Adaptive Video Streaming in Vertical Handoff: A Case Study

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Abstract

Video streaming has become a popular form of transferring video over the Internet. With the emergence of mobile computing needs, a successful video streaming solution demands 1) uninterrupted services even with the presence of mobility and 2) adaptive video delivery according to current link properties. In this paper we study the need and evaluate the performance of adaptive video streaming in vertical handoff scenarios. We use Universal Seamless Handoff Architecture (USHA) to create a seamless handoff environment, and use the Video Transfer Protocol (VTP) to adapt video streaming rates according to "Eligible Rate Estimates". Using testbed measurements experiments, we verify the importance of service adaptation, as well as show the improvement of user-perceived video quality, via adapting video streaming in the vertical handoffs.

1. Introduction

As the demand, production and consumption of digitized multimedia has intensified in recent years, the latest application trends have created an increasing interest in providing practical multimedia streaming systems to meet the needs of mobile computing. In order to provide uninterrupted services and maximum user-perceived quality, a successful video streaming solution needs to adapt appropriately to mobile handoff scenarios.

As previously identified in [3][4], in order to provide a system that addresses quality of service in mobile computing environments, the following key issues need to be resolved: 1) seamless mobility across heterogeneous networks, 2) application adaptation to maximize the end user's perceived quality, and 3) adaptation to network dynamics such as wireless channel errors and congestion.

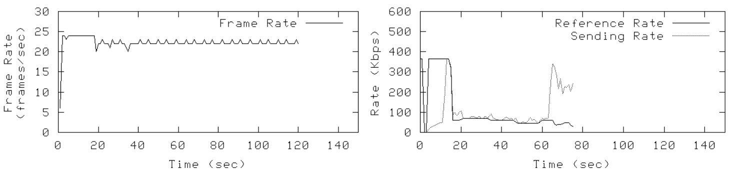
To accommodate mobile users switching between networks of different capacities, a seamless handoff technology is needed to tackle the first issue; the best way would be to preserve existing application sessions in the presence of mobility. Also, since mobile users may roam in an arbitrary pattern, an adaptive multimedia streaming technology is needed to address the second and third issues; adaptation may help provide better response to the dynamically varying available resources as well as maximize the end user's perceived quality. As a result, a complete solution will need to incorporate both seamless handoff and adaptive multimedia streaming technologies.

In this work, we have implemented a fundamentally adaptive, end-to-end multimedia streaming system that allows a mobile user to receive uninterrupted service of best possible quality multimedia, while roaming among multiple heterogeneous wireless networks. Although the general concepts of providing adaptive services are not new, we aim to provide insights on end-to-end dynamics of such system from an implementation perspective instead of a simulated one. Actual system measurements collected from our testbed show that the combination of USHA [2] and VTP [1] can indeed provide substantial improvements to streaming performance, in terms of perceived video quality (smooth video frame rate), and robustness against sudden changes in link capacities.

2. Experiments

In this section, we present measurement results of adaptive video streaming in vertical handoff scenarios using a 2-minute movie trailer encoded in MPEG-4 at three discrete levels. We denote them as levels 0, 1 and 2, corresponding to the encoding rates (VBR) of below 100, 100~250, and above 250 Kbps, respectively. The VTP server is implemented on a stationary Linux desktop; the client is on a mobile Linux laptop. The USHA system is also set up in Linux, with custom configured NAT and IP tunneling. Both the VTP server and client are connected to the handoff server, the former via 100 Mbps Ethernet; the later via 802.11b and 1xRTT provided by Verizon Wireless. The 802.11b is set at the 11 Mbps mode; the bandwidth of 1xRTT varies with cross traffic, the typical value is around tens of Kbps. In all experiments, one-time handoff occurs at 60 sec after the start of the experiment. In each scenario, we have tested both non-adaptive and adaptive video streams. In the non-adaptive case, video of fixed quality is sent throughout the experiment, while in the adaptive case the video quality adapts accordingly.

In the first set of experiments, we evaluate the performance of video streaming when the mobile host performs handoff from the lower-capacity interface of 1xRTT to the higher-capacity interface of 802.11b. Figure 1-a shows the frame rate received by the mobile client, and Figure 1-b shows the sending rate at the VTP server. In Figure 1-b, "Reference Rate" means the source rate of the video stream (note that the source rate is variable, even within a given encoding scheme), whereas the "Sending Rate" means the instantaneous transmission rate of the data, which depends on the link capacity and thus may exceed the source rate.

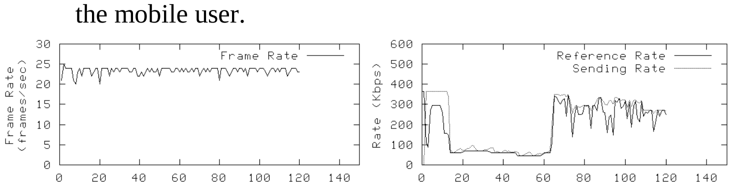


(a) (b)

Figure 1: Non-adaptive video streaming (a) Frame Rate received at the Mobile Host (b) Sending Rate at the Video Server

In Figure 1-a, the video frame rate is stable and consistently between a visually pleasing range of 20 and 25 frames/sec (fps) shortly after it is started. Even in the presence of a handoff from LOW to HIGH at 60 sec, the frame rate remains unaffected. This proves our USHA to be transparent to applications. The video quality is overall very good in terms of smoothness. However, Figure 1-b reveals more insightful information. In this non-adaptive experiment, the reference rate and video quality remain low after the handoff at 60 sec, where they could increase to take the advantage of the increased “sending rate” and bandwidth. This justifies the exploration of adaptation in video streaming applications. Note that after the handoff, the actual sending rate is much higher than the reference rate, so the server finishes sending quickly (before 80 sec).

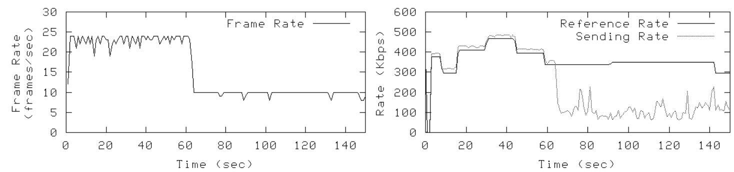
In Figure 2-a, we show the frame rate received by the mobile client where the adaptive video streaming (VTP) is applied. Still it is stable and consistently in a range that gives good perceived quality. No dips in frame rate are found when the handoff event occurs. Figure 2-b shows the reference and sending rates on the VTP server. Prior to the handoff at 60 sec, Figure 2-b looks very similar to Figure 1-b. The difference emerges after the handoff. The reference rate jumps up and strives to match the sending rate (~300 Kbps), indicating that high quality video is now being transmitted across the 802.11b channel. In other words, VTP successfully detects (within fractions of a second) the change in available bandwidth and adapts its video encoding level to maximize the perceived quality of the mobile user.



(a) (b)

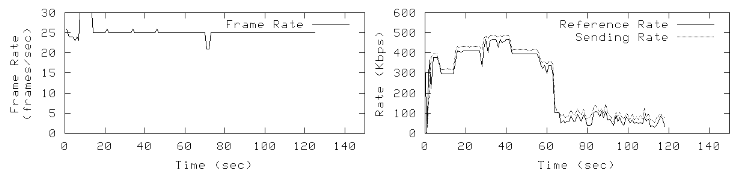
Figure 2: Adaptive video streaming (a) Frame Rate received at the Mobile Host (b) Sending Rate at the Video Server

Another set of experiments is done by performing handoff from the high-capacity interface of 802.11b to the low-capacity interface of 1xRTT. To make results comparable to the previous experiments, the one-time handoff is also generated 60 sec after the experiment is started. Figure 3 and Figure 4 show the experiment results, and it is obvious that the adaptive video streaming outperforms the non-adaptive video streaming as well.



(a) (b)

Figure 3: Non-adaptive video streaming (a) Frame Rate received at the Mobile Host (b) Sending Rate at the Video Server



(a) (b)

Figure 4: Adaptive video streaming (a) Frame Rate received at the Mobile Host (b) Sending Rate at the Video Server

3. Conclusion

In this paper, we have studied the need and evaluated the performance of adaptive video streaming in vertical handoff scenarios. We have proposed an integrated solution of seamless handoff and adaptive video streaming, and implemented it on a Linux testbed, consisting of a USHA server and a VTP streaming system. Experiments on both non-adaptive and adaptive video applications, with handoffs from 1xRTT to 802.11b and vice versa, have been carried out to evaluate the performance of our proposed solution. From the measurements results we have seen that the USHA/VTP solution can effectively hide handoff events from the application and provide uninterrupted transport and application sessions during handoffs. Moreover, the adaptive streaming system is able to detect available bandwidth changes and adjust the video quality and sending rate accordingly. In summary, such a combination of adaptive video streaming and seamless vertical handoff will become very desirable in the emerging ubiquitous mobile computing environment.

4. References

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