EASR: Graph-based Framework for Energy Efficient Smart Routing in MANET using Availability Zones

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Abstract: Energy and Routing efficiency is a long-research topic from past decades in the area of MANET. The prior research contribution focusing on addressing both the issues are associated with issues like i) few benchmarked studies, ii) adoption of conventional routing protocols based on shortest path to mitigate both issues, and iii) inefficient design principles of routing. Hence, this paper presents a novel routing protocol in Mobile Adhoc Network (MANET) termed as MECOR i.e. Minimal Energy Consumption with Optimized Routing. MECOR presents a simple communication strategy based on mathematical and signaling properties of mobile nodes in MANET to jointly address the energy and routing issues in MANET. The outcome of the MECOR is compared with conventional routing algorithm as well as recent studies of energy efficient routing policy to find that MECOR can minimize 58.82% of energy in most challenging mobility scenario of MANET.

Key-Words: - Mobile Adhoc Networks, Energy Efficiency, AODV, Routing, Network Life Time, Energy Model

1. Introduction

Mobile Adhoc Network is one of the most active field of research owing to its potential features as well as the ongoing problems being continuously investigated from last 2 decades. Basically, a Mobile Adhoc Network (MANET) consists of multiple numbers of mobile nodes that are interconnected to each other without any aid of infrastructure (or access point). The prime target of MANET system is to ensure seamless connectivity for the nodes even when they are moving. However, it is not a simple fact, because when the node moves the mobility may cause signal breakage. Hence, in order to address the seamless communication system in MANET, there are set of standard routing protocol [1] that ensures the stability of links even when the nodes are in movement. MANET has already found its identity in vehicular communication [2] and defence applications [3]. When the nodes are in mobility mode, it has to continuously spend its battery as a source of energy to ensure that the mobile nodes are always connected. The energy consumption takes place as the nodes has to send control message as well as data packet for which the nodes requires certain minimal energy. Such energy is required for both receiving as well as transmitting the messages among the nodes. It is said that transmittance energy is quite higher as compared to receiving energy, but this fact is not completed true in case of MANET. As, in MANET, there are various type of mobile nodes e.g. source node, destination node, and intermediate nodes. One unique point to observe here is that source node may be more studied for transmittance energy and destination node may be studied for receiving energy. Unlikely the energy dissipation in source and destination node, the pattern is completely different for intermediate nodes. Although intermediate nodes assist as a hop to receive the data packet from sender and forward to destination node, the intermediate node can also act as source node for some other destination node and even destination node for some other source node. Hence, energy consumption for intermediate node can be said to be much higher even compared to source node and destination node. In MANET, which works mainly on multi-hop, there are numerous intermediate nodes and therefore, assuring the optimal network lifetime is one of the biggest challenging tasks of the network engineers. Moreover, the mobile nodes also depletes power when it is not forwarding any data packet. One or other way, a mobile node has continuous energy dissipation that is quite difficult to be solved. Therefore, routing principles must adhere to such energy constraints in MANET and should come up with significant solution. In this paper, it is discussed that there were various attempts in past that has focused on energy efficiency by introducing various routing protocols. It was seen that the existing approaches were tested analytically, less benchmarked, and majority of the studies are found to adopt conventional routing protocol to incorporate features of energy control. The success factor in such approach is only applicable in the scenario proposed by prior researcher, which doesn't ensure much applicability in real-time study. Moreover, it was also found that design principles of existing energy aware routing policies lacks signaling techniques and mathematical approaches for which reason, the reliability factor is still needs to be authenticated.

Hence, the proposed paper introduces a novel routing protocol that is incorporated with simple and yet robust mathematical modelling carrying the signaling properties of MANET for jointly addressing both energy and routing efficiency. However, the study is more inclined towards energy efficiency. The discussion of introduction in Section 1 is followed by Section 1.1 that highlights about background of study followed by problem discussion in Section 1.2. Section 1.3 introduces the proposed model followed by elaborated discussion of research methodology in Section 2. Section 3 discusses about the Result and discussion being accomplished from the study along with performance comparative analysis that is further followed by conclusion in Section 4.

1.1 Study of Background

This section discusses about the patterns of prior research technique in solving routing and energy issues in MANET. Shivashankar et al. [4] have introduced a framework for ensuring the energy aware routing in MANET for the purpose of enhancing the network lifetime. The design of this framework ensures the selection of routes with maximized capacity of data packet. The outcome of the study is found to have 20% energy preservation compared to DSR protocol. The evaluation of the study was done using energy, packet delivery ratio, and delay.

Zhang et al. [5] have proposed a routing protocol for securing the paths in MANET. The study has used cryptographic technique to secure communication in both network layer and MAC layer. The outcome of the study was compared with AODV considering delay, packet delivery ratio, and load. Gupta and Das [6] have also focused on both energy and routing in MANET using cost metric of routes. However, the term cost metric was only applicable for the nodes with higher energy depletion to retain remnant energy. The outcome of the study was compared with AODV with respect to energy, delivery rate, delay, and routing load on multiple numbers of sources. The outcomes claims to retain 65% energy preservation in static environment, but there was no discussion for mobility environment extensively.

Kawamoto et al. [7] have introduced the concept of cyber-physical scheme for ensuring improved network lifetime in MANET. The authors have used graph theory for formulating a reliable topology in MANET to ensure sufficient connectivity with minimized energy depletion from the mobile nodes. The outcomes of the study were not found to be benchmarked and analyzed using energy and time mainly. Wang et al. [8] have introduced a technique to conserve energy in MANET using MAC layer approach. The study was more inclined towards minimizing latency causing due to transmission and minimize unnecessary energy drainage. The outcome of the study was not bound to be benchmarked and was evaluated with respect to number of alive nodes and energy in both static and mobility environment.

Huang et al. [9] have presented discussion of an unique routing mechanism considering real-time application environment. The authors have considered the real-time traffic environment of Manhattan where the mobility is rendered by standard random mobility model. The outcome of the study have considered coverage and signal outage factor for the mobile nodes as prime performance parameters under variational node density, and connection time. However, outcomes were not found to be benchmarked. More studies were found to work on routing policies to ensure security. One of such work is seen in the work of Zhu et al. [10] who was more concern with the privacy issues. Although the study was on security, but it has certain robust routing technique discussed for supporting massive data transmission in MANET.

Mitra and Rabek [11] have focused on clustering concept to preserve the energy in MANET. The study has introduced a clustering service to cater up the communication requirement of large scale MANET. The outcome of the study was not found to be benchmarked and was evaluated for effectiveness using mean degree of clusterheads and stabilization factor mainly. Chin et al. [12] have investigated MANET routing protocols e.g. AODV and DSDV on multiple node and multiple hop environment. The authors have carried out real-time implementation using 802.11 WLAN cards in Linux machines. The authors commented that both AODV and DSDV don't support routing stability in multi-hop network in MANET.

Zhenqiang Ye et.al [13] presents a frame work for Robust Secure, Robust, Reliable routing in mobile adhoc networks. The objective was to provide robustness to both intermittent (or short term) and long term node failures in ad hoc networks. These failures could be a result of either fading, battery failure or compromise. Fu et al. [14] have investigated on vehicular network to analyze the routing principles in MANET. The authors have introduced a routing algorithm that enables the mobile nodes to know the information about density of neighborhood and thereby enhances the routing performance by improving the packet delivery ratio. The simulation study was carried out on Manhattan Grid model with respect to coverage and delivery ratio.

Javad Vazifehdan et al[15] propose novel energy-aware routing algorithms .It considers the energy consumption and the remaining battery energy of nodes as well as quality of links to find energy-efficient and reliable routes that increase the operational lifetime of the network. Ahmed et.al in[19] Proposes an alternative routing protocol to find out the to find out the multiple disjoint routes between the source and destination. The proposed scheme yields a better performance than AODV protocol.

Jinhua Zhu et.al in [21] proposes a new link cost model to more accurately track the energy consumption due to various factors. PEER performs much better than normal energy-efficient protocol in both static scenario and mobile scenario, and under all circumstances in terms of node mobility, network density, and load

Hence, it can be seen that there are various studies that have been discussed in the past for the purpose of enhancing the performance of routing protocols in MANET. It was noticed that majority of the prior studies have emphasized on discussing the issues related to exploring and retaining precise routes from source to destination in presence of dynamic topology. Some of the studies e.g. [4][8] etc have discussed about unique and simple technique for designing an algorithm for ensuring optimal energy efficient routing protocols in MANET. However, a biggest issue found in majority of the study is the adoption of shortest path algorithm. The algorithms were mainly enhanced from the existing shortest path algorithm and hence, whatever the flaws exists in shortest path-based routing procedure, similar flaws also existing to slight extent in enhanced version too. Hence, less novelty in the prior approaches has been observed. Association of energy with routing is another gap found in the existing literatures as the addressing mechanism for both (energy and routing) were not found to be discussed with respect to impact for each other. Moreover, few studies were found to focus on sustainance on dynamic topology inspite of adoption of random mobility model. The existing studies were found majorly to concentrate on designing protocol considering conventional performance metrics like delay, packet delivery ratio, etc with least focus on extensive simulation on energy efficiency.

Hence, it can be inferred that designing routing protocol along with assurity of energy preservation is still a challenging topic of research and calls for further extensive study. A simple mathematical and analytical approach is highly required to measure the energy effectiveness. Moreover, there is a higher necessity of performing a benchmarking of the outcomes, which was found to be considerably mission in existing studies.

1.2 Problem Identification

This section discusses about the problems that have been identified in the investigation of proposed study.

- *Challenging Design Principle of MANET:* Designing MANET routing protocols merely don't only rely on conventional simulation parameters like number of nodes, transmission region, energy factor etc. The design principle should have mitigation policies for various channel state which are highly error prone. Existing studies discusses but doesn't address much about hidden node problem, because of which the unwanted energy dissipation cannot be controlled. The existing studies toward such problem are more analytical and less mathematical with few extent of emphasis on signaling properties of mobile nodes under dynamic topology.

- *Shortest Path Technique:* It cannot be denied that shortest path technique is the backbone of majority of the existing routing protocols in MANET. It has its advantages, but it has its limitations too. The primary limitation of existing shortest path is that although the routing can be established in shortest time and distance, but it often ignores various other impending factors like the interference, scattering, fading, and noise for the routes being explored in the process. Moreover adoption of shortest path technique often causes network partition causing the mobile nodes to deplete maximum energy to perform repeated route discovery process. Energy is another important factor that has to be associated with the shortest path technique to further redefine the effectiveness of shortest path. It can be said that cost and computational complexity of the existing routing protocols can be mitigated to a large extent using the energy-metrics in the routing protocols in MANET.
- *Frequently Used Routing for Mitigating Energy:* In this direction, it was found that AODV is the most frequently adopted routing policies for ensuring energy effectiveness in MANET. Although AODV has advantage features like lesser delay and route establishment on demand, but still it is shrouded with various loopholes when it comes to ensure energy effectiveness in MANET. AODV results in inconsistent routes for stale sequence numbers that drastically gives rise to retransmission effect in large scale and dense MANET system. This phenomenon finally results in unnecessary energy dissipation that is quite challenging to control.

Hence, for the above problems being identified in due course of investigation, it is essential that design principles be more emphasized and strengthened with simple and yet robust mathematical modelling. It is essential that routing strategy should be designed merely based on random links or just using route maintenance event for correcting the routes during energy control phase. The solution towards energy consumption starts from the route discover process itself and hence, it is required the enough studies should be performed more in-depth to visualize such issues and give a novel ideas to solve such issues. The next section will discuss about a novel routing protocol to address these problems.

1.3 Proposed Solution

The prime aim of the proposed system is to formulate a novel routing protocol in Mobile Adhoc Network (MANET) to ensure the best energy efficiency for large scale network. The optimization process towards energy efficiency is performed using cost based metrics and hence the model is coined as Minimal Energy Consumption with Optimal Routing (MECOR) for large scale MANET. For effectiveness in computation, the proposed MECOR associate a cost metric towards the link for all the available routes from the source to destination node for the motive of choosing routes with minimum cost. The secondary motive of the MECOR technique is also to accomplish higher precision in the cost computation for achieving the best energy efficient path while performing routing in MANET. The proposed MECOR technique will be executed over 802.11 MAC.

2. Resarch Methodology

2.1 Energy Model

The design of the energy model in [21] will initiate by considering the existing MAC techniques viz. point coordination function [15] and distributed coordination function [15]. However, MECOR chooses distributed coordination function because as point coordination function is mainly focused on centralized architecture. According to the distributed coordination function, when a mobile node wants to transmit the data to another mobile node, usually the network allocation vector (virtual carrier sensing method in IEEE 802.11 and 802.16) is initially checked. If the network allocation vector is found to be greater than zero than the node has to halt until the value of network vector allocation reaches to zero.

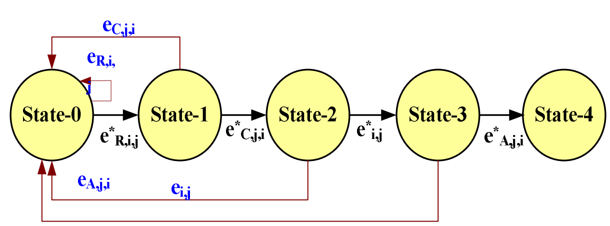

Figure 1. State-Diagram[21]

For mitigating the problem of hidden node in MANET, the proposed system in[21]will use two different types of control message i.e. CM_{RTS} and CM_{CTS}. CM_{RTS} will possess the information about duration, frame control, receiver access, transmitted access, and frame check sequence, while CM_{CTS} will possess the information about duration, frame control, receiver access, and frame check sequence. The process is followed by the transmission of CM_{RTS} packet by the source mobile node to the receiver in case of availability of the channel for an extended duration higher than interframe space of distributed coordination function. After receiving CM_{RTS} packet, the destination mobile node (or receiver) forward CM_{CTS} packet. Retransmission phenomenon takes place on the sender mobile node in case it has not received the CM_{CTS} packet within a specific interval of time. The source node upon receiving the CM_{CTS} will transmit the data packet and receiver forwards acknowledgement packet upon successful receiving of data from source node. The entire process is iterated until the source node receive acknowledgement packet from the receiver. In order to perform an effective discussion of MECOR, state-transition diagram is used to elaborate the operation being incorporated. Figure1 highlights the communication interms of state-transition diagram[21], where the discussion focuses on transaction of various control message among the mobile nodes. The model denotes $e_{R,i,j}$, $e_{C,j,i}$, $e_{i,j}$, and $e_{A,j,i}$ as error rates in the control message for request to send, clear to send, data packet, and acknowledgement in routing process. Figure 1 shows the state-diagram that exhibits its stages by State-0,…, State-4. In the above diagram, State-0 is the first stage of source node *i*, which upon transmitting the RTS packet to next node *j* changes its state to State-1 with probability $e^*_{R,i,j}$ or choose to stay in State-0 with probability $e_{R,i,j.}$ It all depends if the node *i* have received the CM_{RTS} packet precisely. The node j transmits the CM_{CTS} packet after receiving the CM_{RTS} packet from node *i*. Node *i* receives the CM_{CTS} packet with probability $e^*_{C,j,i}$ and state State-1 transits to State-2. The state may also roll back to State-0 with probability $e_{C,j,i}$. The data packet will then be transmitted by the node i after receiving the CM_{CTS} packet. Node *j* receives the data packet with probability $e^*_{i,j}$ where the state transits from State-2 to State-3. The state again roll back to State-0 with probability $e_{i,j}$. Once the data packet is received by the node j, it transmits acknowledgement packet to node i with probability $e^*_{A,j,i}$. Finally, the state again transits from State-3 to State-4. The state again returns to State-0 with probability $e_{A,\,j,i}$. Hence, it can be seen that node i will require to transmit $1/e^*_{R,i,j}$ packets of CM_{RTS} to ensure precise receiving of the packet by the node *j*. Node *j* will require to transmit $1/e^*_{C,j,i}$ packets of CM_{CTS}, node *i* will require to transmit $1/e^*_{i,j}$ packets of data, while node *j* will require to send $1/e^*_{A,j,i}$ packets of acknowledgement. Hence, mean quantity of CM_{RTS} packet can be represented as $1/(e^*_{R,i,j}e^*_{C,j,i}e^*_{i,j}e^*_{A,j,i})$, mean quantity of CM_{CTS} packet can be represented as $1/(e^*_{C,j,i}e^*_{i,j}e^*_{A,j,i})$, mean quantity of data packet can be represented as $1/(e^*_{i,j}e^*_{A,j,i})$, and mean quantity of the acknowledgement packet can be represented as $1/e^*_{A,j,i}$. For the purpose of easiness in computation, the proposed system considers η, η_H, η_R, η_C, and η_A as size of data packet, size of header, size of CM_{RTS} packet, size of CM_{CTS} packet, and size of acknowledgement packet respectively. Therefore, the system in[21] uses below mentioned notations for further computation:

$$\eta_{802}= \eta+ \eta_H+ \eta_o$$

$$\eta_{R1}= \eta_R+ \eta_o$$

$$\eta_{C1}= \eta_C+ \eta_o$$

$$\eta_{A1}= \eta_A+ \eta_o$$

in the above formulations, η_o denotes the overhead on the physical layer. Hence, integrating probability theory and energy model computation, the proposed system in [21]evaluates the cumulative energy required for transmitting the data packet can be denoted as:

$$\overline{E_T(i,j)} = \frac{E_m \eta_{R1}}{e^*_{R,i,j} e^*_{C,j,i} e^*_{i,j} e^*_{A,j,i}} + \frac{E_m \eta_{C1}}{e^*_{C,j,i} e^*_{i,j} e^*_{A,j,i}} + \frac{E_{i,j} .\eta_{802}}{e^*_{i,j} e^*_{A,j,i}} + \frac{E_{j,i} \eta_{A1}}{e^*_{A,i,j}}$$

$$= \frac{E_m(\eta_{R1} + \eta_{C1} e^*_{R,i,j})}{e^*_{R,i,j} e^*_{C,j,i} e^*_{i,j} e^*_{A,j,i}} + \frac{\eta_{802} .E_{i,j} + \eta_{A1} E_{j,i} e^*_{i,j}}{e^*_{i,j} e^*_{A,j,i}}$$

In the above equation, E_r is considered as the receiving energy and E_m denotes energy required in MAC layer. Hence the cumulative energy for receiving the data packets in [21]can be exhibited as:

$$\overline{E_R(i,j)} = E_r \frac{\frac{\eta_{R1}}{\eta_{802.11}} + \left(\frac{\eta_{C1}}{\eta_{802}} + e^*_{i,j} + \frac{\eta_{A1}}{\eta_{802}} e^*_{i,j} e^*_{A,j,i}\right) e^*_{C,j,i}}{e^*_{C,j,i} e^*_{i,j} e^*_{A,j,i}}$$

Between the source node *i* and destination node *j*, the system is assumed that there are (n-1) intermediate nodes. The mobile nodes are indexed as 0, 1, 2, …, M. The mean cumulative energy for carrying out effective data dissemination process in[21] can be now represented as:

$$\overline{E_{cum}} = \sum_{i=0}^{n-1} (\overline{E_T(i,i+1} + \overline{E_R(i,i+1)})$$

In the above equation[21], the route cost metric is therefore considered as $(\overline{E_T(i,i+1} + \overline{E_R(i,i+1)})$.

2.2 Attribute Evaluation of Route Cost

From the discussion in previous section, it can be seen that majority of the attributes can be easily computed. However, some of them are not as easy as error attributes and energy required for transmission. MECOR considers signal attenuation that may be caused owing to arbitrary mobility of the nodes, where the rate of attenuation can be defined as ($1/D^p$). *D* is considered as spatial distance among the nodes and *p* is considered as path loss exponent. Hence, it can be said that the received energy level E_r in [21] is directly dependent on ratio of E_t and D^p, where E_t is the energy required for transmission. Mathematically, it can be represented as:

$$E_r = \alpha . \frac{E_t}{D^p}$$

In the above equation, *α* is an environmental dependent attribute that can be changed in real-time experiments. Hence, using the above equation, each mobile node can now transmit the data packet with a predefined level of energy and can evaluate the required energy for transmission even for other data packets too using the level of receiving energy of known data packet and anticipated energy for receiving. It is known that the errors in the data packet are caused owing to various external factors e.g. noise, interference, and collision. The process uses carrier sensing area for better recognizing the collision concept and interference concept. In case the packet error occurs within the carrier sensing area, the system will like to term it as *collision* or else *interference*. However, it is quite non-trivial to accomplish the significant noise intensity as well as significant level of interference as every mobile node can perform network coding to understand the real-time status of the channel and can easily make out of the channel is busy or free. Therefore, using the attributes of noise and interference level, the system can also evaluate the bit error rate depending on the modulation scheme as well as energy at receiving level. Hence, if the system posses bit error rate (BER) value for s number of packets (in bits), than the packet error rate can be evaluated as=$1-(1-\text{BER})^s$. Hence, it is highly feasible to evaluate the packet error rates even for the control messages like data, clear to send packet, acknowledgement packet etc. depending on the size of the packet, interference, receiving energy, and noise. However, in case of request to send, it only depends on two attributes collision and interference for computing packet error rates. Considering the packet error rates causing due to i) noise and interference in the available wireless environment as e_{IN}, ii) collision as e_{CL}, the rate of packet error for request to send packet can be computed as:

$$e_{R,i,j} = e_{IN} + e_{CL} - e_{IN}.e_{CL}$$

2.3 Energy-Aware Routing

The proposed MECOR technique aims to explore the routes that are highly energy efficient during the process of discovering new routes. The technique also assists in periodically maintaining the routes so that it can mitigate the adverse effect of dynamic topology in MANET.

The proposed MECOR technique offers a faster exploration of the energy efficient routes. Just like conventional routing algorithm in MANET, MECOR initiates its process by finding the shortest path. Considering a possible scenario in Figure 2, it can be seen that there are three possible paths from source (X) to destination node (Y). Considering all the available nodes that lies in the path, the possible shortest path can be denoted as XPQY, XRSY, and XTUY.

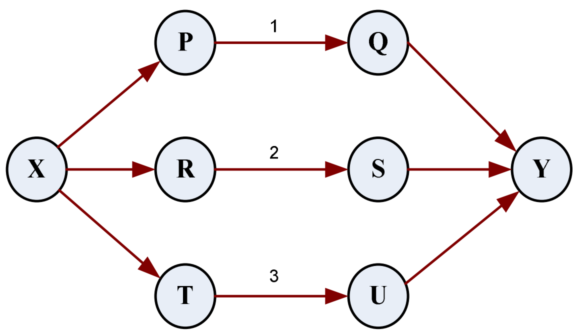

Figure 2. Possible routes between source and destination node [21]

Consider S represents the group of paths between the receiver (X) and transmitter (Y), N_s by the number of the hops for s path, and $E_{s,i}$ is energy dissipated for the path s. Hence, the formulation of the shortest path in this case will be,

$$S_p = \arg\min(N_s), s \in S$$

Similarly, it is possible to define the energy-efficient shortest path as

$$S_{ep} = \arg\min\left(\sum_{i=1}^{N_s} E_{s,i}\right), s \in S_p$$

Therefore, the proposed MECOR formulates a routing strategy that ensures to first find shortest path and the filters the shortest path with shortest energy efficient path. The system also designs the RREQ message incorporated with information pertaining to energy dissipation and availability of hops. In the preliminary stage, the source node forwards the RREQ message with both of these information, which upon receiving by the other nodes (intermediate), the intermediate nodes updates the count of the hops as well as level of energy dissipation (from the source node to this intermediate node). The system also set up two significant condition for the intermediate node to perform rebroadcasting: i) if the same packet didn't reached the intermediate node before (to avoid redundancy) and ii) if the packet has originated from the path with the equivalent quantity of the hops as the optimal route till that instant of time with lower energy consumption. The reasons to formulate these two conditions are that shortest path is opted by ensuring first condition while the energy efficient shortest path is ensured from the second condition.

2.4 Optimal Routing

After the energy-efficient routing is performing, there is still space for optimization as it is quite possible that evolution of energy-efficient shortest path technique may lead to energy consumption slightly for large scale MANET. Apart from it, there is another problem related to dynamic topology for which reason the mobile nodes depletes maximum energy. Various challenging environment surfaces up e.g. i) the prior energy-efficient shortest path may no longer exist, ii) dynamically changing channel condition, iii) random node movement. Hence, the energy-efficient shortest path routing discussed in previous section will require certain optimization for mitigating such issues. The proposed MECOR will avoid using extra episodic control message and thereby it can ensure mitigating overheads as well as minimization of energy dissipation owing to reduction of signaling messages during optimization stage. According to the proposed technique, all the mobile nodes in MECOR approach can actually evaluate the required energy for performing transmission as well as route cost for the adjacent mobile nodes using the control message. In MECOR, all the nodes that are transmitting the packet will also embed the route cost into the header of the packet mainly aiming for its nearest receiving hop. In such scenario, all the mobile nodes will perform evaluating the communication of the data packet in its adjacent mobile nodes for extracting the information related to the route cost and deploy such route cost metric to evaluate the cost of the specific route. In every phase of communication system in MANET, the node will store the following information into the new routing table as i) source node, ii) destination node, iii) header ID, iv) route cost between source and destination, and vi) time. Among all the attributes, information pertaining to sender and receiver can be extracted from MAC header, while route cost, source node, destination node, header ID, and time can be extracted from IP header. In order to avoid storage complexity, such information for the routes will kept for small range of time for facilitating accurate information processing. Using the new routing table, any mobile node will now have the precise information about their cost-efficient path as well as cumulative cost to be incurred in that path. In the proposed system, the control message are only transmitted when the better energy-efficient shortest path is identified and therefore, MECOR has significantly low overhead.

3. Results and Discussions

This section discusses about the results being accomplished after simulation study of MECOR with multiple challenging network environment in MANET. The proposed system is implemented in normal 32 bit machine with Windows OS. The programming of MECOR logic was done using Matlab. For the purpose of effective benchmarking, we choose to consider the most recent study performed by Smail et al. [16]. The reason for selecting this study is because of the similar aim of energy efficiency. Smail et al. [16] have presented an energy-preservation routing technique considering multi-hop network in MANET. The design aspect of Smail et al. [16] is basically based on on-demand multipath routing. At the same time, it was found that some of the significant studies e.g. [17][18] have also discussed energy efficient routing using AODV routing protocol. Hence for the purpose of benchmarking, we choose to compare the outcomes of MECOR with standard AODV and most recent technique proposed by Smail et al. [16].

However, the simulation environment as well as design principle of Smail et al. [16] is very different from MECOR, and for performing comparative analysis, we require using the similar test bed. Therefore, in order to implement the routing principle introduced by Smail et al. [16], we have amended AODV for exploring the reduced cost link as per our proposed schema. The distance required for per hop transmission for the mobile nodes is configured to 300 meters and various smaller units of hops are considered for the purpose of energy preservation. We apply our energy management technique in all the methods considered for simulation study (MECOR, Smail et al. [16], and original AODV), where the sender node tune itself to the required transmittance power depending on the genuine spatial values to the consecutive hop of destination. The simulation is carried out considering 1500x1500m^2 where all the mobile nodes are randomly distributed in the simulation area. We also use the simple discrete probability distribution mechanism for mapping the principle of arrival rate of particular session.

Random waypoint model is chosen to design the mobility of the nodes in the simulated area with pause time of 20 seconds. The simulation outcomes are extracted after completing 35 rounds. The preliminary phase of the simulation study will consider that mobile nodes do not posses any scheme to control energy dissipation as each mobile node will dissipate energy either in active state or in passive state (idle listening state). In MANET, a mobile node plays a multiple role, where each node can act as source node, destination node, as well as intermediate node. Hence, we also consider that certain amount of energy is also consumed when the mobile node starts overhearing data packet during multi-hop transmission. Hence, MECOR hypothesize that it is not totally feasible to control the receiving power of nodes. Therefore, MECOR doesn’t emphasize on receiver energy and concentrated its evaluation only on transmission energy.

The proposed system considers energy as the prime performance metric to analyze the outcomes. The energy parameter is analyzed with respect to multiple other parameters e.g. number of nodes, size of data packet, connection arrival rate, and mobility. Figure 3 exhibits the outcome accomplished for energy parameters with respect to increasing number of mobile nodes. The evaluation considers cumulative energy being depleted by the mobile nodes divided by the cumulative amount of data packets being received by the mobile nodes. The investigation is done to understand energy being depleted by each request message to under the efficiency.

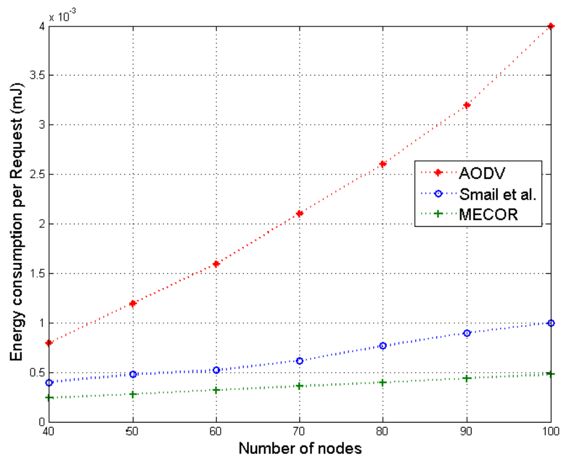

Figure 3. Energy Consumption per Request Vs Nodes

The proposed study has perform simulation of request message around 25, 000 links for MECOR, AODV, and Smail et al. [16]. The outcome exhibited in figure.3 shows that AODV has almost linear increment of energy consumption with the increasing number of mobile nodes. Hence, probability of node death is much higher in AODV owing to less occurance of periodic updates and formulation of route inconsistence. Because of this problem in AODV, there is also a significant amount of latency in route setup particularly at a time when there is a need of new communication channel. This forces the node to dissipate more energy in order to be in connectivity with other nodes in AODV. The prime reason behind this is that with the increasing number of nodes, there is also an increasing number of intermediate mobile nodes in simulation study. This phenomenon significantly leads to increased inconsistent routes, for which reason, degree of energy depletion is quite higher. However, it was seen that Smail et al. [16] have better performance compared to conventional on-demand routing technique like AODV. However, Smail et al. [16] approach uses an iterative computation principle to find remnant energy of nodes at each round leading to slight complexity. Hence, MECOR technique proves better energy efficiency as it doesn’t have any such complexity involved in iterative process of energy computation from the nodes. MECOR principle is designed from link-cost metric for which reason the processing of the nodes to select the optimal path is quite faster resulting is considerable preservation of energy.

Figure 4 exhibits the energy being consumed with the increasing traffic load. The traffic load is evaluated using increasing number of packet size. The design principle of AODV works on shortest path theory, while both MECOR and Smail et al. approach [16] works on energy efficient routing theory. According to Figure 4, AODV doesn’t guarantee better energy preservation when the traffic increases its size. Hence, it can be said that AODV could be positively used in heavy and dense traffic condition (increasing packet size) in MANET.

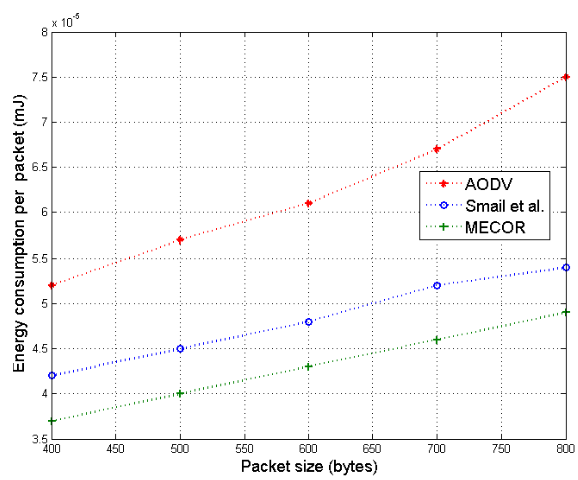

Figure 4. Energy Consumption per Request Vs Packet Size

The outcome shown in Figure 4 clearly shows poor performance for AODV with respect to the energy efficiency. The prime reason behind this is with increase in number of packet size (in bytes), AODV arranges all the incoming data packet in a particular queue system until and unless the routing protocol is done with its finding of a new route for transmitting the data packets that it is respositing in queue. This results in increasing energy consumption with increasing number of data packets incoming. Hence, AODV cannot be said to sustain load of increasing numbers of data packet for a large scale network. The performance of Smail et al. [16] approach is far better than AODV but couldn't excel better optimization as MECOR does on other hand. The prime reason behind this is i) owing to emphasizing on precision on design principle of link metric, MECOR can explore better energy efficient routes compared to Smail et al. [16], ii) owing to iterative principle of Smail et al. [16] approach, the computational complexity increases with respect to overhead, which is not the case in MECOR, and iii) MECOR has instantaneous tuning with the dynamic topology of MANET resulting in faster deployment. These are some of the significant reasons, why MECOR can sustain better even in dynamic traffic condition of MANET.

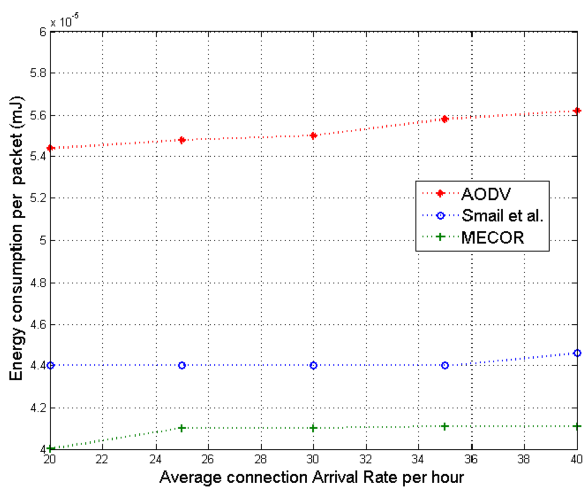

Figure 5. Energy Depletion Vs Connection Arrival Rate

Figure 5 highlights the analysis for energy depletion with respect to rate of connection arrived. The outcome shows that AODV has higher energy consumption compared to Smail et al. [16] and MECOR. The prime reason behind this is the design principle of routing strategies of all the three techniques. In MECOR, the design principle adopts CM_{RTS} and CM_{CTS} as a technique to solve the hidden node issue and supports precise configuration of network allocation vector. Hence, the moment the principle of energy control is applied to stop depleting energy; it is highly possible that reduction in transmission power of one particular mobile node will also result in minimization of transmission zone for other mobile nodes for the purpose of identifying the neighbor nodes. This is the initial occurrence of link breakage in AODV. In AODV, it is also quite feasible that data transmission may vary significantly depending on the incoming connections arrived per hour leading to higher degree of transmission zone. This phenomenon in AODV has adverse affect in energy as well as even in routing for larger traffic size. However, Smail et al. [16] approach and MECOR is designed on principle of energy efficient routing, hence if the there is a less chances of collision as the node that is hidden will also transmit data packet (using CM_{RTS}/CM_{CTS}). This transmission of data packet using CM_{RTS} and CM_{CTS} will have lesser energy depletion in MECOR as energy of control packets are considerably less than data packet and hence MECOR can ensure better transmission with reduced energy consumption. However, Smail et al. [16] technique doesn't include such signaling principle owing to energy depletion and it significant under-emphasize link cost metric. Smail et al. [16] technique attempted to extract the best routes from the maximum number of available hops. Hence, MECOR outperforms both AODV and Smail et al. [16] approach and exhibits better energy optimization with dynamic connection arrival rate per hour.

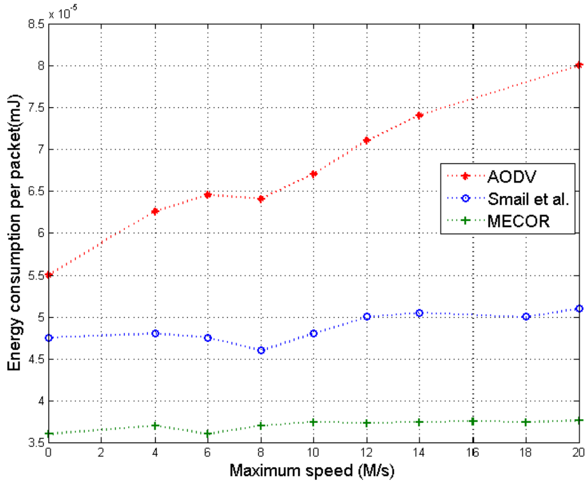

Figure 6. Energy Consumption per Request Vs Mobility

Figure 6 basically highlights the impact of mobility on the energy being consumed on each receiving and transmission of data packet by the mobile nodes. A closer look into Figure 5 and Figure 6 on the curve of AODV and Smail et al. [16] will show that there is an increment in energy dissipation when mobility factor is considered. Also, a closer look into the curve of MECOR both from Figure 5 and Figure 6 will show that there is slight optimized degree of energy conservation even in dynamic mobility environment. Smail et al. [16] approach couldn't able to adapt itself to the increasing mobility factor for which reason the routes created are less stabilized compared to MECOR. However, owing to optimized routing schema, MECOR can significant sustain on increased mobility of the nodes, where the reduction of energy dissipation is found to be very high. In the above experimental cases, it was found that AODV is able to conserve (8.5-5.5/8.5x100=) 35.29%, Smail et al. [16] is able to conserve (8.5-4.7/8.5x100=) 44.70%, and MECOR is able to conserve (8.5-3.5/8.5x100=)58.82%. A closer look into the outcome also shows that MECOR technique is highly independent of conventional queuing mechanism (like in AODV) or have iterative operations for discovering a robust route (like in Smail et al. [16]), hence, the applicability of MECOR can be said to be on any time-critical applications in MANET as it offers extensive energy conservation of approximately 59% as compared to existing system. MECOR is also not much affected by the variable speed of a mobile nodes in MANET, which makes its quite suitable for vehicular-based applications. With the increasing number of data packets, MECOR can well sustain the traffic load as compared to the existing system, which makes it quite suitable for usage in multimedia traffic in MANET systems. Hence, MECOR offers quite a good range of flexibility in communication over MANET without using any complicated design approach or have any dependency of external devices of third parties.

4. Conclusion

This paper has developed a theory that strongly associated energy efficiency with optimized routing as the backbone of successful communication model in MANET. The proposed system introduces a technique MECOR to fulfill the objectives of this theory. The outcomes accomplished from the study were compared with conventional AODV and recently published work on demand routing using energy as the prime performance parameters. The outcomes shows the highly optimistic preservation degree of energy from mobile nodes that can sustain dynamic topology of MANET and yields a cost efficient routing principle.

References

[1] S. Guo, Ad-hoc, Mobile, and Wireless Networks, Springer. 2014; 1-575

[2] A. Laouiti, A. Qayyum, M. N. M. Saad, Vehicular Ad-hoc Networks for Smart Cities, Springer, Computers. 2014; 1-650

[3] D. Taniar, O. Gervasi, B. Murgante, E. Pardede, B. O. Apduhan, Computational Science and Its Applications, Springer Science & Business Media, Computers . 2010 1-597

[4] Shivshankar, H.N. Suresh, G. Varaprasad and G. Jayanthi, "Designing Energy Routing Protocol with Power Consumption Optimization in MANET", IEEE Transactions on Emerging Topics in Computing, 2014; 2(2),192-197

[5] Y. Zhang, W. Liu, W. Lou and Y. Fang, “MASK: Anonymous On-Demand Routing in Mobile Ad Hoc Networks,” IEEE Transactions on Wireless Commns. 2006;5(9),2376-2385
[6] N.Gupta and S. R. Das, "Energy-aware on-demand routing for mobile ad hoc networks", In Distributed Computing, Springer Berlin Heidelberg. 2002; ,164-173,
[7] Y.Kawamoto, H.Nishiyama, N.Kato, "MA-LTRT: A Novel Method to Improve Network Connectivity and Power Consumption in Mobile Ad-hoc Based Cyber-Physical Systems," IEEE Transactions on Emerging Topics in Computing. 2013 ; 1(2), 366-374
[8] C-Y.Wang, C-J.Wu, G.N.Chen, and R-H. Hwang, "p-manet: Efficient power saving protocol for multi-hop mobile ad hoc networks", In Information Technology and Applications. ICITA, Third International Conference. 2005; 2, 271-276
[9] E.Huang, W. Hu, J. Crowcroft, and I. Wassell, "Towards commercial mobile ad hoc network applications: A radio dispatch system", In Proceedings of the 6th ACM international symposium on Mobile ad hoc networking and computing.2005; 355-365
[10] B.Zhu, Z. Wan, M. S. Kankanhalli, F. Bao, and R. H. Deng, "Anonymous secure routing in mobile ad-hoc networks", In Local Computer Networks, 29th Annual IEEE International Conference.2004; 102-108, 2004.
[11] S.Mitra and J. Rabek, "Energy efficient connected clusters for mobile ad hoc networks", In 3rd Annual Mediterranean Ad Hoc Networking Workshop. 2004;386-397
[12] K-W.Chin, J. Judge, A. Williams and R. Kermode, "Implementation experience with MANET routing protocols", ACM SIGCOMM Computer Commn Review.2002; 32(5) , 49-59.
[13] Zhenqiang Ye, Srikanth V Krishnamurthy, Satish K Tripathi “A frame work for reliable routing in mobile adhoc networks”, IEEE infocom 2003 :, 0-7803-7753/03
[14] Q. Fu, B. Krishnamachari, and L. Zhang, “DAWN: A Density Adaptive Routing for Deadline-Based Data Collection in Vehicular Delay Tolerant Networks”, IEEE- Tsinghua Science And Technology.2013; 18(3).
[15] Javad Vazifehdan, R. Venkatesha Prasad, and Ignas Niemegeers “ Energy-Efficient Reliable Routing Considering Residual Energy in Wireless Ad Hoc Networks”, IEEE Transactions on Mobile Computing.2014;13(2).434-447
[16] O. Smail, B. Cousin, R. Mekki and Z. Mekkakia, “A multipath energy-conserving routing protocol for wireless ad hoc networks lifetime improvement”, EURASIP Journal on Wireless Communications and Networking.2014; 2-12
[17] A.Tripathi, R. Kumar, “MECB-AODV: A Modified Energy Constrained Based Protocol for Mobile Ad hoc Networks”, International Journal of Distributed and Parallel Systems (IJDPS) .2012 ; 3(6),15-30 .
[18] N. H Masulkar, A. A Nikose, “An Improved Multipath AODV Protocol Based On Minimum Interference”, IOSR Journal of Computer Science.2014; .01-04
[19] Ahmed M. Abd Elmoniem, Housy M . Ibrahim, Marghny H Mohamed, Abdel-Rehman Hedar “ Ant colony and load balancing Optimization for AODV Routing Protocol”, International Journal of Sensor networks and Data Communication . 2012; 1 , 01-14
[20] R. Beraldi and R. Baldoni “A Caching Scheme for Routing in Mobile Ad Hoc Networks and Its Application to ZRP” , IEEE Transactions on Computers.2003; 52(8),1051-1062
[21] Jinhua Zhu and Xin Wang, Member, IEEEModel and Protocol for Energy-Efficient Routing over Mobile Ad Hoc NetworksIEEE Transactions on Mobile Computing, Vol. 10, No. 11, November 2011.