Flexible Group Management on Ad Hoc Network using Mobile Agents

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Abstract

In this paper, we propose a flexible group management method on ad hoc networks. Unlike the group management systems on fixed networks, such as NIS and NT-domain, our method does not need centralized servers. So our method is suitable on ad hoc network where not every node can always communicate with the server. In addition, we use mobile agents to represent group information and to manage groups. This enables the users to define group behavior freely, and enables the group management system to manage it. This implies the dynamic group management becomes possible.

Keywords

Group Management, Ad Hoc Network, Mobile Agent, Authentication, Authorization, and Accounting (AAA)

1. Introduction

Usually, in a fixed network, a mechanism for dividing the computers on the network into the logical group – the group management system – is used in order to limit the access to the resources and to control the communication among the groups. For example, NIS (Network Information Service) [1] and NT-domain [2] are popular group management systems used in fixed networks. On such a group management system, the terminals and its users usually belong to several groups. Whenever we want to communicate with other computers, the group information is required to check the authority for the resource access.

Recently, it is getting popular to build a wireless network among mobile computers by using wireless devices such as Bluetooth [3] or Wireless LAN (IEEE802.11b). By using such the devices, direct communication among mobile computers are possible by constructing ad hoc networks. To support ad hoc communication, we have been studied the methods of exchanging and sharing the information among mobile computers [4]. However, the group management on ad hoc networks has not been considered so far. On the other hand, the group management is required as well as the case in the fixed networks in order to check the authority for the resource access. Therefore, it is necessary to consider the group management for ad hoc networks.

The existing group management systems in fixed networks are performed by centralized server. However, in ad hoc networks, network topology changes dynamically, and so not every computer can always communicate with the particular server. Therefore, a group management technique, which does not need the fixed server, is required. Moreover, we consider to the existence of some specific groups to ad hoc networks. We will describe an example of those groups in the following section.

In this paper, we propose a group management method using mobile agents that are adapted to ad hoc networks. As we have described, on ad hoc networks, it is difficult to manage groups by using a centralized server. Therefore, we propose a method that each mobile computer has a group management system and cooperate with each other systems to perform group management in ad hoc networks. In addition, to enable the group management system to define a group behavior freely and manage it, we divide the group management system into a managing membership module and a managing each group's unique information module. We call these modules Group Manager and Group Agents respectively.

Group Manager is installed to every mobile computer, and manages the information about what groups the computer belongs to. This module exchanges the belonging information with same modules on other computes, then each computer will know which computer on the ad hoc network belongs to same groups to which it belongs to. By this member discrimination method, it becomes possible that each computer on the ad hoc networks discriminates the group member similarly.

Group Agent manages the information for each group, such as a group name and so on. Group Agent is implemented by mobile agent. Each agent manages the information and behavior of the group. By using a mobile agent technique, it is possible to implement various ways of group managing by programming. In addition, the group management system can perform more flexibly by autonomy of a mobile agent. For example, it is possible to change a member automatically according to the surrounding situation. This characteristic enables the group management system to manage specific groups to ad hoc networks.

Each member of the group has the group information defined by the agent program code. Because mobile agents can move with the execution state and the program code, in case one adds a member to a certain group, it isn't necessary that the new member has its program code beforehand. By the above mechanism, it is possible to distribute and manage the group information easily.

We make full use of mobile agents to realize a flexible group management.

The rest of this paper organized as follows. Section 2 describes the issues that occur in performing group management on ad hoc networks. Then, we mention the characteristics that the group management system in ad hoc networks should have. In section 3 and 4, we propose the group management method

in ad hoc networks, and in section 5, we show a prototype group management system. Section 6 introduces the related works and Section 7 describes future works. Finally, section 8 concludes the paper.

2. Group Management Issues on Ad Hoc Network

As we described in section 1, the group management system in ad hoc networks should be a system that does not need a fixed server. However, there are another requirements for the group management system. In this section, we introduce some kind of groups that might be useful in ad hoc networks, although it have no use in fixed networks. And then, we describe the functions that are necessary for group management system on ad hoc networks.

In the following, we use a term "node" to express a computer on a network.

2.1. Diversity of Group in Ad Hoc Network

We think that there are some specific groups to ad hoc networks. The following groups can be considered.

- **Conventional Groups used in the Fixed Networks**
  For example, groups depend on organization relation – *Nagoya University group*, *Inagaki laboratory group*, and so on.
- **Ad Hoc Groups**
  To perform ad hoc communication, ad hoc groups are required. Those groups would be used when the person who met by chance want to perform temporary work, such as exchanging the business card.
- **Connection Dependent Groups**
  For example, a group, which consist of only nodes that can directly communicate with a particular node.
- **Location Limited Groups**
  Groups, which membership is restricted to only nodes within particular area. For example, a group that consists of the nodes in the conference room is considered.

The group, which membership dynamically changes according to movement of the node, can be utilized in ad hoc networks. Such kinds of groups are not considered in conventional group management systems in fixed networks. In addition, there might be various kinds of groups that are required in ad hoc networks. It is very difficult to prepare beforehand the every kind of the groups that might be utilized by the group management system. Therefore, the group management method in ad hoc networks must be possible to represent and manage various groups.

As we mentioned above, the group management system in ad hoc networks should have at least following characteristics.

- Ability to manage groups by using no centralized server
- Ability to represent and manage various groups flexibly

3. Distributed Group Management

The group management system for ad hoc networks should not use centralized servers. In this section, to construct group management system using no centralized server, we propose the distributed management technique of group information, and group identifier based membership recognition method. By this technique, it is possible to manage groups without centralized server.

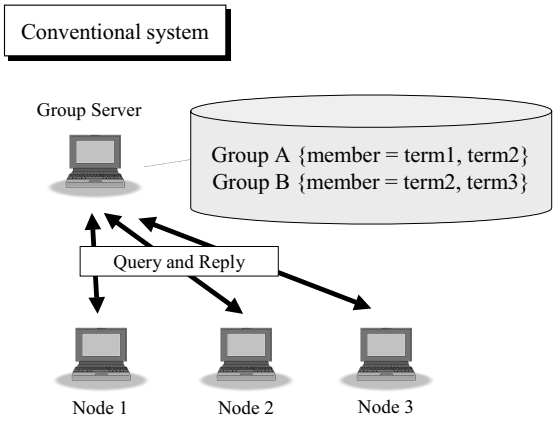


Figure 1: Group Management using the Server

In the following, to simplify the discussion, we assume that the each node is used by one person.

3.1. Distributed Management of Group Information

Usually, in the centralized group management system, for example NIS, the server has group information such as the lists of group name and its membership information (Figure 1). Then, clients of the system could get group information and recognize its membership by querying to the server. When we try to use this method in ad hoc networks, all nodes should be a server and have membership information to enable every node in the ad hoc network to manage groups and get membership information.

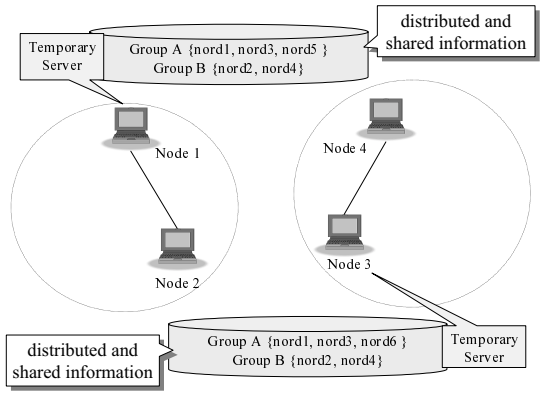
To construct such a group management system, we propose a distributed group management technique. In our method, every node in ad hoc networks are required to install the group management system, called Group Manager (GM). GM manages the information of the groups the node belongs to. In other words, every node that belongs to same group has the information of that group.

3.2. Problem of Membership Recognition

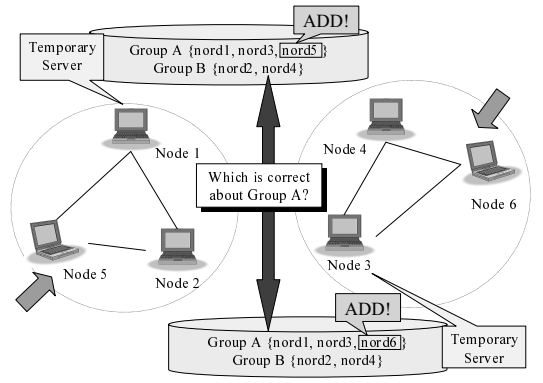
As membership recognition method on distributed situation, we might consider the method that selecting one node in the ad hoc network as a temporary server, and that server manages group information and reply queries from other nodes. If the network topology changes and several nodes cannot communicate with the temporary server, it seems possible for that nodes to get group information by selecting new temporally server. However, this method has a synchronization problem of membership lists.

Since group information is shared data, every temporary server must have same information. So a mechanism to notify of a data update and to synchronize the changed data is required.

On the other hand, in the case that the shared data is changed at same time on separate nodes that cannot communicate with each other, a fatal mismatching of the data may occur (Figure 2). These mismatching are hardly to correct automatically. In the Shimizu's technique [4], the mismatching needs to be correct by human hands. Also, in ad hoc networks, it is impossible to prevent occurring fatal mismatching of shared data



(a) Each temporary server has been synchronized



(b) Joining new member to Group A, and fatal mismatching occurred

Figure 2: Member Recognition Problem using Distributed Member Lists

without any restriction against the authority for data changing.

In the distributed group management, it may possible to prevent occurring fatal mismatching of membership list using some rule that restrict the authority for changing group membership to GM on particular nodes. However, because it makes the group management less flexible, it is not desirable introducing such restriction on the group management system.

3.3. Group Certification based Membership Recognition

To solve the problem we described above, we propose a group management technique based on Group Certification.

In our method, each group has a group identifier that could not been altered easily. We call such identifier "Group Certification". Group Certification proves that the owner node belongs to that group. Therefore, we can define belonging to a group and its membership as follows.

- **Belonging to a group**
  Having the Group Certification of that group in the GM on that node
- **Group membership**
  The collection of the nodes that has same Group Certification in its GM (Figure 3)

GM manages Group Certifications instead of member lists. The group management system does not necessary to have

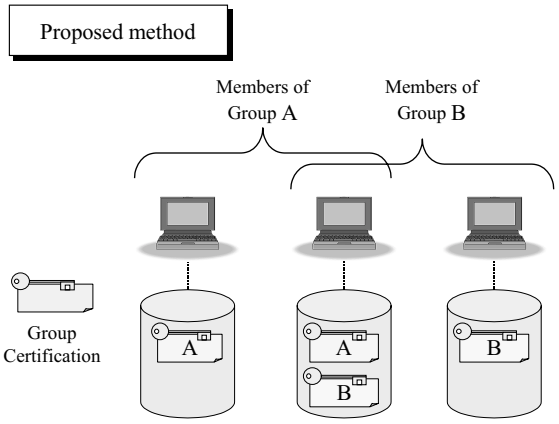


Figure 3: Group Management based on Group Certification

membership lists in our proposal. Each node can obtain the list of group members by exchanging the information about Group Certifications. And, every node in same network can obtain the same membership information of each group.

Otherwise, it is impossible for the node to know complete membership if every member is not in the network. However, the list of group members who are in a network is enough to utilize groups and communicate with them within the network.

3.4. Group Creation

In our method, every node has the authority for creating new group. When node makes a new group, the Group Certification containing the unique ID is created, and it is registered to the GM. To guarantee the uniqueness of Group Certification (ID), we make Group Certification by using the information about the date and time when the group creates and other information. However, to guarantee uniqueness of Group Certification strictly in the whole networks, a group certification server might be required to ensure uniqueness of Group Certification.

3.5. Membership Management

Because there is no server manages group membership, membership management is performed by cooperation of each GM. For example, the addition of group member is performed by issuing a copy of Group Certification and registering that Group Certification to GM of the target node. The deletion of group member is performed by unregistering the Group Certification from GM of the target node.

A node, which wants to join some group, has to get Group Certification from a node that belongs to that group. Because GM does not know what groups are utilized in the whole network, it is inconvenient for the node that wants to utilize temporary collaboration group. From this reason, the mechanism to collect what groups are utilized in the network is required.

Because the nodes would not always want the list of groups utilizing in network, an on-demand method to collect the utilizing group information is preferable. Simple on-demand method is as follows.

1. A node (sender node) that wants the group list sends a query to nodes in the whole network.
2. When the nodes receive the query, they send back the belonging group list to the sender.
3. The sender collects lists for particular period.

Because it is very simple method, other method that can collect the distributed information more efficiently is desirable.

By the way, there would be some groups that do not want to advertise the existence. Therefore, it is necessary to manage this advertisement state.

There are also many issues about the authority for group management, for example the authority for member addition/deletion. We describe these issues in Section 4.3.

3.6. Group Communication

By using Group Certification, a communication among the nodes, which belong to the same group, can be performed.

Simple way is to flood communication over networks. The sender node makes a group communication packet, and floods it. When the nodes receives group communication packet, they check whether they belong to the target group, and if they belong to, they accept the packet.

By using multicast [5][6], it is possible to perform group communication more efficiently.

4. Group Management using Mobile Agents

To construct a group management system that can represent and manage various kinds of groups, the distributed group management technique that we proposed in Section 3 is not enough. In this section, we propose an extended group management technique using mobile agents to realize more flexible group management. Then, we propose the group management system that is constructed by using techniques combined with that we described in Section 3.

4.1. Group Representation with Mobile Agents

We use mobile agents to represent group information and a way of managing that group. In our method, each mobile agent represents single group.

Because of following characteristics of mobile agents, the group management system that use mobile agents can represent and manage various groups.

- **Programmability**
  User can define a group unique information and its management method by programming. Therefore, it is possible to represent and manage groups flexibly.
- **Autonomy**
  This enables group management system to change membership and other group information automatically. For example, it is possible to change group membership according to the surrounding situation of the node.
- **Ability of movement over the network with itself program code and execution state**
  Because of this, in the case that one adds a member to a certain group, it isn't necessary that the new member has its program code.

4.2. The Configuration of the Group Management System

Our proposed group management system consists of following two modules (Figure 4).

- Group Manager (GM)
- Group Agent (GA)

Group Manager is a module that is installed every node in the ad hoc network (Section 3.1). This module manages only belonging information, namely, manages the registration state of Group Agents. By registering GA to GM, the node belongs to a group that the GA represents.

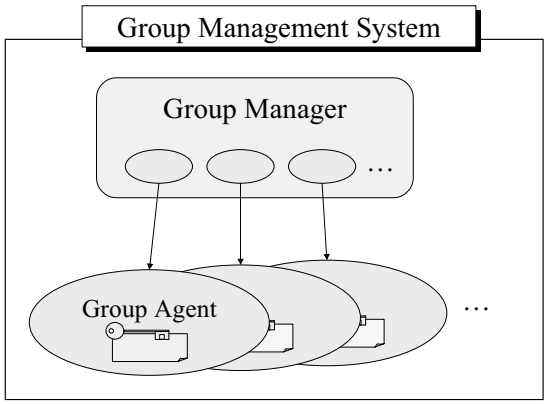


Figure 4: The Configuration of Group Management System

Group Agent is a module implemented by mobile agent, and that manages unique information of each group. Each GA has Group Certification of group that the GA represents and manages. GA can register/unregister itself to GM, so that dynamic change of group membership becomes possible.

In addition, by dividing the group management system into GM and GA, it becomes unnecessary for GM to know how to manage the all kind of group. Therefore, it is possible to reduce a size of the indispensable portion of group management system (in our method, it is GM).

GM and GA have follower API at least.

- GM
  - Registering/Unregistering GA
  - Creating/Deleting Group (GA)
  - Listing belonging groups
  - Judging the node belongs to particular group
  - The interface to notify of changing belonging information of the node
  - Searching neighbor member of particular group
- GA
  - Registering/Unregistering GA
  - Creating/Deleting Group (GA)
  - Interface to display/modify common information
  - The interface to notify GM that the group information modified

4.3. Authorization Management

The authorization management is necessary to use group management system securely. Because there is no server in our group management method, the authorization for changing group information, for example, the authority for issuing a copy of Group Certification, is managed cooperatively by each node.

We consider that the authority for following items is necessary at least.

- **Changing the group membership**
  This authorizes the node to make a copy of the Group Certification

Figure 5: Running Display of Group Management System

- **Changing the common information that every Group Agent has.** (For example, Group Name)
  This authorizes to update the group information when a node wants to update it.
- **Advertising group**
  This authorizes to reply an advertisement request. (Section 3.5)

Authorization is performed to each GA. By managing authorization to GAs that have same Group Certification, it is possible to define various style of group managing policy.

Of course, there might be other kind of authority. We have been considered about this, and it remains as future works.

5. Prototype System

We have implemented a prototype group management system using the proposed technique. The system operates on MAGNET (Mobile AGent NETwork) [7][8]. MAGNET is a framework based on mobile agents to construct an ad hoc network, and implemented by the Java language.

The implemented group management system mainly consists of following two modules (Classes) that is described in Section 4.2.

- **GroupManager**
  manages registration information of Group Agents.
- **GroupAgent**
  manages group information. This is super class of every Group Agent on our group management system.

Figure 5 shows a working display of Group Management system that we have implemented. In figure 5, three mobile nodes, mb1, mb2 and mb3, construct ad hoc network on the network emulator. Three windows at the lower side of the figure are Group Managers of each node. The right side of GM is Group Agent list that are registered in GM. In the figure, mb1 and mb2 belong to a group named "Meeting", mb1 and mb3 belong to a group named "Nagoya Univ".

We have also implemented a chat agent as sample application. This agent can communicate with only group members by using Group Communication agent.

5.1. Samples of Group Agent

We have implement several kinds of Group Agents listed as follows.

- **Link Dependent Group Agent**
  It is the group that member only consists of nodes that can communicate with a master node directly.
- **Time Limited Group Agent**
  This group has an expiration lifetime. When the time has come, this agent expires its Group Certification and unregisters itself from GM.
- **Time Limited and Lind Dependent Group Agent**
  This group has both features of Link Dependent Group Agent and Time Limited Group. This group consists of two type members – regular members and temporary members. Regular members consist of nodes that can communicate directly with a master node. Temporary members consist of nodes that can communicate directly with regular members, but cannot with master node. GAs of temporary members have an expiration time, and when it has come, the GA unresiters itself from GM.

5.2. Group Communication Agent

To communicate only with group members, we implemented the simple Group Communication agent using flooding (broadcasting) technique that we described in Section 3.6. At first, sender node selects a group, and make Group Communication agent for that group. Then, Group Communication agent moves to other node in the network, and checks what groups that node belongs to. If the node belongs to selected group, the agent registers the group message (mobile agent). Otherwise, the agent does nothing.

6. Related Works

There is no group management system that considers ad hoc networks strictly. However, there are some techniques to make groups in ad hoc networks. They can make ad hoc groups to perform the group communication. They do not consider about the authorization for a group management. In order to use groups for limiting access for resources, the authorization and authentication mechanism is needed.

ODMRP [6] is a multicast protocol for ad hoc networks. ODMRP makes multicast groups based on receiver advertisement for requests of multicast sender node. However, there is no system to manage multicast receivers.

"Nakayoshi" [9] is a mobile groupware system supporting local area collaboration, and it has a mechanism to manage groups. However, Nakayoshi's group means that constructing some particular logical network in the ad hoc network. Therefore, in Nakayoshi, a group is available only in the networks where the group created. On the other hand, our group management system manages groups that represent a relationship among nodes (users) in the real world. The groups are independent of the networks where the node is in, and nodes can recognize whether other node belongs to same group or not.

7. Future Works

The group management method we proposed in this paper realized the technique to create groups and to recognize member. Therefore, there are many subjects must be solved to make group management system really utilizable and more flexible.

7.1. Security of the Group Management System

Because our proposed method is based on Group Certification, it is fatal for group management system to rewrite Group Certification illegally. If it would be done, a node becomes possible to behave as if it belongs to certain group although the node

does not belongs to that group in fact. Therefore, the securities system for Group Certification and authenticating it are very important.

In addition, it is necessary for Group Agent to prevent rewrite its unique information defined by user – for example, the group name, authority information, the date when the Group Certification expires, and so on.

In our proposed method, all information about group such as Group Certification is managed by Group Agents. Because GA is a mobile agent, the security of information that is held by Group Agents deeply depends on the security of mobile agent. There are many researches about the security of mobile agent [10]. We have also studied the security of mobile agent [11]. We consider that it is possible to protect the security of GM and GA by using Tamper Resistant Hardware and Encryption.

7.2. Hierarchical Structure of Group Agents

There are groups that have some relationships each other. For example, the Nagoya University group is parent of the Department of Engineering of Nagoya University group. In addition, Nagoya University group consists of Department of Engineering of Nagoya University group, Department of law of Nagoya University group, and some more groups. Like this example, the group that consists of two or more groups exists. Therefore, the technique that enables for Group Agent to consist of some other Group Agents is desirable. In addition, if it could define a character of the Group Agent by combination of several Group Agents, it becomes possible to represent group more flexibly.

8. Conclusion

In this paper, we have proposed the flexible group management method in ad hoc networks using mobile agents. In our method, the group management system consists of two modules. Group Manager, which is installed in every node in the ad hoc networks, manages the belonging information of the node itself. Group Agent, which is a kind of mobile agent, represents and manages each group. By using the mobile agent, it becomes possible to implement various kinds of groups, and manage them by programming. The autonomy of mobile agents enables to implement flexible group management.

We have also implemented the prototype system on MAGNET. We have implemented some sample Group Agents, such as Time Limited Group, Link Dependant Group, and Time Limited and Link Dependant Group. In our method, the users can define various groups easily. However, there are many problems to be solved in order to implement really usable, and more flexible group management system.

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