Location Service Management Protocol for Vehicular Ad Hoc Network Urban Environment

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Abstract. Location based service is used in vehicular ad hoc networks (VANET) to locate a node's position before the start of any communica- tion. The existing location services proposed for Mobile Ad hoc Networks (MANET) suffer from low scalability in VANET environments. Protocols proposed for VANET do not consider load balance on location servers, and do not consider realistic information for selecting location servers which affect the protocols efficiency. This paper proposes a Quorum- Based Location Service Management Protocol (QLSP) which is designed for urban area topology utilizing specific node information such as the distance to intersection centre point, and speed in selecting main loca- tion server. Formation of quorum location servers is achieved by the main location server through the nomination of other nodes located at the in- tersection based on their direction of movement. QLSP shows excellent performance in reducing overhead of control packets, provides a high de- livery ratio of packets to destination, and reduces the end-to-end delay of routing packets. The performance of the protocol is then compared to other existing location service protocols.

Keywords: vehicular ad hoc networks, location service protocol, load balance.

1 Introduction

Vehicular Ad Hoc Networks (VANETs) integrate the capabilities of wireless networks to transportation systems. This may offer blanket connectivity to mobile users and provides the exchange of useful information between them.

VANETs applications are wide and promise useful services such as cooperative intersection safety and map localization [1]. VANET's applications need positions of nodes in order to route messages between source and destinations. Position-based routing protocols are suitable routing protocols for VANET environments compared to reactive and proactive protocols. This class of protocols needs, as a prerequisite, a location service that could determine the location of a given destination ID in order to enable the position-based protocol to communicate with the destination.

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Many location service protocols have been proposed. However, they all employ different strategies when selecting nodes to act as location servers as well as different update schemes used to pinpoint the location of related nodes in relation to their corresponding location servers. The majority of these protocols are designed for MANET [2] and sensor networks environments. Location service protocols suffer from limitations and challenges, especially when they are applied in VANET urban environments. The nature of urban areas, such as intersections and obstacles represented by buildings and the restricted movement of vehicles on roads affect the performance of the protocol in determining the location of various destinations.

This paper considers a location service protocol designed especially for urban environments, avoiding some of the limitations faced by current location services when applied to the VANET environment. The Quorum-Based Location Service Protocol (QLSP) utilizes the quorum group of location servers in order to distribute the load on multi servers. QLSP uses two parameters: vehicle distance to the centre point of an intersection and the speed of the node in selecting the main location server. The node which demonstrates the best distance values to the centre point of intersections, combined with low speed, is nominated as a main location server (MLS). In addition to MLS, a group of nodes is selected by the MLS to form the members of a quorum group called Passing Location Servers (PLSs). The functions of PLSs are to distribute the load onto intersec- tions within the vicinity and to minimize packet transmission delays.

The rest of the paper is organized as follows. Section 2 reviews some location service protocols and discusses the problems faced by these protocols when applied in the VANET environment. Section 3 describes the proposed location service protocol. Section 4 discusses the simulated result, while section 5 concludes the paper.

2 Related Work

This section gives a review of some of current location service protocols for MANET and VANET. In addition, discussion concerning the urban environment and the main challenges faced by location services in VANET urban environment are also included.

Mainly, the location service protocols are divided into two branches: Flooding-based, and Rendezvous-based. Rendezvous based protocols were classified into two categories: hashed-based and quorum-based [3].

One of the early location services is Distance Routing Effect Algorithm for Mobility (DREAM) [4] which floods node location information in the network. The main problem with these flooding based location services is network overhead, especially when the network is dense as in VANET urban area which can cause packet collisions and delays.

A flat hashing-based location service algorithm called Intersection Location Service (ILS), was proposed in [2]. ILS utilizes the characteristics of street intersections. For fault tolerance, a distributed hash function called Chord algorithm, which is also used for query process, is used. ILS chooses a location server for every intersection and hashes this location server to selected intersection using intersection ID. This is a limitation because it does not ensure the stability of the selected location server because the lowest node ID could be a fast moving which will only be assigned for a short period of time. Map Based Location Service (MBLS) [5] uses specified points to select location servers. MBLS selects location servers based on waypoint, which cannot guarantee a good location in selecting a location server.

In ad hoc networks, quorum systems were used in different ways for different purposes such as location service, disseminating information, and location tracking [6] [7]. Quorum systems show good performance in terms of load balance and fault tolerance. The mobile nature of nodes in ad hoc networks increase the possibility of node failure due to nodes moving outside the range of other nodes or out of a specified region, in addition to failure of battery in sensor network and MANET. In XYLS protocol [8] [9] a node starts sending its location and ID information in a north-south direction. Any nodes receiving these messages broadcast it either south or north, and so forth. Consequently, nodes on this line will form location servers, thus they can reply to any received query. The problem facing this protocol is that if any node along the north-south line moves away, the connection to other nodes is lost and delivery updates cannot be achieved. Some solutions were proposed for this problem, but it assumes immobile nodes or movement in the same direction, however, it might not be a realistic solution in real world environments.

The existing location services have been designed the first time for use in MANET applications [10]. These location services perform well in MANET environments, but not when applied to VANET, as the environment is dramatically different. The differences are due to the high speed nodes of VANET, where the high speed of mobile nodes in ad hoc environments causes a high frequency of link breakage [11]. Losing a connection with a destination pushes the source to locate the destination location again by querying the location server nodes about the location of this destination. This process generates another problem represented in control packet overhead generated by query requests and reply packets in dense networks. Second, the restricted mobility in VANETs environment such as in urban and highway roads makes it different than MANET where the mobility of nodes is considered random.

From the previous observations on the current problems facing location services, it is clear that the main problem is updating location of nodes efficiently and getting high ratios of packet delivered to destinations with low overhead. Thus, this paper addressed the problems faced by current location services in VANET environment and handled this solution efficiently by proposing QLSP protocol enhancing packet delivery packets and reducing overhead and distributing the load on multi servers.

3 Proposed Location Service Protocol

This section explains the design of Quorum-Based Location Service Protocol (QLSP), which consider urban environment topology where selecting location servers is done near the road intersections. Centre point is defined as the intersection of roads. The intersection coordinates (*Xc, Yc*) are provided to nodes, thus each node can compare its position relative to the intersection centre point. A node can be nominated as a location server if its position is inside the intersection vicinity, moving at low speed, and closest to centre point. Main location server is selected among nodes at the intersection because it is here where nodes usually stop, providing the high probability of a stable node. The trade-off between a nodes' distance to intersection centre point and slow speed values is practical for selecting the most stable node. A stable node is the node that has the chance to stay for a longer time within an intersection area and close to the centre, making it within range of most of nodes in that vicinity. This stability is designed to reduce control packets overhead, leading to increased performance of end-to-end communications. It is assumed that each node is provided with 802.11 communication abilities in order for them to communicate with each other. Additionally, each node knows its position through global positioning system (GPS) and knows its neighbours location through beacons, which include ID, position, speed, and direction of node. Each node receives information of its speed and direction from the mobility model and propagates through beacons to inform neighbour nodes.

3.1 Location Server Selection

A node always checks the beacon it receives from neighbouring nodes to see if there are any location servers in range. Beacon packets include useful information about each node as shown below, which enables the location server to distinguish it from other nodes. The ID of a node is used to distinguish a node among other nodes, while the position is required to enable position based routing protocol to forward message to destination. Speed is one of the criteria used in determining the best candidate for a location server. Direction will be used to select other members of the quorum group for each direction. The LS field indicates the role of a node. The field is set to 1 if a node is a location server; a 0 indicates it is a normal node. The Flag field determines the quorum group of location servers a node belongs to. With the beacon information, nodes are able to know each other's information and the information is used during the nomination of the best node as a main location server which is based on shortest distance and lowest speed.

BEACON = (ID, Position (X, Y), Direction,Speed, LS, Flag)

QLSP uses two parameters in selecting a location server: velocity of a node's movement, and its distance from the centre point. A node periodically checks its position to determine whether it is inside the intersection vicinity or not as depicted in Fig. 1. It also checks beacons it receives from neighbours. If a node finds itself close to the centre of the intersection and it stops or moves at a lower speed compared to its neighbours, it will be nominated as a location server. Once it is nominated, it will change its status in the beacon to declare itself as a location server. Nodes close to this location server one or two-hops away need to send their updates to this LS. The location server located at intersection vicinity is called Main Location Server (MLS), and this MLS will construct quorum group by selecting some nodes to hold the location information of nodes called Passing Location Server (PLS). If MLS moves away from the intersection centre point, it has to send its location table to the newly nominated MLS in order to avoid reconstruction of locations table.

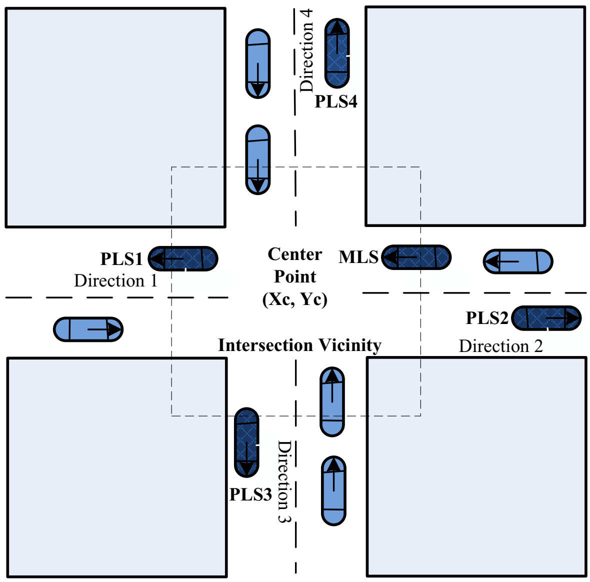

Fig. 1. Selecting Location Server inside Intersection

A criterion for selecting these PLSs is basically based on their direction of movement. MLS will select n number of PLSs which is equal to the number of roads which branch out of the intersection. Both MLS and PLSs form one quorum of location servers for an intersection. MLS selects PLSs based on their direction of movement. The main LS periodically checks the number of PLSs within its range; if the number is below a threshold it then selects other nodes to be the new PLS. Selecting new PLSs is based on a hybrid method combining unicast and multicast sending. If the number of available PLSs in range of MLS is, for example, 1, and there are still 3 more PLSs to fulfil the four road segments going out of that particular intersection, a multicast sending is invoked by MLS. But if the needed number of PLSs is only 1, then MLS only unicasts the location information table to that particular node. QLSP avoids broadcasting packets inside intersection vicinity to avoid packet collisions which usually leads to degradation in network performance.

PLS has two main functions. Firstly, it functions as a backup in case of MLS failure, and secondly, it acts as a location server answering queries sent to MLS at intersection vicinity. This reduces overhead on MLS and reduces the hop count a query packet may take to reach an MLS that has the location destination node. MLS updates PLSs of new nodes joining the intersection and hash their nodes to MLS. Algorithm 1 shows the sequence of steps to select the location server and construct the quorum.

Algorithm 1. Location Server Selection Algorithm

```
Node arrives at intersection vicinity
do while node inside intersection
    if it is first node inside intersection
        then nominate self as an MLS
        Change Beacon's LS status to 1 and indicate quorum group in flag field
        Start locations table construct
        Check neighbors in location table for selecting PLSs
    else if it is not first node or it is MLS and moves away of intersection's vicinity
        Input to bestNode method node's speed and distance
        Input to bestNode method neighbors' speed and distance
        if distance < neighbors' distance and speed < neighbors' speed
            then nominate self as an MLS
            Change Beacon's LS status to 1 and indicate quorum group in flag field
            Check neighbors in location table for selecting PLSs
        else
            Nominate closest neighbor with slowest speed as MLS
            Transfer locations table to new MLS
            Change Beacon's LS status to 1 and indicate quorum group in flag field
            Check neighbors in location table for selecting PLSs
        endif
    endif
enddo
```

3.2 Location Update

The update packet contains a node's ID, position, speed, direction, quorum group ID, and MLSs position. Intermediate nodes forward the packet through a geographical forwarding scheme based on closest neighbour to destination. Once the update packet is received by any PLS, it does not directly send this update packet to MLS; instead, it collects the received update packets and invokes the sending of update messages to the MLS after a period of time. This process ensures less frequent sending of packets towards MLS and intersection vicinity. The node stops sending updates to its MLS once it becomes closer to another quorum group of location servers. It then hashes itself to the newly discovered MLS and starts to update its location to the new location server.

3.3 Location Query

Source nodes send a location query message to acquire the location of the destination node. Initially, the source node is assumed to know the destinations ID, and then it includes this ID in the query packet along with source ID, source position, and source quorum of location servers information in addition to times- tamps. The query message is sent to MLS at intersections that it is hashed to, if it is one hop away as shown in Fig. 2. Otherwise, the forwarder that receives the query will check its

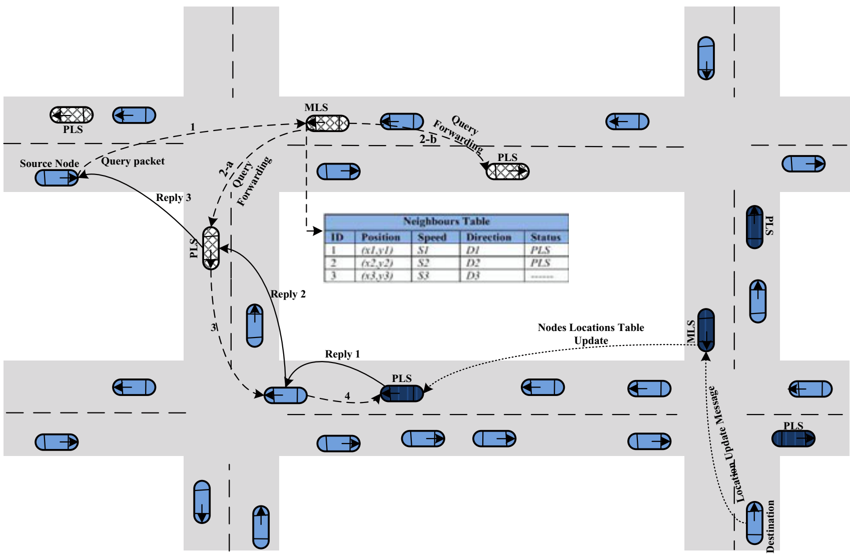

Fig. 2. Querying a destination's location

database about any cached up-to-date information entry of the destination. If there is an up-to-date location for destination, then a reply message is generated and sent it to the query originator to stop forwarding towards MLS. Otherwise, intermediate nodes keep forwarding query packets to MLS or any near PLS. Once MLS or PLS receives this query it looks up its own location table which includes all nodes information hashed their locations to it. If there is an entry to the queried node then the destination node resides on the same intersection. MLS or PLS reply with the latest received location of destination to source, and then the source uses this location to communicate with the destination. In the case that MLS and PLS have no location information about destination, the query packet will be forwarded as shown in Fig. 2 (messages 2-a and 2-b) to surrounded location servers quorums on surround intersections.

The query packet has a TTL field which expires after a given period of time to avoid looping over the network. The query originator has the right to originate another query after a period of time equal to TTL. If there is no reply about a query after a period of time equal to TTL, the originator will resend the query.

4 Results and Discussion

The performance measures of QLSP protocol are evaluated using Jist/SWANS simulator [12]. Simulated road scenarios for an urban area are extracted from TIGER/Lines map files [13] representing down-town Chicago, with a dimension of an area of around 800 square meters. The distance between adjacent intersections is 200 meters horizontally. Benchmarking QLSP is done against three location service protocols; Self Organizing Location Servers (SOLS) [14], ILS [2], and Terminode [15]. SOLS is a location service protocol designed for MANET, while ILS is a hash-based VANET location service, while Terminode is a home region location service protocol. Simulation parameters for the simulation are summarized in Table 1 below:

Table 1. Simulation Parameters

Parameter	Value
Simulation area	800m * 800m
Number of vehicles	200
Transmission range	100m
MAC protocol	IEEE 802.11 DCF
Simulation time	300s
Beacon Interval	1 beacon/second
Maximum Vehicles velocity	14 meter per second

The metrics used to evaluate the performance of the proposed protocol are control packet overhead, ratio of packet delivery, and end-to-end delay against vehicle speed.

Fig. 3 shows the load distribution around the intersections as represented by the number of queries answered by MLS and its PLSs quorum members of QLSP. Each

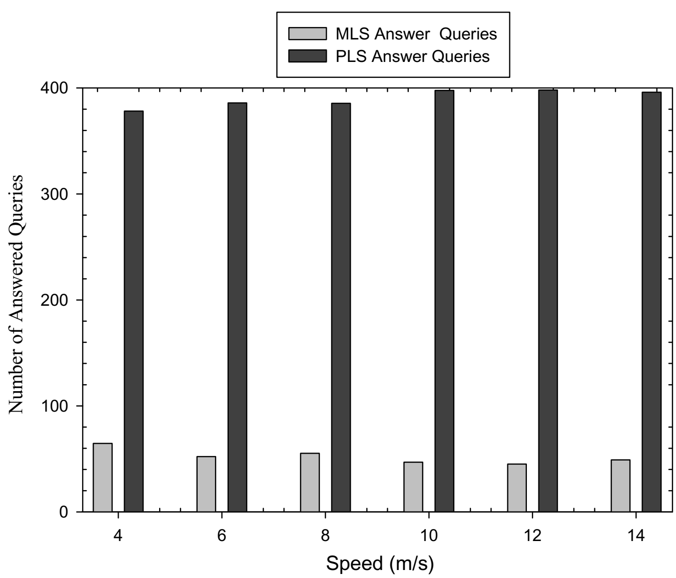

Fig. 3. Load balance around intersection vicinity

PLS is assigned a different direction and then all PLSs surround MLS from almost all directions. PLSs are thus enabled to answer any query sent to MLS. Other protocols such as SOLS do not select slave location servers based on directions; instead it selects them based on the number of nodes inside the wireless range of the master node, such that the majority of the queries are answered by the master node. As ILS assigns each intersection a location server, it answers all the queries, leading to degradation in overhead as discussed the in sections below. Thus, balancing the loads on MLS's located at dense areas (i.e., intersection) is successfully handled by QLSP. The higher the load on MLS, the higher the contention on the transmission medium among nodes located in the vicinity of intersections. Consequently, a high load on the main location server degrades the overall performance of the protocol. However, QLSP avoids this issue and distributes the load onto multi servers.

QLSP in Fig. 4 shows superior packet delivery compared to other protocols over all different speeds as the urban area topology is followed, and location based servers are assigned to intersections in addition to the distribution of PLSs on road segments surrounding the intersections. In ILS, for instance, delivery is lower than QLSP as all queries are sent directly to the intersection location server and the area is already dense. This may lead to a high rate of packet collisions, which degrades the delivery of packets to their destinations. QLSP avoids this by distributing the load on multi-servers. The Terminode protocol broadcasts every received packet inside home region, as a result, low packets delivery.

Fig. 5 shows that QLSP overhead is lower than other protocols, as expected, from the load balance results. This is because with the vicinity of intersections, the number of control packets such as beacons, update locations, and queries with their replies is high. Thus, selecting PLSs for different directions to work as location servers reduces

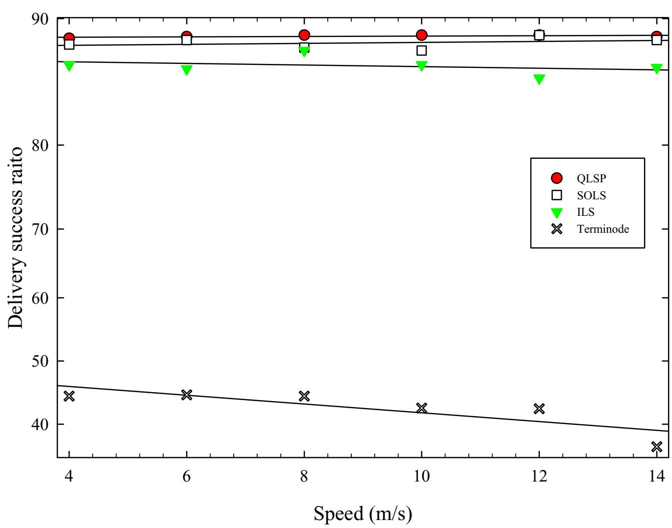

Fig. 4. Average packets delivery ratio

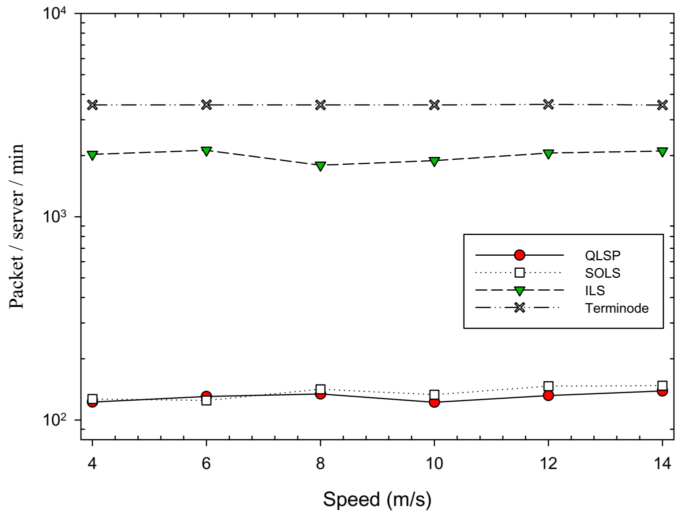

Fig. 5. Overhead per server

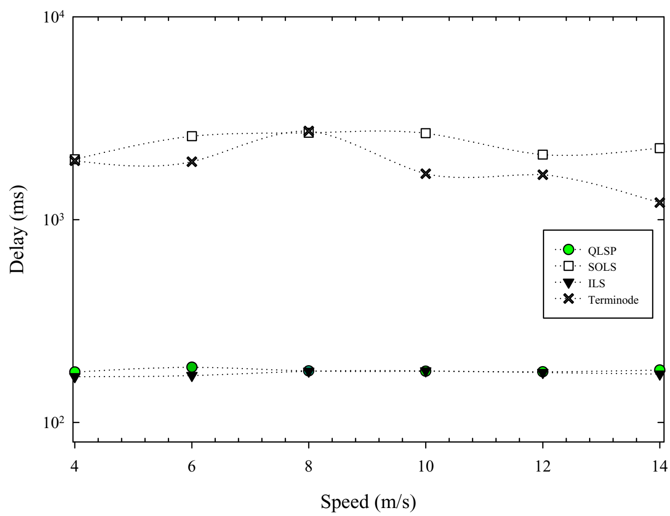

Fig. 6. Average end-to-end delay

the load in the vicinity of intersections ILS manages too many control packets because all packets, such as query and updates, are sent directly to the location server located at the intersection which is increasing the overhead on this server. SOLS broadcasts duplicate nodes locations to slaves, leading to additional overhead, but here the additional overhead is minor as SOLS does not select location servers based on intersection. Thus, location servers could be located at places with a low number of nodes, and low overhead, but at the cost of high packet routing delays. Terminode has very high overhead, mainly due to the broadcast of each received packet by Terminodes inside the home region.

Fig. 6 shows that the end-to-end delay of QLSP is lower than SOLS and Terminode and this is because PLSs in QLSP minimizes the number of hops a packet should usually take. The selection of location servers, based on intersection, efficiently directs the forwarding of queries and update packets over well connected nodes until they reach a PLS or MLS of the specified quorum group. Terminode and SOLS show higher end-to-end delays as they use specified regions within the network area and assign a number of nodes to work as location servers. As a consequence, packet routing suffers as a high number of hops are required to reach the specified location server.

5 Conclusion

In this paper, a location service protocol is proposed for urban area topology that exploits intersections to select the best node to act as a main location server based on two parameters: nodes distance to center point of intersection and speed. QLSP protocol efficiently designates the nodes located at the intersection to be location servers. Having MLS as the main location server and PLSs as backups provides not only a fault tolerance system but also provides load balance at dense intersections leading to reduced communication overhead and end-to-end delay.

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