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An Efficient Clustering Scheme for Vehicular Ad Hoc Networks

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***Abstract*:** *Several medium access control protocols have been proposed in the recent past in vehicles for accessing radio channels and for distributing timely safety messages for inter-vehicle communication in Vehicular Ad hoc Networks (VANETs). As contention period for channel access is high in Medium Access Control (MAC), MAC is unable to distribute timely safety messages. To reduce the contention, Region based Clustering Mechanism (RCM), which caters to the reduction of contention by limiting the number of vehicles for each cluster, is applied with MAC protocols. RCM also resolves the competition among vehicles to access radio channels for inter-vehicle communication. Ad Hoc On-Demand Distance Vector (AODV) routing protocol is used for providing shortest path between source and destination so as to increase the amount of packet reception with less energy than the existing method.*

***Keywords*:** Ad Hoc On-Demand Distance Vector (AODV), Medium Access Control (MAC), Safety-Critical Application (SCA), Region based Clustering Mechanism (RCM), Vehicular Ad-hoc Network (VANET).

I. INTRODUCTION

Vehicular Ad Hoc Network (VANET) consists of wireless routers or wireless nodes. Normally, the transmission range of VANET is 100 to 300 meters range. Inter-vehicle communication takes place with ad-hoc networks. Information such as speed and position of each vehicle is known by other vehicles.

VANET is an important mode of inter-vehicle communication for Intelligent Transportation Systems (ITS) [1], [2]. In such a network, each vehicle is equipped with a wireless communication and an on-board GPS device. Data forwarding is then performed collaboratively among vehicles in a multihop relaying manner. One of the most important applications for VANET is the distribution of active safety messages to improve driver safety, namely Safety-Critical Application (SCA) that requires timely and reliable message dissemination. Information about SCA is exchanged so as to notify the drivers about the car accident and to perform control actions in coordinated systems [3]. Other applications are also permitted for shortening the deployment cost of VANET and for speeding up its adoption period. Medium Access Control (MAC) protocols of VANET resolve contentions among vehicles for channel access. The dominant standard for vehicular networks is IEEE 802.11p based Dedicated Short Range Communications (DSRC) [4], [5]. Its random access mechanism is based on IEEE 802.11 Distributed Coordination Function (DCF) relying on the Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) mechanism. Other important MAC protocols include ADHOC, MAC [6], [7] that are designed for an European project. These protocols depend upon a Time Division Multiple Access (TDMA) based protocol called Reliable R-ALOHA (RR-ALOHA) for radio access control; Space Division Multiple Access (SDMA) [8], [9] wherein the geographical area is divided into multiple space division units and one radio channel is dedicated to serve the vehicle in a space division unit. Important issues related to MAC for VANET include mobility (i.e., the MAC protocol should support vehicles to leave and join inter-vehicle communications at high speed), delay bounded (i.e., the communication must be delay bounded and real-time), scalability (i.e., VANET should scale itself according to the number of vehicles present), bandwidth efficiency (i.e., the radio resource should be utilized in an efficient and fair manner), cost (i.e., for cost-efficient and reliable communications, VANET should be fully decentralized), and fairness (i.e., every vehicle should get a fair chance to get the radio channel). The challenge of successfully deploying VANET services lies in ensuring timely and reliable data delivery for mobile vehicles.

The MAC protocols for radio channel access among vehicles are effective under light traffic load. However, when the number of vehicles in the vicinity is large, the protocols may not be able to ensure the desired service due to lack of radio resource (e.g., more contentions among vehicles for random access based protocols like CSMA/CA, and less chance to be allocated a time slot for TDMA based protocols like RRALOHA) and cause a longer contention period to obtain radio resource. Fig. 1 shows the Vehicular Ad Hoc Network.

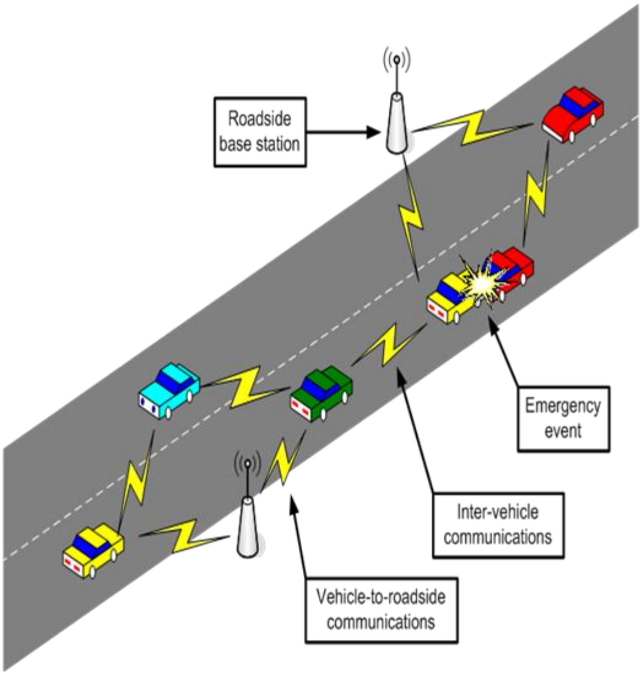

Fig. 1Vehicular Ad-hoc Network

In the literature, several methods (e.g., [10], [11], [12]) have been proposed to reduce the contention period. DUCHA [10] utilizes dual-channel to separate control packets and data packets. Request To Send (RTS) and Clear To Send (CTS) are transmitted on a separate control channel to avoid the collisions with data packets. Fast Collision Resolution (FCR) algorithm [11] redistributes the back off counters to speed up the collision resolution. The FCR algorithm uses a smaller contention window for each station with successful packet transmission and reduces the back off counter exponentially when a station detects a number of consecutive idle slots. MAC-SCC [12] schedules data transmissions to reduce the back off time. The control channel is used to schedule data transmissions by using two different Network Allocation Vectors (NAVs) for the data channel and the control channel, respectively.

Region-based Clustering Mechanism (RCM) is used to improve the performance of MAC operations for VANET [13]. In RCM, the service area is divided into a set of region units and the number of vehicles is limited in each region unit for the contention of radio channels. Each region unit is then associated with a non-overlapping radio channel pool. Since the number of vehicles in each region unit is limited, the contention period is reduced and the throughput is increased. Note that this proposed idea can be applied on top of existing methods (e.g., [10], [11], [12] to improve the contention period performance of MAC protocols for VAENT). RCM is formed with the limited number of vehicles in [13]. In RCM, there is no central controller for channel access. The contention resolution is required to obtain a channel. DSRC(Dedicated Short Range Communication) protocol is used in the existing method which produces the reduced packet transfer and throughput. In the proposed system, Ad- Hoc On-Demand Distance Vector (AODV) protocol is used to maintain shortest path between vehicles.

II. PROPOSED SYSTEM

Fig. 2 shows the block diagram of the proposed system. In the proposed system, mobile nodes are self-configured into an integrated network with distributed control. The connection between nodes in the network is in such a way that it has peer-to-peer communication links. NS-2 tool is used for network creation. Wireless channel is used with Omni antenna. The topological dimension and number of nodes are set according to the requirements.

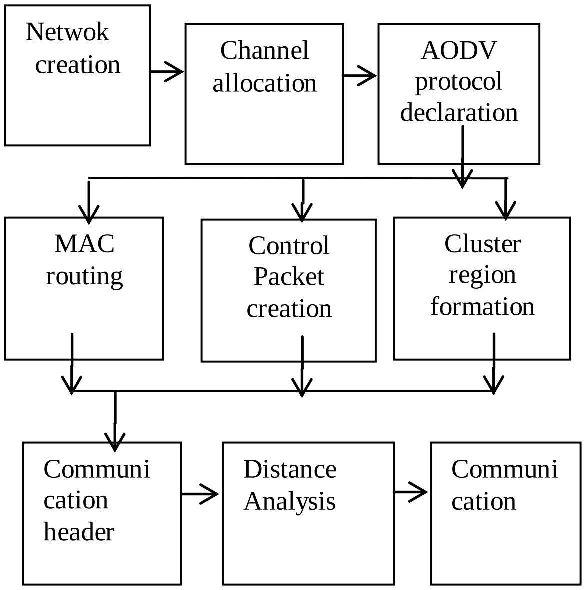

Fig. 2 Block diagram of the proposed system

Network is created with the mobile nodes. Total area is divided into clusters. Then, channel is allocated for each cluster without any overlap for avoiding congestion. AODV protocol is used for selecting the shortest path between source and destination as it does not need any central administrative system to control the routing process. Source node and the intermediate nodes store the next-hop information corresponding to each flow for data packet transmission.

Source nodes and destination nodes are connected with each other through the use of Transmission Control Protocol (TCP) or User Datagram Protocol (UDP). Clustering is formed with a limited number of mobile nodes so as to reduce the contention period spent for channel access. All the nodes of the region are grouped together into various clusters based on the vicinity of vehicles. These vehicles inter-communicate through ad hoc. Cluster head is otherwise known as a sink node because it maintains information about all the vehicles of a cluster. Each vehicle in a cluster moves with different speed and a particular distance is maintained among vehicles. Communication takes place from source to destination through the cluster head. When a cluster head fails, the other highest priority mobile node acts as the cluster head. When a mobile node (vehicle) moves from one cluster to another cluster, radio channel of current cluster with low latency is accessed.

A. Protocol Description

In [13], the R-ALOHA-based protocol is used as an example to show the ways to achieve contention resolution in RCM whereas in proposed system AODV protocol is used for achieving the shortest path among vehicles. Fig. 3 shows the AODV Protocol operation.

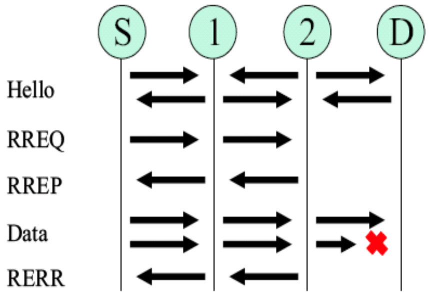

Fig. 3 AODV Protocol operation

AODV routing protocol is designed for use in ad-hoc mobile networks. AODV is a reactive protocol: the routes are created only when it is necessary. It uses traditional routing tables, one entry per destination, and sequence numbers to determine whether routing information is up-to-date and to prevent routing loops.

An important feature of AODV is the maintenance of time-based states in each node: a routing entry not recently used is expired. In case of a route that gets broken, the neighbours can be notified of any unnecessary happening. Route discovery is based on query and reply cycles. The route information is stored in all intermediate nodes along the route in the form of route table entries. The following control packets are used: Routing Request (RREQ) message is broadcasted by a node requiring a route to another node, Routing Reply (RREP) message is unicast back to the source of RREQ and Route Error (RERR) message is sent to notify other nodes of the loss of the link. HELLO messages are used for detecting and monitoring links to neighbours.

Routing protocols in mobile networks are subdivided into two basic classes:

• proactive routing protocols and
• reactive routing protocols

The proactive routing protocols (e.g. OLSR) are table-driven. They usually use link-state routing algorithms for flooding the link information. Link-state algorithms maintain a full or partial copy of the network topology and costs for all known links. The reactive routing protocols (e.g. AODV) create and maintain routes only on demand. They usually use distance-vector routing algorithms that keep information only about next hops to adjacent neighbours and costs for paths to all known destinations. Thus, link-state routing algorithms are more reliable, less bandwidth-intensive, but also more complex and compute- and memory-intensive.

In on-demand routing protocols, a fundamental requirement for connectivity is discovering routes to a node via flooding of request messages.

The AODV routing protocol does not need any central administrative system to control the routing process. AODV, a reactive protocol, tends to reduce the control traffic messages overhead at the cost of increased latency in finding new routes.

AODV reacts relatively fast to the topological changes in the network and updates only the nodes affected by these changes. The HELLO messages supporting the routes maintenance are range-limited for preventing unnecessary traffic overhead in the network. The AODV routing protocol saves storage place as well as energy. The destination node replies only once to the first request and ignores the rest.

The routing table maintains at most one entry per destination. When a node has to choose between two routes, the up-to-date route with a greater destination sequence number is always chosen. If a routing table entry is not used recently, the entry gets expired. When a not- valid route is deleted, the error packets reach all nodes through a failed link on its route to any destination which supports both unicasting and multicasting.

B. Algorithm

Step 1: The total area size 3500*3500 is set
Step 2: Mobile nodes are created
set n [$ns node]
$cbr_($index) set random_ 1
Step 3: The total area is divided into clusters to reduce the contention among mobile nodes
Step 4: cluster is assigned with a limited number of vehicles
Step 5: Each vehicle in each cluster is assigned with different channels
Set val(chan)
set ef($i) [expr (0.2 * $dist($i)) + ($velocity($i) * 0.2) + ($frequency($i) * 0.6)]
Step 6: The long life node in each cluster acts as the Cluster Head (CH)
$ns at 5.0 "$n label CH"
Step 7: Through the cluster head, the mobile nodes communicate with each other
Step 8: AODV protocol used for selecting the shortest path between the mobile nodes.

III. NETWORK SIMULATION

Simulation is done using ns-2.33 Software. Table 1 shows the simulation parameters. The transmission range is 250 meters. Here, the simulation time is 200 seconds. AODV protocol is used for the simulation.

Table 1 Simulation Parameters

Parameter	Value
Examined protocol	AODV
Traffic type	Constant bit rate(TCP)
Transmission range	250 m
Packet size	512 bytes
Data rate	1Mbps
Simulation time	200sec
Antenna type	Omni directional Antenna
Area	3500 m * 3500 m
Number of nodes	93

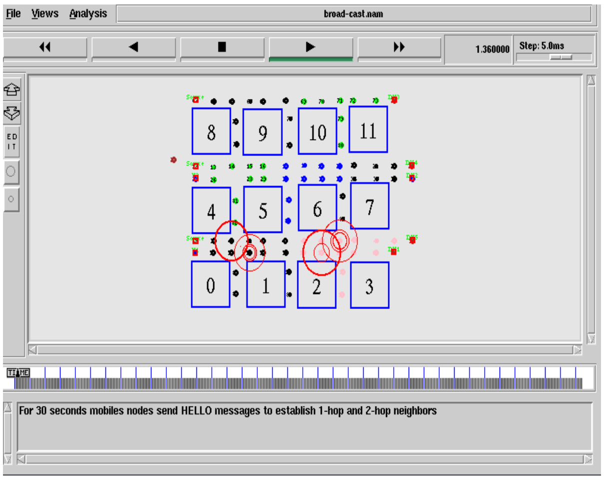

Fig. 4 Cluster formation

In Fig. 4, 93 mobile nodes are created. In this output, seven clusters are formed. When the node 27 leaves the region, the information (position) about this node is retained by node 28 which is the cluster head and this cluster head, in turn, multicast the information about node 27 to all the nodes (12, 13, 14, 15, 16, 25, 26, 29) of that cluster. The square box represents the building. The gap between the square box is the road way.

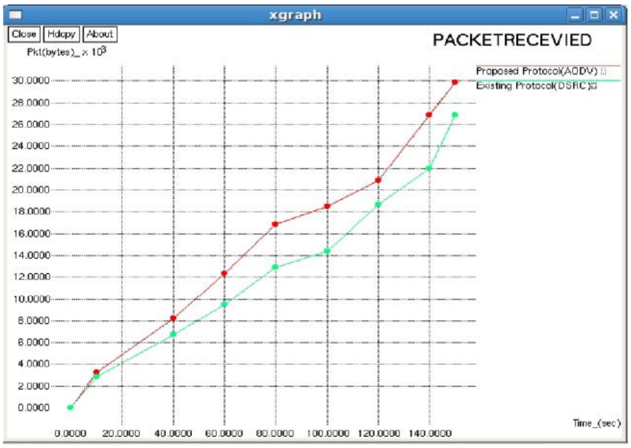

Fig. 5 Packet Reception

Fig.5 shows the simulated graph between time (in sec) and packet reception. In the AODV, the packet reception is high than the existing DSRC. The amount of packet reception gets increased with the increase in time.

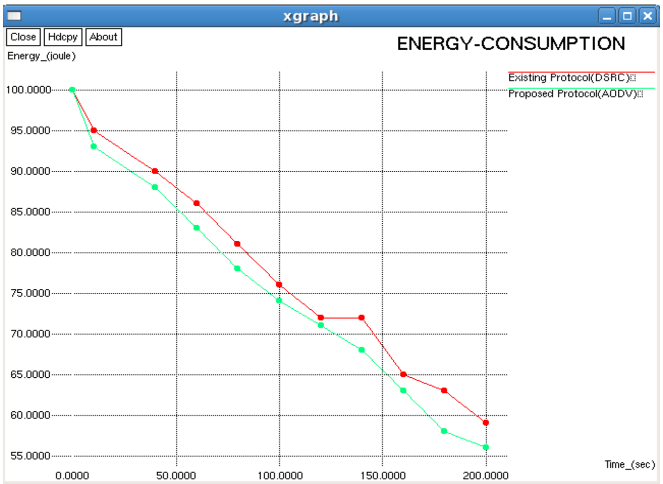

Fig. 6 Energy Consumption

Fig.6 shows the simulated graph between time (in sec) and energy consumption. The energy required for proposed AODV protocol is less compared to the existing method.

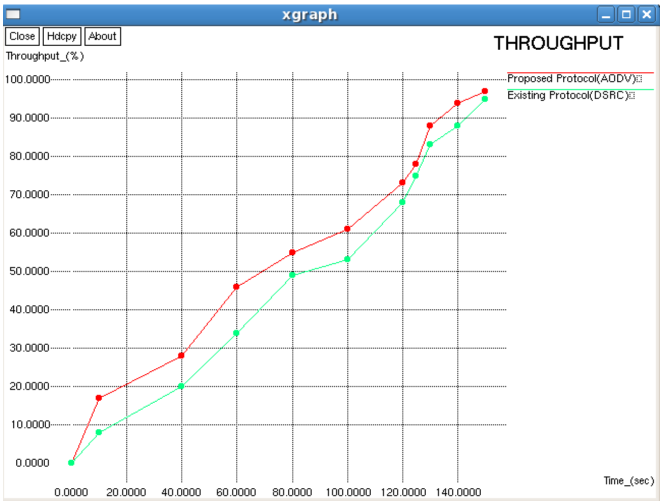

Fig. 7 Throughput

Fig. 7 shows the simulated graph between time (in sec) and throughput. In the proposed method, the throughput is increased more through the use of AODV protocol than the existing DSRC method. Table 2 shows the simulation results.

Table 2 Simulation Results

Time (in sec)	Parameters	Existing	Proposed(AODV)
140	Packet reception in bytes	21987	26882
150	Throughput	95%	97%

At the time of 140 (in sec), the packet reception for the proposed system is 21987 bytes and the packet reception of the existing method is 26882 bytes for the same time limit.

At the time of 150 (in sec), the throughput for the proposed method is 97% which is high by 2% than the existing method.

IV. CONCLUSION

Thus, the contention problem in VANET is solved by using region based global clustering mechanism. The long-life node of a cluster acts as the cluster head which maintains information all the nodes of that cluster. Source and destination nodes communicate with each other through cluster heads. AODV protocol facilitates the selection of the shortest path from source to destination by taking into account the minimum number of hop count and it increases packet reception and throughput.

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