Power Aware Location Aided Routing Based on Adaptive Fuzzy Threshold Energy

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Abstract— **In this paper, the Fuzzy Thresholded Power Aware Location Aided Routing (FTPALAR) protocol is proposed. It is an on-demand routing protocol, which considers both location and residual energy of the nodes as routing metrics. It ensures reduction in energy consumption in the network. The novelty of the proposed work is that it achieves routing in the direction towards the destination using the nodes with sufficient residual energy. This leads to increase in the network lifetime. The performance of the proposed FTPALAR protocol is compared with LAR. From the simulation results, it is found that the proposed FTPALAR protocol outperforms LAR in terms of average energy consumption and network lifetime**.

Index Terms—**MANET, residual energy, network lifetime, location aided routing**

I. Introduction

In the next generation of wireless communication systems, there will be a need for the rapid deployment of independent mobile users. Significant examples include establishing survivable, efficient, dynamic communication for emergency/rescue operations, disaster relief efforts, and military networks. Such network scenarios cannot rely on centralized and organized connectivity, and can be conceived as applications of mobile ad hoc networks (MANETs)**.** A MANET is an autonomous collection of mobile users that communicate over relatively bandwidth constrained wireless links. Since the nodes are mobile, the network topology may change rapidly and unpredictably over time. Since the network is decentralized, all network activity including discovering the topology and delivering messages must be executed by the nodes themselves, i.e., routing functionality is incorporated into mobile nodes. The set of applications for MANETs is diverse, ranging from small, static networks that are constrained by power sources, to large-scale, mobile, highly dynamic networks. The design of network protocols for these networks is a complex issue. Regardless of the application, MANETs need efficient distributed algorithms to determine network organization, link scheduling, and routing. However, determining viable routing paths and delivering messages in a decentralized environment where network topology fluctuates, is not a well-defined problem. While the shortest path (based on a given cost function) from a source to a destination in a static network is usually the optimal route, this idea is not easily extended to MANETs. Factors such as variable wireless link quality, propagation path loss, fading, multiuser interference, power expended, and topological changes, become relevant issues. The network should be able to adaptively alter the routing paths to alleviate any of these effects .There are basically two types of routing protocols for MANETs. The routing protocols that do not use location information and those that use location based information. When the routing protocol does not use the location information of the mobile node, then the routing is topology-based routing. AODV, DSR etc. are the examples. If the location information is used in the routing protocol, then the routing is position-based routing. There are two methods of forwarding data packets in location-based routing: greedy forwarding and directional flooding. In greedy forwarding, the next hop node is the closest in distance to destination. Greedy Perimeter Stateless Routing Protocol (GPSR) uses the greedy forwarding. In the directional flooding, the source node floods data packets in a geographical area towards the direction of the destination node. Location Aided Routing (LAR) uses directional forwarding flooding. But these traditional routing algorithms consider path length or end-to-end delay as their main metric for routing. Since all the mobile devices run on battery power, efficient utilization of battery power is very much essential. That is, it is needed to apply some energy conservation technique to the traditional routing algorithms to see that the mobile device and hence the network runs for a longer period. The application of power control techniques to ad hoc networks has many challenges and implementation complexities. The power control is of great significance in ad hoc networks because of their organizational structure and lack of central management. With the implementation of effective power control techniques, the ad hoc network can improve their vital parameters, such as power consumption, interference distribution, throughput, routing, connectivity, clustering, backbone management, and organization. The main objective of power-aware protocols is to maximize the time before the network partitions. For this purpose, power management methods are used at physical, medium access control and network layers.

The energy model has three states where energy is consumed: transmitting, receiving and idle state. Every node starts with initial value which is the level of energy defined by user at the beginning of the simulation. It also has transmitting power (P_{tx}), receiving power(P_{rx}) and idle power parameters required by the node's physical layer. These values also can be defined by user. Initial energy level is decremented for transmission and reception of packets by P_{tx} and P_{rx}. When energy level in a node becomes zero, the node does not accept or send any packets.

The following are the energy-related metrics that have been used to determine energy efficient routing path instead of the shortest one.

- energy consumed per packet,
- time to network partition,
- variance in node power levels,
- cost/packet, and
- maximum node cost

The first metric is useful to provide the min-power path through which the overall energy consumption for delivering a packet is minimized. Here, each wireless link is annotated with the link cost in terms of transmission energy over the link and the min-power path is the one that minimizes the sum of the link costs along the path. However, a routing algorithm using this metric may result in unbalanced energy spending among mobile nodes. When some particular mobile nodes are unfairly burdened to support many packet-relaying functions, they consume more battery energy and stop running earlier than other nodes, disrupting the overall functionality of the ad hoc network. Thus, maximizing the network lifetime (the second metric shown above) is a more fundamental goal of an energy efficient routing algorithm. Given alternative routing paths, select the one that will result in the longest network operation time. However, since future network lifetime is practically difficult to estimate, the next three metrics have been proposed to achieve the goal indirectly. Variance of residual battery energies of mobile nodes is a simple indication of energy balance and can be used to extend network lifetime. Cost-per-packet metric is similar to the energy-per-packet metric but it includes each node's residual battery life in addition to the transmission energy.

The power control approaches considered in the wireless ad hoc network can be loosely classified into two categories, power controlled topology management and power aware routing. Power controlled topology management schemes try to find lowest transmission power level for each link as far as network-wide connectivity is guaranteed. On the other hand, power aware routing schemes find routes which consist of links consuming low energy. In this paper, the objective is to propose a power aware location aided routing (LAR) protocol based on local energy aware routing (LEAR) technique using adaptive fuzzy threshold energy (AFTE).

II. Location Aided Routing

LAR uses the basic flooding algorithm with an exception that it uses location information of a particular node to limit the flooding in the network. The location information can be gathered using the Global Positioning System (GPS). Using the location information, LAR calculates the expected zone of a particular node.

A. *Expected Zone*.

Consider a node S that needs to find a route to node D. Assume that node S knows that node D was at location L at time t_0 and that the current time is t_1. Then, the "expected zone" of node D, from the view-point of node S at time t_1, is the region that node S expects to contain node D at time t_1. Node S can determine the expected zone based on the knowledge that node D was at location L at time t_0. For instance, if node S knows that node D travels with average speed v, then S may assume that the expected zone is the circular region of radius v (t_1 - t_0), centered at location L (Fig. 1).

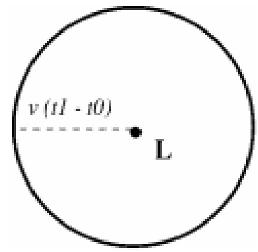


Fig.1 Expected Zone

If actual speed happens to be larger than the average, then the destination may actually be outside the expected zone at time t_1. Thus, expected zone is only an estimate made by node S to determine a region that potentially contains D at time t_1. In general, it is also possible to define v to be the maximum speed (instead of the average) or some other measure of the speed distribution.

B. Request Zone.

Again, consider node S that needs to determine a route to node D. The LAR algorithm uses flooding with one modification. Node S defines (implicitly or explicitly) a request zone for the route request. A node forwards a route request only if it belongs to the request zone. To increase the probability that the route request will reach node D, the request zone should include the expected zone (described above). Additionally, the request zone may also include other regions around the request zone.

III. Literature Survey

In [1], an approach to utilize location information to improve performance of routing protocols for ad hoc networks is suggested. By using location information, the proposed Location Aided Routing (LAR) protocol limits the search for a new route to a smaller "request zone" of the ad hoc network. This results in a significant reduction in the number of routing messages. In Greedy Perimeter Stateless Routing (GPSR) [2], a novel routing protocol for wireless datagram networks that uses the positions of routers and a packet's destination to make packet forwarding decisions. GPSR makes greedy forwarding decisions using only information about a router's immediate neighbors in the network topology. When a packet reaches a region where greedy forwarding is impossible, the algorithm recovers by routing around the perimeter of the region. By keeping status information only about the local topology, GPSR scales better in per-router state than shortest-path and ad-hoc routing protocols as the number of network destinations increases. An algorithm that finds the QoS routes based on the QoS metrics such as link lifetime and the delay is proposed in [3]. It ensures that the routes are link reliable and delay aware. The QoS metrics for the route are computed dynamically. The QoS metrics are measured by varying the Mobility, Speed of movement and number of Nodes. In [4], an improvement to LAR (Location-Aided Routing) is proposed to make it power aware. It considers both areas of routing and bandwidth. It proposes a routing method which improves the quality of services and bandwidth aware method to select proper transmission bandwidth node by using a threshold value of bandwidth. In energy aware GPSR protocol [5], referred to as EGPSR, a method to optimize the greedy forwarding mode is proposed. A forwarding node, first determines a candidate set of neighbor nodes – the nodes that lie closer to the destination than itself. The weight of each such candidate neighbor node is then computed to be the sum of the fraction of the initial energy currently available at the neighbor node and the progress (i.e., the fraction of the distance covered between the forwarding node and the destination) obtained with the selection of the neighbor node. The candidate neighbor node that has the largest weight value is the chosen next hop node to receive the data packet. This procedure is repeated at every hop where greedy forwarding is possible. A new routing algorithm, called Local Energy-Aware Routing (LEAR), which achieves a trade-off between balanced energy consumption and shortest routing delay, and at the same time avoids the blocking and route cache problems is proposed in [6]. An approach to utilize location information using Geographical Routing Protocol (GRP) to improve performance of Dynamic Source Routing protocols for mobile ad hoc networks is proposed in [7]. By using location information, the proposed GRP with Location Aware Routing (LAR) protocol limits the search for a new route to a smaller request zone of the mobile ad hoc network. A new energy efficient AODV-based node caching routing protocol with adaptive workload balancing (AODV-NC-WLB)is proposed is [8]. The various issues related to MANETs such as energy, scalability and quality of services are discussed in [9]. Several energy-aware routing protocols have been proposed above. In this paper a new energy efficient routing protocol based on the distance of neighboring nodes from the base line and also on their residual energy, has been proposed.

IV. PROPOSED WORK

A new power-aware location based routing protocol based on the distances of the neighboring nodes from the baseline and on the adaptive fuzzy based threshold energy has been proposed. The basic algorithm used is location aware routing protocol, in which, a baseline is the line that joins the source (S) and the destination (D). Whenever source S wants to communicate with destination D, it sends Route Request (RREQ) packets to all the neighboring nodes in the rectangle that is formed between the source S and the destination D. The RREQ packet contains two additional parameters viz. fuzzy threshold energy (E_{TH}) and node's distance (d) from the base line (initialized to 0). After receiving the RREQ packet, every neighboring node compares its residual energy RE_i with the E_{TH}. If its residual energy is greater than E_{TH}, then it determines its distance (d_i) from the baseline using Eq. (1) (Fig. 3). Then it forwards the RREQ packet to its neighbors after updating E_{TH} with newly computed E_{TH}, and adding d_i to d. This process is repeated till RREQ reaches the destination D. The destination D, which receives RREQ packet along several paths from the same source S, will send route reply along the path which has least value for d. This method ensures that the packets are sent in the direction of the destination D using the nodes with sufficient residual energy. The distance d_i is given by the equation:

$$d_i = \left| \frac{aX_i + bY_i + c}{\sqrt{\left(a^2 + b^2\right)}} \right| \quad \ldots . \; (1)$$

where, (X_i , Y_i) are the coordinates of a neighboring node i.

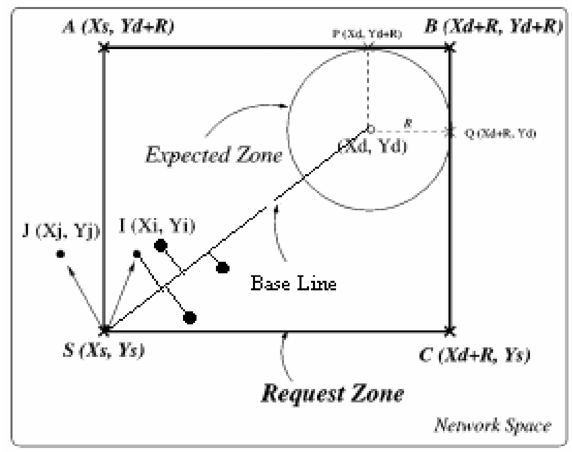


Fig. 2. Distance of nodes from the baseline

A. The procedure to determine the adaptive fuzzy threshold energy (AFTE):

Let RE_i, i = 1,2, …… , n , be the residual energies of the n neighboring nodes of a source node. Let minRE = min{ RE_i} , maxRE = max { RE_i } and midRE = (minRE + maxRE) / 2. We define the three fuzzy subsets of these nodes with low, medium and high residual energy whose membership functions μ_{low} , μ_{medium} and μ_{high} , respectively, are given below (Fig. 3).

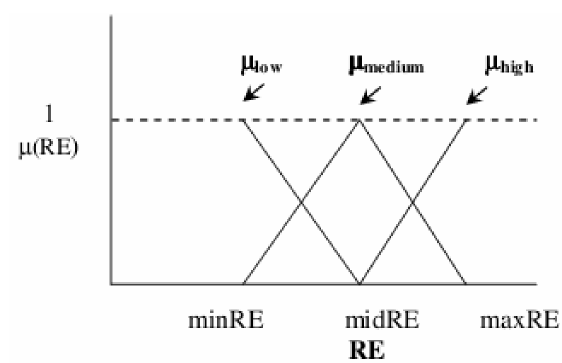


Fig. 3. Membership functions for nodes with fuzzy RE levels.

$$\mu_{low}(RE_i) = \begin{cases} \dfrac{RE_i - \text{midRE}}{\text{min RE} - \text{midRE}} & , \ \text{min RE} \le RE_i \le \text{max RE} \\ 0 & , \ \text{midRE} \le RE_i \le \text{max RE} \end{cases}$$

$$\mu_{medium}(RE_i) = \begin{cases} \dfrac{RE_i - midRE}{min\,RE - midRE}, & min\,RE \le RE_i \le midRE \\ \dfrac{RE_i - max\,RE}{midRE - max\,RE}, & midRE \le RE_i \le max\,RE \end{cases}$$

$$\mu_{high}(RE_i) = \begin{cases} 0, & min\,RE \le RE_i \le midRE \\ \dfrac{RE_i - midRE}{max\,RE - midRE}, & midRE \le RE_i \le max\,RE \end{cases}$$

Then, the membership value μ of RE_i for the i^{th} node is given by:

$$\mu_i(RE_i) = \max\left\{\mu_{low}(RE_i), \mu_{medium}(RE_i), \mu_{high}(RE_i)\right\}$$

Let RE_{TH} be the value of RE_i for which the membership value is minimum among neighboring nodes, i.e,

$$\mu_{Th}(RE_{TH}) = \min_{1 \le i \le n}\left\{\mu_i(RE_i)\right\}$$

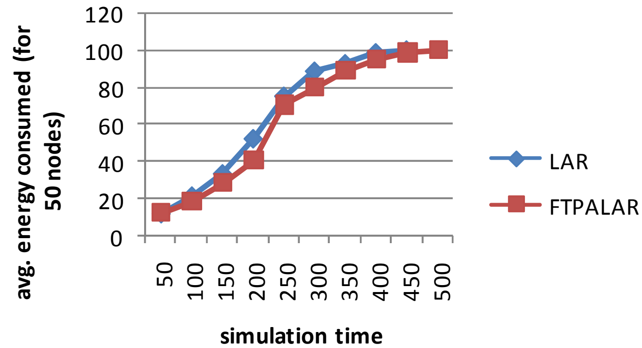
If there is a tie, it is broken by selecting the node with min RE among the nodes with the same minimum membership value. Then, RE_{TH} obtained by this defuzzification process, is used as the threshold energy value, which is transmitted in RREQ packet to the neighboring nodes.

V. RESULTS AND DISCUSSIONS

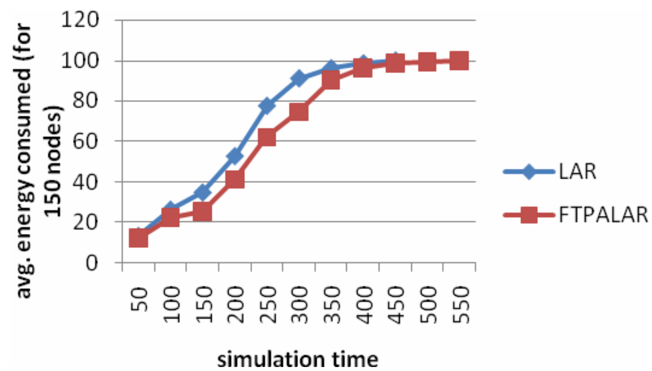
The proposed protocol, namely, fuzzy thresholded power-aware location aided routing (FTPALAR) is implemented using NS2 simulator, for different simulation times (50,100,.., 500), and for different number of nodes (50,100,…, 300). The other parameters used for simulation are given below in Table 1. The simulation results for 50,150 and 250 nodes are shown below in Fig.4–5. The complete simulation results are given in Table 2. The results of the proposed protocol are compared with LAR protocol in terms of average energy consumed and network lifetime.

TABLE 1.
SIMULATION PARAMETERS

Parameter	*Value*
Simulation Time	50 … 500 sec.
Terrain Area	500 X 500 sq. mts
Number of Nodes	50…300
Node placement	Random
Propagation Model	RWP
Channel Frequency	2.4 G.Hz.
Routing Protocol	LAR, FTPALAR
Transmission Range	250mts
Initial Energy for each node	100 Joules



(a)



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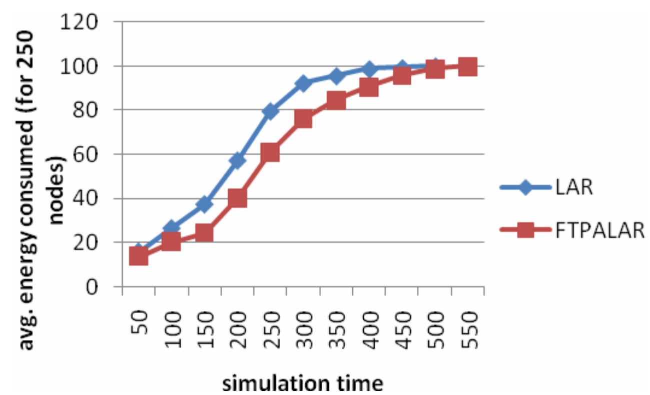
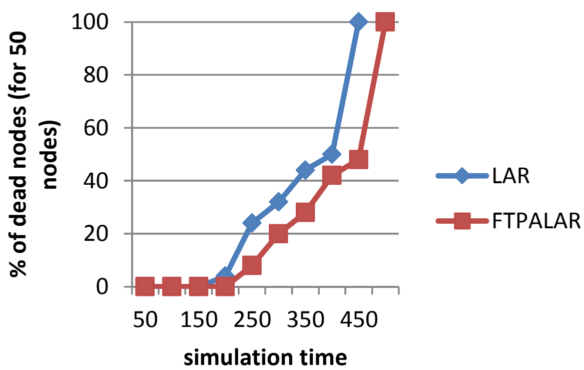


(c)

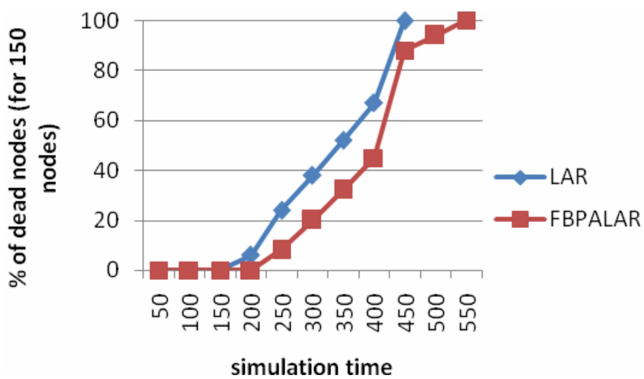
Fig.4. The average energy consumed vs. simulation time

From Fig.4, it can be seen that as the simulation progresses, there is increase in the average energy consumed. For both LAR and FTPALAR, this increase is gradual. On an average, the proposed protocol FTPALAR, consumes 12.5 Joules of energy less as compared to LAR. This is because, while establishing the route, the nodes closer to the baseline in the direction towards the destination are considered.

The network life time depends on the lifetime of the nodes.



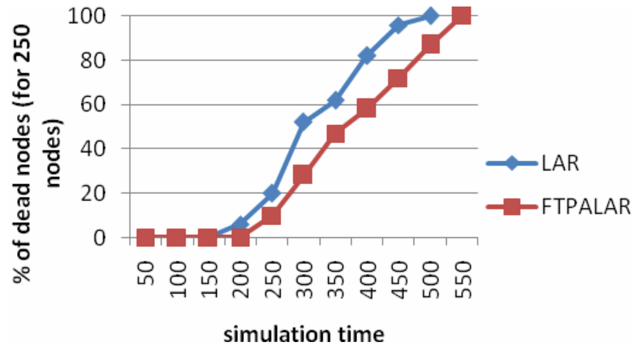
(a)



(b)

Network partitioning is usually defined [9] according to the following criteria:

- The time until the first node burns out its entire battery budget.
- The time until a certain portion of the nodes fails.
- The time until network partitioning occurs.



(c)

Fig. 5. % of dead nodes Vs simulation time

The Fig.5 shows percentage of dead nodes against simulation time for first node failure, 50% node failure and 100% node failure. Considering the first node failure, it can be seen that FTPALAR achieves a lifetime of 20 to 33% more than LAR protocol. For 50% node failure case, FTPALAR routing protocol provides 30 to 40% more lifetime and for the case of 100% node failure, there is an increase in the lifetime by about 9 to 22% as compared to LAR protocol. The proposed protocol is able to extend the lifetime of the network due to the application of adaptive fuzzy threshold energy.

VI. Conclusion

In this paper, a new power efficient routing protocol FTPALAR is proposed. Routing is based on the location of the node and also on its residual energy. The nodes that are nearer to the baseline and whose residual energy is greater than adaptive fuzzy based threshold energy are considered for routing. The proposed routing algorithm is compared with LAR. It is observed that FTPALAR is able to provide about 30% additional network lifetime as compared to LAR.

TABLE 2.
.Performance Comparison of FTPALAR and A LAR Routing Protocols for different node densities

No. of Nodes	**Time when first node's residual energy becomes zero**		**Time when 50% of nodes' residual energy becomes zero**		**Time when 100% of nodes' residual energy becomes zero**	
	LAR	FTPALAR	LAR	FTPALAR	LAR	FTLAR
50	161	210	250	350	450	500
100	175	212	425	440	450	500
150	160	212	342	413	450	550
200	205	210	330	430	450	550
250	160	212	300	375	500	550
300	153	204	320	380	500	550

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