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A New Approach for Path Selection Using Energy in Multipath Routing for Wireless Mobile Ad Hoc Networks

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ABSTRACT
Mobile ad-hoc networks are wireless mobile nodes and interconnected with wireless links. Most ad hoc mobile devices today operate on batteries. Hence, power consumption becomes an important issue. To maximize the lifetime of mobile networks, the power consumption rate of each node must be evenly distributed, and the overall transmission power for each connection request must be minimized. But many proposed routing protocols don't consider energy as an important factor for selecting routes. This causes earliest exhaustion of nodes and network in trouble. Also it leads to additional route discovery for new routes and overheads to maintain new routes. In this paper, we propose a new approach for path selection using energy factor. During the route selection process the node is considered only when the node is having above the minimum energy threshold value. By this way the node with less battery power will be excluded from the selection process. The proposed model is tested with the NS2 simulator and the result we obtained is significant.

Keywords Mobile Ad Hoc Networks, Multipath routing, AOMDV, Energy factor**.**

Introduction

Mobile ad hoc mobile network [1] [2] is an autonomous system consisting of mobile hosts that do not rely on the presence of any fixed network infrastructure. Depending on the nodes' geographical positions, their transceiver coverage patterns, transmission power levels, and co-channel interference levels, a network can be formed and unformed on the fly. This ad hoc network topology changes as mobile hosts migrate, "disappear" (failure or depletion of battery capacity), or adjust their transmission and reception characteristics.

The nodes used in a MANET are resource constrained, they have a low processing speed, a low storage capacity and a limited communication bandwidth. Moreover, the network has to operate for long periods of time, but the nodes are battery powered, so the available energy resources limit their overall operation. To minimize energy consumption, most of the device components should be switched off most of the time. Furthermore, changes in the physical environment, where a network is deployed, make also nodes experience wide variations in connectivity and thus influencing the networking protocols.

Energy is a precious resource in MANET. For many multi-hop scenarios require efficient energy management to ensure connectivity across the network. Energy efficiency is a critical issue in MANETs [3] [4] [5]. The existing energy-efficient routing protocols often use residual energy, transmission power or link distance as metrics to select an optimal path. But most of the methods take into account routing metrics such as delay or hop count. They don't consider about transmission energy cost and remaining battery energy. So energy efficiency is directly connected to network lifetime or network capacity. The design of energy-efficient routing protocols in MANETs [6] is influenced by many factors. These factors must get over before efficient communication can be achieved in MANETs. Here is a list of the most common factors affecting the routing protocols design:

- *Node Deployment*
- *Node/Link Heterogeneity*
- *Energy Consumption Without Losing Accuracy*
- *Scalability*
- *Network Dynamics*
- *Fault Tolerance*
- *Connectivity*
- *Transmission Media*
- *Quality of Service*

Because of all these disparities, several new routing mechanisms have been developed and proposed to solve the routing problem in MANETs. These routing mechanisms have taken into account the inherent features of MANETs along with the application and architecture requirements. A high efficient routing scheme will offer significant power cost reductions and will improve network longevity. The main design goal of MANETs is not only to transmit data from a source to a destination, but also to increase the lifetime of the network. This can be achieved by employing energy efficient routing protocols.

In this paper, the focus is on energy efficiency in MANETs and the route selection policies with novel metrics in order to increase path survivability of MANETs. The selection of the energy efficient protocols in MANETs is a really critical issue and should be considered in all networks. The main objective of current research in MANET is to design energy-efficient routing protocols that could support various aspects of network operations. So, techniques and protocols that would consider energy efficiency and transmit packets through energy-efficient routing protocols and thus prolonging the lifetime of the network, are required. The potential task of the protocols is not only to find the lowest energy path from a source to a destination, but also to find the most efficient way to extend the network's lifetime. The continuous use of a low energy path frequently leads to energy depletion of the nodes along this path and in the worst it case may lead to network partition.

The remaining of the paper organised as follows. Followed by the simple introduction, Section 2 briefs the related work done in this field and Section 3 illustrates the proposed scheme. The results obtained from the proposed scheme are discussed in Section 4 and Section 5 concludes the paper.

Related Work

MTPR (Minimum Total Transmission Power Routing) [7] finds the path with the minimum power consumption. MTPR considers the SNR (signal to noise ratio) and sets a threshold (BER, Bit Error Rate) in order to select a path in which each link in the selected path satisfies, where SNR is the signal-to-noise ratio; i and j are the sending and the receiving nodes, respectively; Pi is the transmitting power of the sending node; Gi,j is the enhancement of the link between nodes i and j; μ_j is the noise detected by the receiving node; k is a neighbouring node of the receiving node; and β_j is the threshold BER. A sending node can determine the minimum power necessary to transmit packets in order to minimize power consumption. To find the path with the minimum power consumption, MTPR collects all the paths in which each link in a path satisfies SNR and P_l, where Pl is a path in which each link satisfies SNR. Accordingly, MTPR selects from all paths the one path that consumes the minimum power, as shown in $P(r_0)$

$$SNR_j = \frac{P_i G_{ij}}{\sum_{k \neq i} P_k G_{kj} + \mu_j} > \beta_j (BER)$$

$$P_l = \sum_{i=0}^{d-1} P(n_i, n_{i+1}) \ for\ all\ node\ n_i \in route\ l$$

$$P(r_0) = \min_{l \in r_*} P_l$$

MTPR causes the nodes in the routing path to use less transmission power in order to reduce power consumption. However, the decreased transmission power is significantly related to the threshold; that is, if the threshold is too high, a path in which the links satisfy SNR may not be found. If the threshold is too low, the decreased transmission power may result in poor transmission bandwidth, resulting in increased transmission delay and power. With power control, a receiving node can easily move out of the communication range of a sending node, leading to path breakage because of the mobility of the nodes.

The Minimum Battery Cost Routing (MBCR) [8] takes into account the remaining power of nodes to prolong network lifetime by selecting one path with the maximum remaining power from all available paths. To find the path with the maximum remaining power, MBCR calculates the sum of the remaining power of each node in a path, using Eq. (4) and (5)

$$f_i(t) = \frac{1}{C_i(t)}$$

$$B(r_d) = \sum_{i=0}^{d} f_i(t)$$

$$B(r_0) = \min_{rd \in r*} (B(r_d))$$

where $C_i(t)$ is the remaining power of node i at time t and $B(r_d)$ is the sum of the inverse of the remaining power of nodes in path d. MBCR uses Eq.(6) to select from set r_* of all paths the path $B(r_o)$ with the maximum remaining power. Although MBCR uses the inverse of the remaining power of the nodes in a path to select the desired path, the selected path may have a node with low remaining power. This may cause path breakage during data transmission.

Vergados et al. proposed xMBCR [9], which is an improved version of MBCR and MMBCR, to have higher network lifetime than MBCR and MMBCR. xMBCR modifies the battery cost function of MBCR, as shown in

$$f_i(t) = \left(\frac{1}{C_i(t)}\right)^p$$

where $C_i(t)$ is the remaining power of node i at time t and p is a constant. When p is 1, the battery cost function of xMBCR is equal to the one of MBCR. In addition, when p is equal to zero, xMBCR can find the shortest routing path. When p grows, the behaviour of xMBCR is more and more similar to MMBCR. When p is approaching to an infinite quantity, xMBCR is almost equal to MMBCR. Therefore, with the adjustment of the p value, xMBCR has higher network lifetime than MBCR and MMBCR.

The Min–Max Battery Capacity Routing (MMBCR) [10] selects the path in which the minimum remaining power of nodes in this path is greater than the maximum remaining power in other paths, using

$$P_{MMBCR} = \min_{R \in S}\left[\max_{n \in R} \frac{1}{BC_n}\right]$$

where S is the set of all paths, R is a path, and BCn is the remaining power of node n. In MMBCR, a routing path that contains a node with low remaining power can be avoided. However, MMBCR does not take transmission power into account.

To solve this problem, Condition Min–Max Battery Capacity Routing (CMMBCR) [11] which considers both the power consumption during data transmission and the remaining power of nodes, was proposed. Taking into account the transmission power and the remaining power, CMMBCR combines MBCR and MMBCR. CMMBCR has a pre-defined threshold for the remaining power of nodes. When the remaining power of a node is greater than the threshold, the MTPR protocol is used to reduce power consumption. However, when the remaining power of nodes is less than the threshold, the MMBCR protocol is used to prevent nodes with low remaining power from becoming a part of the routing path.

The Minimizing the Maximum used Power Routing (MMPR) [12] selects the path that has minimum power consumption for data transmission by finding all the routing paths from a source node to a destination node and calculating the power consumed by each path. In addition, MMPR also takes into account the power consumption of each node to balance the total power consumption, so the result is network lifetime is increased. In the path discovery phase, MMPR computes the power consumption of each node for data transmission to obtain the total power consumption of a routing path using

$$B(r_0)=\min_{r_d \in r*}(B(r_d))$$

where $B(r_d)$ is the power consumption of path r_d and r is the set of all paths. With regard to the balance of power consumption of the nodes, MMPR computes the "loading value" of a node by taking into account the remaining power, transmission power, receiving power, overhearing power, and threshold value. If the loading value of a node is larger than that of another node, then the node consumes more power. To balance the power consumption of nodes in a network, a node with a high loading value has a low probability of being a part of the routing path. In MMPR, although the power consumption for data transmission and the balance of power consumption among nodes are taken into account, the result depends on the threshold value. If the threshold is too high, the routing path may be difficult to construct. By contrast, if the threshold is too low, the effect of balancing the power consumption may not be obvious. Channel contentions and transmission bandwidth are not considered in MMPR.

Gomez et al. Proposed [13] the PARO protocol which evaluates the distance between two nodes to determine the transmission power needed to reduce power consumption. In PARO, it is assumed that each node can directly communicate with all the other nodes in the network (a one-hop network). A sending node uses the maximum power to transmit the first packet to the destination node. After the source node transmits the first packet to the destination node and receives the ACK packet successfully, the source node can use d^4 and T_{min} to determine the distance from itself to the destination node, as well as the minimum power needed for data transmission to the destination node. Here d is the distance between the source node i and the destination node j; Ti,j is the power consumed to send a packet from node i to node j; Ri,j is the signal strength of packets that are received by node j and that are sent by node i; Gt and Gr are the antenna gains of the sender and the receiver, respectively; and ht and hr are the antenna heights of the sender and the receiver, respectively. In addition, in T_{min}, for node i, Rmin i is the minimum received power strength of the received packets sent by receiving node j and Tmin i,j is the minimum power needed for transmitting packets from node i to node j.

$$d^4 = \frac{T_{i,j} G_t G_r \cdot h_t^2 h_r^2}{R_{j,i}}$$

$$T_{i,j}^{min} = \frac{R_i^{min} d^4}{G_t G_r h_t^2 h_r^2}$$

In addition, because the network is fully connected, other nodes in the network also receive the data packet sent by the sending node and the ACK packet issued by the receiving node. Therefore, using the above equations a node can determine whether less power is consumed when a source node transmits a data packet through it to the destination node or when a source node transmits a data packet to the destination node directly. If the source node transmitting data via that node consumes less power, the node broadcasts a message to the source and the destination nodes to help with data transmission. After the source and the destination nodes receive the message from the node, the source and the destination nodes can modify the data transmission with the help of the mobile node.

Wang et al., proposes ES-AODV [14] to reduce power consumption, it uses the relationship between the distance and signal strength to determine the minimum power for data transmission. To prevent transmission failure due to signal decay, ES-AODV takes the desired received power strength P0 and divides it by the signal decay ratio to obtain the minimum data transmission power Pmin. Accordingly, to transmit data, ES-AODV selects from all available paths the one path that consumes minimum power, as shown in Eq., where P(i,j) is the power consumed in transmitting data from node i to node j, n is the number of nodes in path l, and P(l,n) is the power consumed in transmitting a packet along path l. When the signal decay ratio (SAR) is taken into account, the power P_ (l,n) consumed in transmitting a packet along a routing path is as shown in Eq.

$$P_{(l,n)} = \sum_{i=1}^{n-1} P_{(i,i+1)}$$

$$P`_{(l,n)} = \sum_{i=1}^{n-1} P_{min} = \sum_{i=1}^{n-1} \frac{P_{(i,i+1)}}{SAR_{(i,i+1)}}$$

In ES-AODV, the power control method is used and the signal decay problem is taken into account to reduce power consumption. However, because of the mobility of the nodes, the transmission path can be easily broken during data transmission.

PAMP (Power-Aware Multi-Path routing protocol) [15] assumes that the source node knows the amount of power consumed in transmitting a unit of data. In the path discovery phase, the remaining power of nodes is recorded in the RREQ packet. The minimum remaining power of nodes in a path is the amount of power available for the path for data transmission. After the destination node receives the first RREQ, it records the amount of power available for a path and computes the amount of data transmitted to determine whether the available amount of power can complete the data transmission. If the available amount of power for the path is not adequate to complete data transmission, the destination node waits for the later RREQs until the amount of power is available for a path that satisfies the data transmission or until all RREQs arrive at the destination. The destination node also records all paths which the received RREQs have taken. After finding the desired path or after receiving all RREQs, the destination node replies by sending the RREPs for all recorded paths to the source node in order to construct multiple paths. During data transmission, if path breakage occurs, PAMP uses another path to continue the data transmission. PAMP constructs multiple paths so that data transmission can continue if path breakage occurs. However, the transmission bandwidth of the alternative paths may decrease, causing more power to be consumed because of the mobility of the nodes.

REAR (Reliable Energy Aware Routing protocol) [16] finds a stable path in order to reduce the number of path breakages. In the path discovery phase, REAR excludes the nodes with low remaining power so that nodes in the found path have enough power to complete data transmission. In addition, REAR also finds another backup path that can continue data transmission if path breakage occurs. With the backup path, the rerouting overhead due to path breakage can be reduced. However, the backup path may be broken or have low transmission bandwidth if it is used to transmit data.

LAMOR (Lifetime-Aware Multipath Optimized Routing) [17] takes into account multimedia data for transmission. To prolong network lifetime, LAMOR uses multiple disjoint paths to transmit data simultaneously in order to prevent the nodes in a routing path from consuming too much power. In LAMOR, the threshold value of the remaining power is used to exclude the nodes with low remaining power from being a part of the path. When the remaining power of a node is less than the threshold, the node goes into sleep mode in order to save power. During the path discovery phase in LAMOR, each node helps to transmit a RREQ once to reduce the overhead for discovering multiple paths. After the destination node receives multiple RREQs, multiple disjoint paths are discovered. LAMOR uses the rate allocation algorithm to distribute mass data flow in multimedia data transmission.

Meng Li, et.al. proposed a protocol Energy-aware Multipath routing Protocol (EMPR) [18] for MANET. In this scheme by sharing information among physical layer, MAC sub-layer and network layer, EMPR efficiently utilized network resources. EMRP calculates weight *(w)* of each node along the path to makes a decision to select that path.

$$W = \sum_{i=1}^{n} (\alpha \times W_{energy}^{i} + \beta \times W_{queue}^{i})$$

EMPR sorts all available routes in an ascending order of *W* and takes the top *N* sets of routes as primary paths to transmit data and take next *N* sets of routes as backup paths. Simultaneously transmitting packets along these routes need extend the lifetime of node and whole network..

Multipath Energy-Efficient Routing Protocol (MEERP) is proposed in [19]. The protocol selects energy-efficient and node disjoint paths based on the residual energy and successful transmission rate. In this protocol only a single path is used at data transmission from the multiple paths. Simulation result of the protocol shown that the protocol increases network lifetime but packet delivery ratio is less.

Omar Smail et al. [20], propose a new algorithm called Ad Hoc On-Demand Multipath Routing with Lifetime Maximization (AOMR-LM), which preserves the residual energy of nodes and balances the consumed energy to increase network lifetime. To define the node energy and average energy path as shown below

$$e_{averageNet}\left(P(u_0, u_n)\right) = \frac{e_{sum\,(P_i(u_0,u_n))}}{\sum \overline{P_l}(u_0, u_n)}$$

$$e_{level}^{u_0,u_n}(u_j) = \frac{w(u_j)}{e_{averageNet}(P(u_0, u_n))}$$

Based on the individual nodes energy level the average energy path level is defined to select best path to transfer the data during communication.The authors introduce threshold and co-efficient factors for selecting homogenous paths in terms of energy. However, reliability of the link and transmission energy cost are taken into account for path selection, they minimizes to network partitioning and re-route discovery.

Minimum Transmission Power Consumption Routing protocol (MTPCR) [21], takes into account high transmission bandwidth as a path selection parameter. MTPCR considers power consumption, distance and transmission bandwidth for discovers the desired routing path that has reduced power consumption during data transmission. Also path maintenance mechanism to maintain good path bandwidth and efficiently reduces number of path breakages. Thus, little additional overhead is required for the computation of the transmission bandwidth in the route discovery process.

Localized Energy-Aware Restricted Neighbourhood routing (LEARN) [22], consider critical transmission radius and energy mileage to guarantee energy- efficiency in route selection. This protocol is based on geographical localized routing, so the routing decision only uses local information of distance and energy consumption. Thus, mobility and link cost is taken into account for optimal path selection, this avoids path failures and congestion.

Sungoh kwon et al. [23] presented a novel Energy-efficient Unified Routing (EURo) algorithm that adapts to varying wireless environments. This algorithm takes into account four key wireless system elements such as transmission power, interference, residual energy and energy replenishment in great manner. Based on the above key factors the algorithm calculates weight vector for energy replenishment and link scheduling. The interference level also considered as main factor for classifying the nodes on the path, Hence, this algorithm is capable for large scale networks in terms of topology changes and energy conservation.

Chi Ma and Yuanyuan Yang introduce Battery-Aware Routing Scheme (BAR) [24] and prioritized BAR for wireless ad hoc networks. This scheme implements battery awareness in routing protocols. By dynamically choosing the devices with well-recovered batteries as routes and leaving the fatigue batteries for recover. The BAR scheme can effectively recover the device's battery capacity to achieve higher efficiency. This BAR & PBAR scheme increases network lifetime and data throughput up to 28% and 24% by considering energy consumption and distance, but it could fail to support link reliability and mobility.

Javad Vazifehdan et al. [25] propose two novel energy aware routing algorithms called Reliable Minimum Energy Cost Routing (RMECR) and Reliable Minimum Energy Routing (RMER). RMECR select paths based on its remaining battery energy, energy consumption and quality of links. RMER finds routes minimizing the total energy required for end-to-end packet traversal. Both schemes considers minute details such as energy consumption of processing elements, Limited number of retransmissions, packet sizes, Link weight, expected energy cost into detail. This reduces delay in finding path and support bandwidth constraints.

Young-Min Kim presented Ant Colony Optimization based Energy Saving Routing (A-ESR) [26] to overcome the energy-consumption minimized network (EMN) problem. The A-ESR scheme introduces the traffic centrality concept to measure traffic volumes along the nodes on the route. Based on the above factor every node on the path determines delay information and chooses lightly-loaded links for transmission. It balances the traffic load efficiency, but fails to support minimizing energy consumption and remaining battery energy.

EA-AOMDV Protocol:

Energy efficiency is an important factor to be considered when transmitting data within nodes. Here energy efficiency is meant to say about the life time of a node. In MANET, the nodes within a network are usually electronic devices that require energy after certain period. The devices when losing its energy gets slow and it will get off when heavy load is put on it during its low energy level.

So considering the energy level of the devices, we introduced a new scheme named EA-AOMDV (Energy Aware Ad-hoc On-demand Multipath Distance Vector Routing Protocol). The main motive of EA-AOMDV is to maintain prolong node energy to increase lifetime of the nodes and as well as whole network. Our scheme is incorporated at RREQ phase for selecting energy aware paths for sending packets and RREP phase for calculating energy cost for transmitting a packet from source to destination. The basic idea of our proposed scheme is to select a path based on energy level of the node and energy transmission cost. Our proposed scheme will work based on the following procedures:

1. In every path, nodes are selected depending on the energy threshold value
2. Each RREQ and RREP packets are to be forwarded or discarded depending on the threshold value.

Network Model:

We consider a wireless network with a graph G(N,E), where N and E are set of nodes and links. Each node is assigned a unique identifier number between 1 to M=|N|. All nodes are battery equipped. The initial battery energy for all nodes is set to be 100 Jules. Consider a node s and its remaining battery energy is RBE_s, where s € N. If RBE_s of a node falls below a threshold EF_{th} (Energy Factor), then node s is considered to be neglected from the forward path selection. Every node on the path is examined that its RBE_s is greater than $EF_{th.}$

$$\text{i.e. } EF_{th} \leq RBE_s$$

A Given network model, we define energy factor threshold to find energy-aware path, if its remaining battery energy is above the $EF_{th.}$ The EF_{th} is defined by

$$EF_{th} = IBE_s - ET_{(s,u)} / 5$$

Also the main objective of energy efficient routing mechanism is to reduce the energy cost for data communication. Energy cost for data communication depends on the size of the packet being transmitted. In this paper, we consider remaining energy power and transmission energy cost for path selection. So to transmit a packet [x-bit size] from node s to u, where s,u € N. The energy cost for transmitting a packet ET (Energy Cost for Transmission) is

$$ET_{(s,u)} = T_{(s,u)} + R_{(s,u)}$$

Where $T_{(s,u)}$ is Transmission Energy needed to transmit a packet [x-bit size] from node s to u and $R_{(s,u)}$ Receiving Energy needed to receive a packet [x-bit size] from node s to u. A routing protocol E is set to be energy-aware routing protocol, if ET and EF_{th} are energy efficient as well as energy cost efficient. The Algorithm 1: shown below details the implementation of the EF threshold energy simulation factors within the existing algorithm.

EA - AOMDV path discovery process

```
if (seq_num_i^d < seq_num_j^d) then
        seq_num_i^d := seq_num_j^d;
        advertised_hop_count_i^d := ∞;
        route_list_i^d := NULL;
   if (j=d) then
        insert (j,i,1) into route_list_i^d;
   else
        insert (j,last_hop_jk^d. advertised_hop_count_j^d + 1) into
        route_list_i^d;
   end if
else if ((seq_num_i^d = seq_num_j^d) and
        (advertised_hop_count_i^d > advertised_hop_count_j^d)
        and (RBE_i^d<= EF Threshold)) then
    if (j==d) then
      if (( k1: ( next_hop_ik1^d = j)) and (k2: ( next_hop_ik2^d = j))
        then
        insert(j,i,1) into route_list_i^d
      end if
    elseif ((: ( next_hop_ik3^d = j)) and (k2: ( next_hop_ik4^d = j))
        then
        insert(j,last_hop_jk^d. advertised_hop_count_j^d + 1) into
        route_list_i^d ;
     end if
end if
```

Algorithm 1: Modified energy based Route update algorithm of EA-AOMDV

Selection Criteria

When source node has packets for destination, it initiates Route Discovery phase. Also it assigns (Energy Factor) Threshold value for acquiring energy aware paths. First a source node makes a search of its route cache for intended destination. If no routes are available on the route cache, it floods or broadcasts RREQ packet with assigned values over the network. RREQ packet contains an ID, Threshold value for evaluation, source and destination address along with request ID, which uniquely identifies the current route discovery.

Route Discovery phase

When intermediate node receives RREQ packet, check itself whether it is the specified destination or not. If yes means, it will send a RREP packet to the destination. Otherwise it checks if it has any valid path on its route cache and send that details to source node. Before re-broadcasting, the intermediate node itself makes a decision whether it is qualified one for communication. The following condition is used for qualifying the intermediate node as:

EF (Energy Factor) Threshold $_{(RREQi)}$ > = RT's (RBE) $_{(node\ i)}$

When the above mentioned condition fails on any intermediate node, then that node will be dropped from the path. By doing so, the overloaded nodes are excluded and nodes minimum energy is prolonged. When RREQ packet reaches the specified destination, it creates RREP packet to the source. Also RREP packet calculates the transmission cost of packet from node i to j. Every node on the path must calculate its Residual Battery Energy (RBE) value and it can be added in the RREP packet. Calculating RBE by the node is as follows:

Energy Cost for Transmission $_{(node\ u,v)}$ = Transmitting Cost$_{(node\ u)}$ + Receiving Cost $_{(node\ v)}$

Route Maintenance

In the event of link failure or an intermediate node moving away, a RERR packet is transmitted to the source node to delete the path containing the broken link from its cache. Then source node will choose another path to resend the load. If all paths are broken at the same time it will start route discovery procedure again. After the route discovery phase data packet are forwarded simultaneously through the network using multiple paths.

Illustration of Proposed Scheme

To illustrate the proposed scheme, we consider a network model as shown in Figure-1 with 19 wireless nodes. Let us consider that the nodes S, R and B are source nodes and D, Z and Y are their corresponding destinations and they use multipath routing scheme. The possible paths for each pair are:

(i) (S-D) - {(S-A-N-D), (S-P-M-N-D), (S-A-K-X-D), (S-P-Y-Z-D), (S-A-K-L-X-D)}
(ii) (R-Z) - {(R-A-M-Z), (R-A-M-Y-Z),(R-A-K-N-Z), (R-A-P-Y-Z), (R-S-P-Y-Z)}
(iii) (B-Y) - {(B-A-P-Y), (B-A-M-Y), (B-A-S-P-Y), (B-R-S-P-Y)}

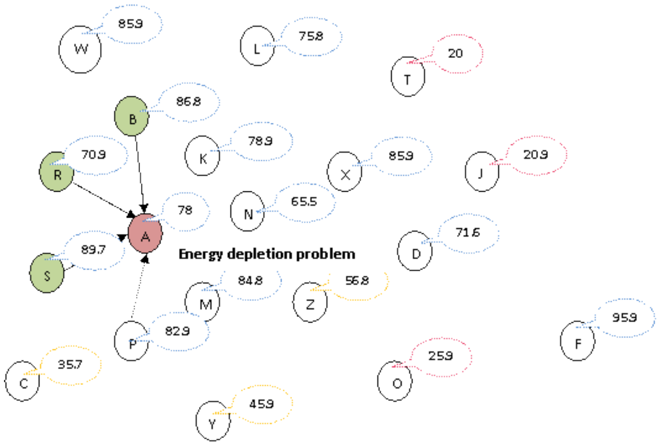

Figure-1: Contention and Energy Problem of node A

In the above diagram, let us consider node A whose energy level at time T_1 is 78 jules. The node A accepts paths from nodes (S, R, B) respectively. At the same time the node A also transmits the received packets to other nodes through available paths mentioned above. So the energy level of node A gets reduced due to the transmission of data.

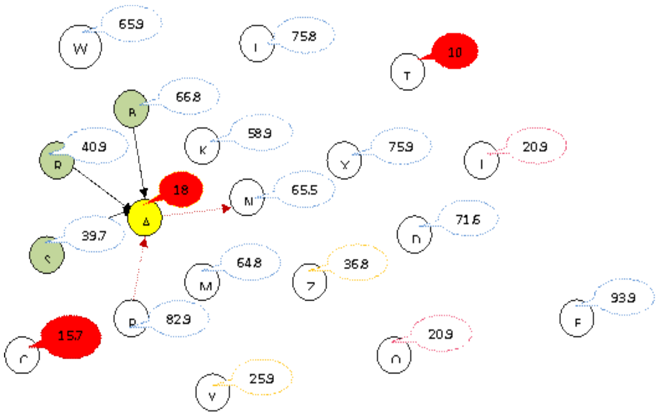

Figure-2: Our proposed scheme to alleviate contention and energy problem of node A

From Figure-2 at time T_2 based on the routing information, node P sends its RREQ (P) to node A for transmission of packet and node A compare its RBE value with EF threshold value. Node A RBE value is 18 jules. By comparing these value, node A drops the RREQ(P) and not involves the new communication at any node. Also sending of packet from node A to node N is rejected because energy level is low and will not be able to withstand till the complete packet transmission.

Results and Discussion

We consider the AOMDV to compare with the proposed EA-AOMDV and NS2 [27] is used to simulate the results. The performance metrics such as Average End-to-End Delay, Minimum Energy consumption, Packet delivery fraction, Packet loss Ratio and Throughput are taken into account. The considered simulation parameters are given in Table-1

Table-1: Simulation Parameters for EA-AOMDV

Parameter	Value
Number of nodes	100
Simulation time	100 seconds
Simulation Area	1520x1520 m^2
Transmission Range	250 m
Packet Size	512 bytes
Traffic & Mobility model	CBR/TCP
Traffic Rate	10 packets/second
Simulation Model	RandomWayPoint
Pass Time	10 seconds

Average End-to-End Delay

Average End-to-End Delay is represented by how much time it takes for successful packet transmission. The average end-to-end delay for tested AOMDV protocol increases when increasing the network traffic, but in EA-AOMDV delay is decreases with significant value. The proposed scheme show significant improvements with number of connection increases. The Table-2 and Figure-3 illustrate an average delay time by each protocol.

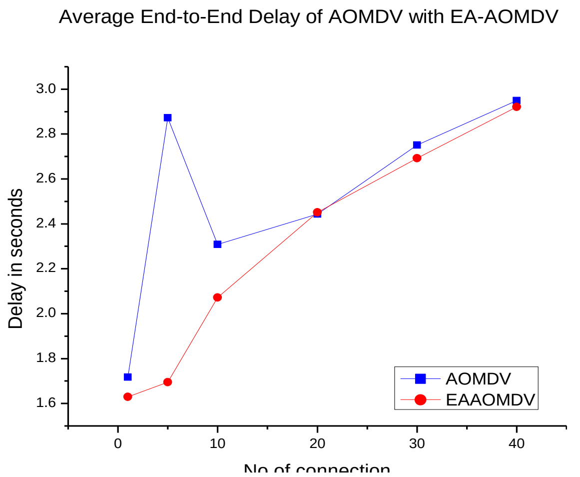

Figure-3: Average end-to-end delay of EA-AOMDV with AOMDV

Table-2: Average End-to-End Delay

No of connections	AOMDV (inseconds)	EA-AOMDV (in seconds)
1	1.717	1.629
5	2.873	1.695
10	2.308	2.072
20	2.444	2.451
30	2.751	2.692
40	2.949	2.921

Minimum Energy consumption

The energy consumption for packet transmission (transmitting and receiving) is taking into account. Here we consider maximum residual node energy as a main factor for route selection. Thus EA-AOMDV balances the energy among all the nodes and prolongs the individual node lifetime and hence the entire network lifetime. Our scheme finds path with minimum energy and compare residual energy of node in Table-3 and Figure-4

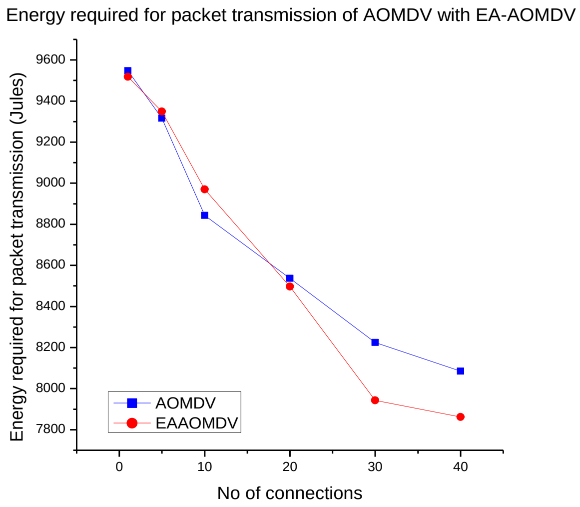

Figure-4: Energy consumption of EA-AOMDV with AOMDV

Table-3: Minimum Energy consumption

No of connections	AOMDV (Jules)	EA-AOMDV (Jules)
1	9547.96	9518.62
5	9316.46	9349.21
10	8843.42	8970.26
20	8537.26	8496.52
30	8225.14	7942.65
40	8085.13	7862.26

Packet Delivery Ratio

The packet delivery ratio can be represented as the ratio of an amount of successive received packets of a destination from an amount of transmitted packets by a source node during the simulation time. The Table-4 and Figure-5 shows packet delivery fraction of EA-AOMDV and AOMDV.

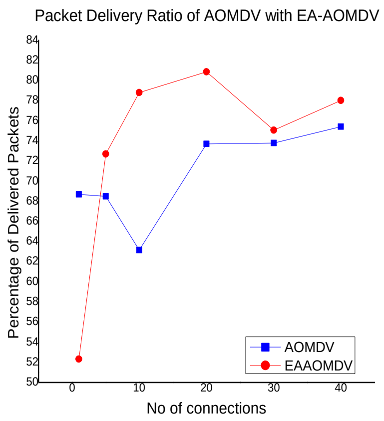

Figure-5: Packet Delivery Ratio of EA-AOMDV with AOMDV

Table-4: Packet Delivery Ratio

No of connections	AOMDV (in %)	EA-AOMDV (in %)
1	68.687	52.320
5	68.499	72.718
10	63.167	78.817
20	73.707	80.873
30	73.804	75.076
40	75.422	78.019

Packet Loss Ratio

The reasons for packet drops can be incorrect routing information, mobility & power management. AOMDV cannot maintain precise routes and drops, when nodes move often. The usage of state routes from its caches is the major reason for AOMDV packet drops. The Table-5 and Figure-6 illustrate that the number of packets dropped by each protocol. EA-AOMDV has fewer packet drops compared to AOMDV, when number of connections is increases and nodes move very often.

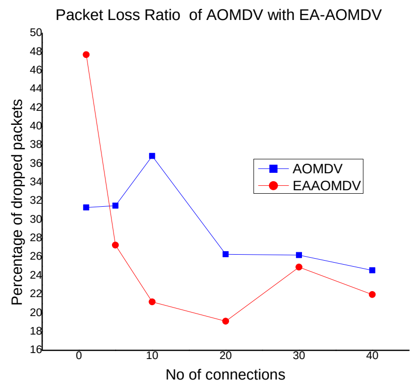

Figure-6: Packet losses of EA-AOMDV with AOMDV

Table-5: Packet Loss Ratio

No of connections	AOMDV (in %)	EA-AOMDV (in %)
1	31.313	47.680
5	31.501	27.282
10	36.833	21.183
20	26.293	19.127
30	26.196	24.924
40	24.578	21.981

Throughput:

Throughput is obtained by calculating how many packets are received at the destination from the source at a specified time interval (kbps). The Table-6 and Figure-7 show throughput of each protocol in packet delivery fraction. EA-AOMDV protocol throughput becomes high when nodes scalability is increased. But AOMDV protocols throughput becomes less when nodes scalability increased

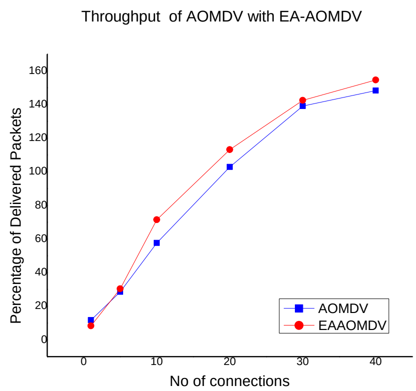

Figure-7: Throughput of EA-AOMDV with AOMDV

Table-6: Throughput

No of connections	AOMDV (in %)	EA-AOMDV (in %)
1	11.681	8.341
5	28.605	30.414
10	57.673	71.478
20	102.846	113.095
30	139.061	142.425
40	148.360	154.571

CONCLUSION

Even though many factors are to be considered to improve the QoS aspect of MANET, routing is standing front of all. Among the routing protocols, recently energy efficient multipath routing protocols attained very big attention among the research communities. In this paper we proposed a novel scheme called EA-AOMDV to improve the performance of the AOMDV routing protocol. By introducing the new threshold variable, the nodes lifetime is extended. From the simulated result it is found that the proposed scheme give a better result than the existing AOMDV with respect to Average End-to-End Delay, Minimum Energy consumption, Packet delivery fraction, Packet loss and Throughput.

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