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Computer Standards & Interfaces 31 (2009) 209–218
COMPUTER STANDARDS & INTERFACES
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A fuzzy-based Power-aware management for mobile ad hoc networks

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Received 3 May 2006; received in revised form 22 November 2007; accepted 20 December 2007
Available online 4 January 2008

Abstract

In recent years, people have become more dependent on wireless network services to obtain the latest information at any time anywhere. Wireless networks must effectively allow several types of mobile devices send data to one another. The Mobile Ad Hoc Network (MANET) is one important type of non-infrastructure mobile network that consists of many mobile hosts, usually cellular phones. The power consumption rate and bandwidth of each mobile host device becomes an important issue and needs to be addressed. For increasing the reliability of the manager in Hierarchical Cellular Based Management (HCBM), this paper proposed a Power-aware protocol to select a stable manager from mobile hosts by fuzzy based inference systems based on the factors of speed, battery power, and location. Further, our protocol can trigger a mobile agent to distribute the managerial workload.

Keywords: Mobile ad hoc network; Distribution computing; Routing protocols; Data communication

1. The background and motivation

In general, the mobile host (MH or node) of a traditional fixed wireless network is built by specific intermediaries (ex: mobile station) to communicate with each other. However, the infrastructure can easily be destroyed by external environment, such as natural disasters and wars. Therefore, the Mobile Ad Hoc Network (MANET) is more flexible due to absence of a fixed infrastructure. A MANET consists of mobile hosts that can flexibly and quickly obtain the latest location information for automated battlefield, disaster relief, and rescue situations.

There exist several challenges to the MANET due to its dynamic nature, such as a limited bandwidth, battery power, and communication routing [9,13,16,18–21]. As mentioned, an efficient routing among a set of MHs is one of the most critical issues in MANET. Therefore, the traditional routing protocols [2,4] focusing on the aspect includes the shortest path and cluster methods. The concept of the shortest path method is using the least MHs to forward messages. However, it is difficult to establish co-coordination because the MHs are usually working independently in MANET. In cluster method, the cluster head (manager) can be elected to manage and forward message for MHs within a specific range. Only the manager needs to keep the routing table and other MHs can save the battery power in MANET. Therefore, this paper uses popular cluster method, the Hierarchical Cellular-Based Management (HCBM) is proposed by Chang et al. [2] to assign the manager in MANET.

Unfortunately, the topology of MANET may be destroyed because the manager exhausts its limited energy and bandwidth when overloaded with packets. To prolong the lifetime of manager, the Power-aware manager is invoked by introducing a fuzzy theory inference system [6,25] into the HCBM method. A multi-Mobile Agent (multi-MA) is proposed in this protocol to assist the manager to manage the specific MH when the workload is overloaded.

The rest of this paper is organized as follows. Section 2 illustrates the relevance of the previous work. The details of methodology are shown in Section 3. Section 4 illustrates the results of simulation. The conclusion is presented in Section 5.

2. Previous work

The traditional routing protocols can be divided into two kinds, table and demand driven [4]. In table driven, each MH

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doi:10.1016/j.csi.2007.12.005

has a routing table to route the message. In contrast, the MH in demand driven must find the routing path every time.

The advantage of the table driven routing protocol is that communications can be set up quickly when the source MH wants to send the message to destination MH. This is because each MH must periodically update the latest routing information into the routing table. All MHs must update their routing tables when the MH roams around in MANET. Therefore, this method has additional overhead in network, such as the network congestion and occupies much memory. The related literatures include "Destination–Sequenced Distance–Vector routing (DSDV)", "Clusterhead Gateway Switch Routing (CGSR)", and "Wireless Routing Protocol (WRP)" [17]. Besides, the "Active Route-Maintenance Protocol (ARMP)" [22] is proposed by Tu et al. to periodically detect the connection node status.

On the other hand, the advantage of the demand driven is each MH does not need to note down the routing information in daily work. However, the source MH using the demand driven routing protocol needs to waste more time to set up the routing path. The related researches include "Dynamic Source Routing (DSR)", "Ad Hoc On demand Distance Vector routing (AODV)" [4,15], "Temporally Ordered Routing Algorithm (TORA)" [4,14], and "Associative Based Routing (ABR)" [4].

The routing protocols mentioned above have respective advantages and drawbacks, thus some researchers proposed a hybrid method. The hybrid methods include the "Zone Routing Protocol (ZRP), "GRID" [1,10], and "Hierarchical Cellular Based Management (HCBM) [2]. These hybrid methods can improve the drawbacks of the table driven and demand driven methods to reduce the broadcast storm [12]. A comparison of the routing protocols is shown in Table 1.

For scalability and flexibility, the HCBM and GPS device are used as our backbone to adapt to the dynamic of MANET. HCBM has three critical advantages as follows:

- HCBM can reduce the routing cost similar to that in GRID [1,10]. This is because we can search for MH within a specific range instead of a global search. Therefore, we can more easily manage our MH than other methods.
- The distances among the managers in Fig. 1(a) are equivalent in the HCBM structure. In contrast, the distances among the GRID structure managers are different as shown in Fig. 1(b).

Table 1
The comparison of different routing protocols

Routing protocol items	Table driven	Demand driven	Hybrid
The speed of setting up the connection	Fast	Slow	Medium
Save the power	Worst	Better	Medium
The loading of routing maintenance	Heavy	No	Medium
The performance in the large topology	Worst	Worst	Better
The performance in the small topology	Better	Better	Worst
Related topologies	DSDV, WRP CGST, etc.	ABR, TORA, AODV, etc.	ZRP, GRID, HCBM, etc.

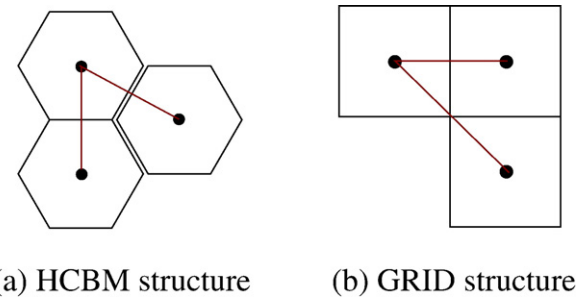

Fig. 1. The strength of transmission power between HCBM and GRID structures.

Each MH has the same transmission power strength in the HCBM structure.
- The source MH can use fewer numbers of mangers to forward messages to destination MH. This is because the signals in the HCBM structure have greater coverage than those in the GRID structure even though the radii are the same. HCBM can also increase the QoS via hierarchical management.

In this paper, an inference system can be used to elect and prolong the lifetime of manager which located in the center of the intra-cell by filtering the factors, such as distance, the average roaming speed and battery power. Further, a multi-Mobile Agent (multi-MA) fuzzy engine is proposed to consider the battery power and bandwidth factors in this paper. This fuzzy technology of our proposed protocol can reduce the Ping Pong Effect [24] among the threshold by triggering the multi-MA appropriately. The manager assignment and fuzzy engine methods are described as next section.

3. Methodology

There are two phases in the proposed method, the Power-aware Manager (PM) election phase and Power-aware multi-MA (PMA) assignation phase. The main job of the PM election phase is electing the appropriate manager for MANET when a management overload exists. The Power-aware multi-MA is elected by the PMA assignation phase to divide the management workload. The assumptions and details of these phases will be described as follows:

- H1: each MH has a unique id.
- H2: each MH has the same transmission radius.
- H3: each MH has the same signal power.
- H4: the communication area can be divided into the cellular (cell) by GPS.
- H5: MHs can periodically receive the current longitude, latitude, and speed from the GPS.
- H6: each MH was distributed equally.
- H7: any MH can ensure the data transmission and receipt successfully.

3.1. The Power-aware Manager (PM) election phase

This phase is divided into three parts. First, the GPS receiver information is used to select a manager for each cell.