Energy Management in Zone Routing Protocol (ZRP)

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Abstract— Ad hoc networks are wireless networks without a fixed infrastructure, and are usually established on a temporary basis for a specific application like emergency rescue or battle field communication. Energy management in wireless networks deals with the process of managing energy resources by means of controlling the battery discharge, adjusting the transmission power, and scheduling of power sources so as to increase the lifetime of the nodes of an ad hoc wireless network. Since, most of the mobile nodes in the network are equipped with low power batteries, it could be difficult for a mobile device to sustain for a long time if it send and receive data more often. To solve this problem here we describe the power management issues in mobile nodes using modified Zone Routing Protocol (ZRP) and it was simulated using NS2 simulator.

Keywords— Ad hoc wireless Networks, battle field communication, Energy Management, Zone Routing Protocol (ZRP), NS2 simulator.

I. INTRODUCTION

A mobile ad hoc network (MANET) is comprised of mobile hosts that can communicate with each other using wireless links. In this environment a route between two hosts may consist of hops through one or more nodes in the MANET. An important problem in a mobile ad hoc network is finding and maintaining routes since host mobility can cause topology changes. [1] MANETs have been employed in scenarios where an infrastructure is unavailable, the cost to deploy a wired networking is not worth it, or there is no time to set up a fixed infrastructure. Some scenarios where an ad hoc network can be used are conferencing, emergency services, home networking, sensor dust, embedded computing. Algorithms for a MANET must self-configure to adjust to environment and traffic where they run, and goal changes must be posed from the user and application. Ideally, a routing algorithm for an Ad hoc network should not only have the general characteristics of any routing protocol but also consider the specific characteristics of a mobile environment—in particular, bandwidth and energy limitations and mobility.

Routing algorithms and protocols need to save both bandwidth and energy and must take into account the low capacity and limited processing power of wireless devices. [2] [3].

Based on the routing information update mechanism, Ad hoc wireless network routing protocols are basically divided into pro-active routing and re-active protocols. The Proactive routing algorithms aim to keep consistent and up-to-date routing information between every pair of nodes in the network by proactively propagating route updates at fixed time intervals. The pro-active routing protocol learns the network topology before a request comes in for forwarding. Since the proactive routing algorithms maintain routing tables for all nodes in the network, a route is found as soon as it is requested. The advantage of these protocols is low latency in discovering new routes and minimizes the end-to-end delay. Examples of proactive protocols are Destination-Sequenced Distance Vector (DSDV) [9], Optimized Link-State Routing (OLSR) [7], Cluster-Head Gateway Switch Routing Protocol (CGSR) [11], Wireless Routing Protocol(WRP)[11] and Topology-Based Reverse Path Forwarding (TBRPF) [8] Protocols.

Reactive or also called on-demand routing algorithms establish a route to a given destination only when a node requests it by initiating a route discovery process. Once a route has been established, the node keeps it until the destination is no longer accessible, or the route expires. The re-active routing protocol becomes active only when a node is willing to forward a request. Reactive protocols tend to be more efficient than proactive protocols in terms of control overhead and power consumption because routes are only created when required. Some of the re-active routing protocols are Dynamic Source Routing Protocol (DSR) [6], Ad Hoc On-Demand Distance-Vector Routing Protocol (AODV) [4] [5], Temporally Ordered Routing Algorithm (TORA) [10], Associativity-Based Routing (ABR) and Preferred Link-Based Routing Protocol (PLBR) [9] [10].

In spite of a reactive protocol gives the low overhead of control messages, it has higher latency in discovering routes as it determine the route using flooding route request packet in the network and builds the route on demand from the responses it receives. On the other hand, proactive protocols need periodic route updates to keep information updated and valid, also many available routes might never be needed all these increases the routing overhead and consume large amounts of bandwidth [3].

II. NEED FOR ENERGY MANAGEMENT IN MANETS

The nodes in an ad hoc wireless network are constrained but limited battery power for their operation. Hence, energy management is an important issue in ad hoc networks. Energy management deals with the process of managing energy resources by means of controlling the battery recharge, adjusting the transmission power, and scheduling of power sources so as to increase the lifetime of the nodes of an ad hoc wireless network. The energy efficiency of a node is defined as the ration of the amount of data delivered but the node to the total energy expended.

The reasons for energy management in ad hoc wireless networks are:

1. As the field of mobile computing and communication advances, there is an increasing gap between the power consumption requirements and power availability and it adds to the importance of energy management.
2. In situations like battlefields, it is difficult to replace or recharge the batteries. Hence, energy conservation is essential in such scenarios.
3. Batteries tend to increase the size and weight of a mobile node, to reduce the size of the battery, energy management techniques are necessary to utilize the battery capacity in the best possible way.
4. An optimal value for the transmission power increases the number of simultaneous transmissions.
5. Power control is essential to maintain the required signal to interference ratio (SIR) at the receiver and to increase the channel reusability.
6. If the relay traffic allowed through a node is more, then it may leads to a faster depletion of the power source for that node.

Power consumption of a wireless radio depends on the operation mode. Operation modes of a radio can be categorized into the following: (i) transmit mode, (ii) receive mode, (iii) idle mode, and (iv) sleep mode [46].

Table I presents the typical values of power consumption of several Network Interface Cards (NIC) in transmit, receive, idle, and sleep modes.

TABLE I
POWER CONSUMPTION VALUES OF SOME IEEE802.11 (2.4GHz)
WIRELESS CARDS IN DIFFERENT OPERATION MODES (mW)

Radio	Transmit	Receive	Idle	Sleep
Aironet PC4800 [102]	2500	900	110	20
Aironet 350 PCI [103]	1870	1620	1440	910
Lucent Bronze [104]	1300	970	840	66
Lucent WaveLAN [105]	1400	1200	1000	150
Cabletron Roamabout [106]	1400	1000	830	130

A. Classification of Energy Management Schemes

To increase the life of an ad hoc wireless network, it is required to understand the capabilities and limitations of the energy resources of the nodes. A longer lifetime of the node can be achieved by increasing the battery capacity. Increasing the capacity of the battery at the nodes can be achieved by either battery management, which concerns the internal characteristics of the battery, or power management, which deals with utilizing the battery capacity to the maximum possible extent. The routing protocol must be designed such a way to reduce the amount of information exchanged among the nodes, since communication incurs loss of energy. Increase in the number of communication tasks also increases the traffic in the network, which results in loss of data, retransmissions, and hence more energy consumption. Adaption of the routing algorithm to the continuous topological changes is important as far as hoc wireless networks are concerned. The power consumption occurs at the network layer is because of communication and computation operations. The power conserved in communication operations is due to transmit-receive module present in the nodes. The computation power of a node is the power spent in calculations during routing and power adjustments. For power efficient routing protocol, a trade-off between the number of computation and communication tasks performed by the node is achieved.

Fig 1 Classification of Energy Management Schemes

In [32], the authors proposed a common power control (COMPOW) that attempts to increase the battery lifetime of all the nodes, increasing the traffic-carrying capacity of the network, and reducing the contention among the nodes. The COMPOW protocol works well only in a network with a homogeneous distribution of nodes. In [33], the authors proposed power control clustering (CLUSTERPOW) protocol, in which each node runs a distributed algorithm to choose the minimum power to reach the destination through multiple hops. [34] And [35] attempt to find the trade – off between minimizing the overall transmission power and distributing the power consumption evenly among the nodes. In [36], the authors proposed an optimal power scheduling and routing protocol which tries to minimize the total average power in the network, subjected to the constraints like peak transmission power of the nodes and achievable data rate per link. In [41], authors proposed an algorithm that calculates the minimum power level for each node that is required to maintain network connectivity based on the global information from all the nodes.

III. ZONE ROUTING PROTOCOL (ZRP)

Zone Routing Protocol (ZRP) [12] is a well-known hybrid routing protocol that is most suitable for large-scale networks. The ZRP framework is designed to provide a balance between the contrasting proactive and reactive routing approaches. Its name is derived from the use of “zones” that define the transmission radius for every participating node. ZRP uses a proactive mechanism of node discovery within a node’s immediate neighborhood, while interzone communication is carried out by using reactive approaches.

ZRP utilizes the fact that node communication in ad hoc networks is mostly localized, thus the changes in the node topology within the vicinity of a node are of primary importance. ZRP makes use of this characteristic to define a framework for node communication with other existing protocols. Local neighborhoods, called *zones*, are defined for nodes. The routing zone of a given node is a subset of the network, within which all nodes are reachable within less than or equal to *zone radius* hops. The size of a zone is based on ρ factor, which is defined as the number of hops to the perimeter of the zone. There may be various overlapping zones, which helps in route optimization. [13]

Fig. 2 A Routing Zone with Radius $\rho = 2$ hops

An example of a routing zone for node S of radius 2 is shown in figure 1[14]. The nodes from 1 to 10 belong to the routing zone of S, but not node 11. The nodes 6 to 10 are called peripheral nodes because hop distance from S is equal to radius of the routing zone. The information about neighbors is required to construct a routing zone of a given node. A neighbor is defined as a node with whom *direct* communication can be established.

Neighbor discovery is accomplished by simple “Hello” packets (periodic transmission of beacon packets (active discovery) or with promiscuous snooping on the channel to detect the communication activity (passive discovery)) [15]. IARP [16] is proactive approach and always maintains up-to-date routing tables. Route queries outside the zone are propagated by the route requests based on the perimeter of the zone (i.e., those with hop counts equal to ρ), instead of flooding the network. The Interzone Routing Protocol (IERP) [17] uses a reactive approach for communicating with nodes in different zones. Route queries are sent to peripheral nodes using the Bordercast Resolution Protocol (BRP) [18]. Since a node does not resend the query to the node in which it received the query originally, the control overhead is significantly reduced and redundant queries are also minimized.

Fig. 3 Design Diagram of ZRP

ZRP provides a hybrid framework of protocols, which enables the use of any routing strategy according to various situations. It can be optimized to take full advantage of the strengths of any current protocols [12]. Neighbor discovery information is used as a basis for proactive monitoring of routing zones through the Intrazone Routing Protocol (IARP) [16]. Since ZRP assumes that local neighbor discovery is implemented on the link-layer and is provided by the Neighbor Discovery Protocol (NDP) [15] [33], the first protocol to be part of ZRP is the Intrazone Routing Protocol, or IARP [16]. Hence the larger the routing zone, the higher the update control traffic. The paths to the nodes which are outside the routing zone can be achieved by IERP [17]. If the destination belongs to its own zone, then it delivers the packet directly. Otherwise, source node bordercasts the *Route Request* to its peripheral nodes.

If any peripheral node finds the destination node in its *routing zone*, then it sends a *Route Reply* back to source node indicating the path; otherwise, the node rebroadcasts the *Route Request* packet to the peripheral nodes and this procedure continues till the destination is identified [12].

IV. ISSUES IN ZRP

Here we address two major issues that need to be considered and they are outlined below

A. Power Management

In ZRP, the packets are forwarded with full power without considering the node's position inside the zone. According to Inverse Square Law, the power received by the receiving node is inversely proportional to square of the distance between the nodes (i.e)

$$\gamma = P_t / 4\pi r^2$$

The node could waste power if the distance between the sender and the receiver node is less.

B. Bandwidth Utilization

As the distance between the sender and border nodes increases, the zone area will also increase, which means the radio coverage of the sender node will not be able to reach the border nodes in the zone. Due to that reason, the sender node will increase the number of broadcasts to find the border nodes in the zone, which will obviously increase the bandwidth utilization.

V. MODIFIED ZRP

A. Power Factor in ZRP

Whenever the node forwards a packet to the intermediate or border node in the zone it uses the maximum power to reach the destination [5]. By following this approach the node will lose its full power in a very short period of time. To avoid this problem, the ZRP protocol is modified to create zones with respect to two power levels, for example 20mW and 50mW. The reason for creating a zone with two power level is that, if a node is elected as a border node or as an intermediate node and if the node is moving at a particular speed of 2 m/sec. Then the corresponding nodes should be in that respective state (intermediate or border node) for a particular period of time to avoid the rapid fluctuation from border node to intermediate node or vice-versa. So by doing this, the node can avoid generating unnecessary routing updates or change its state more frequently.

Fig.4 Routing Zones of Node 1 & 3, Threshold powers are 20 & 50mW

From the above figure it can be seen that every node creates their own routing zones and initially when the node switches ON, it creates the zone with 20mW and 50mW, since that is the threshold power level set initially by the protocol. But if a node is unable to find a border node since the node's threshold power level is high (20 & 50mW), then the corresponding node will start reducing its threshold power level until it's able to find the border node. The reason for creating a dynamically changing zone is that, if a node has no border nodes elected but full of intermediate nodes elected then the intermediate nodes inside the zone will not be able to talk with its neighboring zone nodes. Because according to this protocol one zone can communicate to another zone through the border nodes only [1]. If we consider the above diagram, if node 1 wants to talk with node 4 then node 1 should pass through one of its border nodes to reach the neighboring zone, they are nodes 2, 5 or 3.

To calculate the power consumption, consider node 1 wants to forward a packet to destination node 8. The source node sends a broadcast with 50mW to all its border nodes (i.e) nodes 2, 5 and 3. Then the corresponding nodes check their own routing table and in that node 3 can reach node 8 since it is the border node of node 3's zone. After seeing that, node 3 sends a unicast packet to destination node 8 with 50mW. Therefore, the source node found the destination node by shedding only 50mW in the modified ZRP protocol.

But in the actual ZRP protocol the node would have spent 100mW to reach the destination since all the nodes form zone with respect to hop count and it always forwards the packet with full power level (100 mW) [1]. So as the number of broadcasts increase, the power usage will also increase according to the formula

$$P=C*N,$$

Where C=Transmit power and N=Number of Broadcasts. [2]

VI. SIMULATION RESULTS & ANALYSIS

The ZRP was modified to test the power utilization of the node and it was simulated in NS2 simulator. The simulation parameters are shown in the table below.

TABLE II
PE ZRP SIMULATION PARAMETERS

Channel Bandwidth	2 Mbps
Power Levels Used	20,30, 50 and 100 Mw
Transmission Range	Obstruction: 300 to 600 ft Without Obstruction: around 32ft
Packet Size and Rate	150 Bytes, 5 packets/sec

Fig. 5: IERP Power Consumption

Fig. 6: IARP Power Consumption

From the above simulation results, we can observe that ZRP protocol consumes more power compared to the Power Efficient (PE) ZRP protocol, which is the modified version of ZRP. Since ZRP protocol forwards packet with 100mW constantly, the node wastes more power as the number of packets increases. But in the case of PA ZRP, the power consumption was less; because packets were sent with 20 or 50 mW power levels. Since the simulation is in initial stages, the protocol was tested only for power consumption and with less number of packets.

VII. ZONE ROUTING PROTOCOL (ZRP)

In this paper a new method was proposed to reduce the power consumption using ZRP protocol and since the design and simulation is in initial stages, the protocol was tested with less number of packets and only for packet level power consumption. The future scope of this protocol is to successfully simulate it for a very large network and implement it with a voice application to study the performance and efficiency of the PE ZRP protocol. Also, Power control can be used to dynamically adjust the size of Zone. If open-loop power control is used, the node sends out a beacon, and nodes that hear the beacon join the zone. If the node velocity is high, then the node can reduce beacon signal strength so fewer nodes will hear it and size of the zone is decreased.

On the other hand, if the node velocity is low, the node can increase its beacon signal strength to increase the zone size. This is our next research work on which we are focusing.

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