A Survey on Energy Efficient Routing Algorithms for Ad-Hoc Network

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ABSTRACT

Mobile ad hoc network is highly dynamic and distributed in nature hence routing is one of the key issues in it. In particular, designing efficient algorithm for routing may be the most important criteria for MANETs since mobile nodes have limited battery capacity. This results in short continuous operations which is the general constraint in wireless communication. Power failure of a mobile node may affect its ability to forward packets on behalf of other nodes and thus the overall lifetime of the network. For this reason, many research efforts have been devoted to developing energy aware routing protocols. Here a survey on energy efficient routing protocols for wireless Ad-Hoc networks is presented. This discussion is centered on proposed energy efficient routing algorithms. Here analysis of some conventional protocols has been done and some modifications have been suggested to make these protocols energy efficient and to overcome the shortcomings in these protocols.

Keywords

ad hoc network. MANET, energy efficient routing

1.INTRODUCTION

A Network is a collection of nodes which are highly interconnected. This interconnection can be wired, wireless or wired cum wireless. Mobile devices coupled with wireless network interfaces is an essential part of computing environment that consist of *infra-structured* and *infrastructure-less* mobile networks [1]. Wireless Local Area Network (WLAN) is the most prevalent infra-structured mobile network which is based on IEEE 802.11 standard, where a mobile node communicates with a fixed base station, and thus a wireless link is limited to one hop between the node and the base station. *Mobile Ad hoc Network* (MANET) is an infrastructure-less multihop network where each node communicates with each other either directly or indirectly through intermediate nodes [1].

1. The mobile ad hoc network has the following typical features [19]:

- Unreliability of wireless links between nodes. There is limited power supply and continuous motion of the nodes, the wireless links between mobile nodes in the ad hoc network are not stable for the communication participants.
- Constantly changing topology. Due to mobility of nodes, the topology of the mobile ad hoc network changes constantly: the nodes can continuously move across the radio range of each other in the ad hoc network, and because of this movement the routing information will be changing all the time. Lack of incorporation of security features in statically configured wireless routing protocol not meant for ad hoc environments. Since the topology of the ad hoc networks is changing constantly, it is necessary for each pair of adjacent nodes to incorporate in the routing issue so as to prevent some kind of potential attacks that try to make use of vulnerabilities in the statically configured routing protocol.

The nodes which comprise MANET have routing capabilities and forward traffic for other communicating parties that are not within each other's transmission range. They are characterized by lower computing and energy resources. Therefore, ad hoc routing is challenged by power and bandwidth constraints, as well as by frequent changes in topology, to which it must adapt and converge quickly [2]. Conventional routing protocols for wired networks cannot be employed in such an environment due to the factors described above. This fact has given rise to the design of ad hoc-specific routing protocols.

The main challenges in mobile ad-hoc networks are as follows [3,18]:

- Limited Power Supply
- Dynamically Changing Topology
- Limited Bandwidth
- Security
- Mobility-induced route changes
- Mobility-induced packet losses
- Battery constraints

So an ad-hoc routing protocol must meet all these challenges to give the average performance in every case. A brief description of challenges in ad hoc network is given in [16,18].

How routing information is acquired and maintained by mobile nodes is one of the most popular methods which is used to distinguish mobile ad hoc network routing protocols. Using this method, mobile ad hoc network routing protocols can be divided into *proactive routing*, *reactive routing*, *hybrid routing* and *location based routing* [5]

Table 1. Comparison among Different Routing Approaches

Sr. no	Approach	Definition	Example	Advantages	Disadvantages
1	Proactive	Unicast routes between all pairs of nodes are maintained regardless of whether all routes are actually used or not	Destination-Sequenced Distance Vector (DSDV) and Fisheye State Routing (FSR)	maintains fresh lists of destinations and their routes by periodically distributing routing tables throughout the network	-Respective amount of data for maintenance. -Slow reaction on restructuring and failures.
2	Reactive	Routes are established only when need arises.	Dynamic Source Routing (DSR) and Ad-Hoc On-Demand Distance Vector (AODV)	Route discovery and route maintains operations are performed only when there is demand of creating path between two nodes	- High latency time in route finding. - Excessive flooding can lead to network clogging.
3	Hybrid	Combination of proactive and reactive	Zone Routing Protocol, Hazy Sighted Link State	The routing is initially established with some proactively prospected routes and then serves the demand from additionally activated nodes through reactive flooding	- Advantage depends on number of nodes activated. - Reaction to traffic demand depends on gradient of traffic volume

2. ENERGY EFFICIENT ROUTING

Designing efficient algorithm for routing may be the most important criteria for MANETs since mobile nodes will be powered by batteries with limited capacity. Power failure of a mobile node may affect its ability to forward packets on behalf of other nodes and thus the overall lifetime of the network.. Hence, many research efforts have been devoted to developing energy aware routing protocols. In the scientific papers reviewed, the lifetime of a network is usually defined according to the following criteria [2]:

- the time until the first node burns out its entire battery budget;
- the time until a certain proportion of the nodes fails; and
- the time until network partitioning occurs.

Wireless devices can be used “anywhere at any time”. One of the greatest limitations to that goal, however, is limited battery power supplies. Since batteries provide limited power, mobile terminals perform the short continuous operation [6]. Therefore, power management is one of the most challenging problems in wireless communication. Also as mentioned in [15] energy efficient routing is necessary for providing quality of service (QOS) for ad hoc network.

Energy efficient routing mechanisms proposed for MANETs can be broadly categorized based on *when* the energy optimization is performed [1]. A mobile node consumes its battery energy for performing various operations in active as well as in idle mode. Thus, energy efficient routing protocols minimize either the *active* communication energy required to transmit and receive data packets or the energy during *inactive* periods. *Transmission power control* and *load distribution* belong to the former category, and *sleep/power-down mode approach* belongs to the latter category. Another important approach to optimizing active communication energy is *load distribution approach*. While the primary focus of the above two approaches is to reduce energy utilization of individual nodes, the main goal of the load distribution approach is to balance the use of energy among the nodes and to increase the network lifetime by avoiding over-utilized nodes when selecting a routing path.

Energy-related metrics that may be used to determine energy efficient routing path instead of the shortest one are [1, 6, 21, 22]

- energy consumed/packet,
- time to network partition,
- variance in node power levels,
- cost/packet, and
- maximum node cost.

Minimize Energy consumed/packet

To conserve energy, the amount of energy consumed by all packets traversing from the source node to the destination node needs to be minimized. That is, the total amount of energy the packets consumed when it travels from each and every node on the route to the next node should be known. The energy consumed for one packet is given as:

$$E = \sum_{\iota=1}^{k-1} T(m_i, m_{i+1}) \quad (1)$$

where, m_i to m_k are nodes in the route while T denotes the energy consumed in transmitting and receiving a packet over one hop. Then, minimum E for all packets is taken. However, this metric suffers a drawback as the nodes tend to have widely differing energy consumption profiles resulting in early death for some nodes.

- **Maximize Time to Network Partition**

For a given network topology, removal of a minimal set of nodes will cause the network to partition. Therefore a routing procedure must divide the work among nodes to maximize the lifetime of the network. However, optimizing this metric is extremely difficult as finding the nodes that will partition the network is non-trivial and the “load balancing” problem is known to be an NP-complete problem.

- **Minimize Variance in node power levels**

This metric ensures that all the nodes in the network remain up and running together for as long as possible. It achieves the objective by using a routing procedure where each node sends packets through a neighbor with the least amount of packets waiting to be transmitted. In this way, the traffic load of the network is shared among the nodes with each node relaying about equal number of packets. Therefore, each node spends about the same amount of power in transmission.

- **Minimize Cost/Packet**

For this metric, the path is selected such that it does not contain nodes with depleted energy reserves. In other words, this metric is a measurement of the amount of power or the level of battery capacity remaining in a node and that those nodes with a low value of this metric are not chosen (unnecessarily) for a route. This metric is defined as the total cost of sending one packet over the nodes, which in turn can be used to calculate the remaining power. The cost is given as:

$$C = \sum_{\iota=1}^{k-1} f_i(x_i) \quad (2)$$

node needs to be minimized. That is, the total amount of energy the packets consumed when it travels from each and every node on the route to the next node should be known.

- **Minimize Maximum Node Cost**

This metric finds the minimum value from a list of costs of routing a packet through a node. The costs themselves are maximized value of the costs of routing a packet at a specific time. The equation for this metric is:

Minimize $\hat{C}(t)$, for all t >0,

where, $\hat{C}(t)$ denote the maximum of the $C_j(t)$ and $C_j(t)$ is the cost of routing a packet through node *j* at time *t*.

2.1 Energy Efficient Ad Hoc Routing Protocols

Different energy-related routing metrics have been suggested in order to achieve energy conservation and increase the lifetime of the network. Energy-related metrics used by these energy aware routing protocols can be broadly classified into four categories: *transmission power*, *remaining energy capacity*, *estimated node lifetime*, *and combined energy metrics* [4]. Power/energy efficient routing protocols can be classified into these four categories based on their path selection scheme as follows:

1) The first set of protocols use the energy cost for transmission as the cost metric and aim to save energy consumption per packet. However, such protocols do not take the nodes’ energy capacity into account. Thus, the energy consumption is not fair among nodes in the network. *Minimum Total Transmission Power Routing* (MTPR) is an example protocol for this category.

2) The second set of protocols use the remaining energy capacity as the cost metric, which means that the fairness of energy consumption becomes the main focus. But, these protocols cannot guarantee the energy consumption is minimized.

3) The third set of protocols is similar to the second set, but use estimated node lifetime instead of node energy capacity as the route selection criteria. Therefore, these protocols still aim to fairly distribute energy consumption.

4) In order to both conserve energy consumption and achieve consumption fairness, *Conditional Max-Min Battery Capacity Routing* (CMMBCR) has been proposed to combine these two metrics. CMMBCR is an example of the fourth category of protocols, which use combined metrics to represent energy cost.

Table 2. Different categories of Energy Efficient routing protocols derived from energy related metrics

Sr. No.	Categories	Protocols	Objective	Drawback
1	Total transmission power	MTPR, MPR	Minimize energy consumption	May cause node depletion
2	Remaining energy capacity	MBCR,MMBCR,LEAR-AODV, EAPR, TDOD	Evenly distribute energy depletion	Does not ensure least energy cost path

3	Remaining node lifetime	MDR, LPR	Evenly distribute energy depletion	Does not ensure least energy cost path
4	Combination	CMMBCR, PSR, PAOD	Tradeoff between power consumption and fairness	Hard to find perfect tradeoff

3 MECHANISMS USED FOR ENERGY CONSERVATION

This section describes various sources of power consumption and then gives some general mechanisms to conserve the energy of nodes in ad-hoc network.

3.1 Sources of power consumption:

The sources of power consumption, with regard to network operations, can be classified into two types: *communication related* and *computation related* [6]. Communication involves usage of the transceiver at the source, intermediate (in the case of ad hoc networks), and destination nodes. The computation is chiefly concerned with protocol processing aspects. It mainly involves the CPU usage and main memory, the disk or operations of other components, data compression techniques etc. There exists a potential tradeoff between computation and communication costs. Techniques that strive to achieve lower communication costs may result in higher computation needs, and vice-versa. RandomCast [18] is an energy efficient communication scheme used. Hence, protocols that are developed with energy efficiency goals should attempt to strike a balance between the two costs.

3.2 General conservation mechanisms:

In MAC layer, collision causes retransmission of data which lead to unnecessary power consumption hence collision should be removed from MAC layer. Using a small packet size may reduce energy consumption. In broadcast environment, the receiver remains in listen mode at all times which results in significant power consumption. One solution for this is to broadcast starting time of data transmission for each node periodically. This enables the mobiles to switch to standby mode until the receive start time. Another solution is to turn off the transceiver whenever the node is in idle mode and not receiving any data. The PAMAS protocol [7] uses such a method. Furthermore, switching from transmit to receive modes, and vice versa may consume significant time and power of mobile node. Selecting proper scheduling algorithms as studied in [8] may reduce power consumption during switching operation. The scheduling algorithms are used to drop packet and allow certain high-priority traffic to be transmitted sooner. Such mobile-based adaptive algorithms [9] may used in the context of energy efficiency and channel error compensation.

At the link layer, proper error control techniques are used to conserve power also transmissions may be avoided when channel conditions are poor. In [17] comparison of different MAC protocols based on battery power consumption is given.

Energy efficient routing protocols may be achieved by establishing proper routing algorithms that select proper route having more energy to send data between the nodes, as studied in [2, 11, 12]. This helps balance the amount of traffic carried by each node. Nodes having limited battery power can be skipped from route of data transmission but this may required mechanism for dissemination of nodes battery power. Also, the periodicity of routing updates can be reduced to conserve energy, but may result in inefficient routes when user mobility is high. In [13], the topology of the network is controlled by varying the transmit power of the nodes, and the topology is generated to satisfy certain network properties.

At the OS level, the common factor to all the different techniques proposed is suspension of a specific sub-unit such as disk, memory, display, etc. based upon detection of prolonged inactivity. There are several methods for extending battery lifetime within the operating system and middleware layer which uses techniques like power-aware CPU scheduling and page allocation.

Within the application layer, the power conserving mechanisms tend to be application specific – such as database access and video processing. A summary of software strategies for energy efficiency is presented in [10].

4 AREAS TO BE CONSIDERED IN ENERGY EFFICIENT ROUTING APPROACHES

The transmission power control is an effective approach to reduce energy consumption in a MANET. However, it has to deal with Link error and retransmission overhead and also required Bidirectionality. Transmission control protocols provide an opportunity to save energy by utilizing intermediate nodes between two distant nodes. However, the resultant path with many short-range links may perform worse than a path with fewer long-range links in terms of latency as well as energy consumption [1]. This is because the path with many short-range links would cause more link errors that would result in more retransmissions. To deliver packets with minimum energy, the transmission power control approach adjusts each node's radio power and allows different transmission power levels at different nodes. However, in order for the link-level connectivity of a MANET to work correctly, any pair of communicating nodes must share a bidirectional link

Although the main objective of load balancing routing is the efficient utilization of network resources, none of the studies reviewed above takes energy-wise metrics into account. Due to heterogeneous requirements and availability of energy levels at each node, it is not possible to select same possible load balancing constraints for all nodes to distribute the load evenly in the network. There is no doubt that a better distribution of load leads to the more efficient use of bandwidth, which means that there is less contention and consequently less energy is consumed, but it is not self contained for achieving complete energy efficiency. Since none of the studies applies load balancing for achieving energy efficient consumption, the relevant literature does not contain an energy performance evaluation of load balancing routing protocols.

So it's concluded that all the protocols used for energy efficient routing may have their own advantages and limitations. Following are the basic properties of each protocol to increase energy efficiency like

1. like PEN, it should power down the radio device when it is idle.
2. as in LEAR, nodes decides whether to forward route request message or not. depending on residual battery power so that destination node receives route request message only when all immediate nodes along route have good battery level.
3. decide threshold for given grid (geographical area as in CMMBCR.
4. as in PLR, it is assume that source node has location information of its neighbors and destination. This is not optimal path but source selects next hop through which overall transmission power to destination is minimized. Power consumption of indirect link is less than direct link due to super-linear relationship between transmission energy and distance.
5. try to minimize sum of link costs along the path. As mentioned in FAR, link requiring less transmission is preferred.
6. Use mobile node's page rank which is used in PR-RAM , which means how many routing paths are included to this node. thus higher rank of node is more important than the value of lower rank of node.. so higher rank of node should get the more chance to transmit the data to next-hop node than the lower rank of node.

But it is not possible to add all properties in one protocol. First the working of ZRP protocol for network scenario of 10 nodes as shown below is studied. Zone Routing Protocol (ZRP) is a hybrid protocol which has two sub parts as IARP and IERP. Intra-zone Routing Protocol (IARP) is a vector-based proactive routing protocol and Inter-zone Routing Protocol (IERP) is an on-demand routing protocol. In this scenario node 1 is moving and sending CBR data to node 8 and 10.

Table 3. Simulation Parameter

Simulation Parameter	Value
Channel bandwidth	10 & 25 Mbps
Transmission frame length	14 & 28 ms
Number of mobiles	10
Traffic gen. rate per mobile	75-200
Packet error rate (BER)	10^{-3}

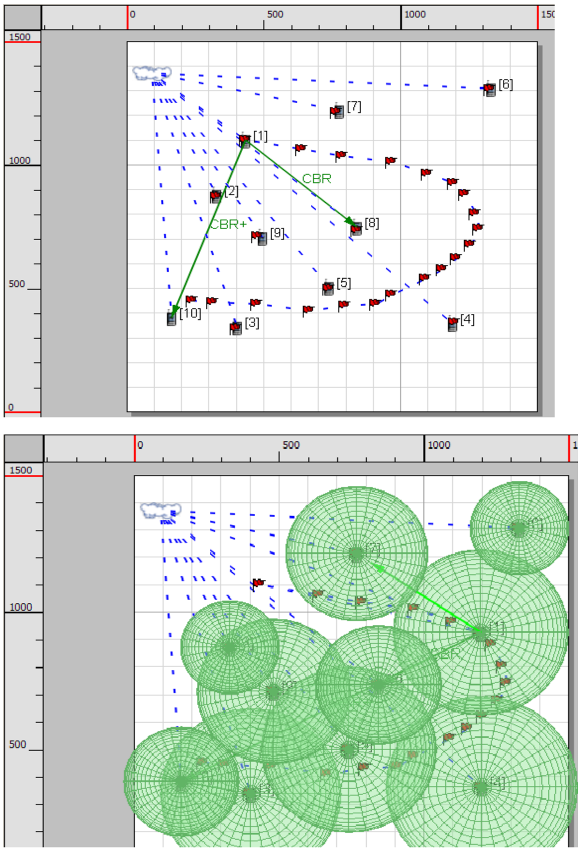

Fig. 2. Simulation results

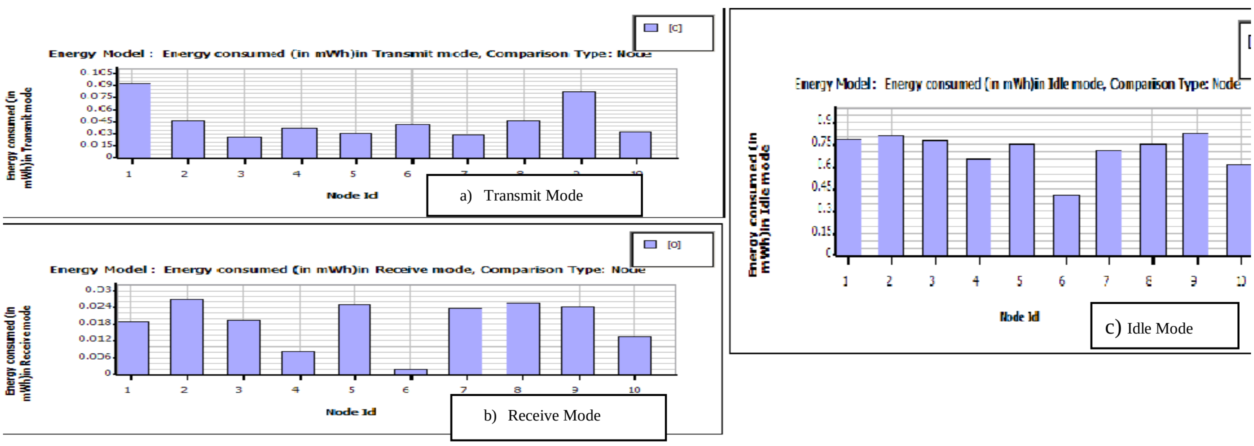

Fig. 3. Energy consumption in transmit, receive and idle mode.

From this it is analyzed that though the nodes are idle and not participating in actual data transfer still there is energy consumption. So measures are taken to reduce this energy consumption by making the nodes to go in sleep mode rather than in idle mode to conserve the energy. Fig.4 shows percentage of time the node remain in particular mode and consume energy. From the network scenario we can see that node 4,6,7 and 9 are not in path of data communication but still there energy is consumed in transmit and receive mode.

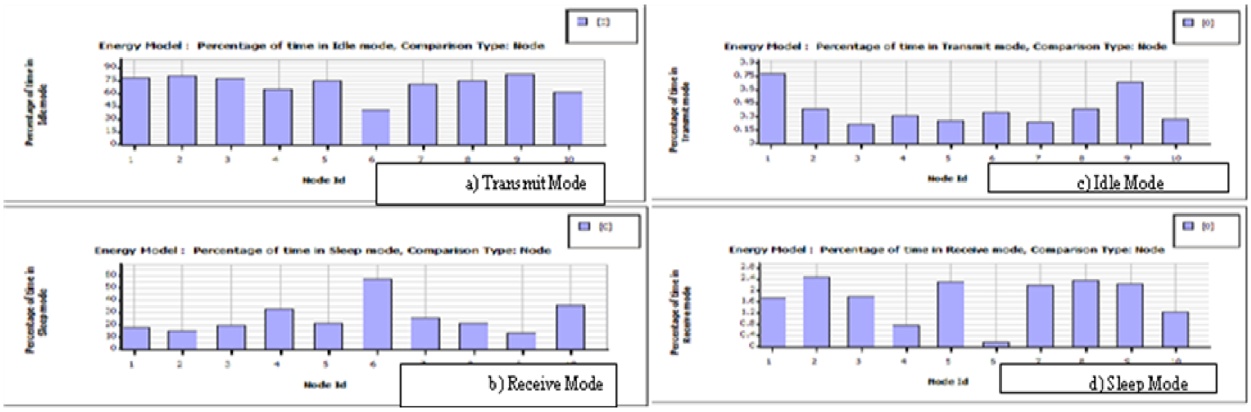

Fig. 4. Percentage of time in transmit, receive, idle and sleep mode.

5. CONCLUSION

In order to facilitate communication within a MANET, an efficient routing protocol is required to discover routes between mobile nodes. Energy efficiency is one of the main problems in a MANET, especially in designing a routing protocol. Here, a number of energy aware routing schemes are surveyed and classified. In many cases, it is difficult to compare them directly since each method has a different goal with different assumptions and employs different means to achieve the goal. Therefore, more research is needed to combine and integrate some of the protocols presented in this paper to keep MANETs functioning for a longer duration. By using this survey it is concluded that there is not a single protocol which can be selected for its best performance in ad-hoc network. Performance of the protocol varies according to the changes in the network parameters. Sometimes the mobility of the node of the network is high sometimes energy of the node is of prime concern. The comparisons of these energy efficient protocols have been discussed.

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