International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-2, December 2019

A Multi Stage Path Indexed Energy Conserving Routing in MANET

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Abstract**: *The technology behind Mobile Adhoc Network is growing day by day. This growth is triggered by the needs of the society and it remarks the influence and usage of MANET around the world. Due to the flexibility, scalability and ease of use, MANET has become a part of everyone's life. So researches are carried out with a sole aim to maximize the throughput. There are many aspects to be covered to improve MANET performance which includes routing, energy usage, bandwidth usage, mobility management etc… Researchers try to bring better performance by tuning the above parameters to an optimal condition so as to bring an overall balance. Management of energy and its conservation by optimization is a critical issue to be addressed in MANET. This paper introduces a novel approach in MANET routing which enables better energy management during data exchange. This method uses a new paradigm which will provide Multi Stage Indexed Energy Conserving Routing in MANET (MSPIEC routing). MSPIEC routing identifies the overall energy equilibrium of the MANET during route discovery, and based on the statistics the data exchange will be carried out. Since MSPIEC routing has the data on energy equilibrium, more data will be passed through healthy routes and less data will be assigned through weaker paths, so that the entire data transfer will be balanced as a whole.***

Keywords: MANET, Energy Optimization, Routing, Energy Management.

I. INTRODUCTION

The world has achieved what it today is being contributed by the hike in networking technology. We cannot omit networking while we think about the advancements in the various domains. The interconnection between two computers which is grown to become networks of networks has a vast story to be told. One of the major contribution is given by MANETs, which is said to be the most flexible and scalable networks in the world. Today almost all networking capable gadgets are deployed in market with MANET enabled. This shows the influence of the MANET in the world and people.

The growth of MANET is not a one shot run. Huge amount of researches were conducted in this area to bring maximum performance. MANET is bounded by certain factors like mobility, routing [1] , on demand join and withdraw, self-powered energy and bandwidth. So these areas were concentrated by the researchers to bring out improvements in the current situation. Among these, mobility [2] is unpredictable since it is solely depend on the node situation. So researchers always relay on predictions on node mobility to handle the MANET performance and it is successful to some extent, but still it is uncertain. The rest of the factors are more or less controllable with better optimizations.

There are many protocols implemented based on these factors for better data transfer. Among them, protocols dealing with energy optimization, energy consumption is the top in discussion since battery power is a limited resource in MANET. Moreover, without power the other factors will not sustain. So energy conservation by optimization has a prominent place in MANET research.

This paper introduces a new Energy Conserving routing (MSPIEC routing) protocol which aims to gain knowledge of the entire energy equilibrium of MANET during the route discovery process. Based on the information, a virtual map of data transfer between source and destination using various paths are analyzed and classified based on its energy statistics. Once the analysis and classification is done, data transfer will be done based on the above decision. The advantage of this approach is the entire data transfer from a source to destination is balanced through high energy, medium energy and low energy paths. Healthier paths will be assigned more traffic and weak paths will be given low data rate and hence the overall energy usage can be balanced.

II. RELATED WORKS

This section reveals the previous studies and research works based on energy optimization in MANETs. Power Efficient Reliable Routing protocol (PERRA) [3] was a MANET routing protocol which aims to identify the residual energy, the total energy to send, receive and process a packet and path stability of the networks. Based on the three factors the path selection will be done. Another protocol named Link-stability and Energy aware Routing protocol (LAER) [4] which focuses on the two metrics 1) link stability between and 2) minimum energy drain rate. The link stability of the nodes is estimated based on historical connection and probability of being alive is predicted and the following is mixed with the energy matric which identifies the health of the paths to carry required amount of data. Adhoc on-demand multipath routing with lifetime maximization (AOMR-LM) [5] which conserves the residual energy by classifying the paths based on energy threshold and energy coefficient.

Revised Manuscript Received on December 30, 2019.
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This path classification helps to improve the network life time as the data transfer is refined through selected paths based on energy. Energy Efficient OLSR Routing Protocol (EE-OLSR) [6] is a proactive routing scheme implemented based on an energy willingness function. Based on the residual energy of each node, a willingness value is set by each node which advertises the willingness to act as a Multi-Point Relay (MPR). This self-advertisement helps to form data paths based on the energy.

Minimum Total Transmission Power Routing (MTPR) [7] is another routing protocol based on the estimation of the total energy required to forward a packet in a path. The residual energy in each node is not accounted in this routing. Minimum Battery Cost Routing (MBCR) [8] estimates a battery cost function of each nodes. Less the value, it is estimated that the node would be better to transmit data. Min-Max Battery Cost Routing (MMBCR) is based on the estimation of weaker nodes in a strong path. Conditional MMBCR (CMMBCR) is a hybrid approach which takes into consideration that as long as all nodes in a path have higher energy than a particular threshold, data transfer can be done. Collision-constrained minimum energy node disjoint multipath routing algorithm for ad hoc networks (ECCA) [9] is based on collision avoidance and energy conservation. The main focus is saving energy by avoiding packet collision. The multipath energy-efficient routing protocol (MEER) [10] is another protocol which finds routes with high power based on the split multipath function.

The above discussed methods are implemented to provide better energy conservation based on various parameters like residual energy, packet transmission power, path energy, link stability, battery coefficient etc.… But most of them failed to deliver better output due to lack of consideration on finding stable paths based on energy and distance. The proposed method is an alternative to the existing approaches by identifying the overall energy equilibrium of the networks and maps the traffic accordingly.

III. ENERGY METRICS

A. Node Energy

Let G=(V,E) be a graph that represents a set of interconnected nodes in the MANET where V is the set of nodes and E is the set of edges. Each of these nodes has the capacity to send, receive and process packets. At the time of route discovery each and every node has to advertise its presence to the immediate neighbors and all has to update the information about their neighbors in the routing table. During routing process when a packet arrives at the node, it will be processed if it is intended to that node else the same will be forwarded to the nearest neighbor in the right direction. In order to do all these works node has to use its energy. All nodes keep track of the energy consumption at the current time and their residual energy.

The energy required to transmit or receive a packet is the product of the Current (Amp), Voltage (V) and the time taken to transmit or receive a packet. So the energy required to transmit a packet from a source s to the destination d is the sum of energy required to transmit the packet from s and the energy required to receive the packet at d. The amount of energy required to process a packet depends on the nodes physical architecture. Let $ET\ (p)$ be the energy required to transmit a packet from source s, $ER(p)$ be the energy required to receive the packet p at the destination d and $EP(p)$ be the energy required to process a packet at a node, then the total energy consumed on a packet transfer is

$$EC\ (p) = ET\ (p)\ +\ ER(p) + \ EP(p)\ Joules \quad (1)$$

Let $EToT$ be the total energy of node. After a packet transfer, the residual energy of a node would be

$$ERES = \ EToT\ -\ EC\ (p)\ Joules \quad (2)$$

Like this so many packets would be transferred across the MANET and for each transfer the $EToT$ will be reduced as the sum of the energy required to transmit the whole packets. So the residual energy of a node can be represented as

$$ERES\ =\ EToT\ -\ \sum_{i=i}^{n} Ec(Pi) \quad (3)$$

where i denotes the packet count from 1 to n

B. Path Energy

The above equation denotes the depreciation of the residual energy [11]–[13] of a node during the packet transfer. This section describes the math formulation of total energy, energy consumption and residual energy of a path which consist of a set of nodes originating from a source s and ending at a destination d.

Let $EPTOT$ be the total energy of all nodes in a path from s to d and the EPC be the total energy being used by the nodes in transmitting a packet in the same path. The residual energy of that path can be calculated as

$$EPRES = EPTOT - EPC \quad (4)$$

Which can be split as

$$EPRES =\ EPToT\ -\ \sum_{i=i}^{n} Epc(Pi) \quad (5)$$

This indicates that the residual energy of a path is directly depended on the amount of energy consumed to transmit, receive and process a packet

C. Path Flow Metrics

Let $Psp(s,d)$ be a shortest path from the source s to the destination d and $\rho sp\{s,d\}$ be a set of all paths from s to d where $Psp(s,d)€\ \rho sp\{s,d\}$ and fs,d represents the flow of packets from the s to d, then the sum of all flows from s to d through the set of shortest paths can be given as

$$fToT\ = \sum_{i=1}^{n} fi \quad (6)$$

where n represents the total number of shortest paths in the set $\rho sp\{s,d\}$.

The intensity of the flow across a path is the main parameter to be considered while evaluating node energy consumption. As the rate of flow increases the energy consumption also increases. So the total remaining energy is directly depended on the rate of flow across the path.

$$EPRES\ =\ \sum_{i=i}^{n}(Epc(Pi) * fi\ ) \quad (7)$$

In order to optimize the energy consumption, the flow of packets across the multiple paths must be governed in such a way that the node power depletion will not happen due to exploitation of energy in a normal path.

D. Path Selection Metrics

Once the energy analysis is complete, it is high time to deliberate the selection and classification of the right path for the data transfer. In most of the previous papers based on energy aware routing, a path with highest energy will be given overburden of transferring most of the data.

But this brings out a problem of network partitioning and unbalance in usage of energy in MANET. Some other works focuses on classifying paths based on energy coefficients. Based on the different classes, data will be transferred. But the coefficients chosen are limited and hence there would be a small set of classes for the paths.

The proposed method uses another technique on classification and path selection which is based on path coagulation based on energy. The basis of this approach is the calculation of total node energy, node residual energy, total path energy and path residual energy. The source node will collect the above information during the route discovery process. For every path the source will put and indexing based of the number of hopes, the weakest node based on energy on the path, total remaining energy and energy required to transfer the packet in hand. The indexing is done as follows.

Let n be the number of hopes, EW be the energy of the weakest node in the path and $ERESP$ be the residual energy of the path and ET be the energy required to transmit the packet across the network.

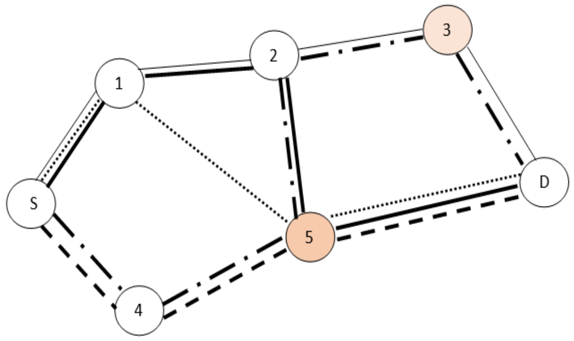

Fig 1. . Topology Description based on path formation

Consider the above network scenario where S is the source and D is the destination. In the route discovery process a total of five possible paths are identified, then

Table- I: Multipath Properties

Path No	Number of hopes	Intermediate nodes	Next hope	Weakest node in the path
P1	3	1-2-3	1	3
P2	2	1-5	1	5
P3	3	1-2-5	1	5
P4	2	4-5	4	5
P5	4	4-5-2-3	5	3(assuming energy of node 5 is > node 3)

After the route discovery process the source S has the above information. Using this information, the source will start indexing each path. In order to index each path source would also collect the information about the energy level of the weakest node in a path and the total residual energy in the path. The purpose of the indexing process is to level the entire set of paths so as to transfer data through every path so that energy equilibrium is preserved by maintaining the network stability.The path indexing process will assign weightage to each of the above parameters in the descending order as below

Table- II: Parameter Ranking

Sl.No	Parameter	Weightage Rank
1	Weakest node	1
2	Path residual energy	2
3	Distance	3
4	Energy required to transfer	4

The indexing process assumes the presence of a weakest node is critical because if this node is power exhausted, then the entire path may break. Also the effect would be catastrophic because this could lead to network portioning and then to route re discovery. Along with the first parameter, Path residual energy has high impact on the indexing. Paths with high energy could be used to deliver most of the packets. Distance and energy required to transfer has the medium impact. Number of hopes to be covered has less significance because conservation of energy is more important than distance. All of the above paths will have a mixture of the above parameters.

The outcome of the indexing is priori list of data transfer paths which has an equilibrium on the above parameters. While analyzing the above example the source has five paths. Let us assume the following energy details for each path

The residual energy of each path is as follows

$$RESP3 > ERESP1 > ERESP2 > ERESP5 > ERESP4 \quad (7)$$

The energies of the weakest nodes of identified nodes are

$$E5 > E3 \quad (8)$$

The number hopes in each path based to smallest to largest is as follows

$$P1 >= P2 >= P3 > P4 > P5 \quad (9)$$

and the energy required to transfer the packets from source S is ET assuming $ET > ERESP$ of all paths

Now the weightage of these parameters are considered for each path and compared as follows

Table- III: Path Comparison between P1 and P2

Comparison P1P2	P1	P2	Optimal path
Weakest node energy	Low	High	P2
Path residual energy	High	Low	
Distance	Equal	Equal	
Energy required to transfer	Optimal	Optimal	

Table- IV: Path Comparison between P1 and P3

Comparison P1P3	P1	P3	Optimal path
Weakest node energy	Low	High	P3
Path residual energy	Low	High	
Distance	Equal	Equal	
Energy required to transfer	Optimal	Optimal	

Table- V: Path Comparison between P1 and P4

Comparison P1P4	P1	P4	Optimal path
Weakest node energy	High	Low	P1
Path residual energy	High	Low	
Distance	Low	High	
Energy required to transfer	Optimal	Optimal	

Table- VI: Path Comparison between P1 and P5

Comparison P1P5	P1	P5	Optimal path
Weakest node energy	Equal	Equal	P1
Path residual energy	High	Low	
Distance	Low	High	
Energy required to transfer	Optimal	Optimal	

Table- VII: Path Comparison between P2 and P3

Comparison P2P3	P2	P3	Optimal path
Weakest node energy	Equal	Equal	P3
Path residual energy	Low	High	

Distance	Equal	Equal	
Energy required to transfer	Optimal	Optimal	

Table- VIII: Path Comparison between P2 and P4

Comparison P2P4	P2	P4	Optimal path
Weakest node energy	Equal	Equal	P2
Path residual energy	High	Low	
Distance	Low	High	
Energy required to transfer	Optimal	Optimal	

Table- IX: Path Comparison between P2 and P5

Comparison P2P5	P2	P5	Optimal path
Weakest node energy	Equal	Equal	P2 OR P5
Path residual energy	Equal	Equal	
Distance	Equal	Equal	
Energy required to transfer	Optimal	Optimal	

Table- X: Path Comparison between P3 and P4

Comparison P3P4	P3	P4	Optimal path
Weakest node energy	Equal	Equal	P3
Path residual energy	High	Low	
Distance	Low	High	
Energy required to transfer	Optimal	Optimal	

Table- XI: Path Comparison between P3 and P5

Comparison P3P5	P3	P5	Optimal path
Weakest node energy	High	Low	P3
Path residual energy	High	Low	
Distance	Low	High	
Energy required to transfer	Optimal	Optimal	

Table- XII: Path Comparison between P4 and P5

Comparison P4P5	P4	P5	Optimal path
Weakest node energy	High	Low	P4
Path residual energy	Low	High	
Distance	Low	High	
Energy required to transfer	Optimal	Optimal	

Now from the above calculations, the second stage of indexing starts. In this step the optimal path is selected in a rank order from the first stage by identifying paths who has been selected as optimal path many times. So the following is the order of occurrence

Table- XIII: Optimal Path Occurrence Count

Sl. No.	Path	Optimal path occurrence count
1	P1	2
2	P2	2
3	P3	4
4	P4	1
5	P5	1

The above table gives insight for the final indexing of the paths from the source to destination d

Table- XIV: Path Ranking

Rank	Path
1	P3
2	P1 AND P2
4	P4 AND P5

In the above ranking there is an ambiguity in the rank 2 and 4 because more than one path holds the same rank. In this case it's better to take the best one from the first stage of the index. So while comparing P1 and P2the optimal path is P2 and in case of P4 and P5 the best path selected is P4. So now the final indexed paths are

Table- XV: Indexed Path

Rank	Path
1	P3
2	P2
3	P1
4	P4
5	P5

MULTI STAGE PATH INDEXED ENERGY CONSERVING ROUTING

1. *Each node should advertise its location, residual energy* and current energy drain rate to its neighbors using a *hello packet*
2. Up on receiving such *hello packets*, each node should prepare its own routing table based on the distance
3. When a source wants to send data to the destination, it starts the route discovery process using *routereq* packet
4. When a node receives a *routereq* packet, if it is not the destination the same will be forwarded to the next hope
5. Once the destination receives a *routereq* packet, it will wait for the all other *routereq* packet to arrive
6. Once all *routereq* packets are arrived, destination will prepare *routereply* packet and will be send in reverse paths
7. Once a node receives the *routereply* packet, if it is not the source the node will add its residual energy and its drain rate and will be forwarded in the reverse path
8. Once the source has all *routereply* packets, it starts indexing the paths based on Weakest node energy, Path residual energy, Distance, Energy required to transfer

IV. SIMULATION RESULTS

A. Simulation Parameters

MSPIEC routing protocol is simulated in NS2. The performance of the protocol is analyzed using the following parameters

Table- XVI: Simulation Parameters

Sl. No	Parameter	Property
1	Area	$870m^2$
2	Nodes	70
3	Node Speed	20 m/s
4	Simulation Time	500 sec
5	Traffic Type	CBR
6	Packet size	512bytes
7	Transmission power	1.4W
8	Reception Power	1W
9	Source Nodes	7,30,45
10	Traffic start time	12s
11	Traffic end time	500s
12	Mobility	Random

Based on the trace data, the analysis is conducted and the results are compared with other existing protocols based on the following parameters

1. Packet Delivery Ratio

2. Normalized Control overhead
3. Average Energy Consumption [5][14]
4. Average Node Residual Energy

B. Simulation Results

The performance of MSPIEC routing protocol is compared with other energy aware routing protocols like LAER, PERRA, EGPSR [15] in various aspects. Node mobility, packet delivery ratio, normalized control overhead, energy consumption and drain rate are the main parameters used in the comparison.

Packet Delivery Ratio

Packet Delivery Ratio (PDR) is the ratio of number of packets received and number of packets sent. The PDR of protocols like LAER, PERRS, EGPSR and MSPIEC is compared on the basis of increasing node movement speed. The node speed 1m/s to 20m/s. The analysis shows that when the node displacement speed is minimum, the PDR is high and as the speed increases the PDR decreases. One of the main reason behind this low PDR is that as the speed increases, path breaks may happen frequently. The proposed method has giving best PDR in low speeds like other protocols. But along with the speed, the PDR tends to low, but still the method achieves as good as others.

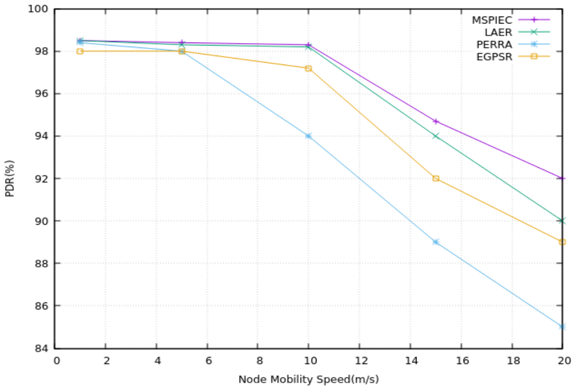

Fig 2. . Packet Delivery Ration Vs Node Speed

Normalized Control Overhead

Control overhead refers to how much control information has to be produced, exchanged and consumed by the nodes for route discovery and route maintenance and data exchange. Highly dynamic environment like MANET tend to have frequent path loss and network partition due to mobility and power outage. As the data transfer progress the over also increases. In our model node mobility is unpredictable and the focus is on energy optimization. The model tries to preserve energy and so the link stability. So the control overhead is much less than the existing algorithms like LAER, PERRA and EGPSR

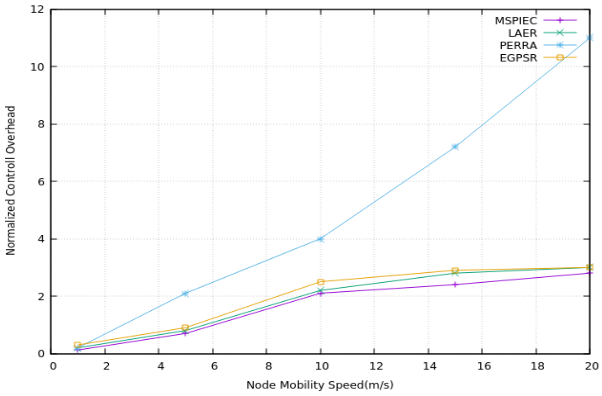

Fig 3. . Normalized Control Overhead Vs Node Speed

Average Energy Consumption Energy consumption is considered for the route discovery, route maintenance and data transfer. The average energy consumption of the proposed model is compared with LAER, PERRA and EGPSR algorithms and the analysis shows the MSPIEC routing protocol has minimal energy consumption. This is because of the path selection based on multi-level indexing strategy followed. As the route discovery process is in progress, various identified paths are classified and indexed based on energy and so major traffic flows through healthy paths and medium and minor traffic will be distributed over moderate and low energy paths. So the average energy consumption of the model stands low when compared with others.

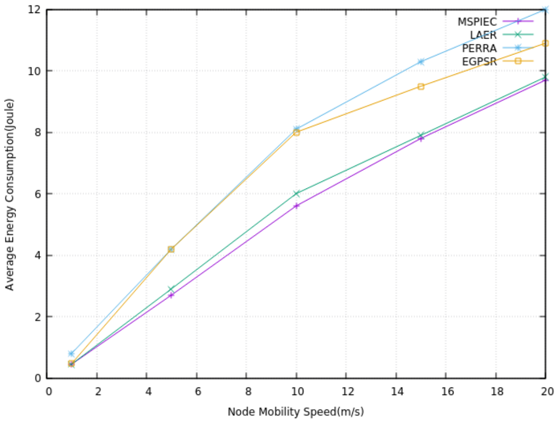

Fig. 4. Average Energy Consumption Vs Node Speed

Average Node Residual Energy

Residual energy represents the remaining energy in nodes. Residual energy of MANET would be high if the energy consumption is optimized and low, otherwise the node power will be depleted very fast. The average residual energy of the nodes is calculated and compared with LAER, PERRA and EGPSR algorithms and found that MSPIEC has the average node residual energy. Energy optimization in the proposed method is high because of the path selection strategy. When data traffic load is balanced and distributed among multiple paths based on energy health, the residual energy tends to be preserved and utilized optimally.

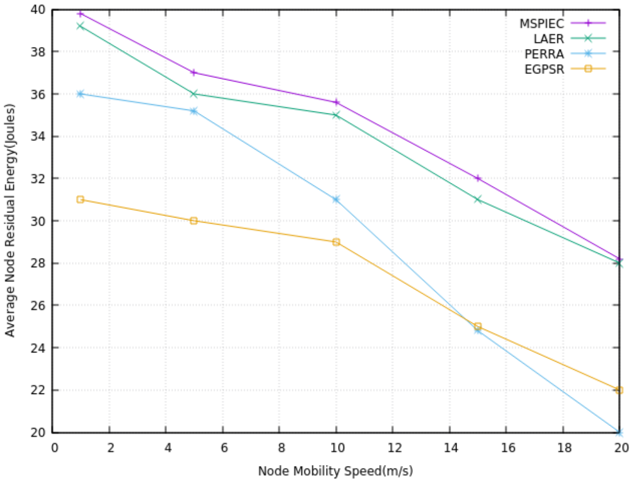

Fig. 5 Average Node Residual Energy Vs Node Speed

V. CONCLUSION

MANET in real world has many application domains and so the performance of the MANET is to be improved to solve many technical challenges in these domains. Most of the routing algorithms simply consider distance as a main metric for routing. This creates problems in establish stable paths. Few algorithms has gone before energy metric as a routing parameter and they have succeeded in performing routing thorough stable routing paths. But most of them have failed to distribute traffic based on path energy. Multi Stage Path Indexed Energy Conserving Routing algorithm uses a different approach were it applies an indexing on the identified paths based on weakest energy node in a path, Path residual energy, distance and Energy required to transfer the data. The above parameters are arranged in a priority order and paths are indexed to formulate a hierarchy. Based on the hierarchy rank quality and healthy paths are used to transfer maximum data and remaining paths will be assigned to carry moderate and minimal data. This approach has shown to have better energy consumption and residual energy preservation which will lead to less path breaks due to power depletion

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