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Scalable MPEG-4 Streaming over the Mobile Networks Environment*

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Abstract- *When a mobile client is moving from subnet to subnet and connects to the same proxy all the way, the transmission quality can not be guaranteed. Thus, the mobile client must switch to a new proxy when it moves to a new subnet. In this paer, we define the procedure of switching the served proxies dynamically as "proxy handoff". In order to solve proxy handoff, a Layered Video Handoff Mechanism (LVHM) based on the scalable MPEG-4 streaming technique is proposed and implemented. LVHM analyzes the situation of cached data in the original proxy and the new proxy, and then decide whether the original server needs to forward the cached data to the new proxy or not. Once the forwarding procedure is required, LVHM can forward the cached video frames according to priority. Two experiments are designed and presented that LVHM can cost less time than receiving data from the corresponding server even if the network is congested.*

Keywords: *Proxy Handoff, Buffer Forwarding, MPEG-4, Scalable Streaming, Multicast*

1. Introduction

The adoption of the server-proxy-client 3-tier architecture to the mobile network environment [1–4] can improve the transmission quality, but it also results in a new problem. Since a mobile client is moving from subnet to subnet and connects to the same proxy all the way, the networking situation, e.g. the transmission rate, between the mobile client and the corresponding proxy can't be always guaranteed. The solution for the problem is to dynamically switch proxies according to the networking situation. In this paper, the dynamic switching of the served proxies is called proxy handoff.

Our work is motivated to improve the proxy handoff latency. When proxy handoff occurs, the mobile client connects to a new proxy. If the new proxy does not cache any useful video data for the mobile client, the new proxy needs to request the video data from the corresponding server. The mobile client must wait a period of time and can not receive any video data during the waiting period. However, the video data is possibly cached in the original proxy before proxy handoff. Thus, if the original proxy can actively forward the cached video data to the new proxy, the waiting time of the mobile client can be reduced or even become zero.

Some researches adopt MPEG-4 technology into the mobile network environment [5–7] because MPEG-4 has a greater compression rate than other encoding technologies. In addition to high compression, MPEG-4 exploits spatial and temporal scalabilities [8, 9] in video objects or frames. The scalability of MPEG-4 can divide the video data into two kinds of layers, base layer and enhancement layer. In this paper, we design and implement a Layered Video Handoff Mechanism (LVHM), which is based on the scalability of MPEG-4, to analyze whether the requested video data is in the new proxy server or not. For example, if the new proxy has the requested video data, the original proxy need not to forward anything to the new proxy; if the new proxy has no requested video data, LVHM can distinguish the priority of each layer and forward the video frames according to their priorities from the original proxy to the new proxy.

This paper is organized as follows. Section 2 surveys related works. Section 3 presents the platform overview. Section 4 describe the proposed LVHM and its technical issues in detail. The performance analysis is given in Section 5. Finally, Section 6 gives the conclusion remarks and future works.

2. Related Works

Some existing works are also to solve the proxy handoff problem. In [10], the authors proposed a technique called "cache handoff" for multimedia streaming applica-

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tions. Cache handoff is designed to maximize the traffic localization of streaming contents and increase the cache hit rate of proxies. Each streaming proxy is associated with a Mobility Status Subscription Server (MSSP) which is responsible for monitoring the movement of mobile clients. When a mobile client moves to a new subnet, the MSSP of the original subnet should inform the original streaming proxy to start to search the new streaming proxy located in the new subnet using SLP. Once the new streaming proxy is found, the original streaming proxy forwards information about the mobile client, such as current streaming content and other authentication information, to the new streaming proxy. In [11], the authors presented a QoS architecture supporting streaming applications over the mobile network environment. In the proposed QoS architecture, two types of proxy servers are (1) Streaming Proxy Server and (2) Mobile Proxy Server. Streaming Proxy Server is to protect mobile clients from the delay jitter. Mobile Proxy Server is responsible for signaling messages of proxy handoff. When the mobile client moves to a neighboring cell, the original mobile proxy server and the new mobile proxy server should initialize the proxy handoff process by sending a PIM Active Join message to the streaming proxy server. If the two join messages arrive at the merge point, the multicast group is created and the path for multicast is also built. The streaming proxy server will re-evaluate the possible delay jitter to adjust the transmission rate.

As we have described above, our work also apply multicast to help the proxy handoff procedure smoothly and experiment on forwarding the cached data from the original proxy to the new proxy. However, unlike the above studies, we propose a Layered Video Handoff Mechanism (LVHM) based on the scalable MPEG-4 streaming technique. When proxy handoff occurs, the cached data can be divided into one base layer and several enhancement layers and forwarded according to the priority of each layer.

3 Platform Overview

The purpose of this paper is to apply the scalable MPEG-4 streaming in the proxy handoff procedure. Because proxy handoff occurs in the 3-tier network architecutre, three main components in the proposed platform are (1) Media Server (MS), (2) Mobile Media Proxy (MMP), and (3) Mobile Host (MH). Figure 1 depicts the abstract scenario of the proposed platform.

Media Servers (MSs) are distributed in Internet and are responsible for providing media contents. Each MS stores a number of MPEG-4 compressed video files. In order to achieve QoS control, an MS extracts video frames from bitstream files. After recognizing which layer the video frames belong to, the video frames are arranged in the transmission order, and then are sent to the network.

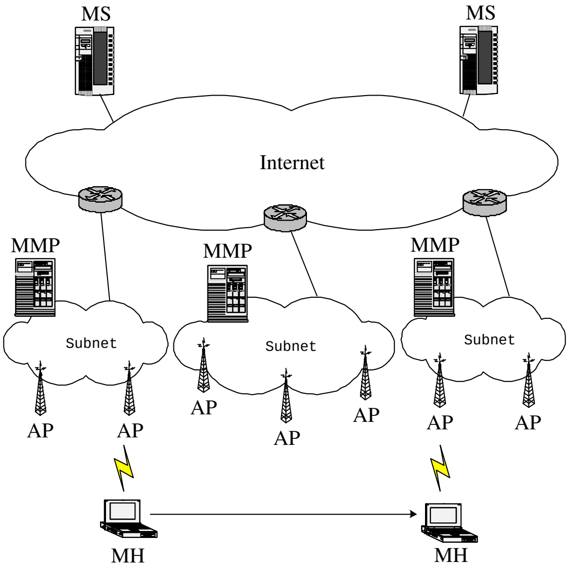

Figure 1. The proposed 3-tier platform.

Mobile Media Proxy (MMP) is responsible for (1) receiving and caching the video streams from MSs and (2) making the handoff of service session from the original MMP to the new MMP smoothly. Since multicast can decrease the bandwidth consumption and reduce the network congestion, MSs adopt multicast to send the media contents to MMPs. Moreover, multicast can help proxy handoff smoothly. During the proxy handoff processing, if the new MMP has joined the corresponding multicast group, the new MMP can continuously transmit media contents to the mobile client. As a result, when an MMP requests a video file from an MS, the video stream is assigned with a multicast group. If a video file is requested in different time points, according to the buffer size for a video file in an MMP, the video is delivered to different video streams with different multicast groups. For example, mobile client X requests Troy at 9:00am and the buffer size for a video file in an MMP is 5 minutes. If another mobile client Y requests the same movie at 9:03am through the same MMP, the video is delivered with the same multicast group. However, if another mobile client Z requests the same movie at 9:30am, the video is delivered with a new multicast group which is different from the multicast group for X and Y.

We assume that there is only one MMP in a subnet. When an MMP is installed in a subnet, the administrator must specify which MMPs are around this new installed MMP. In this paper, we define these specified MMP as the neighboring MMPs. Once the new MMP is initialized to provide services, it will communicate with the neighboring MMPs and gets the information about each neighboring MMP. The information is about which access points are under the coverage of an MMP.

Mobile Hosts (MHs) request and receive video streams through MMPs. When an MH receives video frames, it stores them into the corresponding buffer according to the video type. The MPEG-4 video player in an MH can get video frames from the buffer, decode the compressed video frames to raw data, and then present decoded media contents.

4 The Layered Video Handoff Mechanism

Before introducing the proposed Layered Video Handoff Mechanism (LVFM), we firstly discuss the main issues of the proxy handoff procedure. When a mobile client is moving to the other subnet, three possible situations of video cache in the new MMP are (1) the new MMP does not cache any part of the video, (2) the new MMP caches part of the video but this part of the video is not what the mobile client needs, e.g., the cached part is for the session started at 9:00am, but the mobile client's requested video is started at 9:30am, and (3) the new MMP is receiving the video stream that the mobile client needs. Thus, the first issue is how to determine the situation of video cache in the new MMP.

Issue 1 : How to determine the situation of video cache in the new MMP ?

In LVHM, we can determine the situation of video cache in the new MMP by observing whether the next frame the MH requests is in the new MMP's cache or not. The role which is responsible for determine the situation is the original MMP. Thus, the original MMP must know (i) the last frame stored in the MH's buffer, which is denoted by X, when the MH disconnects from the original MMP and (ii) the first frame stored in the new MMP's cache, which is denoted by Y, when the new MMP joins the corresponding multicast group. In this way, the original MMP can compare X with Y. If $X \geq Y$, it implies that this is the third situation, i.e. the next frame the MH requests has been in the new MMP's cache already. The original MMP needn't forward any video frame to the new MMP. On the contrary, if $X < Y$, it implies that this is the first or second situation, i.e. the next frame the MH requests is not available in the new MMP's cache. Under this condition, the original MMP would forward $(Y - X)$ video frames to the new MMP.

However, there is no certain value for X because the original MMP can't predict the exact time which the MH disconnects from the original MMP. So the second issue is how to determine the value of X.

Issue 2 : How to determine the value of X ?

In LVHM, we can determine the value of X by periodically monitoring the response of the MH. When the MH triggers the MMP handoff operation, the MH starts to send an ACK message for each received video frame of the base layer, in which the ACK message contains the received video frame's sequence number. The MH only sends ACK messages for base layer's frames because the bandwidth decreases when the MH starts the MMP handoff operation. The original MMP sets a timer to monitor these ACK messages. If the original MMP doesn't receive the ACK message in time, it means that the MH has disconnected from the original MMP. The original MMP regards the lastly acknowledged sequence number it receives as the value X.

Nevertheless, the main goal of LVHM is to minimize the latency due to proxy handoff. So, the third issue is how to forward the cached video frames in the original MMP to the new MMP.

Issue 3 : How to forward the cached video frames to the new MMP ?

LVHM is based on scable MPEG-4 streaming technology. When the original MMP must forward some video frames to the new MMP, LVHM will forward these video frames according to the priority of each frame. If the video frames belong to the base layer, the frames would be forwarded first of all. Then the video frames which belong to the enhancement layers would be forwarded in sequence, i.e. enhancement layer 1 is forwarded before enhancement layer 2. In order to restrain the latency due to proxy handoff, LVHM exploits a feedback mechanism. Once the video frame is received after its presentation time point, the MH would send a feedback message to the new MMP and discard the video frames which are forwarded from the original MMP. The new MMP would stop transmitting the video frames forwarded from the original MMP to the MH and inform the original MMP that the forwarding procedure can be over.

Figure 2 depicts the control message flow and data flow of LVFM. The procedure is described as follows.

1. The MH sends the HANDOFF_BEGIN message to the original MMP for triggering proxy handoff .

2. The MMP selects one neighboring MMP as the new MMP to serve the MH.

3. The original MMP sends the HANDOFF_REPLY message to the MH. The MH can get the new MMP's address from this message.

4. The MH starts to send the MH_ACK_SEQ message periodically to the original MMP until it disconnects from the original MMP.

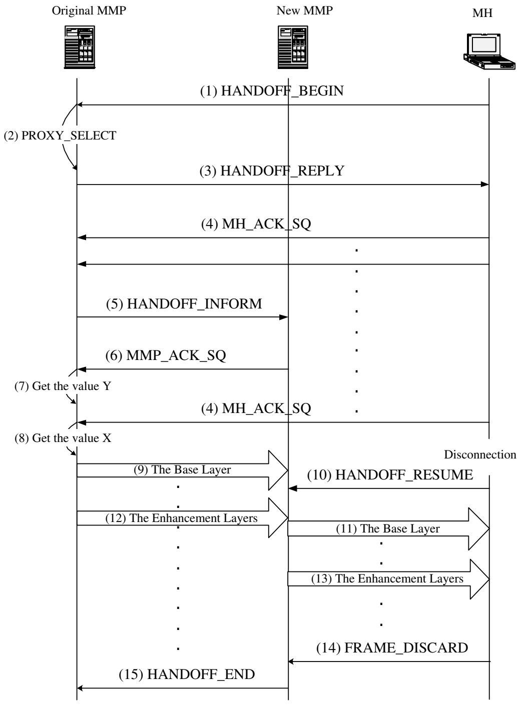

Figure 2. The control message flow and data flow of LVHM.

5. The original MMP sends the HANDOFF_INFORM message to the new MMP and then the new MMP can join the corresponding multicast group for receiving the video frames from the MS.
6. When the new MMP receives the first video frame from the MS, it sends the MMP_ACK_SEQ message to the original MMP to report the buffer status.
7. The original MMP gets value Y from the MMP_ACK_SEQ message.
8. The original MMP gets value X from the MH_ACK_SEQ message and decides whether it needs to do video forwarding or not.
    (a) If $X \geq Y$, the LVHM procedure is terminated.
    (b) If $X < Y$, goto Step 9.
9. The original MMP forwards video frames of the base layer to the new MMP directly.
10. The MH sends the HANDOFF_RESUME message to the new MMP.
11. The new MMP recieves the video frames of the base layer and stores them in a temporary buffer. When the MH connects to the new MMP, i.e. after receiving the HANDOFF_RESUME message from the MH, the new MMP sends the video frames of the base layer to the MH.
12. After forwarding the video frames of the base layer, the original MMP forwards the video frames of enhancement layers according to the priorities of enhancement layers.
13. When the new MMP receives the video frames of enhancement layers, the new MMP inserts these video frames into the corresponding buffers according to their sequence numbering. Then the new MMP sends them to the MH.
14. The MH receives the forwarded video frames and checks their presentabilities. If the video frames are received behind the presentation time, then the MH discards the video frames and sends a FRAME_DISCARD message to the new MMP; otherwise, the video frames are inserted into the buffer according to their sequence numbering.
15. When the new MMP receives the FRAME_DISCARD message from the MH, it means that the original MMP can't forward the video frames in time and must stop the video forwarding procedure. The new MMP informs the original MMP to stop the video forwarding procedure and to leave the multicast group by sending the HANDOFF_OVER message.

5 Performance Evaluation

Figure 3 depicts the experimental environment for evaluating the proxy handoff latency. MS is in subnet A; MMP 1 and MMP 2 are in subnet B and subnet C respectively; subnet A, subnet B and subnet C are connected to a Cisco router which supports multicast routing. There is one 802.11b access point in subnet B and in subnet C respectively. When an MH moves from subnet B to subnet C, it should perform the proxy handoff process. In the executed experiments, a normal re-transmission mechanism is adopted in order to have a comparsion with LVHM. The normal re-transmission mechansim requires to re-transmit the video data from the corresponding MS when cache miss occurs in the new MMP. Moreover, we divide the proposed LVHM into LVHM without feedback and LVHM with feedback. LVHM without feedback means that the MH will not discard the forwarded video frams which may be received after its presentation time. Thus, analysis of LVHM without feedback and the normal re-transmission mechanism can show whether using the scalable MPEG-4 streaming can get advantage or not when proxy handoff occurs, and analysis

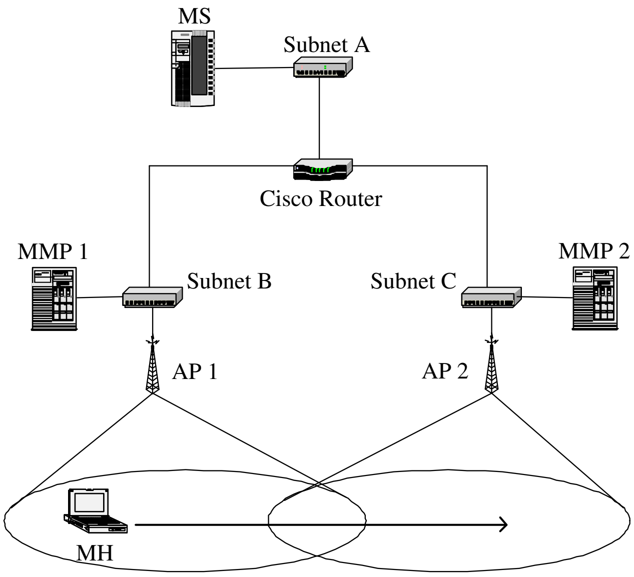

Figure 3. The experimental environment.

of LVHM without feedback and LVHM with feedback can present in which situation the feedback mechanism is effective.

Two factors which affect the value of the proxy handoff latency are (1) the total size of cached data needed to be forwarded and (2) the network condition. First, for the total size of cached data, we try to change the cache size for each streaming data on an MMP, which is denoted by $Cache_{MMP}$. Figure 4 depicts the test results of this scenario. According to the results shown in Figure 4, the greater $Cache_{MMP}$ is, the higher $Latency$ will be. However, $Latency$ of LVHM without feedback is always lower than $Latency$ of the normal re-transmission mechanism. Furthermore, although the resulted latency of LVHM with feedback is similar to that of LVHM without feedback when the cache size is small, LVHM with feedback can keep the value of $Latency$ no greater than 12 seconds when the cache size is increasing. The reason is that, if $Latency$ is more than 12 seconds, the MH using LVHM with feedback will inform the new MMP to stop forwarding and start to discard the delayed video frames. In other words, LVHM with feedback can keep the proxy handoff latency not to be increased with the cache size.

Second, for the network condition, we use Iperf [12] to generate background traffic and evaluate how LVHM, which uses the scalable MPEG-4 streaming technnique, can improve the performance when proxy handoff occurs in the congested network condition. In the experiment, Bandwidth of background traffic denotes $Bandwidth_{Traffic}$. Figure 5 depicts the test results. Approximately, when the

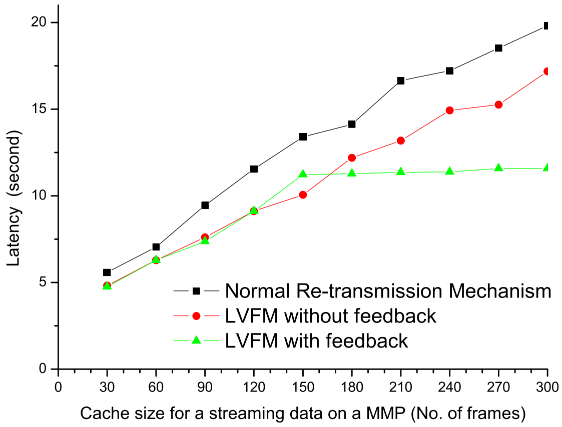

Figure 4. $Latency$ **V.S.** $Cache_{MMP}$**.**

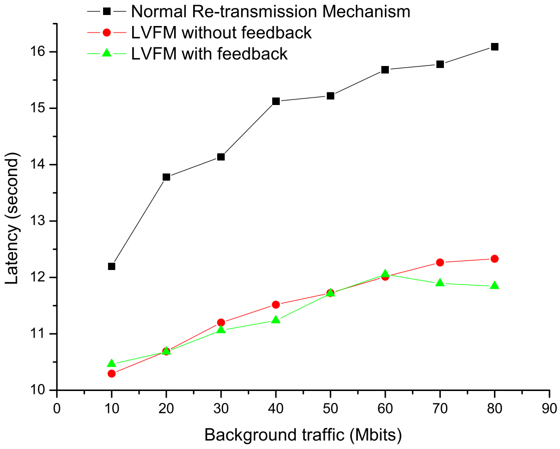

Figure 5. $Latency$ **V.S.** $Bandwidth_{Traffic}$**.**

available bandwidth dreases, $Latency$ increases. However, LVHM with/without feedback have about 25% improvement as compared with the normal re-transmission mechanism. Moreover, when background traffic becomes greater than 60 Mbits, the feedback mechanism starts to work and then $Latency_{Forward}$ of LVHM with feedback is less than that of LVHM without feedback. Therefore, when the network is congested, LVHM can still keep a better transmission quality for proxy handoff.

6 Conclusion

In order to deal with the proxy handoff problem, we have designed and implemented a Layered Video Handoff Mechanism (LVHM) based on multicast and the scalable MPEG-4 streaming technique. Since LVHM is based on the MPEG-4 scalability, LVHM can divide the video data into one base layer and several enhancement layers. When the proxy handoff procedure is required, the base layer video frames which have higher priority in LVHM are firstly forwarded and then the enhancement layer video frames which have lower priority are forwarded. Furthermore, if the proxy handoff latency is too large, i.e. the forwarded video frame is received after its presentation time, LVHM has a feedback mechanism to terminate the forwarding procedure in order to save the network bandwidth for the following transmission. Two experiments are design to evaluate the proposed LVHM and the results show that LVHM can really reduce the proxy handoff latency even if the network is congested.

In this paper, we focus on how to apply the scalable streaming in the proxy handoff procedure. We assume that there is only one MMP in a subnet to serve MHs. But, in most netwrok environments, there may be more than one MMP in a subnet. In this situation, how to select a new MMP and how long to select a new MMP will also affect the proxy handoff latency. Therefore, the future work is to design a scheme for how to select a new MMP which is the most suitable for the MH among multiple MMPs.

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