DESIGN OF AN ACTIVE SET TOP BOX IN A WIRELESS NETWORK FOR SCALABLE STREAMING SERVICES

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ABSTRACT

The popularity of multimedia streaming services via wireless home networks has confronted major challenges in quality improvement for services through a set top box (STB). Even though scalable methods have been suggested to enhance the quality of multimedia streaming services, it is still challenging how to provide scalable streaming services in wireless home networks. Previous studies on scalable streaming services eliminate the corrupted stream at the multimedia client. In this paper, we propose a new method, ***ActiveSTB***, which removes the distorted or unsuitable multimedia data early to save frugal resources. We use a network simulation tool, NS-2, to evaluate our method with various range of cross traffic and error rates. The simulation results show that ***ActiveSTB*** support 12.5% to 40% more packets than the original STB for all ranges of cross traffic and error rates.

Index Terms— Multimeida Streaming Service, Bandwidth Estimation, Set Top Box, WLAN

1. INTRODUCTION

A significant increase in user requests for streaming audio/visual information over the Internet has led streaming services to be as alternative to television or radio services. In addition, competitive prices of electronic devices and the widespread usage of fast wireless networks have given rise to an increase in demand for multimedia streaming services. However, there are many challenging issues in the wireless multimedia streaming environments, such as power management, bandwidth fluctuation and error resilience. For the management of wireless multimedia streaming services, a multimedia streaming system should support the clients with different capabilities, and handle multimedia streams in a scalable and effective manner.

The increase in multimedia streaming services has demanded many technical requirements in multimedia encoding and networking. One of the requirements associated with multimedia encoding and networking is scalability. According to the environments of multimedia streaming services, scalability plays a crucial role in delivering the best possible multimedia quality over unpredictable best-effort networks. However, it remains the problem when and where the quality of a scalable stream is changed.

Although there can be various wireless environments where multimedia streaming services are provided, we mainly focus on the wireless local area network (WLAN) shown in Figure 1, where a set top box (STB) receives television signals, runs interactive applications and transfers digital multimedia signals to the TV. The STB in wireless multimedia streaming services is located between wired and wireless networks, and handles heterogeneous clients. STBs are becoming key devices in home entertainment networks, not only to receive digital television, but also to deliver multiple services as residential gateway. Wired networks can provide high and stable bandwidths, while fragile wireless networks cannot support it. Therefore, as bandwidth efficiency increases, it is critical for the STB to interplay between wireless and wired networks.

For scalable streaming services, it is very critical for the STB to know the available wireless network bandwidth. The STB can be regarded as a bottleneck between the server and heterogeneous client devices, and the bottleneck determines the quality of a delivered multimedia stream to each client. Thus an STB must efficiently distribute the buffered scalable streams to heterogeneous clients. In this paper, we propose an ***ActiveSTB*** is to decide the stream quality, then eliminate dispensable streams to save the limited resource, and additionally simultaneously perform quality-adaptation to the available bandwidth.

The rest of the paper is organized as follows. Section 2 shows the related work. In Section 3, our new method, ***ActiveSTB***, is proposed and known challenges in bandwidth estimation are addressed. After presenting the simulation results of our method and other tools in Section 4, Section 5 concludes this paper.

2. RELATIVE WORK

2.1. Intermediate Node for Streaming Video

There have been a handful studies that show how an intermediate node can improve the quality of multimedia streaming services [1, 2, 3, 4, 12, 13, 14, 15, 16, 17, 18]. To reduce the resource requirements, intermediate node can cache a part of multimedia streaming data, such as data with high quality [1], initial part [2] and variable-sized segments [14]. When a client requests a low quality multimedia stream, intermediate node degrades the cached stream to improve the hit rate [3, 4]. In [12], the multimedia stream system provides scalable multimedia stream and each client joins the multicast channels to meet their request. Error resilience using fine granular scalability (FGS) was introduced [13]. [15] provided the scheme to smooth the quality of multimedia stream via wireless networks.

2.2. Bandwidth Estimation

For the efficiency of multimedia streaming services, it is critical to know the available bandwidth. Since the Cprobe [11] using Internet Control Message Protocol (ICMP) packet trains, many tools [5, 6, 7, 8, 9, 10] for bandwidth estimation have been suggested. Spruce [5] and IGI [6] used the interval of consecutive probe packets. Their method estimates the available bandwidth based on the interval or gap between probe packets that increases in heavy cross traffic. Topp [7] and Pathload [8] were based on the rate of incoming packets. The comparison of the outgoing rate from the sender side with the incoming rate at the receiver side reveals the available bandwidth of the probing link. In Probegap [9], idle rate of a wireless channel was used as milestone for the probation of the available bandwidth on the wireless channel. IdleGap [10] suggested a new method to obtain the idle rate of wireless channel. ***ActiveSTB*** improves the efficiency of wireless stream services using quality-adaptation and estimation scheme, and reconfigures the quality and flow of stream to the client in the change of the situation.

3. ACTIVE STB

ActiveSTB acts as a gateway between wired and wireless networks and also performs quality-adaptation to various network bandwidths. Also, ***ActiveSTB*** is designed to efficiently manage the wireless multimedia streaming services by early dropping of the corrupted multimedia data and estimating the available bandwidth.

3.1. Early Dropping

The removal of the corrupted multimedia data from the ***ActiveSTB*** cache can save the bandwidth of a wireless network. There are two types of losses in scalable streaming services: indirect loss and direct loss. Direct loss occurs when scalable multimedia data is not successfully transmitted, while indirect loss occurs when layers are corrupted by direct loss of other layer. For efficiently management of the wireless channel, ***ActiveSTB*** saves the bandwidth of wireless channel by eliminating indirect loss.

In Figure 1, each group of video (GoV) in the scalable multimedia stream contains 4 layers that include a base layer and three enhancement layers. Decoding a layer requires referring to other layers because of the hierarchical relationship between layers. The STB notices that third layer in GoV 1 is incomplete, so both the third and the forth layers in GoV 1 are early dropped in the STB and not forwarded to client. This scheme of early dropping decreases bandwidth consumption by eliminating corrupted multimedia data.

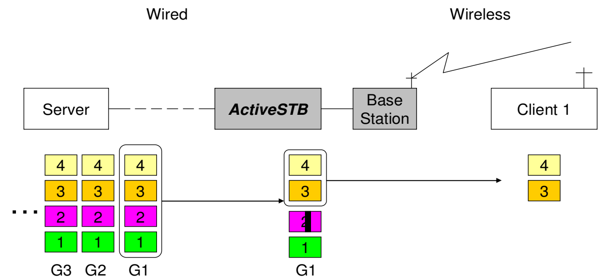

Figure 1. Early Dropping Scheme in the STB

QoS of streaming multimedia data is determined by not only the amount of direct loss but also one of indirect loss. The *ActiveSTB* transmits the only acceptable multimedia data. Table 1 shows the variables used for stream packet transmission and validation equations.

G	*multimedia stream of 'g' GoV's.*
$L_{g,l}$	*layer(l) at GoV(g)*
$P_{g,l,s}$	*The s^{th} packet of layer(l) in GoV(g)*
$NG(G)$	*Number of GoV's in multimedia stream.*
NL_g	*Number of layers in GoV(g)*
$NP_{g,l}$	*Number of packets in layer(l) in GoV(g)*
PLR	*Packet Loss Rate*
$Size(l)$	*size of layer(l).*

Table 1. Packet transmission and validation calculation variables

In Equation 1, the server divides a layer (*l*) in GoV (*g*) multimedia stream into several packets for transmitting:

$$L_{gl} = \coprod_{i=0}^{NP_{gl}} P_{gli} \tag{1}$$

When a layer is complete with all available packets, a client can decode the received layers. One packet loss can cause other packets in the same layer and referring layer to be thrown away. The safe transmission of all packets in a layer (*l*) ensures that the multimedia data at layer (*l*) is valid for decoding as in Equation (2).

$$Valid(L_{gl}) = \prod_{i=0}^{NP_{gl}} (1 - PLR(P_{gli})) \tag{2}$$

Each layer has a hierarchical relationship with other layers as shown as in Equation (3):

$$Valid(L_{gl})\ for\ decoding = \prod_{i=0}^{L_{gl}} \prod_{i=0}^{NP_{gl}} (1 - PLR(P_{gli})) \qquad (3)$$

To reduce a waste of available bandwidth on wireless channel, we filter out corrupted layers before transmission over the shared wireless channel as shown in Equation (5), while complete layers are transmitted to a client through wireless channel as shown in Equation (4):

$$Complete(NG(G)) = \sum_{g=0}^{NG(G)} \left(\sum_{l=0}^{NL_g} \left(Size(L) \times \prod_{i=0}^{L_{gl}} \prod_{i=0}^{NP_{gl}} (1 - PLR(P_{gli})) \right) \right) \qquad (4)$$

$$Filtered(NG(G)) = \sum_{g=0}^{NG(G)} \left(\sum_{l=0}^{NL_g} \left(Size(L) \times \left(1 - \prod_{i=0}^{L_{gl}} \prod_{i=0}^{NP_{gl}} (1 - PLR(P_{gli})) \right) \right) \right) \qquad (5)$$

3.2. Bandwidth Estimation

ActiveSTB decides the max size of transmitted multimedia data in terms of GoV. ***ActiveSTB*** notices the decoding time stamp (DTS) in the stream, then gets the interval of GoV. Also, we can know the available bandwidth in the wireless channel using some estimation tools, such as IdleGap [10], TOPP [7] or Spruce [5]. Since we know the available bandwidth and the information of GoV, we can calculate the max stream size that can be transmitted over the duration of the GoV. When a wireless channel cannot allow transmitting the whole layers in GoV, ***ActiveSTB*** adjusts it by removing layers from individual frames in the GoV.

4. SIMULATION RESULTS

The stream with 24 frames per second is used for our simulation. We compare ***ActiveSTB*** with *basicSTB* and *enhancedSTB* that have limited functionalities. The nomenclatures for ~~tests~~ results recorded in the figures are defined in Table 2. ED(Y)_EST performs early dropping and bandwidth estimation. ED(Y)_NoEST represents the *enhanced STB* that performs only early dropping, while ED(N)_EST stands for the *enhancedSTB* with only bandwidth estimation and quality adaptation. Without early dropping, *BasicSTB* just caches the scalable multimedia stream data and forwards it.

***Active*STB**	***EnhancedSTB***	***BasicSTB***
ED(Y)_EST	ED(Y)_NoEST	ED(N)_NoEST
	ED(N)_EST	

Table 2. STB Measurement Settings

4.1. Simulation Scheme

A three-step simulation is conducted on streaming services using the divider, the merger and the NS-2 simulator. First of all, the divider divides the original stream into several layers, and then logs the size and decoding time of each layer in terms of GoV. Secondly, the NS-2 network simulation is conducted on multimedia streaming services using the log file generated by the divider, and the results of successful or unsuccessful scalable streaming transmissions are generated. Finally, the merger decoded the streamed scalable multimedia data based on the NS-2 results. In the simulation, we use the Forman stream with 1.3M bytes. At the network simulation step, we have three connections including streaming service and two cross traffics. Multimedia server transmits the scalable multimedia data to the STB that caches and forwards the buffered multimedia data to clients over the wireless channel. In our simulation, the maximum of bandwidth of the wireless channel is 1 Mbps.

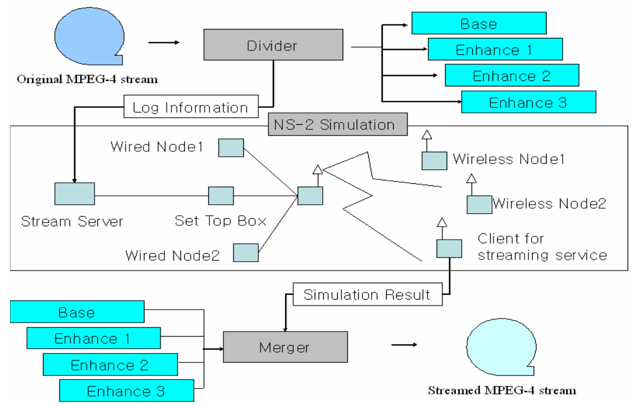

Figure 2. Simulation Process Diagram

4.2. Simulation Result

Figure 3 shows the number of packets decoded. ED(Y)_EST yields more efficient and higher performance transmissions compared to other STBs including ED(Y)_NoEST, ED(N)_EST and ED(N)_NoEST. The management of ED(Y)_EST gains the efficient multimedia streaming performance at large available bandwidth. During 0.3 to 0.75 Mbits of cross traffic, ED(Y)_EST scheme decodes 12.5% to 40% more packets than the other STBs. **Figure** 4 shows how ED(Y)_EST decreases the amount of indirect loss at the clients. ED(Y)_EST and ED(Y)_NoEST shows similar low indirect loss, because early dropping filter out the corrupted layers at the STB.

ActiveSTB can reduce transmission latency by eliminating the corrupted multimedia stream data. In Figure 5 and 6, the latency indicates the average delay time of packet transmission over the entire duration of the stream. Figure 5 shows measurements with 15 % error rates, while the amount of the decoded packet is shown with 25 % error rate in Figure 6. The results confirm low latency results under the ***ActiveSTB*** due to early dropping and bandwidth estimation. In Figure 5, the second well-performing scheme is ED(N)_EST, while Figure 6 indicates that ED(Y)_NoEST is the second. This confirms with earlier observation revealing how early dropping gains more performance as the error increases.

5. CONCLUSIONS

The Internet and wireless home networks have undergone rapid growth which has led to an increase in multimedia streaming services. This increase has necessitated attention to QoS issues to clients. Thus, the optimal channel management is a requisite for QoS. Hence, we showed how ***ActiveSTB*** improved the quality of the multimedia streaming service–through early dropping and bandwidth estimation. We designed ***ActiveSTB*** to solve the challenges of effective usage of the shared wireless channel, reduction of the latency, and QoS improvement. Our results demonstrated ***ActiveSTB*** overcoming these issues by its use of extracting layer information from buffered multimedia stream data using early dropping and bandwidth estimation. Based on the simulation results, we believe the methods implemented in ***ActiveSTB*** will greatly enhance the quality of multimedia streaming service data streamed to clients, thus contributing to an increase in the wireless home network usage and an increase in the growth of the STB market.

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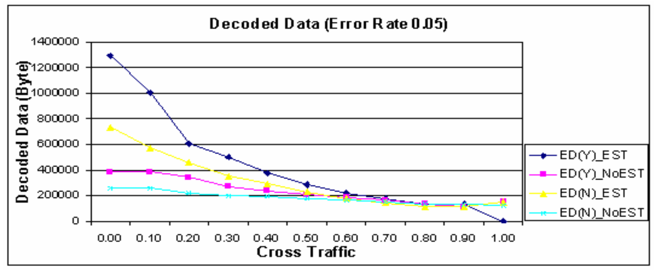

Figure 3. Packets decoded vs Cross Traffic at 5% error rate

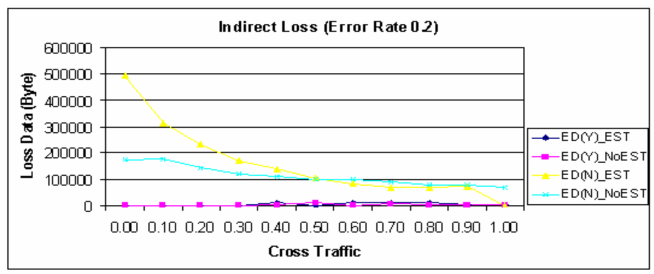

Figure 4 Indirect Loss vs Cross Traffic

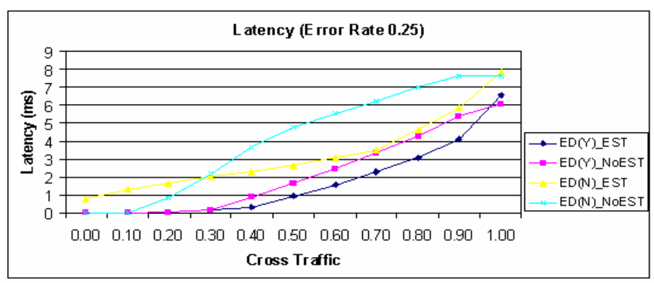

Figure 5. Latency vs Cross Traffic at 15% error rate

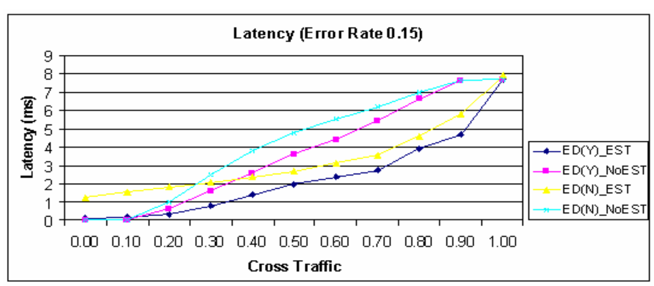

Figure 6. Latency vs Cross Traffic at 25% error rate