EPLAODV: Energy Priority and Link Aware Ad-hoc On-demand Distance Vector Routing Protocol for Post-disaster Communication Networks

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Abstract—**In Mobile Ad-hoc Networks (MANETs) the major issue between nodes for data transfer is link quality. The majority of the MANET routing protocols try to maintain the link quality between nodes but still need improvement. This paper focuses on link quality between nodes in an ad hoc network in emergency scenarios through the design of the Energy Priority and Link Aware Ad-hoc On-demand Distance Vector (EPLAODV) routing protocol. EPLAODV improves the link quality between nodes through SNR. For performance analysis, the NS2.35 network simulator was used. Simulation time and traffic load were the major simulation parameters. From the simulation results, it is observed that EPLAODV performs better than AODV.**

Keywords-mobility; SNR; EPLAODV; link-quality; lifetime

I. INTRODUCTION

Many users use wireless communication devices or channels for the exchange of information. In an MANET, mobile nodes are connected through wireless links. An MANET lacks pre-deployed infrastructure for environment monitoring and disaster scenarios [1-3]. RF frequencies are used from mobile nodes to flood data packets from source to destination nodes. An MANET has flexible and dynamic topology. In dynamic topology, the nodes of the network frequently move with different speeds within the transmission range. Nodes may join or leave the network thus changing its topology. Node mobility is a main cause of frequent link failure. To prolong network lifetime and to get maximum throughput, MANETs use reactive, proactive and hybrid routing protocols to discover shortest, stable, and efficient routes. The reactive routing protocols AODV [4], DSR [5] and TORA [6] are on demand routing protocols which discover routes when required, avoid traffic congestion, reduce routing overhead, minimize end-to-end delay, and reduce traffic collision [7]. Generally, MANET nodes have battery constraints. In a network, the nodes with very low energy level are disconnected. To discover a route, the conventional AODV routing protocol does not consider the fairness of node energy consumption. MANETs are used in various real time applications such as environment monitoring control, air traffic control, in battle fields, and in many emergency scenarios like major accidents and disaster relief operations [8]. In real time scenarios, where the replacement or recharging of batteries is almost not possible, the lifetime of the network is important. To prolong the network lifetime link various energy efficient and link aware routing protocols have been proposed. These routing protocols avoid link failures and consider less node energy consumption [9-12], although the current status in maximizing network lifetime still needs improvement.

In disaster-affected areas, the telecommunication infrastructures are seriously damaged or even collapsed. MANETs can be deployed in critical areas to carry out the rescue operations. Rescue workers or first responders are equipped with mobile devices to share important information about operations at the disaster site. The first responders share videos, make voice calls and send text messages to their supervisors to inform about the situation in the area. Wireless communication is used to support the operational analysis of disaster response. To avoid communication interruption among the rescue works, and to reduce the losses of infrastructure and human lives, critical information travels through high powered nodes or stable links. The proposed energy, priority and link aware ad hoc on demand distance vector (EPLAODV) routing protocol discovers energy efficient and link aware routes from source to destination for the exchange of critical information in disaster operations.

II. LITERATURE REVIEW

MANET routing protocols are used to discover routes from source to destination. Node mobility and unfair consumption of

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node energy and frequent link failure are inherent in an MANET, which causes routing overhead and end-to-end delay. Conventional AODV reactive routing protocol does not consider link stability and energy consumption, while energy consumption is the main issue of MANETs. Different routing protocols based on the node energy consumption and link quality parameters to prolong network life time, have been proposed. Authors in [13] proposed MAODV routing protocol which is based on AODV. The algorithm considers two parameters, node energy level and node distance. The distances among the nodes are measured and a node with a good energy level and with small distances is considered in route selection. MAODV selects an energy efficient route in which all nodes possess good energy level. This protocol consumes less energy and maximizes packet delivery ratio and network lifetime. In [14], authors suggested a local repair method to avoid link breakage. The protocol takes preemptive measures based on the residual energy, and uses three state modes to avoid link failure: normal, selfish, and sleep. The algorithm selects stable and energy efficient routes. It minimizes routing overheads by avoiding link breakages and maximizes network lifetime. Authors in [15] proposed the energy efficient routing protocol Ad-hoc On-demand Distance Vector Energy Aware (AODVEA) which utilizes a min-max algorithm to take routing decisions. A node must have a minimum remaining energy to participate in route selection. The algorithm computes the minimum remaining energy of all possible routes. To prolong the network lifetime and minimize end-to-end delay, the protocol selects the path having maximum value of minimum remaining energy. Authors in [16] proposed the Dynamic Energy Ad-hoc On-demand Distance Vector (DE-AODV) routing protocol. Route selection is based on node energy level. The node energy level is compared with a threshold. A node having more energy is selected in a route. To avoid link failures, the algorithm provides external batteries to the nodes with less energy. The protocol maximizes the network lifetime by minimizing energy consumption. Authors in [17] suggested a new method to improve link quality. The suggested method is based on ant colony optimization (ACO) algorithm. The algorithm considers received signal strength (RSS) as a link quality parameter. The protocol selects nodes in a route that have stable links with good RSS values. The protocol minimizes routing overhead and node energy consumption by avoiding link failure. Authors in [18] proposed the Route Stability and Energy Aware (RSEA)-AODV routing protocol, which considers RSS, drain rate of nodes, remaining energy, and delay as route metrics to select a stable route. In the route discovery process, these parameters are compared with respective thresholds. A less congested node, having good energy level and good RSS values is selected in an energy efficient and stable route. The protocol minimizes energy consumption, end-to-end delay and maximizes network lifetime and packet delivery ratio.

III. The Proposed EPLAODV

In the proposed EPLAODV routing protocol, the discovered routes are based on traffic priority, node energy, and link quality. The RREQ and RREP control packets are modified by adding new priority fields. High priority 0 is assigned to time critical traffic for exchange of information in the form of voice and video. Low priority 1 is assigned to normal traffic for the exchange of information in the form of text and data. When the source node wants to discover a route to a destination, it sets the traffic priority in the RREQ control packet and broadcasts it to all its neighbors. In the following section the route discovery process is discussed in detail.

A. Route Discovery

Assume that node N_s is the source and node N_d is the destination, as shown in Figure 1. The source node initiates route discovery process, N_s assigns a traffic priority 0 in the *RREQ* control packet, and broadcasts *RREQ* packets to neighbor nodes n_1, n_3, and n_5. The intermediate nodes n_1, n_3 and n_5 compare their residual energy with the energy threshold Th_e. If their residual energy is greater than Th_e, they make a reverse path entry and broadcast RREQ packets to their neighbors. If any node among n_1, n_3 or n_5 has a residual energy level lower than threshold Th_e, it drops the RREQ packet. Assuming that these nodes have sufficient residual energy level, node n_1 rebroadcasts the *RREQ* packet to node n_2, which does not accept the packet due to its insufficient energy level. Similarly, node n_3 rebroadcasts *RREQ* packet to node n_4 and node n_5 rebroadcasts *RREQ* packet to node n_6. This process is continued until *RREQ* packet reaches the destination.

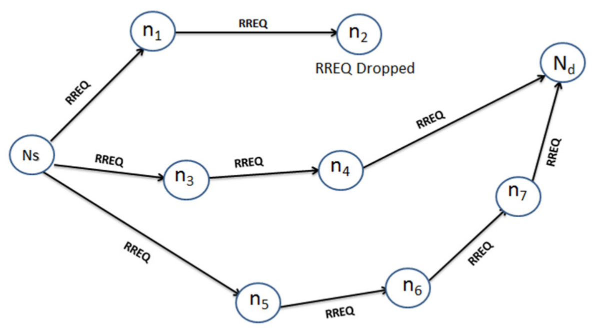

Fig. 1. Broadcasting of *RREQ* packet in time critical traffic

When the *RREQ* control packet reaches the destination node N_d, it updates the priority field in the *RREP* control packets for assigning traffic priority, and the *RREP* packets are unicast to nodes n_4 and n_7. When nodes n_4, and n_7 receive the *RREP* packets, they check their traffic priority value, and their own residual energy and signal-to-noise ratio (SNR) value. If the *RREP* packet contains priority value of 0, the nodes assume that the route is going to be established for high priority traffic, otherwise low priority traffic is established. Intermediate nodes do not accept any *RREP* control packet until they check their node energy level and SNR value. If the residual energy of node n_4 and n_7 is greater than Th_e, and the SNR value of node n_4 or n_7 is greater than Th_{snro}, then node n_4 unicasts the *RREP* packet to nodes n_3 and node n_7 unicasts *RREP* packet to node n_6. If node n_4 or n_7 have residual energy level lower than Th_e and less SNR than Th_{snro}, they drop the *RREP* packet. Node n_5 drops *RREP* control packet due to insufficient energy or insufficient SNR value. This discovery process continues until *RREP* control packet reaches the source node N_s. Finally, node n_3 unicasts the *RREP* packet to the source node N_s and the route $N_s - n_3 - n_4 - N_d$ is established as shown in Figure 2. To discover low priority routes, priority 1 is assigned in *RREQ* and *RREP* control packets and the same steps are taken in route discovery process to establish energy efficient and stable routes. Once the route has been established, the source node forwards data packets to the destination node.

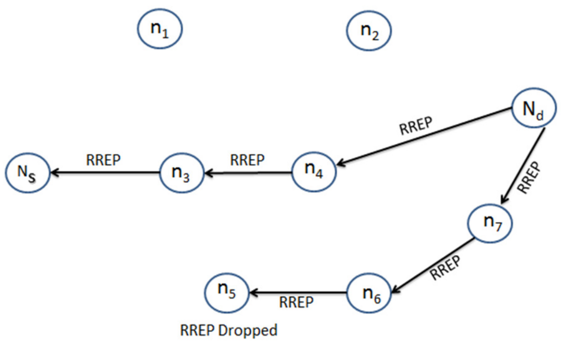

Fig. 2. Unicasting of *RREP* control packet

B. *EPLAODV Algorithm*

In Table I, the route setup process of the EPLAODV protocol is described.

TABLE I. ALGORITHM 1: EPLAODV ROUTE SETUP

Steps	Description
1.	Let N_s denote the source node and N_d denote the destination node.
2.	Let N represent the set of intermediate nodes between N_s and N_d, where N={n_0,n_1, n_2,……., n_m} and n_i represent the current node.
3.	Let n_{ie} represent the residual energy level of the current node.
4.	Let $snr_{i+1,i}$ represent the SNR for node n_{i+1} to node n_i
5.	Let Th_{snr0} represent the SNR threshold for real time traffic
6.	Let Th_{snr1} represent the SNR threshold for normal traffic
7.	Node N_s sets the traffic priority value in the priority field in the *RREQ* packet and broadcasts to its neighbors.
8.	Node n_i receives the *RREQ* packet, where n_i € N.

9.	for every node n_i in the forward route, where n_i € N {
	 if (n_i!= N_d) then { n_i checks its n_{ie}
	 if (n_{ie} <Th_e) then { n_i drops the *RREQ* packet
	 else
	 n_i makes reverse route entry for N_s and forwards *RREQ* to its neighbors }}}

10.	if (n_i= N_d) then {
	 n_i replicates the traffic priority value from the *RREQ* packet into the priority field in the *RREP* packet and forwards the *RREP* to its neighbors
	 }

11.	for every node n_i in the reverse route, where n_i € N
	 if ((n_i!= N_s) && (priority = 0)) then {n_i checks its n_{ie} and $snr_{i+1,i}$
	 if (n_{ie} >Th_e) && ($snr_{i+1,i}$ >= Th_{snr0}) then {
	 n_i drops the *RREP* packet
	 else
	 n_i makes forward route entry for N_d and forwards the *RREP* to its neighbors }}
	 if ((n_i!= N_s) && (priority = 1)) then { n_i checks its n_{ie} and $snr_{i+1,i}$
	 if (n_{ie} >Th_e) && ($snr_{i+1,i}$ >= Th_{snr1}) then {n_i drops the *RREP* packet
	 else
	 n_i makes forward route entry for N_d and forwards *RREP* to its neighbors }}}

12.	if (n_i= N_s) then { n_i makes forward route entry for N_d and starts sending data packets to N_d. }

IV. PERFORMANCE ANALYSIS

The proposed EPLAODV routing protocol is implemented in the open source network simulator NS2 [19]. The simulator helps in evaluating the performance of MANET routing protocols. The proposed EPLAODV is compared with AODV. To measure the performance of the proposed EPLAODV routing protocol, we run different emergency scenarios (simulation) in NS2 environment with varying traffic load and simulation time. The simulation results show that the proposed EPLAODV performs better than the original AODV. The simulation parameters are presented in Table II.

TABLE II. NS2 SIMULATION PARAMETERS

Parameters	Rating
MAC layer	IEEE 802.11
Coverage area	1000m×1000m
Antenna type	Omni directional
Routing protocols	AODV, EPAODV
Number of nodes	50
Packet size	512 bytes
Mobility models	Random waypoint
Traffic type	CBR
Initial energy	30J
Buffer size	50
Topology	Flat-grid
Simulation time	1000s

The simulation results are benchmarked with AODV routing protocol with keeping in mind that energy performance is crucial in MANETs because node mobility drains the energy of the node. Results show that the proposed EPLAODV controls the node mobility in efficient way and prolongs the energy of the node as compared to AODV. Figure 3 shows the simulation results of packet delivery ratio versus simulation time. EPLAODV and AODV are compared for high and low priority traffic. Initially at 200s the packet delivery ratio is less because less number of data packets are generated , and less packets are reaching their destination. As the simulation time increases, packet delivery ratio also increases. In conclusion, EPLAODV performs better for high priority and low priority traffic. Figure 4 shows the simulation results of routing overhead versus simulation time for proposed EPLAODV and AODV. As the simulation time increases, EPLAODV selects more stable routes on the basis of link quality. The protocol generates less number of control packets, which causes less routing overhead. It can be seen that EPLAODV performs better than AODV.

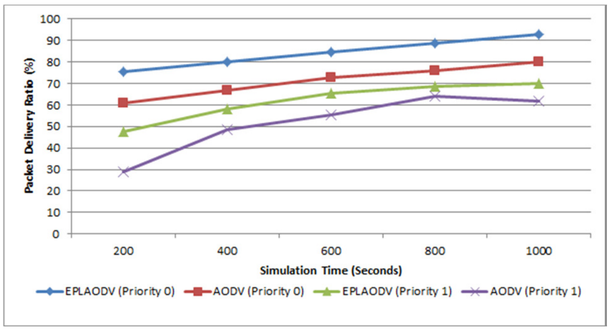

Fig. 3. Packet delivery ratio vs. simulation time

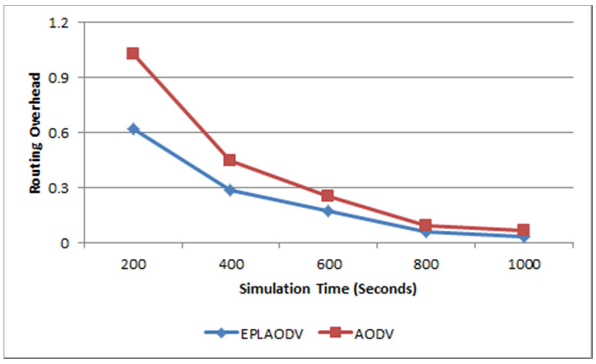

Fig. 4. Routing overhead vs. simulation time

Figure 5 shows the simulation results of network energy consumption versus simulation time for the proposed EPLAODV and AODV. Initially at 200s, the network consumes less energy. As the simulation time increases, EPLAODV generates more control and data packets, causing more energy consumption. EPLAODV discovers energy efficient and stable routes, which minimizes the flooding of control packets and energy consumption. Figure 6 shows the simulation results of end-to-end delay versus simulation time. The proposed EPLAODV and AODV are compared for both high priority traffic and low priority traffic. Initially, at 200s the end-to-end delay is maximum, because more packets are generated, due to congestion or link breakage. As the simulation time of the network increases, end-to-end delay decreases, because EPLAODV selects stable paths based on link quality which helps avoiding link breakage and congested traffic. The proposed EPLAODV performs better for both high priority and low priority traffic.

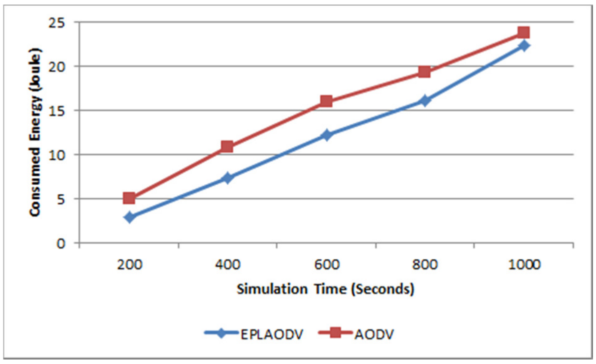

Fig. 5. Consumed energy vs. simulation time

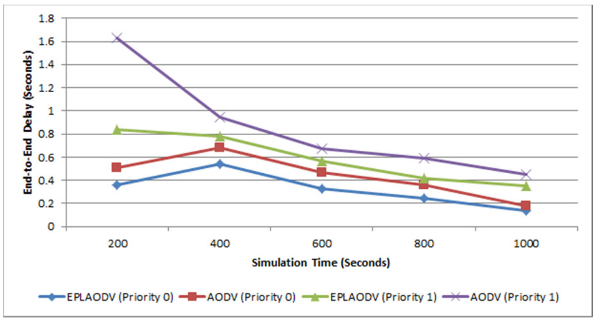

Fig. 6. End-to-End delay vs. simulation time

Figure 7 shows the simulation results of packet delivery ratio versus traffic load for high and low priority traffic. Initially, the packet delivery ratio is maximum. As the traffic load increases, the network becomes more congested, which reduces packet delivery ratio. The proposed protocol EPLAODV performs better than AODV in both cases.

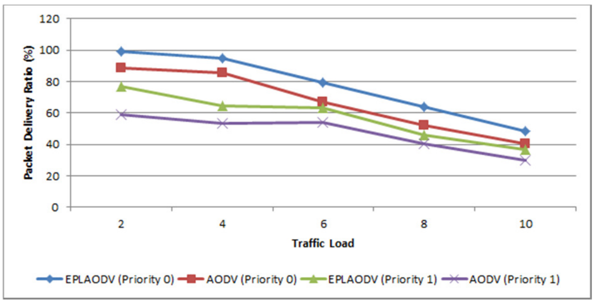

Fig. 7. Packet delivery ratio vs. traffic load

Figure 8 shows the simulation results of routing overhead versus traffic load. Initially the routing overhead of the network minimizes. As the traffic load increases, the congestion of the network also increases, which causes link breakage and increased routing overhead. Again, the proposed EPLAODV routing protocol performs better than AODV.

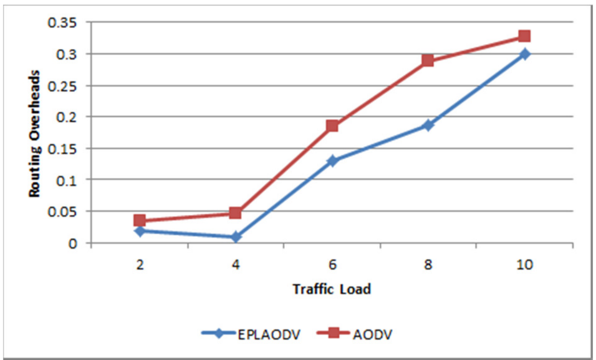

Fig. 8. Routing overhead vs. traffic load

Figure 9 shows the simulation results of network energy consumption versus traffic load. Initially, with minimum traffic load, the energy consumption of the network is reduced. As the traffic load increases, the network becomes more congested. AODV routing protocol generates more control and data packets, causing more energy consumption. The proposed EPLAODV protocol reduces the broadcasting of control packets, in order to minimize energy consumption. The proposed EPLAODV routing protocol performs better than AODV. Figure 10 shows the simulation results of end-to-end delay versus traffic load. EPLAODV and AODV are compared for both high and low priority traffic. Initially, with minimum traffic load, end-to-end delay is reduced. As the traffic load increases, the congestion of the network also increases, which causes more end-to-end delay. The proposed EPLAODV performs better for both cases of high priority and low priority traffic.

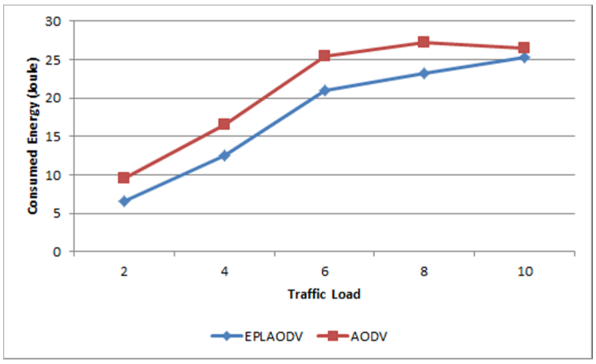

Fig. 9. Consumed energy vs. traffic load

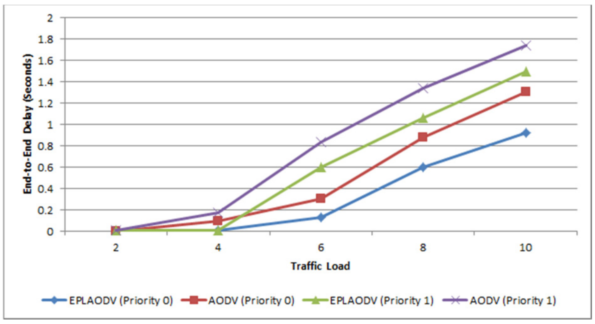

Fig. 10. End-to-end delay vs. traffic load

V. CONCLUSION

An energy, link and traffic aware extension of AODV routing protocol named EPLAODV is introduced in this paper. The EPLAODV selects energy efficient and link aware routes for time critical and normal traffic. Some emergency scenarios have been simulated by varying simulation time and network traffic load. The simulation results show that the proposed scheme performs better than the traditional AODV for real time and textual data in terms of packet delivery ratio, energy consumption, routing overhead, and end-to-end delay for all simulated scenarios.

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