International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 5 (2018) pp. 2490-2498
© Research India Publications. http://www.ripublication.com

Catching energy efficient stable nodes in Ad-Hoc Networks

[1]Kapila Vyas [2]Ajay Khunteta and [3]Amit Chaturvedi

[1]Poornima University, India.
[2]Poorninima University, India.
[3] Government Engineering College Ajmer, India.
[1] kapilapareek@yahoo.co.in;

Abstract

Mobile ad-hoc networks (MANETS) lack a fixed infrastructure and data transmission on constantly changing routes needs to be maintained efficiently with respect to successful delivery and delay. A major challenge to this is that the nodes constituting the links are not energy efficient or they die out. The major aim of this study is to quantify this energy efficiency of nodes. The major contributions of the paper is to (1) associate the energy efficiency of a node to its energy (2) suggests for the first time values for the threshold energy of nodes which would make them energy efficient under different conditions of varying (1) simulation time and (ii) number of nodes. Additionally the performance metrics like PDF, throughput, delay and average energy consumed for these values of threshold energy were measured using simulations on Network Simulator NS-2. The important results of the study indicated that (1) a link could be stable if the nodes used for creating it have sufficient threshold energy. (2) The value of threshold energy chosen depends on the desired performance metric viz. PDF, throughput, delay and average energy consumed. (3) Different values of threshold energy could be used for giving good performance under different conditions of (1) simulation time and (ii) number of nodes.

Keywords: MANETS, Mesh, Multicast, Threshold energy.

INTRODUCTION

Mobile Ad Hoc Networks (MANETs) are a popular area of research since they are most helpful in situations which are power deficient and cannot have a fixed infrastructure as in cases of natural and manmade disasters. Unicast and multicast routing techniques can be used to provide data transfer in MANETs (Garcia Garcia-Luna-Aceves et al., 1999; Viswanath et al., 2006; Vyas & Chaturvedi, 2014). Multicast routing can easily send multiple copies without using multiple routes and gives better performance than unicast (Luo et al.,2008; Biradar & Manvi, 2012a).Multicast routing can be further classified as mesh and tree based. Multicast mesh based routing creates alternate routes between source and destination, unlike a single route, created in a multicast tree. These alternate links in a mesh make it more robust, but do so using energy (Vaishampayan, & Garcia-Luna-Aceves, 2004; Astier &Aljahdali, 2000) and sometimes they do not even last long.

An important reason for the links to break is that the nodes constituting them lose energy and die out. The breakage of links effect the performance of network as (1) The packets transferred on these links are lost and need to be retransmitted(2) energy used for creating such links become wasted (3) nodes could have used this energy to maintain or create other stable links. This wastage of energy in creating links which untimely die out is critical in case of ad hoc networks. Authors (Jabbar et-al., 2016) presented a review of routing schemes in MANETs which suggested schemes to reduce the energy consumed when transmitting The present study is based on the theory of *"All or None*" that is a link should only be created if it would remain stable for an estimated time to provide a good data transfer in the network, otherwise a futile link should not be created.

The current paper is based on a previous work which introduced SLIMMER, Stable Links in Multicast Mesh for Energy Efficient Routing, (Vyas et al., 2016).SLIMMER is an energy efficient improvement of another state of art multicast mesh based protocol PUMA, Protocol for unified multicasting through announcements (Vaishampayan, & Garcia-Luna-Aceves, 2004). In case of SLIMMER a node was included in a mesh only if it had energy more than a predefined threshold. SLIMMER was compared to PUMA and the results showed that SLIMMER gave a much better performance and also consumed much lower energy.

This paper builds on the work and quantifies energy efficiency of nodes. It suggests values for threshold energy of nodes which when applied to SLIMMER, give good performance under different conditions. The threshold energy can be used to improve performance under two criteria (1) first as per the conditions of scenario like number of nodes and simulation time and (2) secondly on the requirements of the protocol which depend on the desired outcome for e.g. whether PDF is to be maximum or energy consumed is to be the least.

This reduces the inconvenience of using different protocols to get good results in different conditions; as the same protocol, with only changed threshold energy value for nodes, get good results even when condition and requirements vary.

Related work was done in Route Stability and Energy Aware Routing (RSEA-AODV) (Srinivasan et al., 2013) where link stability is a measure of residual energy of the nodes. Ring Mesh Based Multicast Routing Scheme in MANET using Bandwidth Delay Product (RMRBD) (Biradar & Manvi, 2012 b) used remaining battery power with mobility, and differential signal strength of the nodes to create reliable pair

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 5 (2018) pp. 2490-2498
© Research India Publications. http://www.ripublication.com

of nodes. The threshold energy was applied as a decision parameter for nodes in energy efficient AODV (EN-AODV) (Sridhar et al., 2013). Residual Energy based Reliable Multicast Routing Protocol (RERMR) used the concept of residual energy (RE) to provide maximum network lifetime and packet delivery (Gopinath & Nagarajan, 2015). Researchers (Walikar & Biradar , 2016)(Sruthi &Umamakeswari, 2017) designed an energy model to calculate residual energy of a node which was used as a decisive factor for node selection. Similar work was carried out by (Yadav et-al., 2017) who calculated the cost function on the basis of delay, bandwidth and residual energy for node selection.

The remainder of the paper is organized as follows: the next section discusses the basic principle used in SLIMMER and reiterates its findings in brief. Results and discussions to compare performance of different values of threshold energy in SLIMMER under varying (i) simulation time and (ii) number of nodes are given in section 3. Section 4 presents conclusions which highlight important findings of the paper by giving best values of threshold energy in different conditions. Finally Section 5 proposes specific directions for future work.

SLIMMER

SLIMMER (Stable Links in Multicast Mesh for Energy Efficient Routing) is a receiver initiated multicast mesh based protocol; wherein the mesh will only be constituted with nodes having energy greater than threshold energy. The threshold energy is given as a percentage of initial energy of the node.

The salient characteristics of SLIMMER are:

a) Maintains routing table at each node
b) Discovers efficient route by:
- creating announcements at each node
- Selecting candidate nodes out of nodes closest to the core, depending on criteria of threshold energy.
- creating efficient links through selection of candidate nodes
- creating stable energy efficient paths using efficient links

c) Creates mesh of stable energy-efficient paths between nodes.

SLIMMER can be described in steps using an Illustrative network as given in figure 1:

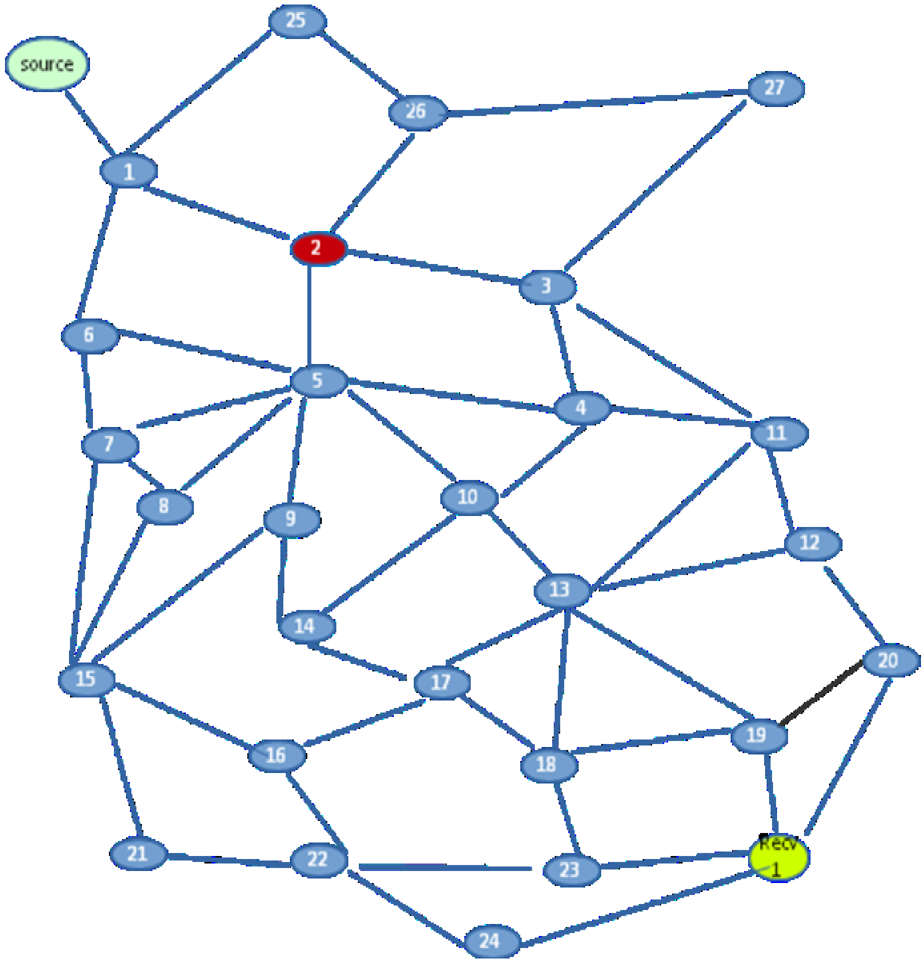

Figure 1. Network model

In the given network, it is assumed that –

(1) the nodes are moving within the transmission range

(2) all packets are of equal size, and

(3) all wireless nodes come with energy detection device

Step1. Whenever a receiver node wants to join a mesh, it checks if it has received an announcement.

Step2. If it has then it updates its routing table and broadcasts the announcement to its neighbors.

Step3. If no announcement has been received, it becomes the core and starts sending core announcement, according to condition in *step 5*.

Step4. All the nodes with distance shortest from the core become the members of set of probable candidate nodes PN. For each member of PN, its energy E decides if the node would become a candidate.

Step5. The nodes with energy $E > E_{thresh}$ become candidates and receive announcement from sender node, all other nodes get rejected. For e.g. in *figure 1*, node *2* becomes the core. *1, 3, 5* and *26* are one hop neighbours of *2*. All these are included in PN and could become candidates if they fulfill the essential requirement of energy.

The protocol uses the concept of energy E of the node which is given by *equation 1*.

$$E = E_{init} - E_{cons} \quad (1)$$

Where E_{init} is the initial energy of the node and E_{cons} is the energy consumed.

A node consumes energy for (i) receiving packets and (ii) transmitting packets. Thus energy consumed E_{cons} is the cumulative energy consumed by the node during transmission and receipt of packets, and can be calculated as:

$$E_{cons} = nrec\ E_{rec} + ntrans\ E_{trans} \quad (2)$$

where E_{rec} = energy consumed by a node in receiving one packet,

nrec = no. of packets received

E_{trans}= energy consumed by a node in transmitting one packet,

ntrans = no. of packets transmitted

Table 1: Selection candidate nodes

nodes in PN	Is $E > E_{thresh}$	Result
1	yes	**Node 1 selected as a candidate node**
3	no	Set the status as sleep mode
5	yes	**Node 5 selected as a candidate node**
26	no	Set the status as sleep mode

After *step 5*, nodes *1* and *5* in the *figure 1* are selected as candidate nodes as per *table 1*.

Step6. This criterion for selecting nodes would continue for the entire network and would create a mesh of stable energy-efficient paths between nodes.

The flowchart for SLIMMER is given as figure 2.

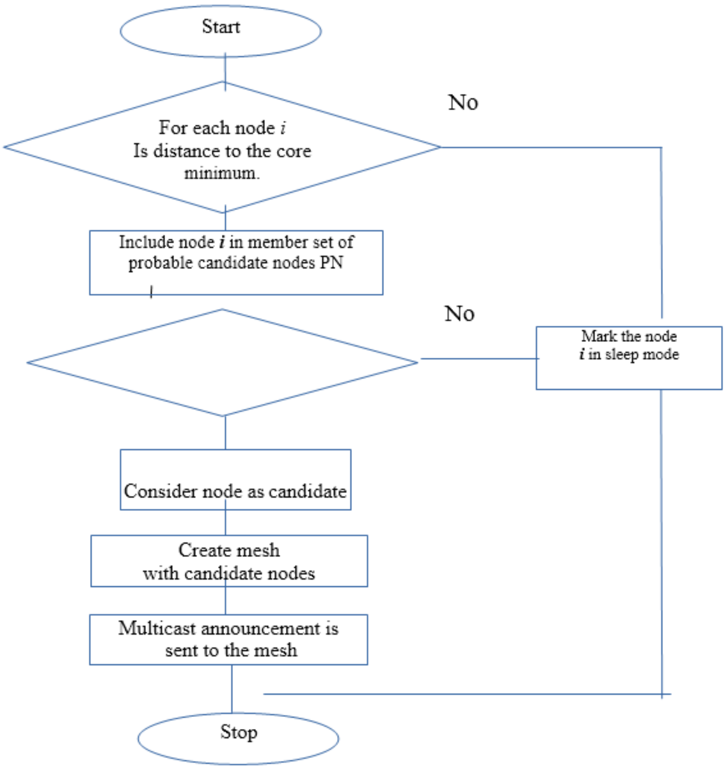

Figure 2. Flowchart for SLIMMER, as reproduced from (Vyas et al., 2016)

RESULTS AND DISCUSSIONS

Simulations were performed on Ns2.35 to suggest an optimum threshold value of nodes under different conditions of (1) simulation time and (ii) number of nodes.

Additionally different values of threshold energy (10% to 50% of initial energy) were compared for performance metrics like PDF, throughput, delay and average energy consumed, to find an optimum value as per each metric.

System details: Ubuntu 14.04 (LTS) 64 bit 2.20 GHz processor with 4 GB RAM

Case 1: Comparison of Performance in SLIMMER for different threshold values with variation in simulation time. Simulation Scenario is given in *table 2*.

Table 2. Simulation scenario for SLIMMER for different E_{thresh} with increasing time

Simulator	NS2.35
Total Nodes	100
Initial energy	10J
Threshold energy **(E_{thresh})**	10%,20%,30%,40% and 50% of E_{init}
Simulation Time	100,150,200,250,300,350,400,450,500 (s)
Simulation Area	1000 m x 1000 m
Pause Time	0
Mobility Model	TwoRayGround
Mobility	0 (m/s)

a. Results: The results obtained for various parameters PDF, throughput, delay and average energy consumed are as given by *figures 3-6.*

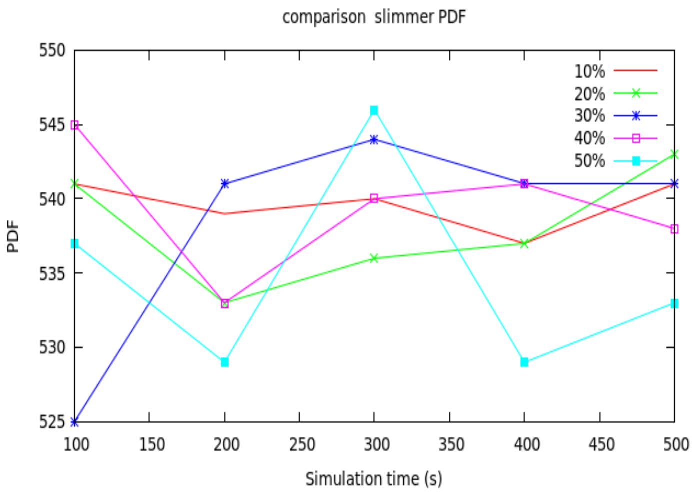

Figure 3: PDF for different E_{thresh} in SLIMMER with increasing time

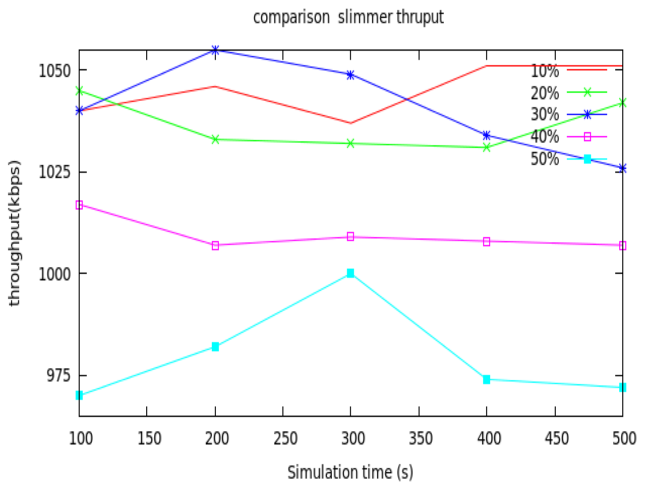

Figure 4: throughput for different E_{thresh} in SLIMMER with increasing time

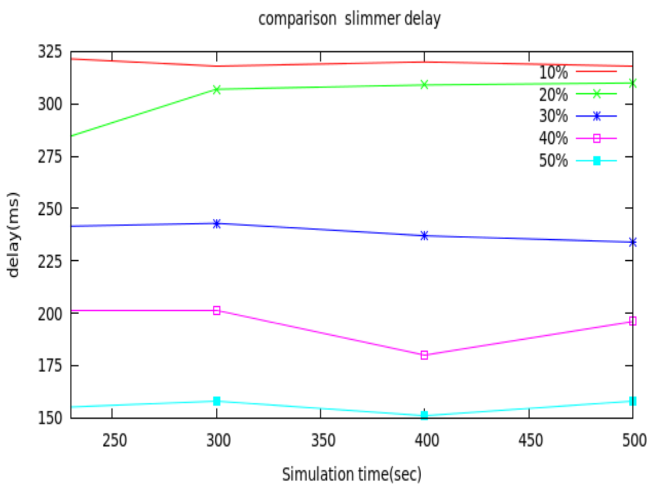

Figure 5: delay for different E_{thresh} in SLIMMER with increasing simulation time

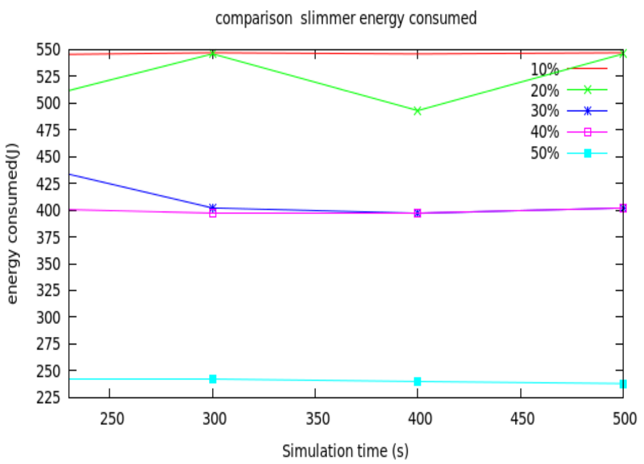

Figure 6: avg. energy consumed for different E_{thresh} in SLIMMER with increasing time

b. Best Values for E_{thresh} for 100 nodes with increasing simulation time is given in table 3.

Table 3: Best values of each performance metric for different Ethresh value with increasing simulation time (no. of nodes=100)

Metric	**Simulation Time (sec)**	**Best Value at E_{thresh}**	**Second best value at E_{thresh}**	**Observation and Discussion**
PDF	0-200	No clear outcome both 10% and 20% good		At 30% PDF increases with time and shows irregular rise at 50%. With time PDF increases between 250 to 300 then start to decrease for sometime but then starts gaining. **Reason**: Initially nodes lose energy so links break but new links are created and network stabilizes.
	200-300	30%	10%	
	300-400	30%	40%	
	>400	20%	30%	
Throughput	0-350	30%	10%	Throughput increases as E_{thresh} decreases E_{thresh} of 30% gives good throughput. It decreases for some time at around 300 but regains. **Reason:** Throughput depends only on number of packets received successfully and not on the lost packets so it increases. It is not as much affected as PDF with increase in time. However with increase in time nodes lose energy so fewer nodes with energy satisfying the higher threshold values available so less throughput for higher threshold values.
	>350	10%	20%	
Delay	0-500	10%	20%	Delay increases as E_{thresh} decreases. Not much effect of increase in simulation time. **Reason**: Delay depends only on nodes reaching successfully.
Avg. energy	0-500	50%	30 % or 40%	Avg. energy consumed is least for E_{thresh} 50% No effect of increase in simulation time.High E_{thresh} less avg, energy consumed. After 300 s E_{thresh} of 30% and 40% consume same energy. **Reason**: The energy consumed is less when threshold value is high as fewer nodes would be available satisfying this higher threshold value.

Case 2: Comparison of Performance in SLIMMER for different threshold values with increase in number of nodes. Simulation Scenario is given in table 4.

Table 4. Simulation scenario for SLIMMER for different E_{thresh} with increasing no. of nodes

Simulator	NS2.35
Total Nodes	100,150.200,250,300,350,400,450,500
Simulation Time	100 (s)
Threshold energy(**E_{thresh}**)	10%,20%,30%,40% and 50% of E_{init}
Initial energy	10J
Simulation Area	1000 m x 1000 m

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 5 (2018) pp. 2490-2498
© Research India Publications. http://www.ripublication.com

a. Results

The results obtained for various parameters PDF, throughput, delay and average energy consumed for case 2 were as given by *figures 7-10*:

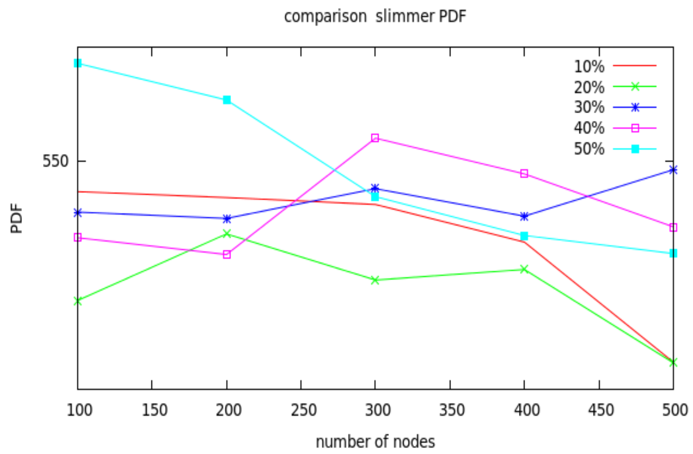

Figure 7: PDF for different E_{thresh} in SLIMMER with increasing no. of nodes

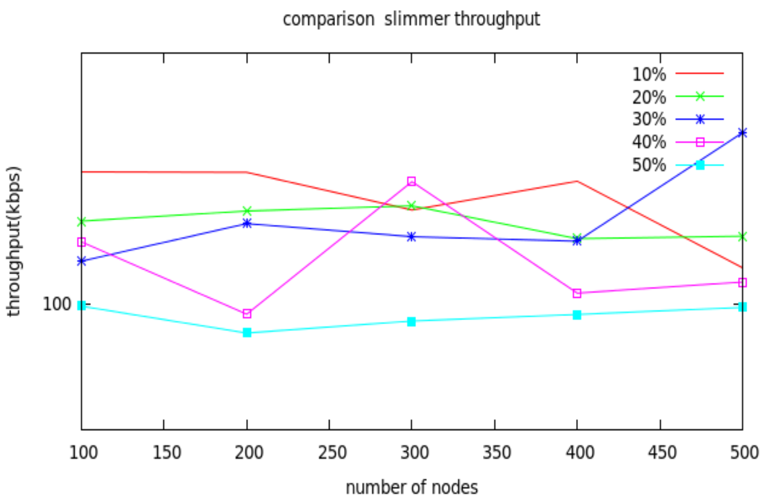

Figure 8: throughput for different E_{thresh} in SLIMMER with increasing number of nodes

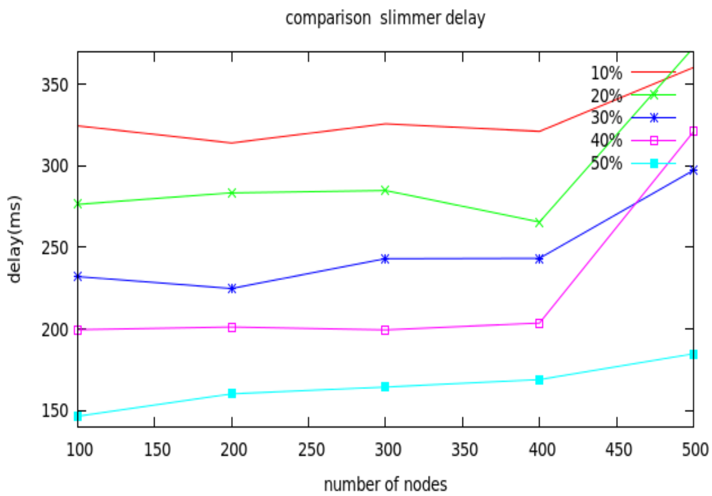

Figure 9: delay for different E_{thresh} in SLIMMER with increasing number of nodes

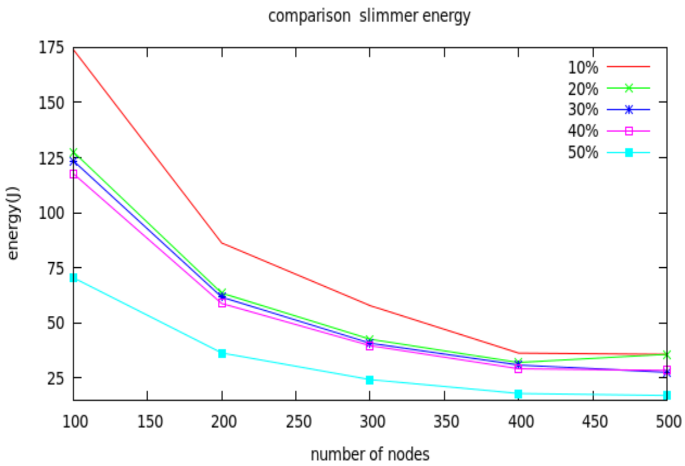

Figure 10:avg.energy consumed for different E_{thresh} in SLIMMER with increasing no. of nodes

b. Values for $\mathbf{E_{thresh}}$ for 100s with increasing number of nodes are given in table 5.

Table 5: Best value of each performance metric for different E_{thresh} value with increasing number of nodes (time=100s)

Metric	No. of nodes	Best Value at E_{thresh}	Second best value at E_{thresh}	Observation and Discussion
PDF	0-250	50%	No clear outcome	• PDF decreases with increase in number of nodes. • For 300 nodes, good PDF for $\mathbf{E_{thresh}}$ of 10%, 30% and 40% • When number of nodes become more than 400 Ethresh 30% becomes best. • **Reason:** Initially all nodes have good energy so quite a number of nodes are available with high threshold energy. As number of nodes increase further traffic increases packets are lost.
	300-450	40%	30%	
	> 450	30%	40%	
Through-put	0-250	10%	20%	• Throughput is highest at 300 nodes like PDF and decrease on either side. • Throughput behaves like PDF. • **Reason**: As number of nodes further traffic hinders successful receival of packets
	300	40%	No clear outcome	
	300-400	10%	20%	
	>400	30%	No clear outcome	
Delay	0-400	50%	40%	• Number of nodes > 400 delay increases in all cases. • **reason** : congestion increases
	> 450	50%	30%	
Avg. energy	0-400	50%	40%	• Avg. energy consumed is least for $\mathbf{E_{thresh}}$ 50% and decreases as number of nodes increases. • **reason**: The energy consumed is less when threshold value is high as fewer nodes would be available satisfying this higher threshold value Average energy consumed decreases with increase in total number of nodes as the average decreases..
	>400	50%	No clear outcome	

The results can be summarized for both the parameters of varying simulation time and number of nodes in table 6.

Table 6: Best Value for E_{thresh} values with change in conditions of (1) increasing simulation time and (2) Increasing number of nodes

E_{thresh}	**Number of nodes 100 Simulation time: 100 to 500s.**	**Simulation time 100s Number of nodes: 100 to 500.**	**Discussion**
10 %	• best delay • for good PDF: time should be 200 to 300 s • for good throughput : time > 350 s	• For good PDF and throughput no. of nodes should be nodes 300-450	When E_{thresh} is 10% small number of nodes and shorter intervals As the number of nodes increases to > 400 performance degrades as traffic increases. As time increases difficult for nodes with small E_{thresh} to maintain links.
20%	• For good PDF and throughput: time should be 200 to 300 • Gives good values of delay	• When number of nodes 100 to 400 gives good throughput	E_{thresh} of 20% follows the same pattern as E_{thresh} of 10%
30%	• Simulation time 200 to 400: best PDF • For a time upto 350s good PDF and throughput	• Best throughput when number of nodes is > 400, • no. of nodes upto 450 gives best PDF	E_{thresh} of 30% gives best results when number of nodes is around 450 and simulation time is also around 400. It gives optimized results for network conditions as node have enough energy and the traffic conditions are also good.
40%	• Fair PDF when simulation time is 300 to 400sec for fair energy consumed	• Good PDF when number of nodes is >300 to 450. • Best throughput when number of nodes is 300 • Good delay if no. of nodes < 400 for fair average energy consumed	E_{thresh} of 40% give good result when number of nodes and simulation time is moderate
50%	• Best PDF when simulation time is 300. • Best average energy consumed for all simulation times	• Best PDF for nodes when number is 100 to 200. • Best delay for almost all number of nodes • not much difference in avg. energy consumed either with time or with number of nodes	• E_{thresh} of 50% number give good results if we have smaller number of nodes to maintain average energy. • Gives best delay values as all nodes have enough energy to reach destination.

CONCLUSIONS

The most important achievement of any network is to provide stable links, which is more difficult in case of ad-hoc networks. The study concludes that a link could be stable if the nodes used for creating it have sufficient threshold energy. However no one value of threshold energy could suffice to all conditions and would depend on either (a) the desired performance metric viz. PDF, throughput, delay and average energy consumed or (b) different conditional parameters of scenario (i) simulation time and (ii) number of nodes. Another important conclusion of the study is that although energy efficient nodes give good performance with increasing time, however as the number of nodes increase, the traffic increases and the performance degrades for all metrics even for high energy nodes.

The energy efficiency of nodes effects PDF more than throughput and delay as unlike PDF, the latter two metrics depend only on successfully received packets.

The study for the first quantifies energy efficiency, as it gives values of E_{thresh} which could be chosen, on the basis of matrices given below:

1. Throughput

Number of nodes	**Simulation time**	**E_{thresh} to be used**
Small	small	10% or 20%
Small	more	50%
More	small	30% ,50% comparable
More	more	30%

2. PDF

Number of nodes	**Simulation time**	**E_{thresh} to be used**
Small	small	10% or 20%
Small	more	30%
More	small	10%, 20% 30% comparable
More	more	30%

3. Delay

Number of nodes	**Simulation time**	**E_{thresh} to be used**
small	small	50%
small	more	50%
more	small	50%
More	more	30% or 50%

4. Average energy consumed

Number of nodes	**Simulation time**	**E_{thresh} to be used**
small	small	50%
small	more	50%
more	small	50%
More	more	30%

FUTURE WORK

Stable links in ad-hoc networks need energy efficient nodes. The energy efficiency of the nodes could be ascertained if their energy lies above a threshold value. The study suggests the value of threshold energy for different values of (1) number of nodes and (2) simulation time. The authors plan to compare the performance of **E_{thresh}** values for other parameters of network like packet size, mobility and pause time etc as a part of the future work.

REFERENCES

[1] Garcia-Luna-Aceves, J. J., & Madruga, E. L.,1999, “A multicast routing protocol for ad-hoc network”, In Proceedings INFOCOM'99, Eighteenth Annual Joint Conference of the IEEE Computer and Communications Societies, IEEE Vol. 2, 784-792.

[2] Viswanath, K., Obraczka, K., & Tsudik, G. ,2006, “Exploring mesh and tree-based multicast Routing protocols for MANETs”, IEEE Transactions on mobile computing, 5(2006), 28-42.

[3] Vyas, K., & Chaturvedi, A.,2014,”Comparative analysis of routing protocols in MANETS”, In Signal Propagation and Computer Technology (ICSPCT), 2014 International Conference on (pp. 692-697), IEEE.

[4] Luo, J., Liu,X., & Danxia, Y.,2008, “Research on multicast routing protocols for mobile ad-hoc networks”, Computer Networks, 52.5 (2008), 988-997.

[5] Biradar, R., & Manvi, S. ,2012, “Review of multicast routing mechanisms in mobile ad hoc networks, Journal of Network and Computer Applications”, 35(1), 221-239.

[6] Vaishampayan, R.,& Garcia-Luna-Aceves, J.J.,2004, “Protocol for unified multicasting through announcements (PUMA)”, Proceedings of the 1st IEEE international conference on mobile ad-hoc and sensor systems (MASS).

[7] Astier, E., & Aljahdali, S. ,2000, “An efficient mesh based multicast routing protocol in mobile ad hoc networks” ,Wireless Communications and Mobile Computing”, 822-36.

[8] Jabbar, W. A., Ismail, M., Nordin, R., & Arif, S.,2016, “Power-efficient routing schemes for MANETs: a survey and open issues”, Wireless Networks, 1-36.

[9] Vyas, K., Khunteta, A., & Chaturvedi, A.2016, “SLIMMER: Stable Links in Multicast Mesh for Energy Efficient Routing”,In Recent Advances and Innovations in Engineering (ICRAIE), 2016 International Conference on (pp. 1-5),IEEE.

[10] Srinivasan , P. , Kamalakkannan ,P., & Shantharajah , S.P. ,2013, “Stability and energy aware multipath routing for mobile ad hoc networks”,International Journal of Computer Applications, 74(16).

[11] Biradar,R., & Manvi , S. ,2012, “Ring mesh based multicast routing scheme in MANET using bandwidth delay product”, Wireless Personal Communications, 66.1, 117-146.

[12] Sridhar, S., Baskaran, R., &Chandrasekar, P. ,2013, “Energy supported AODV (EN-AODV) for QoS routing in MANET”, Procedia-Social and Behavioral Sciences,73 (2013), 294-301.

[13] Gopinath, S.,& Nagarajan, N. ,2015, “Energy based reliable multicast routing protocol for packet forwarding in MANET”, Journal of applied research and technology,13.3, (2015), 374-381.

[14] Walikar, G. A., & Biradar, R. C. ,2016, “Reliable and energy efficient hybrid multicast routing in Mobile Ad Hoc Networks”, In Signal Processing, Communication, Power and Embedded System (SCOPES), 2016 International Conference on (pp. 1077-1083), IEEE.

[15] Sruthi, K. and Umamakeswari, A., 2014, “A study on metrics based Clustering algorithms in Wirelesss Sensor Networks”,International Journal of Advances in Engineering Research (IJAER),7(4).

[16] Yadav, A. K., Das, S. K., & Tripathi, S. ,2017, “EFMMRP: Design of efficient fuzzy based multi-constraint multicast routing protocol for wireless ad-