Development of a Path Maintenance Based EE-OLSR Energy Model for MANETs

N. Kumar[#1], Dr.C. Suresh Gnana Dhas[*2]

[#]Research Scholar, Karpagam University, Coimbatore, TamilNadu, India.

[*] Professor, Department of Computer Science and Engineering, Vivekananda College of Engineering for Women, Tiruchengode, Tamil Nadu, India.

[#]nkvsc.org@gmail.com, [*]sureshc.me@gmail.com

***Abstract*—Energy must be significantly conserved in Mobile Ad hoc Networks (MANETs) by employing energy models. Majority of the energy models address only the hidden terminal issue, but result in higher power consumption due to increased collisions during packet transfer. The existing energy models for MANET are based on OLSR protocol and DE (Differential Evolution) – OLSR protocol with features like QoS (Quality of Service) optimization, accuracy of energy states, distributed clustering, and energy-efficient clustering. An energy model is proposed for MANET involving an Energy-efficient Optimized Link State Routing (EE-OLSR) protocol and a path maintenance scheme. The EE-OLSR energy model is based on a progressive search for the most energy-efficient path. This model reduces the routing overhead and path setup delay, and enhances the network lifetime. The path maintenance scheme uses a flooding mechanism to decrease the control message overhead and enhance the packet delivery. The beacon messages from the primary root nodes track the destination's location. The path maintenance based EE-OLSR model consumes lesser energy compared to the existing energy models, with respect to nodal speed, packet size, average connection arrival rate, number of nodes, grid size and packet inter-arrival time.**

Index Terms—Adjacent Cluster (AC), Cluster Head (CH), Immediate Neighbor (IN), Mobile Ad hoc Network (MANET), Optimized Link State Routing (OLSR), and Topology Control (TC).

I. Introduction

Mobile ad hoc network (MANET) is a self-configuring network of interconnected mobile devices. The energy consumed by the devices in the MANET is an important aspect which is handled by designing various energy-efficient routing protocols. The conventional minimum energy routing protocols involve transmission of signal packets to decrease the hidden terminal issue, as a consequence of using asymmetric transmission powers from different neighboring nodes. The signal packets consume higher power due to increased collisions during the packet transfer.

An energy model is proposed for MANET based on an Energy-efficient Optimized Link State Routing (EE-OLSR) protocol and a path maintenance scheme. The energy consumptions due to various factors are tracked to improve the performance during the path performance. The proposed scheme searches for the most energy-efficient path progressively. This significantly reduces the routing overhead, path setup delay, and enhances the peer-to-peer process.

The path maintenance scheme effectively maintains and repairs the path in case of link failure to reduce the routing overhead. The primary route nodes broadcast beacon messages containing the location of the destination node to their single hop nodes. This method decreases the routing messages by efficiently tracking the mobile destination node.

The remaining part of the paper is organized as follows: Section II involves the works related to the energy models for a MANET. Section III involves the detailed analysis of the path maintenance based Energy-efficient Optimized Link State Routing (EE-OLSR) energy model for MANETs. Section IV involves the comparison of the existing and proposed energy models for a MANET. The paper is concluded in Section V.

II. Related Work

This section gives a brief overview of the existing energy models in a MANET. *Toutouh* and *Alba* proposed an energy-efficient routing protocol for Vehicular Ad hoc Networks (VANETs) [1], [2]. A QoS (Quality-of-Service) optimized version of OLSR is used with Differential Evolution (DE). *Kunz* and *Alhalimi* proposed an energy model for MANETs based on the accurate state information about available energy levels [3]. The energy levels are utilized as the QoS metrics for the routing decisions. A smart prediction technique is used to increase the accuracy of the energy levels under all traffic loads.

Dimokas, et al., proposed an energy-efficient distributed clustering model for improving the energy conservation in MANETs [4]. The clustering process forms a hierarchical structure over a flat MANET. The distributed clustering model is based on the residual energy of each node and the topological features of the nodes. *Minming*, *et al.*, proposed an energy-efficient clustering method for MANETs [5]. Residual energy, neighbor's topology, relative mobility, and relative location of the nodes in a MANET, determine the capability of a node being a cluster head (CH). The cluster maintenance is performed by *Distance Estimation Broadcasting*, which estimates the distance between a cluster member and its CH. The least distance leads to lesser energy consumption during data transmission. An *Off-Duty Threshold* metric is used to restart the clustering operation.

Mian, *et al.*, proposed an energy-efficient protocol for MANETs using IEEE 802.11 MAC (Medium Access Control) protocol [6]. The energy constraints for performing a random walk in the MANET are reduced by using a distributed next hop selection algorithm. *Wei*, *et al.*, proposed a framework for heterogeneous MANETs known as Device-Energy-Load Aware Relay (DELAR) [7]. A heterogeneous MANET consists of normal nodes and powerful nodes. A cross-layer structured DELAR scheme is used to save energy by power control, a hybrid transmission scheduling, and power-aware routing. The power-aware routing protocol integrates the information regarding device heterogeneity, nodal load, and residual energy, to save energy. The hybrid transmission scheduling is an integration of contention-based and reservation-based MAC schemes. Mini-routing is imposed into the data layer and an asymmetric MAC (A-MAC) method supports the MAC-layer acknowledgments. The end-to-end delay performance is enhanced by a multi-packet transmission technique.

Wang, *et al.*, an energy-efficient location service protocol is proposed for MANETs [8]. The efficiency of the location service protocol depends on the accuracy of position information of the destination node. The location service protocol is based on hierarchical hashing. The distance traversed by the query packets and location update is optimized by this protocol, which reduces the energy consumption. *Tavli* and *Heinzelman* proposed an energy-efficient real-time multicast routing protocol for MANETs [9]. The real-time multicasting architecture is known Multicasting through Time Reservation using Adaptive Control for Energy Efficiency (MC-TRACE). The architecture is an integrated cross-layer design between network layer functionality and MAC layer functionality. A passive mesh is used to enclose an active multicast tree in a MANET. Frequent sleeping periods and less redundant data receptions increase the energy efficiency.

Nand and *Sharma* proposed a probability based broadcasting for AODV (Ad hoc On-demand Distance Vector) routing protocol in MANETs [10]. This broadcasting scheme improves the network lifetime, by decreasing the energy consumption. The probability of rebroadcast is dynamically computed using threshold random delay and a node's remaining energy. The energy information of nodes is estimated from the route request packet of AODV routing protocol. The total amount of energy consumed to receive a control message during a broadcast operation is greater than the amount of energy depleted to transmit the message [11].

De Pellegrini, *et al.*, proposed optimal monotone forwarding schemes in delay-tolerant MANETs with multiple node classes [12]. *Altman*, *et al.*, proposed optimal monotone forwarding methods in delay-tolerant MANETs [13]. The tradeoff between delay and energy consumption is modeled as an optimal control problem. The energy-delay tradeoff is modeled as an optimization problem on the basis of a fluidic approximation. The forwarding scheme provides a time-constrained delivery of a message under total energy expenditure constraints.

Yu, *et al*, proposed a key management scheme in tactical MANETs based on hierarchical identities [14]. The dynamic node selection process is modeled as a stochastic problem and the nodes are selected using a private key generator (PKG) under the security constraints and energy states. The conditions are addressed by a security model, energy model, and cost model. *Yi*, *et al.*, proposed a multipath optimized link state routing (MP-OLSR) for increasing the load balancing and energy efficiency in MANET [15]. *Gallina*, *et al*, proposed a probabilistic energy-aware model for MANETs [16]. The model is based on Segala's probabilistic automata combined with schedulers to determine the choices among the target probability distributions. An energy-aware preorder semantics is used to compare the energy consumption of different networks.

Díaz-Báñez, *et al*, analyses the problems in min-energy broadcast for MANETs [17]. For a given set of stations, the min-energy transmission range assignment is computed. *Jin-Hee*, *et al*, surveys the various trust management systems for MANETs [18]. A trust system must be asymmetrical and balance reliability, scalability, fault tolerance, and energy consumption.

Jinhua and *Xin* proposed a model and protocol for energy-efficient routing over MANETs [19]. This model enhances the energy efficiency by decreasing the routing setup time and routing overhead. An energy-efficient routing method known as Progressive Energy Efficient Routing (PEER) is proposed to enhance the performance during the path discovery process. *Urgaonkar* and *Neely* proposed a cell-divided model of a delay-tolerant MANET for analyzing the minimum energy function and network capacity region [20].

III. Path Maintenance Based EE-OLSR Model

A. *Architecture of EE-OLSR Energy Model*

The flow of the Energy-Efficient-OLSR (EE-OLSR) energy model is given in Fig. 1. The major functions of the energy model are neighbor sensing and route maintenance. EE-OLSR protocol has an advantage of high mobility and low bandwidth. The nodes periodically exchange the topology information to determine the routes from any source to any destination.

The transmission of the control messages in the network is limited by a multipoint relay (MPR) technique, involving the tracking of the information about the neighbors and topological information about the network. Each node maintains a routing table based on the information on neighbors and the topology of the network. The computation of the routing table is based on Dijkstra's algorithm. The routing table is updated whenever a variation occurs in the network.

B. Path maintenance scheme

An effective route maintenance scheme is proposed based on quad-oriented forwarding algorithm. This is performed to enhance the data packet delivery ratio while decreasing the number of routing overhead messages through single hop neighbor beaconing of the primary route nodes.

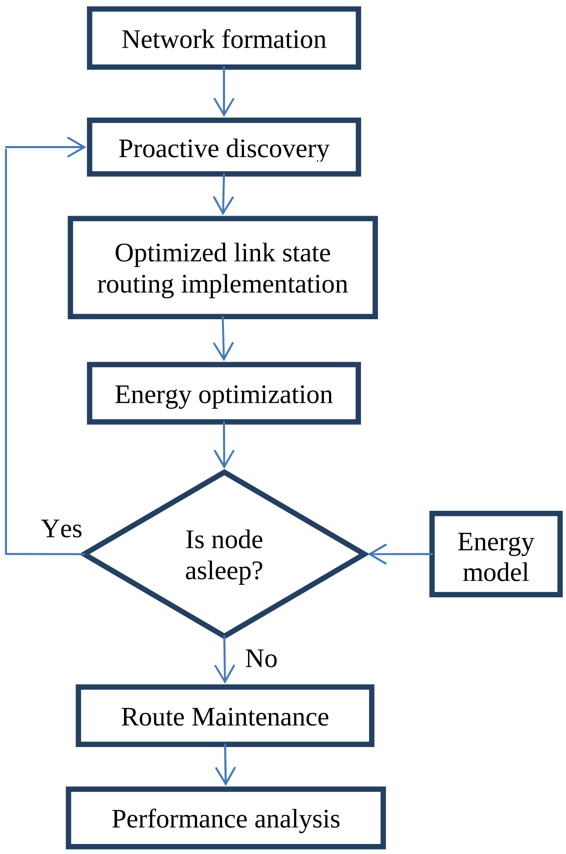


Fig. 1. Flow of energy model based on path maintenance and EE-OLSR protocol for MANETs.

1) Quad-oriented forwarding

The flow of the quad-oriented forwarding algorithm is given in Fig. 2. The location of each node in the MANET is recognized via GPS (Global Positioning System). The location of the primary route node is identified using a beacon message from the single hop neighbor node.

Node *A* comprises of information about its location (x_A, y_A). Node *A* broadcasts its location related details using a beacon message. On receiving the information from node *A*, the nodes *B* and *C* store them in their respective routing tables. Four directions are considered along the diagonal of each four quadrants I, II, III, and IV. Here, node *B* locates the direction in quadrant III from node *A* and node *A* sets the position of the direction in quadrant I from node *B*. Similarly, node *C* locates the direction in quadrant IV from node *A* and node *A* determines the direction in quadrant II from node *C*. Quad directions are preferred because of lesser routing overhead and higher packet delivery ratio compared to other orientation variants.

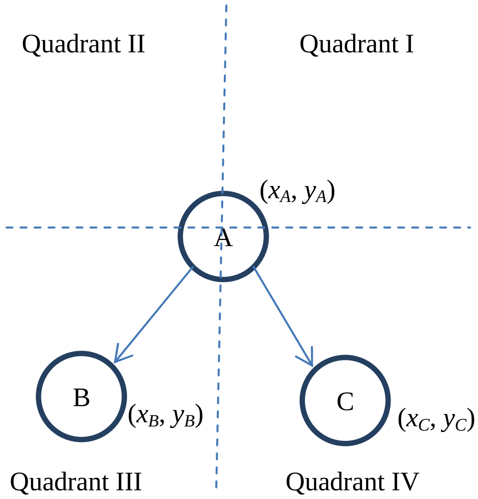


Fig. 2. Quad-oriented forwarding scheme.

ALGORITHM I – Path maintenance algorithm

Messages: Beacon (M_b), Request (M_{rq}), Reply (M_{rp}), and Error (M_e)
Input: N = number of nodes, Node X_n, where n = 1, 2 … N, $(x_d, y_d) \rightarrow$ destination location information, $t_{WAIT\_M_{rp}}$ $\rightarrow$ wait time of M_{rp}
Output: Destination node (X_d) and determination of primary route

```
begin
    for each Xn
        if (Xn does not have (xd, yd))
            Process 1:
                Flood Mrq
                if (Xn is Xd)
                    Send Mrp
                    Send Mb to single hop neighbor from primary route
                    Establish primary route
                    Transmit data
                    Stop
                else
                    goto Process 1
                end if-else
            end Process 1
        else
            quad-oriented forwarding of Mrq
            Process 2:
                if (Xn is Xd)
                    Send Mrp
                    Establish primary route
                    Transmit data
                    Stop
                else
                    if (tWAIT_Mrp > 1)
                        goto Process 1
                    else
                        goto Process 2
                    end if-else
                end if-else
            end Process 2
        end if-else
    end for
end
```

2) Path maintenance algorithm

This scheme uses four message types namely, beacon (M_b), request (M_{rq}), reply (M_{rp}), and error (M_e). Only the primary route nodes can transmit M_b to single hop neighbor nodes by specifying the hop limit of M_b to unity. M_{rq} and M_{rp} are used in the path discovery process, while M_e are used in the path maintenance process. The basic flow of the path maintenance algorithm is given in ALGORITHM I.

a) Local routing table

The local routing table in the path maintenance scheme is updated when it receives M_{rq}, M_{rp}, and M_e. An example local routing table is given in TABLE I.

TABLE I
LOCAL ROUTING TABLE

ID_d	O_d	X_{n+1}	d	n_h	n_s	t_l	State
12	II	24	123	5	264	7	VALID
43	IV	62	168	7	156	0	INVALID
82	I	43	75	6	221	4	VALID

The following describes the fields given in TABLE I:

ID_d Destination node ID determined using the direction values from 1 to 4

O_d Orientation to destination

X_{n+1} Next node

d The distance between two neighbor nodes from under the nodal transmission range

n_h The number of hops to the destination node

n_s Automatic sequential numbers to update the route information

t_l Lifetime of the route details

An INVALID state is obtained when t_l is zero and the respective routing table entry is deleted.

b) Path maintenance

The working of path maintenance in a MANET is shown in Fig. 3. When a multi-hop node moves to a single hop node, the multi-hop node becomes a single hop node. On the other hand a single hop node moving away from the primary route node by more than two hops becomes a multi-hop node. A difference between single hop nodes and multi-hop nodes is the reception of the M_b from one of the primary route nodes.

Node X_1 transmits the location details of the destination node to its neighboring node X_2. The location information is broadcast in an M_b every second to the neighboring nodes of node X_1 by making TTL value equal to unity. Further the nodes X_2, X_3, X_4, and X_5 broadcast the beacon messages to their neighboring nodes containing the address and location details of the destination node. The single hop neighbor nodes from the primary route nodes create the routing tables with the routing information.

The aim of beacon messages is to determine the position of the destination node as soon as the path failure occurs along the primary route nodes. When a path failure occurs, a local repair procedure is executed as shown in ALGORITHM II.

In case of a link failure, an M_{rq} is broadcast to determine the destination node by setting TTL equal to two. When the destination node is not detected, a M_e is transmitted back to all active nodes that are a part of the disconnected link. The nodes that receive the M_e remove the route of the broken link for further communications. Suppose the source receives M_e, it should reinitiate the route discovery process.

When a node along the primary path observes a link failure, the node sends an M_{rq} towards the direction of the destination. This path maintenance scheme would considerably decrease the routing message overhead.

3) Packet forwarding

When a source node determines the location of the destination node, a node from the routing table is chosen toward the destination direction. For a case of multiple nodes being chosen, the source nodes opts the node of the highest n_s and lowest n_h. If there are still multiple nodes, the node with longer d is chosen. The local repair process is executed when there is no appropriate node for packet forwarding. The packet forwarding process with respect to quad directions is given in Fig. 4.

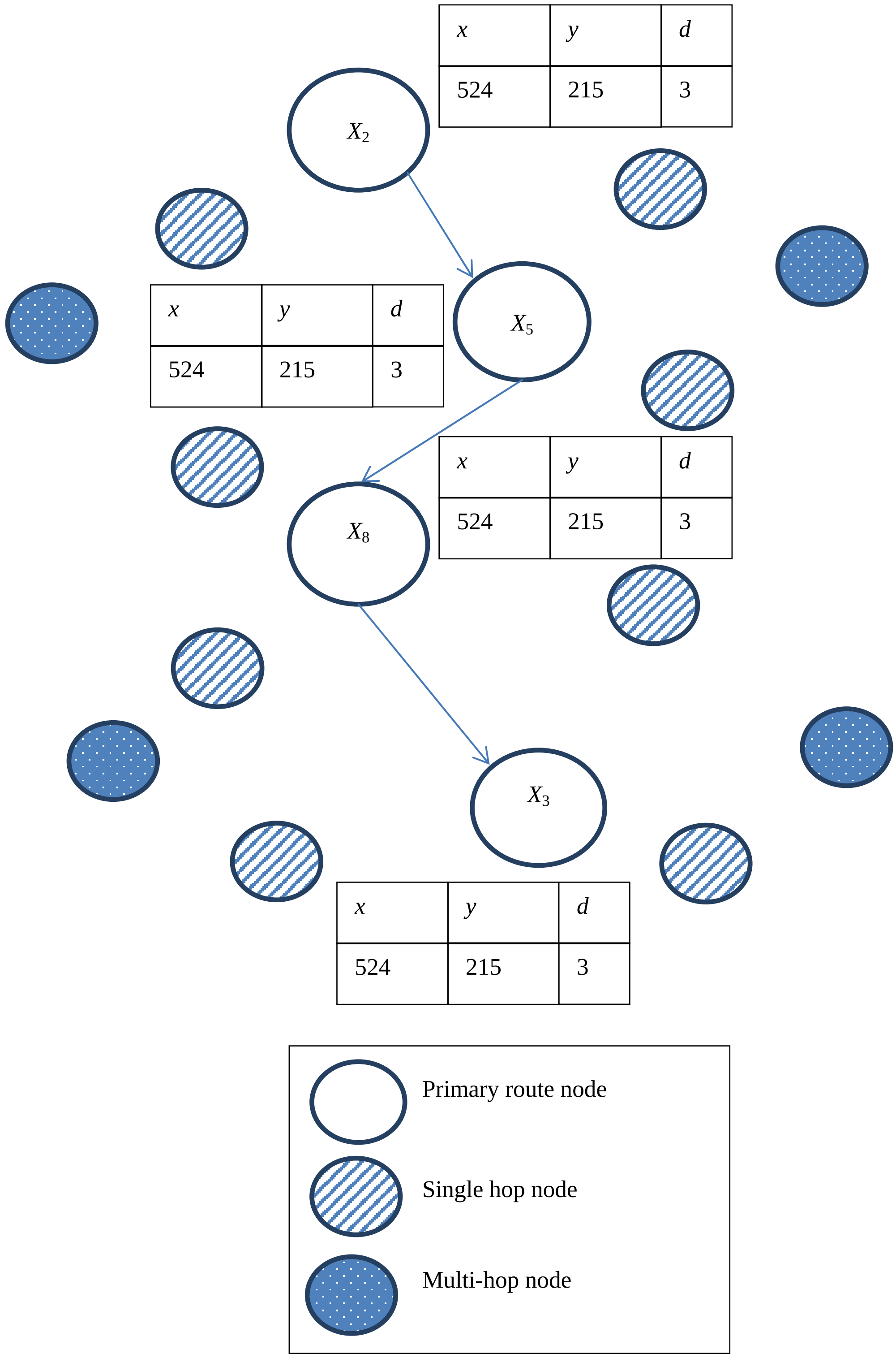


Fig. 3. Flow of path maintenance scheme.

ALGORITHM II – Local repair procedure

```
Messages: Request (M_rq), Reply (M_rp), and Error (M_e)
Input:    N = number of nodes, Node X_n, where n = 1, 2
          … N, O_d → orientation to destination, t_r →
          repair time, X_s → Source node
Output:   Local repair by route reconfiguration
begin
    for each X_n
        Detect link failure
        Notify link failure to X_s
        if (Any alternative route)
            Process 1:
                Reconfigure the path
                Transmit data
                Stop
            end Process 1
        else
            Send M_rq to O_d
            if (t_r >= 0.15)
                Process 2:
                    Send M_e to X_s
                    Flood M_rq for path reconfiguration
                    Stop
                end Process 2
            else
                if (M_rp is being received)
                    goto Process 1
                else
                    goto Process 2
                end if-else
            end if-else
        end if-else
    end for
end
```

- The source node S chooses a forwarding packet from the node in its transmission range.
- Initially, node S chooses nodes A and B possessing the same direction in quadrant I.
- Next, if nodes A and B have similar n_h and n_s, the source node compares the value of d for nodes A and B.
- Finally, node A is selected for forwarding the packet as it has a larger d than node B.

4) Control routing overhead

Two new messages are used to find an alternative route to aid in case of link failures. The two messages are a control message and a control-ACK (Acknowledgement) message. There is no periodical update in the determined alternate node until the occurrence of a communication failure. This can lead to problems when the nodes are in high speed motion. So to avoid this, the primary nodes send a beacon message comprising of destination node's location to their single hop neighbor nodes every second. This message transmission stops when the single hop neighbors move far away from the primary nodes.

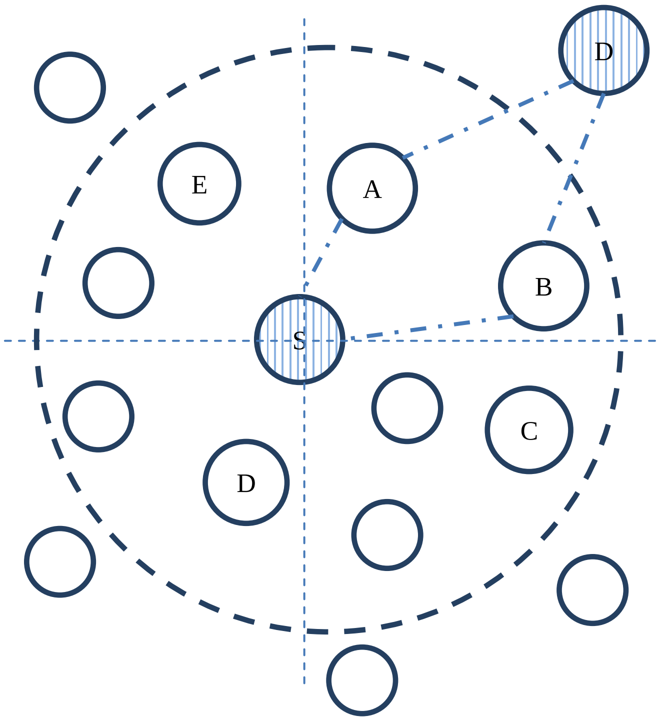


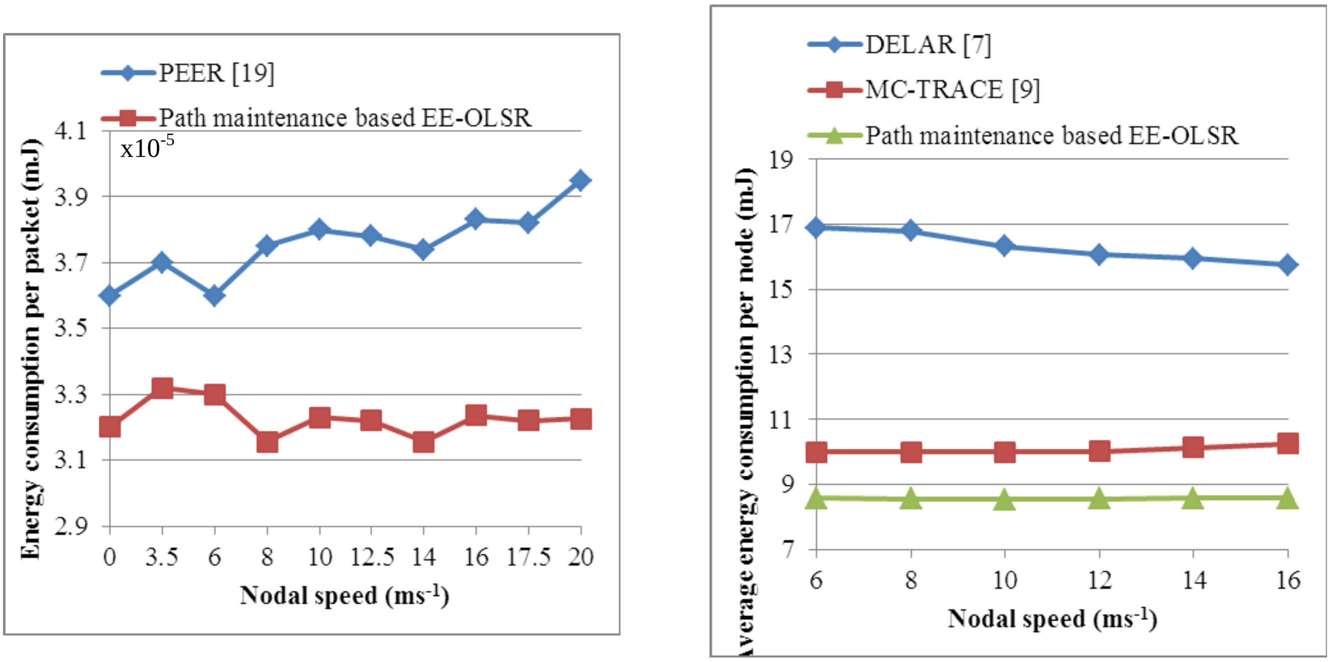
Fig. 4. Packet forwarding process with respect to quad directions.

IV. PERFORMANCE ANALYSIS

The path maintenance based EE-OLSR energy model is modeled in a network of 150 nodes arranged with a density of 94 nodes per square kilometer. The existing energy models considered for the survey analysis are DE-OLSR [1], [2], Energy-efficient proactive routing [3], Energy-efficient distributed clustering method [4], Random Walk with Distribution Selection algorithm (RW-DS) [6], DELAR [7], MC-TRACE [9], hierarchical identity based key management method [14], and PEER [19].

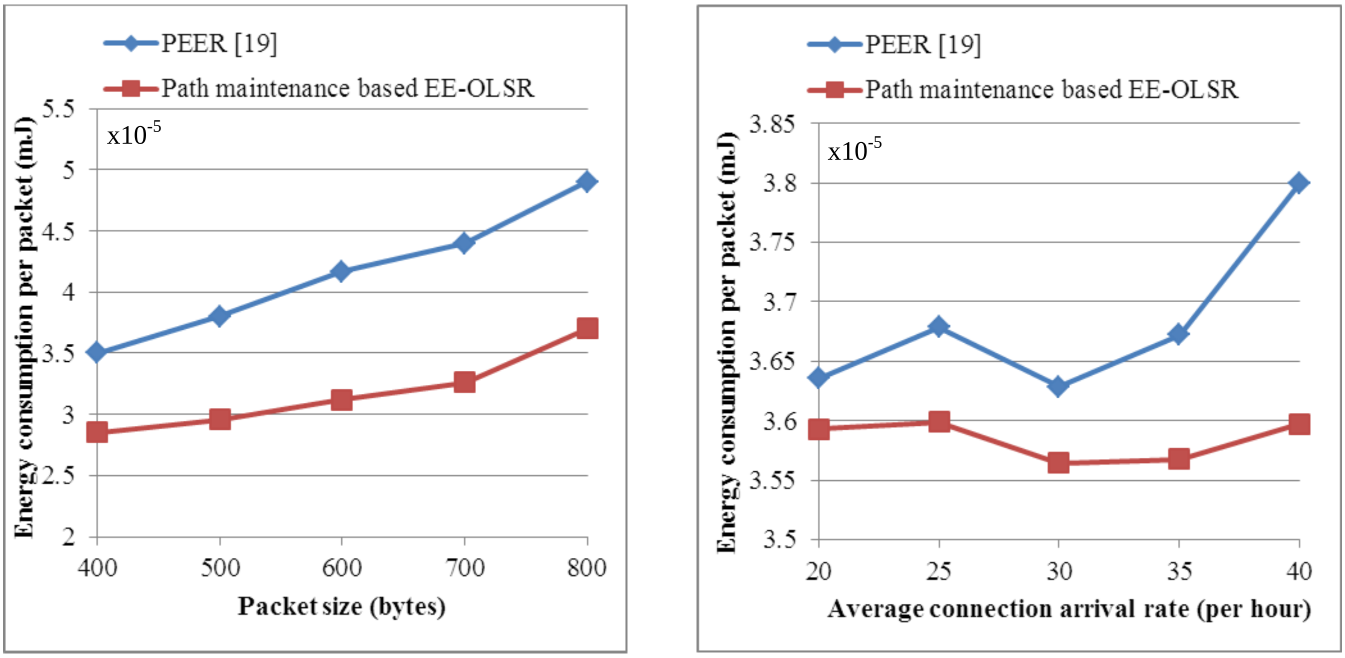
The nodal speed is varied from 1 m/s to 25 m/s. The path maintenance based EE-OLSR energy model is analyzed in terms of energy consumption for a set of nodal speeds, packet sizes, and connection arrival rates. The energy dissipation analysis for a set of nodal speeds is performed per packet, per node and on an average basis. The energy consumption of the system is analyzed for the specified number of nodes and grid size. The path maintenance based EE-OLSR energy model is also analyzed in terms of nodal energy consumption for a given set of packet inter-arrival time, and network lifetime for a given set of nodes.

The total energy consumed during the system modeling by DE-OLSR scheme [1], [2] is 6684.708 J, and by that of the path maintenance based EE-OLSR scheme is 6023.342 J. The amount of energy consumed by the radio to operate the transmitter or receiver (E_{elec}) is 50 nJ/bit by Energy-efficient distributed clustering method [4], and 43.23 nJ/bit by the path maintenance based EE-OLSR scheme. The amount of energy required to operate the transmitter amplifier (E_{amp}) is 100 pJ/bit per m^2 by Energy-efficient distributed clustering method [4], and 95.23 pJ/bit per m^2 by the path maintenance based EE-OLSR scheme.



(a) (b)

Fig. 5. Energy consumption analysis for a set of nodal speeds, (a) per packet analysis in the path maintenance based EE-OLSR scheme and PEER scheme [19], and (b) average energy consumption per node in the path maintenance based EE-OLSR scheme, DELAR scheme [7], and MC-TRACE scheme [9].



(a) (b)

Fig. 6. Energy consumption analysis in the path maintenance based EE-OLSR scheme and PEER scheme [19], (a) for a set of packet sizes, and (b) for a set of average connection arrival rates.

A. *Energy consumption with respect to various parameters*

The energy consumption is analyzed in the various energy models with respect to parameters like nodal speed, packet size, average connection arrival rate, number of nodes, grid size and packet inter-arrival time.

1) Nodal speed

The energy consumption per packet is analyzed in terms of various nodal speeds for the path maintenance based EE-OLSR scheme and PEER scheme [19]. The average energy consumption per node is analyzed in terms of nodal speed for the proposed EE-OLSR scheme, DELAR scheme [7] and MC-TRACE scheme [9]. The comparative analysis is given in Fig. 5.

2) Packet size and connection arrival rate

The energy consumption is analyzed per packet in the path maintenance based EE-OLSR scheme and PEER scheme [19], for a set of packet sizes (bytes) and average connection arrival rates (per hour), and compared in Fig. 6.

3) Number of nodes and grid size

The mean consumed system energy for various numbers of nodes and grid sizes is analyzed in the path maintenance based EE-OLSR scheme and RW-DS scheme [6] and compared in Fig. 7.

4) Packet inter-arrival time

The nodal energy consumption rate is analyzed for a set of packet inter-arrival times in the path maintenance based EE-OLSR scheme and Energy-efficient proactive routing technique [3] and compared in Fig. 8.

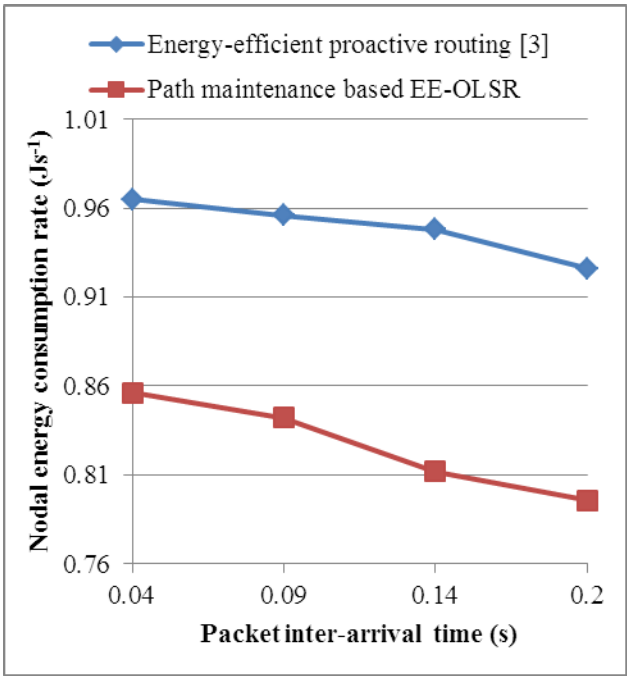
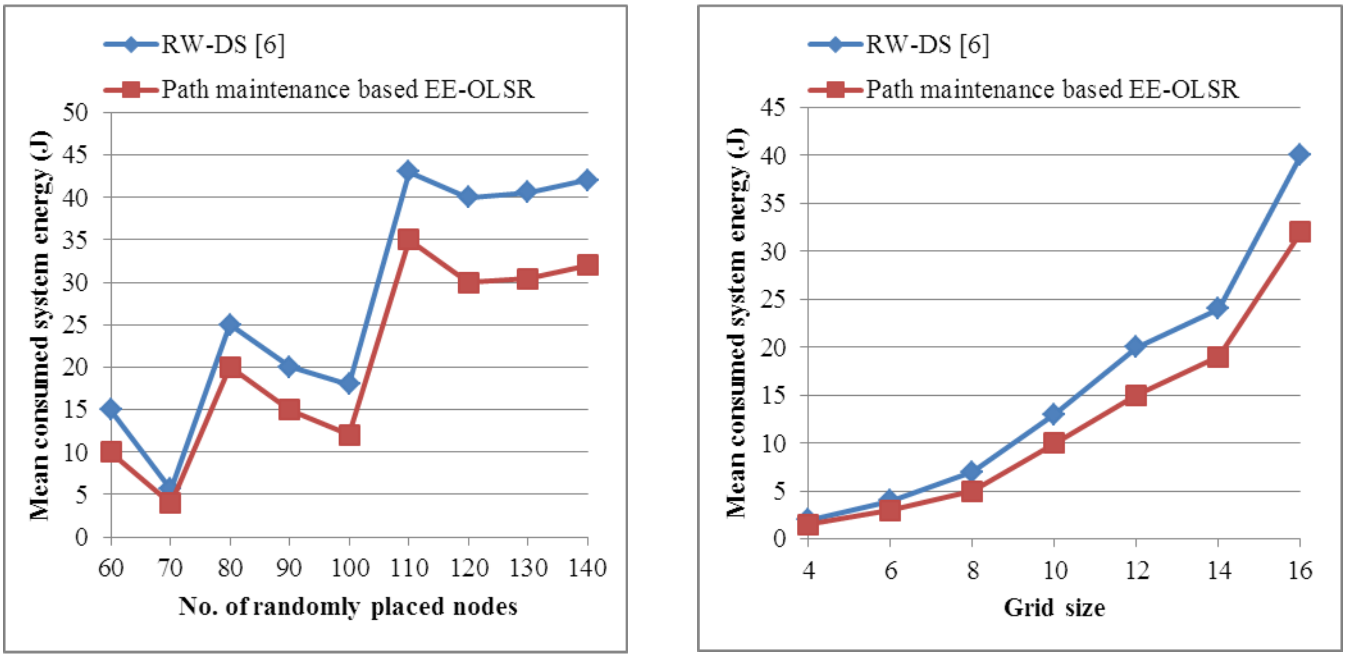


Fig. 8. Comparison of nodal energy consumption rate in the path maintenance based EE-OLSR scheme and energy-efficient proactive routing scheme [3] for various packet inter-arrival times.

B. Network lifetime

The network lifetime is analyzed for various numbers of nodes in the path maintenance based EE-OLSR scheme and hierarchical identity based key management method [14] and compared in Fig. 9.



(a) (b)

Fig. 7. Mean consumed system energy in the path maintenance based EE-OLSR scheme and RW-DS scheme [6], (a) for various numbers of nodes, and (b) for various grid sizes.

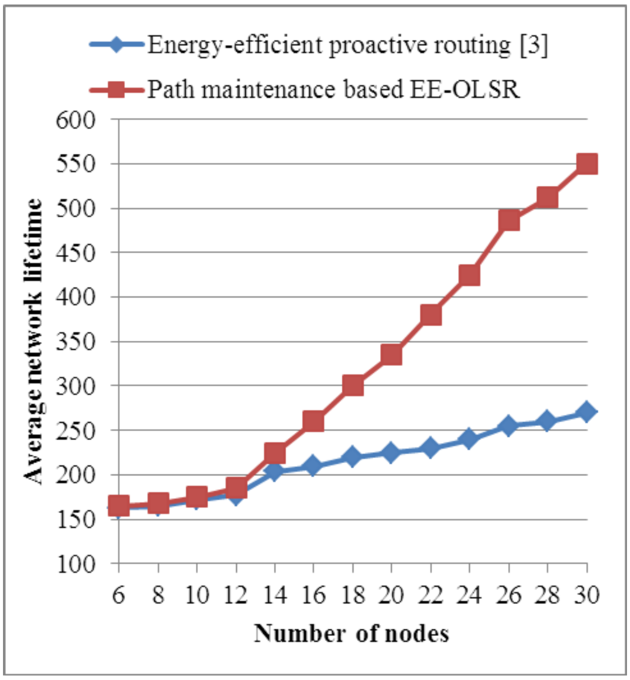


Fig. 9. Comparison of network lifetime in the path maintenance based EE-OLSR scheme and hierarchical identity based key management scheme [3].

V. Conclusion

The conventional energy models for a MANET address only the hidden terminal problem, but fail to decrease the energy consumption due to the increased collisions during the packet transfer. The existing energy models for MANET are based on OLSR protocol and DE–OLSR protocol with features like QoS optimization, accuracy of energy states, distributed clustering, and energy-efficient clustering. An energy model for MANET is designed upon an Energy-efficient Optimized Link State Routing (EE-OLSR) protocol and a path maintenance scheme. The efficiency of the energy model is enhanced due to a progressive search for the most energy-efficient path. This model reduces the routing overhead and path setup delay, and enhances the network lifetime. The path maintenance scheme is based on quad-oriented forwarding algorithm with single hop beaconing from the primary route nodes. The path maintenance based EE-OLSR model consumes lesser energy compared to the existing energy models, with respect to nodal speed, packet size, average connection arrival rate, number of nodes, grid size and packet inter-arrival time.

REFERENCES

[1] J. Toutouh and E. Alba, "An efficient routing protocol for green communications in vehicular ad-hoc networks," presented at the Proceedings of the 13th annual conference companion on Genetic and evolutionary computation, Dublin, Ireland, 2011.

[2] J. Toutouh and E. Alba, "Green OLSR in VANETs with differential evolution," presented at the Proceedings of the fourteenth international conference on Genetic and evolutionary computation conference companion, Philadelphia, Pennsylvania, USA, 2012.

[3] T. Kunz and R. Alhalimi, "Energy-efficient proactive routing in MANET: Energy metrics accuracy," Ad Hoc Networks, 2010, vol. 8, no. 7, pp. 755-766.

[4] N. Dimokas, et al., "Energy-efficient distributed clustering in wireless sensor networks," Journal of Parallel and Distributed Computing, 2010, vol. 70, no. 4, pp. 371-383.

[5] N. Minming, et al., "An Energy Efficient Clustering Scheme for Mobile Ad Hoc Networks," in Vehicular Technology Conference (VTC 2010-Spring), 2010 IEEE 71st, 2010, pp. 1-5.

[6] A. N. Mian, et al., "A robust and energy efficient protocol for random walk in ad hoc networks with IEEE 802.11," International Journal of Parallel, Emergent and Distributed Systems, 2010, vol. 25, no. 5, pp. 363-379.

[7] L. Wei, et al., "DELAR: A Device-Energy-Load Aware Relaying Framework for Heterogeneous Mobile Ad Hoc Networks," Selected Areas in Communications, IEEE Journal on, 2011, vol. 29, no. 8, pp. 1572-1584.

[8] Z. Wang, et al., "Energy-efficient location services for mobile ad hoc networks," Ad Hoc Networks, 2013, vol. 11, no. 1, pp. 273-287.

[9] B. Tavli and W. B. Heinzelman, "Energy-Efficient Real-Time Multicast Routing in Mobile Ad Hoc Networks," Computers, IEEE Transactions on, 2011, vol. 60, no. 5, pp. 707-722.

[10] P. Nand and S. C. Sharma, "Probability Based Improved Broadcasting for AODV Routing Protocol," Procedia Engineering, 2012, vol. 50, no. 2012, pp. 222-231.

[11] N. Meghanathan, "A location prediction based routing protocol and its extensions for multicast and multi-path routing in mobile ad hoc networks," Ad Hoc Networks, 2011, vol. 9, no. 7, pp. 1104-1126.

[12] F. De Pellegrini, et al., "Optimal monotone forwarding policies in delay tolerant mobile ad hoc networks with multiple classes of nodes," in Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks (WiOpt), 2010 Proceedings of the 8th International Symposium on, 2010, pp. 497-504.

[13] E. Altman, et al., "Optimal monotone forwarding policies in delay tolerant mobile ad-hoc networks," Performance Evaluation, 2010, vol. 67, no. 4, pp. 299-317.

[14] F. R. Yu, et al., "A Hierarchical Identity Based Key Management Scheme in Tactical Mobile Ad Hoc Networks," Network and Service Management, IEEE Transactions on, 2010, vol. 7, no. 4, pp. 258-267.

[15] J. Yi, et al., "Multipath optimized link state routing for mobile ad hoc networks," Ad Hoc Networks, 2011, vol. 9, no. 1, pp. 28-47.

[16] L. Gallina, et al., "A Probabilistic Energy-Aware Model for Mobile Ad-Hoc Networks," in Analytical and Stochastic Modeling Techniques and Applications. vol. 6751, K. Al-Begain, S. Balsamo, D. Fiems, and A. Marin, Eds., ed: Springer Berlin Heidelberg, 2011, pp. 316-330.

[17] J. M. Díaz-Báñez, et al., "Min-energy broadcast in mobile ad hoc networks with restricted motion," Journal of Combinatorial Optimization, 2012, vol. 24, no. 4, pp. 413-426.

[18] C. Jin-Hee, et al., "A Survey on Trust Management for Mobile Ad Hoc Networks," Communications Surveys & Tutorials, IEEE, 2011, vol. 13, no. 4, pp. 562-583.

[19] Z. Jinhua and W. Xin, "Model and Protocol for Energy-Efficient Routing over Mobile Ad Hoc Networks," Mobile Computing, IEEE Transactions on, 2011, vol. 10, no. 11, pp. 1546-1557.

[20] R. Urgaonkar and M. J. Neely, "Network Capacity Region and Minimum Energy Function for a Delay-Tolerant Mobile Ad Hoc Network," Networking, IEEE/ACM Transactions on, 2011, vol. 19, no. 4, pp. 1137-1150.