Energy Draining Rate Based-AODV Routing in Wireless Mesh Network

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Abstract

Wireless mesh networks recently emerged as flexible, low cost and multipurpose networking platforms with wired infrastructure connected to the internet. The different routing algorithms such as AODV, DSDV and TORA consider metrics like hop count, expected transmission count and expected transmission time. In this type of network, nodes often have a limited battery supply to use for sending and receiving data. To overcome this, we have proposed a new routing model by modifying the existing AODV algorithm as it is of reactive routing type, on-demand, discovers route only when they are needed, and it incorporates distance vector routing protocol. Energy draining rate based (ERDB) routing AODV model refers to the mechanism of taking into account the remaining battery capacity and energy draining rate of the node in order to decide on whether or not to relay traffic. The usage of nodes having high energy draining rate and low energy capacity should be avoided for relaying traffic to increase network life time. The experiments are simulated using NS3 simulator by considering various situations such as keeping the nodes static and moving nodes dynamically. In this paper, we present the related works, proposed model, Simulation and results.

Index Terms: Energy, Draining rate, AODV, Routing, Wireless mesh networks,

I. Introduction

Wireless mesh networks (WMN) is a special type of wireless adhoc network defined under IEEE 802.11. IEEE 802.11s is a draft IEEE 802.11 amendment for mesh networking[1]. It defines how wireless devices can be interconnected to create a WLAN mesh network, which may be used for static topologies and ad hoc networks. A wireless mesh network often has a more planned configuration, and may be deployed to provide dynamic and cost effective connectivity over a certain geographic area. It is often assumed that all nodes in a wireless mesh network are immobile, but this may not be the case. The mesh routers may be mobile, and be moved according to specific demands arising in the network.

In the Fig. 1, dash and solid lines indicate wireless and wired links respectively. This type of wireless mesh network (WMN) includes mesh routers forming an infrastructure for clients that connect to them. The mesh routers form a mesh of self-configuring, self-healing links among themselves. With gateway functionality mesh routers can be connected to the Internet.

Energy-aware routing or battery-aware routing is a mechanism where the remaining battery capacity of the node is considered to decide route to relay traffic. The node having low capacity that is used for relaying traffic should be avoided.

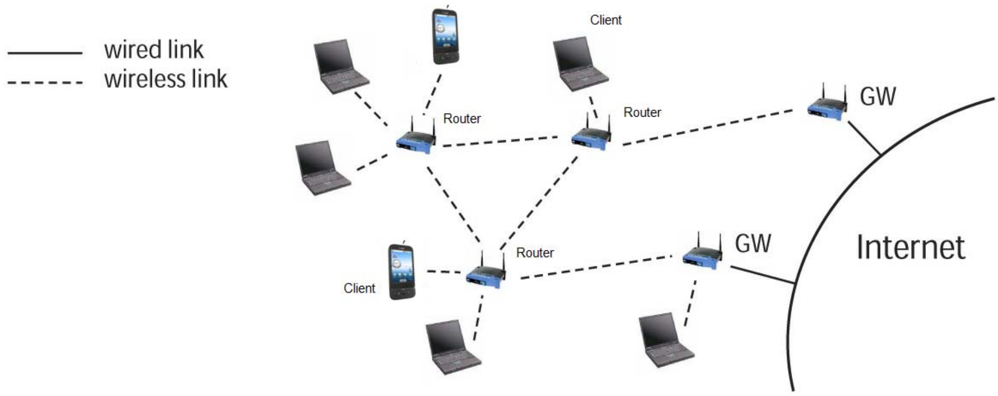

Fig. 1. Example wireless mesh network

In wireless mesh networks battery life of the node will play an important role because it is very difficult to recharge battery regularly. Hence, wireless mesh network nodes operate with finite battery capacity which is managed efficiently to increase reliability of individual nodes and lifetime of whole network. The lifetime can be increased by equally utilizing all nodes. This can be achieved by balancing individual nodes battery level.

Since energy consumption is an important factor in wireless devices and wireless network, there is a need to analyse energy consumption of each node. This can be achieved by adding energy as a metric for making decision on routing. Also routing process in wireless mesh network consumes energy at each node, there is a need to find the energy draining rate of the battery at every node and then select the path with minimum draining rate node to increase network life time. This metrics plays a major role in path selection at routing level which leads in increasing network lifetime.

The rest of the paper is organized as follows: Section 2 unfolds the related work carried out. Section 3 presents the Design of proposed model, Section 4 discusses about the Implementation, Section 5 shows the Experimental Results and Discussions. Conclusion and future work is given in section 6.

II. RELATED WORKS

A WMN typically consists of networks of access points, which are connected through a wireless backbone. Research focus has been diverted in finding ways to minimise the power consumption of these networks. Lamia Romdhani and Christian Bonnet [2] introduced method for optimizing AODV by considering the energy consumption speed. Praveen Gupta, Preeti Saxena [3] showed that, the huge gap between nodes consumes lot of battery power. Hence, the amount of power consumed while transferring the data depends on distance between two nodes. Adeel Akram, Mariam Shafqat [4] introduced a modified AODV routing protocol for battery and frequency optimization to be employed in Wireless Mesh Networks (WMN). Since routing is an essential function of such multi-hop networks, T. A. Le and M. R. Nakhai [5] showed a method to reduce power consumption by avoiding long range communication in favor of multi-hop transmissions. Jharna Chokhawala, Albert Mo Kim Cheng [6] discussed that there are different routing algorithms which consider metrics like hop count and expected transmission count but there is a chance of some repeatedly used node that may get drained earlier. Hence, they proposed an algorithm with one more metric called energy for path selection. Mhalanga et al. [7] introduced an energy optimization based path selection algorithm for IEEE

802.11s WMNs that will maximize the network lifetime addressing the self configuration and cost effectiveness constraints of WMN.

Most of the work carried out consider only hop count as a parameter to AODV routing in WMN, which may result in network failure. In WMNs, battery energy at the nodes is a very limited resource that needs to be utilized efficiently. The failure of some node's operation can greatly reduce performance of the network and even affect the basic availability of the network. The potential problem in current protocols for WMNs is that, they find the shortest path and use same path for every communication. However, this is not the best thing to do for network lifetime. Using the shortest path frequently can lead to energy depletion of the node along that path and in the worst case may lead to network partitioning or network failure. In AODV energy is not included but it is of reactive routing type. It is on-demand and discovers route only when they are needed. It incorporates distance vector routing protocol. We consider two more metric called energy draining rate and remaining energy to select the path in existing AODV routing. Since network simulation tool NS-3 is appropriate to solve energy related problem in wireless mesh network we have used it to simulate.

III. Proposed ERDB-AODV model

In this section, we present the proposed model which is a modification to the existing AODV routing.

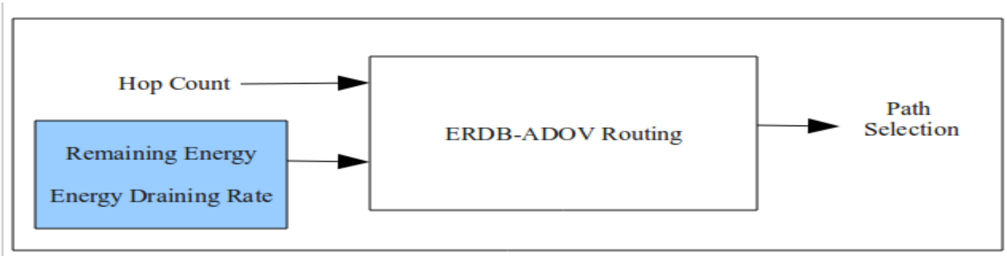

Fig. 2. Proposed ERDB-AODV model

The General AODV routing selects best paths based on hop counts. Hence we propose a new model called ERDB-AODV model. The proposed model is as shown Fig. 2. In proposed Energy Draining Rate Based(ERDB)-AODV model an additional metric called remaining energy and energy draining rate are added to selection path during data transfer. The node's remaining energy factor is added to the existing AODV routing model. The ERDB-AODV routing model consider remaining energy of the node and its energy draining rate as a factor for path selection not only considering hop count. The primary factor for path selection is hop count and secondary factor is remaining energy of node and its energy draining rate.

IV. Design

In this section we present the design of our proposed model.

A. ERDB-AODV process model

Fig. 3 ERDB-AODV process model shows that nodes are selected for data transfer by considering all the three criteria. Initially AODV's hop count is used for shortest path selection, when first node is selected for data transfer according to AODV nodes remaining energy and draining rate is calculated. If particular nodes remaining energy is less than threshold, then that node is not used for data transfer. At the same time nodes draining speed is also considered for taking decision on weather to transfer data or otherwise. If particular nodes draining speed is higher than the remaining nodes, then that node is not used for data transfer.

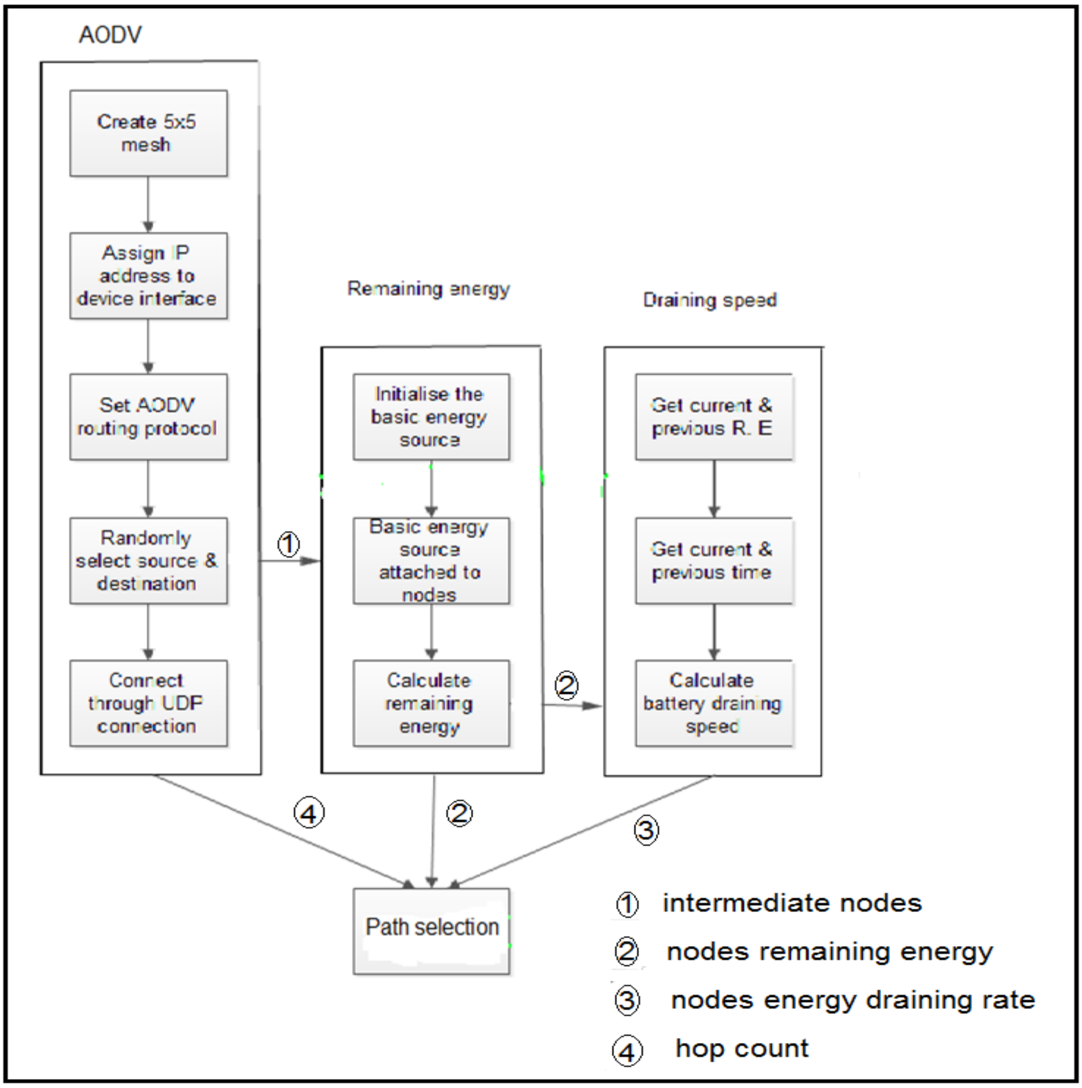

Fig. 3. ERDB-AODV process model

B. Node's Remaining Energy Calculation

The node's remaining energy metric is added to the AODV routing algorithm. The ERDB-AODV routing algorithm consider remaining energy as a factor for path selection besides hop count. *BasicEnergySource* is one of the energy source models available in NS3. This is connected to *WifiRadioEnergy* model which is one of the device energy model. Device energy models is used for calculating the remaining energy and total energy consumption. To calculate the remaining energy, *BasicEnergySource* is initialized with some initial value. The nodes that are attached to energy source model makes a call to device energy model, through which remaining energy of the node is calculated. Suppose a particular node's remaining energy value is less than the threshold value, then the path related to that node is not selected to transfer data.

C. Node's Draining Rate Calculation

The ERDB-AODV model is added with one more metric called nodes draining rate for path selection. The node draining rate will help to avoid particular node, if that node is having higher draining rate than the normal. With the help of this metric, we can preserve all nodes for path selection at all times. The draining rate will be calculated based on nodes remaining energy and time. Since our goal is to create a testbed for modified AODV, we intentionally used a very simple draining rate model. The node draining rate is calculated by,

$$D_R = (E_p - E_c) / (T_c - T_p),$$

where D_R - draining rate of node, E_p - previous energy of particular node, E_c - current energy of particular node, T_c - current time, T_p - previous time.

IV. IMPLEMENTATION

In this section, we present the algorithm and description of the ERDB-AODV, diagrammatic description of the algorithm and pseudo code. The ERDB-AODV is discussed under two sections namely:

1. Remaining energy calculation
2. Energy draining rate.

A. ERDB-AODV Algorithm

Figure 4 shows ERDB-AODV algorithm in which the energy of each node is initially set with the threshold value of 4.5 J. Initially packets have been sent via route1 to reach the destination. The remaining energy of all nodes in the networkis then calculated. The remaining energy of all the nodes for specified interval of time is stored in the file. This is used to calculate the energy draining speed which is again stored ina file. The remaining energy of nodes is compared with energy threshold, if the remaining energy is greater than the threshold, the the same path is followed otherwise sent via neighboring node. The draining speed is also compared with the threshold for balancing energy consumption of the nodes over the entire network. If the particular node consume more energy than threshold, then avoid that node for data transfer.

Fig. 5 shows ERDB-AODV sub algorithm that calculate the remaining energy which is given as input for draining rate calculation. The draining rate is calculated by remaining energy and time as a parameter. Draining rate is calculated by getting the current and previous remaining energy and also using the current and previous time. By

Start
Set Threshold_value = 4.5 J
Send packets via route1 to reach destination.
For each node n.
Calculate $_{R.E}$.
Get battery status of all node stores it in a file.
End for each
For each *node n*
Draining_rate();
Store it in a file.
End for each
Compare Bat_status value and energy draining speed with Threshold_value
If (node->bat_status > energy_Threshold) Then
Continue forwarding packets
Else
Broadcast message "Battery low-send packets via other neighbour node".
If (draining_rate()<rate_Threshold) then
Continue forwarding packets.
Else
Broadcast message "draining rate high-send packets via other neighbour node".
Store data transfer in files.
End

Fig. 4. ERDB-AODV algorithm

B. Sub Algorithm: draining_rate()

Start
Get the current and previous remaining energy of the node.
Get the current and previous time when remaining energy calculated.
Draining rate= (current remaining energy – previous remaining energy)/ (current time – previous time)
Return draining_rate.
End

Fig. 5. ERDB-AODV sub algorithm

utilizing these parameters energy draining rate is calculated. Energy consumption rate is analysed by comparing energy consumption rate of all remaining nodes over the network.

V. EXPERIMENTAL RESULTS AND DISCUSSIONS

A. Simulation Setup

The simulation was setup for the proposed model by creating 5X5 mesh dynamically moving around the specific area in wireless mesh network using NS3. IP address was assigned to every node's device interface and was set with the AODV routing algorithm to whole network. The source and destination nodes have been selected from the 25 available nodes randomly. Each node is connected via UDP. The following parameters are set to AODV routing algorithm as shown in Table I.

To calculate remaining energy of each node, We consider only communication energy rather than considering the algorithm running on it. Initially basic energy source was connected to every node in the network. Energy supply was attached to each node and was set with initial energy. Later, device energy model class was connected to the Basic energy class. The remaining energy and total energy consumed were calculated using the basic energy class.

The energy draining rate is calculated by sending remaining energy and time as the parameter to each node. The current and previous remaining energy and simulation time has been computed.

The path selection was done based on considering all the factors such as hop count, remaining energy and draining rate.

TABLE I
ERDB-AODV PARAMETERS

Parameters	Values
Hello interval	3
Route request retry	5
Route request rate limits	10 pkt/s
Next hop waits	50 ms
Active route time out	100 s
Allowed hello loss	20
Max queue time	30 s
Initial energy	10 j
Energy threshold	4.5 j

B. Results:

1) Remaining energy of intermediate node at different path:

Fig. 6 shows the remaining energy of intermediate node at different paths. It can be noticed from the figure that path 1’s and path 2’s intermediate nodes energy falls below the threshold at time 1250 ms. Path 3’s intermediate nodes energy is above the threshold.

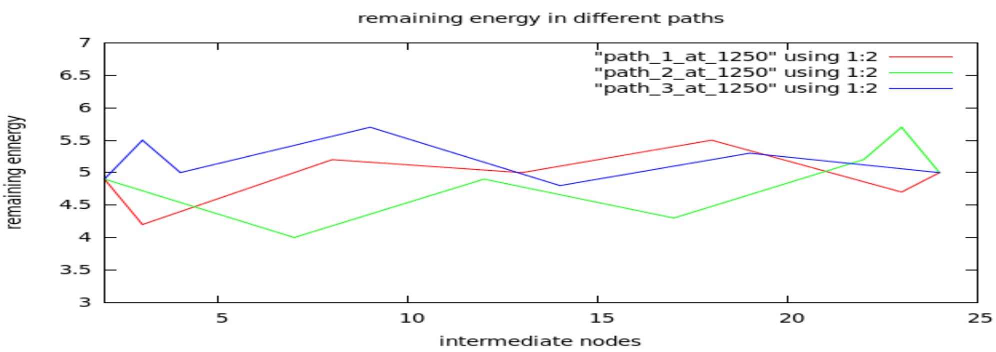

Fig. 6. Remaining energy of intermediate node at different paths

Hence, ERDB-AODV selects path 3 for data transfer as its intermediate node's energy is above the threshold.

2) AODV and ERDB-AODV path selection comparison:

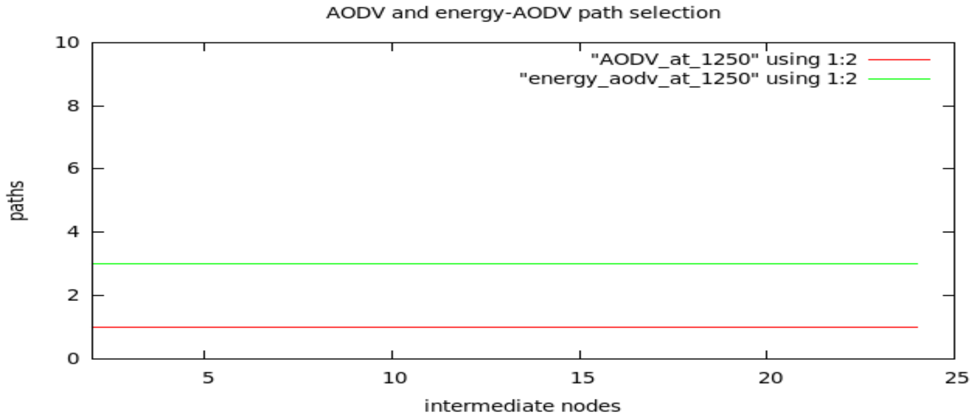

Fig. 7. AODV and ERDB-AODV path selection

Fig. 7 shows the path selection comparison with AODV and ERDB-AODV. The graph show the AODV selects path 1 in time 1250 ms but ERDB-AODV selects path 3 at the same time. The AODV selects best path by considering minimum hop count only but ERDB-AODV selects path by considering hop count, remaining energy and energy draining rate. The remaining energy in path 1’s intermediate nodes is less than threshold, so it results in network failure. Hence ERDB-AODV selects another path.

3) Lifetime of Network in AODV and ERDB-AODV Comparison

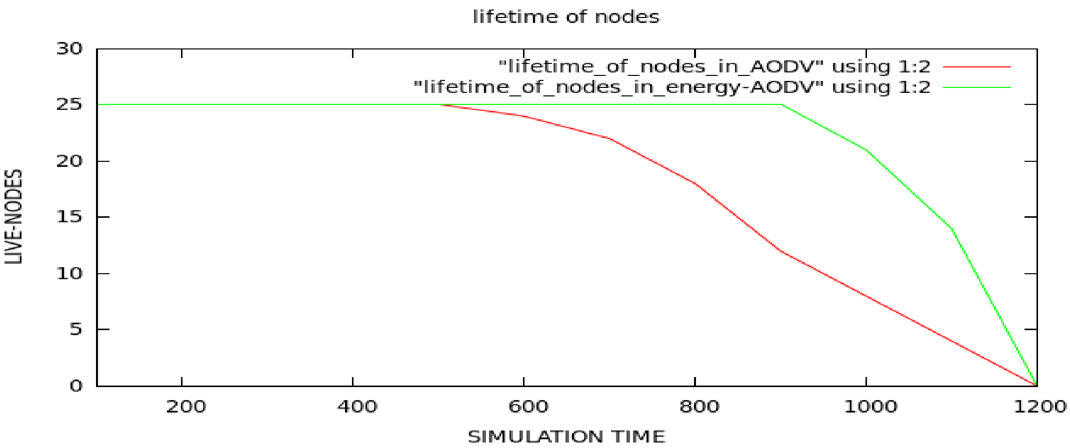

Fig.8. Lifetime of nodes

Fig. 8 show the lifetime of nodes variation over a certain period of time in basic AODV and ERDB-AODV models. We can notice that in basic AODV some nodes die earlier, which leads to network failure because of repeated usage of same node whereas some other nodes lead long life because of these nodes not used over a period of time. In ERDB-AODV all nodes maintain same lifetime because of remaining energy and draining speed factors. From the figure, we can see that all the nodes are active till 1000 sec and all nodes get died over a period of 200 sec. So in ERDB-AODV, all nodes balance their lifetime by considering energy factors in AODV.

C. Discussion of energy consumption behavior of the node

Discussion of energy consumption behavior of the node is done by considering several scenarios such as keeping the nodes position static and changing the nodes position dynamically at a grid during the simulation.

1) Remaining energy variation with node position: static and dynamic

Figure 9 show the variation of energy consumption with node position. Here static node position and dynamic node position are the two situations considered for analyzing the energy consumption of the node. Dynamic nodes will consume more energy than the static nodes, because of nodes dynamic nature energy consumption will be high. So from Figure 9 we can conclude that nodes changing its position dynamically, consumes high energy than static nodes. The energy draining rate is also high depending on the energy consumption.

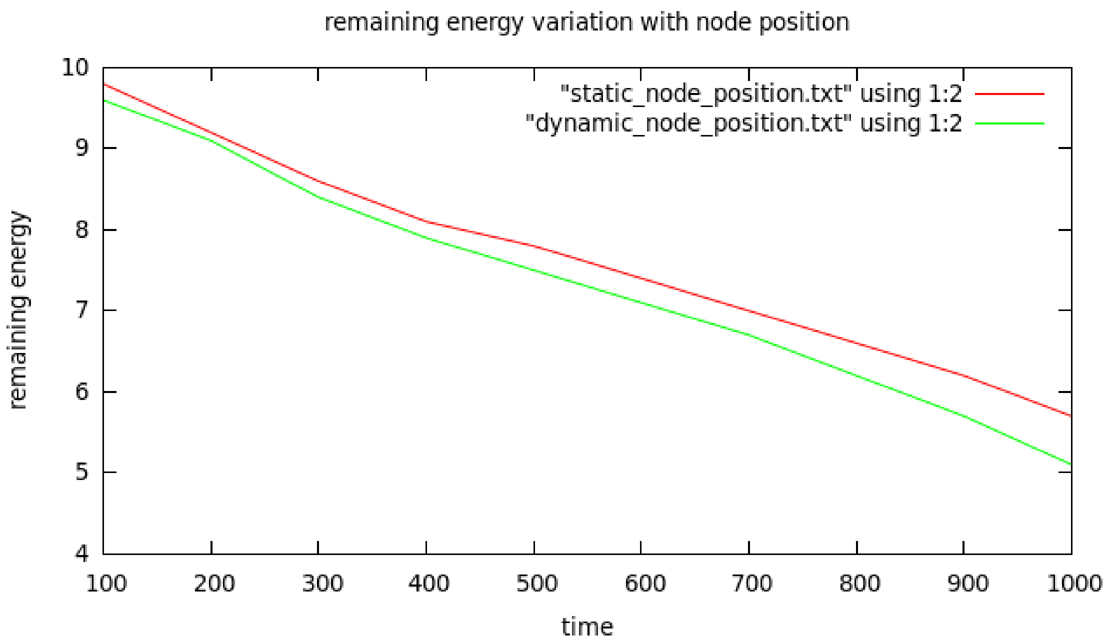

Fig. 9. Energy consumption varies with node position

2) Variation of draining speed with node position: static and dynamic

Fig. 10 show the energy draining speed variation in static node position and dynamic node position. The static nodes consume less energy than the dynamic nodes so energy draining speed of the static nodes is less than the dynamic nodes. The possibilities of dying dynamic nodes are earlier because of its high energy consumption. So lifetimes of dynamic nodes are less than the static nodes. From Fig. 10, we can see that energy consumption is higher in dynamic node position than the static nodes.

The energy consumption behavior of the node varies with node position. The nodes will consume higher energy if their node position is dynamic in all conditions. The energy consumption of the node vary with different network scenarios.

D. Algorithms comparison

Table II shows the comparision of existing AODV algorithm and proposed ERDB-AODV.

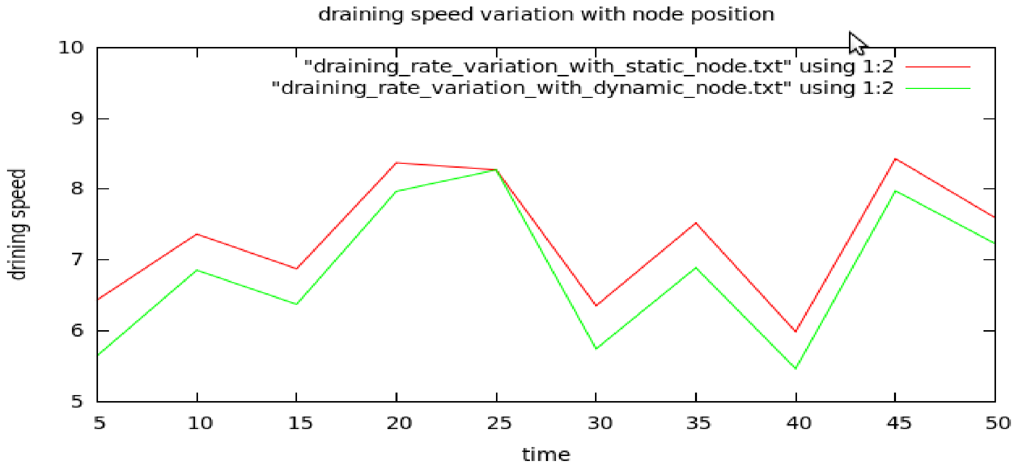

Fig. 10. Draining speed variation with node position

TABLE II
AODV AND ERDB-AODV COMPARISON

Techniques	Path selection	Description
AODV	Path selection based on hop count.	Finds minimum hop count path to reach destination. There is a Quick drop in nodes energy because of repeated usage of same node.
EDRB-AODV	Path selection based on nodes remaining energy and draining rate	Maintains same energy level in all nodes over the network. Without considering the different aspects like application running on node not.

Several studies have been conducted on energy consumption behaviour of the nodes by varying different sources at every node. The path is selected based on the energy draining rate criteria. We can notice that ERDB-AODV algorithm increases the lifetime of the network by inititially estimating the energy draining rate of each path and selecting the path with less energy draining rate of node. This ensures that the network lifetime increases compared to the existing AODV routing algorithm.

VI. CONCLUSION AND FUTURE WORK

The work carried out till date has considered hop count and expected transmission count for routing algorithm in wireless mesh network. In our proposed model, the need of energy metric in routing algorithm is identified and developed a new ERDB-AODV algorithm. The model works on calculating remaining energy and draining rate of each node. These two aspects may take long path to reach destination but it will assure successful data transfer without node failure. The algorithm is developed using dynamic routing to transfer data from source to destination and applied basic energy model. Experimental studies reveal that the proposed algorithm out performs the AODV algorithm.

This work is based on the hop count, remaining energy and average draining speed. Few more studies can be conducted on energy consumption behaviour of the node by varying different parameters such as varying the packet size, data rate, distance between nodes, by keeping node position both static and dynamic. Also suggest a mathematical model for energy consumption based on node’s position considering different parameters. Further, this work can be extended considering other parameters like size of data, delay, type of data and bandwidth available in the network.

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REFERENCES

[1] IEEE, Draft amendment: ESS mesh networking. IEEE P802.11s Draft 12.00, Jun 2011.

[2] Lamia Romdhani and Christian Bonnet, "Energy Consumption Speed-Based Routing for Mobile Ad Hoc Networks", *International Conference on Distributed Computing Systems Workshops, 24th ICDCSW*, 2004.

[3] Praveen Gupta, Preeti Saxena, "Energy Consumption in Wireless Ad hoc Networks", *Third international conference on emerging trends in engineering and technology*, IEEE, 2010.

[4] Adeel Akram, Mariam Shafqat, "Battery and Frequency Optimized AODV for Wireless Mesh Networks", *Canadian Journal on Multimedia and Wireless Networks*, Vol. 1, issue 3, pp. 31- 37, Apr 2010.

[5] T. A. Le and M. R. Nakhai, "Possible power-saving gains by dividing a cell into tiers of smaller cells. IET Electronics Letters", vol. 46, issue 16, pp. 1163–1165, Aug 2010.

[6] Jharna Chokhawala, Albert Mo Kim Cheng, "Real Time System Laboratory. Optimizing Power Aware Routing in Mobile Ad-hoc Networks." *International Journal of Computer Applications*, vol. 1, issue 1, 2011.

[7] Mhlanga, M.M, Olwal, T.O, Mutanga, M.B, Adigun, M.O., "Energy Optimization based Path Selection Algorithm for IEEE 802.11s Wireless Mesh Networks", *IEEE AFRICON*, Zambia, pp. 1-6, Sep 2011.