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A POWER-EFFICIENT MULTICAST ALGORITHM FOR MOBILE AD HOC NETWORK

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ABSTRACT
Mobile Ad hoc Network (MANET) are self-organizing, dynamic topology networks formed by a collection of mobile nodes through radio. The wireless networking environment presents formidable challenges to the study of multicast problems, especially in terms of connection maintenance mechanism and power consumption. This paper focuses on these problems, and proposes an efficient routing protocol called power-efficient preferred link-based algorithm (PPL). The performance metric used to evaluate is energy-efficient and connection maintenance. The result shows that our algorithm performs better than other algorithm in energy-efficient and connection maintenance.

KEY WORDS
Power-efficient, Ad hoc, mobile, multicast and algorithm

1. Introduction

Mobile ad hoc network (MANET) is infrastructureless networks where nodes keep moving all the time, resulting in dynamically changing network topologies. Nodes act as routers/switches as well as end-points. Since MANET does not rely on support from fixed infrastructure, they can be deployed quickly. They can be used for a variety of applications such as immediate collaborative computing, search and rescue operations, and military applications. The majority of these applications require multicast support to establish communication from one or more source nodes to multiple receiving nodes. Designing a multicast protocol for ad hoc networks is a challenging task due to issues such as, mobility of nodes, limited bandwidth avail-ability, error prone wireless links, shared broadcast radio channel, and hidden and exposed terminal problems [1].

Current multicast routing protocols for mobile ad hoc networks can be classified into two categories, tree-based protocols and mesh-based protocols. Mesh-based protocols have high packet delivery ratios compared to tree-based protocols, but incur more control overhead. Though the control overhead involved in tree-based protocols is low, the performance in terms of packet delivery ratio of such protocol decreases with increasing mobility. Therefore, an algorithm is introduced in [1]. The algorithm does well in tree maintenance, and reduces control overhead. But the implementation of this algorithm leads to excessive energy consumption.

Due to energy-efficient, another algorithm was proposed in [2], which did well in tree construction with very low energy consumption. Unluckily, the algorithm was only appropriate in tree construction and assumed location of each node was fixed. Obviously it is not practical.

This paper focuses on better tree maintenance and energy-efficient. New algorithm takes advantage of preferred link-based connections to reduce control overhead and implement tree maintenance mechanism. Different from previous algorithm, the metric of selecting preferred link is energy-efficient oriented.

2. Multicast in MANET

2.1 Key design issues for multicast protocols in MANET

The design of a multicast protocol is a challenging task, because of continuous mobility of nodes with limited energy resources, limited bandwidth availability, error prone shared multicast channel, hidden terminal effect, and limited security. The following are some of the important issues involved [1]:

Robustness: because of mobility of the nodes, link failures are quite common in MANET. Data packets sent by the source may be dropped resulting in low packet delivery. Hence, a multicast routing protocol should be robust enough to sustain the mobility of the nodes and achieve a high packet delivery ratio.

Power management: MANET consists of a group of mobile nodes, each node having limited battery power. A MANET multicast routing protocol should use mini-mum power by minimizing the number of packet transmissions. To reduce memory usage, it should use minimum state information.

Efficiency: In the Ad hoc network environment, where the bandwidth is scarce, efficiency of the multicast protocol is very important. Efficiency is defined as the ratio between the total number of data packets received by the receivers and the total number of (data and control) packets transmitted in the network.

Control overhead: For keeping track of the members in a multicast group, ex-change of control packets is required. This consumes a considerable amount of bandwidth. Since bandwidth is limited in MANET, the design of a multicast protocol should be in such a way that the total number of control packets transmitted for maintaining the multicast group is kept to a minimum.

2.2 Key design issues for PPL

The key issues involved in PPL protocol is following:

Efficiency: Our power-efficient preferred link-based multicast protocol (PPL) is a tree-based receiver-initiated protocol. Hence, each member node by itself is responsible for getting connected to the multicast source. The main advantage of a receiver-initiated multicast protocol is that the responsibility of maintaining the multicast tree is lifted off from the source node. We use a hard state approach for maintaining the tree and hence the overhead of periodic flooding is eliminated.

Longest time the network works: Most energy resource for mobile embedded device is battery now. But the life of battery is limited. So how to prolong the time networks work is the important issue what we think about. Since the power cost for local computing in each node is different, PPL consider no more than the cost of connection maintenance. Remain energy of each node is another key issue. In PPL, Link Cost Parameter is generated as:

$$Cost(n_i, n_j) = \frac{d^{\theta}(n_i, n_j)}{\lambda * Min\{Rm_i, Rm_j\}}$$

Node i and j are denoted by n_i and n_j, the distance between them is denoted by $d(n_i, n_j)$, θ is constant. When the distance is short, θ=2. When the distance is long or obstacle in the way, θ=4. In the experiment of this paper, θ=2. The remain energy of Nodes i and j are denoted by Rm_i and Rm_j, λ is the parameter of the remaining energy, and λ=1 in the experiment of this paper.

Robustness: In previous tree-based multicast protocol, there is only one path between the source node and each receiver node. However, MANET is a mobile-based network. Connections unavailable occur frequently, which leads to the main problem of connection maintenance in previous tree-based multicast protocol. PPL adopts an adaptive distributed connection maintenance method. A NNT (Neighbours' Neighbour's Table) and a PPT (Power-efficient Preferred Table) is maintained by each node to record local topology. In this way a node has access to its local two hop topology information, which it uses for efficient routing and tree maintenance

3. Description of PPL Protocol

3.1 Key data structure

JOIN_QUERY Message: This message is generated by receiver node which initializes multicast session. In message transferring processing, JOIN_QUERY is satisfied by the following issue:

The protocol assumes promiscuous mode support at the MAC layer. When a node operates in the promiscuous mode, it can listen to and extract information out of packets that it hears, that may not be actually intended for it. Hence, in the promiscuous mode, NNT is easy to create in each node.

When each node receives JOIN_QUERY message sent by immediate predecessor, it forward message to nodes in its PPL, which is generated by PPA (power-efficient preferred algorithm), rather than broadcasting.

Each node buffers JOIN_QUERY message, Buffering of JoinQuery helps in reducing the control overhead in certain scenarios. Consider the example shown in Fig. 1. Here the control message travels from n1 and n2 to n4. Unique path between 3 nodes passes through n3. If two member nodes n1 and n2 initiate JoinQuery for the multi-cast source McastSrc to n4, then only the first JoinQuery that reaches the boundary node of n3 is forwarded:

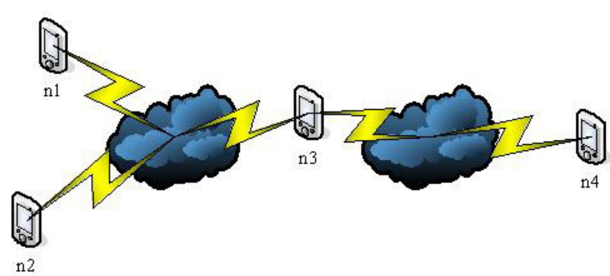

Figure 1: An Example for buffering JOIN_QUERY

NNT Table: Each node maintains information about its neighbours and their neighbours in a table called Neighbour's Neighbour Table (NNT). In this way a node has access to its local two hop topology information, which it uses for efficient routing and tree maintenance.

PPT Table: Longest time for the network working is the goal of PPL protocol. PPT (Power-efficient Preferred Table) Table, which records next hops preferred, is generated by PPA. In the experiment of this paper, the number of preferred next hops is 2.

3.2 The Implementation of PPA

When each node receive JOIN_QUERY message and be notified that it is in the PPT table of its predecessor node, it should generated PPT Table of its own. Obviously, this process is involved by each initial node (receiver node). The Algorithm called power-efficient preferred algorithm, namely PPA, is described below:

Step 1: When receiver node d initializes JOIN_QUERY, best paths, namely preferred next hops in PPT (Power-efficient Preferred List), are generated.

A: Initialize Cost Matrix Cost(n_i, n_j):

If (n_i and n_j are neighbors),

then $Cost(n_i, n_j) = \frac{d^{\theta}(n_i, n_j)}{\lambda * Min\{Rm_i, Rm_j\}}$;

Else Cost(n, □n_j) = +∞;

B: Initialize CostSum[i] and Found[i], CostSum[i] denotes the total cost of transferring from receiver node to node n_i. Found[i] denote whether CostSum[i] of node n_i is final.

CostSum[i]= Cost(n_i, n_j);
Found[i] = FALSE;

C: Choose the node with minimum CostSum[i] and without found, ∑denotes which nodes of current topology local node must considers. For example, in step 1 of receiver node, ∑ means total nodes. And in the other step, current node will ignore nodes which have been found, namely in PPL list of previous node.

u = chooseMin(CostSum, ∑, Found);
Found[i] = TRUE;

D: Each time, a new node is added to PPT, CostSum should be updated:

For(w=0;w<n;w++)
If(!Found[w])
If(CostSum[u] + Cost(n_u, n_w) < CostSum[w])
CostSum[w] = CostSum[u] + Cost(n_u, n_w)

E: Each node must circulate step C□D, until source node is found.

F: After PPTs in every node are generated from receiver node (initial node) to send node (source node), Assume node j in PPL path is denoted by PPL_j (receiver node is denoted by PPL_0) and the best path is denoted by PPL

Step 2: Each node in PPL must calculate backup PPL, denoted by PPL_{bk}, with same algorithm in Step 1. ∑ in Step 2 is denoted by:

$$\sum = \sum - \sum_{o \le x \le i+1} PPL_x$$

Step 3: record backup PPL_{bk} and Δ_{dif}, here Δ_{dif}=CostSum(PPL_{bk})-CostSum(PPL), in node i. In the experiment of this paper, the number of preferred next hops is 2.

3.3 Strategy for Connection Lost

As shown in Fig 2, if node PPL_j find the connection to PPLj+1 is lost, it will lookup whether PPL_{j+2} is in NNT. If yes, it must check whether the cost of route switch with NNT is within limited. If so, route switch is easy to be implemented by NNT. Other than, PPL_{bk} is selected. Here, β is Strategy Select Parameter.

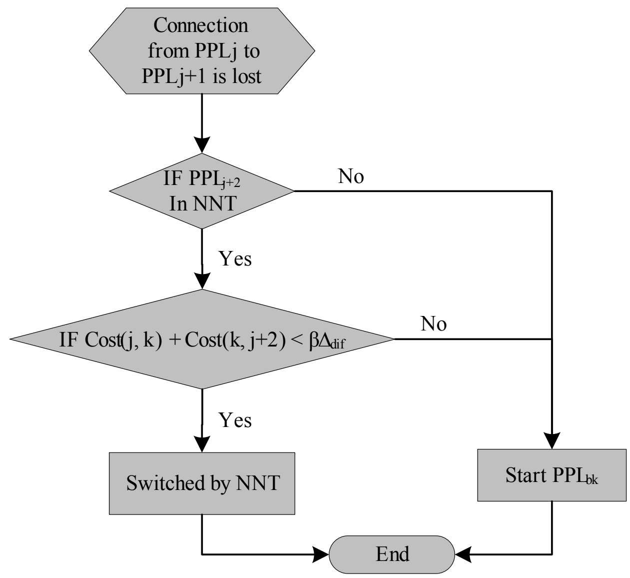

Figure 2: Strategy for Connection Lost

4. Performance Analysis

The performance of our proposed protocol is evaluated by carrying out extensive simulation studies. The simulation tool used was GloMoSim. The MAC protocol used was 802.11 with RTS/CTS.

Free-space propagation model was used. The radio type model assumed was radio capture. The nodes move in a 500m * 500m area. The mobility model considered was random way points. According to this model, a node randomly selects a destination from the physical terrain. It moves in the direction of the selected destination at a speed uniformly chosen between the minimum and the maximum speeds defined initially. Once it reaches its destination, the node stays there in a certain time period (pause time). It then repeats the process to select another destination and moves towards it at a specified speed v. The pause time was taken by 30s. The initial net-work topology consist nodes distributed randomly in the area. The radio transition range was taken as 150m. Channel capacity was taken as 2Mbits/s. Each simulation runs for

5000s and each multicast session run for 200s and iterate for 25 times. A multicast session randomly selects disjoint nodes. Final result was averaged over more than 50 iterations. In all simulations in the experiment, a single multicast group with only one multicast source is considered. And the parameters in proposed protocol should be assumed. θ in link cost parameter was taken as 2. λ in link cost parameter was taken as 1. β in Strategy Select Parameter was taken as 1.2.

The performance metrics used are follows.

Time maintenance: The time most nodes in the network work. The metrics of the term "most" in this experiment is 80 percents. If more than 20% nodes stop working due to lack of energy, the network was assumed as stop.

Efficiency of Data packet delivery ratio: The ratio of the average number of data packets received by the member nodes to the number of data packets transmitted by the multicast source. Efficiency of Packet delivery ratio $=\left(\left(\sum R_m\right)/(N-1)\right)/T_s$, where N is the group size, R_m is number of packets received by members, and Ts is the number of data packets transmitted by the multicast source. Here, the multicast source is not considered a member.

We compare our simulation results with Bandwidth Efficient Multicast Routing Protocol (BEMRP) and Multicast Incremental Power algorithm (MIP). Like PPL protocol, BEMRP and MIP is also a tree-based receiver-initiated multicast protocol. But MIP is a protocol, which assumes nodes should not move. We have chose MIP for our comparison because MIP focus on power consumption with the same goal of proposed protocol.

Table 1: Mean of time network works with same initial power at v = 0.1 m/s

Group Size	BEMRP (sec)	MIP (sec)	PPL (sec)
10	2537	3754	3589
30	2512	3704	3671
100	2496	3697	3726

Table 2: Mean of time network works with same initial power at v = 1 m/s

Group Size	BEMRP (sec)	MIP (sec)	PPL (sec)
10	2501	3417	3513
30	2497	3311	3656
100	2461	3174	3749

Table 1 summarizes mean time network works with same initial power among BEMRP, MIP and PPL. As shown, the time BEMRP works is less than those of MIP and PPL distinctly. After all, BEMRP didn't focus on power efficiency. For MIP and PPL, when the group size is 10, PPL is a little less power-efficient than MIP. But the performance of PPL improves as group size grows. Owe to the flexibility of strategy selecting between NNT and PPT, re-connection is easy to implement in PPL protocol. And less power is lost in connection maintenance. As shown in Table 1, the trend of three algorithms is more less the same. But the time MIP works decreases. The performance of MIP declines seriously badly owe to the lack of mobile connection maintenance. When nodes move, a great deal of energy lost in tree reconstruction. Therefore, the performance of Table 2 declines. This trend will be further indicated in next experiment.

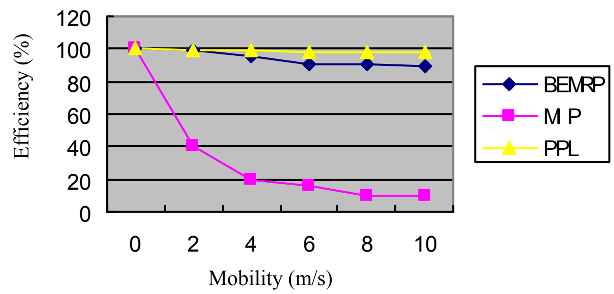

Figure 3: Efficiency vs. mobility for a 100-node network

As shown in Fig 3, when mobility is introduced, the efficiency of Data packet delivery ratio of MIP declines seriously badly, besides time maintenance, owe to the lack of mobile connection maintenance in MIP. The network is thrashing, and nodes are busy for tree reconstruction. Many packets are lost for un-connection of network. However BEMRP and PPL are good at mobility. More, PPL is a little better than BEMRP, thank for the flexibility of strategy selecting between NNT and PPT in many-node network.

Above experiments summary that PPL consider no more than the cost of connection maintenance. Remain energy of each node is considered too. With PPA algorithm and the flexibility of strategy selecting between NNT and PPT in many-node network, the minimum energy is cost in each tree construction and maintenance. The experiments show that PPL do well in both Efficiency of Data packet delivery ratio and energy-efficiency.

5. Conclusion and Future Work

This paper focuses on connection maintenance mechanism and power consumption, and proposes an efficient routing protocol called power-efficient preferred link-based algorithm (PPL). Strategy for connection lost, using selecting between NNT and PPT, make connection maintenance more robust. And PPA focuses on power-efficiency and longer network work time. The result shows that the algorithm introduced in this paper performs better than other algorithm in energy-efficient and connection maintenance.

Current version of this algorithm is not very quick at connection construction phrase. Future work includes decreasing the time of connection construction and decreasing the amount of control packets.

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