Power Aware Routing for MANET Using On-demand Multipath Routing Protocol

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Abstract

Energy in mobile adhoc networks is of much important. Similarly shortest path from source to destination is also important for routing. To address these issues a routing protocol is proposed which gives an optimum between these issues. Power aware adhoc on-demand multipath distance vector (PAAOMDV) is proposed to overcome the issue of energy and shortest path in a single routing protocol. This protocol helps in updating the routing table with both the node route list and their corresponding energies. As this is a multipath protocol, it shifts the route without further overhead, delay and loss of packets. Simulation results shows that PAAOMDV performs well compared to ad-hoc on-demand multipath distance vector (AOMDV) routing protocol even after introducing energy related fields in PAAOMDV.

Keywords- *Power aware adhoc on-demand multipath distance vector, residual energy, shortest path, system lifetime, traffic anticipation*

1. Introduction

A mobile, ad hoc network is an autonomous system of mobile hosts connected by wireless links. There is no static infrastructure such as base station. If two hosts are not within radio range, all message communication between them must pass through one or more intermediate hosts that double as routers. The hosts are free to move around randomly, thus hanging the network topology dynamically. Thus routing protocols must be adaptive and able to maintain routes in spite of the changing network connectivity. Such networks are very useful in military and other tactical applications such as emergency rescue or exploration missions, where cellular infrastructure is unavailable or unreliable. Commercial applications are also likely where there is a need for ubiquitous communication services without the presence or use of a fixed infrastructure. Examples include home-area wireless networking, on-the-fly conferencing applications, networking intelligent devices or sensors, communication between mobile robots, etc.

Almost all mobile devices are supported by battery powers, so the energy-efficient issue is one of the most important design issues in MANET. Solutions to the energy-efficient issue in MANET can generally be categorized as follows: 1) Low-Power Mode, in which mobile devices can support low-power sleeping mode. The main research challenges in low-power mode are that at what time mobile node can turn to sleeping mode, and at what time it should wake up. Corresponding issues are addressed in [1], [2], [3] and etc; 2) Transmission Power Control: In wireless communication, transmission power has strong impact on transmission range, bit error rate and inter-radio interference, which are typically contradicting factors. By adjusting its transmission power, mobile node can select its immediate neighbors from others, thus the network topology can be controlled in this way. How to determine transmission power of each node so as to determine the best network topology has been addressed in [4], [5], [6] and etc; 3) Power-Aware Routing: Other than the common shortest-hop routing protocols, such as DSDV [7], AODV [8], DSR [9], and etc, power-aware routing protocols take various power metrics or cost functions into account in route selection. S. Singh, M. Woo, and C. S. Raghavendra proposed five different metrics along with their impacts on the performance in [10]. J.H. Chang and L. Tassiulas presented a routing algorithm for static MANET in [12], which aims to maximize system lifetime by balancing the energy consumption. I. Stojmenovic and X. Lin proposed a new power-cost metric based on the combination of both node's lifetime and distance based power metrics in [12]. In this paper, we present a power-aware on-demand routing protocol called PAAOMDV with the objective to maximize the system lifetime of MANET, which is defined as the time once some node uses up its energy for the first time. The main ideas of PAAOMDV include: 1) traffic anticipation, i.e. the source is able to anticipate the traffic of the request; 2) energy reservation, i.e. the node on the route should make the energy reservation for the request according to the anticipated traffic; 3) energy threshold, i.e. a node could participate in route discovery only when its logical residual energy, which is defined as the physical residual energy subtracting all reserved energy, is greater than the energy returned by a threshold function; 4) a new path cost function is used in route selection which takes both shortest-hop and maximum lifetime into consideration.

2. Related Work

We propose a power-aware routing protocol which extends the Ad-hoc On-Demand Multipath Distance Vector (AOMDV) routing protocol [13]. We call it PA-AOMDV. AOMDV is, itself, an extension of the Ad-hoc On-Demand Distance Vector (AODV) routing protocol [14]. In this section we review the details of these two predecessor protocols that are useful to our discussion in this paper.

2.1 AODV

AODV is a single-path, on-demand routing protocol. When a source node, n_s, generates a packet for a particular destination node, n_d, it broadcasts a route request (RREQ) packet. The RREQ contains the following fields:

<source IP address,
source sequence number,
broadcast ID,
destination IP address,
destination sequence number,
hop-count>

where the source and destination IP addresses remain constant for the lifetime of the network, source sequence number is a monotonically increasing indicator of packet "freshness", destination sequence number is the last known sequence number for n_d at ns and hop-count is initialized to zero and incremented at each intermediate node which processes the RREQ. A RREQ is uniquely identified by the combination of source sequence number and broadcast ID. An intermediate node only processes a RREQ if it has not received a previous copy of it. If an intermediate node has a route to n_d with destination sequence number at least that in the RREQ, it returns a route reply (RREP) packet, updated with the information that it has. If not, it records the following information:
source IP address, source sequence number, broadcast ID, destination IP address and expiration time for reverse path route entry, and forwards the RREQ to its neighbors. Like the RREQ, a RREP is only processed on first sighting and is discarded unless it has a greater destination sequence number than the previous RREP or the same destination sequence number but a smaller hop-count. The RREP packet contains the following fields:

<source IP address,
destination IP address,
destination sequence number,
hop-count,
route expiration time>

The route expiration time is the time after which the route is considered to have expired and a new route discovery process must be undertaken. ns sends packets via the first path it hears about. If it receives a later RREP which has either fresher information or a shorter hop-count, it swaps to that, discarding the original route information. When an active route link breaks, a route error (RERR) packet, with sequence number incremented from the corresponding RREP and hop-count of ∞, is sent by the upstream node of the broken link to n_s. Upon receipt of a RERR, ns initiates a new route discovery process if it still has packets to send to n_d. Nodes also periodically send "hello" messages to neighboring nodes to maintain knowledge of local connectivity.

2.2 AODV

The key distinguishing feature of AOMDV over AODV is that it provides multiple paths to n_d. These paths are loop-free and mutually link-disjoint. AOMDV uses the notion of advertised hop-count to maintain multiple paths with the same destination sequence number. In both AODV and AOMDV, receipt of a RREQ initiates a node route table entry in preparation for receipt of a returning RREP. In AODV the routing table entry contains the fields:

<destination IP address,
destination sequence number,
next-hop IP address,
hop-count,
entry expiration time>

where entry expiration time gives the time after which, if a corresponding RREP has not been received, the entry is discarded. In AOMDV the routing table entry is slightly modified to allow for maintenance of multiple entries and multiple loop-free paths. Firstly, advertised hop-count replaces hop-count and advertised hop-count is the maximum over all paths from the current node to n_d, so only one value is advertised from that node for a g iven destination sequence number. Secondly, next-hop IP address is replaced by a list of all next-hop nodes and corresponding hop-counts of the saved paths to n_d from that node, as follows:

<destination IP address,
destination sequence number,
advertised hop-count,
route list: {(next hop IP 1, hop-count 1),
(next hop IP 2, hop-count 2), . . .},
entry expiration time>

To obtain link-disjoint paths in AOMDV n_d can reply to multiple copies of a given RREQ, as long as they arrive via different neighbors.

3. Power-Aware On-Demand Routing Protocol for MANET

In this section, we first present an overview of PAAOMDV followed by some definitions in PAAOMDV. Then the main ideas of PAAOMDV will be presented in detail. Finally, the protocol optimization and brief analysis will be presented.

3.1 Overview of Power Aware AOMDV

There are 3 basic assumptions in PAAOMDV:
1. Each mobile node is able to read its own physical residual energy;
2. Each mobile node knows its transmission power, based on which it could estimate the energy consumption of sending a packet;
3. The source node of a request is capable of anticipating the number of the packets to be transmitted.

The traffic of a request in some network applications can be anticipated easily and accurately. For example, when a user wants to copy a shared file from another, the traffic of the request is equal to the length of the file. However in some real-time applications, it is difficult to anticipate the traffic accurately. In these cases, the traffic could be anticipated approximately based on the historical experience or statistic. And improving the performance of PAAOMDV in the cases of inaccurate traffic anticipation will be one of our future works. PAAOMDV works in a similar manner with DSR [9], a well-known on-demand routing protocol. In both PAAOMDV and DSR, mobile nodes only maintain the routes to the active destinations, and a route discovery process is needed for every new destination. Although DSR is a shortest-hop routing, it is close to a minimum-total energy- consumed routing in the case that each node is with approximately same transmission power. The objective of PAAOMDV is to maximize the system lifetime of MANET. But as a routing protocol, PAAOMDV also should guarantee the delivery rate, i.e. maximize the number of packets correctly delivered. To maximize both the system lifetime and delivery rate, PAAOMDV must try to balance the energy consumption in the whole network. The main improvements of PAAOMDV over DSR are that:

1)The intermediate nodes on the route make energy reservation based on the traffic anticipation made by the source, thus each node knows not only its physical residual energy, but also the expected energy possibly to be consumed in the future, and hence it will report its energy status more accurately. For example, in this way the node with high physical residual energy but already on some routes will be not preferred in route selection;

2)As mentioned above, PAAOMDV could take both shortest-hop and maximum-lifetime into consideration in route selection based on the precise energy status reported by intermediate nodes;

3)PAAOMDV applies an energy threshold function in route discovery for first filtering out the nodes with low logical residual energy, and second reducing the broadcast operations in route discovery. From the global viewpoint of a MANET, the energy threshold function aims to guide all nodes consuming their energy approximately synchronously. The node that consumes its energy too fast will be protected from routing while others will be encouraged. In this way, the energy consumption will be balanced in the whole network.

3.2 Definitions of Power Aware in Routing

We'll make the following definitions before presenting PAAOMDV in detail.

1. Node Lifetime and System Lifetime N = {1, 2, … , n} is the node set of MANET, while n
is the node number;
NLT(i) = the time when node i uses up it energy;
System Lifetime(N) = min{NLT (i) | i N};

2. Physical Residual Energy Ei(t) and Logical Residual Energy $LE_i(t)$
$E_i(t)$ = the physical residual energy of node i at time t;
$LE_i(t) = E_i(t)$ - Σ(Reserved Energy of node i at time t);

3.3 Ideas in PAAOMDV

In PAAOMDV, each node should maintain an Energy Reservation Table (ERT) instead of the route cache in the common on-demand protocols. Each item in ERT is mapped to a route passing this node, and records the corresponding energy reserved. The entries of an item in ERT are Request ID, Source ID
Destination ID, Amount of Energy Reserved, Last Operation Time, Route, and their functions will be presented in detail below.
The basic operations of PAAOMDV include route discovery, packet forwarding and route maintenance.

3.3.1 Route Discovery

Route discovery in PAAOMDV is an enhanced version of route discovery in AOMDV, incorporating energy fields for choosing energy efficient path. The duration, E, of a path is defined as the minimum residual energy over all of its links,

$$E \triangleq \min_{1 \le h \le H} residual\ energy_h \qquad (1)$$

where h is link number, and H is number of links/hops in the path. The energy, E, is also recorded in the RREQ, updated, as necessary, at each intermediate node. Thus, all information required for calculating the residual energy is available via the RREQs, minimizing added complexity. Similarly to the way the longest hop path is advertised for each node in AOMDV to allow for the worst case at each node, in PAAOMDV the minimum E over all paths between a given node, n_i, and n_d, is used as part of the cost function in path selection. That is,

$$E_{min}^{i,d} \triangleq \min_{C \in path\_list_i^d} E_C \qquad (2)$$

where $path\_list^d_i$ is the list of all saved paths between nodes n_i and n_d. The route discovery update algorithm in PAAOMDV is a slight modification of that of AOMDV. If a RREQ or RREP for n_d at ni, from a neighbor node, n_j , has a higher destination sequence number or shorter hop-count than the existing route for n_d at n_i, the route update criterion in PAAOMDV is the same as that in AOMDV.
However, if the RREQ or RREP has a destination sequence number and hop-count equal to the existing route at n_i but with a greater E_i, E_{min}, the list of paths to n_d in n_i's routing

Table 1: Comparison of routing table entry structures in AOMDV and PAAOMDV.

AOMDV routing table	PAAOMDV routing table
Destination IP address	Destination IP address
Destination sequence number	Destination sequence number
Advertised hop count	Advertised hop count
Path list{(next hop IP 1, hop count 1),(next hop IP 2, hop count 2),……..}	E_{min}
	Path list{(next hop IP 1, hop count 1,E1), (next hop IP 2, hop count 2, E2),……..}
Expiration time out	Expiration time out

table is updated. So, in PAAOMDV, path selection is based on E_i, E_{min} as well as destination sequence number and advertised hop count. The routing table structures for each path entry in AOMDV and PAAOMDV are shown in Table1.

3.3.2 Packet Forwarding

Once the route has been established, the source starts sending the data packets to the destination. After the node on the route forwards a d ata packet, it will update the corresponding item in the routing table by firstly subtracting the amount of energy just consumed from the amount of energy reserved.

3.3.3 Route Maintenance

When a node finds an error in forwarding a data packet, it will initiate a route error packet (RERR) and send it back to the source. Each node that receives the RERR packet would remove the corresponding item from routing table and switch to alternate path. For the nodes that could not receive the RERR packet on the route, expiration time out is used to switch from that path to other.

4. Simulation Model

The simulation platform is ns-2 [15] which is a discrete event simulator. The simulation scenario is a common used 1000m*1000m physical area. The max node speed is 10 m/s with 100 n odes investigated. Each node is with the same transmission power. The initial energy of all nodes is set as 1. Each simulation run lasts for 100 seconds.

4.1 Simulation Results

Throughput is based on the number of packets and is compared between PAAOMDV and AOMDV. Results from Fig. 1 shows that PAAOMDV is better than AOMDV based on throughput. Throughput reduces when simulation time increases, even then throughput of PAAOMDV is higher for complete simulation duration.
Average end to end delay is based on the source to destination delay and is compared between PAAOMDV and AOMDV. Results from Fig. 2 shows that PAAOMDV is better than AOMDV. This is because of the routing updates taking place for every path and switches the path when there is problem in other.

Table 2: Simulation parameters

No. Of nodes	100
Area size	1000*1000
Simulation time	100 seconds
Mobility model	Random way point
Mac	802.11
Radio range	250m
Traffic source	CBR
Packet size	512

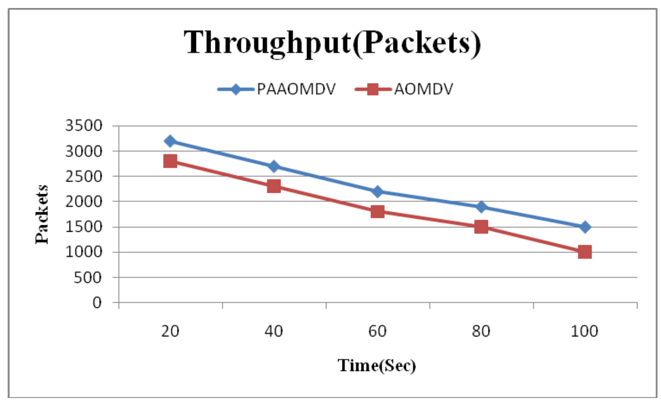

Fig. 1 Throughput comparison.

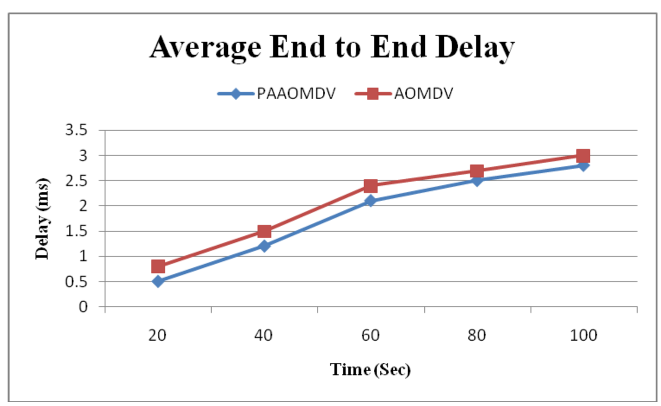

Fig. 2 End to End delay comparison.

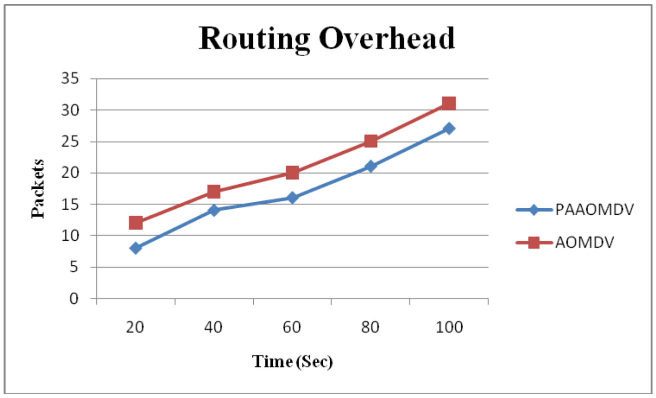

Fig. 3 Routing overhead comparisons.

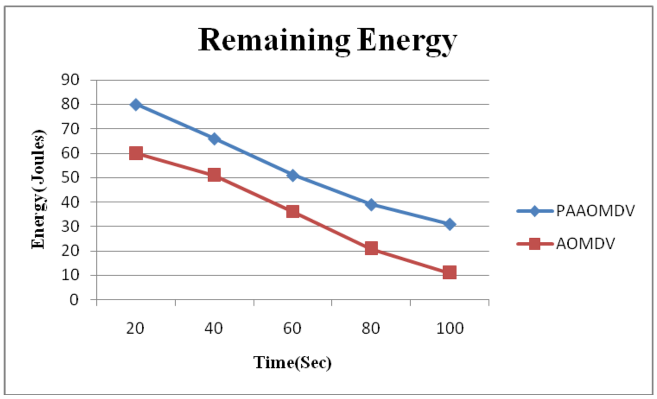

Fig. 4 Remaining energy comparisons.

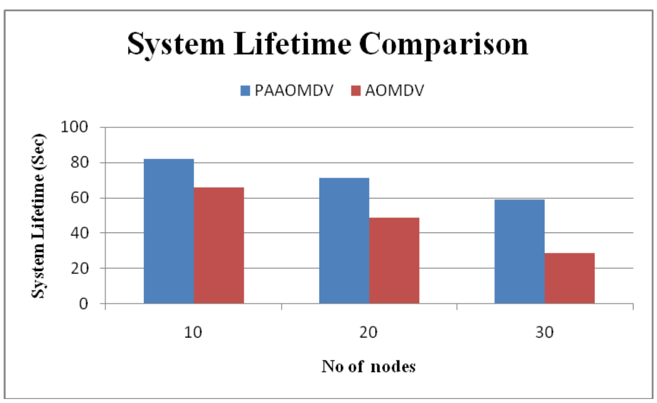

Fig. 5 System lifetime comparisons.

Fig. 3 shows Routing overhead comparison for PAAOMDV and AOMDV. Routing overhead is less for PAAOMDV because of updates which the routing table holds.
Fig. 4 shows the remaining energy during progress of simulation. This gives a better performance based on energy for PAAOMDV over AOMDV. This is mainly because of the energy details with the routing protocol.
System lifetime is compared between PAAOMDV and AOMDV. Fig. 5 shows that PAAOMDV has system lifetime than AOMDV even number of nodes are varied.

5. Conclusion

In this paper, power awareness is introduced in AOMDV so that shortest path along with maximum energy is established. Hence, based on the simulation results PAAOMDV has better through put, end to end delay, routing overhead, energy and system lifetime than AOMDV. PAAOMDV controls routing with efficient energy. This power awareness can be established to other routing protocols in future.

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