Effective Implementation of Location Services for VANETs in Hybrid Network Infrastructures

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Abstract—**In this paper we propose and evaluate a heterogeneous architecture for location service in vehicular environments. The proposed Location Service utilizes the infrastructure of cellular networks to offload the Dedicated Short Range Communication (DSRC) systems from the signalling overhead required for the location service. We evaluate the performance of such a hybrid solution in terms of overhead and end-to-end delay. The results suggest that a heterogeneous network with an IEEE 802.11p access network for data delivery and a LTE network for Location Service can provide better system performance in high density and high load scenarios.**

***Index Terms*—location service, vehicular ad-hoc networks, heterogeneous networks, position based routing.**

I. INTRODUCTION

Safety applications are the main focus of today's Intelligent Transport System (*ITS*) research. These applications require broadcast or sometimes geocast routing techniques. However, the future in *ITS* applications lays in infotainment, where users can share content with others, download or stream videos and music, etc. Such applications mainly rely on unicast routing techniques. Position-based routing has become a standard for *VANETs* [1]. One of the requirements of unicast position-based routing, is that each node can identify the position information of any other node in the network. This can be achieved with the use of a Location Service (*LS*), which is the scope of this paper.

The Location Service architecture is based on the client-server paradigm with two main processes. The first process is the location update where a client sends its location information to one or more servers. The second process is the position query, where a node asks one or more servers about the location information of a destination node. Location Services for *MANETs* are well studied [2]–[4]. Their aim is mainly to reduce overhead introduced by *LS* and increase success rate of queries. The expected routing overhead for this kind of *LS* has been formulated in [5] as $\Omega(n^{1.5}\log(n))$, where n is the number of nodes, assuming the mobility of the nodes is independent. Such an assumption is not valid in vehicular environments where car-following models usually describe the mobility of the nodes. Since *MANETs* are usually infrastructure-less, *LS* design is also based on distribution of the service among the mobile nodes. However, in vehicular environments we can capitalize on the existence of infrastructure; either that of cellular networks or dedicated Roadside Units (RSUs). A more detailed analysis of different *LS* is presented in Section II.

In this paper, we propose and evaluate a centralised location service architecture that is based on the existence of infrastructure. In order to off-load the wireless 802.11p-based access network, we propose a hybrid solution that utilizes also existing cellular network (e.g. LTE). Such capabilities are feasible for vehicles and are evaluated now in field trials in projects like DRIVE C2X [6]. The results of the performance evaluation suggest that in higher traffic loads and higher vehicle densities, homogeneous networks (e.g. 802.11p, LTE) suffer from congestion. The proposed heterogeneous architecture however, can cope better in such scenarios.

The remainder of the paper is organised as follows. In Section II, we present related work on location services emphasizing on those designed for *VANETs*. In Section III, we present the architecture of our proposal for a location service. Section IV presents the performance evaluation of the proposed architecture. Finally, section V concludes the paper.

II. RELATED WORK

A. *Taxonomy and characteristics*

There are several architectures and approaches to categorise Location Services (*LS*) for VANETs. Most of the research is focused on the infrastructure-less *LS* where the mobile nodes play the role of location server. These *LS* are divided into two main categories. The first is the flood-based approaches where every node is a location server and either flood the whole network with position updates (e.g., DREAM [7]) or with position requests (e.g., LAR [8]). Such methods result in high volume of overhead and waste of resources which degrade the performance of the network. On the other hand, in rendezvous-based *LS*, some nodes play the role of the location server and hold position information for other nodes. This association is specified either by a hash function (in hash-based *LS*) or by groups (in quorum-based *LS*). In quorum-based *LS*, a node A sends location updates to a subset or region of the network, and the other nodes send requests for node A to a potentially different subset or region of the network. These two subsets are designed such that they intersect and the queries can be resolved. Such an example is the XYLS

[9], where the updates are disseminated along the north-south direction and the request along the east-west. Hash-based *LS* use a strong hash function $H(x)$ (e.g., SHA-1, MD5) to map a node's unique identifier (e.g., MAC address, IP address) to other nodes or regions that act as location servers for node *A*. This hash function is known to all network nodes, so when a node wants the position information of node *A* it calculates $H(A)$ and sends requests to those nodes or regions. Node *A* sends its updates to the same nodes respectively.

However, especially for VANET scenarios where infrastructure can be available, either with the use of cellular networks or designated Road Side Units (RSUs), a centralized architecture may be more suitable. Such approaches are generally used in cellular network to track the mobility of nodes over different base stations. An example is presented in [10], where RSUs are utilized to provide mobility management for nodes over GSM network. Position requirements for cellular networks are much lower than those needed for position-based routing in VANETs. In cellular networks, we only need the base station serving the node whereas in VANETs the exact location and more information (heading, velocity, etc.) are required.

Other characteristics that are important for location services is the locality of the servers. Some approaches select the location servers randomly among all nodes, in which case some updates and requests might take long time to reach the location server. To solve this problem other *LS* set constraints on the selection of the location servers so as to be near the serving node. Additionally, location servers can form a hierarchy that can help with the locality. The lowest level of the hierarchy reduces the cost of updates and local queries. If a query further away comes, it is resolved following the *LS* hierarchy. Finally, there are different update triggering mechanisms. There are *LS* that trigger the update periodically after a timer has expired, others with distance after the node has moved certain distance or crossed a boundary, and finally those which have both time and distance triggers.

B. Infrastructure-less LS

Considering the distinct characteristics of vehicular networks such as the lack of strict energy constraints and the high mobility of the nodes (vehicles) constrained by the road topology, several *LS* have been proposed. MALM [11] uses the Kalman filtering to calculate the current position of a node based on historical location information of other nodes. The approach is based on intelligent flooding of location information, which however results in high overhead. In [12], a Vehicle Location Service (*VLS*) is proposed that utilizes digital map information to assign the location servers through a hash function. Another hash-based *LS* that uses 'responsible sections', such as traffic-light controlled intersections or bus stops, is presented in [13]. Vehicles at those sections are assigned as location servers assuming that they slow down or stop for some time at those areas. These locations are known to all nodes a priori, so they can send their queries towards these locations by calculating a hash function to find the responsible ones.

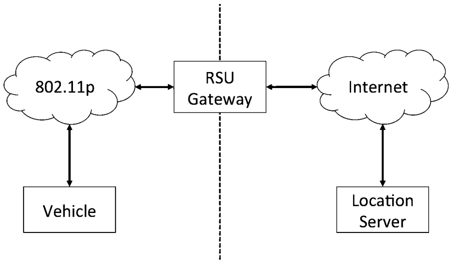
A quorum-based *LS* (RLSMP) is presented in [14]. It divides the network in regions (called segments), which then are divided in cells. Nodes within a segment form a geographical cluster. Each cell has a leader (*CL*) that gathers all the location information for that cell. The nodes in the central cell of a segment play the role of location server for all the nodes of the cluster. They only get an aggregated summary of the location information stored in *CL*. However, this approach results in overhead in order to maintain location information in *CL* nodes that change dynamically. Also, even though the clustering is static and based on the position of each node, determining the *CL* and transferring location information from the old *CL* to the new selected *CL* causes extra overhead. MG-LSM [15] is another quorum-based *LS* where the network is divided in regions each of which has a fixed location server called region head. Vehicles moving nearby and in the same direction form clusters and the cluster head takes the role of location server for the rest. To reduce the overhead, it reports to the region head only its exact location and for the rest of the nodes only membership information (unique identifiers of nodes in cluster) or changes of that. When a node wants the location of another node, it sends a query to its region head, which then searches for the cluster head associated with the node requested. The region head sends another query to the corresponding cluster head that replies with the exact location information of the node. As it can be seen, although the update overhead is reduced the query overhead and delay is increased.

C. Infrastructure-based LS

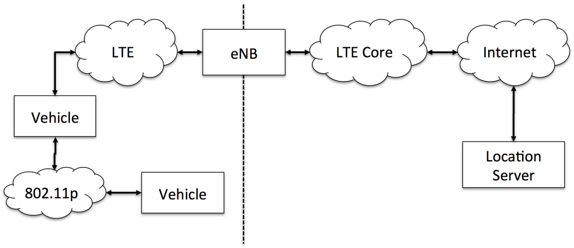
Finally, two *LS* that utilize infrastructure are MRLSMP [16] and LEMM [10]. MRLSMP is a modified version of [14] to take into account the existence of infrastructure as location servers. The *CL* is designed to be a fixed RSU in order to reduce the overhead of transferring location information from an old *CL* to a new *CL*. However, the RSUs are not connected with any backbone wired network, and the *LS* is still a decentralized process. On the other hand, LEMM uses RSUs that are interconnected and there is only one centralized location server that can predict which RSU will serve each node. But, LEMM is not used as a mechanism to provide position information to unicast routing protocols running on vehicles but as a mobility management mechanism for cellular networks in highway scenarios.

III. PROPOSED ARCHITECTURES

Intuitively, a *LS* with the use of infrastructure, which can be available in vehicular scenarios, can improve the performance of the system. A centralized location server might be seen as single point of failure. However, with the introduction of cloud computing, it can be realized as a cloud service that will be available over a specific address, thus increasing the reliability of the service and resistance to node failures. We propose and evaluate two architectures for *LS* that employ infrastructure and a centralized location server as seen in Fig. 1; one working with wireless (IEEE 802.11p-based) network and one utilizing cellular (LTE) network.



(a) Reference Scenario using 802.11p



(b) Reference Scenario using LTE and 802.11p

Fig. 1. Proposed Architectures

A. *Everything over IEEE 802.11p*

The reference scenario for this architecture can be seen in Fig. 1a. In this scenario, inter-vehicle communications as well as vehicle-to-infrastructure are done over the 802.11p network. Assuming urban scenarios, RSUs have to be placed at every intersection due to the channel characteristics[1]. RSUs are connected with a backbone network to the internet and through this to the location server. Vehicles send unicast location updates (LSUPDATE) and queries (LSREQ/LSREPLY) to the location server that are routed through the nearest RSU. One drawback of this approach is the need of large number of RSUs. If multi-hop location updates and queries were to be employed, then this number could be lowered. Additionally, the use of same channel for location update and data dissemination, reduces the available bandwidth. The benefit of this approach is that vehicles need only one type of transceiver.

B. *Data over IEEE 802.11p and control over LTE*

The second architecture is depicted in Fig. 1b, where inter-vehicle communications are done over 802.11p network but LSUPDATE and LSREQ/LSREPLY are routed through existing cellular network (e.g., LTE). The benefits of such an approach are threefold: (a) utilizing existing cellular infrastructure and not requiring dedicated RSUs, (b) the communication range of LTE is larger than 802.11p, thus less base stations are required for covering larger areas, and (c) we offload 802.11p network from the overhead introduced by *LS*. However, vehicles are required to have two types of network interface cards and packets that pass through the LTE core are potentially experiencing more delay.

TABLE I
SIMULATION PARAMETERS

Parameter	**Value**
Number of vehicles	100, 200, 300, 400
Vehicle Avg. Velocity	0 - 20m/s
Number of RSUs / eNB	25 RSUs / 4-9 eNB
Nominal Comm. Range	500m (at line-of-sight) & shadowing
Number/Type of Connections	10 / UDP, Car-to-Car
Offered Load (per connection)	1-20 KBps / 500bytes/packet
MAC/PHY protocol	IEEE 802.11p, 6Mbps
LTE scheduler / RB alloc.	Prop. Fairness / 75 UL, 100 DL
VANET Routing protocol	CLWPR [18], cache limit 5sec
HELLO interval	Adaptive with speed
Loc. Service Update interval	5sec (time triggered)
Background Traffic	15 uE-uE connections (64kbps/con)
Internet Delay / Traffic	average 25ms / 50% link utilization

C. *Piggybacking Location Header*

In addition to the two proposed architectures for *LS*, we investigate the effect of piggybacking location information in the form of Location Header (*LH*) to all data packets. With this architecture, only the source will have to ask the *LS* for location information of the destination. When it sends a packet, it piggybacks that information to the packet, so intermediate nodes won't have to send queries to *LS*. This approach potentially reduces the delay and overhead introduced by the *LS*, but decreases the 'goodput' of the wireless communications.

IV. PERFORMANCE EVALUATION

In this section, we present the performance evaluation of the two proposed architectures (802.11p and Hybrid), with and without the use of Location Header, along with a full LTE network where all data are routed through the cellular network. Background traffic is generated in the LTE access network as well as the Internet for more realistic scenarios. The simulation area is a 5x5 Manhattan network; a benchmark scenario in the literature [17]. We simulated scenarios of different vehicle traffic density, vehicle speed and offered load using ns-3.15. A summary of the simulation parameters are presented in Table I. The performance metrics we used are the average *end-to-end delay* of data packets and the *overhead* introduced by the location service (ratio between LSREQ sent and received packets). In addition, we evaluated the *success ratio* (LSREPLY / LSREQ) of the Location Service under different request rates. All the results are averaged over 15 independent simulation runs.

Success Ratio: First of all, we measure the success ratio of the Location Service Requests of the two architectures (802.11p and Hybrid). The requests are send following Poisson distribution with different rates and randomly selected pairs. Each request is send once, and if it fails it is not retransmitted. The results presented in Fig. 2 correspond to a scenario with 100 vehicles, moving with average speed of 15m/s. As it is expected, the demand on the location service has an effect on the success rate. For lower demand, 802.11p-based architecture can provide almost 100% success rate but it is degraded for higher demand due to increase contention level and packet losses due to collisions. LTE-based architecture on

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[1] Location service packets are not forwarded from other vehicles.

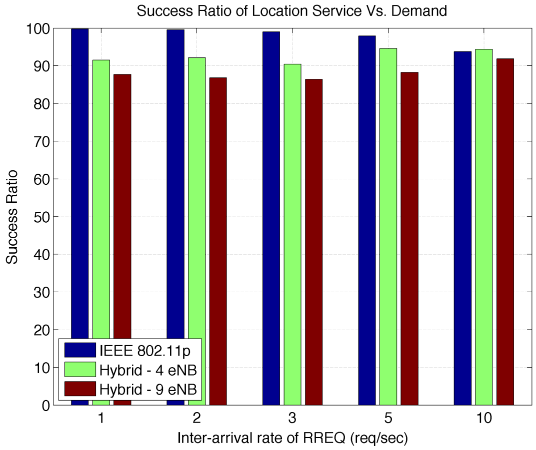

Fig. 2. Loc. Service success ratio under different request rate

the other hand, is not affected by the Location Service packets since this demand is low compared to background traffic. The small difference in the results between the 4 eNB and 9 eNB configuration is due to the handover procedure. Smaller cells cause more frequent handover and packets might be lost.

End-to-End Delay: Next, we present how *end-to-end delay* is affected by different parameters such as average vehicle speed, node density and traffic load. The results presented in Fig. 3a suggest that LTE-based networks are not affected by the average speed of the vehicles as much as 802.11p-based ones, due to the large area of the cells. However, node density and traffic load influence LTE-based networks more, making it a less desirable choice (Fig. 4a, 5a). On the other hand, hybrid networks result in lower delay for the most challenging scenarios (high mobility, density and load). The effect of piggybacking Location Header on delay is more apparent in high mobility where the lack of intermediate *LS* requests reduces the delay.

Overhead: Finally, we evaluate the *overhead* introduced by the Location Service. As expected, increasing the average vehicles' speed and node density result in equivalent increase of the overhead (Fig. 3b, 4b). This is due to the dynamic nature of the network and the interconnections. Different nodes are selected per hop, so more frequent requests are sent to the location server. It is expected that the use of *LH* reduces the overhead in higher velocities. On the other hand, overhead is decreased as the traffic load is increased (Fig. 5b) and this is because of the time that Location information stays valid in a node. After that time expires a new request has to be send.

V. CONCLUSIONS

In this paper, we propose and evaluate two architectures for centralized Location Service in a urban VANET scenario, a homogeneous 802.11p-based and a heterogeneous combining 802.11p and LTE networks. The results suggest that in higher traffic loads and vehicle densities, congestion and capacity limit the performance of homogeneous networks. The use of LTE network only for traffic related to *LS* off-loads some traffic from 802.11p network and does not introduce excessive load on the LTE network. For future infotainment ITS applications the use of pure LTE networks could be an option; however a large number of sites should be deployed (potentially femtocells), which increases the cost of infrastructure. In addition, LTE networks may not be dedicated to ITS services, there are other users that increase the background load on this network. Therefore, using dedicated IEEE 802.11p-based access networks to deliver data in VANETs seem more suitable.

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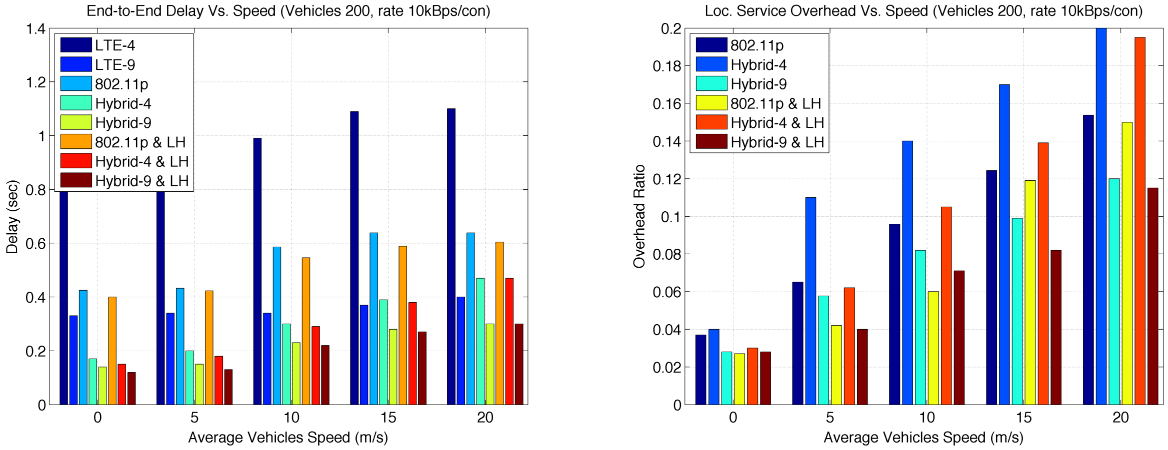
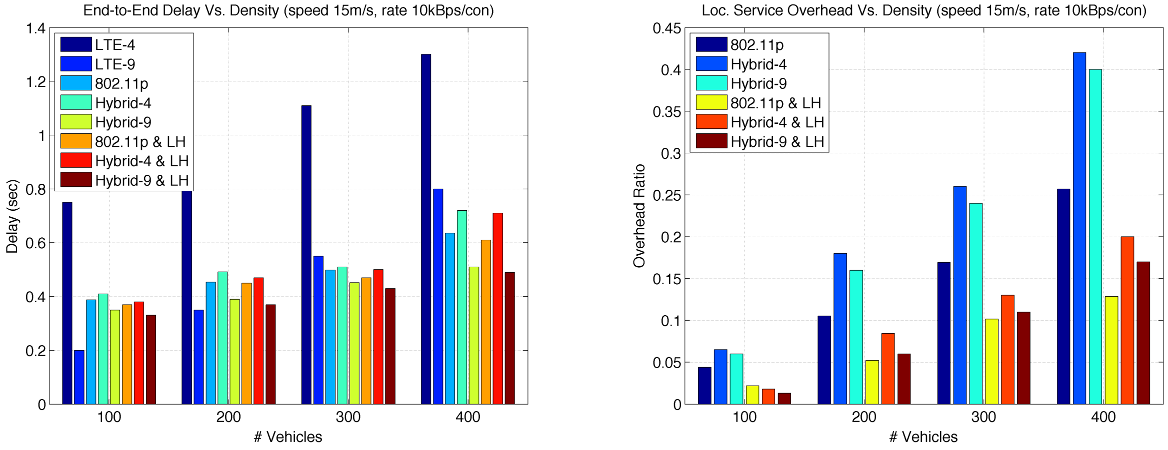


(a) End-to-End Delay

(b) Loc. Service Overhead

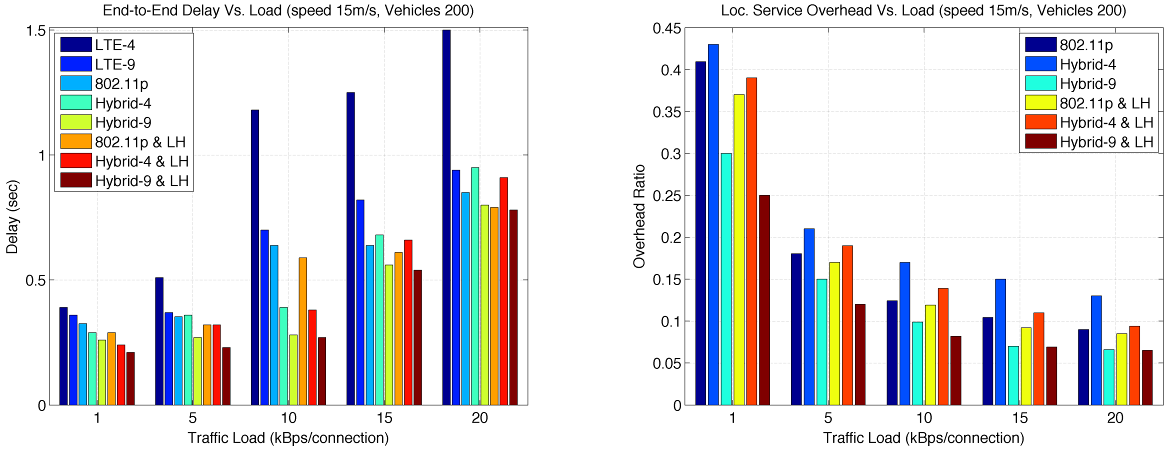
Fig. 3. Impact of vehicles' speed



(a) End-to-End Delay

(b) Loc. Service Overhead

Fig. 4. Impact of vehicles' density



(a) End-to-End Delay

(b) Loc. Service Overhead

Fig. 5. Impact of traffic load