SEAMLESS NETWORK MOBILITY MANAGEMENT FOR REALTIME SERVICE

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Abstract. A mobile network is a set of IP subnets connected to the Internet through one or more mobile routers. When a mobile router moves into or out of a subnet, it suffers from the same handover problems as a mobile node does in the Mobile IP. A seamless handover scheme with dual mobile routers is proposed for a large and fast moving network such as trains. Each of the dual mobile routers is located at each end of the moving network for space diversity, but they perform a handover as one logical mobile router. Since one of the two mobile routers can continuously receive packets from its home agent, the proposed scheme can provide no service disruption time resulting in no packet losses during handovers. Performance evaluation showed that the proposed scheme can provide excellent performance for realtime service, compared with existing schemes.

1 Introduction

Mobile communication has become more popular due to the increased availability of portable devices and advanced wireless technology. In addition, the need for broadband wireless Internet connectivity, even on fast moving vehicles such as trains, has increased [1][2].

The IETF Working Group for network mobility (NEMO) is currently standardizing basic support protocol for moving networks [3]. The nodes residing in a moving network are attached to a special gateway, so-called mobile router (MR), through which they can reach the Internet. As like a mobile node (MN) in the Mobile IPv6, if a mobile router (MR) changes its location, then it registers its new care-of-address (CoA) at its home agent (HA) with a binding update (BU). Through the MR-HA bidirectional tunnel, the nodes residing in a moving network can continuously send and receive packets without perceiving that the MR changed its point of attachment.

Recently, various multihoming issues have been presented in the NEMO Working Group. The multihoming is necessary to provide constant access to the Internet and to enhance the overall connectivity of hosts and mobile networks [4][5]. This requires the use of several interfaces and technologies since the mobile network may be moving in distant geographical locations where different access technologies are provided.

The additional benefits of the multihoming are fault tolerance/redundancy, load sharing, and policy routing.

This paper proposes a seamless handover scheme with dual mobile routers for a large moving network such as trains. Each of dual MRs is located at each end of the moving network for space diversity. One of the two MRs can continuously receive packets from its HA while the other is undergoing a handover. This can support a seamless handover providing with no service disruption or packet loss.

The remainder of this paper is organized as follows: In Section II, we discuss about handover for mobile networks. In Section III, we introduce a seamless handover scheme with dual MRs, and then in Section IV we evaluate the performance of the proposed scheme. Finally, we make a conclusion in Section V.

2 Handover for Mobile Networks

The NEMO basic handover consists of two components, L2 handover and L3 handover. The term L2 handover denotes network mobility that is handled by the MAC (medium access control) and its support for roaming at the link-layer level, while the L3 handover occurs at the IP (network) layer level. Usually, the L3 handover is not dependent on the L2 handover, although it must precede the L3 handover.

Fig. 1 shows the components of handover latency in the NEMO basic operation. The L2 handover at the link layer involves channel scanning, authentication, and MR-access router (AR) association. The total L2 handover latency is about 150 to 200 msec. The L3 handover at the IP layer involves movement detection, new CoA configuration, and binding updates, which lead to about a 2 to 3 second handover latency. The L3 handover latency can be reduced by link-layer triggering or pre-registration schemes [6]. However, this handover latency can cause a service disruption resulting in packet losses.

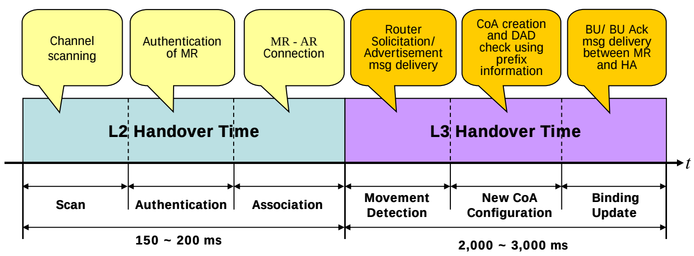


Fig. 1. Components of handover latency in the NEMO basic operation

Fig. 2 shows the L3 handover procedure in the NEMO basic operation based on Mobile IPv6. While an MR stays in an AR's coverage area, the MR receives periodic router advertisement messages from the AR. If the MR does not receive any messages from the AR during a predetermined time, it sends a router solicitation message to the AR to confirm its reachability. Nevertheless, if the AR does not respond, the MR detects its unreachability to that AR and sends router solicitation messages to new ARs for re-association. If a new AR replies with a neighbor advertisement message, the MR receives the prefix information from the AR and forms an association with the new AR by creating a CoA. Then, the MR sends a BU to its HA. After receiving the BU message, the HA replies with a binding ACK message and then can deliver data traffic from a correspondent node (CN) to the MR via the new AR.

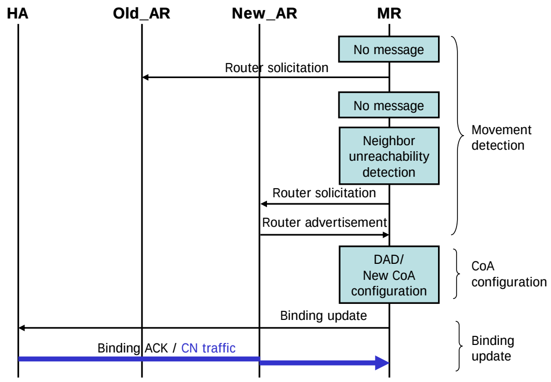


Fig. 2. The L3 handover procedure in the NEMO basic operation

3 Seamless Handover Scheme with Dual MRs

This section propose a seamless handover scheme with dual MRs for a large and fast moving network such as trains. Each of dual MRs, which associate with the same HA, is located at each end of the moving network for space diversity. One of the two MRs can continuously receive packets from its HA while the other is undergoing a handover.

3.1 Handover Procedure

The dual MRs, called as Head_MR and Tail_MR, are located respectively at each end of a train. Two MRs act as one logical MR, but the Tail_MR plays a major role in the L3 handover, thereby this gives the HA an illusion that only one MR exists in the mobile network.

Fig. 3 shows the handover procedure of the proposed scheme. When both MRs stay in the Old_AR's coverage area, the Tail_MR communicates through the Old_AR, while the Head_MR waits for an impending handover.

1. Phase 1: As the mobile network moves, the Head_MR reaches New_AR's coverage area prior to the Tail_MR and then performs a handover. After the Head_MR receives the prefix information from the New_AR and associates with the New_AR by creating a CoA, it sends a proxy BU message to its HA. The Proxy BU message contains the Head_MR's new CoA and the Tail_MR's home address (HoA), instead of the Head_MR's. This makes the HA to be under the illusion that the Tail_MR moves into the New_AR's coverage area. The Tail_MR, however, actually continues to send and receive packets in the Old_AR's coverage area, thus packet loss can be prevented. After receiving the

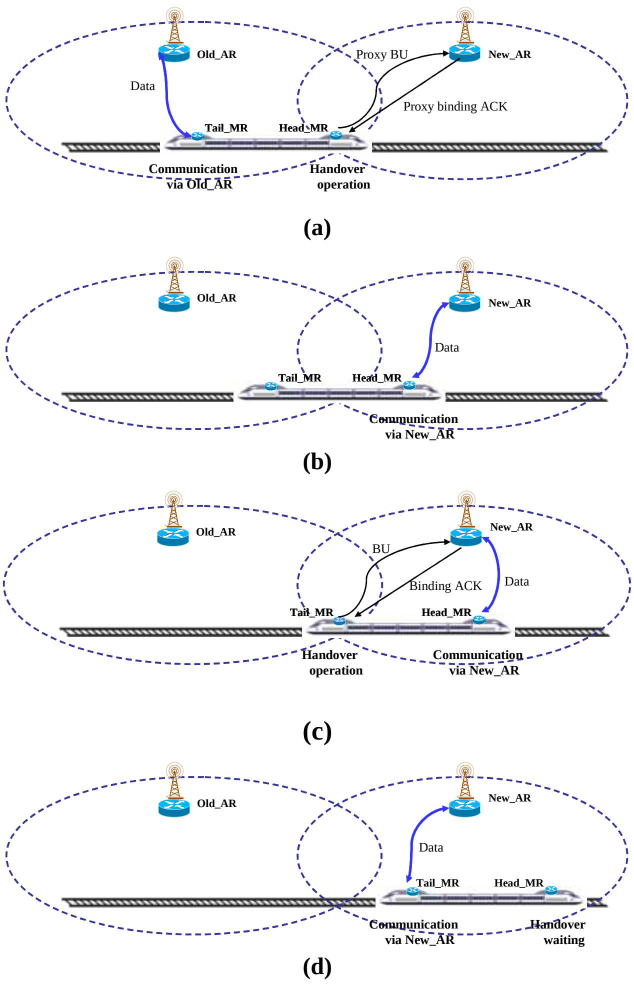


Fig. 3. Handover procedures of the proposed scheme
(a) Phase 1, (b) Phase 2, (c) Phase 3, and (d) Phase 4

proxy BU message, the HA updates the binding and delivers packets to the Head_MR through the New_AR. When the Head_MR receives a proxy BU ACK message from the HA, it enters into the data communication mode and sends a handover completion message to the Tail_MR. The Head_MR in the data communication mode can send and receive packets in the New_AR's coverage area.

2. Phase 2: When the Tail_MR stays in the Old_AR's coverage area and the Head_MR stays in the New_AR's coverage area respectively, the Head_MR can send and receive data packets through the New_AR, and the Tail_MR may receive data packets destined to the Old_AR.

3. Phase 3: If the Tail_MR receives a router advertisement message from the New_AR, it performs a handover. Unlike the Head_MR, the Tail_MR sends a general BU message including its own CoA and HoA through the New_AR. After receiving a BU ACK message, the Tail_MR can send and receive packets through the New_AR.

4. Phase 4: When both MRs stay in New_AR's coverage area, the Tail_MR communicates with the New_AR, while the Head_MR waits for an impending handover.

In the proposed scheme, the proxy BU and the proxy binding ACK messages are introduced. The formats of these messages, however, are the same as those of the general BU and binding ACK messages in the Mobile IPv6. The only difference between the proxy BU message and the general BU message is about the content of the messages. That is, the Head_MR inserts the Tail_MR's HoA into the Proxy BU message instead of its own HoA. Fig. 4 shows message flow diagram of the proposed scheme.

Table 1 shows the binding information maintained in the HA. With the binding information in this table, two MRs act as one logical MR during handovers.

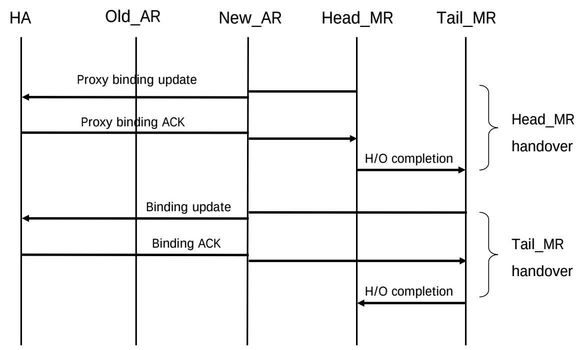


Fig. 4. Binding update messages for handover in the proposed scheme

Table 1. Binding information in the HA

Phases \ Binding	HoA	CoA
Phase 1	Tail_MR's HoA	Head_MR's New_CoA
Phase 2	Tail_MR's HoA	Head_MR's New_CoA
Phase 3	Tail_MR's HoA	Tail_MR's New_CoA
Phase 4	Tail_MR's HoA	Tail_MR's New_CoA

For outgoing packets to the Internet, the Tail_MR is configured as default router in the mobile network. When the Tail_MR can not communicate with the Old_AR, the Tail_MR will redirect or forward the received packets to the Head_MR.

3.2 Condition for Application

The proposed handover scheme exploits the difference between the handover execution time points of the Head_MR and the Tail_MR. In order to apply the proposed scheme for a moving network, the following condition should be satisfied:

$$\frac{d}{v} > T_{HO} \tag{1}$$

where d and v represent the distance between the two MRs and the speed of a moving network, respectively, and T_{HO} indicates the total handover latency during a handover.

Fig. 5 shows the relationship between the handover latency and the speed of a moving network for different distances between two MRs. The region under each curve indicates the range which satisfies the above condition (1). For example, an express train with 300 meters long, traveling at a speed of 300 km/hour, is large enough to apply the proposed handover scheme, even though the total handover latency is assumed to be 3 seconds.

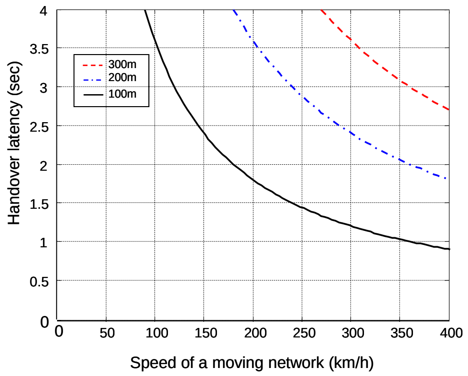


Fig. 5. The relationship between the handover latency and the speed of a moving network for different distances between two MRs

4 Performance Evaluation

This section compares the performance of the proposed handover scheme with the NEMO basic support protocol through analysis and simulation. Two critical performance criteria for realtime service are service disruption time and packet loss during handovers.

4.1 Analytical Results

Service Disruption Time. Service disruption time during a handover can be defined as the time between the reception of the last packet through the old AR until the first packet is received through the new AR. In this paper, we regard the service disruption time as the total handover latency, T_{HO}. Table 2 shows the parameters for performance evaluation.

Table 2. Parameter definitions

Parameters	Definition
T_{HO}	Total handover latency
T_{MD}	Time required for movement detection
$T_{CoA\text{-}Conf}$	Time required for CoA configuration
T_{BU}	Time required for BU
τ	Router advertisement interval
$RTT_{MR\text{-}AR}$	Round-trip time between MR and AR
$RTT_{AR\text{-}HA}$	Round-trip time between AR and HA

As shown in Fig. 2, the total handover latency during a handover in the NEMO basic support protocol can be expressed as a sum of its components and signaling delays:

$$\begin{aligned} T_{HO} &= T_{MD} + T_{CoA\text{-}Conf} + T_{BU} \\ &= 2\,\tau + RTT_{MR\text{-}AR} + RTT_{MR\text{-}HA} \\ &= 2\,\tau + 2RTT_{MR\text{-}AR} + RTT_{AR\text{-}HA} \end{aligned} \tag{2}$$

where the delays for encapsulation, decapsulation, and the new CoA creation are not taken into consideration. Generally, the L3 movement detection delay, T_{MD}, includes the L2 handover latency.

Each of dual MRs in the proposed scheme suffers from the same disruption in service during a handover as an MR does in the NEMO basic operation. However, in the proposed scheme, handovers of the Head_MR and the Tail_MR alternate each other, thereby the total service disruption time will be zero. Fig. 6 illustrates that one of the two MRs can continuously receive packets from its HA while the other is being engaged in a handover.

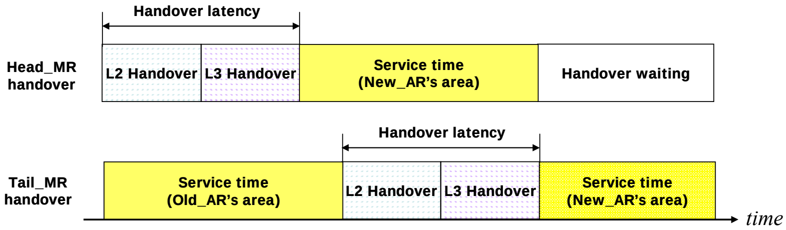


Fig. 6. Handover relationship between dual MRs

Fig. 7 compares the service disruption time between the proposed scheme and the NEMO basic support protocol. We assume that the router advertisement interval is 1 second, the radius of AR cell coverage is 1 km, and $RTT_{MR\text{-}AR}$ is 10 msec. As shown in this figure, the service disruption time of the NEMO basic is about 2 to 2.5 seconds, while the service disruption time of the proposed scheme is zero. This means that the proposed scheme can support a seamless network mobility for realtime service.

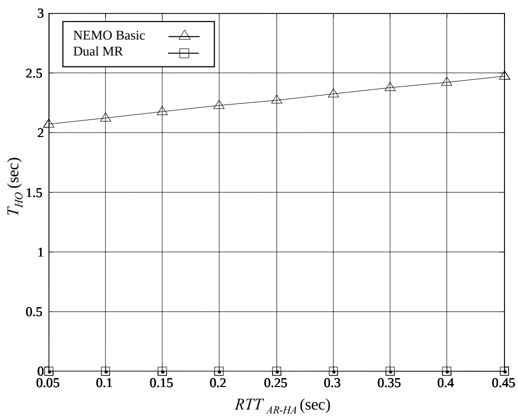


Fig. 7. Comparison of the service disruption time

Packet Loss Ratio. Since packet loss does not occur during the time when the CN traffic travels from the HA to an MR after the completion of the BU, the packet loss period during a handover can be expressed as T_{HO} - $0.5RTT_{MR\text{-}HA}$. Hence, using (2), the packet loss period can be given by:

$$T_{loss} = 2\,\tau + 1.5RTT_{MR\text{-}AR} + 0.5RTT_{AR\text{-}HA} \qquad \textbf{(3)}$$

Also, the packet loss amount can be expressed as a product of the packet loss period and the bandwidth of the Internet link:

$$L = T_{loss} * BW \quad \textbf{(4)}$$

where L represents the packet loss amount, and BW represents the bandwidth of the Internet link. In the case of the proposed scheme, there is no packet loss during a handover because T_{loss} is zero.

Packet loss ratio (ρ_{loss}) is defined as the ratio of the number of lost packets during a handover to the total numbers of transmission packets in a cell. This can be also expressed as:

$$\rho_{loss} = \frac{T_{loss}}{T_{cell}} \times 100 \quad (\%) \quad \textbf{(5)}$$

where T_{cell} is the time it takes an MR to pass through a cell.

Fig. 8 shows the packet loss ratio according to the speed of a moving network. In this figure, $RTT_{AR\text{-}HA}$ is assumed to be 100 msec. As shown in this figure, the packet loss ratio of the NEMO basic is proportional to the speed of a moving network, while the packet loss ratio of the proposed scheme will be zero regardless of the speed of the moving network.

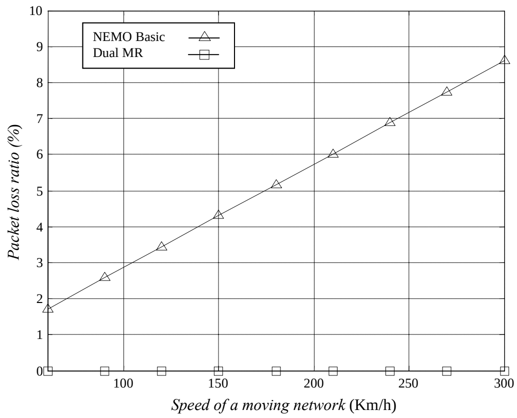


Fig. 8. Comparison of packet loss ratio

4.2 Simulation Results

We compare the TCP/UDP goodput of the proposed scheme with those of the NEMO basic by simulation using NS-2.

Simulation Model. Fig. 9 shows the network model for simulation. We assume that the coverage area of an AR is 250 meters in radius, and the ARs are 400 meters apart each other. Therefore, there is 100 meters overlapping area between the adjacent ARs.

The router advertisement interval is assumed to be 1 second. In our simulation we consider the IEEE 802.11b as the wireless LAN. The link characteristics, (the delay and the bandwidth), are shown beside each link in the Fig. 9. With regard to the MR, we only consider a linear movement pattern where the MR moves linearly from one AR to another at a constant speed. Also, the distance between the dual MRs is assumed to be 200 meters.

We have simulated for two traffic types: UDP and TCP. For UDP, the 512-byte packets were sent repeatedly at a constant rate of 20 packets per second from the CN to a mobile network node (MNN) residing in the train. For TCP, FTP traffic was generated with a full window.

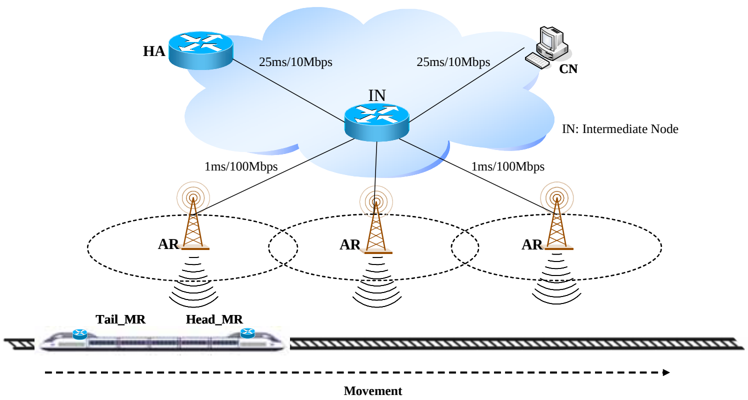
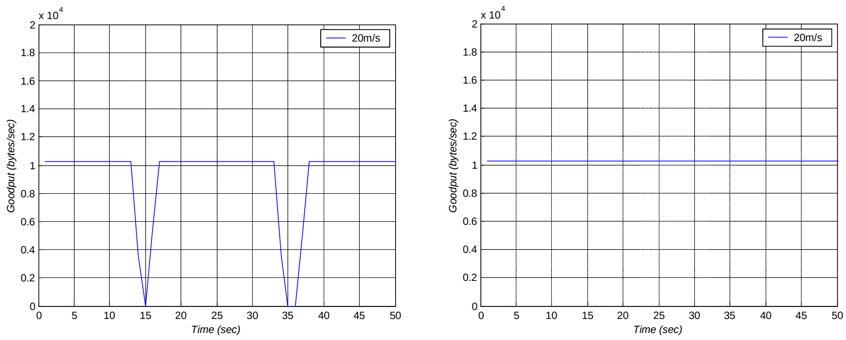


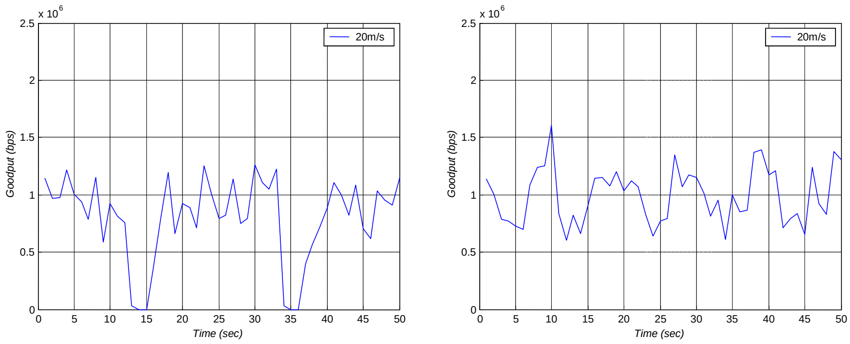
Fig. 9. Network model for simulation

Goodput. Fig. 10 and 11 compare the UDP and the TCP goodput behaviors between the proposed scheme and the NEMO basic, respectively. From these two figures, we note that the proposed scheme can provide a higher goodput in both cases of the UDP and the TCP, because the proposed scheme has no service disruption during handovers.



(a) NEMO basic (b) Dual MR

Fig. 10. Comparison of the UDP goodput behaviors at the speed of 20 m/sec



(a) NEMO basic (b) Dual MR

Fig. 11. Comparison of the TCP goodput behaviors at the speed of 20 m/sec

5 Conclusion

This paper proposed a seamless handover scheme with dual MRs for a large and fast moving network such as trains. Each of the dual MRs is located at each end of a mobile network for space diversity. One of the two MRs can continuously receive packets from its HA while the other is undergoing a handover. Therefore, the proposed scheme can provide no service disruption and no packet loss during handovers, which is very useful for realtime service. Performance evaluation showed that the proposed scheme can provide excellent performance for realtime service, compared with the NEMO basic support protocol.

The additional advantages of the proposed scheme are as follows: no modification requirements for existing network entities except MRs, support for load balancing and fault tolerance in special cases, and applicability to non-overlapping networks as well as overlapping networks. However, the proposed scheme has some overhead in comparison with NEMO basic support. The overhead involves the cost to maintain dual MRs with additional signaling messages.

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