International Journal of Emerging Science and Engineering (IJESE)
ISSN: 2319–6378, Volume-1 Issue-3, January 2013

Implementation and Evaluation of GPSR and M-LAER in mobile WiMAX Networks

M. Deva Priya, M.L Valarmathi, M. Deepa, K. Jaya Bharathi

Abstract - An appropriate routing protocol is mandatory for scalable wireless networks. Various routing protocols have been proposed in the literature for mobile WiMAX networks. The reliability of a path depends on the stability of the links constituting the path. A long lasting path is desirable. Energy is an important factor that should be taken into consideration as nodes are energy contingent. In this paper, the behavior of GPSR and Modified Link-StAbility and Energy aware Routing (M-LAER) are analyzed for WiMAX environment.

Index Terms - GPSR, WiMAX, LAER, Routing, Energy, M-LAER.

I. INTRODUCTION

In wireless communications, the analysis of energy efficiency and reliable packet transmission has attracted much interest. A wireless node can transmit and receive a finite number of bits before the battery runs out. In wireless networks, operation at all levels of the communication protocol stack has an impact on the energy consumption and therefore, energy efficiency has to be addressed in device, physical, link, and network layers jointly.

In the networking literature, minimum-energy routing algorithms, which select paths with minimum total transmission power over all the nodes, were developed. If the links are assumed to be error-free, there is no need for retransmission; energy-efficient routing algorithms choose the minimum-hop paths [1].

This work deals with designing a stable, bandwidth-aware, energy-efficient, SNR-based routing protocol for WiMAX networks.

The IEEE 802.16 standard, Air Interface for Fixed Broadband Wireless Access Systems, has been ratified by IEEE as a Wireless Metropolitan Area Network (WMAN) technology. This technology aims at providing broadband wireless last-mile access in a Metropolitan Area Network (MAN), with performance comparable to traditional cable [2][3]. IEEE 802.16 [4][5][6], one of the major competing mesh technologies for Metropolitan Area Networks has attracted significant interests recently. IEEE 802.16 can operate in either a cellular-like PMP (Point-to-Multipoint) mode or a Mesh mode.

While 802.16 has a transmission range of few kilometers, it also supports Quality of Service (QoS) by providing various service classes and by having high bandwidth. The service classes in 802.16 have been carefully designed to support real time applications like voice, video and non-real time application like large file transfer. 802.16 based systems are becoming increasingly more feasible because of the ease of deployment in remote areas where wire line connectivity would be prohibitively expensive. Different kinds of traffic supported by 802.16 networks are as follows (1) Unsolicited Grant Service (2) Real-time Polling Service (3) Non-Real-time Polling Service and (4) Best Effort Service.

II. ROUTING - GENERAL IDEA

There are many routing algorithms available in literature. The sections that follow discuss the various algorithms existing for routing in wireless networks. Finally, a novel path stability based algorithm is proposed for WiMAX networks.

A. Shortest Path Algorithm

Besides minimizing latency, the shortest path routing is good for overall energy efficiency in a static network because the energy needed to transmit a packet is correlated to the path length. However, the algorithms that aims at minimizing the path length may ignore "fairness" in routing - for example, the shortest path routing is likely to use the path with less number of hops to relay packets for a source and destination pair. This will heavily load the nodes on the path even when there are other feasible paths. Such an uneven use of the nodes may cause some nodes to die much earlier, thus creating holes in the network, or worse, disconnecting the network.

Routing based on shortest path is not suitable for a mobile (WiMAX) network, as the path changes dynamically. Unbalanced use of nodes may discourage the nodes from participating in routing. Since the biggest energy drain comes from the transmission of packets, energy consumption of a node can be measured by the total size of packets relayed by the node.

B. Load-balanced routing

Load-balanced routing is to minimize the maximum load on the nodes in a network. The ideal algorithm would be to minimize both, the latency and the maximum load simultaneously. However, these two goals are conflicting to an extent. The shortest path routing restricts the resources that can be used, while load balanced routing aims at using all the available resources to yield a uniform load.

Manuscript received on January 2013

M. Deva Priya, Assistant Professor, Department of CSE, Sri Krishna College of Technology, Coimbatore, Tami Nadu, India.

Dr.M.L Valarmathi, Associate Professor, Department of CSE, Government College of Technology, Coimbatore, Tamil Nadu, India.

M. Deepa and K. Jaya Bharathi, PG Scholars, Department of CSE, Sri Krishna College of Technology, Coimbatore, Tami Nadu, India.

One can easily construct an example to show that these two goals are indeed conflicting, i.e. the shortest path routing algorithm necessarily creates heavily loaded nodes and the optimum load-balancing algorithm necessarily uses long paths [10].

C. Need of the hour - Energy Conservation

Traditional routing protocols do not take into account the limited energy supply. Optimal routing tries to maximize the duration over which communication can take place, but requires future knowledge. More uniform resource utilization can be obtained by shaping the traffic flow.

The nodes in a WiMAX network are energy stringent. Communication consumes more power. If a path is frequently chosen for transmission, there are chances that the energy along the path might get depleted soon. Hence an energy-efficient protocol that chooses the best path is needed.

The energy conservation issue is currently handled at the MAC layer and the network layer. As discussed in [7], one way of addressing this problem at the MAC layer, is by reducing the transmission range (i.e. sending a weaker signal) and delivering a packet in a multihop fashion.

As the power consumed by the Network Interface Card (NIC) is directly proportional to the strength of the transmitted signal, a weaker signal means more node life. This may be especially advantageous in areas of high node density [8]. At the network layer, this problem is handled by designing efficient routing protocols.

Information from the source should be communicated to gateways or users who tap into the network. This communication occurs via multi-hop routes. The nodes have a limited energy supply and hence low-power operation is a must. Multi-hop routing protocols for these networks should be designed with a focus on energy efficiency.

A centralized algorithm would result in a single point of failure, which is unacceptable in critical applications.

Some authors have used information on battery reserve and energy cost to find optimal routes [9]. The routing protocol in [7] is based on the node’s location, transmit energy and the residual battery capacity.

Energy efficiency is based on matching the routes to energy constraints in order to increase the network lifetime. When the energy of the nodes in some region of the network is low due to heavy communication activity in the past, the cost of routing through this area is increased to protect the nodes from early energy depletion.

The assumption of the knowledge of residual energy of each node can be justified by the fact that, if the initial energy of a node at the start of a time interval and its communication activity in that interval is known, the residual energy of that node can be found at the end of that interval.

III. EXTENDING NETWORK LIFETIME

It is critical to design efficient routing algorithms with the objectives of

a) Minimizing the overall energy usage in routing packets and the path length in terms of hops.
b) Maximizing the packet delivery rate and network lifetime.
c) Distributing the energy uniformly among the nodes in the networks.

Energy is consumed at two levels during routing, namely communication energy and the energy dissipated at the nodes. The communication energy or the energy needed per routing task can be optimized if nodes can adjust their transmission power to efficiently select the next hop along the route. This is equivalent to hop count if the transmission power is kept constant [12].

Routing algorithms that solely focus on the communication energy are not eventually a good choice for network lifetime. Some of the nodes (hot spots) in this approach will be chosen very often and this will ultimately drain out the battery power of these nodes quickly, therefore partitioning the network abruptly.

Routing algorithms that minimize the energy required per routing task are called power/energy aware algorithms. On the other hand, cost aware routing algorithms ensure the optimal use of node's battery power and hence prolong network's life time.

The position-based algorithms are classified as deterministic and randomized. In the first category, the current node holding the packet selects the next node deterministically out of its neighbors, whereas in the second case the selection is random.

For example, in deterministic greedy [13, 14] and compass [15] algorithms, the current node holding the packet, always forwards it to a neighboring node that minimizes the distance or direction to the destination, respectively.

In randomized energy aware algorithms [16], the current node first selects two of its neighbors such that the distance or direction to the destination is minimized along with the optimal energy dissipation, and then chooses one of them based on some probability distribution.

In greedy and compass algorithms, packets may get trapped during communication. Routing loops might reduce the throughput. Both algorithms select a route with almost the same number of hops as the shortest path when they succeed. However, these algorithms are not suitable for energy aware routing because they choose some nodes very often, and hence make their battery lifetime shorter.

Randomized Energy Aware Routing in [16] tries to optimize communication energy with high packet delivery rates. But the authors did not evaluate the performance of their algorithms on network lifetime.

The network lifetime, in other words the total energy in the network can be preserved in many ways. The literature shows that there are various methods to extend the lifetime of nodes.

A. Energy Aware Routing (EAR)

It is a reactive protocol that increases the lifetime of the network [11].This protocol maintains a set of paths instead of maintaining or reinforcing one optimal path. The maintenance and selection of paths depend on a certain probability, which relies on how the energy consumption of each path can be minimized. The protocol maintains routing tables based on costs for the paths. These multi-path protocols are not applicable to mobile networks.

B. Sleep and Wake up modes

Nodes can switch between active and sleep modes to save energy. Nodes that are awake transmit and receive data. They remain awake for one time unit, during which they transmit data to the central controller, receive new sleep time, set their sleep timer to the new time and enter sleep mode.

The nodes that are awake at a particular instant should be known in order to route the data. One approach is to schedule the nodes such that the lifetime of the system is maximized. The schedule matrix is prepared at the central controller and sent to each node. The workload matrix is available at the central controller [17]. Any change in the topology should be made known to the central controller. Based on the available nodes (awake and functioning), the route keeps changing. This approach does not provide security and is not energy-efficient.

C. Energy Efficient OLSR routing protocol (EE - OLSR)

The OLSR specification has a variable, the “willingness” of a node, representing the availability of that node to act as a MPR for its neighbours. By default, each node declares a default willingness value. In EE-OLSR, each node, calculating its own energy status, can declare an appropriate willingness based on the available energy. The willingness selection is based on 2 metrics: the battery capacity and the predicted lifetime of a node. Another mechanism that allows energy saving in OLSR protocol is the overhearing exclusion. The devices can be turned off when a unicast message is transferred in the neighbourhood thus saving a large amount of energy [39].

D. Routing Algorithm based on per packet energy

Singh et al. proposed in [18] several power aware routing metrics to increase the lifetime of the nodes and the network. Conventional routing protocols in ad hoc networks use delay or hop count to calculate the path to the destination. This approach might accelerate the battery drainage of some specific nodes, which forward packets for many source-destination pairs. The effect would be early node failure and network partition. Following a longer path of a set of nodes with plenty of energy would be a better choice.

The first energy-aware metrics as proposed by Singh et al. is minimum energy consumed per packet. This metric is used to minimize the total communication energy of a packet regardless of the available energy at the nodes. Assume a packet j traverses a set of nodes n_1, n_2 . . . n_k, where n_1 is the source and n_k is the destination.

Let P (n_i, n_{i+1}) be the power needed to forward j from the node n_1 to n_{i+1}. The total energy consumed by packet j to reach the destination is then the sum of the energy over the entire path. The optimization of this metric, which is called power metric in Reference [12], is then subject to

$$\mathbf{e_j = \sum_{i=1}^{K-1} P(n_i, n_{i+1})} \tag{1}$$

Another metric is the minimum cost per packet metric that tries to prolong the lifetime of the nodes and networks through the careful selection of next route node with plenty of energy. Let $f_i(x_i)$ be a function that denotes the cost or weight of node i, where x represents the total energy that node i already expended. Hence, the total cost c_j of sending a packet j from the node n_1 to n_k is sum of the cost of the entire route. The optimization of this metric is then subject to

$$\mathbf{c_j = \sum_{i=1}^{K-1} f_i(x_i)} \tag{2}$$

There are chances for the same path to be chosen often. A short path will contain minimum number of nodes which contribute to the minimum cost per packet or minimum energy consumed per packet, since the number of nodes the packet traverse through is reduced. These metrics deal with one way packet transfer.

E. Routing based on Energy Drain Rate

The drain rate is the metric that measures the energy dissipation rate in a given node. Each node monitors its energy consumption caused by transmission, reception and overhearing activities and computes the energy drain rate, for every ‘t’ seconds sampling interval by averaging the amount of energy consumption and estimating the energy dissipation per second during the past ‘t’ seconds [19].

F. Power Efficient Reliable Routing protocol for mobile Ad hoc Networks (PERRA)

PERRA uses a new routing cost metric that selects the optimum path based on considering the minimum residual energy of the nodes on a path, the total energy consumed by a path to transmit and process a packet, and the path’s stability in accordance with the node mobility [20]. It increases the power efficiency and decreases route reconstructions due to residual power shortages and node mobility. During the path set-up procedure, an energy requirement is added to the route request message so that only paths with nodes that satisfy the source's energy requirement are constructed. Among these paths, PERRA selects the optimum path using a new total cost function, which considers the minimal residual energy of the nodes on the path, the estimated total network energy consumption per packet transmission and processing, and the predicted life-time of the path. To reduce the link-breaks caused by node energy shortages and movement from the link coverage, route maintenance mechanisms are included that warn of possible errors, so an alternative path can be used before the actual errors occur.

Several papers have considered routing metrics which explicitly include residual node energy [21-23].

G. Lifetime Prediction Routing (LPR)

It is an on-demand source routing protocol that uses battery lifetime prediction. This dynamic distributed load balancing approach avoids power congested nodes and chooses paths that are lightly loaded. It considers a probability model derived through the subdivision into cells of the area where mobile nodes move and on the observations of node movements in these cells. Transition probabilities are calculated and a state-based model of the movement of nodes is considered. The wireless link dynamic is determined between a mobile node and its neighbours, permitting the calculation of the link lifetime.

Through the assumption of independent link failure, the route breakage probability is derived. LPR achieves minimum variance in energy levels of different nodes in the network [24].

H. Distributed Power Control (DPC)

DPC is a distributed power control strategy that works at two different levels: hop-by-hop and end-to-end. In particular, it is based on the preliminary selection of a suitable transmits power level, with the aim of reducing the energy consumption and to increase the overall network performance. Furthermore, this transmit power level is used as the link cost function in the path discovery and selection. This hop-by-hop power level selection is also used to select the path guaranteeing low energy consumption [25].

IV. LINK STABILITY

So far, in the above sections, energy based routing algorithms were discussed. But selection of paths based on energy alone, may lead to insubstantial routes. Links should be stable. The stability of a link is given by its probability to persist for a certain time span, which is not necessarily linked with its probability to reach a very high age. Link stability indicates how stable the link is and how long it can support communication between two nodes.

A. Signal Stability based Adaptive Routing (SSA)

SSA uses the average signal strength and location stability to estimate the stability of a link. Each node observes the signals from its neighbours. A highly stable link is the one which has signal strength more than a threshold. The location stability determines the channel which exists for a longer period of time. A route that is formed with these strong links is more stable than an ordinary route. If it fails in finding a route in first trial, it searches a route on all available links. The new route found is similar to the one found using DSR. Weak links are likely to suffer from signal strength fluctuation and should be avoided [26].

B. Associativity Based Routing (ABR)

It differentiates between stable links over transient links [27]. It classifies a link as stable or unstable based on link age.

ABR uses pilot signals to determine link stability. Each node determines the age of a link with its neighbours based on the number of beacons periodically received from that neighbour. If a node receives incessant pilot/ beacon signals from its neighbour and the number of signals is greater than associativity threshold, A_{thresh}, the link with the neighbour is considered stable. If a node does not receive pilot signal through a link within a time limit, then the link is an unstable link. Route search in ABR is different from SSA. In ABR, it searches all possible routes to find a route that contains more strong links.

C. The Flow Oriented Routing Protocol (FORP)

It is an on-demand routing scheme that uses mobility prediction. It utilizes the mobility and location information of nodes to approximately predict the expiration time of a wireless link. It is similar to calculating a link's residual lifetime or route expiration time from a mobile's own speed and the speed and distance of the connected node. However, this method strongly depends on the assumption of a free space propagation model. GPS equipment is needed for distance measurements and time synchronisation.

These requirements can hardly be fulfilled in a realistic environment. Only active routes are maintained and permanent route tables are not needed. When the source has a flow to send, it constructs a route to the destination on demand and injects the flow. The destination predicts the change in topology ahead of time and determines when the flow needs to be rerouted or "handoffed" based on the mobility information contained in data packets [28].

D. Route lifetime Assessment Based Routing (RABR)

It is a local optimal routing algorithm that maximizes route lifetime with perfect knowledge of link lifetime. The lifetime of a link i-j is predicted using a metric called the "affinity" a_{ij} and it is a measure of the time taken by node i to move out of the range of node j. It tries to predict the time when the received signal strength falls below a critical threshold using a measured value of average change in received signal strength. The rate of change of signal strength is given as:

$$\Delta(S_{ij}) = \frac{S_{ij}(current) - S_{ij}(prev)}{\Delta t} \tag{3}$$

It anticipates a link break before it actually happens and issues a new route discovery before the old route breaks. It relies on the movement patterns. The stability estimation disregards the effects of path loss as well as the possibly strong fluctuations in signal strength caused by small scale fading effects [21].

E. Theoretical link availability prediction method

This method is precisely based on the Random Walk Model and there is no assurance about its performance for real world scenarios. This method estimates the availability of a radio link at a certain point in time, without considering its stability until then [29].

F. Edge effect

In a highly dense wireless network, shortest route is very unstable. This led to the identification of edge effect. The shortest route is composed of links that connect farthest neighbours. Nodes are located at the edge of other node's radio transmission range. In this situation, a small positional change of any node can easily break the link [30].

G. GPSR

Greedy Perimeter Stateless Routing (GPSR) is a novel routing protocol for wireless datagram networks. It makes packet forwarding decisions by using the positions of routers and a packet's destination.

The algorithm consists of two methods for forwarding packets: greedy forwarding, which is used wherever possible and perimeter forwarding, which is used in the regions greedy forwarding cannot be.

GPSR makes *greedy* forwarding decisions using only information about a router's immediate neighbours in the network topology.

When a packet reaches a region where greedy forwarding is impossible, the algorithm recovers by routing around the perimeter of the region [31].

H. Advanced signal strength based link stability estimation model (ASBM)

ASBM is proposed in this paper by enhancing SBM. SBM decide link stability only with signal strength. In ASBM, we added differentiated signal strength (DSS) as a parameter. DSS indicates the signal strength is going stronger or weaker.

If it becomes stronger, it means that two nodes will be closer and the link between them would have longer lifetime. In SSA, a link with signal strength exceeding a certain limit is considered as a stable link. In ASBM, we consider both strong signal links and weak signal links that are coming closer as stable links [30].

I. Routing algorithm with link stability estimation

Link stability estimation models presented above are two-level estimation. The estimation results are stable or unstable. Because route lifetime is determined by the weakest link composing the route, to find a route with longer lifetime, we must find a route only with stable links. However, if we use only stable links, the route availability would be decreased. To avoid this phenomenon, we used two stage routing algorithm used in SSA. In first stage, a source node tries to search a shortest route to a destination only with stable links using centralized floyd-warshall. If this fails, it enters into second stage and searches a route with all available links. After finding a route, at every unit time, it monitors whether the route that was found before is valid or not. If the route is invalid, it searches a new route again. If no route is found in both stages, the node waits one unit time and tries finding a route again [30].

J. DSR (Dynamic Source Routing)

DSR is known as well-performing and lightweight routing algorithm in ad-hoc networks. DSR is based on source routing and uses flooding mechanism to find a route to the destination. Data packets carry information about the route from the source to the destination in the packet header. As a result, intermediate nodes do not need to store up-to-date routing information in their forwarding tables. This avoids the need for beacon control neighbour detection packets that are used in the stability-oriented routing protocols. Route discovery is by means of the broadcast query-reply cycle. In DSR, route cache is used to reduce route search overhead caused by flooding. Every node caches routes to other nodes and this reduces routing overhead. Flooding mechanism used in DSR finds a shortest path theoretically. When flooded packets are forwarded at same speed and latency, it finds shortest path. However, each flooding packets are forwarded in different speed and latency due to different loads and status of forwarding nodes [32, 33].

K. Ad Hoc On-demand Multipath Distance Vector protocol (AOMDV)

This paper proposes multipath extensions to single path routing protocol, AODV. The resulting protocol is referred to as Ad hoc On-demand Multipath Distance Vector (AOMDV). Primary design goal behind AOMDV is to provide efficient fault tolerance in the sense of faster and efficient recovery from route failures in dynamic networks. The protocol computes multiple loop-free and link-disjoint paths. The notion of an “advertised hop count” is used to maintain multiple loop-free paths. A particular property of flooding is used to ensure link-disjointness of the multiple paths computed within a single route discovery [34].

L. Split Multipath Routing protocol (SMR)

Split Multipath Routing (SMR) establishes and utilizes multiple routes of maximally disjoint paths. Multiple routes, of which one is the shortest delay path, are discovered on demand. Established routes are not necessarily of equal length. Providing multiple routes helps minimizing route recovery process and control message overhead. This protocol uses a per-packet allocation scheme to distribute data packets into multiple paths of active sessions. This traffic distribution efficiently utilizes available network resources and prevents nodes of the route from being congested in heavily loaded traffic situations [35].

M. Preemptive Routing

In this paper, a class of algorithms that initiates proactive path switches when the quality of a path in use becomes suspicious is discussed. The proactivity avoids using a path that is about to fail and eliminates the associated costs of detecting the failure and recovering from it, significantly improving the performance of the network.

In this work, addition of proactive route selection and maintenance to on-demand ad hoc routing algorithms are investigated. More specifically, when a path is likely to be broken, a warning is sent to the source indicating the likelihood of a disconnection. The source can then initiate path discovery early, potentially avoiding the disconnection altogether. A path is considered likely to break when the received packet power becomes close to the minimum detectable power (other approaches are possible) [36].

N. Metrics to predict lifetime of a link

Statistical methods are introduced to estimate the stability of paths in a mobile wireless ad hoc environment. Identifying stable paths helps in reducing control traffic and the number of connection interruptions [37]. The following Link stability metrics are used:

- Select the oldest link.
- Select the youngest link.
- Select the link with maximum expected residual lifetime.
- Select the link with maximum “persistence probability”.
- Select the link with the lowest failure probability.

Path Stability metrics used are:

- Minimise the Number of Instable Links
- Maximise the Expected Residual Lifetime
- Maximise the Persistence Probability
- Maximise a Residual Lifetime Quantile
- Avoid Instable Links

O. Multi-objective Approach for Energy Consumption and Link Stability

A novel analytical framework that jointly accounts the energy consumption and the link stability of mobile nodes. Two indexes for energy and link-lifetime are defined and a multi-objective integer linear programming problem has been defined. The target function separates the energy and the link-stability contributions in order to differently change the weights of two opposite characteristics of mobile ad hoc networks [38].

P. Link-StAbility and Energy aware Routing (LAER)

In [40], the authors have proposed an algorithm based on link stability and minimum energy drain rate. In this paper, multiobjective mathematical formulation for the joint stability and energy problem is presented. The protocol is based on a geographic paradigm. A novel stability metric based on the residual link lifetime concept has been adopted.

A novel energy aware-metric, is introduced in the proposed optimization model in order to consider not only the residual energy but also its time variation associated with the traffic load. A stable link is chosen based on Residual Energy (RE), age of the link and average distance.

$$s_{i,j} = \frac{d_{i,j}^{avg}}{R_{i,j}(a_{i,j}) \cdot k} \qquad \forall (i,j) \in A, \tag{4}$$

The coefficient $S_{i,j}$ can be interpreted as a reciprocal measure of the stability.

V. PROPOSED SYSTEM

In this paper, LAER is extended to include Signal-To-Noise (SNR). The next hop node with less Noise Ratio and high RE is selected. The SNR threshold is 10 dBm and that of RE is 30%. SNR is determined from the MAC layer while the RE calculations are done at the network layer using the Energy Model. If no node satisfies the above mentioned constraints, then SNR is left out. In other words, if there is no next hop node to forward the packets, then the links are chosen based on RE alone. If RE is not sufficient, then the packets are dropped in the worst case.

VI. PERFORMANCE ANALYSIS

GPSR and M-LAER are simulated using ns2 for WiMAX networks and the results are analyzed. The system parameters are listed below.

Table 1: Parameters

Parameters	**Value**
Network Size	1000 x 1000 m
Transmit Power	35 mW
Initial energy	100 J
RSSI Threshold	-75 dBm
Mobility model	Random-Waypoint
Propagation	Two ray ground
MAC protocol	802.16
Packet size	1024 bits
SNR Threshold	10 dBm
Antenna	Omni directional
Model	
Data Rate	2 Mbps
Routing protocol	GPSR
Carrier frequency	2.4 GHz
Nodes number	100
Transmission Range	250 - 400 m
Speed of nodes	3, 6, 9, 12 m/s

The following graphs show the Packet Delivery Ratio (PDR), Routing overhead and Average energy consumed for both GPSR and LAER. LAER shows better performance.

It yields high PDR, involves less overhead and consumes less energy. The results show that the proposed method outperforms the traditional GPSR and provides a reliable route.

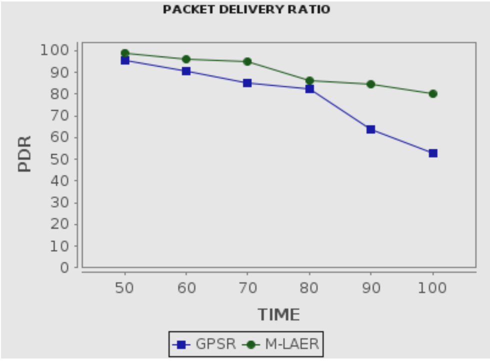

Figure 1 : PDR

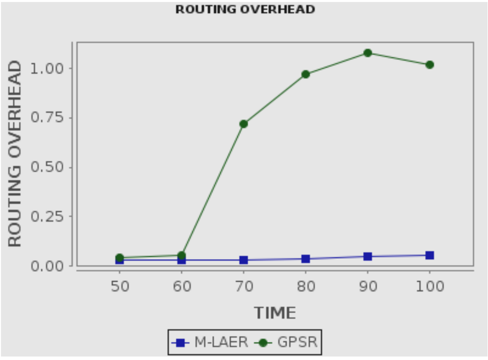

Figure 2 : Routing Overhead

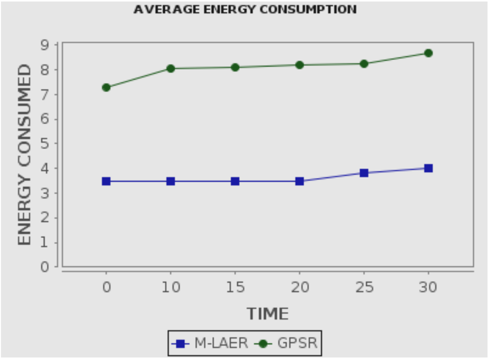

Figure 3 : Average Energy Consumption

VII. CONCLUSION

The performance of Modified Link-StAbility and Energy aware Routing (M-LAER) is better when compared to GPSR in terms of routing overhead, PDR and average energy consumption. The LAER algorithm can be enhanced by taking other parameters like Signal-to-Noise Ratio (SNR) in addition to energy.

REFERENCES

1. Qing Chen and Mustafa Cenk Gursoy, Energy-Efficient Modulation Design for Reliable Communication in Wireless Networks, 2009.
2. IEEE standard 802.16-2004, IEEE standard for local and metropolitan area networks-part 16: Air interface for fixed broadband wireless access systems, 2004.
3. IEEE standard 802.16.2-2004, IEEE recommended practice for local and metropolitan area networks coexistence of fixed broadband wireless access system, 2004.
4. IEEE standard 802.16-2004/cor1, Corrigendum to IEEE standard for local and metropolitan area networks –part 16: air interface for fixed broadband wireless access system, Draft 5, 2005.
5. Sarat Chandra and Anirudha Sahoo, An Efficient Call Admission Control for IEEE 802.16 Networks.
6. IEEE Standard for Local and Metropolitan Area Networks, IEEE 802.16 Standard 2002.
7. Stojmenovic, I., Lin, X., Power-Aware Localized Routing in Wireless Networks, IEEE Transactions on Parallel and Distributed Systems, 12 (11), pp. 1122 - 1133, 2001.
8. Rabiner,W., Kuli,J., Balakrishnan,H., Adaptive Protocols for Information Dissemination in Wireless Sensor Networks, MobiCom’99, pp. 174-185, 1999.
9. Chang J.H, Tassiulas L, Energy Conserving Routing in Wireless Ad-Hoc Networks, INFOCOM’ 00, Tel Aviv, Israel, pp.22-31, 2000.
10. Jie Gao, Li Zhang, Load Balanced Short Path Routing in Wireless Networks, IEEE Transactions on Parallel and Distributed Systems,17(4),pp.377-388, 2006.
11. R C. Shah and J. M. Rabaey, Energy aware routing for low energy ad hoc sensor networks, In Proc. IEEE Wireless Communications and Networking Conference, pp.350-355, 2002.
12. Stojmenovic, I., Lin, X., Power aware localized routing in ad hoc networks, IEEE Transactions on Parallel and Distributed Systems, 12(10),1023-1032, 2001.
13. Finn, Gregory G, Routing and addressing problems in large metropolitan-scale internetworks, ISUIRR-87180, USC ISI, Marina del Ray, CA, 1987.
14. G.G. Finn, Routing and addressing problems in large metropolitan-scale internetworks, ISI Research Report ISU/RR-87-180, 1987.
15. Kranalkis E. Singh H, Urrutia ,Compass routing on geometric networks, In Canadian Conference on Computational Geometry (CCCG '99), pp. 51-54 ,1999.
16. Haque IT, Assi C, Atwood JW, Randomized energy aware routing algorithms in mobile ad hoc networks, In 8th ACM/lEEE International Symposium on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MsWim 05), 2005.
17. Hai Liu, Xiaohua Jia, Peng-Jun Wan, Chih-Wei Yi, S.Kami Makki, S.K. and Pissinou,N. Maximizing Lifetime of Sensor Surveillance System, IEEE/ACM Transactions on Networking, 15(2), pp. 334-345, 2007.
18. S.Singh, M.Woo and C.S. Raghavendra, Power-aware routing in Mobile Adhoc Networks, MOBICOM, pp.181-190 , 1998.
19. Dongkyun Kim, Garcia-Luna-Aceves, J.J. , Obraczka, K. , Cano, J.-C. , Manzoni, P. Routing Mechanisms for Mobile Ad Hoc Networks Based on the Energy Drain Rate, IEEE Transactions on Mobile Computing, 2(2) pp. 161-173, 2003.
20. K.-J. Kim and S.-J. Yoo, Power-Efficient Reliable Routing Protocol for Mobile Ad-Hoc Networks, MWSCAS’04, pp. 481-484, 2004.
21. Agarwal, S., Ahuja, A. , Singh, J.P. ,Shorey, R. Route-lifetime assessment based routing (RABR) protocol for mobile ad-hoc networks. IEEE International Conference on Communications. ICC 2000, New Orleans, LA, USA, 18-22, pp.1697-701, 2000.
22. Tragoudas, S., Dimitrova, S., Routing with energy considerations in mobile ad-hoc networks. 2000 IEEE Wireless Communications and Networking Conference, Chicago, IL, USA, 23-28, p.1258-61, 2000.
23. Kyungtae Woo, Chansu Yu, Dongman Lee, Hee Yong Youn, Lee B. Non-blocking, localized routing algorithm for balanced energy consumption in mobile ad hoc networks. MASCOTS 2001, pp.117-24, 2001.
24. Maleki, M., Dantu, K., Pedram, M. Lifetime Prediction Routing in Mobile Ad Hoc Networks, Proc. IEEE Wireless Communication and Networking (WCNC ’03), pp. 1185-1190, 2003.
25. P. Bergamo, D. Maniezzo, A. Travasoni, A. Giovanardi, G. Mazzini, and M. Zorzi, Distributed Power Control for Energy Efficient Routing in Ad Hoc Networks, Wireless Networks J.,10(1), pp. 29-42, 2004.
26. Dube, R., Rais, C.D., Kuang-Yeh Wang; Tripathi, S.K., Signal Stability-Based Adaptive Routing (SSA) for Ad Hoc Mobile Networks, IEEE Personal Communications, 4(1), pp. 36-45,1997
27. C-K. Toh, Associativity based routing for ad hoc mobile networks, Wireless Personal Communications Journal, 4(2), 103–139, 1997.
28. W. Su, S. Lee, and M. Gerla. Mobility Prediction and Routing in Ad Hoc Wireless Networks, International Journal of Network Management, 3–30, 2001.
29. McDonald, A.B. and Znati, T. A Path Availability Model for Wireless Ad-Hoc Networks. In Proceedings of the IEEE WCNC, pp. 35–40. IEEE, 1999.
30. G. Lim, K. Shin, S. Lee, H. Yoon, and J. S. Ma. Link stability and route lifetime in ad hoc wireless networks. In International Workshop on Ad Hoc Networking (IWAHN’02), 2002.
31. Brad Karp, H. T. Kung, “GPSR: Greedy Perimeter Stateless Routing for Wireless Networks,” In Proceedings of the 6th annual international conference on Mobile computing and networking (MOBICOM ‘00), pp. Pages 243-254, August 06 - 11, 2000.
32. Johnson, D. B. and Maltz, D. A. , Protocols for Adaptive Wireless and Mobile Networking, IEEE Personal Communications, 3(1), pp. 34-42, 1996.
33. D. B. Johnson, D. A. Maltz and J. Broch, DSR: The Dynamic Source Routing Protocol for Multi-hop Wireless Adhoc Networks in Ad hoc Networking, Chapter 5, C. E. Perkins, Eds. Addison Wesley, pp. 139 – 172, 2000.
34. Marina, M. K. and Das, S. R., On-demand multipath distance vector routing in ad hoc networks. In Proc. of IEEE International Conference on Network Protocols, pp. 14 -23, 2001.
35. Lee, S.-J. and Gerla, M. Split multipath routing with maximally disjoint paths in ad hoc networks. In Proc. IEEE International Conference on Communications 2001 (ICC’01), pp. 3201–3205, 2001.
36. T. Goff, N. B. Abu-Ghazaleh, D. S. Phatak, and R. Kahvecioglu. Pre-emptive routing in ad hoc networks. In ACM Seventh Annual International Conference on Mobile Computing and Networking (MOBICOM’01), pp. 43 - 52, 2001.
37. Gerharz, M., de Waal, C., Martini, P. and James, P., Strategies for Finding Stable Paths in Mobile Wireless Ad Hoc Networks, In Proceedings of IEEE 28th Annual Conference on Local Computer Networks (LCN ’03), pp. 130-139, 2003.
38. De Rango, Guerrerio, F., Marano, S., A Multi-Objective Approach for Energy Consumption and Link Stability Issues in Ad Hoc Networks, IEEE Communication Letters, 10(1), pp. 28-30, 2006.
39. F. De Rango, M. Fotino, and S. Marano, “EE-OLSR: Energy Efficient OLSR Routing Protocol for Mobile Ad-Hoc Networks,” In Proceedings of the IEEE Military Communications Conference (MILCOM ’08), pp. 1-7, 16 - 19 Nov. 2008
40. Floriano De Rango, Member,Francesca Guerriero and Peppino Fazio, Link stability and Energy Aware Routing Protocol in Distributed Wireless Networks, IEEE Transactions on parallel and distributed systems, 23(4), 2012.