Research Article

Energy Aware Clustering Aggregate Node Rotation with Sink Relocation (EAC-ASR) Protocol for MANET

[1]A.Vinodh Kumar and [2]S. Kaja Mohideen
[1]Department of Electronics and Communication Engineering, B.S. Abdur Rahman
University, Chennai, India
[2]School of Electrical and Communication Sciences, B.S. Abdur Rahman University, Chennai, India

Abstract: The main aim of this study is to propose an Energy Aware Clustering Aggregate Node Rotation with Sink Relocation (EAC-ASR) protocol for improving the energy efficiency of the Mobile Ad-Hoc Network (MANET). MANET has gained more popularity and deployed for numerous applications, as a result of significant improvement in the technological development, diverse sensing and mobility capabilities. Reduction in the energy consumption is the most important challenge in the MANET, to improve the communication efficiency at the individual nodes. The EAC-ASR protocol is proposed in this study to achieve reduction in the energy consumption of the MANET. The energy aware clustering process is done to improve the access control mechanism of the network. Aggregation of data from the nodes is performed using the data collection algorithm. Rotation of the mobile nodes and relocation of the sink are performed, to balance the energy consumption in the network, during the data transmission process. The simulation results show that the proposed EAC-ASR protocol reduces the energy consumption and increases the lifetime of the MANET.

Keywords: Cluster head, data aggregation, Energy Aware Clustering Aggregate Node Rotation with Sink Relocation (EAC-ASR) protocol, energy efficiency, Mobile Ad-hoc Network (MANET), mobile node rotation, network lifetime

INTRODUCTION

Usage of the portable and high speed computing and communication devices are increasing nowadays, owing to the advancement in the Wireless Communication Technologies. The Mobile Ad-hoc Network (MANET) is suitable for the cost-effective and quick network setup within a short period of strategic communication in the Military and rescue operations. Clustering is a most significant research area in MANET, because it improves the performance of flexibility and scalability when the network size is huge with high mobility. Energy consumption becomes an important issue in the MANET. Due to its dynamic and distributed nature, routing is one of the significant issues in MANET. In particular, energy efficient routing has become a most important design criteria for MANETs, since the mobile nodes are powered using the batteries with limited capacity. Power failure of the mobile node affects its packet forwarding ability and reduces the overall lifetime of the network. Thus, the energy efficient routing protocols minimize the active communication energy during the inactive periods.

The routing protocol can easily achieve energy efficiency during the packet forwarding process. These protocols try to route the data through the path with maximum energy bottleneck, or to reduce the end-to-end packet transmission energy. However, the DSR protocol does not support multicasting. The throughput is reduced, since the data packet header consists of the address of the intermediate route along with source and destination. The packet routing load of the network is increased, since it sends route reply packets through all routes through the route request packets are received. DSR does not contain a route entry invalidation mechanism or a route prioritization mechanism, for selecting a route from multiple routes. MTPR tries to select a path having minimum total transmission power. A node requires a path to a distant node broadcast route request (RREQ) to all its neighbors. This process continues at each and every intermediate nodes till the packet reaches a destination node. The destination node receives RREQs from various nodes, but selects the path with minimum total transmission power. The total transmission power balances with transmitted distance depending on the environmental conditions. In most cases, this routing approach selects the routes with more hops than others. The Minimum Transmission Power Routing (MTPR) is deployed for reducing the overall power consumption per packet transmission, but

it does not directly affect the node lifetime. However, reduction in the transmission energy varies from the shortest hop routing, if the nodes can adjust transmission power levels. Hence, the multiple short hops are more advantageous than a single long hop, based on the energy level. The main drawbacks of the MTPR protocol are network congestion and participation of more number of nodes for forming a routing path.

To mitigate the drawbacks of the existing routing protocols, this study proposes an Energy Aware Clustering Aggregate Node Rotation with Sink Relocation (EAC-ASR) protocol to enhance the energy efficiency of the network. Deployment of the mobile node is carried out by the Network formation, division of regions, calculating the number of nodes, coverage area and probability calculations for the divided regions. The energy aware clustering process reduces the energy consumption and improves the access control mechanism of the network. Then, the data aggregation is performed by the data collection algorithm that leads to effective multi-hopping process. Rotation of the mobile nodes and relocation of the sink are performed, to balance the energy consumption in the network, during the data transmission process. By rotating the mobile nodes, continuous working of the particular intermediate hop nodes is reduced. Node rotation and sink relocation process is performed, based on the energy level of the nodes. The theoretical and simulation analysis shows that the proposed EAC-ASR protocol reduces the energy consumption and increases the network lifetime.

Suresh *et al.* (2014) proposed an Efficient Power Aware Routing (EPAR) protocol for increasing the lifetime of MANET. The proposed protocol identifies the node capacity using the expected amount of energy spent in reliable forwarding of data packets over a specific link. The EPAR protocol selects the path having maximum packet capacity, using a mini-max formulation. The proposed scheme has reduced the total energy consumption and mean delay in the high load networks and achieved high packet delivery ratio. EPAR schemes make the routing decisions to optimize the performance of the energy related evaluation metrics. The selection of the routes is performed based on the performance requirement policies, irrespective of the deployed underlying ad-hoc routing protocols. Routing is performed, by choosing a path with the maximum lowest hop energy. Thus, the power aware routing schemes are transferred between the underlying ad hoc routing protocols. The proposed approach is a dynamic and distributed based load balancing method that eludes power-congestion nodes and chooses the lightly loaded paths. The main drawback of the EPAR protocol is that it does not consider the frequent movement of the nodes and hence the mobility is not determined. Also, there is no alternate paths for the transmission of data packets in case of depletion of nodes in the original path.

Barati *et al.* (2012) discussed about the power consumption aspects of the MANET routing protocols. The comparison of the average energy consumption and routing energy consumption of the Dynamic Source Routing (DSR) and Ad hoc On-Demand Distance Vector (AODV) routing protocols are explained thoroughly. Then, an evaluation of the routing protocols was performed, based on the energy consumption result. De Rango *et al.* (2012) proposed a novel routing strategy for achieving better link stability and Minimum Drain Rate (MDR) to increase the network lifetime. The performance of the proposed Link stability and Energy aware Routing protocol was evaluated based on the Packet Delivery Ratio, Link duration, lifetime of the nodes, Average energy consumption and Normalized Control Overhead.

Simaremare *et al.* (2012) proposed a modified AODV routing protocol combining gateway mode and reverse route mechanism. The modified protocol has reduced the energy consumption for random waypoint movement, when compared to the reference point group mobility model. Yitayal *et al.* (2014) designed a novel balanced battery usage routing protocol to maximize the network lifetime and balance energy consumption of the MANET. The simulation results show that the novel energy aware algorithm enables the network to be active for a long period of time and equal distribution of energy consumption across the nodes on the network. Costagliola *et al.* (2012) suggested the usage of an Optimized Link State Routing (OLSR) protocol exploiting Dijkstra's algorithm for discovering the optimal paths across the network. The lifetime and average end-to-end delay of the network were improved, due to the unicast routing of the proposed protocol. Sarkar and Datta (2012) introduced an energy consumption model for calculating the node energy-factor and then suggested a trust based protocol for the energy-efficient routing in MANET. A trust module is adopted to track the routing metric value. The proposed protocol has reduced the delay, routing overhead and increased packet delivery ratio with low energy consumption, when compared to the existing routing protocols.

Maleki *et al.* (2014) presented a bi-objective intelligent routing protocol to reduce the energy cost and end-to-end delay of the path. A reinforcement learning-based algorithm is proposed to approximate the optimal routing policy. Srinivasan and Kamalakkannan (2012) proposed a novel, stability and energy based Quality of Service (QoS) routing protocol, to handle the throughput and delay constraints. The proposed protocol achieves has shown better packet delivery ratio, control overhead and end-to-end delay in comparison with the popular existing protocols. Loutfi *et al.* (2014) proposed a novel energy based clustering algorithm for the OLSR routing protocol. The main objective of the proposed algorithm is the selection of reasonable number of cluster heads for the hierarchical routing process. The network lifetime was increased by considering the ad hoc residual energy and the delay of

carried flows was optimized using a selective forwarding approach based on the hierarchical routing model. Basurra *et al.* (2015) discussed the Zone based Routing process deploying the Parallel Collision Guided Broadcasting Protocol, by using a one hop clustering algorithm to divide the network into zones. The proposed protocol has minimized redundant broadcasting and accelerated the path discovery, while reducing the node energy consumption and maintaining a high reachability ratio.

Ramrekha *et al.* (2012) presented an energy efficient and protocol independent mechanism for MANET routing in the disaster rescue operations. The routing performance of the proposed mechanism was improved, when compared to the AODV and OLSR routing protocols. Ramesh *et al.* (2014) proposed an Energy Efficient Preemptive Dynamic Source Routing for the MANET. The conserved energy level was evaluated based on the available and required energy of the communication node. The proposed routing method has achieved better end-to-end delay and data packet delivery ratio. Jain and Sharma (2014) presented a novel energy efficient secure multipath AODV routing protocol including filtering forwarding scheme that reduces the spread of excessive route requests initiated by a node per unit time and prevents Denial of service attacks. The energy consumption of the network was reduced and packet delivery ratio and throughput of the network was improved, by using the proposed algorithm. Preethi and Ramachandran (2011) proposed an energy efficient route discovery process for the AODV protocol. Reduction in the energy level of the nodes and routing overhead was achieved, by mitigating the redundant rebroadcasting of route request packets. The energy consumption and collisions were reduced significantly by the proposed protocol. The performance of the Dynamic Source Routing (DSR) protocol was proved to be inefficient for the medium and large ad-hoc networks.

Protecting the network layer from the malicious attacks and performance improvement is proposed by Ayyaswamy *et al.*, (2011a, b). They have implemented and tested using QualNet 5.0 establishes the soundness of the proposal.

To overcome the drawbacks in the conventional energy efficient routing protocols, an EAC-ASR is proposed in this study. The main objective of the proposed protocol is to reduce the energy consumption and increase the network lifetime of the MANET. The proposed protocol includes Energy aware clustering, data aggregation and mobile node rotation with sink relocation.

METHODOLOGY

This section describes about the proposed EAC-ASR protocol for enhancing the energy efficiency of the MANET. In the proposed technique, Deployment of the mobile node is carried out by the Network formation, division of regions, calculating the number of nodes, coverage area and probability calculations for the divided regions. Selection of the neighbor node is performed using the top-disc algorithm. The response mechanism associated with the Top-Disc algorithm varies from the trivial approaches. It selects only a subset of nodes to respond to the topology discovery queries. The approximate topology of the network is formed by the combination of the neighborhood lists of the selected subsets of nodes. The subset is selected in such a way that each node in the network becomes a part of the subset or a neighbor of a node in the selected subset. Thus, the selected subset exists as a controlling set for the network and should possess minimum cardinality for optimal consumption of the resources. Figure 1 shows the flow diagram of the proposed technique.

Energy aware clustering process: Clustering ensures scalability and load balancing in the MANETs and increases the system capacity by facilitating the spatial reuse of resources. Also, it elects a cluster head for the enhanced coordination of the transmission activities. This reduces the transmission collision of mobile nodes, to ensure the energy saving and reduced resource consumption. Generation and spreading of the routing information are controlled by forming a virtual backbone for inter-cluster routing including cluster heads and cluster gateways. Therefore, each node stores and processes a fraction of the total network routing information, thus saving a lot of resources.

Energy aware clustering is adopted to enhance the energy efficiency of the network. Generally, the mobile nodes are deployed randomly in a specific region. The distance from a node to the corresponding cluster head or sink is less than or equal to d_0. Energy dissipation in the cluster head during a single round is specified by the Eq. (1):

$$E_{CH} = (\frac{n}{k} - 1) \times B \cdot E_{elec} + \frac{n}{k} B \cdot E_{DA} + B \cdot E_{elec} + B \cdot \varepsilon_{fs} \cdot D_{AVG} \quad (1)$$

where, B is the number of bits in the message, D_{AVG} is the average distance between the cluster head and base station and E_{DA} is the required energy for data fusion or aggregation in a single round. Energy consumed in the non-cluster head is given by Eq. (2):

$$E_{NCH} = B \times (E_{elec} + \varepsilon_{fs} \times D_{CH}) \quad (2)$$

where, D_{CH} represents the average distance of the node from the cluster head. The total amount of energy consumed in the cluster is given by Eq. (3):

$$E_{Cluster} = E_{CH} + (\frac{n}{k} - 1)E_{NCH} \approx E_{CH} + (\frac{n}{k})E_{NCH} \quad (3)$$

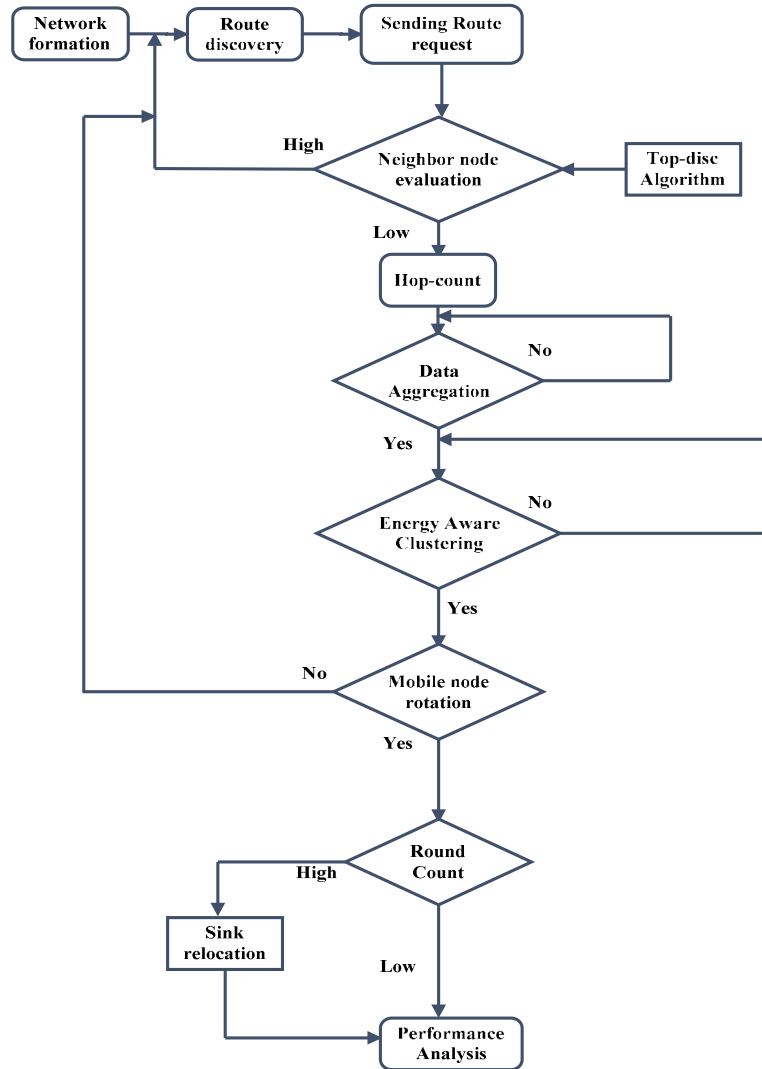The total energy dissipation level of the network is given by Eq. (4):

Fig. 1: Flow diagram of the proposed technique

$$E_{Total} = B \times (2nE_{elec} + nE_{DA} + k\varepsilon_{fs}D_{AVG}^2 + n\varepsilon_{fs}D_{CH}^2) \quad (4)$$

The optimal number of the clusters can be computed by finding the derivative of E_{Total} with respect to k and equating it to zero:

$$k_{opt} = \frac{\sqrt{n}}{\sqrt{2\pi}} \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \frac{M}{D_{AVG}} \quad (5)$$

$$R = \frac{E_N}{D.E_{round}} \quad (6)$$

$$D_{AVG} = 0.765\frac{M}{2} \quad (7)$$

The optimal probability of a node to become as a cluster head is specified by the Eq. (8):

$$P_{opt} = \frac{k_{opt}}{n} \quad (8)$$

Election of the cluster heads for normal nodes is performed using a probability scheme, based on the average energy and residual energy of the normal nodes. Let, n be the number of nodes and m be the fraction of the number of the nodes with β times more energy than normal nodes. Powerful nodes are known as advanced nodes and the rest (1-m) ×n as normal nodes. The initial energy of each normal node is E_{init} and advanced node has $E_{init} \times (1+\beta)$. Intuitively, advanced nodes have to become CHs more often than normal nodes, since the energy of the advanced nodes is greater than the energy of the normal nodes. The value of P_{opt} does not change, but the total energy of the network is changed. The total initial energy of the heterogenous network is given by (8):

$$T.E = N \cdot (1-m)E_{init} + N \cdot mE_{init}(1+\beta) = N \cdot E_{init}(1+\beta m) \quad (9)$$
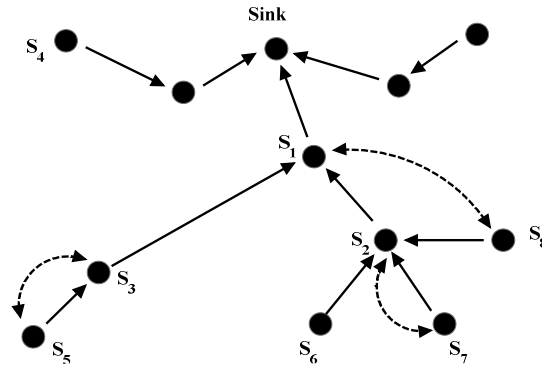
Fig. 2: Mobile node rotation process

E_R and E_{NAVG} denotes the residual energy and the average energy of a normal node. Since the threshold calculation depends upon the average energy of normal sensor nodes in a round r, therefore it should be calculated. The average energy of normal nodes is estimated as:

$$E_{NAVG} = \frac{1}{N} E_N (1 - \frac{r}{R}) \qquad (10)$$

Here R represents the total round of the network lifetime and R can be estimated as:

$$R = \frac{E_N}{D.E_{round}} \qquad (11)$$

D.E_{round} denotes the total energy dissipated in a round of the network and E_N is the total energy of normal nodes in the network. Cluster head threshold for the normal nodes are multiplied by the ratio of the residual energy and average energy of the normal nodes in a round, since the energy of the normal nodes is less when compared to advanced nodes. Hence, the normal nodes will become a cluster head, only when it have sufficient energy.

Data aggregation process: The Cluster Head (CH) is responsible for the aggregation of data received from the cluster members and then send the aggregate data to the Base Station (BS) or neighboring CH through the gateway. The cluster node gathers data and send to the CH, if the energy of the CH is below the average energy. The cluster-head is selected based on the energy. The associate cluster head is selected, when the energy of the CH is below the energy of the non-CH nodes. The size of the aggregated packet does not depend on the number of packets aggregated during data fusion, irrespective of the number of nodes in the cluster.

Consider a cluster with a single cluster head node and 'n' sensor nodes. The node density is assumed to be constant, hence the number of nodes in each cluster 'n' is proportional to the area of the cluster. During each data collection process, the cluster head receives "n" packets from the nodes in its cluster, performs data

Table 1: Cluster head data collection

Cluster Head Data Collection ()

{
- Association of the number of nodes with various parameter or node parameters.
- Aggregation of all nodes at cluster level.
- Collecting the parameters useful for node information and storing at each cluster head.
- Cost Evaluation on the basis of collected parameters.
- Evaluation of Minimum global cost.
- Sending all cost parameters to the cluster head for further association.
- Transferring the cost parameters to the base station.

}

aggregation and produces $\lambda(n)$ packets of the same length. Thus, the number of the output packets is a function of the number of the input packets. Then, the number of packets in the aggregated output is:

$$\lambda(n) - cn + h \qquad (12)$$

In this model, h corresponds to the overhead of aggregation, while c is the compression ratio (Table 1).

Mobile node rotation with sink relocation: The mobile nodes are rotated to balance the energy consumption in the network. A node at the high energy consumption location swaps its position with a node at the low energy consumption location. Here, multiple mobile sensors swap their positions once or multiple times. The three nodes initially at locations S_1, S_2 and S_3 consume more energy than the nodes at other locations. The node at S_3 consumes more amount of energy because it is located far from its parent node at S_1. Using the mobile node rotation, multiple nodes are rotated through high energy consumption locations. From the Fig. 2, the nodes at the tailback locations S_1, S_2, S_3 can rotate with the nodes at the locations S_8, S_7 and S_5 respectively, after a specific time period, to balance the energy consumption between the high and low energy consumption locations. As a result, the amount of energy required at a high energy consumption location is shared by the two nodes
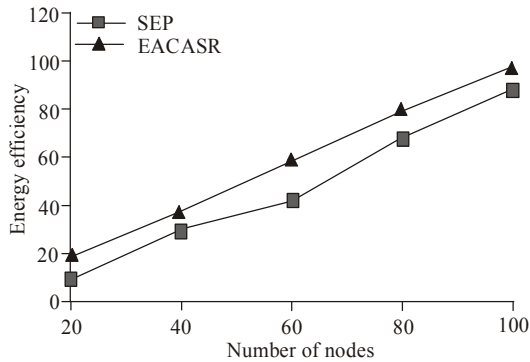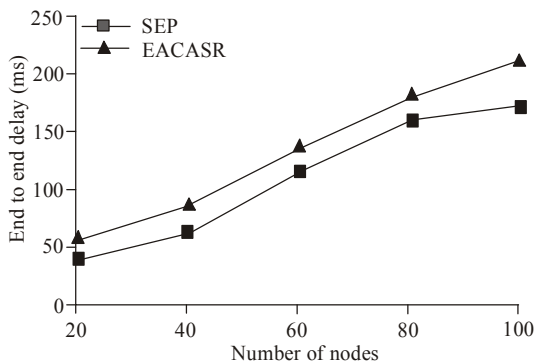
Fig. 3: Energy efficiency vs number of nodes

Fig. 4: End-to-end delay vs number of nodes

instead of only one node. Hence, the lifetime of the network is significantly increased due to the mobile node rotation.

To improve the network lifetime, the sink is moved towards the last-hop relays. To moderate the relocation, a point G is defined as the equidistant position from these relay nodes in term of distance×traffic. To avoid the domination of nodes due to less traffic, the final position of the sink is fixed between its actual position and the point G. This position is determined using a dichotomy approach based on an evaluation formula. Finally, the sink is moved using a straight line movement. The repositioning of sink is accepted if the energy gain exceeds a fixed threshold. The threshold computation is performed based on the overhead generated by the sink movement. The obtained simulation results show that the sink repositioning achieves decrease in packet energy consumption, increase in the average node lifetime and reduction in the transmission delay.

RESULTS AND DISCUSSION

This section describes about the comparison of the performance of the proposed Energy Aware Clustering Aggregate Node Rotation with Sink Relocation (EAC-ASR) protocol and existing Stable Election Protocol (SEP). The performance evaluation of the proposed protocol is performed using the performance metrics
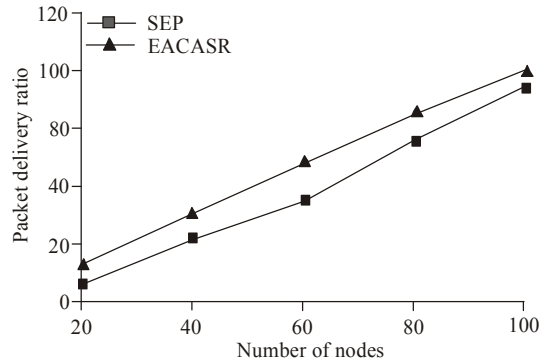

Fig. 5: Packet delivery ratio vs number of nodes

such as Energy Efficiency, End-to-End delay and packet delivery ratio.

Energy efficiency: Energy efficiency is defined as a way of managing the increase in the energy consumption of the network. Figure 3 shows the graph illustrating the relationship between the number of nodes and Energy Efficiency of the proposed protocol and existing protocol. The energy efficiency of the proposed protocol is 96.75 and existing protocol is 87.98. This implies that the proposed protocol achieves high energy efficiency than the existing protocol.

End-to-end delay: The end-to-end delay in the network specifies the amount of time taken by the data to travel from one node to another node or endpoint. Figure 4 shows the graph depicting the relationship between the number of nodes and end-to-end delay of the proposed protocol and existing protocol. The delay produced by the existing protocol is 211.449 ms and the delay produced by the proposed protocol is 172.457 ms. From the graph, it is clearly evident that the proposed protocol achieves lower end-to-end delay than the existing protocol.

Packet delivery ratio: The packet delivery ratio is defined as the ratio of the number of data packets delivered to the destination. Figure 5 shows the graph describing the variation in the packet delivery ratio with respect to the increase in the number of nodes, for the proposed protocol and existing protocol. The packet delivery ratio of the existing protocol is 88.68 and the delivery ratio of the proposed protocol is 95.35. When compared with the existing protocol, the proposed protocol performs well in terms of the delivery ratio. Hence, it is clearly understood that the proposed protocol is highly efficient in terms of the energy efficiency, end-to-end delay and packet delivery ratio, when compared with the existing protocol.

CONCLUSION

In this study, an Energy Aware Clustering Aggregate Node Rotation with Sink Relocation (EAC-

ASR) protocol is proposed to enhance the energy efficiency of the MANET. The access control mechanism of the network is improved, by the energy aware clustering process. Aggregation of data from the nodes is performed using the data collection algorithm. Rotation of the mobile nodes and relocation of the sink are performed, to balance the energy consumption in the network, during the data transmission process. Henceforth, the energy loss occurred due to the continuous multi-hopping concept is mitigated and energy consumption due to the cluster communication is also comparatively reduced. From the simulation results, it is clearly evident that the proposed EAC-ASR protocol achieves reduction in the energy consumption and improvement in the network lifetime. The proposed protocol achieves better performance than the existing DSR, MTPR and EPAR protocols.

REFERENCES

Ayyaswamy, K. and S. Rengaramanujam, 2011a. ETUS: An enhanced triple umpiring system for security and performance improvement of mobile ad hoc networks. Int. J. Netw. Manage., 21(5): 341-359.

Ayyaswamy, K. and S. Rengaramanujam, 2011b. ETUS: Enhanced triple umpiring system for security and robustness of wireless mobile ad hoc networks. Int. J. Commun. Netw. Distrib. Syst., 7(1/2): 153-187.

Barati, M., K. Atefi, F. Khosravi and Y.A. Daftari, 2012. Performance evaluation of energy consumption for AODV and DSR routing protocols in MANET. Proceeding of the International Conference on Computer and Information Science (ICCIS, 2012), pp: 636-642.

Basurra, S.S., M. De Vos, J. Padget, Y. Ji, T. Lewis and S. Armour, 2015. Energy efficient zone based routing protocol for MANETs. Ad Hoc Netw., 25: 16-37.

Costagliola, N., P.G. López, F. Oliviero and S.P. Romano, 2012. Energy-and delay-efficient routing in mobile ad hoc networks. Mobile Netw. Appl., 17(2): 281-297.

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(4): 713-726.

Jain, H.R. and S.K. Sharma, 2014. Improved energy efficient secure multipath AODV routing protocol for MANET. Proceeding of the International Conference on Advances in Engineering and Technology Research (ICAETR, 2014), pp: 1-9.

Loutfi, A., M. Elkoutbi, J. BenOthman and A. Kobbane, 2014. An energy aware algorithm for OLSR clustering. Ann. Telecommun., 69(3-4): 201-207.

Maleki, M., V. Hakami and M. Dehghan, 2014. A reinforcement learning-based Bi-objective routing algorithm for energy harvesting mobile ad-hoc networks. Proceeding of the 7th International Symposium on Telecommunications (IST, 2014), pp: 1082-1087.

Preethi, S. and B. Ramachandran, 2011. Energy efficient routing protocols for mobile AdHoc networks. Proceeding of the International Conference on Emerging Trends in Networks and Computer Communications (ETNCC, 2011), pp: 136-141.

Ramesh, V., K.S. Supriya and P. Subbaiah, 2014. Design of novel energy conservative preemptive dynamic source routing for MANET. Proceeding of the International Conference on Computing, Communication and Networking Technologies (ICCCNT, 2014), pp: 1-7.

Ramrekha, T.A., V.N. Talooki, J. Rodriguez and C. Politis, 2012. Energy efficient and scalable routing protocol for extreme emergency ad hoc communications. Mobile Netw. Appl., 17(2): 312-324.

Sarkar, S. and R. Datta, 2012. A trust based protocol for energy-efficient routing in self-organized MANETs. Proceeding of the Annual IEEE India Conference (INDICON), pp: 1084-1089.

Simaremare, H., A. Syarif, A. Abouaissa, R. Sari and P. Lorenz, 2012. Energy consumption analysis of modified AODV routing protocol under random waypoint and reference point group mobility models. Proceeding of the International Conference on Advanced Computer Science and Information Systems (ICACSIS, 2012), pp: 47-51.

Srinivasan, P. and P. Kamalakkannan, 2012. REAQ-AODV: Route stability and energy aware QoS routing in mobile Ad Hoc networks. Proceeding of the 4th International Conference on Advanced Computing (ICoAC, 2012), pp: 1-5.

Suresh, H.N., G. Varaprasad and G. Jayanthi, 2014. Designing energy routing protocol with power consumption optimization in MANET. IEEE T. Emerg. Topics Comput., 2(2): 192-197.

Yitayal, E., J.M. Pierson and D. Ejigu, 2014. A Balanced Battery Usage Routing Protocol to Maximize Network Lifetime of MANET Based on AODV. In: Balandin, S. *et al.* (Eds.), NEW2AN/ruSmart, 2014. LNCS 8638, Springer International Publishing, Switzerland, pp: 266-279.