# A Location Aware Virtual Infrastructure for VANETs

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**Abstract – The dynamical network topology is the source of most challenges in VANETs (Vehicle Ad hoc Networks). In urban area, however, it is feasible to meet the challenge by taking advantage of the heavy traffic. This paper proposes a location aware virtual infrastructure (LAVI) based on recognition memory. Combining the memory of past cooperation with the location information, the mobile nodes can construct cooperative groups with recognized peers and in turn to provide a virtual infrastructure.**

***Keywords:*** Virtual infrastructure, VANETs, Recognition memory, Location aware information.

## 1. Introduction

Although infrastructure independence makes VANETs (Vehicle Ad hoc Networks) flexible, it invalidates most of the existing protocols that work well in wired networks where fixed infrastructure is available. Alternative approaches have been proposed to address challenges such as robust routing, multicasting, quality of service, media accessing, network management, cross-layer protocols, and security issues [1], [2], [3], [4], [5].

Among those open questions, multicasting is a hot topic. The node mobility makes it very difficult to track the members of a multicast group. In particular, constructing and maintaining a multicasting tree become a nontrivial task considering the dynamical network topology.

However, in urban area, the activities of the mobile nodes provide some help. Let's consider the vehicles on road every day. In a city or a community, although some vehicles that travel long distance go through and will not appear any more, most of the vehicles travel among limited points repeatedly determined by the activity of the driver. Each single moving is not predictable, however, statistically the set of node of a VANET in urban area is stable and the areas they may appear are limited. These limited points imply that peers a vehicle meets on the road are not all strangers. It is feasible to tell whether peers are willing to cooperatively carry out communication tasks such as helping storing/forwarding packets.

In this paper, we propose a novel *location aware virtual infrastructure* (LAVI) that is able to provide a stable virtual infrastructure statistically on top of a collection of mobile nodes. The rationale is resulted from the above observation regarding the daily activities of the owner of a vehicle.

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## 2. Location Aware Virtual Infrastructure

### *A. Rationale of LAVI Scheme*

Essentially, the LAVI provides a stable logic network fabric for VANETs that tolerates the network topology dynamics. The rationale is to construct an overlay network that screens the mobility as long as the mobility won't break the logical connections in the overlay network.

Assume the area that covered by a VANET is divided into small subareas called cell and each vehicle can obtain its location information. In each individual cell a vehicle is selected as a virtual infrastructure node (VIN) that functions as a router in the Internet. When the VIN node is moving away from the cell, it hands the responsibility to someone else in the cell. Effectively, as long as there is a VIN vehicle in a cell, we can maintain a network link.

The location information is critical to four essential functionalities to establish LAVI: 1) It is used to make routing decisions when a node needs to forward packets; 2) When a vehicle is leaving a cell, it need to fulfill hand off operation; 3) Based on the location and moving direction, a vehicle can decide whether it is the "best" candidate to take over the responsibility of VIN; and 4) The location information is useful to update the network topology.

Figure 1 illustrates the LAVI architecture. The area covered by the network is divided into multiple cells as the hexagons. Each vehicle is aware of its location in a cell and the range of the cells. If a cell is not empty, there is one and only one vehicle plays the role of contacting point of that cell. Such a node is called virtual infrastructure node (VIN) that maintains the logic connections between the cells.

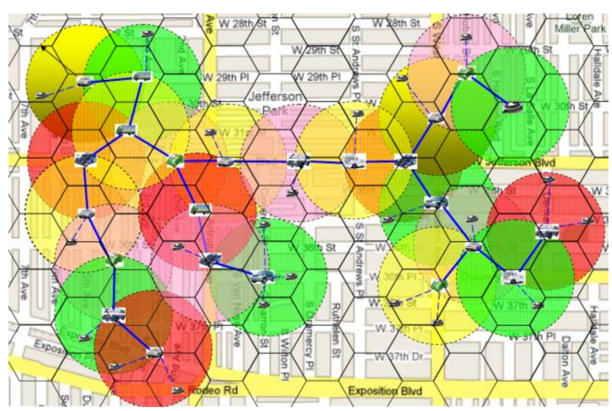

**Figure 1. LAVI Architecture**

The VIN of each cell maintains a simple data structure called register table (RT), which records the location information of all mobile nodes in the cell. The contents of the RT are updated periodically to track the nodes in a realtime manner. When a mobile node enters a cell and registered with the VIN, a new entry is created; and this entry will be removed when it leaves the cell. Figure 2 shows an example that how VINs update their RTs when node $N_A$ moves from Cell#1 to Cell#0. Note VIN also registered itself in the RT with its original node ID. If a cell is empty, the newly moving in vehicle will automatically claim itself as the VIN of this cell and start to contact VINs of neighbor cells. Then a new virtual node is established.

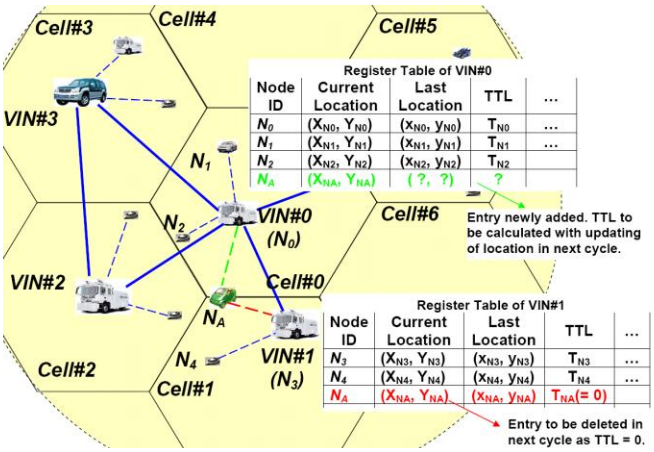


**Figure 2. RT update in VINs.**

In the RT, one of the most important items is the TTL (time to leave) that tells how long a vehicle will be in the cell. By updating the position of the nodes periodically, the VIN can calculate the moving speed and direction. With the knowledge of location and geographic condition, VIN can roughly tell how long a node will be in the cell.

### *B. VIN Switching Mechanism*

When the VIN node moves close to the edge of the cell, it handles the duty to one of the registered vehicles. Therefore, the network topology will not change. To minimize the overhead, it is desired to reduce the VIN switching operation. When a VIN node is leaving the cell, it looks up in the register table to find the node with the largest TTL value. Then the new VIN node will get the RT and other data from the leaving VIN. If the VIN is the only node in that cell, it needs to notify the neighboring VINs to update the network topology since one connection is disappearing.

It is highly desired that the VIN switching operation is transparent to upper layer applications. As long as there is a successor in the cell, there should be no change observed from the perspective of network topology, routing, QoS, etc. To achieve this goal, the LAVI architecture is designed as a logic network on top of the physical VANETs. Each VIN matches to a mobile node's ID when it plays the role. The binding of a VIN ID to the mobile node ID is transparent to upper layers.

Figure 3 illustrates the procedure of the preliminary VIN switching. Based on the current location and previous location, the VIN determines the direction and speed of each node in the cell. That information in turn tells the VIN that $T_{NA}$ is the largest among all TTLs currently in RT. Then $N_A$ is selected to be the new VIN and the RT is transferred to it. In the new RT, $T_{N0}$ is small, and this entry will be removed once $N_0$ leaves the cell. To VIN#1, $N_0$ is nothing more than a newly arrival common node and registered normally.

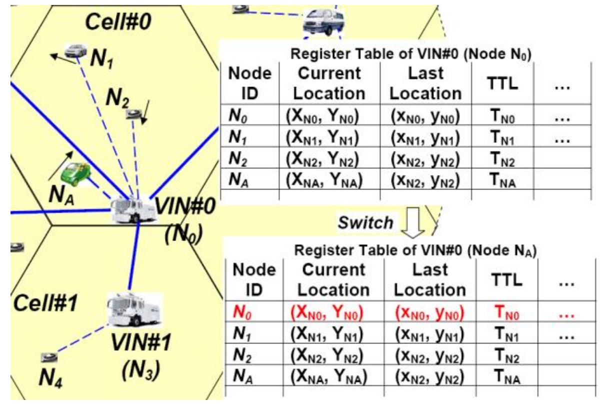


**Figure 3. VIN switching procedure.**

## 3. Conclusions

This paper proposed LAVI scheme that constructs a stable virtual network infrastructure for VANETs by hiding the node mobility. A lightweight but effective evolutionary cooperation mechanism has been adopted that enables a low-cost and transparent VIN switching operation. Intuitively, a stable network infrastructure is available if the density of mobile nodes is reasonably high. It is not a challenge for most of the typical applications of VANETs. For instance, in a battle field, it is reasonable to expect certain amount of vehicles and/or soldiers; in the case of disaster recovery, the density of vehicles and personnel involved also would not too low in certain area. The construction of LAVI architecture makes it suitable to support multicast services. Currently, we are designing the multicasting protocol and conducting experimental study to evaluate the performance of the LAVI architecture.

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