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An Energy Reverse AODV Routing Protocol in Ad Hoc Mobile Networks

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***Abstract*—**In this paper we present a full performance analysis of an energy conserving routing protocol in mobile ad hoc network, named ER-AODV (Energy Reverse Ad-hoc On-demand Distance Vector routing). ER-AODV is a reactive routing protocol based on a policy which combines two mechanisms used in the basic AODV protocol. AODV and most of the on demand ad hoc routing protocols use single route reply along reverse path. Rapid change of topology causes that the route reply could not arrive to the source node, i.e. after a source node sends several route request messages, the node obtains a reply message, and this increases in power consumption. To avoid these problems, we propose a mechanism which tries multiple route replies. The second mechanism proposes a new adaptive approach which seeks to incorporate the metric "residual energy " in the process route selection, Indeed the residual energy of mobile nodes were considered when making routing decisions. The results of simulation show that protocol ER-AODV answers a better energy conservation.

***Keywords*—**Ad hoc mobile networks, Energy AODV, Energy consumption, ER-AODV, Reverse AODV.

I. Introduction

A Mobile Ad-hoc network is a set of wireless mobile nodes dynamically forming a temporary network. The goal of this architecture is to provide communication facilities between end-users without any centralized infrastructure.

Energy management in Ad-hoc networks is of paramount importance due to the limited energy availability in the wireless devices. Since wireless communication consumes a significant amount of energy, it is important to minimize the energy costs for communication. To this end, there has been a good deal of research works in designing energy efficient protocols. Current literatures about energy efficient or power aware routing protocols can generally be divided into three categories: (i) switching on/off radio transmitters to conserve energy [1] [2], (ii) power and topology control by adjusting the transmission range (power) of transmitters [3] [4], and (iii) routings based on the energy efficient metrics [5].

In this paper, we consider the cost of data packets sent in the network, and the cost of control packets used to maintain the network. To do this, we define ER-AODV (Energy Reverse Ad-hoc on-demand Distance vector routing). ER-AODV is a reactive routing protocol based on a policy which combines two mechanisms used in the basic AODV (Ad hoc On-Demand Distance Vector) protocol [6]. We choose AODV as one of the on demand MANET routing protocols because; it consumes less energy than other similar routing protocols such as DSDV and TORA as shown in [7].

AODV and most of the on demand ad hoc routing protocols use single route reply along reverse path. Rapid change of topology causes that the route reply messages (RREP) could not arrive to the source node, i.e. after a source node sends several route request (RREQ) messages, the node obtains a RREP, and this increases in power consumption. To avoid these problems, we propose a mechanism which tries multiple route replies. In this way we obtain a routing path with less RREQ messages**.**

In the AODV routing process, a minimum hops algorithm is applied to establish routes between sources and destinations. To improve the routing in term of energy conservation we propose the second mechanism witch consider another metric in the route establishment process. This parameter includes in route cost computation the speed of energy consumption. We believe that by this way we avoid nodes that participate in communications more than other and we choose nodes that participate less than the other in the communications.

The remainder of this paper is organized as follows. In Section 2, we give the most important characteristics of AODV routing protocol and its main limitations. In Section 3, we describe our two mechanisms in detail. Simulation methodology and performance evaluation of our proposal ERAODV are detailed in Section 4. At this level of our study, we discuss only the results of our first mechanism (Reverse AODV). Section 5 concludes the paper by summarizing results.

II. Basic AODV Routing Protocol

II.1 Overview

The Ad hoc On Demand Distance Vector (AODV) is a reactive routing protocol [6]. In fact, it is self-starting, enables multi-hop routing between participating mobile nodes wishing to establish and maintain an ad hoc network. This protocol builds routes between nodes only as desired by source nodes. It discovers routes quickly for new destinations, and does not

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require nodes to maintain routes to non-active destinations. AODV ensures link breakages and breakdowns are handled efficiently.

The AODV protocol establishes routes using a Route REQuest (RREQ) / Route REPly (RREP) query cycle. So, when a node requires path to destination, it broadcasts RREQ message to its neighbors which includes latest known sequence number for that destination. This message is flooded, until information required is complete by any means. Each node receiving the message creates a reverse route to the source. The destination sends back RREP message which includes number of hops traversed and the most recent sequence number for the destination of which the source node is aware. Note that if an intermediate node has a fresh route to the destination it doesn't forward the RREQ and it generates a RREP toward the source.

Each node receiving the RREP message creates a forward route to the destination. Thus, each node remembers only the next hop required to reach any destinations, not the whole route. Each node receives a duplicate of the same RREQ, it drops the packet. Moreover, AODV uses sequence numbers to ensure the freshness of routes. In fact, the routes to any destination are updated only if the new path toward that destination has greater sequence number than the old one or it has the same sequence number but with less number of hosts. So, AODV protocol builds routes between nodes regarding the shortest path parameter.

AODV Limitations: Routes, in AODV protocol, are established based on minimum hop count. This consideration might have a bad effect when the number of communications increases. So it is more likely to include other parameters that have a significant effect on, network connectivity and lifetime. Furthermore, power is a very important constraint in wireless network. If a node that participates in a route establishment has very low energy, this later will break very soon. Moreover, this can has also a bad effect on the network lifetime: there are some nodes that will dead very faster than another ones. To deal with these problems, the power should be taken into account in the route establishment algorithm. To this end, we propose a mechanism that considers the residual energy of mobile nodes when making routing decisions.

III. ER-AODV PROTOCOL

Taking into account the various problems and constraints described above, we propose a reactive routing protocol ERAODV which aims to maximize the lifetime of the network and improve the performance obtained by the basic AODV routing protocol. Thus, the goal is to reduce the cost of control packets used to maintain the network by incorporating the mechanism called "Reverse AODV", and routing around nodes that we expect that they have more residual energy than other by integrating mechanism "Energy AODV" into our protocol.

IV. REVERSE AODV

Overview of the mechanism: The principle of this mechanism is to establish a routing path with less RREQ messages, which tries to answer using a multiple route replies to gain energy consumption during the dispatch of control packets. We propose this mechanism to avoid RREP loss and improve the performance of routing in MANET. As illustrated in Figure 1, Reverse AODV uses absolutely same procedure of RREQ of AODV to deliver route reply message to source node. This mechanism can reply from destination to source if there is at least one path to source node. When a source node receives the RREP packet, the data packets routing can start immediately. In this manner, Reverse AODV prevents a large number of retransmissions of route request messages.

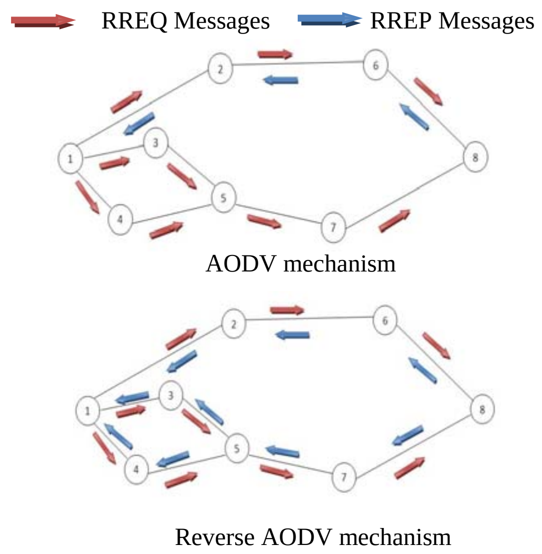

Fig. 1 Both AODV & Reverse AODV mechanisms

Route Discovery: Mobile nodes using Reverse AODV, exchange three types of control packets: RREQ, RREPs and RRERs. The RREQs and RRERs have the same format as RREQs and RRERs defined in [6] for AODV, whereas RREP format has been slightly modified.

The RREP Message (Figure 2) contains following information: reply source id, reply destination id, reply broadcast id, hop count, destination sequence number, reply time (timestamp)

Type	Reserved	Hop Count
Broadcast ID		
Destination IP address		
Destination Sequence Number		
Source IP address		
Reply Time		

Fig. 2 RREQ Message Format in Reverse AODV

When broadcasted RREP message arrives to intermediate node, it will check for redundancy. If it already received the same message, the message is dropped, otherwise forwards to next nodes. Furthermore, node stores or updates following information of routing table:

- Destination Node Address
- Source Node Address
- Hops up to destination
- Destination Sequence Number
- Route expiration time and next hop to destination node.

Whenever the original source node receives first RREP message it starts packet transmission, and late arrived RREPs are saved for future use. The alternative paths can be used when the primary path fails communications.

Energy AODV: This mechanism proposes a new adaptive approach which seeks to incorporate the metric "residual energy of nodes" instead of the number of hops in the process route selection. Indeed, we define the rate of energy consumption for each node to estimate its lifetime. Then, we define a cost that fits this lifetime and the energy level. This information is then used to calculate routes cost.

V. Control Packets And Data Structures

RREQ Message: A field called « *min_bat*» has been added to RREQ packets. It takes as value the minimum of residual energies of nodes traversed by the RREQ packet.

Routing Table: This structure is used to store every candidate route in destination nodes, indexed by source node identifier. Every entry in the routes table contains the following fields:

- *Src:* maintains the identifier of source node who initiated the route discovery procedure.
- Seq: maintains the RREQ sequence number.
- *Route:* contains the nodes sequence traversed by RREQ packet.
- *Min_bat*: keeps the minimal residual energy of nodes traversed by RREQ packet.
- *Arrival_time:* keeps the arrival time of RREQ packet at the destination node.

Content of the first four fields is directly extracted from arriving RREQ packets.

Computing the expected residual lifetime : In our mechanism, we do not only consider the current energy level value of a node, we observe also the speed of energy consumption at each constant period (Tupdate) [8]. For each node, we follow the following formula to compute energy speed consumption:

$$\text{Energie}_{\text{consom}}\ (\text{j}) = \frac{\text{Energie}_{\text{rest}}\ (\text{J}-1) - \text{Energie}_{\text{rest}}\ (\text{j})}{\text{T}_{\text{Update}}}$$

Where $\text{Energie}_{\text{rest}}$ (J) is the estimated residual energy computed at period j as follow:

$$\text{Energie}_{\text{rest}}\ (\text{J}) = \max\ \ \{\text{Energie}_{\text{cour}}\ (\text{j}) - \sum_{i=1}^{I=N\ \text{pkts}} \text{E}_{\text{Tx}}\ (\text{i}), 0\}$$

Where $\text{Energie}_{\text{cour}}$ (j) is the current energy value of the node, and E_{Tx} is the value of the power that will be consumed to transmit the N_{pkts} remaining packets in the buffer.

Then, we can estimate the expected residual life time $T_{lifetime}$ (j) in each node considering the energy speed consumption $\text{Energie}_{\text{consom}}$ (j) and the estimated residual energy $\text{Energie}_{\text{rest}}$ (J) values computed at each time interval j as follow:

$$\text{T}_{\text{lifetime}}\ (\text{j}) = \frac{\text{Energie}_{\text{rest}}\ (\text{J})}{\text{Energie}_{\text{consom}}\ (\text{j})}$$

Computing the route establishment cost : Using the $T_{lifetime}$ (j) value, each node computes a cost at each route request demand. This cost is defined as following :

$$\text{Cout}_{\text{res-life}}\ (\text{j}) = \text{T}_{\text{lifetime}}\ (\text{j}) * \text{W}_{\text{k}}$$

Where Wk is a multiplicator factor in the interval [0,1] defined for each energy interval k . Hence, k go from 1 to 4 referring four energy intervals: the first one is from 50% to 100% of initial energy value (Wk =1), the second one is from 30% to 50% (Wk =0.75), the third one is from 10% to 30% (Wk =0.5) and the last one is from 0% to 10% (Wk =0.25).

Thus the route establishment cost from source to destination is calculated as follows:

$$\frac{\sum_{i=1}^{i=\text{nbr node}} \text{Cout}_{\text{res-life}}\ (\text{j})}{\text{nbr node}}$$

Wher nbr node is the intermediate nodes number.

VI. Performance Results

In this section, we first describe the simulation environment used in our study and then discuss the results in detail. Our simulations are implemented in Network Simulator (NS-2) [9].

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At this level of our study, we discuss only the results of our first mechanism Reverse AODV. Simulation parameters are as follows:

- Number of nodes: 10, 20, 30, 40, 50, respectively.
- Testing area: 1000m x 1000m.
- Mobility model: random way point model (when the node reaches its destination, it pauses for several seconds, e.g, 1s, then randomly chooses another destination point).
- Traffic load: UDP, CBR traffic generator.

Each simulation is run for 100 seconds and repeated for 10 times. To evaluate performance of R-AODV, we compare our proposed R-AODV with AODV, using the following metrics:

- Delivery Rate: the ratio of packets reaching the destination node to the total packets generated at the source node.
- Average End-to-End Delay: the interval time between sending by the source node and receiving by the destination node, which includes the processing time and queuing time.
- Average Energy Remained: mean value of energy remained in each node.

Figure 3 shows packet deliver ratio of AODV and R-AODV, by increasing number of nodes brings apparent difference between the two protocols, more exact result is shown on Figure 4.

Packet delivery ratio difference in figure 4 calculated as below:

$$\frac{\text{delivery ratio of ER. AODV} - \text{delivery ratio of AODV}}{\text{delivery ratio of AODV}} * 100\%$$

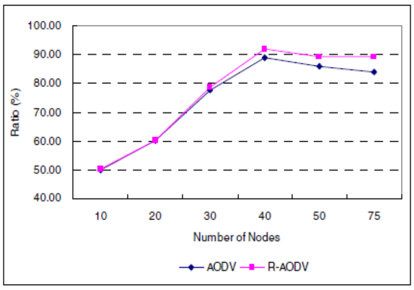

Fig. 3 Packet Delivery Ratio, when the number of nodes varies

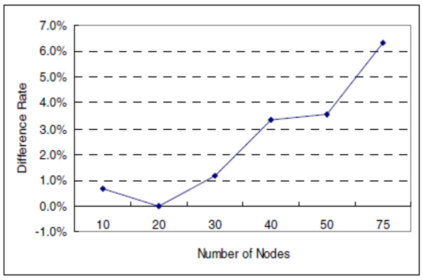

Fig. 4 Packet delivery ratio difference between two protocols, when the number of nodes varies

Figure 5 shows the average energy remained of each protocol. We have to mention that it is a mean value of energy remained each node at the end of simulation. Remained energy in R-AODV is higher than AODV; even it has sent more data packets to destination as shown on figure 3 and 4.

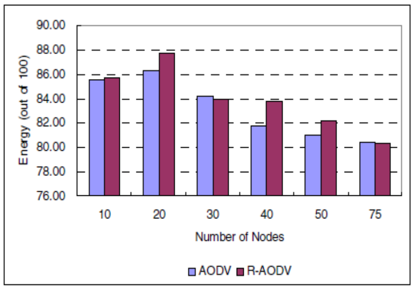

Fig. 5 Average energy remained, when the number of nodes varies

Figure 7 shows the average end-to-end delay of each protocol. It should be noted that the delay is considered for the packets that actually arrive at the destinations. We can see that R-AODV has lower delay than AODV. The reason is that AODV chooses route earlier, R-AODV chooses recent route according to reverse request.

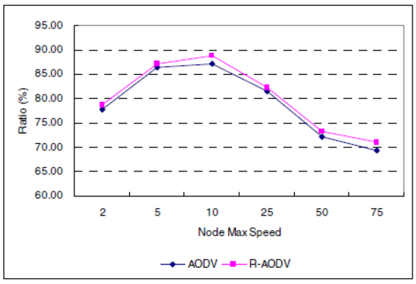

Fig. 6 Average end to end delay, when the number of nodes varies

VII. Conclusion

Successful delivery of RREP messages are important in on-demand routing protocols for ad hoc networks. The loss of RREPs causes serious impairment on the routing performance. This is because the cost of a RREP is very high. If the RREP is lost, a large amount of route discovery effort will be wasted in terms of number of control packets, and in terms of energy.

We proposed the idea of reverse AODV, which tries multiple route replies. R-AODV route discovery succeeds in fewer tries than AODV. The results show that R-AODV improves the performance of AODV in most metrics, as the packet delivery ratio, end to end delay, and energy consumption. Our future work will focus on implementing Energy AODV mechanism to conserve more energy.

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