QoS Based Power Aware Routing in MANETs

Vinay Rishiwal, S. Verma and S. K. Bajpai

Abstract—**In this paper, QoS based power aware routing protocol (Q-PAR) is proposed and evaluated that selects an energy stable QoS constrained end to end path. The selected route is energy stable and satisfies the bandwidth constraint of the application. The protocol Q-PAR is divided in to two phases. In the first route discovery phase, the bandwidth and energy constraints are built in into the DSR route discovery mechanism. In the event of an impending link failure, the second phase, a repair mechanism is invoked to search for an energy stable alternate path locally. Simulation was performed to determine the network lifetime, throughput and end to end delay experienced by packets and for other parameters. The results indicate that Q-PAR is able to discover the required path with lesser overheads, the network lifetime increased by around 24-29 % for small networks (20-50 nodes), the packet delivery ratio improved and the packet experienced a low average delay. Moreover the local repair mechanism was able to find an alternate path in most of the cases enhanced the network lifetime and delayed the repair and reconstruction of the route.**

Keywords—**MANET, Power, QoS routing**

I. Introduction

The dynamic topology and lack of central coordination in MANETs [1] makes QoS provisioning very challenging. In general, QoS Routing relies on a) selecting network paths that have sufficient resources to satisfy the QoS requirements of all admitted connections and b) achieving global efficiency in resource utilization.

QoS routing algorithms for wired networks relies on the availability of the precise state information. However, nature of wireless channel makes the available state information inherently imprecise [6]. Moreover, the topology is fluid; nodes may join, leave and rejoin the network at any time at any location. The QoS routing problem is to find a route that has sufficient resources to satisfy the QoS requirements. This requires the translation of the user requirements into independent network parameters, determination of the resources, the discovery of the optimal route with sufficient resources, resource reservation along the route and maintenance of the route. The QoS constraints that need to be met are delay, bit error rate, bandwidth, route length etc. along with MANET specific requirements like energy, route stability and route reliability. Once the resources are estimated, a route discovery protocol is run to determine the feasible routes. An optimal path is selected and resources are reserved along the path, if possible. This optimal path is, then, used for sending the packets. If a link on the path is broken due to mobility or energy depletion of a node, the route needs to be repaired. This route maintenance can resort to reactive or proactive local repair or reconstruction of the entire end to end path. Thus, a QoS routing protocol for a mobile ad hoc network should be able to determine the orthogonal QoS constraints, the resources required for QoS provisioning, discovery and selection of the appropriate route and finally monitoring of the parameters needed for route maintenance of the selected path. In mobile ad hoc networks, the process from route selection to route maintenance must be power efficient and power aware to maximize the network lifetime.

In [2], DSR is extended to provide QoS routing. Fuzzy logic is used to select the appropriate QoS in multiple paths searched in parallel to deal with imprecise information. To achieve the desired speed of execution, hardwired implementation of fuzzy logic is proposed. The bandwidth reservation problem is considered in [3] support QoS routing. A route discovery protocol is proposed to find a route with a given bandwidth. A simple TDMA based model is assumed on a single common channel shared by all nodes and hidden and exposed terminal problems are taken into consideration while reserving bandwidth on a channel. In [4], QoS features are incorporated in AODV protocol. Stability defined as a function of number of packets sent successfully, is chosen as a major parameter for route selection.

The routing protocol in [5] extends DSR and considers different parameters like link transmission delay, available bandwidth, packet loss rate, battery life, link stability etc. The parameter selection is done on the basis of pre defined algorithms. Therefore, no new mechanism is defined for route discovery. A route maintenance phase is invoked in the protocol and whenever an error takes place, a message is send back to source node while continuing packet sending to the destination by recorded route. In [6] a ticket based probing scheme has been. A ticket represents permission for searching a path. This scheme achieves a high ratio for success rate. However, proactive nature of the protocol where periodical updates are used to maintain the routing information makes it deficient and unscalable. The enhancement to ticket based probing [7], an on demand location aided, ticket based QoS routing protocol (LTBR) is presented. Two special cases, LTBR-1 uses single ticket to find a route with QoS constraints. It improves the performance of the localized location based algorithms by finding a path with better QoS requirement. LTBR-2 uses multiple tickets for finding a QoS route. LTBR-2 achieves performance close to flooding with lower routing overhead in networks with any density. In Core Extracting Distributed Ad hoc Routing (CEDAR) [8], Only core hosts maintain local topology information, participate in the exchange of topology

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and available bandwidth information, and perform route discovery, route maintenance, and call admission.

As QoS provisioning is an important aspect for mobile adhoc networks, similarly energy conservation is a critical issue in adhoc wireless networks for node and network life, as only battery power nodes. Therefore energy must also be treated as an indirect measure of QoS, because path selection without energy efficiency may lead to premature depletion of a network or a node. A lot of work on energy efficient routing in mobile adhoc networks has been done as few is available in [9-15]. In [9] several energy aware metrics have been discussed, which results in energy efficient routes. This effort tries to maximize the time for network partition and reduces variations in power levels of nodes. It is hard to use these metrics directly in a network without any central control. In [10] an on demand power management framework has been designed to adapt the variations in traffic load . Network connectivity was considered in [11] to reduce the overall battery consumptions. In [12] and [13] the nodes are made to sleep during idle periods but [12] considers it at MAC layer while [13] considers it at the network layer. Few more proposals for transport and application layer are available in [14][15].

Rest of the paper is organized in different sections. Section II discusses the route discovery procedure of the proposed protocol in detail. Route maintenance procedure for the proposed protocol is given in section III. Simulation and results have been presented in section IV. Section V concludes the paper.

II. QOS POWER AWARE ROUTING (Q-PAR)

In Q-PAR a feasible path is searched out which satisfies the bandwidth constraint. In contrast to the flooding based algorithms, Q-PAR search only a small number of paths, this limits the routing overheads. In order to maximize the chance of finding a feasible path, the information is collectively utilized to make hop by hop selection.

This protocol does not consider the QoS requirement only but also considers the optimality of the routing path in terms of energy efficiency. If a specific QoS request is not being asked by a user then high energy paths are chosen by Q-PAR in order to improve the overall network lifetime.

In case of Q-PAR a simple energy consumption model has been used to calculate the energy values at different times. This model is discussed below.

Energy consumption of a node after time t is calculated using equation (1):

$$E_{c(t)} = N_t * a + N_r * b \tag{1}$$

Where

$E_{c(t)}$, energy consumed by a node after time t.

N_t, no. of packets transmitted by the node after time t.

N_r, no. of packets received by the node after time t.

a and b are constant factors having a value between 0 and 1.

If E is the initial energy of a node, the residual energy ERes of a node at time t, can be calculated as:

$$E_{Res} = E - E_{c(t)} \tag{2}$$

A. Route Discovery Algorithm

In case of Q-PAR, route discovery starts with source node creating a route request packet (*RREQ*). ***RREQ*** has three special fields (*E_{min}, **AP**, **AP_{desire}***), here minimum energy level E_{min} is the energy level of the weakest node along the route. Application Parameter ***AP*** represents type of request and AP_{desire} represents the desired value for application parameter. In this paper bandwidth is taken as ***AP***. Initially source node generates a RREQ with E_{min} set to 100 %. All intermediate nodes sets minimum energy level field of ***RREQ*** to their energy level. An intermediate node on receiving RREQ, overwrites minimum energy level E_{min} of the RREQ packet iff $E_{Res} < E_{min}$, where E_{Res} is the residual energy of the node and is calculated as given in equation (2). Otherwise, E_{min} remains unchanged. Now intermediate node forwards route request to its neighbors. This process goes on until RREQ reaches to the destination.

Suppose the energy required by node x to transmit a packet over link <x, y> to node y be $E_{x,y}$. Let source and destination are S and D. Let us assume that the residual battery power at a certain instance of time at node x is E_{Res}.

Now if Q-PAR selects a path P from S to D that includes the link <x, y>, then maximum number of packets that node x can forward over this link is $E_{Res} / E_{x,y}$. Accordingly we can define a node health metric, $H_{x,y}$ for the link <x, y> as:

$$H_{x,y} = \frac{E_{Res}}{E_{x,y}} \tag{3}$$

The key point in this formulation is that the cost metric includes both a node specific parameter, the battery power, and a link specific parameter, the packet transmission energy for communication across the link. Clearly the life time of the chosen path, defined by the maximum number of packets that may be potentially forwarded between S and D using path P, is determined by the weakest intermediate node one with the smallest value of $H_{x,y}$. therefore the lifetime NLT associated with route P is

$$NLT = \min_{(x,y)\leftarrow P} \{H_{x,y}\} \tag{4}$$

Destination node may receive multiple copies of ***RREQ*** from different routes. Destination maintains a timer T, which is set to some value when first ***RREQ*** is received. Destination waits for other route request packets until either timer expires or three ***RREQ*** are received. After receiving all the ***RREQs***, a route is selected with QoS constraint if it is asked otherwise a route is selected with Max {E_{min}} and rests of the ***RREQs*** are discarded. A route reply packet RREP is generated sent to source along the selected route. After RREP arrives at the source, the newly established route now can be used to send the data packets.

1) At a source node S

If RREQ is for QoS roué Then
Set AP=1 && APdesire = required value (AP)
If RREQ is normal, set AP=0;

2) At a neighboring node N

If (ERes < Emin)
Then Set Emin = ERes
End if
If (AP == 1)
Then If (APavailable >= APdesire)
Forward the RREQ to all the neighbors

Else discard the RREQ
End if

3) At a destination node D

A timer is set to some value when first RREQ is received.

Destination waits for other RREQ until either timer expires or a maximum of three RREQ are received.

4) After receiving N values of RREQ

5) If (AP == 1 && N == 1)

Then Select this route and send a RREP packet to the source.

Else if (N > 1)

Select a route with Max NLT using equation (3) and equation (4), and send a RREP packet to the source.

End If.

If (AP == 0 && N == 1)

Then Select this route and send a RREP packet to the source.

Else if (N > 1)

Select a route with Max {Emin} and send a RREP packet to the source.

End If.

B. Energy Based Path Selection in Q-PAR

Fig. 1 shows a network with 23 nodes deployed randomly on a plane. Node 1 is chosen as the source S and node 9 as the destination D. Nodes have been assigned different energy levels randomly (for illustration purpose only).The route request packet is stamped by respective Emin through S and broadcasted to reach D from various paths. The first three RREQ packets to reach D are considered. The paths are:

Path 1: 1-16-8-7-18-9, Emin-path1= 77 %
Path 2: 1-16-8-7-6-9, Emin-path2 = 80 %
Path 3: 1-16-14-12-10-9, Emin-path3 = 78 %

Route discovery procedure of Q-PAR selects the path with Max {Emin-path1, Emin-path2, Emin-path3}. Path 2 with maximum value of Emin is selected. Finally selected path 2 (1-16-8-7-6-9) is shown in the Fig. 1 with dotted arrows.

III. Route Maintenance in Q-PAR (Q-PAR-LR)

The nodes involved in the communication are continually in motion and also deplete their energy in transmission and reception of each bit. An out of range node or an energy depleted node may cause a link failure.

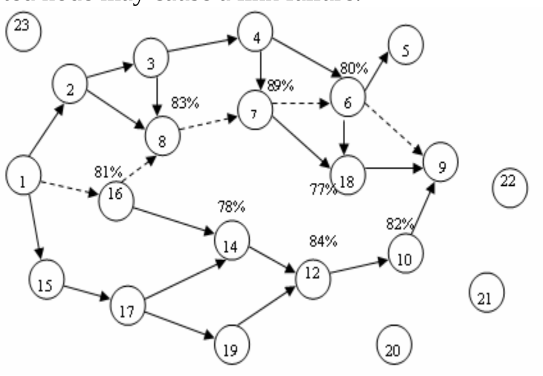

Fig. 1 Route Discovery procedure for Q-PAR

A link failure may trigger an end to end reconstruction of the route through fresh route discovery process or a local repair that determine an alternate path to circumvent the failed link. Global reconstruction is costly and prohibitive when frequent link failures occur. Q-PAR uses the local repair for route maintenance. Most of the routing protocols depend on IEEE 802.11 with acknowledgement to confirm packet delivery. When a node does not receive any acknowledgement in a limited period of time, the link is considered as broken; and route maintenance starts. Whenever a link failure takes place either due to energy depletion or mobility, Q-PAR invokes a route maintenance phase.

Table I: Simulation Scenario and Parameter Values for DSR, Q-PAR and Q-PAR-LR

Parameter	Value
Simulation Time	180 Minutes for NLT 500 seconds for PDF and End to End Delay
Mobility Model	Random Way Point Model, Pause Time (0-400 seconds) Speed (0-15 m/sec)
MAC Protocol	802.11
Routing protocol	DSR
Network Scenario (s)	For 20 and 50 Nodes
Propagation Model	Two Ray Ground
Time Between Retransmitted requests	500 ms
Size of Source Header Carrying an Address	4n + 4 Bytes
Timeout for Non Propagating Search	30 ms
Maximum Rate for Sending Replies from a Route	1/s
Traffic Rate	1-6 Mbps
Node Transmission Range	100-200 mtr.
Transmit Power	1.327 W
Receive Power	966.96 mW
Idle Power	843 mW
Terrain Area	1000 x 1000 m^2

A. Route Maintenance Due to Energy Depletion

Each node monitors its energy level, if its energy falls below a threshold; it informs its immediate neighbor but continues to forward the packets that reach it. The threshold value answers that there is enough residual energy to perform these functions. Each intermediate node along the route monitors its energy level from the time a route is established. Each packet transmission causes energy level of the node to drop. When its energy level drops below a threshold value it informs its downstream node DS along the route, providing the information of its upstream node US. The downstream node DS initiates a process to establish a new link to US node. A local repair route discovery ensures the following

1) The number of hops in the delay incurred by the new section does not violate the delay constraints.

2) The QoS parameters are met by the new section.

3) The route discovery process is a local search from US to DS. To avoid loss of packets, this process itself does not cause a long delay.

B. Route Maintenance Due to Topological Changes

The movement of the nodes causes link failures when nodes move away and generation of new links when nodes come close. Position of the upstream node is decided according to the signal strength of the upstream node. Each intermediate node along the route monitors the health of the links involved in communication and also the formation of new links. The power required for sending information form one node to another node is a function of distance. Neighboring nodes involved in communication exchange data and acknowledgement packets to check their transmission power to the active route. Signal strength of the upstream node is calculated as given in [18] to decide whether US is going far from DS or coming closer. This is utilized by a node to have a rough estimate of the link's health. When an upstream node is estimated to cause a link breakage, local repair is initiated. Packets continue to be sent to the neighbor till the alternate path is discovered. To ensure this, the local route repair message with age field set to an appropriate value is broadcasted by DS to its neighbors. If DS is able to successfully establish a link to US, data packets are forwarded using new link otherwise a route error message is sent by DS to the source. In this case source node again initiates the route discovery procedure. In this case source node again initiates the route discovery procedure.

IV. Simulation and Results

The proposed scheme is simulated using network simulator NS-2 [16] and the performance is compared with well known on demand protocol DSR. Network test beds have been setup for 20, and 50 nodes in an area of 1000 * 1000 m^2. In the different scenarios, value for packet delivery ratio has been observed by varying pause times from 0 to 400 seconds. The speed varies from 0 m/sec to 15 m/ sec. This speed of 15 m/sec is a fairly high speed as compared to movement in a busy traffic model. The performance of the proposed scheme has been measured in terms of the network lifetime enhancement, packet delivery fraction and end to end delay Simulations were run for DSR, Q-PAR and Q-PAR-LR with specific simulation scenarios and parameters as given in Table 1. Values for transmit, receive and idle power have been used directly as mentioned in energy model of [17].

A. Network Lifetime

Network life time is defined as the time taken for 50 % of the nodes in a network to die. The effect of pause time and speed of nodes on network lifetime is evaluated.

1) Nodes 20, Speed 2 m/sec, without local repair

In Fig 2(a), a 20 nodes network has been considered with a speed of 2 m/sec and a pause time of 10 seconds. It can be seen from the figure that in Q-PAR, less number of nodes are dead for all the values of simulation time after 48 minutes. It can be seen that out of 20 nodes network, 50% nodes of DSR dies at a simulation time of 135 minute. While in case of Q-PAR, 50% of nodes are dead after 155 minutes. In a simulation time of 170 minute a total of 14 nodes are dead in case of DSR while only 12 nodes are dead in Q-PAR. There is a clear increase of 14.8% of network lifetime in case of Q-PAR as compare to DSR.

2) Nodes 20, Speed 2 m/sec, with local repair

In Fig. 2(a), network lifetime of Q-PAR is shown with local repair also. It can be clearly seen that the number of dead nodes in Q-PAR-LR are much less as compare to DSR and Q-PAR for all the times at a simulation of 180 minutes. In case of Q-PAR-LR, 50% of the nodes are dead at a simulation time of 170 minutes. Therefore its network lifetime is increased by 25.9 % as compare to DSR and 11.1 % more than that of Q-PAR without local repair.

3) Nodes 20, Speed 10 m/sec, without local repair

In Fig. 2(b), again a 20 node network has been considered with a speed of 10 m/sec and a pause time of 10 seconds. Now it can be observed from the figure that with a high speed of 10 m/sec, 50 % nodes in DSR are dead at a simulation time of 132 minutes. While in Q-PAR, 50 % of the nodes are dead at a simulation time of 150 minutes. Hence there is a increase of 13.6% network lifetime in Q-PAR as compare to DSR.

4) Nodes 20, Speed 10 m/sec, with local repair

Again considering Fig. 2(b), it can be clearly seen that in case of Q-PAR with local repair (Q-PAR-LR), 50% of the nodes are dead at a simulation time of 163 minutes. This shows an increase of 23.4% of network lifetime as compare to DSR and a increase of 9.8% network lifetime over simple Q-PAR without local repair.

5) Nodes 50, Speed 2 m/sec, without local repair

In Fig. 3(a), a 50 node network has been considered with a speed of 2 m/sec and a pause time of 10 seconds. It can be easily observed from the figure that less number of nodes are dead in case of Q-PAR at different values of simulation time.

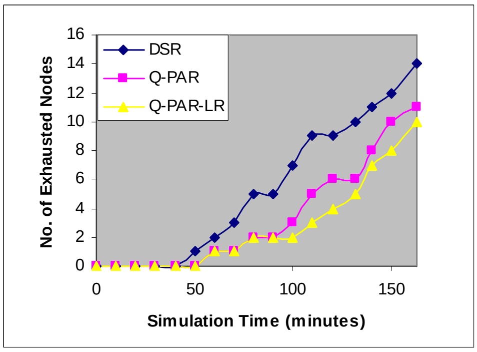

Fig. 2 (a): Simulation time Vs Exhausted nodes at a speed of 2 m/sec in 20 nodes network

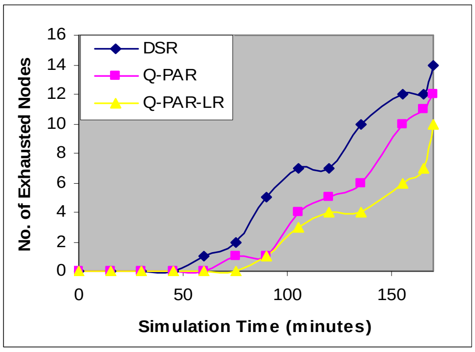

Fig. 2 (b): Simulation time Vs Exhausted nodes at a speed of 10 m/sec in 20 nodes network

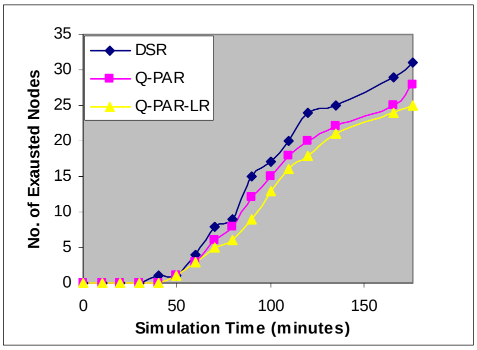

Fig. 3(a): Simulation time Vs Exhausted nodes at a speed of 2 m/sec in 50 nodes network

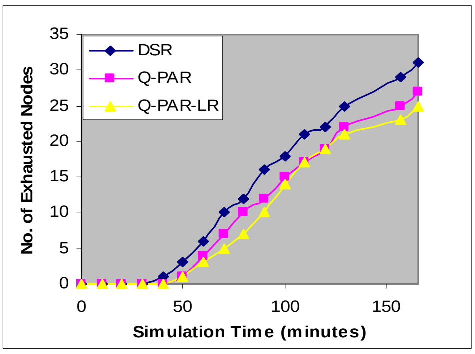

Fig. 3(b): Simulation time Vs Exhausted nodes at a speed of 10 m/sec in 50 nodes network

In case of DSR 50% of the nodes are dead at a simulation time of 135 minutes while in case of Q-PAR 50% of the nodes are dead at a simulation time of 166 minutes. Therefore DSR dies about 22.9 % earlier then Q-PAR.

6) Nodes 50, Speed 2 m/sec, with local repair

In Fig 3(a), it can be seen that for a 50 node network and at a speed of 2 m/sec, the total number of dead nodes in case of Q-PAR-LR is always less than that of DSR and Q-PAR. It is evident from the figure that 50% of the nodes of Q-PAR-LR are dead at a simulation time of 176 minutes. This shows an increase of 28.9 % network life time in case of Q-PAR-LR as compare to DSR and an increase of 6% network lifetime as compare to simple Q-PAR.

7) Nodes 50, Speed 10 m/sec, without local repair

As shown in Fig. 3(b), total numbers of dead nodes in case of Q-PAR are less than as in DSR. In case of Q-PAR, 50% of the nodes are dead at a simulation time of 157 minutes. While in case of DSR, 50% nodes are dead at a simulation time of 130 minutes. It shows that there is an increase of 20.7% of network lifetime in case of Q-PAR as compare to DSR

8) Nodes 50, Speed 10 m/sec, with local repair

Again as shown in Fig 3(b), it can be seen that for a 50 node network and at a speed of 10 m/sec, the total number of dead nodes in case of Q-PAR-LR is always less than that of DSR and Q-PAR. It is evident from the figure that 50% of the nodes of Q-PAR-LR are dead at a simulation time of 166 minutes. This shows an increase of 25.7 % network life time in case of Q-PAR-LR as compare to DSR and an increase of 5% network lifetime as compare to simple Q-PAR.

B. Packet Delivery Fraction (PDF)

Packets may be lost due to sudden link failures, or during route maintenance phase. PDF is the fraction of successfully received packets, which survive while finding their destination. This performance measure determines the efficiency of the protocol to predict a link breakage and also the efficacy of the local repair process to find an alternate path. The completeness and correctness of the routing protocol is also determined.

1) Nodes 20, Pause Time: 0-400 seconds, Speed: Constant (5 m/sec)

In the second phase performance of the algorithm is evaluated in terms of *PDF* by keeping the *speed* constant and varying the pause time. Initially scenario has been setup for a small network of 20 nodes. As depicted in Fig. 4, DSR, Q-PAR and Q-PAR-LR take time in the beginning for route creation and route reply message generation. This time becomes even more crucial when speed of nodes is high, and pause time is very small. In the initial stage performance of Q-PAR is poor than DSR due to more time spent in route discovery phase. Once system gets stable, performance of proposed scheme Q-PAR improves. While Q-PAR with local repair (Q-PAR-LR) is delivering more number of packets as compare to both DSR and Q-PAR without local repair. This improvement in *PDF* is due to less route rediscoveries at the time of link failures.

2) Nodes 50, Pause Time: 0-400 seconds, Speed: Constant (5 m/sec)

Now scenario has been setup for 50 nodes. As depicted in Fig. 5, the dense medium changes some features of the protocols under study. The performance of proposed algorithm Q-PAR-LR is best for 50 nodes proving the point that it was better to provide local repair mechanism. Q-PAR-LR is much better than its counterpart DSR and simple PAR for 50 nodes. The reason is easy availability of alternative paths at the time of local repair. It can be easily observed in Fig. 5 that Q-PAR-LR is delivering more than 99 % packet at higher pause times.

3) Nodes: 20 and 50, Speed: 0-15 m/sec, Pause Time: Constant

Now the performance of the algorithms is evaluated in terms of *PDF* by keeping the *pause time* constant i.e. 10 seconds and varying the speed from 0 m/sec to 15 m/sec. Fig. 6 and Fig. 7 depicts that both Q-PAR and Q-PAR-LR outperform DSR in the network of 20 as well as 50 nodes, when speed is less than 5 m/sec. Q-PAR and Q-PAR-LR exhibits better performance when speed goes beyond 5 m/sec though performance of all the three protocols DSR, Q-PAR and Q-PAR-LR degrades at a speed of higher then 5 m/sec. But still Q-PAR-LR and Q-PAR are maintaining higher delivery ratio as compare to DSR. It can be seen by Fig. 10 that in a 50 node network Q-PAR-LR is delivering more than 96% packets successfully even at a higher speed of 15 m/sec.

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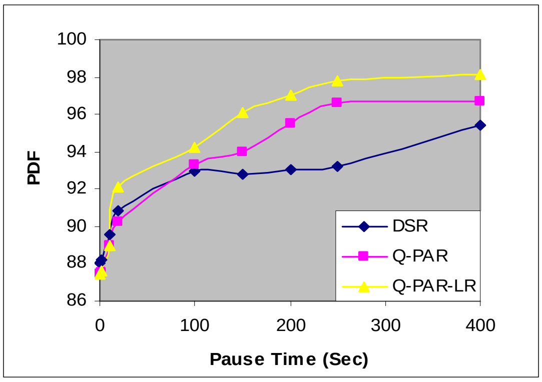

Fig. 4 Pause Time Vs PDF for 20 nodes

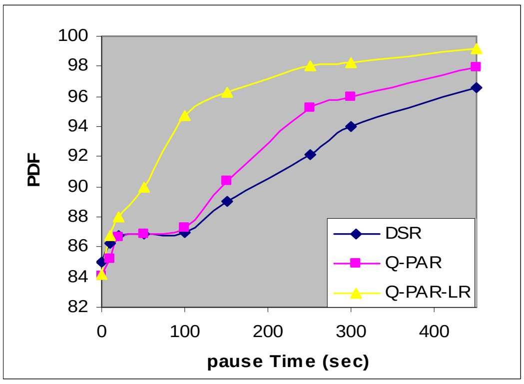

Fig. 5 Pause Time Vs PDF for 50 nodes

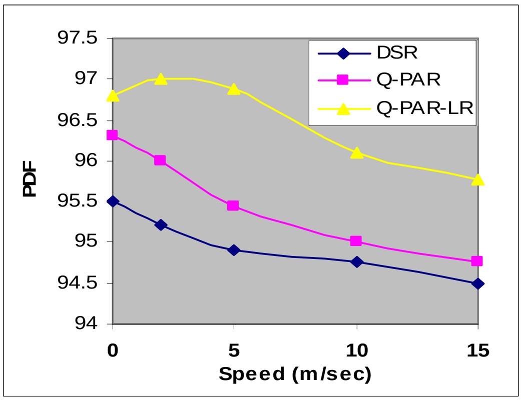

Fig. 6 Speed Vs PDF for 20 nodes

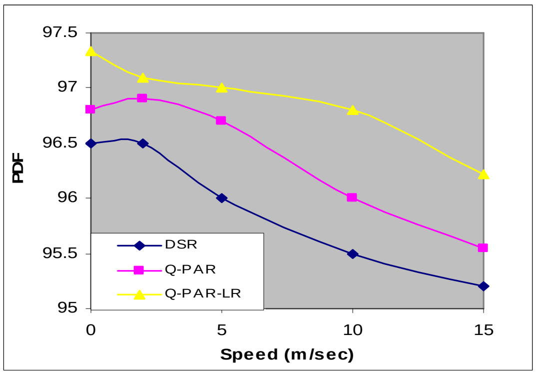

Fig. 7: Speed Vs PDF for 50 nodes

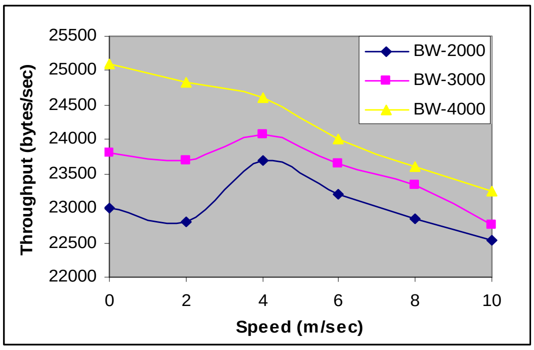

Fig. 8 Throughput Vs Mobility for Q-PAR-LR

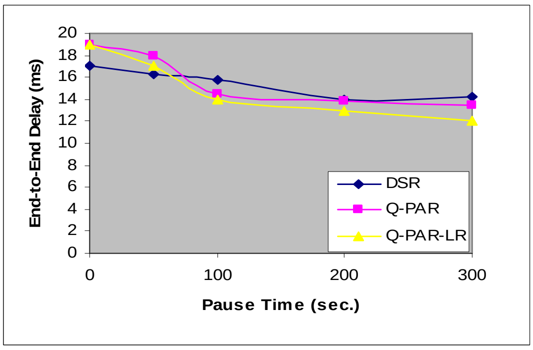

Fig. 9 End to End Delay Vs Pause Time

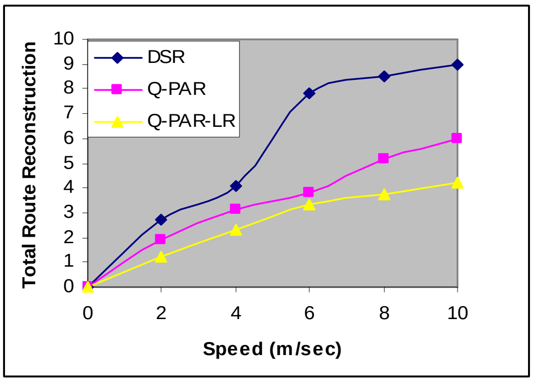

Fig. 10 Route Reconstruction Vs Mobility

4) Throughput of Q-PAR: (Nodes: 50 Bandwidth Requirements: 2000-4000 Packets/sec)

In Fig. 8 an analysis of Throughput against mobility is shown for Q-PAR-LR, while the value of the demanded QoS parameter changes. It is evident from the figure that with the high speed more than 4 m/sec the value for throughput for all demanded QoS path decreases for Q-PAR-LR. Because frequent route failures due to mobility causes more route reconstructions which leads to more packet loss. It can also observe from the figure that high bandwidth demanded QoS connections has high throughput all the time at different speeds.

C. End-to-End Delay

Average end-to-end delay is the delay experienced by the successfully delivered packets in reaching their destinations. It denotes the efficiency of the underlying routing technique as delay primarily depends on optimality of path chosen.

Scenario 1: Nodes: 50, Pause Time: 0-400 seconds, Speed: 5 m/sec

A simple experiment has been performed to check end-to-end delay at different pause time varying from 0 to 300. Packets are sent from source to destination 100 times and average end-to-end delay is calculated for different pause times. Fig. 9 represents the results. It is clear from Fig. 9, that initially the proposed scheme Q-PAR and Q-PAR-LR suffers slightly higher delay due to the initial calculations involved at the time of route discovery. It is observed from the graph that end to end delay decreases in case of the proposed scheme as the pause time increases. In this case also Q-PAR_LR bears less delay in compare to both DSR and simple Q-PAR due to an efficient local repair mechanism at the time of link failures.

D. Route Reconstruction in Q-PAR

Whenever a link failure takes place either due to energy depletion or due to mobility, route reconstruction or route repair phase is invoked in the routing protocols.

Scenario 1: Nodes **50, Pause Time: 10 sec., Speed: 0-10 m/sec**

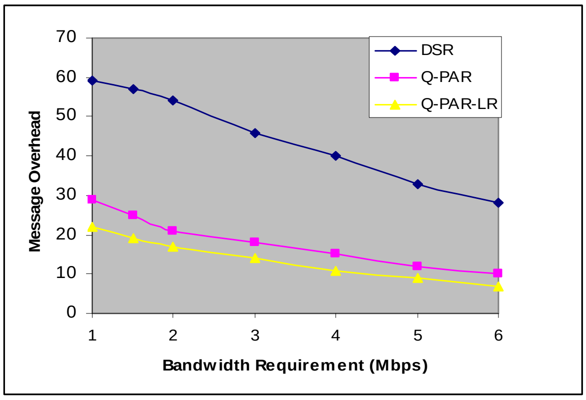

Fig. 11 Message overhead per connection request

An analysis of total route reconstructed (average) for a particular simulation time is performed over DSR, Q-PAR and Q-PAR-LR against the mobility. Results of the analysis are shown in Fig. 10. It can be observed from the figure that number of route reconstruction in Q-PAR-LR are less as compare to Q-PAR which in turn is better than DSR. It shows that Q-PAR selects more stable paths as compare to DSR and Q-PAR with local repair is more stable than that of DSR and Q-PAR both.

E. Average Message Overheads

Average message overhead is defined as the ratio of total no. of message sent upon total no. of connection request.

1) Nodes: 50, Bandwidth Requirement: 1-6 Mbps, Speed: 5 m/sec

Average message overheads per connection against bandwidth requirement are analyzed for DSR, Q-PAR and Q-PAR-LR and results are shown in Fig. 11. It is observed from the figure that Q-PAR-LR and Q-PAR bears significantly less overheads then that of DSR. It is also observed that Q-PAR with local repair has slight fewer overheads even as compare to Q-PAR. It is evident from the fig. 14 that even at a higher input bandwidth requirement, in Q-PAR message overheads per connection request is less than 10 while for the same situation DSR incurred around 35 message overheads per connection request. This significant reduction in message overheads is achieved due to limited broadcast nature of Q-PAR.

V. Conclusion

The energy stable QoS routing technique is determine bandwidth constrained paths that are most likely to last for the session in adhoc networks that have paucity of energy. The protocol considers only energy stability for local reconstruction of the routes to avoid packet loss and costly global reconstruction. The protocol is able to enhance the network lifetime delay repair due to energy depletion of nodes and significantly improve the overall efficiency of packet delivery. However a priori estimation of the bandwidth and admission control to ensure bandwidth availability between wireless links is required to ensure the performance of the protocol.

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