A Power-Based Source Routing for Wireless Mobile Ad Hoc Communications

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***Abstract* - This paper proposes a novel reactive power-based source routing (PBSR) protocol for wireless mobile Ad hoc communications. The routing scheme adjusts the node's transmission power to keep the connectivity of the network topology and controls its components' life times to follow the variation of the network conditions. PBSR is a source routing and is driven by events. In simulations, the components' contribution to the protocol performance is shown. Comparing with DSR, PBSR has the relatively advantage especially when nodes move in networks.**

Keywords: Wireless communication; Ad hoc network; Routing protocol; Power adjustment; Source routing; Reactive routing.

1. INTRODUCTION

With the development of computer networks and wireless communications technologies, advanced portable wireless devices have been applied widely in civil and military applications. Mobile ad hoc networking (MANET) [8] is instantly deployable without any wired base station or fixed infrastructure. It is expected to play an important role in many applications such as cooperation workgroups, wireless conferences and electronic teaching. In ad hoc communications, limited bandwidth, communication energy constrained, frequently changing topology and unpredictably with hosts moving randomly make interesting for many researchers.

For designers of portable wireless devices, the limitation on power consumption is an important factor. Some engineers design low power consumption chips [3] and high efficient batteries to improve the performance of portable wireless devices. Some engineers design power-aware algorithms to efficiently use batteries or to balance the energy consumption in the network [2,7,11,12,15]. Many protocols are designed concerning device energy conservation, such as Minimum Total Transmission Power Routing (MTPR), Minimum Battery Cost Routing (MBCR), Min-Max Battery Cost Routing (MMBCR) and Conditional Max-Min Battery Capacity Routing (CMMBCR) [13]. These schemes focus on optimizing routes for minimum energy consumption to save power of a battery-powered terminals in ad hoc networks, detailed in [10]. The other researchers focus on power control to create a desired network topology [9]. They attempt to maintain a connected network topology with minimum energy consumption.

We propose a power-based source routing (PBSR). The routing scheme is an on-demand source routing and is realizable in portable wireless device. It adjusts transmission power depending on the change of the network topology to keep the connectivity among nodes in the network. PBSR has some advantages of throughput and average energy consumption in networks. By the simulation results, we analyze the characteristic of PBSR. With changes of the parameters in the routing scheme, its components' contribution to the protocol performance is shown under different networking conditions.

The paper is organized as follows. In section 2, we will describe the Power-based Source Routing (PBSR). Section 3 shows the simulation model and results and is followed by the conclusion in section 4.

2. THE PBSR PROTOCOL

2.1. *Protocol Overview*

PBSR is a reactive source routing [16] and is driven by three events. Each node should keep a routing table which indicates the active paths in order to reach a destination. When a source node begins to send data packets to a destination, it checks its routing table to find a route to a destination. If a valid route for the destination of the data packets exists, it fills the route in IP headers of data packets and transmits data packets.

Firstly, for a node to work in an ad hoc network, using PBSR protocol, it needs to keep three tables which include all routing and management information. They are a Routing Table, a Neighbor Table and a Request Table.

- *Routing Table*—In PBSR, each node has a routing table to store routing information of received route reply messages. Each active route is an entry in the routing table. Each entry has four fields which are a destination node ID, a route timer, a hop count and a path to the destination. A destination may have several entries in a routing table.
- *Neighbor Table*—A node's neighbor table stores the information of nodes which can be heard by the node. Each entry in neighbor table has two fields which are neighbor ID and a neighbor timer. A node gets the information of node degree that is the number of neighbors from its neighbor table to adjust its transmission power.
- *Request Table*—A node's request table recodes the information of route request messages which is transmitted by the node to avoid request flood. Each entry in quest table has two fields which are the

table has two fields which are the destination ID for the searching route and the sequence number of the request. The sequence number of a request distinguishes those different requests to the same destination.

Secondly, we use three timers to refresh the route states. They are Route Timer, Neighbor Timer and Mode Timer.

- *Route Timer*—Route Timer accounts the time when a route idles in a routing table and triggers a route update process. It controls a route's life time.
- *Neighbor Timer*—Neighbor Timer accounts the time when a neighbor node is active and triggers a neighbor table update process. It controls a neighbor's life time.
- *Mode Timer*—Mode Timer accounts the time when a node has no data packets to transmit and triggers the node into Sleep Mode.

Thirdly, we introduce PBSR work mode and describe an overview of the three drive events which are Data Transmission, Route Discovery, and Route Failure.

- *Data Transmission*—When a node has data to send, a procedure called Data Transmission is required. At the source node, which data packets generate, the routing table is looked up to find a valid route entry that indicates the path to reach the destination of the data packets. If, however, there is no route information available, a procedure called Route Discovery is invoked to establish a route to the destination. When the route to the destination is ready, the data packets are transmit along the route. In addition, a node that receives a data packet determines whether it is expected intermediator. If yes, the data packet is forwarded to the next hop on the route in IP header of the data packet. If no, the packet is aborted.
- *Route Discovery*—When a node send a Route Request message to establish a route, a procedure called Route Discovery is triggered. A node which receives a request helps to propagate the request if 1) the request has not been forward previously and 2) the node is not the destination of the route request. When a request arrives in its destination, a Route Reply message is sent to the source of the request along the reverse path which gets from the request. In the other case, when a node which receive a request send a Route Reply message to the source of the request if it lookups its route table and finds a route to the destination of the request. In addition, a node which receives a reply message record the routing information in its routing table if the route information is newer than that in its routing table.
- *Route Failure*—When a node receives a link break message from the link layer, a procedure called Route Failure is invoked. A node which detects a link break send modifies its routing table and send a Route Error message along the reverse path to the source. When a node which is a hop in the reverse path receives a error message, it modifies its routing table and forwards the error message.

2.2. *The Strategy of the Transmission Power Adjustment*

We designed a strategy of the transmission power adjustment in PSBR. In the power adjustment strategy, we define the node degree and a method of power adjustment. The node degree is the number of the node's neighbors. The method adjusts the transmission power of the node depending on the events. When a node is the source or the destination of data transmission, its transmission power is increased to the highest value. When the node is an intermediator to forward data packets, it adjusts its transmission power to keep the desired node degree. And when the node idles for a period, its transmission power is decreased to the lowest value.

2.2.1. Basic information

Rmanathan and Rosales-Hain proposed a distributed heuristics for topology control, namely Local Information No Topology (LINT) [9]. In LINT, they got a simply result to gain the desired transmission power which is used to keep better connectivity in the network topology. By their work, we get a method to control the transmission power. Now we review simply the result.

We assume that all neighbors are bidirectional neighbor. Bidirectional neighbor means the link between the neighbor and the centre node is bidirectional. Based on the propagation models [17], n is the path loss exponent and depends on the surroundings. The value of n is about between 2 to 5. In our experiments, we use 4. We can list the propagation loss function Eq.(1),

$$\begin{aligned} &l(r) = l(r_{th}), \qquad if \quad r < r_{th} \\ &l(r) = l(r_{th}) + 10 \cdot n \cdot \log_{10}(\frac{r}{r_{th}}), \qquad if \quad r \geq r_{th} \end{aligned} \tag{1}$$

where r is the distance, r_{th} is a threshold distance below which the propagation loss is a constant.

Let p_d and p_c denote the targeted transmission power and the current used transmission power, respectively. Let d_d and d_c denote the desired node degree and the current used node degree. Let r_d and r_c denote the communication range of the node with the targeted power p_d and the communication range of the node with the current power p_c, respectively.

We assume that the nodes are uniformly distributed in the network range and the density of the network is *den*.

Then,

$$\begin{aligned} d_c &= den \cdot \pi \cdot r_c^2 \\ d_d &= den \cdot \pi \cdot r_d^2 \end{aligned} \tag{2}$$

Let *rs* denotes the receiver sensitivity of the radio. Then,

$$\begin{aligned} &p_c - (l(r_{th}) + 10 \cdot n \cdot \log_{10}(\frac{r_c}{r_{th}})) = rs \\ &p_d - (l(r_{th}) + 10 \cdot n \cdot \log_{10}(\frac{r_d}{r_{th}})) = rs \end{aligned} \tag{3}$$

We substitute for r_c and r_d from Eq.(2) and simplify Eq.(3). We get the result Eq.(4).

$$p_d = p_c + 5 \cdot n \cdot \log_{10}(\frac{d_d}{d_c}) \quad (4)$$

2.2.2. Power adjustment method

In our routing scheme, a node has three running modes depending on its transmission power. They are:

- *Source-Destination Mode*—in the Source-Destination mode, the transmission power of a node is increased to the maximum values (the upper limit);
- *Intermediate Mode*—in the Intermediate Mode, the transmission power of a node is changed between the lower limit and the upper limit. A node adjusts its transmission power by Eq. (4) to keep connectivity of the network;
- *Sleep Mode*—in the Sleep Mode, the transmission power of a node is decreased the minimum value (the lower limit).

The transmission power of all nodes is set to the minimum value (the lower limit) initially. When a data packet will be transmitted at the source node, the transmission power of the source node is augment to the maximum value (the upper limit).

When a node receives a request packet and decides to broadcasts it, it uses Eq. (4) to adjust its transmission power and then broadcasts the request packet. When the request packet reaches its destination node, the destination node increases its transmission power to the maximum value and sends a reply packet along the reserve path in the request packet to the source node. When the data packet drop occurs, a route error packet is sent, the node adjusts its transmission power using Eq. (4) and then sends the route error packet. When any packets that include data packets and route packets are transmitted at a node, the node should reset its Mode Timer. If the value of the Mode Timer reaches the selected threshold, the node decreases its transmission power and enters Sleep Mode.

In short, when a node will transmit a packet except for the route error packet, if the node is the source node or the destination node for the packet, the node runs in Source-Destination Mode, however, if the node is neither the source node nor the destination node for the packet, the node runs in Intermediate Mode. When a node transmits a route error packet, it will runs in Intermediate Mode. If a node stops to transmit packets for a long time, it enters Sleep Mode to save energy. Therefore, by the strategy of the transmission power adjustment, the connectivity in the range of the active route between a source node and a destination node can be kept to the desired state.

3. SIMULATION AND ANALYSIS

3.1. *Simulation Mode*

The PBSR scheme was implemented within the Global Mobile Simulation library [14]. The GloMoSim library is a scalable simulation environment for wireless network systems using the parallel discrete-event simulation language called PARSEC [1]. In our experiments, IEEE 802.11 [4] was used as the MAC layer. We used the two-ray propagation pathloss model. It uses free space path loss (path loss exponent is 2.0, sigma is 0.0) for near sight and plane earth path loss (path loss exponent is 4.0, sigma is 0.0) for far sight.

In most of the experiments, the network model consists of 50 nodes whose communication ranges are from 100 to 300 meters and channel capacity is 2 Mbits/sec. The simulation area is 1500x300 square meters. Each simulation executes 10 minutes of simulation time. The nodes in the simulation move according to the ‘random waypoint’ model. At the beginning of the simulation, each node waits for a pause time. Then it randomly selects its destination and moves to this destination with a speed that varies between 0.9v to 1.1v where v is the mean speed. When it reaches the destination, it pauses again and repeats the above procedure until the end of the simulation.

The traffic is UDP session and the size of data packet is 512 bytes. During the whole simulation time, the number of communication pairs is 10. We used different seed numbers to run each experiment and averaged measurements over these runs.

3.2. *Simulation Results and Analysis*

Our experiment reports the performance of PBSR over different parameters and compares PBSR with DSR. In the paper, two performance metrics are measured:

- *Data Packet Delivery Fraction*--The ratio of the data packets received by the destinations to those transmitted by the sources (shown by solid line);
- *Average Energy Consumption of Data Packets*--The average energy consumption of a node used to transmit/receive a data packet (shown by dashed line).

As we know, when desire node degree is bigger, the connectivity of the network topology is better. The destinations receive more data packets, but they cost more energy to reach the desire degree (shown in Fig. 1).

The influences of three timers’ parameters are shown in Fig. 2, Fig. 3 and Fig. 4. When neighbor life time is short, the neighbor tables are modified frequently and some neighbors may be lost. Due to the transmission power are changed, network topology is changed. Some packets are lost and nodes cost more energy to transmit packets. When neighbor life time is long, the connectivity of the network topology cannot keep desirable condition and the performance of the network is influenced. The effects are shown in Fig. 2. In Fig. 3, the performances are slightly influenced by different route life times. When route life time is short, nodes spend more time and more energy on building routes. When route life time is long, more packets are lost due to stale routes in the route tables. The effects of node's active time relate to their speed (shown in Fig. 4). When nodes move slowly, the network topology change slowly. The short node's active time can save energy and decrease interference among nodes. When nodes move fast, the long node's active time can keep the connectivity of the network and decrease the packet loss. Hence, the shorter node's active time have better performance at slow speeds and the longer node's active time have better performance at high speeds. In Fig. 5, we can find the total effects of the three times. In Fig. 5, '+' marks the results when the three times are unlimited long. Under the condition, the performances are worse than that of the three definite values (marked by 'x').

We select a similar on-demand source routing, DSR [5,6], to compare with PBSR. DSR is introduced by the mobile ad hoc networks working group [8], which is an active Internet Engineering Task Force (IETF) working group.

PBSR and DSR are the source routing operated by on-demand scheme. However, they are some differences. Firstly, in DSR, the transmission powers of all nodes keep a constant. In PBSR, every node's transmission power waves in a range. Secondly, PBSR uses a route timer to refresh the route table. The method avoids the stale route in the route table comparing with DSR. Thirdly, PBSR uses neighbor table to record neighbor information to help the transmission power adjustment.

The reflection of the differences between DSR and PBSR is demonstrated in the simulation. Compared with DSR, PBSR has high throughput and small average energy consumption (shown In Fig. 5). Especially, when nodes move, PBSR presents the great advantage than DSR.

4. CONCULSION

We propose a novel reactive power-based source routing scheme which adjusts the node's transmission power to maintain the connectivity of the network topology and refreshes nodes' states to follow the variation of the network topology. With the change of the parameters, the PBSR shows different performances. We need to select the suitable parameters depending on different network conditions. Especially, PBSR have far better performance in ad hoc communications than DSR. In the future work, we will refine PBSR's components to improve the performance of the protocol.

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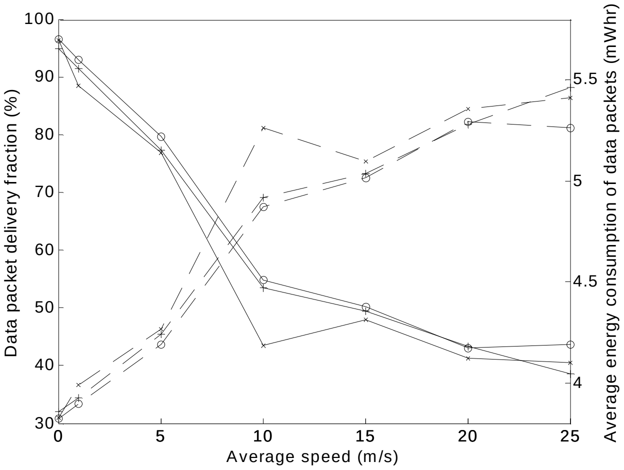

Fig. 1. Data packet delivery fraction and average energy consumption of data packets with different node degrees, i.e. 3 (x), 4 (+) and 5 (o).

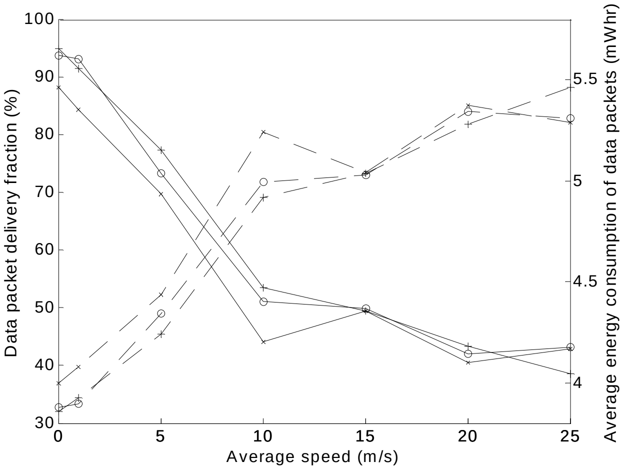

Fig. 2. Data packet delivery fraction and average energy consumption of data packets with different neighbor life time, i.e. 5(x), 10(+) and 30(o) seconds.

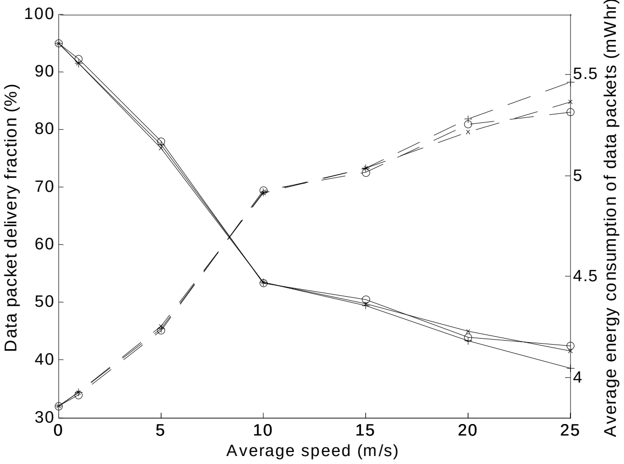

Fig. 3. Data packet delivery fraction and average energy consumption of data packets with different route life time, i.e. 5(x), 10(+) and 30(o) seconds.

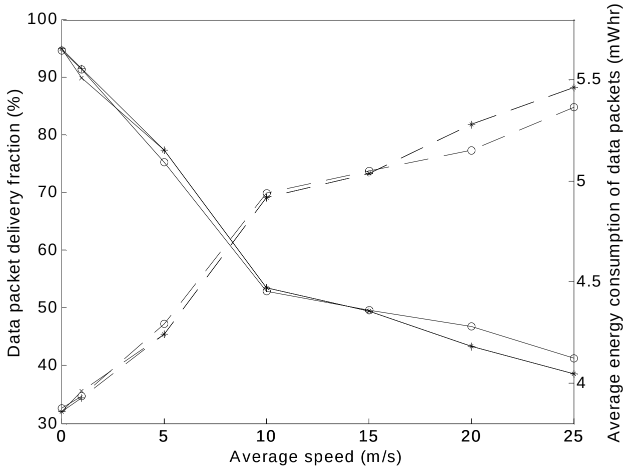

Fig. 4. Data packet delivery fraction and average energy consumption of data packets with different node active time, i.e. 5(x), 10(+) and 30(o) seconds.

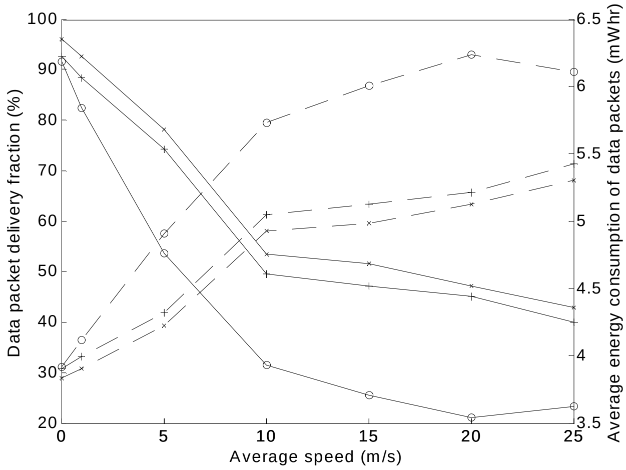

Fig. 5. Data packet delivery fraction and average energy consumption of data packets in different routing schemes, PBSR(x), PBSR-unlimited times(+) and DSR(o).