Network Issues and Implementation for a Mobile Police Information System (MPIS)[1]

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Abstract

Due to the fast growth of mobile communication technologies and mobile computing needs, we are eager to develop a practical mobile information system. An example for a Mobile Police Information System (MPIS) is proposed. To match the future possible mobile network trends, a new network control architecture, which is designed to support real-time applications and have instant infrastructure capability, is first proposed. Both network issues and solutions are discussed and explained in this paper. Implementation platforms will demonstrate the concept proof.

1. Introduction

As the technology of radio and wireless data transmission speed improve, and the wide diversity of internet users, personal communication dream will gradually come true in the near future. Wireless communication networks and mobile computing environment enable people to obtain information at any time and at any place. Multimedia applications and quality of service (QoS) are more and more needed not only in the wireline networks but also in the wireless mobile networks. Especially, high-speed and QoS requirements are indeed great challenges for the wireless networks. Nowadays, many mobile data communication networks are getting mature and still in great efforts to improve the performance. In order to make full use of characteristics of a mobile information system that can utilize the current technology and our research/implementation efforts, we build up a Mobile Police Information System (MPIS)[9]. The requirements, objective, network issues and implementation will be addressed in the following sections respectively.

1.1 MPIS Requirements

We use the following scenarios to illustrate the mobility requirements of the police information system.

- 110 (119, 911) receives an emergency call on a robbery case, a small team of policemen rushes to the scene by a motorcycle which is typical in Taiwan. In order to make a proper move, they may have to evaluate how dangerous and how important the suspects are. Thus they may need to access to the pictures and associated information of all wanted suspects that are close to the crimes on the scene.
- A large group of policeman is in a task to search an important and dangerous suspect in an open field. They need to quietly communicate to each other as well as keep track of the positions of all members through their PDAs. (This is actually very similar to a battle field.)

In a recent kidnaping crises in Taipei City, a large scale search effort failed to catch the suspect due to the inefficiency of real-time coordination among hundreds of policemen. If every policeman were equipped with a PDA showing the street map and the locations of all policemen in the scene, they might had had a more efficient search.

In a recent kidnapping crisis in Taipei City, some policemen has sneaked into the house where the hostages were held by the kidnapper. However, these policemen couldn't obtained any further instruction from their commanders

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so that they couldn't take any action to shoot the kidnapper unless there was any immediate danger. If they had a PDA(or Palm PC) based communication system available, the crises might have a good chance to be solved earlier.

• In a fire fighting crises, fire fighters will want to know whether there is any dangerous chemical material stored in the building that is catching the fire. If they can access the needed information in time, they might be able to reduce a great deal of dangers. A few years ago, several fire fighters were killed immediately by a chemical factory fire only a few second after they arrived the scene. If they could access the information about the factory right on the way to the scene, this tragedy would have been avoided.

The requirements specific to this environment are summarized as follows:

• On-line real-time query capability to a central multimedia database, (Police Information Management System). For example, to query the picture of a suspect or to retrieve the map of a street area.

• On-line report authoring.

For example, to report a crime case with scene picture (or the picture of the suspect) uploaded.

• Personnel location tracking.

• Expert system providing on-line real-time consultation. For example, to provide specific steps to collect evidences in a crime scene.

• Bidirectional image communication capability.

• Authentication and security.

The security of mobile units is a special concern due to its vulnerability. The cached data must be secure even the PDA unit is lost.

1.2 Objective

The objective of this network architecture is to facilitate every policeman a real-time multimedia information service anytime any where. In modern society, crimes are usually very complex and criminals are highly mobile. It is very helpful if every law enforcement member can access the needed information conveniently without any constraint in time and place. Thus, a ubiquitous information system that allows every policeman access an information-rich database any time any where will be able to fulfill this need.

2. Network Architecture

In the near future, every policeman is assumed to be equipped with a PDA (or palmtop PC) that has basic multimedia capability such as image capturing and voice input. (The PDA can take the picture and voice from a suspect in the field and send to the back-end database to match with the pictures and voices of the wanted suspects.) Further, there is only one central police information management system (central database). Because the computing and storage capacities of a PDA is very limited, each PDA can only cache very limited information. There is a need to allow each PDA to access the central multimedia database anytime any where.

The first approach is to equip each PDA the capability to access the central database via a nationwide mobile data service. This approach is very expensive and may not be able to support real time multimedia communication since a typical nationwide mobile data service can only support up to 19.2 kbps bandwidth. The air time charge is at least NT$10 per Kbytes. Therefore, we propose the following hybrid network architecture.

In this architecture, we first classify all information based on one-day update frequency into two categories: real-time and non-real-time. For those data that may not be updated more than once per day is classified as non-real-time data. The non-real-time data is fully replicated to every police car nationwide. The replicates can be only a location dependent partition if the storage capacity is not sufficient for a full replication. Further, most image data, such as street maps and pictures of suspects are very likely classified as non-real-time data. These replicas are updated every night through a private police information network. Each police car is equipped with a mobile data communication capability via a nationwide mobile data service network. Finally, every police car and PDA is equipped with a multi-hop wireless LAN capability. Any arbitrary group of PDAs can form an arbitrary multi-hop wireless LAN anytime any where. If any police car joins the group, it can act as a proxy server and network gateway to the group such that every PDA can access the full database through this police car in the following way:

1. Each PDA can access non-real-time data from any nearby police car.
2. Each police car can provide a gateway function to help any nearby PDA to access the central database via its mobile data communication capability.

In the first scenario mentioned above, when a police team arrives scene of crime, they can connect their PDAs to form an ad hoc multi-hop wireless LAN for the communications among all members. Further this LAN can connect to the gateway in a nearby police car, referred to as a mobile gateway (MG) , to obtain a full multimedia database access capability (See Fig.1).

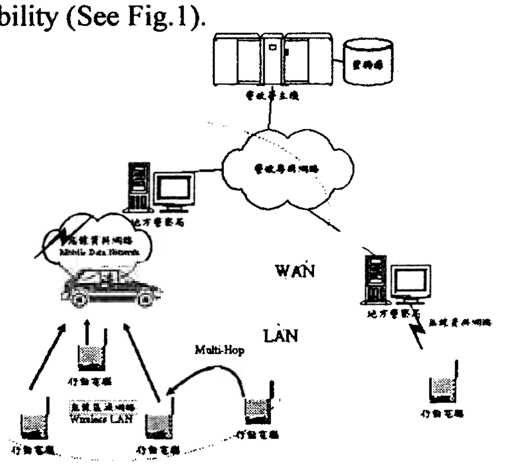

Fig.1 MPIS Architecture

2.1 Multihop WLAN

A WLAN is a LAN without wired connection. The physical layer of the network can be viewed as a miniature mobile data communication system with limited transmission distance, higher bandwidth, and without MSC. The base station in a WLAN is called Access Point . The mobile terminals are connected to the Access Point through a common radio channel, usually in the ISM (Industry, Science, and Medical) band (900M or 2G Hz). Mobile terminals connected to the same Access Point are grouped into a Basic Service Set (BSS). A terminal can also roam over from one Access Point to another within the defined Extended Service Set (ESS). Security can be enforced within a BSS or ESS. IEEE has established a standard (IEEE 802.11)[1,5] for interoperability. However, current products are all designed before the standard is set so that the interoperability is still too far to reach. The bandwidth of a typical wireless LAN is about 2 Mbps and may be increased to 10 Mbps in the near future. Thus, it is sufficient to support basic multimedia communication within the LAN.

In most wireless network environments, the radio channel is used to connect the mobile client (PDA) to a base station (mobile gateway) in a single hop. The base station itself serves as a gateway connecting to WAN. Consider a system where there is no wired infrastructure yet connectivity must be maintained among users who can move around arbitrarily and can at times not be in direct transmission range of each other.

In such instant infrastructure environment, multihop-capable communications become extremely important, especially because, due to transmitted power constraints, not all radios are within the range of each other, and packets may need to be relayed from one radio to another on their way to their intended destinations.

Instant infrastructure systems are more complex to design and manage than traditional single-hop, centrally controlled systems.

In our architecture, we assume all PDAs in a group of policemen can form an ad hoc wireless LAN instantly. Some PDAs may be blocked by some obstacles or aparted too far so that they cannot communicate with each other directly. Therefore, there is a need to implement a multi-hop Wireless LAN system allowing all PDAs help each other to carry out the complete group communication as well as the capability to access the mobile gateway.

2.2 Mobile Data Networks for WAN

A mobile data service network provides mobile data communication to all the data terminals within the service area. It functions like a cellular mobile phone but with data communication characteristics. In other words, it is a packet switching network. The frequency bandwidth allocated to each data channel is very limited. Typically, it can only support up to 19.2 Kbps data rate. A typical mobile data network consists of a number of base stations and a set of control switches, usually called mobile station controller (MSC). In a simplest case, there is only one MSC. Each base station communicates with mobile terminals through wireless air links and connects to a MSC by a leased PSTN (Public Switched Telephone Network) link.

2.3 Integration

Assuming that the clients in the field need to communicate with a stationary server through a mobile data network, there are several potential architectural approaches. The choice of architecture depends on the economy of the communication media.

Basically, there are two communication "legs" between two communication parties. Assume that there is only one MSC in our environment. One leg is a client (mobile gateways) in the field to the MSC. The other leg is the stationary server (Police Information System) in the back-end. These two legs join together at the MSC. The leg from a mobile gateway to the MSC is through the mobile data service network, while the leg from server to the MSC must be a higher speed connection in order to serve many mobile gateways. It doesn't need mobility support.

3. Network Issues and Our Solutions

Obviously, there are many challenging mobile data base issues which mainly have to take care of query and reply while an unstable, low-speed wireless connection is concerned. However, we focus only on network issues [7,8,10] for a MPIS in this paper. There are at least the following research issues that need to be studied, namely, multihop architecture control, routing, QoS(bandwidth management), and roaming/Mobile IP.

3.1 Multihop Architecture Control

Although each MG can be treated as a base station as in the cellular networks, MGs share the same medium bandwidth and have to control all the mobile clients through multiple hops. On the other hand, clients also need to register to at least one MG through the relay companion clients' help. We propose the following solution which is also same as the location tracking problem. As illustrated in Fig. 2, the algorithm works as follows:

a. MG periodically sends out "hello" message which contains its own IP, Sequence number (increment by 1), hop number (hop distance to the MG).
b. In the single hop range, as node A, B, C in Fig.2, can receive the hello message. They record and create their messages by increasing hop number by 1, and indicating the timestamp. Next, node A, B, C will send out "register" message to MG. MG obviously will record the message.
c. After client sends out "register" message, it will send out "hello" message. Nodes receiving the "hello" message will decide if the Sequence number is more recent, and the hop number is less. Nodes' routing tables will be updated by the minimum hop distance criterion. Sequence number is needed for avoiding looping. If the tables get updated, nodes send out "register" message via the register path up to the MG. The relay node will relay the "register" message to MG, and also record those nodes which need its relay.
d. "De-register" uses timeout by checking the timestamp of each entry.

Location Tracking and Routing

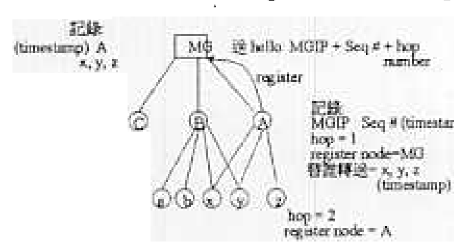

Fig.2 Multihop Architecture Control

3.2 Routing

With help of the location tracking algorithm, the minimum hop routing algorithm can be also performed. Each client can choose the MG with minimum hop distance to register to, and transit all its internet data to this MG, then internet routing will take care of the rest. If source and destination are within the coverage area of the MG, traffic can be routed via distributed Bellman-Ford routing, or routed to MG first, then down to the destination, depending on whichever is easier to implement and wastes less routing overhead. For the former approach, each client needs to compute all the paths to all the nodes in the same MG area. However, for the latter approach, each client needs only to keep track of one path up to its MG, and source routing can be used for down paths from MG to its client nodes. For both approaches, the MG keeps track of all the paths to all the nodes in the same MG.

3.3 QoS (Bandwidth Management)

With the above architecture control, we can easily use TDMA (or PRMA)[2,3,6] or polling in IEEE 802.11 PCF[1,5] period to serve real time traffic. The role for an MG plays as an access point in wireless LANs or a base station in cellular networks. The difference is that each MG is mobile, and needs to control all its clients by multihop. The MAC protocol for supporting QoS must be dynamic to catch up the mobility. Since the MG needs to collect the bandwidth information in order to support bandwidth guarantee for real time applications, each node must send the traffic flow information associated with it to MG. This can be done along with the location tracking algorithm explained above. After collecting required information, MG computes the optimal slot scheduling (i.e. performs bandwidth assignment) if using TDMA[4], or polling frequency assignment for each real time connection request by its QoS (bandwidth) requirement.

3.4 Roaming and Mobile IP

IEEE 802.11 compliant wireless network adapters can automatically roam among the same subnets. In our case, if location tracking is done, then roaming will be also enabled. If IP availability is not acceptable, the mobile IP mechanism can be considered. In this case, MGs can naturally work as foreign agents. However, the limit of commercial Windows system may discourage us because we already make lots of unsuccessful trials. Maybe Linux is the good platform to do this.

4. Implementation

We worked on 2 popular platforms, namely Windows and Linux, to implement our proposed architecture and network system. In order to fulfill the required functionalities, the platform must have the ability to support the following functions: multihop, TCP/IP socket transparency, MG, and roaming. We will address the difficulties and our efforts to solve the above functions in the following subsections.

4.1 Windows

The network supporting interface on Windows operating system is through NDIS (Network Driver Interface Specification), showed in Fig.3. However, NDIS is tightly combined within the Windows kernel, and source code is hard to obtain. The only source code we can obtain is the interface to the NDIS which functions as a VxD (Virtual Device Driver), and provides some library entry to NDIS. We have obtained a VxD called "rawether" which can capture and replicate all TCP/IP packets passing NDIS. However, VxD works very closely with the device driver (in our case, wireless LAN network adapter). It is hard to obtain the source code for the device driver. Therefore, "rawether" can only provide some limited functions [11,12] as we want unless we are able to obtain device driver to modify altogether.

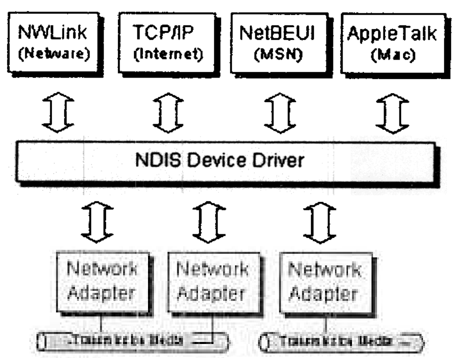

Fig.3 NDIS in Windows

In parallel, we search for other solutions. Currently, we are using 'winproxy' and 'wingate'. Winproxy and wingate are kind of a proxy server. We can set the relay client whose proxy points to MG, and the remote client (needs multihop service) whose proxy points to the relay client. Thus, multihop function is achieved as illustrated in Fig.4. In addition, on MG, wingate can control 2 network adapters at the same time, and provide the interconnection between 2 LANs. The IP is transparently capsulated through the 2 different LANs (current version supports: ftp, telnet, http). In this way, MG is working as we want. The disadvantage of this approach is lack of dynamics. It is not possible to dynamically change proxy server IP through a program. We should do it by hand because source code is not obtained.

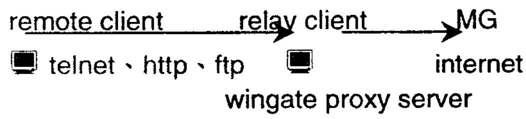

Fig.4 The proxy server

To solve the dynamic problem, we are working on another direction. We provide a special winsock function along with multihop relay daemon. In Fig.4, the multihop relay daemon is run on every client and MG. With help of location tracking program, each remote client knows the path to its MG. Therefore, whenever a remote client wants to make a connection to its MG, it calls the special winsock function instead of the standard winsock Windows provide. The special winsock makes a winsock connection to the relay client first, then the relay client makes another winsock connection up to the MG. All the connections are done transparently with users. So applications don't need to know how the lower layers make this connection. Thus, multihop is working.

4.2 Linux

Linux is the platform where we can obtain free source codes very easily. We use its 'bridge' function and make a little modification to let the relay node have capability to relay packets. Also, we develop an interface program through which the routing and location tracking programs can on-line interact to change the path dynamically. Also, as for interconnection for 2 LANs (i.e. IP transparency from MG), we adopted IP Masquerade. This enable MGs to work like a gateway between WLAN and internet. Details can be found through the Web: http://sparc1.cs.nccu.edu.tw/~s8427.

5. Current Status

Due to the difficulties of implementation on Windows NDIS, the location tracking program is implemented on socket level. In the near future, this program will be tightly working with multihop platforms for both Windows and Linux. Currently, simple minimum hop routing algorithm is used. QoS regarding bandwidth allocation (scheduling) algorithm will be also developed. Roaming capability will be tested. Finally, query application programs will be fully integrated and tested in the field.

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