International Journal of Applied Information Systems (IJAIS) – ISSN : 2249-0868
Foundation of Computer Science FCS, New York, USA
Volume 3– No.4, July 2012 – www.ijais.org

Performance Evaluation of Multicast Video Streaming over WiMAX

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ABSTRACT
The demand for Mobile Multimedia streams has been increasing in the past few years. Multimedia streams can be delivered to mobile devices over a variety of wireless networks, including 3G (Third Generation mobile communication standards), Wi-Fi (Wireless Local Area Network technologies based on IEEE 802.11 set of standards) and WiMAX (Worldwide Interoperability for Microwave Access IEEE 802.16 standard) networks. The paper deals with multicasting of scalable video streams over WiMAX networks. The main goal is to perform video streaming over WiMAX networks. Multicast routing protocol PUMA is used to achieve scalability in the network. PUMA achieves desired packet delivery ratio with variable number of nodes. It proposes an experimental setup for simulation study to multicast those selected substreams to Mobile Stations (MS) via WiMAX Base Station (BS). The WiMAX patch of NIST forum is used to carry out the simulations.

Keywords
Scalability, WiMAX, Multicast

1. INTRODUCTION
With the steady increase in the Internet access bandwidth, more and more applications start to use the streaming audio and video contents. Recent development in high speed wireless networks has made it possible to provide real-time video streaming. Among those wireless standards, Worldwide Interoperability for Microwave Access (WiMAX) is prominent on the aspects of high-data rate and long-range coverage. The standard of WiMAX networks is IEEE 802.16 [1] [2] that has been developed to accelerate the introduction of broadband wireless access into the market place.

However, the quality of video streaming over WiMAX networks can drastically be degraded by varying network conditions such as transmission bandwidth [3] .Recently defined video coding schemes, like H.264/SVC (Scalable Video Coding) [4] has achieved significant improvements in coding efficiency with an increased degree of supported scalability relative to the scalable profiles of prior video coding standards. Transmitting SVC encoded videos over WiMAX networks is an effective solution which solves many of the video transmission problems over these networks.
Unicast protocols send a separate copy of the media stream from the server to each client. This is simple, but can lead to massive duplication of data on the network. Multicast protocols undertake to send only one copy of the media stream over any given network connection, i.e. along the path between any two network routers. This is a more efficient use of network capacity, but it is much more complex to implement. Thus multicasting over wireless networks is challenging goal. Multicasting is a more efficient method of supporting group communication than unicasting or broadcasting [5], as it allows transmission and routing of packets to multiple destinations using fewer network resources.
In this paper, the main goal is to scalably stream multimedia element (video) over WiMAX networks. In particular, multicasting of multiple scalable video streams to mobile receivers is considered. A scalable video stream is composed of multiple layers, where each layer improves the spatial, temporal, or visual quality of the rendered video to the user [4]. The above scenario is implemented by the WiMAX module supported by NS-2. After simulation, the received video stream is reconstructed, and then compared with the original one, in order to evaluate the effects of the scenario.
The remainder of this document is organized as follows: in Section 2.0, a brief introduction to SVC encoding, the IEEE 802.16 standard of WiMAX and the multicasting protocol PUMA is provided, in section 3.0, the problem statement is defined, and in Section 4.0, the Experimental setup or simulation environment is briefed and simulation results are explained in Section 5.0. Finally, a brief conclusion is drawn in Section 6.0.

2. BACKGROUND
A background on the work can be obtained by understanding the following terminologies and concepts.

2.1. H.264 Scalable Video Coding
H.264/SVC [4] introduces the capability of encoding a video into a bitstream which contains one or more subset bitstreams, i.e., a base layer plus one or more enhancement layers, which can themselves, be decoded independently to achieve the desired level of quality of the decoded video. Video scalability is obtained through the selection of one or more subset bitstreams and discarding unnecessary information.
The base layer consists of successive GOPs (Group of Pictures) and is fully compatible with the H.264/AVC standard. More specifically, each GOP contains an I-frame (Intra-coded picture) in the beginning, which is coded independently of the other pictures in the GOP, P-frames (Predictive pictures) containing motion-compensated difference information and B-frames (Bi-directional predictive picture). The base layer is composed of a sequence of key frames, (either I-type, or P-type), while enhancement layers are composed by hierarchically encoded B-type or P-type frames which refine the base layer up to a certain desired video quality level.

There are three main types of scalability supported by SVC – spatial, temporal, and quality (SNR) scalability. Spatial scalability means the bitstream can provide different spatial resolutions. Temporal scalability means various frame rates are available. And SNR scalability means the visual quality is scalable. To achieve the scalability, the video data is encoded into several layers. The lower layers contain lower resolution data. This data is more important because it provides basic video quality with low bit-rate. The higher layers contain the refinement data. It refines the lower resolution data to provide higher resolution video. The refinement data is less important and can be removed when the bandwidth or decoding capability is not sufficient.

2.2. IEEE 802.16/WiMAX

WiMAX is a broadband wireless data transmission technology for fixed and mobile users. It is based on the air interface protocol specified by the IEEE 802.16 standard[1] [2], which detail the Physical (PHY) and Media Access Control (MAC) layers for the wireless link between the BS and the MS. The standard for the fixed user scenario was given in IEEE 802.16d, which was later enhanced to support user mobility in IEEE 802.16e. As the MAC layer can support multiple PHY specifications, we propose the use of Orthogonal Frequency Division Multiple Access (OFDMA) PHY in which the BS allocates transmission resources to multiple MSs and data transmission is done on a frame-by-frame basis. An OFDMA frame is a fixed-sized contiguous region, in both the time and frequency domains, which is divided into downlink and up-link sub-regions. Within an OFDMA frame, the BS scheduler allocates slots to MSs, where a slot is the smallest transmission resource in a frame. In addition, we may use the Point-to-Multipoint (PMP) mode of IEEE 802.16e and the duplexing scheme to be employed is Time Division Duplex (TDD).

A service flow constitutes a flow of packets between the BS and MS with pre-defined QoS parameters. The resources allocated to a flow within an OFDMA frame is based on the QoS requirements of the service flow. The IEEE 802.16e standard supports five scheduling services to accommodate flows with diverse QoS requirements. Of these five services, the real-time Polling Service (rtPS) is designed for flows that transport variable bit rate (VBR) traffic, such as MPEG video streaming, while the Unsolicited Grant Service (UGS) is designed for flows that transport constant bit rate (CBR) traffic. We may use any of these depending on the scenario and the need for study. For example, if the primary goal is to investigate the impact that different reserved rates have on the perceived video quality, simulations can be performed using UGS and only its maximum sustained traffic rate QoS parameter can be considered.

The IEEE 802.16 supports multiple Modulation and forward error correction Coding Schemes (MCS). Based on the channel condition experienced by the MS, the BS can choose to employ different MCSs for different MSs, which can further change dynamically across frames for the same MS. Choosing a more robust MCS allows the transmission to tolerate poorer channel conditions, but results in lower data rate.
The QoE for a streaming service depends on conventional network metrics such as bit rate, packet loss rate, packet delay and jitter, and various video sequence specific factors, such as its encoding scheme and the video streaming application. Two important QoE metrics in a video streaming service are the receiver starvation probability and the received video quality. The starvation probability is the long-run fraction of frames or packets that miss their playout deadline at the receiver. The received video quality can be measured using subjective or objective video quality metrics.

2.3. Layered Transport of SVC

In order to support streaming of SVC, a new payload format for the Real-time Transport Protocol (RTP) and new signalling features for the Session Description Protocol (SDP) are currently being specified in IETF [6]. An extended media file format supporting the new features of SVC is in the process of standardization in MPEG.

Figure.1 shows an example for RTP packetization of an SVC bit stream for layered transmission. The upper part of the figure shows how the data is allocated within a media file where information of different scalability layers can be found in subsequent Access Units (AUs = video frame). In a media file, a layer or a subset of the layers representing an operation point of the scalable bitstream is assigned to a tier. Subsequent NAL units of the same tier within the same access unit are grouped by aggregators (Aggr.). The lower part shows the resulting RTP packet sequence with three RTP streams. This example illustrates the usage of different packet types. Different packet types exist like Single NAL unit packets, packets carrying fragments of NAL units or aggregation packets carrying multiples of NAL units. The latter packet type can carry NAL units of the same time-instance (AU) – Single Time Aggregation Packet (STAP) or it can carry NAL units of multiple time-instances (AUs) – Multi Time Aggregation Packet (MTAP). In the example, NAL units of layer 3 (tier 3) are aggregated from first and second access unit into one MTAP, consequently NAL units of layer 2 (tier 2) from the second access unit are sent later.

For a layer or a subset of layers of the SVC bitstream, a single RTP session may be established, i.e. in multicast scenarios the client joins multiple multicast sessions (Layered Multicast). The availability of different sessions and their dependencies need to be announced through the set-up of an RTP sessions in the Session Description Protocol (SDP).

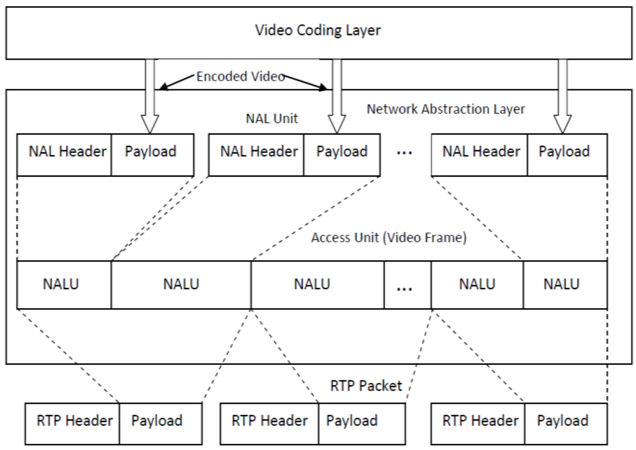

Figure 1: RTP packetization of an SVC bit stream

The layered multicast approach minimizes the need for standard extensions and leaves some flexibility for different applications. Encryption or Forward Error Correction (FEC) mechanisms can easily be applied to individual layers. Synchronization across RTP sessions between different layers will be supported by RTP timestamps. Recovering the decoding order will be achieved by an extended decoding order number (DON).

In order to allow adaptation of SVC bitstreams within a network, Media Aware Network Elements (MANEs), in the RTP terminology translators or mixers, may be used. MANEs can extract the information needed for certain operations such as layer dropping from the NAL unit header. A MANE located near the edge of a (core) network would mix several RTP streams into a single session tailored to the clients in reach or adapted to the throughput of the link on the last hop (or access network). Such an approach also reduces the number of open ports needed for that connection and thus minimizes the number of pinholes, when traversing a firewall. In this case a MANE acts like an end-point for the RTP session on its input while setting up a new RTP connection to the client on its output.

2.4. PUMA in WiMAX

Protocol for Unified Multicasting through Announcements (PUMA) [7] is used to multicast the scalable video streams over WiMAX networks. It aims to support the transportation of information from a sender to multiple receivers in a group while trying to use the available bandwidth efficiently. In PUMA, any source can send multicast data to a multicast group without having to knowing the constituent members of the group. Moreover source does not require joining the group to dispatch the data. PUMA is a receiver initiative approach where receivers join the multicast group using the address of a special core node. Every receiver connects to the elected core along all shortest paths between the receiver and the core. All nodes on the shortest paths between any receiver and the core collectively form the mesh. A sender sends a data packet to the group along any of the shortest paths between the sender and the core. When the data packet reaches a mesh member, it is flooded within the mesh, and nodes maintain a packet ID cache to drop duplicate data packets. PUMA uses a single control message for all its functions, the multicast announcement.
Multicast announcements are used to:

- elect cores dynamically
- determine the routes for sources outside a multicast group to unicast multicast data packets towards the group
- join and leave the mesh of a group
- maintain the mesh of the group

Each multicast announcement specifies a sequence number, the address of the group (group ID), the address of the core (core ID), the distance to the core, a mesh member flag that is set when the sending node belongs to the mesh, and a parent that states the preferred neighbour to reach the core. Figure.2 depicts the multicast announcement packet format.

Mesh Membership code	Distance to core
Group ID	
Core ID	
Sequence Number	
Parent ID	

Fig 2: Multicast Announcement Packet format

Successive multicast announcements have a higher sequence number than previous multicast announcements sent by the same core. With the information contained in such announcements, nodes elect cores, determine the routes for sources outside a multicast group to unicast multicast data packets towards the group, notify others about joining or leaving the mesh of a group, and maintain the mesh of the group.

3. PROBLEM STATEMENT

This work focuses on streaming the scalable video streams over WiMAX using PUMA. Consider a scenario in which numbers of scalable video streams are available at the WiMAX Base Station. Each stream is to be multicast using PUMA protocol to the group of mobile subscribers. Since it is receiver initiative multicasting protocol, mobile subscribers needs to send the data request message (multicast announcement) to the group in which WiMAX Base Station is the core node. As multicast announcement propagates through the network, it establishes the connectivity list at every node in the group. It will help in building mesh. If the core is changed, all nodes have to rebuild the connectivity list.

A node forwards a multicast data packet it receives from its neighbour if the parent for the neighbour is the node itself. Hence, multicast data packets move hop by hop, until they reach mesh members. The packets are then flooded within the mesh, and group members use a packet ID cache to detect and discard packet duplicates [14]. Figure 3 depicts the basic architecture diagram about streaming of the encoded videos over WiMAX environment.

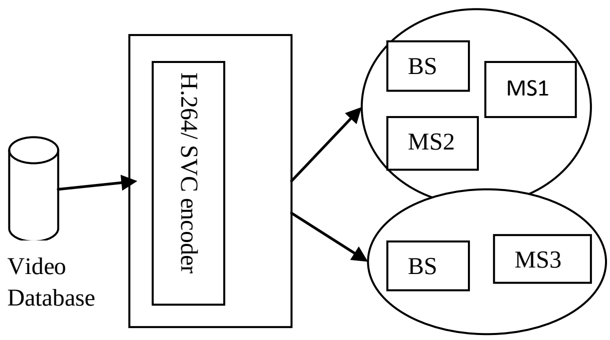

Figure 3: Video Streaming Architecture

4. SIMULATION FRAMEWORK

The goal of the evaluation framework we developed is to assess the performance of multicast video streaming using SVC over WiMAX by means of simulation. The process consists of three main phases: encoding, simulation, and decoding with the help of some post-processing operation. Figure 4 shows the flow diagram of the simulation scenario.

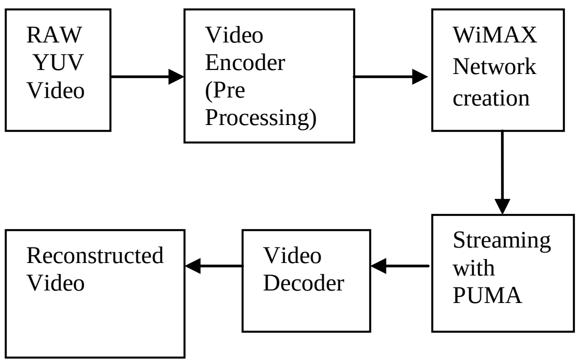

Figure 4: Flow diagram

Network Simulation environment (NS2) [8] is used for setting up the experimental setup for multicasting the scalable video streams over WiMAX. A point-to-multipoint WiMAX multimedia multicast simulator is implemented for streaming video using scalable video traces. For generating the video traffic, raw video files (YUV files) [9] is retrieved from video trace repository of Arizona State University. Then the videos are encoded into H.264/SVC format using the JSVM reference software [10]. Temporal scalability feature of the coding standard is used. Table 1 summarizes the information of the data rate and quality values of the each layer of the input video file which is fed to the WiMAX network and streaming using PUMA. After simulation, the output is post-processed in order to allow for the next operation, which is the decoding of the video stream, as it was received by the end user as a result of the simulation.

Table 1: Data rate and quality values of the input video

Layers	Data rate(kbps)	PSNR(db)
1	516	31.66
2	269	32
3	137	32
4	516	32.33
5	68	37.33

4. SIMULATION RESULTS

A performance analysis was carried out for H.264/SVC video transmission over a WiMAX network. The assessment has been performed by means of a simulation framework that allows evaluating the PSNR of an actual video streamed over a packet-based simulator. In particular, a video has been encoded with H.264/SVC temporal scalability.

A survey was conducted by allowing test subjects between the ages of 18 to 40 to view videos of varying PSNR. The PSNR values of the videos given to them were of the range of 5 to 50. The opinions were recorded in a questionnaire and the table compiled with the mean opinion score is shown in Table 2.

TABLE 2
PSNR TO MOS Conversion and impairment scale

PSNR (dB)	MOS	Impairment
>37	5 (Excellent)	Imperceptible
31-37	4 (Good)	Perceptible, but not annoying
25-31	3 (Fair)	Slightly annoying
20-25	2 (Poor)	Annoying
<20	1 (Bad)	Very annoying

4.1 PSNR

PSNR is generally used to analyse quality of image, sound and video files in dB (decibels). PSNR calculation of two images, one original and an altered image, describes how far two images are equal. PSNR mathematically is given by,

$$PSNR = 20 \log \frac{MAXI}{\sqrt{MSE}}$$

where PSNR is Peak Signal to noise ratio, MAX_I is the Maximum possible pixel valueand MSE is the Mean square error.

Our analysis showed that the PSNR value in the WiMAX network is higher than that of WLAN indicating the tremendous potential of using SVC in this network. It was observed that the Y PSNR value shows an average of 35.84 in WLAN while it shows an average of 40.73 in WiMAX for Node 1, indicating better luminance. The overall PSNR for WLAN is 26.19 while it is 31.44 for WiMAX which gives it an MOS of good as observed from Table II. While for WLAN, the MOS is fair for the same simulation scenario.

The PSNR comparison results show that H.264 SVC is an effective way of encoding videos to be sent in a WiMAX network.

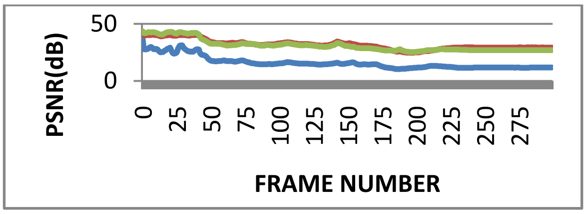

Figure 5: Video Quality evaluation-Plot of PSNR plot for the IEEE 802.11 standard

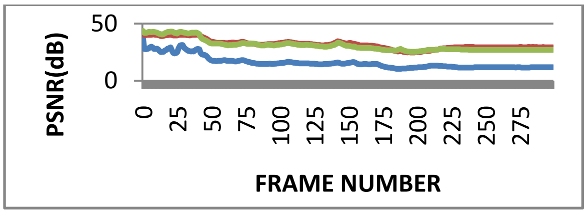

Figure 6: Video Quality evaluation –Plot of PSNR for the IEEE 802.16 standard

4.2 Peak End-to-End Delay

As video streaming is a delay sensitive application, we also compared the peak end-to-end delay between WLAN and WiMAX for a single node.

$$Pe2edelay[pktid] = received\ time - sendtime$$

From the Figure 7, it is clear that the delay is reduced tremendously in a WiMAX network. Hence the delay sensitive videos can be sent efficiently in this network.

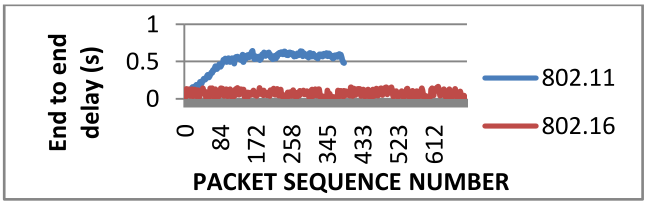

Figure 7: Delay comparison of IEEE 802.11 and IEEE 802.16 standards

5. CONCLUSION

In this work, the video was encoded using Scalable Video Coding and streamed through the multicast WiMAX network. Performance analysis was done and the quality metrics like PSNR were analyzed. The PSNR was compared with the MOS values. The end to end delay was also calculated. It was also noticed that SVC performs better in WiMAX networks than WLAN. Devising video-aware BS scheduling algorithms is a promising subject for further investigation.

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