Network Architecture for a Mobile Police Information System (MPIS)

Yao-Nan Lien, Hung-Ching Jang, Tzu-Chieh Tsai
Department of Computer Science, National Chengchi University
Taipei, Taiwan, R.O.C.

Wen-Shyen E. Chen
Institute of Computer Science, National Chung-Hsing University
Taipei, Taiwan, R.O.C.

Abstract

In this paper, we propose a hybrid network architecture to support mobile police information system, which requires a nationwide real-time multimedia communication capability. The proposed architecture integrates a nationwide low-speed mobile data communication network and some high-speed wireless local area networks with the help of data partitioning to fulfill this real-time multimedia requirement.

1. Introduction

1.1 Objectives

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.

1.2 Requirements

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

1. 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.

2. 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 kidnaping crises 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 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.

3. 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.

1. This work is supported by NSC Grant (87-2213-E-004-002).

- 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.

2. Current Database Architecture

Currently, a centralized information system (database) containing eight subsystems is already in place. The database is partially replicated to all the branches of police stations. The updates are all performed in the central database and are propagated to all replicates everyday. Every policeman in the field is equipped with a simple PDA (Personal Digital Assistant) with a very limited cache data. This information is updated every night manually. Therefore, the information available to the policemen in the field is very limited and out of sync. by one day in the best case. (The update operation may not be executed on schedule. Further A criminal may change the license plate several times a day.)

3. Overall Network Architecture for MPIS

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-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*, to obtain a full multimedia database access capability.

3.1 Supervisor PDA

There is pitfall in our network architecture. When a group of PDA can't reach any nearby mobile gateway (police car), the group will be isolated from the network and will lost its capability to access back-end database. Some PDAs, called *Supervisor PDA*, can be equipped with nationwide mobile data service capability to solve this problem. To simplify the design, we do not assume any supervisor PDA in our architecture.

3.2 Wireless LAN Architecure

3.2.1 Wireless LAN (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 (902-928 MHz). 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) 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.

3.2.2 Multi-hop Wireless LAN

In most wireless network environments, the radio channel is used to connect the mobile terminal (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.

3.2.3 Our Architecture: Ad Hoc Multihop Wireless LAN

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.

3.3 Mobile Data Network 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 simpliest 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.

3.4 Mobile Gateway

As mentioned above, each mobile gateway is cached with a replica of the non-real-time part of the central database. The mobile gateway is equipped with 2 cards: one is a mobile data card, the other is WLAN card. It can provide the gateway or router function between these two networks. Thus, the mobile gateway can serve as an intermediate proxy server to the PDAs via the wireless LAN, and also act as a client to a remote primary server via the mobile data network.

4. Integration with Mobile Data Network

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. The natural choice is to connect the server to the MSC through a leased PSTN line. However, a leased PSTN line is too expensive to our project. A more economic alternative is to let the server connecting to the mobile data network through a dial up service. The solution will be easily extended to a more luxury solution.

4.1 EGAnet: An Operational Mobile Data Network

The Easy Data Inc. has been granted with a license to provide mobile data services to the north area of Taiwan. Their MSC is located in the Taipei city. Their base station construction plan is going to have a pretty good coverage over several metropolitan areas including Taipei and HsinChu Cities. Easy Data Inc. also has roaming agreements with other mobile data service operators in other parts of Taiwan so that their customers can receive nationwide services. Virtually, the three regional mobile data service operators are going to integrate into a nationwide mobile data service, call *EGAnet*. Easy Data Inc. has agreed to donate some air time to our project (for the first two years, probably). They are also willing to set their system up to accommodate our special needs.

4.2 Integration Architecture

4.2.1 Integration as an Intranet

In this approach, the EGAnet MSC will be facilitated with a computing server and a terminal server. Customers can install their services (e.g. our database server) right in their computing server. The management of services provided by any customer can be done through a dial up service. In other words, we have to use a terminal to dial up to the computing server in their MSC to manage our server.

4.2.2 Integration as an Extranet

In this approach, the EGAnet MSC will also be facilitated with a computing server and a terminal server. However, the terminal server is able to provide TCP/IP service. A typical example is the PPP protocol. Thus, our server can locate right at our site and be directly managed by us. Mobile gateways in the field can access to our server through the TCP/IP protocol. However, there is a technical issue that the mobile gateways may not know exactly the IP address of the server since it's IP address is usually dynamically assigned by the PPP terminal server. Easy Data Inc., agrees to provide a fixed IP service to accommodate our need. Under this circumstance, our server is integrated with the MSC complex into an Extranet.

4.2.3 Integration as an Internet

Above two approaches require an active phone line connecting our server to the EGAnet MSC. It may incur some management problem unless the phone line is always active.

A more convenient alternative is to have our server connected to the EGAnet MSC though Internet. In other words, the entire EGAnet serves as an Internet gateway between our server and our mobile gateways.

5. Research Issues

5.1 Mobile Databases

- Indexing, query processing for air data broadcasting [4].
- Data model, query language for mobile database [1].
- Data Replication and consistency mantenance [7,8].
- Database security.
- Query processing for multiple database by mobile agents [3,4,10,11].

5.2 Client Mobility

In the prospective application, the mobile police information system, the location of each client changes constantly. On the other hand, it is necessary to track the physical locations of all clients (policemen) for various reasons. This is referred to as *client mobility*.

A client mobility management system is responsible for the following services [2]:

- Distribution of network management facility
- Client registration/de-registration
- Client mobility analysis
- Client location tracking
- Dynamic topology information access
- Multicast control
- Multi-path generation and optimized path selection

To provide these services, a set of issues are to be exploited:

- Strategy of registration as a mobile client joins a new mobile gateway.
- Strategy of selecting adjacent mobile clients for connections as a mobile client joins a new mobile gateway.
- Strategy of de-registration as a mobile client moves across a mobile gateway.
- Strategy of dynamic connections and disconnections to adjacent mobile clients.
- Strategy of preventing mobile clients from loosing connections to any mobile gateways.
- Strategy of keeping the hop number within a threshold considering the end-to-end throughput of multi-hop.
- Strategy of dealing with the flooding routing problem when doing broadcast in multi-hop.
- Strategy of reconfiguring the topology to prevent mobile clients from missing connections as a mobile gateway is removed
- Strategy of preventing messages from lost when doing multi-cast.
- Strategy of determining the minimal number of casts required to carry the broadcasting.
- Strategy of dealing with hidden terminals problem.
- Strategy of dealing with overhead of high frequency of tracking due to the nature of rapidly and dynamically change of mobile client location.
- Strategy of caching policy. Traditional cache policy doesn't perfectly apply due to the nature of rapidly and dynamically change of mobile client location.
- Strategy of determining multi-path as a mobile client connects to more than one client that belonged to distinct mobile gateways for the purpose of communications enhancement.

5.3 MAC Layer Protocol

- Improvement of Quality of Service (QoS)
- PCF Protocol to support real time communications
- TCP/IP protocol enhancement for mobile computing environments [3].

5.4 Multi-Path Interference and Topology Management

In a multi-hop wireless network, there may have more than one air path to reach a desired mobile gateway from a client PDA. It is a very interesting problem to find a distributed algorithm for all the members of the network to establish the paths from all clients to the mobile gateway.

In a Multi-hop Ad Hoc wireless LAN, each client may have more than one adjacent clients which can offer relaying service to reach the network. This "multi-path" problem may interfere the communications between the client and the mobile gateway(s). One possible solution is to designate a fixed path for each client to reach the designate mobile gateway at any given configuration of the network. However, there are numerous possible topologies to be constructed in any given snapshot. Different applications may prefer different topology due to their unique requirements. For example, some applications, such as "telnet", may prefer low noise path but do not concern available bandwidth. On the other hand, some other applications, such as voice data, may demand higher bandwidth paths but do not care too much about the noise. The objective of topology management is to construct the network with the topology best to the individual applications.

6. Summary

In this paper, we propose a hybrid network architecture to support mobile police information system, which requires a nationwide real-time multimedia communication capability. The proposed architecture integrates a nationwide low-speed mobile data communication network and some high-speed wireless local area networks with the help of data partitioning to fulfill this real-time multimedia requirement.

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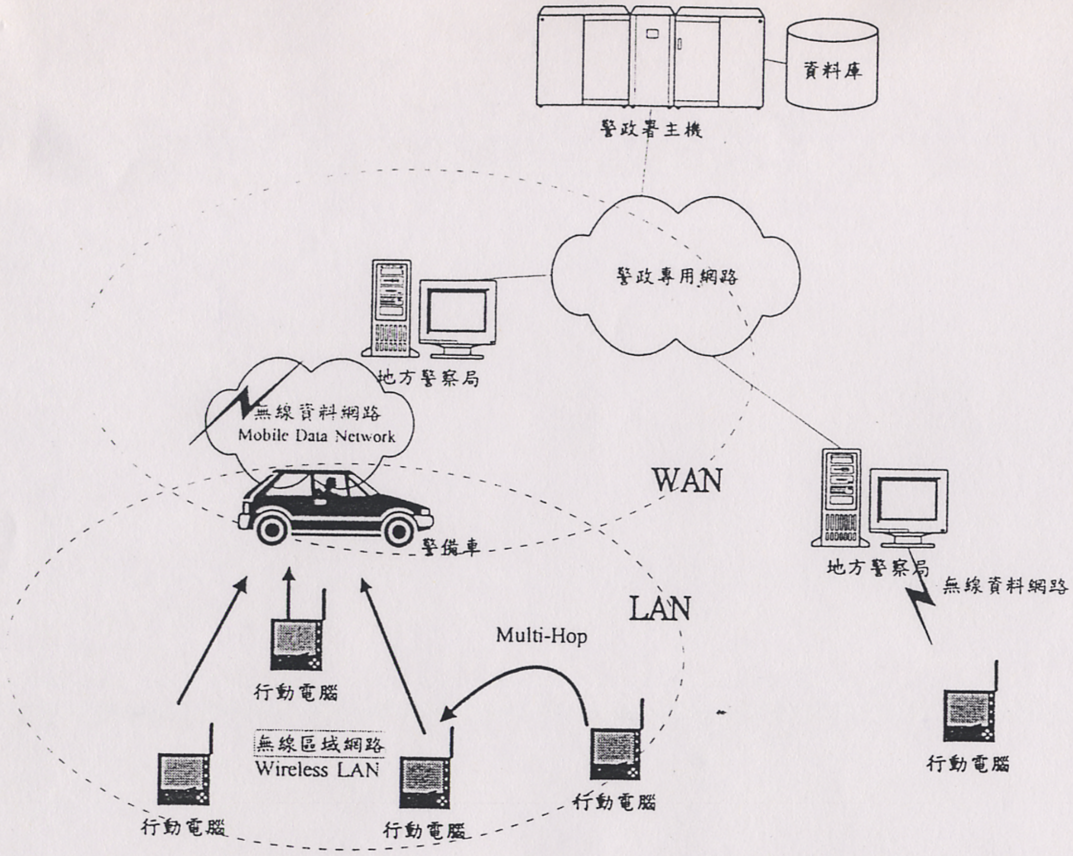

Figure 1. Mobile Police Information System