Energy Efficient Routing Protocol Prolonging Network Lifetime For MANETs

Himanshu Sharma, Omkar Singh, Vinay Rishiwal, MIH Ansari

Abstract: Mobile Ad-hoc Network (MANET) is a group of mobile nodes, each of which communicates over wireless channels. Wireless networks have perceived a detonation of attention from patrons in recent years due to their solicitations in mobile and peculiar communiqué. One of the foremost restraints in MANET is high prospect of letdown due to energy-exhausted nodes. So, if the path selected for communication has minimum battery life then the path breaks early and re-discovery of path occurs again which causes overheads in network. In this paper, an Energy Efficient Routing Protocol (EERP) has been proposed and evaluated. This protocol selects an energy rich path amongst alternative disjoint paths between a source and destination pair. EERP prevents unequal consumption of nodes' energy. In other words, it felicitates the balanced energy consumption in order to minimize the breakages. As a result, probability of communication path breakage gets reduced. This approach also reduces routing overheads caused by frequent node failures during communication. Simulation results show that EERP reduces E2E delay 36%-38%, prolongs network lifetime 28%-33%, packet delivery ratio 18%-23%, minimizes energy consumption 26%-30% and reduces packet loss 32%-36%. All over EERP performs well as compare to its counterpart of EE-HRP, SEEC and MC-TRACE for all considered performance parameters over different network size.

Index Terms: MANETs; Routing; EE-HRP; SEEC; MC-TRACE; EERP.

1 INTRODUCTION

Mobile Adhoc Network (MANETs) represents adaptable type of network and works in various situations. MANETs [1] has dynamic topology changes overtime. All nodes in MANETs support unobstructed movement. MANET works with the medium of wireless communication that is susceptible to failure of connection and interference. Therefore, participating nodes reconstruct the network themselves. MANETs [2] are characterized by several challenges like frequent topological changes, energy efficiency, security and much more. The challenges get severe when dealing with different configuration nodes in the network. The potential applications in MANET [3] have opened a new horizon in the field of communication. MANET is composed of mobile nodes having different hardware configurations. The nodes are self-configuring to support the communication and interchange data with any other node in the network. The problem in routing (usually shortest path) [4] approach with homogeneous network is that nodes along shortest paths may have low energy batteries, which can be exhausted faster due to extreme use. MANET is wireless network of self-organizing and multi-hop system with transceiver and receiver radio nodes. Due to restriction of limited radio range two nodes can't communicate unswervingly and need help of other nodes for transmitting the data packets. MANET [5] does not have any structured network like others and have many characteristics such as dynamic topology, self-organizing network, unidirectional wireless links. Basically MANET [6] specially used military scenarios, mobile communication cooperation, and communication in emergency scenarios, sensor network and wireless access.

- *Himanshu Sharma, Computer Science and Engineering, I.F.T.M. University, Moradabad, India; E-mail: cs.himanshu@gmail.com*
- *Omkar Singh, Computer Science and Information Technology, M.J.P. Rohilkhand University, Bareilly, India*
- *Vinay Rishiwal, Computer Science and Information Technology, M.J.P. Rohilkhand University, Bareilly, India*
- *MIH Ansari, Computer Science and Engineering, I.F.T.M. University, Moradabad, India*

Efficient route should be constructed between the nodes in MANET [7] for effective communication with router and end system. A node in MANET [8] smoothly works and cooperates like conformist routing protocol build up with assumptions of trusted and cooperative nodes. In MANET [9], energy is a crucial issue during transmitting a data packet successfully in energy efficient manner. Each node has its own energy level to perform operation. Node's energy is consumed during transmitting and receiving the data packets among the nodes [10]. When packets are dropped by the node that means nodes have not sufficient energy for transmitting the data packets. Security issues arise due to absence of infrastructure in MANET [11], wireless medium usage and communication among the nodes can be easily bothered. Mobile nodes can be contaminated by malicious nodes and need to perceive intrusion executed by every node using a particular strategy [12]. Since mobile node has limited power capacity, therefore intrusion detection system can be tackled in energy efficient manner for prolonging network lifetime and network reliability could be maintained. Multipath routing permits the formation of multi-paths between a one source and one destination. These multi-paths could be secondhand to recompense for the vigorous and erratic environment of ad hoc MANET [13]. Multi-path strategy is characteristically projected in directive to escalation the consistency of data broadcast and balances the load throughout the network [14]. Multi-path routing applications include QoS, reliability, power consumption and load balancing. Multi-path strategy provides route flexibility from an accountability forbearance viewpoint. If numerous paths are secondhand concurrently for transmitting the data, the cumulative bandwidth of the route may placate the bandwidth prerequisite of application [15].

2 RELATED WORK

N. Kumari et al. [1] has proposed multi-path routing (AMR) and network size defined carefully in terms of length and width. In this approach network size is defined before initiated then other broadcasting information are defined such as transmitting power, length of packet, pattern of bit and total number of packets to be sent using multipath with energy efficient manner. The hop information is maintained holding number of mobile nodes, network size and neighbor's nodes.

Due to signal direction and node movements, loss paths are evaluated and given high signal power. Developed algorithm further improves path losses, signal strength and energy consumption. Clustering Algorithm (CA) [2] proposed by N. Khatoon and Amrirtanjali focuses on mobility and energy effectiveness problems in MANET by PSO. Cluster heads selection considers mobility and residual energy with the degree of connectivity for selecting of CHs which could work long time in network. Cluster formation is executed using the clustering algorithm with PSO. Proposed algorithm performs better in terms of prolonging network lifetime, cluster formation, packet delivery and energy consumption. If $E_{residual}(ch_a)$ be the remaining energy of CH and *STD* is stability deviation then strength of CH can be calculated as follows:

$$S(ch_a) = \frac{E_{residual}(ch_a)}{STD(ch_a)} \quad (1)$$

AODV [3] creates route on the basis on demand and uses three types of messages route request *RREQ*, route error *RRER* and route reply *RREP* for data packets transmission and establishing route. DSDV is called hop to hop protocol and works like table driven protocol. In this, each node contains its own table including route information from one node to other nodes and hop distances. DSDV minimizes E2E delay for packets data forwarding and reduces setup process. Trust based route selection algorithm TBRS [4] finds the optimum paths using trustworthy neighbors. It saves the energy throughout network and prolongs network lifetime. During the communication, source node discovers multi-route with destination but sometimes loses the trust with destination, but in TBRS destination node maintains the trust with intermediate nodes of multi-hop route. MDA-AODV [7] precludes nodes with high mobility till threshold value in route discovery process. In RREP when an *RREQ* packet reaches the destination or any intermediate node has active route towards destination, then MDA-AODV selects best path among the discovered paths. It provides stable and much reliable route for data packet transmission. RRR approach [10] establishes the routes to destination through dominations nodes. In domination set all nodes can be connected within the network very quickly. Therefore, destination finding is easy. When any route failures happens then domination nodes catch up new route very quickly and saves by dropping packets, as well as it floods route failure reports to other domination nodes. Initially domination nodes makes the adjacency matrix where each node finds its neighbor node by sending *HELLO* message and neighboring nodes list is to be sent for adjacency nodes for preparing adjacency matrix. This approach reduces E2E delay and enhances packet delivery ratio. Packet transmission probability can be calculated as follows:

$$p_{i,j} = \frac{(\tau_{ij}^{\alpha})(\tau_{ij}^{\beta})}{\sum (\tau_{ij}^{\alpha})(\tau_{ij}^{\beta})} \quad (2)$$

Specific symbols and notations used in Eq. (2) have been described by author in [10]. RA-AODV [11] is based on RREQ forwarding control packets finding all possible existing nodes from source node to destination node. There after all paths are arranged according to their hop counts increasingly. RA-AODV selects first path and check all QoS requirements satisfying of E2E delay and bandwidth consumption. M-DSR [12] shares the information within the network to all nodes for building global repute system and makes precise decisions. All observations from the nodes are identified and exchanged throughout the nodes for improving the performance of network in terms of network traffic. Every node monitors traffic and sends to neighboring nodes as well as keeps the reputation value. The reputation values of *X* node with respect to *Y* node can be calculated as follows:

$$R(X) = \frac{SP(X)}{FP(X)} \quad (3)$$

MLP [13] uses hidden layers neurons for transmitting data using multipath strategy; supervised learning is used to learn the network. Neurons multi layers functions allow network for learning input, so that network could work in efficient manner. MLP is a weighted sum of inputs x_i with their weights w_{ij} as shown in Eq (4).

$$A_j(\bar{x}, \bar{w}) = \sum_{i=0}^{n} (x_i, w_{ij}) \quad (4)$$

FLOW-AODV [14, 16] uses internet and without internet spoofing, in case of no IP spoofing exist, RREQ process added new features. It enables hop neighboring meters and detects attackers using received routes counts. First it checks the neighbor is one hop or not, if yes then updates information throughout the network. It discards the flowing requests and improves the network performance. Proposed model [17, 18] includes three main characteristics channel modeling, queuing modeling and threshold based transmission data and support QoS on physical layer. Channel modeling includes path loss, channel fading, density and path gain. Threshold apparatuses to compute video packets with threshold and queuing model reduce E2E delay, bandwidth and enhances throughput and PDR. If g_s^f be the channel gain then probability density function can be defined as follows:

$$P(g_s^f = b) = \exp(-\frac{b}{\Omega})\frac{1}{\Omega}.b \geq 0, f \in F \quad (5)$$

Specific symbols and notations used in Eq. (5) have been described by author in [17]. ANT-DSR [19, 20] paradigms an optimal route from source node to destination node including congestion, number of hops and residual energy on each node. Every node keeps the network information in routing table [21, 22]. The pheromone value of link and signal strength can be calculated as follows:

$$PC_{ij} = \frac{Rn_{ij} \times En_j}{Cn_j \times Hn_{ij}} \quad (6)$$

$$RSS_{ix} = \frac{G_e \times G_t \times S_t}{(4\pi \times \frac{x}{\lambda})^2} \quad (7)$$

Specific symbols and notations used in Eq. (6 & 7) have been elaborated by author in [19]. JAYA [23-25] algorithm has been tested with existing benchmark functions; it solves constrained and unconstrained problems. JAYA provides the effective solution of the problem; it minimizes the delay and bandwidth. The delay and bandwidth using the function can be estimated as follows:

$$D(p(s,t)) = \sum \frac{e \in P(s,t) delay(e) +}{\sum e \in P(s,t) delay(n)} \quad (8)$$

$$B(p(s,t)) = \min\{ bandwidth \quad (e), e \in p(s,t)\} \qquad (9)$$

Specific symbols and notations used in Eq. (8 & 9) have been described by author in [24]. Energy Efficient Hybrid Routing Protocol (EE-HRP) [26] uses routing approach which balances and minimizes the energy utilization throughout the network and evades fatigue of discrete nodes. Multiple threshold values are used to calculate residual energy of the node in the network. Energy aware algorithm is implemented for balancing the energy consumption. Implemented algorithm prevents nodes from early battery collapse and prolongs network lifetime. Signal and Energy Efficient Clustering (SEEC) [27] algorithm is based on energy level and signal strength to improve the performance of network. Proposed algorithm focuses on CH election and repairs and avoids death of CH. SEEC focuses special care of CH formation and retains alive after initial formation. It avoids re-election of CH when energy level and signal strength reaches convinced threshold values. Multicasting through Time Reservation using Adaptive Control for Energy efficiency (MC-TRACE) [28] is based on cross layer design, where functionality of MAC layer and network layer are achieved by a single incorporated layer. The basic design strategy behind MC-TRACE is to establish and uphold an active multicast tree bounded by reflexive mesh. Integrating and reengineering of mesh and tree structures makes extremely energy competent for real time data multicasting. Performance evaluation of existing routing protocols with its merits and demerits has been given in Table 1.

TABLE 1

EXISTING ROUTING APPROACHES WITH MERITS AND DEMERITS

Approach	Objective	Drawback
AMR [1]	Provides high signal power, improves path loss and reduces energy consumption.	AMR is not scalable
CA [2]	Prolongs network lifetime, reduces energy consumption, enhances packet delivery ratio.	Sustenance only heterogeneity, evades data accumulation and idleness
AODV [3]	Minimizes end to end delay, reduces setup process.	High unconventionality time prerequisite, essential scalability
TBRS [4]	Enhances network lifetime and throughput, reduces energy consumption.	Link cost enhances
MDA-AODV [7]	Provides reliable route, uses multipath routing and reduces energy consumption.	Irrelevant information assortment
RRR Approach [10]	Reduces E2E delay, enhances packet delivery ratio and improves packet transmission probability.	Supports only heterogeneous environment, not scalable
RA-AODV [11]	Reduces end to end delay and bandwidth consumption and provides scalability.	Works on lesser networks, packet loss in high dynamic topology
M-DSR [12]	Improves network traffic and network performance, increases throughput.	Downstairs in multicast routing
MLP [13]	Prolongs network lifetime, reduces energy consumption and decreases E2E delay.	Requires high time complexity
FLOW-AODV [14]	Improves network performance, enhances throughput and E2E.	High link cost, inappropriate weight dissemination
Proposed Model [17]	Reduces packet loss, E2E delay, bandwidth consumption, enhances throughput and PDR.	Not scalable
ANT-DSR [19]	Provides high signal strength, reduces bandwidth consumption, and improves network reliability.	High link cost
JAYA [24]	Minimizes delay and bandwidth.	Does not support scalability
EE-HRP [26]	Reduces power consumption, enhances PDR, reduces E2E and prolongs network lifetime	Network performance degrades on high mobility of nodes
SEEC [27]	Prevents death of CH, enhances network lifetime and reduces energy utilization	Protocol is not scalable.
MC-TRACE [28]	Minimizes energy utilization, improves QoS and bandwidth.	Deviation from highly dynamic scenarios.
EERP proposed protocol	Minimizes E2E delay, prolongs network lifetime, increases packet delivery ratio, enhances throughput, minimizes packet loss and energy consumption.	-

3 ENERGY EFFICIENT ROUTING PROTOCOL (EERP)

In this paper, energy efficient routing protocol called EERP has been proposed. Generally *RREQ* is advertised by source node, many routes are discovered to the destination and packets will be transmitted through these routes without significant quality of link. But in EERP, the selection of route is completely different when *RREQ* received and broadcasted, the source node has two types of information to find optimized and shortest path with minimum energy consumption. The source node includes:

- Energy consumed in route discovery and route distance.
- Individual node's energy information.

Less energy consumption route has shortest path and highest level of energy. Sender uses highest energy level route for transmitting the packets and estimates consumption of energy. EERP initiates route discovery process on failing all routes to destination. When route fails, sender selects alternate path from routing table having minimum energy and shortest path. The optimal route with less energy and distance can be estimated as:

$$OR_a = \frac{\sum \alpha(n) \in O_R . Energy \quad \alpha(n)}{\sum \alpha \in V . Energy \quad (\alpha)} \tag{10}$$

where *α* shows vertices nodes with optimum route O_R and *V* represents all vertices nodes in the network. It selects highest energy route by comparing energy level of all routes. Alternative route is estimated as per its distance. EERP selects route of highest energy level from routing table of least route distance. The estimation of shortest route can be calculated as:

$$OR_b = \frac{\sum \beta(n) \in O_R . Dist \ \ \beta(n)}{\sum \beta \in E} \tag{11}$$

where *β* represents edges with optimum route and *E* shows all links within the network. It compares optimum links within the network. In the simulation of EERP, OTcl script includes topology and network parameters such as node speed, traffic source, queue size, number of nodes, protocols and other parameters also. Algorithm includes following input parameters:

S: Source
D: Destination
RD: Route Discovery
BR-RP: Broadcast Routing Packets
DN: Direct Nodes
SRT: Source Routing Table
B: Beacon
SET: Source Energy Table
$Info_E$: Energy Information
$Info_L$: Location Information
HC: Hop Count
PRD: Periodic Route Discovery
PBM: Periodic Beacon Message

Algorithm: EERP

---

1. ***process** Select **S** and **D***
2. ***for RD** initiate by **S***
3.   ***BR-RP** to **DN***
4.   *Update **SRT***
5.   ***S** initiates **B***
6.   *Update **SRT** ← $Info_E$ & $Info_L$*
7. ***end for***
8. ***If**(**Energy**>= highest && **Dist**<= lowest && **HC**<=lowest) Eq. (1 & 2)*
9. *Select Transmission route*
10. ***else***
11.   ***If**(**Energy**>=highest && **Dist**>=highest && **HC**<=lowest) Eq. (1)*
12.   *Select Transmission route*
13.   ***else***
14.   ***If**(**Energy**<=lowest && **Dist**<=lowest && **HC**<=lowest) Eq. (2)*
15.   *Select Transmission route*
16.   ***end if***
17.   ***end if***
18. ***end if***
19. *Send **PRD***
20. *Send **PBM***
21. ***end process***

EERP initially send *RREQ* for collecting the information of existing routes to the destination, energy function computes the network for locating nodes of higher energy nodes. Sender node will receive *RREP* information on the existing routes towards receiver node with their level of energy. Energy function finds the routes with highest energy after comparing and route's distance is considered. Optimum route contains higher energy level and minimum distance. Higher energy level route has the highest priority. If higher energy route does not have the shortest distance, in that case it is chosen but has the less priority. If the intermediate nodes are situated between sender and receiver node with less energy compared with other nodes within the network then energy function selects the route based on existing shortest distance. In all the scenario, with energy level and distance route is selected by energy function has minimum energy consumption and prolongs network lifetime.

4 SIMULATION FRAMEWORK

Proposed protocol EERP has been simulated on NS-2.34 and compared with existing routing protocols EE-HRP, SEEC and MC-TRACE with diverse network size 10-50 nodes. The nodes are blowout in the network area 1000*1000 m2 tremblingly. The reflected parameters for simulation to judge the efficiency of protocols are quantified in Table 2.

Table.2: *Simulation Parameters*

Parameters	Values
Simulation Time	500 seconds
Topology Size	1000m x 1000m
Number of Nodes	10, 20, 30,40 and 50
Routing Protocols	EE-HRP, SEEC, MC-TRACE, EERP
Traffic type	CBR
MAC	IEEE 802.11
Data Rate	2 Mbps
Transmission Range	250 mtr.
Initial Energy	1 Joule

5 PERFORMANCE METRICS

Performance metrics includes simulation experiments are as follows

5.1 End-to-end delay

E2E delay considered average time taken successfully transmitted packets from source to destination. If *R* be the receiving node and *S* be the source node then E2E delay can be premeditated as follows:

$$E2E\_Delay = \frac{\sum_{i=1}^{n} R_i - S_i}{n} \tag{12}$$

5.2 Network Lifetime

Nodes which have zero energy or losses their energy during the simulation are called exhausted nodes or dead nodes. Dead nodes affect the performance of network lifetime.

$$Network\_Lifetime = \sum_{i=1}^{n} (Energy \ (i) = 0) \tag{13}$$

5.3 Packet delivery ratio

PDR is the ratio of data packets delivered to the destination node to the data packets generated by the source. The higher PDR represents better performance of the network. PDR can be calculated as follows:

$$PDR = \frac{Number \quad of \quad packets \quad received}{Number \quad of \quad packets \quad transmitted} \qquad (14)$$

5.4 Throughput

Throughput shows number of bits received by destination successfully. It can be calculated as follows:

$$TH = (Number \quad of \quad bytes \quad received \times \frac{8}{Simulation \quad Time}) \times 1000 \quad kbps \qquad (15)$$

5.5 Average energy consumption

Energy consumption refers spent energy of the nodes within the simulation. It is obtained by estimating energy of each node at the end of simulation. Energy consumption model is used to calculate total energy consumption is as follows:

$$E_{N/M} = l_{n>0}(l_{M=N} E_{T_{ack}} + l_{M \neq N} E_{R_{ack}}) + _{m>0}(l_{M=N} E_{T_{pck}} + l_{M \neq N} E_{R_{pck}}) \qquad (16)$$

where

$E_{N/M}$ = Energy consumed at node N corresponding to node M

$E_{T_{ack}}$ = Energy consumed for packet acknowledgement

$E_{T_{pck}}$ = Energy consumed for packet transmission

$E_{R_{ack}}$ = Energy consumed for receiving of acknowledgement

$E_{R_{pck}}$ = Energy consumed for receiving of packet

$$l_p = \begin{cases} 1 & p \ is \ true \\ 0 & otherwise \end{cases}$$

6 SIMULATION RESULTS

The performance of the proposed protocol has been measured in terms of end to end delay, Network Lifetime, PDR, throughput, average energy consumption and packet loss. Simulations were run for EE-HRP, SEEC and MC-TRACE with specific replication parameters as specified in Table 2. E2E delay has been checked on varying size of network as shown in Fig. 1. E2E delay provides the reliability of network and reduces energy consumption. EERP has less delay than considered routing protocols EE-HRP, SEEC and MC-TRACE. EERP reduces the delay 36%- 38% than EE-HRP, SEEC and MC-TRACE.

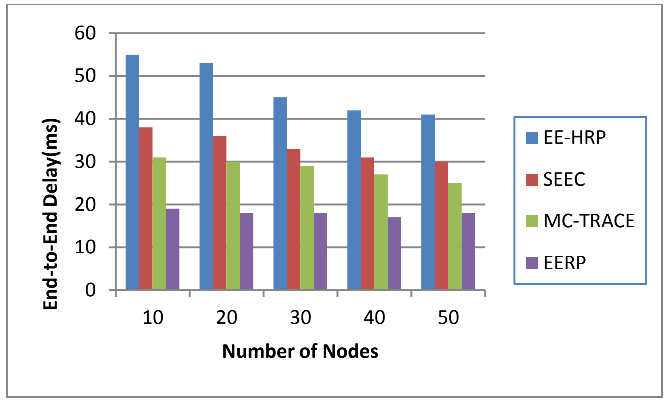

Fig. 1: *End-to-end delay*

Network lifespan has been considered in terms of number of exhausted nodes on different network size. Fig. 2 represents that in EERP, fewer nodes are lifeless for all the values of replication after 48 minutes. 60% nodes of EE-HRP, SEEC and MC-TRACE die at a replication of 135 minute. Although in case of EERP, 50% of nodes are lifeless after 155 minutes. Therefore, it is clear that network lifetime enhances 28%-33% in EERP than EE-HRP, SEEC and MC-TRACE.

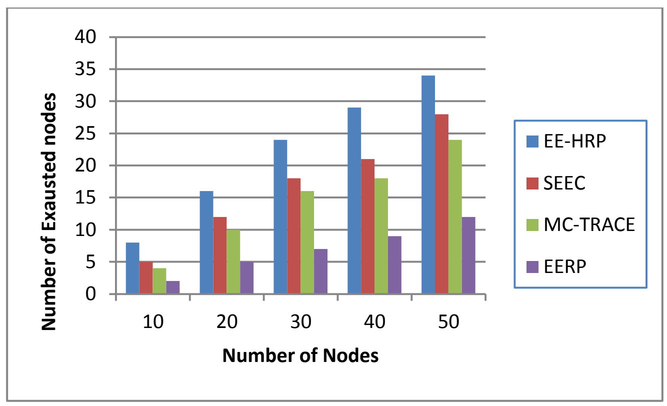

Fig. 2: *Network Lifetime*

Link a failure tends to packet loss, PDR shows received packets successfully with their destination. If any link failure occurs then alternate path is selected for transmitting the data packets. Minimum number of packets drop in the network represents the reliability of protocols. From the simulation results as shown in Fig. 3, it is clear that proposed routing protocol EERP gives better results 18%-23% than EE-HRP, SEEC and MC-TRACE.

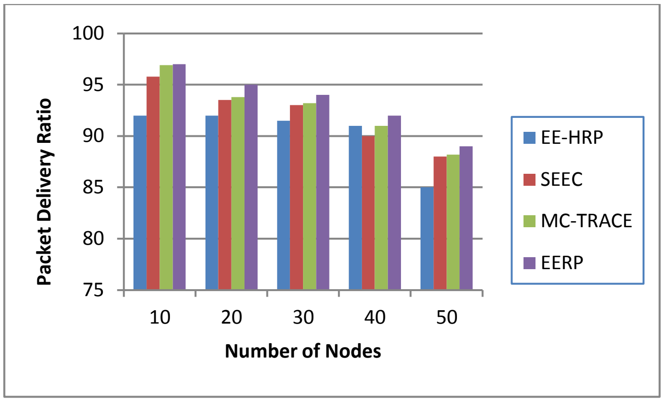

Fig. 3: *Packet Delivery Ratio*

In Fig. 4, an analysis of Throughput against different network size has been shown. EERP protocol performs better than considered routing protocols EE-HRP, SEEC and MC-TRACE. High throughput reduces delay and energy consumption. EERP provides network reliability and decreases packets loss.

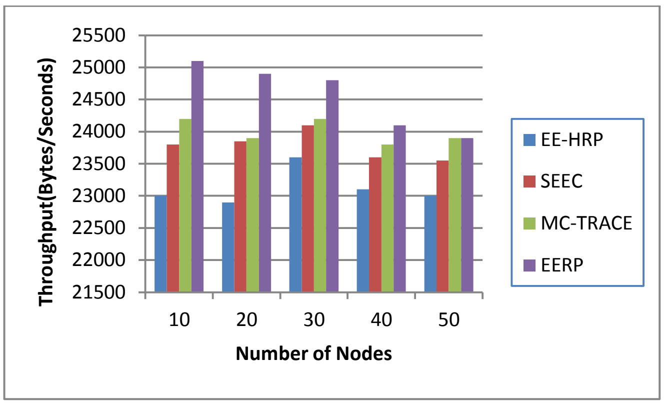

Fig. 4: *Throughput*

Average energy consumption shows average variance of the entire delivered energy and entire remaining energy with the network. Fig. 5 exemplifies the comportment of EERP, EE-HRP, SEEC and MC-TRACE. Simulation results represents that EERP reduces energy consumption 26%-30% than EE-HRP, SEEC and MC-TRACE protocols from energy feasting point of interpretation and prolongs network lifetime.

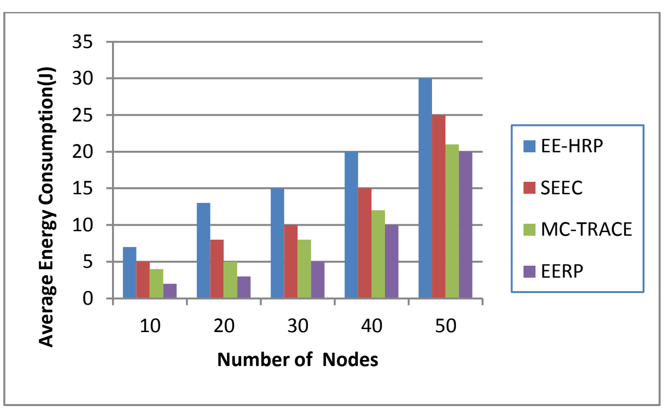

Fig. 5: *Average Energy Consumption*

Fig. 6 shows the packet loss in network of different network size. From the simulation results it is clear that proposed routing protocol EERP reduces packet loss 32%-36% than considered routing protocols EE-HRP, SEEC and MC-TRACE. Minimum packet loss saves the energy and enhances network lifetime.

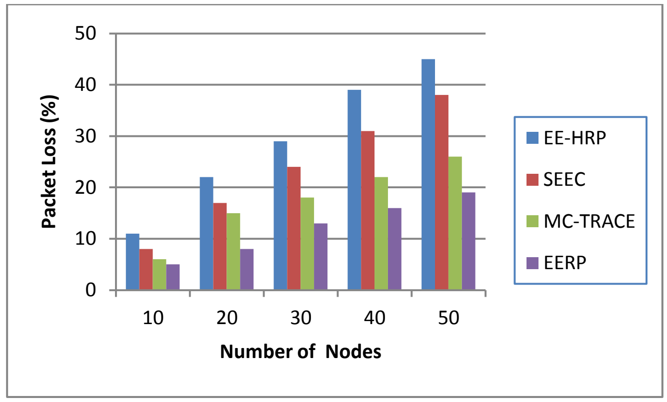

Fig. 6: *Packet Loss*

7 CONCLUSION

In this paper, a new routing protocol EERP has been proposed, analyzed and evaluated over extensive simulation parameters under various network size 10-50 nodes over area 1000 * 1000 m^2 for MANETs. It is seen that EERP reduces E2E delay 36%-38%, prolongs network lifetime 28%-33%, packet delivery ratio 18%-23%, minimizes energy consumption 26%-30% and reduces packet loss 32%-36%. All over EERP performs well as compare to its counterpart EE-HRP, SEEC and MC-TRACE for all considered performance parameters over different network size.

REFERENCES

[1] N. Kumari, R. Kumar and R. Bajaj "Energy Efficient Communication Using Reconfigurable Directional Antenna in MANET", ICSCC, vol.125, **2018**, pp. 194-200.

[2] N. Khatoon and Amrirtanjali, "Mobility Aware Energy Efficient Clustering for MANET: A Bio-Inspired Approach with Particle Swarm Optimization",Wireless Communications and Mobile Computing, vol.2017 , **2017**, pp. 1-12.

[3] P.Yadav, R. Agarwal and K. Kashish "Performance Evaluation of ad hoc Wireless Local Area Network in Telemedicine Applications", ICSCC, vol. 125, **2018**, pp. 267-274.

[4] E. Natalizio, D. Cavalcanki, K. Chaudhary et al. "Advances in Wireless Communication and Networking for Cooperating Autonomous Systems", Adhoc Networks, vol. 68, **2018**, pp. 1-194.

[5] S. Aluvala, K.R. Shekhar and D. Voodnala, "An Empirical Study of Routing Attacks in Mobile Ad-hoc Networks", ICCC, vol.92, **2017**, pp. 554-561.

[6] S. Tarapiah, K.Aziz and S. Atalla "Analysis the Performance of Vehicles Ad Hoc Network", ISICO, vol. 124, **2017**, pp. 682-690.

[7] A. Swidan, H.B.A. Eng, R. Saifan et al. "Mobility and Direction Aware Ad-hoc on Demand Distance Vector Routing Protocol", MobiSPC, vol. 94, **2017**, pp. 49-56.
[8] D. Kanellopoulus, "Congestion control for MANETs: An overview", ICT Express, vol. 22, **2018**, pp. 841-858.
[9] A.A. Chavan, D.S. Kurule and P.U.Dewre "Performance Analysis of AODV and DSDV Routing Protocol in MANET and Modifications in AODV against Black Hole Attack", ICCCV, vol. 79, **2016**, pp. 835-844.
[10] K.G.Preetha and A. Unnikrishnn, "Improving the Routing Performance of Mobile Ad hoc Networks Using Domination Set", ICICT, vol. 46, **2016**, pp. 1209-1215.
[11] S. Tyagi, S. Som and Q.P. Rana, "A Reliability based Variant of AODV in MANETs: Proposal, Analysis and Comparison", ICCCV, vol.79, **2018**, pp. 903-911.
[12] Q.M. Yassen and M. Aldwairi "An Enhanced AODV Protocol for Avoiding Black Holes in MANET", EICM, vol. 134, **2018**, pp. 371-376.
[13] A.Pal, J.P.Singh and P. Dutta "Path length prediction in MANET under AODV routing: Comparative analysis of ARIMA and MLP model", Egyptian Informatics Journal, vol.16, **2017**, pp. 103-111.
[14] M.R.Hasan, Y. Zhao, Y. Luo et al. "An Effective AODV-based Flooding Detection and Prevention for Smart Meter Network", ICIIK-IoT, vol.129, **2018**, pp. 454-460.
[15] F.T.A Dhief, N. Sabri, M.S. Salim et al. "MANET Routing Protocols Evaluation: AODV, DSR and DSDV Perspective", MATEC Web, vol.150, **2018**, pp. 190-207.
[16] G. Berretha, P.Dvorak, M. Luglio et al. "Improvement of Ka-band satellite link availability for real-time IP-based video contribution", ICT Express, vol. 3, **2017**, pp. 124-127.
[17] Asha and G. Mahadevan, "A combined scheme of video packet transmission to improve cross layer to support QoS for MANET", Alexandria Engineering Journal, vol. 67, **2018**, pp. 1501-1508.
[18] A.M. Desai and R.H. Jhaveri, "Secure routing in mobile Ad hoc networks: a predictive approach", International Journal of Information Technology, vol.23, **2018**, pp. 1-12.
[19] D. Sarkar, S. Chaowdhary and A. Majumder, "Enhanced-Ant-AODV for optimal route selection in mobile ad-hoc network", Journal of King Saud University - Computer and Information Sciences, vol.28 , **2018**, pp. 1-29, 2018.
[20] S. Mueller, R.P. Tasang and D. Ghosal, "Multipath Routing in Mobile Ad Hoc Networks:Issues and Challenges", PTANS, vol. 13, **2018**, pp. 1-10.
[21] X. Yang, Q. Chen, C. Chen et al. "Improved ZRP Routing Protocol Based on Clustering", ICICT, vol. 131, **2018**, pp. 992-1000.
[22] S.D. Mohanty, V. Thotakura and M. Ramkumar "An Efficient Trusted Computing Base for MANET Security", Scientific Research, vol. 5, **2016**, pp. 192-206.
[23] H. Elwahah, M. Gamal, A.A. Salama et al. "A Novel Approach for Classifying MANETs Attacks with a Neutrosophic Intelligent System based on Genetic Algorithm", Security and Communication Networks, vol. 2018 , **2018**, pp. 1-10.
[24] T. Sudhakar and H.H. Inbarani, "Intelligent Path Selection in Wireless Networks using Jaya Optimization", RoSMa, vol.133, **2018**, pp. 976-983.
[25] A. Koujalagi, "Considerable Black Hole and Analyzing its Performance on AODV Protocol in MANET (Mobile Ad Hoc Network)", AJCSIT, vol.6 , **2018**, pp. 1-8.
[26] S. Ghode and K. Bhoyar, "Optimized Energy Efficient Hybrid Routing Protocol (EE-HRP) for Minimum Battery Power Consumption in MANET", IES, vol. 18 , **2018**, pp. 59-73.
[27] A. Roy, M. Hazarika and M.K. Debbarma, "Energy Efficient Cluster Based Routing in MANET", ICCICT, **2012**, pp. 1-5.
[28] B. Tavil and W.B. Heinzelman, "Energy-Efficient Real-Time Multicast Routing in Mobile Ad Hoc Networks", IEEE TRANSACTIONS ON COMPUTERS, vol. 60, **2011**, pp. 707-722.