An improved handoff scheme using SIP for time-shifted service in heterogeneous network

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Abstract

Multimedia service is widely developed with the convergence of network, but it is sensitive to the data delay and packet loss introduced by mobility. The time-shifted service is a typical application in multimedia service. An improved application-layer handoff scheme using SIP is proposed in this paper to reduce the delay user experienced in time-shifted service under IMS architecture. The improved handoff scheme includes horizontal handoff and vertical handoff which supports terminal mobility and mode mobility in time-shifted service. Theoretical analysis and simulation results show the delay user experienced is greatly reduced by the improved handoff scheme which ensures the seamless experience for time-shifted service.

Keywords: time-shifted, handoff, SIP, delay of handoff, delay user experienced

1 Introduction

With the development of broadband IP technologies and the progress of network convergence, multimedia service is widely applied in heterogeneous network. The traditional multimedia service is deployed onto handheld device, which changes the user experience from settled to moveable. Furthermore the generation and development of time-shifted technologies changes the user experience in time dimension [1]. However, the multimedia service is much sensitive to the data delay and the packet loss introduced by various mobilities. The waiting time for time-shifted request from user is an important factor to influence the user experience. Therefore a good mobility management scheme is necessary to improve the user experience by reducing the delay user experienced, which is introduced by mobilities. We focused on reducing the delay user experienced in time-shifted service in our work and proposed an improved handoff scheme, which is described in detail in next sections by theoretical analysis and experimental analysis.

The rest of this paper is organized as follows. In section II, the background is introduced as well as related work. The related definitions are described in section 3. And then the delays introduced by the original handoff scheme and the improved handoff scheme are analyzed in section 4. Next in section 5, simulations are performed to show that the improved handoff scheme can ensure the seamless experience for time-shifted service. Finally, section 6 concludes the paper and gives some research directions in future.

2 Background

2.1 Layers of Mobility Management

As described in Figure 1, mobility management of network can be functionally divided into location management and handoff management.

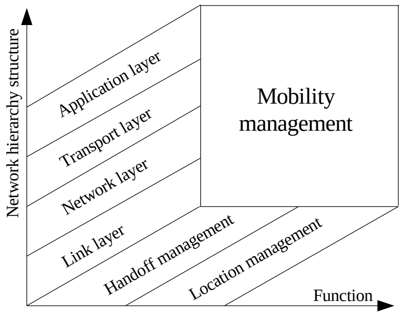

FIGURE 1 Mobility management of network

The location management is responsible for the location updating and locating the terminal. The handoff management helps for the connective of communication when the situation is changed. Mobility management of network also can be divided into four layers according to the network hierarchy structure. The layers of mobility management are not concerned about the access mode and transparent for the higher layers. They work together to contribute to the location and handoff of mobility management.

The link-layer mobility management only is applied in homogeneous network environments. The network-layer mobility management is related with only network layer

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and a series of Mobile IP (MIP) [2] protocol are drafted by IETF focusing on mobility management in IP network, such as MIPv4 [3], MIPv6 [4] and HMIPv6 [5]. MIP needs modifying the network layer protocol and adding mobile proxy to support mobility management. The transport-layer mobility management methods modify various transport layer protocols to support end-to-end mobility management in transport layer, such as mTCP [6] and mSCTP [7]. These methods are respectively designed for different transport layer protocols and need to modify the transport layer protocol stack. The application-layer mobility management doesn't need to modify the lower layers protocols and concentrates on application only, which helps it easily be deployed in a new application. SIP [8] which supports various motilities is such an application protocol to solve the application-layer mobility management. The research on application mobility management using SIP [9, 10] is widely carried out in broad network communication field. SIP can easily support location management while user moving. In this paper, the delay introduced by handoff is the important factor to be optimized.

2.2 Mobilities in Time-shifted Service

Mobility is an important feature of modern heterogeneous network with various access technologies. With the growth of network complicacy, network mobility is not limited to terminal mobility. It also contains other kinds of mobility, such as personal mobility, session mobility, service mobility and mode mobility [11]. There is such a scenario that time-shifted service is supported by both the mobile multimedia broadcasting network and the wireless communication network, which is described in Figure 2.

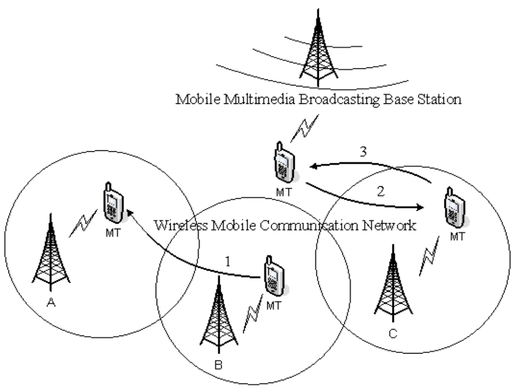

FIGURE 2 Mobility and handoff in time-shifted service

The mobile terminal (MT) is supported by both the mobile multimedia broadcasting network and the wireless mobile communication network. While user is enjoying time-shifted service, the following two mobilities are involved: terminal mobility and mode mobility. The terminal mobility means when MT moves between home network and visited network, the connected session is interrupted by IP address changed, which is described by arrow 1 in Figure 2. In terminal mobility, handoff must be occurred, which is called horizontal handoff because MT moves between homogeneous networks [5]. On the other hand, the mode mobility includes the following two situations:

1) when user changes service from live broadcasting to time-shifted service by sending time-shifted requests, vertical handoff from mobile multimedia broadcasting network to wireless mobile communication network should take place, which is called B-M vertical handoff described by arrow 2 in Figure 2;

2) when user begins receiving data synchronic with the live broadcasting by sending fast forward request or changing the channel, MT should perform vertical handoff from wireless communication network to mobile multimedia broadcasting network, which is called M-B vertical handoff described by arrow 3 in Figure 2.

3 Related definitions

3.1 Definitions of Entities Related

Our discussion is base on IMS which is the core network of wireless mobile communication contributing for the network convergence. In IMS, various mobilities in multimedia service can be easily supported by SIP. CSCF is the important entities in IMS architecture [12], which is used to process signalling. The time-shifted service system based on IMS is described in Figure 3.

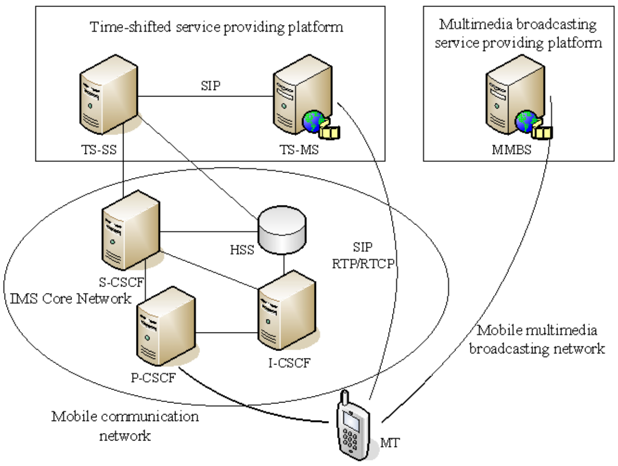

FIGURE 3 The network topology of time-shifted service system based on IMS

As Figure 3 described, the mobile terminal is a dual mode terminal. On the one hand, MT can receive the broadcasting data from the multimedia broadcasting service providing platform in the mobile multimedia broadcasting network. On the other hand, MT can receive the time-shifted data from the time-shifted service providing platform in the wireless mobile communication network. In the multimedia broadcasting service providing platform, the mobile multimedia broadcasting server (MMBS) is defined to deliver broadcasting multimedia data through the mobile multimedia broadcasting network. In the time-shifted service providing platform, the time-shifted server is defined as the mainly function entity which is responsible for the time-shifted service. According to the principle that data transmit and control signalling are separately, the time-shifted server is divided into two logical entities: time-shifted signalling server (TS-SS) and time-shifted media server (TS-MS). On the one hand, the TS-SS is responsible for providing service logic to the mobile terminal user by signalling interaction with S-CSCF of IMS core network. On the other hand, the TS-SS manages the time-shifted media data on the TS-MS. The TS-MS is responsible for the communication with the mobile terminal user. Meanwhile, TS-MS performs the time-shifted service data distribution according to the instructions by TS-SS.

3.2 Definitions of Two Kinds of Delay

When handoff is taken place, delay of handoff is an important indication of handoff efficiency. Delay of handoff is defined as the period of time through the whole handoff procedure, which is expressed as $D_{Handoff}$. But from user's view, user is more concerned about the delay he feels than the actually delay introduce by handoff itself. Therefore, a new parameter called delay user experienced is introduced in our paper, which is expressed as D_{UX}. It is defined as the period of time of data streaming interruption which is experienced by user. The ultimate goal of our work in this paper is to reduce the delay user experienced.

3.3 Other Definitions

Before modelling, the following definitions should be introduced:

1) T_{Tran}: the time of one signalling transmited on one link. It is determined as, $T_{Tran} = \beta L_{Tran}$, where L_{Tran} means the number of hops through transmit and β means the delay of each hop.

2) T_{CSCF}: the time of REGISTER or INVITE sojourning in CSCF.

3) μ_{CSCF}: the average rate of REGISTER or INVITE processed by CSCF.

4) T_{Other}: the time of the other kinds of signalling except REGISTER and INVITE processed by one CSCF, such as REFER, SUBCRIBE, NOTIFY, OK, ACK and BYE. So T_{Other} includes T_{REFER}, $T_{SUBCRIBE}$, T_{NOTIFY}, T_{OK}, T_{ACK} and T_{BYE}.

5) ω: the equivalent coefficient of sojourn time of T_{Other} with T_{CSCF}, which is expressed as $T_{Other} = \omega T_{CSCF}$, where the parameter ω is less than 1 usually because the time used to process REGISTER or INVITE signalling is more than the time used to process the other kinds of signalling.

6) n: the number of CSCFs for processing signalling.

7) $T_{TS\text{-}SS}$: the time of REGISTER or INVITE sojourning in TS-SS.

8) $\mu_{TS\text{-}SS}$: the average rate of REGISTER or INVITE processed by TS-SS.

9) $T_{TS\text{-}MS1}$: the time of INVITE sojourning in TS-MS.

10) $\mu_{TS\text{-}MS1}$: the average rate of INVITE processed by TS-MS.

11) $T_{TS\text{-}MS2}$: the time of time-shifted request sojourning in TS-MS.

12) $\mu_{TS\text{-}MS2}$: the average rate of time-shifted request processed by TS-MS.

According to the queuing theory [13], the T_{CSCF}, $T_{TS\text{-}SS}$, $T_{TS\text{-}MS1}$ and $T_{TS\text{-}MS2}$ can be expressed as:

$$\begin{cases} T_{CSCF} = 1/(\mu_{CSCF} - \lambda_{TS}) \\ T_{TS\text{-}SS} = 1/(\mu_{TS-SS} - \lambda_{TS}) \\ T_{TS-MS1} = 1/(\mu_{TS-MS1} - \lambda_{TS}) \\ T_{TS-MS2} = 1/(\mu_{TS-MS2} - \lambda_{TS}) \end{cases},$$

where λ_{TS} means the average rate of time-shifted request arrival.

4 Improved handoff scheme and delay analysis

With the above definitions, the improved handoff scheme is designed as follows in details, which reduces the delay user experienced to ensure the seamless experience for time-shifted service. It includes horizontal handoff and vertical handoff, and vertical handoff is furthermore divided into two situations: B-M vertical handoff and M-B vertical handoff as described in section II. In the following discussions, we use three suffixes, –H, –BM and –MB to distinguish them from each other. Furthermore, an apostrophe is used as the superscript when the delay of the improved handoff scheme is expressed. For example, $D_{Handoff\text{-}H}$ means the delay of handoff in the original horizontal handoff scheme and $D'_{UX\text{-}MB}$ means the delay user experienced in the improved M-B vertical handoff.

4.1 Horizontal Handoff Scheme

4.1.1 Delay of the original horizontal handoff scheme

The original procedure of horizontal handoff is shown in Figure 4 without the steps in the dotted rounded rectangle, which is described as follows:

1) The time-shifted multimedia streaming data is transmitted between MT and TS-MS.

2) When MT moving into the coverage area of two wireless mobile communication base stations, MT only knows the existing of the new base station but does not establish IP-CAN bearer.

3) MT establishes IP-CAN bearer to perform P-CSCF discovery and obtain a new IP address.

4) MT sends re-INVITE request to its TS-MS with the new IP address. Then TS-MS answers OK message to MT. Finally MT sends an ACK request to TS-MS to confirm this session to be established.

5) The new time-shifted data is transmitted between MT and TS-MS.

6) MT re-register to its home network and update its new IP address.

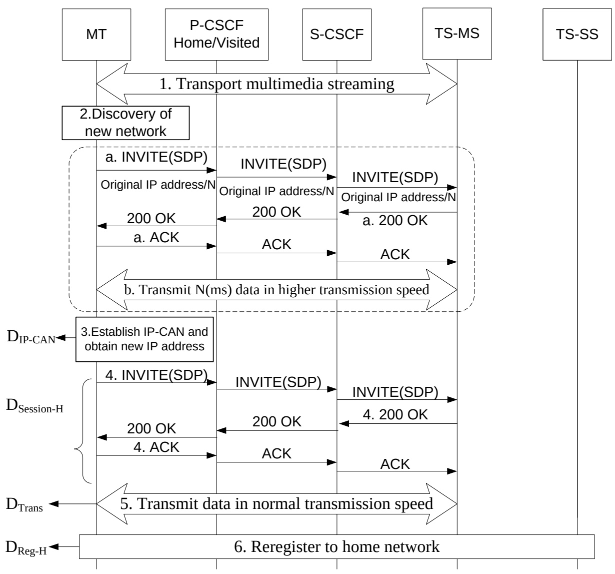

FIGURE 4 Horizontal handoff in time-shifted service

According to the above flows, the delay introduced by the original horizontal handoff in time-shifted service includes:

1) $D_{IP\text{-}CAN}$: the time of IP-CAN established and a new IP address assigned.

2) $D_{Session\text{-}H}$: the time of session reestablished using Re-INVITE request with the new IP address from MT to TS-MS.

3) D_{Trans}: the time cost by establishing data connection on a new link.

4) $D_{Reg\text{-}H}$: the time of finishing register by register procedure initiated by MT to home network and update IP address.

The multimedia data streaming is reconnected after the new session is re-established, so $D_{UX\text{-}H}$ doesn't include $D_{Reg\text{-}H}$. Therefore, the delays introduced by the original horizontal handoff, $D_{Handoff\text{-}H}$ and $D_{UX\text{-}H}$, are expressed as:

$$\begin{cases} D_{Handoff-H} = D_{IP-CAN} + D_{Session-H} + D_{Trans} + D_{Reg-H} \\ D_{UX-H} = D_{IP-CAN} + D_{Session-H} + D_{Trans} \end{cases} \tag{1}$$

4.1.2 Delay of the improved horizontal handoff scheme

In order to reduce the delay user experienced, the following prefetching strategy is introduced: when user discovers a new network while moving, MT uses a re-INVITE request to prefetch some data before IP address modified. The addition steps for the prefetching strategy are shown in dotted rounded rectangle in Figure 3, which is described as follows:

a) MT sends re-INVITE request to its TS-MS to ask for another N (ms) multimedia data with its original IP address. Then TS-MS answers an OK message to MT. Finally MT sends an ACK request to TS-MS to confirm this session to be established.

b) N (ms) time-shifted multimedia data are transmitted between MT and TS-MS in higher transmission speed.

The delay introduced by additional re-INVITE session is equal to $D_{Session\text{-}H}$.

Parameter N is the number of saved milliseconds of prefetching data, which is determined by the following parameters: $V_{Wireless}$, V_{Media}, V_{Move} and S. N is expressed as

$$N = max\left\{0, \left(\frac{S}{V_{Move}} - D_{Session-H}\right)\right\}\frac{V_{wireless} - V_{Media}}{V_{Media}} \tag{2}$$

The parameters in Equation (2) are defined as follows:

1) $V_{Wireless}$: the transmission rate of wireless network.

2) V_{Media}: the bit rate of multimedia streaming.

3) V_{Move}: the speed of MT.

4) S: the distance of MT moving from new network discovered to conduct horizontal handoff enabled in lower layer.

According to the above discussion, the delays introduced by the improved horizontal handoff, $D'_{Handoff\text{-}H}$ and $D'_{UX\text{-}H}$, are expressed as:

$$\begin{cases} D'_{Handoff-H} = D_{IP-CAN} + 2D_{Session-H} + D_{Trans} + D_{Reg-H} \\ D'_{UX-H} = max\{0, (D_{IP-CAN} + D_{Session-H} + D_{Trans} - N)\} \end{cases} \tag{3}$$

4.2 B-M Vertical Handoff Scheme

4.2.1 Delay of the original B-M vertical handoff scheme

As described in section 2, the original procedure of B-M vertical handoff is shown in Figure 5 ignoring the dotted line, which is described as follows:

1) MT is receiving multimedia broadcasting data from MMBS.

2) MT send a time-shifted request.

3) MT establishes IP-CAN bearer to perform P-CSCF discovery and obtain a new IP address.

4) MT proforms register procedure with the P-CSCF address.

5) MT sends an INVITE message with SDP which describes the MT's time-shifted request to TS-SS. Then TS-SS answers an OK message to MT. Finally MT sends an ACK request to TS-MS to confirm this session to be established.

6) TS-SS find out the TS-MS which can provide time-shifted data to MT.

7) TS-SS sends a REFER[14] message to tell MT the address of TS-MS.

8) MT answers an Accepted message to TS-SS.

9) MT sends an re-INVITE request to TS-MS. Then TS-SS answers an OK message to MT. Finally MT sends an ACK request to TS-MS to confirm this session to be established.

10) Time-shifted multimedia data are transmited between MT and TS-MS.

11) MT stops receiving multimedia broadcasting data from MMBS.

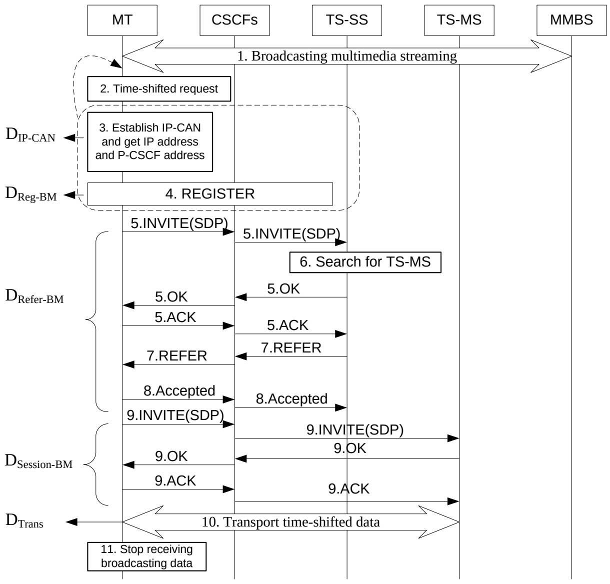

FIGURE 5 B-M vertical handoff in time-shifted service

According to the above flows, the delay introduced by the original B-M vertical handoff in time-shifted service includes:

1) $D_{IP\text{-}CAN}$: the time of IP-CAN established and a new IP address assigned.

2) $D_{Reg\text{-}BM}$: the time of finishing register procedure using REGISTER request from MT.

3) $D_{Refer\text{-}BM}$: the time of get available TS-MS's address by using INVITE and REFER requests.

4) $D_{Session\text{-}BM}$: the time of session established using INVITE request to TS-MS.

5) D_{Trans}: the time cost by establishing data connection on new link.

According to the procedure in Figure 5, $D_{UX\text{-}BM}$ is equal to $D_{Handoff\text{-}BM}$, because user feels the data interrupted from step 2 to step 12. Therefore, the delays introduced by the original B-M vertical handoff, $D_{Handoff\text{-}BM}$ and $D_{UX\text{-}BM}$, are expressed as

Therefore, the delays introduced by the original horizontal handoff, $D_{Handoff\text{-}H}$ and $D_{UX\text{-}H}$, are expressed as:

$$\begin{cases} D_{Handoff\text{-}BM} = D_{IP\text{-}CAN} + D_{Reg\text{-}BM} + D_{Refer\text{-}BM} + D_{Session\text{-}BM} + D_{Trans} \\ D_{UX\text{-}BM} = D_{Handoff\text{-}BM} \end{cases} \quad (4)$$

4.2.2 Delay of the improved B-M vertical handoff scheme

In order to reduce the delay user experienced, the step 3 and step 4 are put ahead of user's time-shifted request to finish as shown by the dotted line in Figure 5. Therefore, the delay of handoff is the same as before and the delay user experienced is reduced, which is shown as:

$$\begin{cases} D'_{Handoff\text{-}BM} = D_{Handoff\text{-}BM} \\ D'_{UX\text{-}BM} = D_{Refer\text{-}BM} + D_{Session\text{-}BM} + D_{Trans} \end{cases} \quad (5)$$

4.3 M-B Vertical Handoff Scheme

4.3.1 Delay of the original M-B vertical handoff scheme

As described in section 2, the original procedure of M-B vertical handoff is shown in Figure 6 without the steps in the dotted rounded rectangle, which is described as follows:

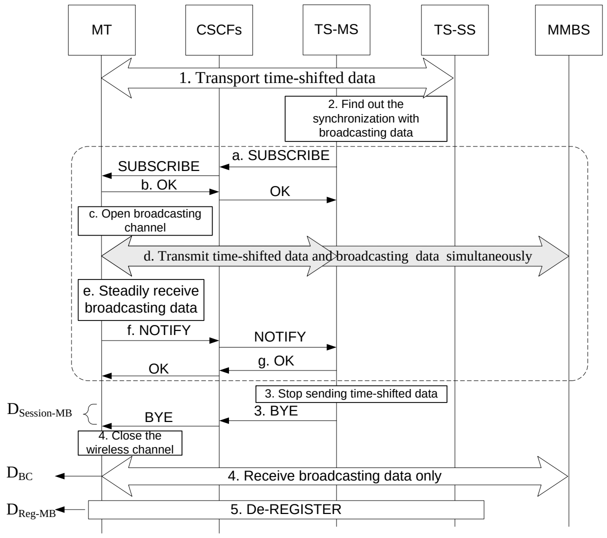

FIGURE 6 M-B vertical handoff in time-shifted service

1) MT is receiving time-shifted multimedia data from TS-MS.

2) TS-MS finds out the synchronization with the multimedia broadcasting data.

3) TS-MS stops sending the time-shifted data to MT and send a BYE message to MT.

4) MT closes the wireless communication channel and only receives the multimedia broadcasting data.

5) MT de-registers from the IMS.

According to the above flows, the delay introduced by the original M-B vertical handoff in time-shifted service includes:

1) $D_{Session\text{-}MB}$: the time of session terminated using BYE request to MT.

2) D_{BC}: the time that MT spends on tuning with the broadcasting radio and finish synchronizing, usually about 1-2s.

3) $D_{Reg\text{-}MB}$: the time of finishing de-registration with de-register procedure initiated by MT.

Therefore, the delays introduced by the original M-B vertical handoff, $D_{Handoff\text{-}MB}$ and $D_{UX\text{-}MB}$, are expressed as

$$\begin{cases} D_{Handoff\text{-}MB} = D_{Session\text{-}MB} + D_{BC} + D_{Reg\text{-}MB} \\ D_{UX\text{-}MB} = D_{Session\text{-}MB} + D_{BC} \end{cases} \quad (6)$$

Because the de-register procedure is behind of receiving broadcasting data, the $D_{UX\text{-}MB}$ doesn't include $D_{Reg\text{-}MB}$.

4.3.2 Delay of the improved M-B vertical handoff scheme

MT is a dual mode terminal in our discussion, which can access both the mobile multimedia broadcasting network and the wireless mobile communication network. Therefore, we use the soft handoff [10] for reference in M-B vertical handoff. The additional steps are shown within dotted rounded rectangle in Figure 6, which is described as follows:

a) TS-MS sends a SUBSCRIBE request to MT.

b) MT answers an OK message.

c) MT opens mobile multimedia broadcasting channel.

d) MT receives both the time-shifted data from TS-MS and the broadcasting data from MMBS.

e) MT steadily receives broadcasting data.

f) MT sends a NOTIFY request to TS-MS.

g) TS-MS answers an OK message to MT.

As described above, a SUBSCRIBE [15] request is used to tell MT to open broadcasting channel when TS-MS finds out time-shifted data is synchronous with broadcasting data. After MT steadily receiving broadcasting data, it sends TS-MS a NOTIFY[15] request to terminate sending time-shifted data. The delays introduced by SUBSCRIBE and NOTIFY are expressed as D_{SN}.

According to the above discussion, the delays introduced by the improved M-B vertical handoff, $D'_{Handoff\text{-}MB}$ and $D'_{UX\text{-}MB}$, are expressed as:

$$\begin{cases} D'_{Handoff\text{-}MB} = D_{SN} + D_{BC} + D_{Session\text{-}MB} + D_{Reg\text{-}MB} \\ D'_{UX\text{-}MB} = 0 \end{cases} \quad (7)$$

5 Simulations and results analysis

5.1 Delays in detailes

Firstly, we discuss the delays related with session establishing in Equations (1)-(7). Here, we only explain how to analyze the expression of $D_{Session\text{-}H}$. As shown in Figure 4, three signallings, including INVITE, OK and ACK, are used to reestablish session in horizontal handoff. Therefore, $D_{Session\text{-}H}$ should include the following delays:

1) Three times the signalling transmission delay on one link.

2) N times the time of processing signallings in CSCFs. The time of processing signallings in CSCFs includes the time of processing three signallings, include INVITE, OK and ACK. N is the number of CSCFs for processing signalling, which is defined in section 3.

3) The time of INVITE sojourning in TS-MS.

According to the above analysis and the definitions in section 3, $D_{Session\text{-}H}$ can be expressed as:

$$D_{Session\text{-}H} = 3T_{Tran} + n(T_{CSCF} + T_{OK} + T_{ACK}) + T_{TS\text{-}MS1} \ .$$

Therefore, using the above analysis method, we can analysis the expressions of the other delays related with session establishing in Equation (1)-(7) according to the procedures in Figure 4-6. Finally, all of the delays related with session establishing in Equation (1)-(7) are expressed as follows:

$$\begin{cases} D_{Session\text{-}H} = 3T_{Tran} + n(T_{CSCF} + T_{OK} + T_{ACK}) + T_{TS\text{-}MS1} \\ D_{Reg\text{-}H} = D_{Reg\text{-}BM} = 2T_{Tran} + n(T_{CSCF} + T_{OK}) + T_{TS\text{-}SS} \\ D_{Refer\text{-}BM} = 2T_{Tran} + n(T_{CSCF} + T_{REFER}) + T_{TS\text{-}SS} \\ D_{Session\text{-}BM} = 3T_{Tran} + n(T_{CSCF} + T_{OK} + T_{ACK}) + T_{TS\text{-}MS2} \\ D_{Session\text{-}MB} = T_{Tran} + nT_{BYE} \\ D_{Refer\text{-}MB} = 2T_{Tran} + n(T_{CSCF} + T_{OK}) + T_{TS\text{-}SS} \\ D_{SN} = 2T_{Tran} + n(T_{SUBSCRIBE} + T_{NOTIFY}) \end{cases},$$

where the parameters are defined in section 3.

The other delays except the above can be preset based on experience. $D_{IP\text{-}CAN}$ is set to 2s and D_{Tran} is set to 20ms which are determined by link technologies in the bottom layers and the current network status. D_{BC} is set to 1.5s as usual.

5.2 Preset Parameters

As described in Table 1, the related parameters are preset to perform simulations. The unit expressed as msg/s means messages per second.

TABLE 1 Related Parameters

Parameter	Value	Parameter	Value
β	1ms/hop	μ_{CSCF}	2500 msg/s
L_{Tran}	20hop	$\mu_{TS\text{-}SS}$	1000 msg/s
$D_{IP\text{-}CAN}$	2s	$\mu_{TS\text{-}MS1}$	1000 msg/s
D_{Trans}	20ms	$\mu_{TS\text{-}MS2}$	500 msg/s
D_{BC}	1.5s	ω	0.25
n	3	λ_{TS}	Variable

5.3 Result Analysis

5.3.1 Delay Analysis of Horizontal Handoff

As we all known, in mobile environment the $V_{Wireless}$ is not a constant value which is various with the speed of MT (V_{Move}). And according to Equations (2) and (3), we know $D'_{UX\text{-}H}$ is various with V_{Move}. Therefore, we discuss the relationship between $D'_{UX\text{-}H}$ and V_{Move} firstly.

According to the 3G mobile communication standard, we set the following parameter value as:

$$V_{Wireless} = \begin{cases} 384kbps & V_{Move} \le 6km/h \\ 144kbps & V_{Move} > 6km/h \end{cases}$$
$$V_{Media} = 128kbps \quad (8)$$
$$S = 50m$$

In order to keep the system to be stable, we set λ_{TS} = 400 msg/s. Then we use MATLAB to draw the relation curve of $D'_{UX\text{-}H}$ and V_{Move} as Figure 7.

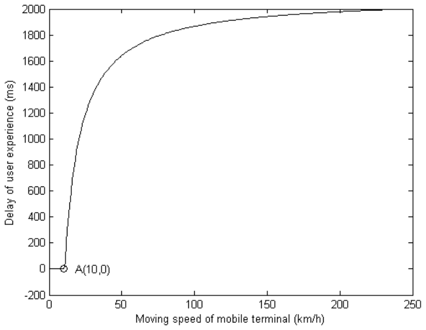

FIGURE 7 Relationship between D'_{UX-H} and V_{Move}

As Figure 7 described, with the parameters preset in our paper, when the moving speed of mobile terminal is equal or less than 10km/h, D'_{UX-H} can be reduced to 0. And when the moving speed of mobile terminal is greater than 10km/h, D'_{UX-H} increases as the moving speed of mobile terminal increases.

In order to simplify the issue, we only consider the situation that V_{Move} is equal or less than 6 kilometer per hour, where $V_{Wireless}$ can reach 384kpbs in 3G environment.

With the parameters preset in Table 1, MATLAB simulations are performed to intuitively show the performance of the improved horizontal handoff scheme. The delay comparisons of the two delays of the original horizontal handoff scheme and the improved horizontal handoff scheme are described in Figure 8.

As Figure 8 described, we can see that the delay of handoff and the delay user experienced are both more than 2 seconds before using the improved horizontal handoff scheme. However, after using our improved horizontal handoff scheme, under the condition that the moving speed of mobile terminal is equal or less than 6 km/h, the delay user experienced introduced by the improved horizontal handoff is reduced to zero with a little increase of delay of handoff. It is worth a little increasing of delay of handoff to get the seamless experience. By our improved horizontal handoff, the seamless experience can be got when the moving speed of mobile terminal is not so high. But when the moving speed of mobile terminal is so high that the prefetch data can not compensate the data interrupt in horizontal handoff, the delay user experienced will increase as the moving speed of mobile terminal increasing. Therefore, under this situation, the seamless experience can not be ensured only by application layer mobility management but also the lower layer mobility management should be used.

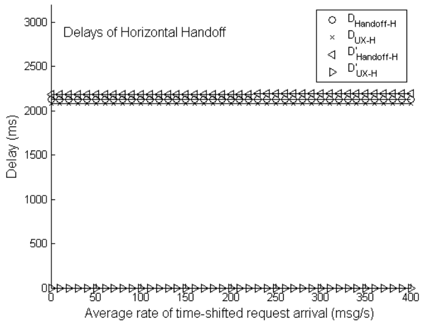

FIGURE 8 Delay comparison of horizontal handoff

5.3.2 Delay Analysis of B-M Vertical Handoff

According to Equations (4) and (5), MATLAB simulations are conducted with the parameters preset in Table 1. Then the delay comparison of B-M vertical handoff is intuitively described in Figure 9.

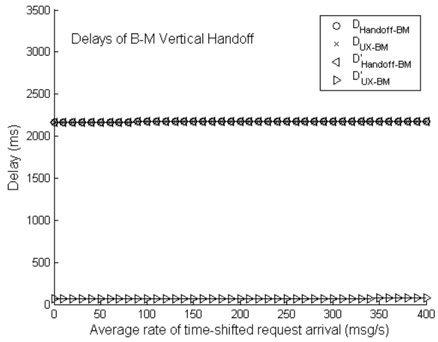

FIGURE 9 Delay comparison of B-M vertical handoff

As Figure 9 described, by using the improved B-M vertical handoff scheme, the delay user experienced is reduced to dozens of milliseconds magnitude without increase of handoff delay. Therefore, the improved B-M vertical handoff scheme almost ensures the seamless experience in B-M handoff in the time-shifted service.

5.3.3 Delay Analysis of M-B Vertical Handoff

According to Equations (6) and (7), MATLAB simulations are conducted with the parameters preset in Table 1. Then the delay comparison of M-B vertical handoff is intuitively described in Figure 10.

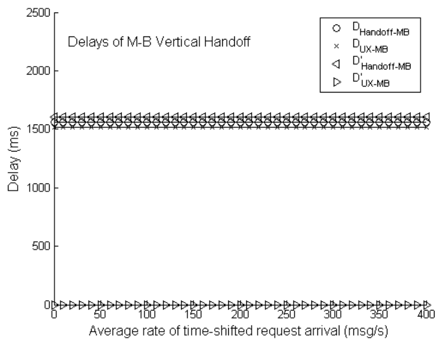

FIGURE 9 Delay comparison of B-M vertical handoff

As Figure 10 described, by using the improved M-B vertical handoff scheme, the delay user experienced is reduced to zero with a little increase of handoff delay. Therefore, the improved B-M vertical handoff scheme almost ensures the seamless experience in B-M handoff in the time-shifted service. In the improved M-B vertical handoff scheme, the MT should open two channels to receive the media data from both the mobile multimedia broadcasting network and the wireless mobile communication network. Therefore, a certain amount of power consumption is used to ensure the seamless experience in the improved B-M vertical handoff.

6 Conclusions

Application-layer mobility management is widely used because it is not concerned about the lower layer protocol. However, the multimedia applications are sensitive to the delay introduced by handoff. In this paper, we have tried to analysis the mobilities of time-shifted service in heterogeneous network and then proposed an improved handoff scheme including horizontal handoff and vertical handoff to reduce the delay user experienced. The simulation results show the performance of the improved handoff scheme is excellent which supports seamless experience in time-shifted service. In order to simplify the issue, we only take low-speed terminals into consideration in our work. The future research can focus on the mobile terminals with high speed.

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