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Ad Hoc Cross Layered Energy based Multihop Routing Protocol

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ABSTRACT
The design of efficient routing protocols for Ad hoc networks is a complex issue. These networks need efficient algorithms to determine ad hoc connectivity and routing. MANET aims not only to provide correct and efficient routes between pair of nodes but also to provide energy efficient route to maximize the life time of ad hoc mobile networks. In this paper, a dynamic energy conscious routing algorithm ACE-AODV where cross layer interaction is provided to utilize the energy related information from physical and MAC layers. This algorithm avoids the nodes which are having low residual energy. By maximizing the lifetime of mobile nodes routing algorithm selects a best path from the viewpoint of high residual energy path as part of route stability. The RTS/CTS transmission is a crucial step towards saving the energy of mobile nodes. The SINR value is also considered in the path selection. Directional antenna adds to the system, increased throughput and improved channel reuse. The receiving power of sender, intermediate nodes and receiver are also another part of route stability. The protocol is implemented for achieving quality of service (QoS) in terms of average energy consumption, packet delivery ratio, end-to-end delay and throughput.

Keywords
Routing protocols, Ad Hoc networks, Cross Layer design, Quality of Service

1. INTRODUCTION
Mobile Ad Hoc Network (MANET) is collection of multi-hop wireless mobile nodes that communicate with each other without centralized control or established infrastructure. In MANET each node communicates with other nodes directly or indirectly through intermediate nodes. Thus, all nodes in a MANET basically function as mobile routers participating in some routing protocol required for deciding and maintaining the routes. Routing is one of the key issues in MANETs due to their highly dynamic and distributed nature.

The routing protocols of MANETs are divided into two categories as table-driven and on-demand. In table-driven routing protocols, each node attempts to maintain consistent, up-to-date routing information to every other node in the network. Many routing protocols including Destination-Sequenced Distance Vector (DSDV) [1] and Cluster-Head Gateway Switch Routing Protocol (CGSR) protocol belong to this category. In on-demand routing, routes are created as and when required. Route discovery and route maintenance are two main procedures: The route discovery process involves sending route-request packets from a source to its neighbor nodes, which then forward the request to their neighbors, and so on. Once the route-request reaches the destination node, it responds by sending a route-reply packet back to the source node via the neighbor from which it received the route-request. When the route-request reaches an intermediate node that has a sufficiently up-to-date route, it stops forwarding and sends a route-reply message back to the source. Once the route is established, the route maintenance process is invoked until the destination becomes inaccessible along the route. Note that each node learns the routing path as time passes not only as a source or an intermediate node but also as an overhearing neighbor node. In contrast to table-driven routing protocols, on-demand routing protocols don't maintain all up-to-date routes. Dynamic Source Routing (DSR) and Ad-Hoc On-Demand Distance Vector (AODV) are popular On-demand routing protocols.

AODV [2],[3],[5] protocol is a mixture of both DSR [4] and DSDV [5] protocols. It keeps the basic route-discovery and route-maintenance of DSR and uses the hop-by-hop routing sequence numbers and beacons of DSDV [5]. When a node needs to know a route to a specific destination it creates a ROUTE REQUEST. Next the route request is forwarded by intermediate nodes which also create a reverse route for itself from the destination. When the request reaches a node with route to destination it creates again a ROUTE REPLY which contains the number of hops that are require to reach the destination. All nodes that participate in forwarding this reply to the source node create a forward route to destination. This route created from each node from source to destination is a hop-by-hop state and not the entire route as in source routing.

In addition to simply establishing correct and efficient routes between pair of nodes, one important goal of a routing protocol is to maximize the lifetime of Ad-hoc mobile networks. The residual battery energy of mobile nodes is a simple indication of energy stability and can be used to extend network lifetime. This information has to be taken from the physical and medium access control layers of data link layer since these layers are responsible layers to compute the power consumption and residual energy computation. Many MAC layer protocol [6],[7] has been discussed previously. The proposed power based stability routing prefers the wireless link requiring minimum and optimized receiving energy, but at the same time avoids the node with low residual energy- by maximizing the lifetime of mobile nodes, the best path from the viewpoint of power constraint as part of route stability are selected. Hence, routes requiring minimum receiving power are preferred. The power related information are acquired from both physical and MAC layers. MAC layer functions are modified to provide the RTS/CTS packets after the route is discovered.

RTS/CTS mechanism is used to avoid Hidden Terminal problem during transmission. A successful transmission is a four way mechanism, RTS-CTS-Data-ACK. RTS/CTS signaling is used to reserve the path for further transmission in the route selected. RTS means Ready to sent and CTS means Clear to sent.

2. RELATED WORKS

Jinhua Zhu and Xin Wang [8] developed a new energy efficient protocol PEER has been developed to reduce the energy consumption and to improve the performance during the path discovery. The protocol reduces the overhead during the route discovery and have more efficient route maintenance scheme. The paper also discusses about the problems in the traditional energy efficient routing protocols. The RTS/CTS are transmitted at maximum power level P_m in order to reduce the hidden terminal problem, while DATA and ACK packets are transmitted at the minimum required transmission power level.

In energy consumption model, we consider DCF in MAC layer. IEEE 802.11 DCF is based on Carrier Sensing Multiple Access with Collision Avoidance (CSMA/CA) mechanism. It consists of two carrier sensing schemes, namely physical carrier sensing and virtual carrier sensing. The virtual carrier sensing scheme is implemented with Network Allocation Vector (NAV). If a node receives a packet (such as RTS, CTS, and DATA packet), it will update NAV with the duration included in the received packet. The NAV value indicates when the on-going transmission session will end.

In the state diagram figure 2, a node I need to transmit the data to a node j. The node I needs to transmit $1/P_{r,i,j}^*$ RTS packets so that node j can correctly receive, i.e. stage transition from S0 to S1. In state S1 to S2 node j needs to transmit $1/P_{c,j,i}^*$ CTS packets to the node i, then in state S2 to S3 node I needs to transmit $1/P_{i,j}^*$ data packets, and node j needs to transmit $1/P_{a,j,i}^*$ ACK packets.

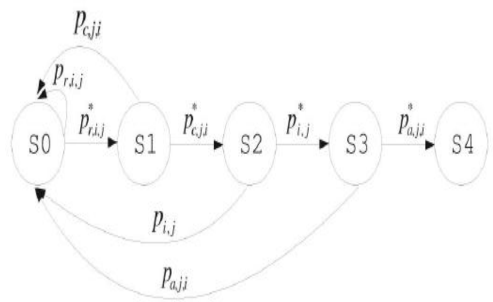

Fig.1 State diagram for the four frame exchange scheme.

The PEER (Progressive Energy-Efficient Routing) searches for the energy-efficient path quickly during route discovery process, and maintains the route actively so that it can respond to topology and channel changes quickly. the basic searching algorithm would be: 1) search for all shortest (fewest hops) paths, 2) pick the minimum energy path among the shortest paths. Three route with same energy consumption and same no of hops. The destination node D may get same type of paths having same energy consumption and same hop length paths Fig 2. So the node D has to select the suitable path from it using three options: 1) Route reply will be sent through all paths. 2) The destination sets up timer after it receives a route request packet. In that time period, if any other request comes timer is reset, or else the request came is selected. 3) A time window is set up and the destination node will select the best path in that window.

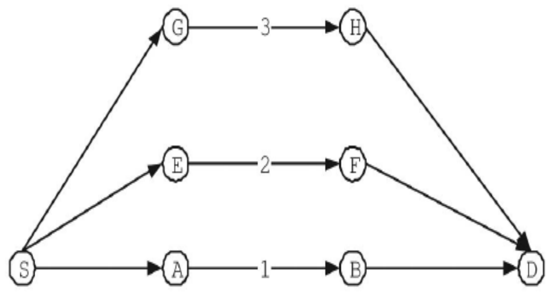

Fig.2 Paths to the destination from Source

In route maintenance, an observing node will passively monitor data packets exchanged in its neighborhood and collaborate with its neighbors to look for a more energy-efficient path. The neighboring node will act before the link breaks, thus avoiding energy wastage to link breaks.

Rekha Patil and A. Damodaram [9] developed a cost based power aware cross layer design to AODV is proposed. 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. The nodes having less battery power than the specified threshold value is not considered during path selection. Protocol named “Cost Based Power Aware Cross Layer AODV (CPACL-AODV)” presents a new routing algorithm to select path. It is designed to increase the network survivability by maintaining network connectivity & to lead to a longer battery life of terminals. Physical and MAC layer information is used for routing such as: 1) Transmit power 2) Full charge battery capacity 3) Remaining battery capacity of node at time t.

In CPACL-AODV, we have a module called power module to which the MAC layer passes the information, Figure 3. When a node have to sent a data to the destination, the link cost of all node links are calculated by flooding RREQ packets to all nodes except source and destination. 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. The cost is computed in the power module & is made available to the network layer In 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. When the destination receives the RREQ, 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.

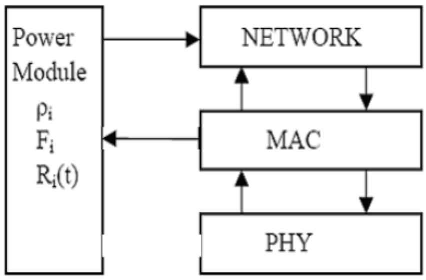

Fig. 3 Information sharing in CPACL-AODV

Morteza Maleki, Karthik Dantu, and Massoud Pedram [10] proposed a routing protocol Power-aware Source Routing (PSR) is to extend the useful service life of a MANET. This is highly desirable in wireless ad hoc network since death of certain nodes leads to a possibility of network partitions, rendering other live nodes unreachable. This algorithm assumes that all and that the energy dissipation per bit of data and control packet transmission or reception is known and presents a new source- initiated (on-demand) routing protocol for mobile ad-hoc networks that increases the network lifetime. In PSR, both the node mobility and the node energy depletion are considered in route selection. All nodes except the destination calculate their link cost and add it to the path cost in the header of the RREQ packet.

In Route maintenance, we have to consider two parameters- Mobility and Energy Depletion. In case of mobility, a new RREQ is sent out and the entry in the route cache corresponding to the node that has moved out of range is changed. In case of Energy Depletion at a node, we have two approaches: Semi-global Approach and Local Approach. Local approach is used in which each intermediate node in the path monitors the decrease in its remaining energy level from the time of route discovery as a result of forwarding packets along this route. When this link cost increase goes beyond a threshold level, the node sends a route error back to the source as if the route was rendered invalid. This route error message forces the source to initiate route discovery again. This decision is only dependent on the remaining battery capacity of the current node and hence is a local decision. PSR adopts the local approach because this approach minimizes control traffic, while semi-global approach increase the overhead.. As the remaining energy level of a node decreases, the link cost of the node increases.

Jenn- Hwan TARNG, Bing-Wen CHUANG and Fang-Jing WU [11] proposed a novel stability-based ad hoc routing protocol called Ad-hoc On-demand Stability Vector (AOSV) routing protocol, is discussed properly and effectively to discover stable routes with high data throughput and long lifetime by considering the radio propagation effect on signal strength. Here, a stochastic mobile-to-mobile radio propagation model is proposed to predict path loss as well as received signal strength between adjacent nodes, and the estimation of link/route stability is derived from the prediction of signal strength. With awareness of link and route stabilities, a path finding algorithm is designed to explore the stable route with largest route stability for a source and destination pair.

3. QOS ROUTING CHALLENGES IN MANETS

In MANET's, the path selected for transmission should be stable. The factors deciding the stability can studied by the following:

1. Existence of mobile nodes (Mobility factor)
2. Limited battery /energy factor
3. Multiple paths
4. Node-disjoint paths

4. AD-HOC CROSS LAYERED ENERGY BASED MULTIHOP ROUTING PROTOCOL (ACE-AODV)

The proposed protocol is a modified AODV routing protocol. The ACE-AODV uses minimum energy and residual energy in selecting the path. In MANET, there is a high power consumption for sending RTS and CTS signals. Here the RTS/CTS handshaking happens after the route discovery but before the data transmission. In existing protocols RTS/CTS signals are used during route discovery process, which uses more power from the nodes, which leads depletion of nodes. During route discovery the RREQ and RREP messages are used to find out the suitable path during route discovery. The RREQ is sent from the source node to destination through intermediate nodes to the destination to find the path. The destination reply with RREP to the source through the selected path by destination, having the highest residual energy. ACE-AODV increase the lifetime of nodes as well as the stability of the routes.

The ACE-AODV routing protocol reduces the energy depletion of nodes due to the selection of stable paths during route discovery. The path with highest residual energy is selected from the paths available. SINR values are calculated at physical layer to check the signal strength between the nodes during transmission. The nodes with SINR more than a threshold is chosen to transmit the RREQ packets, so that the receiving signal strength is good between the nodes. Local repair mechanism during route maintenance adds to the stability of the paths.

Basic Assumptions

All the nodes in the given area have same transmit power and each node selects a threshold energy level (E_{th}) and each node must maintain the value in their routing table to select the nodes during route discovery. The residual battery energy value can be obtained to the network layer where it is stored in the routing tables to make routing decisions based on the battery energy. When the residual energy is less than threshold energy value, that node is avoided in the route selection by the destination. On receiving the RREQ the intermediate nodes calculates the received signal (r(t)) strength

$$r(t) = f(t)\,m(t) + A(t) \qquad (1)$$

In general, the fading process f(t) can be written as

$$f(t) = a(t)\, e^{j\theta(t)} \qquad (2)$$

a(t) = fading amplitude process

θ(t) =fading phase process

The node then calculates the residual energy E_{res} using the following parameters:

E_I – Initial energy taken by the node

E_t – Energy consumed in transmitting packets

E_r – Energy consumed in receiving packets

E_i – Energy consumption in IDLE state.

$$E_{res} = E_I - (E_t + E_r + E_i) \qquad (3)$$

The node then piggybacks this residual energy along with the required minimum receiving power in the RREQ packet. Using this method every node will forward the RREQ till it reaches the destination. The selection of best route is based on the remaining battery energy and transmission power of all intermediate nodes. The route with maximum remaining energy and minimum receiving power is selected by destination node.

SINR = power of the received signal (Pr)/(get power level -Pr) (4)

SINR is the signal to interference plus noise ratio. SINR calculates the signal strength of the received signal at a node. If the SINR ratio is high the signal exchange will stronger enough to continue the communication between nodes.

A. *Route Discovery Process.*

In route discovery process, when a node want to transmit data to the destination, a Route Request message (RREQ) is sent to the destination through the neighboring nodes. The Route Request contains the minimum receiving power and set Tsifs time for retransmission of the RREQ messages. When the neighboring nodes receive the RREQ message, the node checks its residual energy with a threshold value. The node adds a node identifier to the packet if the residual energy is above threshold and transmits it to the destination. The destination node on receiving the RREQ message, store the energy and path in a table at destination. In nodes a threshold value is set, to check the energy lost by receiving and transmitting by the node is less than the threshold value. SINR is calculated at each node to check the signal strength of the message transmitted. Destination may be receiving RREQ message from many paths, destination selects the path with maximum residual energy and minimum energy for transmission. The intermediate nodes on receiving the Route Reply (RREP) message, add the best path to its entry tables. After reaching the RREP message at the source node, the data starts transmitting the data. During the data transmission through the best path, RTS/CTS signals are used to reserve the path before transmission of data.

B. *Route Maintenance Process*

In the ACE-AODV routing protocol, Local Repair mechanism is used , which selects an alternative route before the link or the path breaks. There are back nodes near to the path, which selects the alternate path, in case of link breaks. So the packet loss is less compared to the AODV protocol. The selection of stable path during route discovery increase the life of the path selected for data transmission.

5. PERFORMANCE EVALUATION

Simulation is done to evaluate the performance of the proposed routing protocol. NS-2 Simulation is used to study the performance. The result of the proposed routing protocol is compared with the AODV protocol. To implement the ACE-AODV routing protocol, the PEER protocol is modified to find the efficient path and increase the lifetime of nodes. The RTS/CTS signals are used only after the route discovery procedure. We use directional antenna for transmission of signals or data packets. Stability of the path throughout the communication between the two nodes is the main objective of our protocol. SINR is calculate in the physical layer and residual energy of the nodes are calculated. Routes with high residual energy is taken for communication for high stability.

A. *Average energy consumption*

It is the average energy consumed by each node in the network. It is the ratio of the total energy consumed with the no. of nodes. In the simulation, AODV routing protocol consumes an energy of 453 joules when compared to that of MPEER protocol 95 joules. The energy consumption is reduced due to controlled usage of RTS/CTS signals in MAC layer in route discovery, reduction in routing overheads and control overheads in route maintenance procedure. The average energy consumed by each node is 1.9 joules when compared to AODV protocol of 9.2 joules.

As the times goes, the avg energy consumption is maintained in a linear fashion. The reduction in avg energy consumption leads to increased life of routes and also of the nodes.RTS/CTS retransmission is avoided in route selection.

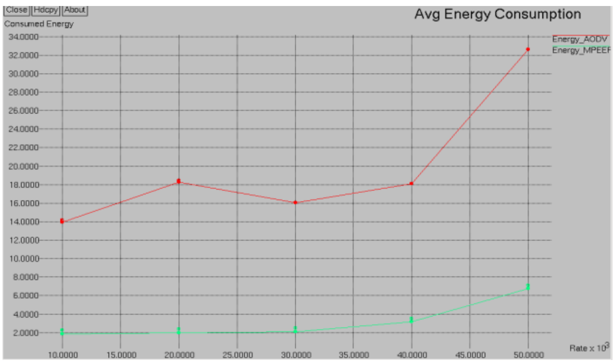

Fig. 4 Average Energy Consumption with time

B. *Contol Overhead*

It is the number of contol messages in the route maintenance phase. In AODV routing protocol, the control messages where high due to frequent path breaks during mobility and energy depletion of nodes. In the MPEER protocol, energy efficient paths are selected by considering its residual energy. During the route discovery, each node is compared with a threshold value in order to select the route. So the route breakups due to energy depletion are avoided.

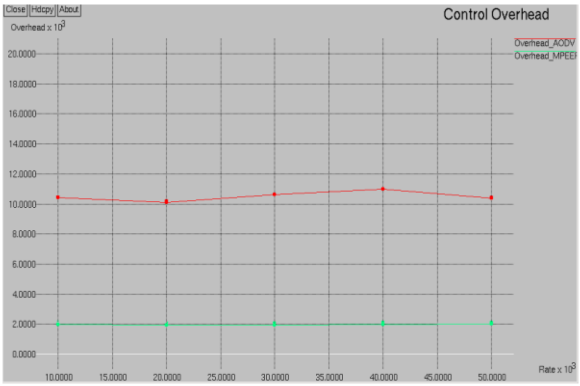

Fig. 5 Control Overhead with time

The control overhead is reduced by five times compared to AODV routing protocol. The Local repair mechanism in route maintenance also help in reducing control overheads, since no breakups occur during data transmission.

C. *Data Transmission Delay*

Packet transmission delay is very low compared to AODV routing protocol. Its is in linear fashion as the time goes on.

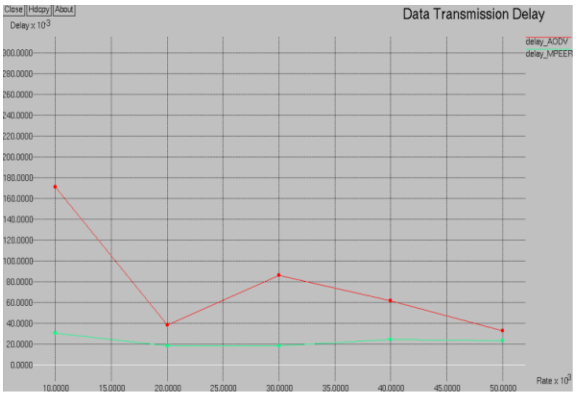

Fig. 6 Data Tansmission Delay with time

D. *Packet Delivery Ratio*

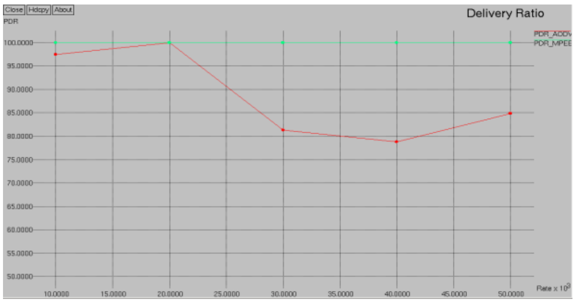

Fig. 7 Packet Delivery Ratio

Data delivery ratio can be calculated as the ratio between the number of data packets that are sent by the source and the number of data packets that are received by the destination. Packet delivery ratio is 99 percent in MPEER routing protocol. The route is maintained by local repair mechanism without any path breaks.The paths are selected based on the SINR and residual energy, which leads to energy efficient and stable path.

E. *Path Setup Delay*

In MPEER routing protocol, the routing overhead is considerably reduced. The routing overhead is reduced by 90% in simulation for 50 nodes. As the routing overhead is reduced, the path setup time is also reduced.

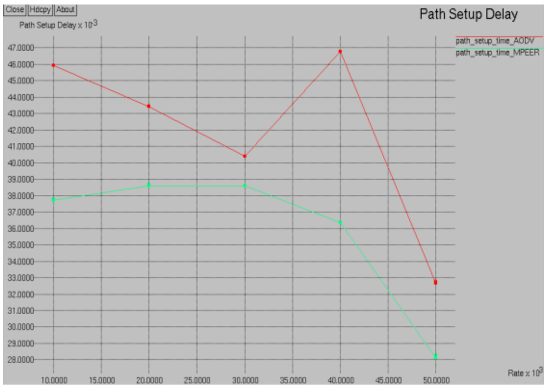

Fig. 8 Path Setup Delay with time

F. *Throughput*

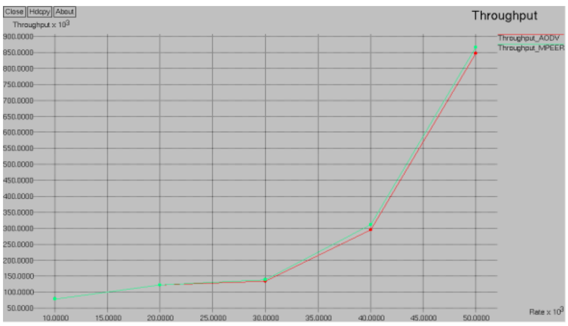

Fig. 9 Throughput with time

Throughput is the average rate of successful message delivery over a communication channel. Throughput has relationship with the route selected. The route selected is stable and energy efficient so less breakups occurs. There is successful delivery of packets due to stable paths. Throughput also increases, since the SINR values of the nodes are calculated at the physical layer for path selection. All these factors leads successful delivery of packets, hence increase the throughput.

6. CONCLUSION

In MANET's, there is no such power conscious algorithm which rectifies all the problem in the adhoc networks. In our proposed system, we use the residual energy in nodes in selection of path to the destination. The SINR value at physical layer is used to decide the signal strength between nodes and minimum energy to transmit data through a path is used to select the best path. So the path is stable. The RTS/CTS signals are reduced to a level, to reduce the energy loss, since it is used in selected path only. A cross layer interaction adds advantage to this routing protocol. QoS is maintained due to stable paths. The packet loss is considerably reduced due to local repair mechanism.

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