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A Link Cost Prediction Method Based on Node Energy Computation for Dynamic Route Switching in MANET

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Abstract: The creation of an ad hoc network suffers from technical barriers due to its limited energy source, unpredictable wireless connectivity, and dynamic network topology, which is a challenging concern in predicting link quality among the nodes. Therefore, it is essential to predict link trade-offs between the nodes in such a dynamic network and also preserve the energy resource to have a better link and longer life of the network. This paper presents an efficient link cost prediction method (LCPM) for dynamic route switching based on the node energy source. The LCP method determines the stable and minimum link cost route to minimize the packet loss which might cause due to node mobility and link failure in reactive routing protocols. It initially suggests a mechanism to predict the least energy utilization route between source and destination to reduce the routing overhead. Later, it defines the methodology of establishing the least link cost route using LCP to achieve better throughput and low packet loss. The experiment evaluation results through varying nodes scalability show the effectiveness of the proposal. It shows the improvisation of LCPM through achieving an average of 3.35% better PDR, 2.93% of lower routing overhead and 8.105J lower energy consumption. It also achieves an average of 90ms with 20 nodes and 50ms with 100 nodes lower E-2-E delay in compare to the existing methods.

Keywords: Link cost prediction, Energy saving, Dynamic route switching, Routing, MANET.

1. Introduction

Routing protocols have to react quickly to link failure, while at the same time minimizing the unavoidable overhead and conserving energy sources. In such cases, a strong direction is required for the ability to believe a link cost before initiating a routing. Several studies on link cost and energy conservation have been explored [1, 2] in the past. But most of them are focusing on controlling packet rate transmission or routing protocols and link layer alterations. In such cases, it is challenging to keep a node operating longer without knowing the link cost among the nodes. Also, in a few application scenarios of the sensor networks and dynamic ad hoc networks, it may not be suitable to change the battery of the device. Hence, it is highly essential to predict a link cost between nodes before routing. Link costs are associated with energy utilization for the mobile devices in a communication network and are a major part of the energy and link-based routing protocols that require more efficient solutions to increase the throughput and lifetime of the network [3, 4].

MANET does not depend on pre-organized network structure, so it can employ efficiently where no proper infrastructures are available. This is very helpful where communication networks need to be set up quickly and where non-existent communication infrastructure exists, such as in disaster situations, geographically remote locations, and so on. However, to have a quality routing an end-to-end link cost based on the energy consumption should be lowest and assured [5]. Several energy-efficient protocols were recommended for energy saving in literature but very few works are focused on link cost estimation.

Chandravanshi et al. [6] worked on adaptive multipath multichannel energy efficient (MMEE) routing approach based on the energy consumption, bandwidth, queue and utilization of a channel for route selection. It aims to balance to network load through multichannel to avoid the data collision, and the reliability of the route was predicted based on the node energy. The results show an improvisation in packet delivery ratio (PDR). Since, the multipath routing achieved here through dividing the existing bandwidth multiple channels which attains higher network overhead initially and same time it with increasing number of nodes it attains higher energy consumptions.

Lim et al. [7] proposed a "RandomCast" method for the proximity nodes to decide whether to overhear or not based on the energy and routing efficiency. Routing efficiency is an essential part for dynamic routing protocols which needs to overhear to get the network information. The designed method discards the redundant broadcasting packets to preserve the energy losses and making an efficient balance between energy and routing performance. It primarily identifies the factors that need to consider for adaptive energy-efficient communication for the overhearing/rebroadcast decision. The obtain results shows an improvisation in PDR with energy efficiency, but with high overheads in the network.

Wang et al. [8] suggested a localized energy-aware restricted neighborhood routing (LEARN) which assure the energy efficiency route to destination. It determines the transmission power or the battery residual level of the mobile node. It investigates the routing cost to reduce the energy losses in MANETs. It presents a critical network model for computing path efficiency through a critical transmission radius of LEARN. We derive the mechanism of RandomCast and LEARN to incorporate the reduction of overhearing and to predict the energy efficient path for routing.

All of these ideas focus on minimizing energy savings as much as possible. However, due to limited transmission resources and high mobility, MANETs often make a synchronization error, which cause energy loss and requires a lot of additional energy to achieve results. Therefore, effective estimation of the link cost makes it very effective for energy saving as well as in maximizing throughput. Most existing link cost estimates do not take into account the actual energy needs during routing, as they do not take into account the additional energy consumption to control packet switching at the data link layer [9]. In the case of the 802.11b communication model, the level of transmission energy for relay and control is higher in comparison to normal data transmission packets. The tracking effect is caused by the frequent loss of the connection, which affects the loss of node data packets, causing a large number of control packets to be switched between the source (SRC), intermediate, and destination (DEST) nodes. This leads to additional energy losses over the line.

Several energy-aware routing protocols are proposed to determine the transmission power or the battery residual level of the mobile node. This energy-aware routing protocol through investigating the routing cost and path selection might reduce the energy losses in MANETs [10]. In the past several routing protocols are proposed to extend the lifetime of the node and network, in such multipath routing is mostly preferred. In the process of multipath routing, the source node selects the best route among multiple routes. This reduces the repetition of path discovery processes in case of link failure because alternate paths are available in the cache for easily switch to reduce energy utilization and also enhance throughput with low latency. So, in this proposal we employ multipath routing to have an optimized routing for MANET.

In this paper, we present an effective link cost prediction method (LCPM) for dynamic route switching based on computing energy efficient path (EEP) between the SRC and DEST node, and the pre-estimated energy needed in a path for the communication. It aims to contribute the following to achieve an enhancement in optimize routing:

1) A multipath route to destination through predicting the neighbour node energy.
2) A node energy identification process by EEP for energy efficient route construction.
3) EEP identify the highest energy node in the routing process and determine the number of hops, total distance, and least link cost to create an efficient route.
4) The prediction of EEP is made through deriving the procedure of RandomCast [7] and LEARN [27] to build the energy efficient routes to the destination.
5) Later we predict the low link cost path for the energy efficient (EE) routing and dynamic route switching to achieve better PDR and low delay and overhead.

The subsequent paper is structured into 5 sections. Section 2 discuss the related works relevant to energy-efficient routing to have a low link cost. The section 3 describes the proposed link cost prediction method (LCPM) for dynamic route switching. Section 4 describes the result analysis of the experimental evaluation and section 5 is the conclusion of the paper.

2. Related works

The process of routing is highly challenging due to limited resources, dynamic network topology, and infrastructure less communication in MANET. The availability of a dynamic route supports the lifetime of each specific node on this route [11]. A path between any pair of target nodes is considered invalid if all nodes in the path die from a lack of energy [12]. To solve this problem, routing protocols need to be aware of remaining or present energy and ensure proper resource utilization of the network while routing which is challenging to solve.

Marydasan et al. [13] address the problem of QoS with respect to node density in multiple paths in MANET. It presents a reliable and stable TA-AOMDV (RSTA-AOMDV) to improve path reliability and stability for data transmission. It implements an optimal forwarding selection algorithm to predict the stable and reliable routes in the network between the nodes by destination region selection (DRS) and computing weighted closeness and connectivity (WCC). The mechanism of relaying packet hop-by-hop fashion for the local information captured from its single-hop adjacent node shows an additional overhead. It shows high overhead and E-2-E delay with increasing number of nodes in the network.

Hao et al. [14] propose an energy-efficient routing algorithm (LASEERA) for MANET to solve the energy constraint and stable routing problem based on the automatic (LA) theory. Furthermore, each node in a MANET initially has limited energy, so energy consumption and balancing must be considered. An effective routing strategy must be not only stable, but also energy efficient and balanced in a changing network environment. It defines an optimal power ratio function and creates a new node stable measurement model. It constructs an optimal route selection method for MANET using feedback method based on LA theory. The defined energy ratio function works on node-weighted value which is based on the feedback mechanism, where nodes update their own weighted value during execution to build an optimized routing model. The obtain results of the work shows an improvisation in PDR with lower End-2-End delay. But it shows high energy consumption with increased density of nodes in the network.

Bhardwaj et al. [15] proposed a fitness function utilizing genetic algorithm for Ad hoc on-demand multipath distance vector (AOMDV) routing protocol to obtain the optimized routes as AOMDV-GA. It aims to focus the reduction of energy and delay to enhance the PDR. It presents a combine algorithm using genetic algorithm (GA) with fitness function (FFn) to build optimized route to destination. These protocols provide an optimization process to select the shortest path, high residual energy, and efficient paths with high fitness values despite random loss of data traffic. It implements the concept of FFn, which takes into account the distance between the source node and the destination node, congestion control and energy consumption. It also uses a method that minimizes congestion and random loss to select optimal paths with high fitness. The simulation results enhance the PDR performance with an average network overhead. But with increasing nodes in the simulation shows higher End-2-End delay with average energy consumption as a limitation

Since, energy is a limited resource for movable devices which typically run on the energy supplied by the batteries, so an additional development for energy saving mechanism is much needed to enhance MANET lifetime [16]. Under these critical conditions, optimal design of link cost-effectiveness is an urgent requirement for MANETs, focusing on the most cost-effective manner to utilize mobile energy while confirming suitable procedures of the network. Much attention has been paid to the previous literature on improving link cost-effectiveness in mobile communication systems [17].

To overcome these disadvantages of the existing methods many approaches are made. Few of them which focus on energy-efficient routing methods recently for the ad-hoc networks are discussed above in Chandravanshi et al. [6], Lim et al. [7], Wang et al. [8], Marydasan et al. [13], Hao et al. [14] and Bhardwaj et al. [15]. These protocols are used in different ways to balance energy efficiency or battery consumption. In general, these protocols try to find several system-level procedures to prevent flooding and retransmit unwanted packets, but the foremost drawback of these routing protocols is that they do not have information to address congestion and routing quality. A new traffic management model is proposed for efficient path management in MANET [18]. It handles excessive traffic, a major cause of network congestion and losses.

Several energy-efficient routing protocols have been proposed in the past and optimal solutions have been sought among them. Due to the difficulty of constraining techniques, optimizing search, and discovering, many essential adaptations have been made to make reactive routing such as DSR to make it work as an efficient routing protocol like other protocols [19].

2.1 Energy preservation in Ad hoc routing

The main objective is to maximize the lifetime of a node by conserving intuitive energy and sharing the connection costs of routing the packet carefully. A few routing procedures based on the least energy utilization measure [2, 6, 8] are given below.

- *Least Energy Utilization*: It is considered an essential criterion that reflects our understanding of energy conservation. A packet *p is* transmitted from SRC as n_1 to reach DEST n_v having x intermediate node in between, and the energy needed to send 1 pkts among them is represented by $Q(a,b)$, where a and b are direct link nodes. Hence, the total energy needed to reach DEST is given in Eq. (1) as E_n.

$$E_n = \sum_{d=1}^{v-1} C(n_d, n_{d+1}) \qquad (1)$$

So this measurement determines to identify the least E_n needed to travel a packet from n_d to D. It makes us choose the least energy route from the discovered routes to DEST. In some cases, this might change the path preferred by the shortest route of the identified hop path when employing the parameter. Thus, the benefits of having more than one short route if a constant quantity of energy is consumed for transmission. But it faces a severe disadvantage due to a few low-energy nodes dying with the substantial changes in energy distribution in the course of data routing.

Several links and energy-cost-effective routing approaches are proposed in the earlier works, which suggest energy is the vital form that defines the communication of wireless networks [20]. To improve routing in MANETs, different approaches have been devised to take energy-related contexts related to conventional measurements based on delay [21], hop distance, and flow control models [22]. Typically, the energy is described as a utility required to associate through the link to have a connected network. However, to minimize the overall energy consumption several energy-optimal algorithms are suggested in the reactive routing mechanism.

2.2 Energy-efficient routing

Existing routing algorithms may become familiar with non-traditional principles for energy-associated factors such as "delay" or "hop distance". The correlation parameter for the nearest energy is known as a method of the communication energy for works [23]. However, there is a lack of guidance on the selection of low-power, averaging algorithm techniques to reduce global energy consumption. Because it focuses on environmental directives, it explains how to conserve energy and make decisions in the sense that environmental directives only work as energy-efficient mechanisms. Many energy-efficient routing protocols using different techniques have been proposed in the past, some of which we discuss below.

Hao et al. [1] proposed a stable and energy efficient routing algorithm, based on the automatic learning theory of MANETs. First, it constructs a new model to quantify node stability and defines an actual energy ratio method. A dynamic topology regulating protocol for mobile nodes is proposed by Jeng et al. [3]. The protocol permits every node to agree on whether to assist energy-efficient paths or preserve specific energy. Moreover, the broadcast energy of mobile nodes can be greatly reduced through beacon messages.

Kim et al. [5] proposed a numerical and computer simulation analysis of MANET AAP message complexity to measure node activity changes and communication errors. All links within a given radio range are assumed to have the same probability of connection failure. This approach is used to simplify digital representation, protocol design, and computer simulation. In practice, however, communication error rates vary and change over time. By comparing the prediction error instances, finding the prediction error rate, and using the average error rate as the transient prediction error possibility, the results can be directly utilized for a complex study.

Khabbazian et al. [24] explore the abilities of the “Local Broadcast Algorithm (LBA)” to minimize the transmissions requires to perform a complete transmission. It describes that the LBA algorithm might not assure low usage of energy if the route is incorrect. It is seen that relative location information provides a simpler constraint on the number of nodes that can be reduced by the static policy methodology. Zhu et al. [25] proposed a significant proposal to create an energy-efficient routing protocol known as PEER for dedicated mobile networks. In standard observation, it defines a transmission protocol that is more energy efficient than the existing transmission protocol. It shows that energy-preserving routing protocols can introduce high latency and overhead with increased network traffic through simulations, and can gain more energy than traditional routing protocols in mobile environments. This approach allows accurate monitoring of energy utilization and routing-related maintenance issues. It recommends that a fast and compact search path can reduce power consumption, especially in mobile environments.

The reactive routing protocol maintains the packet switching path between the SRC and DEST. Hence, these routing prior knows the full path to DEST [23]. Repeated topology changes require regular route traversal, which is incompetent for overhead, causing the search flow to consume significant energy. Multipath routing protocols construct routing requests to explore multiple paths to a destination to forward packets. Since the energy resources of mobile nodes are limited, the energy of these nodes must be utilized to prolong the life of the network. But, still, there are several problems with multi-routing protocols being observed. One of them is finding the most efficient route from SRC to DEST. The problem becomes more complicated when multiple mobile nodes are associated to transmit data. In such conditions, most of the work goes into finding the shortest path, and more energy is consumed during the data transmission process.

The enhancement of MANET usage in various applications of IoT and sensor devices increases the communication overhead and resource consumption of nodes. The study of literature identifies the following the limitation.

- Existing routing network is not adaptable for optimal routing due to high energy consumption and routing overhead.
- The continuous sending of data packets lead to increase congestion and it probe to dropping of packets and increase the delay and reduce the packet delivery ratio.
- Link cost-effectiveness are also being studies in the past to reduce the energy, but in multipath routing it is challenging to find the most energy efficient link to destination.
- Frequent link loss due to node mobility and long path leads to high energy loss which makes a node die quickly and increase the network overhead and energy consumption.

To solve this problem, routing protocols have to be aware of node energy to ensure proper resource utilization of the node while routing for an increased density of nodes in the network. It requires energy efficient path to have a stable link in multiple path routing to handle excessive traffic and density of nodes in the network.

3. Proposed link cost prediction method

Reactive routing protocols are most suitable for the MANET environment due to their dynamic adaptability and rediscovering their route in case of path loss [26]. The event of energy consumption at each node was carried during the packet transmission and receiving [27]. Most of the dynamic and reactive routing protocols lose energy due to various overloads caused due to network flooding, link loss, and mobility [28]. Furthermore, MANETs are extremely sensitive to resource-limited battery-driven energy sources and energy-related issues, thus requiring a routing protocol that takes energy criteria into account and aims at extending the lifetime of the network.

Table 1. Notations list

Notations	Description
E_{Pr}	Energy used on processing
E_{Tx}	Energy used on Transmission
E_{Rx}	Energy used on Receiving
$E_{(S,x)}$	Energy consumption for 1-hop transmission
R	Range of communication
T_{SPatth}	Total minimum energy for the shortest paths
$E(Q)$	Energy utilization of node Q

3.1. Prediction of energy efficient path (EEP)

EEP prediction extends the mechanism to the path-finding process using LEARN [27] procedure, which includes the routing method to construct a dynamic switch using the link cost routing method. Node search is the primary action that MANET executes to find the route to the DEST node. To do so, a broadcast of an RREQ is to each node within its reach and the receiving node retransmits if RREQ is received the first time, and continues till the DEST node is discovered in the network. However, this process of retransmission results in significant energy loss because of the regular receiving and retransmission of the RREQ. Therefore, the issue of controlling energy loss by limiting repetitive activity can be resolved by addressing this problem in MANET.

To illustrate a network model let's consider a set of nodes as N distributed in a two-dimensional space having a unique id. The range of communication among these nodes is only possible if they are available within the range of transmission, R. So, if the distance of node x and $y < R$ then the communication can be established and a continuous network model is formed of the range nodes belongs to N, as shown in Fig. 1 for a set of 7 nodes including SRC and DEST nodes.

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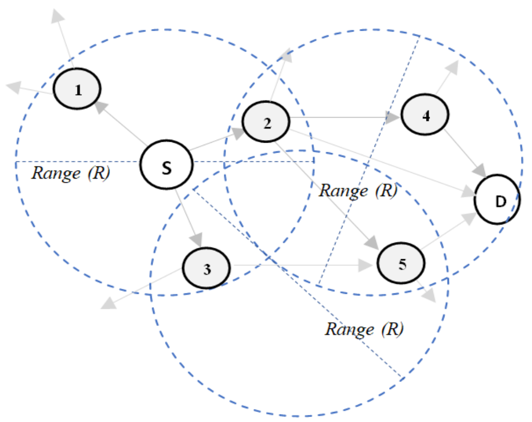

Figure. 1 Network broadcasting model for RREQ

Figure. 2 Stages of energy utilization events by a node

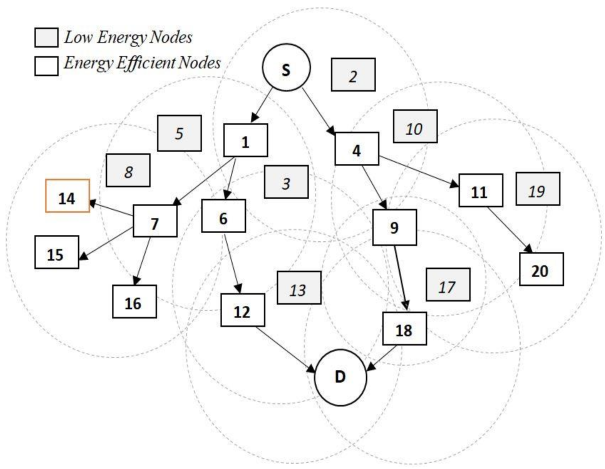

Figure. 3 An EEP-based route discovery

To illustrate a network model let's consider a set of nodes as N distributed in a two-dimensional space having a unique id. The range of communication among these nodes is only possible if they are available within the range of transmission, R. So, if the distance of node x and $y < R$ then the communication can be established and a continuous network model is formed of the range nodes belongs to N, as shown in Fig. 1 for a set of 7 nodes including SRC and DEST nodes.

The unit of energy utilization requires to perform a transmission between two nodes can be computing the summation of the energy loss for the events a node during receiving and transmission as shown in Fig. 2.

Let's consider node, S and x are in the range of communication, R and if S transmits a packet to x it has to utilize an E_{Tx} energy unit, and to receive and process a reply it has to utilize E_{Rx} and E_{Pr}. Similarly, node x has to utilize the same amount of energy to receive, process, and retransmit. Hence the overall energy consumption to perform a one-hop communication can be computed using Eq. (2).

$$E_{(S,x)} = (E_{Tx} + E_{Rx} + E2_{Pr}) \tag{2}$$

So, in case S has k nodes in its range of communication, then for each RREQ it broadcast it needs to accept k replies. Hence the total energy utilization by S for each broadcast as $E_{(S \rightarrow k_{(1,n)})}$ can be computed using Eq. (3).

$$E_{(S \rightarrow k_{(1,n)})} = \sum\left(E_{Tx} + k(E_{Rx} + E_{Pr})\right) + \sum\left(k(E_{Rx} + E_{Tx} + E_{Pr})\right) \tag{3}$$

Therefore, in the discovery method, each node rebroadcasts the first time it receives the RREQ message from the SRC. The nodes which are in the range of SRC must have rebroadcasts to further make them reach other nodes in ranges. This will be continuing till it reaches the DEST nodes address. This mechanism utilizes all the nodes in the range irrespective of knowing the level of energy of the nodes. This results in an indefinite route which might be lost due to energy loss during routing and causes regular switching to new paths which might be longer and result in a high loss of energy. To minimize this loss EEP is discovered the route with energy stable node only. An illustration of the EEP route discovery mechanism is shown in Fig. 3.

The process of EEP predetermines the energy level of nodes in the ranges. A threshold value (E_{TH}) is configured to consider a node for rebroadcasting. The node which is above the E_{TH} is allowed to participate in the discovery and SRC receive only those selected node reply. It reduces the energy losses of the weaker nodes and also limits the overall route discovery energy loss. For an example let's consider 20 distributed nodes in a plane constructs a dynamic network and an SRC node S initiates an RREQ to discover DEST node D. In case of a normal dynamic path discovery the k value will be 20 as these entire nodes participate in the discovery, but in case of EEP, the k value is reduced to 11, which makes the energy usage reduction. The discovered paths are utilized for dynamic route switching as per the link cost value during routing we discussed below.

3.2 Link cost prediction

The route discovery using EEP provides nodes

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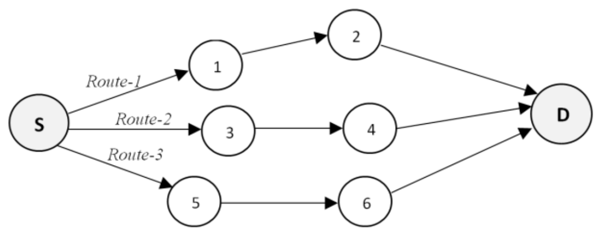

Figure. 4 EE path discovered between S and D

with cost-effective links in the network. However, by the supporting nodes with the number of data packets transmitted, there is still the potential for energy loss due to excessive link loss or overload. Thus, it is important to know the expected power along a path before transmitting data.

The distance to the DEST node completely depends on the next hop selection from the availability of the neighbor [27], because these nodes direct the data packets to DEST nodes. But, these selections might not be always energy-efficient or might not be linked to cost-efficient in the case of similar hops to DEST. In addition, the overall distance should be shortened to reduce energy utilization as much as possible. Thus, it creates classified areas that determine dynamic route switching for routing. So, according to this process, possible energy-preserving paths are identified and link costs for each of these are pre-computed in advance. Hence, it provides to switch to the most link cost-effective route to achieve better throughput with low latency and longer network lifetime.

According to Fig. 4, SRC node *S* has three routes to reach DEST node *D*. All three routes are having a similar number of hops, so preferring the shortest route, is not in scope. In case it switches to a route that registers first during discovery it might not be energy efficient. In such a case, the perception of the distance energy model [33] can be used to compute the real-time energy required. It can be computed as the ratio of the distance, *d* between the nodes, and energy utilization of node *Q* as *E(Q)* for transmit is defined as "*d*/*E(Q)*".

Let's assume *v* is the distance of a node *N1* from SRC node *S*, and *d* is the maximum range of *S*, then the energy utilization of *N1*will be "*v/E(N1)*" and for node *S* it will be "*d/E(S)*". In such case to be the range of communication among them should be $v/E(N1) \leq d/E(S)$. So, during the mobility, the value of *v* of the node may vary and in such case, if distance $v>d$ then loss of packet occurs. Hence, in any condition, the maximum communication distance will be given as, $\sqrt{E(N)}$.

Let *Z* be a set of the path discovery between the SRC and DEST and each element of *Z* consist of *N* number of the node to reach the destination and each node of the path is denoted as N_z. The minimum energy needed to establish a link *l* is represented as $E_{z,r}$. Hence, the total minimum energy for the shortest paths will be referred to as T_{SPatth}, calculated as,

$$T_{SPath} = min\left(\sum_{n=1}^{N} E_{z,l}\right), z \in Z \tag{4}$$

The T_{SPath} might have more than one shortest path, but a routing protocol can select exclusive path support on certain criteria, such as a turn-around time of the request packet. The first condition causes the node to pick the shortest path and in the other situation, it prefers the least energy route from the available shortest paths set based on link cost computed using Eq. (4) as given in Table 2.

Table 2. Link cost table

Next Hop	**Distance (*d*) in *meter***	**Primary Hop Energy *(E(N))***	**Energy Needed *(d/E_n)***
S→1	2	$E_s = 8$	0.25
S→3	1	$E_s = 8$	0.125
S→5	2	$E_s = 9$	0.22
1→2	1	$E_1 = 7$	0.14
3→4	3	$E_3 = 5$	0.6
5→6	2	$E_5 = 5$	0.4
2→D	1	$E_2 = 6$	0.166
4→D	3	$E_4 = 8$	0.375
6→D	1	$E_6 = 9$	0.11

Table 3. Routing link cost

Path	**Total Link cost for Routing (P_E)**
S→1→2→D	*P*(0.25+0.14+0.166) = 0.556
S→3→4→D	*P*(0.125+0.6+0.375) = 1.1
S→5→6→D	*P*(0.22+0.4+0.11) = 0.73

Utilizing the computed values of each link in the shortest path the least link cost route is selected for the routing. Table-3 shows the total link cost for each route. But the value of link cost changes at runtime due to the dynamic mobility of the node hence regular updating and switching is needed.

Periodically computing the value of link cost makes SRC switch the path dynamically to minimize the link loss and enhance the throughput and also retain the network life longer.

4. Experiment evaluation

4.1 Setup and measures

The network structure is constructed using a network simulator with the required MANET

Table 4. Simulator configuration parameters

Parameters	Values
Terrain Dimension	1200m X 1200m
Mobility Model	RWP
CBR	4 pkt/sec
Mobility Speed	10 m/s
Size of Packets	512 bytes
Pause Time (sec)	60
Simulation:	**By Varying Number of Nodes**
No. of Nodes	20, 40, 60, 80, 100
No. of (S-D)Pairs for Communication	5, 10, 20, 30, 40

configuration. The simulation was carried out with 50 nodes distributed randomly in a plane of 1200m X 1200m dimension for a RWP mobility model. For the evaluation of the proposal, we employ the configuration parameter given in Table 4. The configurations are made to evaluate the scalability of the network by varying the number of nodes from 20 to 100 in a constant mobility of 10m/s with a pause time of 60 sec.

The outcome of the simulation results is measured in terms of packet delivery ratio (PDR), routing overhead, End-2-End delay and Avg. energy efficiency as defined below.

- *PDR:* It states the number of data packets delivered successfully to the DEST node. It is calculated as a ratio between the numbers of packets transmitted by the SRC with the number of packets received by the DEST node.
- *Routing overhead:* It states the additional packets being transmitted to manage the routing smoothly. It is calculated directly by summing the number of control packets utilized in the communication period.
- *End-2-End delay (E-2-E)*: It is computed using Eq. (5) with the summation of delay values which includes transmission delay of a packet to the destination due to congestion, processing and link failure [29].

$$\text{E-2-E} = \frac{\sum_{j=0}^{n} D_j - S_j}{n} \quad (5)$$

In this equation, D_j defines the destination receiving time for j^{th} data packet, and S_j defines the sender transmission time for j^{th} data packet, and n represents the successful deliver of data packets.

- *Throughput*: It states the number of bits delivered successfully to the DEST node, which is measured in Kbps, and higher the values better the throughput of the network. It computed as a ratio of total byte received over the time of simulation.
- *Avg. energy consumption (EC_{Avg}):* It computes the average energy consumption using Eq. (6) for the complete communication cycle. It is measured as a ratio of the total energy consumed over the total number of nodes.

$$EC_{Avg} = \frac{\sum E_{consume}(REQ_{Tx} + REP_{Tx} + RERR_{Tx} + CTR_{Tx} + DP_{Tx})}{N} \quad (6)$$

In this equation, the energy consumption for $RREQ_{Tx}$ as route request; $RREP_{Tx}$ as route reply; $RERR_{Tx}$ as route error; CTR_{Tx} as control pkts and DP_{Tx} as data pkts transmission for the N number of nodes. The lower the EC_{Avg} value the better the energy efficiency.

4.2 Performance results

The performance result of the proposed LCPM is compared with the state-of-methods of MMEE [6], RSTA-AOMDV [13], LASEERA [14] and AOMDV-GA [15] to evaluate the enhancement. The outcome of the simulation is measured with PDR, E-2-E delay, routing overhead and Avg. energy efficiency as discussed below.

A. Packet delivery ratio (PDR)

It describes the percentage of data successfully is received by the destination node. Higher the PDR illustrates the better performance of the protocols.

Fig. 5 shows the comparison of PDR with the state-of-arts methods. It shows that the proposed LCPM improvisation in PDR in compared to other methods. The proposed LCPM shows a result of 95.22% with 20 nodes, 95.58% with 40 nodes, 89.37% with 60 nodes, 85.13% with 80 nodes and 69.99% with 100 nodes. It shows a drop in the PDR with increasing number of nodes due to delay in optimal path selection and increase in network traffic. But it shows an average PDR enhance of 3.75% with MMEE [6], 13.258% with RSTA-AOMDV [13], 6.48% with LASEERA [14] and 10.82% with AOMDV-GA [15].

The achievement of better PDR is due to the dynamic route switching of the path with prior determining the energy-efficient nodes which provide low link failure and high PDR, whereas state-of-arts methods in search of reliable and stable paths attains high delay and overhead which leads

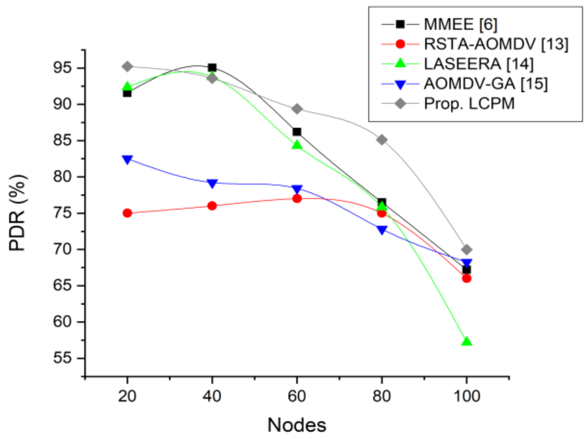

Figure. 5 Comparison of packet delivery ratio (PDR)

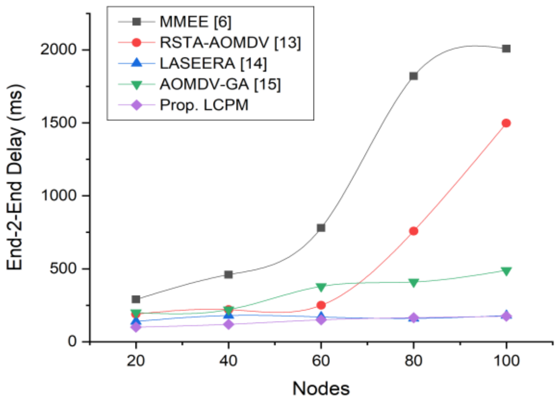

Figure. 6 Comparison of End-2-End delay

low PDR with increasing nodes.

B. End-2-End (E-2-E) delay

E-2-E delay is a significant factor for wireless communication. It defines the latency occurs for a data packet delivery through a designed network between receiver and transmitter.

Fig. 6 shows the comparison of E-2-E delay with the various state-of-arts methods. It shows that with increasing node density all the methods shows increase in the E-2-E delay, where the proposed LCPM shows least delay and MMEE [6] shows the highest among all. In comparison LCPM shows an average low delay of 105ms with 20 node and 869ms with 100 node density. The enhancement of LCPM is majorly due to quick switching of routes in case of link loss or low energy node. The optimize selection of routes to the destination lower the E-2-E delay in the communication. The state-of-art methods also use switching of routes as they employ multipath routing but the selection of longer route and non-energy optimize node leads to higher E-2-E delay.

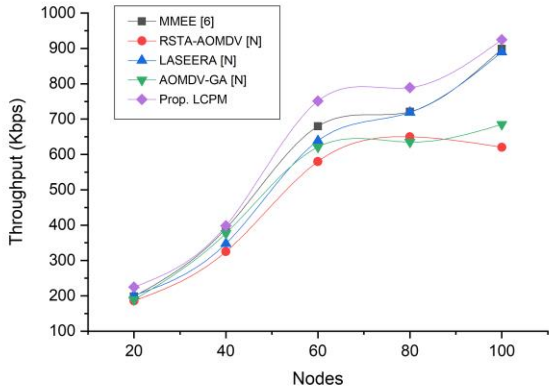

Figure. 7 Throughput comparison

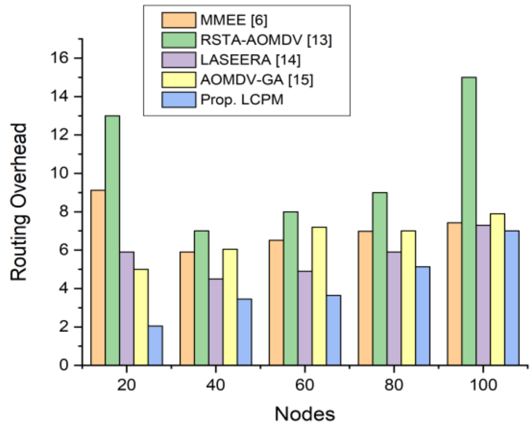

Figure. 8 Comparison of routing overhead

C. Throughput

Fig. 7 shows throughput analysis comparison with the various state-of-arts methods. All the methods show a increase in throughput with increasing node, but the proposed LCPM achieve an average of 40Kb of improved throughput in compared to other methods. It achieves due to the dynamic switching of the path with determining the energy-efficient nodes and stable route to DEST.

D. Routing overhead

It defines the additional data packets being exchanges for efficiently manage the routing operation between source and destination. The lower the overhead the better the PDR performance and lower the energy consumption and longer the network life. It also provides longer network stability for various topology and size.

Fig. 8 shows the comparison of routing overhead with the various state-of-arts methods. With increasing number of nodes in the simulation all the methods show increase in overhead. The proposed LCPM shows a linear increase in overhead in compare to existing methods with an average of

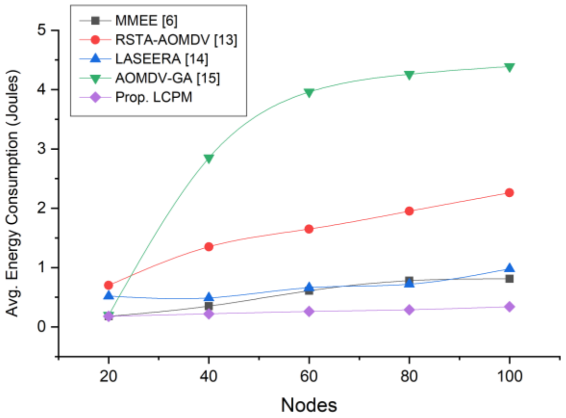

Figure. 9 Comparison of Avg. energy consumption (Joule)

29.3% lower. It is due to the reduction of link loss and better PDR. This improvisation makes the network stable for a longer period and achieves high PDR due to low delivery failures.

E. Avg. energy consumption

The efficiency of energy consumption analyses the possibility of the lifetime of a network. It is depends on the energy utilized by the nodes during the communication. The lower the consumption makes the network more energy efficient.

Fig. 9 shows average energy consumption comparison between the existing methods. It shows that with a varying number of nodes, the energy consumption also increases at an average rate by all methods. The energy consumption of MMEE [6] shows the highest among all the comparison, whereas the proposed LCPM shows the lowest among all. It is due to the prediction of the energy-efficient path and the utilization of energy collectively will be low and energy efficiency will be high.

The mechanism of runtime predicting and switching enhance the performance of the network. With an increasing number of nodes more utilization of energy and control packets drops the energy efficiency, similar to increasing nodes frequent link loss between nodes makes it utilize more energy to establish the connection which makes the dropping of energy efficiency. But LCPM shows better results in comparison due to its dynamic selection of the shortest and most energy-efficient path.

5. Conclusion

This paper presents a dynamic route switching method based on estimating link cost for MANET routing known as LCPM. It initially discusses an energy-efficient path discovery mechanism to minimize the route discovery energy losses. It provides the shortest and most energy-efficient node for routing. This approach provides cost-effective link routing between source and destination under scalable and dynamic node mobility conditions. The LCPM method finds the energy needed to communicate the next hops in the route with distance and hop energy in the shortest path discovered. Later it computes the link cost of each route and dynamically switches to that to perform the most efficient routing. The experiment analysis with node scalability setup shows the enhancement of the proposal with the measure of PDR, E-2-E delay, routing overhead and average energy consumption. It shows a result of 95.22% with 20 nodes, 95.58% with 40 nodes, 89.37% with 60 nodes, 85.13% with 80 nodes and 69.99% with 100 nodes. It shows a drop in the PDR with increasing number of nodes due to delay in optimal path selection and increase in network traffic. It shows an average low delay of 105ms with 20 node and 869ms with 100 node density. It shows a linear increase in overhead in compare to existing methods with an average of 29.3% lower. It is due to the prediction of the energy-efficient path and the utilization of energy collectively will be low and energy efficiency will be high. In the future, dynamic route switching can be explored in route segmentation and cluster routing to achieve more scalability and enhance the network life longer.

Conflicts of interest

The authors declare no conflict of interest.

Author contributions

Conceptualization, methodology, software, validation, Jayanthi; formal analysis, investigation, resources, data curation, Syeda Ambareen Rana; writing—original draft preparation, writing—review and editing, Syeda Ambareen Rana; visualization, supervision, Dr. Bharati Harsoor.

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