Variable Transmission Range Power Aware Location Aided Routing

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ABSTRACT
A Mobile Ad-Hoc Network (MANET) is a temporary, infrastructure-less and distributed network having mobile nodes. The MANET has limited resources like bandwidth and energy. Due to limited battery power, nodes die out early which leads to lesser network lifetime. To make network last for a longer period the routing protocol used must be energy efficient. In this paper, location aided routing (LAR), an on-demand routing protocol is modified to make it energy efficient. The proposed protocol, variable transmission range power aware location aided routing (VTRPALAR), controls the transmission power of a node according to the required transmission range which depends on the minimum number of neighboring nodes required to maintain the connectivity of the MANET. Further, it also includes energy information on route request packet and selects the energy efficient path to route data packets. 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 protocol is compared with location aided routing (LAR) and fuzzy thresholded power aware location aided routing (FTPALAR) protocols.

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

Keywords
Manet, Location Aided Routing, Transmission Power, Fuzzy Threshold Energy.

1. INTRODUCTION
In contrast to current cellular networks which rely on a wired structure with a wireless last hop, ad hoc wireless networks are infrastructureless. The nodes which comprise them have routing capabilities and forward traffic for other communicating parties that are not within each other's transmission range. Every node consumes power whenever it transmits or forwards a packet to its neighbor. Therefore, ad hoc routing is challenged by power and bandwidth constraints, as well as by frequent changes in topology, to which it must adapt and converge quickly. Conventional routing protocols for wired networks cannot be employed in such an environment. This fact has given rise to the design of ad hoc specific routing protocols. The earlier routing protocols designed for ad hoc networks, based their routing decisions on the minimum number of hops, shortest path, etc. However, the main shortcoming of this criterion in terms of energy utilization is that the selection of routes in accordance with the min-hop principle does not protect nodes from being overused. These are usually nodes in the core of the network. When they run out of power, the network becomes partitioned and consequently some sessions are disconnected. In order to alleviate this problem and to achieve energy-efficiency, many solutions have been proposed as an extension of the already existing ad hoc routing protocols. In this paper, a position-based routing protocol is modified to make it energy efficient. When the routing protocol does not use the location information of the mobile node for routing, then such routing is called topology-based routing. If the position information is used in the routing protocol, then the routing is said to be position-based routing.

There are two methods of forwarding data packets in position-based routing: greedy forwarding and directional flooding. In greedy forwarding, the next hop node is the closest in distance to destination. The 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. The location aided routing (LAR) uses directional forwarding flooding. In the position-based routing protocols, each mobile node uses a directional antenna or GPS system to estimate its (x, y) position. If GPS is used, every node knows it's (x, y) position assuming z = 0. The positions of the two mobile nodes in Fig. 1 are (x1, y1) and (x2, y2) respectively. Using Fig. 1, the distance d between the two mobile nodes is calculated using Eqn. (1). The angle θ is defined as shown in Fig. 1 and is calculated using Eqn. (2).

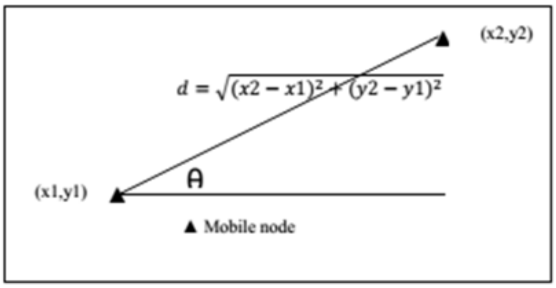


Fig.1: Position-based routing protocol that uses GPS to determine mobile nodes (x,y) positions

$$d = \sqrt{((x2 - x1)^2 + (y2 - y1)^2} \quad (1)$$

$$\theta = \tan^{-1}\frac{(y2 - y1)}{(x2 - x1)} \quad (2)$$

1.1 Location aided routing (LAR)
The LAR [7] 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.

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 t0 and 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. 2).

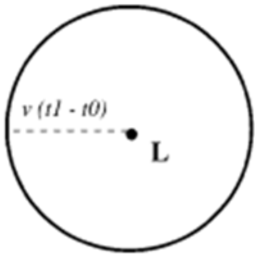


Fig.2 Expected Zone

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.

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.

In this paper, the position based routing protocol location aided routing (LAR) is modified by introducing variable transmission range for each node based on the minimum number of neighboring nodes and a power aware routing at each node to make it energy efficient.

2. RELATED WORK

A location aided Energy Efficient Routing (LAEER) protocol is proposed in [1]. It is an on-demand routing protocol that considers location and residual energy of the nodes as the routing metric. Only the forwarding neighboring nodes are involved in routing, while, the non-forwarding nodes are switched to idle state. This ensures reduction in energy consumption in the network. Energy efficiency is an important design consideration for sensor networks. Motivated by the fact that sensor network queries may often be geographical, an energy efficient routing algorithm is designed and evaluated in [2]. It propagates a query to the appropriate geographical region, without flooding. This geographic and energy aware routing (GEAR) algorithm uses energy aware neighbor selection to route a packet towards the target region and recursive geographic forwarding or restricted flooding algorithm to disseminate the packet inside the destination region. A location-aided power-aware routing protocol that dynamically makes local routing decisions so that a near-optimal power-efficient end-to-end route is formed for forwarding data packets is proposed in [3]. The protocol is fully distributed such that only location information of neighboring nodes is exploited in each routing node. An energy aware routing scheme in location based ad hoc network has been proposed in [4]. This method modifies the LAR protocol in which the virtual grid is applied to ad hoc network region and high energy node is selected as header for each grid which communicates information about nodes in that particular grid. The transmit power of nodes is used to according to the distance between them. The next hop node will be chosen based on transmit power and its distance from the destination. In [5], a concept which decides the baseline between the source node and the destination node, for route discovery procedure has been discussed. The next hop is selected on the basis of baseline by broadcasting the request packets in request zone. The neighboring nodes that are in radio range to the baseline are considered for the next hop node. This method helps in reduction of control packets overheads by finding a better routing path than LAR scheme. An energy efficient location aided routing (EELAR) Protocol for MANETs that is based on the Location Aided Routing (LAR) has been proposed in [6]. The EELAR makes significant reduction in the energy consumption of the mobile node batteries by limiting the area of discovering a new route to a smaller zone. Thus, the overhead of control packets is significantly reduced. In EELAR a reference wireless base station is used and the network's circular area centered at the base station is divided into six equal sub-areas. At route discovery instead of flooding control packets to the whole network area, they are flooded to only the sub-area of the destination mobile node. The base station stores locations of the mobile nodes in a position table. In [7], an approach to utilize location information to improve performance of routing protocols for ad hoc networks is suggested. By using location information, the 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. A fuzzy thresholded power aware location aided routing (FTPALAR) protocol is proposed in [8]. 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. It achieves routing in the direction towards the destination using the nodes with sufficient residual energy. This leads to increase in the network lifetime.

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. In this paper, a variable transmission range based power aware location aided routing protocol has been presented. The proposed protocol is a cross layer design technique with adaptive transmission power control at MAC layer and adaptive power aware routing at network layer.

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 adaptive transmission power control (ATPC). 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. (3) (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 of a node from the baselineis given by the equation:

$$d_i = \left| \frac{aX_i + bY_i + c}{\sqrt{(a^2 + b^2)}} \right| \qquad (3)$$

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

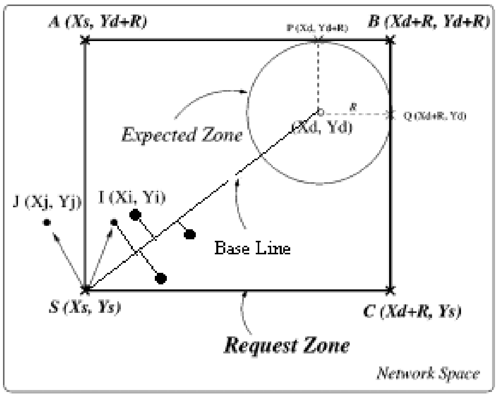


Fig. 3. Distance of nodes from the baseline

The power control approach consists of adjusting the transmission range of a node depending on the number of neighboring nodes to ensure network connectivity. Here, 10% of the total number of nodes is considered to be the minimum number of neighboring nodes to maintain connectivity. Initially, the transmission range is set to 50 mts. Then, if the number of neighboring nodes is more than or equal to 10% of the total number of nodes, we proceed further, otherwise, we increase the transmission range by 50 mts. and repeat the same till the number of neighboring nodes is greater or equal to 10% of the total number of nodes. 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. (4).

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

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 adaptive transmission power control and the adaptive fuzzy threshold energy routing for location aided routing, is as given below:

Procedure *Adaptive Transmission Power Control (ATPC):*

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 Eqn. (4))
2. Determine the number of neighbours N_C of the current node.
3. If $N_C >= 0.1\ N_0$
   then select the next node using procedure to determine the adaptive fuzzy threshold energy (AFTE) 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;
   else increase the transmission power such that transmission range d is incremented by 50 mts and go to step 2
4. Stop.

Procedure *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. 4).

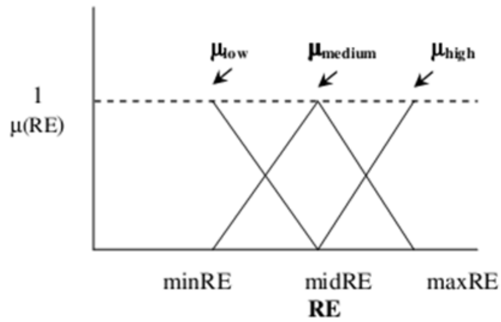


Fig. 4: Membership functions for nodes with fuzzy RE levels.

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

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

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

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,

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

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.

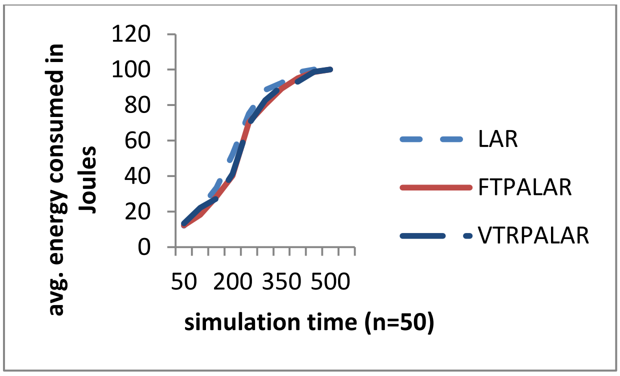
4. RESULTS AND DISCUSSIONS

The basic routing algorithm used is location aided routing. This protocol has been modified to incorporate variable transmission range which depends upon the minimum number of neighboring nodes to maintain network connectivity and fuzzy based power aware routing in the direction towards the destination. The NS2 simulator is used for simulating the experiment for different node densities ranging for 50 to 300 in steps of 50 and for different simulation time ranging from 50 sec. to 600 sec. in steps of 50 sec. The other simulation parameters used are given 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 FTPALAR protocols in terms of average energy consumed and network lifetime.

In Fig.5, it is observed that as the simulation time increases, the average energy consumed by the mobile nodes keeps on increasing. The proposed routing algorithm VTRPALAR consumes lesser energy as compared to LAR, and FTPALAR routing algorithms. The slope of the graph shown in Fig.5 is highest for LAR and lowest for VTRPALAR. It means that the rate at which the energy gets drained off is highest for LAR and lowest for VTRPALAR. The drain rate for FTPALAR falls in between. All the nodes drain off their residual energy by 450 sec. for LAR protocol, for FTPALAR protocol it occurs at 500-550 sec., for the VTRPALAR protocol it occurs at 550-600 sec. Thus for the proposed VTRPALAR protocol the lifetime extends up to 600 sec.

Table 1, Simulation Parameters

Parameter	Value
Simulation Time	50 … 600 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, FBPALAR,VTRPALAR
Transmission Range	250mts
Initial Energy for each node	100 Joules



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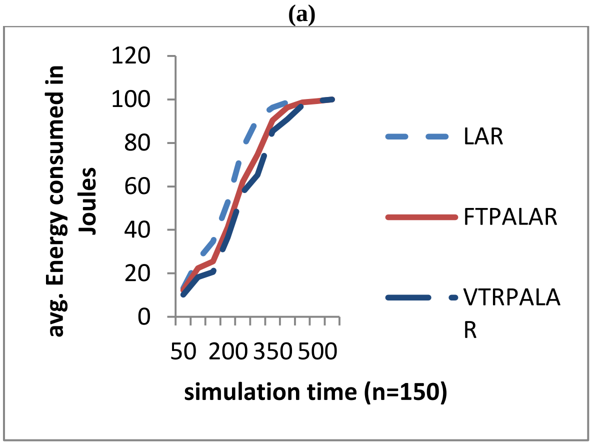

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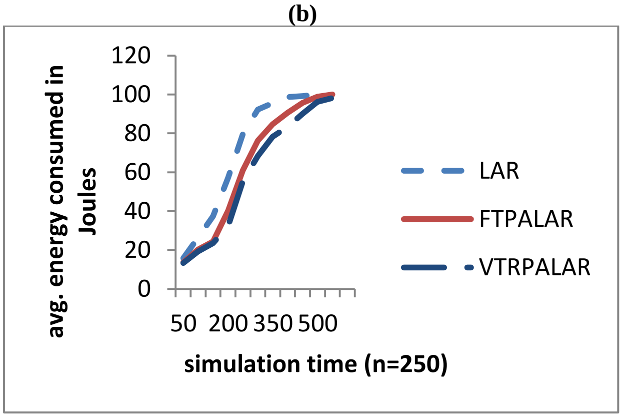


(c)

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

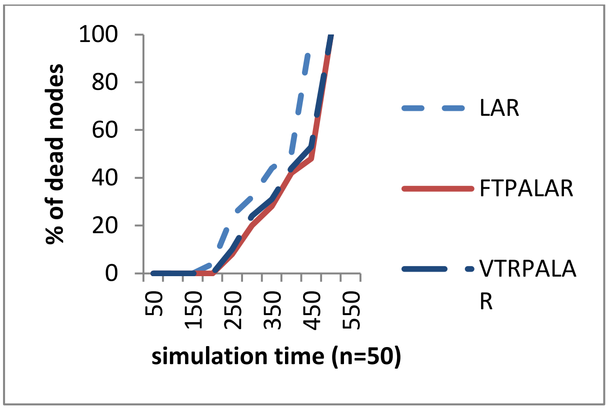
The Fig.6 shows the percentage of dead nodes as the simulation time varies from 50 to 600 sec. in steps of 50 sec. When the nodes lose all their residual energy, they can be declared as dead nodes. The network life time depends on the lifetime of the nodes. Network partitioning is usually defined [9] 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.

Considering the first node failure, it can be seen that in case of LAR protocol the network partitioning occurs at 170 sec., for both FTPALAR and VTRPALAR protocols, the network partitioning occurs between 200 to 250sec. The residual energy of all the nodes for LAR becomes zero at simulation time 450-500 sec. for all node densities. It can also be seen that the residual energy of all the nodes becomes zero at simulation time t=500, at t=550 correspondingly for (n= 50,n=150) and n=250 for the FTPALAR protocol. For the proposed VTRPALAR protocol it occurs at t=500, at t=550 and at t=600 sec. correspondingly for n=50, n=150, n-250. Further, it can be seen that the nodes lose all their residual energy (thus become dead) rapidly in case of LAR protocol as compared to FTPALAR and VTRPALAR protocol. As the node density increase in the percentage of dead nodes is more in FTPALAR as compared to VTRPALAR. Hence, the VTRPALAR protocol consumes less energy and is able to provide more lifetime for the network. The results of simulation for all nodes ranging from 50 to 300 in steps of 50 are given in the Table 2. From the Table 2, it is observed that, for all node densities, considering the network partitioning due to a single node failure, both FTPALAR and VTRPALAR protocol have almost the same performance and provide 33% more lifetime as compared to LAR. Considering network partitioning due to 50% node failure, the performance of VTRPALAR is better as compared to LAR and FTPALAR. It provides 50-64% and 30-40% more network lifetime as compared to LAR and FTPALAR respectively. When 100% node failure is considered, VTRPALAR achieves 20% to 30% extra lifetime than LAR, up to 9% more lifetime as compared to FTPALAR.



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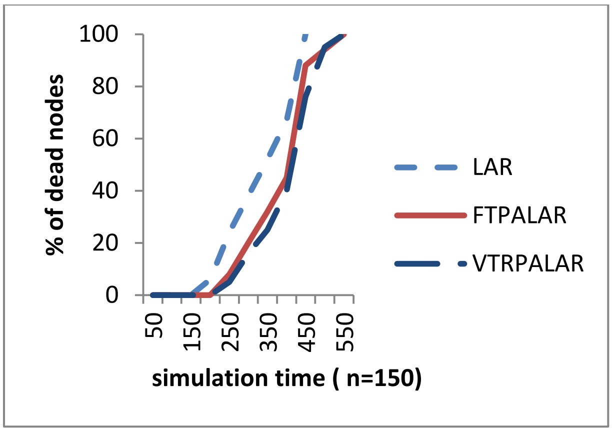

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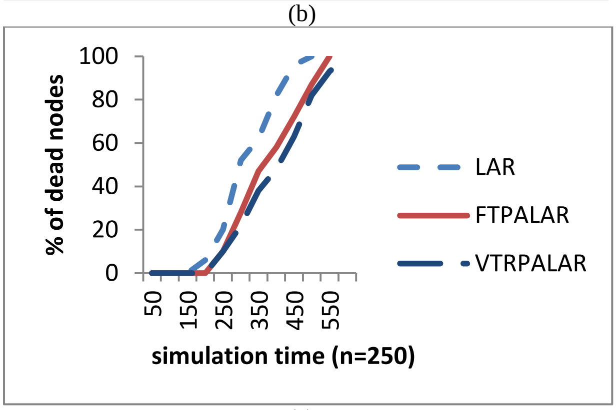

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Fig.6: % of dead nodes vs simulation time

TABLE 2.PERFORMANCE COMPARISON OF LAR,FTPALAR AND VTRPALAR 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*	*VTRPALAR*	*LAR*	*FTPALAR*	*VTRPALAR*	*LAR*	*FTPALAR*	*VTRPALAR*
50	161	210	212	250	350	410	450	500	500
100	175	212	214	425	440	425	450	500	500
150	160	212	214	342	413	422	450	550	550
200	205	210	212	330	430	425	450	550	600
250	160	212	212	300	375	420	500	550	600
300	153	204	214	320	380	420	500	550	600

5. CONCLUSION

In this paper, a novel on demand routing protocol based on variable transmission range and fuzzy based threshold energy is proposed. In the proposed protocol, the energy of a mobile node is conserved by employing variable transmission power depending on the minimum number of neighboring nodes to maintain network connectivity and routing based fuzzy threshold energy. The simulation experiments have been conducted using NS2 simulator. The experimental results show that the proposed protocol VTPALAR performs better as compared to the LAR and FTPALAR routing protocols.

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