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Adaptive interface selection over cloud-based split-layer video streaming via multi-wireless networks

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HIGHLIGHTS

- We model an adaptive multi-interface selection video streaming system.
- A prototype is developed on iOS (iPhone5s) device via LTE and WiFi network.
- We evaluate the system in an emulated environment and diverse real-world network.
- Maximizing video quality is guaranteed which the aggregate bandwidth can accommodate.
- System shows the cost-effectiveness by lower LTE bandwidth consumption.

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ABSTRACT

As mobile devices such as tablet PCs and smartphones proliferate, the online video consumption over a wireless network has been accelerated. From this phenomenon, there are several challenges to provide the video streaming service more efficiently and stably in the heterogeneous mobile environment. In order to guarantee the QoS of real-time HD video services, the steady and reliable wireless mesh is necessary. Furthermore, the video service providers have to maintain the QoS by provisioning streaming servers to respond the clients' request of different video resolution. In this paper, we propose a reliable cloud-based video delivery scheme with the split-layer SVC encoding and real-time adaptive multi-interface selection over LTE and WiFi links. A split-layer video streaming can effectively scale to manage the required channels on each layer of various client connections. Moreover, split-layer SVC model brings streaming service providers a remarkable opportunity to stream video over multiple interfaces (e.g. WiFi, LTE, etc.) with a separate controlling based on their network status. Through the adaptive interface selection, the proposed system aims to ensure the maximizing video quality which the bandwidth of LTE/WiFi accommodates. In addition, the system offers cost-effective streaming to mobile clients by saving the LTE data consumption. In our system, an adaptive interface selection is developed with two different algorithms, such as INSTANT and EWMA methods. We implemented a prototype of mobile client based on iOS particularly by using iPhone5S. Moreover, we also employ the split-layer SVC encodes in streaming server-side as the add-on module to SVC reference encoding tool in a virtualized environment of KVM hypervisor. We evaluated the proposed system in an emulated and a real-world heterogeneous wireless network environments. The results show that the proposed system not only achieves to guarantee the highest quality of video frames via WiFi and LTE simultaneous connection, but also efficiently saves LTE bandwidth consumption for cost-effectiveness to client-side. Our proposed method provides the highest video quality without deadline misses, while it consumes 50.6% LTE bandwidth of 'LTE-only' method and 72.8% of the conventional (non-split) SVC streaming over a real-world mobile environment.

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1. Introduction

In the recent years, the amount of multimedia contents consumption has increased dramatically. Especially, real-time video streaming accounts for a large amount of web traffic [1]. The emergence and proliferation of mobile devices such as tablet PCs and smartphones have further accelerated the online video consump-

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tion. The consumption of long and high definition multimedia contents is also increasing because of mobile devices with a bigger screen and high-performance hardware [2]. In addition, large TV networks such as ESPN, BBC and HBO have deployed broadcast model with on-demand applications. From this phenomenon, there are many challenges to provide the video streaming service on the mobile environment more efficiently and stably.

The High-Definition (HD) 720P videos generally use 3 Mbps of bitrate, and furthermore a few Video-on-Demand (VoD) service providers support 4K Ultra-HD videos which require bitrate higher than 20 Mbps. To guarantee the stable HD video streaming, the download bandwidth should be higher than the bitrate of videos. Moreover, the steady and reliable wireless network is required to satisfy quality of service (QoS) of real-time video services. Lately, mobile devices are equipped with multiple network interfaces, including 3G/LTE and WiFi. In a lot of countries, the coverage of 4G LTE has expanded which allows higher bandwidth than 3G networks. Through this advantage of LTE network, the HD video consumption on mobile devices is accelerated. However the wireless service provider sets the expensive price for LTE in many countries, and almost every country has not adopted unlimited LTE plans. Even an unlimited plan has restrictions on daily data usage at the highest speed due to the limited capacity of the mobile backhaul. Thus, the reckless using of the LTE network for the QoS of video streaming services would be an enormous burden to clients with expensive LTE cost. On the other hand, the WiFi network is preferred to consume the multimedia content since the WiFi network provides free or very low price as compared to LTE with acceptable download bandwidth. Even though the WiFi has advantages, they have weaknesses in the limited coverage of routers and their handover problem.

In this study, we present a reliable video delivery scheme with a guarantee of QoS and cost-effectiveness over unpredictable and unstable heterogeneous wireless networks. Especially, we developed a novel method with the adoption of the split-layer Scalable Video Coding (SVC) and adaptive multi-interface selection of LTE and WiFi links simultaneously.

Due to the development of heterogeneous mobile devices, various streaming environments with different display sizes and different network conditions have accelerated video streaming to the masses. For example, some desktop or laptop clients request high-resolution video contents with their large size display and smooth network environment. On the other hand, mobile clients want to consume low-quality video contents because of their relatively small size screen or the unsuitable wireless network environment. For this reason, the VoD service providers have to concern not only efficient managing of the rapidly increasing traffic, but also maintaining of the QoS by provisioning streaming server to respond the clients' request of different video resolution.

To cope with these problems, there have been efforts for coupling the SVC [3] with video streaming service over cloud infrastructures [4,5]. Cloud services have several advantages over the conventional Internet hosting, as proven by the increasing demand of cloud infrastructures. Cloud computing can provide scalable and elastic amounts of computing resources to service providers on demand. Cloud services have enabled the auto-scaling and the economical usage of resources without over-provisioning. Managing resources, such as CPUs, are a must in order to adapt to increasing client connections [6]. Furthermore, in a network-bounded service such as video streaming, the ability to rapidly increase channels in consideration of bandwidth is another factor to consider [7,8].

SVC is the scalable extension of H.264/AVC, which supports spatial, temporal and quality scalability. SVC provides scalability at a bitstream level, and a video encoded with SVC has several substreams with a layered structure, namely a base layer and enhancement layers. A base layer (BL) is the reference to the other enhancement layers (ELs). They refer to the base layer and can provide the video in a higher quality.

In our work, we use a split-layer SVC encoding [9] for an adaptive multi-interface selection over the cloud environment. By separately controlling streaming instances of the base layer and enhancement layers with Layer-splitting SVC encodes, resource utilization can be improved. In our previous study [9], we proved the effectiveness of split-layer video streaming in the cloud environment for the VoD service provider. Our proposed split-layer video streaming can effectively scale to manage the required channels on each layer of various client connections with a superior in resource utilization and network bandwidth saving. Moreover, split-layer SVC model brings streaming service providers a remarkable opportunity to stream video with multiple interfaces (e.g. WiFi, LTE, etc.) selection with a separate controlling based on their network status. We implemented a split-layer module by add-on own C code on the SVC reference encoding tool, namely JSVM.

Through the multiple wireless network interfaces, many approaches have been developed for bandwidth aggregation. Most of the previous studies have two different approaches, the packet scheduling over multi-path network [10–12] and extension of TCP to multipath (MPTCP) support [13–15]. Although previous approaches presented good performance of an experimental result, there are few challenges to effect on the real mobile environment. It is well-known that the packets arrive out of order if the multiple links have different latency, loss or bandwidth. Furthermore, *out-of-order packet delivery* is more harmful on video streaming services because most of all approaches used to deliver packets over the multi-path network after dividing the video bitstream to chunks by temporal basis. A video streaming services require time-sensitive delivery than other web services. However, if the prior packet for playback was allocated on unreliable or low bandwidth path, not only the packet is delayed and a quality of playback would degrade, but also raises latency and overhead by severe packet reordering.

On the other hand, our proposed system transfers packets via multi-path network after splitting in the spatial basis of the SVC encoding, instead of splitting packets in a time-sequential manner. With this spatial basis splitting, we prevent out-of-order packet delivery and also provide the highest quality of video stream within the available aggregated bandwidth. Our proposed adaptive multi-interface selection model is a mobile-side solution for compatible with a split-layer SVC streaming, it is a middleware in order to facilitate the downloading base layer and enhancement layers bitstream with asymmetric link management. Each link downloads video bitstream with independent logical segments, and our system determines download interface for a later segment through the real-time measurement an average download bandwidth of the previous downloaded segment. We assign LTE interface the initial download link for a base layer because of its priority, and other enhancement layers are downloaded over the WiFi interface initially. After the streaming starts, the interface selection system switches a download link for the base layer if the average throughput of the WiFi network was sufficient to download all bitstream include enhancement layers. On the contrary, the system switches the enhancement layers' download link to LTE if the WiFi network had a poor bandwidth for downloading enhancement layers. The detailed description of the system design is explained in Section 4.

It is possible to offer the reliable and cost-effective streaming system in unpredictable wireless network environments by using adaptive link management and maximizing the WiFi bandwidth. We implemented a prototype on iOS (iPhone5S) for a practical study. Also, we designed emulated network environment for

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