Secure Data Dissemination Using Multi-Hop Cluster Based Hybrid Architecture in VANET

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Abstract: Communication methods based on VANET are generally focused on IEEE 802.11p-WAVE standards. There are two issues in such communication at high and low vehicular densities namely disconnection of networks and broadcast storm. A pure cellular technology is not feasible. Hybrid architecture with the combination of LTE and IEEE 802.11p is proposed named as VMASc-LTE is clustering based algorithm. Members of the cluster are connected to its head through direct connection using IEEE 802.11p communication standard but cluster head will communicate with eNodeB using LTE connection. The proposed system shows better performance and it is more efficient than previously proposed algorithms.

3. INTRODUCTION

Vehicular ad hoc network (VANET) is an important subclass of Mobile ad hoc Networks (MANET), where vehicles forms a network spontaneously which are equipped wirelessly while travelling along the road. Even when there is no telecommunication infrastructure, there is possibility of wireless communication that can communicate directly from vehicle-to-vehicle. According to frequency allocation made by FCC, application can be categorized as two main classifications in VANETs. The first category provides application based on safety in roads, i.e., safety applications which enhances performance and to increase service area. The second class of application provides commercial services to the users, i.e., comfort applications in which application offers commercial services, such as accessibility to internet while travelling in road and to download music inside the vehicle itself. In both the classes of application messages can be exchanged between vehicles.

In recent times, VANET had significantly shown improvement in safety applications of transport systems with timely and safety dissemination of data regarding events like traffic jams, accidents and road conditions which are generally beyond the knowledge of driver. Driver’s behavior creates unique characteristics of VANET, which depends on mobility and high speed making topology predictable and rapid with frequent fragmentation and uneven network density. Requirements of such dynamic network are packet delivery and strict delay for feasibility in such applications. Several safety applications extracted from VANET is shown in Table1 in which update rate is referred as the rate at which nodes packet generation occurs, maximum dissemination distance can be termed the distance in which message based safety application can be broadcasted and maximum delay is defined as maximum delay under tolerance for dissemination of safety message. Packet delivery ratio is the ratio of successfully received packets within the maximum disseminated distance which ranges from 90% to 100%.

Up to now, in various VANET studies the communication techniques used is based on WAVE standard i.e., IEEE 802.11p. In which, for short distance of communication approximately 300m the data rate ranges from 6Mbps to 27Mbps. For the communication over large area intelligent multi-hop broadcast is required such that, the mechanism can handle to two major issues: disconnected networks and broadcast storm. At high vehicular density, broadcast storm occurs in which as the count of the vehicles attempting to send packets simultaneously increases, the number of collisions at the MAC layer increases. This problem can be addressed by probability flooding and clustering. On the other hand, at low vehicular density, disconnected network problem occurs in which the number of nodes required proper dissemination is not sufficient. This problem can be addressed by store-carry forward, where the dissemination is performed by using vehicles in opposite lane. The solution addressing both the problems shows network delay ranging from few seconds to several minutes and the packet delivery ratio goes to lesser than 60 percent. Recently, a
In this architecture, IEEE 802.11p is used merely low latency is exploited as shown in Table I. Communication and low cost of IEEE 802.11p with architecture was proposed in which wide range architecture not that feasible. Recently, Hybrid density and high cost makes pure LTE based frequency of hand off occurrence at high vehicular less than 5ms transfer latency. Due to increase in link peak rate, 75Mbps of up-link peak rate with specification of LTE is given as 300Mbps of down.

Evolution can also be used for such application. LTE can increase the capacity and speed which can be termed as core network improvements. The LTE can increase the capacity and speed which can be termed as core network improvements. The specification of LTE is given as 300Mbps of down link peak rate, 75Mbps of up-link peak rate with less than 5ms transfer latency. Due to increase in frequency of hand off occurrence at high vehicular density and high cost makes pure LTE based architecture not that feasible. Recently, Hybrid architecture was proposed in which wide range communication and low cost of IEEE 802.11p with merely low latency is exploited as shown in Table I.

In this architecture, IEEE 802.11p is used for the communication of the cluster members with cluster head and cellular technology is used for the cluster heads communicates to base station. The main goal is to reduce the usage of cellular technology by decreasing the number of cluster heads which lowers the amount used and frequency of hand off occurrence. But for efficient clustering with minimum overheads cluster head should not be reduced. In this hybrid architecture delay is reduced without effecting multi-hop clustering mechanism by optimizing all the parameters.

In this paper, VMASc-LTE hybrid architecture is proposed, which is a combination of IEEE 802.11p based clustering in multi-hop fashion and LTE for achieving low delay with high data packet delivery ratio by using minimum cellular infrastructure via by reduction of heads of the clusters and maximizing the stability of cluster.

The original contributions of the paper by using VMASc-LTE hybrid architecture are listed as follows:

First time in the literature, Hybrid architecture using IEEE 802.11p-LTE based on Multi-hop clustering is proposed. Various feature of VMaSC-LTE hybrid architecture are head of the cluster is selected using relative mobility such as its average speed is less with respect to neighboring vehicles. Cluster connections are made using direct connection to neighbor instead of connecting to the head by multi-hops with minimum overhead. The structure of the is maintained by disseminating periodic hello packets to the cluster member information is disseminated with periodic hello packets, without excessive consumption of network resources relative clustering is used. Hop limited merging of cluster mechanism and size efficiency is maintained using the information that is exchanged by the cluster. An extensive analysis of performance is made by integrating all these features of the multi-hop cluster based hybrid architecture of IEEE 802.11p-LTE with its performance metric in wide range such as control overhead, packet delivery ratio, delay and throughput. Alternative routing mechanism is done on a realistic vehicle mobility scenario on highway which includes flooding with cluster based routing. The trade-off illustration between applications reliability with respect to delivery ratio and usage of LTE determined by the number of heads present in the network is provided.

<table>
<thead>
<tr>
<th>Service Maximum</th>
<th>Distance of Dissemination</th>
<th>Update Rate</th>
<th>Max Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety Recall Notice</td>
<td>400 meters</td>
<td>-</td>
<td>5 seconds</td>
</tr>
<tr>
<td>Approaching Emergency Vehicle Warning</td>
<td>1000 meters</td>
<td>-</td>
<td>1 second</td>
</tr>
<tr>
<td>Wrong Way Driver Warning</td>
<td>500 meters</td>
<td>10 Hertz</td>
<td>1 second</td>
</tr>
<tr>
<td>Emergency Vehicle Signal Preemption</td>
<td>1000 meters</td>
<td>1 Hertz</td>
<td>1 second</td>
</tr>
<tr>
<td>Vehicle Diagnostics and Maintenance</td>
<td>500 meters</td>
<td>10 Hertz</td>
<td>5 seconds</td>
</tr>
</tbody>
</table>

**TABLE I: Requirements on VANET Safety Application**

1. **SYSTEM MODEL**

The envisioned hybrid architecture based on LTE and IEEE 802.11p is shown in Figure 3. A multi hop clustered network topology is formed using vehicles. Cluster member (CM) are the vehicles under the range of transmission with respect to head of the cluster (CH), transmission range is denoted by R and is shown dotted line surrounding CH in the figure. This dotted line in the figure denotes direct communication between CH and CM. The vehicles or nodes which are away from CH in terms of multi-hop becomes multi-hop CM and in such conditions packets are transferred to
CM in order to connect to corresponding CH. Information regarding vehicles and its neighboring vehicle in the range of predetermined maximum hop denoted by MAX_HOP is stored in terms of vehicular information base (VIB). Members and cluster heads are generally determined by using VIB. There are two types of communication: IEEE 802.11p and LTE. Members will communicate with its cluster only through IEEE 802.11p whereas, head of the cluster will communicates with its CM using IEEE 802.11p and CH can communicates with eNodeB using LTE. For broadcasting the generated data within VANET, LTE infrastructure is used using radio access network (RAN) within a geographical area. Evolved Packet Core (EPC) consists of Packet Data Network Gateways (PGW) and server gateway (SGW), eNodeB is basically a base station which is complex such that it can handle radio communication with many devices and carries out decisions regarding handover and radio resource management. PGW is responsible for quality of service, setting transfer paths of vehicle data packets, authentication and control whereas SGW provides functionality of forwarding and routing of data packets to neighboring eNodeBs. EPC which as global information regarding locations of eNodeBs are connected to eNodeBs by wired networks. Cluster head (CH) sends data packets to eNodeB via radio network. The EPC determines eNodeBS present within the geographic safety broadcasting region and sends the packets to then, these packets are in turn multicasted to all the heads under the coverage region of eNodeB.

![Figure 1: Hybrid architecture of IEEE 802.11p-LTE.](image)

### 3. EXISTING SYSTEM:

Several VANET Network studies were targeted on IEEE 802.11p based communication methods, which forms Wireless communication Access for Vehicular Environment (WAVE) standard. But broadcasting storm and disconnected networks were the problems encountered in WAVE communication, which were degrading system by effecting on delivery ratio and delay. Recently as an alternative cellular technology was used but purely cellular technology are not feasible due to very less latency and communication in wide range. Considering high mobility in vehicles, the number of hand off occurrence at base station is high and the costs for communication between vehicles were also high.

### EXISTING SYSTEM DISADVANTAGE:

1. Occurrence of problems based on network at low and high vehicle densities.
2. Dissemination of messages was with delay and low delivery ratio.
3. Latency and wide range communication.
4. Such communication is not that feasible because of high cost communication.
5. Considering high mobility of the vehicles, the frequency of number of hand off occurrence at base station is more.

### 4. PROPOSED SYSTEM:

The goal of proposed hybrid architecture based on LTE and IEEE 802.11 is to broadcast the data generated to all the vehicles in network with small delay and high packet delivery ratio. In this architecture LTE is used to provide connectivity in between the nodes even when IEEE802.11p based network is disconnected.
DESIGN OF PROPOSED SYSTEM

The data flow of the design is given:
1) Unicast to CH from its CM.
2) CH Broadcasts to eNodeB and to its CMs.
3) Unicast to EPC from eNodeB.
4) Multicast to the neighboring eNodeBs from EPC covering a part of the geographical area targeted for the dissemination of the DATA_PACKET.
5) Multicast to the CHs under the coverage area from eNodeBs.
6) Broadcast to all its CMs from CH.

PROPOSED SYSTEM ADVANTAGE:
1. High ratio packet delivery is achieved with low delay by maintaining the implementation of the cellular technology at minimum level.
2. Vehicular Multi-hop algorithm for Stable Clustering.
3. Number of cluster heads is reduced while increasing their stability.
4. Cluster connection are made with less overhead by introducing direct connectivity to its neighbor that is already a head or member of a cluster instead of connecting to the cluster head in multiple hop fashion.

5. VMASc:

The features of VMASc multi-hop cluster based algorithm are as follows:

1. Selection of head of the cluster is stable, cluster heads are selected by using relative mobility metric such as average relative speed.
2. By providing connection directly to the neighbor which can be a CM or CH in multi-hop and by disseminating periodically through hello packets, cluster connection with minimum overhead can be achieved.

3. Reactive clustering is implemented to balance the cluster structure without overhead in excessive range through packet transmission.
4. By minimizing the overlap of clusters, minimum inter-cluster interference can be achieved.
5. Cluster merging mechanism helps to efficiently maintain the cluster size.

State transition diagram of VMASc algorithm is given by:

![State transition diagram of VMASc algorithm](image)

Vehicle states

At any given time, each and every vehicle will be any of the following states:

- INITIAL(IN) is the beginning condition of the vehicle
- STATE ELECTION (SE) transition to the next state is decided by a vehicle in this state based on VIB information.
- CLUSTER HEAD (CH), cluster head of cluster is declared to a vehicle in this state.
- ISOLATED CLUSTER HEAD (ISO-CH), when a vehicle cannot connect to any existing clusters then this state makes a transition denoting that this vehicle cannot connect to its neighbor.
- CLUSTER MEMBER (CM) is the state showing that the vehicle is attached to the existing system.
VIB Generation and Update

The information of the vehicle in neighborhood and vehicle itself within MAX_HOP hops are stored in VIB. VIB is updated in terms of vehicle’s information or by receiving HELLO_PACKET periodically from any of its nearby vehicle within MAX_HOP hops. Vehicular information such as its velocity, its direction, the hops to reach the cluster head if it is a cluster member, its clustering state and the vehicles ID are included in the HELLO_PACKET. HELLO_PACKET can be retransmitted to the nearby vehicle within MAX_HOP hops. If the VIB is not updated for certain time period then VIB is deleted.

AVGREL_SPEED_i clustering metric for vehicle I is calculated as

\[
AVGREL\_SPEED_i = \frac{\sum_{j=1}^{N(i)} |S_i - S_j|}{N(i)}
\]

Where, N(i) is number of neighbors in same direction within MAX_HOP hops for vehicle i, ij is the ID of the j-th neighboring vehicle of vehicle i, Si is the vehicle i’s speed. The mobility of the vehicle compared to its neighbor depends on average relative speed lower the average relative speed.

Cluster State Transitions

Figure 3 illustrates all possible transition states of the vehicle/node. The vehicle begins in IN state and stays in the same state for a IN TIMER period of time. HELLO_PACKETs are exchanged periodically in this state by using its own VIB information. As discussed in the algorithm, the vehicle varies its state to SE in order to decide its next state. If the JOIN_RESP is received by the vehicle then the vehicle makes transition from SE state to CM state which shows that the join request is successful. If CH_CONDITION is satisfied then vehicles changes its state from SE state to CH state. In such condition vehicle cannot be connected to their neighboring CM or CH. There will be at a time a vehicle which is in SE state, the vehicle which is in SE state with relatively minimum speed with respect to its vehicles that are its neighbor will have a transition to ISO-CH state. ISO-CH state indicates that the vehicle cannot communicate to any neighboring vehicles. If the vehicle with CH state has no neighbor vehicles or members, then the vehicle moves makes transition from CH state to SE state. When vehicle with CH state has MEMBER_CH is null for the duration of CH_TIMER. Then the vehicle with CH state changes to SE state. When the vehicle is in ISO_CH state and if a member gets connected to that vehicle after ISO_CH_TIMER then the vehicle varies its state to CH. When a vehicle is either in CH or CM state and if it does not exist in VIB then the vehicle moves to SE_BACK state which stays in same condition for a SE_TIMER duration. The vehicle makes transition from CH to CM if it get MERGE_RESP from another CH. When vehicle changes its transition from CM to SE if it loses its connection from PARENT cluster obtained for VIB and if its connectivity is lost for CM_TIMER duration then vehicle assumes that its connectivity is lost.

Cluster Formation

A vehicle in SE state tries to communicate to a cluster which is exists with an intension to reduce the number of cluster head. Generally the preference is given to neighboring CH than neighboring CM in order to decrease the delay and to perform smaller number of hops.

To increase relative mobility vehicles first scans neighboring CH. Even if the CH count is more, the vehicle still tries to connect to CH using TRY_CONNECT by sending JOIN_REQ packet if JOIN_RESP packet is received within JOIN_TIMER period then the vehicle changes from SE state to CM state.

If the vehicle does not have any neighboring vehicle in CH state then the vehicle tries to connect through the CH using multiple hops. CMs are also scanned based on relative mobility similar to that of CH. If there is no vehicle while scanning then the vehicle changes its state to ISO_CH state.

Inter-cluster Interference

When a cluster gets overlapped a interference called as space inter-cluster interference occurs. Such interference leads to inefficient flooding and high medium contention.

This overlapping is reduced by two methods in VMASc:

1. The vehicle which is in SE state joins any cluster that is present before declaring itself as ISO-CH or CH.
2. By considering feasibility, CH merges their clusters eith the clusters that are in the transmission range.

6. VMASc Algorithm

Algorithm 1: State election algorithm is given by:
1. for all the CH belonging to V IB do
   2. if TRY_CONNECTCH is false then
   3. if MEMBERCH < MAXMEMBER_CH then
      4. JOIN_REQ is sent;
      5. if JOIN_RESP received then
         6. Vstate = CM;
         7. Exit;
   8. Else
      9. TRY_CONNECTCH will be true;
   10. For all the CM belonging to V IB do
      11. if TRY_CONNECTCM is false then
          12. if MEMBERCM < MAXMEMBER_CM then
              13. if HOPCM < MAX_HOP then
                  14. Send JOIN_REQ;
                  15. if JOIN_RESP received then
                      16. Vstate = CM;
                      17. Exit;
          18. Else
              19. TRY_CONNECTCM = true;
          20. if Not exists SE 2 V IB then
              21. Vstate = ISO-CH;
              22. Exit
          23. else if AVGREL_SPEEDcurr = minSE2V IB(AVGREL_SPEEDSE) then
              24. Vstate = CH;
              25. Broadcast CH_ADV;
              26. Exit;

Algorithm 2: Algorithm for IEEE 802.11p-LTE Cluster member

7. Simulation results

Algorithm 3: Algorithm for IEEE 802.11p-LTE Cluster head

1. On DATA_PACKET generation or receipt:
   2. Extract IDDATA and SEQDATA;
   3. if (IDDATA; SEQDATA) belongs to V IB then
      4. if DATA_PACKET is from PARENTcurr then
         5. Multicast DATA_PACKET to CHILDRENcurr;
         6. Else
         7. Unicast DATA_PACKET to PARENTcurr;
         8. Update V IB;
   9. On DATA_PACKET generation or receipt:
      2. Extract IDDATA and SEQDATA;
      3. if (IDDATA; SEQDATA) belongs to V IB then
         4. if DATA_PACKET is from eNodeB then
            5. Broadcast DATA_PACKET into cluster;
            6. Else
               7. Broadcast DATA_PACKET into cluster;
               8. Put data in LTE_DATA_PACKET and forward it to eNodeB;
               9. V IB is updated;

Figure 4: Comparison graphs of Control overhead
Figure 5: Comparison graphs of Bit Error Rate
Bit error rate is more in existing as compared to proposed.

Figure 6: Comparison graphs of Throughput
Throughput is more in proposed as compared to existing system.

Figure 7: Comparison graphs of Packet Delivery Ratio
Packet delivery ratio is more in proposed as compared to existing system.
8. CONCLUSION

In this paper a novel architecture which combines 3GPP/LTE with IEEE 802.11p named as VMASc-LTE is proposed in VANET networks. VMASc-LTE is a cluster based algorithm featuring cluster head and cluster member to form a cluster. Here a vehicle is selected as cluster head using relative mobility. Vehicle with less relative mobility is declared as cluster head. Cluster connections are made with minimum overhead and the structure of cluster is also maintained. Cluster merging mechanism is introduced to reduce the number of cluster member. Cluster merging is performed such that the trade-off between cost and cluster structure is balanced.

An extensive analysis based on the performance of the hybrid architecture with a wide range of performance metrics was performed. The trade-off between the packet delivery ratio based reliability for the application measured and the cost of the LTE usage determined by the number of heads of the in the network is illustrated.

9. Future Work

As future work, we aim to make use of this hybrid architecture in urban traffic conditions with an extension of this architecture with data collection can be implemented and calculation of the clustering metric with additional data such as the most possible route information of the vehicles.

10. REFERENCES