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Research Article

Quality-of-Service Routing Using Path and Power Aware Techniques in Mobile Ad Hoc Networks

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Mobile ad hoc network (MANET) is a collection of wireless mobile hosts dynamically forming a temporary network without the aid of any existing established infrastructure. Quality of service (QoS) is a set of service requirements that needs to be met by the network while transporting a packet stream from a source to its destination. QoS support MANETs is a challenging task due to the dynamic topology and limited resources. The main objective of this paper is to enhance the QoS routing for MANET using temporally ordered routing algorithm (TORA) with self-healing and optimized routing techniques (SHORT). SHORT improves routing optimality by monitoring routing paths continuously and redirecting the path whenever a shortcut path is available. In this paper, the performance comparison of TORA and TORA with SHORT has been analyzed using network simulator for various parameters. TORA with SHORT enhances performance of TORA in terms of throughput, packet loss, end-to-end delay, and energy.

1. INTRODUCTION

In mobile ad hoc networks (MANETs), all nodes are connected dynamically in an arbitrary manner. All nodes behave as routers and take part in discovery and maintenance of routes to other nodes in the network. Routing protocols find a path to be followed by data packets from a source node to a destination node. MANETs routing protocols can be classified into three major categories based on routing information update mechanism. They are proactive or table-driven routing protocols, reactive or on-demand routing protocols, and hybrid routing protocols. Several routing protocols have been discussed in the literature. In this paper, TORA, a reactive routing protocol, is taken for analysis [1].

TORA is designed to discover routes on demand, provide multiple routes to a destination, establish routes quickly, and minimize communication overhead by localizing algorithmic reaction to topological changes. SHORT is a mechanism that optimizes the route length result in significant performance gain over the underlying routing protocols. The proposed schemes monitor the routing path and try to shorten the path length when it is feasible. A shorter path not only reduces the latency but also enhances the throughput [2]. The rest of the paper is organized as follows. In Section 2, the previous work related to QoS routing protocols is briefly reviewed. In Section 3, self-healing and optimizing routing technique (SHORT) is described. The extension of SHORT for TORA is discussed in Section 4. In Section 5, the simulation results are shown. In Section 6, the result of the work done is summarized.

2. PREVIOUS WORK

QoS routing protocols search for routes with sufficient resources in order to satisfy the QoS requirement of a flow. QoS routing protocol should find the path that consumes minimum resources [3]. Some key design considerations in providing QoS routing support and review of previous work addressing the issue of route selection subject to QoS constraints are discussed in [4]. A framework of self-healing and optimizing routing techniques for mobile ad hoc networks has been proposed in [5].

SHORT techniques for both ad hoc on-demand distance vector routing (AODV) and dynamic source routing (DSR) algorithm have been analyzed and evaluated in the literature. Simulation results show that higher-delivery rate and longer network lifetime are achieved by adopting SHORT [5]. Flooding is a strategy that supports QoS routing, which works by flooding a route searching message across the entire network to search for a QoS route on demand. Intermediate nodes forward nonduplicate route searching messages, that they receive, provided that the given QoS requirements have not been violated yet. Once the intended destination receives a route searching message, a QoS route is discovered. This strategy is used to acquire constrained paths in time-slotted ad hoc networks [6]. AODV-backup routing has some similarity to SHORT in the sense that it lets neighboring nodes around a route be aware of the route. Each neighboring node computes an alternative short route for a nearby link on the route and when the link breaks, relevant neighboring node will salvage the route and help to deliver the affected packets to the destination [7]. With geographic positioning system (GPS) support, a novel link cost function is proposed in [8]. The cost function serves as a localized power aware routing, which includes not only the necessary transmission energy but also the distance between the transmitting node and the final destination node.

TORA-based QoS routing protocol for MANETs called INORA (INSIGNIA + TORA) is presented in [9]. INORA is a network layer QoS support mechanism that makes use of the INSIGNIA in-band signaling mechanism and TORA routing protocol for MANETs. In INORA, QoS signaling is used to reserve and release resources and setup, tear down, and renegotiate flows in the network. QoS-TORA proposed in [10] 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. A framework of self-healing technique for TORA is proposed in this paper.

3. SELF-HEALING AND OPTIMIZING ROUTING TECHNIQUE (SHORT)

Two broad classes of SHORT are proposed: path aware (PA)-SHORT and energy aware (EA)-SHORT. PA-SHORT is concerned with optimizing and healing paths to reduce the number of hops, whereas the the EA-SHORT is to conserve power in MANETs.

3.1. *Path aware (PA)-SHORT*

The basic scenario of the shortcut discovery process is shown in Figure 1. The hop-count (HC) field is initialized to zero at the source node and gets incremented by one at every hop the packet takes. This information is maintained as an array termed as the hop comparison array. Each of the elements of the array has an expiration time after which they are invalidated [5]. Consider a routing path from a source node A to a destination node D as shown in Figure 1(a). This initial path is determined through the path discovery process, and the packet takes four hops while getting routed from S to D. Mobility of the nodes may make the shape of the routing path similar to the one shown in Figure 1(b) while retaining the connectivity. In this new shape, C is in the transmission range of A. The current routing path is shown by the solid lines in the figure. The example is analyzed in steps where a step defines the events during the broadcast of a packet at a node. The entry of the hop comparison array at the end of each step at each of the node is shown in Table 1.

Table 1: The entry of the hop comparison array.

	S	A	B	C	D	Shortcut
(i)	(0, S)	(0, S)	—	—	—	—
(ii)	(0, S)	(0, S)	(1,A)	(1, A)	—	—
(iii)	(0, S)	(0, S)	(1, A)	(2, B)	—	—
(iv)	(0, S)	(3, C)	(1, A)	(2, B)	(3, C)	Found at A
(v)	(0, S)	(0, S)	—	(1, A)	(2, C)	—

(i) S needs to forward a packet to A. An entry is initialized in A's hop comparison array (S, D, 0, S). It broadcasts the packet while marking HC as 0. Node A is in the transmission range of S and receives the broadcast. So it records (S, D, 0, S) in its hop comparison array.

(ii) Node A broadcasts the packet with a HC of 1 destined for D. Nodes B and C also receive the packet as they are in the transmission range. B and C record (S, D, 1, A) in their hop comparison array.

(iii) Node B broadcasts the packet with a HC of 2. Nodes A and C have an entry corresponding to (S, D). Since the difference in HCs not more than 2, nothing is updated.

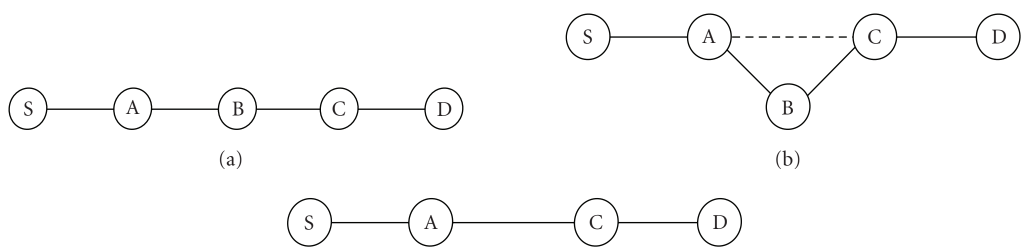
(iv) While forwarding the packet to D, C broadcasts the packets with a HC of 3. Nodes A, B, and D are in the transmission range. Node to D consumes the packet as it is the destination node. B compares the HC with its stored entry. As the difference in HC is not more than 2, nothing is updated at B. At A, the HC difference is 3. So, node A then updates its own routing table to point to C as the next hop node for destination D.

(v) The corresponding entry of the hop comparison array at S, A, and C is deleted. Thus, path A-B-C is shortened to A-C. The final path is shown in Figure 1(c). This shortcut path formation is termed as (2, 1) reduction.

3.2. *Energy aware (EA)-SHORT*

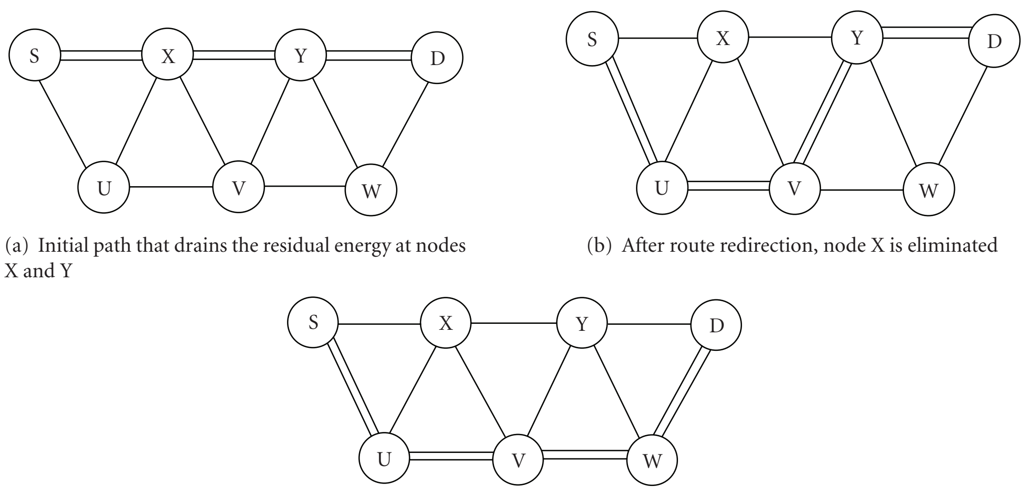
Energy aware (EA)-SHORT extends node and network lifetime by routing packets through nodes that have sufficient remaining power and avoiding nodes that are low on battery supply. To achieve routing fairness, routing protocols use self-healing mechanism so that it can drag itself out of the situations in which certain nodes are being over-used while other nodes are idle.

Energy aware (EA)-SHORT will fairly distribute the traffic load among all the participating nodes in the network [5]. Consider a part of an MANET shown in Figure 2(a), the path S-X-Y-D is the optimal path for a connection from source S to destination D. Nodes X and Y will continuously be used in forwarding the traffic, leaving the other nodes free from the traffic load. Nodes X and Y will eventually be drained out of battery supply and die early. However, an energy-aware routing scheme will try to divert the traffic to other nodes. As the data packets are successively forwarded by the two nodes (X and Y), node U overhears the same



(a) (b) (c)

Figure 1: Hop (2, 1) shortcut path formations.



(a) Initial path that drains the residual energy at nodes X and Y

(b) After route redirection, node X is eliminated

(c) After route redirection, node Y also eliminated

Figure 2: Successive local route redirection operations.

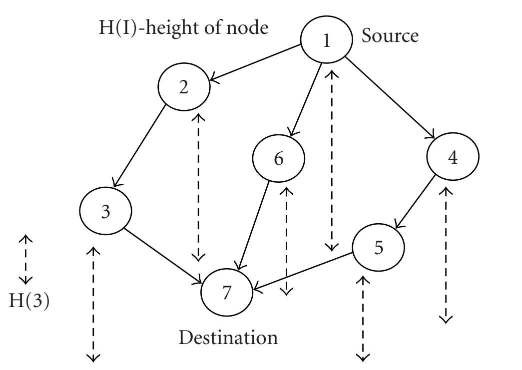


Figure 3: Illustration of temporal ordering in TORA.

packet and finds out the energy difference at node X and at itself with help of overhear table. If it is significant enough, node U will do the redirection. Similarly, the energy level difference between Y and V is significant enough, and then the node V will do the redirection. With successive local redirection operations, the route will gradually converge to an alternative node disjoint path S-U-V-W-D as shown in Figures 2(b) and 2(c). An overhear table is maintained at each node.

4. SELF-HEALING OPTIMIZATION ROUTING TECHNIQUE FOR TORA

SHORT is a general technique that should work with any mobile ad hoc routing protocol. TORA is a source-initiated on-demand routing protocol which uses a link reversal algorithm [11]. Path length and power aware techniques are incorporated into TORA protocol. SHORT improves routing optimality by gradually shortening the routes whenever possible. When shortcut occurs and is estimated to be stable, it will be utilized to shorten the route. It should be noted that the SHORT algorithm does not react to every little change in the topology or transient conditions. Let us consider the network topology shown in Figure 3. 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.

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. 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. By doing this, a set of directed links from the node which originated the query to the destination node 7 is created.

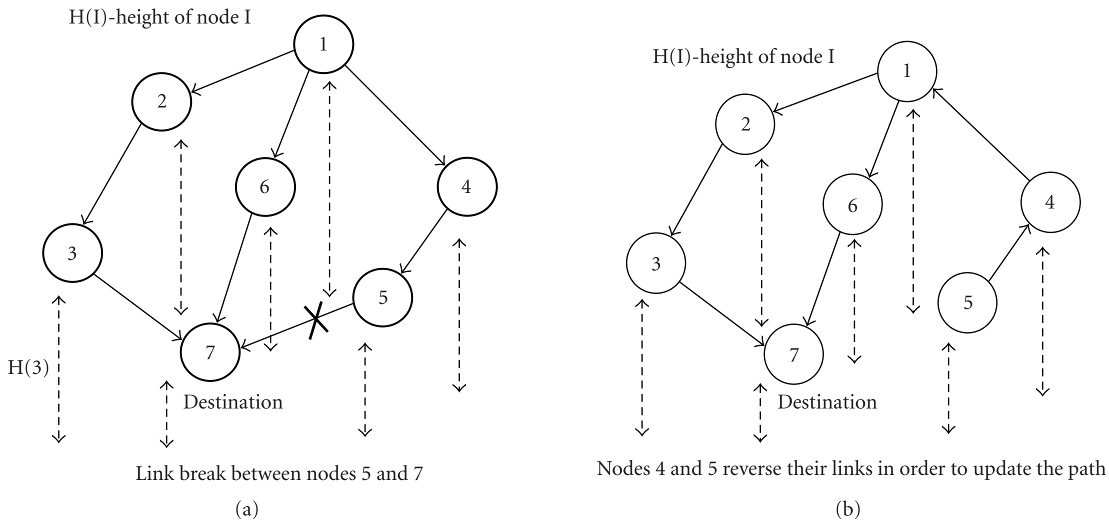


Figure 4: Illustration of route maintenance in TORA.

This forms the directed acyclic graph (DAG) depicted in Figure 3. When an intermediate node discovers that the route to the destination node is invalid, as illustrated in Figure 4, 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. In TORA-SHORT, both the hop comparison array and overhear table are maintained in each node. The format of each entry in the array is ⟨SA, DA, HC, NA⟩, where NA is the neighbors address from which the packet was broadcasted. Each entry overhear table contains the following three fields source-destination pairs, sequence number and overhear list. Each entry represents a traffic flow in the network, identified by the source-destination pair field. Each new entry has three fields as hop counter, residual energy level, and the sender. The residual energy field records the residual energy level of transmitting node of the packets.

5. PERFORMANCE EVALUATION

The performance of the proposed protocol TORA-SHORT is evaluated using the nanoseconds-2 simulator [12]. QoS parameters like delay, throughput, packet loss, and control overhead are analyzed. Table 2 lists the simulation parameters and environments used.

5.1. Throughput

The effects of mobility and pause time on throughput for the protocols TORA and TORA-SHORT are shown in Figures 5 and 6. During high mobility, both protocols show small degradation in throughput due to high-link breakage. TORA-SHORT shows around 3% improvement in throughput over TORA. The higher the pause time is, the longer each node remains stable before the next movement.

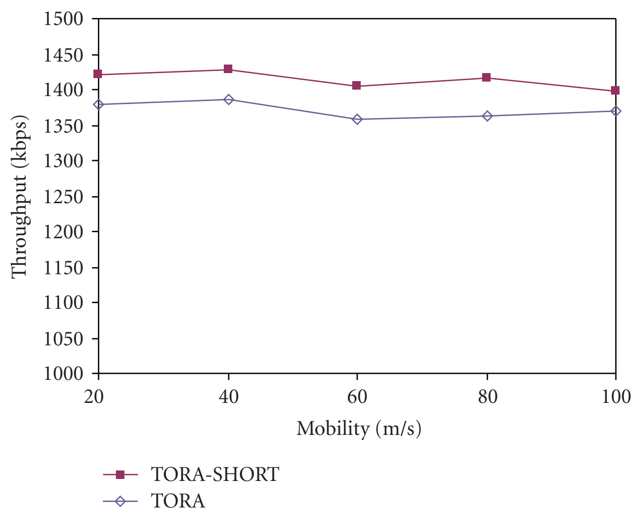


Figure 5: Effect of mobility on throughput.

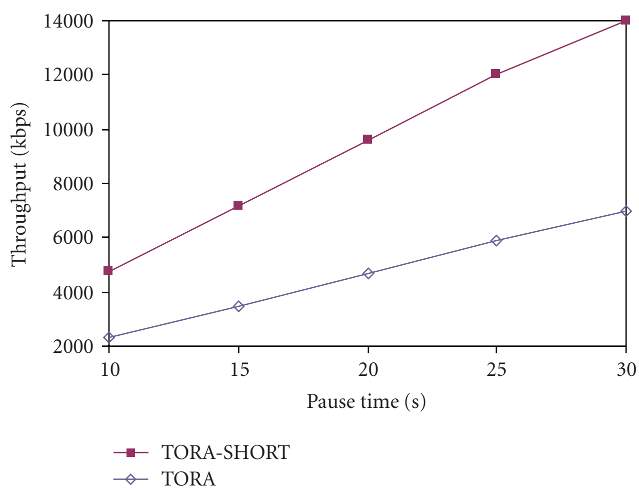


Figure 6: Effect of pause time on throughput.

Table 2: Simulation parameters.

Parameter	Value
Simulation area	500 m × 500 m
Node communication range	250 m
Routing protocol	TORA, TORA-SHORT
Medium access mechanism	IEEE 802.11b
Traffic source model	Constant bit rate
Bandwidth	2 Mbps
Packet size	1024 Bytes
Mobility model and speed	Random waypoint, 20–100 m/s

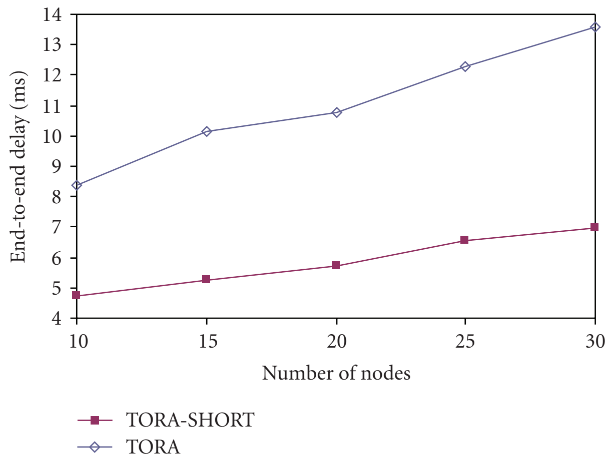


Figure 7: Effect of number of nodes on delay.

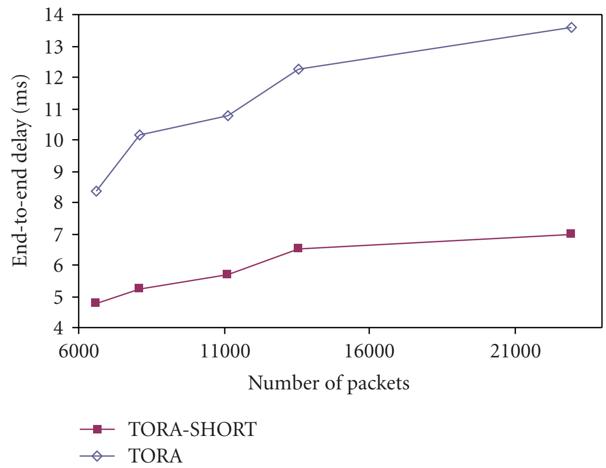


Figure 8: Effect of number of packets on delay.

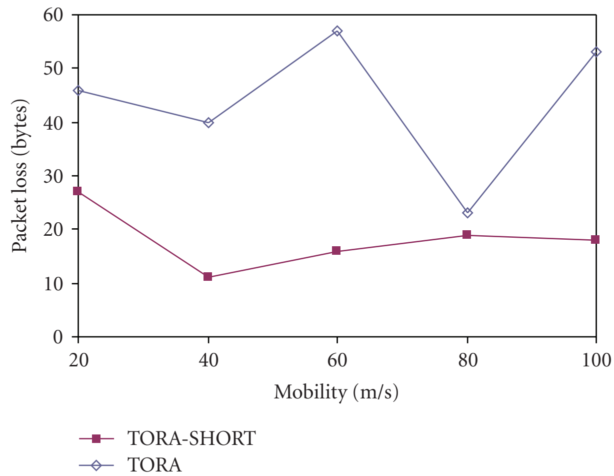


Figure 9: Effect of mobility on packet loss.

Throughput increases with the increase in pause time, due to less number of link breaks. The performance improvement over TORA is around 50% when the pause time varies from 10 to 30 seconds. This is because SHORT will gradually heal and rectify if there is a shortcut path, thus resulting in better throughput.

5.2. End-to-end delay

Figure 7 shows the effect of number of nodes on end-to-end delay. When the number of active mobile nodes in a network increases, the delay increases. This is due to the increase in traffic in network.

Delay of TORA-SHORT is less than TORA. Here, the reduction in delay is about 50%. When the number of packets increases, the delay also increases in both cases. Figure 8 shows the effect packets on end-to-end delay. This is also due to the increase in traffic in network. Delay of TORA-SHORT is less than TORA. Here, the reduction in delay is about 50%. This is due to the fact that SHORT improves routing optimality by gradually shortening the routes whenever possible.

5.3. Packet loss

Figure 9 depicts the effect of mobility on packet loss. When the speed of the node increases, the packet loss also increases. Here, the node speed is varied from 20 m/s to 100 m/s. In TORA, there is a nonlinear variation in the packet loss. This is due to sudden changes in the number of link breaks. A linear decrease in the packet loss for both the cases from 20 m/s to 40 m/s mobile speed. In TORA-SHORT, there is a slight increase in packet loss in the 40 m/s to 100 m/s. The reduction in packet loss varies from 17 to 73%. The packets in TORA-SHORT follow a shortest path and also eliminate node which is low in energy level. Figure 10 depicts effect of number of nodes on packet loss. It is observed that when the number of the nodes increases the packet loss also increases. The reduction in packet loss varies from 12 to 57%. The result shows a low-dropped packet loss for TORA-SHORT than the conventional one due to the fact that the packets follow a shortest path, and also the probability of a link to get break is reduced.

5.4. Routing overhead and average energy

When the number of active mobile nodes in a network increases, the routing overhead increases. This is due to the

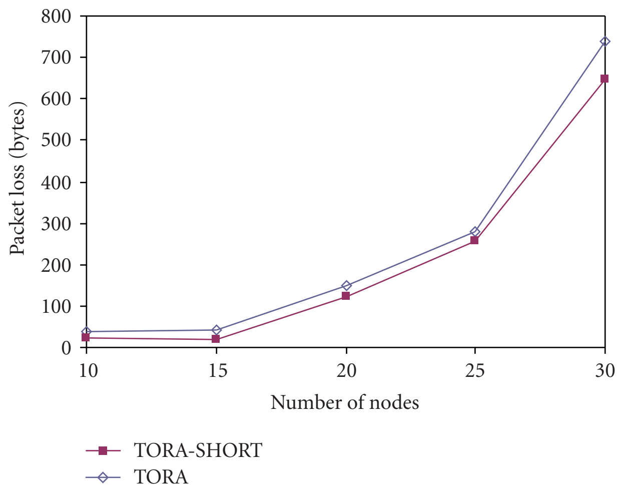


Figure 10: Effect of number of nodes on packet loss.

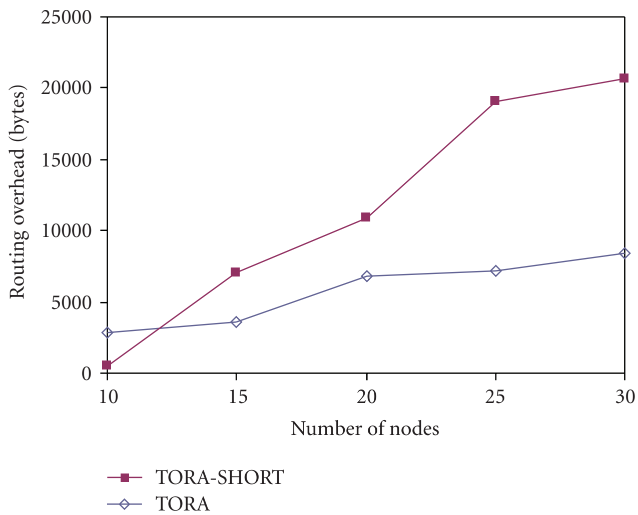


Figure 11: Effect of nodes on routing overhead.

increasing number of routing packets between the ad hoc nodes. Figure 11 depicts the effect of nodes on routing overhead. TORA-SHORT has high-routing overhead compared to TORA.

TORA-SHORT uses a very small amount of memory space to maintain the hop comparison array for every shortcut formation, only one extra message is necessary to inform one of the neighboring nodes to update its routing table. TORA-SHORT routing overhead also includes shortcut informing messages as well. Figure 12 shows the average energy with respect to number of nodes. When the number of active mobile nodes in a network increases, the average energy increases in both protocols. EA-SHORT will fairly distribute the traffic load among all the participating nodes in the network. Average energy of TORA-SHORT is more than TORA. The improvement in average energy over TORA is about 43%.

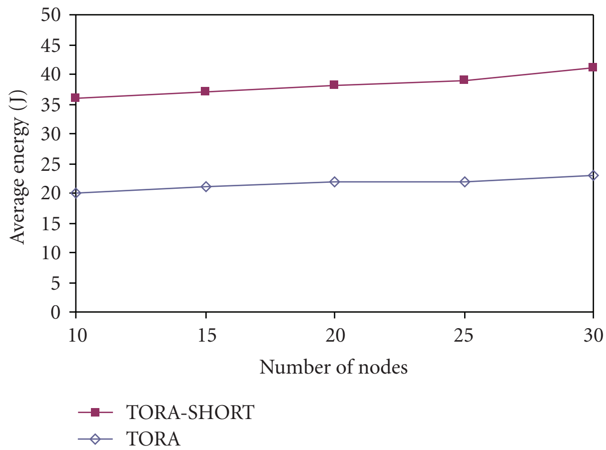


Figure 12: Effect of nodes on average energy.

6. CONCLUSION

The performance comparison of TORA and TORA with SHORT has been analyzed in this paper using network simulator-2. The performance of TORA is improved by using self-healing technique which optimizes path length and power. SHORT can be used to improve routing optimality by monitoring routing paths continuously and gradually redirecting the path whenever a shortcut path is available. Path length and power aware techniques are incorporated into TORA protocol. SHORT improves routing optimality by gradually shortening the routes whenever possible. When shortcut occurs and is estimated to be stable, it will be utilized to shorten the route. Simulation results show that higher throughput, lower end-to-end delay, lower delay, and higher network life time are achieved. In the simulation study, it has been found that TORA-SHORT outperforms the TORA protocol in terms of throughput, end-to-end delay, packet loss, and network life time. In future, this can be extended to other QoS routing metrics.

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