Cost Based Power Aware Cross Layer Routing Protocol For Manet

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Summary
Mobile Ad-Hoc Networks (MANETs) are wireless networks consisting of a collection of mobile nodes with no fixed infrastructure, where some intermediate nodes should participate in forwarding data packets. So energy conservation is a critical issue in ad hoc wireless networks for node and network life. This issue is crucial in the design of new routing protocols. To design such protocols, we have to look away from the traditional minimum hop routing schemes. In this paper, we propose a cost based power aware cross layer design to AODV. The discovery mechanism in this algorithm uses Battery Capacity of a node as a routing metric. This approach is based on intermediate nodes calculating cost based on Battery capacity .The intermediate node judges its ability to forward the RREQ packets or drop it. That is it integrates the routing decision of network layer with battery capacity estimation of MAC layer. Simulations are performed to study the performance of power aware cross layer AODV protocol using NS2. The simulation shows that the cross layer protocol improves packet delivery ratio & throughput and also nodes energy consumption is reduced by routing packets using energy optimal routes. In summary our design offers a simple but efficient power aware cross layer routing protocol to support routing in AdHoc networks.

Key words:
Mobile AdHoc networks(MANETS) ,cross layer design, adhoc on demand distance vector , energy consumption

1. Introduction

The increasing progress of wireless local area networks (WLAN), has opened new horizons in the field of telecommunications. Among the various network architectures, the design of mobile adhoc network (MANET) has attracted a lot of attention [1], [2], [3], [4], [5] and [6] A MANET is composed of a set of mobile hosts that can communicate with one another. No base stations are supported in such an environment and mobile hosts Communicate in a multi-hop fashion. Such networks are needed in situations where temporary network connectivity is required, such as in battlefields, disaster areas, and meetings, because of their capability of handling node failures and fast topology changes. A set of ad hoc routing protocols has been proposed in the IETF's MANET [1] group to ensure the network connectivity.

They operate in either proactive or reactive modes. Building such routing algorithms poses a significant technical challenge, since the devices are battery operated. The devices need to be energy conserving so that battery life is maximized. The shortest path is the most common criteria adopted by the conventional routing protocols proposed in the MANET working Group. The problem is that nodes along shortest paths may be used more often and exhaust their batteries faster. The consequence is that the network may become disconnected leaving disparity in the energy, and eventually disconnected sub networks. Therefore, the shortest path is not the most suitable metric to be adopted by a routing decision. Other metrics that take the power constraint into consideration for choosing the appropriate route are more useful in some scenarios (e.g. sensor networks).

Research on cross-layer design in ad-hoc networks has recently attracted a significant interest [8][9]. It is concerned with sharing information between various protocol layers. A simple cross layer design between PHY and MAC layers for power conservation based on transmission power control is proposed in [7].

In this paper we propose a simple but efficient approach based on cross layer design that rejects the paths with nodes having less battery power than the specified threshold value. We investigate by implementing needed changes in the route discovery process using cross layer approach in the well known on demand routing protocol AODV, as a case study. This cross layer design is suitable to implement with all reactive protocols which use a route request/query packets in the route discovery phase. Using NS2, we evaluate the performance of our cost based power aware cross layer design to AODV, which is named as cost based Power Aware Cross Layer AODV (CPACL- AODV) in mobile AdHoc networks. The rest of the paper is organized as follows.Section 2 reviews related work, section 3 presents CPACL- AODV,we study performance evaluation & numerical results in section 4, finally section 5 summarizes our conclusion.

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2. Related Work

Developing core protocols (at different layers, e.g.,MAC and network layers) for MANETs has been an area of extensive research in the past few years. Since most of nodes in MANETs rely on batteries, we experienced the advent of studies to address energy-constraint in MANETs.

In [12], Shu-Lin Wu et al., proposed a new mechanism to reduce power consumption whileincreasing channel utilization. The approach tries to adapt the power level used by a mobile host to transmit data packets as a function of the relative distance to the target node according to the strengths at which RTS/CTS packets are received. S. Singh and C. S. Raghavendra [13] proposed the PAMAS protocol, a new channel access protocol for ad hoc networks. PAMAS uses two different channels, separate data and signaling channels. The signaling channel tells the nodes when to power off their RF devices if a packet is not being transmitted nor received. In addition, Wan et al., [14] proposed a routing solution for minimum energy broadcasting dedicated to static MANETs. Laura Feeney presented in [15] a combination of simulation and experimental results showing that energy and bandwidth are substantively different metrics and that resource utilization in routing protocols is not fully addressed by bandwidth- centric analysis. Recently, some routing protocols targeting efficient power utilization have been proposed. Recently some routing protocols to efficiently utilize energy power have been proposed. The MTPR (Minimum Total Transmission Power Routing) [16] was initially developed to minimize the total transmission power consumption of nodes participating in the acquired route. According to [17], the transmission power required is proportional to d , where d is the distance between two nodes and between 2 and 4. This means that the MTPR prefers routes with more hops having short transmission ranges to those with fewer hops but having long transmission ranges, with the understanding that more nodes involved in forwarding packets can increase the end-to-end delay. In addition, since the MTPR does not consider the remaining power of nodes, it fails to prolong the lifetime of each host. Furthermore, since schemes trying to reduce only total transmission power do not reflect the nodes' remaining power, some other proposals, like the Min-Max Battery Cost Routing (MMBCR) [18], appeared that consider the remaining power of nodes as the metrics for acquiring routes in order to prolong the lifetime of each node. Finally, C. K. Toh [19] presented the Conditional Max-Min Battery CapacityRouting (CMMBCR) protocol, which is a hybrid protocol that tries to arbitrate between the MTPR and MMBCR.

Research on cross-layer design in ad-hoc networks has recently attracted a significant interest. It is concerned with sharing information between various protocol layers. In [12] impact of routing protocols and channel conditions on the link layer ARQ is studied. A simple cross layer design between PHY and MAC layers for power conservation based on transmission power control is proposed in [13] and it has been shown that the amount of power conserved dependent on the accompanying routing protocol.

3. Cost Based Power Aware Cross Layer AODV (CPACL-AODV)

This section presents the new energy efficient routing algorithm. it is designed to increase the network survivability by maintaining network connectivity & to lead to a longer battery life of terminals. This is in contrast to AODV, which does not consider power but optimizes routing for lowest delay. The CPACL-AODV ensures survivability of the network by establishing routes that ensure that all nodes equally deplete their battery power. It is a reactive protocol & is based on the AODV routing protocol described below.

3.1 AODV Protocol

AODV routing protocol is a reactive routing algorithm. It maintains the established routes as long as they are needed by the sources. AODV uses sequence numbers to ensure the freshness of routes.

Route Discovery: The route discovery process is initiated whenever a traffic source needs a route to a destination. Route discovery typically involves a network-wide flood of route request (RREQ) packets targeting the destination and waiting for a route reply (RREP).

1) When a node receives a RREQ packet for the first time; it sets up a reverse path to the source. If a valid route to the destination is available, then, it sends a RREP to the source on the reverse path; otherwise, it broadcasts it to the other nodes. 2) When the destination receives a RREQ, it sends a RREP to the source via the reverse path.

Route Maintenance: Route maintenance is done using route error (RERR) packets. When a link failure is detected, a RERR is sent back via separately maintained predecessor links to all sources using that failed link. Routes are erased by the RERR along its way. When a traffic source receives a RERR, it initiates a new route discovery, if the route is still needed.

3.2 CPACL-AODV

Utilizing physical & Mac information for routing purpose is at the heart of cross layer design. The proposed cross layer design is based on sharing the following MAC & physical layer information.

1. Transmit power.
2. Full charge battery capacity.
3. Remaining battery capacity of node at time t.

having access to this, the activity begins with the source node flooding the network with RREQ packets when it has data to send all nodes except the source & destination calculates their link cost C_i [6] using the following formula.

$$C(\pi,t)=\sum_{i\in\pi} C_i(t)\,, \tag{1}$$

$$C_i(t)=\rho_i\left(\frac{F_i}{E_i(t)}\right)^{\alpha} \tag{2}$$

Where
ρ_i = transmit power of node i.
F_i = full charge battery capacity of node i.
E_i (t) = remaining battery capacity of node i at time t.
α = +ve weighting factor.

After computing, a node adds it to the path cost c(π,t). a node before forwarding the RREQ packet learns about its remaining battery capacity & drops the packets when it has a lower battery level than its threshold value (E_r <= ϴ).This gives chance for another RREQ that flows through nodes with adequate battery level to result in successful route discovery.

In our, cost based power aware cross layer AODV implementation for simplicity we have a module called power module to which the MAC layer passes the information. The cost is computed in the power module & is made available to the network layer as shown in fig 1.

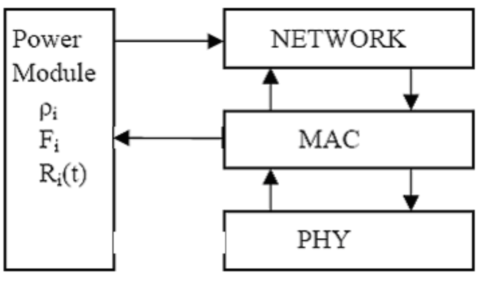


FIG-1 Information sharing in CPACL-AODV.

The link cost C_i is added to the path cost in the header of the RREQ packet. Hence the route discovery process of CPACL- AODV performs the following steps in a node.

1. A intermediate node when receives a RREQ packet it keeps the cost in the header of that packet as min cost
2. If additional RREQ's arrive with the same destination & sequence number, the cost of the newly arrived RREQ packet is compared to the min-cost

Three cases are possible
1. If the new packet has a lower cost and if the intermediate node does not know any valid route to the destination, Min- Cost is changed to this new value and the new RREQ packet is rebroadcast.
2. If the new packet has a lower cost but the intermediate node knows a route to the destination, the node forwards (unicast) a COMPUTE_Cost message. The COMPUTE _Cost calculates this route cost.
3. Otherwise, if the new packet has a greater cost, the new RREQ packet is dropped.

When the destination receives either a RREQ or a COMPUTE_Cost message, it generates a RREP message. The RREP is routed back to the source via the reverse path. This reply message contains the cost of the selected path. The source node will select the route with the minimum cost. This CPACL-AODV does not need any major modification in the basic AODV. Handling of RERR packets of basic AODV are left as they are and no other functions of routing layers including communication ith Mac & network layers is changed. Only a simple computation module is incorporated that is used in decision making step to decide whether to forward or discard the RREQ packet during route discovery phase.

If there are any other parameters they can be easily included in the cross layer information sharing structure if they are needed at routing layer for effective decision on RREQ forward.

4. Evaluation & Numerical results

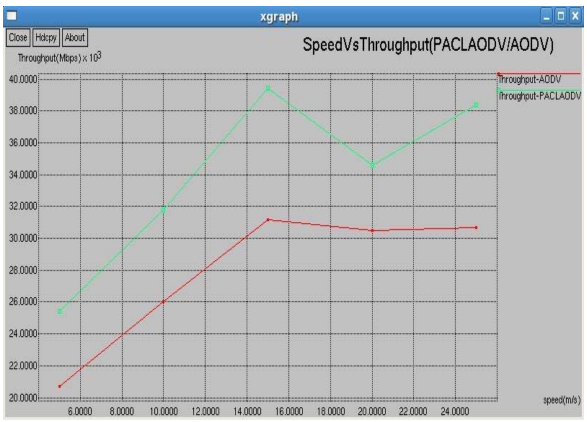
The performances of our algorithms are evaluated using NS2 [10]. The simulation consists of a network of 40 nodes confined in a 1000 * 1000 m² area. Random connections were established using CBR traffic (at 4 packets/second with a packet size of 1024 bytes). The initial battery capacity of each node is 10 units. This initial energy is progressively reduced by data transmission/reception. When it reaches zero units, the corresponding node cannot take part any more in the communication, and is regarded as died. Each node has a radio propagation range of 250 meters and channel capacity was 2 Mb/s. We consider the simple case when the transmit power is fixed. Network performance of our algorithm is compared to AODV since they are derived from it. Graphs show the considerable performance improvement of the CPACL-AODV over basic AODV.

Throughput: The measure of number of packets passing through the network in a unit of time. This metric shows the total number of bytes that have been successfully delivered to the destination nodes.
Both CPACL-AODV and AODV have higher throughput when nodes move at low speeds,and when speed increases all routing protocols suffer a decrease in throughput. Higher speed causes frequent link changes and connection failures. CPACL-AODV shows better throughput as it integrates cross layer decision (Graph 1).

Packet Delivery Ratio: The ratio of the data packets delivered to the destination to those generated by CBR sources. This metric illustrates the effectiveness of best effort routing protocols CPACL-AODV & AODV for delivering packets to their intended destination. CPACL-AODV has better PDR than the reference system (Graph 2).

Overhead: The number of routing packets transmitted per data packet delivered at the destination. Each hop wise transmission of a routing packet is counted as one transmission. The number of control packets for the routing protocol over the number of data packets sent increases with speed (Graph 3).

End-to-End Delay: This includes all possible delays caused by buffering during route discovery latency, queuing delay during other processes, transmission delay at the MAC and propagation delay. There is significant increase in time taken for packets to reach destination (End to End delay) (Graph 4).



Graph 1:Speed Vs Throughput.

Graph 2: Speed Vs Packet Delivery Ratio.

Graph 3: Speed Vs Overhead.

Graph 4: Speed Vs End to End Delay.

Graphs show the significant performance improvement over the reference system. At all the condition of the load the proposed algorithm works better than the reference system.

5. Conclusion.

This paper proposed cost based power aware cross layer protocol results in improved throughput, packet delivery ratio and average end-to-end delay performance. Also, significant reduced overhead, both in routing and MAC layers is achieved. CPACL-AODV saves the precious lifetime of batteries of low power nodes and other network resources. The low power nodes are identified and rejected in RREQ flooding phase itself and not after facing any RREP transmission failures.

When a node has a lower battery level than its threshold value ($R_r <= \Theta$), any request is simply dropped therefore the source will not receive a RREP message even if there exists a route between the source and destination. In our future work, we will aim to effectively address this problem with simple and efficient cross layer design.

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