Novel Seamless Mobility Protocol for Next Generation Wireless Networks

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***Abstract*--In next-generation wireless networks, mobile nodes (MNs) need to freely change their network attachment point while communicating with others. Accordingly, it is crucial for mobile operators to provide efficient seamless mobility support. Several mobility protocols have been standardized by the working groups of the Internet Engineering Task Force (IETF). However, none of them can provide seamless mobility support for users in the next-generation wireless network. This paper proposes a new seamless mobility support protocol, and presents performance comparison with existing mobility protocols, such as MIPv6 and its enhancements.**

Keywords-next-generation wireless networks; mobility management; seamless handover

I. INTRODUCTION

In next-generation wireless networks, mobile users can freely perform roaming from one wireless access network to another while communicating with others. Accordingly, it is crucial for mobile operators to provide efficient seamless mobility support.

Generally, mobility management allows wireless system to locate roaming users to deliver call or data, and to maintain their network connection when they are on the move. That is, mobility management consists of two aspects: location management and handoff management. This paper will focus on the latter. Handoff seamlessness is defined as the ability for MNs to stay connected while roaming across different networks [1], without losing ongoing connectivity and without disruptions in the communication [2].

Several mobility protocols have been standardized by the working groups within the Internet Engineering Task Force (IETF), such as Mobility Support in IPv6 or MIPv6 [3], Hierarchical MIPv6 (HMIPv6) Mobility Management [4], Mobile IPv6 Fast Handovers or FMIPv6 [5], Fast Handover for Hierarchical MIPv6 or F-HMIPv6 [6] [7], Proxy MIPv6 (PMIPv6) [8], and Fast Handovers for Proxy Mobile IPv6 or F-PMIPv6 [9]. MIPv6, HMIPv6, FMIPv6 and F-HMIPv6 are host-based protocols, while PMIPv6 and F-PMIPv6 are network-based. Our work focuses on host-based handoff management.

The objectives of our research are to:

1)Reduce mobility signaling overhead and handover latency as much as possible;

2) Establish bidirectional tunnels before handover to improve the performance of FMIPv6;

3) Remove completely the Duplicate Address Detection (DAD) process from handover.

The remainder of the paper is organized as follows. Section 2 provides the research background and related works. Section 3 elaborates the proposed protocol: Enhanced Seamless Mobile IPv6 or e-SMIPv6. Section 4 presents performance analysis with numerical results. Section 5 draws the conclusion mark.

II. LITERATURE REVIEW

According to the research done by the International Telecommunication Union (ITU) on February 2013, there were 6.8 billion mobile subscriptions all over the world. As Smartphone becomes more popular than ever before, next-generation wireless networks have to choose all-IPv6-based infrastructure to support roaming users. In this context, the first IPv6-based mobility management protocol, MIPv6, is born, proposed and standardized by IETF.

To be always connected to the Internet regardless of its current location, a mobile node (MN) first needs to configure a new IPv6 address while connected to a new access network. This IP address is called care-of address (CoA). And then the MN will inform of the home network to bind its home address (HoA) with the CoA. The router at the home network, also named home agent (HA) then intercepts the MN's packets, and tunnels them to MN's new location. This solution is good for applications that are not delay-sensitive, but results in a problem with real-time applications, because of triangular routing.

To fix it, MIPv6 defines a process of route optimization, which allows one or more correspondent nodes (CNs) to maintain the same address binding as what the HA does. As a result, CNs can directly communicate with the MN without passing through the MN's home network.

Everything has its own pros and cons, and MIPv6 is not an exception. It is obvious that MIPv6 is an elegant solution for global mobility. However, it has some inherent drawbacks [10] [11]. That is, when an MN changes its access point (AP), there is always a short period during which it cannot send or receive packets due to link switching and IP protocol operations. Such a period is defined as handover latency [12]. MIPv6 mobility management process provides long handover delays, significant packet losses, and high mobility signaling overheads, thus unacceptable and detrimental for real-time applications, causing user-perceptible service deterioration during handover [11][13]

To improve the performance of MIPv6, many mobility protocols have been proposed by IETF and researchers at industry and university, such as FMIPv6 [5], HMIPv6 [4], F-HMIPv6 [6] [7], simultaneous bindings for FMIPv6 or sb-FMIPv6 [14], a novel FMIPv6 and HMIPv6 integration mechanism [15], enhanced fast handover with low latency for mobile IPv6 [16], simplified fast handover in mobile IPv6 networks [17], an efficient scheme for fast handover over HMIPv6 [18], seamless MIPv6 (SMIPv6) [19], to name a few. These solutions can be sorted into two categories: network architecture design and fast handover scheme. This paper focuses on the design of fast handoff solution.

FMIPv6 allows MNs to rapidly detect their movements and formulate a new CoA while still connected to their current subnets [5]. It also enables MNs to use available link-layer triggers to accelerate network-layer handoffs. Consequently, delays are completely eliminated during handoff due to network prefix discovery (or movement detection) and generation of new CoA. To reduce packet loss rate, a bidirectional tunnel is setup between the previous access router (PAR) and the new access router (NAR). The PAR maintains a binding between MN's previous CoA (PCoA) and its new CoA (NCoA), it intercepts those packets addressed to MN, and tunneled to the MN's NCoA. This avoids sending out Binding Update (BU) message during handoff, to MN's home network, and to its peers if route optimization is deployed.

However, FMIPv6 cannot determine the exact time when to start forwarding MN's traffic from PAR to NAR. In this case, packet losses are inevitable if PAR performs tunneling too early or too late with respect to the time when MN starts link switching. Neither can FMIPv6 support ping-pong moving MNs. In this context, the solution sb-FMIPv6 is proposed to reduce packet loss during handoff [14]. Traffic for the MN is bi-cast or n-cast for a short period to one or more future locations [20]. A new Simultaneous Binding flag B is inserted into Fast BU (FBU) message, so PAR can forward MN's packets to one or more NARs. This protocol reduces packet loss, but introduces more useless data traffic to the network, thus degrades system performance. Besides, sb-FMIPv6 cannot support seamless mobility for MNs with ongoing multimedia application, because the handover delay is about 257ms [20].

All these mobility protocols cannot know the exact moment when MN starts link switching. Consequently, packet losses are unavoidable when PAR forwards MN's packets too early or too late to one or more NARs. Simultaneous binding could be an interesting solution for this challenge. However, it cannot support seamless handover, due to high handoff latency. That is, none of these protocols can support handoff seamlessness.

III. PROPOSED SEAMLESS MOBILITY PROTOCOL

The proposed e-SMIPv6 includes two stages: setting up bidirectional tunnels among ARs before handover and managing seamless mobility when MNs change their network attachment points.

Zhang and Marchand proposed to establish bidirectional secure tunnels before actual handover and give MNs the priority to use their PCoAs in a new visiting network [21]. To do so, new routing policy is designed to deliver packets to a MN when it uses a topologically invalid IPv6 address in a visiting access networks. An access router (AR) with such new routing policy is called intelligent AR or iAR. Each iAR is able to create a Host Route Entry (HRE) for the MN's PCoA. By this means, arriving packets do not invoke the procedure of neighbor discovery until the iAR detects the MN's presence on its link.

The new protocol, e-SMIPv6, supports two operation modes: predictive and reactive modes. The following sections will elaborate the mobility management procedures in detail.

A. *Predictive Seamless Mobility Management*

The predictive seamless handover takes place when an MN can send a Seamless Binding Update (SBU) while still connected with PAR, which then bi-cast the MN's traffic on both links: PAR and NAR, even before the MN attaches on the NAR's link.

It is assumed that an MN is connecting with the PAR with a valid PCoA. That is, the HA and all the CNs maintain a binding between the MN's HoA and PCoA.

In an overlap zone, the MN receives beacon frames (or other link-layer frames) from nearby APs. Such link-layer information will help the MN to decide which AP to be associated with. After selecting the new AP (NAP), MN sends an SBU message to PAR while still attached on its link.

Once received an SBU, PAR maps the NAP's ID to NAR's IP address, and then bi-casts the MN's traffic on both links. To do so, PAR splits a stream of packets into two streams, continues the transmission of one stream on its own link while simultaneously tunnels the other stream to NAR.

Upon receipt the tunneled packets from PAR, NAR removes the outer header, figures out that the MN has not yet attached on its link and the packets are destined to MN's PCoA. NAR will buffer these packets and waits for MN's attachment. At the same time, NAR creates a Host Route Entry for MN's PCoA.

After link switching to the new link, MN sends immediately a Seamless Neighbor Advertisement (SNA) to NAR, which then verifies its Host Route Entry to check if the MN is given the priority to utilize the PCoA on the new link. If so, NAR forwards those buffered packets to MN. NAR also pick a CoA from its Duplicate-free CoAs List, and sends it to MN. By this means, the DAD process is completely removed from handover.

B. *Reactive Seamless Mobility Management*

The reactive seamless handover happens when MN cannot send an SBU message to PAR on the old link or the SBU sent out is lost over the air.

Once connecting to the new link, an MN sends immediately an SNA message to NAR. For the sake of security, the MN encrypts the payload of its outgoing packets using the preconfigured shared key (PSK) with PAR. NAR intercepts MN's packets, which use a topologically invalid IPv6 address. Instead of dropping these packets, NAR searches PAR's IP address via MN's PCoA, and then checks if there is a pre-configured tunnel to PAR. NAR also needs to check whether the MN is given the priority to use its PCoA in NAR's territory. If all the conditions are met, NAR tunnels MN's packets to PAR.

Once received the tunneled packets from NAR, PAR removes the outer header, performs ingress filtering for MN's PCoA. Upon success, PAR decrypts the payload using the PSK shared with the MN. And then wraps the decrypted payload with normal IP header, and sends it to the CN.

IV. PERFORMANCE EVALUATION

Normally, performance evaluation for mobility protocols is based on simulation and test-bed approaches [20] [22]. However, network scenarios for simulations are changing very much, as a result, performance comparison is rarely viable. In this case, analytical models [11] [12] [23] are designed to analyze system performance when mobile nodes roaming in next generation wireless networks.

In the literature, there exist different mobility models [24], such as random walk, random waypoint, fluid flow, random trip, Gauss-Markov and city section. The random waypoint is the most commonly used model because of its simplicity. However, this model assumes that MNs follow straight line movements. Such an assumption cannot present the reality because MNs cannot move freely in space; they must follow traffic rules [25]. Under these circumstances, the city section mobility model is selected to analyze the performance of e-SMIPv6 while comparing it with FMIPv6.

The following paragraphs will describe our analytical results using the city section mobility model, which is proposed by Zhang and Pierre [12].

The total cost is the sum of global and local binding update (BU) cost, binding refresh cost, and packet delivery cost.

The global BU cost consists of the costs related to home registration, return routability (performed to ensure security among MN, CN and HA), and correspondent registration.

The local BU cost is composed of signaling costs within involved local subnets among MN, PAR and NAR. To keep the binding between HoAans CoA valid, before a binding expires, signaling messages are exchanged between MN and HA, between MN and CN, as well.

The packet delivery cost is defined as the cost to deliver packets from a CN to MN. It can be specified as follows:

$$C_{pd}^{FMIP} = C_{pd}^{eSMIP} = N_{mn} \times N_{cn} \times \lambda_s \times \left\lceil \frac{\theta}{\tau} \right\rceil \times C_{cn-mn} [1]$$

Where λ_s is session arrival rate, θ is average packet size, □ is the maximum transmission unit (MTU), N_{mn} is the number of MNs in a wireless system while N_{cn} is the number of CNs that can communicate with a MN directly.

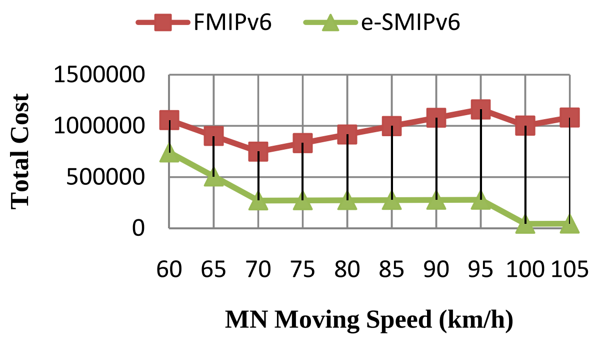

FIGURE I. TOTAL COST VS. MN MOVING SPEED.

Figure 1 illustrates the total cost when we change MN's moving speed. The number of CNs is set to 2. These CNs are simultaneously communicating with an MN. The number of mobile subscribers in the network is set to 2000. We can find that when MN moves faster, e-SMIPv6 requires less signaling costs than FMIPv6. This is because e-SMIPv6 allows MN to use its PCoA within a NAR's access network. Duplicate address detection is eliminated from handoff process. By this means, seamless mobility can be guaranteed. The average total cost for e-SMIPv6 is 298581.21 while 978310.16 for FMIPv6. That is, e-SMIPv6 presents 69.48% performance improvement, in comparison with FMIPv6.

V. CONCLUSION

Next generation wireless networks aim to integrate heterogeneous access technologies towards universal seamless access and omnipresent computing. This omnipresent computing is now represented by cloud computing in the big data era.

One of the main challenges for seamless mobility is to provide available and reliable intra- and inter-system handoff [26]. This implies the design of new efficient mobility management schemes to not only optimize quality of service to mobile subscribers, but also offer flawless mobility. In this context, our future research activities will focus on the combination of seamless mobility and security management together. Test beds will be established to evaluate the system performance while changing mobile users' behaviour.

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