Power-aware Ad hoc On-Demand Distance Vector Routing for prolonging network lifetime of MANETs

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Abstract

We present in this paper a new version of AODV that incorporates with "Minimizing Maximum node cost" by formulating that metric as a cost function of residual energy of nodes. An additional parameter is added to the cost function to consider the routing performance along with power-efficiency. The motivation of adding that new parameter is originated from the trace off between power-saving behaviors and routing performance.

1. Introduction

Mobile devices coupled with wireless network interface are likely to be the future of computing infrastructure. Among researches on mobility for future networks, Mobile Ad hoc NETwork (MANET) is an outstanding topic because of its flexibility and rapid deployment characteristics. A MANET is a collection of mobile nodes that form a network dynamically without the presence of fixed infrastructures such as base stations or access points. In this environment, intermediate nodes need to forward data packets from a source to destinations. Thus, a suitable routing scheme plays a significant role in overall network performance.

Ad-hoc On-demand Distance Vector (AODV) is recently considered one of the most potential routing protocols for MANETs because of its efficient bandwidth usage and quick adaptation to topology changes. However, this routing algorithms use "shortest path" as the metric to select a route and this may raise unfairness issues during the MANET operation: Nodes standing in some critical region may be overused by lots of data packets going through it. Batteries of these nodes, as a result, will soon be depleted causing network partitioned and reducing network lifetime. Thus, load sharing in term of node residual energy is an important aspect for routing protocol.

Dealing with power-related issues in MANET, the papers [3, 8] described noticeable metrics for routing protocols to extend network lifetime. These prior researches also proved that "lowest cost routing" instead of "shortest path routing" is beneficial for actual operations of MANETs [3]. However, in AODV, the behaviors that nodes only exchange routing information when a source wants to send data to destinations and intermediate nodes drop Route Request packets that they have received create difficulties to apply these metrics to AODV routing protocol.

Aiming at combining advantages of both power-aware routing metrics and AODV protocol, in this paper, we will consider power aware routing metrics and extend AODV routing protocol to adopt a suitable power aware metric. In our customized version of AODV, named PAODV, both routing performance and power balancing will be considered with an attempt to maximize the network life time and reduce network partition rate caused by power exhaustion while still maintaining reasonable performance of an ad hoc routing algorithm.

This paper is organized as followed. Related work is summarized in the next section. I will analyze each power-aware routing metric in term of power balancing and briefly describe AODV routing protocol. Section 3 is for our proposed solution to extend AODV protocol. Simulation and performance evaluation is presented in section 4. And finally, conclusion and future work will close this paper.

2. Related work

1st. Existing power efficient routing schemes

Routing metrics are the basic part of every routing protocol. With regard to power efficiency, there are several metrics proposed in [3, 8] including:

a) *Minimize Energy consumed/packet*: Packets are routed via routes that consume least power.
b) *Minimize Cost/Packet:* Each node consumes some *cost* when it forwards packets to next hops and packets are routed via routes that offer minimum total cost.

c) *Minimize Maximum node Cost:* the cost of a route is the highest cost among those of nodes in the route. Packets should select the route with minimum route cost.

As shown in [8], the above metrics cannot solve the unfairness problem except the third one. Thus, it is the most suitable metric for routing protocols in case that we want to distribute load evenly instead of minimizing network power consumption.

2nd. Ad hoc On-demand Distance Vector routing

The way to collect topological information is another part of a routing protocol. With regard to this aspect, Ad hoc On-demand Distance Vector (AODV) is considerable because of its quick adaptation to topological changes and its efficient bandwidth utilization in comparison with other routing protocol for ad hoc network such as DSDV, DSR, TORA [1, 7, 9]. The specific AODV's characteristic in term of collecting topological information is reactive or on-demand. To discover the shortest path to a destination, a node floods a *route request* (RREQ) packet across the network to search the destination and waits for a *route reply* (RREP) from the destination or from a node that has a fresh route to that destination. The RREP is sent in correspondence with the first-come RREQ that has traveled through the shortest route. Nodes will also immediately drop duplicate RREQ packets to reduce unnecessary route discovery traffic.

Analyzing the above previous works directs us to some judgments:

- Minimizing power consumption may be more efficient if it is implemented at physical and datalink layer instead of at network layer. Several mechanisms introduced in [3, 4, 10] reinforce this point.
- Power balancing incorporated with a routing protocol may extend network lifetime. Thus "*Minimize Maximum node Cost*" is the best metric to incorporate with AODV.

Thinking about applying power aware metrics to AODV routing protocols, we believe that the following characteristics of AODV creates several difficulties in integrating new metrics to this routing protocol:

- A node does not know all other nodes in the network. Thus, if another metric is used instead of shortest path, a node does not know whether it collect enough routing information or not.
- Duplicated RREQs are dropped by intermediate nodes. This leads to a fact that some routes with good quality in term of other routing metric than "shortest path" may be excluded from possible routes.

Actually, the reactive characteristic of AODV sticks to shortest-path metric since it considers the route represented by the first-come RREQ as the shortest route. Thus to change routing metric in this case is rather difficult.

3. Proposed solutions:

In order to adopt "*Minimize Maximum node Cost*" metric, we customize AODV as follows:

- Thirteen bits *reserved field* in RREP and RREQ headers is used to store power-aware routing metric. We call it MPRE (Minimum Path Residual Energy).
- Whenever a node sends a RREQ or RREP packet, it assigns its nominal residual energy to this MPRE field.
- Whenever a RREQ or RREP visits a node, the visited node compares its nominal residual energy with MPRE value inside the RREQ/RREP packet and the smaller value will be assigned to MPRE of this packet before forwarding this packet further.

Thus, MPRE of a RREQ/RREP packet contains the minimum residual energy of the path that this packet has traversed.

- The route table will have one more field to store MPRE of routes corresponding to each entry in this route table.
- When a node receives a duplicated RREQ, instead of immediately dropping this packet, this node compares the cost of the route in its route table with that of the route represented by the RREQ and updates its route table with information inside the RREQ if the new route offers lower cost value than the old route. After that the node will drop that duplicated packet.

Actually, following the above scheme, nodes still drop some RREQ carrying "good route" when it drops duplicated packets after updating it routing table. However, forwarding these duplicated packets will create a lots of RREQs and severely consumes network power.

Cost function:

To calculate the cost value of a route, we used a cost function that considers both MPRE and hop count value of a route:

$$cost = \alpha \times \frac{1}{MPRE} + (1-\alpha) \times hopcount$$

In which α is the significance of power aware aspect.

If α increases to 1, the weight of "power aware" increases while the weight of routing performance decreases. When α is equal to 1, only power aware metric is taken into consideration.

On the other hand, if α decreases to 0, the weight of "power aware" decreases while the weight of routing performance increases. If α is equal to 0, the proposed approach is identical to the original AODV.

4. Simulation and performance evaluation

In this section, numerical simulations for evaluating the proposed metric are presented. For simulation, we used ns-2 (version 2.1b9) with CMU extension. The simulation scenarios are setup with 50 mobile nodes moving randomly in a 500mx500m. The proposed extension is considered in terms of number of alive nodes and average residual energy of network. Traffic used in the simulations is TCP and data exchange happened between an arbitrary pair of nodes. The pair of nodes creates connections for data transmission and each connection exists in a randomly selected amount of time. In our experiments we run simulation scenarios for different number of connections and record simulation metrics. Our simulation metrics includes:

- Number of alive nodes in a specific point of time during simulation.
- Statistical parameters on average residual energy of nodes in the network.

Because average latency in packet transmission does not only depend on network scale but also on node arrangement, it is left for future work when we have more well-defined requirements for simulation scenarios.

In terms of extending network life time, PAODV outperforms the original AODV as seen in figure 1a, b. But, the benefit of the routing metric depends heavily on nodes arrangement. That explains why the numbers of alive node vary from one scenario to another scenario. However, AODV with the new metric usually gain power benefit in comparison with pure AODV.

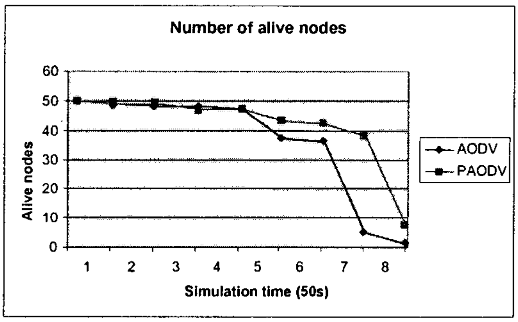

Figure 1a: Number of a live nodes when $\alpha=1$, number of connections = 10

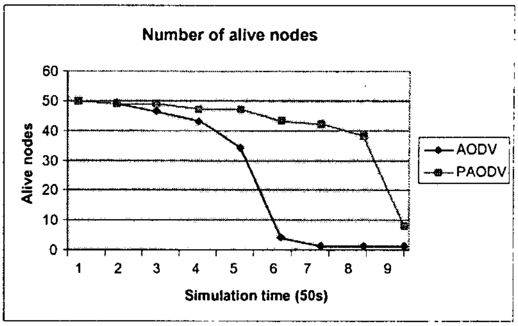

Figure 1b: number of alive node when $\alpha=1$, number of connections = 15

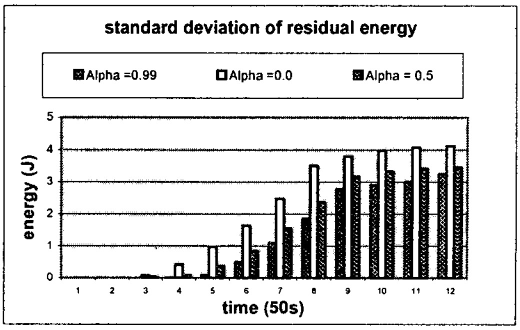

Figure 2: standard deviation of nodes' residual energy.

Statistics result of simulations illustrated in figure 2 shows common the trend of distribution of energy among nodes in the network. The data in this simulation is recorded during simulations with 50-node, 10-connection scenarios. However the data is still not enough to determine an optimal α. This is left for future work.

5. Conclusion:

In this work, we introduce a new version of AODV that considers power aspect. Our proposed solution achieves a better performance in sense of power consumption in comparison with the conventional AODV.

There exists a trade-off between routing performance (in term of time delay) and getting better power consumption. Also, the benefit of new version of AODV varies case by case. However, to some extent, it fulfils the requirement of power-aware metric for AODV.

From the work, we think that the further work should be considered for completely investigation the evaluation of the proposed approach, especially in the cost function to choose the best one.

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