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A Robust Mobile Video Streaming in Heterogeneous Emerging Wireless Systems

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Abstract

With the rapid development of heterogeneous emerging wireless technologies and numerous types of mobile devices, the need to support robust mobile video streaming based on the seamless handover in Future Internet is growing. To support the seamless handover, several IP-based mobility management protocols such as Mobile IPv6 (MIPv6), fast handover for the MIPv6 (FMIPv6), Hierarchical MIPv6 (HMIPv6) and Proxy Mobile IPv6 (PMIPv6) were developed. However, MIPv6 depreciates the Quality-of-Service (QoS) and FMIPv6 is not robust for the video services in heterogeneous emerging wireless networks when the Mobile Node (MN) may move to another visited network in contrast with its anticipation. In Future Internet, the possibility of mobile video service failure is more increased because mobile users consisting of multiple wireless network interfaces (WNICs) can frequently change the access networks according to their mobility in heterogeneous wireless access networks such as 3Generation (3G), Wireless Fidelity (Wi-Fi), Worldwide Interoperability for Microwave Access (WiMax) and Bluetooth co-existed. And in this environment, seamless mobility is coupled according to user preferences, enabling mobile users to be "Always Best Connected" (ABC) so that Quality of Experience is optimised and maintained. Even though HMIPv6 and PMIPv6 are proposed for the location management, handover latency enhancement, they still have limit of local mobility region. In this paper, we propose a robust mobile video streaming in Heterogeneous Emerging Wireless Systems. In the proposed scheme, the MN selects the best -according to an appropriate metric- wireless technology for a robust video streaming service among all wireless technologies by reducing the handover latency and initiation time when handover may fail. Through performance evaluation, we show that our scheme provides more robust mechanism than other schemes.

Keywords: robust video streaming, heterogeneous emerging wireless networks

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1. Introduction

In recent years, with the proliferation of wireless technologies and mobile electronics devices, there is a fast growing interest in Future Internet [1][2]. One of the main challenges in Future Internet is to support a robust video service such as Internet Protocol Television (IPTV), Voice over Internet Protocol (VoIP) [3] and video streaming [4][5] by supporting fast and seamless handover between heterogeneous wireless access networks. In this environment, seamless mobility is coupled according to user preferences, enabling mobile users to be “Always Best Connected” (ABC) so that Quality of Experience is optimised and maintained. Further the core network of the heterogeneous wireless access networks is evolving into all-IP based network. Accordingly, Mobile IPv6 (MIPv6) [6] has become a global mobility solution of Internet Engineering Task Force (IETF) that provides host mobility management. However, the long handover latency and packet loss problem in MIPv6 depreciates the Quality-of-Service (QoS) especially in mobile video service applications. To reduce the handover latency and solve the packet loss problem in the MIPv6, fast handover for the MIPv6 (FMIPv6) [7] is proposed in the IETF. FMIPv6 tries to reduce the address resolution time through the address pre-configuration. It reduces the packet loss and handover latency by providing fast IP connectivity as soon as a new link is established. However, FMIPv6 is not robust for mobile video streaming in Future Internet. Even though Hierarchical MIPv6 (HMIPv6) [8] and Proxy Mobile IPv6 (PMIPv6) [9] are proposed for the location management, handover latency enhancement, they still have limit of local mobility region. Therefore, we focus on FMIPv6 enhancement to cover Global Mobility as well as Local Mobility in Future Internet.

In FMIPv6, a Mobile Node (MN) is previously configured with only one new Care-of Addresses (CoA) before it is attached to the new link. This address pre-configuration is useless when the MN may move to another visited network in contrast with its anticipation or select the inappropriate wireless technology leading to fluctuating mobile video streaming quality due to lack of resources and unreliable wireless channel quality. In this case, FMIPv6 follows the handover procedure of MIPv6 so that the handover latency increases undesirably. Some work has already tried to improve MIPv6 and FMIPv6.

To achieve fast handover in IPv6 mobility, reference [10] proposed the L3-driven fast handover mechanism using the abstract link layer information and primitives. They are independent of the link layer (L2) protocols and devices [11]. Through the L2 primitives, the network layer (L3) can know a sign of the L2 handover and L3 can prepare for the L3 handover in advance. As a result, the total handover delay is dramatically reduced. L2 handover means that the MN switches AP (Access Point) from pAP (previous Access Point) to nAP (new Access Point) and L3 handover means that the MN switches AR (Access Router) from pAR (previous Access Router) to nAR (new Access Router). To present an enhanced handover mechanism, reference [12] also utilized the additional primitives and parameters by newly adding them to the media independent handover (MIH) services defined in the IEEE 802.21 [13]. It can reduce handover latency by removing the router discovery time and design the network cost-effectively by reducing coverage overlap between adjacent cells. To eliminate Duplicate Address Detection (DAD) delay, reference [14][15] proposed a fast handover mechanism using fast neighbor discovery and DAD for fast moving MNs. They modified Neighbor Cache with look up algorithm for a quicker DAD checking speed. Therefore it solves the shortcomings of conventional DAD when a router has more than two links. Optimistic DAD (oDAD) [16] eliminates DAD delay based on the premise that DAD is far more likely to succeed than fail. To do this, an optimistic MN modifies the standard IPv6 operation rules of [17] and [18] while keeping backward interoperability. However, although this optimistic approach reduces handover latency in non-collision case, if the address collision occurs, it can incur some penalty to both optimistic MN and rightful owner of the address. Therefore, oDAD cannot be the unique solution for the DAD problem. Furthermore, since it is a complete end-to-end approach, only MN can initiate the registration process with the new optimistic address [19]. To realize the fast vertical handover, reference [20] provides the virtual MAC address scheme. That is, to reduce the L3 handover, the virtual MAC address becomes a unique identifier for a MN within the Mobile Ethernet. However, this scheme has limits to implement and needs the additional layer in each MN. To support the seamless handover between the specific heterogeneous emerging wireless networks such as cellular and wireless local area networks [21] or IEEE 802.16e broadband wireless access system [22] or UMTS-WLAN [23] or WiBro System [24] or 802.11 [25], they provides details on the use of the framework or algorithms for the seamless handover. Reference [21] has introduced a framework that can be used for integrating cellular and WLANs. The main features of this framework are its hierarchical and distributed architecture, which provides scalable solution to seamlessly roam across a number of WLANs and cellular networks while supporting call continuity through predictive handoff, QoS mapping, intersystem message translation, and provision in the WLAN for user-subscribed services. Reference [22] presented fast handover algorithm for IEEE 802.16e. According to existing IEEE 802.16e standard, handover procedure consists of network topology acquisition, scanning, initial ranging, authorization, and registration. These procedure causes waste of channel resource. Therefore, they reduced the process of handover for fast and optimized handover. Reference [23] introduced a practical UMTS-WLAN interworking architecture based on 3GPP standards and proposed a seamless handoff method which guarantees low delay and low packet loss during UMTS-WLAN handoff. For low handoff delay, the proposed handoff scheme performs pre-registration and pre-authentication processes before L2 handover. Moreover, it uses packet buffering and forwarding functions in order to reduce packet loss during the handoff period. Reference [24] proposed an effective fast handover mechanism for IPv6 based WiBro system by employing the packet buffering and tunneling mechanism. As a result, it reduces the handover latency, packet loss and eliminates the out-of order problem by integrating L2 and L3 handovers efficiently. Reference [25] presents an effective and simple solution in IEEE 802.11 wireless LANs (WLANs) using IP tunneling mechanism. However, these handover schemes are only applied to the specific wireless networks and did not consider QoS applications such as the video streaming.

References [26, 27, 28] propose a seamless mobility management scheme for multi-homed mobile node in heterogeneous wireless network environment. But, they need the additional module to set up a new connection and an address server to select suitable CoA for the desired application. References [29][30][31][32] investigate the radio-resource management and network-selection schemes in heterogeneous wireless networks. However, they only assume the static position of MN and did not consider QoS applications. References [33][34][35][36] provide high quality video streaming with network coding capabilities over wireless networks considering both the erratic and time varying nature of a wireless channel and the stringent delivery requirements of media traffic. However, they also only consider the static position of MN in the specific homogeneous wireless networks. Reference [37] presents new video coding techniques in the recent MPEG SVC standard with network diversity to provide the adaptive and flexible media streaming. Reference [4] provides a video codec that exploits the unique properties of video as well as wireless channels to deliver graceful performance. Reference [5] adopts an integrated design for video and PHY layer coding, making the whole network stack act as a linear transform. However, they only focus on the PHY techniques such as video coding or codec and did not consider efficient and transparent handoff solutions in heterogeneous emerging wireless network. Consequently, to reconnect to the best new Access Point, MN should actively probe the network to discover alternatives like MIPv6. Such handoff delays may be penalizing for media streaming applications with strict timing constraints. Reference [38] proposed a distributed video scheduling scheme for providing a satisfying video streaming over multi-channel multi-radio networks. They have the goals of minimizing the video distortion and achieving certain fairness. Reference [39][40] presents a cross-layer scheduling for QoS Support in single-channel multi-hop wireless networks. To improve the video performance, they design the architecture where different layers exchange information each other. To improve the video sharing mechanism, reference [41][42][43][44] provides Digital Living Network Alliance (DLNA)-based Multimedia Sharing System for OSGI framework with Extension to P2P Network. It can overcome the restriction of previous multimedia sharing on intranet, integrate P2P network, and employ related mechanism to help adapting to dynamic change of network, while improving user service quality. But, they also did not consider robust handoff solutions in heterogeneous emerging wireless networks and propose the layer based simple approach..

We summarize our contributions and the differences between our work and previous related works in the following. All previous related works still do not satisfy the high quality mobile video streaming in heterogeneous wireless access networks and consider the handover delay under imperfect prediction of the MN, out-of sequence problem and appropriate metric for the selection of the wireless technology considering QoS resources availability at a new wireless technology. In Future Internet, heterogeneous emerging wireless technologies, numerous types of mobile devices and mobile video streaming will be more radiply developed. Cisco visual index, mobile video traffic will grow 66 fold over a period of five years [4][5][45]. And the possibility of mobile video oservice failure is more increased because MNs consisting of multiple wireless network interfaces (WNICs) can frequently change the access networks according to their mobility in heterogeneous wireless access networks such as 3Generation (3G), Wireless Fidelity (Wi-Fi), Worldwide Interoperability for Microwave Access (WiMax) and Bluetooth co-existed.

In this paper, we propose a robust mobile video streaming based on the seamless handover in heterogeneous emerging wireless systems of Future Internet. To the best of our knowledge, this work is the first one to deal with the robust mobile video streaming problem in heterogeneous emerging wireless networks. Unlike FMIPv6 that uses one tentative CoA at a MN handover, the proposed scheme exploits multiple tentative CoAs to prevent a fast handover from being failed in a new visited network for which there is no provisional CoA in case of FMIPv6. By making a fast handover possible in any situations, the scheme definitely reduces the handover latency in average and seervices the robust mobile video streaming. Furthermore, the proposed scheme minimizes the handover initiation time by proactively managing the tentative CoAs available among the neighboring access routers. In our scheme, each AR maintains a set of unused IP addresses in its access networks by periodically performing DAD. Each of neighboring ARs allocates a few of unused IP addresses to be used as tentative CoAs to the other AR, and notify its allocation to the other AR by sending Router Advertisement (RA). Thus, each AR collects a set of tentative CoAs to be temporarily used in other neighboring access networks. AR provides the tentative address list which contains tentative CoAs for each neighboring access network with the MN before handover. As a result, at handover the MN can use a tentative CoA to be instantly used without DAD in new visited network for fast IP connectivity. In addition, we define a metric that captures the contribution of each wireless technology to the mobile video streaming quality improvement taking into account the importance of video packets (in terms of video distortion and playout deadlines) and the load-balancing service with the resources.

Our main goal of the proposed scheme is indeed a mechanism that selects the best -according to an appropriate metric- wireless technology for a robust mobile video streaming service among all wireless technologies by definitely reducing the handover latency in average and analyzes the effect of perfect handover prediction and imperfect handover prediction in heterogeneous emerging wireless networks. Through performance evaluation, we show that our scheme provides a more robust mechanism than other schemes such as FMIPv6, HMIPv6 and PMIPv6 for mobile video streaming services. The rest of this paper is organized as follows. We start in Section 2 by giving the general system architecture for the proposed scheme. A robust mobile video streaming in heterogeneous emerging wireless systems is described in Section 3, 4. Section 5 presents the analysis and performance results. Finally, we conclude the paper in Section 6.

2. System Architecture

In Future Internet, generally several heterogeneous wireless networks are coexisted as shown in Fig. 1. The internet is a backbone connecting the home network and several heterogeneous visited networks such as 3G, Wi- Fi, WiMax and Bluetooth [3]. The home network is where a MN has its global IPv6 address (home address). IPv6 address is 128bist and it consists of the prefix of AR (64bits) and MAC address of MN (64bits). Home address is a unicast routable address assigned to the MN, used as the permanent address of the MN. Standard IP routing mechanisms will deliver packets destined for a MNs home address [6]. A domain of visited network is comprised of several ARs and wireless APs which a MN can make a connection with [19]. We assume that each AR has an interface which is connected with a distinct set of APs and the same network prefix cannot be assigned to the interface of a different AR. That is, ARs are distinguished with its own prefix each other. In general, a MN can send and receive packets to Home Agent (HA) or Correspondent Node (CN) with CoA. HA is a router in the MNs home network with which the MN has registered its CoA. While the MN is away from home network, HA intercepts packets destined to the MNs home address, encapsulates them, and tunnels them to the MNs registered CoA. The association between a MNs home address and CoA is known as a binding for the MN. While away from home network, a MN registers its new CoA with a home address. The MN performs this binding registration by sending a Binding Update message to the HA. The HA replies to the MN by returning a Binding Acknowledgement message. CN is a peer node with which a MN is communicating. The CN may be either mobile or stationary. CoA is a unicast routable address associated with a MN while visiting a new visited network. CoA is composed of the prefix of nAR in a new visited network and the MAC address of the MN. CoA is made after DAD. DAD corresponds to the most part of handover latency as it requires time in the order of seconds to detect whether the MNs new CoA is duplicated or not [16].

Fig. 1. Architecture with heterogeneous wireless access networks in Future Internet

Parallel to the advances of heterogeneous wireless technologies is the development of robust mobile video streaming paradigm [4][5]. Therefore, we consider mobile video streaming over several heterogeneous wireless networks where the MN are able to forward video packets to other the MNs, as shown in **Fig. 1**. Finally, we propose the appropriate selection metric of the wireless technology that can be used at the MN to maximize video quality and throughput for a robust mobile video streaming service among all heterogeneous wireless technologies. It can be possible due to the reduction of the handover latency and initiation time when handover may fail.

3. A Robust Mobile Video Streaming In Heterogeneous Wireless Systems

In this section, we detail the proposed scheme with the appropriate metric selection of the wireless technology and the temporal reuse of tentative CoAs for the robust mobile video streaming in heterogeneous emerging wireless networks, along with the architectural view depicted in Fig. 2. For the robust mobile video streaming, MN in the previous visited network selects the best -according to an appropriate metric- new visited network among all wireless technologies with the seamless handover with the tentative address management performed proactively by ARs. As the appropriate metric for the video quality of an encoded sequence, we use the average PSNR [51][59], i.e., the peak-signal-to-noise ratio based on the luminance (Y) component of video sequences, measured in dB, and averaged over the entire duration of the video sequence. And MN performs the handover procedure composed of the movement detection using L2 trigger, L3 handover through fast IP connectivity with tentative CoA, and binding updates.

3.1 A Metric Selection Of The Wireless Technology

In order to choose the best wireless technology, we first need to define a metric that captures the contribution of each wireless technology to mobile video quality improvement. Let $Q_{w_i}(c_j)$ be the improvement in mobile video quality at the MN (c_j), when the wireless technology w_i is selected:

$$Q_{w_i}(c_j) = \sum_{p=1}^{N} (1 - e_{p,w_i}) \cdot I_{p,w_i} \cdot R_{p,w_i} \quad (1)$$

where each factor in this formula is defined as follows:

- p mean the video packet and N is the total original video packets included in MN (c_j).

- $e_{p,\,wi}$ is the loss probability of packet p in the wireless technology w_i due to latency or channel errors. It is given by

$$e_{p,w_i} = \int_{\tau}^{\infty} f(t)dt + (1 - \int_{\tau}^{\infty} f(t)dt) \cdot f(s) \quad (2)$$

In equation (2), the first part describes the probability of a video packet arriving late; τ is the remaining time until the playout deadline and $f(t)$ is the distribution of the forward trip time. The second part describes the loss probability (of a packet that is still on time) due to effects of the wireless channel, such as noise, fading, interference, etc; $f(s)$ is the loss probability at state s of the channel.

- $I_{p,\,wi}$ is the improvement in mobile video quality, Peak Signal-to-Noise Ratio (PSNR) as a standard metric of video quality [51][59], if packet p is received correctly and on time at the wireless technology w_i. PSNR is calculated on the frame and most easily defined via the mean squared error (MSE) which for two $m \times n$ monochrome frames I and K where one of the frames is considered a noisy approximation of the other is defined as:

$$PSNR(dB) = 10 \cdot \log_{10}\left(\frac{MAX_I^2}{MSE}\right) = 10 \cdot \log_{10}\left(\frac{MAX_I^2}{\frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2}\right) \quad (3)$$

Here, MAX_I is the maximum possible pixel value of the frame.

To compute $I_{p,\,wi}$, we decode the entire video sequence with this packet missing and we compute the resulting distortion. We assume that this computation is performed at the MN (c_j) offline and that the distortion value is marked on each packet.

- $R_{p,\,wi}$ is indicator function that expresses whether it is possible for the wireless technology w_i to service mobile video packet p with the resources. The resources are the unused IP addresses that can be used as temporal CoA by a visiting MN (see Section 3.2). We define $R_{p,\,wi} = 1$ if mobile video packet p is serviced at the wireless technology w_i, or 0 otherwise.

Therefore, the proposed scheme chooses the wireless technology w_i that maximizes the total mobile video quality improvement among all wireless technologies: It is given by

$$\max_{w_i} Q_{w_i}(c_j) \quad (4)$$

3.2 Tentative Address Management (TAM)

As shown in **Fig. 2**, each AR such as nAR and pAR manages the tentative address pool containing the unused IP addresses that can be used as temporal CoA by a visiting MN. We denote those addresses to tentative CoAs. The AR makes sure that the tentative CoAs registered in the pool are currently not used by other MNs by performing DAD for each tentative address periodically. Basically let us assume that each AR maintains tentative CoAs as many as the number of neighbor ARs. A tentative CoA is deleted from the pool if it is proved as being used by another node through DAD. If the number of tentative CoAs is smaller than the number of neighbor ARs, then the router adds new tentative CoAs into the pool by searching available IP addresses. We assume that each router can periodically send and receive the modified Neighbor Router Advertisement (mNRA) including the non-overlapping several tentative CoAs to each other. As a result, each router can manage available tentative CoAs about the access networks of one-hop neighbor. In general, NRA contains router information [7]. We modified the reserved field in NRA to include the several tentative CoAs. As shown in **Fig. 2**, when pAR receives modified Router Solicitation for Proxy (mRtSolPr) from the MN, pAR informs modified Proxy Router Advertisement (mPrRtAdv) containing several tentative CoAs about neighboring access networks to the MN before it moves to one of visited networks. Then the MN sends Last Packet (LP) message to pAR for informing the handover of MN and moves to one of the new visited networks from the previous visited network. After the handover of MN, the corresponding tentative CoA of new visited network included in modified Fast Neighbor Advertisement (mFNA) message is used by the MN for fast IP connectivity. The fast IP connectivity enables the MN to perform binding update using the tentative CoA i.e. FBU1 and BAcK1. After the MN acquires its original CoA containing its own MAC address by performing DAD, it replaces the fast IP connectivity using tentative CoA to its normal IP connectivity using the original CoA (see Section 4.2 and 4.3). Recycling of tentative CoAs is possible because these tentative CoAs are temporally used by MNs to reduce handover delay until the MN completes binding updates using its new original CoA, i.e BU2 and BAcK2. We explain more details on Fig. 2, in particular, the functions of each part in Section 4.2 and 4.3.

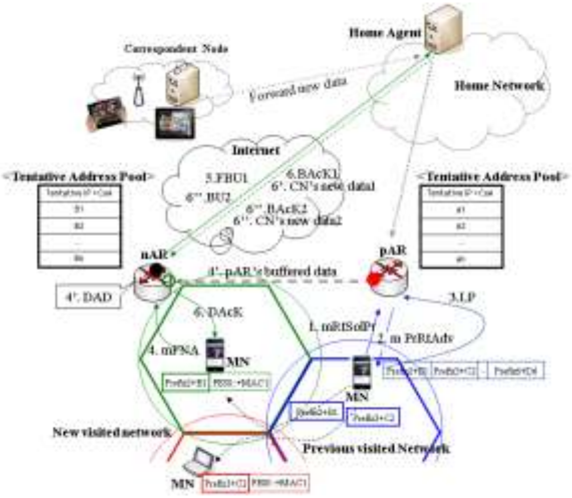


Fig. 2. Architectural view for a robust mobile video streaming based on seamless handover scheme with tentative CoAs in Future Internet

4. Handover Procedure

In general, a handover procedure can be divided into two components: a link layer handover (L2 handover) and a network layer handover (L3 handover). In the L2 handover, the link layer of the MN changes the access point (AP) to which it is connected. That is, the term L2 handover denotes its support for roaming at the link layer level and effects as the hint of the

MNs movement. The L2 handover precedes the L3 handover even though the L3 handover is independent of the L2 handover.

For independence between L2 handover and L3 handover, IEEE 802 has been developing standards to enable interoperable handover between heterogeneous networks [46][47][25]. In special, IEEE 802.21 specification defines Media Independent Handover (MIH) primitives to provide the link layer intelligence and other related network information to the upper layers to optimize handovers between heterogeneous media [13][26]. One of the primitive categories is event service. It is used for the hint of L3 handover. Events provide the condition of the L2 data links to the L3 layer or reflects the response of the L3 layer. The representative event primitives includes link going down, link down, link up, etc (see Section 4.1). L3 handover occurs when the network point-of-attachment of the MN changes after an inter-network movement (inter-network or intra-foreign-network movement) [28]. Inter-network or intra-foreign-network movement means the MN changes from oAR to nAR. When L3 handover happens, the MNs ongoing transmissions are disrupted and IP-connectivity via its home IP address and old CoAs is lost because the nAR can not recognize the MNs old CoAs. Therefore, to support the seamless handover, the L3 handover consists of the two phases. In the first phase, a new CoAs is generated and DAD is executed when a MN moves to the new visited network. In the second phase, the new CoA is registered with the HA through the binding update.

Fig. 3. shows the handover procedure of the proposed scheme for mobile video streaming in Heterogeneous Emerging Wireless Systems. For comparison, we annotate the differences in handover procedure between FMIPv6 and our scheme. 1) modified Router Solicitation for Proxy (mRtSolPr) : a MN initiates the handover procedure by sending mRtSolPr to pAR when link going down is triggered. mRtSolPr is used for the MN to inform pAR of MNs movement to one of new visited networks and ask the tentative address list containing the unused IP addresses that can be used as temporal CoA by a visiting MN. In FMIPv6, a MN initiates the handover procedure by sending RtSolPr to nAR. It is used for the MN to ask the nARs prefix which will be used to make a new original CoA. 2) modified Proxy Router Advertisement (mPrRtAdv) : when pAR receives mRtSolPr from the MN, it sends mPrRtAdv containing several tentative CoAs about one-hop neighbors to the MN. In FMIPv6, when pAR receives RtSolPr from a MN, it sends PrRtAdv containing the prefixx of nAR where a MN will handover. 3) Last Packet (LP) : The MN sends the LP message when the calculated RSSI of received beacon is less than the link going down and greater than the link down. It makes to pAR stop forwarding ongoing packets to the MN because the MN is about to handover. pAR receives the LP from the MN and checks the last packet in the red circle buffer of **Fig. 3.**

In FMIPv6, instead of the LP, the MN exchanges FBU and FBAcK with pAR involving in the signaling [7] with nAR to get the prefix information of nAR. After having sent FBU, pAR stops forwarding packets to the MN. This causes a long packet delay and handover delay because the MN can not receive the packets after FBU. 4) modified Fast Neighbor Advertisement (mFNA) : the MN sends mFNA including a tentative CoA for fast IP connectivity and the unique MAC address of the MN for making its original CoA to nAR as soon as it handovers. As a result, nAR simultaneously performs DAD of the original CoA of the MN while forwarding the buffered packets to the MN using the tentative CoA. Although the MN moves to the other place in contrast with the anticipation, the MN can send new mFNA without the additional DAD by choosing a corresponding tentative CoA in the tentative address list. In FMIPv6, the MN sends FNA including the CoA made at handover initiation between pAR and nAR in advance. In that case, if MN moves into the other place to which the CoA is not applicable (i.e., MN cannot use the CoA directly), the fast IP connectivity becomes impossible so that MN has to make a new CoA for the visited network as in MIPv6. 5) Binding Update (BU) : nAR performs FBU1 for a tentative CoA in a new visited network before BU2. Because BU2 is possible after the MN makes the original CoA including its own MAC address through DAD. After FBU1, the packets directed from HA or CN may be delivered earlier than the buffered packets from pAR. This may cause an out-of sequence problem. To solve this problem, each router uses the separate two bu_ers. One is for the packets relayed from pAR during the MNs handover and the other is for the packets forwarded directly from HA or CN, the two bu_ering points are depicted as the red and black circles in **Fig. 3**. In FMIPv6, nAR performs one binding update with new CoA if the handover succeeds. However, it does not take care of the out-of sequence problem. 6) DAD Acknowledgement (DAcK) : DAcK is a signaling message newly introduced in the proposed scheme. The MN gets its original CoA through DAcK after DAD of nAR, it also continues to perform normal binding update, BU2, while communicating with CN via the tentative CoA.

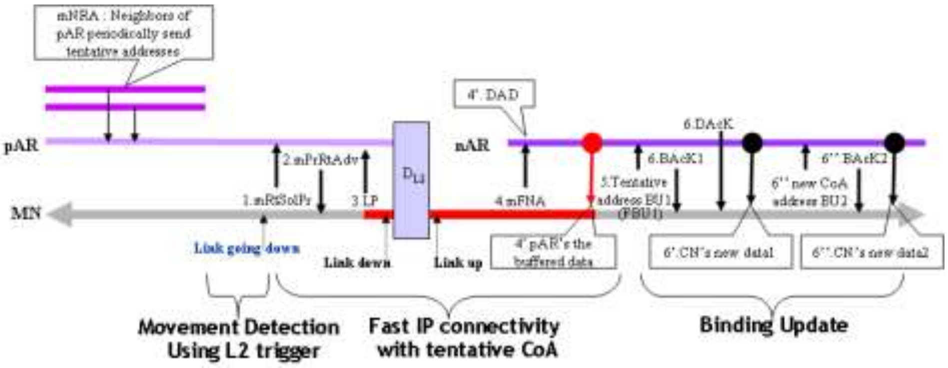


Fig. 3. A Robust Seamless Handover scheme for mobile video streaming in Heterogeneous Emerging Wireless Systems

4.1 Movement Detection using L2 trigger

The primary aim of movement detection is for the MN to prepare L3 handover. Our scheme uses the L2 triggers as used in FMIPv6 to trigger L3 handover initiation in advance [12][13][48][49]. As stated above, L2 handover means that the MN switches the AP from pAP to nAP. For exmaple, when L2 of the MN senses the weakening of the signal strength from pAP, it recognizes its mobility from pAP to nAP. And it informs its mobility of L3 of the MN through L2 triggers. As a result, the MN prepares L3 handover which means that the MN switches the AR from pAR to nAR. We consider three kinds of L2 triggers. These are link going down, link down and link up. Link going down means that a link down event will be occurred in the near future, so L3 of the MN must initiate the handover procedure. Link down indicates that the link of pAP cannot be used for data transmission any more. Link up is provided to L3 of the MN when a new link of nAP is connected. Each L2 triggers are occurred when the calculated RSSI (Receive Signal Strength Indicator) of received beacon is smaller than the predefined RSSI threshold [56].

4.2 Fast IP Connectivity with Tentative CoA

Handover latency means an elapsed time period from the time instant a MN receives the last packet from its pAR until the time instant the MN receives the first packet from its nAR. To compare the handover latency in handover schemes, we illustrate the overall handover procedures of MIPv6, FMIPv6 and our proposed scheme in **Fig. 4.** As represented by the red bold lines in **Fig. 4**, the handover latency of our proposed scheme is shorter than that in other schemes because managing tentative CoAs allow the MN to receive packets as soon as it handovers to a new access network. In case of using a tentative CoA, DAD of the original CoA is independently progressed while maintaining the fast IP connectivity to which the tentative CoA is applied. Thus, it does not affect the handover latency. Comparing with MIPv6, the handover latency of our proposed scheme can be reduced at least 1sec of DAD. In addition, the proposed scheme reduces packet latency because the MN can receive the packet from pAR until the MN sends the LP message to pAR. In FMIPv6, the MN is pre-configured with one corresponding CoA at handover initiation before it is attached to a new access network. If the MN moves to another access network for which the MN does not have a preconfigured CoA, the fast IP connectivity fails because the acquired CoA is useless in the access network. Thus, in the unexpected case, the handover latency of FMIPv6 may become longer than even MIPv6. In contrast, our proposed scheme using tentative CoA is very robust because it can still provide the fast IP connectivity by choosing one of tentative CoAs dedicated to the visited network. In Section 5, we detail on the effect of imperfect handover prediction of FMIPv6.

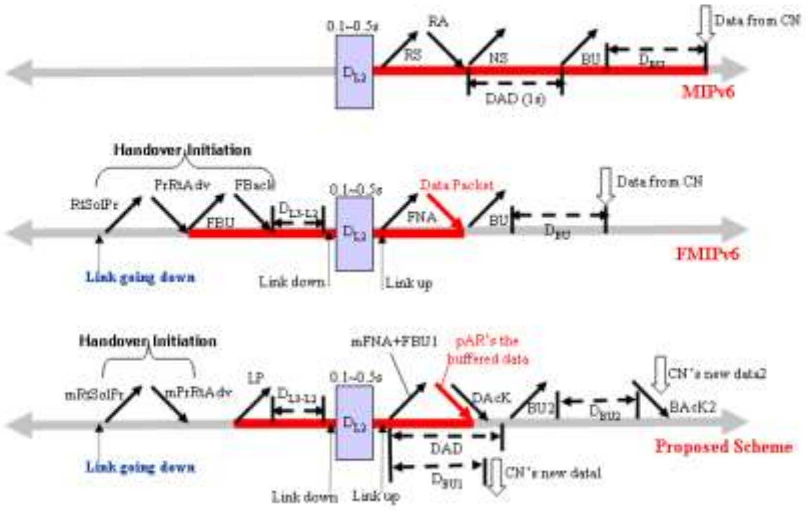


Fig. 4. Handover procedure of MIPv6, FMIPv6, Proposed Scheme

4.3 Binding Updates

In MIPv6, CN communicates with the MN using global IP of the MN via HA before direct binding update between MN and CN. And HA maintains the binding cache composed of CoA of MN and global IP of the MN. Therefore, the MN should inform a new CoA to HA when the MN moves to a new visited network. After binding updates, CN and HA can send packets to the MN. In our scheme, two binding updates occur. One is a binding update with the tentative CoA and the other is that with the original CoA composed of the prefix of router and the unique MAC address of the MN. In this case, as simultaneously progressed while maintaining the fast IP connectivity using tentative CoA, the second binding update with the original CoA does not affect the handover latency in **Fig. 3.**

5. Performance Evaluation

To evaluate the performance of the mobile video streaming with other schemes and our proposed scheme, NS-3 simulation was performed with various parameters as shown **Table. 1** such as coverage of AR, beacon interval, traffic type, link delay and so on. And **Fig. 5** shows a network topology used in our simulation. In this simulation topology, we use several entities, including HA, CN, AR, and MN. Link delay is assigned to 5ms for MN-AR links and AR-Router links, 10ms for Router- CN/HA links and AR-AR links. Link delay contains propagation delay, processing delay and queuing delay. The velocity in which MN is moving across the network is 2 m/sec. We use 2 Mbps standard video traffic such as Carphone, Foreman, and Mother & Daughter **[60]** that constantly are sent from CN to MN. As performance measures for the proposed scheme and other schemes, we use the average PSNR for the video quality of an encoded sequence and the handover delay.

Table 1. Simulation Properties

Parameter	Value
Coverage of AR	120m
Beacon interval	0.1s
Traffic type	2Mbps video traffic
Link delay (MN-AR links and AR-Router links)	5ms
Link delay (Router-CN/HA links and AR-AR links)	10ms
Velocity	2m/sec
Channel model	Rayleigh fading
Simulation time	180s
Video sequenc	Carphone, Foreman, Mother & Daughter

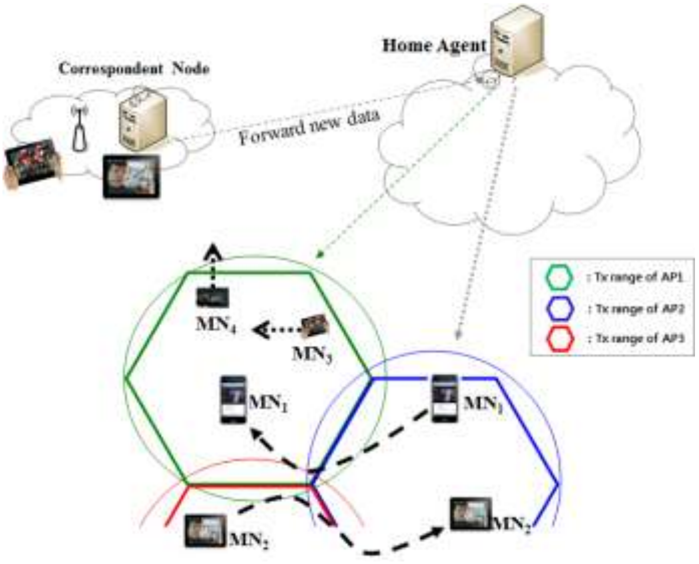


Fig. 5. Simulation Network Topology

5.1 Handover Delay Under Perfect Prediction

Fig. 6 shows video streaming delay based on handover schemes such as MIPv6, FMIPv6, PMIPv6, HMIPv6 and the proposed scheme when the MNs move according to Fig. 6. Video delay shows better performance according to the order of our proposed scheme, PMIPv6, FMIPv6, HMIPv6 and MIPv6. Comparing to PMIPv6, FMIPv6 and other schemes, video streaming delay of the proposed scheme is prominently reduced and that is improved than the previous work [58]. The reason is directly from that the MN can receive the video packets from pAR until the MN sends LP (Last Packet) to pAR and also can receive video packets as soon as moving to new visited networks by using tentative CoAs based on the appropriate selection metric of the wireless technology. However, Hierarchical MIPv6 (HMIPv6) [8] and Proxy Mobile IPv6 (PMIPv6) [9] are proposed for the handover latency enhancement in the local mobility region. Therefore, we focus on FMIPv6 enhancement to cover Global Mobility as well as Local Mobility in the proposed scheme.

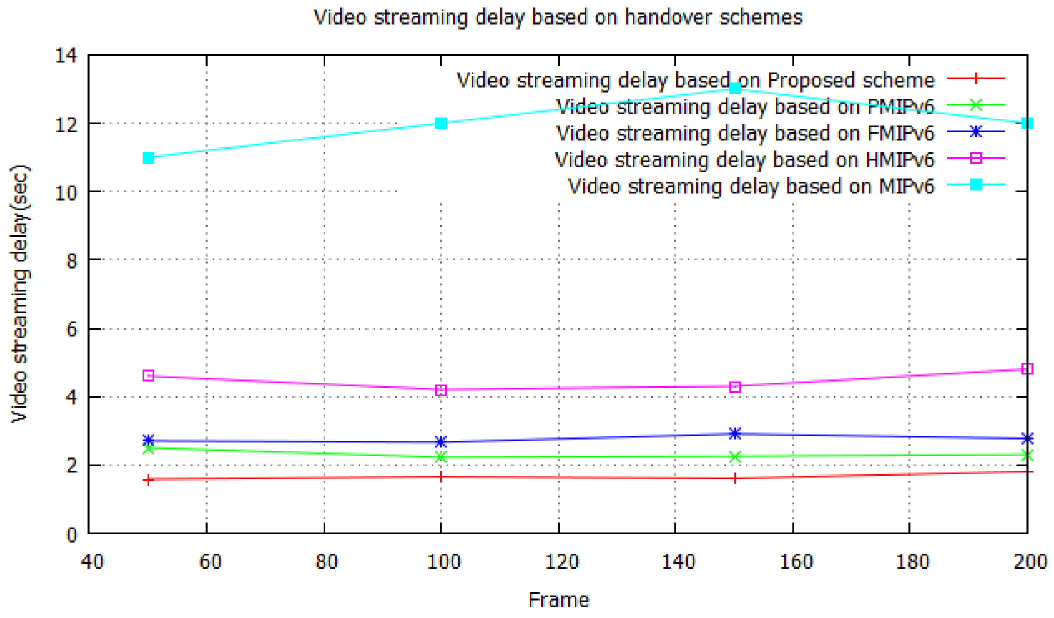


Fig. 6. Video streaming delay based on handover schemes

5.2 Handover Delay under Imperfect Prediction

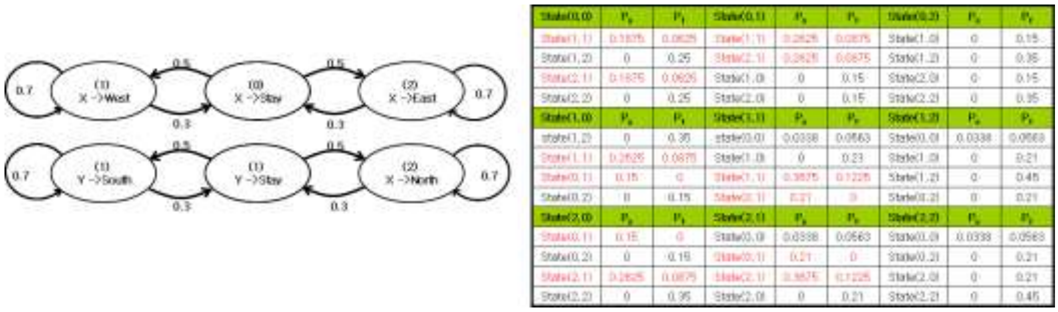
To compare our proposed scheme with FMIPv6 in the existence of imperfect handover prediction, we utilize several mobility models such as Random Walk Model, City Section Model and Linear Walk Model [57]. First of all, we analyze and simulate FMIPv6 and our scheme by using Random Walk Model. It is useful to understand mobility patterns according to direction and speed.

Fig. 7(a) shows that Random Walk Model has total 9 states with the combination of each x and y states and each state means the direction (i.e. north, south, east, west, north-east, north-west, south-east, south-west and stay) and speed. The numeric number of the arrow means the transition probability. Each state changes to the next state according to the transition probability. In this paper, we only consider the direction of MN to simplify the analysis.

We randomly locate the MN in a part of the overlapping area shadowed with black triangle as shown in **Fig. 8(a)**. This area is common part out of link going down range of each visited networks. The MN randomly chooses one of initial 9 States with the same probability. And then changes to one of 4 next states as in **Fig. 8(b).** We assume that Area A is pAR of the MN and the MN predicts to move to Area C at once. In this case, let us say that the handover succeeds as the MN really handovers to Area C and otherwise it fails. We first analyze the handover success probability (P_s) and the handover failure probability (P_f) according to the MNs initial state based on the transition probability as shown in **Fig. 7(a).** And then we simulate the random walk procedure with sample size 10000 to verify the result of analysis. **Fig. 7(b)** shows the analysis result of P_s and P_f . P_s can be calculated when the MN moves to one of the following states: State(1,1), State(0,1) and State(2,1) in Area C. P_f can be calculated when the MN handovers to other areas except Area C.

Fig. 9 shows the video streaming delay of FMIPv6 and our proposed scheme according to the initial state. Initial states are possible locations where the MN can be located. As expected, our scheme provides shorter delay than FMIPv6 because it is more robust in case of handover failure situations in dynamic mobility environment.

Fig. 10 shows the proposed scheme achieves higher PSNR than the other schemes with mobile node position. In other words, when the transmitted flows are the mobile video streams, the proposed scheme selects the proper wireless network having temporal CoAs to maximize not only the network throughput but also the video quality.



State(0,0)	**P_s**	**P_f**	**State(0,1)**	**P_s**	**P_f**	**State(0,2)**	**P_s**	**P_f**
State(1,1)	0.1875	0.0625	State(1,1)	0.2625	0.0875	State(1,0)	0	0.15
State(1,2)	0	0.25	State(2,1)	0.2625	0.0875	State(1,2)	0	0.35
State(2,1)	0.1875	0.0625	State(1,0)	0	0.15	State(2,0)	0	0.15
State(2,2)	0	0.25	State(2,0)	0	0.15	State(2,2)	0	0.35
State(1,0)	**P_s**	**P_f**	**State(1,1)**	**P_s**	**P_f**	**State(1,2)**	**P_s**	**P_f**
state(1,2)	0	0.35	state(0,0)	0.0338	0.0563	State(0,0)	0.0338	0.0563
State(1,1)	0.2625	0.0875	State(1,0)	0	0.23	State(1,0)	0	0.21
State(0,1)	0.15	0	State(1,1)	0.3675	0.1225	State(1,2)	0	0.45
State(0,2)	0	0.15	State(2,1)	0.21	0	State(0,2)	0	0.21
State(2,0)	**P_s**	**P_f**	**State(2,1)**	**P_s**	**P_f**	**State(2,2)**	**P_s**	**P_f**
State(0,1)	0.15	0	State(0,0)	0.0338	0.0563	State(0,0)	0.0338	0.0563
State(0,2)	0	0.15	State(0,1)	0.21	0	State(0,2)	0	0.21
State(2,1)	0.2625	0.0875	State(2,1)	0.3675	0.1225	State(2,0)	0	0.21
State(2,2)	0	0.35	State(2,0)	0	0.21	State(2,2)	0	0.45

Fig. 7. In Random Walk Model, (a) Flow chart of the probabilistic version of Random Walk Model, (b) Prob. of P_s and P_f according to the MNs initial state

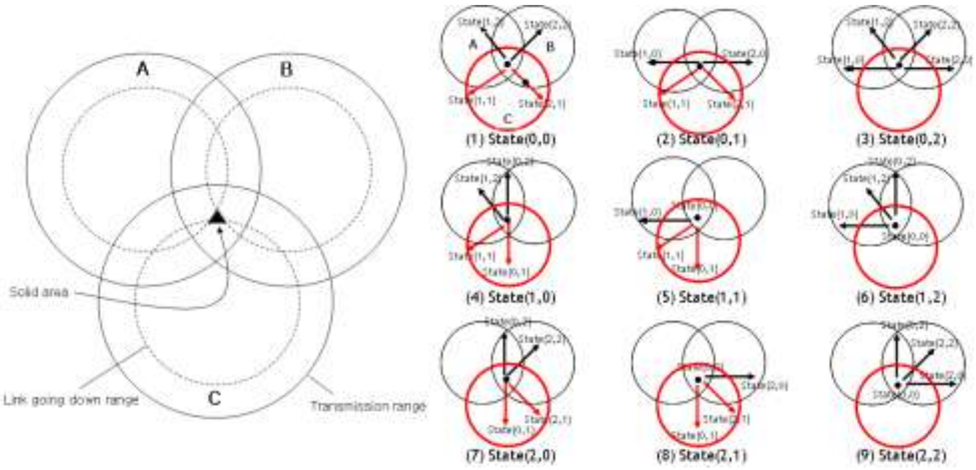


Fig. 8. In Random Walk Model, (a)MNs initial location within solid area, (b)MNs 4 next State according to MNs each initial State

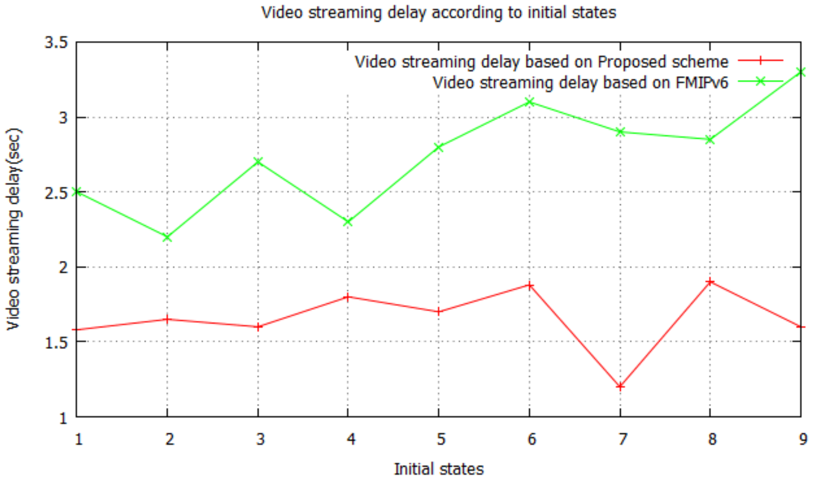


Fig. 9. In Random Walk Model, video streaming delay according to initial States of FMIPv6 and our proposed scheme

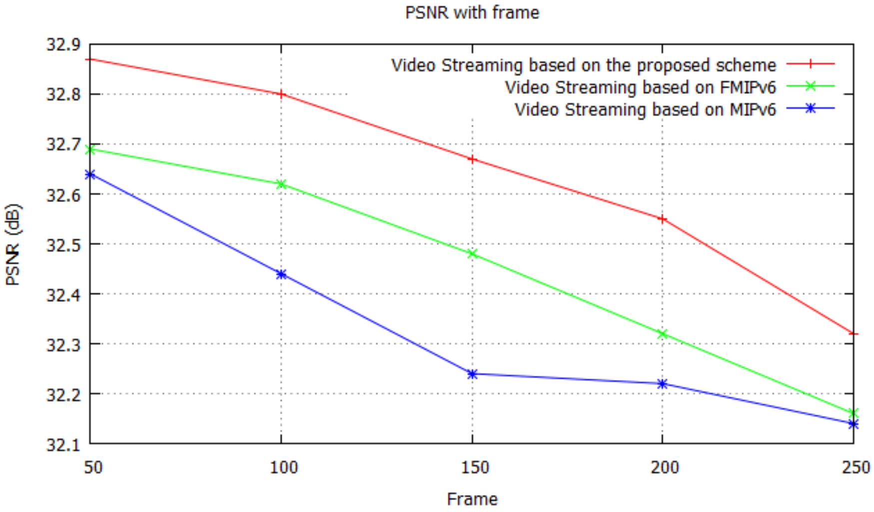


Fig. 10. Peak Signal-to-Noise Ratio (PSNR) with Frame

Conclusion

With the remarkable development of wireless technologies and the mobile video streaming, the need to support the robust mobile video streaming service based on the seamless handover in heterogeneous wireless networks is growing. To support the seamless handover, several handover schemes such as MIPv6, PMIPv6, FMIPv6 and HMIPv6 protocols [54][55] were developed. However, these schemes especially do not satisfy the Quality-of-Service (QoS) in the mobile video streaming applications because of the long handover latency and packet loss problem and handover failure and out-of sequence problem. In Future Internet, the possibility of service failure is more increased because mobile users can frequently change the access networks according to their mobility in heterogeneous wireless access networks such as 3G, Wi-Fi, WiMax and Bluetooth co-existed. Therefore, we consider the robust mobile video streaming over several heterogeneous wireless networks where the MN is able to forward the mobile video packets to other the MNs. Finally, we propose the appropriate selection metric of the wireless technology that can be used at the MN to maximize video quality and throughput for the robust mobile video streaming service among all wireless technologies. To do that, we consider the reduction of the handover latency and initiation time when handover may fail through the temporal reuse of tentative CoA that does not require DAD. Finally, the proposed scheme provides a robust seamless handover scheme with tentative CoA for the mobile video services in heterogeneous emerging wireless networks. Through performance evaluation based on Random Walk, City Section and Linear Mobility Models, we show that our proposed scheme is more robust mechanism than other scheme such as FMIPv6 for the mobile video streaming in Future Internet.

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