

Modeling of an Energy-Efficient Routing Protocol over **MANET's**

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Abstract - Energy preservation is Important for ad hoc networks. Different energy efficient algorithms is been proposed based on the energy cost metrics. In conventional system the energy consumption models are only based on the exchange of the data packets. For reliable data transmission the wireless protocols require control packets such as ACK, retransmission etc... In previous models the energy cost of control packet is not been considered. So in this paper we propose an energy consumption model and a minimum energy routing protocol based on exchange of data, retransmission and the control packets. By simulation results, we want to show that the performance of the proposed model is efficient than the conventional models. .

Key Words: route discovery, link cost, AODV, route maintenance, minimum energy based routing and PEER protocol.

1. INTRODUCTION

In today's world, energy consumption plays an important role in every field. In wireless networks, devices such as PC, laptops, Mobile devices are battery powered. Current battery techniques for the electronic devices cannot support to work long enough. In applications such as sensor networks in remote location changing the battery is not possible. Therefor energy preserving is significant in ad hoc networks. As the technology is getting smaller, so communication energy cost and the energy efficiency happens to be important part in the total energy consumption. So energy saving scheme are the best way to preserve the energy.

While transmitting on a wireless network, the signal is reduces by $1/d^n$ rate where d represents the distance between the sender and the receiver and n represents the exponent path loss which is in between 2 and 6. Rather than setting up a constant maximum transmission power, based on the distance between the receivers and the sender, the energy efficient model should adjust the transmission power such a model is said to be as power control model. Many energy based routing models have been proposed . Based on energy schemes the protocol can be divided into two categories 1.Maximizing network

lifetime routing model and 2.Minimum energy routing model. Where minimum energy is required to transmit the data information from the source to target is called minimum energy routing protocols. Utilizing the battery power of each node is obtained by network life time routing protocols due to which network life time is maximized. Based on the type of link cost the minimum energy routing protocols are further classified into three classes namely Minimum Total Reliable Transmission Power (MTRTP), Minimum Total Trans receiving Power (MTTCP) and Minimum Total Transmission Power (MTTP). Based on transmission power as a link metric and search for path with minimum transmission power between the source and the destination MTTP protocols are used. Where as in MTTCP protocols both the transmission and receiving power is used as a link metric. In the MTRTP protocol, for reliability the total transmission power from one node to its neighboring nodes is considered as a link cost for the transmission of data packets. Based on link cost table most of the previous work is determined. If a new link cost is derived then protocols such as bellman ford, DSR and AODV can be customized to the new link cost table for shortest path but comes with a cost of long route setup time, high route discovery, routing overhead which consumes high energy and the for dynamic mobility scenarios the route maintenance scheme is not suitable.

So as to overcome these issues, in this paper we propose a progressive energy efficient routing (PEER). PEER progressively search more energy efficient paths where as other energy routing protocols finds the optimal path at one's. PEER finds the smallest path which is more energy efficient and adjusts the nodes when required between the source and destination so as to provide energy efficient routing.

2. ENERGY CONSUMPTION MODEL FOR IEEE 802.11

2.2 AODV protocol

Based on demand energy efficient routing the AODV protocol is centered. On demand routing protocol like AODV, It begins from route discovery process from the

source to the destination. Primarily a route request packet is broadcasted to the destination and waits for the acknowledgement from the destination. In between the source and destination node there are neighboring nodes, the route request packet is broadcast from the source through the neighboring nodes it will be reached to the **destination node**. If the request packet doesn't reach to destination then the neighboring nodes rebroadcast the first route request packet by this the route over head is reduced and the duplication of the route request packet will be stopped. The destination node responds only to the first route request packet only

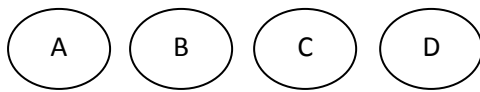


Fig 1: A Linear Topology

In fig.1 a linear topology of nodes is illustrated, where The A and D represent the source and the destination and the B and C are neighboring nodes. A broadcast the route request packet, then the neighboring nodes B and C receive the packet. Later the B send the route packet then C, D and A receive this packet. The node C and A discard the route packet if it already has the route request packet. Finally route will be ABD. The overhead for this routing is $O(n)$, where n represents the number of nodes. **Considering energy efficient protocol, it's not easy to discard the route request.** For energy efficient routing the route request packet should also respond. So that energy efficient routing can be obtained even by considering the control packets such as route request packet. Consider an example from the fig.1 where nodes may require transferring many times. Suppose C transfer the packet for B and A nodes. Consider that the ABC path is energy efficient than AC. We acquire the routing overhead based on Bellman – ford algorithm. The routing overhead requires lot of network resource and energy consumption particularly if the network has many nodes.

2.3 Link cost estimation

For energy efficient routing protocols link cost is important. Optimal routing can be obtained only with the accuracy of the link cost for energy efficient routing. Some assumption has been considered in this paper in MAC and physical layers and then an efficient way to deal with the estimation of link cost is proposed. Each node should dynamically adjust the transmission power by using PEER there by resulting in retrieving the received power and noise in the channel information.

In most routing protocols these assumptions are common, so we consider 802.11 power controls for MAC protocol. In order to decode the data correctly the DATA and ACK packets are broadcasted using minimum power and CTS and RTS packets transmitted are transmitted at maximum power level through MAC protocol.

Some precaution should be taken to avoid collisions like the signal is sensed but not decoded correctly, so PEER protocol should set the Extended Inter frame Space (EIF) and the **Network Allocation Vector (NAV"s)** [10]. An energy consumption model is derive from [6]. The Packet sizes of the DATA, ACK, RTS and CTS are represented by N_d, N_a, N_r and N_c , And the packet error rates between i and j node for packet DATA, ACK, CTS and RTS are represented as $p_{ij}, p_{a,ij}, p_{c,i,j}, p_{r,ij}$. The mean value of variable x is represented by x^* which is nothing but $1-x$. From node i to the neighbouring node j the average power transmission power is given as

$$\begin{aligned} \overline{P_T(i,j)} &= \frac{P_m N_r}{p_{r,i,j} p_{c,j,i} p_{i,j} p_{a,j,i}} + \frac{P_m N_c}{p_{c,j,i} p_{i,j} p_{a,j,i}} + \frac{P_{i,j} N_s}{p_{i,j} p_{a,j,i}} + \frac{P_{j,i} N_a}{p_{a,j,i}} \\ &= \frac{P_m(N_r + N_c p_{r,i,j}^*)}{p_{r,i,j}^* p_{c,j,i}^* p_{i,j}^* p_{a,j,i}^*} + \frac{P_{i,j} N_s + P_{j,i} N_a p_{i,j}^*}{p_{i,j}^* p_{a,j,i}^*} \end{aligned} \quad (1)$$

Where p_{ij} and p_{ji} represents the DATA and ACK packets and the represents the maximum power. The packet size and the header size of DATA, ACK, RTS and CTS are represented as $N, N_{hdr}, N_{data}, N_{ack}, N_{rts}, N_{cts}$ respectively. We define the following symbols such as,

$$\begin{aligned} N_a &= N_{ack} + N_{phy}, & N_c &= N_{cts} + N_{phy}, \\ N_s &= N + N_{phy} & \text{and } N_r &= N_{rts} + N_{phy}, \end{aligned}$$

and, where P_r represents the receiving power and N_{phy} represents the physical layer overhead size then total receiving power from node i to node j can be given as

$$\overline{P_R(i,j)} = P_r \frac{N_r + \left(\frac{N_c}{N_s} + p_{r,i,j}^* + \frac{N_a}{N_s} p_{i,j}^* p_{a,j,i}^* \right) p_{c,j,i}^*}{p_{c,j,i}^* p_{i,j}^* p_{a,j,i}^*} \quad (2)$$

Suppose consider that there are 0 to M nodes are there in which $M-1$ nodes represents intermediate nodes between source and destination and the average total power from source node 0 to destination node M is given as

$$\overline{P_{total}} = \sum_{i=0}^{M-1} (\overline{P_T(i,i+1)} + \overline{P_R(i,i+1)}) \quad (3)$$

Based on eqn. (3) the link cost table between node can be i and $i+1$ defined

$$\overline{P_T(i,i+1)} + \overline{P_R(i,i+1)} .$$

Parameters such as the packet error rates and transmission power a bit hard to obtain where as the

other parameters can be easily acquired. Power estimation scheme from [10] is adopted by PEER protocol. At a maximum level a packets such as DATA, ACK, RTS and CTS are transmitted from node A to node B then the desired transmission power can be calculated by node A to transfer to node B is given by desired power derived from maximum power level P_m and received power P_r is given as

$$P_{desired} = P_{rthres} * C$$

Where c represents constant and P_{rthres} represents the minimum received signal strength.

3. Proposed work

3.1 Route Discovery Process

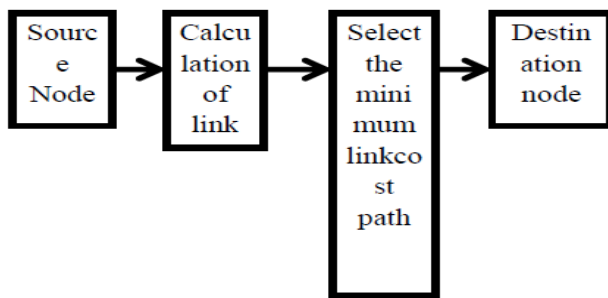


Fig-2: Route discovery Phase

The shortest path routing scheme is the easiest way to find the path between the nodes with few number of hops between the source and the destination node. Assuming an example as shown in fig.3 where S and D represents the source and destination node and A, B, E, F, G and H represents the neighboring nodes. There are six possible shortest paths namely (SAD, SBD, SED, SFD, SGD and SHD). Among all these paths it's important to select an energy efficient path. Consider L set of paths between the source and destination and the number of hops is represented by N_L for l paths, energy consumption for link i in path l is represented by $E_{L,i}$. Then the resultant shortest paths L_s is given as

$$L_s = \text{arg min}(N_l); l \in L$$

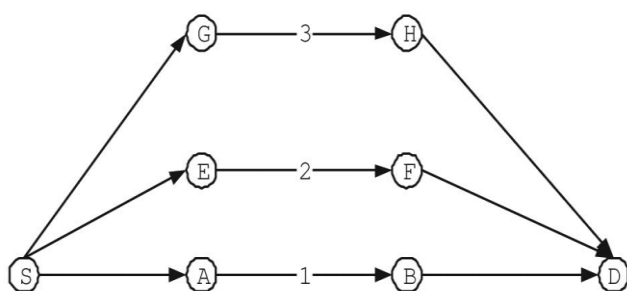


Fig.3. The routes between S and D

The set of minimum energy shortest paths is represented by L_{ms} is given by

$$L_{ms} = \text{argmin} \left(\sum_{i=1}^{N_l} E_{l,i} \right), l \in L_s$$

There is possibility that more than one minimum energy shortest path might find in L_{ms} , then the routing protocol should choose the one path which unique based on priorities such as route request packet arriving time.

The searching algorithm can be defined by the previous definitions 1. Search for smallest paths 2. Select the path which is maximum energy efficient path from (1). In order to implement this algorithm two possibility of information need to carry. One the energy consumption and the other is hop count.

The source node transmits the route request packet with energy consumption initially to 0 and hop count. Once the packet is received by the intermediate node firstly it updates the energy consumption between sender and itself and also increases the hop count by value 1. In order to retransmit the route request packet the one of the following condition it should have:

- 1) The node hasn't received the packet from the shortest path (small number of hops).
- 2) The packet comes from a path where the energy consumption is lower.

Even though the destination D receives the route request packets from all the minimum energy shortest paths it cannot select the minimum energy shortest path. There are many ways to deal with this kind of problem. One is to send the reply to the route request packet from where it received but it consumes lots of energy. The another way to solve this problem is to set up timer at the destination after receiving route request packet. If the destination node receives other route request packet before time out then it will reset the timer on the other hand, and if the timer goes off then will pick the best shortest path and it will reply with route request packet by this the route setup time increases but the energy consumption is reduced. In this paper we consider the second way by allowing the route request to pass through intermediate nodes which helps in preserving energy. To improve the speed parallel route reply is applied from destination to source. When nodes which are not with minimum energy shortest path they will check whether they are lower energy path between sender and the receiver.

3.2 Route Maintenance

Each node can evaluate its link cost and the transmission power to one its neighboring node once it receives the DATA, ACK, RTS and CTS packets. Each node appends its link cost in the IP header of the receiver and monitors the data packet broadcasted to its neighbor node. When the node receives the data packet or transmit it to another node it will record the information in the link cost table. (a) sender (b) receiver (c) link cost between the sender and the receiver (d) source (e) destination (f) IP header ID (g) the current time. From the above parameters the sender and the receiver can be acquired from the MAC header. The link cost and the IP header can be obtained from IP header, whereas the information in the link cost table is meant for shorter time for accuracy and also to reduce overhead.

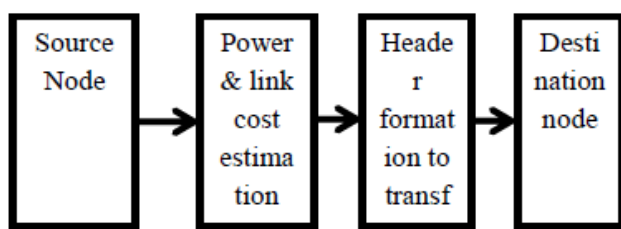


Fig.4.Route maintenance phase

A node obtains information about how the packet is passed through its neighbor and the link cost by using the link cost table. Suppose consider an example from the table where the link energy of node D's is determined. Parameters such as source, destination and header can identify the packet.

TABLE 1
 Link energy table

(a)	(b)	(c)	(d)	(e)	(f)	(g)
A	B	5	S1	D1	1	0
B	C	4	S1	D1	1	1
D	B	3	S2	D2	3	3
F	G	7	S3	D3	5	4
B	E	2	S2	D2	3	5

From the table one can see that node D path information for three packets: P2 (S2, D2, 3), P3 (S3, D3, 5) and P1 (S1, D1, 1). The first packet (P1) uses two-hop path (ABC) in D's neighborhood & the total link cost obtained is around 9(5+4) where as the second link cost is around 5(3+2)

which uses the two hop paths (DBE). The link cost of the third packet which uses one hop path (FG) whose link cost is around 7. Each node will enhance its corresponding end to end and the local path by (remove, replace and insert) operations as described in fig.5 for node D.

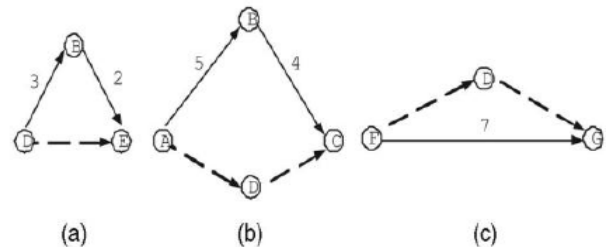


Fig.5. Remove, replace and insert

(a) Remove

Some of the rules for remove operations are illustrated.

Let's consider a two hop path XAB with the total link cost T in link cost table „X” with destination node D. If X finds the link cost between X and B is smaller than that of the two-hop path, it will update its routing table by setting the next hop for destination D to B.

From the fig.5 (a) one can see that the node D has DBE path which is nothing but two hop path. For such path the link cost is 5. The D node can estimate the link cost as E is the neighboring node then the packet transmitted to node E is and its links cost to E ($P_T(D,E)$) from the CTS or RTS packets transmitted by node E. The routing table will be updated by D when ($P_T(D,E) < 5$) and set the next hop for destination D2 to E. then all the packets from D2 will transferred to E straightly.

(b) Replace

Some of the rules for replace operations are illustrated.

Let's consider a two hop path ABC with the total link cost T in link cost table „X” with destination node D. If X finds the total cost for the path AX is smaller than that of the two-hop path ABC, X will update its routing table by setting the next hop to destination D to C. In addition, it will request A to update A's routing table by setting the next hop to the destination D to itself (X).

From the fig.5 (b) one can see that the node D has (A → B→C) path which is nothing but two hop path. For destination D1, for such path the link cost is 9. For D node, the A and C are neighboring nodes then one can estimate the link cost between them by using D node which is referred as ($P_T(D,A)$, $P_T(D,C)$) .. Considering the condition ($P_T(D,A)+P_T(D,C) < 9$), then the path A → D→C is energy efficient in comparison with the A → B→C. So the next hop as destination D1 to C is set up by node D thereby requesting node A for updating next hop as D1 destination to D. Suppose if A reject the request of D then the packets routing for the destination D1 at node D will be removed after a timeout period. If the request from D node is accepted by the A node then all the packets is transferred to D1 and D will further transfer them to C.

(c) Insert

Some of the rules for replace operations are illustrated.

Let's consider a one hop path AB with the total link cost T in link cost table „X“ with destination node D

If X finds the total cost for the path AXB is smaller than that of one-hop path, it will update its routing table by setting the next hop to destination D to B. In addition, X will request A to update A's routing table by setting the next hop to the destination D to itself (X).

From the fig.5 (c) one can see that the node D has (F → G) path which is nothing but one hop path. For destination D3, for such path the link cost is 7.

For D node, the F and G are neighboring nodes then one can estimate the link cost between them by using D node which is referred as $(P_T(D,F), (P_T(D,G))$. Considering the condition $(P_T(D,F) + (P_T(D,G) < 7$, then the path $F \rightarrow D \rightarrow G$ is energy efficient in comparison with the $A \rightarrow F \rightarrow G$. So the next hop as destination D3 to G is set up by node D thereby requesting node F for updating next hop as D3 destination to D.

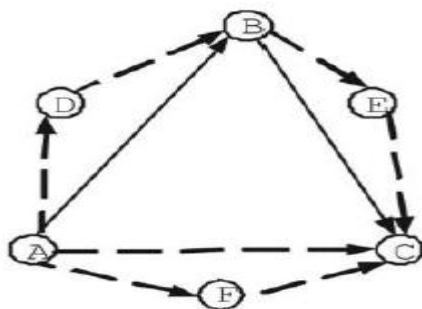


Fig.6. An undesired improvement

In the remove, insert and replace operation only two operations namely insert and replace operations require a control message. When an energy efficient path is observed then only the control message will be sent which helps in maintaining very low overhead. The control message has contains: the total link cost for new path, next hop, requester ID, operation ID destination.

In the replace operation, The D node sends the control messages the node A as [Replace, D, D1, B, the total link cost for ADC].while in Insert operation, The D node sends the control messages the node F as [Replace, D, D3, G, the total link cost for FDG]. After receiving the control message the node first verifies the information about routing in the routing table for the destination.. Suppose the next hop for destination node shown is different from control message. Since the route differs now so it will discard such control message. Insert operation has higher priority than the remove and replace operations because one need to only verify the one op transmission. Considering an example as shown in fig.6 where node A broadcast the data to nod B. So as to save the energy the node D sends the data to node A indicating energy

preservation between AB link. In the same way E is inserted between Band C. ADBEC is the final path but we o have two other shortest path AFC and AC. Considering the AFC as the best path because remove and replace operations has higher priority than that of the insert operations. In PEER protocol when a node receives insert or replace or remove request the protocol wait before making a decision.

If it has replace and remove operations request then.It will pick the one which is energy efficient. As an example node A has insert (by node D) and replace and remove (by node F). As $(P_T(A,F) + (P_T(F,C) < (P_T(A,C)$ (where AFC is better path than that o f the AC so it will pick replace operation from the insert, remove and replace operation.

4. PERFORMANCE EVALUATION

In this section the performance of the proposed method is evaluated and described. Using mat lab the simulation is performed for evaluating the performance of AODV, MTRTP and the proposed PEER approach.

For the evaluation purpose, during simulation we considered the following parameters.

- ☑ Number of nodes: 30
- ☑ Packet size : 512(byte)
- ☑ Network area : 1200x200 m
- ☑ Per hop transmission distance: 250 m
- ☑ Node distribution: Random Fashion
- ☑ Transmission power: 35mW
- ☑ Pause time: 30sec
- ☑ Remembering rate: 0.99
- ☑ No. of runs: 20

Assume that nodes have no power saving mode. A node consumes energy while overhearing the packet or during **monitoring if it doesn't receive the packet. As a result the receiving power cannot be controlled.** So during simulation only transmission power is focused there by neglecting the receiving power. Firstly we calculate the accuracy of proposed model and the evaluate the performance of the each protocol model such as AODV, MTRTP and the PEER proposed mode and then evaluation of the control packets such as RTS and retransmission for energy consumption in mobile and static scenarios is considered.

4.1 Routing Overhead and Setup Time

During simulation 100 nodes for each protocol is considered and evaluated the performance of the AODV, MTRTP and the PEER in terms of total number of routing packets, total energy consumption, and total setup time on each simulation. The simulation results and its performance are shown in Fig.7-9.

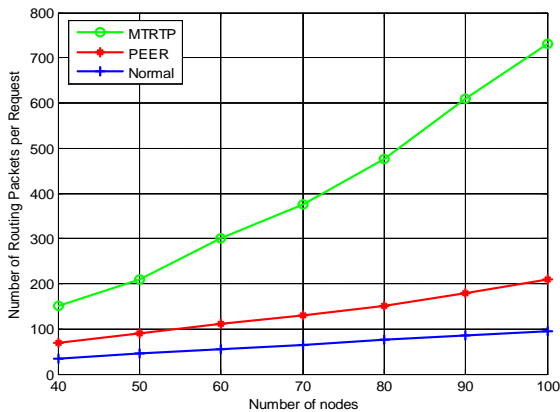


Fig.7 Routing overhead

From the results shown the performance of the normal on demand routing protocol performance is best and the later is the PEER protocol followed by minimum energy routing protocol in terms of setup time, energy consumption for routing over head and routing overhead.

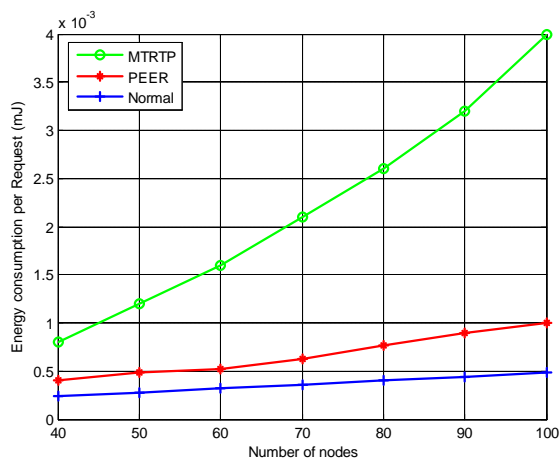


Fig.8. Energy consumption over routing overhead

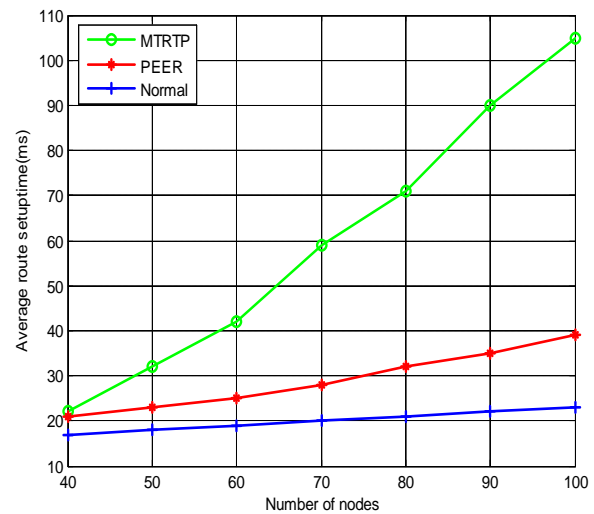


Fig.9. Route setup time

From the fig.8 and fig.9 the performance of the minimum energy routing protocol in terms of routing overhead and the setup time consumes much as the number of nodes increases in comparison with the on demand routing protocol. The reason is the routing over head for the MTRTP is $O(n^2)$ as described in section II. The performance of the PEER protocol is better in comparison with the MTRTP. Where as the performance of the on demand routing protocol is better than that of the PEER and MTRTP, as the no of nodes are increasing the scalability of the PEER protocol is high as the route set up and the routing overhead increases linearly.

4.2 Static Scenario

The performance of the each protocol has been evaluated in terms of the RTS retransmission and the energy consumption in static environment with different connection arrival rate, density and the packet size by considering the simulation time around 5 hrs. The total number of packets received and the energy consumption is monitored at the destination nodes. In order to evaluate the protocols are evaluated based on energy consumption packet metric which is defined as total energy consumption divided by the total number of packets received. For each protocol, the total energy consumption metric replicates the energy efficiency

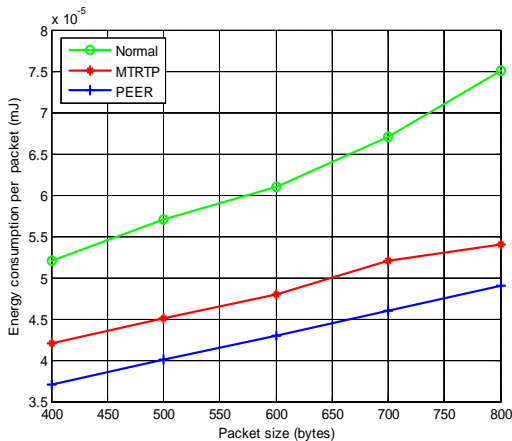


Fig.10. Different packet size versus Energy consumption (mJ)

In energy consumption the MTRTP and PEER protocol performance is much better than that of the normal protocol and PEER protocol performance is better than that of the other protocols.

4.3 Mobile Scenario

Each protocol performance has been evaluated in terms of the RTS retransmission and the energy consumption in mobile environment with different connection arrival rate, density and the packet size. From the fig.11, In terms of the energy consumption in mobile environments the performance of the PEER protocol is better than that of the other protocols

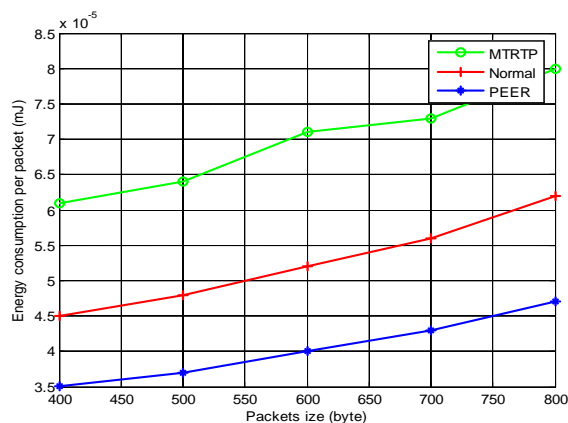


Fig.11. Different packet size versus Energy consumption (mJ)

5. Conclusion

A new link cost model is stated in this paper so as to monitor the energy consumption occurred because of various parameters. For minimum energy routing protocol, the route maintenance and route discovery topic has been illustrated. Based on the new link cost metric. In mobile environment a PEER protocol has been proposed for

energy efficient path maintenance scheme. In terms of path setup delay and overhead, the PEER protocol performance is better than the existing protocols in both mobile and static environments.

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