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A Review of Energy-Aware Routing Protocols in MANETs

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Abstract: **Mobile Ad Hoc Networks (MANETs) is a collection of multi-hop wireless mobile nodes that communicate with each other without centralized control or established infrastructure. The energy efficient routing may be the most important design criteria for MANETs, since mobile nodes will be powered by batteries with limited capacity and the nodes in MANET are mobile. Energy efficiency doesn't mean only the less power consumption, it means increasing the time duration in which any network maintains certain performance level. So, power management becomes critical issue. The paper focuses on recent development and modifications in this widely used field and proposed energy saving algorithms, the conventional protocols and also how these are modified to make these protocols energy efficient.**

Keywords: MANETs, Power Management, Energy saving algorithms.

1. Introduction: Power failure of a mobile node not only affects the node itself but also its ability to forward packets on behalf of others and thus the overall network lifetime. A mobile node consumes its battery energy not only when it actively sends or receives packets, but also when it stays idle listening to the wireless medium for any possible communication requests from other nodes. Thus, energy-efficient routing protocols minimize either the active communication energy required to transmit and receive data packets or the energy during inactive periods [1]. The transmission power control approach can be extended to determine the optimal routing path that minimizes the total transmission energy required to deliver data packets to the destination [2]. For protocols that belong to the latter category, each node can save the inactivity energy by switching its mode of operation into sleep/power-down mode or simply turns it off when there is no data to transmit or receive. This leads to considerable energy savings, especially when the network environment is characterized with low duty cycle of communication activities. However, it requires a well-designed routing protocol to guarantee data delivery even if most of the nodes sleep and do not forward packets for other nodes. Another important approach to optimizing active communication energy is load distribution approach [3]. While the primary focus of the above two approaches is to minimize energy consumption of individual nodes, the main goal of the load distribution method is to balance the energy usage among the nodes and to maximize the network lifetime by avoiding over-utilized nodes when selecting a routing path. The paper classifies numerous energy efficient routing mechanisms proposed for MANETs. The main focus is on motivation, research challenges, recent development and modifications in this widely used field and also see how conventional routing protocols are modified to make them as energy efficient. While it is not clear whether any particular algorithm or a class of algorithms is the best for all scenarios, each protocol has definite advantages/disadvantages and is well-suited for certain situations. However, it is possible to combine and integrate the existing solutions to offer a more energy-efficient routing mechanism. Since energy efficiency is a critical issue in other network layers, considerable efforts have been devoted to developing energy-aware MAC and transport protocols.

The paper is organized as follows. In section 1 the Introduction and general discussion on energy efficiency is presented. Section 2 presents classification of routing protocols. The definition and need for energy efficiency is discussed in section 3. Section 4 provides energy efficient routing techniques and researches in energy efficient routing. Finally conclusion and future work is discussed in section 5.

2. Classification of Routing Protocols

Routing protocols can be classified according to various approaches as shown in figure 1.

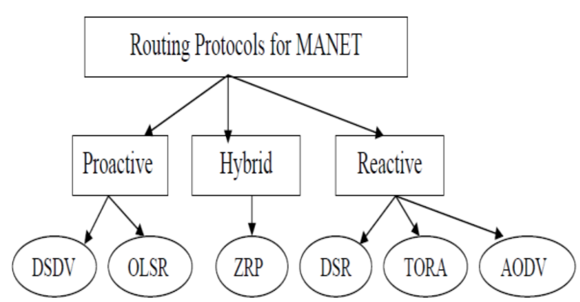

Figure 1 Classification of routing protocols for MANET

2.1 Proactive Routing: These types of protocols are called table driven protocols in which, the route to all the nodes is maintained in routing table. Packets are transferred over the predefined route specified in the routing table. In this scheme, the packet forwarding is done faster but the routing overhead is greater because all the routes have to be defined

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before transferring the packets. Proactive protocols have lower latency because all the routes are maintained at all the times.. E.g. are DSDV, Wireless Routing Protocol and Optimized Link State Routing, TBRPF [4].

2.2 Reactive routing: It is also called on demand routing. It is more efficient than proactive routing and most of the current work and modifications have been done in this type of routing for making it more and more better. The main idea behind this type of routing is to find a route between a source and destination whenever that route is needed whereas in proactive protocols we were maintaining all routes without regarding its state of use. So in reactive protocols we don't need to bother about the routes which are not being used currently. This type of routing is on demand. E.g. of Ad-hoc On Demand Distance Vector (AODV), Dynamic Source Routing (DSR) [5].

2.3 Hybrid Routing: Hybrid protocols are the combinations of reactive and proactive protocols and takes advantages of these two protocols and as a result, routes are found quickly in the routing zone. E.g. ZRP (Zone Routing Protocol), Hazy Sighted Link State.

Current research challenges in ad-hoc networks are as follow:

- Energy Saving
- Limited wireless transmission range
- Broadcast nature of the wireless medium
- Packet losses due to transmission errors
- Mobility-induced route changes
- Mobility-induced packet losses
- Battery constraints
- Potentially frequent network partitions
- Ease of snooping on wireless transmissions (security hazard)
- Limited Power Supply

3. Energy Efficiency: Definition and Need

In the recent past years energy efficient routing in Ad hoc network was addressed by many research works which has produced so much innovation and novel ideas in this field. Most of the work today is based on energy efficient routing because power is main concern in ad hoc wireless networks. Each and every protocol has some advantages and shortcomings. None of them can perform better in every condition. It depends upon the network parameters which decide the protocol to be used. Several protocols have been given regarding energy efficient routing and their modifications have also been proposed for use in ad hoc networks.

Definition: For a wireless networks, the devices operating on battery try to pursue the energy efficiency heuristically by reducing the energy they consumed, while maintaining acceptable performance of certain tasks. Using the power consumption is not only a single criterion for deciding energy efficiency. Actually, energy efficiency can be measured by the duration of the time over which the network can maintain a certain performance level, which is usually called as the network lifetime. Hence routing to maximize the lifetime of the network is different from minimum energy routing. Minimum energy routes [6] sometimes attract more flows and the nodes in these routes exhaust their energy very soon hence the whole network cannot perform any task due to the failure on these nodes [7]. In other words, the energy consumed is balanced consumed among nodes in the networks. Routing with maximum lifetime balances all the routes and nodes globally so that the network maintains certain performance level for a longer time. It goes without saying that node failure is very possible in the wireless network. Hence saving energy at the time of broadcasting in order to recover from the node failure or to re-routing around the failed nodes is essential. By the same token, multicast has the same challenge to achieve the energy efficiency [8]. For unicast, it is highly related to the node and link status, which require a wise way to do routing as well. Sometimes, shortest path routing is possibly not the best choice from the energy efficiency point of view.

Need for Energy Efficiency: The greatest challenge in the design of wireless ad hoc networks is the limited availability of the energy resources. These resources are quite significantly limited in wireless networks than in wired networks. Energy-efficient communication is critical for increasing the life of power limited wireless ad hoc networks. Each of the mobile nodes is operated by a limited energy battery and usually it is impossible to recharge or replace the batteries during a mission. Since wireless communications consume significant amounts of battery power, therefore the limited battery lifetime imposes a severe constraint on the network performance. Energy efficient operations are critical to enhance the network lifetime. Extensive studies on energy conservation in wireless ad hoc networks have been conducted. Wireless communications consume significant amount of battery power, and therefore energy efficient operations are critical to enhance the life of such networks. Some amount of power is lost even when a node is in idle mode. A recent study shows that the power consumed in transmitting and receiving packets in standard WaveLAN cards range from 800 mW to 1200 mW. During the past few years, there has been increasing interest in the design of energy efficient protocols for wireless ad hoc networks. Most mobile nodes in a wireless ad hoc network are powered by energy limited batteries, the limited battery lifetime is a hindrance to network performance. Therefore, energy efficiency is of vital importance in the design of protocols for the applications in such networks and efficient operations are critical to enhance the network lifetime. Since the Nodes are battery-powered, thus energy is a precious resource that has to be carefully used by the nodes in order to avoid an early network partition and hence the study and implementation of energy-efficient algorithms for wireless networks quite constitutes a vast area of research in the field of ad hoc networks.

4. Energy Efficient Routing Techniques

4.1 Lifetime Prediction Routing (LPR) [9]: This routing protocol uses battery life prediction to maximize the network lifetime by founding routing solutions. It maximizes the variance of the remaining energies of the nodes batteries in the network. Based on the past activity each node can try to estimate its battery lifetime. Simple Moving Average (SMA) predictor is used to keep track of the last N values of residual energy and the corresponding time instance for the last N packets received by each mobile node. The first drawback of this routing protocol is that it introduces additional traffic for route maintenance [10]. The second and most important is that it doesn't include the transmission power to minimize total energy consumption per packet. Large amount of energy consumption per packet may lead to die node sooner. The third is that the history may not predict accurately for high mobility of nodes in the network.

4.2 Energy Saving Dynamic Source Routing [11]: This protocol makes the DSR an energy/power aware protocol. In this protocol senders can adaptively adjust the transmission power level to suite the current need of communication rather than using fixed level. The system uses energy saving cost metrics, which selects the route with maximum "lifetime" remaining. Remaining life of a node is the remaining node energy divide by power required to transmit packet to the next node. This is known as the max-min algorithm. Energy saving dynamic source routing does not consider the energy capacity of the receiver nodes. Significant amount of energy is consumed to receive the packet. The process of receiving packets drains out the battery energy of the receiver nodes. So, energy efficient routing protocols have got to consider the receiving node battery energy capacity for route cost computation.

4.3 Energy Dependent DSR (EDDSR): DDSR is energy dependent DSR algorithm which helps node from sharp and sudden drop of battery power. EDDSR provides better power utilization compare to least energy aware routing (LEAR) [12] and minimum drain rate (MDR). EDDSR avoids node with less power supply and residual energy information of node is useful in discovery of route. Residual battery power of each node is computed by itself and if it is above the specific threshold value then node can participate in routing activities otherwise node delays the rebroadcasting of route request message by a time period which is inversely proportional to its predicted lifetime. With help of ns-2 simulator author performed simulation which shows MDR and EDDSR is better than DSR in terms of node lifetime. EDDSR has further advantage over MDR because it can use route cache used by DSR.

4.4 Energy Efficient broadcast OLSR [13]: A new protocol EBOLSR adapts the OLSR protocol in order to maximize the network lifetime for broadcast communications. In EBOLSR energy efficient MPR [8] selection is done by the residual energy of nodes. In this protocol we consider the weighted residual energy of energy efficient MPR candidate and its one hop neighbors. The basic phenomenon about this EBOLSR protocol was to select the energy efficient multipoint relays [MPR's].

4.5 Weight Based DSR (WBDSR) [14]: Weight Based DSR is an improvement of conventional DSR. In this protocol, the weight of each route is considered as metric for route selection. Weight of each route can be calculated by computing the node weight of each node weight i= battery level of this node + Stability of this node. The route-weight is the minimum of all node weights included in this route. Select the main route which has the maximum route-weight. If two or more routes have the same route-weights then choose the route which has minimum hops.

Thus WBDSR gives always the longest network life time in both high mobile networks and static networks because it timely change the used route with another one which maintains the use of the nodes which enhances the network life time.

4.6 Energy-Efficient Location Aided Routing (EELAR)[15]: Energy Efficient Location Aided Routing (EELAR) Protocol was developed on the basis of the Location Aided Routing (LAR). EELAR makes significant reduction in the energy consumption of the mobile node batteries by limiting the area of discovering a new route to a smaller zone. Thus, control packet overhead is significantly reduced. In EELAR, a reference wireless base station is used and the network's circular area centered at the base station is divided into six equal sub-areas. During route discovery, instead of flooding control packets to the whole network area, they are flooded to only the sub-area of the destination mobile node. The base station stores locations of the mobile nodes in a position table. Simulations results using NS-2 [16] showed that EELAR protocol makes an improvement in control packet overhead and delivery ratio compared to AODV, LAR, and DSR protocols.

4.7 Power-aware Routing (PAR) Protocol[17]: Power-aware routing (PAR) maximizes the network lifetime and minimizes the power consumption by selecting less congested and more stable route, during the source to destination route establishment process. PAR focuses on 3 parameters mainly Accumulated energy of a path, Status of battery lifetime and Type of data to be transferred. At the time route selection, PAR focuses on its core metrics like traffic level on the path, battery status of the path and type of request from user side. With these factors in consideration, PAR always selects less congested and more stable routes for data delivery and can provide different routes for different type of data transfer and ultimately increases the network lifetime. Simulation results shows that PAR outperforms similar protocols such as DSR and AODV with respects to different energy-related performance metrics even in high mobility scenarios. The route that can last for a long time and encounter significant power saving has been discovered. Although, PAR can somewhat incur increased latency during data transfer.

4.8 Energy-aware Node Disjoint Multipath Routing (ENDMR)[18]: The technique of this routing is to increase the network lifetime with low overhead. It significantly reduces the total number of route request packets which results in an increased packet delivery ratio, decreasing end to end delay and decreasing power consumption. It selects optimal path using power-aware metric and optimizes the power consumption, overhead and bandwidth. The drawback is that each route request carries the cumulative cost, so very little bit overhead is increased to carry the cumulative cost but it is negligible.

4.9 Niranjan Kumar Ray et al.'s method [19] is to reduce the number of RREQ packets by putting restrictions on inter group communication. The node of one group will not forward the RREQ message to other group. Only common node will support inter-group communication to reduce the number of RREQ. In this the geographical area is partitioned on the basis of number of nodes present in it. There are two types of nodes, nodes present in the overlapping area of group are called common node and nodes belonging to particular group called active nodes. When an active node wants to send RREQ message it appends its group number in the packet and broadcast the message. Message will forwarded by the other node if they belongs to the same group otherwise message will be dropped. When CN prepares the RREQ message it adds one group number from the group it belongs depending upon the shared index calculation.

4.10 Maximized Energy Efficient Routing Algorithm (MEER) [20]: The goal of this algorithm is the selection of routes on the remaining energy levels of the nodes of the route. In MEER, the source node 'knows' about the energy levels of the intermediate nodes and can choose the most energy efficient route. MEER differs from the conventional DSR only in the Route Discovery. The selection of the best route is based on the following algorithm: the destination node first determines the least power level in each route whose RREQ packet is received. Then it compares these least power levels and chooses the highest among them and selects the corresponding route. The destination node then transmits the RREP packet through this route. The destination copies the energy information from the RREQ packet to the RREP packet. Thus, the destination node selects the route with the highest life time from a set of available routes.

5. Conclusion and Future Work

There is not a single protocol which can give the best performance in ad hoc network. Performance of the protocol varies according to the variation in the network parameters and ad hoc network properties continuously vary. So, the choice of the protocol is the basis to perform in a particular type of network. Apart from the availability of protocols for energy efficiency, further research is needed to identify the energy efficient routing protocols for multiple environments. These contexts can include nodes positioned in three-dimensional space and obstacles, nodes with unequal transmission powers or networks with unidirectional links. The future work can also include designing routing algorithms by adding congestion considerations.

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