REDEFINING ROUTE MAINTENANCE FOR VANETS THROUGH LOGICAL ROUTE UPDATE

MCS

By

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ABSTRACT

Vehicular Ad hoc Network (VANETs) is an emerging network environment that aims to improve the road safety and at the same time provide various services on fly. It is a special case of Mobile Ad hoc Networks (MANETs) having distinguishing characteristics like relatively high speed and variable node density. The routing protocols for such versatile networks must establish optimized route(s) and maintains them in an efficient manner. The two types of routing protocols, which are proactive and reactive respectively, may be used in such scenario. However, we are working on reactive protocols because of lesser standing overheads and lesser traffic generation for maintenance.

The mobile scenario effects the routing in terms of frequent breakage of paths. In such a scenario, route error and maintenance will be frequently triggered. The route breaks because of the increased distance between the nodes or because of the non availability of receiver.

In this thesis, we propose a preemptive approach for route maintenance in which it triggers before the actual route breaks. Based on the distance of a node from its next hop node and the density of nodes around it, route maintenance would be triggered before the breakage of route(s). A large distance amongst two nodes corresponds to weak signal strength and vice versa. A relative increase in routing overheads would help in enhancing the performance of the network in terms of throughput and increased connectivity time.

Hence, the research work focuses on discovering new routes before the breakage of the old routes. The likelihood of obtaining the same route would remain there.

DEDICATION

All praises and thanks to the Almighty Allah, who is the most gracious and the most merciful, who is the Master of the Day of Judgment.

This work is dedicated to my family, thesis supervisor and the guidance committee for their continuous and steadfast support and guidance.

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LIST OF ABBREVIATIONS

AG	Aggregation
AODV	Ad hoc on Demand Distance Vector
AODV-ND	Ad hoc on Demand Distance Vector-Neighbors Distance
ARIB	Association of Radio Industries and Businesses
ASTM	American Society for Testing and Materials
ASK	Amplitude Shift Keying
BA	Block Acknowledgement
CALM	Communications Air-Interface for Long and Medium range
CEN	European Committee for Standardization
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
DCF	Distributed Coordination Function
D-MAC	Directional MAC
DSRC	Dedicated Short Range Communication
EDCA	Enhanced Distributed Channel Access
ITS	Intelligent Transportation System
MAC	Medium Access Control
MANETs	Mobile Ad hoc Networks
ND	Neighbor Distance
OBU	On-Board Unit
OFDM	Orthogonal Frequency Division Multiplexing
OLG	Online Gaming
PSK	Phase Shift Keying
QoS	Quality of Service IP: Internet Protocol
RD	Reverse Direction
RSU	Road Side Unit
SDOS	Self Denial of Service
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
VANETs	Vehicular Ad hoc Networks
VoD	Video on Demand
WAVE	Wireless Access in Vehicular Environment
VoIP	Voice over Internet Protocol

Chapter 1

Introduction

1.1 Overview

VANET (Vehicular Ad hoc Network) is a contemporary and challenging domain in the field of wireless networks. It deals with communications between mobile vehicles and fixed units. Within VANET, there is a concept of three communication modes i.e. V2V (vehicle-to-vehicle), V2I (vehicle-to-infrastructure i.e. roadside units) and I2I (infrastructure-to-infrastructure) as shown in Figure 1.1.

It primarily relates to driver safety applications but also focuses on traffic management and non-safety applications. It is subset of Mobile Ad hoc Network (MANET) [1]. Inter-Vehicular communication has recently become a hot topic for research in field of networking and has opened new challenges in research that exceed those of classical mobile Ad hoc network research.

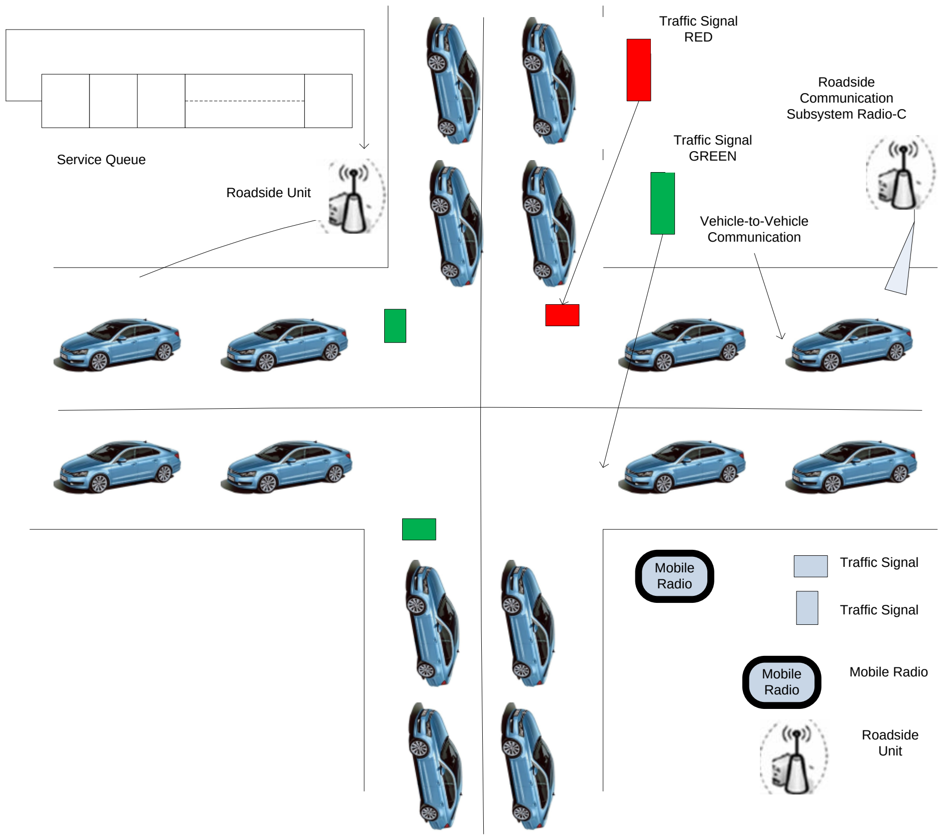

Figure 1.1 Vehicular Ad hoc Networks

VANET differs from MANET in various aspects like direction predictability and the fast vehicular movement. The high mobility and high density of nodes in Vehicular Ad hoc networks (VANETs) result in highly dynamic networks. Quick and reliable information delivery therefore becomes eminent in VANETs. Routing protocols that can provide longer connectivity between source and destination are required. However, with frequent movement of nodes it is difficult to achieve this goal.

1.2 Problem Statement

Mobility in Ad hoc networks is becoming the core research area for many future network applications. How to find best possible route between source and destination is being researched since the emergence of computer networks. However, in mobile networks influence of high speed may lead to sudden topological changes. Mobility severely hampers the performance of routing protocols as routes are frequently broken.

1.3 Objectives

The research work focuses mainly on initializing route maintenance routine in different routing protocols [7]. In this regard reactive mechanism is selected. The reason for not selecting proactive protocols is that they are inefficient for rapidly changing network scenarios like VANETs [11].

It is pertinent to mention here that the proposed approach could be made applicable on Ad hoc Networks routing protocol. The decision of initializing the discovery process for new route would be made prior to route break without exerting extra overheads. Same is classically done on route breakage in reactive protocols [18]. The study would also assist in detecting Malicious and Abnormal activities within the network.

After detailed study of working principle and limitations of routing protocols, the research work is focused to achieve one objective only. Propose a scheme for triggering route maintenance in reactive routing protocols. The aim is to devise a scheme that could preemptively trigger the route maintenance in routing protocols. This is required because, once a link is broken, time is wasted to acquire the new route. In order to achieve this, a parameter which may not burden the routing overheads would be searched.

1.4 Achieved Goals

The contribution of this research lies in identification and assessment of methodology for MANETs routing protocols for their viability in VANETs. Following goals are achieved at the end of this research:-

a. New preemptive route maintenance methodology in which new routes would be discovered before the breakage of old routes in mobile Ad hoc networks.

b. Using distance between devices and neighbor density for evoking route maintenance mechanism with minimal additional routing overheads.

c. Performance evaluation of the selected protocol with preemptive route maintenance methodology in terms of Throughput, End-End Connectivity Time and Packet Delivery Ratio.

1.5 Relevance to National Needs

As already discussed that lots of research is underway on VANETs however a lot more may still be required for its secure implementation. Thus our work would not only focus on optimizing the functionality of routing protocols but also pave way for defining the security framework for VANETs. In long run this would be benefiting the implementation of such networks at large scale. At national level, the importance of this research may be huge in future. This is so because in under developing countries like Pakistan where resources for expansion of basic infrastructure are very limited, induction of this technology would result in preservation of both valuable time and money. Application of this research could be an assistance to emergency services like fire brigade, ambulance, police etc. in avoiding rush areas and, in tracing multiple routes and exact location of the place of incident. This application could bring an overall improvement in the safety of motor vehicles and pedestrians on road [4].

1.6 Area of Application

The implementation of VANETs requires lot of research in achieving robustness in existing routing protocols. Its applications could include availability of various services on mobile nodes either through other nodes or through some fixed roadside units. Besides road safety related services, the vehicles becoming part of this mobile network would get services like internet, guiding information etc. Vehicles like police vans etc. could also get private information like engine number, chassis number, particulars of owner etc. of vehicles joining the network. Moreover, vehicular nodes could have real time knowledge of traffic density on lanes which is especially required for emergency services [11].

1.7 Previous Work Done on the Subject

Route Discovery schemes have been frequently proposed for reactive protocols in Ad hoc and highly mobile Ad hoc network scenarios [2, 6]. However, route maintenance schemes have not been studied at a large scale. Though cross layer architectures have also been proposed however they remained application specific. They were only useful in certain scenarios and thus do not provide a generic solution [11]. Route discovery has been the key point of research and a number of strategies have been proposed for Adhoc as well as mobile Adhoc networks. In recent times the research has been focused on cross layered architecture for route discovery which pertains to certain applications [24]. However, route maintenance has remained a less research topic on the network layer i.e. how preemptive route maintenance would be conducted [11, 24].

1.8 Organization of Thesis

This thesis report is organized in six chapters. Chapter-1 presents the introduction and preamble to the subject. Chapter-2 presents the basic structures and concepts of MANETs and VANETs. Furthermore, the routing protocols available for the MANETs are also discussed here. Route Maintenance of routing protocols is also discussed here. Chapter-3 presents the architecture of reactive routing in Ad hoc Networks. Furthermore, advantages and disadvantages of reactive routing are also discussed here. This chapter also comprises of detail study of working principle, features and drawbacks of under deliberation AODV (Ad hoc On-Demand Distance Vector) routing protocol. In addition to this, the targeted weakness of AODV is also discussed in this chapter. Chapter-4 presents the Neighbor Distance (ND) based proposed technique to overcome the identified problem. The proposed Route Maintenance strategy is discussed here with the help of a flow chart. Chapter-5 presents the simulations and results for the proposed methodology. In addition, comparative analysis of proposed technique with original protocol is discussed here. The analysis has been carried out for better understanding of the proposed technique and for making suitable recommendations for future works. Chapter-6 presents the concluding remarks which are followed by achievements and recommendations of future research avenues.

Chapter 2

Literature Review

Despite numerous routing protocols having been developed in MANETs, a large number of those are incompatible with VANETs. VANETs can be considered a very challenging class of MANETs. They are geographically spread and highly mobile rapidly changing communication networks created by mobile nodes. They are therefore characterized by dynamic nodes with constrained level of freedom in their mobility patterns [5, 6].

2.1 Route Maintenance of Routing protocols in VANET

One of the important issues for VANET is route maintenance. Broadcast communications are carried out by Safety applications. However, when we discuss unicast communications, it is clear that robust routing protocols are required in VANET. A protocol should be able to perform route maintenance in the best possible manner without exerting overheads. Therefore, strategies are required which can build new route when old route break or about to be broken [12].

Various studies have been carried out by researchers to address the core issue of frequent route breaks in mobile Adhoc networks. In this regard various ideas of link breakage prediction have also been presented [30]. In link breakage prediction technique, an alarm is raised if there is a possible link breakage in near future. This is done by constantly accessing the availability of the link. On the basis of this alarm the route maintenance is carried out before route breaks. This study has used number of nodes per route, node mobility speed and node transmission range as parameters for predicting link breakage. The methodology was implemented on a reactive protocol Dynamic Source Route (DSR). Packet Delivery Ratio (PDR) and Average End-to-End Delay were monitored at different speeds for DSR and its modified version.

The results depicted in Figure 2.1 and Figure 2.2 clearly shows that DSR modified outperforms DSR original.

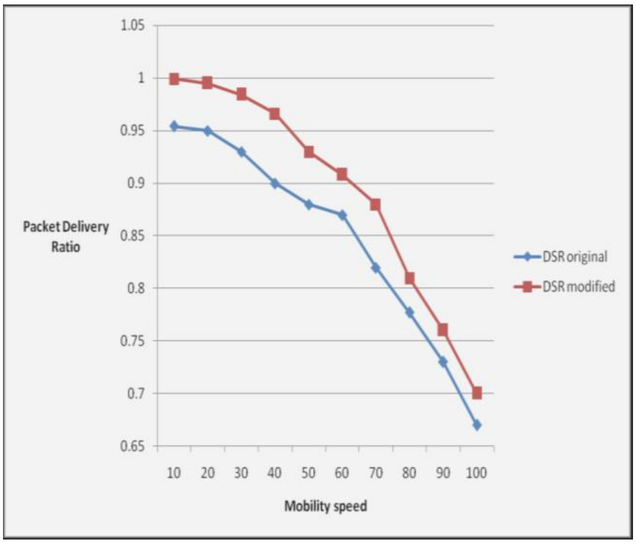

Figure 2.1 PDR with Mobility

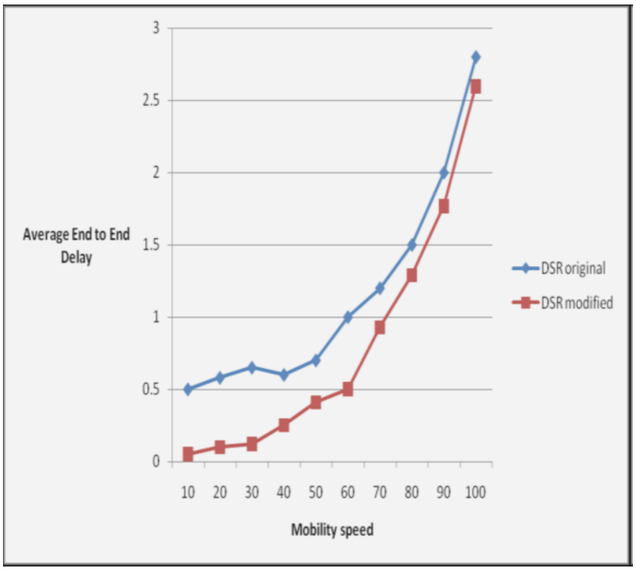

Figure 2.2 Average End-End delay with Mobility

In a similar approach a path is considered likely to break when the received packet power becomes close to the minimum detectable power [31]. The minimum detectable power is termed as Pre-emptive Threshold here. The threshold value is critical to the efficiency of the algorithm. The value set high would generate the alarm too early whereas the value set too low would not give sufficient time to discover new route before route breaks. Here, proactive route selection and maintenance have been suggested for on demand Adhoc routing protocols. There is a possibility of false alarms due to fluctuations in received power caused by fading, multi path effects and similar random transient phenomena. The key to successful operations of the proposed methodology lies in selection of an optimum threshold value under ideal and fading environments. Pre-emptive ratio is the ratio of threshold power at the edge of the region to the minimum power that could be received by the device (source). Figure 2.3 and Figure 2.4 shows that Pre-emptive Dynamic Source Routing (PDSR) outperforms DSR in terms of broken paths and latency. Latencies on established paths can be expected to increase slightly because proactivity limits the effective range slightly. An "optimal" path with a link below the proactivity threshold is rejected in favor of a longer path with higher quality links.

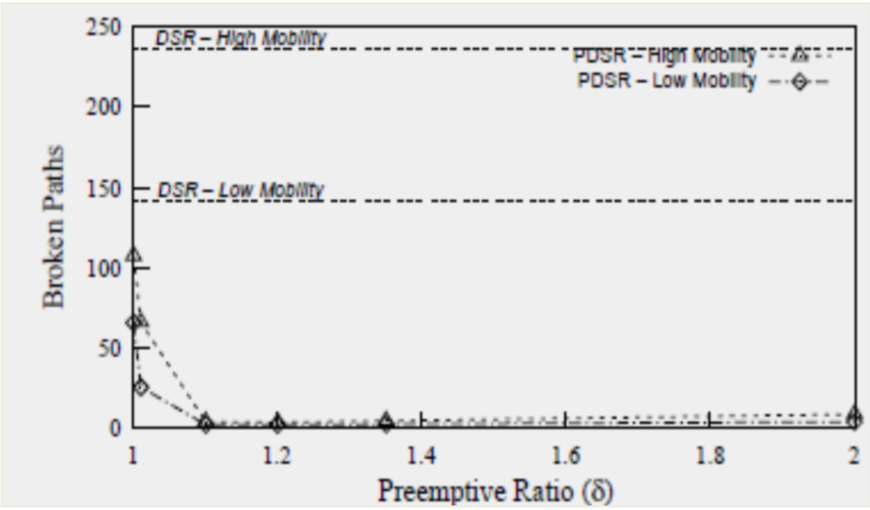

Figure 2.3 Broken Paths with Preemptive Ratio

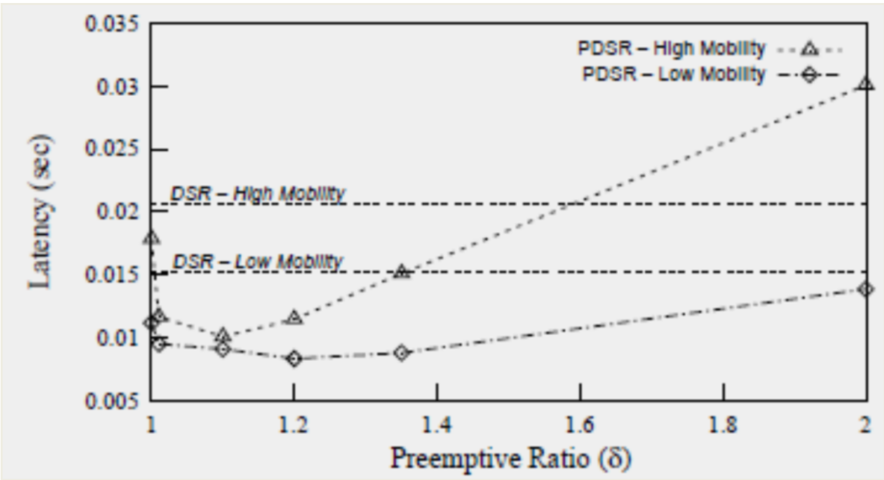

Figure 2.4 Latency with Preemptive Ratio

In a similar study Proactive Route Maintenance (PRM) is proposed to replace the naive route mechanism in existing reactive on-demand routing protocols [29]. It is based on assumption termed as communication locality i.e. most of the communication takes place on few active routes. This protocol combines reactive route discovery and proactive route maintenance (PRM) of active routes, which adapts well to highly dynamic networks and reduces the frequency of costly route recoveries. In PRM, multiple optimal and suboptimal paths form a mesh structure that connects source and destination to meet certain Quality of Service (QoS) requirements. All optimal paths are active in forwarding data packets. Sub-optimal paths are backup and activated only when all optimal paths have failed. The mesh structure is self-healing and self-optimizing. It can survive many link failures without causing route discovery or non-optimal routing. Table 2-1 shows an improvement in performance of AODV on application of PRM.

Table 2-1 Comparison – Main Characteristics of AODV and AODV-PRM

Protocol	**Delivery Ratio**	**Average Delay**	**Discovery Overhead**	**Maintenance Overhead**
AODV	89 %	0.299 s	2236 Pkt	0 Pkt
AODV-PRM	91.29 %	0.153 s	1688 Pkt	5033 Pkt

In another study a location-based hybrid routing protocol has been proposed to improve data packet delivery and reduce control message overhead in mobile Adhoc networks [21]. At high speeds it is difficult to maintain and restore route paths. A new flooding mechanism to control route paths is proposed. The basic operation of the scheme is similar to AODV. The scheme adds a greedy forwarding algorithm, location information of a GPS and directional flooding to the AODV algorithm. The essence of the proposed scheme is its effective tracking of the destination’s location based on the beacon messages of the main route nodes. These beacon messages are only broadcasted to one hop neighbours of the main route nodes by selecting TTL of these packets accordingly. The purpose of beaconing is to find the location of the destination immediately when route failure occurs along the main route nodes. This procedure is used as an effective type of local repair. Regarding the local repair procedure of an AODV, it broadcasts an RREQ message to find the destination node set as TTL field = 2 when a node finds a link failure. If no destination node is found, it then sends an RERR message back to all active nodes that are dependent on the broken link. When every node receives the RERR message, those nodes delete the route of the broken link. Particularly for a source that receives such an RERR message, it can restart the route discovery procedure; a stale route is expired according to a timer-based technique in what is known as an AODV local repair procedure. In the present scheme, when an upstream node detects a link failure, the node sends an RREQ message toward only the direction of the destination. These procedures contribute toward reducing the routing message overhead. Figure 2.5, Figure 2.6 and Figure 2.7 shows that the propose protocol overall outperforms protocols like AODV, Zone Routing Protocol (ZRP), Location Aided Routing (LAR) and AODV-Directional Forwarding Routing (DFR) in terms of Packet Delivery Ratio (PDR), Control message overhead and number of control message per delivered message respectively.

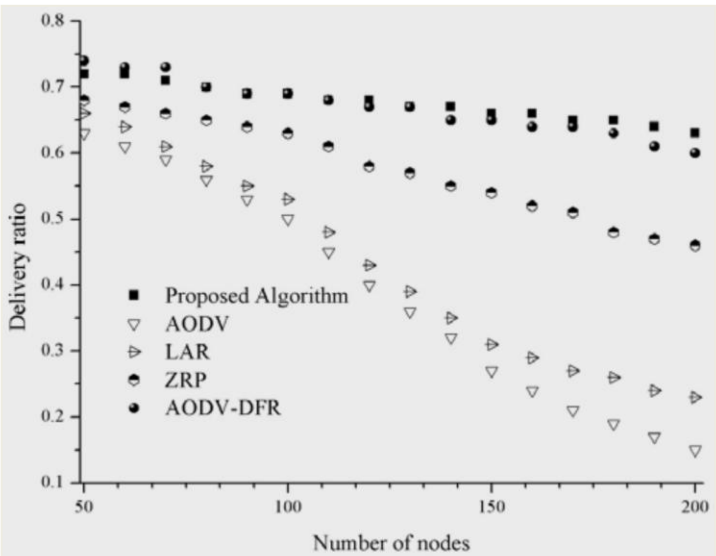

Figure 2.5 Delivery ratio with number of nodes

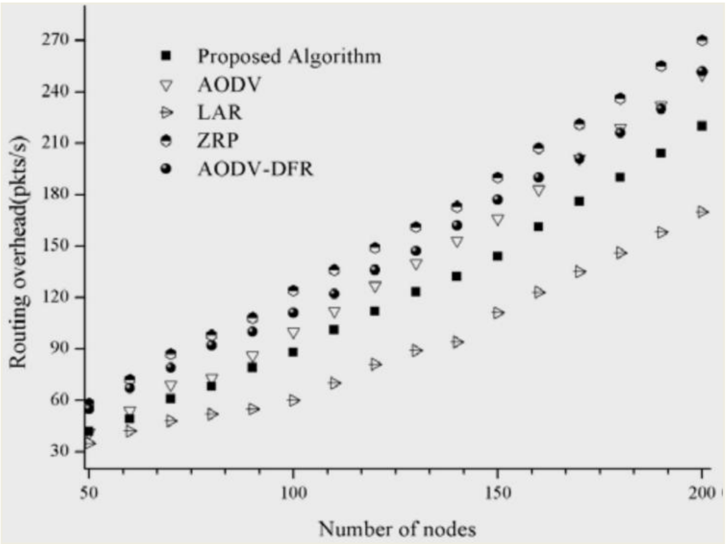

Figure 2.6 Routing Overheads with number of nodes

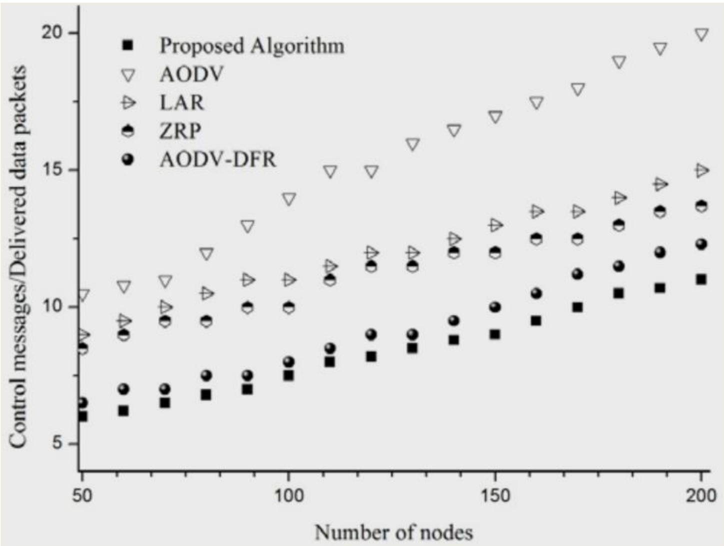

Figure 2.7 Control messages per delivered message with number of nodes

VANET is a new emerging domain of MANET. Routing protocols in MANET can be classified in two main categories. These are table-driven / proactive and on-demand / reactive routing protocols. Additionally, Geographical (Position based) routing protocols are also being studied for their viability in VANETs.

2.1.1 Proactive Routing

This type of protocols maintains fresh lists of destinations and their routes by periodically distributing routing tables throughout the network. Upon occurrence of any change in network topology, every node executes an update of its routing table. Link-state routing (e.g. OLSR) and Distance-vector routing (e.g. DSDV) strategies are implemented in the proactive algorithms [20]. The following sections provide the working details for the two popular proactive routing protocols:-

Destination Sequence Distance Vector Routing (DSDV) utilizes Distance Vector shortest path routing algorithm through which single path (which is loop free) to the destination is provided. Two types of packets are transmitted by DSDV and these are “incremental” and “full dump”. Complete routing information is transmitted in full dump packets and incremental is utilized for updates for route maintenance. Incremental decreases bandwidth utilization since only updates are sent instead of the completed routing information. However, this incremental information still detrimentally impacts the network overhead. The reason is that incremental packets are very frequent and that results in its unsuitability for large scale networks.

Optimized link state routing (OLSR) [28] performs route maintenance by transmitting information of link state. After a change in topology occurs, selected nodes carry out update transmissions for selective nodes only. With this methodology, only one update is received by every node. Unselected nodes for transmission can only read updated information however cannot re-transmit the updates.

2.1.2 Reactive Routing

These protocols are designed in order to lessen overheads. This is achieved by performing route maintenance only for the active routes. Active route is one currently under utilization for exchange of data packets between source and destination [25].

Reactive routing protocols carry out route discovery by transmitting RREQ (Route Request) from a node when there is requirement from a route to transmit data to a particular target. Post transmission of an RREQ, the node thereafter waits for the RREP (Route Reply). When an RREP hasn’t been received within a pre-determined period of time, the source node assumes unavailability or expiry of route. When the destination has received RREQ and source has also received a RREP; then unicasting is utilized to transmit information to destination. This process ensures availability of the route for communication [27].

There are two classifications for Reactive routing - source-routing or hop-by-hop routing. For the case of source routing, the full information of source-to-destination route is a component of the packets of data. When the data packets are forwarded to other intermediate nodes in the network, each node takes information of route from the data packet and stores it in the header of data packet. Therefore, each intermediate node does not require updating all route information in order to send packet to the particular destination.

Source routing may not be applicable for highly dynamic large scale networks. The first reason could be high probability of route failure due to the large numbers of nodes in such Ad hoc networks. The second reason could be the increase number of intermediate nodes resulting in increase routing overheads (header information) of each node.

Each data packet in hop-by-hop reactive routing contains next hop and destination addresses. Hence, Hop-by-hop reactive routing is advantageous as compared to on-demand source routing. The nodes which are intermediate between source and destination carry the routing table information so as to transmit data packet specific destination. This can be quite supportive for dealing with abrupt modifications of the network topology. Thus when topology change occurs, nodes are in receipt of updated routing table information and thus select new routes with the aid of new tables. Subsequently, these selected routes are now utilized to transmit data packets to their destinations. Such routing protocols carry out a continuous update of the corresponding routing information and carry the information of all neighboring nodes. As a result, hop by hop reactive routing protocols are generally considered relatively feasible for highly mobile Ad hoc networks like VANETs.

2.1.3 Position Based Routing

The nodes in VANET are very dynamic and highly mobile due to rapid changes in their locations. Therefore, there is high demand for such routing methodologies which are able to deal with dynamic environments. These demands tend the researchers to utilize the positions of nodes so as to provide successful communication from source to destination. This method that utilizes geographical positions of nodes so as to execute routing of data between source and destination is called Position-based Routing.

The primary assumption of Position based routing is that all nodes are knowledgeable about their physical / geographic positions. In contrast to topology based routing, the position based routing utilizes the additional information of each participating node to applicable in VANET, that additional information is gathered through GPS. Position based routings provide hop-by-hop communications to vehicular networks. The position based routing protocol comprises a number of major components and some examples of that are "location service and servers", "beaconing" and "recovery and forwarding strategies" [2].

Location service and servers: When a node does not contain current geographical location of a specific node in its location-table, location service assist in finding out the current location. To acquire current physical location of desired node, the requesting node transmits a location query which includes the unique ID of the desired node, sequence number and total number of hops. The neighbors send replies to this message till the desired node is discovered. If the desired node exists among near neighbors of the requested node then it replied with its current physical position message.

Beaconing: In Beaconing, the packets, with the current location and the unique ID (IP Address), are forwarded by nodes. Whenever a node receives beacon from its neighbor, the node carries out an update in the location table. Thus beaconing is utilized to gather information regarding one-hop or next-hop neighbor of nodes.

Forwarding and Recovery strategy: This is utilized to forward data between source and destination node. Three types of forwarding methods are utilized for VANET by Position based routing protocols to forward data packets from source to destination:-

a. Restricted directional flooding
b. Hierarchal forwarding
c. Greedy forwarding

Restricted directional flooding transmits data packets into the geographical area of specific node and the “forwarding zone "part of geographical area. This methodology is not dependent upon information regarding neighboring nodes. The forwarding zone is created between source and destination nodes and the source node flood packets into the forwarding zone so as to transmit the packets towards their destination.

Hierarchal forwarding is a position based forwarding strategy for the routing protocols. In this strategy, protocols hierarchy is utilized as different steps to forward packets. The hierarchal forwarding executes routing for neighboring nodes and also for nodes at greater distance.

Greedy forwarding is another efficient forwarding strategy for position based routing. In this strategy, a node transmits packet to nodes in close proximity of destination. The sending node determines smallest hop count for the packets to destination. When there is no node that is adjacent to the destination, a recovery strategy is utilized to mitigate such situation.

Contrary to the topology based routing, the position based routing protocols do not necessitate the requirement for route maintenance. Route is determined only when there is a requirement for forwarding a packet. Another advantage of position based routing is that it includes information of source, destination and their neighboring nodes. This characteristics makes position based routing a suitable candidate for VANET. Several routing protocols that utilize nodes position information for routing decisions, with all facing lot of challenges, have been proposed by researchers.

2.2 Conclusion

Proactive routing protocols, also known as table-driven routing protocols, contain information on every node and update the routing table information periodically. In DSDV and OLSR, typical proactive routing protocols, the source node is equipped beforehand with information appertaining to the pathway of the destination node before it sends data packets there. As a fatal drawback of the proactive routing approach, however, a mass of route-updating messages flood the entire network periodically to maintain the route information fresh. Furthermore, each node unnecessarily stores the full set of route information, especially in a highly mobile environment where the routing table of a node is updated frequently for dynamic topology. Each node must find the latest broadcast routing path information periodically. Such periodic updates cause unnecessary network overhead.

Reactive routing protocols, also known as on-demand routing protocols, do not conserve the routing table information; instead, they execute a route discovery procedure to determine a route to the destination only when the source node requires a path to the destination node. Once a route has been discovered, the route is maintained until the destination becomes inaccessible or the route is no longer desired. AODV and DSR are representative examples of reactive protocols. Particularly with a large number of nodes, reactive routing protocols are more appropriate than a proactive routing approach.

C h a p t e r 3

Architecture of Reactive Routing in VANETs

3.1 Introduction

In last chapter, routing and route maintenance strategies for reactive and proactive routing protocols are discussed. Proactive based routing protocols may not be appropriate for high mobility and high density of nodes because of the following reasons [14, 25]:-

a. Proactive routing requires large bandwidth in order to accomplish the sharing function of routing information with neighbors.

b. In addition, tables are quite large in large networks which require lots of memory and processing.

Since, vehicular nodes are large in number and highly mobile rendering rapid topological changes; the Proactive routing protocols have generally not been considered a viable option for VANETs. This is also likely because of large bandwidth and memory requirements. Reactive routing protocols, particularly hop-by-hop type, may be considered appropriate for high mobility and high density of nodes because of the following reasons [2, 7, 25, 26] :-

a. Since each data packet contains next hop and destination addresses which is helpful during route maintenance.

b. The reactive nature of protocols cause low overheads which lessens the standing cost in the whole network.

c. Establishment of on-fly links is the key characteristic of such protocols which saves network resources in terms of both memory and processing.

d. The nodes which are intermediate between source and destination carry the routing table information so as to transmit data packet specific destination. This can be quite supportive for dealing with abrupt modifications of the network topology.

e. Whenever topology change occurs, nodes are in receipt of updated routing table information and select new routes with the aid of new tables. Subsequently, these selected routes are utilized to transmit data packets to their destinations.

f. Such routing protocols carry out a continuous update of the corresponding routing information and carry the information of all neighboring nodes.

As a result, hop by hop reactive routing protocols are generally considered feasible for highly mobile Ad hoc networks like VANETs [26]. A comparison of the important generic characteristic of reactive and proactive routing protocols is depicted in Table 3.1 for their selection in high mobility and high node density scenario [24].

Table 3-1 Comparison – Main Characteristics of Reactive and Proactive Routing Protocols

Routing class	Proactive	Reactive
Availability of route	Always available	Determined when needed
Control Traffic volume	Usually high	Lower than proactive routing protocols
Storage Requirements	High	Depends on the number of routes kept or required. Usually lower than proactive protocols
Delay level	Small since routes are predetermined	Higher than proactive
Scalability problem	Usually up to 100 nodes	Source routing protocols up to few hundred nodes. Point-to-point may scale higher
Handling effects of mobility	Occur at fixed intervals	Local route discovery

3.2 Advantages and Disadvantages of Reactive Protocol

The main advantage of reactive protocol like AODV is that it establishes routes on demand basis and uses destination sequence numbers to find the latest route to the destination. The HELLO messages used in route maintenance are range-limited so they do not cause unnecessary overhead in the network. It is well suited for large networks as compared to other protocols. Its advantages include adaptation to the dynamic link conditions, low memory and processing overhead, low utilization of network and determination of unicast routes to destinations within the Ad hoc network. Destination sequence number provides assurance of loop freedom in fairly straight forward mechanism [25].

A disadvantage of such protocol is that intermediate nodes can lead to inconsistent routes if the sequence number is very old and the intermediate nodes have a higher but not the latest destination sequence number. The connection setup delay is more as compared to proactive protocols. Multiple Route Reply messages in response to a single Route Request packet can lead to heavy control overhead. The periodic HELLO message leads to gratuitous bandwidth consumption [25].

3.3 Ad-hoc on Demand Distance Vector Routing Protocol

AODV is the most common referencing protocol in the research community. Also, our research methodology revolves around distance estimation not location estimation in order to find out a generic solution. Due to this reason, we did not select any location protocol. Our research methodology is focused on observing strength of signal on basis of distance.

AODV (Ad hoc on Demand Distance Vector Routing) [27] is a multi-hop type of reactive routing protocol. The AODV routing protocol executes its tasks completely on-demand basis. It makes use of an efficient routing methodology. This minimizes load on network by broadcast of route discovery information and by dynamic update of routing data at each intermediate node. Topology changes and loop free routing are maintained in AODV.

3.3.1 Route Request (RREQ) Message

AODV does not play any role as far as nodes contain valid communication connections to each other. When a node requires communication with a non-neighbor node, it broadcasts an RREQ (route request packet). The RREQ includes RREQ ID, IP Address (of destination), Serial Number (of destination), IP Address (of source), Sequence Number (or source) and Hop Count. The Destination Sequence Number is the most updated sequence number that has been received, by the source, in the past for any path towards the destination. Source Sequence Number is the most updated number that is to be utilized in the route entry pointing towards the source of RREQ. Every node's route table entry must include the most recent sequence number for the nodes in the network. It is updated whenever a node receives RREQ, RREP or RRER related to a specific node.

3.3.2 Route Reply (RREP) Message

Upon discovery of a valid route to the destination, either an intermediate node or the destination node itself transmits an RREP message. This node responds to the source-node along with route reply packet RREP and then discards it. If RREP is generated by an intermediate node, the node replicates the known sequence number into Destination Sequence Number field that is part of RREP packet. The RREP packet comprises Destination IP Address, Destination Sequence Number, Originator IP Address and Lifetime.

3.3.3 AODV Route Table Management

The management of routing table in AODV is required to avoid entries of nodes which do not exist in the source-to-destination route. The destination sequence numbers are required to manage routing table information in AODV. The following characteristics are required to be maintained:-

a. Destination's IP address
b. Hop-count to the destination
c. Next hop nodes
d. Sequence number for Destination
e. Active neighbors: nodes currently using the active route
f. Expiration time: the total validity time for the route

3.3.4 AODV Route Maintenance

Upon detection of an invalid route for communication, the node erases the complete corresponding entries from the route table as applicable for that route. At the same time, it transmits the RERR to its current active neighboring nodes and thus informing them about the invalidity of that route. AODV retains only the routes that are loop-free. When the source node obtains the link failure notification, it either starts the rebroadcasting RREQ process or the source node stops transmitting data through the invalid route. In addition, AODV utilizes the information of active neighbor to continue tracking of currently used route. The detection of link failure in AODV is based on occurrence of one of the following conditions:-

a. Neighboring nodes periodically exchange hello message. Absence of hello message is used as an indication of link failure
b. Failure to receive several MAC-level acknowledgements may be used as an indication of link failure

3.3.5 Route Error (RERR) Message

In order to maintain a smooth conduct of operations, a recovery mechanism is invoked within AODV. For reasons of acknowledgement or for repeated action, a node creates RERR message, in one of the following scenarios:-

a. While sending the data, if it observes a break in link for the next hop (neighbor) of an active route in its routing table. In this case, the node initially creates, in the routing table, the list of unreachable destinations and unreachable neighbors.
b. If it is in receipt of a data packet that requires sending to a destination node for which it does not carry information of an active route.
c. If it receives an RERR from a neighbor regarding one or more active routes.

A unique RERR message is generated by the concerned node. It comprises fields of varying lengths which are explained in Table 3-2.

Table 3-2 Description of Fields in RERR Message

Field	Description
Type	3; RERR packet
N	Repair flag (used for multicast)
Reserved	Sent as 0 (ignored on reception)

Field	Description
Destination Count	If nonzero, the 5-bit Prefix Size identifies that the indicated subsequent hop may be utilized for any nodes that have the common outing prefix (as defined by the Prefix Size) as the requested destination.
Unreachable Destination IP Address	The destination's (for which route is supplied) IP address for which route is supplied.
Unreachable Destination Sequence Number	The sequence number for the destination that is associated to the route.

When a node is passed around in a MANET, the RERR packet allows route adjustment by AODV. The RRER indicates unreachable destinations. Each node maintains a "precursor list" which contains the IP addresses for all its neighbors which are likelihood to utilize it as a next hop towards destination. The precursor list's information is obtained during RREP packet's generation. Invoke methodology on generation of Route Error message in a typical scenario is mentioned below:-

a. When an intermediate node is unable to forward packet from one node to other node on a link, it generates a RERR message

b. Intermediate node increments the sequence number of the destination node and cached at itself

c. The incremented sequence number is included in the RERR

d. When the source node receives the RERR, it initiates a new route discovery for destination node

3.3.6 AODV Operation

AODV delivers messages between nodes that are mobile. For out-of-range nodes, AODV permits the nodes to transmit messages to the intended node via the neighbor nodes. AODV achieves this by searching routes along which messages can be propagated. In Figure 3.1, Node-1 requires transmittal of message to Node-3. However, Node-3 is out of the direct range of Node-1.

As a result, Node-1 is not certain as to how to reach Node-3. The range of transmission of each node is illustrated via circles around each node [27].

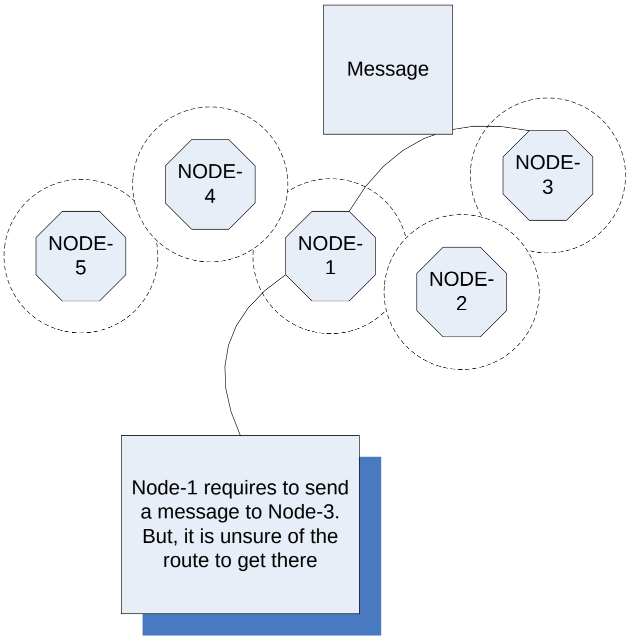

Figure 3.1 Node-1 Requires to Communicate with Node-3

In the above Figure 3.1, Node-1 is trying to establish communication with Node-3. However, Node-3 is beyond its direct range. Therefore, Node-1 broadcasts the RREQ message to the neighbors' nodes (Nodes -2 and -4) as shown in Figure 3.2.

Nodes -2 and -4, which are neighbors to Node-1 are in receipt of the RREQ. If any of the two nodes have an already existing route to Node-3, it returns the RREP message. Else, both the neighbor nodes carry out route request's rebroadcast to their respective neighbors. The cycles continue till the required destination is discovered or lifespan/TTL of the RREQ message is over. If after certain time if it does not receive any reply, Node-1 can retransmit the RREQ message with longer lifespan.

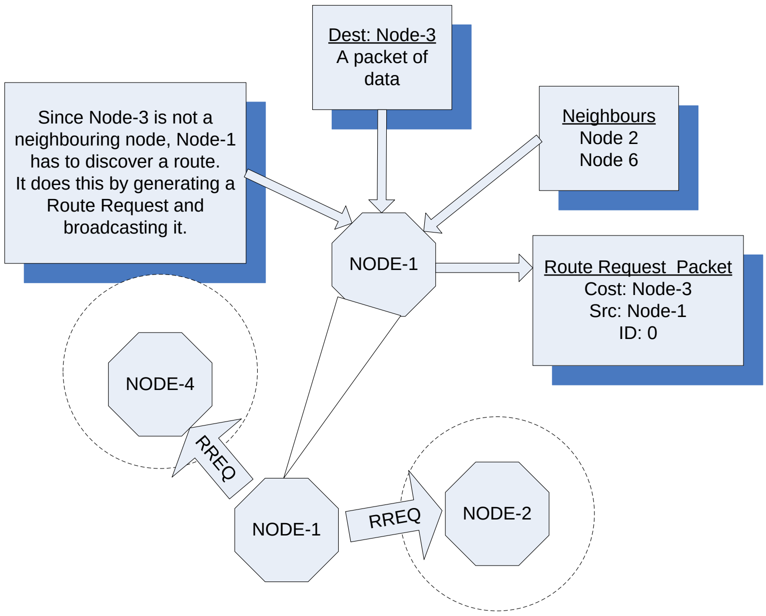

Figure 3.2 Node-1 Broadcasts the Route Request

As illustrated in Figure 3.3, Node-2 has route to the required destination which is Node-3. Therefore, Node-2 transmits RREP message to Node-1. It is to be noted that Node-4, which does not carry the destination route, carries out a message broadcast to Node-5.

Routes become invalid due to movement of the mobile nodes Route Error (RERR) message which allows nodes to readjust the routes when route becomes invalid. Figure 3.4 below illustrates the three scenarios where a node sends an RERR message. In very first case, node transmits an RERR message when it receives a message that it is required to forward but for which it does not carry the required route. In the second case, node receives an RERR message which invalidates the existing route. So this node will transmit RERR message with all the nodes that are now un-reachable via this node. In the third case, node detects link breakage with one of its neighbor. In such cases, node checks its route table and the nodes marked as reachable via this neighbor are now marked as invalid.

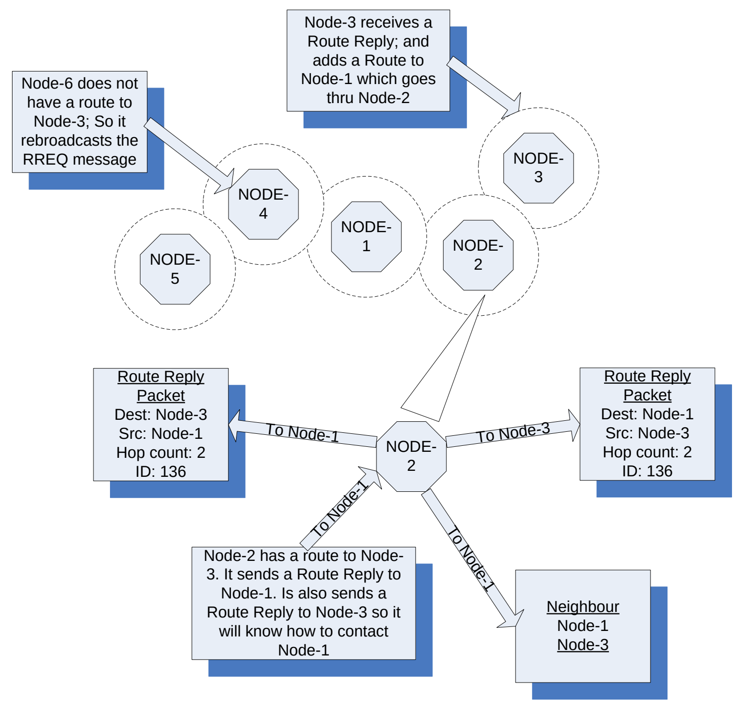

Figure 3.3 RREP Message by Node-2 to Node-3

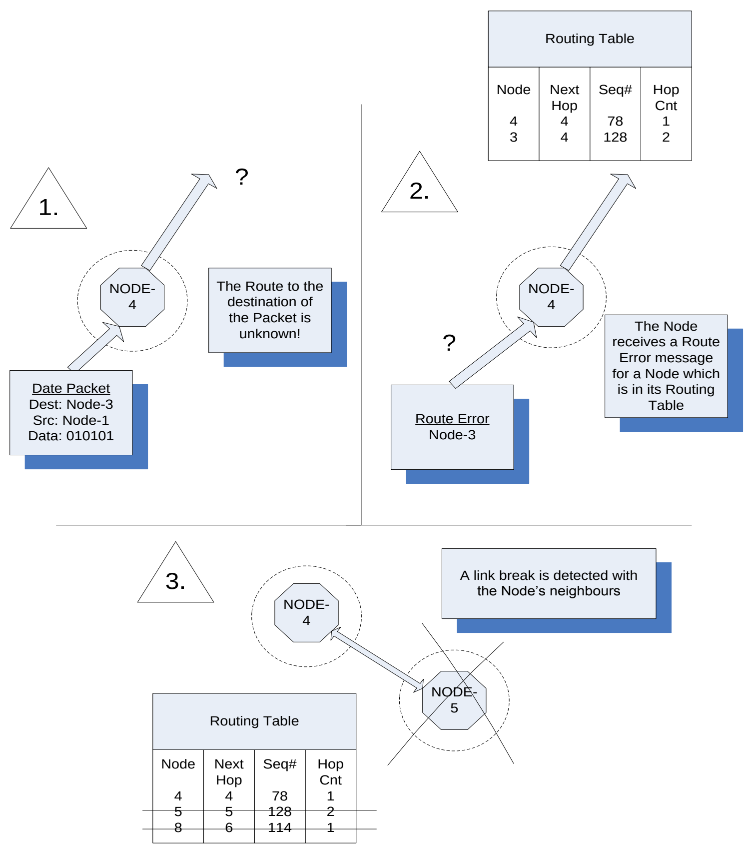

Figure 3.4 Route Error Message

3.3.7 AODV Features

AODV addresses number of issues that are generally faced in proactive routing protocols. AODV provides on-spot communication requirements for high density Ad hoc networks. In comparison to proactive routing protocols, AODV assists in minimizing flooding of messages which results in reduced network overhead. AODV reduces routes' redundancy and requirement of extensive memory.

AODV utilizes destination node sequence numbers to eliminate loop-free routes. For instance when a particular route becomes invalid, then an RREQ with greater number of destination sequence number is sent by the source node. This assists towards rebuild of the route. AODV utilizes the broadcast route discovery method to control network overhead [27].

Another important feature for AODV is its response to link failure in the network. Information of the neighbors that are using the currently active route is kept to maintain the link breakage. AODV is applicable on large scale Ad hoc networks as compared to Hybrid or Proactive routing protocols; an another important feature of AODV [7, 13].

3.3.8 Weakness of AODV

The requirement of Route Maintenance in AODV enhances significantly with high mobility and high node density. The quick and sudden change in network topology outperforms AODV in such high speed networks. Route maintenance in rapidly changing environment becomes a problematic job for the routing protocol. This is because of an increase in latency during path setup. Moreover, broadcasting of route requests over the network increases the network load.

In order to remove this inherent weakness of AODV, preemptive route maintenance strategy has been proposed here. The new scheme would search for a new route not after the breakage of old route rather just before the breakage of old route. In other scenario when the old route is becoming inefficient, the propose scheme would attempt for an efficient route.

ND based Route Maintenance for Mobile Networks

4.1 Introduction

The work is based on defining the route maintenance scheme in which a new route would be discovered before interruption or serious degradation occurs in the old route. The idea of utilizing neighbor count and neighbor distance for calling the route maintenance routine has been suggested.

With mobility the routes frequently break as devices move out of each other radio range. As a result, new routes are searched in reactive protocols that decrease the overall throughput and increase unwanted routing layer messages to flood the network. Let's consider an inefficient route scenario in Figure 4.1, where nodes are initially not in each other's radio range. After a while, the nodes came so close where everyone can communicate directly with others. The following sequence of events occurred in the given scenario:-

a. N1 and N3 were initially connected on two hop distance through N2.

b. After some time all the nodes came so close such that N3 comes in one hop range of N1.

c. Being a reactive protocol, no route maintenance routine is called at this stage for the discovery of a possible direct route between N1 and N3.

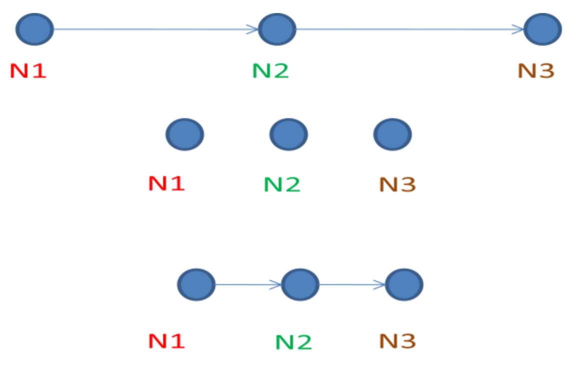

Figure 4.1 Inefficient Route Scenario

Let us consider, a high latency scenario in Figure 4.12. Here, N1 & N3 are communicating directly with each other while N2 remains inactive in between. After a while the node N2 becomes active. The following sequence of events occurred in the given scenario:-

a. N1 and N3 directly communicating while N2 is now active.

b. Nodes started to move away such that the communication link N1-N3 to exceed one Hop Range (about to break).

c. Being a reactive protocol, no route maintenance (pre-emptively) for possible indirect route N1-N2-N3 before route breaks.

d. Route N1-N3 breaks which causes interruption and loss of data.

e. RERR generated and communication resumed after discovery of route N1-N2-N3.

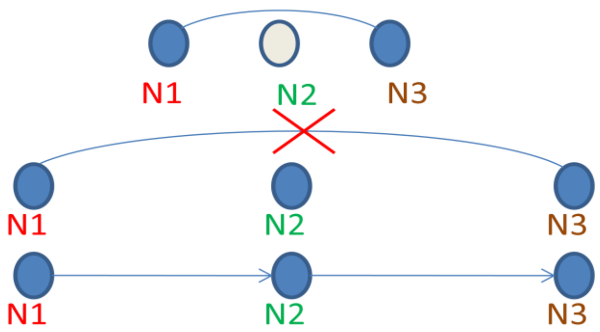

Figure 4.2 High Latency Scenario

4.2 Operation of Proposed Route Maintenance Scheme

The proposed technique lies in defining the route maintenance mechanism on basis of distance between devices. This is because of the fact that under all conditions, distance is inversely proportional to signal strength. The greater the distance between transmitter and receiver, and/or lesser the distance between transmitter and other active nodes, weaker would be the signal strength between transmitter and intended receiver, and vice versa.

For computing the selected parameter, Neighbor Distance (ND), we calculate received signal strength relative to Euclidean distance between nodes. Number of active neighbors around receiver is the prime parameter on basis of which our proposed mechanism would be evoked. The proposed route maintenance mechanism would be evoked only when two or more neighbors are present around the receiver. Otherwise, the original route maintenance mechanism would be evoked. The number of neighbors is selected considering that an additional transmitter around would not interfere the signal strength to a greater extent. However, two or more transmitters around would degrade the signal strength to a considerable extent.

Low Euclidean distance between the transmitter and the receiver would correspond to high value of ND and vice versa. Similarly, low Euclidean distance between the intended receiver and an active node (interferer) would correspond to low value of ND. Since, there could be number of active interferers around the intended receiver and there affect would add on therefore ND would change depending upon the sum of Euclidean distances of the receiver and interferers.

$$ND = \frac{\text{Sum of Euclidean Distances b/w Receiver \& Interferers}}{\text{Euclidean Distance b/w Transmitter \& Receiver}}$$

$$ND = \frac{\sum_{.i \in \varphi_s} (d_i)}{(d_t)}$$

$$ND = \frac{\sum_{.i \in \varphi_s} \sqrt{(x_r - x_i)^2 + (y_r - y_i)^2}}{\sqrt{(x_r - x_t)^2 + (y_r - y_t)^2}}$$

Therefore the ND computed at the receiver node is the ratio of sum of Euclidean distances between receiver and all interferers to Euclidean distance between transmitter and receiver.

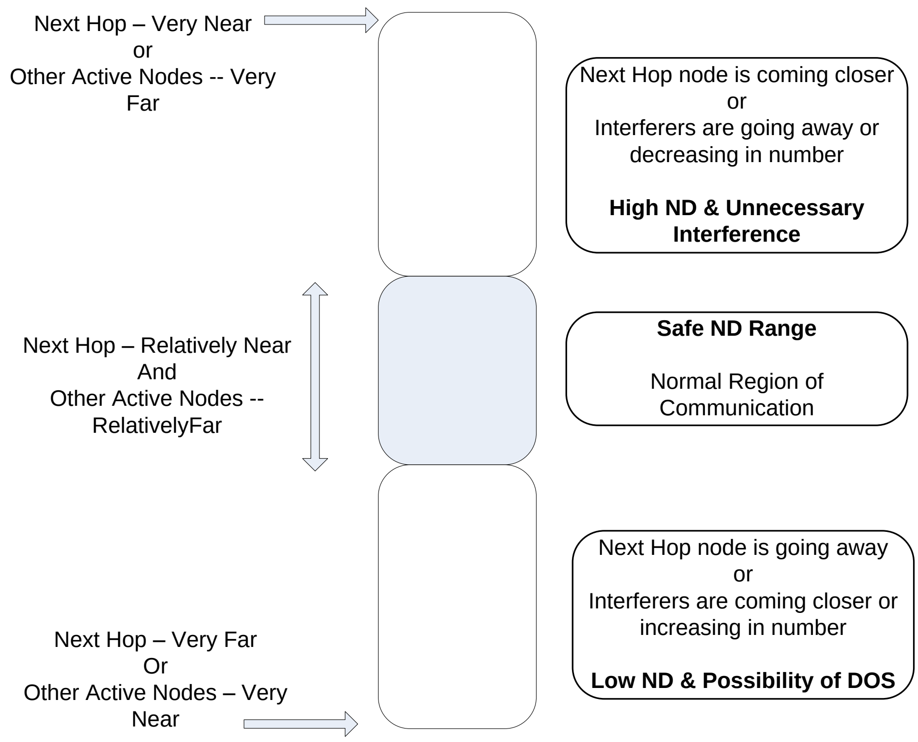

Figure 4.3 ND Bar Three Regions

Figure 4.3 illustrates the ND bar depicting the three possible regions of operations. The shadow region is actually the region of interest. This is the region where the value of ND is such that there requires no route maintenance. This region is the safe region where most of the communication would generally takes place. If the value of the ND is lying within this boundary, the route maintenance routine would not be invoked.

The area below the shaded region is one which would occur less frequently under normal circumstances for a number of nodes in the network. However, ND in this region could be because of outside interferers attempting DOS through uncontrolled transmissions or the legal neighbors have gathered around the receiver. As soon as the current ND value enters in this region the route maintenance routine would be invoked because either the route is like to get break or the increase interference is going to degrade the performance.

The area above the shaded region is one which would also occur less frequently under normal circumstances. However, having the current ND value in this region could be because of availability of the intended destination node in the near vicinity. As soon as the current ND value enters in this region, the route maintenance routine is to be invoked, because there is now a possibility of direct communication with the intended node instead of having a multiple hops communication. If the route maintenance routine is not called at this age, avoidable interference level would exist in the network.

4.3 Route Maintenance Flow Chart

The data flow and route maintenance mechanism for the proposed methodology is shown in Figure 4.4. Whenever data is required to be delivered, the minimum neighbor density "β" around the receiver transmission range would be checked first. The number of neighbor nodes present would be computed with the help of active nodes coordinates being shared amongst nodes. If number of neighbors is less than "β", then simple route maintenance methodology would be invoked. For number of nodes greater than or equal to "β", the proposed route maintenance mechanism would be invoked.

A safe range of the selected distance based parameter is required within which the proposed route maintenance mechanism would not be invoked. This range refers to recursive values of the parameter ; region where most of the communication takes place. This would be learnt from the initial communication between the nodes. If ND exist in the safe range then packet would be simply forwarded on the route. However, if ND is out of the suitable range then at first place local repair with exclusion of existing route would be tried out. If this could be achieved new route would be discovered and packets would be forwarded. Otherwise, after a time out local repair with inclusion of existing route would be tried out. Similarly, if this could be achieved the packets would be forwarded on the new route. However, if a route could not be discovered this time RERR would be generated after a time out. It is pertinent to mention here that possibility of re discovery of the same old route is always there.

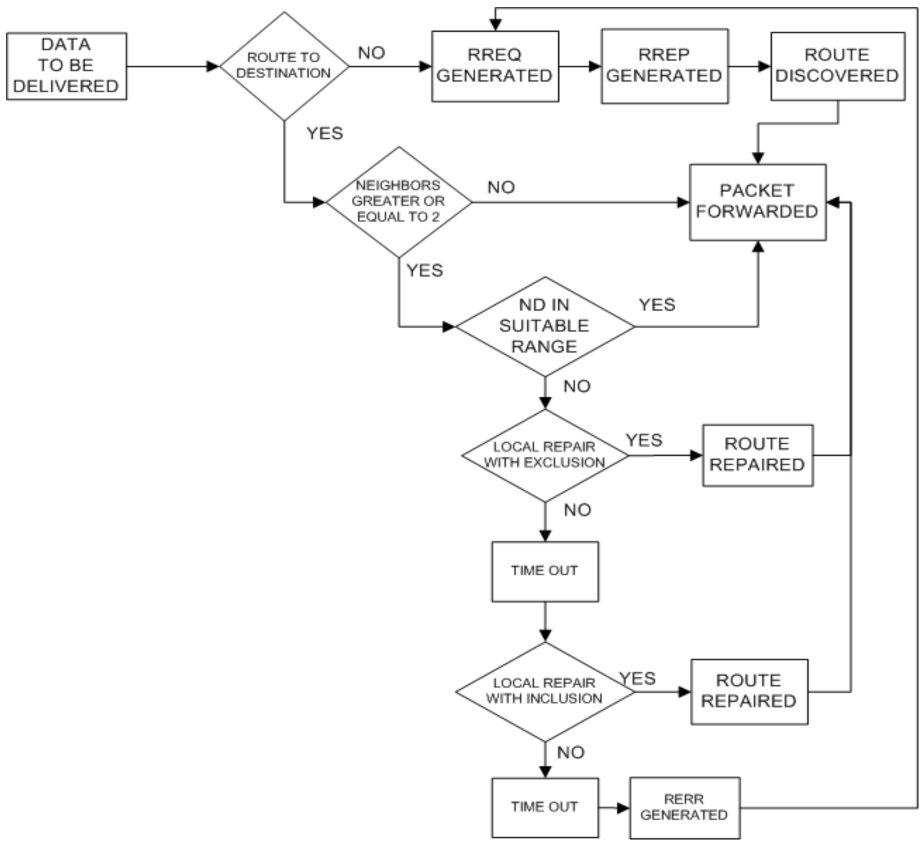

Figure 4.4 Flow Chart of the Proposed Route Maintenance Methodology

4.4 Summary

We have proposed here a route maintenance strategy based on the selected distance based parameter. The propose mechanism would provoke the route maintenance before the route break. The mechanism would monitor the parametric value such that, whenever it crosses the safe range, the route maintenance routine will be called.

In the next chapter we will show from our results that how route maintenance decisions based on the neighbors' distance could affect the throughput.

Simulations and Performance Evaluation

5.1 Introduction

In this chapter performance metrics and simulation results with original and proposed model of AODV are presented.

Depending on the radio range, the nodes communicate in an Ad hoc network. The mobility pattern of the nodes is an important factor in explaining the behavior of the nodes [15]. How frequently nodes interact with each other at high speeds and high node density would impact the performance of the network. For the purpose of our study, we prepared a four lane highway architecture in such a manner that nodes would interact with each other depending upon the selection of speed and direction. The width of the lanes is five meters with inter vehicle distance of ten meters. The two featured highway mobility models are depicted in Figure 5.1 and Figure 5.2 respectively. Additionally, two urban mobility models are also depicted in Figure 5.3 and Figure 5.4 respectively.

Figure 5.1 Nodes on Four Lanes Moving in One Direction

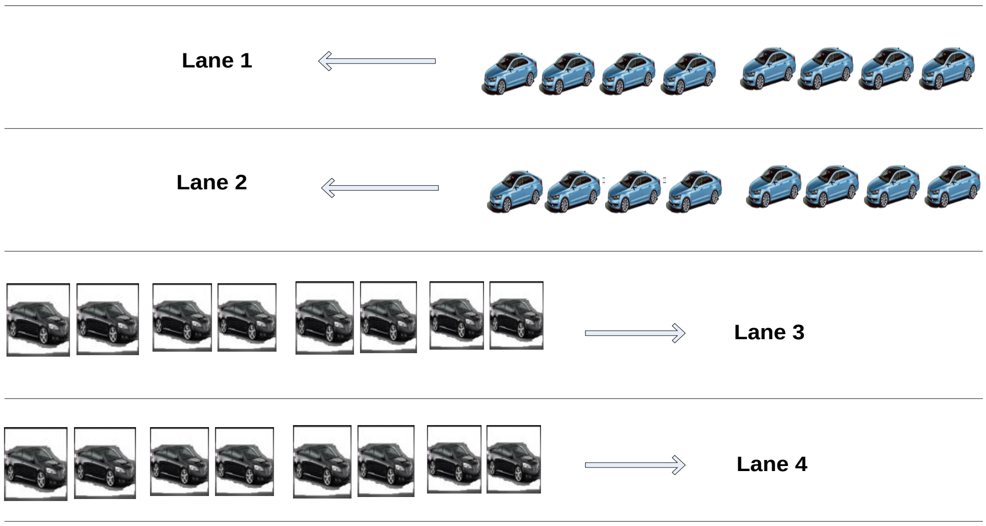

Figure 5.2 Nodes on Four Lanes Moving in Two Directions

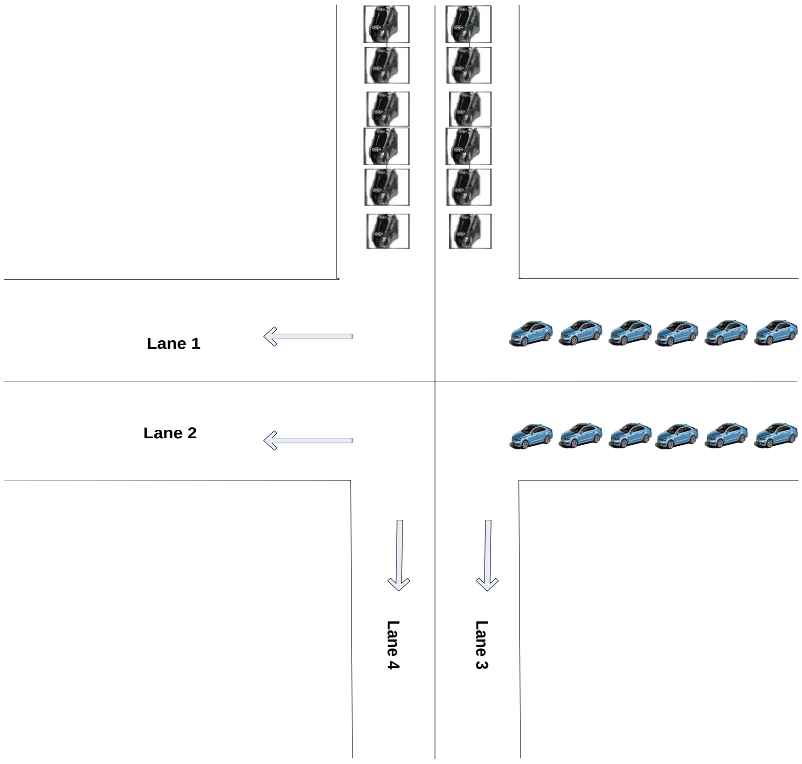

Figure 5.3 Nodes on Four Lanes Moving in Two Directions

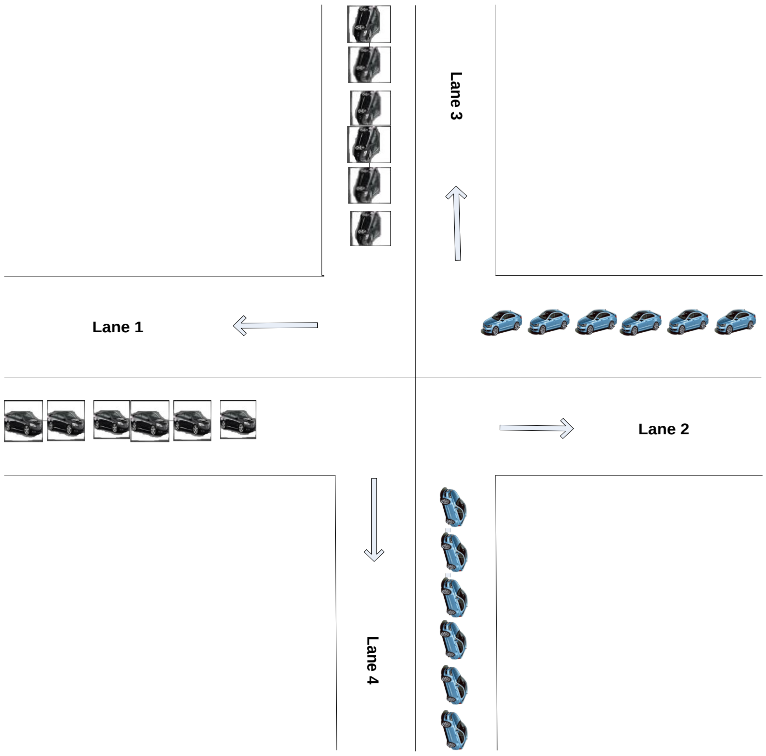

Figure 5.4 Nodes on Four Lanes Moving in Four Directions

Requests from a source to destination are either sent on single hop or two/three hops with maximum hop distance of 1000 meters. The communication nodes are selected from different lanes. As discussed earlier the nodes have been deployed here in four groups considering the four lanes scenario. A total of hundred nodes have been initially selected amongst which twenty nodes communicates at constant bit rate with twenty other nodes to check the response at high node density. Simulations were run with different number of nodes 10/25/50/75/100 and different set of speeds 30/60/90/120/150 km/hr. The nodes are selected to move on straight lanes with different destination points towards the end of their respected lanes. The selected nodes in different lanes communicate at constant bit rate typically of 128 kbps with packet size of 1,000 bytes.

5.1.1 Performance metrics

The evaluation of routing protocols, within the defined network environments, is carried out with the help of different performance metrics. On basis of Throughput, End-End Connectivity Time and Packet Delivery

Rate the performance of proposed technique against AODV is evaluated [14, 20].

5.1.2 Throughput

It is defined as the average count of data packets that are successfully delivered on a network node or communication network. Stated in a different way, 'Throughput' is defined as the number of bits per second at the receiver. Throughput is calculated in bytes/sec or data packets per second. The simulation result for throughput in ns-2 illustrates that the total received packets at destination in bps; mathematically throughput is indicated as follows:

$$\text{Throughput (bytes/sec)} = \frac{\text{Total number of received packets at destination* packet size}}{\text{Total simulation time}}$$

5.1.3 Packet Delivery Rate

Packet Delivery Rate is defined as the total count of the packets of data that can successfully reach their destination. Packet drop may occur due to various reasons such as faulty hardware, congestion or overflow of queue etc. The packet drop has a detrimental effect on performance of network vis-a-vis consumption of time and extra bandwidth required for packets to be resent. Higher packet delivery rate indicates better protocol performance.

Packet Drop Ratio (PDR) = 1 - (Rx Count / Send Count)

5.1.4 End-End Connectivity Time

This is time lapse from the transmission of first packet to the reception of last packet. It further helps in calculating the delays occurring in a network.

Total Rx Time = Last Packet Rx Time - First Packet Rx Time

Table 5-1 Network Parameters

Parameter	Protocol / Value
MAC and PHY layer	IEEE 802.11p
Radio-propagation model	Two-ray ground
Bandwidth	27 Mbps
Traffic environment	Urban area highway traffic scenario
Traffic flows	Constant bit rate (CBR) selected at run time
CBR flow rates (Mbps)	Selected from 1 to 25
Transport layer protocol	UDP
Number of nodes	10/25/50/75/100
Speed selections km/hr	30/60/90/120/150

5.2 Simulation Results

For understanding the concept of the proposed route maintenance mechanism we carried out the simulations in two phases. This was done as speed of nodes and number of nodes are the two elements that differentiate VANETs from MANETs. In first phase of simulations, we kept the speed of nodes constant for different number of nodes. Whereas in the second phase, we kept the number of nodes constant for different set of speeds.

For the first implementation of highway scenario, different number of nodes as 10/25/50/75/100 for multiple iterations with various starting positions in the lane were selected. In this phase the speed of all nodes is set to 100 km/r. The simulation was run for 500 seconds with 20 nodes transmitting for the duration of simulation to 20 different nodes. Distances between the vehicles are randomly selected. The aim behind simulating highway scenarios is to check the behavior of AODV and AODV-ND routing protocols for VANET in terms of Throughput, End-End Connectivity Time and Packet Delivery Ratio. The results for the said set of simulation are compiled here.

End-End Connectivity Time

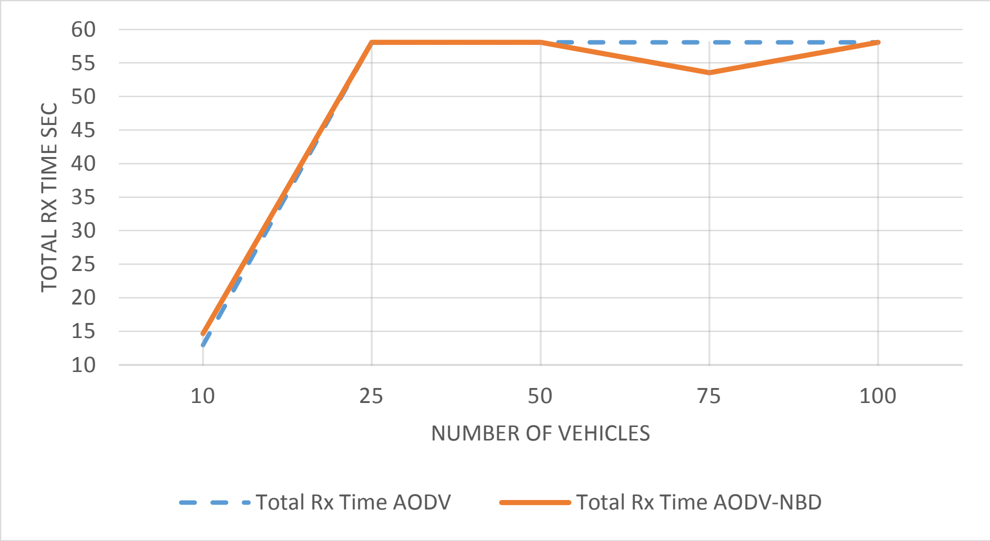

Figure 5.5 End-End Connectivity Time for Number of Nodes at 100 km/hr

It can be extracted from Figure 5.5 that the End-End Connectivity Time in a constant speed VANETs scenario with different number of nodes is relatively same for the two protocols. This is so because the inter-vehicular distance is not changing because of fix speed of the nodes. For reasonably low number of nodes, the behavior of two protocols is very much same. However, with further increase number of nodes the receive time gets better for AODV-ND. This behavior is likely because our propose route maintenance mechanism has invoked at high node density.

Throughput

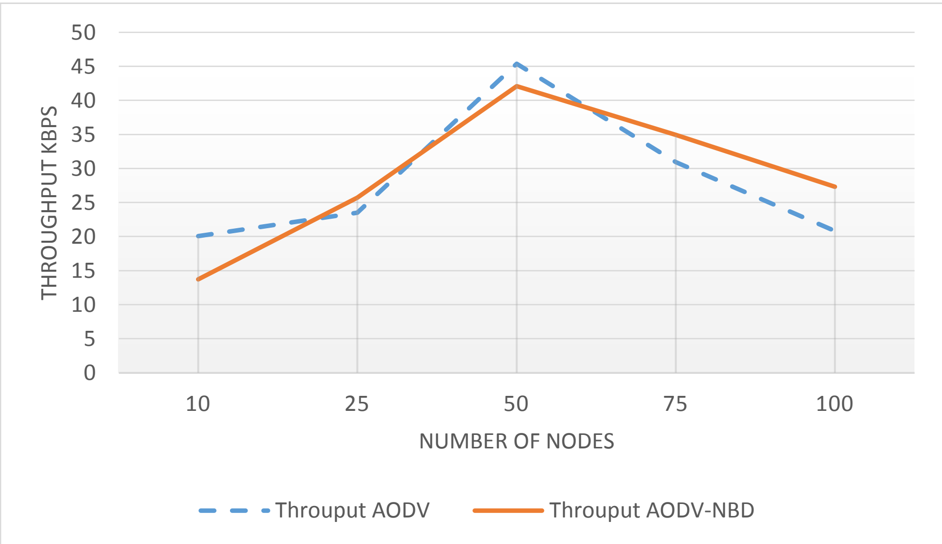

Figure 5.6 Throughput for Number of Nodes at 100 km/hr

It can be extracted from Figure 5.6 that the Throughput for a constant speed VANETs scenario with different number of nodes is relatively varying for the two protocols. It is pertinent to mention that the data rate has been selected in low range. For reasonably low number of nodes, the behavior of AODV seems to be a better however as the number of nodes or node density increases AODV-ND substantially gets better than AODV. Such performance is because of high node density causing our route maintenance mechanisms to invoke.

Packet Drop Ratio (PDR)

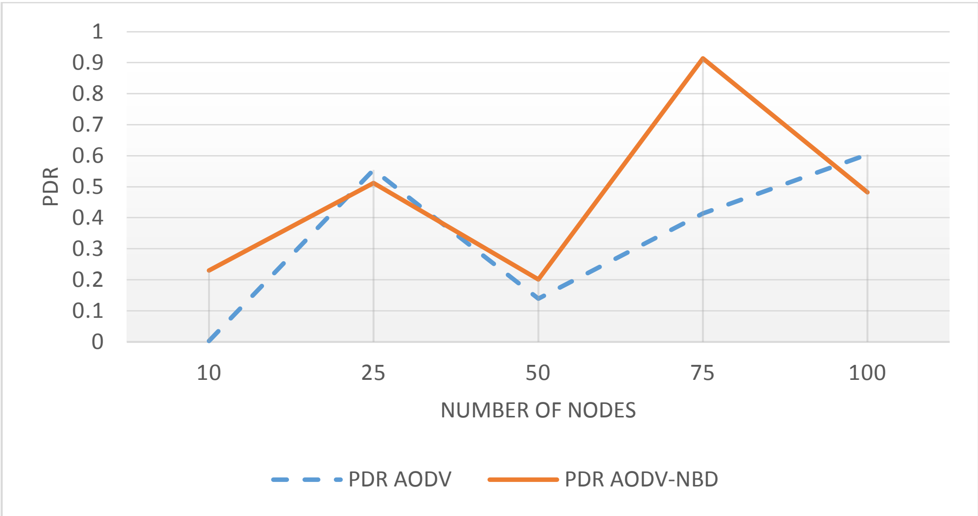

Figure 5.7 Packet Drop Ratio (PDR) for Number of Nodes at 100 km/hr

It can be extracted from Figure 5.7 that Packet Drop Ratio (PDR) in a constant speed VANETs scenario with different number of nodes varies for the two protocols. For reasonably low number of nodes, the behavior of AODV proves to be better however as the number of nodes or node density increases AODV-ND gets better than AODV.

For the second implementation of our urban scenario, we selected speed of the vehicles to be 30 / 65 / 90 / 120 / 150 km/hr. However, the number of nodes was set constant to 100. The nodes started at different time instances. Distances between the vehicles were randomly selected.

End-End Connectivity Time

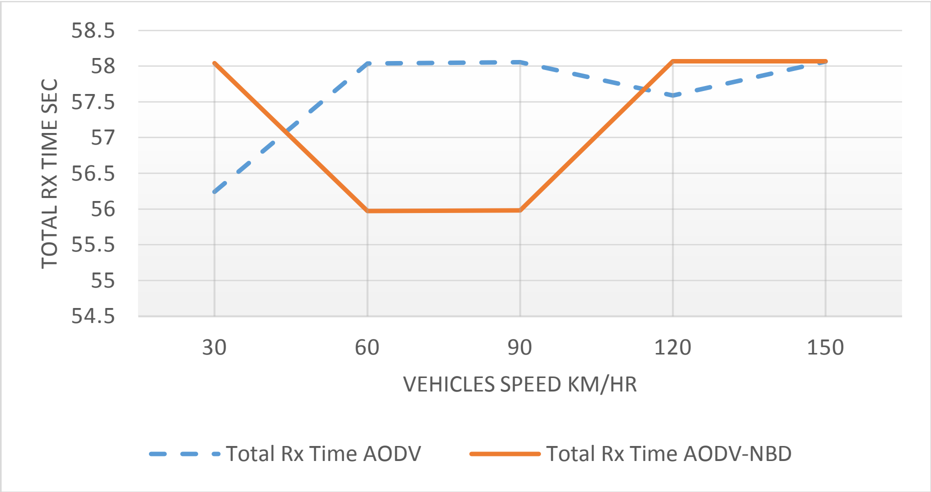

Figure 5.8 End-End Connectivity Time for Normal Nodes

It can be extracted from Figure 5.8 that the End-End Connectivity Time in a constant number of nodes scenario with different speeds is overall better for AODV-ND. For reasonably low speeds, the behavior of two protocols is very much same. However, at high increase speeds AODV-ND protocol outperforms AODV. The primary reason behind such behavior could be recursive requirement of route maintenance.

Throughput

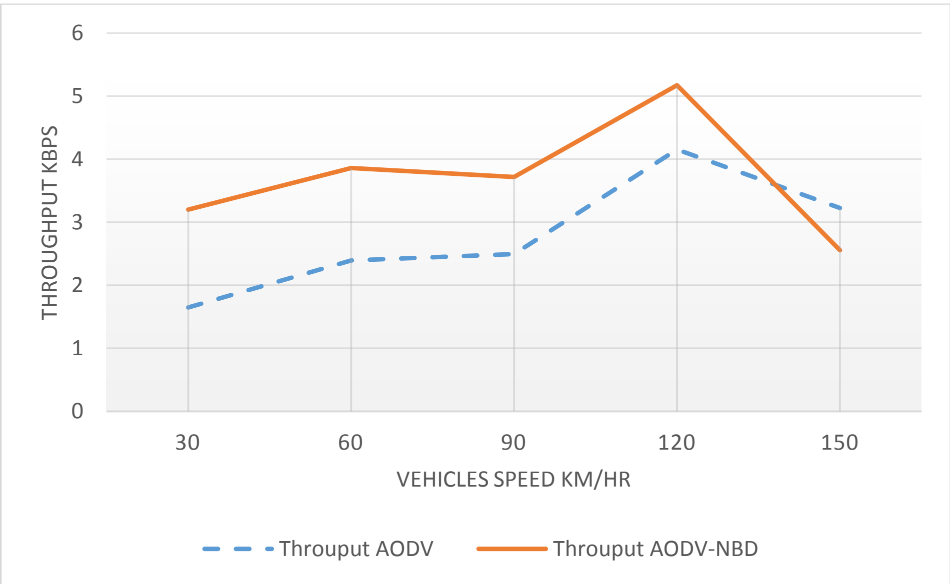

Figure 5.9 Throughput for Normal Speeds

It can be extracted from Figure 5.9 that the Throughput in a fixed number of nodes scenario with different speeds is relatively varying for the two protocols. It is pertinent to mention here that for all speed ranges AODV-ND is simply outperforming AODV except at above normal speed (very high speed). This is main advantage of AODV-NBA over AODV as throughput is the ultimate parameter of accessing the network's performance.

Packet Drop Ratio (PDR)

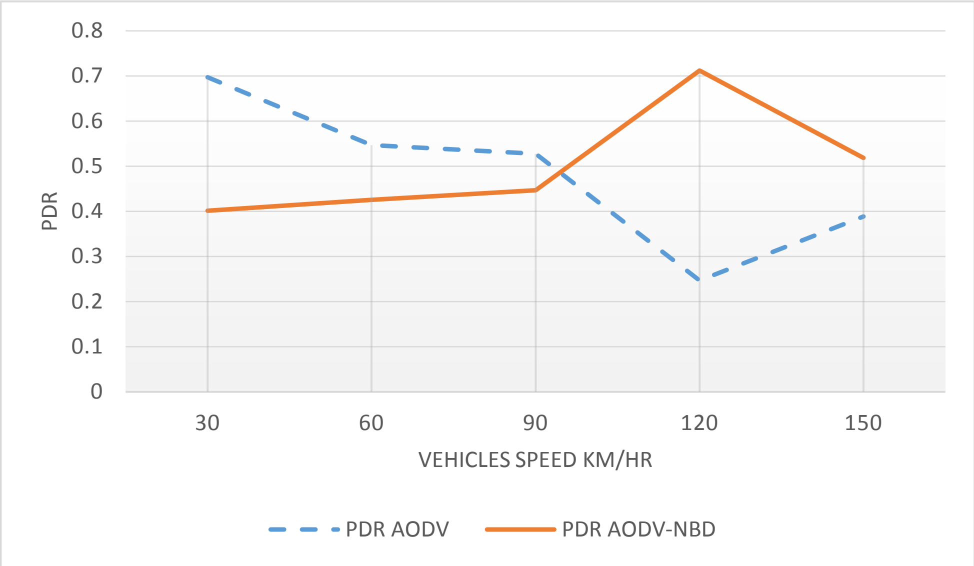

Figure 5.10 Packet Drop Ratio (PDR) for Normal Speeds

It seems from Figure 5.10 that Packet Drop Ratio (PDR) in a constant number of nodes scenario with different speeds differs for two protocols. For reasonably low speeds, the behavior of AODV seems to be better however as the number of nodes or node density increases AODV-ND outclasses AODV.

5.3 Summary

This chapter highlighted the results of application of our proposed technique on the defined network architecture in a high mobility scenario. The results clearly show the viability of AODV-ND for VANETs especially at high speed and high node densities. As explained earlier it was an effort to re-define the route maintenance mechanism such that the reactive protocol should not wait for the route to break.

C h a p t e r 6

Conclusion and Future Work

6.1 Overview

The work has focused only around modifying the route maintenance scheme for reactive protocol while the route discovery scheme remains intact. The modified scheme preemptively predicts for a better route for data transportation. This is done so that an efficient route can be made available before the route breaks.

This chapter concludes the report by summarizing the goals achieved during this research, and provides the direction for future work.

6.2 Achievements

This research work has been carried out with prime target being the proposal of an appropriate methodology and platform with specific concentration on the identified deficiencies. The steps in the proposed scheme have been theoretically presented and illustrated using implementations in ns-2. In order to ensure the effectiveness of the proposed methodology each constituent step was well aligned with some predefined goals of design. The proposed methodology can prove to be a foundation for researchers in carrying out improvement in the existing vulnerable VANETs for bringing the level of confidence of the vehicle manufacturers and their users in exploiting its features.

The research phase has been very fruitful in achieving an understanding of innovative methodologies for identification of the problem areas and thereafter achieving solutions in an independent environment.

6.3 Future Work

We plan to establish new route maintenance schemes based on one of physical layer parameters like throughput, delay, jitter etc. Thereafter, we plan to propose a route maintenance methodology based on our proposed parameter and multiple physical layer parameters. Thereafter, an analysis of the new scheme could be done such that it assists in proposing an optimal route maintenance methodology for VANETs. In addition to this we are also interested in the emulation and real time implementation of our proposed and the future propose route maintenance schemes on VANET's. This will likely provide a foundation for exciting and prolific works in future.

We also plan to implement our mechanism on various other types of reactive, hybrid and proactive routing protocols to see their viability in VANETs. Furthermore, we are also interested in improving the performance of AODV-ND in case of low speeds and low node densities.

And most importantly, we would like to propose a framework for detecting and circumventing DOS attacks using our proposed route maintenance scheme. On successful construction of the said framework we would like to implement the same.

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