Immediate Multihoming Solution for UMTS and WLAN Interworking System

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ABSTRACT

Multihoming is an attractive feature for mobile nodes (MN) equipped with multiple network interfaces in a converged networking environment. However, the current standard Mobile IP (MIP) lacks support for multihomed MNs. Accordingly, this paper presents an immediate solution to resolve the problems of multihomed MNs in a UMTS and WLAN interworking system. The interworking system is based on a hierarchical architecture according to the UMTS and WLAN coverage characteristics. The MIP is only operated in the WLANs, and not in the UMTS, allowing the MIP to be used for multihomed MNs with minimal modifications. In addition, MIP binding filters are used to realize the advantages of multihoming, enabling different traffic flows to be transmitted simultaneously through different interfaces. The overall design aims to minimize the modification to the MIP and impact on existing UMTS and WLAN systems. We evaluate the performance of proposed scheme using an OPNET simulator.

Key Words : Multihoming, Interworking, Umts, Wlan, Handover

Ⅰ. 서 론

The worldwide deployment of cellular data networks, such as a GPRS (General Packet Radio Service) or UMTS (Universal Mobile Telecommunications System), provides users with public mobile services over large geographical areas, where the highest available data rate in a UMTS is about 2Mbps. In contrast, WLANs are mainly deployed in indoor environments for low-mobility and high-speed data applications, where the bit rate of the IEEE 802.11 system is between 11-54Mbps. Thus, with the increased deployment of business and public WLANs worldwide, this has created a growing need for users to be able to handover or roam between a cellular network, such as a UMTS, and business or public WLANs. Several methods have already been proposed for interworking between WLANs and 3G networks [1-5].

To achieve a seamless handover between WLANs and 3G networks, a mobile node (MN) needs to use two interface cards to access the different wireless networks. Therefore, this kind of MN, called a multihomed MN, includes either multiple addresses that are used as a source address or multiple tunnels to transmit packets [6]. A multihomed MN has a number of advantages: i) it can realize load sharing and load balancing through the simultaneous use of multiple interfaces, ii) it can integrate several types of access technology, thereby providing ubiquitous access, improving reliability, increasing the available bandwidth, and selecting appropriate networks based on the user preference [7], and iii) it can minimize the latency and packet loss during a vertical handover.

However, different problems arise in order to provide full support to a multihomed MN.

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i) Since the movement detection of the current Mobile IP (MIP) is only based on a router advertisement (RA) message received by an MN through one specific network interface [8], RA messages received from other network interfaces do not affect the operations of the MN (movement detection and vertical handover decision). However, in the case the MN is under a UMTS and WLAN overlay network, the two MN interfaces can receive RA messages from the two networks at the same time.

ii) If a multihomed MN only has one home address (HoA), yet two care of addresses (CoA) are received from UMTS and WLAN networks respectively, the MN will register the two CoAs with a single HoA. Thus, managing multiple CoAs bound to a single HoA and managing a vertical handover between different CoAs are important issues [9].

iii) The current MIP does not clearly define the relationship between HoAs and CoAs. If an MN has two HoAs that are related to separate UMTS and WLAN interfaces, the MN cannot bind a new CoA with a particular HoA. Moreover, a HoA may be considered as a CoA in relation to another home link of the MN.

iv) Furthermore, a number of general problems also need to be solved to realize the advantages of a multihomed MN. For example, how to redirect flows from one interface to another; how to use the interfaces differently according to preference settings; how to allow the MN to use two interfaces simultaneously; and how to ensure TCP transparency when the MN's HoA changes due to a vertical handover.

Several studies have already attempted to address such multihoming problems. In [10], an interface switching agent was introduced to hide the two physical interfaces and isolate the interface changes from the MIP, allowing direct use of the MIP with a multihomed MN without modification. However, this scheme requires significant modification of the MN's stack to provide a virtual interface, along with complicated software to abstract and map the physical interfaces. Moreover, various research groups dedicated to multihoming, such as NOMAD, MONAMI, and Ericsson's Nomadic-Lab have recently proposed certain modifications to make the MIP more practical for multihomed MNs [11-14]. Yet, none of these modifications can completely solve all the problems related to multihomed MNs, plus it will take a long time to standardize the MIP improvements.

Accordingly, this paper proposes an immediate solution to support multihoming in a UMTS and WLAN interworking system. The design objective is also to minimize the modifications of the MIP and both systems. A hierarchical architecture is considered for the interworking system. Within one GGSN (Gateway GPRS Supporting Node) visited domain, the MIP is only operated in the WLANs, and not in the UMTS, allowing the MIP to be used for multihomed MNs with minimal modifications. In the proposed scheme, the multihomed MN does not configure multiple (HoAs, CoAs) bindings, but a unique (HoA, CoA) binding in both the global and local domain, thereby avoiding the confusion of multiple (HoAs, CoAs) bindings and enabling a graceful transparency of multihoming over the interworking system. Moreover, to realize the benefits of a multihomed MN, MIP filters [11] are used to distribute the flows between the two points of attachment for each interface simultaneously through GTP-tunneling (GPRS Tunnel Protocol) and MIP-tunneling.

The remainder of this paper is organized as follows: Section II describes the interworking architecture, then the proposed multihoming support scheme is explained in detail in Section III and simulation results presented in Section IV. Finally, Section V offers some concluding remarks.

Ⅱ. Interworking Architecture

The goal of the proposed scheme is to provide an immediate multihoming support scheme with minimal changes to the existing infrastructures. As such, a practical interworking architecture is provided in Figure 1, where the WLANs connect to

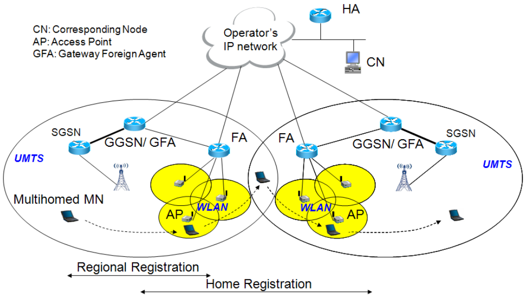


Fig. 1. Architecture of UMTS and WLAN interworking system.

the UMTS directly at a GGSN without any modification to the entities and protocols of either system. In the case the WLAN and UMTS providers are different, this study assumes a mutual agreement between them. The WLAN also directly connects to other IP networks to support the other general users which only have a single WLAN-interface.

According to 3G TS 23.060 [15], UMTS/GPRS provides IP mobility within a UMTS/GPRS network. However, IP mobility for inter-UMTS/GPRS networks (i.e., inter-GGSN areas) can not be supported. Thus, without an MIP-like solution, an MN must stay within a fixed GGSN area as long as the PDP (Packet Data Protocol) context is activated. In such an interworking scheme, the MIP is used to provide global inter-GGSN IP mobility based on 3G TS 23.923 [16]. Plus, the HA can be located in a UMTS or different network, as defined in [16].

Furthermore, UMTS and WLAN systems have different coverage characteristics. A UMTS system provides a global service, while WLANs only service certain "hotspots", such as hotels and airports. In such an overlay wireless network architecture, the WLAN systems look like separate islands within the extensive UMTS sea. Therefore, the proposed interworking system is based on a hierarchical structure, where each area covered by one GGSN is a visited domain, and the WLANs are under their adjacent GGSN domain. In this way, all the interworking signaling is restricted to the GGSN visited domain, and the vertical handover latency reduced when an MN moves between the two systems.

MIP Regional Registration (MIP-RR) [17] is used to provide mobility in the hierarchical interworking system. The GGSNs are enhanced with a gateway foreign agent (GFA) function according to [17]. When an MN first arrives at a GGSN visited domain, it performs a home registration, i.e. registers with its HA. During this home registration, the MN registers the address of the GGSN/GFA as its CoA with its HA. Thus, when moving between different WLAN FAs within one GGSN visited domain, the MN only needs to make a regional registration with the GGSN/GFA. During this regional registration, the MN registers the address of the FA in the WLAN network as it local CoA (LCoA) with its GFA. Thus, within one GGSN visited domain, even though the MN's LCoA changes, the HA continues to use the GGSN/GFA address as the CoA of the MN. Plus, the regional registrations are performed transparently to the HA.

With such a practical architecture, the service providers can realize the interworking of the two systems immediately without waiting for a lengthy standardization process. Moreover, the current design is based on MIPv4, due to its wide application, yet the design can easily be extended to MIPv6.

Ⅲ. Multihoming Support Scheme

The proposed scheme for a UMTS and WLAN interworking system focuses on mobility management using the MIP, and avoids dealing with the authentication and security procedures in each system.

3.1 Multihoming

In the 3G technique specifications [16], the MIP provides IP mobility for inter-UMTS/GPRS networks through a three-stage evolution. Stage I allows an MN to roam between a UMTS and a WLAN within one GGSN domain, stage II supports IP mobility between two GGSN domains during one session. While stage III provides the same mechanism as stage II, except the SGSN and GGSN are combined into one node, called an Internet GPRS Support Node (IGSN). As such, the proposed scheme only modifies first two sta ges to support multihomed MN roaming in an interwo rking system.

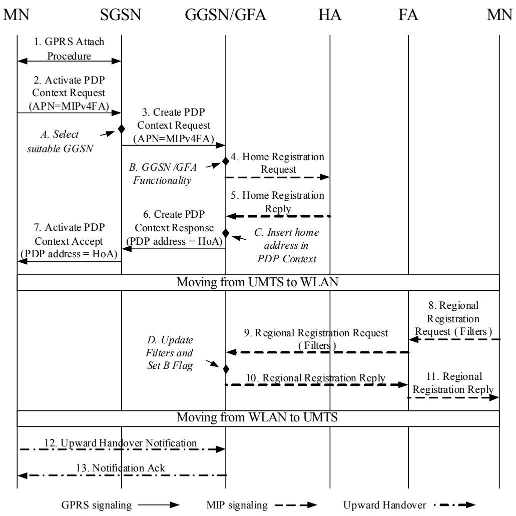


Fig. 2. Message flow for roaming between the UMTS and a WLAN in the stage I.

3.1.1 Stage I: vertical handover within one GGSN domain

As the current MIP operation is based on RA messages received from one specific interface, the MIP function is only configured at the WLAN interface of multihomed MNs to provide mobility management over the WLAN networks. Meanwhile, in the UMTS domain, GPRS mobility management and session management (GMM/SM) are used instead of the MIP to provide tunnel-related management for packet rerouting in the core network, as specified in [15]. Therefore, this section shows how the MIP and GMM/SM work together to provide a vertical handover between the two systems within one GGSN domain.

In stage I, the message flows for roaming between the UMTS and a WLAN are shown in Figure 2, and based on the following procedures:

- Steps 1-3: The standard GPRS attach procedure and PDP context activation are executed as defined in [15].
- Point A: The access point name (APN), MIPv4FA, instructs the SGSN (GPRS Support Node) to forward the PDP context activation request to the GGSN using an FA function. The PDP address should be omitted (set to 0.0.0.0).
- Point B: The GGSN needs to be enhanced with a GFA function, according to IETF specifications. As defined in [16], the GGSN/GFA needs to send a dedicated RA message after sending the Create PDP Context Response, as this RA message is used by the FA to announce its presence and parameters. These parameters are then used by the MN to detect movement and configure a CoA. Since the MN can detect movement on the basis of other UMTS network parameters, and use the GFA address as its CoA with its HA according to [16], the RA message does not need to be broadcast over the UMTS radio interface. Furthermore, in this paper, since the MIP is not implemented over the UMTS interface of multihomed MNs, the RA message is omitted and the Home Registration directly executed instead.
- Steps 4-5: Before responding to the Create PDP Context message, the GGSN/GFA sends a Home Registration Request message on behalf of the MN to the HA. The MIP function at the GFA is modified to enable it to send an MIP Registration Request message when it receives the PDP context activation. As long as the MN does not know its IP address, it can use 0.0.0.0 as the HoA. According to [16], the mobile-Node-NAI extension was proposed to handle a temporarily assigned HoA. Thus, the HA assigns an HoA to the MN and includes this address in the Home Registration Reply message. These Registration Request and Reply messages are also used to set up a tunnel between the GFA and the HA [17].
- Point C: The GGSN/GFA receives the MIP Home Registration Reply message from the HA, extracts the HoA, and inserts it as the PDP address in the PDP context [16].
- Steps 6-7: The GGSN inserts the PDP address in the PDP context response message and replies to the MN.

  The home registration procedure is only executed between the GFA and the HA. Plus, the LCoA field of the visitor list entry at the GFA is 0, as there is no FA entity in the UMTS [17]. After the Home Registration, the GGSN/GFA is required to map the HoA to the local link address, the TID

(GPRS Tunnel ID) in the UMTS network. Meantime, the HA maintains a mobility binding list entry of the MN's HoA (PDP address) corresponding to the MN's CoA (GFA's address), as shown in Figure 3.

Moving from UMTS to WLAN: Suppose the MN moves into a WLAN within the same GGSN domain. It will then receive an RA message sent from the FA in the WLAN network.

- Steps 8-11: The MN performs a Regional Registration GFA according to [17]. The FA's address is set as the LCoA in the Regional Registration request.

  This Regional Registration procedure is transparent to the HA, so the global binding (HoA, CoA) in the HA does not change. After the Regional Registration, the LCoA field of the visitor list entry at the GFA is filled with the FA's address, as shown in Figure 4.

Moving from WLAN to UMTS: As the UMTS system does not support the MIP function, an Upward Handover Notification message is introduced to

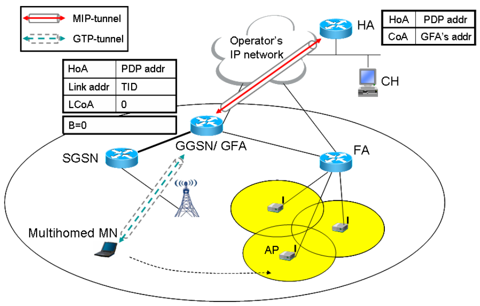


Fig. 3. Change of visitor list entry at GFA and mobility binding list entry at HA after PDP context activation.

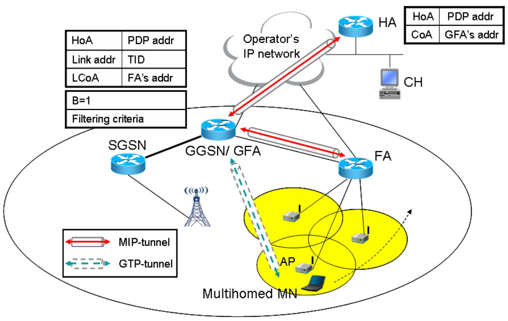


Fig. 4. Change of visitor list entry at GFA after MIP-RR registration.

deregister the MIP-RR regional binding when the MN detects it is moving out of the WLAN. Therefore, the proposed system also includes a mechanism for making an upward vertical handover decision. The MIP provides a mechanism based on the "lifetime" field in the ICMP RA message, as defined in [18]. In this case, if the MN fails to receive another advertisement from any agent within a specified lifetime, the MN assumes that it has lost contact with a WLAN FA. This is an absolute network layer solution. Other cross layer schemes, such as a link layer trigger, can also be used here to reduce the handover latency.

- Steps 12-13: Once the MN detects movement, the MN is required to send an Upward Handover Notification message to the GGSN/GFA through the UMTS network.
- If the PDP context created earlier is still alive, the MN can just resume its transmission. Otherwise, a new PDP context is created, as discussed earlier. Thereafter, the MN works as other standard 3G subscribers using its UMTS interface.

3.1.2 Stage II: IP mobility between two GGSN domains

Stage II introduces an additional optimization to stage I. During a session, the GGSN in the communication path can be changed in two situations: route optimizing after an inter-SGSN handover and load balancing purposes, according to [16]. When changing the GGSN, two tunnels are maintained between the new SGSN and the old GGSN, and between the new SGSN and the new GGSN to reduce the possibility of packet loss. Figure 5 shows the procedure for changing SGSNs and GGSNs in stage II.

Point A): After an SGSN handover, the new SGSN has the possibility to change the GGSN/GFA. The GGSN change is controlled by the SGSN based on the SGSN's knowledge of its GGSNs.

Point B): After successfully creating a new PDP Context, a timer is set to count until the old PDP Context is deleted.

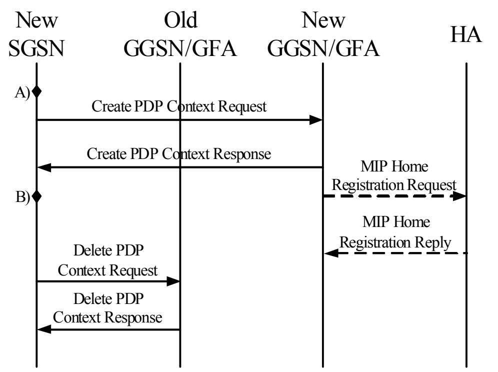


Fig. 5. Inter-GGSN/GFA handover signaling in the stage II.

The Create PDP Context and Delete PDP Context procedures are executed as defined in [16]. The new GGSN/GFA performs the MIP Home Registration as described in stage I steps(4-5). However, the HoA field is filled with the PDP address assigned by the HA during the initial Home Registration. After the HA has registered the new GFA address as the CoA for the MN, the MN performs Regional Registration when moving into the WLAN network, as in stage I steps(8-11).

3.2 Flow distribution with filters

Although the scheme proposed in Section 3.1 can resolve most of the multihoming problems listed at the beginning of this paper, some other problems still remain unsolved, such as how to redirect flows from one interface to another, how to use the interfaces differently according to preference settings, and how to allow the MN to use the two interfaces simultaneously. Thus, to solve these problems, this subsection describes how to distribute the flows to the MN using a simple filter mechanism.

The MIPv4 working group already provided a solution, "Filters for Mobile IPv4 Bindings" [11], for the simultaneous use of multiple CoAs for different flows, where each flow is identified by filtering criterion, then directed to the corresponding CoA according to a predefined preference. As explained in the last section, after Regional Registration, there is only one LCoA instead of multiple CoAs configured for the MN. Therefore, in the proposed scheme, the filtering criterion can just be used to filter those flows where the preference is transmission by the WLAN.

To deploy the filter mechanism, the GGSN also works as the Filtering Agent, as defined in [11]. The GGSN extends the visitor list for each MN using extension parts that include a Binding flag (B) and filtering criterion information (see Figure 4). Each visitor list entry corresponds to the PDP address of each MN. A B flag indicates that the MN has already registered with the HA from the WLAN network and its WLAN-interface is now available. The default value is 0. The filtering criterion is used to filter flows to the specific interface of the multihomed MN according to the user preference. In [11], the filtering criterions are values for any fields within the IP datagram, such as the service type, protocol type, source address, and source port number.

Once the MN moves into a WLAN, it configures its new LCoA at the WLAN-interface, then executes Regional Registration with the GGSN/GFA. The MN also piggybacks the filtering criterion information in the filter extension field in the Regional Registration message, as defined in [11]. When the GGSN/GFA receives the registration request message, it stores the filtering criterion information in the visitor list for this MN and sets the B flag to 1 (see Figure 4). The filtering criterion information can also be set in advance in the PDP context during subscription. In this case, the filter extension field in the Regional Registration message is not needed any more.

The filter registration procedure at the WLAN interfa ce is independent of the original packet transmission over the UMTS interface. Figure 6 shows how flows

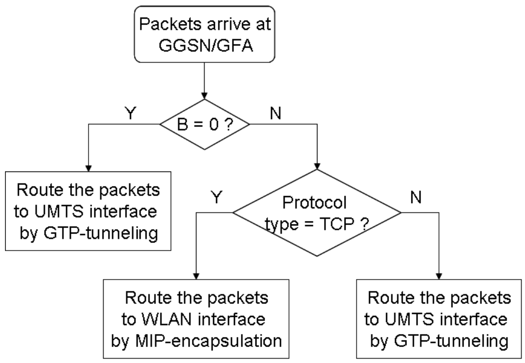


Fig. 6. Example of flow distribution according to filters at GGSN/GFA (filtering criterion is the type of transport protocol).

are delivered to each interface by the GGSN/GFA. In this example, the filtering criterion is the transport protocol type, where the user prefers the flows with the TCP protocol to be transmitted using the WLAN, and the others to be transmitted via the UMTS. Thus, when packets arrive at the GGSN/GFA, if B is equal to 0 (which means that the MN is only under the UMT S network), the packets are directed to the MN using GTP tunneling. Alternatively, if B is equal to 1 (which means that the MN is under both the UMTS and WLA N networks), the GGSN/GFA distributes the flows acc ording to the filtering criterion stored in the visitor list. If the flows match the filtering criterion for trans mission through the WLAN (i.e. the transport protocol is TCP), the GGSN/GFA routes the traffic flow to the MN's WLAN-interface to the WLAN using MIP-e ncapsulation. Otherwise, the GGSN/GFA routes the traffic flow (such as VoIP, which uses the UDP protoc ol) to the MN's UMTS-interface to the UMTS using GTP-tunneling. It is also possible to utilize both syste ms for simultaneous data transmission.

Ⅳ. Scheme Evaluation

4.1 Comparisons with "vertual interface" scheme

There are many research works are published about the interworking between UMTS and WLAN networks. Most of them resolve the multihoming problem with a "virtual interface" scheme [4], [10]. This scheme uses a virtual interface which hides multiple physical interfaces and only exposes a single (virtual) network interface to the IP stack in an MN. Thus, when the MN attaches to networks with multiple interfaces, all interfaces use the same HoA which configured on the virtual interface. All the physical interfaces receive the RA messages from their accessed network and send these RA messages to the virtual interface.

However, since the IP layer only sees the one interface connected to it, a significant modification of the MN's stack is needed to provide a virtual interface, along with complicated software to abstract and map the physical interfaces. Furthermore, the MIP function at the terminal must to modified to be able to deal with multiple RA messages from different networks and register multiple CoAs to the HA. The MIP function at the HA also need to modified to simultaneously bind multiple CoAs with one HoA [12].

While in the proposed scheme, the MN's multiple interfaces connect to the IP layer directly and each interface of the MN works independently, like the interface of a router. Without the abstraction layer added between the IP layer and physical interfaces, the MN's stack is simpler than that in the virtual interface scheme. The MIP can be used as before without any modification because the MIP function is only configured on the WLAN interface. Therefore, the RA messages in the UMTS are omitted. The MN only receives the MIP RA messages through the WLAN interface. There are no multiple CoAs registered to the HA. The MIP only work for the WLAN network as defined in RFC3344 [18]. The downward vertical handover decision is based on the RA messages from the WLAN, while the upward vertical handover decision is based on a link layer trigger.

4.2 Other advantages and overheads

In addition, the proposed scheme can resolve most of the multihoming problems listed at the beginning of this paper.

i) Except flow distribution with filter, the proposed scheme realizes the interworking between UMTS and WLAN networks without more modification to the MIP. Therefore this scheme provides an immediate multihoming support scheme for a UMTS and WLAN interworking system.

ii) From the global perspective, the MN is identified by a single HoA instead of one HoA per interface. This single HoA then ensures TCP transparency during a flow handover between the two interfaces. Plus, the single HoA also enables a graceful transparency of the MN's multihoming at the CN, since the CN is released from the burden of maintaining a list of the MN's addresses and selecting destination addresses to initiate or resume a session.

iii) For inter-GGSN domain mobility management, only one CoA is registered for the multihomed

MN at the HA. Meanwhile, for intra-GGSN visitor domain mobility management, only one LCoA is registered for the multihomed MN at the GFA. As such, this kind of address configuration avoids the confusion of multiple (HoAs, CoAs) binding. Therefore, a multihomed MN appears as a non-multihomed MN and the MIP can work as for single-interface MNs without much modification.

However, the proposed scheme has certain overheads:

i) The GGSN in the UMTS should be improved with the GFA function in order to management the MIP registration from the WLAN network, in the proposed hierarchical architecture.

ii) In order to realize flow distribution with filter, the MIP function in the MN and GGSN/GFA should be modified according to [11].

4.3 Validation using simulation

The simulation aimed to validate the proposed multihoming support scheme for a UMTS and WLAN interworking system. An OPNET Modeler 11.5.A simulator was used to implement the system simulation. All the vertical handovers were implemented within one GGSN network. Since the Home Registration procedure did not affect the simulation results, the simulation was implemented with the MIP instead of MIP-RR. The UMTS was the home network without the MIP function, while the WLAN was the foreign network. The GGSN was enhanced with an HA and Filtering Agent function. The MN was multihomed with the UMTS and WLAN radio interfaces under the IP layer. The multihomed MN also understood the protocol stacks of both systems to allow roaming between the two networks. The MIP was only configured for the WLAN interface.

All the simulations were conducted so that the MN moved from the UMTS to the WLAN, then followed the same path back to the UMTS, as shown in Figure 7. Except for the MN, FTP server, and voice CN, there were no other users in the scenario. The simulation parameters are given in Table 1. The MN had two applications: a downloaded file from the FTP server and a VoIP service with a voice CN. The filtering criterion to use the WLAN for packet transmission was the TCP transport protocol. Thus, after the handover to the WLAN, the flow destined for the MN was routed to the WLAN using MIP tunneling. Meanwhile, the MN VoIP service was only transmitted through the UMTS network.

Table 1. parameters in simulation.

Parameters	Value
UMTS cell diameter	1000 m
UMTS data rate	2 Mbps
WLAN cell diameter	300 m
WLAN data rate	11 Mbps
MN moving speed	1 m/s
FTP file size	15 Mbytes
VoIP duration	120 seconds

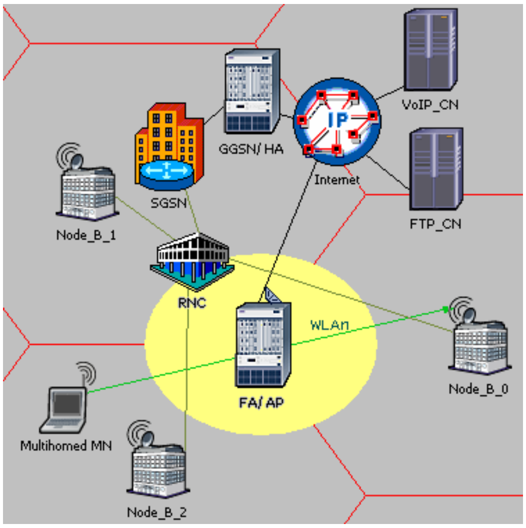
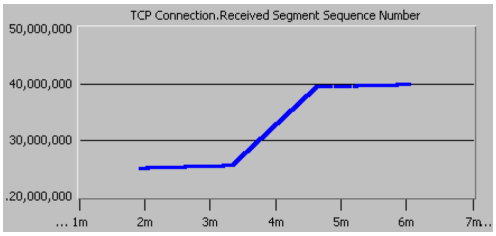
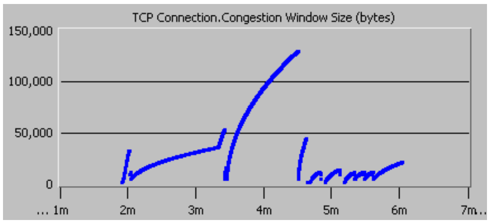


Fig. 7. Network topology for simulation.

The simulation results for the FTP application validated the feasibility of the proposed multihoming solution in a UMTS and WLAN interworking system. Figure 8 shows the received TCP sequence number for the MN and congestion window of the FTP server during the UMTS-WLAN-UMTS vertical handovers for the FTP application. After the downward handover, the FTP traffic flow was redirected to the WLAN through the MIP from 200 seconds to 280 seconds. Based on the slope of the TCP sequence



(a) TCP received sequence number for MN.

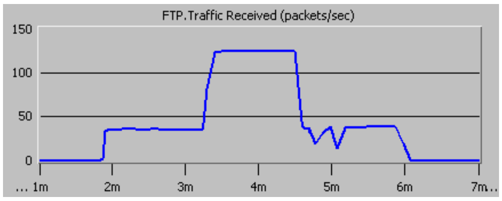


(b) Congestion window of FTP server.

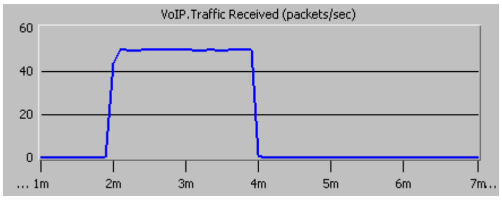
Fig. 8. UMTS-WLAN-UMTS vertical handovers for FTP application.

number and congestion window, the TCP throughput drastically increased due to the WLAN's high bandwidth. Therefore, the use of the WLAN for high load traffic improved the overall performance of the interworking system.

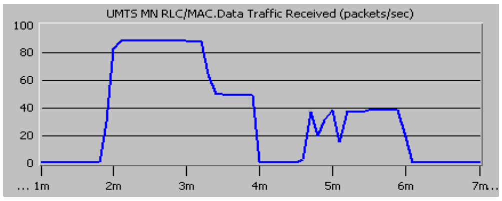
Figure 9 shows the results of the flow distribution among the UMTS and WLAN networks according to the filter mechanism. The FTP application started at 110 seconds and stopped at 360 seconds, as shown in Figure 9 (a). Meanwhile, the VoIP application started at 120 seconds and stopped at 240 seconds, as shown in Figure 9 (b). The VoIP flow was transmitted through the UMTS at a constant rate of 50 packets/sec. Figure 9 (c) shows the total traffic received by the MN from the UMTS during the UMTS-WLAN-UMTS vertical handovers. At the beginning, both flows were transmitted through the UMTS, so the total throughput received by the MN from the UMTS was about 90 packets/sec during the initial 120-200 seconds. When the MN moved into the WLAN after 200 seconds, the FTP traffic flow was redirected to the WLAN according to the filter mechanism, since the simulation filtering criterion was the TCP transport protocol. As a result, the total traffic received by the MN from the UMTS dropped to 50 packets/sec (only the VoIP traffic flow). The total traffic received then dropped to 0 due to the VoIP



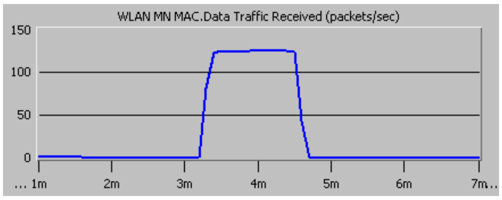
(a) Traffic received by MN for FTP traffic flow.



(b) Traffic received by MN for VoIP traffic flow.



(c) Total traffic received by MN from UMTS.



(d) Traffic received by MN from WLAN.

Fig. 9. Flow distribution among UMTS and WLAN networks according to filter mechanism.

call release after 240 seconds. The FTP traffic flow transmitted through the WLAN can be seen in Figure 9 (d) during 200-290 seconds. The two interfaces of the MN were also used simultaneously for different flows during this period. When the MN moved out of the WLAN after 290 seconds, the FTP traffic flow was redirected to the UMTS again. The total traffic received by the MN from the UMTS was up to about 40 packets/sec, representing the FTP traffic flow received by the UMTS.

The magnified plot of the upward handover point (from WLAN to UMTS) in Figure 10 shows that the two interfaces were used separately and simultaneously for the TCP uplink and downlink traffic flow to implement the vertical handover.

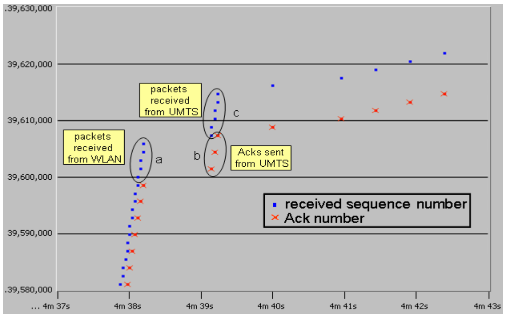


Fig. 10. TCP received sequence number and Ack number for MN at upward handover point.

The MN began to send an upward handover notification signaling message when it found itself at the edge of the current WLAN cell. After receiving notification Ack signaling message, the MN redirected the following TCP Ack packets to the CN through the UMTS (see area b in Figure 10), where the Ack packets were acknowledgments of the packets directed by the GGSN/GFA through the WLAN network (see area a in Figure 10). Meanwhile, the GGSN/GFA sent the following packets through the UMTS (see area c in Figure 10) after it sent notification Ack signaling message. The GGSN/GFA was able to send a lot of packets within the short interval (see c), as it received the consecutive TCP Ack packets (see b), which allowed the CN to maintain the same sending window as that over the WLAN. Thereafter, the MN returned to the UMTS and worked as other standard UMTS users.

In summary, the simulation results confirmed that the proposed scheme could provide multihoming and a vertical handover when the multihomed MN moved between the UMTS and the WLAN. In addition, the simulation also showed that different traffic flows were distributed to different routes via the UMTS or WLAN, according to the filter mechanism.

V. Conclusion

This paper proposed an immediate multihoming support scheme for a UMTS and WLAN interworking system, with minimal modifications to the MIP and existing systems. The interworking system is based on a hierarchical architecture. Only one HoA is configured for the multihomed MN. Instead of directly interworking the two networks using the MIP, the MIP function is only configured for the WLAN networks and only one LCoA bound to the GFA. With such a single HoA/CoA address configuration, the multihomed MNs appear as non-multihomed MNs, plus a filter mechanism is used to realize the benefits of multihoming. As a result, the multihomed MNs can use the two interfaces simultaneously to distribute traffic flows according to the user preference. Finally, simulations demonstrated the feasibility of the proposed practical solution for effective multihoming mobility management between UMTS and WLAN networks.

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