Construction of IP-Based Multi-tier Network for Mobile Multimedia Communication Services

Ying-Hong Wang, Chih-Hsiao Tsai, Chih-Chieh Chuang
Department of Computer Science and Information Engineering
Tam Kang University, Tamsui, Taipei, Taiwan, R.O.C
Phone: +886-2-8631-6518
inhon@mail.tku.edu.tw, g8190163@tkgis.tku.edu.tw, g6190058@tkgis.tku.edu.tw

Abstract

Nowadays, wireless communication that provides voice only is not sufficient to support the user's need. Therefore, it's an important feature of next generation wireless communication to offer this capability through mobile Internet. Mobile IP allows mobile hosts to change their location and reduce data packet loss probability in wireless communication networks. However, mobile IP still have some defects in handoff and route aspects. Thus, cellular IP protocol is proposed for routing of IP diagrams to mobile stations and fast handoff control in a limited geographical area. It can cooperate with mobile IP to provide wide area mobility support. In this paper, we offer a Soft-handoff method to improve Quality of Service and resource switching management to reduce data packet loss for mobile multimedia communication in cellular IP and mobile IP network.

1. Introduction

Comparing to GSM cellular communication services, the major advantage of third generation wireless communication (3G) are more high speed of communication, providing packet data communication, mobile internet, and mobile multimedia data communication, etc. To approach these objectives, the problems of frequency band and system capacity need to be solved. Moreover, the mechanisms and strategies of the architecture of communication, mobile IP[1][2] and cellular IP[3] management, mobility management...etc need to be designed and find the optimal solutions.

The major objective of this paper is to propose multi-tier wireless communication architecture based on cellular IP to support the service requirements of mobile Internet and mobile multimedia communication. Based on this architecture, there are some issues of research will be executed. How to satisfy the users' requirement for mobile Internet through wireless communication? In the proposed architecture, we decrease the overhead of system management and improve the total effectiveness. We also offer a Soft-handoff method to improve Quality of Service and resource switching management to reduce data packet loss.

This paper is organized as follows: in next section, we give the background of related technologies and the overviews of mobile IP and cellular IP network architectures, two of the most important techniques for providing the multimedia services over mobile communication. Section 3 describes our proposed multi-tier architecture based on Cellular IP and Mobile IP networks. Section 4 describes the soft-handoff and Quality of Service progresses in our proposed network architecture. In section 5, we draw our future work and conclusion.

2. Background of Related Technologies

2.1. Third Generation Wireless Communication

Second generation wireless systems enabled mass market appeal while third-generation wireless systems will introduce value that extends beyond basic telephony. As widespread growth of the Internet extends into the wireless realm, the challenges include the merging of voice and high-speed data without loss in coverage or capacity, support access to the Internet and other multimedia applications like video conferencing. To successfully meet this challenge, 3G-radio access must provide[4]:

- High speed Internet access (384kbps~2Mbps)
- Flexible bearer services
- Circuit and packet data services

Amongst the most important 3G concerns for operators are backward compatibility and protection of existing investments. The chosen 3G standard must facilitate efficient migration from the 2G radio access networks. Thus, an evolution rather than a revolution to 3G from

2G-world success in this scenario.

2.2. Multi-tier Architecture

In the future, mobile Internet architecture is considered including an overlap hierarchical framework. Each framework has its individual feature, i.e. satellite, macro-cell, micro-cell and pico-cell area. Such that, by applying this framework, we can support different transfer rates between mobile nodes and distinct geographical areas.

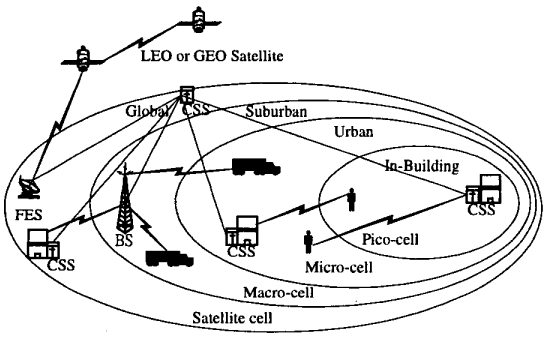

Figure2.1 Multi-tier Cellular Architecture

Multi-tier cellular architecture has different cell ranges (fig. 2.1):

- Mega-cell: provides wide overlay area and is used in a location which has the lowest communication, communication range between 100km~500km.
- Macro-cell: provides big overlay area and is used in a location, which has the lower communication, communication range is smaller then 35km.
- Micro-cell: provides for low mobility area and is used in a location, which has higher communication, communication range is smaller then 1km.
- Pico-cell: provides for indoor mobility area and is used in a location which has the highest communication, communication range is smaller then 1km.

Different cells can cover in the same area and communicate with each other to provide better services.

2.3. Overviews of Mobile IP & Cellular IP

In addition to provide to the convenient voice communication, third generation (3G) wireless communication must connect to access wireless data communication services of internet application in anytime, anywhere. It can combine wireless multimedia communication like voice, data, image, and videoconference, etc, will become the main stream of the future mobile Internet.

To approach to the multimedia services over the 3G wireless communications, there are two of the most important technologies have been proposed.

2.3.1 MOBILE IP. One of the basic architecture of Mobile network is shown as fig. 2.2. Mobile IP defines three main functional entities where its mobility protocols can be implemented:

Mobile Node(MN) — A node which can change its point-of-attachment to the Internet from one *link* to another while maintaining any ongoing communications and using only its(permanent) IP home address.

Home Agent(HA)—A router with an interface on the mobile node's home *link* which :

a. the mobile node keeps informed of its current location, as represented by its care-of-address, as the mobile node moves from link to link;
b. in some cases, *advertises reach ability* to the *network-prefix* of the mobile node's *home address*, thereby attracting IP packets that are destined to the mobile node's *home address*; and
c. intercepts packets destined to the mobile node's *home address* and tunnels them to the mobile node's current location; i.e., to the care-of-address.

Foreign Agent(FA)—A router on a mobile node's *foreign link* which:

a. assists the mobile node in informing its home agent of its current *care-of-address*;
b. in some cases, provides a *care-of-address* and *de-tunnels* packets for the mobile node that have been *tunneled* by its home agent; and
c. serves as a default *router* for packets generated by the mobile node while connected to this *foreign link*.

Home Network—the original network, have power of manage mobile node.

Home Address—is an IP address assigned by home network manager to the mobile node "permanently"; It does not change as a mobile node moves from link to link.

Foreign Network—beside home network, connect to mobile node's networks.

Care-of Address—is an IP address associated with a mobile node that is visiting a foreign link.

Registration—when mobile node moves to foreign network, it must register to home agent to get a temporary care-of-address.

Tunnel—when home agent transfers packets to foreign agent, home agent will encapsulate these packets(encapsulation), and then transfer to foreign agent. This action calls tunnel.

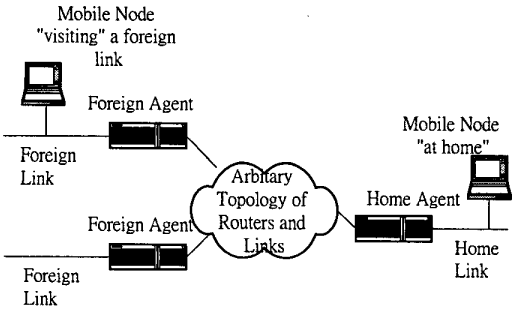

Figure2.2 Mobile IP Entities and Relationships

2.3.2. Mobile IP Procedures. Mobile IP procedure can divide into two steps:

- Step 1
  - (a) When a mobile node (MN) moves from home network to foreign network, foreign agent (FA) will send an *agent advertisement message* to detect whether any mobile node has existed.
  - (b) If any MN exists, it will send a *Registration Request message* through FA to home agent (HA).
  - (c) After HA reply a *Registration Reply message* and registration success, FA then will give a temporary care-of-address to MN.

Hence, no matter anywhere mobile node move, other nodes can keep transfer without break down.

- Step 2

After completed step1, mobile node has established contact with home agent. At this time, there are two conditions of transfer packets:

- (a) any hosts transfer packets to mobile node. When a host transfers packets to MN, all packets will receive by MN's HA. Then HA add FA's address (encapsulate, fig. 2.3) to packets and transfers to FA.

Finally, FA needs to restore packets and transfer to MN.

- (b) mobile node transfers packets to host which has fixed location.

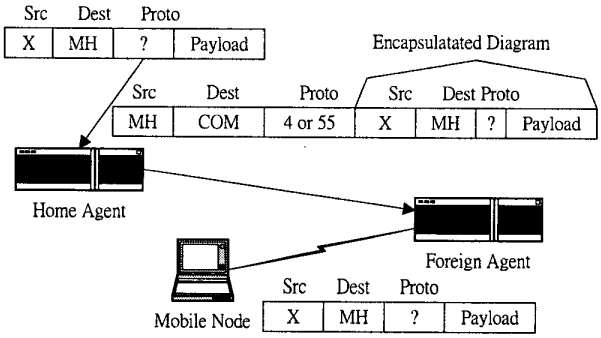

Figure 2.3 Mobile IP Procedures

2.3.3. Cellular IP. Cellular IP[5] represents a new mobile node protocol that is optimized to provide access to a mobile IP enabled Internet in support of fast moving wireless nodes. It can offer fast handoff, less delay, a few or even no packet loss between base stations.

In the scenario illustrated in fig. 2.4, just like regular Internet communication protocols; Internet communication protocol router has replaced by Cellular IP router. Cellular IP via gateway router to access network and IP address is management by base stations.

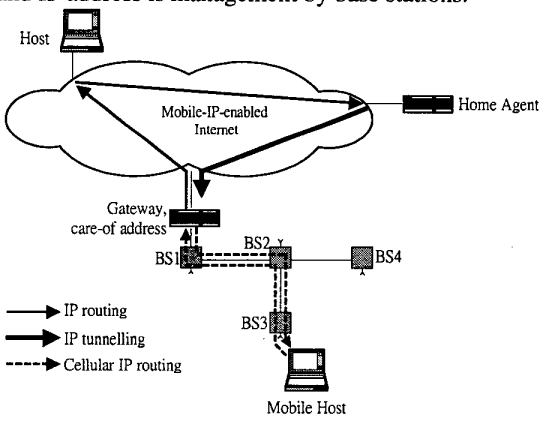

Figure 2.4 Cellular IP access Network

In Cellular IP, location management and handoff support are integrated with routing. To minimize control messaging, regular data packets transmitted by mobile nodes are used to refresh node location information. Paging is used to route packets to idle mobile nodes in a Cellular IP network.

Routing

Routing is an important devise of Cellular IP. It has defined three substantives:

- a. Routing Cache: a special cache space in base stations to store mobile node's path.
- b. Route-update-packets: keep mobile node's routing cache mapping valid, update base stations MN's path.
- c. Route-update-time: can control path update time.

Beside any data packets transfer, mobile node still wishes to connect Internet faster. Hence, base stations need getting Route-update-packet during Route-update-time, and this packet has sent by MN in a fixed time. Route-update-packet will transfer to gateway router along base station, which it's the most approach gateway router. The base station along the way will store MN's location information in router-cache. Such that, when network need to connect or have any data want to transfer to MN. It just transfers along base station which it's routing cache has MN's information.

Handoff

Cellular IP supports two types of handoff scheme. Cellular IP *Hard Handoff* is based on a simple approach that trades off some packet loss for minimizing handoff signaling rather than trying to guarantee zero packet loss. Fig. 2.5 illustrated Cellular IP hard handoff scheme. It is equal to the round-trip time between the MN and the *crossover base station.* We define crossover base station as the common branch node between the old and new base stations. Cellular IP *semisoft handoff* exploits the notion that some mobile nodes can simultaneously receive packets from the new and old base stations during handoff. Semisoft handoff minimizes packet loss, providing improved TCP and UDP performance over hard handoff.

Paging

Cellular IP distributes MNs into *Idle* and *Active* states. It defines an idle mobile node as one that has not received data packets for a system specific time *active-state-timeout.* In this respect, idle mobile nodes allow their respective soft-state routing cache mappings to time out. These nodes transmit paging-update-packet to notify new base station that mobile node's new location at regular intervals defined by paging-update-time. When mobile node wants to transmit data, it changes state into *active state.* Paging update packets are sent to the base station that offers the best signal quality.

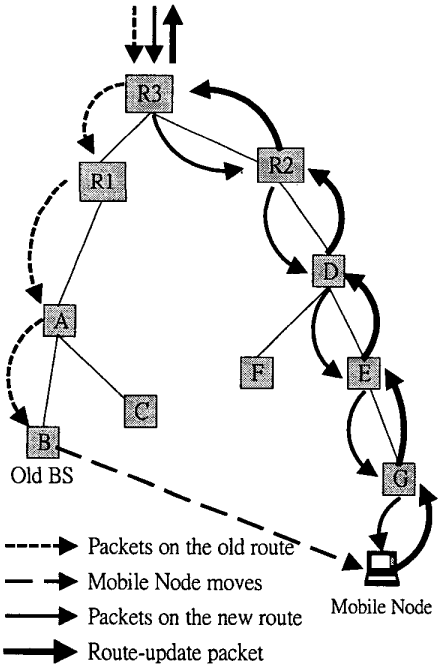

Figure 2.5 Cellular IP Handoff

Security

When mobile node moves into cellular IP network domain, it needs to register at domain gateway router. And gateway constructs a de-tunnel to mobile node's home agent, then the authentication information which paging and routing need is transmitted through this tunnel.

3. Multi-tier Architecture Supporting Mobile Multimedia communications

It can be seen that one of the best wireless communication model of 3G is multi-tier architecture[6][7]. However, there is no a full proposal to solve mobile multimedia communication in a multi-tier architecture. Therefore, we propose a multi-tier wireless communication architecture based on Cellular IP to support following capability:

a. Mobile Internet
b. Seamless Roaming
c. Mobile Multimedia Communication
d. Multimedia Quality of Service
e. Management of Mobile IP

3.1. Cellular IP with Resource Switching Management Center

In our proposed multi-tier architecture, the cellular hierarchy includes two-level cells, they are micro-cell and macro-cell. There are many articles refer to separate micro-tier from macro-tier wireless communication network. The IP policy is that the Mobile IP is used in macro-tier and Cellular IP is used in micro-tier. Moreover, we add an extra component, Resource Switching Management Center (RSMC), in micro-tier to improve capability of Cellular IP network. RSMC is a control center that combines gateway router and cache of BS, which can store MN's location information, forward data packets to MN and authenticate MN's identity. We illustrated our multi-tier architecture in fig. 3.1, it's composed of Micro-cell, Macro-cell, Resource Switching Management Center (RSMC), Base Stations (BS), Mobile Node (MN), Corresponding Node (CN), Home Agent (HA), Mobile Node Location Database (MNLD) and Internet.

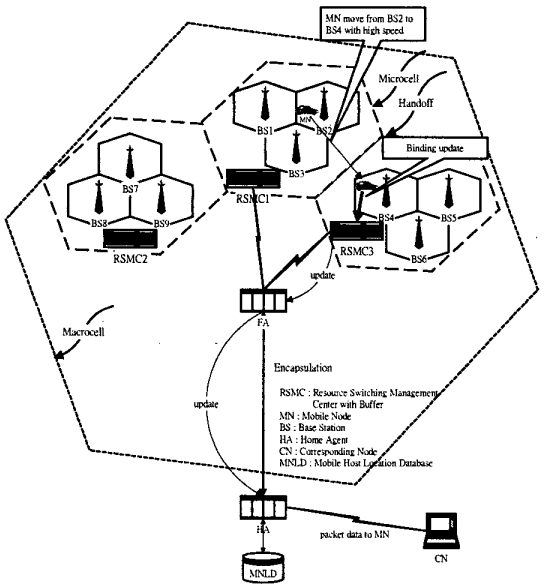

Figure 3.1 Cellular IP Architecture with RSMC

If MN moves from BS1 to BS2, it needs to send a route-update-packet to RSMC during route-update-time. Then RSMC will update MN's location information after got this packet,

and send a message to notify HA and CN. Thus, packets sent by CN will reach MN correctly via RSMC. A RSMC keeps track of its own micro-cell which inside macro-cell, and communicates with others through Foreign Agent (FA). No matter MN is idle(no data transmit) or active(data transmit), it won't waste system resource. In this architecture, we combined routing, paging and location management of Cellular IP by RSMC. Because it is in a limited area, the load of RSMC is very low. And then the FA of Mobile IP communicates to different RSMC. Such that, the multi-tier architecture is constructed which using Mobile IP and Cellular IP network.

4. Soft-Handoff and Quality of Service

In the scenario illustrated in fig. 4.1, we use soft-handoff method to ensure QoS of mobile multimedia communication services. Multimedia data packets sent by CN routing to correctly location of MN via RSMC. When data packets arrived RSMC, it will deliver to both MN's old BS and new BS. Such that, we can reduce the probability of lost data packets. After soft-handoff finished, packets send to MN's new location only, this will promise Quality of Service. If MN moves over macro-cell, we can use FA to send data packets to both old RSMC and new RSMC. And then new RSMC will deliver to new BS. By using soft-handoff method and multi-tier architecture, we firmly believe that mobile multimedia communication services in 3G can be done successfully.

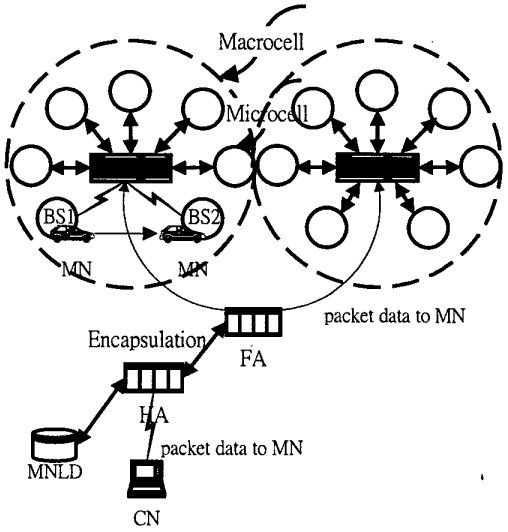

Figure 4.1 Soft-handoff of Cellular IP

5. Conclusions and Future Works

In this paper, we propose a multi-tier solution base on the current IP (IPv4) and are compatible with IPv4. In 3G, mobile multimedia communication is an important issue. Hence, we combine mobile IP and cellular IP network architecture for data packets transfer. By supplying this IP-based multi-tier network, we can simplify cellular IP procedures and provide access to a mobile IP enabled Internet in support of fast moving wireless nodes. We also offer a Soft-handoff method to improve Quality of Service and resource switching management to reduce data packet loss.

Future studies will focus on a multi-tier mobile IPv6 architecture to discuss handoff and QoS issues. How to ensure the Quality of Services in a real time demands, and what's the transfer-coding mode of multimedia data packets.

6. References

[1] Akyildiz, I.F.; McNair, J.; Ho, J.S.M.; Uzunalioglu, H.; Wenye Wang, "Mobility Management in Next-Generation Wireless Systems," Proceedings of the IEEE, Volume: 87 Issue: 8, Aug. 1999 Page(s): 1347 -1384

[2] James D. Solomon, "Mobile IP The Internet Unplugged," PTR Prentice Hall, Upper Saddle River, New Jersey 07458.

[3] Campbell, A.T.; Gomez, J.; Valko, A.G. "An overview of cellular IP," Wireless Communications and Networking Conference, 1999. WCNC. 1999 IEEE, 1999 Page(s): 606 -610 vol.2

[4] Y.S. Rao, Wing-Cheong Yeung; Anil Kripalani. "Third-Generation(3G) Radio Access Standards," Communication Technology Proceedings, 2000. WCC-ICCT 2000. International Conference on, Volume: 2, 2000 Page(s): 1017 -1023

[5] Perkins, C.E.; Kuang-Yeh Wang, "Optimized smooth handoffs in Mobile IP," Computers and Communications, 1999. Proceedings. IEEE International Symposium on, 1999 Page(s): 340 –346.

[6] Iera, A.; Modafferi, A.; Molinaro, A. "Access control and handoff management in multi-tier multimedia wireless systems," Wireless Communications and Networking Conference, 1999. WCNC. 1999 IEEE, 1999 Page(s): 1518 -1522 vol.3

[7] Ganz, A.; Haas, Z.J.; Krishna, C.M. "Multi-tier wireless networks for PCS, " Vehicular Technology Conference, 1996. Mobile Technology for the Human Race, IEEE 46th, Volume: 1, 1996 Page(s): 436 -440 vol.1