Energy Efficient Routing Algorithm for Future Ad-hoc Wireless Networks

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Abstract: ***This study addresses a critical issue in the field of mobile ad hoc networks (MANETs) by proposing a routing technique that combines load balancing and power-saving strategies. This research is highly relevant in the context of wireless communication, where energy efficiency and network performance are of paramount concern. Conventional efforts have primarily concentrated on energy-saving shortest path-based schemes, which may lead to network failure because certain nodes may run out of energy quickly due to frequent use, while other nodes may not be used at all. This may result in an imbalance of energy and a decrease in network performance. It is suggested an energy-effective ad hoc on-demand protocol for routing that fairly distributes the energy load among nodes and also keep all inactive nodes into sleep mode. It is focused on increasing the packet delivery ratio (PDR) and energy savings. The proposed protocol is compared with contemporary protocols, Dynamic Source Routing (DSR) and Efficient Load Balancing Method (ELBM). It is found that the proposed approach uses 13% less energy than DSR and 6% less than the ELBM model. In contrast, PDR has increased by 6% and 5% in relation to DSR and ELBM, respectively.***

Keywords: Multipath routing, Load balancing, Power saving, and MANET

1. Introduction

Mobile ad hoc networks are regarded as autonomous, multi-hop wireless networks. They have no centralized administration, no static infrastructure, and can adapt extremely quickly to any platform, anywhere, at anytime [1-3]. They are deployed in applications such as disaster recovery, defence and military communications, and sensor networks. Furthermore, as sensor-enabled smart phones have developed, they have become a portal for the construction of smart city infrastructure. All of the node objects in the MANET are switched in order to establish a network and to enable cooperative behaviour. Because of this, MANET's whole network topology is extremely dynamic. Also, the nodes are battery operated; hence efficient utilization of battery is important. Developing an energy-efficient routing algorithm that is optimised for MANETs is one of the research topics related to MANETs [4-5].

Multipath routing algorithms [6-7] create multiple paths between a source-destination pair. They select the path based on shortest distance and maximum battery power of node. These techniques may cause congestion and delays in the network. In addition, the network may be split if some nodes fail along the path. Recent research demonstrates that when traffic volume increases, multipath on-demand protocols based on least delay and maximum battery power pathways experience performance loss.

In densely populated or highly trafficked networks, load-balancing-based solutions are favoured for mitigating energy imbalance issues. They can choose a path with intermediate nodes that have sufficient power levels or they can distribute loads over several paths to balance the energy consumption among all nodes. However, these methods do not ensure that the least energy-consuming route is chosen, which raises the energy cost per packet [8-10].

In this study, an energy efficient load balancing routing technique is proposed. The routing technique combines the advantages of load balancing and power saving strategies. The technique discovers multiple disjoint paths and provides fair load distribution among them based on path congestion value. Then, a power saving strategy is applied to convert inactive nodes into sleep mode. The proposed technique improves network performance in terms of packet delivery ratio and also increases the network life period.

The remainder of this study is arranged as follows: section II provides comprehensive review of energy-aware load balancing routing techniques. Section III presents the proposed method. Section IV discusses the results for performance evaluation and section V concludes the paper.

2. Related Works

The localized energy aware routing protocol [15] provides balanced energy consumption among the nodes. Based on residual energy, the algorithm adjusts the DSR protocol's route discovery process. The technique can find the shortest path between several energy-dense paths. Although this approach is straightforward, it ignores other options. Applications that are sensitive to delays can use this technique.

A novel method of load balancing based on node’s residual energy was introduced by Allalili et al. (2012) in [16] [11]. The method aim is to divide traffic equally among network nodes. This method takes advantage of the multipath routing protocol, AOMDV, which in each route discovery specifies link-disjoint pathways between the source and the destination.

A different strategy that investigates energy-balanced consumption among object nodes was created in [17]. By altering the notion of a threshold, this algorithm aims to choose the minimal energy path that will allow all nodes in the path to have energy remaining over a threshold measurement. The approach extends the lifetime of nodes, provides fair node usage, and reduces transmission power. However, battery power is not continuously tracked.

In addition to reducing the frequency of route discovery, the multipath and energy-aware on demand source routing protocol balances energy usage across nodes [12-14]. Based on the number of hops in the path and the remaining energy of the path nodes, it chooses the main path among the multiple paths. Still, the approach has a large overhead because it permits intermediary nodes to produce duplicate RREQ packets [18].

In [19], a technique for accomplishing load balancing among the nodes without the use of energy metrics was created. Data packets are sent over several paths between the source and destination object nodes in order to achieve load balancing. Its basis is converting the OLSR approach's proactive features into a reactive route-computation approach. This mechanism's main fault is that it uses link quality rather than path detection.

The advancement of routing algorithms has presented numerous obstacles for wireless ad hoc networks, leading to the subsequent refinement of various routing protocol classifications, such as location-based and multi-cast routing protocols. For location-based routing protocols to calculate effective routes, nodes must be located geographically. GPS or other methods are used to determine the position of nodes. The location of nodes is taken into account by a number of energy-conscious routing protocols in order to find routes that are both energy-efficient and minimise routing overhead [20].

Power-efficient location-based techniques [21, 22] work well in networks that experience significant dynamic topological changes because they use node location data to estimate node distances, which lowers energy consumption, lengthens network lifetime, and reduces flood of control overhead. These methods, however, make the unavoidable assumption that every node is a mobile device with GPS capability.

Multicast based routing algorithms allow data broadcasting from a single node to numerous nodes within the group while making efficient use of available bandwidth. By taking advantage of radio link's built-in broadcasting capability, the multicasting technique increases their efficiency. Two instances of this type of routing technique are the multicast AODV [23] and the on demand multicast routing protocol [24].

In order to lessen the variance of node's remaining energy, power metrics like transmission power and path remaining energy are included in the multicast routing approach in [25]. Similar to this, in [26] scalability and overhead issues are addressed by using a multicast approach with predicted remaining energy levels. In order to reduce energy consumption and lengthen the network lifetime, Varaprasad G. proposed a high stable power-aware multicast routing method in [27] .This method uses relay energy capacity and remaining energy capacity as route metrics.

The following conclusions are reached as a result of the literature review:

- The current routing protocols build the paths using the minimum hop count as a metric. These routing strategies might not be energy-efficient. The amount of power used by the inactive nodes was neglected.
- The suggested routing method aims to save power and distribute loads fairly. This routing method keeps idle nodes in sleep mode and directs clear of congested paths caused by the data forwarding process.

3. Proposed method description

The proposed technique is a DSR based multipath routing strategy in which a metric known as the path congestion index is used in order to achieve equitable load distribution among the nodes. The metric is used to keep track of every path that could be taken and select a different route when congestion arises on the main path. Moreover, a sleep/wake-up scheme is included to optimise the efficiency of the suggested method. The suggested sleep/wake-up scheme maintains the nodes in the sleep state except the nodes along the possible paths. The goal of the suggested method is to reduce energy usage and raise the pack dispatch proportion.

3.1 Path congestion index

Path congestion index indicates the degree to which a path is involved in the message forwarding process. Rather than emphasising shortest paths, the proposed technique involves less congested nodes in the data forwarding process. Based on the load on the nodes, the method constructs an efficient path to achieve this goal. The following metrics are taken into account when calculating the congestion index:

Node load value, *Node-load of* n_i: shows the total number of connection that the node n_i has firmly established for the data forwarding process.

Maximum load on a path, P_k: represents maximum connection value along a path, p_k. It is represented as *load max* (p_k) and given by the equation (1):

$$load\ max(p_k) = \max \text{of} \{load\ on\ n_1, load\ on\ n_2, \ldots load\ on\ n_p\} \quad (1)$$

Here *n1*, *n2* and so on *np* are the nodes along the path *Pk*. The maximum connection on a path denotes a path bottleneck.

Average load on path Pk, *avg load (Pk)*: it shows the average quantity of connections made by nodes along the path Pk. It's computed using equation (2):

$$avg\ load(p_k) = \frac{(load\ of\ n_1 + load\ of\ n_2 + \cdots load\ of\ n_p)}{p} \quad (2)$$

Here *p* is the number of nodes along the path *Pk*.

The congestion index of a path *Pk* is defined by the equation (3):

$$cong\ index(p_k) = x\frac{1}{max\ -load\ (p_k)} + y\frac{1}{avg\ -load\ (p_k)} + z\frac{1}{hop\ -count\ (P_k)} \quad (3)$$

Hop-count (Pk) is helpful in determining the shortest path that can accommodate additional traffic. x, y, and z are the weights of the metric. The node connection value is given the most weight, followed by the average path connection and hop count so that the load balancing strategy becomes more effective. The maximum connection count, average connection count, and congestion index of a path are all inversely correlated. For data transmission, a path with the highest congestion index is chosen.

3.2 Sleep/wake-up technique

Nodes in idle mode use a lot of power without sending or receiving any packet, which drain the battery. The proposed method combines a power management technique in order to enhance the battery life of nodes. The suggested technique aims to preserve node energy by putting idle nodes into sleep mode without changing the network topology. Sleep/wake scheduling is a common power management technique used to save node energy. This method necessitates that every object periodically transition to idle mode in order to detect the wireless channel. Although a proper sleep/wake schedule can save a lot of energy, there are drawbacks. First, because it depends on the application, the general power management technique based on the sleep/wake-up approach is difficult to design. Second, improved sleep/wake algorithms necessitate node cooperation, which includes providing time synchronisation services. The limited processing capacity and wireless medium of the nodes make it difficult to implement precise time synchronisation among them. The proposed method implements an on-demand wake-up technique in which a paging signal is used to switch nodes from sleep mode to listening mode. This method is very energy efficient, since paging signal operates at low power than the periodical wake-up signals.

The proposed approach's behaviour is depicted in the flow chart presented in Figure 1. When source node S needs to send data, it searches its cache for a valid route to destination D. The source node writes the route in the packet header and sends the data to the destination if the route is found.

Table 1: RREQ Packet format

Unique ID	Path list (nodes)	Source ID	Destination ID

Let's say that the source initiates the route discovery process by sending out a large number of RREQs in the direction of the destination if it is unable to locate the route. Table 1 displays the format of a route request packet (RREQ).

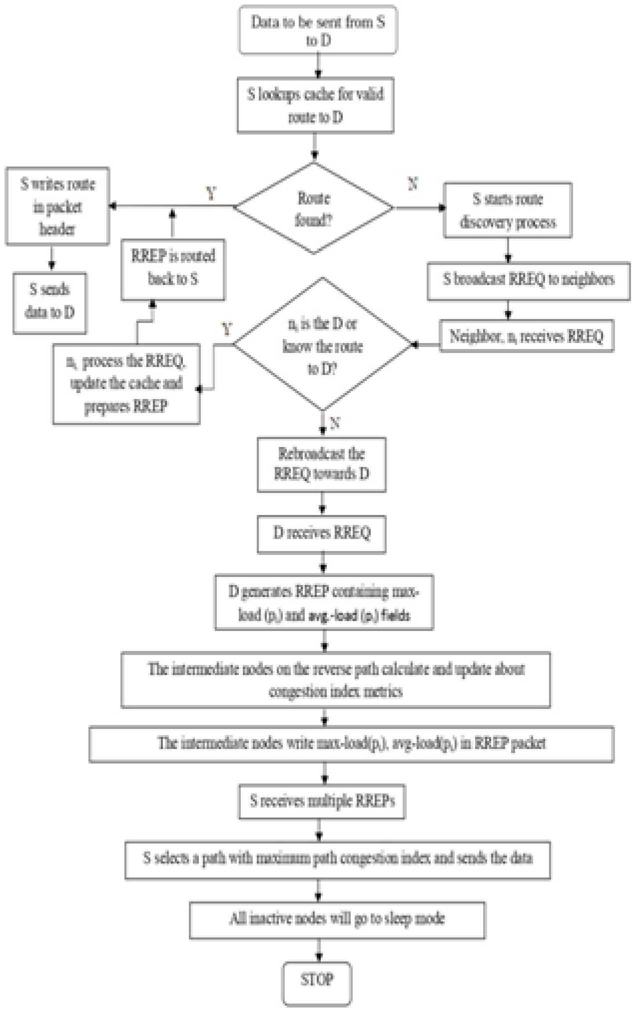

Figure 1: Flow Chart of the Proposed Routing Algorithm

When a neighbor receives an RREQ, it rebroadcasts the RREQ to its neighbors if it doesn't know a valid route to the destination and prepares an RREP to the source. Every relay node in the chain continues this process until the RREQ reaches its destination. Each request is prepared by the destination, which then sends it back to the source via the opposite route that the request took. The fields in the reply packet format are as indicated in Table 2. A Neighbor, n_i receives RREQ and prepare a RREP to the source if it know valid route to the destination; else, it rebroadcast the RREQ to its neighbors. This process is continued at every relay node until the RREQ reach the destination. Destination prepares a reply to each request and sends back to the source in reverse path taken by request. The format of reply packet contains the fields as shown in table 2.

Table 2: RREP packet format

Des ID	SrcID	Hop_count	Path [ ]	Avg_load(P)	Max_load(P)

The initial values of the path P's average and maximum loads are set to zero. Returning to the source is the route taken by the reply packet. Upon receiving the reply, each intermediate node on the reverse path updates both its cache and reply packet. The fields listed in Table 3 are contained in the node cache structure.

Table 3: Route Cache Table Format of a Node

DesId
Hop_count
Path node list
Path avg. load
Path max. load
Node load value
Path congestion index

Every time an intermediate node establishes a connection, they raise their load value by one. The maximum load on a path is then calculated as the total load on all of the path's nodes that have been travelled thus far. Multiple RREPs and all paths to the destination are received by the source. The congestion index is used to determine the order of these paths. The data is sent after choosing a path with the highest path congestion index. All dormant nodes will eventually enter sleep mode.

4. Simulation results and discussion

This section examines over the results of reflection and compares the effectiveness of the suggested work with well-known previous works, such as DSR protocols and the Efficient Load Balancing Method. The fixed parameters used in the simulation setup are shown in table 4. The node's speed in the experiment is fixed at 10 m/s. The experiment has been conducted for varying number of nodes (40, 60, 80, and 100) scenario in order to analyse protocol scalability.

Table 4: Fixed Parameters used in Simulation

Parameter	**Value**
Simulation area	1000 X 1000 Sq. m.
Mobility model	Random waypoint
Traffic model	CBR (constant bit rate)
Packet size	512 bytes
Rate	500 kbps
MAC protocol	IEEE 802.11b
Initial energy	25 J
Receiving power	300 milli watts
Transmission power	350 milli watts
Sense power	100 milli watts

4.1 Energy consumption

Over the 20-second simulation period, a source-destination pair is chosen for data communication in the experiment. The suggested method's main goal is to extend the lifetime of the network by conserving node's energy. The method choose an alternate route with fewer congested nodes and putting all silent nodes into sleep mode.

Based on the congestion that occurs on the primary path, the ELBM method selects a different path. The suggested approach will put all nodes in sleep mode except the nodes that are involved in ELBM transition. Therefore, the recommended method uses less power overall.

Table 5: Energy consumption (Joules) with variation in nodes

Nodes	Proposed method	ELBM	DSR
40	10.01	10.76	11.51
60	11.02	11.79	12.55
80	12.1	12.76	13.52
100	13.01	13.755	14.5

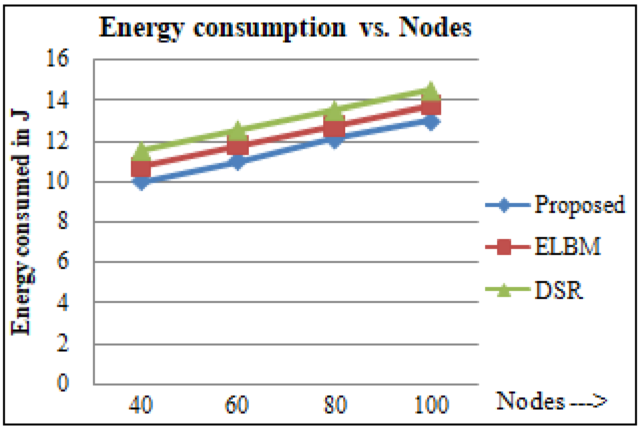

Figure 2: Total energy consumption versus nodes

Table 5 lists the energy consumption values for various scenarios with varying numbers of nodes. The impact of nodes with energy consumptions for each of the three protocols is shown in Figure 2. In this case, the suggested approach reduced energy consumption, and it used less power overall than the other protocols. The suggested approach uses 6.03 % less energy than ELBM and 13.01 % less than DSR.

4.2 Packet Delivery Ratio

The impact of Packet Delivery Ratio (PDR) on each of the three protocols is shown in Figure 3. Table 6 lists the PDR values for various scenarios with varying numbers of nodes. The results of the simulation indicate that the recommended approach maintains a higher PDR as the number of node objects rises. This is because the suggested method can select an alternate path for data transmission in order to avoid congested paths. However, in all three methods the PDR decreases as the number of nodes rises. This is because, in a highly mobile network, packet loss happens frequently as a result of route failure brought on by the node's constant topological changes. In proposed method PDR is increased by 5% and 6.15% when compared with ELBM and DSR respectively.

Table 6: PDR with variation in nodes

Nodes	Proposed method	ELBM	DSR
40	85.07	79.1	80.35
60	78.84	74.3	72.13
80	67.52	64.6	63.44
100	61.08	59.23	58.31

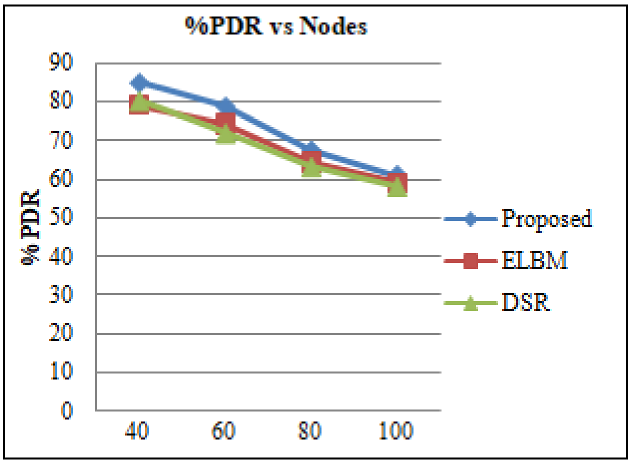

Figure 3: PDR versus Nodes graph

5. Conclusion

The Dynamic Source Routing (DSR) protocol is a foundation for the proposed routing technique as DSR is a well-established protocol in the MANET literature. The proposed routing technique combines load balancing and power-saving strategies. It includes two main phases: Route discovery and power saving. Route discovery phase builds efficient paths between a source and destination based on path congestion index. It evenly divides the traffic to lessen the load on one path, which will enhance efficiency and reduce the number of delays. The power saving phase is employed to keep all inactive nodes into sleep mode, which increases the power savings in the network. The experimental results show that the proposed method uses 13% less energy than DSR and 6% less than the ELBM model. In contrast, PDR has increased by 6% and 5% in relation to DSR and ELBM, respectively. The proposed method is scalable and adaptive to dynamic network conditions than the traditional method DSR.

Performance of the proposed method is better because it determines multiple disjoint paths between a source-destination pair. The load is uniformly distributed among the paths dynamically based on path congestion index. In future work, it is planning to design an algorithm which addresses the issues of potential routing overhead in proposed mechanism.

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