Adaptive Multi-Rate Video Transcoding Method

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Abstract: In this paper, we propose a multiple-transcoding tree (MTt) based on video streaming to deliver smooth and continuous flow of audio visual information to multiple-users with a different quality requirement. MTt exploit the user terminal devices to transcode videos and forward to other devices. In MTt, each user determines a video quality requirement according to his/her environment capability: bandwidth, resolution, memory, processing, decoding, etc. Alone MTt transcoding tree, each receiver can receives video with specified quality.

Keywords: Transcoding, Video Streaming, Video compression, Heterogeneous access network.

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1. Introduction

Currently, one of the most essential challenges in spreading of multimedia systems is to deliver smooth and continuous flow of video contents, regardless of time and place.

A modern multimedia system may contain of various devices (laptops, Smartphones, PC’s, etc.) interconnected through a heterogeneous network (Wired/Wireless) as one eco-system. In this ecosystem, is compressed multimedia information with a particular format may require bitrates adjustment and format conversion to allow smooth delivery by the receiving devices with different capabilities: bandwidth, processing, decoding, resolution, memory, etc. Thus, an efficient transcoding mechanism is needed to make the adjustment coding content and the capabilities of user device and networks.

One more abstract definition of video transcoding is a process that enables encoding video source (V_s) in a different size, bit rates, and standards for various terminal devices, and re-encodes video after the decoding for conversion of the features of the encoded target video (V_t).

The video transcoding is classified in the three categories of video transcoding which update the bitrate of the streamed video content [1, 2].
First category is called: closed loop transcoding or Cascaded Pixel Domain Transcoder (CPDT) [3]. The original video is fully decoded, and then encoded. The second one is named: Open Loop Transcoding (OLT) [4] doesn't fully decode the stream but concerns with the DCT phase. This solution saves CPU time but the quality offered is not good as we compare with the CPDT solution. Finally, is an intermediate solution that pushes the decoding process deeper than OLT. This category is named DCT Domain Transcoder (DDT) [5] and an implementation has been realized [6].

In general, video transcoding plays several roles, such as bitrate and format conversions, to convert one compressed video stream to another. Transcoding can enable multiple receivers of diverse capabilities and formats to delivery video content on heterogeneous network platforms, such as the Internet. One example is delivering a high quality video source to various devices (Desktops, PDAs, laptops, etc.) on wired and wireless networks. The transcoder may be placed either in the transmitter or receiver to generate a suitable bitstream directly from the source bitstream without having to decode and re-encode. To adapt available network bandwidth, transcoder can perform dynamic adjustments in the bit-rate of the video bitstream without additional functional requirements in the decoder [1, 2].

Another example, the video conferencing systems transcoding on the Internet, which the users may be using different devices. A video transcoder can provide conversion format to enable content exchange, and perform dynamic bit rate adjustment to proper using of network resources. Thus, video transcoding is one of the fundamental components for current and future multimedia systems to provide universal access [3, 13].
The transcoding is divided into homogeneous and heterogeneous transcoding. A heterogeneous transcoding performs conversion between different video coding standards [1]. Homogeneous transcoding converts bit-streams within the same standard with frame-rate adjustments, an adaptive quantization and a resolution conversion [6]. Nowadays, several compression standards exist for different video applications. Each standard may be used in a range of applications. ITU (International Telecommunication Unit) H.261, H.263, and H.264 are designed for low bitrate video streaming applications such as videophone and videoconferencing [4, 5]. MPEG-1/2/3/4 standards were defined by ISO (International Organization for Standardization). MPEG1 was defined for Video on digital storage media (CD-ROM). Then MPEG-2, which was designed for high bit rate high quality applications such as digital TV broadcasting and DVD, and MPEG-4, for multimedia applications including streaming video applications on mobile devices [6, 7]. An enhanced MPEG-7, for search content description multimedia database, MPEG-21 was developed as standard with many phases. Such as MPEG-21, Digital Item Adaptation (DIA), defines tools for the adaptation of Digital Items, e.g. audio and video streams [8]. MPEG-21 Bit-stream Syntax Description (BSD) allows retrieving a variety of adapted versions of media streams from a single bit stream by performing efficient editing style operations. MPEG-21 DIA does not define interactions with existing transport and network technologies [8]. Finally, H.264/MPEG-4, a combined standard which was defined for improve video compression from 10-100kbs. As the integration of different applications and networks (wired/wireless) with each other, inter-compatibility between various systems and platforms are becoming more important and desirable. Thus, transcoding mechanism is needed to provide interoperation of multimedia streams within and across different standards. Fig.1, presents abstract transcoding schema of compressed video, spatial and temporal resolution conversions. [5, 6, 8].

2. Related Works

In the previous works, several approaches have proposed for video delivery to multiple-users with various quality requirements.

Online transcoding technique [6], the video is transcoded at a server or an intermediate device to videos with different qualities, the video received according to the users demand, and forwarded to the receivers. However, large computation power required for transcoding can be a problem.

In multi-versions method [7], the source video is segmented into multiple segments or versions of videos with various bit-rates, all users can receive the best one, according to his/her resource limitation. However, in multi-versions implementing control mechanism is simple, but not efficient in terms of network bandwidth usage and server storage.

In the layered multicast technique [8, 9], an original video is encoded by using layered coding techniques such as [10, 14], any user can

![Fig.1 Transcoder schema](image-url)

Table 1: An overview of video compression standards

<table>
<thead>
<tr>
<th>Standards</th>
<th>Applications</th>
<th>Bit-rate</th>
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<tbody>
<tr>
<td>H.261</td>
<td>Video teleconferencing over ISDN</td>
<td>64-kbps</td>
</tr>
<tr>
<td>MPEG-1</td>
<td>Video on digital storage media (CD-ROM)</td>
<td>1.5-mbs</td>
</tr>
<tr>
<td>MPEG-2</td>
<td>Digital TV</td>
<td>2-20mbs</td>
</tr>
<tr>
<td>H.263</td>
<td>Video telephony over PSTN</td>
<td>&gt;33.6kbs</td>
</tr>
<tr>
<td>MPEG-4</td>
<td>Multimedia over internet, object based coding</td>
<td>Variable</td>
</tr>
<tr>
<td>H.264/MPEG-4</td>
<td>Improved video Compression</td>
<td>10-100 kbs</td>
</tr>
<tr>
<td>MPEG-7</td>
<td>Content description multimedia database searches</td>
<td>Variable</td>
</tr>
<tr>
<td>MPEG-21</td>
<td>Multimedia terminal specification</td>
<td>Variable</td>
</tr>
</tbody>
</table>
decode the video by receiving many layers as possible within his/her resource limitation. In this method, when the number of user's is increase, then more layers are required in order to enhance user satisfaction degree. However, decoding process to getting video from many layers is required large computing power, and buffers.

There are a numerous study has been offered on video streaming in peer to peer networks. Ref [11] has proposed the Overlay Multicast Network Infrastructure. In this method, the user device plays two roles: works as a service provider and/or a service user. In this method, all users can receive a video via multicast delivery tree. One of the main characteristics of this method is to adapt the change of the user device distribution and the network conditions. In the ref [12] proposed a CoopNet method, when the server load is high, the user device cache parts of stream data, and deliver them via multiple diverse distribution trees to the user devices. The aim of this approach is adaptive video delivery service while dynamic change in the video server.

However, all previous works do not manipulate with video delivery to multiple-users with the various quality requirements, and the heterogeneity between users of various capabilities (such as available bandwidth, computation power, display resolutions, memory, decoding, etc.) over heterogeneous and homogeneous networks (wireline/wireless) as one ecosystem.

3. Theoretical Model of Expected Distribution

To show how our model works in detail, first, define the multiple-transcoding tree. Then explain the structure of multiple Transcoding tree (MTt) algorithm and how the user specifies the quality is demand. Finally, the MTt and failure recovery is handled.

3.1 Definitions of Multicast tree Notations

We denote \( s \) a video content server, and let \( N = \{ n_1, n_2, \ldots, n_i \} \) set of user devices. For each device \( n_i \) available upload-bandwidth \( n_i.up \), and download- bandwidth \( n_i.dwn \). Let \( n_i.q \) a video quality requirement. The video quality requirement consists of multiple video parameters: bit-rate, picture-size and frame-rate are determined. In this work, we assume that the video quality requirements represent only bit-rate of video. Let \( n_i.trs \) presents the maximum number of video transcoding by device \( n_i \). Let \( n_i.fr \) denote the maximum number of video forwarding by device \( n_i \). In this propose, we proposed a multicast video streaming tree, which consist of \( s \) is a root device and user devices in \( N \) are internal or leaf devices. This Tree named a Multiple-Transcoding tree (MTt).

3.2 The Structure of the MTt

Internal devices in MTt, transcode and transmit videos to the children devices. We assume \( K \) is a predetermined constant. To decrease the number transcoding of between the root device and each leaf device, we construct MTt, with multiple video streaming trees. In the MTt, for each device \( n_i \epsilon N \) available \( n_i.q \) and to each of its child devices \( n_j \), and \( n_j.q \leq n_i.q \) must holds. The children have the same \( n_j.q \) grouped together; we called that: layer. We assume that \( R \) is pre-determined constant, Fig. 2 shows that. All user devices within a same layer, receive the same video quality. Here, this quality is named the layer-quality. A relationship between all layers on the MTt is named layer-tree.

To control or manage this relation MTt, we vote one device within a layer to represent information of layer; this device is called c-device. An election of c-device is to select leader device in order to keep the leader role to serve all devices in layer as much as possible. This selection include the device position with respect to the device center, the residual energy, CPU computing power, the available memory and mobility speed.

All the devices broadcast their capability to be a leader to all the devices inside their layer. So, the device with the highest capability will be the c-device and then should announce its representative device inside the layer and for the c-device devices of all layers rather than flooding it to all the c-device in the network in order to reduce the number of control packets and reduces the overhead produced from maintaining information about the global network.

Fig.1 shows an example of MTt with devices and layers, \( K = 2 \) and \( R = 3 \). So that, each bitrate (such as 800kbps) represents the layer-quality:
Fig. 2. Example of MTt, Where K=2 and R = 3.

3.3 The Operation of MTt
In MTt based, divides N into the set of candidate internal device $Ni$ and the set of leaf devices $nj$. We always put $s$ into $Ni$. Each $ni$ determines a proper tree to join based on $ni.up$ access link bandwidth or $ni$ requirement. In MTt, the video content is encoded into multiple different qualities, and each quality $q$, is delivered over one tree as shows in Fig. 3. To keep the internal devices balanced among different trees, a new device is added as an internal device to the tree that has the minimum number of internal devices, and quality layer of $ni.q \geq nj.q$. To maintain short trees, a new internal device is placed as a child for the device with the lowest depth that can accommodate a new child require quality $q$. In the latter case, the new device replaces the leaf device and the partitioned leaf should rejoin the tree similar $nj.q$ to a new $nj$.

2.4 MTt and Failure Recovery
When an internal device $ni$ of a tree departs (or die) or broken link, each one of its child devices $nj$ as well as the subtree rooted at them are partitioned from the original tree, and thus should rejoin the tree as shown in Fig. 4. Device in such a partitioned subtree initially wait for the root of the sub-tree to rejoin the tree as an internal device. If the root is unable to join the subtree after a certain period of time, individual devices in a partitioned subtree independently rejoin the tree with the same position as leaf or internal device this is present in Fig. 4. The content delivery is a simple push mechanism where internal devices in each tree simply forward any received packets for the corresponding description to all of their child devices. Therefore, the main component of the MTt streaming approach is the tree construction method.

4. Results Analysis
We used network simulation-2 (NS-2), in order to test the simulator and study the performance of the method. This simulation was run using a networks tree with 5-10 devices moving over of 500 m 500 m area over 30 seconds of simulation time. The traffic generator used by the source in the simulation is constant bit rate (CBR). The generator initiated the first packet in different time and sends 512 bytes packets every 20ms time interval. Devices in our simulation move according to the Random Way Point mobility model provided by NS-2. We consider a scenario with 1 source and 5 destinations in all experiment. The IEEE 802.11 Distributed Coordination Function was used as the medium access control protocol.

In Fig. 5, we can show the relation between the ratios of packet delivery and the devices mobility. We can observe from Fig.5, when the device mobility speed increases, the packet delivery ratios decrease because of link broken. Fig. 6 shows the relation between different mobility speeds and the throughput. It is clear that when their no device mobility the number of bits transmitted per second gains the highest value and then decreased with increasing the devices movement speed. This is due to the increasing percentage of broken links caused by devices movement.
5. Conclusions and Future Works

Today, streaming is a very promising model to construct various distributed multimedia applications. With streaming, a user does not have to wait to download video file to play it and can watch the video in real-time. We propose a multiple-transcode tree (MTt) based on video streaming to deliver video for multiple users with the diverse quality demands and exploit user devices to transcode videos and forward to other devices. In MTt, each user can determine video quality requirements according to his/her resource limitation (bandwidth, display, memory, processing, decoding, etc.). Alone MTt, each user can receive video with specified quality. In this paper we presented a centralized method, as part of the future works we will design a free distribution algorithm.

References: