Research of an Optimized Mobile IPv6 Real-time Seamless Handover Technology

Lei Zhuang[1], Chao Wang[2], Wei Song[1]
1. Department of Computer Science and Technology, School of Information Engineering, Zhengzhou University, Zhengzhou, China
2.Department of Network Engineering, School of Software, Nanyang Institute of Technology, Nanyang, China
Email: ielzhuang@zzu.edu.cn

Abstract–**Mobile IPv6 provides mobility support for hosts connecting to the Internet, it solves addressable problems of the mobile terminal, and the mobile terminals can obtain network services without changing IP addresses. But MIPv6 can introduce substantial network expenses and lengthy handoff delay during the mobile handover process, meanwhile, more and more delay sensitive real-time applications require a packet lossless QoS guarantee during a handoff. It proposes an optimized seamless handover mechanism on the basis of existing handoff methods in this paper, it builds on top of the hierarchical method and the fast handoff mechanism and adopts a decision engine-based dynamic distributed architecture, at last it verifies that using this new handoff scheme can reduce packet loss and handoff delay efficiently and improve handoff efficiency by doing simulation experiments.**

Index Terms–**mobile IPv6; seamless handover; decision engine; delay; efficiency**

I. INTRODUCTION

With the development of next generation network technology, how to make mobile communication with each other in All-IP network has become an important research area of future network. People are often in mobile environment and their workplaces are unstable now due to economic development, as a result, people hope they can use terminals to get, process and exchange data during mobility procedure. Traditional TCP/IP network adopts network-prefix route, IP packet data unit will be routed to network segment corresponding to network prefix, then they will be forwarded to destination host. When mobile host moves between different networks, IP packets sending to this host can not be forwarded correctly, thus the host can not acquire network services as usual. To solve the host problem of moving between various networks, IETF mobile IP workgroup worked out mobile IP standard draft, it is a network layer solution for supporting mobile host and has scalability, reliability and security. Users can keep uninterrupted connection when moving from one coverage area to another by using mobile IP technology, therefore the actual all-IP network can come true.

In mobile IP network[1], every mobile node(MN) has a static home address, for the purpose of registration it will send binding update(BU) to home agent(HA), then HA intercepts all packets destined to MN, and tunnels to the current location of MN. Handover delay consists of movement detection, registration time and the time needed to configure new care-of address. There has been two methods to reduce handover delay at present, one uses hierarchical management architecture to reduce registration time, the other is to reduce address resolution time by pre-configuring care-of address, corresponding to HMIPv6 and FMIPv6 proposed by IETF. Furthermore, IETF draft put forward a scheme integrated hierarchical handover with fast handover technology. Though the experiment demonstrated that this scheme improved handover performance, it can not satisfy the need of packet lossless handover environment in IP layer, moreover, the ping-pang movement problem of the MN has not been solved.

An optimized seamless handover technology on the basis of fast and hierarchical handover mechanism is proposed in this paper, it adopts dynamic distributed architecture, adds decision engine(DE) entity, and modifies the internal data structure of the access router(AR) to implement the function of tracker and mobility anchor point(MAP), it adds MAP buffer in MN as well. A new MAP selection algorithm based on information is used in this method, it can minimize handover delay, reduce packet loss, it also has high fault tolerance and scalability, solves the possible packet loss and out of order problem generated by FHMIPv6. The second section of this paper introduces existing handover technology, the optimized seamless handover mechanism is described in third section, experiment analysis is given in fourth chapter, and at last we summarize this paper.

II. CURRENT HANDOVER TECHNOLOGY

A. Hierarchical Mobile IPv6 Mobility Management Scenario

Mobility anchor point(MAP)[2] is introduced in hierarchical mobile IPv6, it is a router located in a network where the MN visited, and receives packets on behalf of the MN it serves, then encapsulates these packets and sends them to the current place of the MN, the implementation of this method has nothing to do with the underlying access technology. A MN supporting the hierarchical mobile IPv6 is called a HMIPv6-aware node,

doi:10.4304/jnw.6.9.1373-1378

at first it obtains the global address of the MAP through the router advertisement message sent by AR, at the same time it detects whether it is in the same MAP domain through the MAP option. If it roams in the same MAP domain, only an binding update(BU) sent to MAP is needed; if the MAP address changes, then a new regional care-of address registered to HA and correspondence node(CN) is required. If the MN is not a HMIPv6-aware node, it will use normal mobile IPv6 protocol to do mobility management.

We reduce the signal exchange between MN and external network by using local hierarchical architecture, this is particularly important for the wireless link which has limited bandwidth. However, this hierarchical management scenario is static and centralized, one MAP is in charge of all traffic of the whole regional network, it can lead to single point failure and performance bottleneck problem.

B. *Fast Handover Mechanism*

The fast handover mechanism[3] introduces prediction technology, it is initialized by wireless link layer trigger. Once MN receives handover direction message, it will send Router Solicitation for proxy Advertisement (RtSolPr) to previous AR (PAR), as a response, the PAR sends Proxy Router Advertisement (PrRtAdv) to MN. MN forms a new care-of address according to the network prefix option in this message, then it sends fast binding update (FBU) message to PAR, and receives fast binding acknowledgement (FBAck) later. After that PAR sends Handover Initiate (HI) message to New Access Router (NAR), this message contains new care-of address and current care-of address of the MN. After receiving HI NAR sends Handover Acknowledge (HAck) to PAR indicating that if this new care-of address can be used by MN. If so, PAR will set up a tunnel destined to this new address, otherwise it will establish a tunnel toNAR and forward packet units to NAR, then NAR forwards them to MN. MN will send Fast NeighborAdvertisement (FNA) to NAR in case it connects tothe new link, enabling its neighbor to update buffer.This fast handover mechanism reduces interruption time of the communication, however, it limits the movement speed of the MN.

In view of the problems existed in above handover mechanisms, this paper comes up with an optimized seamless handover mechanism, it not only reduces handover delay and packet loss, but also solves ping-pang movement and the packet out of order problem, the mobile terminal user will perceive a seamless connectivity.

III. OPTIMIZED REAL-TIME SEAMLESS HANDOVER TECHNOLOGY

This new mechanism adopts a dynamic distributedarchitecture[4], it is a hierarchical overlay network, and has several characteristics such as low latency, scalability, fault tolerance. A MAP router exists in thehighest layer, the second layer contains middleware nodes, including Decision Engine (DE), and the third layer consists of AR, MN, HA, and CN. We use a synchronized packet simulcast (SPS) mechanism and hybrid handover mechanism to reduce packet loss in the MAP, SPS will send these packets to the current network and external network. Hybrid handover mechanism enables MN to know its present locationso as to initiate the handover procedure, on the other hand, it can help the network system to determinewhich network the MN should handover to, this decision is made by movement tracking, it can differentiate if MN is in linear, stochastic or static moving state near the overlapped boundary between two network coverage areas.

In the second overlay network, we choose a node as decision engine (DE)[5], its function is similar to regional MAP, and it makes handoff decision for its network domain. Besides, DE maintains a global view of the connection state of any mobile devices in its network domain, as well as the movement patterns of all these mobile devices. It is also capable of offering load balancing services. Furthermore, iTracker is introduced into the current Provider Portal for Applications (P4P) architecture to optimize performance, it enables network provider to interact with various real-time applications and to do traffic control, however, nobody has applied this method to the mobile handover mechanism by now. In view of this point, we modify data structure of the AR, add policy, distance, and capability interface[6] into ARs of the third overlay network to implement functions similar to trackers. The policy interface allows MN to obtain diverse link usage policies, this can reduce packet loss or out of order. The distance interface allows MN to query the cost and distance between different access networks, and determine which external network MN should handoff to. MN can also make access control to some received packets in order to preserve security and privacy through capability interface. At the same time, each AR can serve as MAP to reduce packet loss rate between AR and MN, and the number of AR inside the MAP domain is regulable based on users, coarse-grained packet sequencing mechanism is used inside each AR.

In this mechanism, each AR can serve as MAP, and MN computes the number of optimal AR for each AR chose as MAP can encompass. MN maintains a buffer area for the current MAP, AR information this MAP has visited is stored in this buffer in order of preference. Once MN connects to a new AR that is not in the buffer, it will calculate whether the size of current MAP domain has exceeded its optimal value, if so it uses MAP selection mechanism so as to re-assure the current MAP. There has been multiple methods to select MAP at present, such as dynamic MAP discovery mechanism, MAP selection algorithm based on distance, renumbering the routers and so on. A new scenario proposed in this paper uses dynamic distributed algorithm[7] based on information which belongs to the b-matching problem to select regional MAP, this algorithm used in b-matching problem is to solve the many-to-many maximum weighted matchings. In this algorithm, MN sends PROP message to its neighbor AR periodically in order to establish connection, if AR also sends PROP message to MN, then MN will store this AR as a candidate MAP in its MAP buffer, meanwhile, set P is used to record the adjacent ARs that MN wants to connect to, set A records the nearby ARs that are willing to connect to MN, set K represents the AR that has been in MAP's cache buffer, set U keeps the nearby ARs that have not been connected to. If MN's MAP buffer is fully loaded, it will receive the REJ message sent by the last AR located in the cache buffer, after that it will send PROP message to AR in the next MAP domain. Function topRanked() will select the optimal AR as regional MAP dynamically. Set K contains AR information that has been accessed in MAP buffer when the algorithm terminates. The concrete description of this algorithm is made as follows:

```
$K=\Phi$; $A=\Phi$; $P=\Phi$; $U=\zeta i$;
While($|P|<bi$)
do $P=P\cup$topRanked($U\backslash P$)
for all $AR\in P$ do send (PROP, AR)
while $U\neq\Phi$ do
receive (m, u)
   if m=PROP then A=A□u
   if m=REJ then $U=U\backslash u$
      if $u\in P$ then $P=P\backslash u$
AR=topRanked($U\backslash P$)
      $P=P\cup AR$
     send(PROP, AR)
if $\exists AR\in(P\backslash K)\cap A$ then $U=U\backslash AR$
        $A=A\backslash AR$
        $K=K\cup AR$
if $P\backslash K=\Phi$ then for all $AR\in U$
do send (REJ, AR)
         $U=\Phi$
```

Once received beacon notification message sent byadjacent AR, MN will send RtSolPr message to previous AR(PAR) so as to initiate the handover process,this indicates that MN wants to carry out seamless handover, it then generates the current tracking state(CTS) message and sends it to the nearby AR, DE, Signal strength of the AR and its corresponding ID is included in CTS. After receiving the RtSolPr message, PAR will send PrRtAdv message to MN atfirst, then send carrying load state(CLS) message to DEperiodically, this CLS message shows the number of mobile devices related to AR and MN's IP address, handover initiate(HI) message is sent to adjacent AR later, the required new care-of address and current care-of address are included in it, as a response,adjacentAR will send handover acknowledge(HAck)message to PAR to indicate whether it accepts the new address or not. If it accepts, PAR will set up a tunnel to the new care-of address, otherwise it only tunnels packets to nearby AR. Analyzing the CLS, CTS message and tracking the movement state of MN in a shortperiod of time, DE sends handover decision(HD) message to all ARs, PAR extracts the content of handover notification(HN) message from HD and sends HNmessage together with PrRtAdv to MN to indicate the network it will handover to, MNsends fast bindingupdate(FBU) message to PAR to bind its current linkaddress with new care-of address after receiving HN,meanwhile it selects an optimal AR as MAP in its MAP buffer based on dynamicdistributed algorithm, then sends BU to it to bind its current care-of address with local care-of address. After that PAR sends simulcast (Scast) message to MAP to initiate packet simulcast process, MAP will duplicate each packet marked with S bit sent by CNand send them to PAR and NAR's cache buffer, PAR and MAP sends FBAck to MN at the same time.PAR can forward the packets destined to MN's newcare-of address to NAR it selects as soon as the transmission of simulcast packets come to an end. MNwill send fast neighbor advertisement (FNA) message to NAR once it connects to the new link. NAR contains two buffers named f-buffer and s-buffer, thismethod solves packet out of order and packet loss problem introduced by asynchronous forwarding mechanism effectively. F-buffer contains packets forwarded by PAR, packets marked with S bit sent by MAPare included in s-buffer. NAR starts to forward buffered packets to MN after it receives FNA message, this behavior avoids the possible packet loss problem especially when MN gets to NAR before it makes a new connection, or sends FBU message to PARafter it attaches to NAR. NAR can not receive forwarded packets until the transmission of simulcast packets is over in the handover process. However, onceMN connects to the new link, NAR has to forward packets in s-buffer to MN after the transmission of packets in f-buffer comes to an end. NAR sends Simulcast Off (Soff) message to MAP, MAP forwards this message to DE when the transmission of packets in s-buffer is over. Until now the handover process finishes and the communication returns to normal hierarchical mobile IPv6 mode.

To solve the ping-pang movement problem of MN, if MN is in a stochastic movement state, HD message will inform AR to use anticipation mode, AR needs to maintain its binding cache with MN even if MN isn't associated with this AR, HN message sent by PAR to MN will indicate MN can use FNA message to execute handover freely. If MN is in a static state near the boundary between two covered areas, HD message will indicate multiple bindings between MN and several ARs, MN can use a number of care-of addresses to make handover. If MN does linear movement, HD message will indicate which AR it should handover to.

What's more, for the movement pattern detection of MN, DE needs to sample various position tracking information periodically, the accuracy of this detection depends on sampling period and movement speed of MN. We assume MN's traveling speed is 1m/s in this optimized scenario, and we start sampling when MN sends CTS message to DE through AR, the sampling period is set to 1s. The experimental result shows that at least 3samples are required to establish MN's movement direction, once we know its movement direction, we can judge the motion mode of MN according to it.

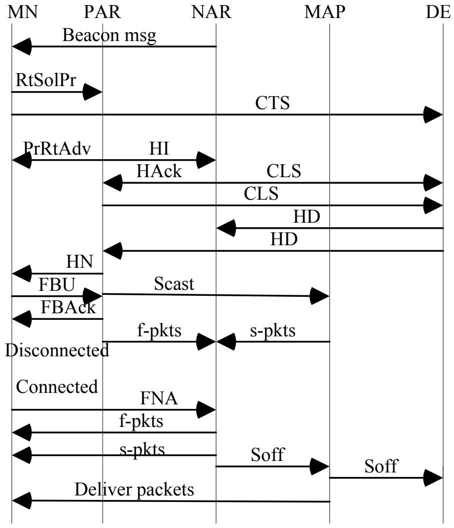

Figure 1. The OSFHMIPv6 handover mechanism

IV. EXPERIMENT ANALYSIS

This experiment environment is configured based on ns-allinone-2.31 platform in Linux Redhat 9.0 operating system, ns-allinone-2.31.tar.gz and FHMIP1.3.1 are needed to install in Redhat9.0, it is worth noting that wireless extension protocol NOAH is included in FHMIP1.3.1. In this experiment, HA and CN connect to the intermediate node N1 through a link which has 10ms delay and 100Mbit/s bandwidth, a 50ms delay, 100Mbit/s bandwidth link is located between N1 and MAP. MAP is connected to N2 and N3, a 2ms delay and 10Mbit/s bandwidth link is between them. N2 and N3 connect to PAR and NAR respectively, using a 2ms delay, 1Mbit/s bandwidth link. The link between MAP and DE has a 2ms delay, 10Mbit/s bandwidth. The type of N2-PAR and N3-NAR link is set to be DropTail queue, the rest of these links use random early detection (RED) queue.802.11 is used as access technology, radius of the covered area is set to be 50m, propagation tool is utilized to get valid wireless transmission distance. CN is bound with TCP source agent, while MN associates with receiver agent. CN and MN start to communicate with each other after 5s, MN moves in a linear manner with 1m/s[8]. We modify mip-reg.cc and corresponding code in TCL script file to make the next experiment after each group experiment has been done. The network topology of this experimental scenario is showed in Figure 2.

First we analyse the packet transmission delay[9] in each scenario. In HMIPv6, MN performs link layer handoff, then starts to execute MAP discovery and address configuration, at last sends binding update to MAP. Having bound with MAP successfully, MN receives unordered packets, then it will send ACK message to CN repeatedly through MAP and HA hoping to receive some packets before they become unordered, otherwise it can not submit correct data to applications. CN starts to retransmit data after receiving at least 3 ACK messages, this process happens at about 26s, TCP congestion window adds up to 4.3 at first, then decreases to 0 after retransmission, at last it enters into a slow start stage, the whole handover process takes about 347ms.

In FMIPv6, The time required by fast handover consists of sending time of RtSolPr and receiving time of PrRtAdv, MN sends FBU to PAR and receives FBAck, the interaction time of HI, HACK between PAR and NAR. On the other hand, only after MN sends FNA message and confirms it has connected to the new link can receive packets sent by CN, as a result, the sequence number of packets may be incorrect due to some delayed datagram in the handoff procedure. At this time MN sends ACK to CN, requiring it to retransmit the delayed packets, TCP packets are retransmitted at about 17s, congestion window adds to 2.5, then it enters into slow start stage, handoff delay is about 306ms.

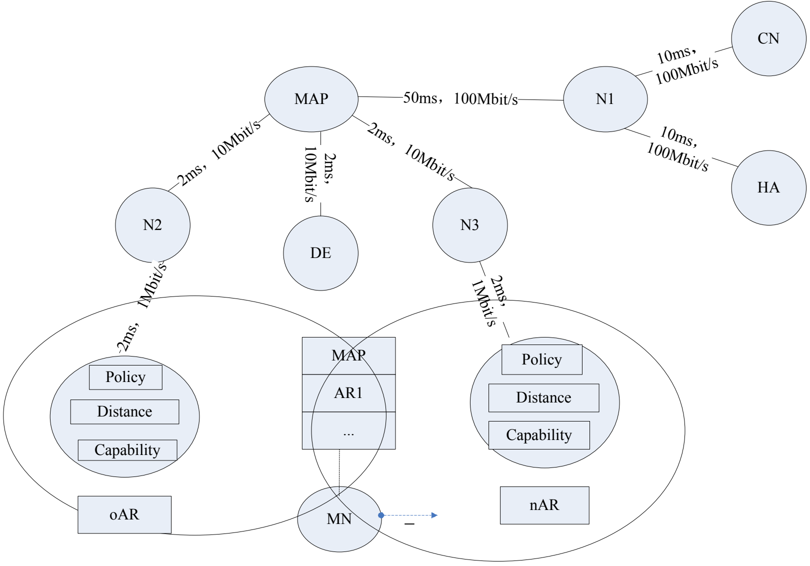

Figure 2. The network topology of this experimental simulation

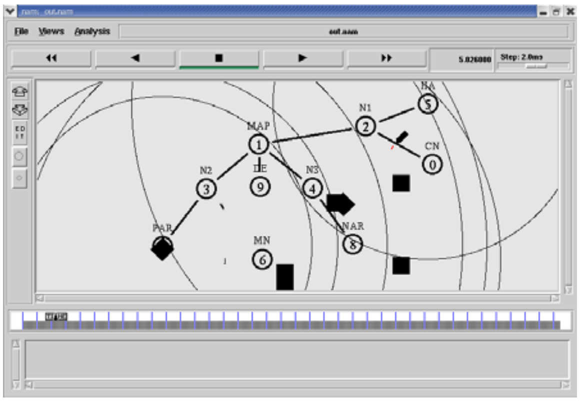

Figure 3. The screenshot of this simulation experiment

In the optimized seamless mobile IPv6 handover mechanism, DE is introduced into this architecture, so as soon as MN attaches to NAR, it can receive forwarded packets on the new link by sending FNA message, if the sequence number of received packetsis higher than anticipated value, then we can deducesome packets must be delayed or lost. MN will send ACK to CN to require the desired sequence number, CN starts to perform TCP congestion control andretransmit the desired packets after receiving ACK, congestion window increases up to 4.5, this process happens at about 24s, the slow start stage terminates when MN receives lost packets. After that the communication returns to normal stage, the overall handoverdelay is about 190ms.

Furthermore, we compare throughput, packet loss numbers and jitter rate in these handoff mechanisms, the result is shown in table 1. We can find that the scenario which has lower delay doesn't have higher throughput, and the number of lost packets is also not always less than other scenarios, such as fast handover mechanism. In HMIPv6, packet loss problem mainly comes from the registration to new MAP, HA and CN when MN roams among different MAP domains, besides, it has to send BU message to previous MAP so as to notify its new LCoA. The previous MAP can not forward packets to MN until it receives BU as a result of the link delay, and this will lead to packet loss. In addition, the service interruption will happen if the current MAP fails, packet loss can also generate during the failure detection and recovery procedure. In FMIPv6, NAR can not forward packets on behalf of MN because it doesn't know MN's new CoA, this happens at the time after MN connects to the new link and before it sends FNA, thus packet loss problem comes up. What's more, the packets sent to NAR before MN connects to the new link, and the packets arrived at PAR during the time after MN binds with NAR and before it sends FBU message will be lost[10]. We can draw a conclusion that this optimized seamless handover method has lowest delay, minimum packet loss numbers, highest throughput and less jitter rate among all the handover mechanisms according to the figures in this table, mobile users can feel a smooth seamless connection when they move from one network to another, but this good characteristic is achieved at the cost of adding entity device and signaling, modifying the data structure of AR.

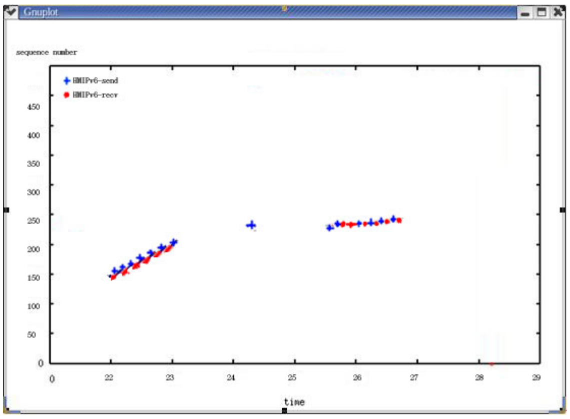

Figure 4. CN sends and receives packet sequence number in HMIPv6

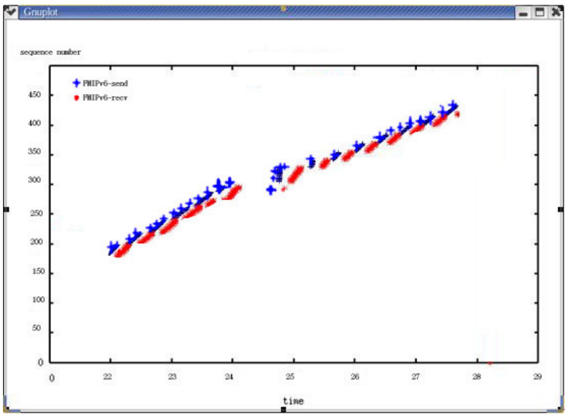

Figure 5. CN sends and receives packet sequence number in FMIPv6

TABLE Ⅰ
PERFORMANCE COMPARISON OF HMIPV6, FMIPV6 AND OSFHMIPV6

Handover Mechanism	*Handover Delay (ms)*	*Throughput （Kbytes/s）*	*Packet lossnumber*	*Jitter Rate (%)*
HMIPv6	347	164	15	0.02
FMIPv6	306	162	20	0.0025
OSFHMIPv6	190	208	3	0.002

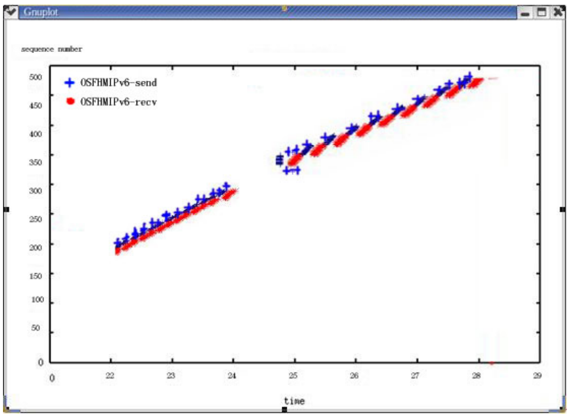

Figure 6. CN sends and receives packet sequence number in OSFHMIPv6

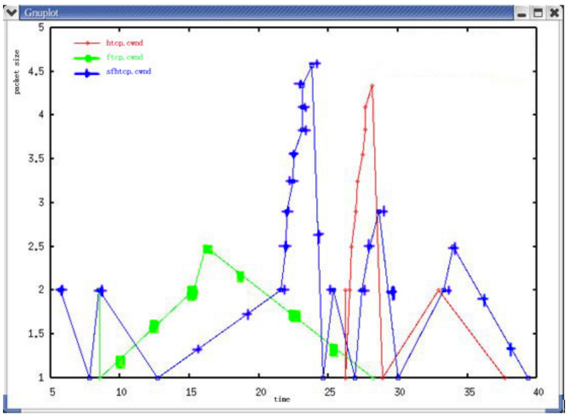

Figure 7. Size of TCP congestion window in HMIPv6, FMIPv6 and OSFHMIPv6

V. SUMMARY

Fast handover mechanism is classified into different types, only pre-handover mechanism is introduced in this paper. The optimized seamless handover mechanism achieves peer-to-peer communication mode to some extent between MN and CN in the handover process. Though increases signaling cost, it reduces the number of lost packet and solves ping-pang movement of MN as well as packet out of order problem, the whole architecture has scalability, fault tolerance and robustness. The experiment shows that this scenario can satisfy the need of real-time users. On the other hand, only network layer handover is discussed in this paper, link layer handover is not included. The security problem, the handover policy when MN moves swiftly and frequently near the covered areas among multiple access networks, the integration of MIPv6 with wireless communication technology and so on are all needed to make further research.

REFERENCES

[1] Johnson D, Perkins C, Arkko J, “Mobility Support in IPv6”[S], RFC 3775, 2004.

[2] Hesham Soliman, Claude Catelluccia, Karim ElMalk i, et al, “Hierarchical Mobile IPv6 mobility management(HMIPv6)”[S], IETF RFC 4140, 2005.

[3] Rajeev Koodli, “Fast Handovers for Mobile IPv6”[S], IETF RFC 4068, 2005.

[4] Xie J, Akyildiz I F., “A novel distributed dynamic location management scheme for minimizing signaling costs in mobile IP”[J], IEEE Transaction on Mobile Computing, 2002: 163-174.

[5] Robert Hsieh, Zhe Guang Zhou, Aruna Seneviratne, “S-MIP: A Seamless Handoff Architecture for Mobile IP”[C], InfoCom, San Francisco, USA, 2003: 1774-1784.

[6] Haiyong Xie, Richard Yang Y, Arvind Krishnam urthy, et al, “P4P: Provider Portal for Applications” [M], 2008.

[7] Giorgos Georgiadis, Marina Papatriantafilou, “Ov erlays with preferences: Approximationalgorithms for matching with preference lists”[R], http://www.cse.chalmers.se/~georgiog/pub/technical_report_2009_06.pdf, 2009.

[8] Leiming Xu, Bo Pang, Yao Zhao, “NS and Network Simulation”[M], POSTS & TELECOM PRESS, 2003.

[9] Tutorial for the Network Simulator “ns”[EB/OL], http://www.isi.edu/nsnam/ns/tutorial/index.html, 2006.

[10] Kempf. J, Wood. J, Fu. G, “Fast mobile IPv6 handover packet loss performance measurement for emulated real time traffic”, In IEEE WirelessCommu nications and Networking, 2003: 1230-1235.

Lei Zhuang was born in Zhengzhou, China, in 1963. She received the B.S and M.S in the computer science and technology from Zhengzhou University, China in 1986 and 1988, respectively, and the Ph.D degree in the computer software and theory from the National Digital Switching System Engineering & Technological Research Center, China, in 2004. She was visiting professor of Wollongong University, Australia, and Chalmers University, Sweden. She has worked in computer science and technology department of Zhengzhou University since 1988. As a result of her outstanding accomplishment, she was promoted in advance to associate professor and full professor in 1993 and 1998 respectively. She has published over 40 papers in journals and conferences in the areas of peer-to-peer networks. Her currently research interests include peer-to-peer computing, timed automata and model checking. Her research activities have been supported by the Natural Science Foundation of China, Hi-tech Research Development Plan of China, the Major Research Project of Henan Province, China, and The Research Project of Department of Education of Henan Province, China.

Prof. Zhuang is the Secretary General of Henan Province Computer Federation. She is the Committee Member of Theoretical Computer Science of Professional Committee, CCF and senior member of CCF respectively.

Chao Wang was born in April, 1986. Wang gainedbachelor’s degree of network engineering in Information Engineering University in 2007, and won master’s degree of computer application technology in Zhengzhou University in 2010, Wang’s research topic iscomputer network. Now Wang works in school of software of Nanyang Institute of Technology.

Wei Song was born in December, 1972. Song gained bachelor’s degree of compuetr software in Zhengzhou University in 1995, and won master’s degree of computer software and theory in Zhengzhou University in 2007,Song’s research topic is computer network and software engineering. Now Song is lecturer of school of information engineering of Zhengzhou University.He is also the member of CCF.