Mobility Management of IP-Based Multi-tier Network Supporting Mobile Multimedia Communication Services

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Abstract

Wireless communication that provides voice only is not sufficient to support the necessity of user. It is 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 the losing probability of data packets in wireless communication networks. However, mobile IP still have some defects in handoff and route aspects. Therefore, 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, a handoff method is proposed 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, and so on. To approach these objectives, the problems of frequency band and system capacity need to be solved. Moreover, the architecture of communication, the strategies of mobility management, the mechanisms of mobile Internet and so on need to be designed and found the optimal solutions.

The major objective of this paper is to propose multi-tier wireless communication architecture based on mobile IP and 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, the overhead of system management is decreased and the total effectiveness is improved. Furthermore, the handoff and location management methods are presented to improve Quality of Service. By the way, resource-switching management is introduced to reduce data packet loss.

This paper is organized as follows: next section introduces 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. In section 3, the handoff and location management progresses are presented in the proposed network architecture. Section 4 describes the proposed multi-tier architecture based on Cellular IP and Mobile IP networks. At last, conclusions and future works are drawn.

2. Background of Related Technologies

2.1. 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.

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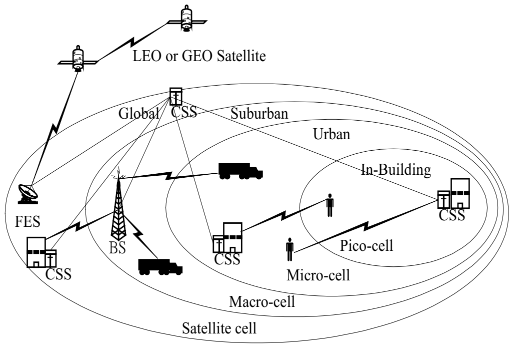

Figure2.1 Multi-tier Cellular Architecture

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

2.2. Overviews of Mobile IP & Cellular IP

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

2.2.1 MOBILE IP One of the basic architecture of Mobile network is shown as fig. 2.2. Mobile IP [2][3] 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 *home link* of mobile node 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 *foreign link* of mobile node 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*.

Procedures of Mobile IP are divided 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 to, other nodes that can contact to it without break down.

- Step 2

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

(a) any hosts transfer packets to the mobile node:
When a host transfers packets to the MN, all packets will receive firstly by HA of this MN. Then HA add address of FA (encapsulate, shown as fig. 2.2) to the original packets and transfers them to FA.

Finally, FA needs to decode the encapsulated packets and transfer to the MN.

(b) mobile node transfers packets to other hosts:
The data transfer just the same as traditional Internet.

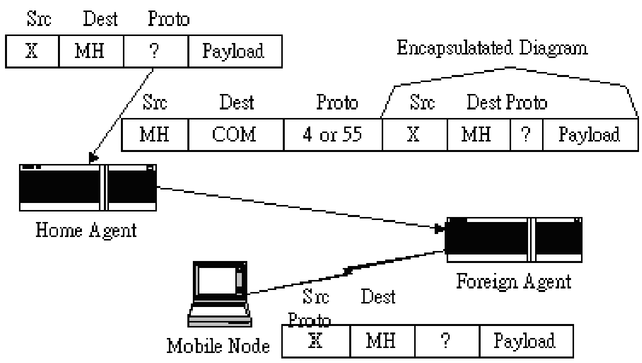

Figure 2.2 Mobile IP Procedures

2.2.2 Cellular IP Cellular IP [4][5] represents a new mobile node protocol that is optimized to provide access 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.

The scenario illustrates in fig. 2.3. Just like regular Internet communication protocols, however, the router of

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Internet communication protocol has replaced by Cellular IP router. Base stations manage cellular IP via gateway router to access network and IP address.

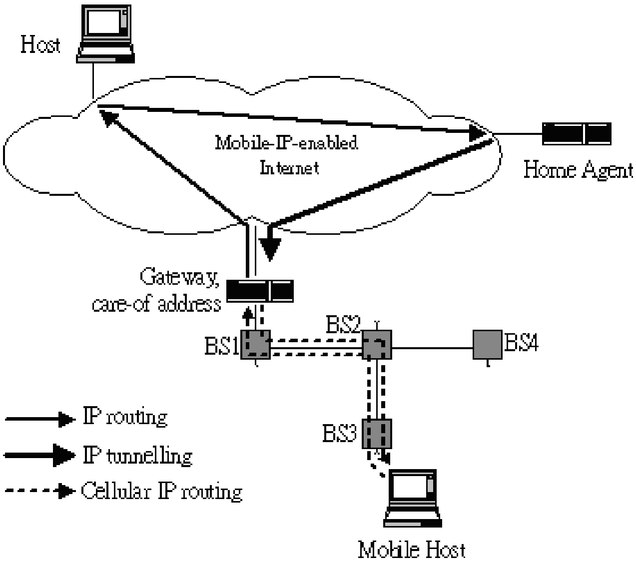

Figure 2.3 Cellular IP access Network

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

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 the path of mobile node.
b. Route-update-packets: keep the mapping path of MN in routing-cache valid, update the path of MN in base stations.
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 to get 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 is the most approach gateway router. The base station along the way will store the location information of MN in Routing-cache. Such that, when network need to connect or have any data want to transfer to MN. It just transfers along this base station which Routing-cache has the related information of MN.

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. 2.4 illustrates Cellular IP handoff scheme. It is equal to the round-trip time between the MN and the *crossover base station.* Crossover base station is defined 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 new location of mobile node 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.

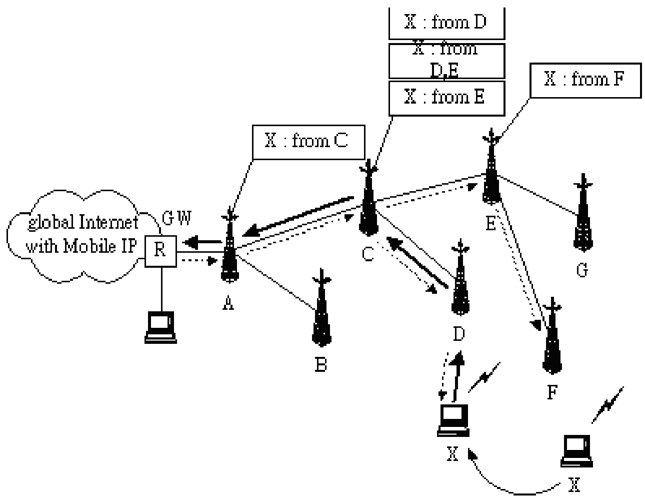

Figure 2.4 The Handoff of Cellular IP

3. Location Management and Handoff Strategy

3.1. Location Management

The basic conception of this paper focuses on multi-tier architecture constructed as macro-tier and micro-tier. Figure 3.1 illustrates the way of data transmission on the proposed communication architecture. In which, *A*, *B*, *C*, *D*, *E*, and *F* are base stations (BS) of micro-cell, while *R1*, *R2* and *R3* are

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BSs of macro-cell. In the same cell type, macro-cell is separated into two levels of tiers. However, micro-cells may be located on same level or distinguished on more than one levels. Thus, this multi-tier architecture includes the characteristics of "Hierarchy". In the proposed architecture, the location information of MN is stored into cell table. In the micro-cell, such as *A*, *B*, *C*, *D*, *E*, and *F*, has a **micro_table**. Macro-cell, *R1*, *R2*, and *R3* not only have a **macro_table**, but also have a **micro_tables** of micro-cells under its control region. The location information and related information of each MN will be stored into one of these two tables. When system needs to track the location of MNs, BSS (Base Station System) just search its cell table. Macro-cell will search its micro_table first, if not find, its macro_table will be searched.

To maintain the correctness of these two tables, MNs need to send a *"Location Message"* to the most upper layer of macro-tier while it uses the BS services of micro-cell. For example, there is a MN(*X*) (shown as Fig.3.1) in the coverage of BS(*B*) and there will have a location information (*X*, *B*) store in the micro_table of *B*. When *X* send a location information to micro-tier periodical, the micro_table of *A*, *R1* and *R3* will keep this record (*X*, *B*), (*X*, *A*) and (*X*, *R1*) in its micro_table, respectively. All records in micro_table and macro_table have a specific time-limitation. Over the limit time and does not have any location information from this MN, the location record of the MN will be erased from the cell tables.

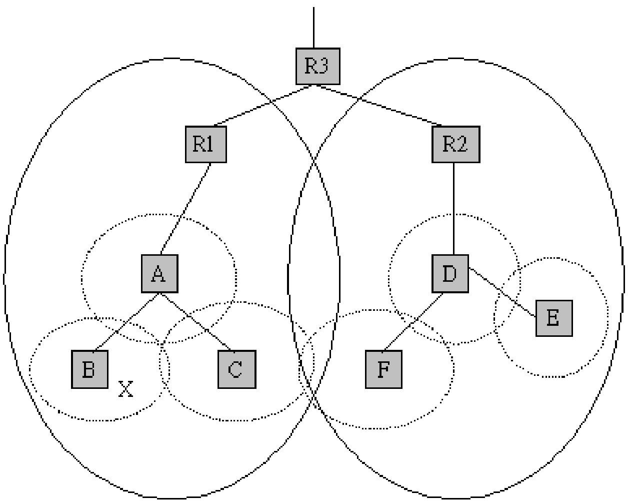

Figure 3.1 Multi-tier Architecture

3.2. Handoff Strategy

In general, there are three kinds of handoff processing mechanism. They are: (1) managed by MN, (2) managed by BS, or (3) managed by BS through MN assisted. The proposed architecture adopts the first method as its handoff mechanism. When MN demands a handoff request, three kinds of factor are considered to decide the suitable tier that MN should hop. The first is the speed of MN, the power of signal from BS is considered also, and the last is the resources of BS.

This multi-tier architecture defines a domain to be coverage of macro-tier. Hence, handoff strategies can be distinguished into Inter-domain handoff and Intra-domain handoff:

- **Inter-domain Handoff:**

  When MN moves from one domain to the other, Inter-domain handoff is happened and it has two following situations:

a. ***The upper layer BS of these two domains is same***

Shown as Fig. 3.2, when MN moves to a new domain, it needs to ask the BS of macro-tier for handoff. If macro-tier has no free channels for handoff, MN turns to ask micro-tier for handoff. MN will send a location message to *R3* through micro-tier or macro-tier BS to update its location information after successful handoff.

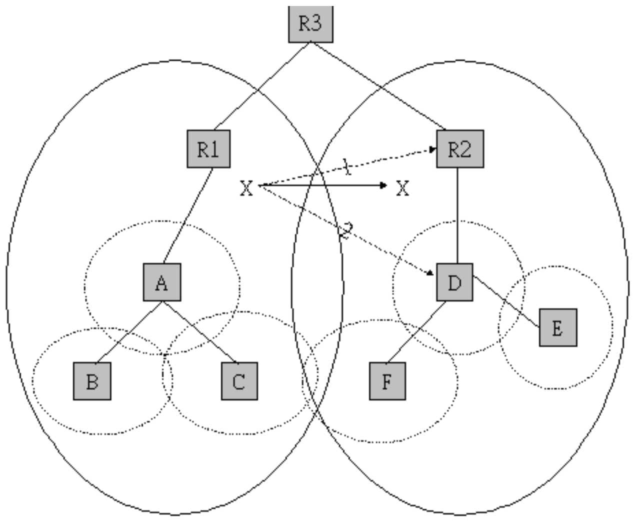

Figure 3.2 the upper BS of these two domains is the same

b. ***he upper layer BS of these two domains is different***

While new domain permits handoff, as shown as Fig. 3.3, MN sends an update-location-message to new macro-tier, and macro-tier will send this message to its upper layer. Due to the upper layer BS of these two domains is different, the most upper layer BS needs to deliver this message to home network of MN. Then, home network will reply new location information to original domain. However, this record will keep a while until MN has completed handoff.

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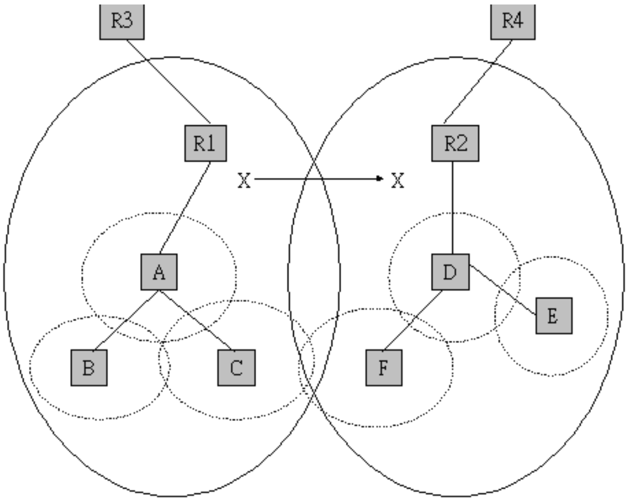

Figure 3.3 the upper BS of these two domains is the different

- **Intra-domain Handoff:**

Due to the proposed multi-tier network architecture is consisting by macro-tier and micro-tier, Intra-domain Handoff can be separated into three conditions as follows:

a. Macro-cell to micro-cell:

When MN moves to the area that macro-cell and micro-cell are overlapping or while MN needs more bandwidth when it was served by a macro-cell, system will switch MN to micro-cell.

If MN demands more bandwidth, it must wait system to accept its request and then start switch to micro-cell. Furthermore, it must send an *"Update Location Message"* to new BS and a *"Delete Location Message*" to old BS in the same time.

For example, MN *X* presented in Fig. 3.4 changes from coverage of macro-tier *R1* to micro-tier *B*, *"Update Location Message"* must send to *R3*. Therefore, Cell *B*, *A*, *R1* and *R3* will store data (*X*, *B*), (*X*, *B*), (*X*, *A*) and (*X*, *R1*) respectively.

b. Micro-cell to macro-cell:

Shown as Fig. 3.4, when MN *Y* moves to the areas that do not cover by micro-cell, it needs switching to the BS of macro-cell. Therefore, MN will send a handoff request message first. If system accepts its request, it will send an *"Update Location Message"* to the BS of macro-cell to store location information of MN in macro_table. It will forward the message to update the macro_table of its parent macro-cell BS.

c. Micro-cell to micro-cell:

When MN *Z* (see Fig. 3.4) moves from one micro-cell *F* to the other *E*, as long as arrival a area that needs to demand a handoff request, it musts send a request message to new BS. After new BS accepts its request, it will send an *"Update Location Message"* to *D* and modify the record of micro_table. If there are no enough bandwidths of micro-cell, it will turn to macro-cell for a handoff request. In this situation, the handoff procedure is same as case ***b.***

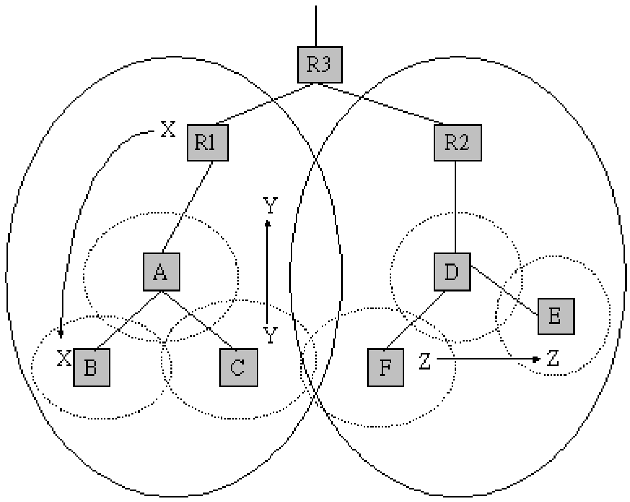

Figure 3.4 three situations of Intra-domain Handoff

4. 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 over multi-tier architecture. Therefore, this section proposes 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

In the proposed multi-tier architecture, cellular hierarchy includes three-level cells, pico-cell, micro-cell, and macro-cell. The focused facilities of mobility management and handoff strategy are separated into 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, an extra component, Resource

Switching Management Center (RSMC), is located 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 the location information of MN, forward data packets to MN, and authenticate identity of MN. The proposed multi-tier architecture is illustrated in Fig. 4.1; it is composed of Pico-cell, 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.

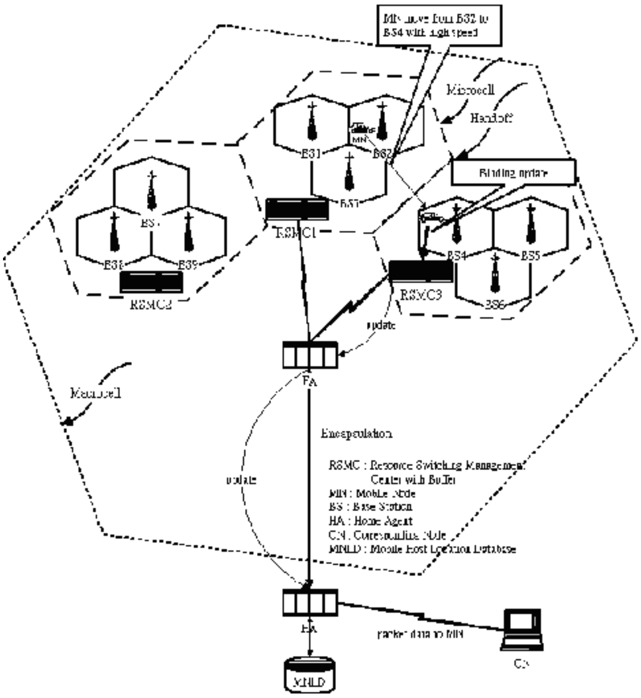

Figure 4.1 The Architecture of Cellular IP with RSMC

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 the location information of MN 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, the routing, paging and location management of Cellular IP are combined 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.

5. Conclusions and Future Works

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

Further 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.

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