RESEARCH ARTICLE

Information retrieval in two-tier VANET/P2P using RSU as a superpeer

Anjali Verma , Raghavendra Pal , Arun Prakash , Rajeev Tripathi

Department of Electronics and Communication Engineering, Motilal Nehru National Institute of Technology, Allahabad, 211004, India.

Abstract: Since traffic is increasing considerably day by day so information exchange for vehicular environment is very important to increase safety and to provide proper guidance of road side services available to driver during journey. Because of increased attraction towards Intelligent Transportation System (ITS) services it is required to design a system which can retrieve information very efficiently. A two-tier VANET/P2P system is basically the integration of two different type of services which are used for information exchange. Low-tier vehicular Ad-hoc networks (VANETs) can be used for achieving low lookup latency whereas high-tier infrastructure based Peer-to-Peer (P2P) can be used for increasing lookup success rate. In proposed protocol distance based reachability has been used. Reachability reduces lookup latency while maintaining moderate lookup success rate. Parameters for proposed adaptive lookup two-tier mechanism have been compared with the conventional two-tier lookup mechanism using Network Simulator (NS 2.34).

Keywords: Peer-to-Peer, VANET, Inter-Vehicle communication

1. Introduction

To provide innovative services to vehicles Intelligent Transportation Systems are used. It enables vehicles to share various type of information that can be required at the time of driving. ITS supports multiple services in vehicular environment. For example Collision avoidance, infotainment services and emergency vehicle notification etc. For example if a particular vehicle wants to retrieve the information of petrol pump in a particular area then it will transmit the lookup query for that particular area and vehicles present in that area will respond to the query. Since vehicles are increasing abundantly all over the world, requirement of Intelligent Transport Systems is increasing.

For retrieval of information in vehicular network wireless communication[8–9]

technology is used. Wireless communication is bifurcated on the basis of many different parameters and the most important classification is done on the basis of range a technology offers. For short range communication ad-hoc communication technology is being used. For mobile network this technology is termed as Inter-Vehicle Communication (IVC)[8]. For long range communication infrastructure based technologies, such as WiMax can be used.

Inter-Vehicle communication (IVC) is used by the users when destination is near and an ad-hoc network can be es-

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tablished to complete the data transmission and reception. For exchange of information among vehicles, vehicles form a vehicular ad-hoc network in hop-by-hop manner. For large distance also this type of communication scheme can be used but the probability of disconnectivity is very high.

To overcome the disconnectivity issue an infrastructure based communication [9] technology can be used for long range communication. Infrastructure based cellular communication is useful in long range scenario. In particular, an infrastructure based Peer-to-Peer overlay network has been built and with the help of this network vehicles share and retrieve information with ease. In this type of communication significant delay may appear because bandwidth available for communication is limited.

2. Related Works

To support several ITS services initially a Peer to Peer approach[5]has been proposed for traffic safety applications. In this approach each peer maintains a peer space which is done on the basis of a particular rule mechanism for maintaining traffic safety but more adaptive algorithm were required to design an efficient Information Transportation System. Later on VANET came into existence and single-tier VANET has been used for information sharing and retrieval. For example a Vehicular Information Transfer Protocol (VITP) [11], a location aware, application-layer, communication protocol designed to support a distributed service infrastructure over Vehicular Ad-hoc Networks. In single-tier VANET query is forwarded in hop by hop manner. Since network is mobile so, disconnectivity issue is very prevailing in case of single-tier VANET scheme.

With the aim of resolving the issue of single-tier VANET a single-tier infrastructure based P2P approach has been proposed in PeerTis[3]. In this scheme a dynamic cooperative traffic information system using an Internet-based peer-to-peer overlay network is used. An application layer overlay is designed to cooperatively share and retrieve information. A peer can forward the query over P2P overlay to retrieve information. But this scheme introduces high communication latency because in comparison to VANET delay in any infrastructure based cellular communication is significantly large.

To design an efficient protocol for information retrieval a two-tier VANET/P2P has been proposed. In two-tier mechanism vehicles are envisioned with both VANET and P2P overlay network[2]. Use of two-tier mechanism ensures high lookup success rate because there wouldn't be any disconnectivity issue. Since a vehicle forwards a query on both networks so it introduces irrelevant delay. For reducing irrelevant delays it was required to design a protocol which could adaptively make a decision that on which network query should be forwarded. An adaptive lookup protocol[1] has been proposed in which reachability model is used to select the network scheme. In this protocol Bloom Filter is used to calculate the reachability probability for a particular vehicle.

This paper proposes a distance based reachability model for a two-tier VANET/P2P network. This reachability model reduces the complexity of protocol while reducing the lookup latency significantly and maintaining moderate lookup success rate.

3. Proposed Method

Information Retrieval System:

For retrieving the information efficiently in a vehicular environment it is required to use two-tier VANET/P2P network. VANET is considered as a low-tier network which does not have any infrastructure whereas P2P overlay network is application layer overlay network. P2P network is infrastructure based network which ensures the high lookup success rate. In this section low-tier VANET and high-tier P2P overlay network is illustrated briefly. Each vehicle is provided with VANET but only few peers are equipped with P2P and these peers are termed as superpeer.

3.1 Assumptions

Since technology is growing every second, it is allowable to assume that each vehicle is equipped with few important technologies. Assumptions made in this paper are described in this section. Before proceeding with the

protocol it is required to mention that it is assumed that information queried by the vehicle is generally related to geographical location. It means that vehicle can query about the traffic condition, nearest petrol pump or route directions. For retrieval of such type of information it is mandatory that each vehicle should be equipped with Global Positioning System (GPS). GPS equipped vehicles are assumed because it is necessary for a vehicle to know its current geographical location, route map and area information.

Each road topology is made up of different road segments and each road segment is provided with a particular Segment ID. Road topology is divided into segments because whenever a vehicle will initiate a query it will ensure that query asked by the vehicle is related to a particular segment and it will mention the segment ID with the query. Vehicle will also mention its unique ID with the query which means that each vehicle is provided with a unique ID.

Most important assumption of this paper is that each road segment is provided with a Road Side Unit (RSU) and Road Side Unit explicitly enabled with both type of communication services. It means that each RSU will be provided with both VANET and P2P overlay network.

A vehicle equipped with VANET communicates with other vehicles in hop-by hop manner. But it is not necessary that a vehicle would be able to communicate with a Road Side Unit through hop-by-hop because network disconnectivity could happen. So, to avoid network disconnectivity between vehicles and Road side units it has been assumed that Road Side Units will be placed in such a manner that each vehicle will be having at least one Road Side Unit in its range.

3.2 Superpeer

In this paper each road segment is provided with a specific Road Side Unit and these Road Side Units are equipped with VANET and P2P network both. Hence in this protocol RSUs will work as a superpeer or clusterhead (CH) for a particular cluster. In a two-tier system CH is termed as a superpeer and rest of the vehicles in a cluster are called as normal peer. Vehicles are equipped with VANET and vehicles always form cluster and head of the cluster is Road Side Unit present in that particular road segment. Whenever a vehicle exits from a cluster it will automatically join a new cluster and will communicate with other peers with the help of single hop VANET. Superpeer and normal peer are same from a VANET perspective. Superpeer and normal peer communicate with each other through IVC.

3.3 Advantage of using RSU as a Superpeer

In conventional two-tier lookup mechanism[2] and adaptive lookup two-tier mechanism clusterhead or superpeer is elected on the basis of a specific parameter. This parameter could be any of these such as node ID, connectivity degree, and vehicle mobility (e.g., direction and speed). For example if it is assumed that CH will be elected on the basis of largest node ID then all the vehicles in a cluster will periodically broadcast their node ID on VANET. After the broadcast node having the largest node ID will be elected as a CH or superpeer and now superpeer will try to join P2P overlay network so that it could both type of services VANET and P2P network. To maintain the high lookup success rate it is mandatory to perform superpeer election very frequently because normal peers may move out of the range of superpeer and in that case normal peer would be able to communicate with neighboring peers only.

Hence it can be concluded that when RSUs are working as a superpeer there is no need of performing superpeer election which reduces complexity of the protocol. Further it can also be concluded that use of RSU will enhance the stability factor of cluster which will reduce delay also.

3.4 High-Tier Peer-To-Peer Overlay Network

Peer-To-Peer overlay networks[7] basically have distributed nature which means there is no hierarchal organization or any centralized server needed. Peer-To-Peer overlay networks are different from client server model in a manner that in this any client can be server and vice-versa. An abstract P2P overlay architecture comprises of multiple components which have been illustrated in **Figure 1.**

Peer-To-Peer approach is being used very efficiently for information sharing and retrieval without requiring any

centralized server. It has been categorized as Unstructured and Structured. Unstructured P2P network is very accommodating for a peer who wishes to join the network. No specific hard and fast rules are embedded in unstructured P2P overlay. In this it is not required by a peer to have prior knowledge of topology. Flooding mechanism is used with a limited scope means when a vehicle receives a flood query it will send all the data regarding the query to the originating peer.

In Structured overlay networks topology is tightly controlled and each peer is provided with a specific routing table which consists of neighbor peer ID and some other information. Hence structured overlay is not suitable for vehicular environment. So, in this paper unstructured overlay network is used.

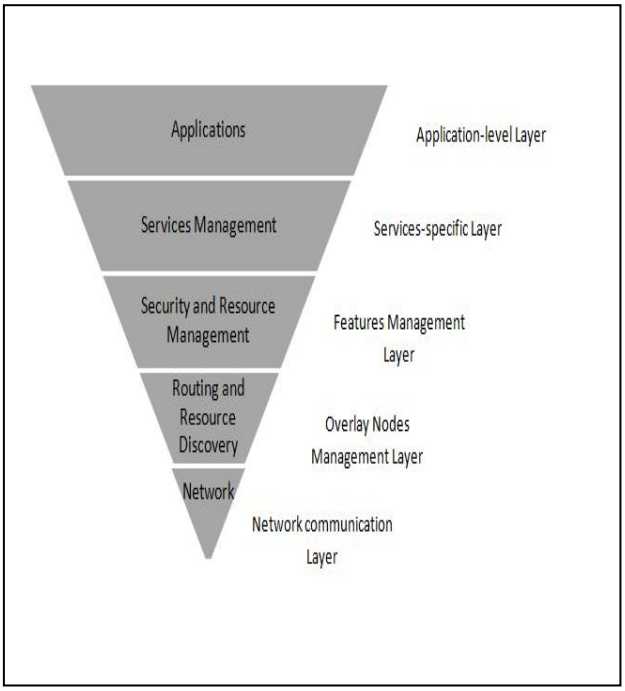

Figure 1;P2P overlay architecture.

3.5 Lookup initiation and forwarding

Whenever a vehicle wants to retrieve any information from a particular road segment it will initiate a lookup query consisting of road segment ID and it will simply broadcast the query over VANET. Road Side Unit present in the range of that vehicle will receive the lookup query and it will forward the query over VANET and Peer-to-Peer overlay network. When query will be received by the Road Side Unit present in the destination segment it will send all the data matching to the query to the originating superpeer. After receiving the response it will forward the response to the query initiator.

In **Figure 2** complete illustrations of lookup initiation and forwarding has been given. Till now no reachability model has been applied. This figure explains conventional two-tier lookup mechanism. In proposed Adaptive lookup two-tier mechanism reachability model will be used.

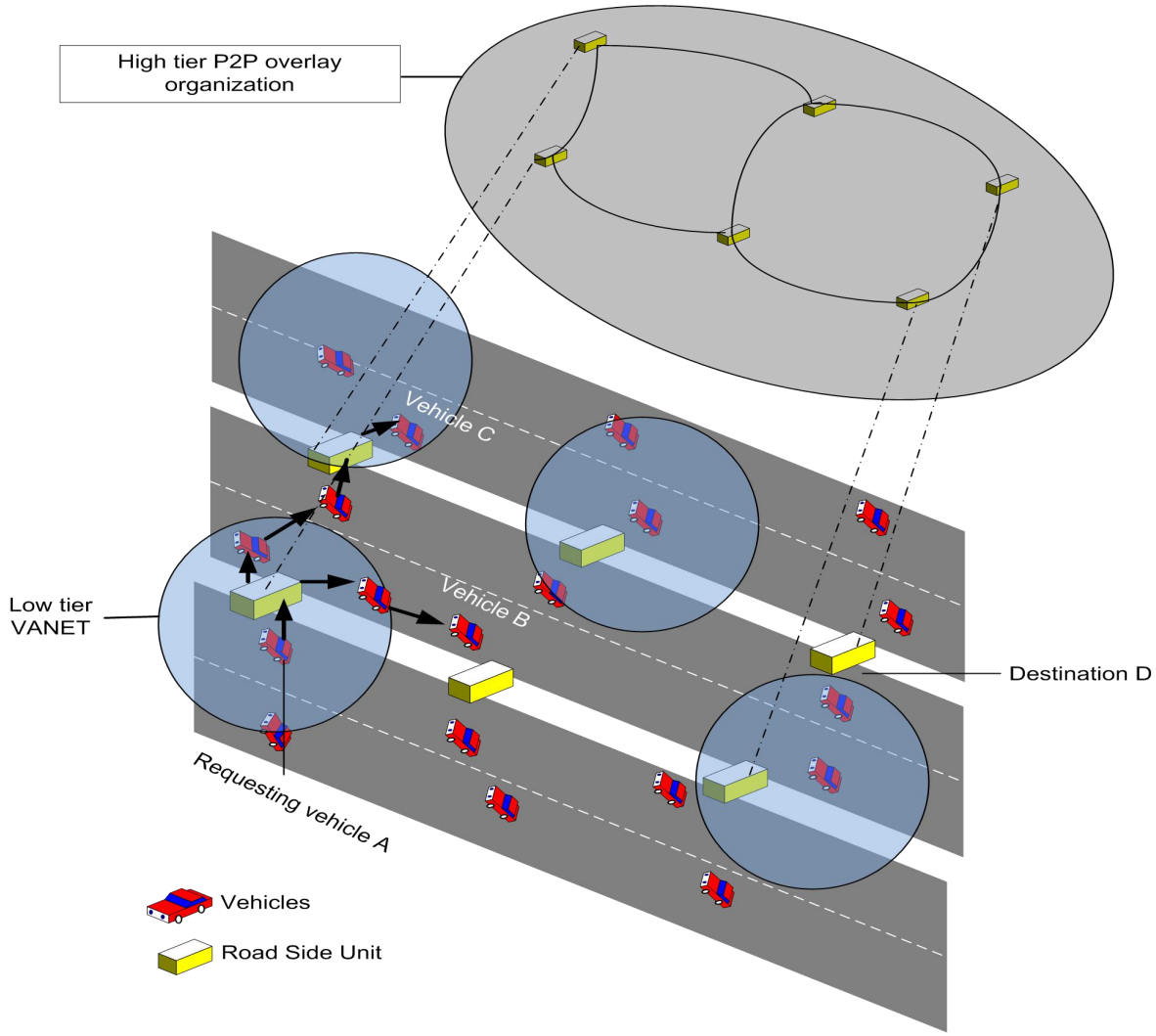

Figure 2; Information retrieval in conventional two-tier lookup mechanism.

In **Figure 2** vehicle A wishes to retrieve some information for the location mentioned as Destination D. For retrieving information it will initiate a lookup and query will be received by RSU and other vehicles present in the range of vehicle A. On receiving a query, RSU will forward the query to other superpeers through Peer-to-Peer overlay network. Lookup query will also be received by the vehicles B and C through IVC but these vehicles will experience network disconnectivity and lookup forwarding will be dropped at this point. However, P2P overlay query will be forwarded towards destination.

Adaptive Lookup two-tier Mechanism (ALTM):

This paper describes an adaptive lookup two-tier mechanism in which unstructured peer-to-peer overlay network has been integrated with vehicular ad-hoc network (VANET). Since the vehicular environment is base of the paper so it is feasible to use unstructured peer-to-peer overlay network because in case of structured peer-to-peer overlay it will become unstable because the topology will change very frequently. Therefore this paper uses an unstructured P2P overlay to illustrate adaptive lookup two-tier mechanism.

From the **Figure 2** description it is very clear that in case of long distance lookup superpeer should not forward lookup through VANET. Because forwarding lookup through VANET (in case of long distance) unnecessarily increases irrelevant messages. So, a reachability concept has been proposed to reduce irrelevant messages.

The main thought behind the reachability model is distance between lookup initiator vehicle and destination. Since it is very obvious that message forwarded through VANET couldn't get received by receiver because of disconnectivity and

this happens because of large distance between initiator and destination. So, whenever a superpeer will receive a lookup query it will firstly calculate the distance between both the segments. After calculating the distance superpeer will compare this distance with range of VANET. After calculating the distance superpeer will decide that on which network it will forward the lookup query.

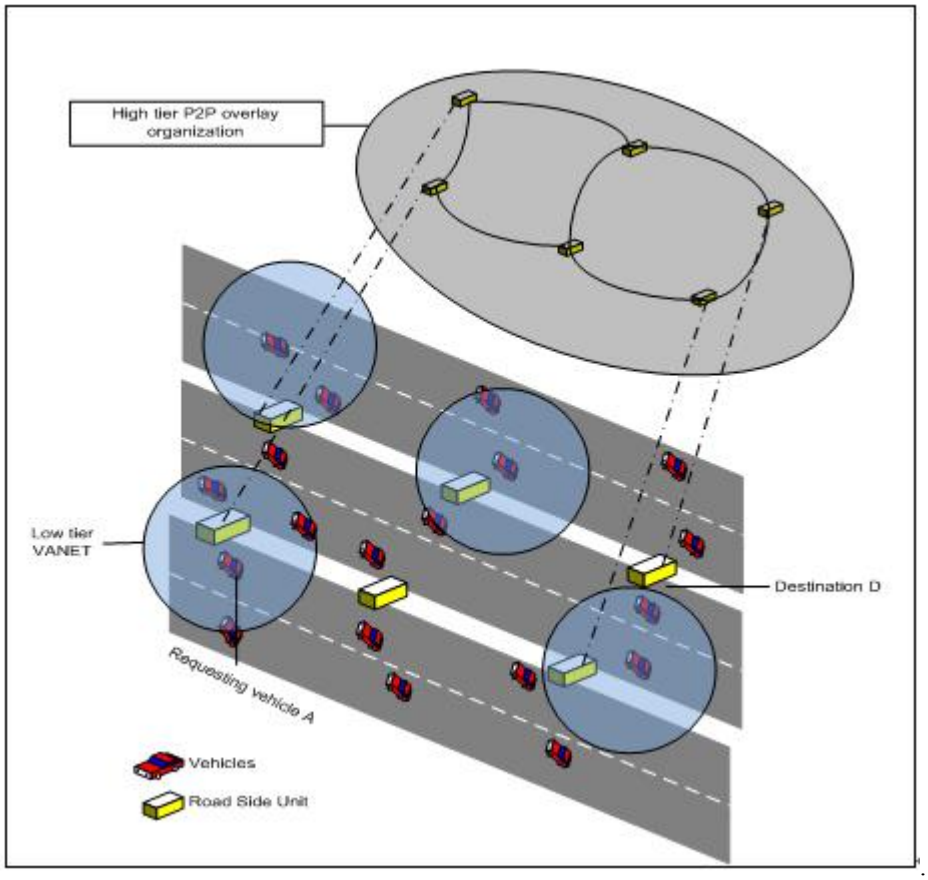

Figure 3; Information retrieval in adaptive lookup two-tier mechanism (ALTM).

A. Lookup forwarding:

In any vehicular environment normal peer or superpeer both can initiate the query. So, whenever normal peer initiates the query it will simply forward the lookup through VANET but when lookup query is initiated or forwarded by superpeer, it is the responsibility of superpeer to decide whether the lookups in IVC and Peer-to-Peer overlay are necessary. Each superpeer is provided with two distance thresholds d_{min} and d_{max}. As mentioned earlier on receiving a lookup query superpeer will calculate the distance between initiator location and destination. After calculating the distance superpeer will compare the calculated distance 'd' with d_{min} and d_{max}. If $d < d_{min}$ then superpeer will forward the lookup through VANET. If $d > d_{max}$ then lookup will be forwarded through Peer-to-Peer overlay network. If d lies between the range of d_{min} and d_{max} then lookup will be forwarded through both VANET and Peer-to-Peer overlay network. For the proposed mechanism value of d_{min} is equal to the range of VANET and d_{max} is thrice of d_{min}. The suggested value of d_{min} lies between 250m to 300m and for d_{max} it lies between 700m to 800m. The main reason behind these values is to avoid network disconnectivity issue.

In **Figure 3** Adaptive lookup two-tier mechanism has been shown. In this scenario vehicle A wishes to retrieve some information from destination D. So, vehicle A will initiate a lookup query and this query will be received by the other vehicles and superpeer present in the range of A. On receiving the query, superpeer will calculate the distance d between itself and destination. After calculating the distance it will compare it with d_{min} and d_{max}. For explanation purpose it has been assumed that $d > d_{max}$. So, superpeer will forward the lookup through peer-to-peer overlay.

Hence because of reachability model irrelevant transmission of lookups through VANET has been reduced.

4. Simulation and Performance Evaluation

In this section Adaptive lookup two-tier mechanism (ALTM) has been evaluated and compared with Conventional two-tier mechanism (CON). For evaluation of performance of adaptive lookup two-tier mechanism network simulator NS 2.34 has been used. Parameters and corresponding values have been listed in Table 1.

Parameter	Value
Simulation Area	10000x10000 m^2
Number of vehicles	20-100
dmin	250m
dmax	750m
MAC interface	Mac/802_11Ext
Interface Queue	Queue/DSRC
Propagation Model	Nakagami
Antenna Type	Omnidirectional
Channel Type	Wireless
Data Rate	3 Mbps

Table 1. Simulation parameters.

The performance of ALTM and CON have been evaluated in terms of Lookup Success Rate, Lookup Latency, VANET overhead and Peer-to-Peer overlay overhead. These parameters are defined as follows.

Lookup Success Rate is defined as the ratio of successful reception of lookups to the total number of lookups initiated. If initiator vehicle receives the response regarding the query then it is called as successful of lookup.

Lookup latency is defined as the time elapsed between the generation of lookup and successful reception of that lookup. Average of all lookups is calculated for calculating lookup latency.

Overhead is basically defined as the average number of lookup transmitted through a particular network. Hence VANET overhead is measured by calculating the average number of lookup transmitted through low-tier VANET.

Peer-to-Peer overhead is measured by calculating the average number of lookup transmitted through P2P overlay network.

For evaluating the performance of this paper scenario shown in **Figure 2** is used. As mentioned earlier, the values of d_{min} and d_{max} are 250m and 750m respectively. Value of d_{max} basically depends on vehicular density. It is directly proportional to the vehicular density. If vehicular density is high enough then d_{max} can be increased.

In **Figure 4** lookup success rate is shown for conventional two-tier lookup mechanism (CON) and Adaptive lookup two-tier mechanism (ALTM). For CON lookup success rate is very high because lookup query is being forwarded in both VANET and P2P overlay network. So, the probability of successful reception of query is very high. For low vehicle density success rate of ALTM is high but for high vehicle density it getting decreased because of VANET congestion. For increasing the lookup success rate contention time for safety and non-safety message could be different. For safety message contention period should be low but in case of non-safety message it should be large enough so that in case of high vehicle density message should not get dropped.

In **Figure 5** lookup latency is shown for Conventional two-tier lookup mechanism (CON) and Adaptive lookup two-tier mechanism (ALTM). For CON lookup latency is very high because of transmission of messages on both the networks. It will cause irrelevant delay. But in case of ALTM Lookup latency is significantly decreased because of reachability model.

In case of CON Lookup latency is decreasing with increasing vehicle density because vehicle connectivity

increases in VANET but in case of ALTM it is increasing with vehicle density because most of the lookups are being performed for long distance and in case of long distance P2P overlay network is used and in P2P network lookup latency increase with increase in vehicle density.

In **Figure 6** VANET overhead has been calculated for Conventional two-tier lookup mechanism (CON) and Adaptive lookup two-tier mechanism (ALTM)

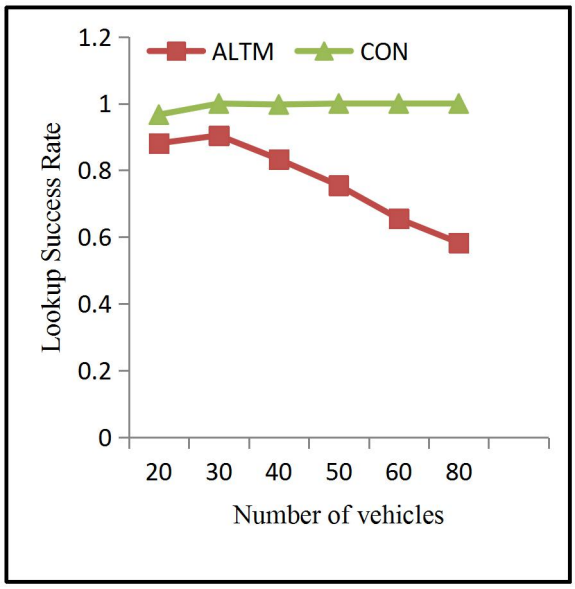

Figure 4; Lookup Success Rate Vs Number of vehicles.

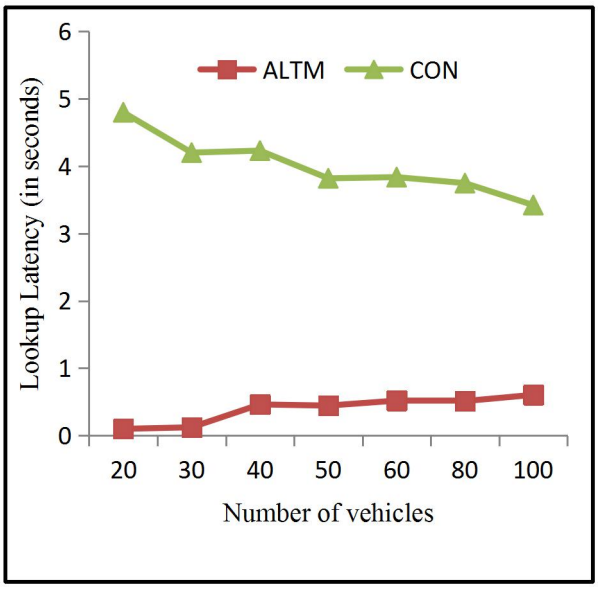

Figure 5; Lookup Latency Vs Number of vehicles.

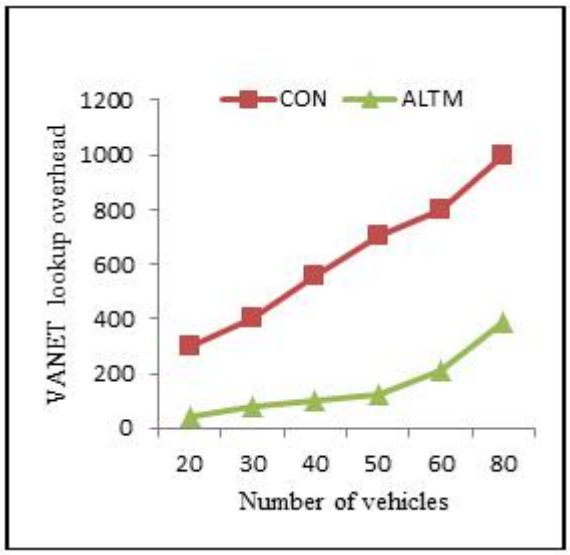

Figure 6; VANET Lookup Overhead Vs Number of vehicles.

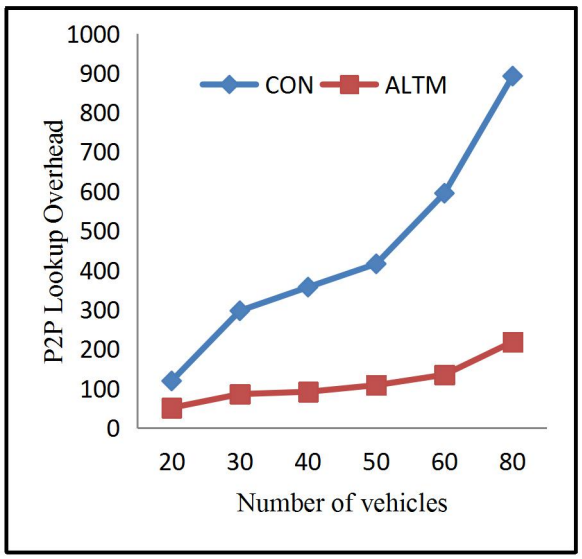

Figure 7; P2P Lookup Overhead Vs Number of vehicles.

In adaptive mechanism reachability model is used to avoid unnecessary lookup in VANET. Hence overhead in VANET is decreased. With increase in vehicle density overhead will increase because of increase in lookup queries.

In **Figure 7** P2P overhead is calculated for Conventional two-tier lookup mechanism (CON) and Adaptive lookup two-tier mechanism (ALTM). P2P overhead is also decreased because of reachability model.

5. Conclusion and Future Work

In this paper, an Adaptive lookup two-tier mechanism has been proposed. Adaptive lookup two-tier mechanism uses the concept of reachability for information retrieval. Distance based reachability concept is used in this paper to decrease lookup latency while maintaining moderate lookup success rate. Since in this mechanism, lookup success rate is decreased so for increasing it data traffic can be prioritized. Prioritized data means varying the contention period of

data according to the priority. In future concept of dynamic threshold for distance can be used. It means according to the vehicle density value of distance threshold should change.

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