行政院國家科學委員會專題研究計劃成果報告
行動資訊服務環境技術之研究與製作(III)：
子計劃七：行動網路之控制架構與通訊協定研究暨應用系統製作(III)
Mobile network control architecture, protocol design and system development

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主持人：蔡子傑　　國立政治大學資訊科學系　副教授

Email: ttsai@cherry.cs.nccu.edu.tw　　Fax: (02) 2234-1494

一、中文摘要(關鍵詞：多階、行動無線區域網路、行動數據網路、服務品質)

在無線區域網路中，每個station可經由同伴station間的轉送，不只利用單階(single hop)也可經由多階(multihop)方式，連結至可移動的基地台(mobile base station)。因為此基地台也可視需要而隨整個無線區域網路移動，故此網路稱之為行動無線區域網路。行動無線區域網路的mobile base station之間背後的網路骨架，以行動數據網路(mobile data service network)相連結，藉此可擴大整個行動網路涵蓋範圍，以及與有線網路的進接服務。因此，為支援以上的網路架構與需求，我們有下列兩個關鍵主題：(1)control of multihop (ad hoc) network: including QoS MAC protocol and multihop routing (peer to peer or route to mobile base station);(2)integration of Wireless LAN and Wireless WAN。最後，我們的實作平台建置了上述的系統雛型，我們建構一個警察資訊系統為例。此系統具備了提供即時性傳輸的功能也展示其具立即隨地展開的多階網路控制功能，最重要的是具有internet access功能。

英文摘要(Keywords：Multihop, mobile WLAN, mobile data service network, QoS)

In the Wireless LAN, each station can communicate with a “mobile” base station via either single hop or multihop with companion station’s forwarding. In this specific WLAN, base stations can move depending on needs. Thus, we call this as a mobile WLAN. The infrastructure connecting all the mobile base station is based on a mobile data service network. With the infrastructure, the entire mobile network can have larger service area, and have access ability to wireline networks. In order to support the above network architecture and requirements, we have the following two key issues: (1)control of multihop (ad hoc) network: including QoS MAC protocol and multihop routing (peer to peer or route to mobile base station); (2) integration of wireless LAN and wireless WAN. As a prototype implementation, we developed a practical mobile information system, named MPIS (Mobile Police Information System). This prototype has demonstrated the capability of both supporting real-time applications and instant infrastructure with internet access.

二、計畫緣由與目的

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). The requirements and objective are:

1. MPIS Requirements:
   (a) One-line real-time query
   (b) Personal location tracking
   (c) Instant deployment
2. MPIS Objective: To facility every policeman a real-time multimedia information service anytime any where.

The network architecture, issues, and implementation will be addressed in the following sections.

三、結果與討論

[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.

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: (a) Each PDA can access non-real-time data from any nearby police car; (b) 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 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).

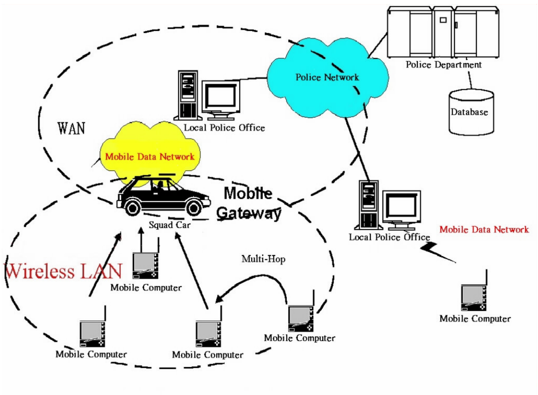

Fig.1 MPIS Architecture

[Network protocols]

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). The idea for using sequence number is derived from DSDV. It is used to avoid message and routing loopings.
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.

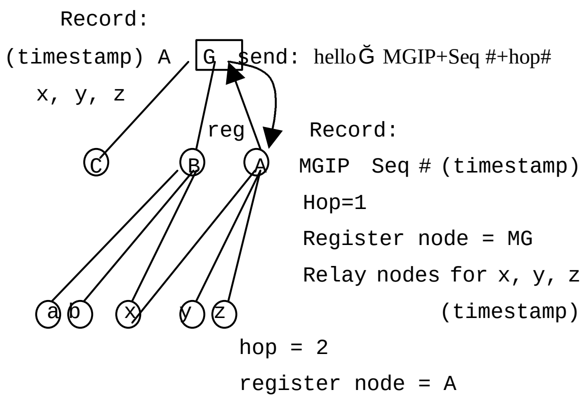

Fig.2 Multihop Architecture Control (Location Tracking)

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/or 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. QoS (Bandwidth Management)
With the above architecture control, we can easily use TDMA (or PRMA) or polling in IEEE 802.11 PCF 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, by routing tree construction, collects information for all its offspring, and sends 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, or polling frequency assignment for each real time connection request by its QoS (bandwidth) requirement. Thus, guaranteed service can be obtained.

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 and lack of source code of wireless adapter's device driver may discourage us because we already make lots of unsuccessful trials. Maybe Linux is the good platform to do this.

[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.

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 as we want unless we are able to obtain device driver to modify altogether.

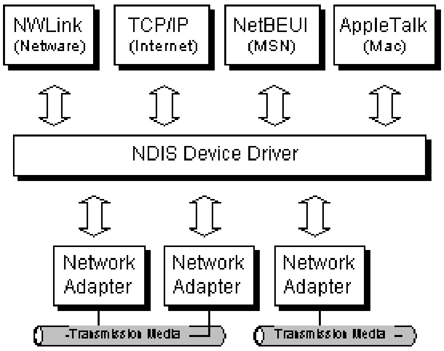

Fig.3 NDIS in Windows

In parallel, we search for other solutions. Currently, we are using ‘winproxy’ and ‘sygate’. Winproxy and sygate 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 (Details can be found: http://www.cherry.cs.nccu.edu.tw/~s8424).
In addition, on MG, sygate 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.

remote clien → relay client → MG
ý telnet、http、ftp ý internet
Sygate proxy server

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.

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.

四、計畫成果自評

參與本計畫的學生，除了研究與本計畫相關的通訊協定外，也清楚學習到各種不同的無線網路架構與產品，如 cellular、數據網路(mobile date)、區域網路。另外，也針對通訊軟體如 wingate、bridging、router、NDIS、driver 等有深刻的實作經驗。透過與我們合作的公司，如義新、大通、智捷、工研院，參與學生也認識到工業界實際需求與運作情形。同時，我們的成果與研究方向，也促使一家公司投入人力著手開發 TCP/IP 的通訊軟體。

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