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Performance Evaluation of AOMDV-PAMAC Protocols for Ad Hoc Networks

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Abstract**—**Power consumption of nodes in ad hoc networks is a critical issue as they predominantly operate on batteries. In order to improve the lifetime of an ad hoc network, all the nodes must be utilized evenly and the power required for connections must be minimized. In this project a link layer algorithm known as Power Aware medium Access Control (PAMAC) protocol is proposed which enables the network layer to select a route with minimum total power requirement among the possible routes between a source and a destination provided all nodes in the routes have battery capacity above a threshold. When the battery capacity goes below a predefined threshold, routes going through these nodes will be avoided and these nodes will act only as source and destination. Further, the first few nodes whose battery power drained to the set threshold value are pushed to the exterior part of the network and the nodes in the exterior are brought to the interior. Since less total power is required to forward packets for each connection. The network layer protocol AOMDV is basically an extension to the AODV routing protocol. AOMDV is designed to form multiple routes to the destination and it also avoid the loop formation so that it reduces the unnecessary congestion to the channel. In this project, the performance of AOMDV is evaluated using PAMAC as a MAC layer protocol and the average power consumption, throughput and average end to end delay of the network are calculated and the results are compared with that of the other network layer protocol AODV.

Keywords**—**AODV, PAMAC, AOMDV, Power consumption.

I. INTRODUCTION

MOBILE ad hoc networks (MANETs) represent complex distributed systems that comprise wireless mobile nodes that can freely and dynamically self- organize into arbitrary and temporary, ‘‘ad-hoc’’ network topologies, allowing people and devices to seamlessly internet work in areas with no pre-existing communication infrastructure, e.g., disaster recovery environments. Ad hoc networking concept is not a new one, having been around in various forms for over 20 years. Traditionally, tactical networks have been the only communication networking application that followed the ad hoc paradigm. Recently, the introduction of new technologies such as the Blue tooth, IEEE 802.11 and Hyper LAN are helping enable eventual commercial MANET deployments outside the military domain. These recent evolutions have been generating a renewed and growing interest in the research and development of MANET [1].

The nodes in an adhoc network are constrained by limited battery power for their operation. The use of multi-hop relaying requires a sufficient number of relaying nodes to maintain the network connectivity. Hence, battery power which is a precious resource must be used efficiently in order to avoid early termination of any nodes. Efficient battery management, transmission power management and system power management are the three major means of increasing the lifetime of a node [2].

Battery management is concerned with problems that lie in the selection of battery technologies, finding the optimal capacity of the battery, and scheduling of batteries that increase the battery capacity. Transmission power management techniques attempt to find an optimum power level for the nodes in an adhoc wireless network. System power management deals with minimizing the power required by hardware peripherals of a node and incorporating low power strategies into the protocols used in various layers of the protocol stack.

Battery–driven systems are those systems which are designed taking into consideration mainly the battery and its internal characteristics. They try to maximize the amount of energy provided by the power source by exploiting the inherent property of the batteries to recover their charge when kept idle. It is shown that [2] by varying the manner in which energy is drawn from the batteries, significant improvement can be obtained in the total amount of energy supplied by them.

Transmission power control on a network wide basis is exercised based on the following observation: Each node in an ad hoc network communicates directly with nodes within its transmission range. To send a packet to a destination, a node forwards the packet to its neighbor, which in turn forwards it to its neighbor, and so on, until the packet reaches the destination. The topology of the Ad hoc network depends on the transmission power of the nodes and the location of the mobile nodes, which may change with time.

There are several MAC layer protocols such as CSMA, MACA and IEEE 802.11. In CSMA protocol, a station wishing to transmit, first listens to the medium in order to determine if another transmission is in progress. If the transmission medium is busy, the station waits, otherwise it may transmit. But CSMA protocol has the limitations of hidden and exposed terminals. The MACA and the 802.11 protocols use the RTS/CTS dialogue for collision avoidance on the shared channel. MACA does not make use of carrier

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sensing for channel access. It uses two additional signaling packets: the request–to-send (RTS) packet and the clear-to-send (CTS) packet. When a node wants to transmit a data packet, it first transmits an RTS packet. On receiving the RTS packet, the receiver node transmits a CTS packet if it is ready to receive the data packet. The reception of the CTS packet at the transmitting node acknowledges that the RTS/CTS dialogue has been successful and the node starts the transmission of the actual data packet. The IEEE 802.11 requires an Acknowledgement (ACK) from the receiver after the successful reception of packets. The RTS/CTS dialogue provides some degree of improvement over the CSMA schemes [2].

But the binary exponential backoff algorithm used in MACA completely blocks the data flow from a specific node over a period of time. To overcome these limitations, a MAC layer protocol denoted as Power Aware medium Access Control (PAMAC) protocol is proposed in this paper. It is coded on lines similar to MACA in the sense that it too uses the concept of RTS/CTS dialogue. Additionally, it incorporates the feature of checking the battery capacity of the nodes in the network.

II. Multipath Routing Protocols

In MANET, the communication is prone to be broken because of the dynamic topology. High route discovery latency together with frequent route discovery attempts in dynamic networks can affect the performance adversely. Multipath on-demand protocols try to alleviate these problems by computing multiple paths in a single route discovery attempt. Multiple paths could be formed at both traffic sources as well as at intermediate nodes. New route discovery is needed only when all paths fail. This reduces both route discovery latency and routing overheads. Multiple paths can also be used to balance load by forwarding data packets on multiple paths at the same time.

The main idea in AOMDV is to compute multiple paths during route discovery. It is designed primarily for highly dynamic ad hoc networks where link failures and route breaks occur frequently [3]. The AOMDV protocol has two main components:

1. A route update rule to establish and maintain *multiple loop-free* paths at each node.
2. A distributed protocol to find *link-disjoint* paths.

A. Computing Multiple Loop-Free Paths

Each route advertisement arriving at a node during AODV route discovery potentially defines an alternate path to the source or the destination. For example, each copy of the RREQ packet arriving at a node defines an alternate path back to the source. However, accepting all such copies naively to construct routes will lead to routing loops. As an example, Source S initiates a flood of RREQ packets. An intermediate node A broadcasts the RREQ. A neighbor B rebroadcasts it, which in turn is heard by A. If A accepts this RREQ copy to form a reverse path, this will form a loop. On the other hand, loop cannot be formed if A accepts a duplicate copy of the RREQ arriving via a trajectory that does not already include A.

A node accepts and maintains multiple next-hop routes as obtained by multiple route advertisements. Now, different routes to the same destination may have different hopcounts. Therefore, a node must be consistent regarding which one of these multiple hopcounts is advertised to others. It cannot advertise different hopcounts to different neighbors with the same destination sequence number.

We build the AOMDV invariant based on a new notion of "advertised hopcount." The *advertised hopcount* of a node i for a destination d represents the "maximum" hopcount of the multiple paths for d available at i. "Maximum" hopcount is considered, as then the advertised hopcount can never change for the same sequence number. The protocol only allows accepting alternate routes with lower hopcounts. This invariance is necessary to guarantee loop freedom. The *advertised_hopcount* is initialized each time the sequence number is updated. A node i updates its *advertised_hopcount* for a destination d whenever it sends a route advertisement for d. Specifically, it is updated as follows:

$$\text{advertised\_hopcount}_i^d := \max_k \{\text{hopcount}_k | (\text{nexthop}_k, \text{hopcount}_k) \in \text{route\_list}_i^d\}$$

A key observation here is that similar to AODV the following condition holds good for two successive nodes i and j on any valid route to destination d.

$$(-\text{seqnum}_i^d,\ \text{advertised\_hopcount}_i^{d,}\ i) > (-\text{seqnum}_j^d,\ \text{advertised\_hopcount}_j^d,\ j)$$

When single path on-demand routing protocol such as AODV is used in such networks, a new route discovery is needed in response to every route break. Each route discovery is associated with high overhead and latency. This inefficiency can be avoided by having multiple redundant paths available. Now, a new route discovery is needed only when all paths to the destination break.

III. Power Saving Routing Protocols

A major issue in the energy constrained ad hoc networks is to find ways that increase their lifetime. The use of multihop radio relaying requires a sufficient number of relaying nodes to maintain network connectivity. Hence, battery power is a precious resource that must be used efficiently in order to avoid early termination of any node. Advances in battery technologies have been slower as compared to the recent advances in the field of mobile communication. However, users' desire to extract more functionality from the mobile device continues. In view of these, low power design and energy saving techniques have become the focus of recent research. A number of works have been reported in the literature with these objectives.

Minimum Total Transmission Power Routing (MTPR) algorithm is proposed by M. Woo et al. [4]. This uses the fact that minimum transmission power is dependent on interference noise, distance between nodes, and desired BER. To obtain the route with minimum total power, the transmission powers between nodes are used as a metric. Since transmission power depends on distance, this algorithm selects routes with more hops than other routing algorithms. Minimum Battery Cost Routing (MBCR) algorithm is proposed by S.Singh and C. S. Ragavendra [5].In this protocol, the remaining battery capacity is used as a metric to prevent hosts from being overused and thereby increases the lifetime of hosts till the network is partitioned. However, this algorithm has the disadvantage that a route containing nodes with little remaining battery capacity may still be selected, since the sum of battery cost functions is considered. This limitation is overcome in the Min _Max Battery Cost Routing algorithm (MMBCR) proposed by Woo et al. [4]. MMBCR defined the battery cost function in such a way that this metric always tries to avoid the route with nodes having the least battery capacity among all nodes in all possible routes. Here, the battery of each host is used more fairly than other protocols proposed by Singh and Woo et al.,(1998) Initially it seems that the lifetime of all nodes will be elongated. However, on closer examination, it reveals that there is no guarantee that minimum total transmission power paths will be selected under all circumstances. It may consume more power to transmit the user traffic from source to destination and may actually reduce the lifetime of all nodes.

It may be noted that the maximization of the lifetime of each node and fair utilization of the battery power cannot be achieved simultaneously by applying MTPR or MMBCR schemes. MMBCR can only fulfill both of them sometimes. To overcome this problem, Power Efficient Battery Capacity Routing (PEBCR) algorithm is proposed by B.Partibane et al.,[6]. In order to select a route between a source and destination, it considers only those routes between the source and the destination in which all the nodes in each of the routes have battery capacity above a threshold. Among the various possible routes satisfying the above criteria, the one requiring the minimum total transmission power is chosen. Since the total power required to forward packets is reduced for each connection, the power spent to relay the packets by most of the nodes will be reduced and their lifetime will be extended. When the battery capacity of a node goes below a predefined capacity, routes going through this node are avoided. Such nodes can only act as either source or destination node.

It is assumed that all nodes transmit packets with a fixed power level [7]. In this case, the path selected by MTPR is identical to the shortest hop path, and MTPR has no power-saving effect compared to other shortest hop path algorithms, such as AODV. Infact, if the MAC layer of each mobile node uses CSMA/CA to broadcast a RREQ packet, energy consumed by MTBR is equivalent to that consumed when using the shortest hop algorithm. Hence, Sun-Ho Lee et al.,[8] proposed a new MAC and network layer algorithms for energy efficient routing . But this algorithm requires the cross-layer design between the MAC layer and network layer.

IV. Proposed Power Aware MAC Protocol (PAMAC)

The proposed Power Aware MAC protocol (PAMAC) uses the basic ideas of PEBCR and it incorporates these features into the MAC layer as it is essential to minimize the total transmission power consumption. The important features of PAMAC are the following:

- A node, on receipt of RTS first checks to see if its battery capacity is above the threshold. This condition has to be satisfied for the node to send a CTS message to the node that sent the RTS message.
- As and when a node keeps transmitting data packets, its battery capacity parameter is appropriately subtracted according to the size of the packet being transmitted and the destination to which it is transmitting the packet.
- If the battery capacity of a certain node reaches the threshold limit, it sends a request message to all the other nodes seeking for a position exchange with one of exterior nodes.
- On receipt of such a request message for exchange, the nodes compare their battery capacity with the certain threshold which is higher than the above mentioned threshold so that the exchange is profitable. They also compare the number of messages that they process to check if it is below a certain minimum. If both the criteria are met then the node sends a positive response to the node that initiated the request.
- By getting the sevice from lower MAC layer protocol, the routing layer protocol AOMDV is choosing the optimum energy path to send the packets.

V. Performance Analysis and Simulation Results

The proposed PAMAC protocol is incoperated in the link layer and simulation works are carried out using GloMoSim [9] by considering thirty nodes randomly distributed in an area of 2000 x 2000 m. The AOMDV routing protocol in incoperated in the network layer and its perfomance is evaluated under CBR traffic with PAMAC as link layer protocol. Within the network, the communications between any two wireless terminals is achieved through Direct Link. The network size is determined based on the magnitude of transmission power. In the simulation, the transmission power is fixed for all wireless terminals. It is assumed that two terminals can hear each other if their distance is in the transmission range. The transmission range is set to 30m. All nodes are assumed to have the same amount of battery capacity at the beginning of simulation process. Here initial battery power and transmitter power are assumed to be 1000mw and 32mw respectively. The average end-to-end delay, throughput and average power consumption are calculated as a function of number of nodes and the results are plotted in the graph.

A. Average End-to-End Delay of Data Packets

This is the average delay between the sending of the data packet by the source and its receipt at the corresponding receiver. This includes all the delays caused during route acquisition, buffering and processing at intermediate nodes, and retransmission delays at the MAC layer.

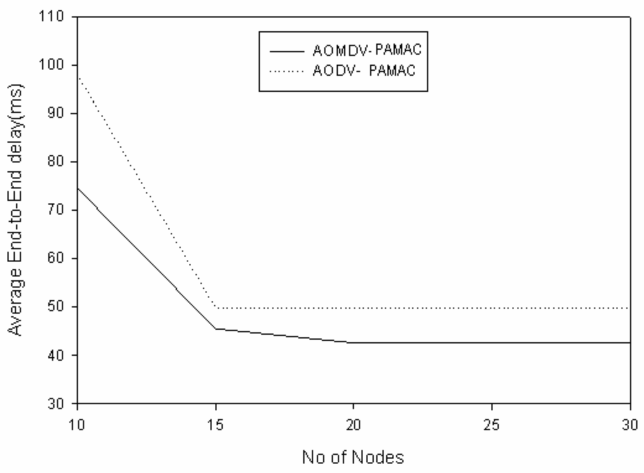

Fig. 1 Number of Nodes Vs Average End-toEnd Delay

Fig. 1 indicates the average end to end delay of the AOMDV-PAMAC with AODV- PAMAC and from the figure it is observed that, due to the link breaks AODV takes more time to send packets compared to AOMDV.

B. Throughput

Throughput is calculated as the number of data bytes delivered to all destinations during the simulation. Fig. 2 indicates the throughputs of AOMDV- PAMAC and AODV-PAMAC. And from the figure, it is observed that, as the numbers of nodes are increasing AOMDV-PAMAC gives more throughputs compared AODV- PAMAC.

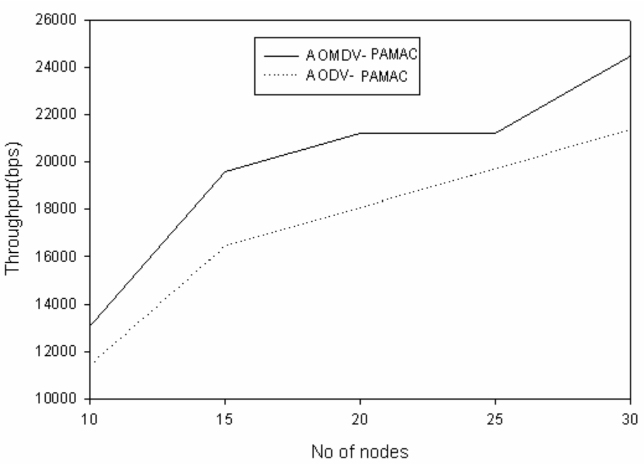

Fig. 2 Number of Nodes Vs Throughput

C. Power Consumption

Power consumption is a significant parameter in adhoc networks. This indicates how much power is required by the nodes to transmit the packets.

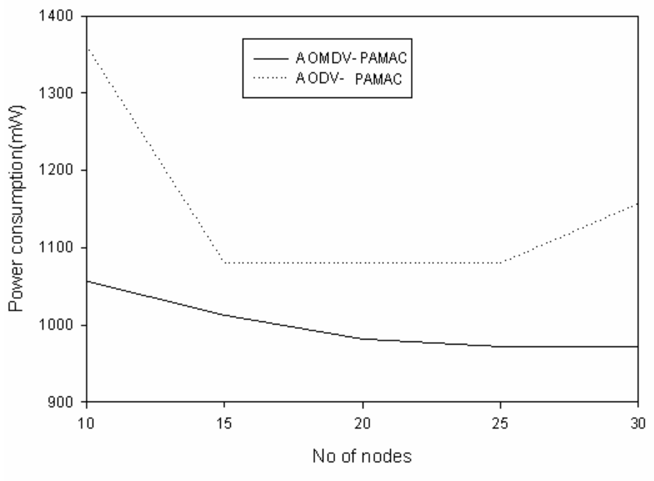

Fig. 3 Number of Nodes Vs Power Consumption

The above figure shows the performance of AOMDV-PAMAC and AODV- PAMAC with respect to number of nodes verses power consumption. From the Fig. 3, it is clear that AOMDV- PAMAC consumes less power, where as AODV- PAMAC consumes more power.

VI. CONCLUSION

Multipath routing protocols compute multiple paths during route discovery to avoid high overhead and latency. It is observed the performance of AOMDV, which is a multipath routing protocol relative to AODV, and the Link layer protocol PAMAC which is the modification to the MACA Protocol, when these two protocols are applied simultaneously it is producing good results compared to the other protocol combination. Through simulation results, it is observed that there is a tremendous reduction in the Average End-to-End delay, power consumption and an increment in Throughput for AOMDV- PAMAC compared to AODV- PAMAC.

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