

E²AODV Protocol for Load Balancing in Ad-Hoc Networks

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Abstract: Problem statement: In mobile ad hoc networks there are a number of challenges in providing quality of service routing with energy efficiency and load balancing. Most routing protocols do not consider the problem of load balance. A routing protocol called energy Efficient Ad-hoc on Demand Vector (E²AODV) is proposed. It addresses the quality of service issues such as throughput, end to end delay, load distribution and energy. **Approach:** This study presents a scheme to balance the load with energy efficiency considering both congestion and the nodes energy usage. A threshold value was used to judge if intermediate node was overloaded, variable and changing along with nodes interface queue length around the backward path. **Results:** The routing protocol called energy Efficient Ad hoc on Demand Vector (E²AODV) that is intended to provide a reliable transmission with low energy consumption was compared with Ad-hoc on Demand Vector (AODV) in terms of the packet delivery ratio, average end to end delay, load distribution and node energy consumption. **Conclusion/Recommendation:** E²AODV protocol chooses an optimum path with low energy usage. It provides a better scheme to balance the load with energy efficiency and packet delivery ratio. It can be further enhanced as a secure routing protocol for mobile ad-hoc networks.

Key words: Load balancing, queue length, routing protocol, energy consumption, average end to end, energy efficient, mobile ad-hoc, energy usage

INTRODUCTION

A Mobile ad-hoc network is a collection of wireless mobile nodes, forming a temporary network without the use of fixed network infrastructure and operating on limited amount of battery energy consumed for transmitting a packet. Protocols are classified as table-driven and on demand routing. The areas in which mobile ad-hoc network has wide applications includes battlefield, emergency, search rescue operation and data acquisition in remote areas. In this study, we propose load balance in proportion to their residual energy and received signal strength. The objective is to assign more loads to under utilize paths and less load to over committed paths so that uniform resource utilization of all available paths can be ensured. Load balancing is especially useful in energy constrained networks because the relative energy level of the nodes does not affect the network life time more than their absolute energy level. Mostly used on demand routing protocols AODV by Perkins and Royer (1999) and Dynamic Source Routing DSR Johnson *et al.* (2004). This study presents energy efficient and load balancing for manet considering traffic balance and energy usage by nodes.

E²AODV provides multiple routes to a destination, to select a single route with low hop count and discards higher hop count. It is implemented in the process of broadcast message with RREQ route request message is flooded in the network based on the queue length, residual energy and signal strength of a node is selected to forward the data. The node will be first judged by a threshold value to determine if it is overloaded node and also checks the value of the nodes energy with respect to threshold. The threshold value is used as criteria which changes dynamically according to the interface queue length of nodes around the backward path. Materials and methods is overviewed in section 2, Section 3 is overviewed with adaptive load balancing in E²AODV, Section 4 describes energy efficient routing. The simulation environment and energy model is discussed in section 5. Simulation results are shown in section 6. Section 7 describes the conclusion.

MATERIALS AND METHODS

In related study, (Lee and Gerla, 2000) have proposed an approach to constrain RREQ packets based on node caching. Vidhyapriya and Vanathi (2007) have

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proposed an energy constraint routing protocol in which routing packets are transmitted based on energy. The load balancing is divided into two types. The first type is “Traffic-size “based proposed by Leashing Tan Pang Yang, Marina and Das (2001) in which the load is balanced by distributing the traffic evenly among the nodes. The Delay based in which the load is balanced by attempting to avoid nodes with high delay. In this the proposed scheme presents to balance the load with energy efficiency considering both congestion and low energy consumption. In this paper, we will review some problems in load balance for exiting routing protocols in ad hoc networks. In this study, the proposed scheme is applicable to most on-demand routing protocols, either unicast routing or multicast routing by Higaki and Umeshima (2004) and Jiang and Jan (2001). The cross talk problem is much more serious in single channel networks, where cross talk also occurs when one path crosses the radio coverage area of another path proposed by Pham and Perreau (2002) and Pearlman *et al.* (2000). It belongs to the “Traffic-size” based type and will distribute the traffic load evenly among the nodes in ad hoc network proposed by (Tan *et al.*, 2007).

Adaptive load balancing in E²AODV: Ad-hoc on demand vector is an E²AODV protocol for computing multiple path with stable link paths. The protocol computes multiple path in order to avoid congestion. To ensure multiple path and node only accepts an alternate path to the destination if it has a lower hop count then the advertised hop count for that destination. The proposed adaptive load-balancing approach is carried out in route request procedure by Zheng (2004). When a source node wants to communicate with a destination node and has no available routing information about the destination, it will flood a route request to find a route by broadcasting a RREQ message. But not every immediate node that receives the message, will respond to the (RREQ) route request. Before broadcasting the (RREQ) route request again, the intermediate node itself first makes a decision if it is qualified. If its interface queue length is under the threshold value, the node is qualified and able to broadcast it.

The queue length means the number of packets waiting to be transmitted in interface queue. If the node’s queue length is over the threshold value, it isn’t qualified and will drop the (RREQ) Route Request. By doing so, the overloaded nodes are excluded from the newly created paths and an on-demand routing protocol using this scheme will distribute the traffic load evenly on the nodes in network.

Here is an example to explain the scheme in Fig. 1, node S is a source and node D is a destination. When S wants to communicate with D, but without any available routing information, it will initiate a route

discovery by flooding RREQ message. Any intermediate node receiving the RREQ will compare its current queue length with its threshold before broadcasting it again. If queue length is greater than the threshold, the RREQ will be dropped simply, such as nodes J and I. They do not broadcast the RREQ so the establish path will bypass these nodes. Otherwise, the node will deal with RREQ normally, such as nodes A, B, and E . In above scheme, the threshold value plays the key role in selecting nodes whether or not to forward RREQ. Every time an intermediate node receives a RREQ, it will recalculate the threshold, according to the nodes’ queue length around the backward path. Therefore, the threshold is variable and changing adaptively with the current load status of network. Here, we present an algorithm to calculate the threshold for each node:

Step 1: The node calculates the average queue length (avg qol) using the nodes current queue length in local area. So the node’s avg_qol can be calculated as following Eq. 1-8:

$$\text{avg_qol} = \frac{\text{qol} + \sum_{i=1}^n \text{nb_qol}_i}{n + 1} \tag{1}$$

$$\text{sum_qol} = \sum_{i=1}^K \text{avg_qol} \tag{2}$$

$$= \sum_{i=1}^K \left[\frac{\text{qol} + \sum_{i=1}^n \text{nb_qol}_i}{n + 1} \right] \tag{3}$$

$$\text{Thr} = \frac{\text{avg_qol} + \text{sum_qol}}{K + 1} \tag{4}$$

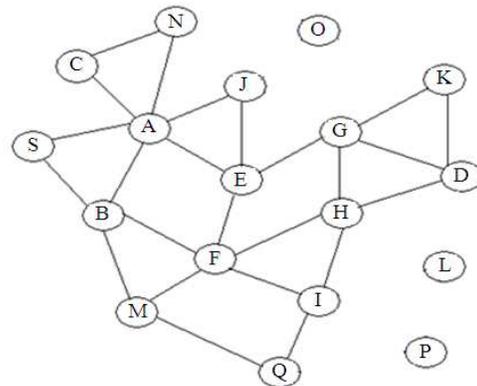


Fig. 1: Route request process with adaptive load balancing

$$= \frac{\frac{\text{loc} + \sum_{i=1}^n \text{nb_loc}_i}{n+1} + \sum_{i=1}^K \left[\frac{\text{loc} + \sum_{i=1}^n \text{nb_loc}_i}{n+1} \right]}{K+1} \quad (5)$$

$$= \frac{\text{qol} + \sum_{i=1}^n \text{nb_qol}_i + \sum_{i=1}^K \left[\text{qol} + \sum_{i=1}^n \text{nb_qol}_i \right]}{(n+1)(K+1)} \quad (6)$$

$$= \frac{\text{qol} + \sum_{i=1}^K \text{qol}_i + (K+1) \sum_{i=1}^n \text{nb_qol}_i}{(n+1)(K+1)} \quad (7)$$

$$\text{Thr} = \frac{\text{qol} + (K+1) \sum_{i=1}^n \text{nb_qol}_i}{(n+1)(K+1)} + \frac{\sum_{i=1}^K \text{qol}_i}{(n+1)(K+1)} \quad (8)$$

where, qol is the node's own queue length and nb_qol_i is the node's neighbor's queue length and n is the number of the node's neighbors. For example, in Fig. 1 The avg_qol of node A can be calculated by qol of node A and nb_qol₁, nb_qol₂, nb_qol₃ and nb_qol₄ of nodes C, S, E and J and n equals to 4. The source will calculate its avg_qol and fill it in sum_qol which is an additional field of RREQ proposed by Yuan *et al.* (2007):

Step 2: The node's threshold (thr) is calculated with the avg_qol of all the nodes along the path. With the node's own avg_qol and the received RREQ's sum_qol which records the sum of avg_qol of the nodes along the backward path.

The threshold of node G can be calculated by its own avg_qol and the sum_qol of received RREQ which is the sum of avg_qol of node S, A and E:

Step3: The node compares its current queue length (qol) with the threshold (thr). When the node gets its thr, it will compare the value with current qol. If thr is greater than qol, it will respond to the RREQ as usual. Otherwise, it will simply drop it.

Proposed protocol: The proposed protocol E²AODV will make the following changes to the existing AODV protocol:

- Paths are selected based on the hop count and queue length
- Load is balanced via alternate paths if queue length processes a certain threshold value
- RREQ packets are forwarded or discarded depending on the queue length

- Based on the threshold value the route request packets will be forwarded
- The Table 1 shows the method to calculate the threshold values. Hence the source node chooses the optimum path

Figure 2 shows the flow chart as how to broadcast route request based on queue length compared with threshold value. Route request are forwarded or discarded based queue length. Based on the threshold value the route request packets are forwarded. Further the node's energy is compared with threshold energy. If the node's energy is less than the threshold energy than the packets are transmitted or less the packets are dropped.

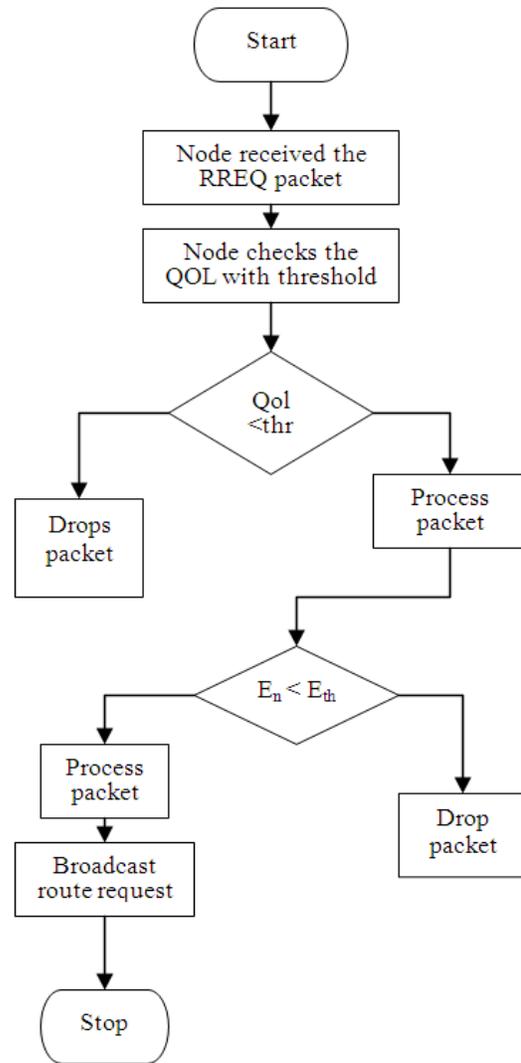


Fig. 2: Flowchart to broadcast route request based on threshold energy

Table 1: Tabulation to calculate threshold

Node	Sum_qoc	Threshold	Req
S	3.333	6.6660	Yes
A	3.333	5.5950	Yes
C	11.190	7.6190	No
E	11.190	5.6630	Yes
G	16.990	5.9260	Yes
M	10.333	6.4440	No
K	23.704	6.5400	No
D	23.704	6.0900	No
B	3.333	5.1666	Yes
F	10.333	6.1110	Yes
H	18.333	6.4330	Yes
L	25.733	6.2660	No
I	18.333	6.6330	No

Energy efficiency routing:

Broadcast message: Consider a network of static with each node knowing its own location. Each node in the network is assigned with ID and performs the task of sending route request for forwarding a given data. Moreover the nodes have invited power, storage and energy. To increase the lifetime of network additional mechanism are done in routing protocols to verify the hop count, to find hop count with intelligent routing. An efficient energy algorithm is proposed for making decision as to which intermediate node to forward the data. Based on residual energy and signal strength a node is selected to forward the data. The node which has greater energy when compared to previous one is likely to be selected as next hop. The nodes which have no work to be done will go to sleep mode, to conserve power.

Path discovery: In order to send the packet from source to destination, the source node will find list of neighbours which is the address of the nodes that are able to transmit data from the source. Broadcast messages are exchanged between the nodes. The Frame Format of Broadcast messages is shown in Fig. 3. It consists of Source ID (SD), Hop Count (HC), Sequence Number (SN), Required Energy threshold (RE), Required Signal Strength (RSS) and Destination ID (DD).

Unlike other energy-aware routing protocols which find minimum energy-cost path, this protocol provides efficient energy path. When an intermediate node receives the broadcast message it checks its available energy. If available energy is less than threshold the node simply discards the route request and if the node has sufficient energy, the node measures the strength of received signal. If the distance between the receiving node and source node is far off then the signal is weak. If none then one node is within the same signal strength threshold and has enough energy. Then there is chance for message collision to occur. To overcome this rebroadcast immediately, a Mac layer with back-off delay scheme is applied.

SD	HC	SN	RE	RSS	DD
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Fig. 3: Broadcast message frame format

Neighbor discovery: Before sending the data to the destination, a node must start the neighbor discovery process to create a neighbor list that is the address of all nodes that are able to transmit data from the source. During this process broadcast messages are exchanged between the nodes. The broadcast message as shown in Fig. 3 consists of the source address, hop count, sequence number to differentiate the messages originating from the same source, required energy threshold to transmit the packets and required signal strength threshold and destination address.

In order to overcome this, broadcast message is not rebroadcast immediately; a back-off delay scheme is applied. After the end of the current message transmission, the nodes chosen to forward the message being broadcasted is selected by associating with a back off timer.

Upon receiving the broadcast message reception, the nodes start timers that implement broadcast back-off delay.

In order to find optimal routes are determined, each receiving node calculates its broadcast back-off delay as a function of its distance away from the destination (this delay decreases along with each hop). When a node's back off timer expires, it sends the broadcast message, which also sends an implicit Acknowledgement (ACK) to the previous sender of this packet. Before its timer expires, it cancels its back-off timer and packet transmission. So, in most cases, the node with the smallest number of hops to the destination will select itself to forward the message, simultaneously making other nodes aware of its selection. The concept described above may result in more than one node selecting itself because, not all receiving nodes may be in the broadcast range of the first selected node to overhear.

Using the above mechanisms, the path to the destination is built utilizing some energy-sufficient nodes. The path request reaching the destination contains one such energy-sufficient path. Thus the node which is having the largest energy among the senders neighbor is the one which is selected.

Route reply: The destination node, upon receiving a new broadcast message, will respond with a route reply packet.

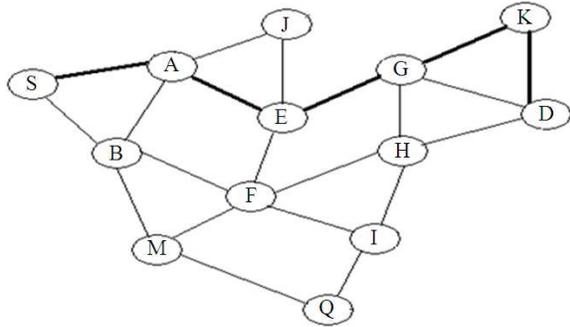


Fig. 4: Path selected in energy aware routing

The packet of this header contains the same fields as those of the request packet, as well as an expected hop count field indicating the expected number of hops needed for the packet to travel to reach the target node (in this case, the destination). Unlike the broadcast message, the route reply packet does not rely on flooding to find its return path back to the source; it just uses the nodes through which it received the broadcast message.

As shown in Fig. 4, there are many intermediate nodes, available in the network. All nodes within the radio range of the nodes receive the broadcast message at the same time. When the destination initially broadcast the message, the nodes A, E and G receive the message. Assume that the available energy at A is larger than at J also A is within the required signal strength threshold; hence node A is selected to broadcast the message to the neighboring nodes. The process continues and node E which is selected sends out the broadcast message which is received by nodes G and H, it is found that both G and H have the same energy level and are within the required signal strength threshold. So both G and H start a back-off timer and if the back-off timer of node G ends before H an implicit acknowledgement is sent by node G which is also received by node H and so node G stops its back-off timer as shown in Fig. 4. The broadcast message is sent to K and then to destination D. The destination transmits the route reply packet through the nodes it received the broadcast message.

RESULTS AND DISCUSSION

In this session we apply load balancing approach in AODV and proposed protocol which is called E²AODV and evaluate the performance of AODV with E²AODV in the simulation environment. E²AODV Energy efficient on demand distance vector selects a path with a lower hop count and discards routes with higher hop count:

- Simulation environment

Here NS-2 is used to conduct the simulation for 50 mobile hosts with transmission range of 250 m:

Parameters	Values
Number of nodes	50
Transmission range	250 m.
Topology size	800 m×800 m
Number of destination	1
Traffic type	constant bit rate
Packet size	512 bytes
Packet rate	5 packets per second
Mac layer	802.11
Bandwidth	2 Mbps
Node placement	Uniform
Initial energy for all nodes	50J
Transmit Power	300 mW
Received Power	500 mW

The average size of the route tables of all the nodes along the path is minimal and average residual power of all the nodes is maximal comparing with outer paths. It is being expressed as Eq. 9-13:

$$\text{Minimize}[\frac{1}{N} \sum_{i=1}^N \frac{\text{sizeof}(\text{rtb}(i))}{\text{Er}(i)}] \tag{9}$$

Where:

- size of (rtb(i)) = Number of entries in routing table of node ‘i’
- Er(i) = Residual energy of node i
- N = Total number of nodes participating in the route

The Energy adopted is given by:

$$\text{Energy} = \text{Power} * \text{Time} \tag{10}$$

The time needed for processing a packet is defined as:

$$\text{Time} = 8 * \text{Packet size} / \text{Bandwidth} \tag{11}$$

Therefore energy needed for transmitting and receiving the packets is given by:

$$\begin{aligned} E_{tx} &= P_{tx} * 8 * \text{Packet size} / \text{Bandwidth} \\ E_{rx} &= P_{rx} * 8 * \text{Packet size} / \text{Bandwidth} \end{aligned} \tag{12}$$

Where:

- P_{tx} = Transmitted Power
- P_{rx} = Received Power

Thus the total energy for forwarding a packet:

$$E = E_{tx} + E_{rx} \tag{13}$$

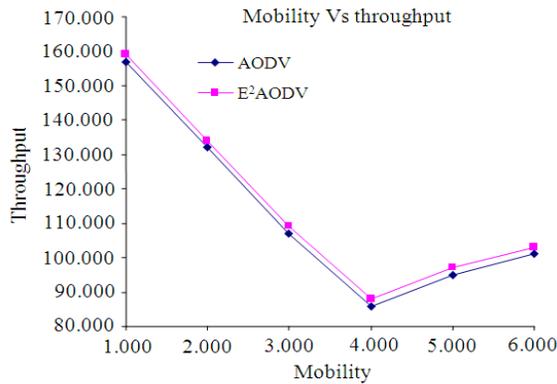


Fig. 5: Throughput Vs packets per second

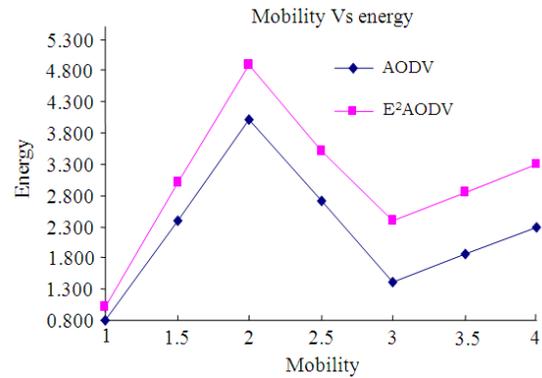


Fig. 8: Mobility Vs Energy

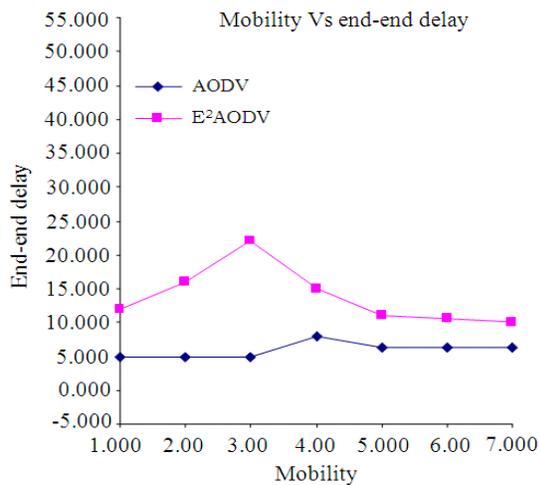


Fig. 6: Average end-to-end delay

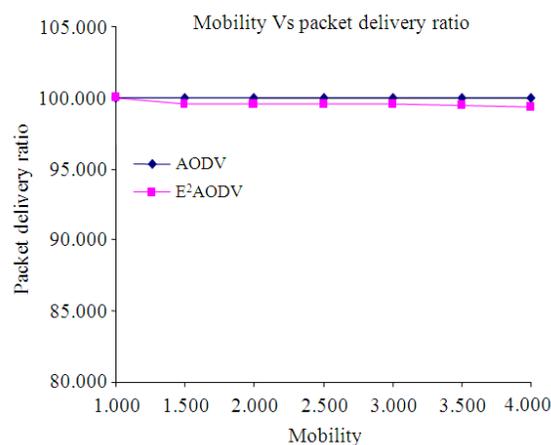


Fig. 7: Packet Delivery ratio

Under this simulation environment four performance metrics have been evaluated:

Throughput

- Packet delivery ratio
- Average End to end delay
- Energy

Performance results: Throughput – is the average rate of packets delivered over a communication channel to the destination.

Figure 5 shows throughput which is average rate of packets received by the destination to the number of packets transmitted from the source, when the load becomes heavy, E²AODV shows good throughput when compared to AODV Most of the packets are delivered to destination because it is able to find route with less congestion.

Figure 6 shows average end to end delay when traffic becomes congested because of the heavy load in the network, the average end to end delay increases in E²AODV because it takes alternative path to reach the destination. The average end to end delay will be reduced in AODV when compared to E²AODV protocol. Figure 7 shows the Packet Delivery ratio, It is defined as the ratio of number of packets received to number of packets transmitted from the source. E²AODV protocol shows good packet delivery ratio when compared to AODV protocol.

E²AODV protocol consumes less energy to forward a packet from source to destination when compared to AODV protocol. The Fig. 8 shows E²AODV protocol performs good with respect to energy when compared to AODV protocol.

CONCLUSION

In the scheme each node checks its interface queue length to determine whether it responds to the received

RREQ or not. The criterion for the decision is a threshold value, which is calculated by each node when a RREQ is received. It is a variable along with the queue occupancy of the nodes around backward path. Therefore, the threshold is adjusted adaptively according to the load status of the network this scheme can distribute the traffic evenly among the nodes in an ad hoc network.

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