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Energy Efficient Ad Hoc On Demand Multipath Distance Vector Routing Protocol

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Abstract — **Mobile Ad Hoc Network (MANET) routing is challenged by power and bandwidth constraints as well as frequent topology changes to which it must adapt to and converge quickly. Energy efficient routing protocols play an important role in MANET. This paper presents an innovative energy aware routing protocol for wireless ad hoc network called Energy Efficient Ad hoc On Demand Multipath Distance Vector (E^2AOMDV) routing protocol. Ad hoc On Demand Multipath Distance Vector (AOMDV) routing protocol presents the advantage of achieving faster and efficient recovery from node failures. We propose the inclusion of Energy Aware (EA) selection mechanism and the maximal nodal surplus energy estimation in the AOMDV routing protocol to improve its energy performance in mobile ad hoc networks. The 'readiness' concept of EA Selection mechanism prolongs the network lifetime and the maximal nodal surplus energy estimation concept increases the energy efficiency of E^2AOMDV routing protocol. A comparison of E^2AOMDV and AOMDV routing protocols can be done using the performance metrics like packet delivery ratio and network lifetime to show that the former outperforms the latter and confirms to be a better performing routing protocol in saving battery energy in a dense mobile network with high traffic loads.**

Index Terms — **Ad hoc network, energy efficiency, Surplus energy, network lifetime, battery capacity.**

I. INTRODUCTION

Mobile Ad hoc Network (MANET) is a dynamically reconfigurable wireless network with no fixed infrastructure [1]. Each node acts as a router and host and it moves in an arbitrary manner. In many ad hoc networks, each node is powered by a battery and has limited energy supply. Over time, various nodes will deplete their energy supplies and drop out of the network. Unless nodes are replaced or recharged, the network will eventually become partitioned. In a large network, relatively few nodes may be able to communicate directly with their intended destinations. Instead most nodes must rely on other nodes to forward their packets. Some nodes may be especially critical for forwarding these packets because they provide the only path between certain pair of nodes. Associated with each node that depletes its battery and stops operating, there may be number of other nodes that no longer communicate. Energy is scarce by the fact that the devices are mobile *i.e.* they must be small and therefore cannot be fitted with large battery packs. For these reasons a number of researchers have focused on design of energy efficient routing protocols [2], [3] and [4].

This paper is distributed as follows – In section II we have discussed about previous such works. Section III gives details about Energy Efficient Ad hoc On Demand Multipath Distance Vector (E^2AOMDV) routing protocol. The analyzed performance of the proposed routing protocol is given in Section IV. Finally, Section V summarizes this paper.

II. RELATED WORK

A. Ad hoc On Demand Distance Vector (AODV)

The AODV routing protocol provides on demand route discovery in mobile ad hoc networks [5]. Route finding is based on a route discovery cycle involving a broadcast network search and a uni-cast reply containing discovered paths. AODV relies on per node sequence number for loop freedom and for ensuring selection of most recent routing path.

B. Ad hoc ON Demand Multipath Distance Vector (AOMDV) routing protocol

It is an extension of AODV routing protocol. It is used to compute multiple paths during route discovery. It is designed primarily for dynamic ad hoc networks. The AOMDV protocol applies a route update rule to establish and maintain multiple loop free routes at each node [6]. A distributed protocol is used to find link disjoint paths.

C. Maximal Minimal Residual Energy Ad hoc ON Demand Multipath Distance Vector (MMRE-AOMDV) routing protocol

The MMRE-AOMDV routing protocol exploits maximal minimal nodal residual energy concept [7]. It balances the nodal energy consumption. This protocol finds the minimal nodal residual energy of each route in the route discovery process, then sorts the multi route by descending nodal residual energy and uses the route with maximal residual energy to forward the data packets.

III. ENERGY EFFICIENT AD HOC ON DEMAND MULTIPATH DISTANCE VECTOR ROUTING PROTOCOL (E^2AOMDV)

E^2AOMDV is a multipath routing protocol that can be designed mainly for highly dynamic energy deficient ad hoc networks where link failure and route break occurs frequently. Energy management is a critical issue for the deployment of these networks because the nodes are small battery powered devices. When a single path on demand routing protocol is used in such networks, a route rediscovery is needed in response to every route break. Each route discovery is associated with high overhead and latency. This inefficiency can be avoided by using multipath routing protocol. Maintaining a routing table for multipath makes the protocol complex. This can be avoided by selecting few of the best paths from the multipath and routing data packets through them. The main idea in E^{2}AOMDV is to select few best paths from the multipath available using energy aware selection technique and to balance the nodal energy consumption to prevent one or more critical nodes from depleting their energy supplies. The AOMDV route discovery procedure is modified to enable the selection of the best paths and for the computation of maximal nodal surplus energy. The RREQ and RREP message includes two additional fields namely readiness factor and max- surplus energy. Fig.1 shows the structure of routing table entries for E^{2}AOMDV. If the readiness factor denotes ‘Discard’, a Route Error (RERR) message is propagated in the reverse path instead of RREP. The RREQ message contains the sequence number, advertised hop count, route list, readiness factor and max-surplus energy. Four important steps are involved in designing this protocol:

1. Energy Aware selection mechanism
2. Finding the maximal nodal surplus energy along the best paths
3. Sorting the multipath in descending order using the nodal surplus energy
4. Forwarding the data packets through the path with maximal nodal surplus energy.

The source node assumes the node’s initial energy as its surplus energy. At the intermediate node energy aware selection mechanism is applied.

A. *Energy Aware Selection Mechanism*

It is a mechanism to involve energetic considerations in best path selection. The E^{2}AOMDV specification has a variable ‘readiness’ representing the availability of that node to act as an intermediate node. Each node calculates its own energetic status and declares an appropriate readiness. The readiness selection is based on battery capacity and predicted lifetime of a node. The heuristic used to associate a readiness (‘Discard’, ‘Moderate’, ‘High’) to a pair(battery capacity, lifetime) is shown in table 1. This mechanism permits better load balancing to be obtained.

Destination
Sequence Number
Advertised-hop count
Route list { next hop1, hopcount1, readiness( ) , max-surplus energy1} { next hop2, hopcount2, readiness( ) , max-surplus energy2} . . { next hop n, hop count n, readiness n ( ) , max-surplus energy n}
Expiration time

Figure 1: Structure of routing table entries for E^{2}AOMDV

Table1. Energy Based Readiness Selection

Lifetime -> Battery	Short [<10s]	Medium [10s<lifetime<100s]	Long [>100s]
Low [<0.1]	EA-Discard	EA-Discard	EA-Discard
High [>0.1]	EA-Discard	EA-Accept moderate	EA-Accept high

In our implementation, we decided to use the ratio between actual and initial energy of a node to measure its battery capacity. We chose to consider less than 10% of residual capacity as low battery values, less than 10 seconds as short lifetime and greater than 100 seconds as long life time.

B. *Finding the Maximal Nodal Surplus Energy*

When the intermediate node receives a RREQ message, it checks if the sequence number specified in the RREQ message is greater than the node’s sequence number. If so, it compares the surplus energy in the RREQ message and the surplus energy of the node. In case the node’s surplus energy is greater than that specified in the RREQ message, the surplus energy variable in the RREQ message is updated with the nodal surplus energy. By this method we are able to achieve the value of maximum surplus energy among all nodes in the specified path. The reverse paths are set up just as in AOMDV.

C. *Sorting Multipath and Forwarding Data Packets*

The paths in the route list are sorted by the descending value of surplus energy. The path with the maximum surplus energy is chosen to forward the data packets. Once the source node receives the RREP message containing the new path with maximum surplus energy, it forwards the data packets through this path.

IV. PERFORMANCE EVALUATION

A. *Simulation Environment*

To evaluate E^{2}AOMDV, we are using the ns-2 network simulator [8]. A dense wireless network of fifty nodes is simulated in a field with 870m*870m area. Each simulation has duration of 400 seconds. During each simulation, 12 constant bit rates (CBR) connection are generated, producing 4 packets per second with a packet size of 512 bytes. The ‘Random Waypoint’ model is used to simulate node movement. Each node starts moving from its initial position to a random target position selected inside the simulation area. When a node reaches the target position it waits for a pause time, then selects another random target location and moves again.

We adopt the energy model as implemented in the *ns*-2.1b8 version. In this model, each node has an initial energy level and a given energy usage on every packet it receives and transmits. The distributed coordination function (DCF) of IEEE 802.11 for wireless LANs is used as the MAC layer. The radio model uses characteristics similar to a commercial radio interface, Lucent’s Wave LAN. Wave LAN is a shared-media radio with a nominal bit-rate of 2 Mb/sec and a nominal radio range of 250 meters. The two-ray-ground reflection model is used as

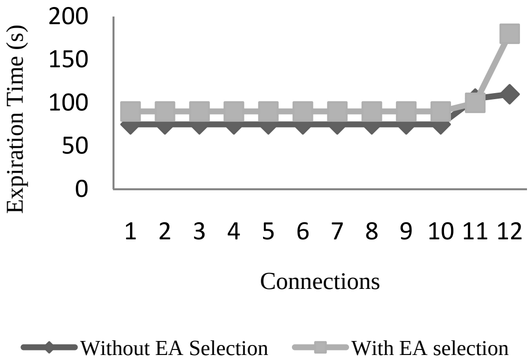

Figure.2 Expiration Time of Connections

propagation model. The default value for the transmitting power as well as the receiving power is 281.8 mW. The energy consumption during the idle time is not considered in this model. In our simulations, we set the initial energy as 60.0 joules per node.

B. Performance Analysis

To show how EA Selection Mechanism improves the performance of a MANET, the expiration time of connections is plotted as shown in fig. 2 [9]. Two key performance metrics are assessed:

i) Packet delivery fraction is defined as ratio of the data packets delivered to the destination to those generated by the CBR sources.

ii) The Network Lifetime is defined as the duration from the beginning of the simulation to the first time a node runs out of energy.

The proposed E^2AOMDV routing protocol can guarantee a longer lifetime than AOMDV and MMRE-AOMDV for every node in the network because nodes with lower residual energy are not stressed in this routing method. Under all the maximum speed conditions, E2AOMDV can be anticipated to lose fewer packets and outperform the classical AOMDV protocol because E^2AOMDV prevents the critical nodes from acting as the intermediate node.

V. CONCLUSION

In this paper a balanced energy efficient routing protocol for mobile ad hoc networks is proposed. E^2AOMDV routing protocol is an extension of the existing multipath routing protocol AOMDV. The routing model uses the energy aware selection mechanism and the maximal nodal surplus energy concept to prolong node's lifetime and preserve node's battery capacity. It prevents the critical nodes from depleting their energy earlier and avoids route rediscovery for every route break.

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