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A virtual subnet scheme on clustering algorithms for mobile ad hoc networks

Cheng-Feng Tai [a], Tzu-Chiang Chiang [b], Ting-Wei Hou [a,*]

[a] Department of Engineering Science, National Cheng Kung University, Taiwan, ROC
[b] Department of Information Management, Tunghai University, Taiwan, ROC

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ABSTRACT

Resolving the broadcast storm problem is an important issue in mobile ad hoc networks (MANETs). In this paper, we propose an approach for constructing a virtual subnet whose nodes are logically related. The virtual subnet can be spread upon clusters of a MANET. An intelligent agent with a routing filtering table is proposed to assist the best known clustering algorithms, the original Least ID algorithm and the original Highest Connection Cluster (HCC) algorithm, to improve group communication efficiency. Our simulation covers the network factors of hop count, deprave rate, and delay time. The simulation results show that when the proposed intelligent agent is used with the HCC algorithm, the delay time was reduced by 81.84% as compared with flooding, and by 49.25% as compared with the Ad Hoc On-Demand Distance Vector (AODV) routing algorithm. The delay time for the Least ID algorithm assisted by the proposed agents reduced by 81.84% compared to that of flooding and by 50% compared to that of AODV.

1. Introduction

MANET is a mobile ad hoc network which uses wireless communication without infrastructure (Royer & Toh, 1999). MANET is aggregated by a group of mobile nodes attached with wireless signaling devices. Mobile nodes exchange information by relaying packets from their sources to destinations. MANET can be used in many scenarios, such as in disaster recovery and home networking applications. MANET uses broadcasting (flooding) because it is simple and immediate. However, flooding introduces the broadcasting storm problem (Ni, Tseng, Chen, & Sheu, 1999). Because the flooding broadcast requires each receiver node to relay and forward a broadcast message to all of its one-hop neighbors, the number of broadcast packets grows exponentially, as shown in Fig. 1. This leads to the broadcast storm problem, and all nodes are transmitting relay packets to their neighbors, packets collision or are lost. Hence, the network performance is degraded.

Resolving the broadcast storm problem to achieve a shorter packet delay time is an important research issue in ad hoc networks. One approach is to group the nodes into clusters (Chlamtac & Pinter, 1987; Ephremides, Wieselthier, & Baker, 1987). Each cluster has a cluster header and the broadcast is limited within the cluster. Each cluster header manages and maintains communication in its cluster, so the interference of wireless communication is reduced. Chiang, Liu, and Huang (2007) proposed a genetic algorithm based on a sequence and topology encoding framework for both global and local topology discovery of shared multicast trees. This approach has significant advantages to effectively find the optimal solution than the genetic algorithm based on Prufer encoding. Sandrasegaran presented a scheme that uses an expert system for the planning of point-to-multipoint radio access networks to perform a real time multicast scheme (Kim, Choe, Choi, & Park, 2008; Sandrasegaran & Prag, 1999). We propose a new partition scheme to separate the path in an ad hoc network using a fuzzy algorithm (Chiang, Tai, and Hou, 2009). Least ID (Baker & Ephremides, 1981; Baker, Wieselthier, & Ephremides, 1982) and Highest Connection Cluster (HCC) (Gerla & Tsai, 1995; Parekh, 1994) are the major cluster algorithms. The former selects the node of least ID as the cluster head, and the latter selects the node with the maximum number of neighbors as the cluster head. Snapshots of a MANET partitioned by the Least ID and HCC algorithms are shown in Figs. 2 and 3, respectively, where the red[1] nodes are the header nodes.

However, clustering can be of more real-world meanings. Consider the scenario in Fig. 4. There is a task force that consists of a Rescue Team, a Red Cross Society Team, and a Volunteer Society Team. Tasks for the Rescue Team include restore for accident field, traffic control, and search for survivors. Tasks for the Red Cross Society Team is include medical treatment, supply for medicine, and transport for patients. Supply food and comfort for human sympathy are tasks for the Volunteer Society. Suppose that each team-member is equipped with a mobile device. Broadcasting can be done among all the mobile devices either by the Least ID

* Corresponding author. Tel.: +886 62757575x63334; fax: +886 62766549.
E-mail addresses: wowwow.cc@gmail.com (C.-F. Tai), steve312kimo@thu.edu.tw (T.-C. Chiang), hou@nc.es.ncku.edu.tw (T.-W. Hou).

[1] For interpretation of color in Figs. 1-3, 5, 6, 8, 9, 11-16, the reader is referred to the web version of this article.

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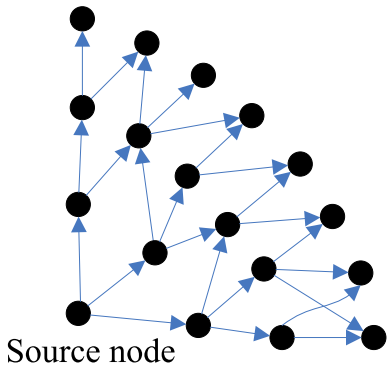

Fig. 1. Scheme of flooding broadcast.

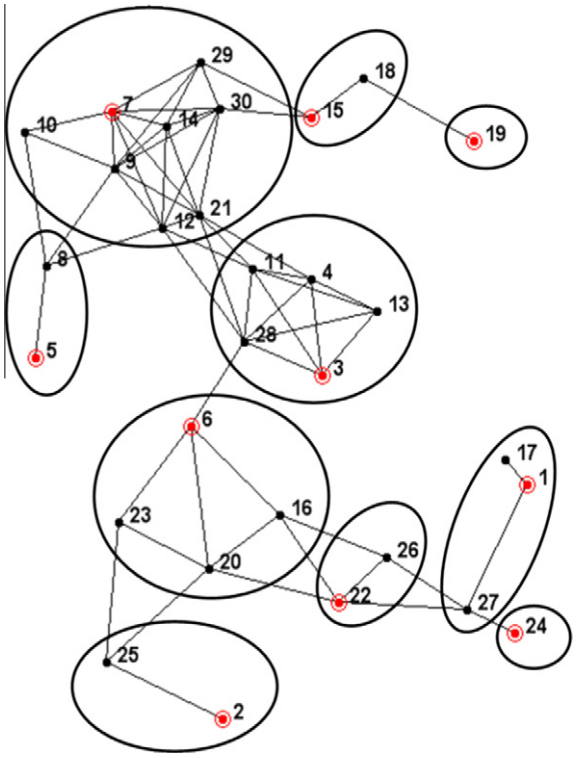

Fig. 2. Clusters constructed using the Least ID algorithm.

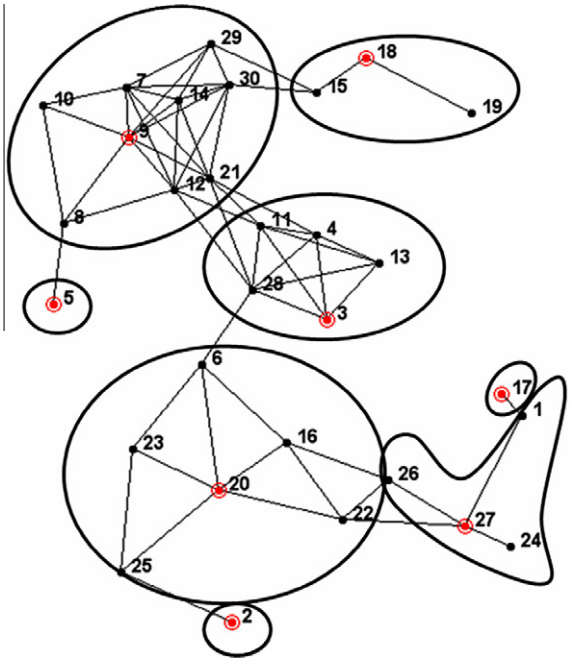

Fig. 3. Clusters constructed by the HCC algorithm.

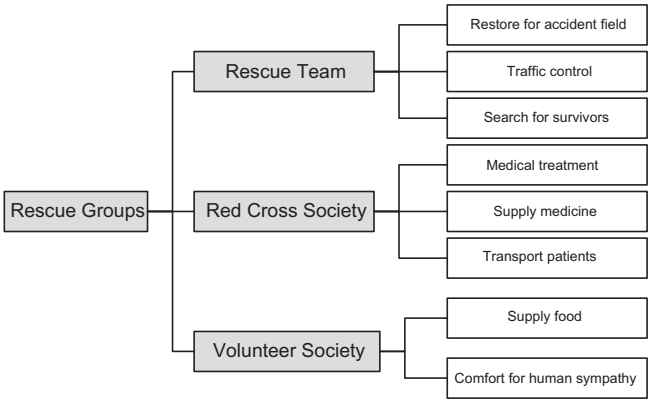

Fig. 4. Real-world groups for disaster rescue.

algorithm or the HCC algorithm. However, the clusters formed by Least ID and HCC algorithms will not be the same as the real-world teams. Hence, there is a need to support group communications for these real-world groups on top of the clusters built on multicast routing algorithms for ad hoc mobile networks.

Hence, we propose a scheme to that supports real-world group communications based on clustering algorithms for MANET. The idea is similar to building a Virtual Local Area Network (VLAN) (IEEE, 1998) in a wired network. The original VLAN scheme for a wired network is shown in Fig. 5(a). The each switch in the wired network as the cluster group. Then we need to assist each cluster head to build and to maintain the VLAN, as shown in Fig. 5(b). Note that there is a key difference: the nodes in MANET can move, while these of a VLAN are fixed. We propose that each cluster header should act as a router and establish the rules of Virtual Subnet Filtering Table in wireless communication. Each cluster header maintains and follows the rules to decide whether to send the received packets to the next cluster header. This scheme can reduce the traffic load of wireless networks.

2. Related works

2.1. Broadcast problem

In an ad hoc network, nodes communicate with each other via multi-hop scheme to transmit and receive messages. Each mobile node either receives packets for itself or acts as a router to forward packets for other nodes.

Each mobile node can join or leave the ad hoc network at any time. Hence, the topology of an ad hoc network changes frequently. To discover mobile nodes and establish communication paths, broadcast is necessary for the pro-active and the reactive routing protocol. For example, the Ad Hoc On-Demand Distance Vector Routing (AODV) (Perkins & Royer, 1999) and Dynamic Source Routing for Mobile Ad hoc Networks (DSR) (Jhonson & Maltz, 1996) use the flooding broadcast.

Flooding (Ho, Obraczka, Tsudik, & Viswanath, 1999; Ko & Vaidya, 2002) is generally used in broadcast. Flooding is simple: each node forwards the received broadcast packet to its neighbors. If the network has n mobile nodes, a broadcast packet would have n cop-