Ad Hoc Network System based on Infrared Communication

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Abstract

Recently, it becomes popular to use small size computers such as notebook computers or PDAs in the mobile environment. It sometimes happens that several computers meet at the same place such as meeting rooms or conference sites. In such environment, there are demands to make a direct communication among mobile computers. Route maintenance and host enumeration are key requirement for such an ad hoc network.

In this paper, we propose a network system based on infrared communication. Our system solves host enumeration as well as route maintenance using diffusing computation. We describe autonomous communication protocol for the ad hoc network and an implementation of mobile system using the protocol.

1. Introduction

Recently, mobile computing becomes popular in favor of the small sized, light-weight PDAs and notebook computers. Sometimes, it can happen that several PDAs and computers gather at the same place such as the conference site, or classrooms. However, without any centralized manager nor additional administrative work, it is not easy to exchange information between the portable computers directly under the mobile environment. The *ad hoc network* is a network which is constructed on demand to enable these communications(Figure 1). Several routing and management protocols for the ad hoc network are proposed so far[1, 2, 3]. However, these protocols are mainly concerning about the wireless networks which are equipped with special radio devices. But, it isn't realistic that all notebook computers and PDAs at the meeting place have the same special radio devices. So, these methods do not solve the situation that we mentioned above.

In this paper, we propose an ad hoc network system based on infrared communication. Infrared devices are currently the most wide-spreaded device for wireless communication. Almost all portable computers have IrDA[6] compatible infrared device. We believe that

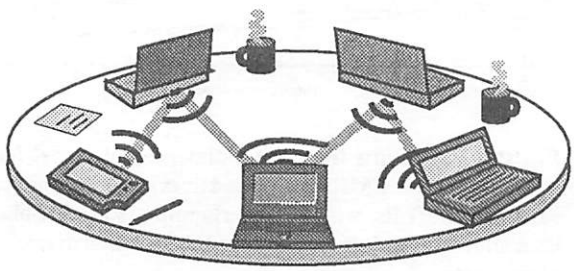

Figure 1: Ad hoc network using infrared

the ad hoc network system should solve following problems.

1. *Route maintenance*
   How to maintain routes between the mobile hosts.
2. *Host enumeration*
   How to count up (and identify) the participants(mobile hosts) of the network.

Routing protocols such as AODV[2], DSR[3] only solve first problem. These protocols can not manage the communication between the hosts which have no information about the network address of each other. To solve second problem, we adopt autonomous route discovery instead of on demand route discovery which is used in these protocols. Autonomous discovery means that each host always tries to exchange the information about other hosts with its neighbor by itself. While obtaining host identifier, each host can also obtain the route to the host. Usually, this needs a lot of overhead for network maintenance messages and makes the network unefficient. We use *diffusing computation* to solve this problem. After the initial computation terminates, each host doesn't have to exchange the information until next change of the network topology.

We have developed an infrared network system(IrNET) as a prototype system. IrNET is implemented by C++ language using IrSock library on Windows95/CE. On the IrNET, we developed mobile applications such as business card exchanger, web

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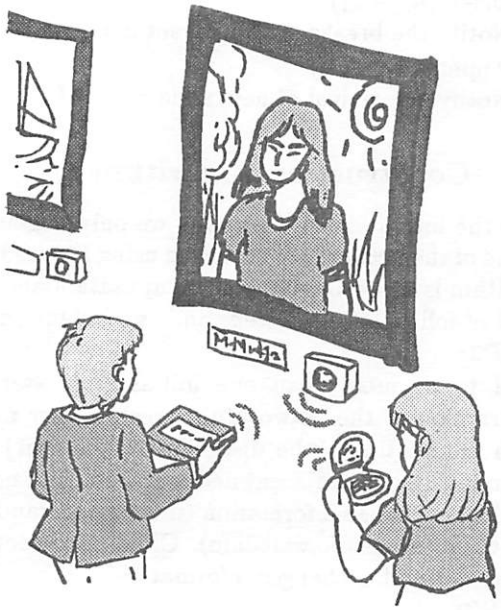

Figure 2: Ad hoc network in the museum

browser, URL memopad and chat system. IrNET works as a network protocol stack for these applications. We also developed the infrared network emulator which has the GUI to simulate the dynamic change of the ad hoc network. The emulator ease the development of the system and simplify the test of the applications.

This paper consists of the following sections. In Section 2, we briefly explain the ad hoc networks. In Section 3, we explain our autonomous algorithm for infrared ad hoc network. Implementation of IrNET is presented in Section 4. Section 5 presents related works.

2. Ad hoc Network

The ad hoc network is a network which is constructed on demand to enable the communications between the mobile hosts equipped with the wireless devices. It has following characteristics. (1)No centralized manager, (2)Before the construction of the ad hoc network, each mobile host has no information about other hosts nor links (No previous administrative work), and (3)Network topology is changed dynamically by movement of hosts.

We intend to implement the ad hoc network system not only notebooks and PDAs, but also desktop computers, cellular phones, voice recorders, pagers and stationary information providers such as kiosks. So, the ad hoc network might be used in some specific situations. In some situations, ad hoc terminal should aware the situation and execute the appropriate application(context-aware). For example, when a user put his terminal near his home desktop computer, the terminal and the desktop aware each other and start to synchronizing information such as schedule data or business cards. The other example, just bring the terminal close to friend's cellular phone, terminal and the cellular phone will exchange phone numbers. By using stationary information provider, for example(Figure 2), in the museum , users can obtain information about the exhibition and can exchange their impressions.

Table 1: Relation symbols

Symbol	explanation
N	iNitial value
S	Self node
P	Parent node
C	Child node
I	Ignore node
H	cHanged node
F	Finished node

Table 2: Info. Table for node n_1

ID	step	rel	AL
n_1	1	S	$[(n_1, n_2), (n_1, n_3)]$
n_2	1	C	[ ]
n_3	2	I	[ ]

Uniform management of the ad hoc network construction, routing, and applications enable the high-level utilization of mobile computers. To implement these features, followings are required. (1)Autonomous ad hoc network construction ,and (2) Context aware management of applications.

3. Infrared Ad hoc Network

In this section, we propose an autonomous distributed algorithms for the ad hoc network construction. Currently, we employ the following assumptions for simplicity.

1. *Each mobile host has a unique host ID.*
   Without unique ID, each host should perform the anonymous network computations[4].
2. *Links are bidirectional.*
   It is difficult to distinguish between the unidirectional link and the link breakage.
3. *Mobile hosts can recognize the adjacent hosts.*
   Without this feature, it is impossible to start a communication with other hosts.

Additionally, because of the restriction from IrDA protocol, mobile host can only communicate with single

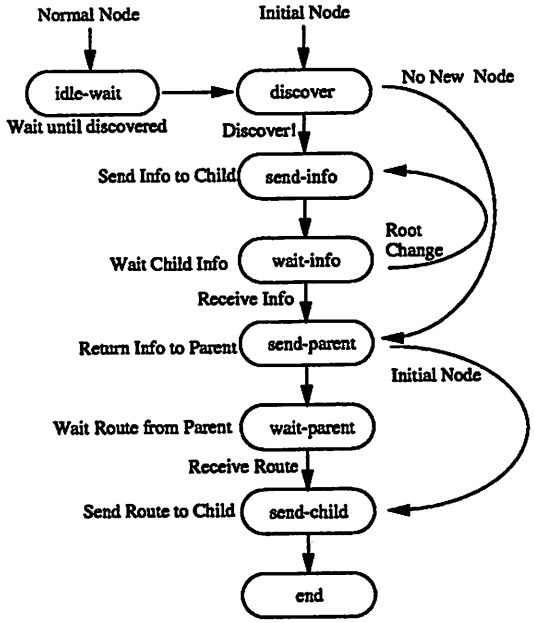

Figure 3: Outline of Algorithm

host at the same time. Each host should repeat the connection establishment with other hosts to communicate with multiple hosts.

3.1. Network Construction Algorithm

In the following, we call each host as node. Starting node is called initial node. Each node n_i keeps I_i and T_i. I_i means "initial node" and $T_i = [t_i^j, \ldots, t_i^k]$ means "info. table" to keep all information about other nodes. Each row of the table $t_i^j = (n_j, step_i^j, rel_i^j, AL_i^j)$ is information for node n_j. $step_i^j$ means the current step of diffusing computation between n_i and n_j. rel_i^j denotes the relation between n_i and n_j and take a symbol within {N,S,P,C,I,H,F}. We explain the symbols in table 1. AL_i^j denotes the adjacent list which is obtained from n_j. The example of information table is shown in table 2. Each node exchanges the following messages.

1. IDandAL(n_i, n_j, n_k, AL_i)
   Info of initial node n_k and adjacent list AL_i in n_i to n_j.
2. Info(n_i, n_j, AL_i)
   Info of adjacent list AL_i in n_i to n_j.
3. Ignore(n_i, n_j)
   Afterward, ignore n_j.
4. Change(n_i, n_j, n_k, AL_i)
   Notify the change of initial node n_k to n_j.
5. Delete(n_i, AL_d)
   Notify the breakage of adjacent list AL_d.
6. Append(n_i, AL_n)
   Notify the arrival of new node with AL_n.

3.2. Construction Algorithm

From the limitation of the space, we only explain the outline of the network construction using Figure3. The algorithm is based on diffusing computation and composed of following three steps and two extensions.

STEP1:
Equal to or more than one initial node start the construction of the network(discover). Other normal nodes are waiting to be discoveried (idle-wait). Initial node discovers adjacent nodes (called child nodes), and then exchange information (message "IDandAL") with them (send-info,wait-info). Child node continues to discover and exchanges information.

STEP2:
When child node cannot discover new node(this means that discovery reach at the terminal of the network), child node returns the information(message "Info") to parent(send-parent). After receiving all information from children, each node will continue to send information to parent(send-parent).

STEP3:
When initial node obtains whole information from all children, initial node sends route information(message "Info") to all children(send-child). Every node continues to pass the route information form their parent to their children.

Loop Detection Extension:
If there are some loops in the network, there will be some nodes which obtain "IDandAL" which contain same initial node. The node only regard first node as a parent and then send "Ignore" message to other nodes. By this procedure, information exchange is performed in tree structure. This guarantees the termination of the algorithm.

Plural Initial Nodes Extension:
If there are several initial nodes, there will be some nodes which obtain several messages with different initial nodes. The node then sends "Change" message to both parent and performs as new initial node.

After the three steps execution, all nodes know the all adjacent list of the network. Each node also obtains information about other nodes. It means that host enumeration is achieved by the algorithm. By creating spanning tree from the network graph, next hop to each node can be calculated. Route maintenance is also accomplished. Table 3 shows the routing table of Figure5.

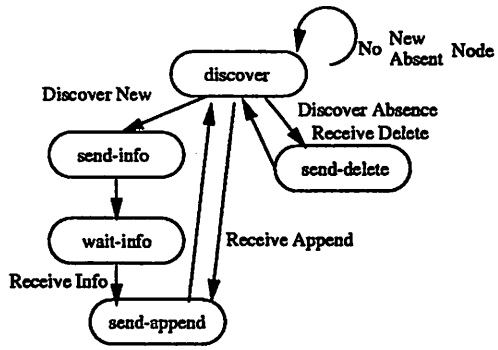

Figure 4: Outline of Network Maintenance

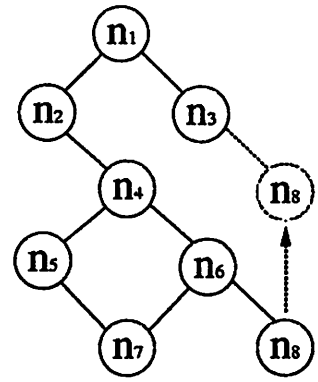

Figure 5: Example ad hoc network

3.3. Adapting Dynamic Change

Ad hoc network is essentially dynamic, so the network system should manage the dynamic change of the network topology. After the construction of the network, each node starts network maintenance algorithm(Figure 4).

Each node continues to discover new node or absent node. When some node discovers absent node, the node sends "Delete" message to other nodes. When some node discovers the new node, the node sends "IDandAL" to the new node and then wait reply. After the new node returns information about it, the node sends "Append" message to other nodes.

3.4. Example

In this section, we explain the procedure to construct the network in figure5. We assume the procedure start from the initial node n_1. STEP1: Node n_1 discovers node n_2, n_3 ,and exchange information. Node n_2 discovers n_4, and exchange information. This cicle is repeated with n_5, n_6, n_7, n_8. Node n_7 is discovered from two nodes. Because initial node in the message is same node n_1, node n_7 only regard first node as a parent and then send "Ignore" message to other nodes. STEP2: Node n_3, n_7, n_8 can not discover new node, then send information to their parent and wait route information from parent. This is repeated until to reach node n_1. STEP3: Finally, node n_1 sends route information to all nodes. Each node passes the route to their children. Table 3 shows the part of final info. table of node n_4.

When node n_8 moves from n_6 to n_3, firstly, node n_6 discovers the absence of node n_8 and send message Delete(n_6, [(n_6, n_8)]) to node n_4 and n_7. Then delete message will pass to all nodes. When node n_3 discovers the arrival of node n_8, node n_3 send IDandAL(n_3, n_8, n_3, [...]) to n_8. Node n_8 then try to discover other hosts, but it can't find other host. So node n_8 send Info(n_8, n_3, []) to n_3. Finally, node n_3 sends Append(n_3, [(n_3, n_8)]) to all other hosts to notify the arrival of new node.

Table 3: Info. Table for node n_4

ID	rel	AL	next hop
n_1	F	[ ]	n_2
n_2	F	[(n_1, n_2), (n_1, n_3), (n_2, n_4)]	n_2
n_3	F	[ ]	n_2
n_4	S	[(n_4, n_5), (n_4, n_6)]	n_4
n_5	F	[(n_5, n_7)]	n_5
n_6	F	[(n_6, n_7), (n_6, n_8)]	n_6
n_7	F	[ ]	n_5
n_8	F	[ ]	n_6

4. Implementation of IrNET

We developed a prototype network system named IrNET. Currently, IrNET is written in C++ on Windows95/CE. The system contains an infrared emulation environment and a "real" infrared routines using IrSock library. We construct the system from several modules to enable the quick development. Figure 6 shows the structure of IrNET.

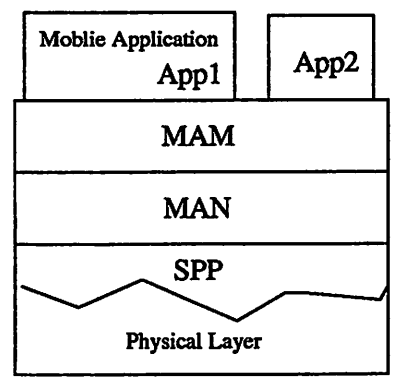

Figure 6: Structure of IrNET

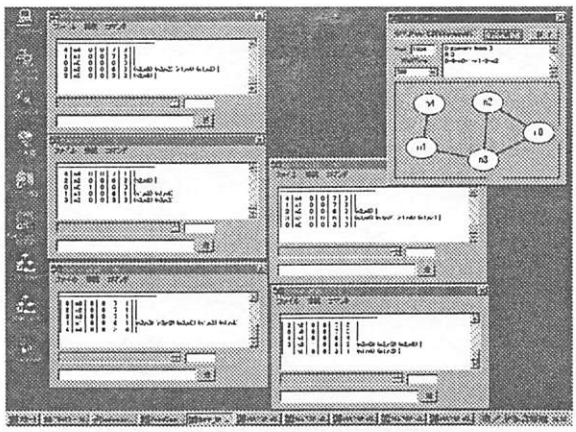

Figure 7: Infrared Network Emulator

- *Physical Layer*
  Infrared medium or emulation environment.
- *SPP(Simple Point to Point) Layer*
  Encapsulate physical layer, discover neighbor host, and detect error.
- *MAN(Mobile Ad-hoc Network) Layer*
  Identify hosts, constructing network, maintain route
- *MAM(Mobile Application Manager) Layer*
  Manage mobile applications, context-aware management.
- *Mobile Application Layer*
  Various mobile applications such as electronic black board, web browser, url memopad, and chat system.

4.1. Infrared Network Emulator

Figure 7 shows the working display of the infrared network emulator and IrNET managers. Right upward window shows the ad hoc network. Each oval node denotes the mobile host, and line denotes a link. User can dynamically move nodes and connect/disconnect links using pointing devices. In this figure, five IrNET managers(MAN+MAM) are connecting to the emulator using TCP sockets. Each IrNET manager can also work on real infrared environment just replacing libraries. By using the emulator, development and testing of the IrNET and mobile applications are significantly improved.

4.2. Mobile Application

We introduce our mobile application "Web browser" (Figure 8) and "URL memopad" (Figure 9). URL memopad can send its URL information into other terminals. It can also get URL from other terminals.

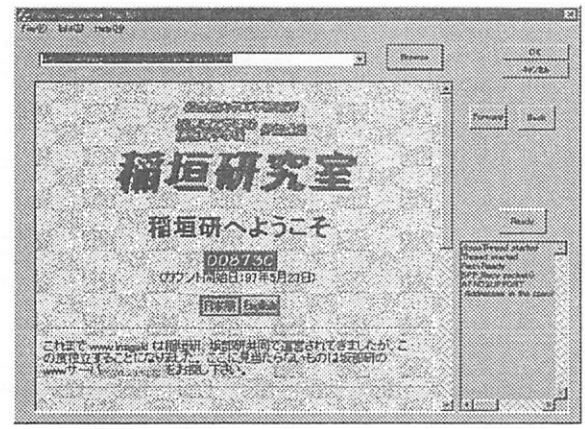

Figure 8: Web browser (Windows 95)

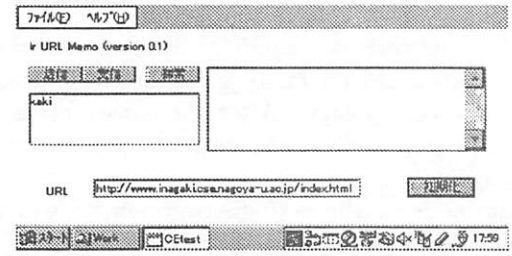

Figure 9: URL memopad (Windows CE)

URL memopad is developed on WindowsCE, so one can bring everywhere to keep one's URL information and record on the fly.

Web browser can show web page from the URL. Web browser can communicate each other and have a facility to show pages synchronously. It also has the same feature with URL memopad. So web browser and URL memopad can exchange URL information. This means that URL memopad can remotely control web browser.

These applications are managed by MAM(Mobile Application Manager). If there is no URL application currently working, suitable URL application is executed by MAM. By using web browser and URL memopad, user can have simple meeting shown in Figure 10.

5. Related Works

For supporting host mobility, there are many studies about routing issues. Mobile IP[7] and VIP[8] are both protocols for supporting mobile host access transparency from other hosts in the Internet. They need special home agent or router as an infrastructure. It is not suitable for an ad hoc network.

DSDV[1] is a distance vector ad hoc routing protocol. This protocol avoids loop using sequence number from each host. DSR[3] is a dynamic source routing protocol for an ad hoc network. Each host sends a packet with source routing. This makes less traffic on

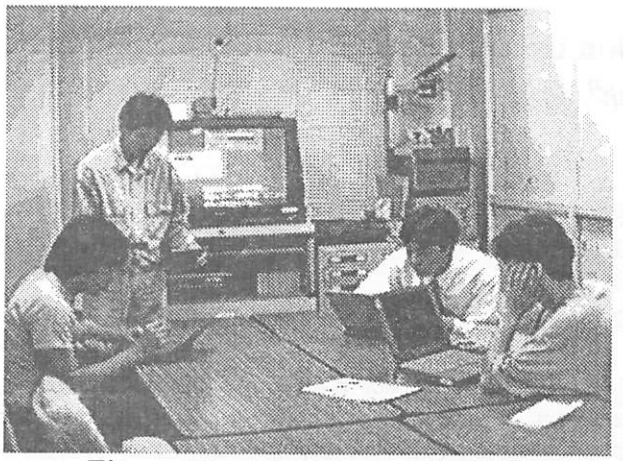

Figure 10: Meeting using IrNET

routing information. When a host doesn't know the route to the destination, route request packet is sent and wait for route reply. AODV[2] can be regarded as a combination of DSR and DSDV. These protocols answer the routing problem in an ad hoc network. But no answer for host enumeration. IrNET answers them by using autonomous discovery and diffusing computation. In favor of diffusing computation, each host can aware the end of construction of the network. So, our system can answer the question "Who is attending the network now?" but others cannot.

There are several ad hoc network proposals from industry. Bluetooth[9]is based on 2.4GHz RF chip which has 1Mbps speed and ranged 10meter. They claim to create the chip in 9mm×9mm size and intend to be installed various systems such as desktops, PDAs, headsets and cellular phones. HomeRF[10] is a 2.4GHz RF proposal standard to be used in home. They propose the protocol SWAP which can enable 127 connection with 1Mbps. IrBus[11] is more home side standard. This is based on infrared remote controller and enables 6-8m range, 75kbps, 8 simultaneous connection. These standards are currently undergoing and can be regarded as our system's physical medium.

6. Conclusion

In this paper, we propose an ad hoc network system using infrared communication. Each mobile host autonomously forms the ad hoc network and enumerates all mobile hosts. So our framework satisfy the both requirements of the route maintenance and host enumeration. We use autonomous discovery and diffusing computation to satisfy these requirements.

We implement our framework as a prototype network system IrNET[1]. Moduled design of IrNET makes the development of the system easier and quicker. We develop an infrared network emulator as well as a real infrared driver. This also helps the debugging and development of mobile applications. From our experience, developing mobile applications adapting the ad hoc networks are not easy. Because the conventional way of communications are not suitable under the dynamic environment. We might need new policy to build a proper application on ad hoc networks.

This system can be widely applicable to various systems. By adopting Java language, Mobile Agent System[5] can be constructed. Physical medium is not restricted to infrared. Using RF or ultra-sonics, network construction in sea,or space might be possible.

There are a lot of future works. Scalability of the IrNET is a big problem. Currently we regard our network is suitable for 5 to 10 mobile hosts. Because creating IrDA connection takes some time(about 500 msec) from its specification. Security problems are also important. The authentication of mobile hosts is another subject.

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