An energy efficient routing scheme for Mobile Ad hoc Networks (MANETs) and Comparison of Routing Protocols

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Abstract--In today's world wireless networking has acquired great importance because it involves simple installation and is cost-effective. Wireless Sensor Networks (WSN) has shown promising prospects to change the way we obtain information from the physical environment. WSN comprises of numerous sensor nodes, which are interlinked or connected with each other for performing the function of information exchange collectively or cooperatively. The most important issue that must be addressed is how to save node energy while meeting the needs of applications/users. In this paper, we shall analyze the requirements and similarities of MANETs (mobile ad hoc network) and sensor networks. Further, we shall be discussing bandwidth optimization and route length in various protocols used in MANETs since it is an important feature that is essentially considered while designing any routing protocol. Also, we shall identify and compare major routing protocols and their energy consumption criteria. In particular, we are suggesting "How power consumption can be improved using Dijkstra's algorithm" which can be used for further research.

Keywords: Dijkstra, broadcasting, MANETs.

I. INTRODUCTION

An ad hoc network is the key to the evolution of wireless networks. Particularly, ad hoc networks are typically composed of equal nodes that communicate over wireless links without any central control. Ad hoc wireless networks inherit the traditional problems of wireless and mobile communications, such as bandwidth optimization, power control, and transmission quality enhancement. In addition, multihop nature and lack of fixed infrastructure generate new research problems such as configuration advertising, discovery, and maintenance, as well as ad hoc addressing and self routing. In ad hoc networks, power management is the paramount importance. Thus, general strategies for saving power need to be addressed along with adaptation to the specifics of nodes of general channel and source coding methods, radio resource management, and multiple accesses.

Basically, two protocols used in Mobile Ad hoc networks (MANET), according to the method of discovering and maintaining routes between all source–destination pairs, are:

A. *Proactive protocols:*

It is referred to as table driven protocol, a connectionless approach. It attempts to maintain routes continuously so that the route is already available when it is needed for forwarding a packet. Routing tables are exchanged among neighbouring nodes each time a change occurs in the network topology. In fact, the control overhead, in terms of both traffic and power consumption is a serious limitation in MANETs.

B. *Reactive protocols:*

It is also referred to as source initiated protocol. It sends a control message for discovering a route between a given source-destination pair only when necessary. Here control overhead is drastically reduced, but it generates a latency period due to route discovery procedure.

Among the existing network models, MANETs are closest to sensor networks. Both these networks share many characteristics. For example, network topology is not fixed; power is an expensive resource; nodes in the network are connected to each other by wireless communication links. However, the protocols and techniques developed for MANETs cannot be directly applied to sensor networks because the two networks vary in the following respects [1]

a. Sensor networks are mainly used to collect information while MANETs are designed for distributed computing rather then information gathering.

b. Sensor nodes mainly use broadcast communication paradigm whereas most MANETs are based on point to point communications.

c. The number of nodes in sensor networks can be several orders of magnitude higher than that in MANETs.

d. Sensor nodes may not have global identification (ID) because of large amount of overhead and large numbers of users.

e. Sensor nodes are cheap and limited in power, computational capacities, and memory whereas nodes in a MANET can be recharged somehow.

f. Usually, sensors are deployed once in a lifetime, while nodes in MANET move really in an ad hoc manner [2].

The objective of this paper is to analyze various issues involved in designing power efficient routing protocol for MANETs, to identify various important and desired features of a routing protocol and, compare and contrast the existing routing protocols with respect to their features. These comparisons will help in further studying the open issues in the area of routing for MANETs. The paper is organized as follows. Section II presents existing routing protocols for MANETs and their advantages and disadvantages. In Section II we have also discussed bandwidth optimization

and route length in various protocols. Desired features of power efficient routing protocols are identified in section III. The techniques to improve power consumption are also discussed in this section. These techniques can be used for further research. Finally, section IV concludes this paper.

II.   EXISTING ROUTING PROTOCOLS FOR MANETs

A MANET consists of a set of mobile hosts operating without the aid of the established infrastructure of centralized administration. Communication is done through wireless links among mobile hosts through their antennas. Due to concerns such as radio power limitation and channel utilization, a mobile host may not be able to always communicate directly with other hosts in a single hop fashion. Thus, each mobile host in a MANET must serve as a router in this multihop scenario, in which the packets sent by the source host must be relayed by several intermediate hosts before reaching the destination host. Routing protocols can be classified in multiple ways as node centric, data-centric, or location-aware (geo-centric), QoS based, reactive or proactive.

A.   Unicast Routing Protocols:

a.   Proactive Protocol:

a) Destination-Sequenced Distance Vector Routing (DSDV): It is based on the traditional distance vector routing mechanism, also called the Bellman-ford routing algorithm, with some modifications to avoid routing loops. Every router collects the routing information from all its neighbors, and then computes the shortest paths to all the nodes in the network. Then router broadcasts this table to all its neighbors. This may also trigger other neighbors to recompute their routing tables, until routing information is stable. One important feature of DSDV is that differentiation of stale routes from new ones is done by sequence numbers. A route will be replaced only when the destination sequence number is less than the new one, or two routes have same sequence number but one out of the two has a lower metric as shown in figure 1.

Figure 1

DSDV performs well under low node mobility, gives high delivery rate but fails to converge for increased mobility scalability for dense networks

b.   On-Demand (Reactive) Routing Protocols:

Observing that a proactive protocol may pay costs to construct routes even if mobile hosts do not have need, thereby wasting the limited wireless bandwidth, it is better to use reactive style protocols, in which routes are only constructed on-demand. Routing protocol for MANET needs to address three issues: route discovery, data forwarding and route maintenance. The topology of MANET may change anytime so maintenance is very important. Various types of reactive protocols that are known include Signal Stability Adaptive Protocol (SSA),

temporally ordered routing algorithm (TORA), DSR and AODV. In this paper, we shall limit our study to DSR and AODV only.

a) DSR (Dynamic Source Routing): It is a topology oriented source routing protocol. If a source node needs a route to a destination node, it broadcasts a ROUTE_REQ (route request) packet to its neighbors. Destination returns a ROUTE_REPLY packet containing the route indicated. The route reply then travels through unicast in the reverse direction of the discovered route, to the source. The source node on receiving the route reply will place the route in its route cache. It follows source routing that is whenever an intermediate host roams away, we must go back to the source host to discover a new route. This may result in high overhead for long paths or large addresses, like IPv6. To avoid using source routing, DSR optionally defines a flow id option that allows packets to be forwarded on a hop-by-hop basis. The major difference between this and the other on-demand routing protocols is that it is beacon-less and hence does not require periodic hello packet (beacon) transmissions, which are used by a node to inform its neighbors of its presence. DSR exhibits good scalability for dense networks. Also, DSR performs well at all mobility rates however this increases overhead of routing tables and control packets.

b) AODV (ad hoc on Demand Distance Vector Routing): It is based on DSDV protocol (destination oriented). It improves DSDV by using an on-demand philosophy to reduce maintenance costs, so hosts that are not on an active path do not have to maintain or exchange any control information. Each host maintains its own destination sequence like DSDV to prevent looping and compare the freshness between routes. ROUTE_REQ and ROUTE_REPLY packets are used in this protocol and the sequence number is considered for broadcasting the packets. On the route reply way back to the source, the next hop routing entry can be created in each intermediate host's routing table. Since routing tables may change dynamically, data packets belonging to the same session necessarily follow the same path. This allows some level of fault tolerance. AODV avoids the counting-to-infinity problem of other distance-vector protocols by using sequence numbers on route updates, a technique pioneered by DSDV. AODV is capable of both unicast and multicast routing.
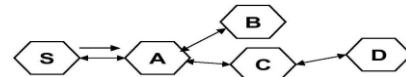

Figure 2

As shown in figure 2, Node S needs a route to D and hence creates a route request (RREQ) and enters D's IP address, sequence number, S's IP address, sequence number and finally broadcasts RREQ to neighbors. Node A receives RREQ and makes reverse route entry for S Dest = S, nexthop = S, hopcount = 1. It has no route to D, so it broadcasts RREQ. Now node C receives RREQ and makes reverse route entry for S Dest = S, nexthop = A, hopcount = 2. It has route to D and seq# for route D > seq# in RREQ. It creates a route reply (RREP) and enters D's IP address,

sequence number, S's IP address, hopcount. Finally, it unicasts RREP to A.

B.   Hybrid Routing Protocols:

a.   Zone Routing Protocol (ZRP):

With respect to each node, the set of nodes within 'r' hops is called a zone, where 'r' is a predefined value. For each host, routing information inside the zone is constantly collected in a proactive fashion. On the other hand, interzone routing is done in a reactive fashion.

C.   Broadcasting Protocols:

In a MANET, due to host mobility, broadcasting is used in route discovery. A straightforward approach to perform a broadcast is to use flooding. This costs n transmissions in a MANET with n hosts. In a CSMA/CA network, straightforward broadcasting by flooding is usually very costly and will result in serious redundancy, contention, and collision, which is referred to as the broadcast storm problem. In a MANET environment, redundancy could be very serious. To get some relief from broadcast storm, we must use threshold based schemes. Reachability-guaranteed approach for reducing broadcast storms in MANET is proposed [6]. The approach is based on location awareness, which means each node in the network needs to equip the positioning device like GPS and exchange location information in the HELLO message with its neighbors [9].

Three mechanisms are included in the proposed approach: Relay set (RS), neighbor coverage (NC), and transmission order (TO). Simulation results have shown that the proposed approach RS+NC+TO has a better performance than the threshold-based schemes and angle-based scheme in terms of 100% reachability, more saved rebroadcast, and shorter average latency to accomplish the broadcast process over the whole network.

D.   Multicasting Protocols:

It is classified based on how multicast trees are constructed: source based (multiple multicast trees) and core based (only one multicast tree rooted at the core host). Video conferencing is a good example of multicasting protocol. Threshold-based multicast allows two clients that request the same video to share a channel without having a delay to the earlier request. It ensures sharing by permitting the client with the later arrival time to join an ongoing multicast session initiated for the earlier request. However, threshold-based multicast does not allow a later arriving client to always join an ongoing multicast session. If it has been some time since the ongoing multicast session was started, a new multicast session is initiated. That is, a threshold is used to control the frequency at which new multicast sessions are started. Results show that threshold-based multicast significantly reduces the server bandwidth requirement.

a.   Optimizing Bandwidth and Route Length in Various Protocols:

Time needed to find a route will increase linearly with respect to the hop count, which is reasonable. One interesting observation is that the bandwidth degrades to ½ when the hop count changes from 1 to 2. The bandwidth further degrades to 1/3 when the hop count changes from 1 to 3. After three hops, the bandwidth still keeps on degrading, but at a slower speed. This shows that optimizing

route length is very critical in a MANET as it improves the end to end bandwidth. Of course, the level of contention on the medium can also be reduced if routes are shorter. If the perfect pipeline is formed, we can improve bandwidth to some extent [5].

III.   DESIRED FEATURES OF POWER EFFICIENT ROUTING PROTOCOLS

One of the chief limitations of MANETS is the limited battery power of the network nodes. Therefore, power management is one of the challenging problems in wireless communication, and recent research has addressed this problem. Routing is a significant consumer of battery power since a packet is routed through many intermediate nodes before reaching its destination. Because the power attenuation of a wireless link is proportional to square or even higher order of distance between the sender and the receiver, multihop routing is assumed to use less energy than direct communication [8]. However, multihop routing introduces significant overhead to maintain the network topology and medium access control. Many research projects and papers have shown that the hierarchal network routing and specially the clustering mechanisms (that assume sensor nodes to be stationary) make significant improvements in MANETs and WSNs in reducing energy consumption and overhead. Hence there is a demand for clustering protocols to support mobile nodes. We shall be dealing with energy consumption behaviour of two ad hoc network routing protocols: AODV and DSR. They have been well studied for their routing capabilities, but their energy characteristics need a further study.

In general, there is a fixed channel-acquisition cost and an incremental cost proportional to the size of packet:

$$Cost = m \cdot size + b \qquad (1)$$

Where m denotes the packet size multiplicative factor and b the fixed channel acquisition cost. The total cost is the sum of all the costs incurred by the source and destination nodes. Traffic is classified as broadcast traffic and point to point. For broadcast traffic, the sender listens briefly to the channel and sends data if the channel is clear, otherwise sender waits and retires later. Fixed channel access costs and incremental payload costs combined in the previous equation result in a new cost equation [5]:

$$Cost = m_{send}.size + b_{send} + \sum (m_{recv}.size + b_{recv}) \qquad n \in S \qquad (2)$$

where msend is the unit cost for sending a byte, mrecv is the cost for receiving a byte, and S denotes the set of nodes that are in radio range of sender's transmitter. For point to point traffic, the fixed cost includes channel access and the MAC negotiations. Nodes which discard traffic also consume energy whose amount is dependent on the MAC implementation. Small control messages are assumed to have the same fixed costs for the sake of simplicity. Since messages may be lost due to collision, equations also factor in the total number of transmission attempts. In the worst case, nodes receive packets and then ignore them if they were not destined for them. More efficient strategy is for non destination nodes to enter a reduced energy consumption state while the media carries uninteresting traffic.

First, receiving a message incurs a high cost. If a broadcast message is received by approximately four neighbors, then total cost of receiving the message is more

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than the cost of sending it[10]. Second, the fixed cost of sending or receiving a packet is large compared to the incremental cost. Source routers headers are quite inexpensive in terms of energy consumption. Third, discarding a packet usually consumes much less energy then receiving it. If discarding costs are high, then the advantages of point to point traffic are collision avoidance and data acknowledgement. However, there are some substantial savings if discarding costs are low. Results show that although DSR is usually most efficient in terms of bandwidth utilization, it is less energy efficient than AODV due to eavesdropping. The detail follows. Broadcasting traffic is used in both the protocols for on demand route discovery. For DSR, most routing traffic is sent point to point.

The amount of traffic received is so much larger then the amount of traffic sent that it accounts for 40-70% of the energy consumption. Results show that operating in ad hoc mode of the network interface incurs a significant cost. Allowing the use of the low power sleep mode will be important to the practical development of ad hoc networks. It will also be necessary for energy aware protocol design in the future. Variable transmit power could also be used in an ad hoc routing protocol. We are considering few power aware routing algorithms for further research in this area:

A. *Global Information-Based Algorithms:*

To reduce energy consumption, increase the life of mobile, and to increase network life, five different metrics are considered: (i) energy consumed per packet; (ii) time to network partition; (iii) variance in power levels across mobiles;(iv) cost per packet; and (v) maximum mobile cost. In order to conserve the energy, the goal is to minimize all the metrics except for the second, which should be maximized. Shortest cost routing protocol with respect to the five energy efficiency metrics would be pertinent. Also, energy can be conserved by routing traffic through lightly loaded mobiles because the energy expended in contention and retransmission is minimized. Therefore, a more energy efficient routing scheme may be obtained by adjusting routing parameters [11].

B. *Local Information Based Algorithms:*

Here routing decisions are made based on the location of a source node's neighbors and the destination. For this we have to assume that the nodes have global positioning system (GPS) receivers to provide location information to nodes, which allows the nodes to use the least transmission power needed for reception. The research considers the networks that may be static or mobile. If nodes have information about the position and activity of all other nodes in the network then Dijkstra's single source, shortest weighted path algorithm can be applied as the optimal power saving algorithm. For this algorithm, each edge has a weight of

$$u(d) = ad^{\alpha} + bd + c \qquad (3)$$

Here a is the coefficient depending upon the physical environment, d is the distance between two nodes, α represents signal attenuation and is adjusted depending upon the model used. Typically $\alpha = 2$ and $\alpha = 4$ are used for free

space and urban environments [5]. The factor c represents energy consumption for activities such as computer processing and encoding/decoding. Finally, Dijkstra's algorithm runs in O (n2), and we can improve it to run in O [n log(n)] for that we will be using more complicated data structures. This will result in higher time complexity for smaller networks.

IV.   CONCLUSION

In this paper, we identified some of the important desired features of routing protocols for MANETs and also compared the existing routing protocols. The work presented included the analysis of energy consumption in ad hoc routing protocols and power aware metrics. We will be working in detail on Dijkstra's algorithm to improve the time complexity for optimal power saving. As our study reveals, it is not possible to design a routing algorithm which will have good performance under all scenarios and for all applications. Although many routing protocols have been proposed for MANETs, many issues still remain to be addressed.

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