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Energy and QoS Efficient Load Aware Routing Protocol for Mobile Ad Hoc Networks

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Abstract: ***Efficient load balancing in Mobile Ad Hoc Networks (MANETs) is widely studied research problem since from last decade. The performance of MANETs routing protocol becoming weak because of frequent routes failure and other constraints such as less capacity, high traffic, less energy etc. In short, load balancing is major cause of frequent routes failure in MANETs. Frequent routes failures always resulted in overall QoS performance degradation in MANET. There are various load balancing techniques introduced by considering the different constraints and characteristics of MANETs routing. The goal of any routing protocol should be optimal performance from routing communications. The existing routing efficient protocols does not guarantee for all the performance metrics efficiency such as energy efficiency, QoS efficiency, routing overhead etc. Some load balancing enabled routing protocols providing the QoS efficiency but failed to achieve the energy efficiency and vice-versa. By considering all the limitations of existing load balancing enabled routing protocols, in this paper novel EELAR routing protocol is designed. The goal of EELAR routing protocol is to achieve the optimized performance for QoS and energy efficiency as compared to all previous routing protocols. EELAR is designed by contributing two algorithms such as link efficiency algorithm and load efficiency algorithm.***

Keywords: AODV, EAODV, ELGR, ELAR, MANET, Load balancing, throughput, packet delivery ratio, routing overhead

1. Introduction

Wireless networks are a very popular into the computing industry. This is particularly true within the previous past decade, where the wireless networks have been adapted to enable mobility. Wireless networks can be broadly categorized into two classes. The first is known as the infrastructure-based wireless network (i.e., a network with fixed and wired gateways).The second type is the Infrastructure less wireless network (ad hoc wireless networks), infrastructure-based wireless networks rely on an access point ,which is a device acts as bridge between the wired and wireless networks, example of infrastructure-based wireless networks are wireless networks set up in airports, offices, homes and hospitals , when a client's connect to internet with the help of an access point the other type of wireless networks does not rely on to the fixed infrastructure, & it has been very commonly known as ad hoc wireless network. Wireless Ad hoc network consists of self-corporate devices & it can be deployed without the infrastructure. There is different example of MANET in ad hoc mode such as the building to building, vehicle to vehicle & ship to ship etc. the communicate with each other by relying on peer-to-peer routing Mobile Ad hoc Networks (MANETs) can be defined as autonomous system of mobile nodes connected via wireless links ignoring some existing network infrastructure. Each node acts as a host as well as a router and forwards each other's packets to enable the communication between nodes not directly connected by wireless links. A central challenge on into the design of the ad hoc networks is a development of dynamic routing protocols that can efficiently find routes between into the communication nodes. This routing protocol should be able to keep up with the high degree of node mobility that is frequent change into the network topology drastically & unpredictably. The combination of link-quality variation with the use of broadcasting nature of the Wireless channels has been revealed a direction in the research of wireless networking, namely, cooperative communication [1] [2].

A mobile ad hoc network (MANET) might be visualized as a self-sufficient system or a multi-hop wireless addition to the Internet. As a self-sufficient system, MANET must present its own routing protocols and robust mechanism of network management. As a multi-hop wireless extension, it must also facilitate a supple, feasible and faultless communication amongst the users or access to the services like Internet. Lately, because of increasing attractiveness of multimedia applications and in anticipation of commercial deployment of MANETs, the quality of service (QOS) prop up in MANETs has become an imperative prerequisite. Though, the QoS support in a MANET network is dissimilar to that of the wire line network or the cellular communication network as wireless bandwidth is collective and is shared amongst neighbouring nodes and the network topology constantly variations with the mobility of comprising nodes. This situation needs widespread association between the nodes, both to set up the route and to secure the resources required for facilitating optimum quality of service (QoS) [3].

Some scientific societies have defined QoS as a set of service requirements to be achieved by the communication network whilst performing transportation of a packet stream from source node to sink or to destination node. Inherent to the perception of QoS is conformity or an assurance by the network to endow with a set of quantifiable pre-specified service attributes to the user in terms of performance parameters like delay, jitter, available bandwidth, packet loss, etc. As in case of the Internet, MANETs are developed for supporting the best-effort service with no guarantees of associated QoS. Consequently, when a packet is lost in a MANET network, the transmitter just retransmits the lost data packet and it might be stated as an effective approach for applications requiring no QoS, but simple end-to-end retransmission of data is derisory or not sufficient for real-time applications that are sensitive to these performance factors such as packet loss, delay, bandwidth availability, etc.

The QoS performance efficiency in MANET is basically addressed by load balancing routing protocols [4] [5] [6]. The term load balancing in routing is nothing but the technique of distributing current workload among multiple routing links in order to achieve the efficient resource utilization, increased average throughput, minimized end to end delay, extending the network lifetime, and keeping the less overhead on mobile nodes. By using multiple communication paths with approach of load balancing is superior to using unipath routing with load balancing. The methods of load balancing are having below two important features such as asymmetric routing load and priority activation. There are number of load balancing methods for MANET routing is presented so far with their merits and demerits [7] [8] [9] [10]. In this paper by taking motivation of two research problems such as QoS efficient load balancing method and energy efficient load balancing method.

The hybrid approach is proposed and designed in this paper to achieve both QoS efficiency and energy efficiency simultaneously for MANETs. This new protocol is named as EELAR protocol. The main objective of proposed EELAR routing protocol is to supports QoS guarantee and extended network lifetime concurrently. EELAR is having two main characteristics like method of link estimation proposed for energy efficiency improvement and another is learning of network load balancing in order to achieve the improved QoS solutions. In section II, the existing algorithm ELGR based on which proposed EELAR routing protocol is designed is explained. In section III, proposed QoS and energy efficient algorithm is proposed. Section IV, discussing the simulation results.

2. ELGR Protocol

In this section detailed design of algorithm ELGR [12] is discussed in below section. The basic operation of ELGR is a two-step process [12]:

A. The relay node determines its position in either FA or DA using information from the packet's header.
B. In the different areas described above, the relay node adopts different forwarding methods.

In FA, the packet is forwarded along a single path in accordance with a strategy for selecting the next-hop node. In DA, single-path forwarding is not effective.

2.1 FA Data Packets Forwarding

ELGR uses a geographical and energy aware neighbour selection formulation to heuristically choose the best next-hop node among all neighbours in the FA that are closer to the destination, and forwards the packet to it. Suppose node i wants to forward a packet P, where Ni is its neighbour set and j∈Ni. Then the forwarding strategy is based on the weight function Wij given by

$$Wij = \propto E(d_{j,}p_j) + (1-\propto)\, L(n_j, e_{remain}) \qquad (1)$$

α (0 < α ≤ 1) is a tenable coefficient, E (dj, pj) and remain (,) j j L n e are functions of energy efficiency and load balance, which are defined below.

A. Energy efficiency function Energy efficiency (Eeff): it is defined as the number of packets delivered to the link for each unit of energy spent by the network:

$$E_{eff} = \frac{1}{t_e \quad total} \qquad (2)$$

where e_{total} is the energy used for transmission and reception during one hop. The total number of transmissions t is given by

$$t = \frac{1}{E(T)} \cdot \frac{d_{src}-sink}{p} \qquad (3)$$

where p is the progress a relay node makes, T is the number of packets sent through a specific link with a certain PPR value, and E(T) is the expected value of T. If the PPR of this link is P0, then

$$E(T) = \lim_{n\to\infty} p0.1 + (1-p0) \quad p0.2 + .. + (1\text{-}p0)^n p0.\ n = 1/p0 \qquad (4)$$

From Eq. (2), Eq. (3) and Eq. (4), we know

$$E_{eff} = \frac{PRR(d).p}{d_{src-sink}} \cdot e_{total} \qquad (5)$$

During a routing decision, dsrc−sink and etotal are constant. Accordingly, the energy efficiency cost for our routing is PRR

$$E(d_j, p_j) = \frac{PRR(d_j p_j)}{r} \qquad (6)$$

B. Load balance function: If there are many packets that need to be transmitted through a certain node, then the energy of this node may be depleted rapidly, which shortens the network lifetime. It is sensible that other neighbour nodes help to deliver some of these packets. The load balance function employs a trade-off between residual energy and packet number in the transmission queue of a certain node. When node i receives a beacon message from its neighbour j, i receives sufficient information about j to apply the load balance function:

$$L(n_j, e^j_{remain}) = \frac{M-n_j}{M} \cdot e^{j\frac{remain}{E}} \qquad (7)$$

where nj is the number of packets waiting for transmission in j, M the maximum number of packets allowed in a node's queue, remain je the residual energy of j, and E represents the maximum energy of a node. If a relay node cannot find its neighbour nodes in the FA, it can use Eq. (1) to select the best next-hop node from the whole transmission range once again. In addition, void problem is not the main focus of this article.

2.2. DA Data Packets Forwarding

ELGR applies a novel forwarding mechanism instead of flooding in the DA. The key concept is to ensure there are as few nodes as possible in the DA forwarding a packet, although all of them receive it. Suppose a node, A, in the DA broadcasts a packet, P. If a neighbour node, B, is far from node A, then the broadcast from B will cover more area than the original broadcast from A, raising the probability that other nodes will receive P. Our method, CM, achieves this as follows. When node B receives a packet P, it reads the position of the last-hop node and ε ($0 \leq \varepsilon < 1$) from P's header, where ε is a coefficient determined by node density. If the distance, d, between B and A is smaller than ε r, then B will not forward P, otherwise B will broadcast P after delay time

$$t_{delay} = \frac{r-d}{(1-\varepsilon)r} \cdot t_{max\_delay} \quad (8)$$

where t_{max_delay} is a constant value.

2.3. ELGR Descriptions

Based on the outline above, ELGR algorithm is designed as below:

Algorithm 1: ELGR Algorithm Steps
Step 1: When a node i (source node or relay node) wants to transmit a data packet P:
1.1. If i is located in the FA, it sends P to the next-hop node in the FA whose value of Eq. (1) is maximal (if there are no neighbour nodes in the FA, it selects the next hop node from the whole transmission area using
1.2. If i is located in the DA, it changes the value of ε in P's header according to its neighbour number, and then broadcasts P.

Step 2: When a node i receive a data packet P:
2.1. If i is located in the FA, it sends P by Step (1).
2.2. If i is located in the DA, it reads the ε in P's header. If the distance between the last-hop node and i is longer than ε r, i waits for a period of time calculated by Eq. (8) and then sends P by Step (1).
2.3. Otherwise, i inspect its cache to see whether it has already received a packet with a payload the same as P. If so, i delete it and cancel the transmission of P.

3. EELAR Protocol

In previous works, QoS efficiency was achieved at some extend using load balancing enabled routing protocols, however it is required further to improve the energy efficiency as well by contributing the link efficiency method for energy efficiency along with the QoS efficiency. In this paper, the performance evaluation is done among AODV, EAODV, ELGR and EELAR with respect to both QoS efficiency and energy efficiency. EELAR was modified in order achieve both QoS and energy efficiency for MANET load balancing. As showing in figure 1, the main goal of this paper is showing in which two main objectives are evaluated such as QoS efficiency and energy efficiency of proposed EELAR routing protocol. For QoS efficiency we have selected average throughput in KBPS performance metrics and for energy efficiency we have selected three energy related performance metrics such as average energy consumption, residual energy of network and network lifetime. These three metrics helps in deciding the energy efficiency of routing protocol.

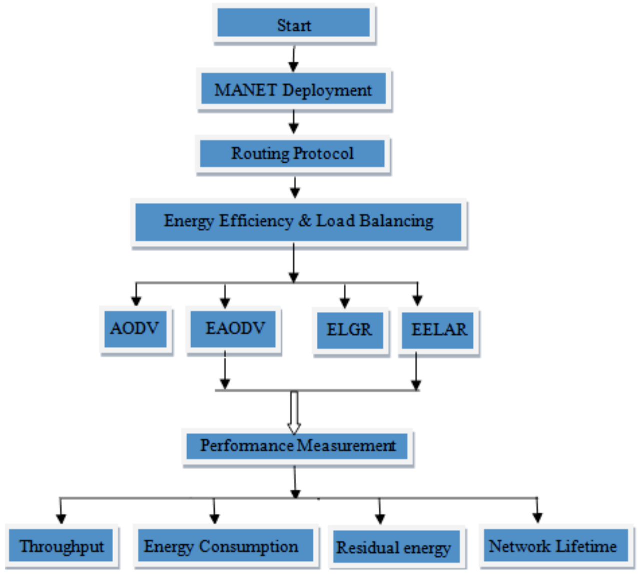

Figure 1: Detailed System Architecture and Flowchart

Algorithm 2: Energy and QoS Efficient ELGR (EELAR)
Inputs:
- Routing Table Entry,
- packet p,
- node ID,
- Set the energy threshold,
- Set load threshold values.

Step 1: Extract the current packet details
Step 2: Define the routing table pointer
Step 3: Extracting the Destination Area (DA) by computing the depth from sink node
Step 4: Extracting the Forwarding Area (FA) by computing the sink node neighbours
Step 5: Finding the shortest path from source to destination
Step 6: Update routing table entries
Step 7: Apply Energy Efficiency function

7.1.: Before starting data transfer, convert all nodes except source node into the sleep state
7.2. If source node is ready to send data on selected active paths, then convert all nodes into active state from sleep state.

Step 8: Apply Load balancing function for data forwarding
Step 9: Refined by Link Efficiency Algorithm [Algorithm 3]
Step 10: If energy level of any node goes below threshold or load on node goes particular threshold, then finds another alternate path in order to balance load or improved the network lifetime performance.
Step 11: If any node detects all its lower depth nodes below current threshold value, then it calculates new threshold and, start sending data on those paths again.
Step 12: Repeat this process still to the simulation ends.
Step 13: Stop.

The existing ELGR protocol is contributed by link efficiency algorithm in which both QoS efficiency as well energy efficiency is achieved. Below is designed algorithm for achieving the link efficiency.

Algorithm 3: Link Efficiency
Inputs: Extraction of neighbour table, RSSI values and remaining energy values from current routing

Step1: For transmitter node, preparation of neighbor table
Step2: Computation of energy values and RSSI values
Step3: Update and maintain neighbor table with neighbor id, values of RSSI and RE.
Step 4: Neighbor table is update and maintain with distance D of all the neighbors of transmitting node.
Step 6: Energy sorting with routes with more remaining energy values will be on top.
Step 7: Arranged Distance table in ascending order. Shortest distance node will be on top.
Step 8: Considering threshold value transmitter node were selecting candidate node for the next hop.
Step 9: If node is not satisfying the criteria were made to sleep.
Step 10: Removal of redundant routing paths
Step 11: Stop

Design of Energy Model

To assess the lifetime of a given topology, it is important to include a model to drain the nodes' energy whenever they perform any action. The energy model will be used in this research is to model the energy consumption of the nodes. It is based on the following Equations

$E_{Tx} = E_{elec}+E_{amp} * R^2_{comm} * \pi$

$E_{Rx} = E_{elec}$

Where

E_{Tx} is the energy spent to transmit 1 bit, E_{Rx} is the energy to receive 1 bit, E_{elec} is the energy used by the electronic components of the radio, and E_{amp} is the energy used by the radio amplifier. The second term is proportional to the square of the transmission range that wants to be achieved by the radio signal. Despite the simplicity of this energy model, it is still commonly used in the literature of wireless mobile networks.

Initial energy source = 1 Joule
Eelec = 50nJ/bit
Eamp = 10pJ/bit/m^2

4. Results and Discussions

In this paper we proposed the improved EELAR routing protocol by considering the energy efficiency along with load balancing efficiency. This is done by adding the link efficiency technique in which communication between source and destination is done by selecting the efficient path which can deliver the energy efficiency and QoS efficiency for MANET. We have compared the performance of three routing protocols using three performance metrics such as AODV, EAODV [11], ELGR and proposed EELAR technique for throughput analysis and energy efficiency performance. For energy efficiency we have measured three energy related performance metrics such as average energy consumption, residual energy and network lifetime. Following are comparative graphs showing the results for the same.

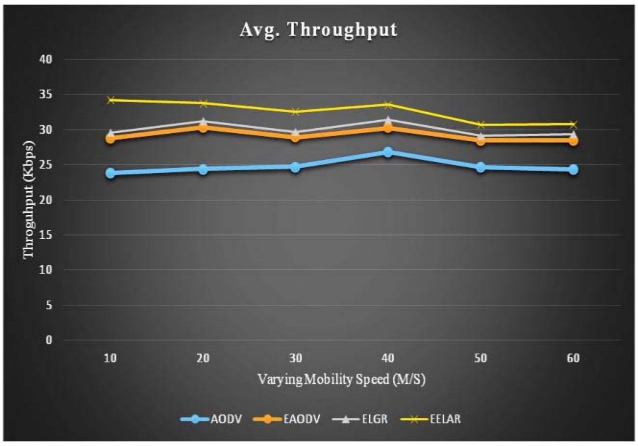

Figure 2: Average throughput analysis for proposed and existing load balancing techniques

From results showing in figures 2, 3, 4, and 5 for average throughput, average energy consumption, residual energy and network lifetime respectively for two load balancing protocols such as existing AODV, EAODV, ELGR and proposed EELAR for selected network scenario depicted in earlier. As per the aims and objectives of EELAR protocol, it is outperforming the existing ELGR protocol in both efficient load balancing means improved throughput as well as energy efficiency means minimizing the energy consumption, increasing the residual energy and network lifetime performance.

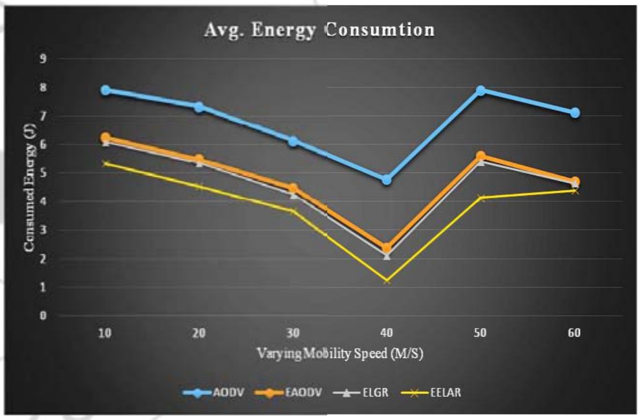

Figure 3: Average Energy Consumption analysis for proposed and existing load balancing techniques

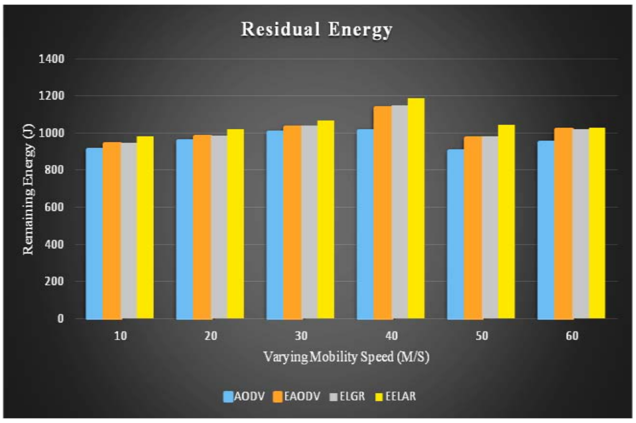

Figure 4: Residual energy analysis for proposed and existing load balancing techniques

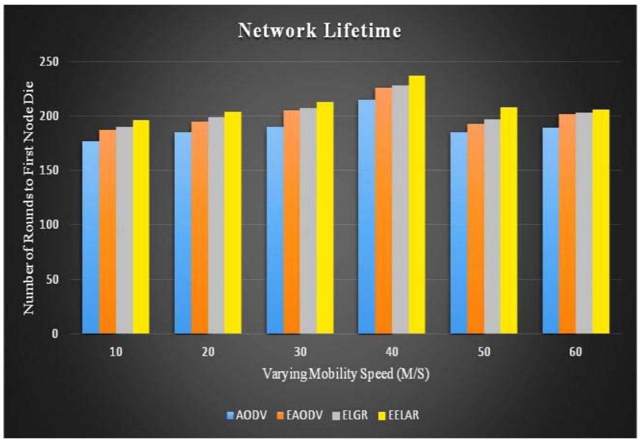

Figure 5: Network Lifetime analysis for proposed and existing load balancing techniques

These simulation results showing that proposed EELAR protocol achieve the set objectives. The improvement showing results is more and significant as compared to ELGR protocol. In conclusion, the results claiming in all three contributions that EELAR routing protocol which is proposed approach in this thesis is showing the significant improvement in energy efficiency and QoS efficiency for MANET. The results are measured by considering the varying network conditions so that scalability and reliability should be achieved. EELAR is resulted as energy efficient load balancing approach.

5. Conclusion

In this paper EELAR routing protocol is proposed, designed and evaluated in terms of QoS and Energy Efficiency performance metrics. The simulation results showing the comparative study among existing load balancing protocol EAODV and proposed load balancing protocols EELAR. From the experimental results it showing the throughput performance of proposed method is improved by 50 % as compared to existing EAODV method. The energy consumption is reduced by 40 % as compared to EADOV protocol and 30 % against ELGR routing protocol. The network lifetime is increased by around 35 %. Still there is scope of improvement for EELAR protocol in different ways and domains. Currently this protocol is built on top on on-demand routing protocols, in future we suggest working on different types of routing methods. For future work, at present most of MANET networks are hybrid MANETs. Hence proposed algorithm should be evaluated by considering in hybrid mobile ad hoc network in future.

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