SHIP Mobility Management
Hybrid SIP-HIP Scheme

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Abstract

In future wireless communication networks such as 4G, different wireless technologies and architectures will coexist. In these heterogeneous network environments, mobility management is a critical issue. Session Initiation Protocol (SIP) is a widely discussed protocol, which is used for signaling and mobility management, especially in Voice over IP (VoIP) environment. However, its mobility management is restricted to SIP sessions only. To provide a full mobility management for services in future wireless IP networks, SIP can be combined with other protocols. In this paper, a new mobility management scheme based on Host Identity Protocol (HIP) and SIP is proposed. The hybrid SIP and HIP (SHIP) scheme is for all services. SHIP has better performance in handoff signaling than SIP. Its signaling overhead is smaller and the signaling delay is much shorter. SHIP has been shown to outperform hybrid SIP and Mobile IP, a widely discussed mobility management scheme, in a number of areas.

Index Terms-- Host Identity Protocol (HIP), Session Initiation Protocol (SIP), mobility management

1. INTRODUCTION

To access wired IP networks, computers use one interface in most of cases. The mobility of terminals is not an issue. However, the advancement of wireless technologies has changed the scenario. Some high-end laptops, PDA models and mobile phones have more than one wireless interfaces, such as CDMA, Bluetooth, Wi-Fi etc. The 4th generation (4G) wireless networks will not specify any particular wireless technologies as the carrier standard. The future wireless environment will be a heterogeneous network. For mobile devices to have seamless connection from one network to another, the networks should provide efficient mobility management. As the future networks will be all IP based, the mobility management will be conducted on top of IP.

Session Initiation Protocol (SIP)[1] is a candidate protocol for mobility management in the application layer of OSI model (Layer 7). SIP is initially developed for Voice over IP (VoIP). It can be used for mobility management, which allowed the data to reach the host when it changes to a new network. However, SIP can only manage the applications with sessions created under SIP, but it cannot support the mobility management in non-SIP based services. To break this limit, many research works are carried out on integrating SIP and other protocols, such as Mobile IP, to provide a full mobility management for all applications.

Mobile IP[2, 3] is a network layer solution of mobility management. It is developed by Internet Engineering Task Force (IETF). Mobile IP uses a "home agent" in "home" network to redirect the package to a new IP address that is assigned to the mobile device in its new location. The strength of Mobile IP is its backward compatibility with legacy hosts.

The fundamental problem of IP mobility is the overloading of IP address, i.e., an IP address identifies the device's location on the network topology in network layer (Layer 3) and identifies the host in transport layer (Layer 4). In current IP network architectures, when a host is moving into another network, its IP address will be changed. Mobile IP solves the problem by hiding the new IP address. It uses the "home agent" IP address for communication with other hosts. However, this structure lead to the performance problem in Mobile IP[4].

Host Identity Protocol (HIP)[5, 6] is an experimental protocol which aims to handle the IP mobility and security using a different approach. HIP introduces a new namespace – Host Identity (HI) and a new layer – Host Identity Layer (3.5 Layer) into current network architecture [5, 6]. HI will replace IP address to identification of the host in transport layer. The IP address is used to identify the location in the network only. This concept is similar to that of SIP Universal Resource Identity (URI), which is used to identify the host of SIP agent.

In the following chapters, the mobility management under SIP and HIP are described. A hybrid scheme SIP and HIP (SHIP) is proposed to provide the full mobility management for all applications. SHIP's performance is analyzed and compared to existing schemes.

Proceedings of the Sixth International Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing and First ACIS International Workshop on Self-Assembling Wireless Networks (SNPD/SAWN'05)
0-7695-2294-7/05 $20.00 © 2005 **IEEE**

2. BACKGROUND

Mobility management was not a big issue in the current wireless networks, in which most likely there was only one wireless standard used in each network. Wireless management can be handled in Data Link layer or Physical layer in the homogenous wireless network. Handover between different base stations and security can be achieved based on the signal strength and coding scheme. However, in the 4G wireless networks, different wireless technologies will be involved. Handover between different wireless networks cannot be handled by the old method. Network Layer and Application Layer are the most suitable layers for the mobility management to be positioned in future heterogeneous wireless network environment.

2.1. Session Initiation Protocol (SIP)

SIP is an application layer protocol used to create or tear down multimedia sessions. IETF recommends SIP as signaling protocol for VoIP service. It supports multi-cast and unicast. SIP URI is the namespace used in SIP protocol, which is an extension of Domain Name System (DNS)[1].

SIP user agent (UA) registers itself with the SIP URI in the SIP Registrar Server by REGISTER message. When a mobile UA moves into a visited network, it will send the REGISTER to its Home Registrar about its new location.

SIP can perform mobility support in the Application Layer[8]. UA uses INVITE message to establish a session with other UA. INVITE message contains session description in Session Description Protocol (SDP) format. When a callee UA is roaming into the other network, the SIP Redirect Server will reply with SIP 302 (User Temporarily Moved) with user's new location Message to the caller UA. The caller UA will send a new INVITE message to new location. If mobile UA is roaming into a new network in the middle of the session, mobile UA will use INVITE message with the new location to re-establish the SIP session with the corresponding host. The corresponding host will update the information and acknowledge the mobile UA with the new IP address[8].

Mobility support in SIP is independent of the underlying wireless technology and network layer element. There is no triangle routing problem in SIP, which always occurs in Mobile IP. 3GPP, 3GPP2 and MWIF have adopted SIP as the session management of the mobile Internet. However, application layer protocol will always get the lowest priority in the networking model and so a long delay in hand-off will occur. Furthermore, the most critical issue in mobility support by SIP is that it does not support mobility in other connections that are not created under SIP (such as HTTP and FTP). The on-going TCP, UDP or other connections, which are not established by SIP, will be lost. SIP is the best choice for real-time application only. To support all-round mobility management, hybrid SIP and other protocols are considered by many researches. Hybrid Mobile IP and SIP is one of the widely discussed scheme [9, 10].

2.2. Host Identity Protocol (HIP)

Host Identity Protocol is a new protocol proposed to IETF by Robert Moscowitz. HIP introduces a new namespace – Host Identity (HI) and new layer – Host Identity Layer (3.5 Layer) [5, 6].

HI is a new namespace in the current IP network model. HI will be used to identify node and endpoint instead of IP addresses. HI is a public cryptographic key of an asymmetric key-pair. Each host will have at least one HI, which is either be public or anonymous.

HIP is the protocol between current IP protocol and TCP/UDP [5, 6]. HI is based on the public key. The length of HI could be different, but in order to simply the network design, 128 bits Host Identity Tag (HIT) is used to represent HI[5].

HIP uses a four-way handshake, that contains a Diffi-Hellman key exchange to establish the connection[5, 6]. There are nine basic HIP packages are defined, and four of them, I1, R1, I2 and R2, are used for this four-way handshake. Session Key will be created under the Diffi-Hellman process, which is used to establish a pair of IPsec Encapsulated Security Payload (ESP) Security Association (SA) between hosts. HIP uses the cookie mechanism in the four-way handshake to protect the responder from the denial-of-service treats.

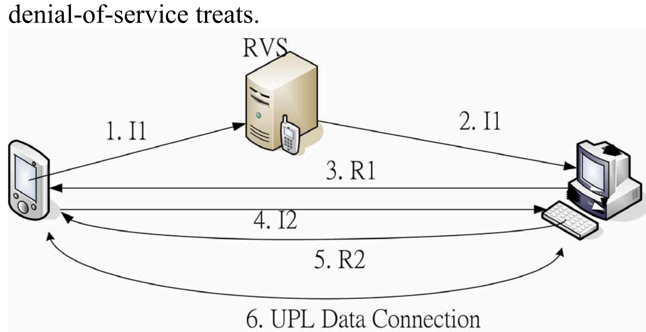

Figure 1 4-way handshake of HIP via RVS

HIP supports mobility management and multi-homing in nature [11]. HI will be mapped to an IP address automatically. This can be done by DNS [12] or Rendezvous server (RVS) [13]. The mapping of Fully-Qualified Domain Name (FQDN) and IP address is stored in DNS in the current Internet model. DNS does not store the recent direct mapping between HIP and IP. Instead, the mapping of FQDN to HI is stored. When a host is looking up a FQDN, the DNS will reply with the IP address and HI[12]. However, when a host is roaming, the DNS may not be able to update immediately. Based on what the common Internet Service Providers (ISP) suggests to their customers, it requires 48 – 72 hours to update all DNS records in the Internet.

Rendezvous server (RVS) is introduced to solve this problem. The role of RVS is similar to the home agent in Mobile IP. DNS will no longer hold the FQDN and IP address of the host; it will carry the mapping between FQDN and the corresponding RVS IP addresses. Direct mapping between HI and IP addresses of the host will be stored in RVS. A mobile node will register in the RVS and update its record in DNS to update the mapping to the FQDN and IP of RVS. When the other host is looking up the mobile node in the DNS server, it will get the HI of the mobile node and the IP of its RVS[13]. The first message in the four-way handshake (I1) will pass through the RVS, but the rest of the messages (R1, I2 and R2) will be communicated between two hosts directly. By this method, pre-session mobility can be achieved.

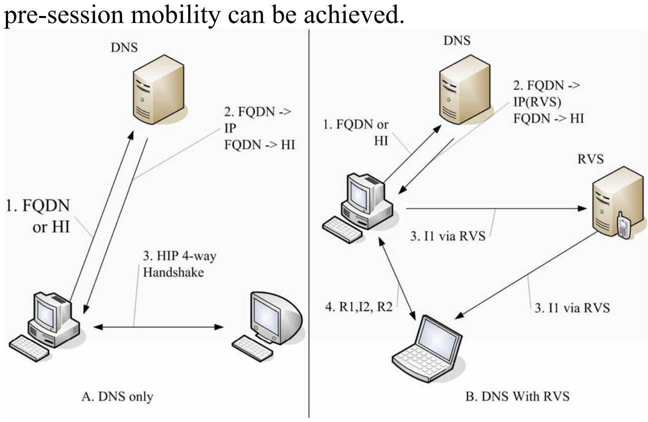

Figure 2 a) HI-IP mapping with DNS only
b) HI-IP mapping with DNS and RVS

Mid-session mobility can be achieved by using the UPDATE package with a Readdress (REA) parameter[11]. When one of the nodes is changing its IP address, it will send the UPDATE package to the other nodes and its RVS. This approach can handle all the scenarios except the following two[11, 13]:

- Double Jump Problem – When two communication nodes are changing their IP address at the same time, UPDATE packages are not be able to reach the corresponding nodes.
- IP address changes during the four-way handshakes – HIP connection is not established until the four-way handshakes are completed, it is impossible to use UPDATE package.

These two problems can be solved by involving RVS. UPDATE package can be done via the RSV to update their IP addresses[11, 13].

Figure 3 HIP Readdress without rekeying

In the future 4G wireless communication networks, mobile devices will have more than one network interface. Packets can reach the mobile device by different interfaces, which is called multi-homing. HIP supports multi-homing and it is one of the candidates for the IPv6 multi-homing (multi6) in IETF[15].

3. Hybrid SIP-HIP (SHIP)

To provide full mobility support, we propose the hybrid SIP-HIP (SHIP) scheme, which is an alternative solution to current hybrid Mobile IP and SIP. This scheme extends SIP to support HIP.

Figure 4 shows the basic scenario of SHIP procedures with RVS server involved. In the current network model, SIP UA needs to send the re-INVITE message to corresponding host when UA is roaming into a visiting network with new IP address. In the SHIP environment, IP address will be replaced by HI in SIP header and SDP packet.

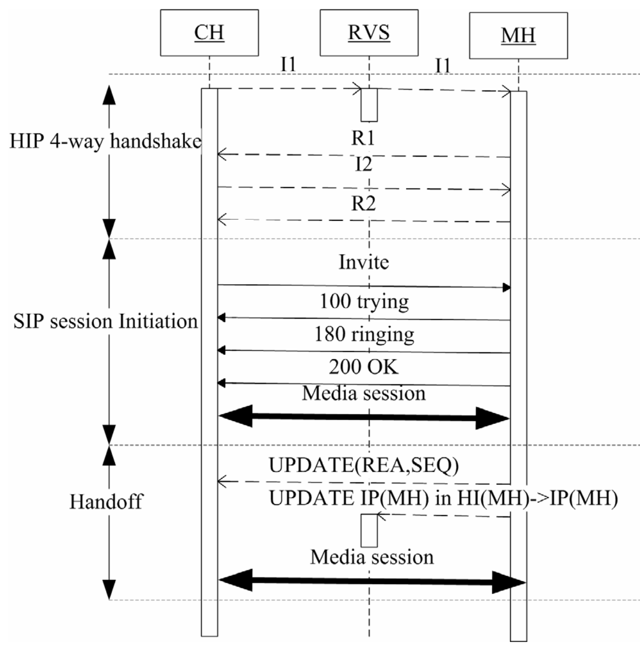

Figure 4 SHIP procedures

Pre-session mobility can be achieved by SHIP. A SIP location server will return the HI address instead of an IP address. Until the mapping of the SIP, URI and HI address is changed, no updates are required in the SIP location server. After HI is returned, four-way handshake will be setup. It may or may not be done via the RVS server. However, for the high mobility host, RVS should be used to provide a better performance.

Media session is created by SIP with HI addresses in SHIP scheme. The header of UDP is using HI address instead of IP address. It shows no differences for the upper layer protocols (ULP) even though the IP address is changed.

In the mid-session mobility, SIP does not need to send re-INVITE message to the corresponding host. HIP will be in change of the updating the mapping of HI address and IP address. HIP UPDATE packet with REA parameter will be sent to the corresponding host to notify the IP address update.

The previous two scenarios cover all the scenarios of the real time application. The non real time application mobility support is same as that of HIP.

4. Handoff Signaling Analysis

Handoff signaling is one of critical factor to the performance of wireless network. It also affects the handoff delay. Handoff signaling analysis in this part will be based on the analysis of [14].Figure 5 shows the basic scenario of the handoff process, $D_{handoff} = D_{dhcp} + D_{notice}$.

shows the parameters and their typical value [14]. SIP and HIP are working at different layers; overhead header of lower layer protocols (LLP) is different. This analysis is focused on the notice message of the protocol itself without overhead header of LLP.

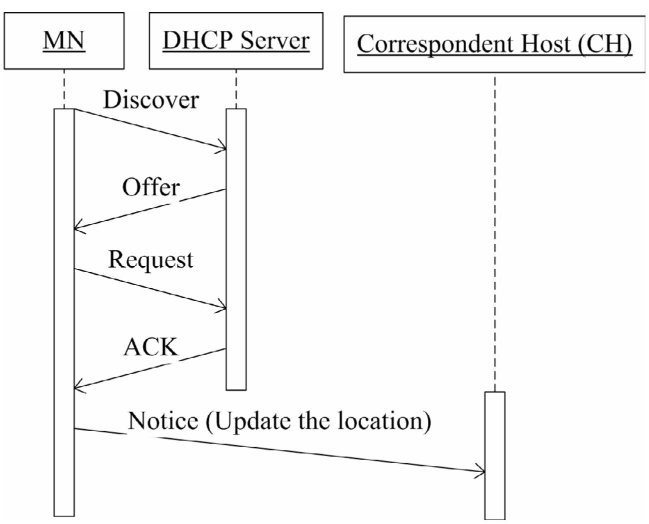

Figure 5 Handoff signaling flow[14]

In the formula, D_{notice} depends on the distance between the Mobile Node and Correspondent Node. The formula can be rewritten as follows:

$$D_{hnadoff} = D_{dhcp} + \left(\frac{L \times (H-1)}{BW_{wired}} + \frac{L}{BW_{wireless}} + L_{wired} + L_{wireless}\right) \quad [14]$$

Figure 6 shows the handoff signaling delay. Comparatively speaking, SIP has the worst performance and Mobile IP provides the best. HIP and SHIP (they are using the same method to notify the change of IP) is slightly worse than Mobile IP. The performance of hybrid Mobile IP and SIP is similar to Mobile IP [9, 10]. However, hybrid Mobile IP and SIP solution need to use home agent to re-direct the packet until the SIP re-INVITE progress is completed, that means, two handoff processes are needed in one handoff [9, 10]. Handoff only needs to be processed once in SHIP. Handoff signaling efficiency of SHIP is better than that of hybrid Mobile IP and SIP. Due to a various packet size of HIP_SIGNATURE (typical 40 bytes) is needed for each HIP UPDATE packet(typical 80 bytes with REA, SEQ and HIP_SIGATURE) [5, 11], it makes HIP/SHIP required a longer handoff signaling delay than Mobile IP and Hybird SIP-Mobile IP .

Table 1 Input parameters for handoff [14]

Symbol	Meaning	Typical value
D_{dhcp}	Delay of DHCP address assignment	1s
D_{notice}	Delay for MH to notify CH of its new location	
BW_{wired}	Bandwidth of wired links	100Mb/s
$BW_{wireless}$	Bandwidth of wireless links	11Mb/s (802.11b)
L_{wired}	Latency of wired links (propagation delay + link-layer delay)	0.5ms
$L_{wireless}$	Latency of wireless links (propagation delay + link-layer delay)	2ms
H	Distance between MH and CH in hops	
L	IP packet length of notice message	140 bytes (SIP re-Invite's SDP message) 80 bytes (HIP UPDATE with REA, SEQ parameters) 56 byes (Mobile IP binding update)
Ts	Average time for which MH remains in a subnet	

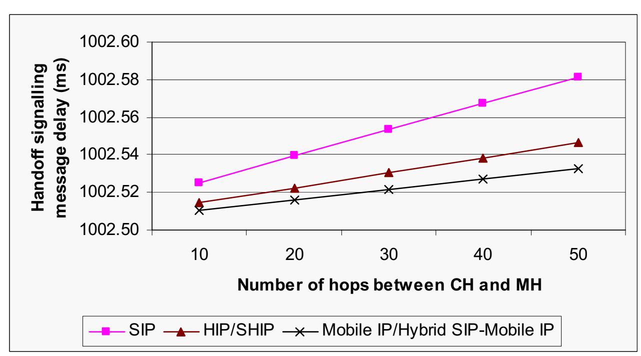

Figure 6 Handoff Signaling Delay

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The signaling overhead for handoff can be shown by $\frac{L \times H}{Ts}$ [14]. Figure 7 shows the overhead of handoff signaling of different protocols. Similar to the result of handoff signaling delay, SIP has the largest overhead, while Mobile IP has the smallest one in a homogeneous protocol environment. However, SHIP is smaller in signaling overhead packets than hybrid Mobile IP and SIP. Overhead of hybrid Mobile IP and SIP scheme will be the sum of the Mobile IP and SIP as two handoff processes are needed in hybrid Mobile IP and SIP scheme. Overall speaking, SIP has the worst performance in this analysis. SHIP has been shown to outperform than hybrid Mobile IP and SIP in major areas.

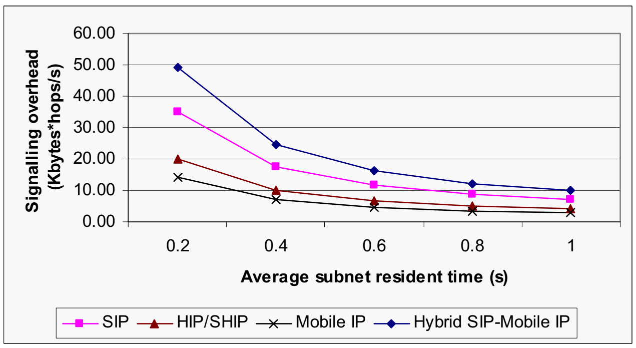

Figure 7 Handoff signaling overhead (H=50)

5. Conclusion

In this paper, we have proposed a new mobility management scheme, SHIP, for future IP based wireless networks. It is a hybrid scheme of SIP and HIP and it can provide a complete mobility management for all services.

Compared with Hybrid Mobile IP and SIP, which is a widely discussed mobility management scheme for all services, SHIP is better in handoff signaling processing efficiency. In the hybrid Mobile IP and SIP scheme, handoffs need to be processed in both Mobile IP and SIP and home agents redirect the packets until SIP re-INVITE process is completed. SHIP avoids the re-INVITE message in SIP and therefore, its signaling message is smaller. In addition, SHIP provides multi-homing support, which does not exist in hybrid Mobile IP and SIP. Its performance and functions could be further enhanced with a future version of HIP. We believe that SHIP can be a good candidate scheme for all-round mobility management in future wireless IP networks.

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