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DYNAMIC RESOURCE ALLOCATION FOR LAYER-ENCODED VIDEO MULTICASTING OVER WIMAX NETWORKS

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ABSTRACT

This paper presents a method to multicast multiple videos to a set of users (Subscriber Stations) from a Base Station using WiMAX networks by incorporating layer encoded streaming technique. This method makes the system dynamically adapt to the channel quality available and also ensures Quality-of-Service (QoS) and maximum satisfaction to all users. The advantage of using this system is that the available bandwidth can be utilized to the maximum and any unused processes can have its resource freed.

Keywords: *WiMAX, QoS, Multicasting, Layer Encoding, Video Transmission*

1. INTRODUCTION

WiMAX (IEEE 802.16) is an emerging broadband wireless technology for residential and commercial users. In such networks, each Base Station (BS) serves as the gateway to access the Internet for multiple Subscriber Stations (SS) located at customer premises. WiMAX provides bit rates up to 70 Mbps and is part of the fourth generation (4G) of wireless communication technology. It offers a signal radius of about 50 km and allows users connectivity without a direct line of sight to a base station. The advantages of using WiMAX are that it provides mobile broadband connectivity across cities, a wireless alternative to cable and triple-play. It also uses Orthogonal Frequency Division Modulation (OFDM) technology, as it lowers power consumption rate. Uninterrupted high-quality video transmission has become a necessity that is needed to be incorporated in any wireless standard. WiMAX is one standard in which this application can be put to maximum use. This paper presents a method to transmit video streams from a BS to multiple SS in as much higher quality as possible. The quality of the transmitted stream is manipulated according to the channel conditions and the distance between the BS and a SS.

The challenge in providing video multicasting over wireless networks is that the link condition of each user in the same multicast group may not be identical due to location of the user and/or congestion of the network. In WiMAX, adaptive coding and modulation is supported, and each SS must negotiate its burst profile with the BS before the connection starts and can also exchange its burst profile with the BS during the connection. Here, the burst profile is the set of coding and modulation settings adopted by the SS so as to reflect the dynamic link condition. Different burst profiles lead to different levels of robustness and transmission rates. The worse the channel condition is, the more robust the burst profile is, and hence the lower the data rate is. In WiMAX, to multicast a video stream to a set of users with different burst profiles, the video is encoded by the BS with the most robust burst profile in the group so that all the users can receive the program with the same video quality. As a result, having more users in a group implies that it is more likely the video stream will be encoded with a more robust profile, and therefore, more resource is consumed to transmit the same amount of data. The fluctuation in video quality over time may significantly hamper the successful deployment of video multicast service over WiMAX.

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In this paper, this problem is tackled by the incorporating layer encoded video multicasting. Layer-encoding of a video stream is the process of encoding the video file at different bitrates and then streaming it through different ports. Here, the possibility of streaming the same video file at different bitrates to different sets of users based on their bandwidth quality is also discussed. Video multicasting is the process of delivering video content to a group of destination devices (Subscriber Stations) in a single transmission from the source server. This system uses IP multicast which is a technique for one-to-many communication over an IP infrastructure in a network. It can be used to multicast to a large number of subscribers by not requiring prior knowledge of how many receiving Subscriber Stations (SS) there are. Multicast uses network infrastructure efficiently as it requires the source to transmit a data packet only once, even while delivering it to a large number of receivers. This system also uses dynamic resource allocation so that bitrate manipulation can be done in real time. Resource allocation is the process of dividing the available radio resource and allocating it to each SS. Dynamic resource allocation is the process of manipulating the quality of video stream based on the available signal strength for a particular user. The signal strength varies with the no. of users in a sector or the distance between the Subscriber Station and the Base Station. This process is performed in real time.

2. RELATED WORK

Many solutions have been proposed to tackle the problem of layer-encoded video multicasting in a wireless network where radio resources are limited. In the work of Wang *et al.* [1] a cooperative multicast scheme is proposed where the resolution of the video that is to be transmitted is adjusted based on the link condition. The problem with this scheme is that it utilizes more memory resource in the back-end server and also does not provide pleasing viewing experience to the users. Zhengye Liu *et al.* [2] propose a Layer Bargaining scheme to reduce packet losses induced by the underlying wireless channel by exploring light-weight feedback. We implement the concept of burst profiles instead of light-weight feedback as it is more resource efficient. Chih-Wei Huang *et al.* [3] propose a joint user scheduling and resource allocation algorithm that provides enhanced quality and efficiency for layered video multicast over Mobile WiMAX. The problem with implementing in Mobile WiMAX is that it is more cost sensitive. Sundaresan *et al.* [4] also propose a scheme which uses multi-resolution modulation for providing real-time video services over OFDMA networks. This scheme also has to deal with the issue of more memory resource usage at the back-end server. In the work of Liu *et al.* [5], it is assumed that the data rate is identical for each receiver and hence Base Station (BS) cannot adjust the transmission rate based on the network condition. Kuo *et al.* [6] [7] have proposed a system where they limited the scope to multicasting IPTV channels. Sharangi *et al.* [8] have proposed a system that reduces the energy consumption of SS devices.

3. PROPOSED SYSTEM

In this paper we present an algorithm for dynamic resource allocation for multicasting video content over WiMAX networks. In our scheme of things, the videos that are to multicast are first encoded at the highest possible quality stored on a server that is then connected to the base station via a dedicated broadband connection. Since the signal coverage area of the base station is divided into three sectors, namely α, β and γ, three separate instances of the proposed algorithm are run. The subscriber station (SS) latches onto a base station (BS) and then the user is authenticated and authorized by the BS. The signal strength of each SS is then sent to the BS. Depending upon the signal strength of the SS and the available radio frequency (RF) resource, the BS streams the suitably encoded video stream from the server. The server encodes the video file at a specific bitrate only after receiving a request from the BS. Since the BS has to transmit multiple video streams simultaneously, each video stream is transmitted through a different port. If the available RF resource is limited, then the BS transmits a marginally lower quality video stream to the SS even if the SS has the network condition to receive a higher quality stream. If a particular stream of bitrate of the video file is not required by any SS, then the encoding of the video file at that bitrate is completely stopped. In this way, the available RF resource can be effectively utilized.

In this type of layer-encoded video multicasting, each layer is represented by a particular bitrate stream of the video file. The layers are divided into two types: the base layer and the progressive layers. The base layer contains the important information about the stream. In our case, the base layer is the video stream of the lowest possible quality. This

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low quality stream should be such that video should be properly viewable without major discrepancies. The progressive layers can be sent to the Subscriber Stations as and when channel quality improves.

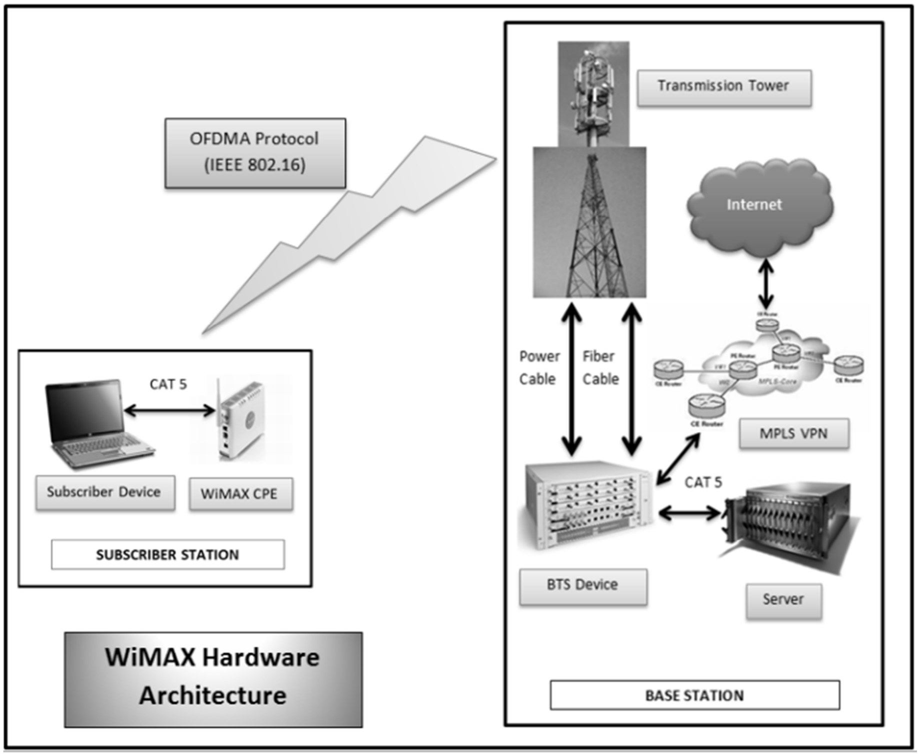

Figure 1: WiMAX Hardware Architecture

The progressive layers are the streams with better bitrates. The number of layers received by the SS is adjustable based on the channel quality. Each SS sends a Burst Profile (BP) to the BS as and when the channel quality changes. When the BP indicates that the channel quality has improved, the BS transmits the next progressive layer to that particular SS. As opposed to this, if the BP indicates that the channel quality has declined, the BS transmits the previous progressive layer i.e. the stream with marginally lower quality video stream. At any point, if the BS determines that the remaining RF resource is limited, it will transmit a lower progressive layer even if the SS is in a better network condition.

In a Base Station, the WiMAX transmission tower is connected to the Base Transceiver Station (BTS) device by a fiber cable. The BTS device is directly connected to a server where the videos to be multicast are stored. The BTS device can also be connected to a MPLS VPN network which is in turn connected the Internet. The MPLS VPN is used to provide traffic isolation. This provides unrestricted internet access to the Subscriber stations. The SS can either be a device with inbuilt WiMAX modem or a device connected to an external modem. The external modems are of two types: indoor and outdoor modems. In Fig. 1, an indoor modem is featured.

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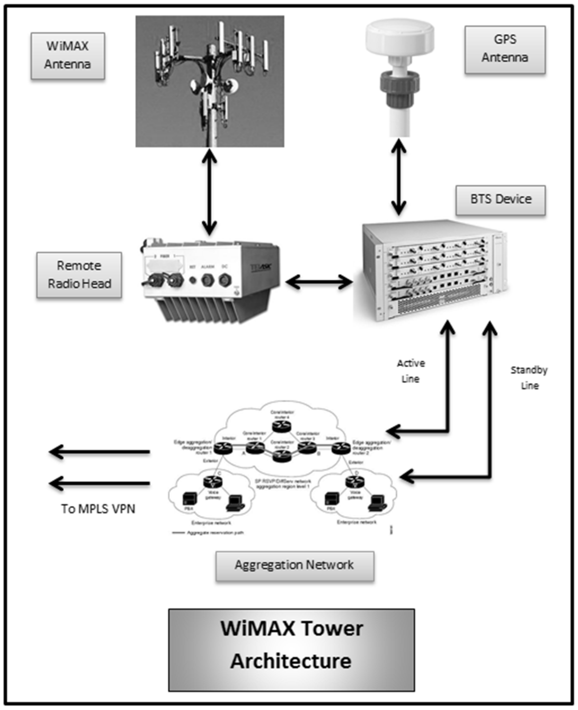

Figure 2: WiMAX Tower Architecture

The antenna in a WiMAX transmission tower is connected to a Remote Radio Head (RRH) so that the BTS device can be remotely controlled. A Global Positioning System (GPS) antenna is also connected to the BTS device. The GPS antenna is used to measure precise time. The BTS device is then connected to an aggregation network in order to aggregate all the towers under a single control station. A standby line is used in case of any emergency.

3.1 Algorithm

Table 1: Dynamic Resource Allocation Algorithm

Let P_1, P_2, P_3, …. , P_n be the programs to be multicast.
Let B_1, B_2, B_3, …. , B_i be the burst profile of each user.
Let L_1, …., L_i be the no. of layers for each program
Assume that the total utility of the entire network is U_s
Let U_T be the threshold utility of the network.

For a user X_j,
  Utility for i^{th} layer of program P_n is U_i
  Burst profile B_i of the user asks for i^{th} layer to be transmitted to itself
If the current U_s exceeds U_T, then
  Allocate $(i-1)^{th}$ layer of program P for new user X_{j+1}
  Reduce one layer of the least popular program for a random user
  Repeat these two steps when new user tunes in
If channel quality for user X_j changes,
  Allocate the layer that corresponds to the channel quality.

Here the programs are ordered based on their popularity. The most popular programs are allocated most resource and the least popular programs are allocated lesser no. of layers even if a user has channel quality to receive it. So the bandwidth saved is utilized to transmit other programs.

4. PERFORMANCE ANALYSIS

The specific video file is streamed from the server using encoding software such as Microsoft Expressions Encoder. Each layer is then streamed through a different port.

Figure 2: *Video is encoded and streamed from Base Station*

Figure 3: Video is viewed from Subscriber Station

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4.1 Video Quality Examples

4.1.1 Case 1

When an SS is located far away from the BS or when the SS is located in a nearby congested sector, a layer of lower order is transmitted to the SS. In this case the video is encoded at a bit rate of 260 Kbps and frame rate of 12 fps.

Figure 4: *Sample video frame from Layer 1*

4.1.2 Case 2

When an SS is located at mid-range distance from the BS, or when the sector is not too congested, a layer of middle order is transmitted to the SS. In this case the video is encoded at a bit rate of 529 Kbps and frame rate of 20 fps.

Figure 5: *Sample video frame from Layer 3*

4.1.3 Case 3

When an SS is located closer to the BS, or when the sector is sparsely congested, a layer of higher order is transmitted to the SS. In this case the video is encoded at a bit rate of 1162 Kbps and frame rate of 30 fps.

Figure 6: *Sample video frame from Layer 5*

5. RESULTS

Through this work it is shown that videos can be effectively multicast to a set of users from the BS without any interruption of the video stream. This is especially crucial when multicasting live streams and other programs with high ratings. It has also been shown that the BS can effectively transmit video to a congested coverage area and also where the link condition is weak. For every burst profile, since only the bitrate is manipulated and not the resolution of the video, the user does not experience notable loss in quality of video transmitted. This system can also be used to transmit IPTV with multiple programs. Hence, this system is more commercially viable.

6. CONCLUSION AND FUTURE WORK

In this paper, a dynamic resource allocation scheme for layer-encoded multicast streaming service in WiMAX networks has been proposed. The system presented in this paper can be effectively used to transmit videos to WiMAX enabled devices either in IPTV or Video-on-Demand format. This system reduces wastage of precious bandwidth in the 4G spectrum. The users are also able to get uninterrupted video transmission even when the signal coverage is weak. The algorithm presented here can effectively manipulate the transmission rate so that all users are satisfied without any interruption. It has also been shown that the system can tune the allocated resource to users according to the number of subscribers and the popularity of each program. A limitation that was faced in this study is that this system was implemented in a back-end server of a SS to SS scenario with small number of users and not from a back-end server of a BS to SS scenario with large number of users. In the future, it has been planned to implement this system in real life large scale BS to SS communication.

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