A QoS Improvement for Mobile Network in Large Vehicles

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Abstract

In large vehicles such as a train, passengers can access Internet through an in-vehicle mobile router to effectively reduce the cost and overhead of roaming to a new network. While we apply the idea of mobile network into large vehicles, the critical issue is how to build up seamless Internet access services between vehicle's mobile network and fixed networks along the moving path or stations.

Mobile router is constructed by the technologies of Mobile IP and double IP tunneling. Through the mobile router, the mobile network in large vehicles can provide passengers a seamless Internet access with the access points outside. However, mobile router inherits the QoS issues in Mobile IP.

In this paper, we apply the idea that large vehicles usually have a fixed or predictive moving path to propose a PPT (Predictive Packet Transmission) scheme to improve the quality of Internet access service in mobile network. Through theoretical analysis and preliminary experiment, we demonstrate that the proposed PPT scheme can reduce not only the network handoff time but also the packet loss.

Keyword: Mobile IP, mobile router, mobile network, double IP tunnel, Predictive Packet Transmission.

1. Introduction*

In recent years, as the technologies of the computer hardware make great progress, computing handsets and notebooks which are advertised for lightness, small and thinness, have become more and more popular. Moreover, the fast development and growth of wireless technology make portable devices more convenient to access various Internet services and they have become a part of our daily life.

However, in current wireless network architecture, the prevalent WLAN standard is still not able to provide the seamless Internet access while mobile node (i.e. MN) roaming to new networks. MN needs to apply the Mobile IP [3] technology to continue the Internet service without reloading the network application.

Mobile IP can provide MN the network access in current IPv4 network architecture by Mobile IP routing protocol. Mobile IP extends the original architecture of IPv4 without modifications to the protocol suite. Mobile IP adds two entities, home agent (HA) and foreign agent (FA), to help MN to achieve mobile Internet access. When MN leaves its home network and arrives to a foreign network, MN can receive packets sent from its peer through an IP tunnel between the FA and HA. No matter where MN roams, the peers who want to communicate with MN just send the packets to MN's original address (i.e. home address).

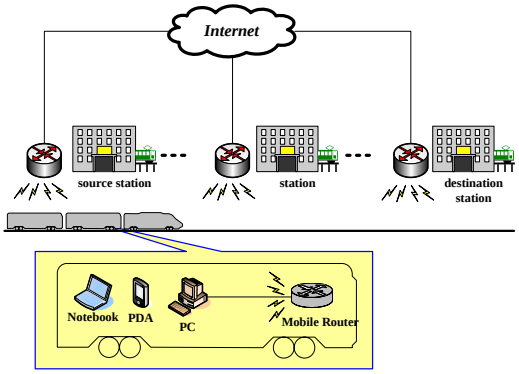

Figure 1. Architecture of mobile network in large vehicles.

In large vehicles such as a train, passengers can access Internet through an in-train mobile router to effectively reduce the cost and overhead of roaming to the same foreign network. As an example of mobile network in train shown in Figure 1, mobile router [10] applies the technologies of Mobile IP and double IP tunneling to extend to a new application–a moving network. When a train moves from a source station to a destination station, in-train mobile router will consider the source station as a home network and other train stations as foreign networks. Mobile router is responsible to provide seamless Internet connections between the access points outside and internal network inside. The major difference between Mobile IP and

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mobile network is that now MN stands for mobile network instead and mobile router carries its entire network to roam in foreign networks.

However, mobile network also inherits QoS issues from Mobile IP. In this paper, we apply the idea that large vehicles usually have a fixed or predictive moving path to propose a PPT (Predictive Packet Transmission) scheme to improve the quality of Internet access service in mobile network. In section 2, we discuss mobile network system and its QoS issues. In section 3, PPT scheme is proposed. We have brief analysis and experiment in section 4. Section 5 will summarize the conclusion and future work.

2. Mobile Network System and QoS Issues

In this section, we will introduce a mobile network system applied in large vehicles and discuss its QoS issues of prolong handoff latency and triangular route inherited from Mobile IP.

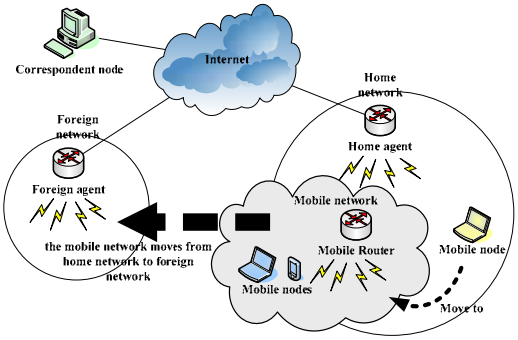

Figure 2. MNS (Mobile Network System)

2.1. Mobile Network System

The mobile network system (MNS) applied in large vehicles is illustrated in Figure 2. In MNS, mobile router (i.e. MR) plays both roles of FA and MN. MR will send agent advertisement messages to portable devices' HA while these portable devices roam to this MR at beginning. MR also needs to register to its own HA by its new FA's agent advertisement message.

The portable devices in MNS won't have to acknowledge their own HAs while the MNS roaming to a new foreign network. Therefore, it will effectively reduce the cost and overhead of handoff while portable devices in MNS roaming to the same network.

2.2. Prolong Handoff Latency

While MN moves to a new foreign network, in addition to consider the handoff latency of layer 2, the handoff latency of layer 3 (network layer) also needs to be considered significantly. According to the mechanism in Mobile IP, when an MN moves to a new network, it will receive agent advertisement message to obtain the information (i.e. care-of address) of new FA, and then MN sends a registration request to HA. Afterward, HA will update binding address table and sends a registration reply to MN. After such numerous operations, MN finally completes the overall handoff procedure. Such long handoff latency usually stalls the network service.

Besides, while MN handoffs to a new network, the number of UDP packet loss will be the product of bandwidth and handoff latency. Therefore, prolong handoff latency will cause more packet loss.

A hierarchical architecture of FAs–HMIP [6] is proposed to relieve the long handoff latency. Besides, there are some other ways to solve prolong handoff latency for MN such as HAWAII [8], Cellular IP [2] and etc.

2.3. Triangular Route

Triangular routing occurs when MN roams to a foreign network, Correspondent node's packets will be forwarded to MN from MN's HA. Therefore, triangular route preserves the following issues:

- **Larger delay time**: longer routing path will introduce larger delay time
- **More packet loss**: triangular route will increase the packet loss probability while unreliable UDP packets traverse in longer routing path.
- **Home network congestion**: all the packets have to pass through HA to FA. The traffic to MN will compete with other traffic in MN's home network. Such traffic may congest the home network.

A route optimization [4] was proposed to solve triangular route problem. Corresponding node (CN) uses cache to store a current mapping of MN's care-of address and home address. Therefore, CN can send packets to MN directly without passing through HA.

In [1], they propose another way to solve triangular route by using DNS and reduce additional control traffic in above-mentioned route optimization. Once CN connects to MN, it can lookup DNS to find MN's care-of address. When MN moves to a new network, MN sends a "Migrate SYN" to acknowledge CN.

Besides, [6] adds a new component TA (Temporary home Agent) for nearby FAs to imitate the functions of HA. TA will assign a THADDR (temporary home address) to MN. Once CN connects to MN, the packets will pass through TA to MN. Geographically, TA reduces the link distance between CN and MN.

3. Predictive Packet Transmission Scheme

Figure 3 illustrates the time flow of controls and packets in conventional MNS and indicates that enormous packets will be lost during the handoff procedure

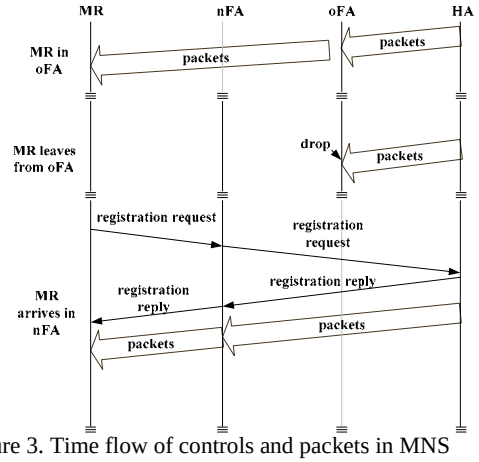

Figure 3. Time flow of controls and packets in MNS

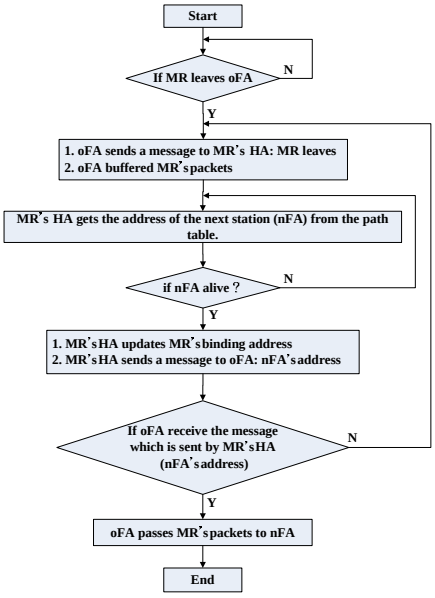

Figure 4. Flowchart of PPT when MR leaves oFA.

Since the large vehicles usually move on predictable paths. While MR leaves previous FA (oFA) for a new FA (nFA), HA can predict the nFA where the MR may roam. At the mean time, oFA can preserve packets from HA before the nFA is known from HA. Once nFA is known, the oFA can send the buffered packets to nFA. Therefore, it can reduce the packet loss during MR handoff.

In predictive packet transmission (PPT) scheme, while MR leaves oFA, oFA will initiate a "MR leaves" message to MR's HA and starts to buffer the packets for MR. When HA receives "MR leaves" message from oFA, a nFA where MR may roam is predicted by. HA will send "ACK" message with predicted nFA address back to oFA. After that, the oFA starts to send the buffered packets to nFA. At the mean time, the nFA also needs to preserve the packets from oFA till MR obtains the care-of address. Once the care-of address is known, MR can immediately receive the buffered packets after handoff. The other packets directly forwarded from HA will be received by MR after MR successfully registering to HA.

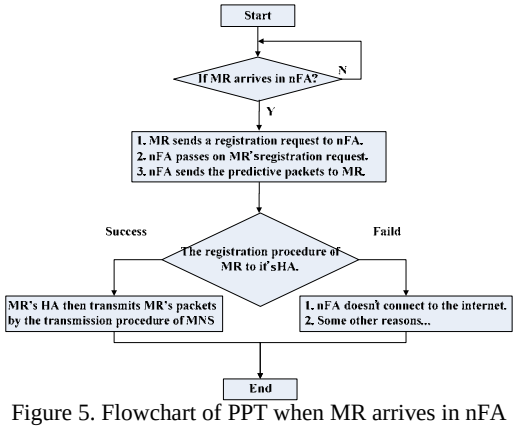

Figure 5. Flowchart of PPT when MR arrives in nFA

While MR leaves oFA, the flowchart of PPT operations is illustrated in Figure 4. Figure 5 illustrates the flowchart of PPT operations while MR arrives in nFA. Therefore, HA will maintain a predict table of possible FA addresses for MR's moving path to predict and acknowledge a nFA address for oFA .

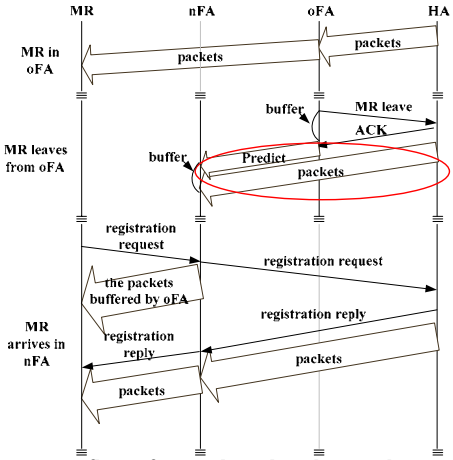

Figure 6. Time flow of controls and packets with PPT

4. Analysis of PPT Scheme

Figure 6 illustrates the time flow of controls and packets in MNS by using PPT scheme. As compared to Figure 3, it indicates that oFA and nFA will keep packets in their buffers respectively for MR to relieve enormous packet loss during handoff.

Figure 7 and 8 illustrate the time lines of packets to MR in MNS without and with PPT respectively. "①" denotes the time when MR moves from oFA to nFA. "②" denotes the time of MR's layer 2 handoff. "③" denotes the time of MR's layer 3 handoff. We can find that when using PPT scheme, MR can receive the buffered packets after layer 2 handoff completes. It can improve the packet delivery performance without waiting the MR to complete the layer 3 handoff.

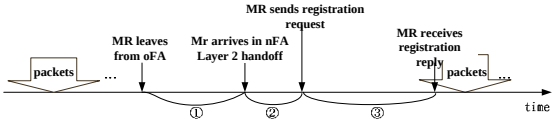

Figure 7. Time line of layer 3 handoff without PPT scheme

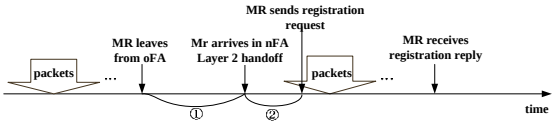

Figure 8. Time line of layer 3 handoff with PPT scheme

If we consider the actual handoff delay components while MR moving from oFA to nFA, the registration time for MR is given in following equation:

$$T_{MR\_reg}=T_{MR\_FAreg}+T_{FA\_HAreg}+T_{HA\_FAreply}+T_{FA\_MRreply} \quad (1)$$

In (1), T_{MR_FAreg} indicates the time of registration request message sent from MR to FA. T_{MR_HAreg} indicates the time of registration request message forwarded from FA to MR's HA. $T_{HA\_FAreply}$ means the time of registration reply message sent from FA to MR. However, when MR moves from oFA to nFA, MR's handoff latency will include the time of layer 2 and layer 3 handoffs:

$$T_{MR\_HO} = T_{MR\_L2HO} + T_{MR\_L3HO} \quad (2)$$

Moreover, MR's layer 3 handoff time includes the time of MR waiting for FA's agent advertisement message and the time of MR registering to HA. Therefore, we can rewrite the equation (2) as follows:

$$T_{MR\_HO} = T_{MR\_L2HO} + T_{FA\_adv} + T_{MR\_reg} \quad (3)$$

After substituting (3) with T_{MR_reg} in (1), we can obtain the actual handoff time components in details:

$$T_{MR\_HO} = T_{MR\_L2HO} + T_{FA\_adv} + T_{MR\_FAreg} + T_{FA\_HAreply} + T_{FA\_MRreply} \quad (4)$$

While PPT scheme is applied, the buffered packets can be received after layer 2 handoff completes and the FA's agent advertisement message. Thus, the handoff latency for PPT scheme is shown as follows:

$$T_{MR\_HO\_PPT} = T_{MR\_L2HO} + T_{FA\_adv} \quad (5)$$

After studying the handoff time in equations (4) and (5), PPT can reduce the handoff latency in MR's registration procedure. Not only the buffered packets can be received ahead in a round trip time of reg/reply messages but also the packet loss is highly reduced.

Our preliminary experimental results based on a Mobile IP project[11] also show that PPT scheme averagely rescue 170 to 220 packets from lost packets ranging from 600 to 810 while MNS handoffs to new FA. This experiment is conducted by sending 200 1Kbyte-sized packets every second from CN to MN with end-to-end delay ranging from 5ms to 500ms.

5. Conclusion and Future Work

In this paper, we proposed a predictive packet transmission scheme to improve the QoS of MNS in large vehicles. We demonstrate not only the improved performance of handoff delay by a theoretic analysis on the delay components in MNS, but also the recovery ratio for the packet loss during handoff in our preliminary experiment.

In near future, we will apply a mobile media streaming service such as VoD to demonstrate that PPT scheme can also highly preserve playback quality.

Reference

[1] A. C. Snoren and H. Balakrishnan, "An end-to-end approach to host mobility," in Proceedings of ACM/IEEE MobiCom '00, Aug. 2000, pp. 155–166.

[2] A. G. Valko, "Cellular IP - a new approach to internet host mobility," ACM Computer Communication Review, vol. 29, Jan. 1999, pp. 50–65.

[3] C. Perkins, "IP Mobility Support for IPv4," IETF, RFC 3344, Aug. 2002.

[4] C. Perkins, et al., "Route optimization in Mobile IP," Draft-ietf-mobileip-optim-09.txt, Feb. 2000.

[5] H. Soliman, et al., "Hierarchical MIPv6 mobility management (HMIPv6) ," draft-ietf-mobileip-hmipv6-05.txt, July, 2001.

[6] R. Zheng, et al., "A case for mobility support with temporary home agents," ACM SIGMOBILE Mobile Computing and Communications Review, vol. 6, Jan. 2002, pp. 32-46.

[7] R. Ramjee, et al., "HAWAII: A domain-based approach for supporting mobility in wide-area wireless network," in International Conference on Network Protocols, ICNP'99, 1999.

[8] S. E. Deering, ed., "ICMP Router Discovery Messages," IETF, RFC 1256, Sept. 1991.

[9] S. Sharma, et al., "Low-latency mobile IP handoff for infrastructure-mode wireless LANs," Selected Areas in Communications, IEEE Journal on, vol. 22, issue 4, pp. 643-652, May 2004.

[10] W. Ivancic, et al. "Application of Mobile-IP to Space and Aeronautical Networks," IEEE Aerospace and Electronic Systems Mag., vol. 16, pp. 13-18, Dec. 2001.

[11] http://dynamics.sourceforge.net/, Dynamics-HUT Mobile IP Project.