Computer Communications 32 (2009) 1631–1641

Contents lists available at ScienceDirect

Computer Communications

journal homepage: www.elsevier.com/locate/comcom

A passive tree-based backbone construction scheme for MANETs

Zhen G. Gao [a,*], L. Wang [b]

[a] College of Automation, Harbin Engineering University, No. 145, NanTong Street, NanGang District, Harbin 150001, China
[b] Department of Computer Science and Technology, Harbin Institute of Technology, Harbin 150001, China

ARTICLE INFO

Article history:
Received 2 September 2008
Received in revised form 1 June 2009
Accepted 2 June 2009
Available online 10 June 2009

Keywords:
Backbone
Tree
Broadcast scheme
MANET

ABSTRACT

Backbone-based broadcast schemes are effective in alleviating the broadcast storm problem in mobile ad hoc networks (MANETs). However, periodically hello packets used to maintain a backbone usually lead to extra control overhead. In this paper, passive tree-based backbone construction scheme (PTBCS) is proposed as a backbone construction scheme for MANETs. Different from other schemes, each node in PTBCS determines its role by intercepting packet transmissions in the air during a special waiting period. Hence, its most remarkable advantage is that there are no periodical packet transmissions specially for backbone construction. The property that the nodes selected by PTBCS make up a connected dominating set (CDS) of the network is proven with several ideal assumptions. Simulation results show that PTBCS is effective when compared with some other typical backbone construction schemes.

1. Introduction

Mobile ad hoc networks (MANETs) [1] are temporary infrastructure-less wireless networks consist of many wireless mobile nodes, which act as both hosts and routers. Broadcasting is a fundamental operation in MANETs. For the broadcast nature of wireless transmissions, flooding is an intuitive way for disseminating information through out a network. Pure flooding requires low complexity algorithm except for a mechanism to detect duplicated packets. This mechanism is commonly implemented by assigning a monotonically increasing number to each packet. However, flooding may result in high broadcast redundancy, much transmission collisions and contentions, which may lead to the collapse of the whole network. This is the so called the broadcast storm problem [2]. Several approaches have been proposed to alleviate the broadcast storm problem in [2]. Among these approaches, backbone-based approach is the most promising one [2], where a backbone should be constructed and maintained periodically to deal with potential topology changes.

However, the construction and maintenance of a backbone lead to extra control packet overhead, which is the main problem of backbone-based schemes. Therefore, in order to resolve the problem, passive tree-based backbone construction scheme (PTBCS) is proposed in the paper. In PTBCS, a node determines its role based on the information gathered by intercepting packet transmissions during a period called role determination period. There are no periodical packet transmissions specially for backbone construction.

* Corresponding author. Tel./fax: +86 451 82519954.
E-mail addresses: gag@hrbeu.edu.cn (Z.G. Gao), lwang@ftcl.hit.edu.cn (L. Wang).

The rest of the paper is organized as follows: Section 2 shows a brief review on related works. Section 3 describes the operation of PTBCS. In Section 4, the property that nodes selected in PTBCS make up a connected dominating set (CDS) of a MANET is proved. In Section 5, simulations are performed to compare the performances of PTBCS and some other typical backbone constructions schemes. Section 6 concludes the paper at the last.

2. Related works

The basic idea to alleviate the broadcast storm problem is to inhibit some selected nodes from rebroadcasting. Approaches to resolve the broadcast storm problem can be classified into five classes: probability-based approach, counter-based approach, distance-based approach, position-based approach, and backbone-based approach [2,3].

2.1. Probability-based approach

Probability-based approach is the simplest way to alleviate the broadcast storm problem. On receiving a new broadcast packet, a node rebroadcasts the packet with probability P. If P is smaller than 1, packet redundancy will be reduced. This approach is effective. However, packet delivery ratio is not guaranteed and the optimal value of P is not known. This approach is analyzed in [4].

2.2. Counter-based approach

A counter-based scheme tries to reduce packet redundancy by utilizing the statistics of duplicated packets received by a node.

0140-3664/$ - see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.comcom.2009.06.001

Before rebroadcasting a packet, a node waits for a random period. During this period, the number of duplicated packets received is tracked. If the number exceeds a predefined threshold, the current node will not rebroadcast the packet. Receiving duplicated packets implies that several neighbors of the current node have already received the packet. If many duplicated packets have been received, a rebroadcast may be inefficient in expanding packet coverage and hence can be prohibited.

2.3. Distance-based approach

In a distance-based scheme [2], a node waits for a predefined time before making decision whether to rebroadcast a packet or not. During the waiting period, each time when receiving a duplicated packet, the distance between the current node and the sender is evaluated, then the minimal distance among all distances between the current node and all these senders is updated. After the period has elapsed, if the minimal distance is smaller than a predefined value, the rebroadcast will be canceled. A distance-based scheme requires distance information, which requires additional hardware. Additionally, it is less efficient than a position-based approach.

2.4. Position-based approach

A position-based scheme greedily appoints the nodes that can extremely extend packet coverage to rebroadcast. However, the scheme requires positioning hardware components, which is relative expensive to some simple nodes. This approach is used in [5,6].

2.5. Backbone-based approach

In a backbone-based scheme, some nodes are selected to form backbones in MANETs. Only nodes belonging to the backbones should rebroadcast packets. Because of the highly dynamic topology of MANETs, the backbones should be constructed and maintained through periodically hello packet exchanging.

According to the method for backbone construction, backbone-based schemes can be classified into three subclasses: cluster-based approach, self-pruning-based approach and neighbor-selection-based approach.

2.5.1. Cluster-based approach

A cluster is a subset of nodes in a network. A cluster consists of a special node called cluster-head and some other nodes called cluster-members. The cluster-head is responsible to relay packets for its cluster-members and packets from other cluster-heads. The information needed when selecting cluster-heads is gathered from periodical hello packets. Different criterions are used when selecting cluster-heads, such as node ID [7–9], node degree [10,11], link stability [12], battery power, speed, or combinations of them [13,14]. After cluster construction process has finished, some other nodes are selected by cluster-heads to act as gateways, which should rebroadcast every packet it received. Gateways can be selected immediately after the cluster construction process has finished, such as source independent connected dominating set (SICDS) in [15,16], or selected on the fly while performing a broadcast session, such as source dependent connected dominating set (SDCDS) in [15,16].

2.5.2. Self-pruning-based approach

In a self-pruning-based scheme, each node should broadcast hello packets periodically, which contains the sender's ID and the list of its neighbors. By caching hello packets, each node maintains its local topology information. The list of several last visited nodes, called as history information, can be piggybacked into broadcast packets. Basing on local topology information and piggybacked information, a node can determine by itself whether it should rebroadcast the packet or not. If the current node finds that some neighbors have not received the packet, the node should rebroadcast the packet. Schemes proposed in [17–19] adopt this approach.

2.5.3. Neighbor-selection-based approach

In neighbor-selection-based schemes, hello packets and history information in broadcast packets are the same to that in self-pruning-based schemes. However, in neighbor-selection-based schemes, nodes that should rebroadcast packets are selected by the senders basing on local topology information and the history information piggybacked in the packets. Those nodes are selected with the precondition that the current node's 2-hop neighbor set is fully covered. The list of those selected nodes is piggybacked into the packet, and then the modified packet is rebroadcasted. Only those selected nodes are responsible to rebroadcast the packet sent by the decision-maker. Such schemes are proposed in [20].

The efficiency of probability-based schemes in alleviating the broadcast storm problem can be tuned by the rebroadcast probability *P*. Though it is more efficient when *P* is smaller, the coverage of the broadcast packet may be reduced seriously. Counter-based schemes may be efficient in resolving broadcast storm problem. However, counter-based schemes introduce more delay because of the waiting period. Distance-based schemes and position-based schemes could be more effective, but they all require special hardware component. Furthermore, long waiting period remains a drawback of them.

Total dominant pruning (TDP) [20] is the most efficient one among some typical backbone-based schemes [20,21]. Comparing to TDP, the connected dominating set (CDS) scheme proposed in [22] has more information for selecting nodes that should rebroadcast packets. Therefore, CDS may be superior to TDP in terms of dominating node number. However, CDS still rely on periodically hello packets to maintain a backbone.

3. Passive tree-based backbone construction scheme

In PTBCS, nodes change their roles autonomously and asynchronously. Each node operates in three phases in a cycle manner: *Raw Operation phase*, *Role Determination phase*, and *Backbone Operation*

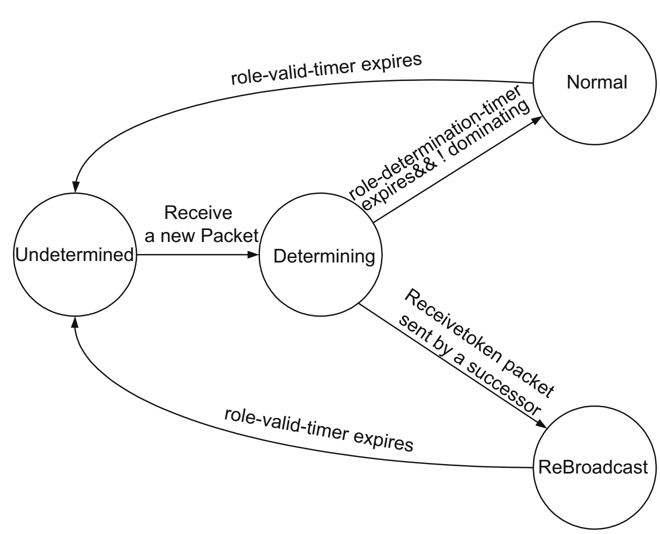

Fig. 1. Asynchronous PTBCS operation cycle of a node.