Research Journal of Applied Sciences, Engineering and Technology 8(21): 2179-2186, 2014
DOI:10.19026/rjaset.8.1217
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: August 22, 2014 Accepted: September 24, 2014 Published: December 05, 2014

Research Article

Link-stability and Energy Aware Multipath Routing in MANET

R. Hemalatha and R.S. Bhuvaneswaran
RCC, Anna University, Chennai, India

Abstract: Energy conservation is important for mobile ad hoc networks where devices are expected to work for longer periods of time without the need for charging their batteries. Therefore there is a need of an intelligent routing protocol that can minimize overhead and ensure the use of minimum energy routes. In Progressive Energy Efficient Routing, energy efficient shortest paths are selected with minimum energy consumption. Here due to the single path routing, there occur end-to-end delay, routing overhead and packet loss. Therefore to overcome these issues, PEER can be extended for multipath routing. Link-stability metrics and energy aware metrics can be applied for path selection. By this method, stable links are selected. In this study, energy efficient routing is done with maximum life time. The proposed Link-Stability and Energy Aware Multipath Routing gives good performance results in terms of packet delivery ratio, packet drop, energy consumption and delay compared with Progressive Energy Efficient Routing.

Keywords: Energy aware, link-stability, mobile ad hoc network, multipath routing

INTRODUCTION

MANET: A Mobile Ad hoc Network (MANET) is defined by the MANET Working Group as "an autonomous system of mobile routers (and associated hosts) connected by wireless links-the union of which forms an arbitrary graph". MANET is a wireless network that is having no fixed infrastructure. It consists of a set of mobile devices that can communicate to each other without having cabled network. They are made up of nodes that are self contained and having ability to connect to nearby wireless node and configure them without having dependency on any pre-defined network infrastructure. There are many real world applications that use Mobile Ad Hoc Networks. Some of them include battlefield applications, rescue work applications, civilian applications like outdoor meeting, money transfers and ad-hoc classrooms.

All nodes in a MANET basically function as mobile routers participating in some routing protocol required for deciding and maintaining the routes. Since MANETs are infrastructure-less, self-organizing, rapidly deployable wireless networks, they are highly suitable for applications involving special outdoor events, communications in regions with no wireless infrastructure, emergencies and natural disasters and military operations.

Routing in MANET: Routing is one of the key issues in MANETs due to their highly dynamic and distributed nature. Because of the antenna's limited transmission range, the nodes in the network may act as a router to forward packets to other nodes and then a routing protocol is needed for this process. Each node in the ad hoc network forwards packets for other nodes, to allow nodes to communicate are those not in direct wireless transmission range. Each mobile node function as both a router and a terminal node which is a source or destination, thus the failure of some nodes operation can greatly hinder the performance of the network and also affect the basic ease of access to the network. Since the mobile nodes in MANET have limited battery power, so it is essential to proficiently use energy of every node in MANET.

Energy aware routing in MANET: Energy is an important resource that needs to be preserved in order to extend the lifetime of the network. Trying to optimize energy can lead to the selection of more fragile routes. To route a packet from a source to a destination involves a sufficient number of intermediate nodes. Battery power of a node is a precious resource that must be used efficiently in order to avoid early termination of a node or a network.

One distinguishing feature of Energy Efficient ad hoc routing protocol is its use of Power for each route entry. Efficient battery management, transmission power management and system power management are the major means of increasing the life of a node. These management schemes deal in the management of energy resources by controlling the early depletion of the battery, adjust the transmission power to decide the proper power level of a node and incorporate low

Corresponding Author: R. Hemalatha, RCC, Anna University, Chennai, India

power consumption strategies into the protocols. Typical metrics used to evaluate ad hoc routing protocols are shortest hop, shortest delay and locality stability. However, these metrics may have a negative effect in MANETs because they result in the over use of energy resources of a small set of nodes, decreasing nodes and network lifetime. The energy efficiency of a node is defined by the number of packets delivered by a node in a certain amount of energy.

In this study, we propose a Link-Stability Energy Aware Multipath Routing protocol and the performance metrics of a MANET were studied. Since mobile nodes are powered by battery, efficient utilization of battery energy is very important. Battery life, therefore, can also affect the overall network communication performance, when a node exhausts its available energy. For that reason, power aware is an important issue in Mobile ad hoc networks. However, the majority of the routing protocols use shortest path algorithms without any consideration of energy consumption, often resulting in rapid energy exhaustion for the small subset of nodes in the network that experience heavy traffic loads. Energy conservation is important for mobile ad-hoc networks where devices are expected to work for longer periods of time without the need for charging their batteries. Therefore there is a need of an intelligent routing protocol that can minimize overhead and ensure the use of minimum energy routes and a MAC protocol that is able to improve energy efficiency by minimizing congestions and reducing loss of packets.

LITERATURE REVIEW

Nema *et al*. (2012) have proposed an Energy based Ad-Hoc on-Demand Routing algorithm that balances energy among nodes so that a minimum energy level is maintained among nodes and the life of network is increased. They focused on increasing the extensive existence of node in the network. In our proposed study we set the minimum energy threshold limit of a mobile node, when a node reached up to the threshold limit the node goes to sleep mode, save energy and join in the event as long as possible. By this algorithm the overall MANET's efficiency is enhanced. However the network lifetime depends mostly in the network load.

De Rango *et al*. (2008) have presented a two novel mechanisms for the OLSR routing protocol, aiming to improve its energy performance in Mobile ah-hoc Networks. They propose a modification in the MPR selection mechanism of OLSR protocol, based on the Willingness concept, in order to prolong the network lifetime without losses of performance (in terms of throughput, end-to-end delay or overhead). Additionally, they prove that the exclusion of the energy consumption due to the overhearing can extend the lifetime of the nodes without compromising the OLSR functioning at all. However there is no efficiency in their life time.

Joshi and Joshi (2011) have proposed a protocol known as Variable Range Energy aware Location Aided Routing (ELAR1-VAR) protocol. The proposed scheme controls the transmission power of a node according to the distance between the nodes. It also includes energy information on route request packet and selects the energy efficient path to route data packets. ELAR1-VAR protocol improves the network lifetime by reducing energy consumption by 20% for dense and mobile network while maintaining the packet delivery ratio above 90%. However there is an impact in the packet rate variation.

Vijayan *et al*. (2013) have presented a solution for energy conservation by a cross layered approach. This can be achieved by applying congestion control algorithm for the MAC layer and then finding the maximum residual energy route in the network layer for packet transfer. To ensure an efficient cross layer interaction, issues related to efficient channel access, Quality-of-Service (QoS) support and congestion control are addressed with an energy efficient MAC protocol that adjusts with the enhancements in the performance of the network layer protocol. However when a node is in idle state i.e., when packet forwarding is not being performed or the node is waiting for an acknowledgement, the node consumes a lot of energy which can be eliminated.

Zhu and Wang (2011) have proposed an accurate analytical model to track the energy consumptions due to various factors and a simple energy-efficient routing scheme PEER to improve the performance during path discovery and in mobility scenarios. This PEER protocol can reduce up to 2/3 path discovery overhead and delay and 50% transmission energy consumption. However the energy consumption reduction is not effective.

Liu *et al*. (2009) have proposed a new multipath protocol called Multipath Routing protocol for Networks Lifetime Maximization in ad-hoc networks (MRNLM). The protocol sets energy threshold to optimize the forwarding mechanism. At the same time it builds an energy-cost function and uses the function as the criterion for multiple path selection. MRNLM is able to balance the energy of the networks with the lifetime increase at least 14% under different nodes pause time. For different packet rate, the lifetime increases no less than 35%.

Mikki (2009) have introduced an Energy Efficient Location Aided Routing (EELAR) Protocol for MANETs that is based on the Location Aided Routing (LAR). EELAR makes significant reduction in the energy consumption of the mobile nodes batteries by limiting the area of discovering a new route to a smaller zone. The EELAR protocol makes an improvement in control packet overhead and delivery ratio compared to AODV, LAR and DSR protocols. However the control overhead in the network is increased slightly as the node density of the network is increased.

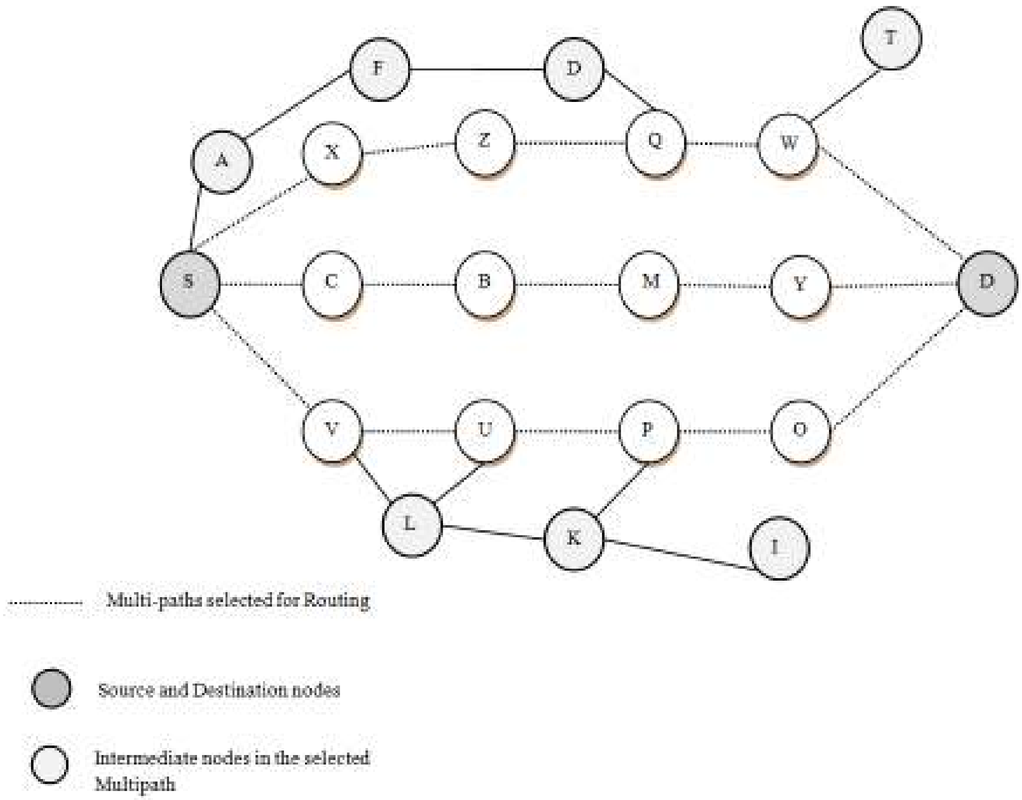

Fig. 1: LSEAMR protocol example

Sridhar *et al*. (2013) have proposed a distributed, scalable and energy-efficiency bee-inspired routing protocol for MANETs-BeeSensor. However, in contrast to typical ACO-based algorithms, BeeSensor utilizes simple heuristic functions and allows complex stochastic routing function at the source nodes only. The BeeSensor delivers superior performance in terms of packet delivery ratio and latency, but with the least energy consumption compared with other SI algorithms. The important reasons for this behavior of BeeSensor are: a simple routing agent model, agent-agent communication to discover optimal paths, fixed size of route discovery agents that not only saves significant amount of energy during their transmission but also makes the algorithm scale to large networks, distributed and decentralized control and self organization to make it resilient to external failures.

METHODOLOGY

LSEAMR protocol: LSEAMR protocol searches for the energy efficient path quickly during route discovery process and maintains the route actively. In LSEAMR protocol, initially energy efficient shortest paths are selected, then among the selected paths link-stability metrics and energy aware metrics is applied. By this the stable links are selected. On the whole our solution is provided with energy efficient routing together with maximum life time.

In this protocol, initially source sends RREQ packets to the neighboring nodes. It contain the three phases:

- Path discovery
- Energy aware metrics
- Link-stability metrics

Path discovery: In path discovery, multiple paths between source and destination were selected for data transmission. Consider the following figure.

In Fig. 1, S is the source and D is destination and when destination got the packet from source, it will send the RREP packets to the sender. When source got the RREP packet from destination, it will check for multiple paths.

In figure, three paths are available to send the data between source and destination, those are:

S→X→Z→Q→W→D
S→C→B→M→Y→D
S→V→U→P→O→D

Energy aware metrics and Link-stability metrics are applied to get better paths.

Energy aware metrics: In this method, for each path energy will calculated and the path which has high energy will be selected for routing.

The energy needed to transmit a packet p from node n_i is:

$$E_{tx}(p, n) = i.\ v.t_p \tag{1}$$

In Eq. (1), i is the current (in Ampere), v the voltage (in Volts), and t_p the time taken to transmit the packet p (in seconds). E_{tx} is the amount of energy spent to transmit the packets from node i to node j. The Minimum total Transmission Power Routing (MTPR) mechanism uses a simple energy metric, represented by the total energy consumed forward the information along the route. The battery cost function is:

$$BC_i(t) = \frac{1}{c_i(t)} \tag{2}$$

In Eq. (2), c_i (t) is the battery capacity of node n_i at time t. The less capacity a node has, the more reluctant it is to forward packets.

If only the summation of battery costs on a route is considered, a route containing nodes with little remaining battery capacity may still be selected. The Minimum Maximum Battery Cost Routing (MMBCR) defines the route cost as:

$$R(r_j) = \max_{\forall n_i \in rj}(BC_i(t)) \tag{3}$$

The desired route r_O is obtained so that:

$$R(r_o) = \max_{\forall r_j \in r_*}(R(r_j)) \tag{4}$$

where, r* is the set of all possible routes.

Power saving mechanisms based only on the remaining power cannot be used to establish the best route between source and destination nodes. If a node is willing to accept all route requests only because it currently has enough residual battery capacity, too much traffic load will be injected through that node. In this sense, the actual drain rate of power consumption of the node will tend to be high, resulting in an unfair sharp reduction of battery power. To address the above problem, the Minimum Drain Rate (MDR) mechanism can be utilized with a cost function that takes into account the Drain Rate index (DR) and the Residual Battery Power (RBP) to measure the energy dissipation rate in a given node. The cost function is calculated using the following equation:

$$BC_i(t) = \frac{RBP_i(t)}{DR_i(t)} \tag{5}$$

In the MDR mechanism, the ratio RBP_i (*t*) /DR_i (*t*) at node n_i, calculated at time t, indicates when the remaining battery of node n_i will be exhausted, i.e., how long node n_i can keep up with routing operations with current traffic conditions. Therefore, the maximum lifetime of a given path r_j is determined by the minimum value of BC_i (*t*) over the path. Finally, the MDR mechanism is based on selecting the route r_O, contained in the set of all possible routes between the source and the destination r_*, having the highest maximum lifetime value.

Since the drain rate is calculated at regular time intervals, its measure is affected by isolated consumption peaks (both positive and negative). To avoid the use of incorrect values of drain rate during these peaks, an α parameter can be introduced. This parameter makes the drain rate value between adjacent intervals smoother, acting in the following manner: after calculating the drain rate sample at interval t, $DR_{sample(i)}$, MDR uses a value of drain rate of:

$$DR_i = (1-\alpha).DR_{sample(i)} + \alpha.DR_{(i-1)} \tag{6}$$

The energy that is expected to be used in order to successfully send a packet across a given link is estimated by a cost function that comprises both a node-specific parameter (battery power B_i of node i) and a link-specific parameter (packet transmission energy $E_{i,\ j}$). The cost of the reliable communication across the link (between nodes i and j) is defined as:

$$C_{i,j} = \frac{B_i}{E_{i,j}} \tag{7}$$

The expected transmission energy is defined by the power needed to transmit a packet over the link between nodes i and j ($T_{i,j}$) and the link's packet error probability ($P_{i,j}$):

$$C_{i,j} = \frac{T_{i,j}}{(1 - P_{i,j})^L} \tag{8}$$

The main reason for adopting the above is that link characteristics can significantly affect energy consumption and can lead to excessive retransmissions of packets. The cost of choosing a particular link is defined as the maximum number of packets that can be transmitted by the transmitting node over that specific link. It is also assumed that there is complete absence of any other cross traffic at that node. The maximum lifetime of a given path is determined by the weakest intermediate node.

Link-stability metrics: Link Stability is not to predict exactly the residual link lifetime of each link, but to decide which of several links are stable, meaning they are most likely of all to stay available for some period of time. This metric does not depend on mobility model parameters such as mobile nodes speed, direction change frequency, pause time, etc. and, thus, it is absolutely general.

A link is considered to be established when two nodes have reached each other's transmission radius and it is considered broken when their distance exceeds the transmission radius.

By following the strategy outlined in De Rango *et al*. (2012), in the mathematical model, the expected residual lifetime $R_{i,j}(a_{i,j})$ of a link (i, j) of age a_{ij}, is determined from the following equation:

$$R_{i,j}(a_{i,j}) = \frac{\sum_{a=a_{i,j}}^{a_{max}} a * AL(a)}{\sum_{a=a_{i,j}}^{a_{max}} AL(a)} - a_{i,j} \quad \forall (i,j) \in A \tag{9}$$

In Eq. (9), AL is array of length a_{max+1} used to store the observed data and a_{max} represents the maximum observed age of the links. $a_{i,j}$ is the age of link and that is calculated using the following equation:

$$a_{i,j} = t_{fin} - t_{in} \tag{10}$$

The coefficient $R_{i,j}(a_{i,j})$ is defined as the ratio between the sum, on all links with age equal or greater than $a_{i,j}$, of the products of the age a and the number of links with age equal to a (that is AL (a)), over the total number of links with age greater or equal to $a_{i,j}$.

The main disadvantage of using the coefficient $R_{i,j}(a_{i,j})$ for path selection is related to the fact that it does not allow discrimination among links of the same age.

In order to overcome this drawback, the average traveled distance $AL^{avg}_{i,j}$ should be taken into account. The rationale is that if two links have the same residual lifetime, a shorter average distance is preferable to a longer distance in terms of link stability.

This adjustment surely affects the metric's ordering of the links. However, this issue is neglected here, since the number of ordering operations is associated with the interval time Δt and it does not affect the performance of routing protocols too much.

Indeed, the transmission and reception operations, associated with data and control packets, are more computational expensive in comparison with the operations associated with the links ordering. This is particularly true in the case of MANETs, for which the node density, defined as the number of neighbor nodes, is very limited even in the case of very high density networks.

For this reasons, this work does not take into account the number of reordering operations of links with different expected residual lifetimes:

$$n_{i,j} = \frac{AL^{avg}_{i,j}}{R_{i,j}(a_{i,j})K} \quad \forall (i,j) \in A \tag{11}$$

where, k is a scaling factor, defined in such a way that the link stability can be compared to the energy consumption.

The coefficient $n_{i,j}$ defined in Eq. (11) can be interpreted as a reciprocal measure of the stability. It has been defined in this way for the following reasons. First of all, it is assumed that the second objective function of the proposed mathematical model has to be minimized.

LSEAMR protocol process:

1. Start
2. Define P[i] = set of paths selected in path discovery
3. E[i] = set of paths selected in energy aware metrics
4. B[i] = Best paths selected for routing
5.
6. If (P[i]! = 0)
7. {
8. Select the each path in the P[i] list
9. Calculate energy using the energy aware metrics
10. Pick the paths which has highest energy
11. E[i] = selected paths
12. }
13. If (E[i]! = 0)
14. {
15. For each path calculate link stability using the link-stability metrics
16. Select the paths which has high link-stability
17. B[i] = best paths for routing
18. }
19. B[i] list send to the source to start routing
20. If the first path fails, then it immediately selects the second path in list
21. End

In the above algorithm, initially set of shortest paths are selected. For each path energy will be calculated separately using the energy aware metrics and the paths which have high energy will be selected. For each selected path calculate the link stability using the link-stability metrics and the paths which have high link-stability will be selected for routing. The source starts the routing with first path in the list and it that path fails it will move to second path.

Performance evaluation:

Simulation setting and parameters: The Network Simulator (2009) (NS2), is used to simulate the proposed architecture. In the simulation, the mobile nodes move in a 1000×1000 m region for 50 sec of simulation time. All nodes have the same transmission range of 250 m. The simulated traffic is Constant Bit Rate (CBR).

Table 1: Simulation parameters

No. of nodes	50, 75, 100 and 125
Area size	1000×1000
Mac	IEEE 802.11
Transmission range	250 m
Simulation time	50 sec
Traffic source	CBR
Packet size	512
Rate	50 kb
Speed	5, 10, 15, 20 and 25

The simulation settings and parameters are summarized in Table 1.

Performance metrics: The proposed Link Stability and Energy Aware Multipath Routing (LSEAMR) is compared with the PEER technique (Taneja and Kush, 2012). The performance is evaluated mainly, according to the following metrics.

Packet delivery ratio: It is the ratio between the number of packets received and the number of packets sent.

Packet drop: It refers the average number of packets dropped during the transmission.

Energy consumption: It is the amount of energy consumed by the nodes to transmit the data packets to the receiver.

Delay: It is the amount of time taken by the nodes to transmit the data packets.

RESULT ANALYSIS

Based on nodes: In our first experiment we vary the number of nodes as 50, 75, 100 and 125, respectively.

Figure 2 to 5 show the simulation results of LSEAMR and PEER protocols. From Fig. 2, 4 and 5 it is concluded that the LSEAMR protocol has 20, 12 and 15%, respectively less than PEER protocol in terms of delay, packet drop and energy consumption for different number of nodes, respectively. Figure 3 shows the delivery ratio results of LSEAMR and PEER protocols for different number of nodes. It is concluded that the delivery ratio of the proposed LSEAMR protocol has 32% higher than PEER protocol.

Based on speed: In our second experiment we vary the mobile speed as 5, 10, 15, 20 and 25 m/sec, respectively.

Figure 6 to 9 show the simulation results of LSEAMR and PEER protocols. From Figure 6 to 9, it is concluded that the LSEAMR protocol has 11, 9 and 11% less than PEER protocol in terms of delay, packet drop and energy consumption for different number of nodes, respectively. Figure 7 shows the delivery ratio results of LSEAMR and PEER protocols for different number of nodes. It is concluded that the delivery ratio

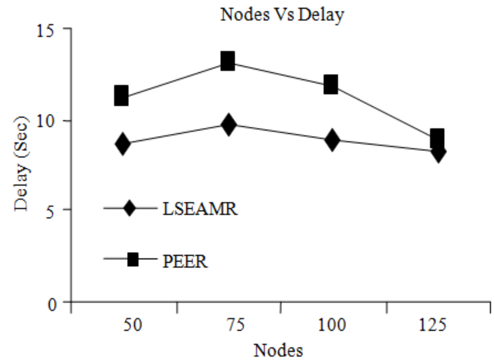

Fig. 2: Nodes vs. delay

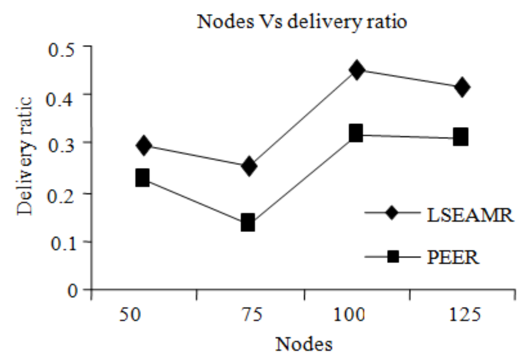

Fig. 3: Nodes vs. delivery ratio

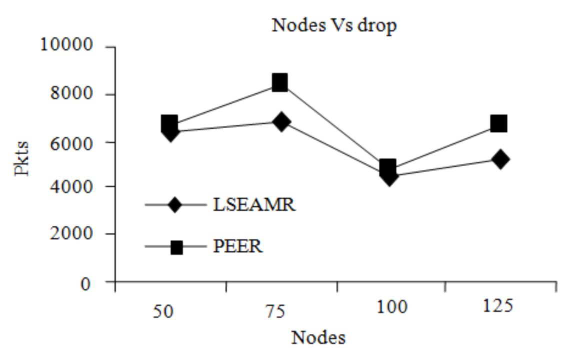

Fig. 4: Nodes vs. drop

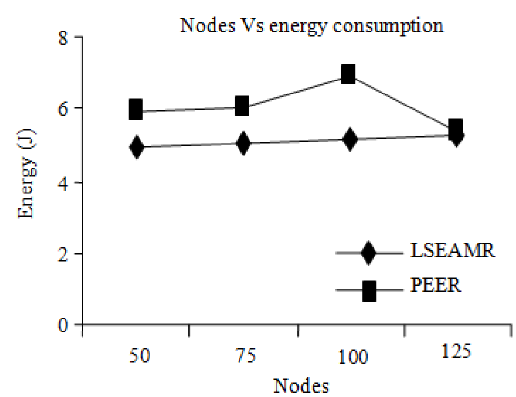

Fig. 5: Nodes vs. energy consumption

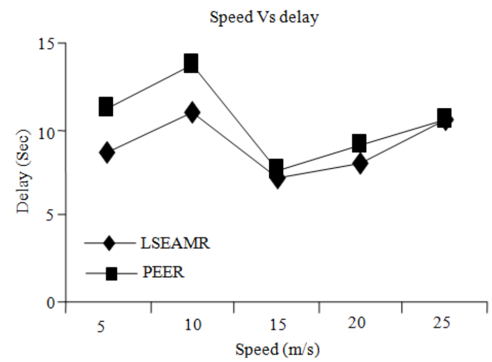

Fig. 6: Speed vs. delay

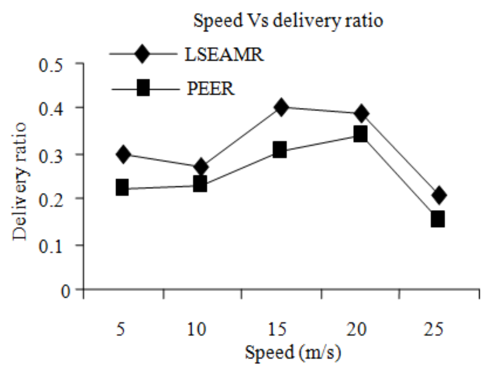

Fig. 7: Speed vs. delivery ratio

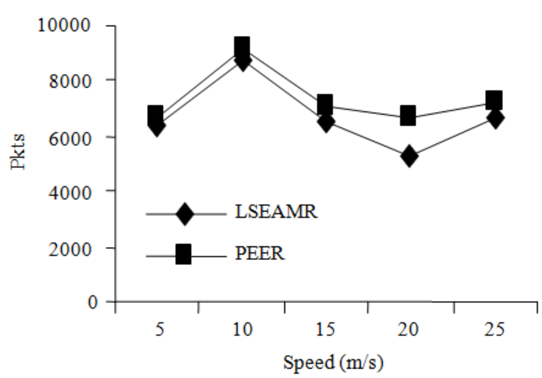

Fig. 8: Speed vs. drop

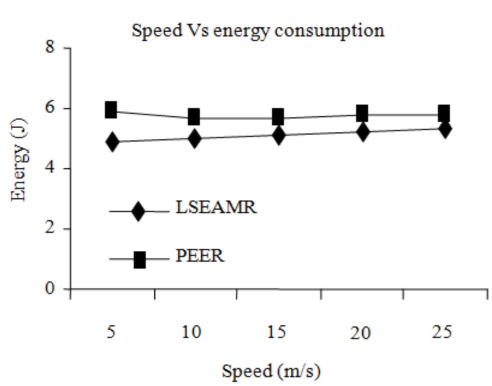

Fig. 9: Speed vs. energy consumption

of the proposed LSEAMR protocol has 20% higher than PEER protocol.

CONCLUSION

In this study, Link-Stability and Energy Aware Multi path Routing is proposed. The performance is evaluated based on Number nodes and Speed in terms of packet delivery ratio, packet drop, energy consumption and delay. Based on Number nodes, the LSEAMR protocol has 20, 12 and 15% less than PEER protocol in terms of delay, packet drop and energy consumption for different number of nodes respectively and delivery ratio of the proposed LSEAMR protocol has 32% higher than PEER protocol. Based on Speed, the LSEAMR protocol has 11, 9 and 11% less than PEER protocol in terms of delay, packet drop and energy consumption for different number of nodes respectively and the delivery ratio of the proposed LSEAMR protocol has 20% higher than PEER protocol. From the simulation results, it is concluded that the LSEAMR protocol yields good results compared with PEER protocol.

REFERENCES

De Rango, F., M. Fotino and S. Marano, 2008. EE-OLSR: Energy efficient OLSR routing protocol for mobile ad-hoc networks. Proceeding of IEEE Military Communications Conference (MILCOM, 2008), pp: 1-7.

De Rango, F., F. Guerriero and P. Fazio, 2012. Link-stability and energy aware routing protocol in distributed wireless networks. IEEE T. Parall. Distr., 23: 713-726.

Joshi, N.N. and R.D. Joshi, 2011. Variable range energy efficient location aided routing for MANET. Comput. Sci. Inform. Technol. (CS&IT), CCSEA-2011, 3: 321-333.

Liu, J., J. Chen and Y. Kuo, 2009. Multipath routing protocol for networks lifetime maximization in ad-hoc networks. Proceeding of 5th International Conference on Wireless Communications, Networking and Mobile Computing (WiCom'09), pp: 1-4.

Mikki, M.A., 2009. Energy efficient location aided routing protocol for wireless MANETs. Int. J. Comput. Sci. Inform. Secur., 4(1-2).

Nema, T., A. Waoo, P.S. Patheja and S. Sharma, 2012. Energy efficient adaptive routing algorithm in MANET with sleep mode. Int. J. Adv. Comput. Res., 2: 431-435.

Network Simulator, 2009. Retrieved form: http:///www.isi.edu/nsnam/ns.

Sridhar, H.S., M. Siddappa and G.C. Bhanu Prakash, 2013. Power aware routing protocol for MANET's using swarm intelligence. Int. J. Adv. Res. Comput. Commun. Eng., 2(8).

Taneja, S. and A. Kush, 2012. Energy efficient, secure and stable routing protocol for MANET. Global J. Comput. Sci. Technol., 12: 24-38.

Vijayan, R., V. Mareeswari and V. Samyukta, 2013. Enhancing Energy Efficiency of Routing Protocol through Cross Layer Interactions in MANET. Int. J. Eng. Technol., 5: 1147-1152.

Zhu, J. and X. Wang, 2011. Model and protocol for energy-efficient routing over mobile ad hoc networks. IEEE T. Mobile Comput., 10: 1546-1557.