Power Aware Routing in Ad Hoc Networks

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Abstract—***A recent trend in ad hoc network routing is the reactive on-demand philosophy where routes are established only when required. Most of the protocols in this category, however, use single route and do not utilize multiple alternate paths. This paper proposes a new scheme called Power Aware Routing Protocol (PARP) to improve existing on-demand routing protocols by introducing the Power efficient scheme in whole scenario. The scheme establishes the multi paths without transmitting any extra control message. It offers quick adaptation to distributed processing, dynamic linking, low processing and memory overhead and loop freedom at all times. This scheme uses the concept of Power awareness among route selection nodes by checking power status of each node in the topology which insures fast selection of routes with minimal efforts and faster recovery. The scheme is incorporated with the Ad-hoc On-Demand Distance Vector (AODV) protocol and the performance has been studied through simulation and scheme performs very well.***

Key words—***Ad Hoc networks, Alternate path, Routing Protocol, Power Consumption, Mobile Computing, Power Factor***

1. INTRODUCTION

An ad hoc network consists of hosts communicating among themselves with portable radios. This network can be deployed without any wired base station or infrastructure support where routes are mainly multi-hop because of the limited radio propagation range. . An Ad hoc network is adaptive in nature and is self organizing. A "mobile ad hoc network" is an autonomous system of mobile hosts which are free to move around randomly and organize themselves arbitrarily. In this wireless topology may change rapidly and unpredictably. A mobile ad hoc network is also called MANET. The main characteristic of MANET strictly depends upon both wireless link nature and node mobility features. Basically this includes dynamic topology, bandwidth, energy constraints, security limitations and lack of infrastructure. MANET is viewed as suitable systems which can support some specific applications as virtual classrooms, military communications, emergency search and rescue operations, data acquisition in hostile environments, communications set up in Exhibitions, conferences and meetings, in battle field among soldiers to coordinate defense or attack, at airport terminals for workers to share files etc. Topology of the network changes frequently and unpredictably since its host moves randomly. Therefore, routing is an integral part of ad hoc communication, and has received interests from many researchers. In traditional "on-demand" routing schemes like Ad Hoc On Demand Distance Vector Routing (AODV) scheme [3], when route disconnects, nodes of the broken route simply drop data packets because no alternate path to the destination is available until a new route is established. When the network traffic requires real time delivery (voice, for instance), dropping data packets at the intermediate nodes can be costly. The Power aware scheme in Ad hoc routing Protocol enables dynamic, self starting, multi hop routing between participating mobile nodes wishing to establish and maintain an ad hoc network. It allows mobile nodes to maintain routes to destinations with more stable route selection. This scheme responds to link breakages and changes in network topology in a timely manner and also takes care of nodes that do not have better power status to participate in route selection. One distinguishing feature of Power aware ad hoc routing scheme is its use of Power status for each route entry. Given the choice between two routes to a destination, a requesting node is required to select one with better power status and more active. The rest of the paper is organized as follows. Section 2 illustrates the routing in ad hoc networks and existing protocols, Section 3 takes a look into the related work which already has been done. New protocol description and system methodology is presented in section 4. Performance evaluation via simulation is presented in Section 5 and conclusions are given in Section 6.

2. ROUTING IN AD HOC NETWORKS

Routing in an ad hoc network is trivial, if all the nodes are within transmission range of each other. All the nodes can be reached with a single hop. The transmission medium works much the same way as in a wired broadcast network. Complexity increases dramatically when distances increase and multi-hop routing is required. Routing in ad hoc networks is usually divided into proactive and reactive routing. The latter is also known as on demand routing.

2.1 Table Driven or Proactive Protocols

In Table Driven routing protocols each node maintains one or more tables containing routing information to every other node in the network. All nodes keep on updating these tables to maintain latest view of the network. Some of the famous table driven or proactive protocols are: DBF [5], GSR [6], WRP [7], ZRP [8] and STAR [9].

2.2 Demand or Reactive Protocols

In On Demand routing or reactive protocols, routes are created as and when required. When a transmission occurs from source to destination, it invokes the route discovery procedure. The route remains valid till destination is achieved or until the route is no longer needed. Some famous on demand routing protocols are: DSR [10], DDR [11], TORA [12], AODV [3], RDMAR [13]. Study has been concentrated for reactive protocols because they work well in dynamic topology.

Table driven	On demand
Attempt to maintain consistent, up-to-date routing information from each node to every other node in the network.	A route is built only when required.
Constant propagation of routing information periodically even when topology change does not occur.	No periodic updates. Control information is not propagated unless there is a change in the topology.
Incurs substantial traffic and power consumption, which is generally scarce in mobile computers	Does not incur substantial traffic and power consumption compared to Table Driven routing protocols.
First packet latency is less when compared with on-demand protocols	First-packet latency is more when compared with table-driven protocols because a route need to be built
A route to every other node in ad-hoc network is always available	A route to every other node is not always available.

Surveys of routing protocols for ad hoc networks have been discussed in [15, 16, and 17].

3. RELATED WORK

Main emphasis of research on routing protocols in Ad Hoc networks has been delivery of packets and network performance. There has been less amount of work on power aware routing schemes, though it is very important aspect in route selection and performance of protocol. Some study has been done in this context and presented is a brief review of them.

3.1 Minimum Power Routing

Singh, Woo and Raghvendra [1] [2] proposed a routing algorithm based on minimizing the amount of power required to send a packet from source to destination. The equation is:

$$\text{Min} \sum_{i \ni path} P(i, i+1)$$

Where P (i, i+1) denotes the power expended for transmitting packet between node i and node i+1. Link cost is calculated separately for the cases when transmit power is fixed and when transmit power is varied dynamically. Variation is in terms of the distance that changes between receiver and sender. For fixed case energy for each operation is given by [2]

E (packet) = b * packet_size + c

Where b denotes packet size-dependent energy consumption and c is a fixed cost for acquiring channel. For varying transmit power Lin [4] proposed a local routing algorithm. The authors assumed the power needed for transmission is a linear function of d^{α} where d is distance between two neighboring nodes and α is a parameter depending on physical environment. This procedure requires GPS equipped systems, which in turn limits its usage and also it is based on least power cost routes which in many cases lead to problems. In this case nodes die soon and most of the cases those nodes die which are most needed to maintain network connectivity.

3.2 Battery cost aware routing

The previous case gave rise to number of battery cost aware routing algorithms as described below:

(a) Minimum battery cost routing algorithm [14]: It minimizes the total cost of the route. It minimizes the summation of inverse of remaining battery capacity for all nodes on the routing path.

(b) Min-Max battery cost algorithm [1] [14]: It is a modification of minimum battery cost routing. It tries to avoid the route with nodes having the least battery capacity among all nodes in all possible routes. It results in better use of battery of each node.

4. PROTOCOL CONCEPT

In this scheme main aim is to provide an efficient, more stable and long lasting path from source to destination. This routing scheme is designed for mobile ad hoc networks with large number of nodes. It can handle low, moderate, and relatively high mobility rates. It can handle a variety of data traffic levels. In this section, the operation details of this scheme are presented. Since the main aim is to improve the performance of existing on-demand protocols, this protocol description is based on AODV. Modifications to AODV for applying this scheme are also introduced. This scheme has been designed for use in networks in which all the nodes can trust each other, and there are no malicious intruder nodes. There are three main phases in this protocol: REQ (Route Request) phase, ERR (Route error and recovery) phase and RE (Route Eraser) phase. The messages are received via UDP, and normal IP header processing applies.

4.1 Route Construction (REQ phase)

Route construction scheme can be incorporated with reactive routing protocols. This scheme does not require any modification to the AODV's RREQ route request process. When a source wants to transmit a data to a destination but does not have any route information, it searches a route by broadcasting a ROUTE REQUEST (RREQ) packet. Each RREQ packet has a unique identifier so that nodes can detect and drop duplicate packets. An intermediate node with an *active route* (in terms of power), upon receiving a non-duplicate RREQ, records the previous hop and the source node information in its route table (i.e., backward learning). It then broadcasts the packet or sends back a ROUTE REPLY (RREP) packet to the source if it has an *active route* to the destination. The destination node sends a RREP via the selected route when it receives the first RREQ or subsequent RREQs that traversed a better *active route*.

Nodes monitor the link status of next hops in *active routes*. When a link break in an active route is detected, an ERR message is used to notify that the loss of link has occurred to its one hop neighbor. Here ERR message indicates those destinations which are no longer reachable by way of the broken link. Taking advantage of the broadcast nature of wireless communications, a node promiscuously overhears packets that are transmitted by their neighboring nodes. When a node that is not part of the route overhears a RREP packet not directed to itself transmit by a neighbor (on the primary route), it records that neighbor as the next hop to the destination in its alternate route table. From these packets, a node obtains alternate path information and makes entries of these active nodes in its route table. If route breaks occurs it just start route construction phase from that node. This protocol updates list of neighbors and their power status periodically.

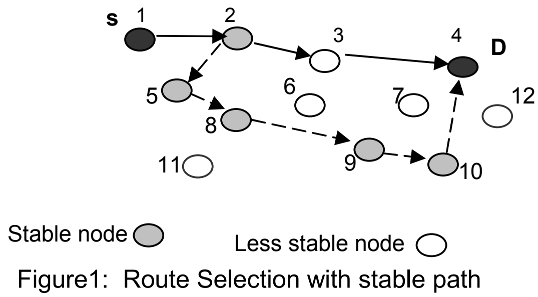

Figure1: Route Selection with stable path

Figure 1 suggests the proposed theory; the route discovered using Power aware ad hoc routing scheme may not necessarily be the shortest route between a source destination pair. If node 3 is having power status in critical or danger zone, then though the shortest path is 1 – 2 -3 – 4 but the more stable path 1- 2 -5 – 8 – 9 -10 - 4 in terms of active power status is chosen. This may lead to slight delay but improves overall efficiency of the protocol by sending more packets without link break than the state when some node is unable to process route due to inadequate battery power

4.2 Route Error & Recovery (ERR)

In this scheme data transmits continuously through the primary route unless there is a route disconnection. When a node detects a link break, it performs a one hop data broadcast to its immediate neighbors. The node specifies in the data header that the link is disconnected and thus the packet is candidate for alternate routing. Upon receiving this packet route maintenance phase starts by selecting alternate path and checking power status. Power factor is calculated using status report based on three states defined as Active, Critical and Danger level.

In this phase when route error message has sent to previous neighbor of any intermediate node it just reinitiates route construction phase by considering power status of all its nodes. All this route maintenance occurs under *local repair* scheme. Local repair scheme tries to get rid off the regeneration of route request phase in the case of route break.

Route Recovery involves Finding active nodes, their Power status, Invalidate route erasures, Listing affected DEST, Valid route update, New route (in worst cases).

(1) Nothing is done if Mobile Host that has moved is not the part of any active route , or power status of that node is below danger level which is not part of active route.

(2) If current host is SRC (Source) and host moved is next_hop then REQ is sent to search VN and Power status is checked.

(3) Local Repair scheme is used if host moved is an active route.

4.2.2 Local Route Repair

When a link break in an active route occurs, the node upstream of that break may choose to repair the link locally if the destination was no farther and there exists neighboring nodes that are in active power state. Node to participate in route selection must be in active state. It can keep on transmission till it is in Critical state and can not participate if it moves in danger state. To efficiently apply power function routines are made to turn nodes not participating in route to sleep mode to conserve energy. A node goes into sleep mode if (a) it is not transmitting any packet (b) If at least one neighbor is transmitting and one neighbor is receiving (c) if at least one neighbor node is transmitting and node is not receiver. All nodes of the topology broadcast these entries after fixed intervals to all nodes and each node updates its routing table. To repair the link break, the node increments the sequence number for the destination and then broadcasts a REQ for that destination. The Time to live (TTL) of the REQ should initially be set to the following value:

TTL = max (neighboring nodes, 0.5 * #hops) + POW,

Where #hops is the number of hops to the sender (originator) of the currently undeliverable packet and POW is the available power state of any specific node.

From this nodes lifetime is calculated as

F (A) = 1 / TTL

This factor is transmitted as weight factor to all nodes to select best available path with maximum power. The entry is done in route table and transmitted along with hello packet. Thus, local repair attempts will often be invisible to the originating node. The node initiating the repair then waits the discovery period to receive reply message in response to that request REQ. During local repair data packets will be buffered at local originator. If, at the end of the discovery period, the repairing node has not received a reply message REP it proceeds in by transmitting a route error ERR to the originating node.

Local repair of link breaks in routes sometimes results in increased path lengths to those destinations. Repairing the link locally is likely to increase the number of data packets that are able to be delivered to the destinations, since data packets will not be dropped as the ERR travels to the originating node. Sending a ERR to the originating node after locally repairing the link break may allow the originator to find a fresh route to the destination that is better, based on current node positions. However, it does not require the originating node to rebuild the route, as the originator may be done, or nearly done, with the data session.

When a link breaks along an active route, there are often multiple destinations that become unreachable. The node that is upstream of the lost link tries an immediate local repair for only the one destination towards which the data packet was traveling. If an alternate route is not updated during the timeout interval, the node removes the path from the table.

4.3 Route Erasure (RE) phase

When a discovered route is no longer desired, a route erasure broadcast will be initiated by Source, so that all nodes will update their routing table entries. A full broadcast is needed because some nodes may have changed during route reconstruction. RE phase can only be invoked by SRC (source).

5. SIMULATION

To evaluate the performance made by the Power Aware Routing Scheme, the simulation results have been compared with that of the AODV protocol with and without applying this scheme. The network simulator NS-2 version 2.26 is used. The Network Simulator NS-2 is a scalable simulation environment for wireless network systems. Simulation modeled a network of 50 mobile hosts placed randomly within a 1000 meter * 1000 meter area. Radio propagation range for each node was 300 meters and channel capacity was 2 Mb/s. Each run executed for 250 seconds of simulation time. Here we are using random waypoint mobility model. Each node randomly selects a position, and moves toward that location with a speed between the minimum and the maximum speed. Once it reaches that position, it becomes stationary for a predefined pause time. After that pause time, it selects another position and repeats the process. The pause time was varied to simulate different mobility degrees. Longer pause time implies less mobility. The minimum and the maximum speed were zero and 20 m/s, respectively.

The Metrics used for Performance comparison are:

5.1 Packet Delivery Ratio

The fraction of successfully received packets, which survive while finding their destination. This performance measure also determines the completeness and correctness of the routing protocol. If F is fraction of successfully delivered packets, C is total number of flows, f is id, R is packets received from f and T is transmitted from f, then F can be determined by

$$F = \frac{1}{C}\sum_{f=1}^{C}\frac{R_f}{T_f}$$

5.2 End-to-End Delay

Average end-to-end delay is the delay experienced by the successfully delivered packets in reaching their destinations. This is a good metric for comparing protocols. This denotes how efficient the underlying routing algorithm is, because delay primarily depends on optimality of path chosen.

$$\text{Average end-to-end Delay} = \frac{1}{S}\sum_{i=1}^{S}(r_i - s_i)$$

where S is number of packets received successfully, r_i is time at which packet is received and s_i is time at which it is sent, i is unique packet identifier.

Simulations have been conducted for 10, 20 and 50 nodes It has been found that in all cases PARP perform better than AODV in packet delivery ratio. Figure 2 shows the throughput in packet delivery ratio for 50 nodes. As is clear this scheme improves the throughput performance of AODV as well.

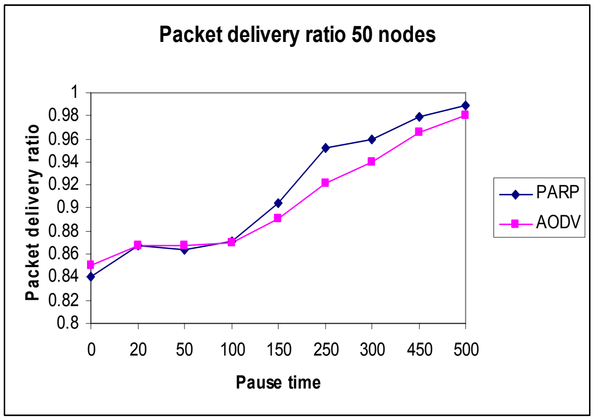

Figure2: Packet Delivery Ratio

As the mobility increases, the performance gain by alternate routes becomes more significant. Due to presence of neighboring nodes which are in active state, nodes attempt to use multiple alternate paths for data delivery in the presence of route breaks, the protocol is able to deliver more packets to the destination than AODV. The proposed scheme has some packet losses. Alternate paths may be broken as well as the primary route because of mobility or power status of nodes, or be unavailable and not discovered during the route reply phase. Moreover, packets can be lost because of collisions and contention problems.

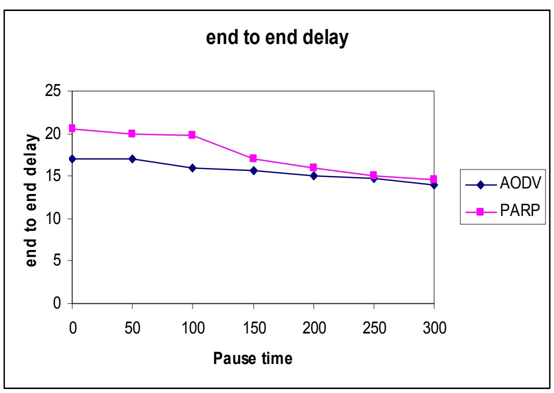

Figure 3: End-to-end delay

End-to-end delay is presented in Figure 3. As expected, New scheme has longer delays than AODV. One can only measure delays for data packets that survived to reach their destination. Proposed scheme delivers more data packets, and those packets that are delivered in Power aware routing but not in AODV, take alternate and possibly longer hop routes. So power aware routing scheme having longer delays than AODV does not represent its ineffectiveness since these protocols use the same primary route.

6. CONCLUSION

A scheme has been proposed that utilizes power status of each mobile node and alternate paths. This scheme can be incorporated into any ad hoc on-demand unicast routing protocol to improve reliable packet delivery in the face of node movements and route breaks. Alternate routes are utilized only when data packets cannot be delivered through the primary route. As a case study, it has been applied to AODV and performance has been studied via simulations.

Simulation results have indicated that new technique provides robustness to mobility and enhances protocol performance. However, this scheme may not perform well under sparse traffic networks. Its performance has been found much better than other existing protocols in dense medium as probability of finding active routes increases. Additionally, plan is to further evaluate this scheme by comparing it with other existing protocols using more detailed and realistic channel models with fading and obstacles in the simulation. The performance of protocol is slightly costlier as compared to AODV and its counterparts and causes slight overhead in route selection initially.

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