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Quality of Service Model for Dynamic Source Routing Protocol

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Abstract: The aim of this paper is to propose a Quality of Service model for Dynamic Source Routing protocol (DSR) by adding extension related to bandwidth metric to its structure to support certain aspect of QoS capabilities. DSR protocol is a simple and efficient routing protocol designed specifically for use in multi-hop wireless ad-hoc networks of mobile nodes. It is an on-demand routing protocol that is based on the concept of source routing and composed of two phases: route discovery and route maintenance. To achieve this goal, the DSR Route Request control packet is modified by adding a new field that will be used to determine the acceptance level of available bandwidth. The mobile node must have to allow data traffics to pass through reaching the destination nodes. In order to test the proposed model, a simulation model is implemented using the Network Simulator (NS-2.28) and different scenarios were tested to see the performance of the modified protocol compared with the original DSR protocol. The results show that not all routes from source to the destination chosen by the DSR routing protocol are suitable for real time traffic transmissions, since there is no QoS considered in the routing protocol; whereas the DSR with QoS shows extremely good results, where the transmission delay is not desired. Also, pure DSR protocol consumes channel and node bandwidth due to large amount of routing packets generated to establishing routes and both protocols are operation well in low congestion network. Thus, from simulation results and analysis, it can be seen that adding QoS to routing protocol is meaningful to optimize the performance of traffic on the network; especially the real time traffic.

Key words: DSR . QoS . ad-hoc mobile network

INTRODUCTION

Wireless networks have received a great attention in scientific research labs since 1970s, as one of the military requirements of that time. This technology continues developing and its popularity increased after being feasible for civil usage. Wireless networks are classified into two types of networks: the first is infrastructure networks (also known as cellular networks), these networks are characterized by having fixed and wired gateways (also known as base stations or bridges) that are capable of establishing routes and routing data packets among communicating nodes, these gateways act as interface between wired environments and wireless environments. This type of technology can be used within offices and companies as Wireless Local Area Network (WLAN).

The second type is infrastructure-less networks (also known as Mobile Ad Hoc Networks, MANETs as abbreviation), these networks don't contains fixed infrastructure (wired links and routers), all node are free to move randomly in any direction with any speed and capable of organize themselves dynamically in an arbitrary manner, nodes of these networks act as a router, responsible for discovering, establishing and maintaining routes among communicating nodes.

Applications of this type of networks can be used in conferences, meetings, emergency search, rescue operations and disaster recovery which users need to exchange information quickly without a central administration and infrastructure environment exit. A Mobile Ad Hoc Network (MANET) is an interconnected system of wireless nodes which communicate over bandwidth-constrained wireless links, such these networks have special Characteristics differentiated from other types of networks. Some of these characteristics were inspired by MANET working group under RFC 2501 [1] such as MANET doesn't have a centralized infrastructure, dynamic topologies, bandwidth constrained (variable capacity links), energy constrained operation and limited physical security.

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MANETs such as a new technology has great features and Characteristics and its application become increasable day by day, but it still face some challenges and limitations that prohibit it. Chong *et al*. (2006) explained the first two limitations [2] and remains mentioned in RFC 2501 [1] such as throughput drop due to more number of hops construct the path between two communicating mobile nodes or due to increasing mobility of mobile nodes and frequent topology changes, delay, security risks and limited battery power. This paper investigates a new QoS model for the Dynamic Source Routing protocol. A simulation model will be implemented to simulate the new model. The simulation results will be compared with DSR to show performance enhancements.

This paper is organized as follows. In the following section, a briefly review of literature work are presented, then some details will be mention about Dynamic Source Routing protocol that will be used in the study and Quality of Service: definitions, performance metrics, models and its benefits, after that the proposed model will be discussed, then the simulation model and the performance metrics used to differentiate between the original protocol and the modified protocol, then simulation results and its interpretation will be shown, summary, conclusions and suggested future work will be presented.

LITERATURE REVIEW

Significant work has been done to study the mobile ad hoc wireless environment along with its routing protocols that operate in this environment to discover many stochastic features such as its characteristics, capabilities, advantages, disadvantages, the operation behaviors and its application areas. Instance of these researches aimed at developing and enhancing the routing protocols like adding certain Quality of Service issues to its operation mechanism to satisfy the requirements of certain application like real time services and others. Although of the necessity of QoS in ad hoc networks, a few QoS relevant works are done due to the challenges of implementing QoS in ad hoc networks as will be described later, however, some of the efforts were carried out as its shown bellow:

Hwa-Chun Lin and Ping-Chin Fung [3] proposed a new method for finding the available bandwidth of a path in multi-hop mobile wireless networks. The proposed method finds the link with minimum current bandwidth and increases its bandwidth. The process is repeated until the bandwidth of the link with the smallest current bandwidth cannot be increased. Then the available bandwidth of the path is found to be the minimum of the current bandwidths of the links along the path. Simulations are performed to compare the performance of the proposed method and that of the method which calculates the path bandwidth hop by hop. The simulation results show that using the proposed method produces significantly lower call blocking ratio than the method which calculates the path bandwidth hop by hop.

Perkins [4] proposed a QoS version for AODV routing protocol. The main idea of making AODV QoS-enabled is to add extensions to the route messages (RREQ, RREP) during the phase of route discovery. A node which receives a RREQ with a quality of service extension must be able to meet the service requirement in order to either rebroadcast the RREQ (if doesn't have an updated route in its cache), or unicast a RREP to the source. If after establishment of such a route, any node along the path detects that the requested Quality of Service parameters can no longer be maintained, that node must originate an ICMP QOS LOST message back to the source (that had originally requested the now unavailable parameters).

Chunhung Lin [5] have presented an admission control over an on-demand routing protocols. The proposed model is more powerful in the resource managements, during the route discovery process, the route request packets are used not only to find paths between the source-destination pairs, but also to calculate bandwidth hop-by-hop. If there is no enough bandwidth to satisfy the bandwidth requirement at any intermediate node, the route is dropped. When the RREQ packet arrives at the destination, the route piggybacked on the RREP packet must have satisfied the end to end bandwidth requirement. However, the route may not be the shortest in hop length. In the route reply process, the route reservation is made hop-by-hop backward from the destination to the source. The admission control can be applied to two important scenarios: multimedia ad-hoc wireless networks and multi-hop extension wireless ATM networks.

Liao Wen-Hwa [6] proposed a TDMA-based bandwidth reservation protocol for QoS routing in MANETs by assuming a common channel shared by all hosts under a TDMA (Time Division Multiple Access) channel model. Existing solutions have addressed the problem by assuming a stronger multi-antenna model, where the bandwidth of a link is independent of the transmitting/receiving activities of its neighboring links, or a less stronger CDMA-over-TDMA channel model, where the use of a time slot on a link is only dependent of the status of its one-hop neighboring links. The proposed mechanism toke into accounts the difficulties of hidden-terminal and exposed-problems when establishing a route, so more accurate route bandwidth is calculated.

Shan Gong [7] gives solutions and summarized some existing schemes for QoS aware routing protocols for MANETs by considering two important metrics: data rate and delay. Evaluations are presented by doing simulations using NS-2.27 with both QAODV and AODV routing protocols. Different data rates and moving speeds are tested in order to see the performance of two simulated protocols. The results show that the QAODV outperforms the AODV in terms of end to end delay when traffic on the network is high. Also founds that when the network begins to be saturated, the route discovery and maintenance process become more important.

DYNAMIC SOURCE ROUTING PROTOCOL

The Dynamic Source Routing (DSR) protocol presented by Johnson and Maltz [8], it is an on-demand routing protocol that is based on the concept of source routing. Mobile nodes are required to maintain route caches that contain the source routes of which the mobile is learn. Entries in the route cache are continually updated as new routes are learned.

The protocol consists of two major phases: route discovery and route maintenance. When a mobile node has a packet to send to some destination, it first consults its route cache to determine whether it already has a route to the destination. If it has an unexpired route to the destination, it will use this route to send the packet. On the other hand, if the node does not have such a route, it initiates route discovery by broadcasting a route request packet. This route request contains the address of the destination, along with the source node's address and a unique identification number.

Each node receiving the packet checks whether it knows of a route to the destination. If it does not, it adds its own address to the route record of the packet and then forwards the packet along its outgoing links. To limit the number of route requests propagated on the outgoing links of a node, a mobile only forwards the route request if the request has not yet been seen by the mobile and if the mobile's address does not already appear in the route record.

Route replies are generated when either the route request reaches the destination itself, or when it reaches an intermediate node which contains in its route cache an unexpired route to the destination. By the time the packet reaches either the destination or such an intermediate node, it contains a route record yielding the sequence of hops taken. If the node generating the route reply is the destination, it places the route record contained in the route request into the route reply. If the responding node is an intermediate node, it will append its cached route to the route record and then generate the route reply. To return the route reply, the responding node must have a route to the initiator. If it has a route to the initiator in its route cache, it may use that route. Otherwise, if symmetric links are supported, the node may reverse the route in the route record. If symmetric links are not supported, the node may initiate its own route discovery and piggyback the route reply on the new route request.

Route maintenance is accomplished through the use of route error packets and acknowledgments. Route error packets are generated at a node when the data link layer encounters a fatal transmission problem. When a route error packet is received, the hop in error is removed from the node's route cache and all routes containing the hop are truncated at that point. In addition to route error messages, acknowledgments are used to verify the correct operation of the route links. Such acknowledgments include passive acknowledgments, where a mobile is able to hear the next hop forwarding the packet along the route.

QUALITY OF SERVICE

The term QoS (Quality of Service) is a common thing describe the performance level of services provided and according to RFC 2386 [9] it is a set of service requirements to be met by the network while transporting a packet flow from the source to the destination and control the relationship between the users and the Internet Service Provides (ISPs) which guarantee a set of measurable pre-specified services to the user in terms of end-to-end network delay, delay variance, bandwidth available and probability of packet loss, etc.

Most ad hoc routing protocols that exist today set up routes with little or no consideration for the actual traffic flow requirements in terms of minimum session delay, minimum bandwidth, jitter etc. Much research is being carried out today to deal with the growing use of multimedia applications and the small degree of tolerance these applications demand.

Depending on the nature of the application, the QoS parameters could include available bandwidth, end-to-end delay, variation in delay (jitter), packet loss, etc. These applications put more demand on the routing protocol being used within a wireless ad hoc network. Multi-hop paths between mobile nodes isn't enough, valid routes are only selected if they provide the QoS constraints required by the application. The discovered routes can only be considered if they provide guarantees of the QoS parameters, such as bandwidth required by the application.

QoS differ from application to application. For example, for multimedia applications, the data rate and delay are the key factors, whereas, in military use, security and reliability become more important. If considering QoS required by emergency cases such as rescue, the key factor should be the availability. In sensor networks, battery life and energy conservation would be the prime QoS parameters. Ad hoc networks differ radically from the conventional wired or cellular networks. The characteristics of these networks make the task of providing QoS guarantees in these networks extremely difficult. Some of these difficulties are well known and well pointed out in many papers like [10] such as unpredictable network topology, scarce radio bandwidth, limited battery power and synchronization effects.

QOS MODEL FOR DSR PROTOCOL

DSR currently provides no control with respects to the quality of service of the routes it establishes between the source node and the destination node. The nature of reactive ad hoc routing protocols is to provide routes when requested, reducing the need for periodic updates of all possible routes between current nodes and thus keeping unnecessary overheads to a moderate level. With some extensions to the existing DSR routing protocol, paths can be found which satisfy certain desired Quality of Service parameters. Some fundamental extensions have to be applied to the current DSR routing protocol in order for the QoS-DSR protocol to handle all cases during route establishment, route failure. The QoS-DSR model proposed in this paper will be simulated using Network Simulator 2 along with DSR that already implemented to show which one can provide best effort service in certain environment. These main steps of the QoS-DSR model are explained in details in the following subsections.

QoS-DSR route request packets extension: The normal DSR Route Request (RREQ) is illustrated in Fig. 1 below [11]. The QoS-DSR RREQ packet has all the fields required during the route request stage of the routing protocol like normal DSR protocol with a field that contains the desired bandwidth. So to achieve this, a new field will added in the RREQ packet, this field can be used for any user specified QoS parameters. To include the user defined minimum data traffic-Quality of service parameters-the DSR RREQ packet is modified. Such adding a field within the normal DSR RREQ packet is used to carry the information during the route establishing process. This extended version of DSR RREQ will be referred as QoS-DSR RREQ packet, Fig. 2. All the remaining fields within the QoS-DSR RREQ packet are exactly the same as the DSR RREQ with the same functions.

QoS-DSR route establishment: To describe how the QoS-DSR works, consider a scenario in which a mobile node, S wishes to communicate with another mobile node D. If node S has no valid path(s) to D in its routing table, then a route request is initiated. Node S broadcasts the extended DSR RREQ packet to its neighbors. Upon receiving these RREQ packets, the intermediate nodes (n_1, n_2, n_j) compare the RREQ QoS bandwidth field value, within the RREQ packet, say, x kbps with their Node Bandwidth Capacity, (NBC) kbps. If these intermediate nodes are already engaged in other traffic sessions (either acting as traffic source nodes or as routers, forwarding data packets) then their total available bandwidth capacity will vary. The nodes which cannot accommodate the user specified minimum bandwidth, x kbps, the 'busy' nodes, will discard the RREQ and not broadcast further. The nodes which do satisfy the bandwidth requirement, broadcast the RREQ to their neighbors. To summaries, all the intermediate nodes (n1, n2,..nj) along the valid QoS-DSR path are selected if they can support the QoS-minimum required session bandwidth x kbps:

QoS-valid intermediate nodes: n1, n2,..nj if the following condition is satisfied:

NBCn1 kbps > x kbps
NBCn2 kbps > x kbps
..
NBCnj kbps > x kbps

where NBCn kbps is the Node Bandwidth Capacity of node n

CASE STUDY

The following example illustrates the idea and shows the difference between DSR and QoS-DSR routing protocols during operation mode. Given a wireless network consists of eight mobile nodes, each node has a transmission range equal 250 meter and the line between two nodes means each node be in the other carrier sensing range, which means that these two nodes begin to share the same channel. There are three traffics as shown in the table 1, how would each routing protocol behave now?

Table 1: Example showing differences between DSR and QoS-DSR

Traffic			
Flow direction	Duration	Required BW [kbps]	Traffic type
Node4→Node3	1.2 sec→20 sec	2.5	CBR
Node1→Node5	3.0 sec→20 sec	1.5	CBR
Node0→Node5	4.0 sec→20 sec	3.0	CBR

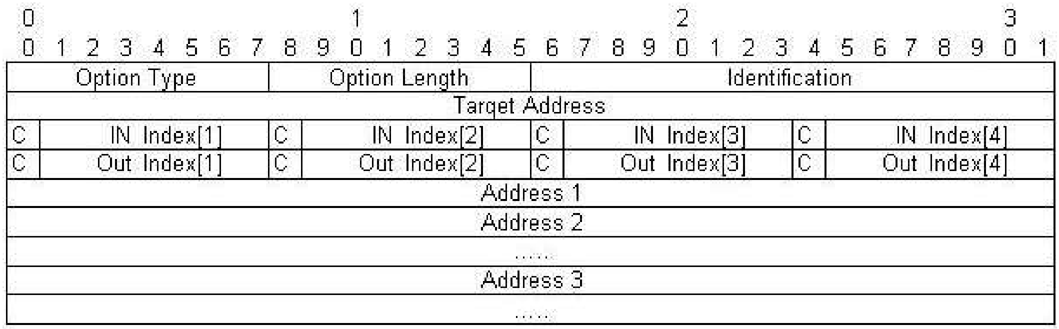


Fig. 1: RREQ packet before adding QoS field

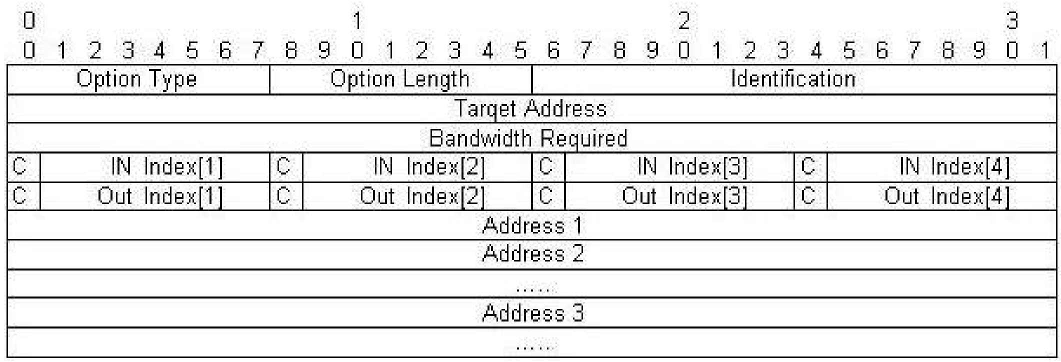


Fig. 2: RREQ packet after adding QoS field

If DSR protocol is used to manage routing in the network-where are no QoS requirements-flow [Node4→ Node3] will establish a route {4-2-3}, also flow [Node1→Node5] will establish a route {1-2-5} and flow [Node0→Node5] will establish a route {0-2-5}. If QoS-DSR protocol is used to manage routing in the network, where there are QoS requirements. Assume total node available bandwidth capacity equal to 5 kpbs as example. At 1.2 sec node 4 send a RREQ message searching for a path to destination node 3, node 2 accept the request because its satisfy QoS and establish a route {4-2-3} and its bandwidth capacity become 5-2.5 = 2.5 kbps and still 2.5 kbps available. The same procedure is done for the second flow [Node1→ Node5] where it establish a route {1-2-5}, now its bandwidth capacity become 2.5-1.5 = 1 kbps after accepting the second flow. But flow 3 is rejected by node 2 because it doesn't have enough bandwidth to satisfy the request. So its continue searching until it accepted by the destination through the route {0-1-4-6-5}. Notice when DSR protocol is used the number of hops maintained for flow 3 is equal 2, where in QoS-DSR the number of hops increases to 4.

SIMULATION MODULE

Simulation environment: Simulation was done with Network Simulator version NS-2.28 [12]. The software was installed on personal computer with the following specifications: Pentium IV 2.5 GHz, 256 KB cache, 256 MB of main memory and KLinux kernel 2.4.22 as operating system. The simulation parameters used in NS-2.28 during the Ad Hoc network simulation are configuring as follow: the channel type is wireless channel, the radio propagation model is Two Ray Ground and MAC layer based on CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance).

Routing protocols will be simulated are DSR and QoS-DSR, both protocols maintain a send buffer of 64 packets. It contains all data packets waiting for a route, such as packets for which route discovery has started, but no reply has arrived yet. To prevent buffering of packets indefinitely, packets are dropped if they wait in the send buffer for more than 30s. All packets (both data and routing) sent by the routing layer are queued at the interface queue until the MAC layer can transmit them. The interface queue has a maximum size of 50 packets and is maintained as a priority queue with two priorities each served in FIFO order. Routing packets get higher priority than data packets. These options are according to research done by Perkins Charles et al, (2001) about comparison of two on-demand routing protocols AODV and DSR [13].

Traffic and mobility scenarios models: Traffic and mobility models used were similar to those previously

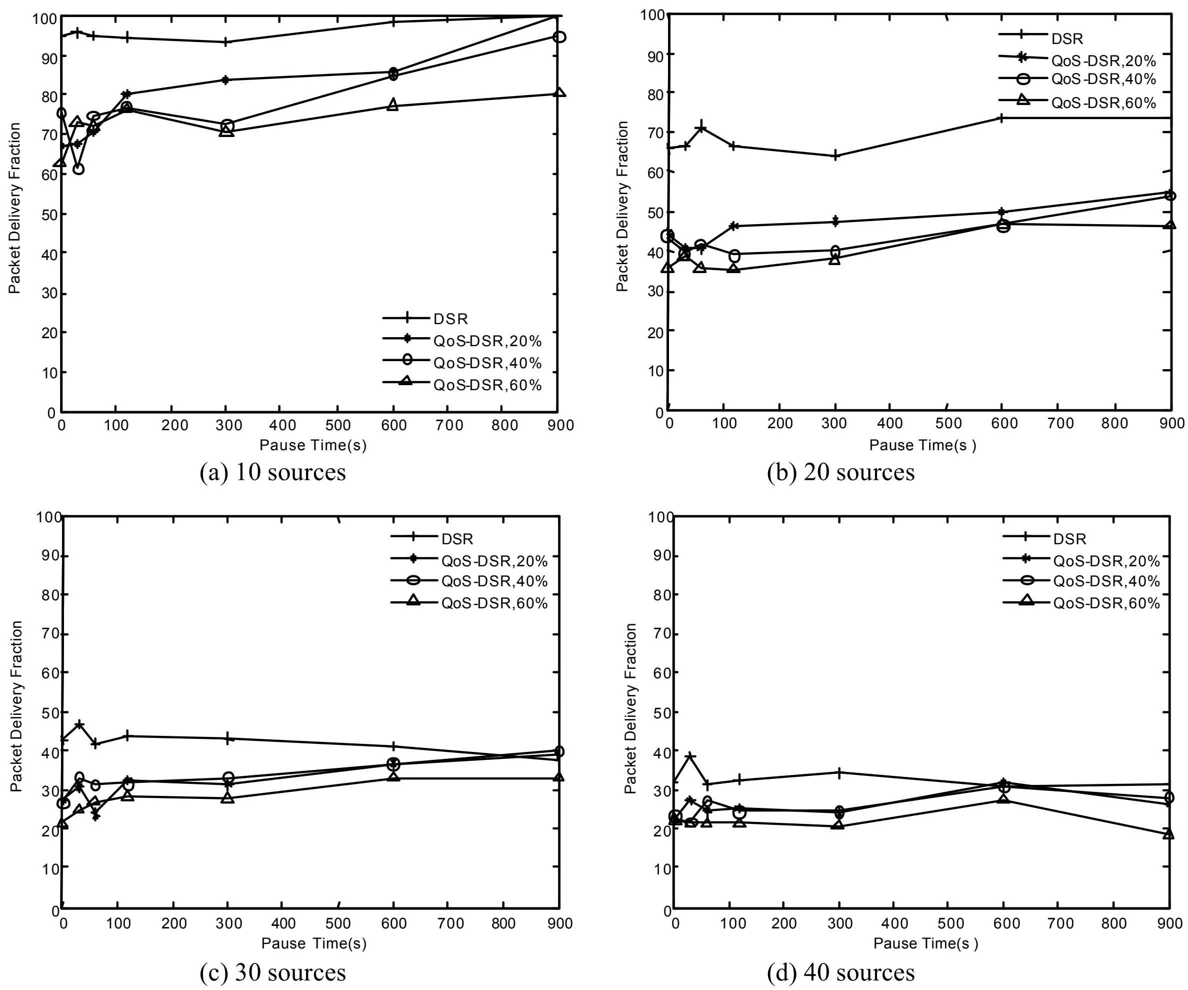


Fig. 3: Packet delivery fractions for the 50-nodes model with various numbers of sources

reported using the same simulator by Broch [14]. Traffic sources are continuous bit rate (CBR). The source-destination pairs are spread randomly over the network. Only 512 byte data packets are used. The number of source-destination pairs is varied to change the offered load in the network. The mobility model uses the random waypoint model [14] in a rectangular field that used by Broch J. and *et al*., (1998). Here, each packet starts its journey from a random location to another random destination with a randomly chosen speed uniformly distributed between 0-20 m/s equivalents to 0 km/hr to 72 km/hr in practical life. Once the destination is reached, another random destination is targeted after a pause. The pause time is varying, which affects the relative speeds of the mobiles. Simulations are run for 900 simulated seconds for 50 nodes. Each data point represents an average of several runs with identical traffic models, but different randomly generated mobility scenarios. Identical mobility and traffic scenarios are used across two protocols.

Simulations ran with movement patterns generated for 7 different pause times: 0, 30, 60, 120, 300, 600, 900 seconds. A pause time of 0 seconds corresponds to continuous motion and a pause time of 900 (the length of the simulation) corresponds to no motion. The simulation will be done using node movement speeds 20 m/s, each run have either 10,20,30,40 sources sending 4 packets per second. In order to enable direct, fair comparisons between the protocols, it was critical to challenge the protocols with identical loads and environments conditions. Each run of the simulator accepts as input a scenario file that describes the exact motion of each node and the exact sequence of packets originated by each node, together with the exact time at which each change in motion or packet origination is to occur.

Performance metrics used: Even though DSR protocol and DSR with QoS share similar structure and behavior, some differences in the protocol mechanism in satisfying certain requirements can lead to significant performance differentials, the performance differentials are analyzed using varying network load and mobility. This part discusses the performance metrics that will be used to judge the performance of the DSR and the QoS-DSR routing protocols. Some explanation for each performance metric will be given here.

Packet delivery fraction: It is the ratio of data packets delivered to the destinations to those generated by the sources. In general, a routing protocol is better if the packet delivery fraction is high. The packet delivery fraction describes the loss rate, which shows the maximum throughput the network can support.

Routing overhead: The total number of routing packets transmitted during the simulation. Routing packet are including route discovery, route reply and route error, both sending and forwarding are counted. Routing overhead is an important metric for comparing routing protocols, as it measure the scalability and the efficiently of the protocol, its performance in congestion or low bandwidth environments and its efficiency of consuming node battery power. Protocols that send large numbers of routing packets can also increase the probability of packet collisions and may delay data packets in network interface transmission queues.

Normalize routing load: It is the number of routing packets sent per one packet delivered at the destination. In general, a routing protocol is better if the normalized routing load is low.

Drop packets: Packets are drop due to two possible causes: from packet buffer for timeout because there no route established and from packet buffer for overflow because buffer overflow.

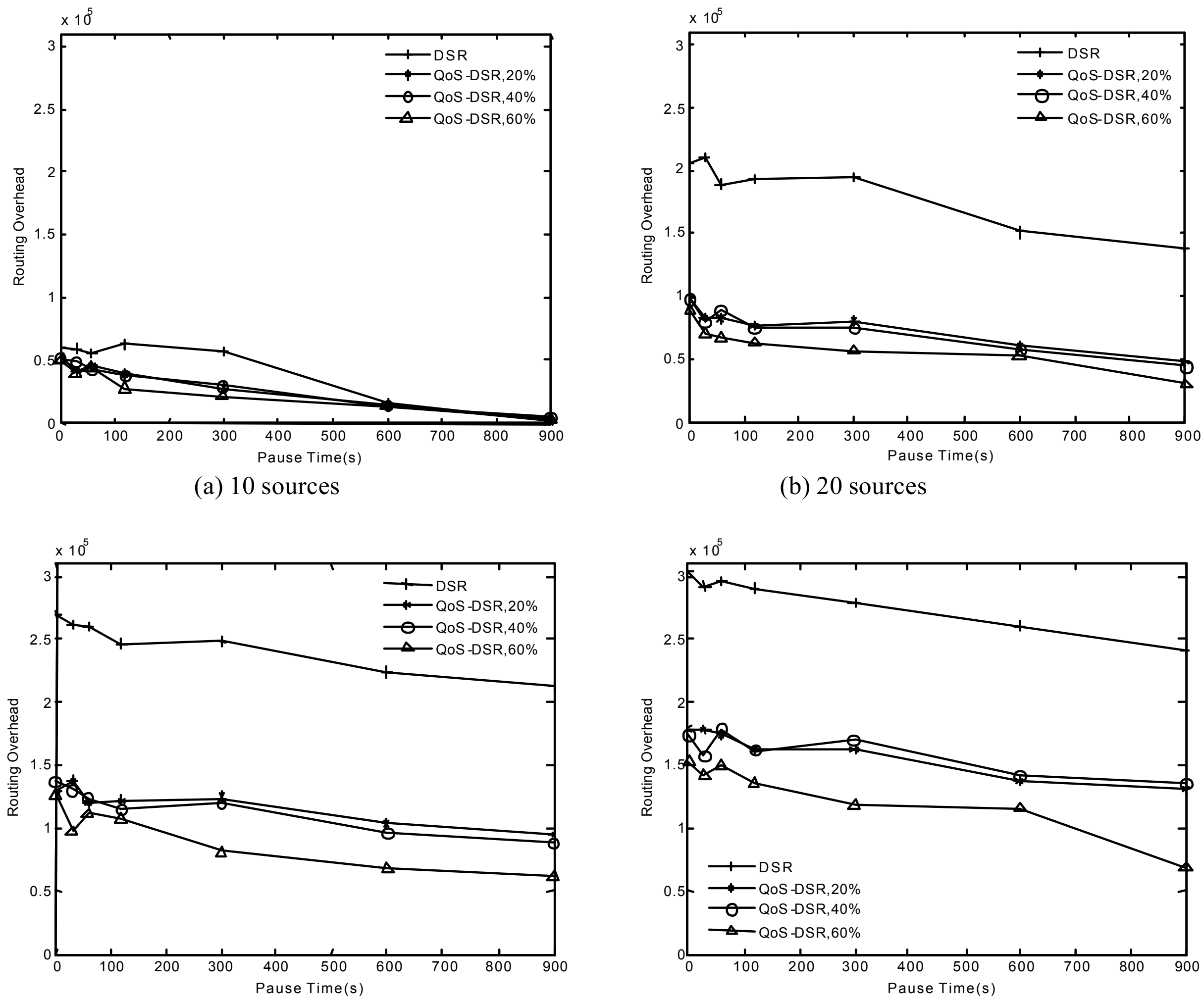
Drop bytes: Also dropped packet can be handling in a byte unit.

Throughput: Throughput is the rate at which a computer or network sends or receives data. It therefore is a good measure of the channel capacity of a communications link and connections to the internet are usually rated in terms of how many bits they pass per second (bit/s), in other words throughput is the amount of data that is transferred over a period of time. Example: If over ten seconds, twenty packets are transferred then the throughput would be 20/10=2 packets per second.

Average end to end delay: It is the duration of the time a packet travels from the application layer of the source to the destination. The end-to-end delay calculates the delay of the packet which is successfully transmitted from the source to the destination. This end-to-end delay includes all possible delays caused by buffering during route discovery latency, queuing in the interface queue, retransmission delays at the MAC, propagation and transfer times. In general, a routing protocol is better if the end-to-end delay is small. End-to-end delay is one of the most important metrics when analyzing the performance in QoS aware routing protocols. End-to-end delay evaluates the ability of the protocol to use the network resources efficiently. The average end-to-end delay is averaged out of all the end to end delay of successfully transmitted packets. Note that some of metrics aren't totally independent of each other. As the network size increases, longer routes must be established and maintained, which increases the probability of a packet drop. This means less sample packets for the end-to-end delay evaluation. The existing samples will even be biased in favor of shorter route lengths, which cause a decrease in measured end-to-end delay. Note: Figures for each group are plotted on the same x, y scale to simply making comparisons among figures.

Simulation results and analysis

Packet delivery fraction details: Figure 3 shows four subfigures about packet delivery fraction. In Fig. 3a, where there are 10 mobile nodes transmitting data to destinations nodes, the packet delivery fraction value for DSR protocol is 95% at high mobility and its reach to a value near to 100% at no mobility. The same behavior is occurring for DSR protocol with different levels of QoS implemented but with lower values. For instance, at pause time 0 second (high mobility) the value of packet delivery fraction located between 60-80% and this value increase at low mobility at pause time 900 seconds. In Fig. 3b, where there are 20 sources, the packet delivery fraction value reduces to 65%. This value is increase and decrease at intermediate values of mobility. For DSR protocol with different levels of QoS the packet delivery fraction located between 35-45% at high mobility and continues light increasing to reach a higher value at mobility stability mode. In Fig. 3c, where there are increasing in the number of traffic sessions about 30 sources, the packet delivery ratio value is 42% at pause time 0 second and the curve of DSR protocol save its trends, but for other levels of QoS its packet delivery ratio value between 20-30% and continue increasing in light way to reach a higher value when the mobility is go out. In Fig. 3d, at high congestion network, where 40 traffic sources are found, the curve for DSR protocol is the similar with its corresponding in 30 sources are used but with a lower scale, but other DSR with different levels of QoS nearly save its behavior. To summarize, when the number of sources are low as in Fig. 3a, both protocols DSR with QoS and without QoS extensions



(a) 10 sources (b) 20 sources

(c) 30 sources (d) 40 sources

Fig. 4: Routing overhead for the 50-nodes model with various number of sources

delivering data in efficient way because the network is not congested due to low number of flows originated thus leading to available routes. This ratio is reducing gradually while number of sources is increased. But why DSR with 60% QoS is frequently the lowest packet delivery ratio?, this due to its ask a hard request, where only one flow can pass through any node, so the dropped packets are increases and the sources that uses this protocol deliver small a mount of data traffic to the identified destinations.

Routing overhead details: Figure 4 shows the number of routing protocol packets are transmitted during the simulation period. A general overview on figures tells that there is a straight increasing in routing packets send, this return to the increased numbers of nodes transmitting. In sub Fig. 4a-4d DSR protocol generates a mount of routing packets when the mobility is high (0 pause time means that nodes doesn't still for any seconds, it always moving), this a mount is reduce to the lowest value when the mobility is very low or no mobility (900 pause time means that nodes are stationary all the simulation duration). What a bout DSR protocol with certain level of QoS? Also it act with the same behavior in there is a continues increasing in a mount of routing packets produced and generate a higher a mount of routing packets in high mobility and low a mount in low mobility. Also in DSR with 20% QoS and DSR with 40% QoS, it’s a mount of routing packets is relatively high like the same normal DSR because the constrained applied is poor, rather than DSR with 60% QoS where is the lowest curve in the curves because each node accept one flow and other flow are dropped.

Normalize routing load details: In Fig. 5a, where 10 sources there, the normalize routing load for pure DSR about 2.2, this value in increase to 4.8, 6.3 and 7 for 20,30,40 respectively at pause time 0 second, but for DSR with different levels of QoS have low values

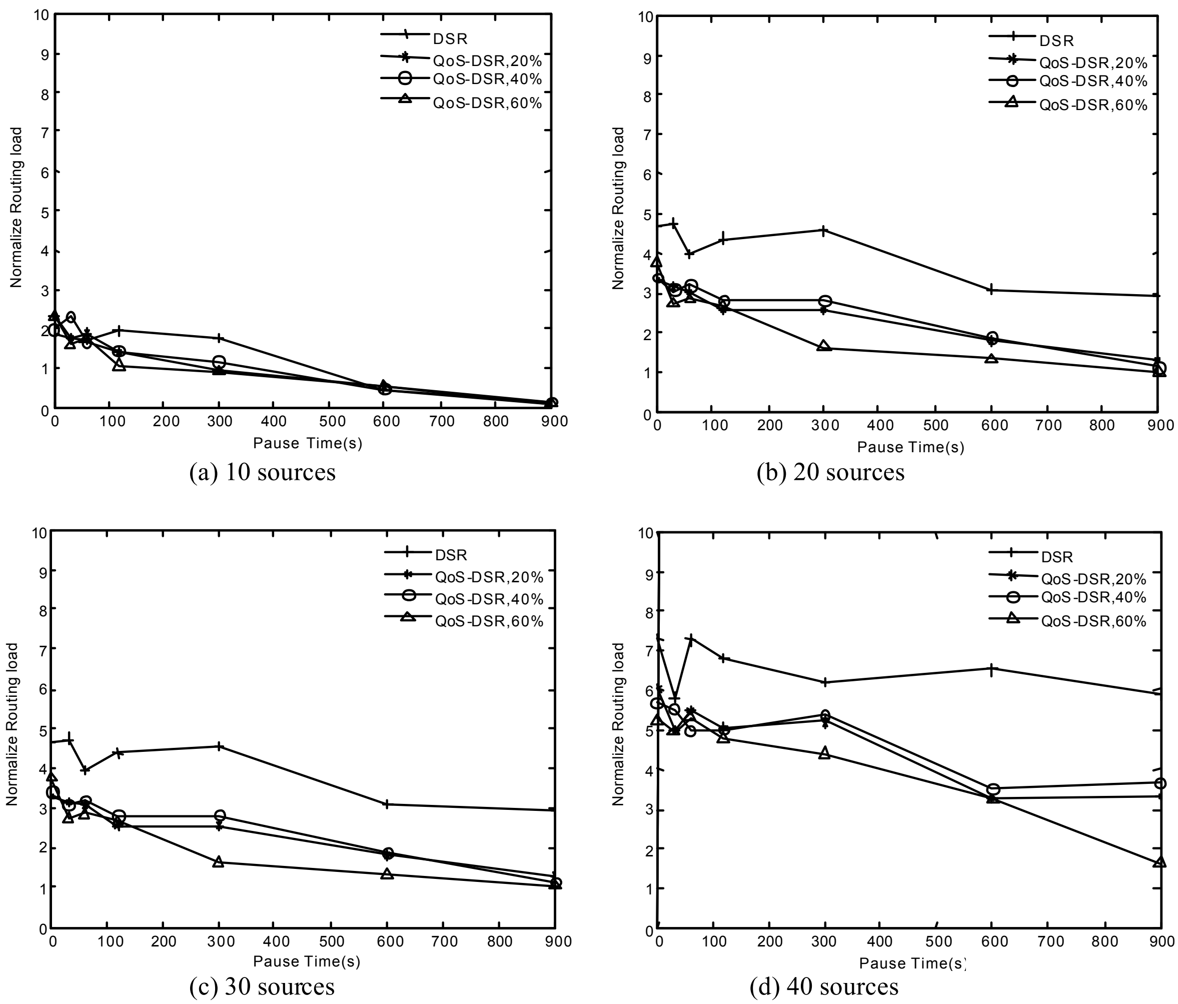
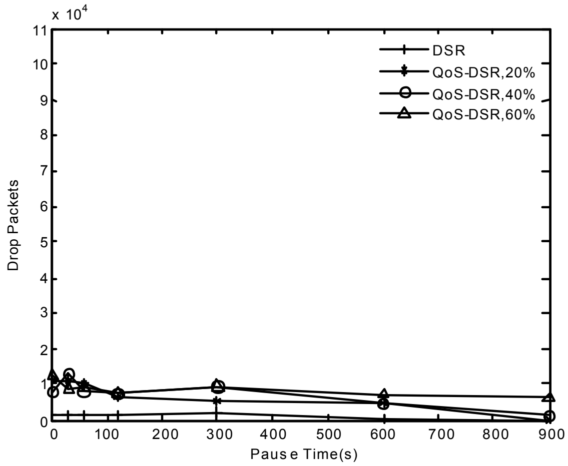


Fig. 5: Normalize routing loads for the 50-nodes model with various number of sources

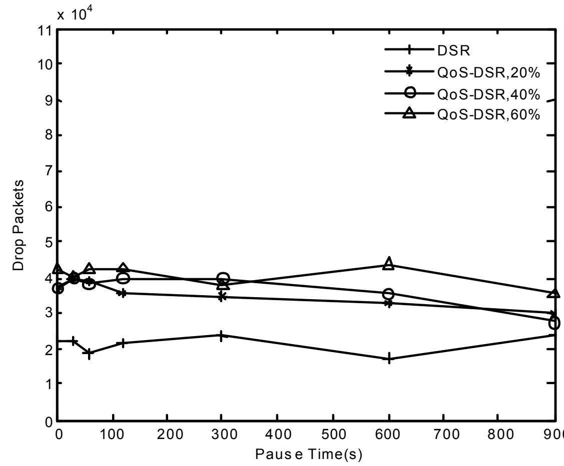
relative to normal DSR without modifications. Along with minimizing the mobility level of mobile nodes, the normalized routing load for DSR protocol is increase also. For instance, the normalize routing load for DSR at 300 pause time is 2, 4.6, 6, 6.5 for 10, 20, 30 and 40 sources respectively, while the corresponding values for DSR with 40% QoS is 1.1, 2.8, 4, 5.1 for 10, 20, 30, 40 traffic flows respectively.

In all cases, DSR demonstrates significantly higher routing load than DSR with QoS extensions and its normalized routing load is fairly stable in increasing along an increasing number of sources, due to no restrictions applied on route request RREQ. A relatively stable normalized routing load is a desirable property for scalability of the protocols, as this indicates the actual routing increases linearly with the number of sources. This means that DSR protocol do its best effort to conduct data to receiver destination, but when there are some constrains on the request, a low a mount of routing packets will be delivered to destination due to the large number of request is dropped because its doesn't satisfy the conditions in the route request packet.

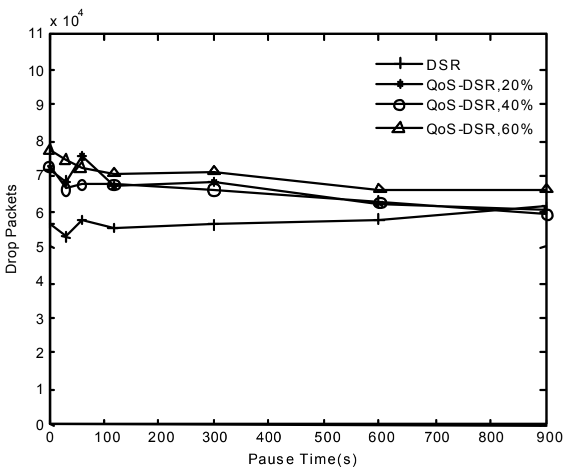
Drop packets details: Drop packet is an important metric for evaluating protocols in wireless environments. Figure 6 present drop packets across DSR protocol plus its QoS extensions. In Fig. 6a where 10 sources are used, the number of drop packets for DSR protocol is small about 2000 packets compare to other DSR with different levels of QoS about 10000 at pause time zero second, the number of drop packets continue to reducing until it reach the least value for both protocols. The situation is differ something when the number of traffic sources 20, where at pause time 0 the drop packet for DSR is about 22000 packets while in the same time slot for other protocol it reach near 40000 packets. These values reduce while the level of mobility is minimized.



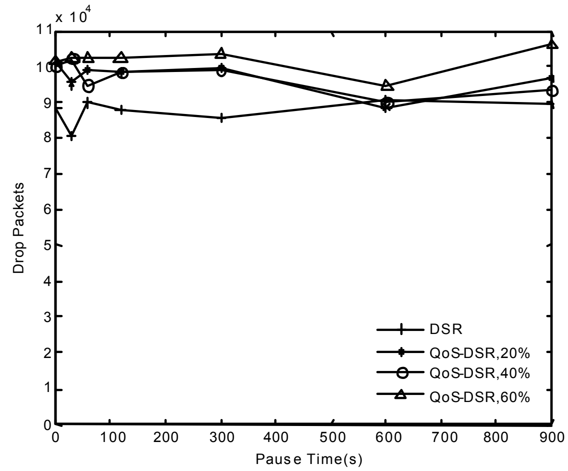
(a) 10 sources



(b) 20 sources



(c) 30 sources



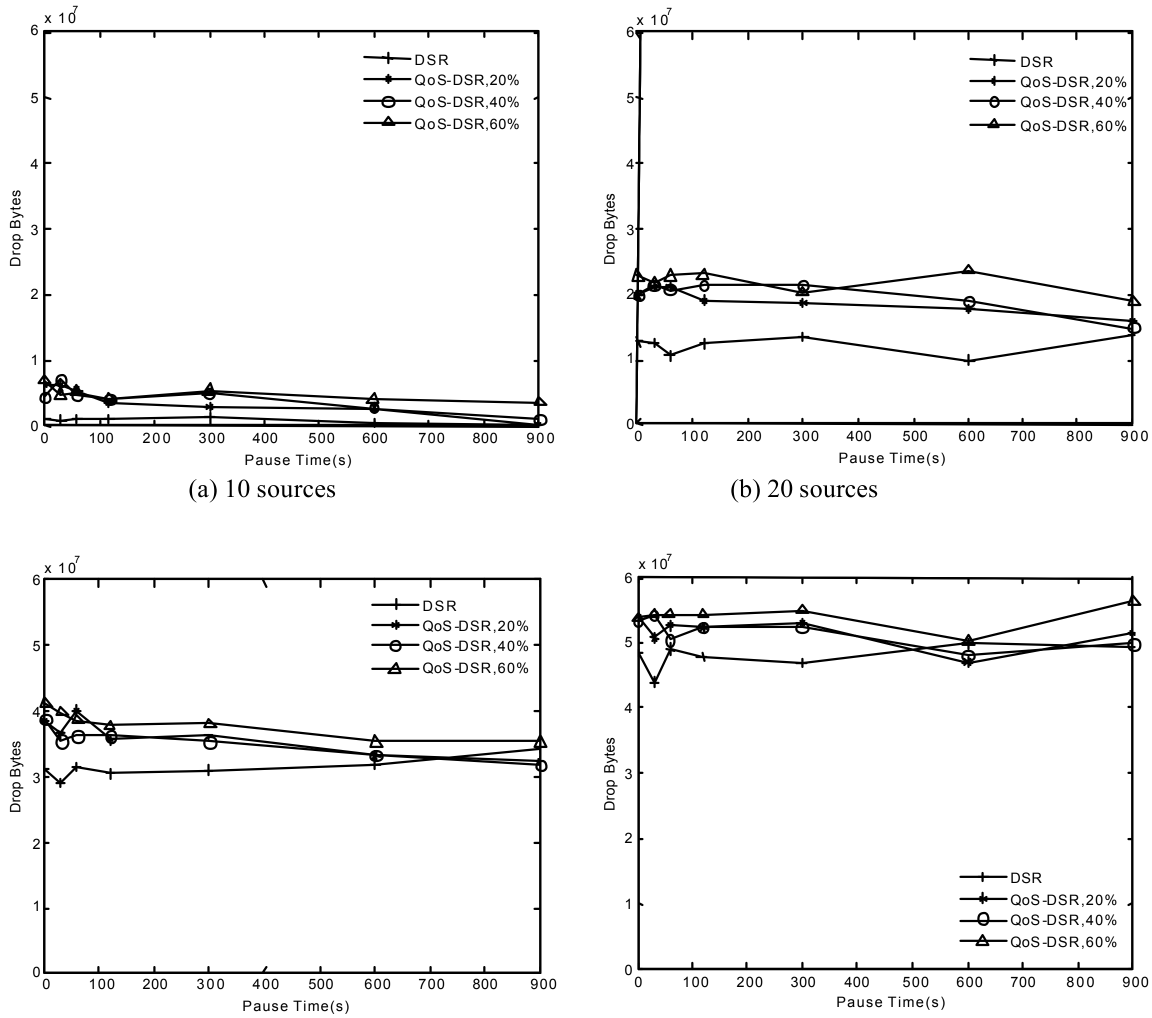
(d) 40 sources

Fig.6: Drop packets for the 50-nodes model with various number of sources

There is high increasing in the value of drop packets for situation where the number of sources increases as shown in Fig. 6c, 6d. To summarize, the value of dropped packet is relatively small when the traffic sources number are limited as shown in Fig. 6a for both protocols. When the number of flows increase there is a straight increasing in drop packets. But there is something a new differ here which DSR has the smallest value for dropped packet and DSR with 60% QoS is the highest value of dropped packets, this due to constrains and restriction applied on the route request, where in normal DSR, there is a request doesn't need any certain constrain.

Drop bytes details and throughput details: Drop bytes fellow the behavior of dropped packets, but the differences located in the value of bytes is greater than the value of packets dropped, as it's shown in Fig. 7. Regarding throughput metric, normal DSR provide a higher throughput than DSR with QoS. Another thing the throughputs are stable for all simulated protocols. In Fig. 8a throughput of DSR protocol is stable about 150 kbps and this value in increase to reach average of 200 kbps for other sources numbers. Also throughput of DSR with QoS relatively is stable, its average 125 kbps at 10 sources and this value increase to reach 150 kbps for other sources

Average end to end delay details: Figure 9 show the average end to end delay, each data point represented is accumulative value for all packets delivered to the destinations of all traffic sessions. In Fig. 9a all protocols share the same values, this due to small number of sources that transmit packets. When number of sources increases the end to end delay for DSR protocol increase in high fashion due to a high level of traffic transmission and every node accept and handle each flow passes from it, thus this flows takes high



(a) 10 sources (b) 20 sources

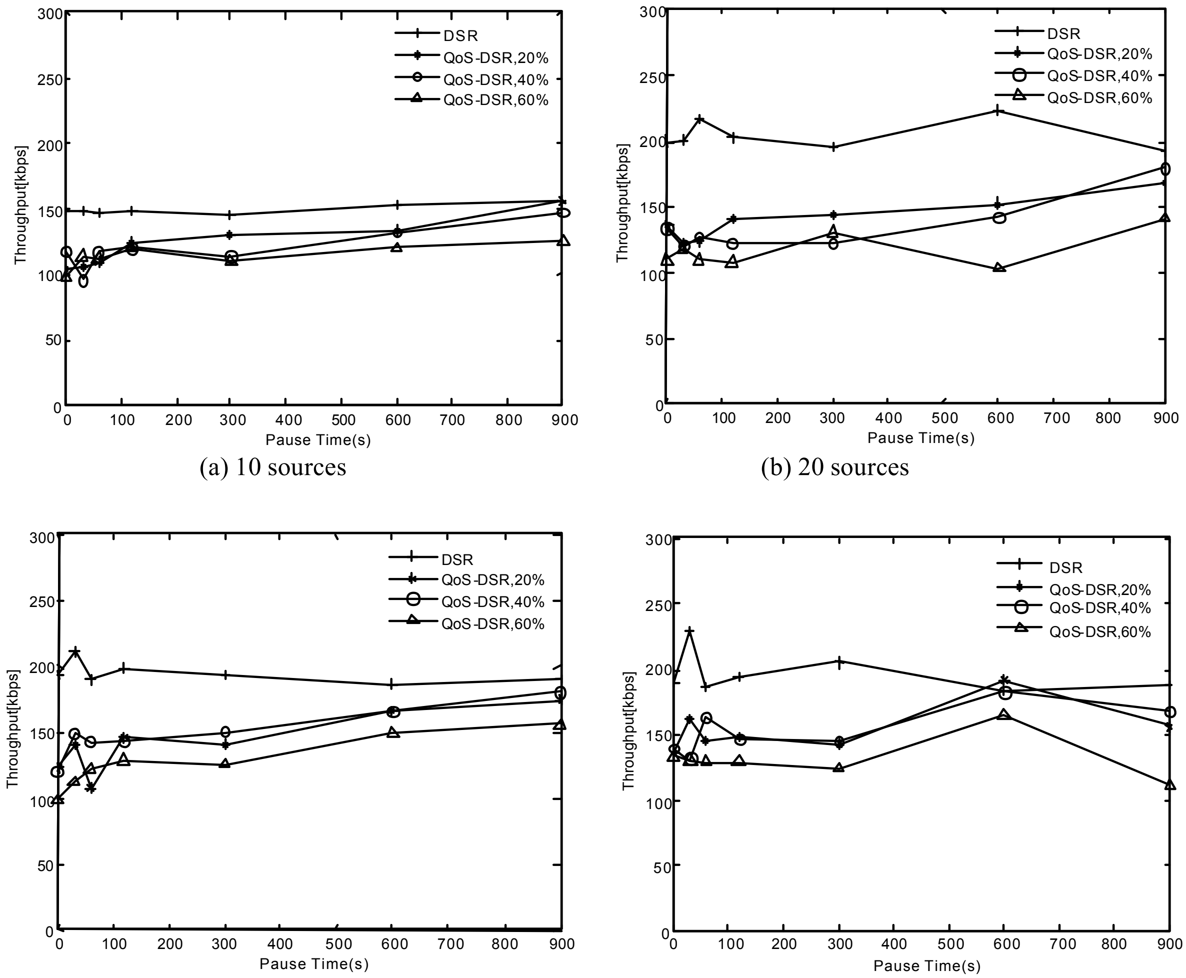
(c) 30 sources (d) 40 sources

Fig. 7: Drop bytes for the 50-nodes model with various number of sources

transfer time, but for DSR with different levels of QoS the delay level is the lowest due to reducing in congestion in links between communicating nodes.

Summary and conclusions: The aim of the research is to design a Quality of Service model for Dynamic Source Routing protocol by modifying protocol structure and its operation procedures. The Dynamic Source Routing protocol is a well-known source initiated on-demand routing protocol run in Ad Hoc environment that use shortest path that containing minimum number of hops without tacking into account certain QoS metrics along the path for finding a route to the destination. The changes that had been done in this research were considered bandwidth availability along the path from the source to the destination that can satisfy the requirements. The proposed model was implemented and tested using simulator software called Network Simulator (NS-2) to study and analyze the modified protocol to evaluate the protocol and show some important issues related to protocol operation mechanism in certain environment.

Because the possibility of implementing and testing the modified protocol practically, using physical equipments is high costly and complex, the simulation methodology was the choice. The paper described how to discover routes that can satisfy certain QoS requirements by adding extensions to Dynamic Source Routing protocol, these extensions specify the service requirements, which must be met by nodes before returning a route reply or rebroadcast a route request to others. The simulation is done and the results are extracted from the simulation output and finally converted to figures and diagrams. When the number of sources is low, the performance metric packet delivery



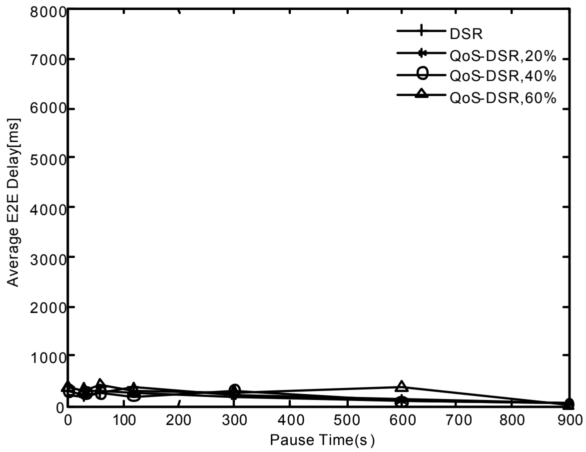
(a) 10 sources (b) 20 sources

(c) 30 sources (d) 40 sources

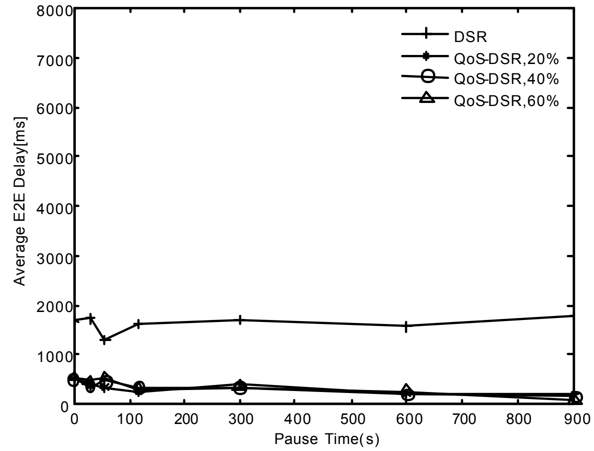
Fig. 8: Throughputs for the 50-nodes model with various number of sources

ratio of DSR and QoS-DSR is similar and relatively accepted regardless of mobility levels. With large numbers of sources, DSR still delivers data better than DSR protocol with different levels of QoS. This is due to constrain that apply to DSR with QoS. Also, the packet delivery fraction metric for both protocols is reaching the highest value when the mobile nodes are in stability mode or low mobility situations in low and intermediate number of nodes, but when there are high number of sources the degree of packet delivery ratio is reduce due to highly congested network. Due to the principle that says when there are large numbers of mobile nodes need to deliver data packets to destinations, they need more routing packets to establish routes and manage the transmission period. This is clearly shown in routing overhead performance metric, where pure DSR delivers large mount of packets; it produces more control messages than other QoS-DSR with different levels of Quality of Service.

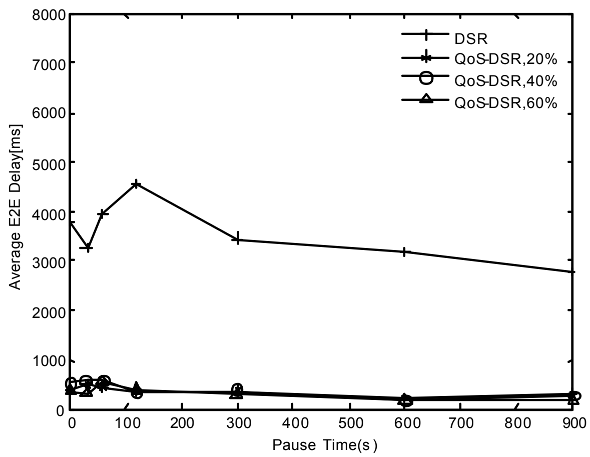
This is also proven using normalized routing load performance metric; that is, the number of routing packet produced or generated for each data packet is delivered to the destination. When the source mobile nodes send data packets to certain destinations and the target nodes don't receive these packets, the send buffer is full or the time exceeding drop packet will occur. There is another reason causing packets dropping; when the mobile nodes don't satisfy the conditions and the requirements of the route request, the mobile nodes immediately discard the packets and don't broadcast or send it. This is shown in the results of drop packets metric, at DSR protocol with 60% QoS (hard constrains are applied to the route request). The amount of packets dropped is large, but normal DSR demonstrates the lowest value because no restrictions are applied on the route request message. The throughput of DSR protocol is higher than other QoS-DSR protocol with different levels of QoS; this is due to the high rate of



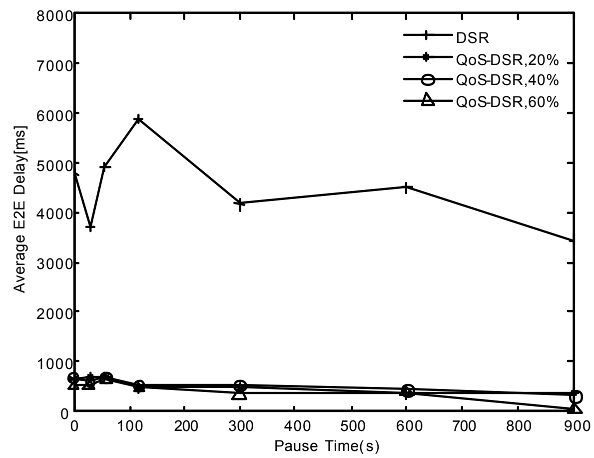
(a) 10 sources



(b) 20 sources



(c) 30 sources



(d) 40 sources

Fig. 9: Average end to end delays for the 50-nodes model with various numbers of sources

successfully received packets using the same time period as shown in packet delivery fraction metric, while other DSR protocol with different levels of QoS demonstrates low throughput. When the number of sources increase, the delay also increases due to high number of transmitted packets, traffic flows generated a high level of network congestion and multiple access interferences at certain regions of the ad hoc network. So, the packets take more time to reach its targets. This is clear in the behavior of DSR protocol while the situation is differing when QoS-DSR is used. DSR protocol performs well without restrictions implemented on it; also DSR with different level of Quality of Service is more efficient than pure DSR protocol in real time applications, where the transmission delay is not desired. DSR protocol consumes channel and node bandwidth due to large amount of routing packet generated to establishing routes; for DSR protocol and all Quality of Service levels are operate well in low congestion network.

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