

The Adaptive Seamless Service Mechanism Design for Scalable Video Coding Extension of H.264/AVC Video Stream over IEEE 802.16e Network

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Abstract—To provide the mobility for mobile stations, handover is a critical issue to be assessed. Many studies about handover addressed the various fast handover schemes for seamless handover. However, shortening the handover latency is not the only and the best cure to apply to all kinds of applications, especially for store-forward video streams and non-interactive live video streams. In this paper, a seamless service handover concept and a mechanism are proposed. The proposed solution approaches the actually best solution to the seamless service for transporting the store-forward and non-interactive live Scalable Video Coding streams over the IEEE 802.16e mobile WiMAX network. The simulation results show that the seamless service strategy and mechanism indeed improve the continuity of the SVC video streaming service when the mobile station moving between two mobile WiMAX base stations and suffering the inevitable handover.

I. INTRODUCTION

In recent years, broadband wireless access networks have gotten significant attention. For popularity, broadband wireless access technologies, such as IEEE 802.16e and 3GPP, provide mobility for mobile stations to facilitate ubiquitous mobile computing. Mobility, however, comes with the critical handover issue to be assessed.

Handover is an unavoidable process, which a mobile station switches communication connections from one base station to another while going across two distinct base stations. There are two types of handover, hard handover and soft handover. Hard handover is featured as break-before-make while soft handover is featured as make-before-break [1]. Because of its feature, hard handover causes the roaming mobile station losing communication service from both of the serving and target base stations at the same time. It prevents the mobile station, however, from persisting in the ongoing application services. Unfortunately, in IEEE 802.16e standard [2], hard handover is mandatory.

Because none of the base stations can provide service for a mobile station, the interruption of application services suffered during hard handover process mainly comes from the absence of consuming data for the application services. To recover application services from the unavoidable interruption within a tolerable short time period, many previous

studies propose a variety of strategies to shorten the handover process. Almost all of these proposed strategies, however, focus on either elevating the authentication, association and etc. processes for obtaining the communication service from the target base station, or improving the IP address updating and binding procedures for mobility management to re-route the consuming data fast, such as fast handover scheme for real-time application [3], cross-layer fast handover scheme [4], network assisted fast handover scheme [5], and etc.. In summary, speeding up the handover process to perform the seamless handover seems the only cure when inspecting the service interruption problem.

Nevertheless, from the mobile user's point of view, seamless handover is not equal to seamless service at all. Just speeding up the handover is not enough, especially for real-time applications, such as video streaming services. Besides, speeding up the handover process is indeed not the only cure to the service interruption. For non-interactive live video streams and store-forward video streams, it is possible for a mobile station to fill up with video data in its own playback buffer. Once the video data possessed is enough to keep playback through the entire handover latency, the service interruption due to handover can be overcome.

Buffer filling must be efficient so that the extended playback time can go through the entire handover latency without overflow the video buffer. To reach the goal, the Scalable Video Coding extension of the H.264/AVC Standard [6][7] is involved to encode video streams transmitted over wireless access networks. The Scalable Video Coding (SVC) provides temporal, spatial, and quality scalability to dynamically adjust the playback bit rate of the video stream according to the channel condition and the capacity of the corresponding mobile station. Upon the QoS supporting in IEEE 802.16e network, with precise resource preservation, the SVC coded video stream can be played with video quality as high as possible under each specific circumstance. By applying the scalability of SVC, an adaptive buffer filling strategy and the corresponding mechanism over IEEE 802.16e network is proposed in this paper. The proposed strategy stands at the side against the methods that making the best efforts

to shorten the handover procedure do. Combining both the proposed strategy and the other handover-shortening method, for real-time store-forward video streaming services and non-interactive live video streaming services, the goal of seamless service is easy to achieve.

II. THE STRATEGY FOR SEAMLESS SVC VIDEO SERVICE

While evaluating hard handover, the application-service interruption is mainly coming from the absence of consuming data for the serving applications. The data absence is due to the mobile station losing radio communication connections from the corresponding base stations during hard handover. In addition, after handover to a distinct network domain, the varying in IP address of the mobile station procrastinates the data retrieve. IP address variance collapses the continuity of the application services further. Most of the studies discussing about handover focused on shortening the handover latency to recover the interrupted application services in a fast manner. If thinking carefully, however, the fact of losing radio communication connection service and varying the IP address means that no any data can be exchanged whenever hard handover is progressing. Because there is no any more data to support data consumption of the application service, the service interruption occurs. In other words, if standing at the opposite side of the problem to inspect the entire situation, while the consuming data stored in the mobile station itself can support the data consumption during handover, the application service can never suffer any interruption. That is, at certain level, to provide seamless service, filling up the buffer of the handover mobile station to extend the service time may be more effective than shortening the handover latency.

In fact, shortening the handover latency still causes a service gap if there is no any data to support the data consumption of the application service, regardless the service gap is tolerable or not. On the other hand, filling up the buffer with the consuming data to keep the service go through entire handover process indeed achieves the seamless service. So, in summary, the seamless handover is not equal to seamless service at all, and only combining both of the fast handover procedure and the buffer filling up strategy can really provide seamless service to mobile stations.

On the other hand, with traditional video service, a user has to download entire video files to local terminal devices, usually a personal computer or a notebook, before playback. Nowadays, the video streaming method is applied to replay the downloading video content. Downloading and replaying the video content at the same time is an efficient approach. A user can watch the video content without waiting for a long file-download time, and further, without taking the risk of uninterested download. In other words, with video streaming technique, a user can watch the selected video content within few seconds or less, right after the “play” button is triggered. Besides, the user can recognize the interest in the video content without wasting the entire download time. To reduce the reaction latency, the video streaming services adopt the method that a video server injects a bit of video frames,

maybe with the amount for few seconds playback or less, and then the user station starts to replay the video while the downloading process is still progressing. The reaction latency is time duration from the “play” button is triggered until the first qualified video image can be displayed. Longer the reaction latency is, higher the possibility the playback procedure keeps smooth.

Not all of the video types are suitable for buffer-injection. For a non-interactive live video stream and a store-forward video stream, such as a live soccer game broadcasting stream and a video-on-demand stream, respectively, it is possible to inject a bit of video frames into the video buffer of a user terminal station before the playback actually starts. However, for an interactive live video stream, such as video meeting, none of the video frames is available to inject the video buffer prior to playback. To keep lively interaction, the interactive live video streaming application needs to send the video frames within a more critical delay bound than a non-interactive live video stream and a store-forward video stream. If the interactive video frames are injected into the video buffer for few seconds prior to playback, the users can be conscious of video lag throughout the entire playback process. In summary, the interactive live video stream is not suitable for pre-buffered. Instead of the interactive video stream, the proposed buffer-filling approach can be applied to both of the non-interactive video stream and the store-forward video stream to prevent the service from interruption during handover.

A. The proposed strategy for seamless SVC video services

To achieve the goal of seamless service, the buffer in the handover mobile station has to be filled up with data. This is a scenario especially meaningful for SVC video streaming services. The SVC is a coding technology with temporal, spatial, and quality scalability. An SVC coded video stream is composed of one base layer and one or more corresponding enhancement layers. With the base layer video data only, the playback video keeps the basic video quality, and based on the base layer, with each one more corresponding enhancement layer, the playback video quality upgrades. According to the channel condition, an SVC video stream can be transmitted and replayed with appropriate video quality by means of the distinct combinations of the three kinds of scalability, and so that the corresponding base layer and adequate enhancement layers.

The main idea of the seamless service is filling up the video playback buffer of the handover mobile station to extend the playback time, and lets the extend playback time can exceed the entire handover latency. To satisfy with the main idea of the seamless service, with the scalable feature of the SVC, the proposed strategy is as follows.

- 1) Under the specific channel condition, video data must be transmitted as much as possible to extend the playback time.
- 2) If the buffer space is critical, at least base layer video data has to be transmitted as much as possible to extend

the playback time and save the buffer space at the same time.

- 3) If the traffic load of the network is slight and the space of the video buffer in the mobile station is enough, video data of the base layer and the enhancement layers can be filled into the buffer as much as possible for degrade the video quality gradually or even keep the same video quality.

The proposed strategy is applied to the preparation period before handover. That is, to provide the seamless service during handover, the handover preparation procedure has to be done.

B. The proposed seamless service mechanism for SVC stream over mobile WiMAX network

On the mobile WiMAX network, there are five QoS categories designed to classify and serve each of the packets flowing on the internet. The complete QoS classification enables the comprehensive treatment to each of the different packets exchanging among the serving base stations and the corresponding served mobile stations. Especially for real-time services such as video streaming services, deploying the QoS mechanism of the mobile WiMAX network enables good quality of service to be guaranteed. The figure 1 [8] summarizes the QoS mechanism deployed on the mobile WiMAX network. According to the Service Flow Identification (SFID) and the Connection Identification (CID), the Base Station (BS) distinguishes and distributes each packet to accurate QoS queues. The packets from video streaming services then are classified belonging to the real-time polling service (rt-PS) category.

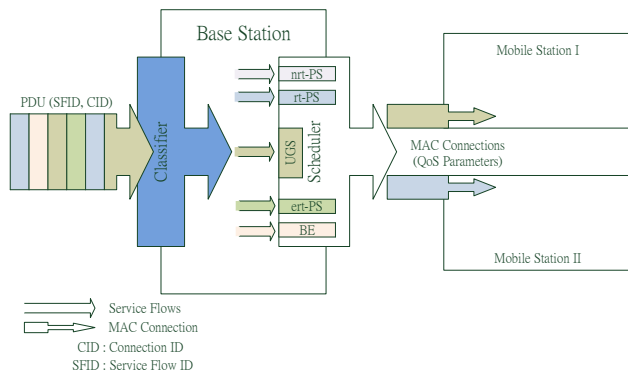


Fig. 1. The QoS Mechanism Deployed on Mobile WiMAX Networks

An SVC encoded stream is composed of one base layer and one or more corresponding enhancement layers with different importance of decoding dependency. To provide the seamless service to an SVC video stream, the importance differentiation among all the layers of an SVC stream must be taken into account. In this paper, the proposed seamless service mechanism deploys a cross-multi-layer QoS mapping strategy to mark each packet belonging to an SVC stream. The QoS mapping strategy assigns the video data of the layers of

an SVC stream into two QoS sub-categories which are both belonging to rt-PS category on the mobile WiMAX network. The sub-categories of the rt-PS category possess different QoS parameter sets indicating the different treatments between the two corresponding types of packets. By the feature of the SVC, a single SVC stream can be split into several sub-streams according to their attributes and importance, and then feed to the proposed seamless service mechanism to obtain the seamless service during hard handover.

The proposed seamless service mechanism is deployed to the serving BS to support the handover preparation. The serving BS executes the handover preparation procedure for a mobile station with handover tendency. To provide the seamless service handover, the serving BS must transmit video data that can efficiently extend the playback time as long as possible. When achieving the target of extending the playback time to exceed the entire handover latency, the video quality is considered to keep as high as possible. For an SVC encoded video stream, the temporal scalability influences the playback fluency. That is, to extend the playback time and keep the playback fluency at the same time, at least the base layer that keeps the frame rate in playback must be transmitted at the duration of the handover preparation procedure. Besides, if the serving BS is at its slight loading condition and the residual space of the video playback buffer at the mobile station is enough to store more video data than just that of the base layer, the video data belonging to enhancement layers shall be transmitted as much as possible to obtain the playback video quality as high as possible. In other words, the seamless service mechanism proposed here gets a high probability of keeping the video playback with both of the smoothness and the quality at the same time.

Figure 2 shows the video data transmission before the handover procedure is executed. In the figure, the directions of arrows denote the transmission directions of the SVC encoded video stream, and each of the small arrows denotes the base layer and enhancement layers of the SVC video stream respectively. In addition, it means that the SVC video stream consists of one base layer (arrows fully painted in blue) and two enhancement layers (arrows painted in blue slash and blank ones). Before the handover preparation procedure is executed, all the base layer and enhancement layers are transmitted to the mobile station to keep a certain quality level in the playback video.

On the other hand, figure 3 shows the condition that a mobile station is in its handover preparation state. From the figure, it shows that the mobile station is filling up with the base layer video data (the arrow fully painted in blue with larger width) as much as possible, and if the transmission bandwidth is sufficient, and the residual buffer space is enough as well, the enhancement layer video data shall be transmitted with less priority than that of the base layer. After the handover preparation procedure, such as showing in the playback buffer in figure 3, the playback buffer is expected to fill up with enough base layer video data and maybe some but less (or even sufficient) enhancement layer video data to extend the

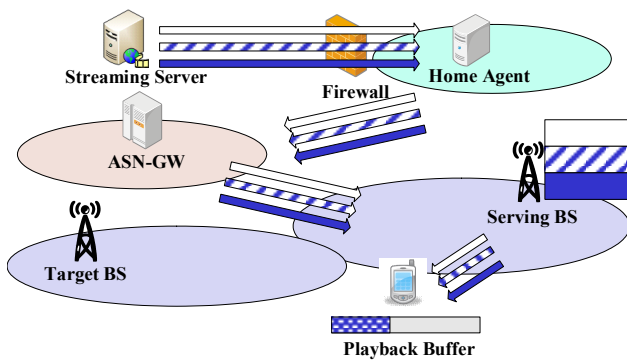


Fig. 2. The video data transmission before handover preparation procedure is executed

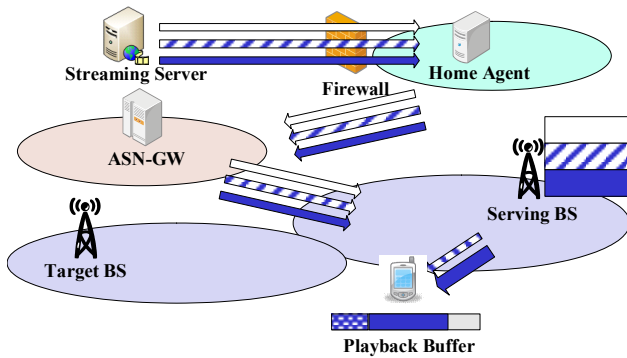


Fig. 3. The video data transmission during the handover preparation procedure

playback time to exceed the entire handover latency. Thus, the seamless service handover can be obtained.

III. SIMULATION AND RESULT ANALYSIS

To verify the benefits coming from the proposed handover preparation procedure and the corresponding mechanism, the simulation is built on the NS-2 [9] simulator.

In the simulation scheme, Mobile IP is deployed for the session continuity of IP layer when handover. Figure 4 shows the topology applied to the simulation. Because the required transmission bandwidth goes un-increased during the handover preparation procedure, so that the entire traffic burden of the wireless access network is not impacted, only one mobile station is deployed to the simulation to evaluate the feasibility of the proposed mechanism. Table I summarizes the attributes of the SVC encoded video stream involved in the simulation, and Table II shows the statistics information of the encoded SVC video stream in layered fashion. The layered statistics information is generated by a software tool, BitStream Extractor, included in the JSVM [10] reference software which is published by the Joint Video Team (JVT) of the ISO/IEC Moving Pictures Experts Group (MPEG) and the ITU-T Video Coding Experts Group (VCEG). It is noticeable that the values aligned in the “Bit Rate” column in Table II are in measures of kilo-bit per second (kbps).

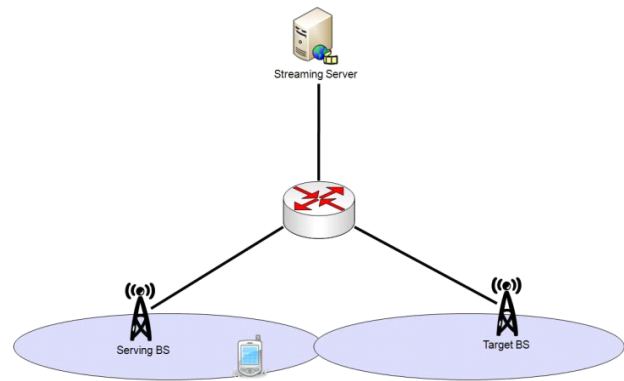


Fig. 4. The network topology applied in the simulation

TABLE I
ATTRIBUTES OF THE ENCODED SVC VIDEO STREAM

Item	Parameter
Source Video Name	Soccer
Resolution	CIF
Video Length	300 Frames
GOP Size	4
Encoding Pattern	IBBBIBBB...

In the simulation, the mobile station is receiving the video streaming service coming from the serving BS at the beginning with the average video transmission rate in 3337.00 kbps, and keeps moving with the direction toward the target BS. While the mobile station goes far away from the serving BS and gets significant collapse in radio strength until the handover preparation threshold is hit, the handover preparation procedure starts. Indeed, the packets carrying the specific SVC stream data can be divided into two sub-categories, “extendable” and “un-extendable”, respectively, for rt-PS service type. The “extendable” sub-category contains the packets that the video data carried on is meaningful to extend the playback time, and with more importance on decoding dependency than that belonging to another sub-category. The two sub-categories of packets are stored in two distinct queues, accordingly. Before the handover preparation threshold is hit, the packets stored in the two corresponding diverse queues are transmitted in

TABLE II
BIT RATE STATISTICS OF THE SVC ENCODED VIDEO STREAM

Layer	Resolution	Frame Rate	Bit Rate(kbps)	DTQ
0	352×288	7.50	371.70	(0,0,0)
1	352×288	15.00	477.20	(0,1,0)
2	352×288	30.00	843.50	(0,2,0)
3	352×288	7.50	762.10	(0,0,1)
4	352×288	15.00	1059.30	(0,1,1)
5	352×288	30.00	1781.00	(0,2,1)
6	352×288	7.50	1411.90	(0,0,2)
7	352×288	15.00	2058.00	(0,1,2)
8	352×288	30.00	3337.00	(0,2,2)

turn according to the transmission order. On the moment of executing the handover preparation, the scheduler of the serving BS serves the packets belonging to the “extendable” sub-category first.

The SVC video stream deployed to the simulation is encoded in fixed spatial scalability and varying in both of the quality and the temporal scalability. Table III summarizes the classification among the layers of the deployed SVC stream. The first type of the classification causes the degradation in video playback fluency, but the average video transmission rate reduces to 371.70 kbps. On the other hand, the second type of the classification keeps the video playback fluency; however, the average video transmission rate reduces to 843.50 kbps only.

TABLE III

THE TWO DISTINCT TYPES OF LAYER CLASSIFICATION OF THE DEPLOYED SVC VIDEO STREAM

QID	TID	First Classification	Second Classification
0	0	base layer (F)	base layer (S)
1	0	enhancement layer	enhancement layer
2	0	enhancement layer	enhancement layer
0	1	enhancement layer	base layer (S)
1	1	enhancement layer	enhancement layer
2	1	enhancement layer	enhancement layer
0	2	enhancement layer	base layer (S)
1	2	enhancement layer	enhancement layer
2	2	enhancement layer	enhancement layer

In the simulation, the playback video buffer allocated in the subscriber terminal mobile device is set to 1024 Kbytes. In addition, the entire SVC video stream is packetized into 24105 packets in total. Under the first type of the classification, the packets belonging to the base layer is about 11.74%, and in the second type of the classification, the packets belonging to the base layer is about 30.8%. Here, the variable varying is the handover preparation duration. It means that starting from the moment of executing the handover preparation to the handover is actually executed, how much time passed by. The variable of the handover preparation duration is going through from 0 ms to 800 ms, and the value of the variable with 0 ms means that no handover preparation is done at all, as the regular handover mechanism can do, while the values of the variable larger than 0 ms denote that the proposed handover mechanism is executed. Figure 5 shows the packet ratio between the total received packets and the received base layer packets of the playback buffer in the mobile station using the first type of classification. From the figure, while the handover preparation duration is extended to 300 ms and up, the base layer packets received cannot increase anymore because of the exhaustion of the “extendable” queue in the serving BS to support no more base layer packets to the mobile station. Besides, the packet ratio of the playback buffer using no any handover preparation shows a value equals to that of the entire SVC stream. It means that the simulation is not bias while considering the simulation scheme.

Figure 6 shows the result coming from the second classifica-

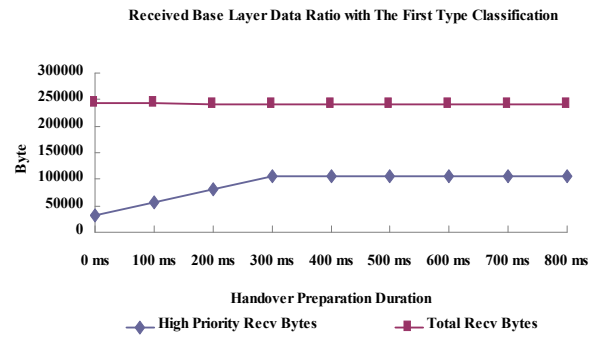


Fig. 5. The ratio between total received data bytes and the base layer data bytes in the mobile station using the first type of packet classification

tion type. As the figure 6 shows, the data-byte ratio of the base layer packets to total packets is increasing while the handover preparation duration is extended. This result is different from that showing in figure 5 for the sake of about triple amount of the base layer packets are served in the second classification type condition comparing that in the first classification type.

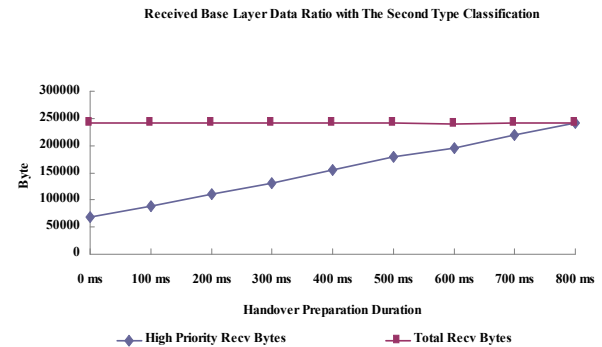


Fig. 6. The ratio between total received data bytes and the base layer data bytes in the mobile station using the second type of packet classification

Figure 7 shows the extended playback time of the SVC video stream. Using the first type of the layer classification, the playback time is extended at most up to about 2 seconds under the condition that the handover preparation duration is longer than 300 ms. However, by the first layer-classification type, only one temporal layer is assigned as the base layer, and thus decreasing the frame rate of the playback video. The decreasing in frame rate collapses the playback fluency. On the other hand, by the second layer-classification type, the playback time is extended to, at most, about 1.5 seconds when the handover preparation duration reaches 800 ms.

IV. CONCLUSION

From the simulation validation, the proposed seamless service handover strategy and mechanism prevent the service from being interrupted efficiently. The varying in the handover preparation duration has the equal meaning of the diverse in

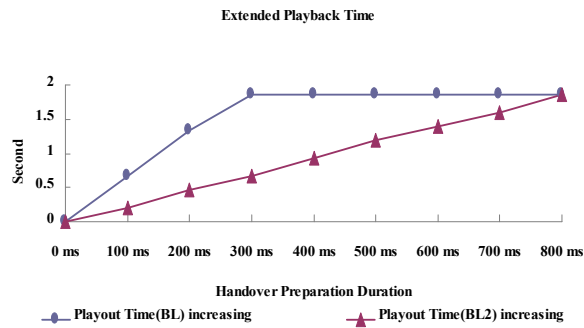


Fig. 7. The playback time extended using both of the first classification type and the second classification type - (BL) denotes the first type and (BL2) denotes the second type

moving speed, that is, under the same handover threshold, the higher speed a mobile station is, the shorter handover preparation duration a mobile station gets. To overcome the situation, the handover threshold must be adjusted dynamically according to the moving speed of the mobile station to attain the goal of the seamless service.

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