

## ADAPTIVE LINK TIMEOUT WITH ENERGY AWARE MECHANISM FOR ON-DEMAND ROUTING IN MANETS

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### ABSTRACT

Mobile Ad Hoc Networks (MANETs) are multi-hop wireless networks where all nodes cooperatively maintain network connectivity. When the size of the network is large and the nodes are highly mobile, the frequency of link failure and energy consumption of the nodes will be more. Link failure will be identified only during the transmission of data packets. Due to this, control load of the network will increase. To overcome this problem, in this paper, an innovative algorithm is suggested to remove the stale paths after a certain timeout period which is made adaptive by taking hop count of the path into consideration. To minimize the power consumption of the entire network, in this paper, an energy aware approach is proposed for on-demand protocols. Energy aware approach is a two-pronged strategy consisting of load balancing approach and transmission power control approach. In this paper, we propose a mechanism which integrates the adaptive timeout approach, load balancing approach and transmit power control approach to improve the performance of on-demand routing. We applied this integrated mechanism on Ad hoc On-demand Distance Vector(AODV) routing protocol to make it as Energy Aware Adaptive AODV (EAA AODV) routing protocol. The performance of EAA AODV is also compared with that of standard AODV with the help of simulations carried out using GloMoSim simulator. From simulation results it is learnt that EAA AODV decreases the number of control packets, increases the packet delivery ratio and reduces power consumption.

**Key words:** Mobile Ad Hoc Networks(MANETs), Route timeout, energy aware routing, on demand routing.

### 1. INTRODUCTION

Mobile ad hoc network (MANET) is becoming increasingly popular as a means of providing instant networking to a group of people who may not be within the transmission range of one another. MANET is self-initializing, self-

configuring and self-maintaining. They are characterized by multi-hop wireless connectivity, frequently changing topology which requires efficient dynamic routing protocols[1]. The routing protocols that can be applied for medium size networks are broadly classified as proactive and reactive protocols. Reactive protocols are more preferred due to their on-

demand nature. Route caching is vital in on-demand routing protocols. In order to reduce routing overhead by making use of available information efficiently, many research works have concentrated on the link life time and path life time. Jain Tang et al [2] have proposed a heuristic algorithm for the formation of link duration prediction table and to find a path with maximum duration. Reza Shamekh and Nasser Yazdani [3] have used routing table stability prediction parameter in routing table entry for selecting a route. Marina and Das [4] have suggested wide error notification to eliminate stale paths which requires the maintenance of state information at intermediate nodes. Wenjing Lou and Yuguang Fang [5] studied the effect of static lifetime assignment and received-control packet based adaptive timeout mechanism on the performance of MANET using DSR. Gautam Barua and Manish Agarwal [6] have proposed a queue structure which acts as a route cache in AODV. In this paper, an adaptive timeout approach is proposed for assigning a timeout period for every cached route based on hop count to remove stale routes.

The failure of a single node in MANET can greatly affect the network performance. Since mobile nodes are usually battery-operated, one of the major reasons of link failure is battery exhaustion. In order to maximize the life-time of a mobile node, it is important to reduce the energy consumption of a node. There are many strategies proposed in literatures to minimize the required active communication energy. C. K. Toh [7] has proposed conditional max-min battery capacity routing (CMMBCR) to choose a shortest path among all paths in which every node has a battery capacity above a predefined threshold value. Sheetal Kumar Doshi and Timothy X Brown [8] have applied minimum transmit power control on Dynamic Source Routing (DSR) protocol. For sensor networks, Frederick J. Block and Carl W. Baum [9] have presented a set of routing metrics that utilize an estimate of remaining lifetime of each node. Mohammed Tarique et al [10] have applied transmission power control and load sharing approach in DSR using the minimum energy to transmit power ratio as the parameter for selecting a route. In our paper, the load balancing approach is based on available energy at every node and required energy for transmitting a packet. In this paper, we have integrated the adaptive timeout approach, load balancing approach and transmit power control approach as a mechanism to improve the performance of on-demand routing. We applied this integrated mechanism on AODV

to make it as Energy Aware Adaptive AODV (EAA AODV).

The rest of the paper is organized as follows: Section 2 gives the overview of AODV protocol. Section 3 describes the adaptive link timeout approach and energy aware approach. Section 4 presents the simulation results and conclusions are summarized in Section 5.

## 2. OVERVIEW OF AODV PROTOCOL

In AODV, a source node that wants to send a message to a destination, for which it does not have a route, broadcasts a Route Request (RREQ) packet across the network. All nodes receiving this packet update their information about the source node. The RREQ contains the source node's address, broadcast ID, destination node's address, current sequence number of source node as well as the most recent sequence number of destination node. Nodes use these sequence numbers to detect active routes. A node that receives a RREQ can send a Route Reply (RREP) if it is either the destination or has a route to the destination with a sequence number greater than or equal to the sequence number that RREQ contains. Otherwise, it rebroadcasts the RREQ. Nodes keep track of the RREQ source address and broadcast ID, discarding any RREQ they have already processed. As the RREP propagates back to the source, nodes set up entries to the destination in their routing tables. The route is established once the source node receives the RREP. This algorithm also includes route maintenance facilities. For every route in a routing table, a node maintains a list of precursor nodes using that route and informs them about potential link breakages with RERR messages. Each node also records individual routing table entries [11].

## 3. ADAPTIVE LINK TIMEOUT WITH ENERGY AWARE MECHANISM

### 3.1 Adaptive Link Timeout Approach

In MANETs, link failure will be identified only during the transmission of data packets. Due to this, latency and control load of the network is increased. On-demand protocols like AODV do not possess any timer based mechanism to identify the stale routes residing in route cache. If not cleaned explicitly by the error mechanism, stale cache entries will stay forever in the cache. Cache may contain routes that are invalid. Then, route replies may carry stale routes. Attempted data transmissions using stale routes incur overheads, generate additional error packets and pollute other caches when a packet with a stale route is forwarded.

To overcome this problem, an innovative approach is suggested to remove the stale paths after a certain timeout period which is made adaptive by taking full path into consideration. This approach can be applied for any on-demand routing protocol and in this paper it is applied to AODV. The algorithmic form of this approach is given below.

3.1.1 Algorithm for Adaptive Link Timeout in AODV

The steps that are performed at the precursor node of a broken link in adaptive approach are as follows:

Step 1: check all route table entries for the forward path.

Step 2: If the next hop for any current entry matches with the next node of the broken link and if the current entry is marked active, go to step 3.

Step 3: Mark the current entry in the route table as inactivated.

Step 4: Get the hop count from the inactivated entry mentioned in step3.

Step 5: Calculate the new bad link life time based on hop count.

Step 6: Set the current hop count to infinity and change the current life time according to new bad link lifetime.

Step 7: Set the AODV timer with new bad link life time.

As the bad-link lifetime is associated with the life time of the particular route, reducing the bad link lifetime reduces the life time of the route concerned.

3.2 Energy Aware Approach

Mobile ad hoc networks are power constrained as most ad hoc mobile nodes today operate with limited battery power. Hence power consumption becomes an important issue. It is important to minimize the power consumption of the entire network in order to maximize the lifetime of ad hoc networks. To accomplish this to a certain extent, in this paper energy aware approach is proposed for on-demand protocols. Energy aware approach is a two-pronged strategy with load balancing approach and transmission power control approach. As per the load balancing approach, on-demand protocols select a route at any time based on the minimum energy availability of the routes returned by the

RREPs and the per-packet energy consumption of the route at that time. As per the transmission power control approach, once a route is selected, transmission power will be controlled to the minimum required level, on a link by link basis to reduce the power consumption of every node in the selected path.

3.2.1 Load balancing approach

Route discovery mechanism in EA AODV is illustrated in Fig. 1. Node1 is the source and node5 is the destination node. Assume that all nodes have empty caches. At time t, when the source initiates a route discovery, the available energy levels of the nodes and their current required transmit power levels are as shown in Figure 1. The source initiates a route discovery by broadcasting the RREQ packet. Node2 and node4 are within the transmission range of node1. Since intermediate nodes2 and 4 are not the destination, these two nodes add their own node-ids in the RREQ and rebroadcast that RREQ packet. Once the destination receives the RREQ packet, it sends a reply to the source by reversing the path through which it receives the RREQ packet.

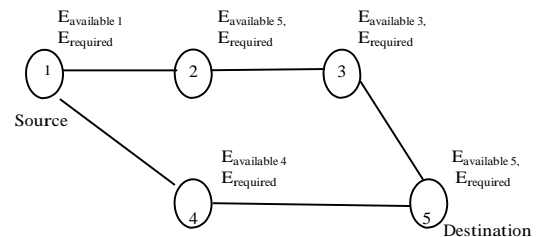


Figure 1. Routing In EA AODV

Let us assume that destination replies back to the source using the route 5-3-2-1. When the intermediate node3 receives the RREP packet it estimates its remaining battery energy using the available energy of node and the required transmit power of a packet at that node and let this value be X. Node 3 records this value in that RREP packet and forwards the RREP to next hop which is node 2. Node 2 estimates its remaining battery energy in the same way. Let this value be Y. It also reads the value X recorded in the RREP packet and compares X with Y. Node 2 will replace X by Y, only if Y is less than X, or else, X will be retained in the RREP. Let Y be less than X. Thus, the RREP carry the value of the minimum remaining battery energy Y of the path 1-2-3-5. So the source 1 records this path in the cache along with Y. Similarly, if source1 is assumed to discover another path 1-4-5 which has minimum battery energy Z, and if Y is greater than Z, the

source then selects the path 1–2–3–5, because this path has higher minimum battery energy than the shortest path 1–4–5. Thus, in EA AODV, the mobile nodes which are very likely to drain out batteries are avoided in the route discovery phase.

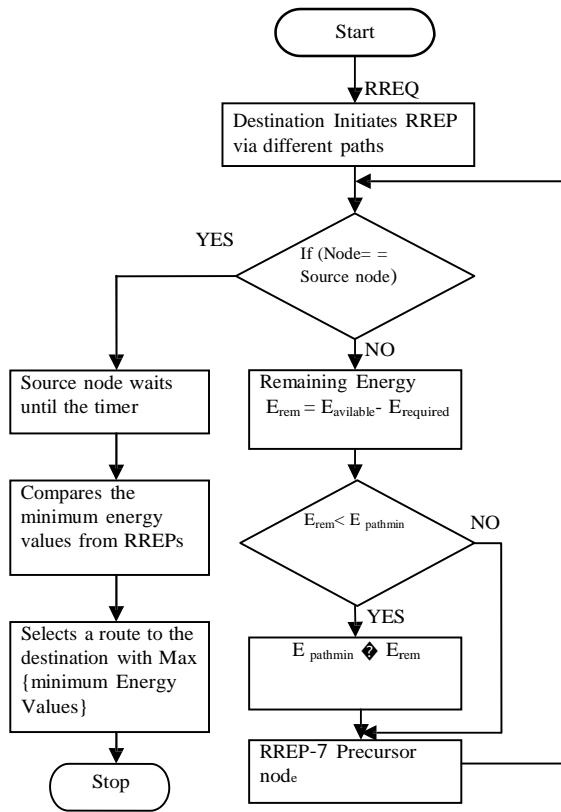


Figure 2. Flowchart for selecting the highest minimum energy route

The available energy level and the required transmit power level of a node are taken into account while making routing decision. The subtraction of current available energy levels and the required transmit power levels of nodes indicate how likely these nodes will deplete battery energy. In order to do that a source node finds a minimum energy route  $E_{rem}$  at time  $t$  such that the following cost function is maximized.

$$C(E, t) = \max \{E_{rem}\} \quad (1)$$

$$E_{rem} = E_{available}(t) - E_{required}(t) \quad (2)$$

Where,  $E_{rem}$  is the remaining energy of node,  $E_{available}(t)$  is the available energy of node,  $E_{required}(t)$  is the required transmit power of a packet at node.

The energy required in sending a data packet of size  $D$  bytes over a given link can be modeled as

$$E(D) = K_1 D + K_2 \quad (3)$$

$$K_1 = (P_t^{Packet} + P^{back}) \times 8/BR$$

$$K_2 = ((P_t^{MAC} D^{MAC} + P_t^{packet} D^{header}) \times 8/BR) + E^{back}$$

Where,  $P^{back}$  and  $E^{back}$  are the background power and energy used up in sending the data packet,  $P_t^{MAC}$  is the power at which the MAC packets are transmitted,  $D^{MAC}$  is the size of the MAC packets in bytes,  $D^{header}$  is the size of the trailer and the header of the data packet,  $P_t^{packet}$  is the power at which the data packet is transmitted and  $BR$  is the transmission bit rate [8]. Typical values of  $K_1$  and  $K_2$  in 802.11 MAC environments at 2Mbps bit rate are  $4\mu s$  per bytes and  $42\mu J$  respectively. Flow chart for load balancing approach is given in Fig. 2

### 3.2.2 Algorithm for Transmission Power Control Approach

Step 1: Transmit power is recorded in the data packet by every node lying along the route from source to destination and it is forwarded to the next node.

Step 2: When the next node receives that data packet at power  $P_{recv}$ , it reads the transmit power  $P_{tx}$  from the packet, and recalculates the minimum required transmit power  $P_{min}$ , for the precursor node.

$$P_{min} = (P_{tx} - P_{recv}) + P_{threshold} + P_{margin}$$

Where  $P_{threshold}$  is the required threshold power of the receiving node for successful reception of the packet. The typical value of  $P_{threshold}$  in LAN 802.11 is  $3.652^{-10}$  watt. To overcome the problem of unstable links due to channel fluctuations, a margin  $P_{margin}$  is included. Because the transmit power is monitored packet by packet, in our work, we maintain a margin of 1dB.

Step 3: The recalculated minimum required transmission power,  $P_{min}$  is sent to the precursor node through acknowledgement (ACK).

Step 4: When the ACK packet is received by the precursor node, it records the modified transmit power in the power table and transmits the remaining packets with  $P_{min}$ .

Step 5: When a node can not find a record in the power table for a particular node, which will be the case when two nodes never exchanged packet before, it transmits with default power level of 280mW.

In this paper, energy aware approach combines the load balancing approach and the transmission power control approach and is applied on AODV to

make it as Energy Aware AODV (EA AODV).Energy Aware Adaptive AODV (EAA AODV) integrates the adaptive link timeout approach and energy aware approach.

#### 4. PERFORMANCE EVALUATION

##### 4.1 Simulation Scenario

The total number of nodes is fixed as 50 for the simulation. The nodes moved inside a simulation area of (1500×300) m<sup>2</sup>.The simulation time is kept at 900 seconds. The nodes move with a maximum velocity of 20m/s and according to the random waypoint mobility model. In this model, a node randomly chooses a speed for the next move which is uniformly distributed between 0 and the maximal velocity and a point in the simulation area,. Subsequently, the node drives to the selected point at constant speed. After arriving at the end point the node remains there for a certain time. Subsequently, the node repeats the operation by selecting a new end point and a new speed. The simulation is performed for different CBR connections with a transmitted power of 15-dBm.This scenario was simulated in GloMoSim [12] simulator for comparing the performance of EAA AODV with AODV.

##### 4.2 Performance Metrics

We evaluate five key performance metrics:

- (i) Packet Delivery Ratio is the ratio of the number of packets received to the number of packets transmitted. This is an important metric because it reveals the loss rate seen by the transport protocols and also characterizes the completeness and correctness of the routing protocol.
- (ii) Routing Overhead is the sum of all transmissions of routing packets sent during the simulation. For packets transmitted over multiple hops, each transmission over one hop, being counted as one transmission.
- (iii) End-to-End Delay is the total delay that a packet experiences as it is traveling through the network. This delay is build-up by several smaller delays in the network.
- (iv)Energy Consumption per packet is the ratio of the total energy consumed by the nodes in the network to the number of packets successfully reached the destinations.
- (v) Average Energy Consumption per node is the ratio of total energy consumed by the nodes in the network to the total number of nodes present in the network.

##### 4.3 Performance Comparison of EAA AODV and AODV

The three performance metrics listed in section 4.2 namely average energy consumption per node, routing overhead and packet delivery ratio have been evaluated as a function of traffic connections for comparing the performance of EAA AODV with that of AODV. Traffic connection refers to the number of source-destination pairs participating in communication. From Fig. 3 it is observed that EAA AODV gives 20% less average energy consumption per node compared with the standard AODV. This is mainly attributed to the energy aware approach and the reduction in number of control packets due to adaptive link timeout approach.

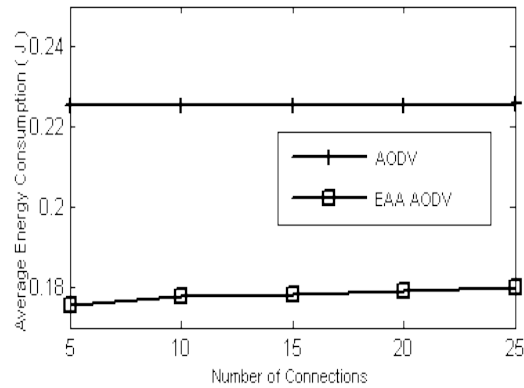


Figure 3. Average Energy Consumption per node

From Fig. 4 it is observed that the number of control packets generated by EAA AODV is less than that of AODV in a high traffic scenario. This effect is due to the reduced congestion in the paths. On an average, the number of control packets generated by EAA AODV is 10% less compared to the basic AODV. In Fig. 5 we can see that EAA AODV performs better than the basic AODV with an average of 3.5% increase in packet delivery ratio.

The other two performance metrics listed in section 4.2 namely energy consumption per packet and average end-to-end delay have been evaluated as a function of varying terrain dimensions for comparing the performance of EAA AODV with that of AODV. Number of source-destination pairs has been fixed as 25. From Fig. 6 it is observed that energy consumption per packet of EAA AODV is much less than that of AODV and it is also observed that per packet energy consumption of both AODV and EAA AODV is increasing slightly as the terrain dimension is increasing. When the area increases, energy consumption per packet increases, because packets may travel via many more hops in larger network area. Fig. 6 is shows that EAA AODV protocol consumes 25% less energy per packet compared to AODV.

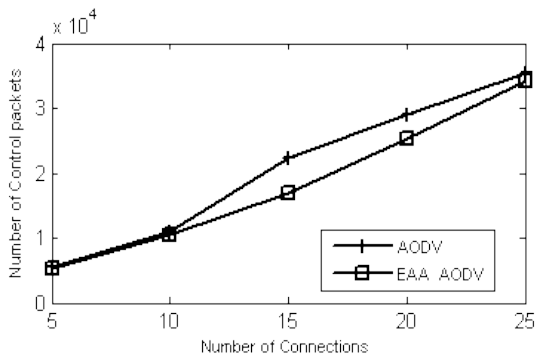


Figure 4. Control Overhead

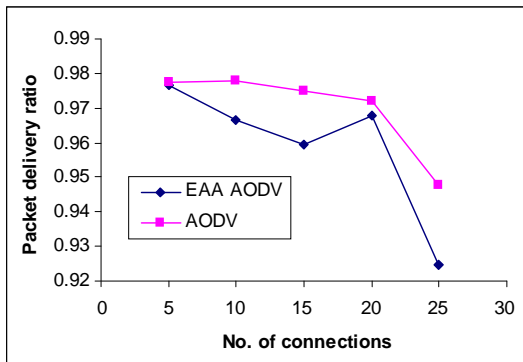


Figure 5. Packet Delivery Ratio

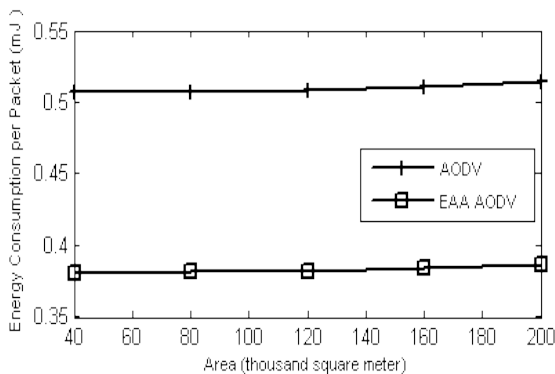


Figure .6 Energy Consumption per packet

Fig. 7 shows that the average end-to-end delay experienced by the packets is more in the case of EAA AODV compared to AODV due to the inclusion of extra information such as remaining battery energy, packet transmission power in the packet header. Moreover, packets are not always sent via minimum hop. Hence average end-to-end delay is 52% high in EAA AODV compared to the basic AODV.

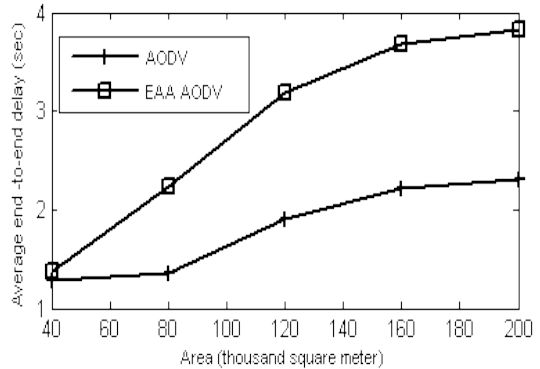


Figure 7. Average End-to-End Delay

Simulation results indicate that the combined application of link timeout approach and energy aware approach on AODV improves its performance by reducing the per-node as well as per-packet energy consumption and by increasing the packet delivery ratio.

### 5. CONCLUSION

In this paper, an efficient mechanism is proposed for on demand routing protocols in MANETs to reduce the control packet load of the network through removal of stale routes and to maximize the lifetime of the network by combining the adaptive link timeout and energy aware approaches. This mechanism has been applied to AODV. From simulation results it is learnt that EAA AODV on an average reduces energy consumption per node by 20% and control packet load by 10% and increases the packet delivery ratio by 3.5% compared to standard AODV. The price paid for this improvement is the 52% increase in average end-to-end delay due to the inclusion of extra information in the packet header. EAA AODV decreases the number of control packets, increases the packet delivery ratio and reduces power consumption.

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