (HA)” that temporarily responds to communication requests on behalf of mobile routers, and “correspondent agents (CA)” that communicates with mobile routers. There are three kinds of MNN: ”Local Mobile Node (LMN)” that conducts communication from mobile router while in move ”Local Fixed Node (LFN)” that conducts communication from mobile router at a fix point ”Foreign Mobile Node (FMN)” that moves in and conducts communication from mobile router while in move; “CA” is denoted the Correspondent Agent, which may be the router or the node in the correspondent side. Fig. 1 presents most of NEMO-related terms:

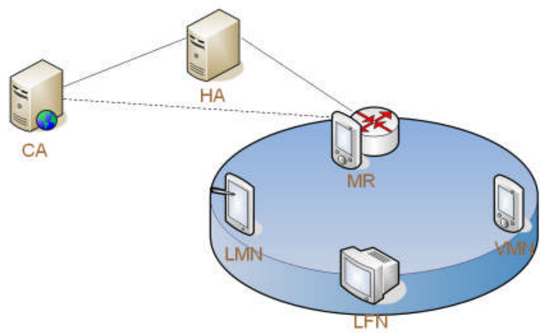

Fig. 1 NEMO Mobile Network

2.2 MANET Routing Protocols

A large number of routing protocols have recently been proposed within the framework of the Internet Engineering Task Force for the execution of routing in MANET networks. They can all be classified as either proactive, reactive, or hybrid. Proactive routing protocols maintain and update information on routing between all nodes of a given network at all times. Route updates are periodically performed regardless of network load, bandwidth constraints, and network size. Routing information stored in a variety of tables and based on received control traffic. Generation of control messages and route calculation are driven by the routing tables. The main characteristic of proactive protocols is that nodes maintain a constantly updated understanding of the network topology. Consequently, a route to any node in the network is always available regardless of whether it is needed or not. While periodic updates of routing tables result in substantial signaling overhead, immediate retrieval of routes overcomes the issue of the initial route establishment delay in case of reactive protocols.

In reactive, which are the flip-side of proactive protocols, route determination is invoked on a demand or need basis. Thus, if a node wishes to initiate communication with another host to which it has no route, a global search procedure is employed. This route-search operation is based on classical flooding search algorithms. Indeed, an RREQ message is generated and flooded, sometimes in a limited way, to other nodes. When the RREQ message reaches either the destination or an intermediate node with a valid route entry to the destination, a route-reply (RREP) message is sent back to the originator of the RREQ. A route is then set up between the source and the destination. Reactive protocols then remain passive until the established route becomes invalid or lost. Link breakage is reported to the source via a Route Error (RERR) message.

2.3 Routing in VANET networks

Based from the aforementioned routing concepts, a set of routing protocols has been proposed for vehicular communications. While it is all but impossible to come up with a routing approach that can be suitable for all VANET applications and can efficiently handle all their inherent characteristics. After all above-mentioned, looks relatively on NEMO BSP but speech, NEMO BSP and combination of MANET can offer high throughput, that can solve the problem that MANET can't be transmitted because of being too far away too. But most MANET routing protocol have not considered the questions of directionality and speed. So we use Receive on Most Stable Group-Path (ROMSGP) solve this problem. Though it might not be the best VANET routing protocol of throughput, a more stable route can be guaranteed to provide better service.

3 Vehicular network

In this section, we present a solution that integrate A Stable Routing Protocol to Support ITS Services in VANET[2] and NEMO[3] in vehicular environments. We suppose that every vehicle deploys a Mobile Router and has three interfaces: One is ingress interfaces, which connect the node within vehicle (NEMO), next is egress interfaces, which connect Internet, and last is ad hoc interfaces, which connect the neighboring vehicle and set up multi-hop networks. In normal condition, MR can communicate with other MRs through NEMO Basic support protocol and vehicles.

3.1 Vehicular ad hoc network

This section describes the most stable group-path (ROMSGP) and link expiration time (LET) to calculate and determine the most stable link. In this mechanism, the route with the longest LET is considered as the most stable link. Detail designs and distinct features are described below.

3.1.1 Link Expiration Time

In MANET network, each mobile node acts as a router to relay packets; however, the property of mobility results in breaks of some paths. In specific, a packet has to hop through some nodes, but one or some of these nodes have changed their location and could not relay packets. Mobile host in a wireless network may move with certain mobility patterns, such as regular and random movement patterns. Normally, VANET belongs to the regular movement patterns for daily life in cities. Su et al. propose the use of mobility prediction to improve the performance of ad hoc routing[5] with non-random behaviors. Their algorithm is described as follows.

If we consider two vehicles i and j with a transmission or line-of-sight range of r, speeds vi and vj , coordinates (xi, yi) and (xj, yj), and velocity angles θ i and θ j, respectively, the predicted LET is

$$LET = \frac{-(ab+cd)+\sqrt{(a^2+c^2)r^2-(ad-bc)^2}}{a^2+c^2} \quad (1)$$

Where

$$a = v_i \cos\theta_i - v_j \cos\theta_j$$

$$b = x_i - x_j$$

$$c = v_i \sin\theta_i - v_j \sin\theta_j$$

$$d = y_i - y_j$$

LET is an estimated duration of how long two cars are in connection range. Obviously, the path with the longest LET is considered as the most stable path.

3.1.2 Receive on Most Stable Group-Path

The ROMSGP algorithm is explained in [2] and is an integration of receive on most stable path (ROMSP) [4]. Furthermore, ROMSGP will group nodes according to their velocity vectors. If two vehicles were in different groups, the connection between the two vehicles is considered to be unstable. Under such situation, a penalty will be added to the routing path. Meanwhile, if a node tries to send a packet, it will search it routing table to find next one with less penalty. Additionally, LET is also taken into consideration to choose the most stable path. It is used to do a new route discovery before the link being expired.

3.2 Discovery of reachable MNPs

Every MR announces its Mobile Network Prefix (MNP) by periodically broadcasting – through the ad hoc interface – a message, that contains its Home Address and an associated lifetime, to allow this information to expire. These messages are announced through the ad hoc interface, by using a hop-limited flooding, so every MR becomes aware of the MNPs that can be reached through the VANET. The MR's HoA is chosen to belong to the NEMO's Mobile Network Prefix. Hence, the MNP can be inferred directly from the HoA (it is the network part of it). With the MR's announcements, every MR is aware of all the MR's HoAs (and associated Mobile Network Prefixes) that are available within the ad hoc network.

3.3 Creation of ad hoc route

In case a Mobile Router detects that there is an ongoing communication between a node attached to it and a node attached to another MR that is available through the VANET, the MR needs to build a multi-hop route to send packets directly through the ad hoc network.

As shown in Fig. 2, it illustrates more details of the proposed mechanism. A device in car A is communicating with another device in car B. This communication is initially being forwarded through the Internet, following the suboptimal path determined by the NEMO Basic Support protocol, thus traversing Home Networks A and B before being delivered to the destination. By listening to the announcements received in the ad hoc interface, MR A becomes aware that the destination of such communication may be also reachable through VANET. Then, MR A may decide to start using the vehicular ad hoc network to route this traffic, instead of sending it through the Internet.

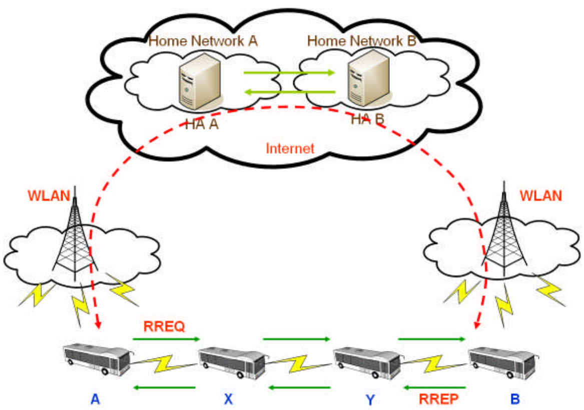

Fig. 2 Creation of a ad hoc route

In accordance with making above-mentioned several procedures in Fig. 2, routing table will be as Fig.3 shows finally; that is, it means that MR A has been aware of an ad hoc path, whose next hop is MR X, to relay packets to MR B.

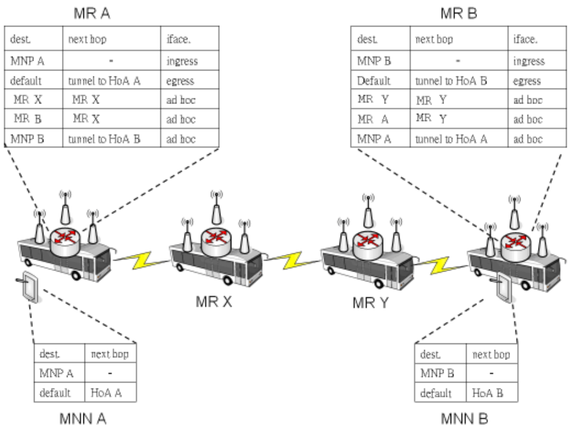

Fig. 3 Overview of packet routing

4 Simulation results

In this section, we used NS2 to make the simulation to analyze routing protocol efficiency that the paper provides. The simulation environment is shown in Table I; then, we compared simulation results with correspondent ones of NEMO BSP. In specific, these comparisons are average routing latency, average frequency of route changes, average route duration time, throughput and average routing load.

Simulation area	1.2 * 1.2 km2
No. of vehicles	100
Communication range	400m
Vehicles speed	10-130 km/h
Simulation time	60 min
Max hop count of vehicles	10
LET threshold	5, 10, 15 s

Table I Simulation environment

In our routing mechanism, LET threshold is a quite important parameter. If it is too high, it results in that a MR often tries to carry out route discovery. Consequently, VANET topology will change fast to be paralyzed. In contrast, if it is too low, link breakage happens before finding new route in MR, the procedure that MR tries to repair this problem makes a large amount of RERR information flooded to influence throughput. In the method of our routing, we compare not only with NEMO BSP and also compare different LET thresholds in simulation result.

Fig. 4 is an average route duration from discovery to setup completion. NEMO VANET is better than NEMO BSP after speed is faster than 50 km/h.

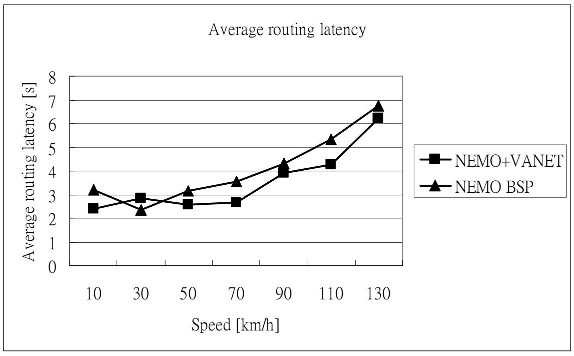

Fig. 4 Average routing latency

Average frequency of route changes in Fig. 5, it means the number of times that NEMO communicates through VANET with LET thresholds being 5, 10, or 15s. We can see that when speed is faster than 70km/h and LET threshold are 5s or 10s, number of route changes is similar, because link breakage happens when LET is above 10s in most of MRs. When LET threshold is 15s, it is lower than LET thresholds are 5s or 10s. Fig. 6 performs the tendency that the higher speed causes the more route duration.

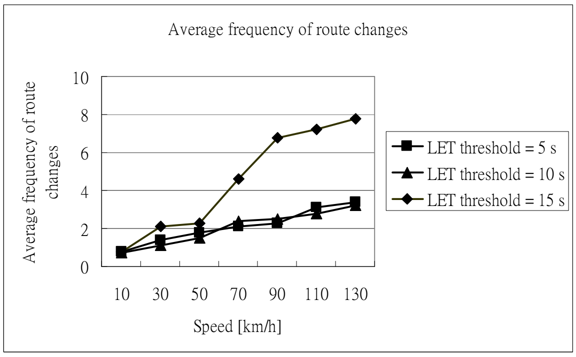

Fig. 5 average frequency of route changes

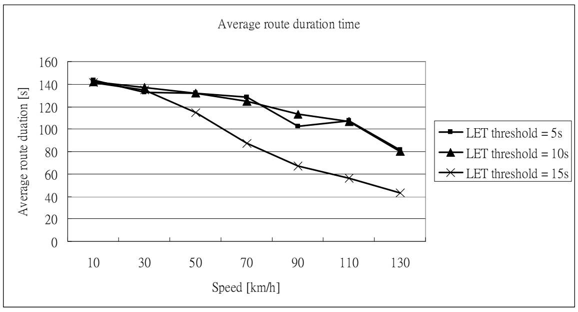

Fig. 6 average route duration time

Fig.7 shows average routing load rate. (control packet per data packet delivered). As long as the speed increasing, average routing load rate also increases. It is because a large amount of RERR will be sent to increase routing load rate. At the same criteria, average routing load has minimum value when LED is 10s.

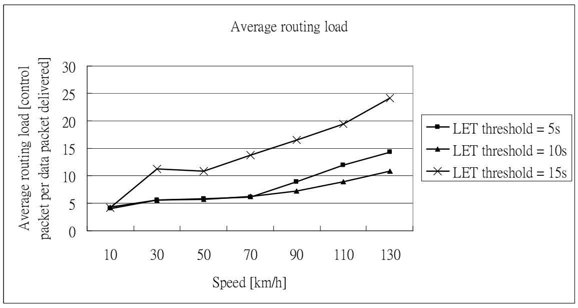

Fig. 7 average routing load rate

Fig. 8 shows end-to-end throughput. When LET threshold is set to 10s, the average throughput is 416.82 kbit/s which relatively is better than other three. Furthermore, the average throughput of NEMO BSP, LET threshold is 314.5 kbits. Three VANET NEMOs have better performance than NEMO BSP before the speed is less than 90 km/h. In specific, MRs will transfer to NEMO BSP mode if the speed is greater than 90 km/h. Besides, In VANET NEMO mode, LET threshold equal to 10s has better performance than LET equal to 5s or 15s. It is because LET equal to 10s can get the balance between NEMO routing changes and link breakage discovery.

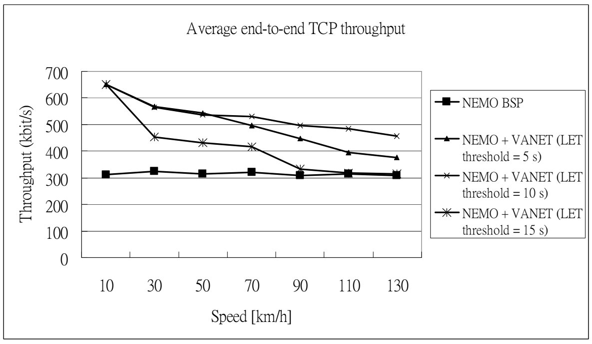

Fig. 8 Average end-to-end throughput

Fig. 9 is the relation among throughput, LET threshold and speed. When the speed is in 70km/h and 90km/h, LET threshold equal to 7s can get higher throughput. At 110 km/h and 130 km/h, LET threshold equal to 9-10s can get higher throughput. Consequently, the vehicle, while running in the city, we can set up LET threshold to 7s, but on the freeway or the high-speed, LET threshold can be set among 9-10s for better performance.

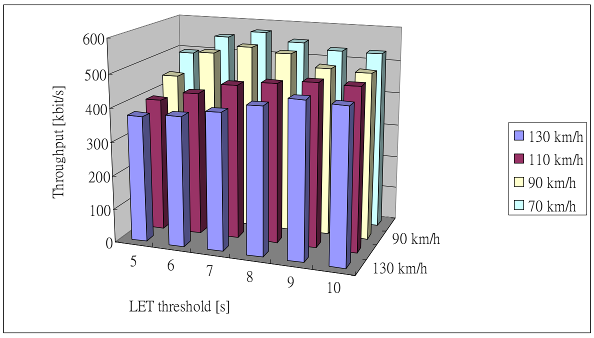

Fig. 9 throughput vs LET threshold vs speed

5. Conclusion

In the paper, route solution that we offer can transmit and pass VANET in Vehicle-to-Vehicle. Vehicle-to-Internet can be reached through NEMO BSP. In simulation results, VNET NEMO has higher throughput than NEMO BSP; meanwhile; it provides the more stability of VANET through ROMSGP and LET threshold mechanism. In the simulation, we just choose three values of 5, 10, and 15 to be evaluated, but the values help us to make a recommendation of LET threshold. If the speed of vehicle is under 90 km/h, the LET threshold can set up LET to 7 seconds; otherwise, if the speed of a vehicle is between 110 and 130 km/h, the LED threshold can be set at the value 9 or 10 seconds. Although VANET routing used in this paper unable to offer the best throughput, it can provide a more stable VANET. In sum, this mechanism can get a better tradeoff between network stability and bandwidth optimization.

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