HIP Based Mobility Management for UMTS/WLAN Integrated Networks

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***Abstract*—Future wireless communication networks will support different wireless technologies, such as UMTS and WLAN. Mobility management in the heterogeneous environment needs to address the smooth integration of different networks and security. Under Mobile IP, interconnection crossing different types of networks can be implemented in lower layers, such as Physical and Data Link layers. Generally, those Mobile IP based schemes have long handover delay. HIP is a new proposed protocol on mobility management and it offers more efficient vertical handover for wireless devices than Mobile IPv6. In this paper, A HIP based UMTS/WLAN architecture is proposed. In the architecture, a newly introduced Rendezvous Server in UMTS system has made the system ready for future public-key based IP network upgrading. The vertical handover process with our "make before break" strategy has much lower delay and cost compared with Mobile IP based solutions**

Keywords-Host Identity Protocol (HIP), UMTS, WLans, Vertical Handover

I. INTRODUCTION

Future wireless communication networks will be heterogeneous IP based networks integrating different wireless systems, such as Universal Mobile Telecommunications System (UMTS) and Wireless LAN (WLAN). Applications, such as VoIP(Voice Over IP), are running on top of IP and wireless terminal's mobility management is a critical issue. In the traditional homogeneous environment, all base stations and radio access points use the same wireless standard, so the handover handling can be achieved in the Physical and Data Link layers. However, the scenario becomes more complex in the heterogeneous networks. Handover handling cannot be achieved without the upper layer involvement. There are some efforts in seeking handover solution in Physical and Data Link layers for crossing different types of networks such as GPRS/WLAN[18] and UMTS/WLAN[2]. Most of works are based on the assumption that Mobile IP[7, 15] is the upper layer mobility management protocol. However, its performance is not satisfactory due to its long delay in handover process. In this paper, we apply Host Identity Protocol (HIP)[12] to a tight coupling UMTS/WLAN architecture to process vertical handover. Our analysis has shown that the new proposed scheme is more efficient in handover than Mobile IP solution.

II. INTEGRATION OF UMTS AND WLAN

Both of UMTS and WLAN can provide the data access for end users. UMTS (Universal Mobile Telecommunications System) is the most popular third generation mobile network (3G) solution for Global System for Mobile Communications (GSM) network. UMTS is designed to be an always-on wide-area covered solution for wireless communication and it can provide 384kbps access link.

WLAN is a rapid growing technology. Its cell covers a small area with a high transmission data rate. There are many different versions of WLAN standardized by IEEE. 802.11b and 802.11g are the most popular versions in the current market, providing 11Mbps and 54Mbps respectively by using 2.4GHz radio frequency band.

There are two main approaches for the interconnection between WLAN and UMTS, i.e. tight coupling and loose coupling[2, 17, 18]. In tight coupling, WLAN gateway is connected with Service GPRS service node (SGSN) of UMTS network and the networks are connected to the Internet via Gateway GPRS service node (GGSN). All the billing and user control in the UMTS network can be reused in the new interconnection network. Loose coupling is similar to that of tight coupling, but WLAN gateway will connect to the Internet directly instead of connected with SGSN.

III. HOST IDENTITY PROTOCOL (HIP)

HIP[11, 12] is a newly drafted secure mobility management protocol by Internet Engineering Task Force (IETF). It introduces a new namespace – Host Identifier (HI) and a new layer – Host Identity Layer, which is seen as a 3.5 layer, i.e. a layer between network and transport layers in OSI model. In the current TCP/IP architecture, an IP address serves as the end-host identity and locator in the topological network. The dual roles of IP address is the main cause of the low efficiency and security problems in IP mobility[3]. HIP decouples the dual roles of IP address. In HIP networks, an IP address is only used for representing the topological network location while HI is for the end-host identity.

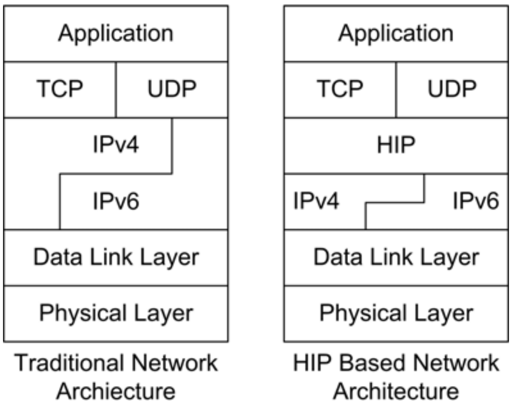

Figure 1. The difference between Traditional Network Architecture and HIP base Network Architecture

HI is a public key of an asymmetric key pair. But due to the various length of HI, it is not practical for HI to be used directly in the protocol. In order to adopt HIP in the current IPv6 application programming interface (API), a 128-bit long Host Identity Tag (HIT), which contains 28 bits for the Overlay Routable Cryptographic Hash Identifier (ORCHID)[14] and 100 bits for the hash of HI, will be used to represent HI in practice.

In the early version of HIP RFC, IPsec Encapsulation Security Payload (ESP)[8] is proposed to be used to secure the connection. IPsec ESP has been decoupled from the HIP in the latest version, in which support is extended to any security scheme. Secure Real Time Protocol (SRTP)[1] transport format is being discussed recently[20]. In this paper, we will focus on the IPsec ESP mode as it is well defined in the IETF HIP Working Group.

A. *Mobility Management*

A pair of IPsec security associations (SAs), which established by HIP Base Exchange, are bound to HI/HIT instead of IP addresses. A host is able to receive packets that are protected by ESP SAs from any IP addresses[4, 6]. It enables a host to change its IP address and continue its communication with its peers.

When a Mobile Node (MN) is roaming into a foreign network, it will get a new IP address. The MN will update its record in its own Rendezvous Server (RVS)[10]. The role of RVS is similar to the Home Agent of Mobile IP[5] and it provides the mapping between HI/HIT and IP address. When the Corresponding Node (CN) wants to communicate with MN, it will start the HIP Base Exchange via RVS.

If a MN is changing its IP address during communication, besides updating the RVS record, it will also send a UPDATE packet with a LOCATOR parameter to notify the CN. The LOCATOR parameter contains the new IP address and the SPI associated with the new IP address[4]. It has been shown that the vertical handover performance in HIP performance is better than Mobile IPv6[9].

B. *Multi-homing and Simulatneous Multi-Access Support*

Mobile devices can have more than one network interface nowadays. Multi-homing is not supported in the traditional IP network. There are many different drafts in the IETF discussing about the multi-homing support in IPv6 network. HIP is one of the candidate[4, 6, 13]. In HIP, MN notifies the CN of the additional interface by using LOCATOR parameter in the UPDATE packet. The ESP_INFO in LOCATOR parameter will keep both "Old SPI" and "New SPI" values to indicate the peer that the SPI is not replacing the exciting one. Besides using UPDATE packet, nodes can also add the additional interfaces in the HIP Base Exchange.

Furthermore, HIP also supports simultaneous multi-access (SIMA)[16]. HIP uses a SIMA_FLOW_BINDING parameter in the UPDATE message for SIMA. A multi-homing host can use different network interfaces to connect with its peer on different situations. For example, in an application (or a service) the slow but reliable interface can be used for signaling packets and a high-speed (maybe unreliable) interface can be used for the data packets. In the following section, we will use the multi-homing and SIMA of HIP to reduce the handover delay in our HIP based UMTS/WLAN architecture.

IV. HIP AWARE UMTS/WLAN ARCHITECTURE

In the integrated UMTS and WLANs networks, smooth handover across two networks is targeted. We propose to use HIP in the upper layer and the objective is to design architecture for seamless vertical handover. A RVS is added into the UMTS/WLAN architecture. In an UMTS system, each GGSN has a home agent implemented in it for Mobile IP. We propose to add a RVS to each GGSN. This makes the network management easier and the architecture is backward compatible to MNs which do not support HIP.

In this proposed UMTS/WLAN architecture, the tight coupling is used. WLAN can reuse the authentication, mobility and billing infrastructures of UMTS directly. This architecture can make routing of the packets from the CN to the network by using the same path during handover. It will minimize the effect of the external factors on the handover performance. Also, additional features can be implemented in GGSN to have further improvement on the handover performance. For example, the local mobility management can be added. However, that is out of scope of this paper and will not be discussed. Furthermore, the loose coupling can also be added in the architecture for load balancing in GGSN and Internet connection backup.

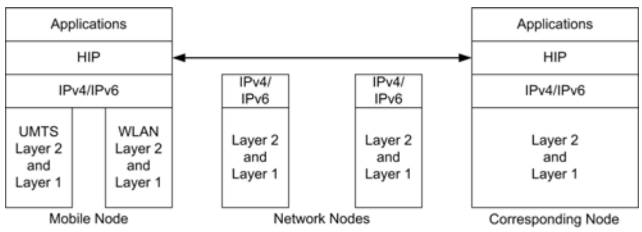

Figure 2. Protocol architecture

The architecture is shown in Fig. 2. The MN and the CN are assumed to be HIP supported. IP address is still used for the packet routing; upper layer protocols use HI/HIT instead of IP address to identify a host. As the length of IPv6 address and HIT are same, only some modification in an application is needed.

A MN has at least two interfaces for the vertical handover between UMTS and WLANs. By the multi-homing feature of HIP, the MN can use these two IP addressees for the vertical handover. In our proposed scheme, we will use Make-Before-Break strategy for the handover process if the situation is allowed, such as the environment shown in Fig. 3.

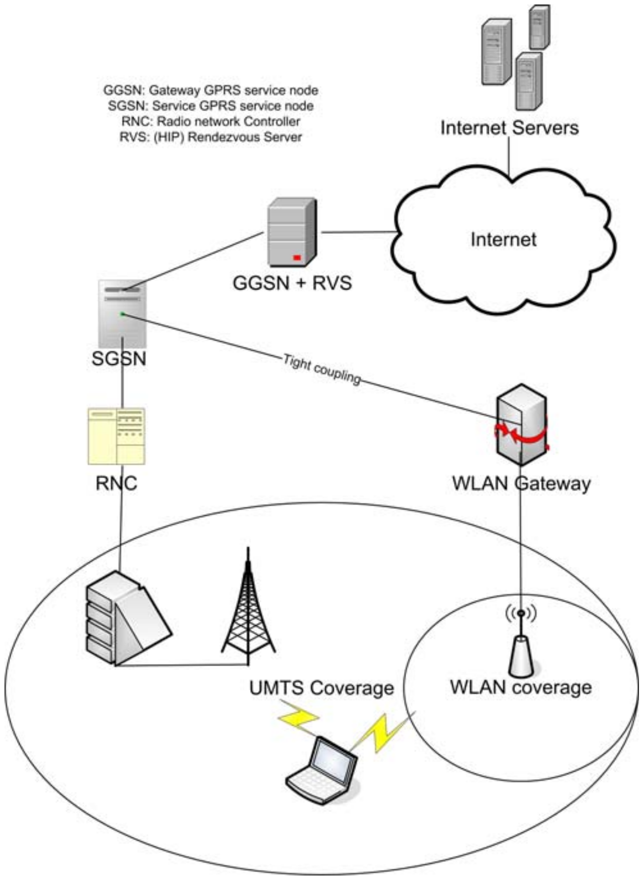

Figure 3. Integrated UMTS/WLAN HIP based Network Architecture

When a MN is moving from one network to another, Layer 1 (Physical Layer) and Layer 2 (Data Link Layer) will make the decision of the handover. In the situation of moving from UMTS to WLAN, after the MN is attached to the wireless access point, it will get a new IP address. MN can use the LOCATOR parameter in the UPDATE packet to notify the CN that it had more than one interface. MN can also set that WLAN interface to be the primary address at the same time to reduce the handover process. After the handover is completed, MN can break the UMTS connection if it is necessary. In the handover from WLAN to UMTS, it is similar to that of UMTS to WLAN. When MN starts the handover from WLAN to UMTS, MN will inform the CN of the changing IP address by UPDATE packet. When the handover is completed, MN will disconnect from the wireless access point. Fig. 4 outlines the vertical handover. The CN will duplicate the data stream and send it to both network interfaces. After the new data stream is established, MN can drop the old data steam. It can shorten the handover delay. For loose coupling mode, the handover process is similar. The only difference is the WLAN gateway will communicate with CN directly instead of via SGSN and GGSN. If two data stream are not allowed, the similar process will be carried out excluding SIMA_FLOW_BINDING.

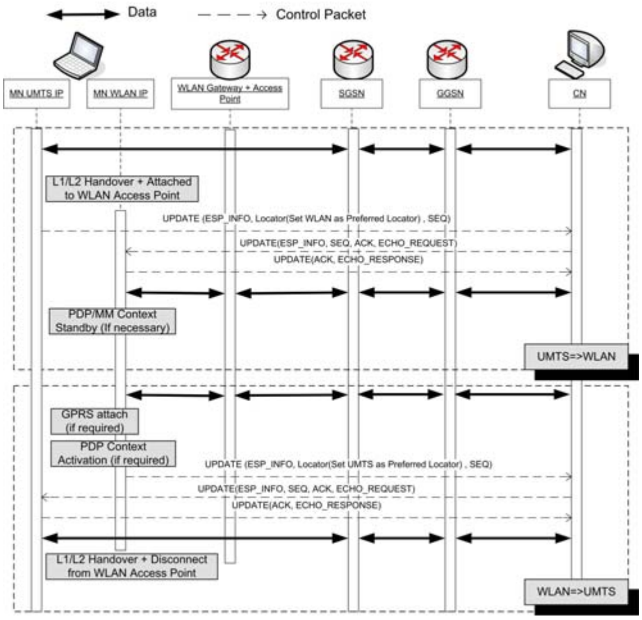

Figure 4. HIP based vertical handover in UTMS/WLAN architecture

V. ANALYSIS AND DISCUSSION

Our HIP based UMTS/WLAN architecture aims at improving vertical handover performance. The idea can be applied to any type of heterogeneous wireless communication networks. The vertical handover from UMTS to WLAN and from WLAN to UMTS are the same, as both UMTS and WLAN are connected to a GGSN. In the proposed architecture, exploiting the HIP multi-homing feature, the handover process can adopt the Make-Before-Break strategy. MN can communicate with the CN through the old network interface, while the control message (HIP UPDATE packets) can be passed via the new network interface. After the handover process has completed and the new data stream is flowing, MN switches from the old network interface to the new network interface. Handover delay is defined as the time gap of switching network interface when the MN is unable to receive any new packets. As using the Make-Before-Break strategy, the handover delay can be close to zero in theory. However, the handover delay can still be detected in practice due to the processing time and buffering strategy in a MN. As Mobile IP does not support multi-homing, its handover strategy has to be Break-Before-Make. The advantage of HIP based strategy over Mobile IP is obvious.

In the HIP based architecture, cross cell handover delay is defined as the gap for switching data stream from one network interface to another. If the mobile node is physically moving from one network to another and both networks share the same wireless technology, the general handover processing time is defined as

$$\text{Handover}_{\text{process}} = \text{T}_{\text{t}} + \text{T}_{\text{p}} \quad (1)$$

where T_t is the sum of transmission durations of all handover control packets and T_p is the processing time including packet buffering.

In the HIP based UMTS/WLAN integrated networks, the T_t is represented as

$$T_t = \sum_{i=1}^{3}\left(\frac{P_s(i)}{B(i)} + P_d(i)\right) \quad (2)$$

where

- Ps(i) is the packet size of UPDATE packet i;
- B(i) is the bandwidth available for transmit update packet i;
- P_d(i) is the propagation delay for transmit UPDATE packet i.

In our proposed scheme, the number of handover overhead packets is less than that in the traditional Mobile IP scheme. The handover binding cost of our proposed scheme is also less than that of Mobile IPv6. The overall handover binding cost in HIP based UMTS/WLAN networks is

$$BC_{HIP} = 2CP_{HIP,CN} + CP_{HIP,MN} + 3CT_{HIP,MN,CN} \quad (3)[19]$$

where

- BC_x is the total binding cost for scheme x,
- $CP_{x,A}$ is the processing cost for scheme x at node A,
- $CT_{x,A,B}$ is the binding packet transmission cost in scheme x between node A and B.

The overall handover binding cost of traditional Mobile IP scheme is

$$BC_{MIP} = 2\left(CT_{MIP,HA,MN} + CT_{MIP,HA,CN}\right) + 4CT_{MIP,MH,CN} + 2(CP_{MIP,HA} + CP_{RR,CN}) + CP_{BU,CN} + CP_{MIP,MN} \quad (4)[19]$$

From (3) and (4), it is very obvious that the binding cost of HIP is less than that of Mobile IP. HIP uses 3 UPDATE packets for the whole vertical handover, while Mobile IPv6 uses 8 packets to complete the handover (Return Routability and Binding Update[7]). For vertical handover in loose coupling of UMTS and WLANs network, using Break-Before-Make strategy for MN without the multi-homing support, HIP is shown to outperforms Mobile IPv6 by 69%[9]. Our proposed scheme can further improve the performance as multi homing feature and Make-before-Break strategy are used. In addition, HIP based handover does not need the involvement of other network components, while Mobile IPv6 relies on Home Agent on the handover. This can reduce the load of GGSN.

VI. Conclusion

Mobile IP based mobility management for UMTS/WLAN has inefficient handover processing. In this paper, a HIP based mobility management scheme is proposed for the UMTS/WLAN integrated networks. The architecture and handover procedure are given in details. The scheme's main improvement over Mobile IP solution is that its vertical handover delay is reduced to almost zero thanks to HIP's multi-homing support and Make-Before-Break handover scheme. Furthermore, there is about 62.5% improvement in the handover packets overheads in the new HIP based mobility management. Handover binding cost is also improved compared with the Mobile IP solution. This HIP based scheme is suitable not only for UMTS/WLAN integrated networks, but also for different types of wireless networks with two or more wireless standards are integrated, such as UMTS/Wi-Max and WLAN/Wi-Max/UMTS.

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