Fuzzy Adaptive Transmission Range based Power Aware Location Aided Routing

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ABSTRACT
Energy efficiency is a major issue of concern in mobile ad hoc networks (MANETs) as mobile nodes rely on batteries, which are limited source of power, and in several environments, it is quite unwieldy task to replace or renew them. Consideration of energy efficiency is very important in the design of routing protocols for MANETs. A cross-layer design approach is often used in designing energy efficient routing protocols. In this paper, a fuzzy adaptive transmission range at MAC layer and fuzzy threshold based power aware routing at network layer are used to design an energy efficient routing protocol implemented for Location Aided Routing (LAR). It is called Fuzzy Adaptive Transmission Range Based Power Aware Location Aided Routing (FTRPALAR). The simulation results are compared with that of LAR and variable transmission range power aware location aided routing (VTRPALAR). It is observed that the proposed protocol performs better as compared to the other protocols in terms of energy consumption and network lifetime.

General Terms
Energy aware routing protocols, Mobile ad-hoc networks

Keywords
Manet, Location Aided Routing, Adaptive Transmission Range, Fuzzy Threshold Energy.

1. INTRODUCTION
Mobile ad hoc networks (MANETs) find wide variety of applications, namely, in battle fields, in disaster situations etc. The nodes in a MANET are driven by batteries with limited energy sources which poses a greater problem in running the network for a longer duration. Wireless channels have less but variable bandwidth compared to wired networks. Several routing algorithms have been proposed to overcome these problems. Many of these routing protocols, namely, AODV, DSR, LAR, etc., use number of hops, end-to-end delay, or distance as a metric for routing. It is very much essential to ensure that the network runs for a longer duration. Thus, a lot of research is being conducted in the design of energy efficient routing protocols that are capable of extending the lifetime of network. As these ad-hoc networks are mainly operated by batteries, the routing protocols need to be energy-aware. Several protocols have been proposed in the literatures that address the above mentioned issues.

The on-demand routing protocols share a common feature of discovering topology information with the help of routing messages and further discovery of any other route using this information in addition to routing tables. However, location based employs a completely different approach that utilizes the global information of the nodes. The on-demand routing protocols are based on flooding the routing packets in all directions irrespective of the location of the destination node, which results in increased bandwidth consumption. The table-driven protocols maintain large amount of information and also perform large computations in order to select the best node, which results in premature loss of battery life. The bandwidth consumption can be reduced by using Location Aided Routing Protocols, which use the Global Positioning System (GPS) to find the direction of propagation of the packets. This type of routing assumes that each node of the network is having a GPS installed in it. So, each node knows its own global position by using the GPS system or any other localization technology.

1.1.Location Aided Routing (LAR)
The 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 determines the expected zone of a particular node.

1.1.1. *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 t0and that the current time is t1.Then, the "expected zone" of node D, from the view-point of node S at time t1, is the region that node S expects to contain node D at time t1. Node S can determine the expected zone based on the knowledge that node D was at location L at time t0. 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(t1- t0), centered at location L (Fig. 1). If actual speed happens to be larger than the average, then the destination may actually be outside the expected zone at time t1. Thus, expected zone is only an estimate made by node S to determine a region that potentially contains D at time t1. 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.

1.1.2. *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. Additionally, the request zone may also include other regions around the request zone.

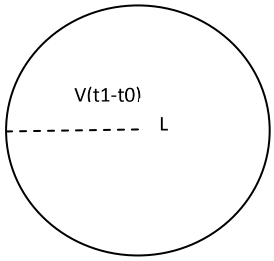


Fig.1 Expected Zone

Several protocols have been proposed in the literature that are obtained by modifying the routing protocols in order to make them energy efficient based on transmission range control and power aware routing.

2. RELATED WORK

A new energy aware routing (EAR) scheme which uses variable transmission range is discussed in [1]. The protocol has been incorporated along with the route discovery procedure of AODV as a case study. Variable transmission range is achieved by controlling the power level for each packet in a distributed manner at each node, thus affecting energy consumption of the network. The EAR protocol is able to extend the network lifetime by 20% as compared to AODV routing protocol. Dynamic transmission power assignment for energy conservation routing (DPAECR) in MANETs has been proposed in [2]. The DPAECR updates the transmission power for every packet transmission. For the purpose of energy conservation, each node can dynamically adjust its transmitting power based on the distance of the receiving nodes. A more accurate analytical model to track the energy consumption due to various factors, and a simple progressive energy efficient routing (PEER) to improve the performance during path discovery and in mobility scenarios are proposed in [3]. 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 that utilizes 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 (AODVNC-WLB) is proposed in [8]. The various issues related to MANETs such as energy, scalability and quality of services are discussed in [9].

In this paper, Location Aided Routing (LAR) protocol is modified in order to make it energy efficient using a cross-layer design approach with fuzzy adaptive transmission range at MAC layer and fuzzy adaptive threshold energy based routing at network layer.

3. PROPOSED METHODOLOGY

The transmission power determines the range over which the signal can be coherently received, and is therefore crucial in determining the performance of the network. It has been shown that a higher network capacity can be achieved by transmitting packets to the nearest neighbor in the forward progress direction. Reducing the transmission range not only reduces the transmission power required, but also decreases the area of the reserved floor, thus allowing for more concurrent transmissions to take place in the same neighborhood. The location aided routing uses the location information to limit 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. The proposed methodology comprises, a fuzzy adaptive transmission range based power aware location aided routing protocol.

The basic algorithm used is location aided routing protocol. A baseline is considered to be the line that joins the source node (S) and the destination node (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, after deciding the required transmission range using procedure fuzzy adaptive transmission power control (FATPC). 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.2). Then, it forwards the RREQ packet to its neighbors after updating E_{TH} with newly computed E_{TH}, and adding distance 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 of a node from the baselineis given by the equation:

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

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

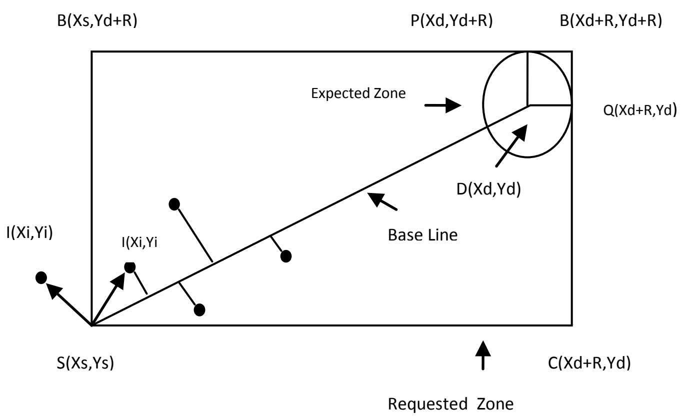


Fig. 2. Distance of nodes from the baseline

When a node's radio transmission power is controllable, its direct communication range as well as the number of its immediate neighbors are also adjustable. While stronger transmission power increases the transmission range and reduces the hop count to the destination, weaker transmission power makes the topology sparse which may result in network partitioning. The transmission power control approach is not only energy efficient, but it also reduces the interference in the transmission ranges of the different nodes. In the method proposed, a new fuzzy adaptive transmission power control based on the number of neighboring nodes is implemented. It also incorporates load balancing by using adaptive fuzzy based threshold energy (AFTE) technique [10]. Thus, the proposed protocol is a cross layer design technique with fuzzy adaptive transmission power control at MAC layer and fuzzy adaptive power aware routing at network layer. The power control approach consists of fuzzification of the transmission range of a node depending on the number of neighboring nodes to ensure network connectivity. The default transmission range is usually 250 mts. The required transmission power (P_t) for a given transmission range (d) is determined by the Eq. (2).

$$P_t = \frac{P_r * d^4 * L}{G_t * G_r * (h_t^2 * h_r^2)} \qquad (2)$$

where, P_r is the receiver threshold power, d is the distance (transmission range), L is the system loss, G_t and G_r are transmitter and receiver gains (usually 1.0), h_t and h_r are the heights of transmitter and receiver (usually 1.5 mts), respectively. The proposed method, which combines the fuzzy adaptive transmission power control and the adaptive fuzzy threshold energy routing, is as given below:

Procedure *Energy efficient LAR based on fuzzy adaptive transmission range and threshold energy*.

1. Let N_0 be the total number of nodes. Set the source node as the current node. Set the transmission power of the current node such that the transmission range *d* is 50 mts. (using Eq.(1))
2. Determine the number N_c of neighbors of the current node.
3. Determine the transmission range for the current node using procedure *fuzzy adaptive transmission range*.Then, select the next node using *adaptive fuzzy threshold energy* routing method and set the selected next node as the current node;
   if the current node is the destination node,
   then go to step 4,
   else go to step 2;
4. Stop.

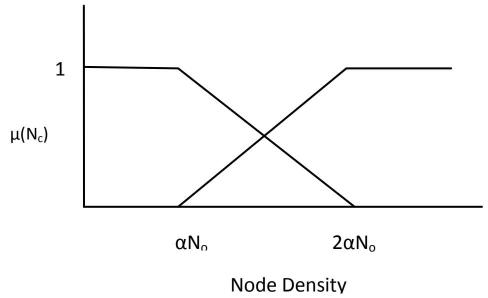


Fig.3. Membership Functions for Neighbor Node Densities

Procedure *Fuzzy Adaptive Transmission Range:*
We define two fuzzy subsets of neighbor nodes with low and high node densities, whose membership functions μ_{low} and μ_{high} are defined as:

$$\mu_{low}(N_c) = \begin{cases} 1 & , N_c <= \alpha \cdot N_0 \\ \dfrac{N_c - 2\alpha \cdot N_0}{\alpha \cdot N_0 - 2\alpha \cdot N_0} & , \alpha \cdot N_0 <= N_c <= 2\alpha \cdot N_0 \\ 0 & , N_c >= 2\alpha \cdot N_0 \end{cases}$$

where α is the percentage of total number of nodes that are neighboring nodes of the current node, and

$\mu_{high}(N_c) = (1 - \mu_{low}(N_c))$, Then, let

$$\mu_{\text{TR}}(N_c) = \max\left\{\mu_{low}(N_c), \mu_{high}(N_c)\right\}$$

We define the fuzzy decision set as follows:

decision = { Incr. TR by 50, No Change in TR }

with membership function for fuzzy decision given by

$$\mu_{\text{decision}}(\text{Incr.TR.by.50}) = \mu_{\text{low}}(N_c)$$
$$\mu_{\text{decision}}(\text{No.Change.in.TR}) = \mu_{\text{high}}(N_c)$$
$$\mu_{\text{decision}}(\text{TR}) = \mu_{\text{TR}}(N_c)$$

We compute,

$$\mu_{decision}(N_c) = \mu_{\text{TR}}(N_c)$$

where TR $\in$ decision.

Defuzzification:

If $\mu_{TR}(N_c) = \mu_{low}(N_c)$, then decision is to increase transmission range by 50mts.

If $\mu_{TR}(N_c) = \mu_{high}(N_c)$, then, decision is no change in transmission range TR.

Procedure *Adaptive fuzzy threshold energy*:

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. 4).

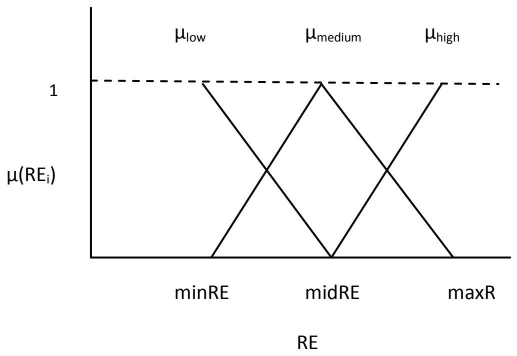


Fig. 4. **Membership Functions for Nodes with Fuzzy RE Levels**

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

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

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

Then, the membership value μ_i of RE_i for the ith 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,

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

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. If the residual energy of the intermediate node is greater than or equal to RE_{TH}, it is selected as the next node.

4. RESULTS AND DISCUSSIONS

The proposed protocols, namely, fuzzy adaptive transmission range and threshold energy is implemented for LAR routing protocols 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.5–6. The complete simulation results are given in Table 2. The results of the proposed protocol are compared with LAR and variable transmission range power aware location aided routing (VTRPALAR) [11] 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, VTRPALAR, FTRPALAR
Transmission Range	Fuzzy adaptive
Initial Energy for each node	100 Joules

From the Fig. 5, it is observed that as the simulation time increases, the average energy consumed by the mobile nodes keeps on increasing. The proposed algorithm FTRPALAR consumes less energy as compared to VTRPALAR. All the nodes drain off their energy by 550 sec. for VTRPALAR. But for FTRPALAR all the nodes drain off their energy by 600-650 sec. From the figure it can also be seen that rate of reduction in the energy is less in FTRPALAR than in LAR and VTRPALAR. The energy depletion rate is very high for LAR. For smaller node density, it is observed that the energy consumption is almost same for both VTRPALAR and FTRPALAR. As the node density increases, the energy saving in case of FTRPALAR is more. The FTRPALAR is able to save 12-18% of energy for higher node densities.

The Fig. 6 shows the percentage of dead nodes as the simulation time increases from 50 to 600 in steps of 50. It can be seen that the FTRPALAR is able to attain more network life time as compared to VTRALAR routing protocol. The FTRPALAR protocol achieves almost same network lifetime for lower node density and 15% to 18% more network lifetime for higher node density, as compared to VTRPALAR.

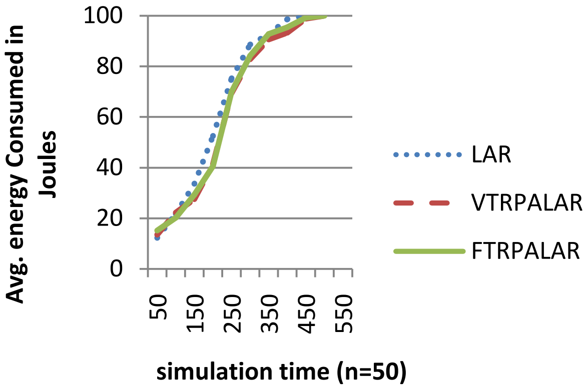
The network life time depends on the lifetime of the nodes. Network partitioning is usually defined [9] according to the following criteria:

- 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 the network partitioning occurs

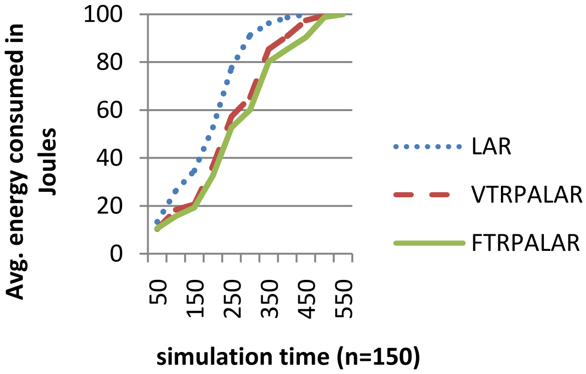
In our simulation experiment for determination of lifetime of a network, we have considered three cases:

- Time at which the first node fails.
- Time at which the 50% of the nodes fail.

- Time at which all the nodes fail.



(a)



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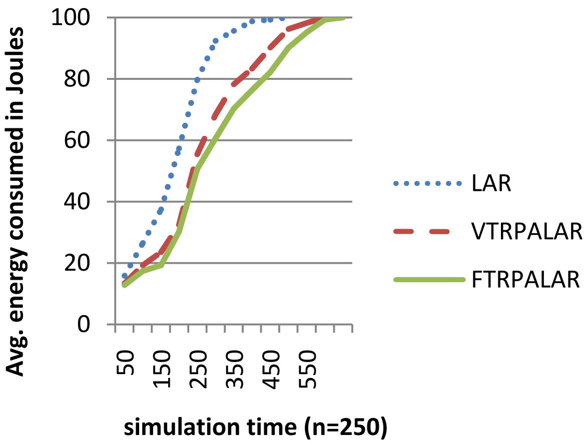
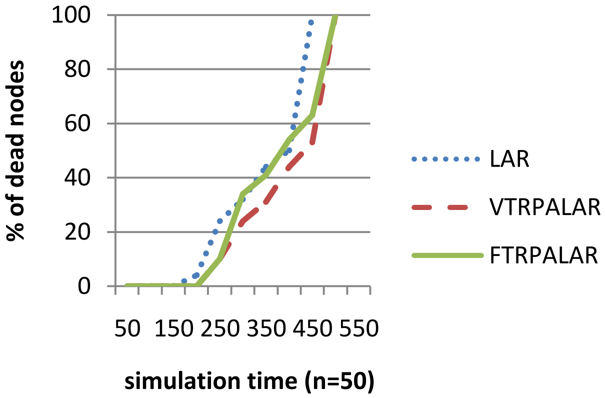


(c)

Fig.5: The average energy consumed vs. simulation time

Considering the first node failure, it can be seen that in case of LAR protocol the network partitioning occurs at 170 sec., it occurs at 214 sec. for VTRPALAR and for FTRPALAR it occurs at around 250 sec..Considering network partitioning due to 50% node failure, it can be seen that it occurs at around 320 sec. for VTRPALAR whereas for FTRPALAR the network partitioning occurs art 425 sec Considering network partitioning due to 100% node failure, it occurs at around 550 sec. for VTRPALAR and for FTRPALAR the network partitioning occurs at 600-650 sec.



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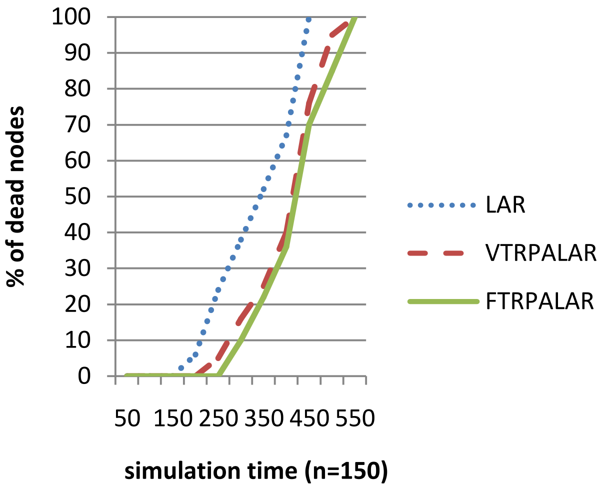

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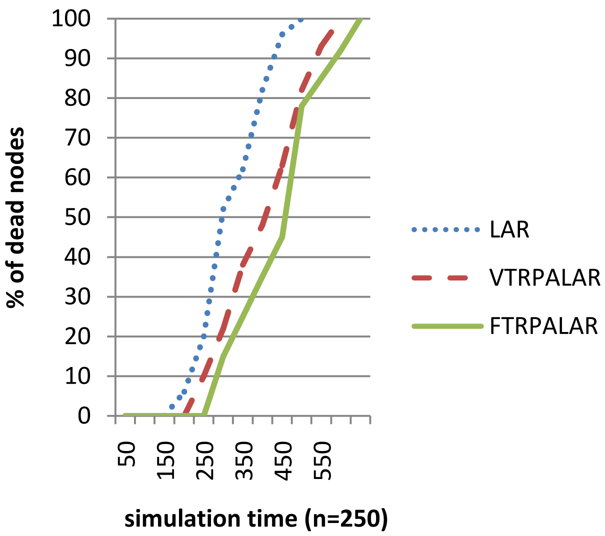

(c)

Fig.6: % of dead nodes vs. simulation time

5. CONCLUSION

In this paper, a novel routing protocol based on fuzzy adaptive transmission range and fuzzy based threshold energy for Location Aided Routing is proposed. In the proposed protocol, the energy of a mobile node is conserved by employing fuzzy adaptive transmission power control depending on the minimum number of neighboring nodes to maintain network connectivity and power aware routing based on fuzzy threshold energy. The simulation experiments have been conducted using NS2 simulator. The experimental results show that the proposed protocol FTRPALAR performs better in terms of average energy consumption and network lifetime as compared to the LAR and VTRPALAR routing protocols. The proposed FTRPALAR is able to achieve 18% more lifetimeas compared to VTRPALAR.

Table 2. Performance Comparison of LAR, VTRPALAR and FTPALAR 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	VTRPALAR	FTRPALAR	LAR	VTRPALAR	FTRPALAR	LAR	VTRPALAR	FTRPALAR
50	161	212	215	250	410	450	450	500	500
100	175	214	214	425	425	430	450	500	500
150	160	214	258	342	422	435	450	550	550
200	205	212	255	330	425	450	450	600	600
250	160	212	253	300	420	500	500	600	650
300	153	214	254	320	420	450	500	600	650

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