Cooperative System for 4G Wireless Communication Networks

Ying-Hong Wang, Hui-Min Huang† and Chin-Yung Yu

Abstract**—**Various services supports are the principal requirements of the Fourth Generation (4G) system; therefore, the need to improve integration of heterogeneous networks is significant. This paper amends EVOLUTE (a project of Information Society Technologies (IST)) to strengthen mobility management. This paper uses Multicast-based Mobility (M&M) to aid Cellular IP (CIP) in micro-mobility management. The aim of this paper is to produce complete integration of heterogeneous networks to support fine-fit mobility management for seamless handoff. The cooperative M&M/CIP is suitable for macro-mobility management, proposed by EVOLUTE, to support real-time and non-real-time data flow in micro-mobility management. Simulation results prove that the proposed system achieves good performance than other existed methods.

Keywords**—**4G, integration of heterogeneous wireless networks, micro-mobility management, hierarchical mobility management

I. Introduction

THE 4G mobile systems will be based on IP protocol [1]. The transfer from voice communication to video communication must be based on inherent technology and economic benefits. Thus, these following four points must be considered [2]:

1. Terminal mobility, session mobility, service mobility and personal mobility must be supported by mobile communication systems. Furthermore, mobility must be available among heterogeneous networks, such as Universal Mobile Telecommunication System (UMTS), and Wireless LAN (WLAN), and even fixed networks.
2. Integration of Authentication, Authorization and Accounting (AAA) mechanisms is necessary, because such integration will uphold required Quality of Service (QoS) and standardize user bills.
3. Flexible and powerful service architectures will be features of next-generation networks. Next-generation networks will require higher bandwidth and a wider range of services than the current network.
4. Mobile users need good mobility management to achieve the objective that anyone could connect to Internet to do anything at anyplace in any way at anytime. In other words, mobility management architecture must provide mobile users with seamless handoff that is efficient and convenient.

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Information Society Technologies (IST) developed the EVOLUTE project. The project achieved the first three aspects mentioned above. EVOLUTE contains multilayer mobility management, vertical handoff among heterogeneous access networks (for example, UMTS and WLAN), placement of AAA functions for granting fast access, ubiquitous service, and seamless handoff in different environments. It allows users to have intelligent and personalized multimedia service. However, the fourth aspect, providing mobile users with seamless handoff capability, is lacking in EVOLUTE. The project chose Cellular IP (CIP) [3] to support micro-mobility management in their mobile communication network. But, CIP cannot satisfy more and more real-time requests in micro-mobility management.

This paper revises micro-mobility management architecture in EVOLUTE for overcoming EVOLUTE architecture deficiencies. This paper presents a novel approach where Multicast-based Mobility (M&M) aids CIP in solving the above problem. The proposed micro-mobility management matches macro-mobility management, which is composed of Session Initiation Protocol and Mobile IP (SIP/MIP) as the approach of EVOLUTE.

The proposed architecture offers satisfactory multimedia service with seamless handoff to mobile users. The simulated results prove the proposed system achieves better performance and lower handoff latency than other micro-mobility management systems.

The rest of this paper is organized as follows. Section 2 introduces some technologies related to this work. Section 3 presents a discussion of operation tactics of cooperative CIP/M&M in micro-mobility management. Section 4 presents simulation results. Section 5 gives conclusions and directions for future work.

II. RELATED TECHNOLOGIES

A.Macro-mobility Management

The Internet Engineering Task Force (IETF) standardized MIP protocol to support the Mobile Host (MH) to have dynamic mobility between Internet and wireless domains. There are two variations of MIP, IPv4 and IPv6.

The MIP [4] process has three main mechanisms, namely agent discovery, registration, and tunneling. Home Agent (HA) and Foreign Agent (FA) advertise their presence by agent advertisement messages so they become known by the MH. An MH requests an agent advertisement message from the attached agent through an agent request message and receives the agent advertisements. Then, it decides whether it is on its home network or on a foreign network. When MH detects it has moved to a foreign network, it obtains a Care-of-Address (CoA) from the foreign network. The CoA is the endpoint of a tunnel toward the MH to receive the packets forwarded by the HA while it is away from home. After gaining a CoA, the MH registers its CoA with its HA to obtain services. Packets sent to the MH’s home address are intercepted and tunneled to the MH’s CoA by the HA. Tunneling is the method used to forward packets from the HA to the FA and, finally, to the MH by encapsulating the original packets in a new IP header containing CoA as the destination address.

The Internet Protocol version 6 (IPv6), a new IP version, has been standardized to connect wireless networks without FA. The address space in Mobile IPv6 (MIPv6) is no longer a problem. A Binding Update (BU) option is defined for mobility support that combines the functions of the registration request for MIPv4 and the BU message for route optimization. The MH entering a foreign network updates its location at the HA and at the Correspond Node (CN) by exchanging BUs/Binding Acknowledgments (BAs) with both entities. Other detailed description about MIPv4 and MIPv6 refer to [4]–[5].

However, MIP is inadequate for real-time traffic because it incurs high jitter, long latency, and disruptive handoff. Notably, MIP solves these problems with route optimization; however, each CH must alter the protocol stack. The application layer includes the SIP mobility management proposed by EVOLUTE; besides, the SIP increases flexibility and reduces jitter and handoff latency. The SIP [2]–[3],[6] is a protocol designed to provide voice signal and multimedia sessions within a packet-switched network. Several wireless technical forums (for example, Third Generation Partnership Project (3GPP), 3GPP2, Mobile Wireless Internet Forum (MWIF)) have recognized that SIP can provide session management, and be the personal and service mobile implementation.

Moreover, the SIP is associated with MIP to support terminal mobility, because SIP extends the MIP protocol, and avoids the failings of MIP. SIP has only been utilized in real-time communication over User Datagram Protocol (UDP); therefore, the best solution would be a cooperative scheme. That is, SIP for real-time services and MIP for non-real-time services.

B. SIP/MIP Combined for Macro-mobility Management in EVOLUTE

This section introduces the approach of macro-mobility management in EVOLUTE [3]. EVOLUTE proposed macro-mobility is based on a combination of SIP and MIP. Routers in the domain edge separate traffic from/toward a MH; therefore, SIP signaling supports Real-time Traffic (RTP over UDP), and MIP supports non-real-time traffic, as shown in Figure 1 [3].

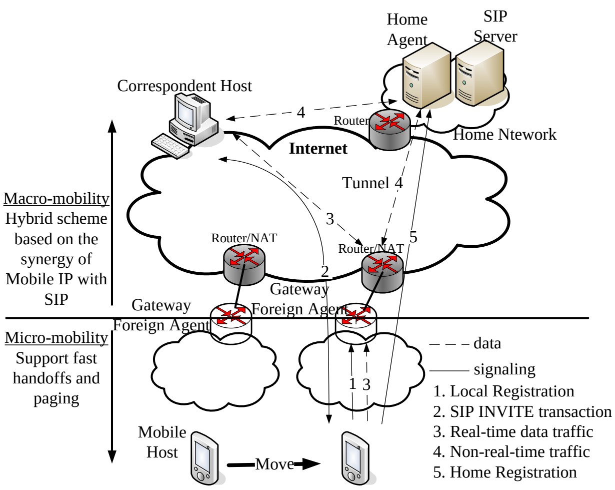


Fig. 1: Combine SIP and MIP for macro-mobility management in EVOLUTE

The MIP aids non-real-time traffic, which bypasses Network Address Translation (NAT). Through the MH home network, this traffic is routed toward the MH using tunneling. Additionally, IP encapsulation is unimportant for these non-real-time applications. However, the real-time traffic of macro-mobility is facilitated by SIP signaling. The use of NAT for real-time traffic creates the problem involving the blocking of IP communications because IP voice and video devices behind the NAT have private IP addresses that are not routable outside their local domain or on the public Internet. The issue is currently under investigation by the IETF working group Middlebox Communication (Midcom). Simple Traversal of UDP through NATs protocol (STUN) has been proposed as a possible solution for the problem faced by Midcom. Furthermore, integration of SIP user agents with STUN client functionality will work based on NAT infrastructure and will allow a wide variety of applications, such as Voice over IP (VoIP).

Both MIP and SIP can be complementary; however, they are unsuited to handling micro-mobility. High mobility within a single domain or Intranet is common; therefore, the MH must be allowed to move freely among wireless Access Points (APs) or Base Stations (BSs). The solution of the move freely can make the movement without informing the distant HA, redirecting services in every movement, and offering idle movement to preserve connections. Multiple standard options will likely be available in the future. Current research exploring micro-mobility management protocols, includes Hierarchical MIP (HMIP), HAWAII, CIP, Cellular IPv6 (CIPv6), and Edge Mobility Architecture (EMA) [7]–[8]. This paper refers a novel architecture M&M that increases the efficiency of micro-mobility management. The CIP infrastructural is utilized to assist the M&M mechanism in providing IP paging, soft handoff, QoS, and context transfer capabilities. The next section introduces the M&M.

C. Multicast-based Mobility (M&M)

In future networks, handoff and packet routing efficiency are vital. By supporting various communicative applications, and developing new services, extra consumers will be attracted to join 4G, and the wireless networks will be popularized. Additionally, a domain with one micro-mobility management method is no longer able to meet the various communicative requests [9].

Although CIP has been an ideal micro-mobility management, CIP only performs well during proactive handoff but not at reactive handoff. Notably, CIP can only provide the bi-cast mechanism, so it does not properly deal with conditions that need multicast. Therefore, other micro-mobility management methods are needed to make up the deficiency of CIP. M&M [10] proposes a multicast-based paradigm for micro-mobility management.

There are some proper nouns presented in M&M, including Regional CoA (RCoA), Multicast CoA (MCoA), Serving Access Router (SAR) and Candidate Access Router Set (CAR-set). When an MH connects to a domain, it is assigned a unicast CoA that is unique within this domain. The unicast CoA is called RCoA, and MH is also assigned an MCoA. The RCoA is a globally routable address, which drives the data packet to the MH between the Internet and foreign domain of the MH. MCoA is within the local domain to which MH belongs. The SAR, which is the AR to which MH belongs, switches the MCoA to the RCoA and sends these packets to the AP to which MH belongs. The CAR-set can be established based on the adjacency of the radio coverage area of the SAR in M&M. The SAR is called the Head of the CAR-set.

The network architecture in M&M is shown in Figure 2 [10]. Through Border Routers (BRs), a network connects to the Internet; also, the connection for the MH is through the radio point—AP. Several APs connects to an Access Router (AR). From the viewpoint of an AR, each AP is a separate subnet.

Figure 2 shows also the transition between RCoA and MCoA. When an MH moves to a new foreign domain, it is assigned an RCoA and achieves inter-domain handoff. Inter-domain handoff includes automatic registration of RCoA to the MH's HA, and the algorithmic derivation of the multicast address (MCoA) through the assigned unicast address (RCoA). The AR triggers a Join Message (J-message) to set up a multicast tree for each MCoA. Packets are sent to the MH's HA by home address, and are then tunneled to the foreign domain and received by BR in RCoA. The BR derives the MCoA from the RCoA and broadcasts these packets to the CAR-set of the MH. (CAR-set will be introduced in a moment.) The SAR transforms the MCoA into the RCoA; thus, these packets do not need a secure mechanism between the multicast mechanism and the MH.

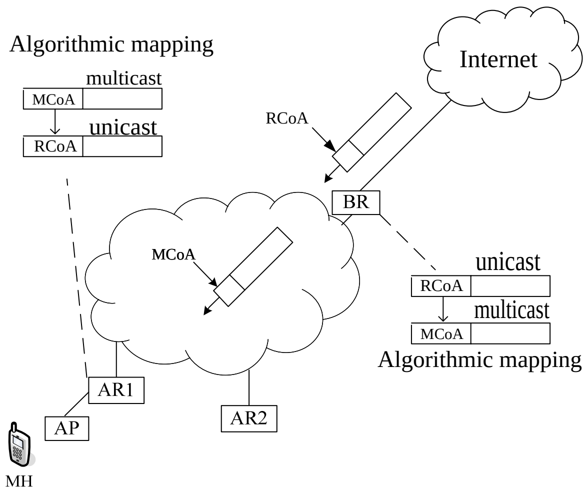


Fig. 2: Data packet flows in the M&M architecture

Membership in the CAR-set is identified by several factors, such as the handoff type, movement direction, and predictable location. This procedure is called the CAR-set prediction algorithm. For example, a handoff can predict a new AR (AR5 in Fig. 3), as the performing of RSVP. After the handoff, the CAR-set is the new AR (AR5 in Fig. 3). If the handoff cannot predict a new AR, the CAR-set is AR1, 4, 5, 6, 8, 9 and 10 while the MH detects the strong signal of AR5 (dotted line in Fig.3). Other specific explanations are provided in [8].

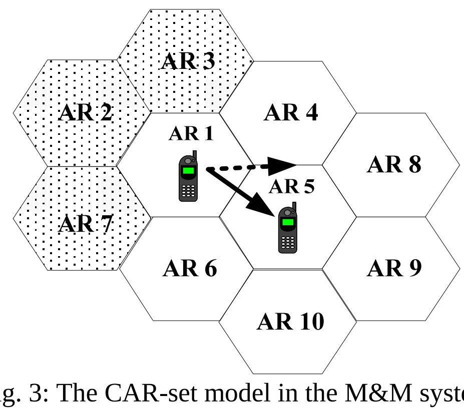


Fig. 3: The CAR-set model in the M&M system

The CAR-set prediction algorithm infers a unique CAR-set for each MH. Additionally, the AR1, AR2,…, AR7 make up a CAR-set (Fig. 3); also, AR1 is the SAR of MH. The CAR-set is a member of a multicast tree and receives the same packets through the MCoA. Therefore, the MH moves to any router in the CAR-set—even without a complete handoff, and it will not cause packet flow interruption.

Other detailed descriptions of M&M are referred to in [8],[10]. One main contribution of the M&M is the handoff framework. Applying the CAR-set effectively completes proactive and reactive handoff. The M&M system obviously surpasses CIP and HAWAII, because of the capability of the CAR-set path setup.

Although the M&M system has outstanding performance for decreasing handoff interruptions, it increases overheads in packet replication between the BR and AR that belong to the CAR-set. From a network perspective, numerous packets are duplicated, even when the duplicated packet is useless to the MH. To meet the customer need of communicatory quality, the multicast mechanism is not used in some cases—for example, for an application that applies CIP instead of multicast. General telecommunications is a typical application that utilizes a simple micro-mobility management, such as CIP, to obtain acceptable communication quality; moreover, the CIP is not costly in dealing with packets. Cooperative CIP/M&M produces a superior micro-mobility management method to the cooperation of SIP and MIP for the macro-mobility management method.

III. The Cooperative CIP/M&M for Micro-Mobility Management

A. Methods of the Hybrid CIP and M&M System

There are two methods of combining CIP with M&M for micro-mobility management of the proposed architecture—CIP/M&M replacement and cooperation. One method is CIP functions first, all packets transform to M&M standardization when the MH requires real-time packets; this method is named the replaceable CIP/M&M. The postponed transmitting and wasted bandwidth are predictable. Also, system transmission will change and complicate the way of bill calculating; so this method was abandoned.

The second method is to take CIP as a basic protocol for micro-mobility management. When real-time traffic trigger the M&M mechanism, the CIP deals with the routes of non-real-time traffic, and the M&M is employed to route real-time traffic. Figure 4 shows the two data flows—real-time and non-real-time. The diagram presents the data packet route for the two data flows that must be transmitted to the MH. There are two CN (CN1 and CN2) that communicate with the MH simultaneously (Fig. 4). Node CN1 requires non-real-time service, and CN2 requires real-time service; so, communication is divided into two parts. One part is macro-mobility management, and the real-time packet is routed by SIP, and the non-real-time packet is routed by MIP. Another part is micro-mobility management, and the real-time packet is routed by the M&M, and the non-real-time packet is routed by CIP.

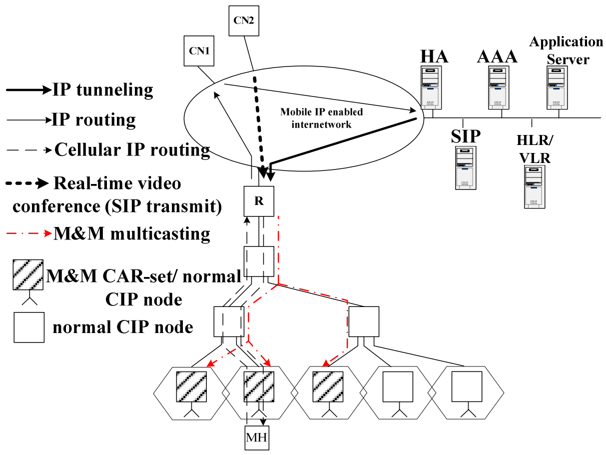


Fig. 4: Overview of the CIP/M&M cooperation policy

Let the packet use the proper route protocol, according to type demanded by the MH, the proposed system then sets up a Routing Information Table (RIT) (such as Table 1). The RIT-BR (similar to Table 1(a)) is maintained by BR and RIT-SAR (similar to Table 1(b)) is maintained by SAR. The tables help separate CIP routing packet and M&M routing packet streams; these two routing packets are transmitted to the same MH. The tables also take the minutes when the M&M protocol is completed.

The most important part of Table 1(a) is the client specific information. The client specific information function is used between a user and service provider to distinguish incoming packets that need the M&M or CIP. In Table 1(b), the packets transmitted by M&M to MH are transformed from a multicast address to a unicast address.

Tables 1: The RIT in cooperative CIP/M&M

(a) The table in BR or FA

The address information of MH	How many applications should be transmitted by M&M now	The total time of performing M&M application	The client specific application need transmitting by M&M
MH's RCoA	2	00:20:45	e.g.1.UDP connection 2.all video conference
MH's MCoA			

(b) The table in SAR and other ARs in the same CAR-set

The address information of MH	How many applications should be transmitted by M&M now	The total time of performing M&M application
MH's RCoA	2	00:20:45
MH's MCoA		

Additionally, M&M does not work all the time in the proposed architecture. For each user, the system always adopts the CIP to offer the packet a route, except the MH requests real-time services. Figure 5 shows how the network works during a videoconference, which needs the M&M mechanism. The figure shows the overhead caused by M&M is temporary.

In fact, CIP and M&M are independent mobility management mechanisms that provide different communication quality for MH. Both CIP and M&M have unique independent transmission systems. Moreover, the two systems do not interfere with each other when they work simultaneously in a domain. From the perspective of a mobile user, whether the mobile user is the initiation or termination of M&M, the change in communication management is not noticeable. When a mobile user requires a real-time application (for example, videoconference), the system will ask the BR (or the FA) for related information. The related information is the key that triggers the M&M, which is stored in the database of the Home SIP server to build the M&M mechanism for the mobile user.

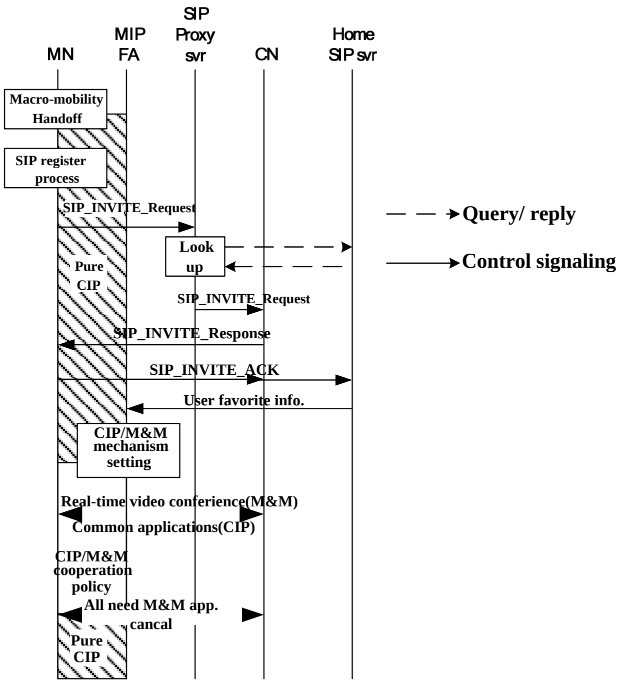


Fig. 5: The flow of cooperative CIP/M&M policy

According to required QoS, the proposed system decides which protocol provides service. Comparing replacement with cooperation of CIP/M&M, there are two advantages of cooperation. One advantage is the charging system is simple, because adopting M&M does not change the transmitted form of the original request. Another advantage is the decrease in wasted resources, as the request only obtains adequate QoS. Therefore, we recommend using cooperative CIP/M&M.

B. *Handoff in Cooperative CIP/M&M*

Another important issue in micro-mobility management is how CIP and M&M handoff when working simultaneously. Noticeably, each CIP and M&M individually prepare the handoff process when the network detects a handoff condition before the handoff. Otherwise, the MH will move to a new AR, and restart the M&M mechanism according to the MH's requirements.

When the MH detects the old BS's signal becoming weak and the signal becoming strong from a new BS, the MH will request a handoff to preserve the connection. The handoff mechanism of the CIP (for example, hard or semisoft handoff) will always work properly because the MH will connect with an AP through the CIP regardless of whether the MH is idle or active. Also, the real-time request of the MH will trigger the M&M handoff. Through the specific triggering [10], the M&M will initiate the CAR-set predication algorithm to predict members of the CAR-set. In fact, the handoff procedures in cooperative CIP/M&M are independent and never interfere with each other. Figure 6 presents the handoff algorithm. The figure indicates the MH triggers handoff by sending a Strong Handoff Radio Trigger (SHRT) to a new SAR when the MH needs a handoff.

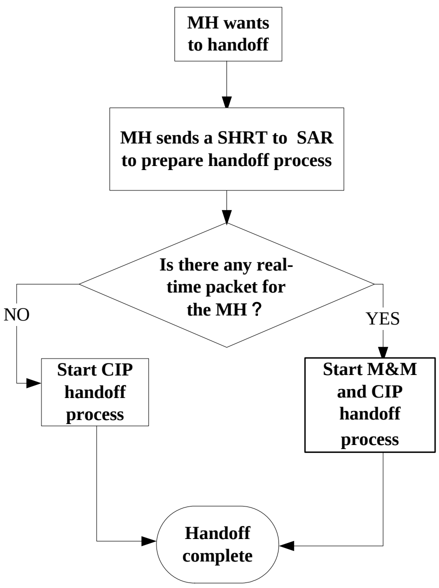


Fig. 6: Handoff algorithm for cooperative CIP/M&M

To simplify handoff description, this paper only describes the proactive handoff. Passive handoff process is where the proposed system starts CIP, and restarts the M&M according to MH's requirements. Figure 4 shows the packet routes before a handoff. Figure 7 (a) shows the packet routes in the period of handoff. Real-time packets have been sent to the MH's CAR-set according to M&M protocol. Non-real-time packets have been sent to the old and new BS, according to CIP protocol. Figure 7 (b) shows the packet routes after a successful handoff.

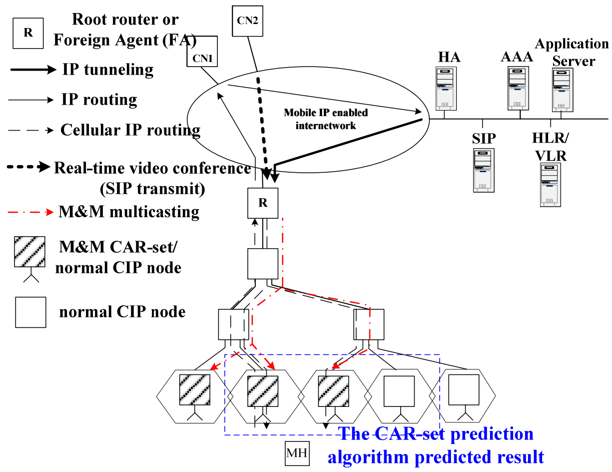


Fig. 7(a): Data flows during a handoff

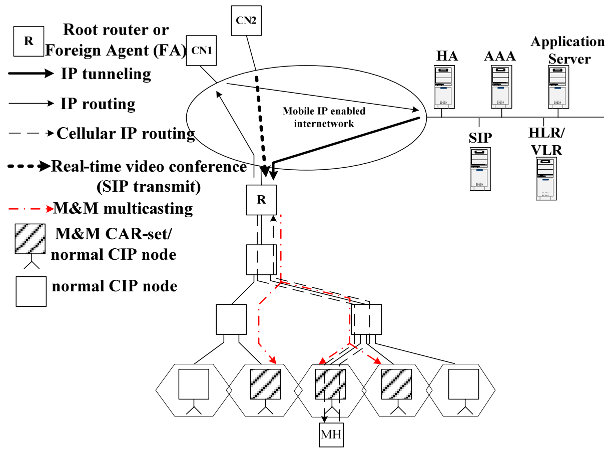


Fig. 7(b): Data flows after a handoff

This paper adopts a new idea of cooperative CIP/M&M to support micro-mobility management for mobile users in the 4G network. The cooperative CIP/M&M and macro-mobility management in the EVOLUTE project will complement each other well. The proposed system will offer many types of services and meet the needs of MH when dealing with special handoff.

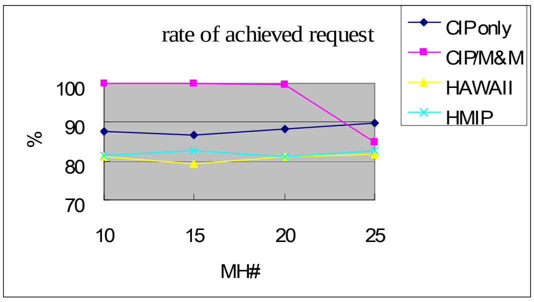
IV. SIMULATION

A. Simulation Environment

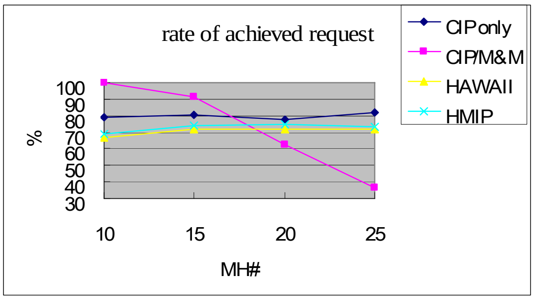
The simulation program was written in C++, and adopts the cooperative CIP/M&M tactic. The system has ten BSs (or APs), and then the average of the ten BSs (or APs) is fetched as result of simulation. Each BS (or AP) has 10–25 MHs, which randomly propose 1–3 real-time or non-real-time requests. The real-time requests have higher priority to obtain bandwidth than non-real-time requests. The real-time requests are serviced by M&M and non-real-time requests are serviced by CIP. The simulation parameters are as follows (Refer to the simulations in [11]–[14]). The real-time requests randomly ask for sufficient bandwidth between 144–384 kb/s, whereas sufficient bandwidth for non-real-time requests is between 4.75–12.2 kb/s.

B. Simulation Results

Requests are refused when there is not enough bandwidth. The simulation tested the ability and efficiency of the proposed system, and is compared with some micro-mobility systems. The proposed system and some micro-mobility management systems are compared by viewing the rate of achieved requests, the rate of used bandwidth, and the latency during handoff. The ratios of real-time to non-real-time were 1:9 and 2:8, as explained in Section 4.3.



(a) Real-time: Non-real-time ration is 1:9

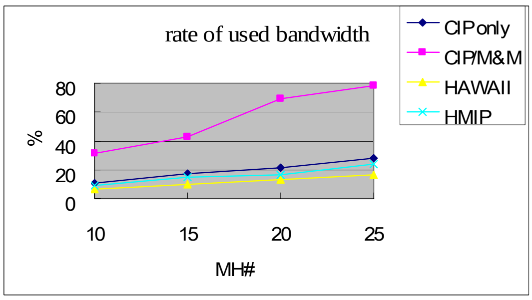


(b) Real-time: Non-real-time ratio is 2:8

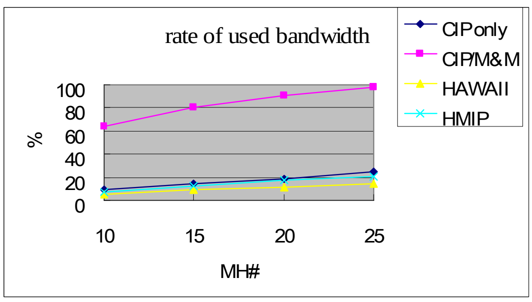
Fig. 8: Rate of achieved requests

Figure 8 shows the rate of achieved request in one BS (or AP). The effectiveness of cooperative CIP/M&M decreases when the number of MH is >16. The following are the two reasons the simulations get the 16. The first reason is each MH could be provided by 3 real-time services at the same time. The other one is the micro-cell is office or coffee bar [15] in our simulated environment, so 16 is the legitimate number.

Figure 9 compares the rates of used bandwidth. The rate of used bandwidth in the proposed system is 47.9% with 16 MHs according to Figure 9 (a), and the rate is 82.8% with 16MHs according to Figure 9 (b). The simulation results reveal the proposed system meets current demands, and the cooperative CIP/M&M has higher utility rate even when the number of MHs is low.



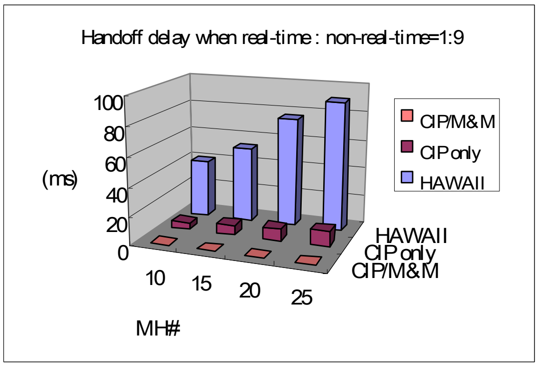
(a) Real-time: Non-real-time ratio is 1:9



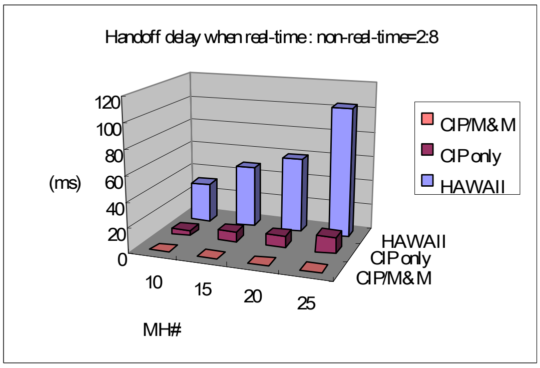
(b) Real-time: Non-real-time ratio is 2:8

Fig. 9: Rate of used bandwidth

When MHs need to handoff, the service provider predicts a new BS. The prediction influences the packets latency during handoff. M&M deals with special handoff to decrease the latency by multicast packets as mentioned above (in Section 2.3 or [8]). The simulated parameters are the same as those adopted in the simulations in [16]. Figure 10 compares the time of handoff latency. The proposed system has a lower latency than pure CIP by roughly 7ms when the number of MHs is 16, according to Figure 10 (a). The proposed system is lower latency than pure CIP roughly 8ms when the number of MHs is 16, according to Figure 10 (b). The simulation results show the proposed system supports fine-fit mobility management for seamless handoff.



(a) Real-time: Non-real-time ratio is 1:9



(b) Real-time: Non-real-time ratio is 2:8
Fig. 10: Handoff delay

V. CONCLUSION AND FUTURE WORK

This paper describes a multilayer mobility management system. The primary contribution of this network architecture is that it supports mobility management in the integration of heterogeneous network in future. The M&M scheme works in cellular systems and WLAN systems. Moreover, M&M can easily cooperate with other micro-mobility management schemes thereby providing network providers with flexible space to set up their own services. According to simulation results, the proposed system meets future demands and effectively uses available bandwidth.

This multilayer mobility management system has several advantages. To support fast handoff, a multicast function, and dealing with different handoff types, this study adopted M&M to aid CIP in micro-mobility management. Macro-mobility management is operated by the cooperation of SIP and MIP in EVOLUTE. According to the simulation results, the proposed system meets future demands and decreases handoff latency.

Further work will produce a scheme for disposing of bandwidth in the cooperative system. The scheme will explore how the system decreases bandwidth from assigned bandwidth and reassigns decreased bandwidth to new requests that have inadequate bandwidth. Thus, the system will increase the rate of achieved services and service provider revenue.

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