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Quality of Service aware Dynamic Source Routing Protocol in Ad hoc Networks: Proposal, Analysis and Comparison

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Abstract

A Mobile Ad hoc Network (MANET) is a self-configured, infrastructure less network. Due to mobility of nodes routing is a very critical issue in MANETs. Finding and selecting an optimal and reliable path that can exist as long as possible is a complex task. Dynamic Source Routing (DSR) protocol is an on demand or reactive, source driven routing protocol. By implementing Dynamic Source Routing, we can design a self configured, infrastructure less multi hop wireless ad hoc network which has dynamic topology with mobile nodes. DSR has low overheads and require less convergence time if an existing route is failed. In DSR protocol periodic routing updates or route advertisement are not disseminated by a node to its neighbors and DSR does not perform link status sensing, these features make DSR a protocol with less overhead. Basic model of Ad hoc network depends on *"Best Effort"* delivery and not provide any guarantee of Quality of Service constraints like minimum bandwidth requirement and maximum allowable delay. Basic frame work of DSR also does not support Quality of Service constraints. In this research paper we will propose a QoS aware DSR and we will analysis and compare our proposed QoS-DSR protocol with traditional Dynamic Source Routing protocol.

Keywords: DSR, MANETs, ns-2, QoS, Routing Protocol

1. Introduction

Conventional wireless networks are infrastructure based network, they require preexisting communication infrastructure like access points or base stations with centralized administration for their operation. In contrast, the so-called (wireless) Mobile Ad hoc Networks, consisting of a collection of more than one wireless nodes, all of which may be mobile, dynamically create a wireless network among themselves without using any such infrastructure or administrative support (Haas 1999; Johnson 1996). Ad hoc wireless networks are dynamic, self-creating, self-organizing, and self-administering in nature. They come into being solely by interactions among their constituent wireless mobile nodes, for achieving necessary control and administrative functional supports such networks are totally depend on such interactions. Besides performing many other critical functions, such interactions use complex routing processes. Routes between two end devices called source and destination nodes may consist of more than one hop through other cooperative intermediate nodes in the network. Consequently, in an Ad hoc network each end-user node is capable of sending, receiving and routing data packets in a distributed manner. Moreover, such networks can be configured to allow nodes for mobility and to perform routing over multiple hops for finding stable and reliable route/routes for themselves as well as for other nodes with which they are creating and organising Ad hoc network. Thus all the nodes work in cooperative manner and carry the same responsibility and take part in discovery and maintenance of routes to other nodes.

The distributed, wireless and self-configuring nature of MANETs (Conti 2002) help them suitable for a wide variety of applications, including

- Virtual classrooms
- Military communications
- Emergency search and rescue-operation
- Data acquisition in hostile environments
- Communications set-up in exhibition, conferences, presentations, meetings, lectures, etc.

Due to evolving technology and most recent development of MANETs, *Ambient Intelligent (AmI), Pervasive Computing and Ubiquitous Computing* paradigms are built upon Ad hoc technology. These technologies are context aware, adoptive, personalized and anticipatory in nature. These technologies refer to electronic environments that are sensitive and responsive to the presence of people and other embedded devices (Carlos 2008; Guo 2011).

In Mobile Ad hoc Networks, host mobility can cause frequent unpredictable topology changes. Constraints such as low bandwidth, limited energy, mobility, non-deterministic topology and the broadcast nature of wireless communication make the efficient routing of data a critical element of ad hoc networks. Therefore, the task of finding and maintaining routes in MANETs is nontrivial.

In dynamic environment of Ad hoc networks achieving route stability is very difficult and it is even more difficult to guarantee Quality of Service (like achieving predefined minimum Bandwidth requirement for a voice/video data stream). Basic model of Ad hoc network depends on *"Best Effort"* delivery and not provide any guarantee of QoS (Crawley 1998). Almost all modern Routing protocols including land mark Dynamic Source Routing (DSR) protocol do not provide QoS support and do not have security mechanism.

This is proven that finding a route with QoS constraint is a NP completeness problem (Lin 2001).In this research paper we will propose QoS aware DSR protocol and analysis and compare QoS-DSR with traditional DSR.

The rest of this paper is organised as follows. Section II describes and summaries need of QoS aware routing algorithm in mobile ad hoc networks. Section III, describes Dynamic Source Routing and its route discovery strategy. Section IV presents proposed QoS aware DSR. In section V we will perform simulation based analysis and comparison of QoS-DSR with traditional DSR. In last section or in section VI we will conclude our research paper.

2. Literature Review

Many protocols have been proposed for mobile ad hoc networks, with the goal of achieving efficient routing. These algorithms differ in the approach used for searching a new route and/or modifying a known route, when hosts move. The characteristics of wireless networks showed that to manage reliable wireless Internet (Conti 2002; Corson 1999); we definitely have to consider the following issues:

- Speed/Bandwidth of wireless links
- Scalability
- Mobility of nodes
- Limited Battery Power
- Disconnection
- Minimum hop and Delay to destination

- Fast adaptability to link changes
- Stable routes selection
- Distributed operation
- Loop avoidance

As in MANETs due to mobility of nodes and limited resources, to find stable paths is complex task. But the usefulness, need and necessity of developing and deploying mobile ad hoc networks, are the major causes for the development and the design of some efficient routing protocols. Some of the efficient routing protocols are Dynamic Source Routing (DSR), Ad Hoc On-Demand Distance Vector (AODV), Temporally Ordered Routing Algorithm (TORA), Associatively Based Routing (ABR) etc. DSR is an on demand, source driven, loop free and efficient routing protocol.

As we already discussed that like Internet (World Wide Web), basic inherit model of MANETs is also depended on *"Best Effort"* services with out guaranteeing any Quality of Service support. But happily, during last few years, lot of research work and advancements are taking place for assuring Quality of Service for different types of data flows offered by MANETs to different end users.

Some of the major constraints or parameters, which are required by user as QoS guarantee are Bandwidth, End to End Delay, Jitter (delay variance), Probability of packet loss, Battery Power etc (Wu 2001; Sarma 2006).

3. Critical Analysis of Dynamic Source Routing (DSR) protocol

Development of DSR was started in 1996 and final draft of protocol which was designed and developed by IETF (Internet Engineering Task force) published in RFC-4728 in February 2007.DSR is an on demand or reactive, source driven routing protocol. Nodes in DSR enabled network maintain route cache; route cache is used for maintaining a data base of all feasible routes from that node which are available at that point of time. Nodes are able to learn or cache more than one route for the same destination makes protocol more robust.DSR uses *"Soft state"* routes means a node can work as an intermediate node for more than two routes and failure of one route will not effected the presence of other routes.

DSR protocol consists of three major phases:

- Route Discovery
- Data Forwarding
- Route Maintenance

As we know every routing protocol uses control packets (messages) for finding optimal route. DSR mainly uses four types of Control packets for route discovery and route maintenance:

- Route Request Packet *(RREQ)*
- Route Reply Packet *(RREP)*
- Route Error Packet *(RERR)*
- Acknowledgement Request Packet *(Ack-Req)*
- Acknowledgement Packets *(Ack)*

3.1 Route Discovery

While source node is sending the data to the destination node, the source checks any available route for that destination in its route cache. If the route is exist in route cache of source node then data will forward at this route. If the route is not listed or not presented in route cache, then the source node broadcast the route request packet *(RREQ)* to the other neighbor nodes situated within broadcast range of source node for find the destination node. Every route request packet *(RREQ)* has three fields *source node address, destination node address and unique identifier number or request number.* This request number is used for finding duplication of route request packets *(RREQs)*, reaching to the same node by two (or more than two) paths. Every node maintains a *route cache* for all available routes from that node. After receiving a route request packet intermediate nodes search their route cache and find out is there any available route to destination node, if yes then that route is append with source to intermediate node route. If the receiving node doesn't have the route for the destination then it again starts the process for finding the route. Every Route request packet maintains a list of all intermediate nodes *(mobile ids)* those are traversed by a route request packet from source node to that intermediate node. This record or list is called *route record* available with *RREQs*. When the route request packet is sending one node to other then it updates its list available in route record field. This route record is used by an intermediate node or by destination node for sending route reply packet *(RREP)* to source node.

The main concept is that if the route reply is generated by the destination node then destination node places the route record in the route reply, early that was in the route request packet. And if the route is found in the cache of the in-between node or intermediate node then intermediate node retrieve that route from route cache and add this route in the route record and then generate a route reply packet. To return the *RREP*, destination node or intermediate node must have a route to the initiator (source node from where route request packet was initiated). If responder node (destination or intermediate node) has a route to initiator node in its route cache, it may use that route. Otherwise, in case of bidirectional and symmetric wireless links (as in 802.11 standard) same path is followed by route reply packet, which was earlier used by route request packet for reaching source node to destination node. It is possible that a link between two nodes may not work equally well in both directions, due to differing antenna or propagation patterns or sources of interference. If wireless transmission is unidirectional and not symmetric, the node may initiate its own route discovery and *piggyback* route reply packet to a new route request packet. In case of symmetric wireless links performance of DSR is increased but DSR also supports unidirectional and asymmetric wireless links.

As we know route discovery process is triggered by first data packet, by which user wants to initiate communication to destination node. In route discovery process, sending node saves a copy of original packet that triggered the route discovery process in a local buffer called *Send Buffer*. Send buffer managed in *FIFO structure*. Send buffer contains a copy of every source packet, for which a route to destination node is not available and for which route discovery process is in progress.

Generally new route request or route discovery is not initiated; during the period in which a source packet is reside in send buffer. Send buffer time out period is 30 seconds.

In case of partitioned network where node density is less and mobility rate of nodes are high, time duration of route discovery is high or may be destination node is unreachable. If new route discoveries are sent by source node, a large number of useless and unproductive route request packets are propagated in network. In DSR, for limiting the number of route discoveries and so the number of route request packets propagated in network, an exponential back off algorithm is used. By using this algorithm, DSR doubles the timeout between each successive new route discoveries initiated for the same destination node. A packet is buffered in send buffer, till the time source node does not receive Route reply packet from destination node.

Dissemination of Route Request Packets from source node can follow one of the mechanisms out of given three mechanisms

3.1.1 Non Propagating Route Request

In this case hop count (Time to Live-TTL) field of RREQ packet is set to 1. Means that RREQs are just send to immediate neighbors because there is a fair chance that one or more of immediate neighbors to that source node have some valid routes for the destination node in their route caches.

3.1.2 Propagating Route Request

Normally routing protocols in MANETs (including DSR) are first try non propagating route mechanism as explained in 3.1.1, after trying to discover a route by non propagating route request mechanism if a route is not fond then RREQs are propagated by using maximum hop count or TTL mechanisms. DSR is well converse in a network with 5 to 6 hop counts.

3.1.3 Expanding Ring Propagation of Route Request

In this mechanism suppose if first time when RREQs are disseminated by source node the value of TTL field is X but if route is not fond by this TTL value then in next route discovery value of TTL field is doubles means value become 2X. In expanding ring propagation TTL field values are 1, 2, 4, 8…..

3.2 Data forwarding

The DSR Protocol allows nodes to dynamically discover a source route across multiple network hops to any destination in the ad hoc network. Every data packet forwarded or originated by source node consist *Explicit Source Route Header*. Each data packet sent then carries explicit source route header and in this header DSR keeps the complete, ordered list of nodes through which the packet must pass. Explicit source route header allows packet routing to be trivially loop-free and avoiding the need for up-to-date routing information in the intermediate nodes through which the packet is forwarded. By including this source route in the header of each data packet, other nodes sending or receiving any of these packets may also easily ***cache*** this routing information for future use.

But clearly this approach increases control overhead per data packet transferred. For overcome with this problem in later development of DSR, a new mechanism called DSR flow state extension *DSRFLOW* is introduced (Hu 2001). In *DSRFLOW* every node maintains a flow table. For each flow forwarded from a node, there is one entry in flow table which minimally must record next hop address.

3.3 Route Maintenance

In route maintenance mechanism, for detecting a link or a route failure DSR uses Acknowledge Request Packets *(Ack-Req)*, Acknowledgement packets *(Acks)* and Route Error packets *(RERRs)*. After a link or route failure *Ack-Req* is transmitted maximum number of time to next hop node. If after maximum retries sender dose not receive Ack packet then it propagated Route Error *(RERR)* packets to all nodes those have route entries in their route cache by using this link. When route maintenance indicates a source route is broken, Source node can attempt to use any other route it happens to know to Destination node, or can invoke route discovery again to find a new route. Route maintenance mechanism is only working during the phase of data forwarding. As in DSR protocol, nodes are able to learn or cache more than one route for the same destination makes protocol more robust and allows route maintenance mechanism easy to implement. In case of route failure route cache is consulted for any optional route.

Except these above discussed basic features of Route Maintenance several optimization have been proposed and are listed below

3.3.1 Data Packet Salvaging

If a data packet reaches on an intermediate node and intermediate node encounters a broken link but has one or more alternate routes for that data packet in its route cache then intermediate node will try to salvage (rescue) data packets by sending them by some alternate path available in its route cache.

3.3.2 Packet Queuing over a Broken Link

If an intermediate node encounters a link failure, and that intermediate node does not has any alternate route in its route cache then data packets are buffered and queued on an intermediate node. Packets are buffered till a new route is not fond or original route is not restored or maximum buffer time out is not achieved.

3.3.3 Automatic Route Shortening

In DSR, for route shortening *"Gratuitous Route Reply"* mechanism is used. When an intermediate node receives a data packet and that intermediate node has any route shorter than the existing route (present in explicit source route header of that data packet) to destination node; then that intermediate node sends a *"Gratuitous Route Reply"* to source of the route with this new and batter route.

3.4 Characteristics of DSR

On behalf of detailed analysis of DSR some of major positive and negative characteristics are listed below.

3.4.1 Positive Characteristics

1. Less control overhead- Due to on demand nature of DSR, routes are maintained only between nodes which need to communicate.
2. Route caching- Due to route caching route discovery overheads are reduced. Route caching allows

multiple paths and due to existence of multiple paths load balancing can be performed.

3. Data Salvaging and Automatic Route Shortening.
4. Support for heterogeneous networks and mobile IP.
5. Flow state extension mechanism.
6. Packet queue over broken links.

3.4.2 Negative Characteristics

1. Due to source routing, packet header size grows with route length.
2. Stale (no longer fresh) route caches may lead to increase overhead.
3. DSR does not have mechanism for adaptive Quality of Service support (Resource Reservation and Resource management).
4. Route Reply Strom problem- Suppose for a specific destination, large number of intermediate nodes have route in their route cache, too many route replies come back to source. This may cause to Route Reply Storm problem. For example, in figure-1 source node A sends *RREQs* for finding destination node G. But all other intermediate nodes B, C, D, and E have route for G in their route cache, so all nodes would send *RREPs* to same route request on basis of their own route cache. This route reply storm may cause local congestion and packet collision.

   We can solve route reply storm problem by implementing random delay mechanism.

4. QoS aware Dynamic Source Routing (DSR) protocol

4.1 QoS Definition

Quality of Service is the ability to assure that a required bandwidth, end to end delay, packet loss probability and/or Jitter (delay variance) may be guaranteed. If not then Quality of Services will not be accepted. Quality of Service mechanism is used for resource reservation control for achieving predefined and certain service quality. For assigning different priorities to different applications/ services or to guarantee a minimum threshold value of performance to any data flow, we use Quality of Service mechanism. For example voice data has transmission priority on text data but packet loss ratio for text data must be less than to voice data.

In recent years some advanced routing protocols which are developed in MANETs are using QoS parameters as constraints (Layuan 2008; Jin 2007). As we know that DSR does not have mechanism for adaptive Quality of Service support (Resource Reservation and Resource management) (AbuHajar 2009).

4.2 Nature of Quality of Service parameter

In MANETs nodes are cooperative and intermediate nodes are participated in source to destination route formation. We know that in MANETs a given path is a collection of wireless links. Required QoS parameter on a given path can be calculated by one of the given ways depends on the nature and behaviour of the QoS parameter.

Additive- End to End delay is an additive Quality of Service parameter. As we know that end to end delay of a path is equal to the summation of delays at each link.

Multiplicative- Probability of packet loss P(u,v) for a packet to reach v from u is the product of packet loss probabilities at each intermediate, individual link

$P(u,v)= P_1(u,u_1)xP_2(u_{1,}u_2)x\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; xP_k(u_{k-1,}v)$

Concave/Minimum- Parameters like bandwidth, security and end to end reliability are concave parameters. Bandwidth along a path from u to v is minimum bandwidth along the links on the path.

It is proved that in multi hop environment; to consider a pair of two multiplicative or additive or one additive and one multiplicative constraint for satisfying QoS needs is NP Completeness problem. In normal practices for reducing combinatory explosion one concave constraint (like bandwidth) and one additive constraint (like end to end delay) or multiplicative constraint (like packet loss probability) are considered for QoS guarantee.

4.3 Proposed QoS parameter in QoS aware DSR

For comparing with DSR, we are proposing a QoS based routing protocol which will use minimum *End to End Delay and Bandwidth as QoS constraint* for selecting best path.

If two or more than two QoS constraints are used for ensuring QoS guarantee, sequential filtering approach is followed. In this approach first we try to find out all possible routes satisfying with any one of the QoS constraint and then applying remaining QoS constraints in sequential manner(one after another) on the given set of routes for satisfying with all QoS constraints. Like in our proposed protocol two QoS parameters Bandwidth and End to End delay are needed to be satisfied, so first we will find all possible routes with bandwidth more than minimum bandwidth required and now from this set we will find out a subset of only those routes which also satisfy maximum allowable end to end delay requirement.

5. Analysis and Comparison

In this section we will analysis the performance of DSR and compare it with QoS aware DSR. We have used ns-2(ns-2 2008) simulator to conduct extensive experiments. We perform this simulation on a small sample set of 25 and 50 nodes and we compare these routing algorithms on behalf of two performance evaluation parameters or performance metrics

- Packet Delivery Ratio
- End to End Delay

The simulation parameters or specifications are summarised in Table1.

For our simulation, we will use random waypoint model. In short, the random waypoint model considers nodes that follow a motion-pause recurring mobility state. Each node at the beginning of the simulation remains stationary for some pause time seconds, then chooses a random destination and starts moving towards it with speed selected from a uniform distribution (0, max speed]. After the node reaches that destination, it again stands still for a pause time interval and picks up a new destination and speed. This cycle repeats until the simulation terminates. The maximum speed of 10 m/sec and pause times of 0 seconds are considered for the purposes of this study.

5.1 Packet Delivery Ratio

Packet Delivery Ratio is the ratio of total number of data packets transferred to destination to total number of data send by source. Figure 2 and 3 depict comparison of PDR in DSR and QoS-DSR. The packet delivery ratio of QoS-DSR is better than DSR, which shows that the route to the destination in proposed scheme is more stable than DSR. QoS-DSR shows better performance due to guarantee of Quality of Service parameter, minimum bandwidth requirement.

5.2 End to End Delay

End to End Delay is the sum of all delays which are possible from source to destination. End to End delay includes queuing delay, processing delay and propagation delay. In results, shown in Figure 4 and 5, clearly due to QoS support QoS-DSR outperform DSR and QoS-DSR shows minimized End to End delays compare with DSR.

In all comparisons of DSR and QoS-DSR which are based on different performance metrics, simulation of 50 nodes (more dense network) indicate even better performance of QoS-DSR.

6. Conclusion

In this research paper, we have proposed a new search strategy for reactive route discovery which is based on two QoS parameters minimum bandwidth requirement and maximum allowable end to end delay. DSR routing protocol is used as a basis for implementing the proposed route discovery mechanism. Using Network Simulator II simulator, we compare the performance of the proposed approach (QoS-DSR) with existing routing protocol (DSR) in scenarios of increasing speed of node mobility. Proposed approach (QoS-DSR) exhibits reduced End-to-End delay while maintaining high Packet Delivery Ratio when compared to DSR.

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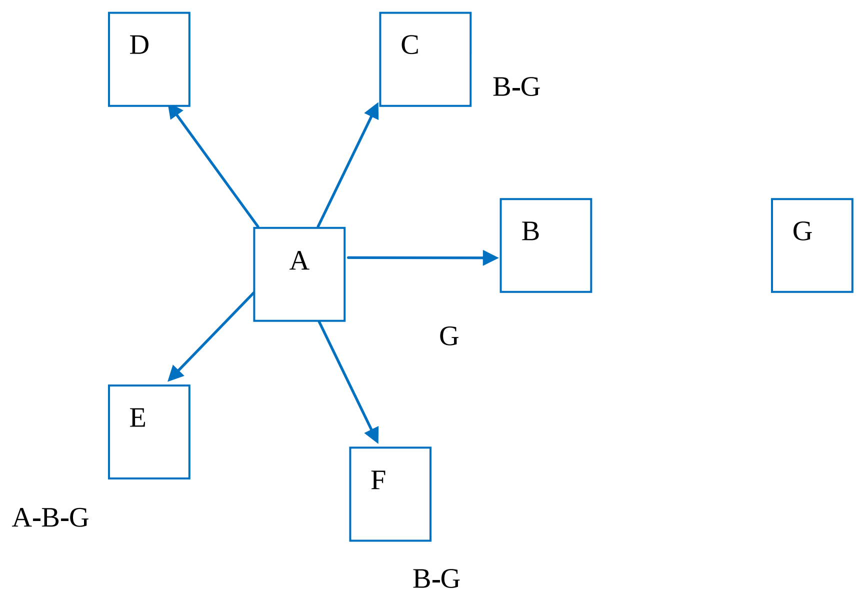

Figure 1- Route Reply Broadcast problem

Parameter	***Values***
Transmitter range	250 meters
Bandwidth	2 Mbps
IF queue length	50 frames
Simulation time	500secs
Pause time	0secs
Packet size	512 bytes
Topology size	500x500m
Number of nodes	25, 50
Maximum speed	10 m/sec

Table 1- Parameters used in the simulation

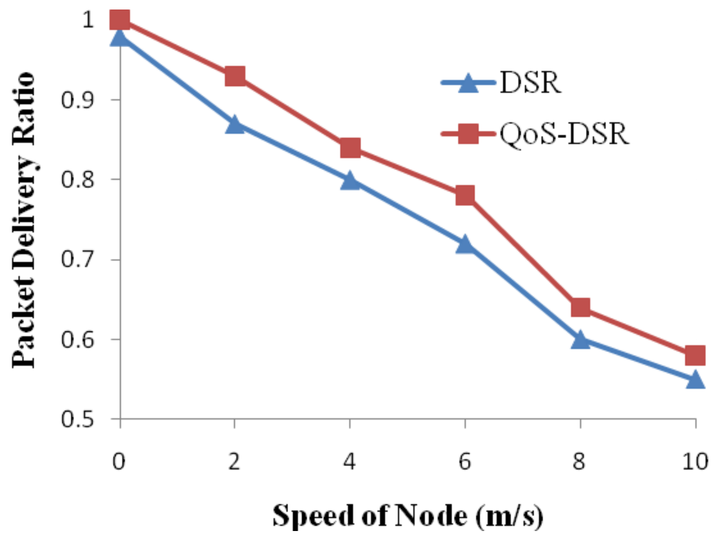

Figure 2- Packet Delivery Ratio for 25 nodes

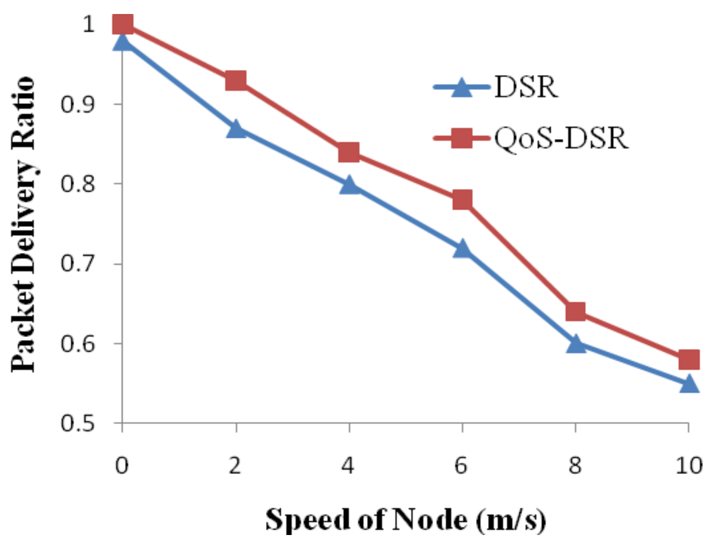

Figure 3- Packet Delivery Ratio for 50 nodes

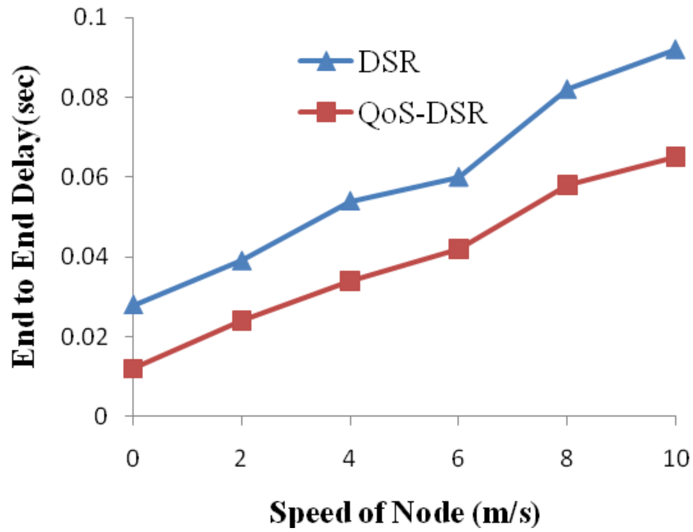

Figure 4- End to End delay for 25 nodes

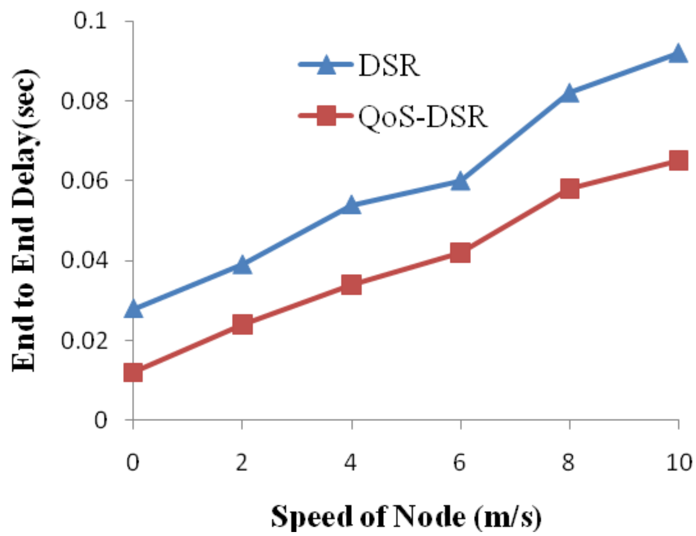

Figure 5- End to End delay for 50 nodes