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An Approach for Reducing the End-to-end Delay and Increasing Network Lifetime in Mobile Adhoc Networks

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***Abstract*—**Mobile adhoc network (MANET) is a collection of mobile devices which form a communication network with no pre-existing wiring or infrastructure. Multiple routing protocols have been developed for MANETs. As MANETs gain popularity, their need to support real time applications is growing as well. Such applications have stringent quality of service (QoS) requirements such as throughput, end-to-end delay, and energy. Due to dynamic topology and bandwidth constraint supporting QoS is a challenging task. QoS aware routing is an important building block for QoS support. The primary goal of the QoS aware protocol is to determine the path from source to destination that satisfies the QoS requirements. This paper proposes a new energy and delay aware protocol called energy and delay aware TORA (EDTORA) based on extension of Temporally Ordered Routing Protocol (TORA).Energy and delay verifications of query packet have been done in each node. Simulation results show that the proposed protocol has a higher performance than TORA in terms of network lifetime, packet delivery ratio and end-to-end delay.

***Keywords*—** EDTORA, Mobile Adhoc Networks, QoS, Routing, TORA

I. Introduction

AS technology advances, wireless and portable computers and devices are becoming more powerful and capable. These advances are marked by an increase in CPU speed, memory size, disk space, and a decrease in size and power consumption. The need for these devices to continuously communicate with each other and with wired networks is becoming increasingly essential. MANET is a collection of mobile devices which form a communication network with no pre-existing wiring or infrastructure. MANETs allow the applications running on these wireless devices to share data of different types and characteristics.

There are many applications of MANETs, each with different characteristics of network size, node mobility, rate of topological change, communication requirements, and data characteristics. Such applications are conferences, classroom, campus, military and disaster recovery. Each node is directly connected to all nodes within its own effective transmission range. Nodes in the network are allowed to move in and out of range of each other. Communication between nodes that are not within range of each other is accomplished by establishing multihop routes that involve other nodes which act as routers. New nodes can join the network at any time and existing nodes can leave the network as well.

Due to the dynamic nature of MANETs, designing communications and networking protocols for these networks is a challenging process. One of the most important aspects of the communications process is the design of the routing protocols used to establish and maintain multihop routes to allow the communication of data between nodes. A considerable amount of research has been done in this area, and multihop routing protocols have been developed. Most of these protocols such as the Dynamic Source Routing protocol (DSR), Ad Hoc on Demand Distance Vector protocol (AODV), Temporally Ordered Routing Protocol (TORA) and others establish and maintain routes on a best-effort basis [1]. While this might be sufficient for a certain class of MANET applications, it is not adequate for the support of more demanding applications such as multimedia, audio and video. Such applications require the network to provide guarantees on the Quality of Service (QoS).

Most QoS routing algorithms represent an extension of existing classic best effort routing algorithms. Many routing protocols have been developed which support establishing and maintaining multihop routes between nodes in MANETs. These algorithms can be classified into two different categories: on-demand (reactive) such as DSR, AODV, and TORA, and table-driven (proactive) such as Destination Sequenced Distance Vector protocol (DSDV). In the on-demand protocols, routes are discovered between a source and a destination only when the need arises to send data. This provides a reduced overhead of communication and scalability. In the table-driven protocols, routing tables which contain routing information between all nodes are generated and maintained continuously regardless of the need of any given node to communicate at that time. With this approach, the latency for route acquisition is relatively small, which might be necessary for certain applications, but the cost of communications overhead incurred in the continued update of

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information for routes which might not be used for a long time if at all is too high.

Furthermore, this approach requires more memory due to significant increase in the size of the routing table. These requirements put limits on the size and density of the network. A third hybrid approach, the Zone Routing Protocol (ZRP), has also been proposed and attempts to reap the benefits of both methods. In ZRP, the network is divided into zones. A proactive table driven strategy is used for establishment and maintenance of routes between nodes of the same zone, and a reactive on-demand strategy is used for communication between nodes of different zones. This approach can be effective in larger networks with applications that exhibit a relatively high degree of locality of communication, where communication between nodes with close proximity to one another is much more frequent than that between nodes which are farther apart.

The rest of the paper is organized as follows. In section II, the previous work related to QoS aware routing protocols is briefly reviewed. In section III, energy and delay aware protocol called energy and delay aware TORA (EDTORA) based on extension of TORA is described. In section IV the major simulation results are shown. In section V, the result of the work done is summarized.

II. Related Work

The primary goal of the QoS-aware routing protocols is to determine a path from a source to the destination that satisfies the needs of the desired QoS. The QoS-aware path is determined within the constraints of minimal search, distance, and trace conditions. Since the path selection is based on the desired QoS, the routing protocol can be termed as QoS-aware. Only a few QoS aware routing protocols have been proposed so far for MANETs, most of which are outlined in this section.

Power-aware multiple access protocol (PAMAS) has been proposed [2]. Here, a node turns off its radio interface for a specific duration of time, when it knows that it will not be able to send and receive packets during that time because of the possibility of multiple access interference. Several energy-aware metrics have been discussed that will result in energy-efficient routes [3]. The metrics included maximizing the time to network partition and reducing variance in node power levels. It is hard to use these metrics directly in a network without any central control. It proposes a routing algorithm based on minimizing the amount of power (or energy per bit) required to get a packet from source to destination. Conditional Max-Min battery capacity routing algorithm proposed in [4].This algorithm chooses the route with minimal total transmission power if all nodes in the route have remaining battery capacities higher than a threshold, otherwise routes including nodes with the lowest remaining battery capacities are avoided.

CEDAR, a Core Extraction Distributed Ad hoc Routing algorithm is proposed as a QoS routing scheme for small to medium size ad-hoc networks consisting of tens to hundreds of nodes [5].It dynamically establishes the core of the network, and then incrementally propagates the link states of stable high-bandwidth links to the nodes of the core. The route computation is on-demand basis and is performed by the core nodes using only local state. An available bandwidth calculation algorithm for ad hoc networks with time division multiple access (TDMA) for communications has been proposed [6].This algorithm involves end-to-end bandwidth calculation and bandwidth allocation. Using this algorithm, the source node can determine the resource availability for supporting the required QoS to any destination in the ad hoc networks.

The protocol named QoS-TORA is based on the link reversal best effort protocol TORA [7]. It is designed to work in a TDMA network where the bandwidth of a link is measured in terms of slot reservations in the data phase of the TDMA frame. This protocol makes use of information in the network and medium access control (MAC) layers. The simulation result shows considerable improvements in the probability of being able to find an end-to-end QoS path. Simulation also shows that QoS-TORA provides higher throughput under higher mobility circumstances. Delay and Throughput aware QoS routing based on Optimized link state routing (OLSR) protocol has been proposed [8]. It shows significant improvement in packet delivery ratio, packet loss and delay over OLSR

Another TORA-based QoS routing protocol for MANETs called INORA (INSIGNIA + TORA) has been proposed [9]. INORA is a network layer QoS support mechanism that makes use of the INSIGNIA in-band signaling mechanism and the TORA routing protocol for MANETs. In INORA, QoS signaling is used to reserve and release resources, and set up, tear down and renegotiate flows in the network. The INORA protocol operates the signalling mechanism independently from the TORA routing protocol. This provides decoupling of the two mechanisms and there is no interaction between them. TORA provides the route between the source and the destination of a flow. Then the signalling mechanism (INSIGNIA) establishes resources for the route provided by TORA.

III. Energy And Delay Aware Tora (EDTORA)

Quality of Service (QoS) routing protocols search for routes with sufficient resources in order to satisfy the QoS requirements of a flow. The QoS routing protocol should find the path that consume minimum resources [10]. Depending on the application involved, the QoS constraints could be available bandwidth, cost, end-to-end delay, delay variation (jitter), energy, probability of packet loss, and so on. The QoS metrics can be classified as additive metrics, concave metrics and multiplicative metrics.

Let m(u,v) be the performance metric for the link (u,v) connecting node u to node v, and path $(u,u_1,u_2\ldots u_k,v)$ a sequence of links for the path from u to v. A constraint is additive if $m(u,v) = m(u,u_1) + m(u_1,u_2) + ... + m(u_k,v)$.For example, the end-to-end delay (u,v) is an additive constraint because it consists of the summation of delays for each link along the path.

A constraint is concave if $m(u,v)=\min\{m(u,u_1), m(u_1,u_2),\ldots,m(u_k,v)\}$.The bandwidth bw(u,v) requirement for a path between node u and v is concave. This is due to the fact that it consists of the minimum bandwidth between the links along the path.

A constraint is multiplicative if $m(u,v) = m(u,u_1) \times m(u_1,u_2) \times ... \times m(u_k,v)$. The probability of a packet prob (u,v), sent from a node u to reach a node v, is multiplicative, because it is the product of individual probabilities along the path. Bandwidth and energy are concave metric, where as cost, delay and jitters are additive metrics. The reliability or availability of a link based on some criteria such as link break probability is a multiplicative metric [11].

A. *Delay*

The delay is the total latency experienced by a packet to traverse the network from the source to the destination. At the network layer, the end-to-end packet latency is the sum of processing delay, packetization, transmission delay, queuing delay, and propagation delay. The end-to-end delay of a path is the summation of the node delay at each node plus the link delay at each link on the path. Node delay includes the protocol processing time and the queuing delay at node i for link (i,j). Link delay is the propagation delay on link (i,j). In wireless link, the propagation delays are very small and almost equal for each hop on the path. The queuing delay and MAC delay are considered as two main factors that accumulated the node's delay.

The relationship between the MAC delay and the neighbor number in mobile ad hoc networks, and an estimation method of the MAC delay is analyzed in [12]. Queuing delay has been analyzed by two dimension finite-state Markov models [13]. The queuing delay distribution is Pr (D>t).The average queuing delay is defined to be the value *D* for which the delay distribution is larger than 90%. Thus, the end-to-end delay of a path can be estimated by adding all the node delays and link delays in the path.

B. *Energy*

On-demand protocols typically pick the shortest path route during the route discovery process and then stick to this route until it break. Continuous use of the route may drain the energy of the nodes. This is particularly true if one or more nodes are on other routes as well. Note that each message transmission and reception drains battery power. If a node runs out of battery energy and is unable to forward any messages, it effectively falls out of the network. In this case, the route breaks then protocols find an alternate route via another route discovery. However, nodes dying such as this adversely affect the operational life time of adhoc network. The aim of this protocol is routing around nodes high on battery power as far as possible. This will prolong the network lifetime. The percentage of the initial energy is taken as the energy metric. It is assumed that the initial energy of the node is the maximum energy provided by the battery when it is fully charged.

C. *Energy and Delay Extension in TORA*

Temporally Ordered Routing Algorithm (TORA) is a source-initiated on-demand routing protocol which uses a link reversal algorithm and provides loop-free multipath routes to a destination node [1]. Each node maintains its one-hop local topology information and also has the capability to detect partitions. TORA has the unique property of limiting the control packets to a small region during the reconfiguration process initiated by a path break. Fig. 1 shows the distance, delay and energy metrics used in TORA. H (N) denotes the height of node N from the destination. TORA has three main functions: establishing, maintaining and erasing routes. The route establishment function is performed only when a node requires a path to a destination but does not have any directed link. This process establishes a destination-oriented directed acyclic graph (DAG) using a query/update mechanism.

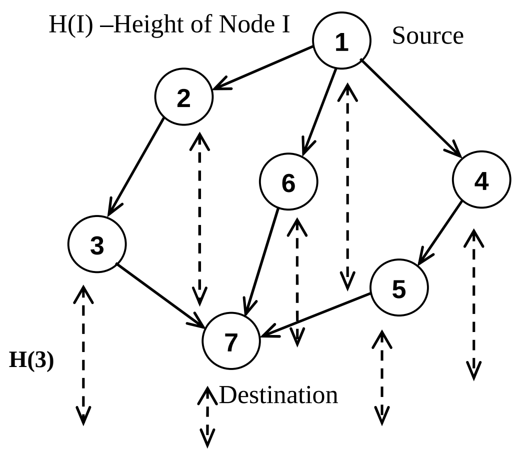


Fig. 1 Illustration of QoS extension in TORA

Let us consider the network topology shown in Fig. 1.When node 1 has data packets to be sent to the destination node 7, a query packet is originated by node 1 with the destination address included in it. Minimum energy and maximum delay fields are also added with the query packet. A source requiring minimum energy and maximum delay transmits a query packet with QoS energy and delay extension. The energy extension indicates the minimum energy required to be available on the entire path between the source and destination. The delay extension gives the maximum delay allowed between the source and destination. As shown in Fig. 1 the QoS energy extension is 30 % (0.3) of node's initial energy and the maximum delay is 100 milliseconds (ms).Both minimum energy and maximum delay verifications of a query have been done in each node. Query packets are discarded if one of the constraints cannot be satisfied.

Before forwarding the query packet an intermediate node compares its available energy to the energy field indicated in the QoS extension. If the required energy is not available the packet is discarded and the process stops. If the energy constraint is satisfied then the delay is estimated and if it exceeds the QoS delay the packet is discarded otherwise the node subtracts its node traverse time (NTT) from the delay bound provided in the extension. The delay value in query packet indicates the delay allowed for a transmission between the source and destination. The query packet is forwarded with updated QoS delay extension.

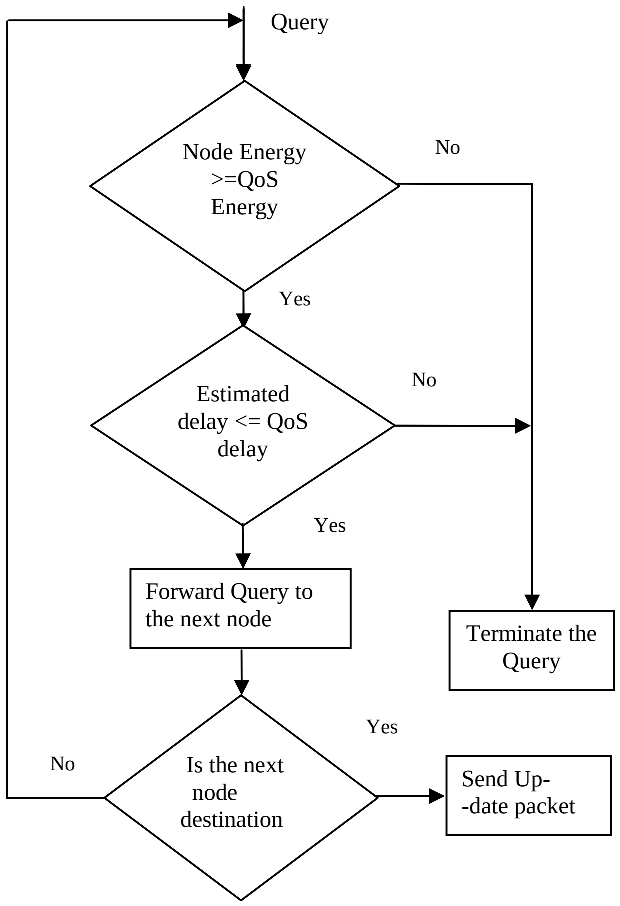
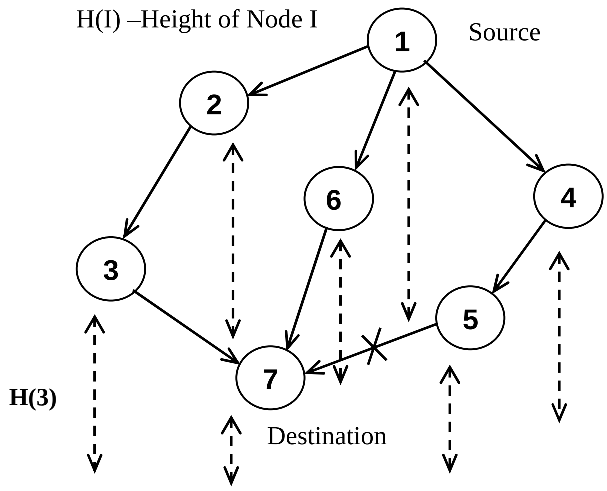


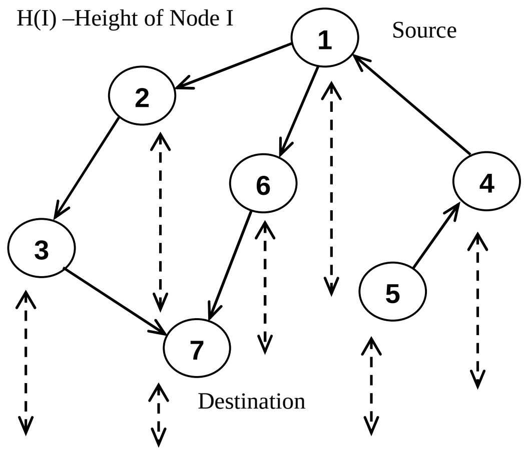
Fig. 2 Flow chart

The flow chart as shown in Fig. 2 describes the sequence of operation. This query packet is forwarded by intermediate nodes 2,3,4,5, 6 and reaches the destination node 7. The node that terminates the query packet replies with an update packet containing its distance from the destination and delay.

The destination node 7 originates an update packet. Each node that receives the update packet sets its distance to a value higher than the distance of the sender of the update packet. In the case of delay intermediate node add its own NTT to the delay field. By doing this, a set of directed links from the node which originated the query to the destination node 7 is created. This forms the DAG depicted in Fig. 1. Once a path to the destination is obtained, it is considered to exist as long as the path is available, irrespective of the path length changes due to the reconfigurations that may take place during the course of the data transfer.



Link break between Nodes 5 and 7



Nodes 4and 5 reverse their links in order to update the path.

Fig. 3 Illustration of route maintenance in TORA

When an intermediate node discovers that the route to the destination node is invalid, as illustrated in Fig. 3, it changes its distance value to a higher value than its neighbors and originates an update packet. The neighboring node 4 that receives the update packet reverses the link between 1 and 4 and forwards the update packet. This is done to update the DAG corresponding to destination node 7.This results in a change in the DAG. If the source node has no other neighbor that has a path to the destination, it initiates a fresh query/update procedure. Assume that the link between nodes 1 and 4 breaks. Node 4 reverses the path between itself and node 5, and sends an update message to node 5.Since this conflicts with the earlier reversal, a partition in the network can be inferred. If the node detects a partition, it originates a clear message, which erases the existing path information in that partition related to the destination.

IV. Performance Evaluation

The performance of the proposed protocol is evaluated using the ns-2 simulator [14]. The simulation model simulates using the random waypoint model. In the simulation, the ns-2 WaveLAN implementation for MAC 802.11 is used. This MAC implementation uses 2 Mbps as channel access rate. The simulation is done for a network of 50 mobile nodes. Each node is moving in an area of 670mx670m. The node radio transmission range is about 250 m. The QoS constraint is set to 250 ms for delay and 30 % of initial energy for energy. The initial energy for each node is set to 20 joules, which represents a combined network wide initial energy of 1000 joules.

The performance metrics are defined as follows.

Packet delivery ratio: It is defined as the ratio of the number of data packets delivered to the destination and the number of data packets sent by the source.

Average end-to-end delay: It indicates the end-to-end delay experienced by packets from source to destination. This includes the route discovery time, the queuing delay at node, the retransmission delay at the MAC layer, and the propagation and transfer time in the wireless channel.

A. Packet Delivery Ratio

The Fig. 4 shows the packet delivery ratio for TORA and EDTORA protocols for mobile speed up to 100 meter/second with 10 seconds pause time. Both protocols have higher throughput when the nodes move at low speeds. When the speed increases, routing protocols suffer a decrease in throughput. Higher speeds cause frequent link changes and connection failures. EDTORA shows 3 % improvement in packet delivery ratio over TORA for high mobility (100m/s).

Fig 5 shows packet delivery ratio for number of nodes from 10 to 50 for different mobile speeds. EDTORA shows 15 % improvement in packet delivery ratio in the 10m/s mobile speed and 23 % improvement in the 20m/s mobile speed over TORA when the number node reaches 50.

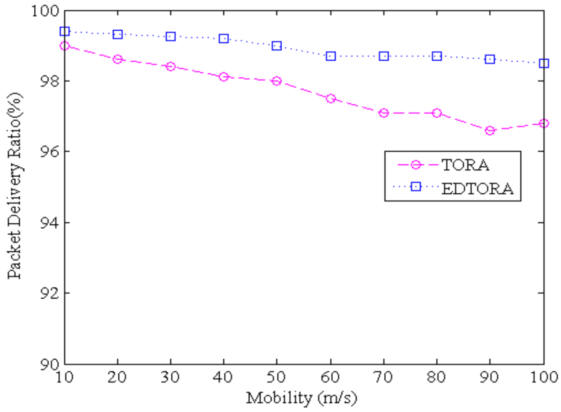
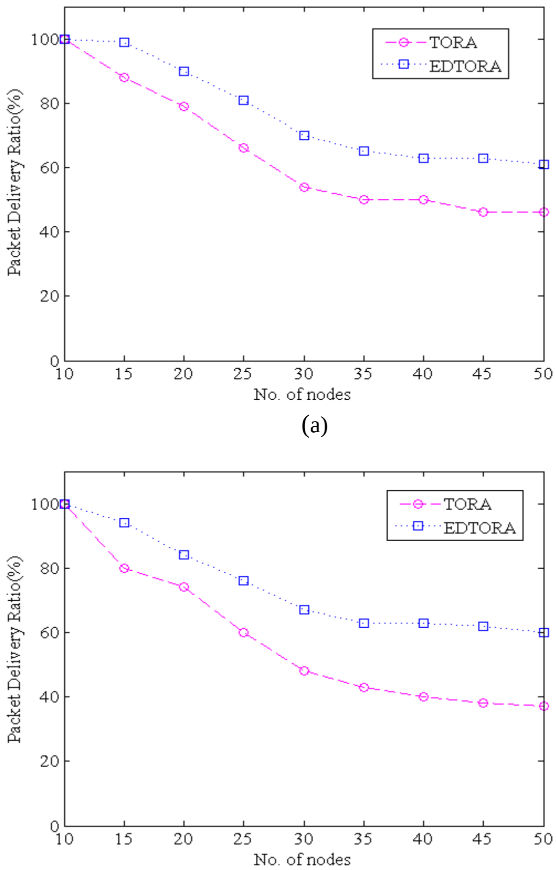


Fig. 4 Effect of mobility on packet delivery ratio



(a)

(b)

Fig. 5 Effect of number of nodes on packet delivery ratio
(a) mobility 10 m/s (b)mobility 20 m/s

B. End-to-end Delay

The Fig. 6 shows measure of end-to-end delay for the QoS requirement 250 ms at different node mobility. The end-to-end delay increases as the node speed increases. Higher mobility causes more links broken and frequent re-routing and thus causes larger end-to-end delay. The end-to-end delay in EDTORA is within the limit (250ms) and gives up to 60 % improvement. But TORA exceeds the QoS requirement. In

EDTORA query packets are discarded if the delay constraint is not satisfied.

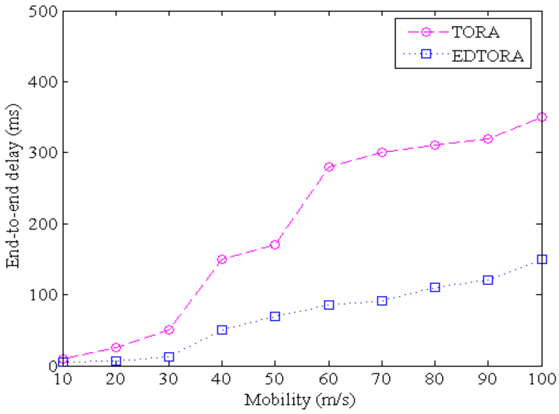
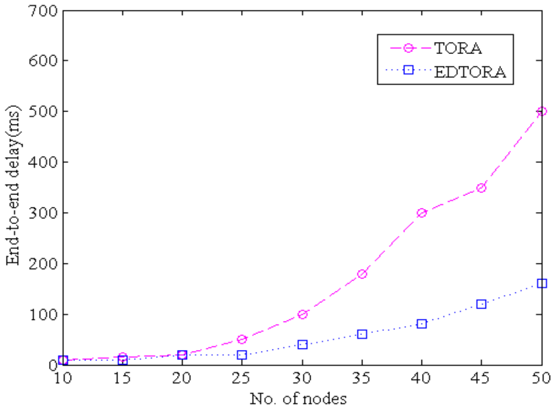
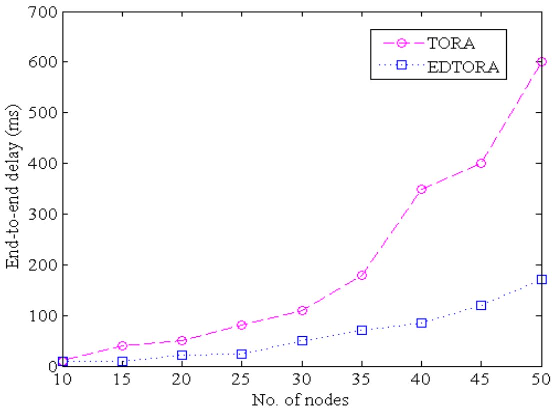


Fig. 6 Effect of mobility on end-to-end delay for pause time of 10 s



(a)



(b)

Fig. 7 Effect of number of nodes on end-to-end delay (a) mobility 10 m/s (b) mobility 20 m/s

Fig. 7 shows end-to-end delay for number of nodes from 10 to 50 at two different mobile speeds. It increases as the number of nodes increases because of more number of links. EDTORA shows better performance than TORA for higher number of nodes in both the cases.

C. Packet Loss

The Fig. 8 shows the effect of increasing node mobility on packet loss of TORA and EDTORA protocols. It can be seen that increase in node speed results in significant increase in the packet loss in both the protocols due to more link breaks.

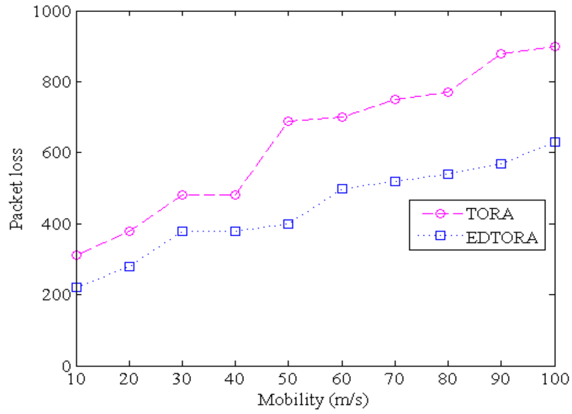


Fig. 8 Effect of mobility on packet loss for pause time of 10 s

The increase in packet loss for TORA is more than that in EDTORA. The difference was small at 10 m/s but the advantage of EDTORA over TORA becomes more prominent as the mobility increases.

D. Node Lifetime

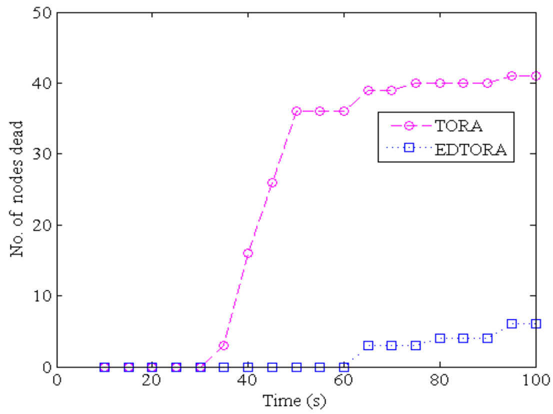


Fig. 9 Number of nodes dead Vs Time

The Fig. 9 shows the time at which certain number of nodes dies, when simulating two protocols. It can be seen from the graph, TORA nodes die earlier than EDTORA nodes. This is due to forwarding the query packet the intermediate node compares its available energy to the energy field indicated in the QoS extension. If the required energy is not available the packet is discarded. The first node dies at 25 seconds in TORA and 65 seconds in EDTORA. At 100 seconds simulation time 41 nodes die in TORA and only 6 nodes die in EDTORA.

V. CONCLUSION

Energy and delay aware protocol EDTORA based on extension of TORA has been proposed. At query phase, nodes that do not have required energy and delay are eliminated. Each node upon receipt of the query packet, determines whether to forward this request based on its energy level and delay or not. At the destination, update packet is generated. Simulation results show that EDTORA satisfies the energy and delay QoS requirements. It has been found from simulation that EDTORA outperforms the TORA protocol in terms of network lifetime, packet delivery ratio, end-to-end delay and packet loss. So it can provide excellent energy and delay assurance while at the same time achieving much higher packet delivery ratio and lower packet loss than the existing protocol. In future this can be extended to other routing protocols. This energy and delay aware protocol works only in the routing layer and exploits only routing-specific information. It will be interesting to use MAC-layer specific information, transport and application-layer specific information. These avenues also can be explored in further research studies.

REFERENCES

[1] V.D.Park and M.S.Corson. "A highly adaptive distributed routing algorithm for mobile wireless networks". *Proceedings of IEEE INFOCOM '97*:pp1405– 1413, April 1997.

[2] S.Singh and C.S.Raghavendra. "PAMAS - power aware multi-access protocol with signaling for ad hoc networks". *ACM Computer Communication Review* (ACM CCR'98), July 1998.

[3] S. Singh, M.Woo, and C.S Raghavendra. "Power-aware routing in mobile ad-hoc networks". *ACM/IEEE International Conference on Mobile Computing and Networking*, pp. 181–190, October 1998.

[4] C.K.Toh, "Maximum battery life routing to support ubiquitous mobile computing in wireless ad hoc networks", *IEEE Communication Magazine*, pp.2-11, June 2001.

[5] R.Sivakumar, P.Sinha and V.Bharghavan, CEDAR: a core extraction distributed ad hoc routing algorithm," IEEE *Journal on Selected Areas in Communication,* pp 1454-1466, August 1999.

[6] C.Lin and J.Liu, "QoS routing in ad hoc wireless networks," *IEEE Journal on Selected Areas in Communications,* pp 1426-1438, August 1999.

[7] I.Gerasimov and R.Simon. "A bandwidth reservation mechanism for on-demand ad hoc path finding". *IEEE/SCS 35th Annual Simulation Symposium,* San Diego, CA, pages 27–33, April 2002.

[8] R.Asokan, M.Pushpavalli and A.M.Natarajan "Delay and throughput aware proactive QoS routing in mobile adhoc networks". *Proceedings of the International Conference on Advanced Communication System (ICACS-2007)* pp1-6, January 2007

[9] D. Dharmaraju, A. Roy-Chowdhury, P. Hovareshti, and J. S. Baras. "INORA-a unified signaling and routing mechanism for QoS support in mobile ad hoc networks". *Parallel Processing Workshops*, 2002 Proceedings. pages 86–93, August 2002.

[10] Prasant Mohapatra, Jian L, and Chao Gui, "QoS in ad hoc wireless network" *IEEE Wireless Communications Magazine*, pp44-52, March 2003.

[11] Baoxian Zhang and Hussein T. Mouftah, "QoS routing for wireless ad hoc networks: problems, algorithms, and protocols" *IEEE Communications Magazine*, pp. 110-117 October 2005

[12] S.T. Shen and J.H. Chen, "A novel delay oriented shortest path routing protocol for mobile ad hoc networks," *Proceedings of IEEE ICC 2001*.

[13] H. Sun and H. Hughes, "Adaptive QoS routing based on prediction of local performance in ad hoc networks", *Proceedings of IEEE WNCN 2003*.

[14] www.isi.edu/nsnam/ns/ns-documentation.html

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