

Optimal Bandwidth Consumption for IPTV Services over WiMAX Multihop Relay Networks

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Abstract—The quick evolution in technologies has allowed IPTV video stream delivery over IP networks. For that reason consumers have anticipated predictions in which the evolution of IP-based next-generation networks may be eventually driven by video service delivery requirements. An IEEE 802.16j mobile WiMAX relay network is a next-generation mobile wireless broadband network. Compared to IEEE 802.16e which also supports mobility, IEEE 802.16j introduces relay stations to the network to offer improved coverage and capacity over multihop radio systems. However, to supply different IPTV services (HD-TV, SD-TV, Web-TV and Mobile-TV) to consumers, providers must have a video server for each IPTV service type, which increases network resource consumption. In this paper, we present a new mechanism for Multicast Broadcast Service (MBS). In particular, the proposed solution allows a provider to offer different IPTV services to varied users requests via WiMAX multihop relay access network. Results show that the proposed scheme ensures network load optimization and reduces bandwidth consumption.

Keywords—Multihop WiMAX Relay; IEEE 802.16j; Bandwidth consumption; IPTV services; Multicast tree.

I. INTRODUCTION

WiMAX (Worldwide inter-operability for Microwave access) or IEEE 802.16 is communication technology used for wirelessly delivering high-speed internet service to a wide geographical zone [1]. In Metropolitan Area Networks (MANs), it is typically considered as the most reliable wireless access technology. Moreover, emerging Multihop relay (MR) wireless networks provide additional coverage or performance advantage in an access network [2]. It also provides a low-cost and flexible infrastructure that can be simultaneously utilized by multiple users for a variety of applications. However, the bandwidth and range of this wireless infrastructure make it suitable to support QoS constraints required by applications, like providing data, telecommunications (VoIP) and IPTV.

Internet Protocol Television (IPTV) is gaining recognition as a viable alternative for the delivery of video by video streaming providers [3]. The mobile IPTV technology enables users to transmit and receive multimedia traffic including television signals, video, audio, text and graphic services through IP-based wireless networks with not only full support of service quality but

also with a quality experience (QoE), and security, mobility, and interactive functions [4].

Even though there are many advantages for using the IP based mobile WiMAX networks there are also some challenges. Due to the high quality IPTV services, it is impossible to guarantee the sufficient amount of the limited mobile WiMAX bandwidth for the mobile IPTV services each and every time. A Service Level Agreement (SLA) [5]-[6] between the mobile IPTV service provider and mobile WiMAX network operator in order to reserve sufficient bandwidth for the IPTV calls can increase the satisfaction level of the mobile IPTV users. For inequality between mobile WiMAX network capacity and bandwidth required by non-IPTV services and IPTV services, some requested mobile IPTV calls are blocked and some ongoing IPTV calls are dropped or quality is degraded.

WiMAX Multihop Relay technology is the adequate technology to provide IPTV services for heterogeneous user requests or their devices, because it supports QoS based multicasting functionality [7]. However, at the moment to provide varied IPTV services, providers transfer several copies of the same video content (channel), one copy for each video stream service (HD-TV, SD-TV, Web-TV and Mobile-TV). This causes increases in: bandwidth consumption and therefore influence provider video channel offering. To address this problem, we propose a solution whose objective is to reduce bandwidth consumption and supports varied services.

This paper is organized as follows. Section II presents an overview of the proposed solution. In section III, we look at the related work and background of the mechanism used. The proposed mechanism is presented in Section IV. In Section V, we present the simulation results for the proposed scheme. Finally, we conclude our paper in Section IV.

II. PROPOSED SOLUTION

In this paper, we are interested in IPTV (internet protocol television), which is an application which is currently increasing. Over the course of the next few years, the number of global IPTV subscribers is expected to grow from 28 million in 2009 to 83 million in 2013[8]. Depending on the network architecture of the service provider, it is possible to have varied services for the same video content (HD-TV, SD-TV, Web-TV and Mobile-

TV). Today, providers' video server architecture model is relatively simple and easy to manage. This is because providers use one server for each IPTV video service as is shown in Fig. 1. But, this increases bandwidth consumption when providers send each IPTV service flow separately.

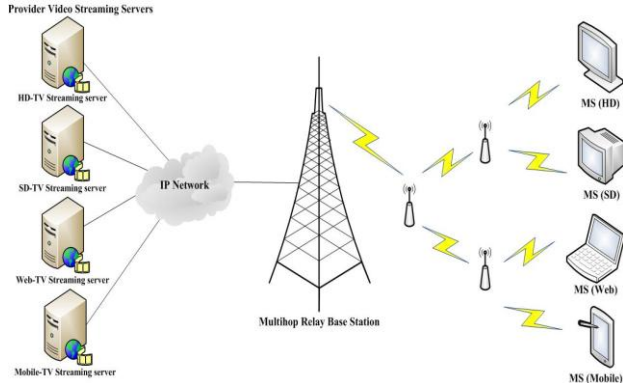


Figure 1. Traditional network architecture for IPTV services.

To solve this problem, we propose a new multicast mechanism for IPTV application over WiMAX multihop relay network, which would make it possible to reduce bandwidth consumption while satisfying QoS requirements. The main idea of our solution is to use only one video streaming server for all IPTV services as is shown in Fig. 2. We use Scalable Video Coding ‘SVC’ to extract video to different IPTV services. Furthermore, we propose a new multicast tree construction method by introducing MT-CID (Multicast Tunnel CID) and Transmission Identity (TxId). The TxId is attributed for each IPTV services (HD-TV, SD-TV, Web-TV and Mobile-TV) to extract video contents towards its destination with the requested quality.

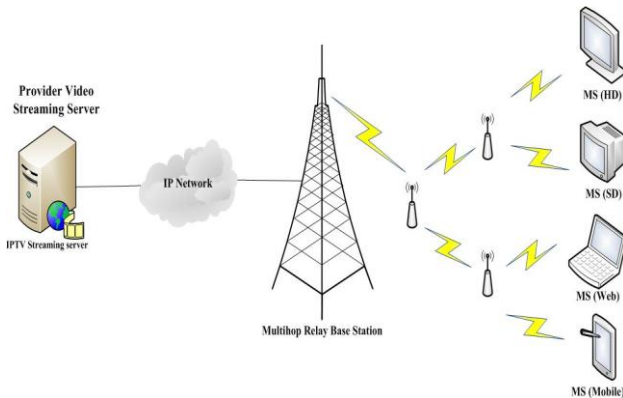


Figure 2. Proposed network architecture for IPTV services.

III. RELATED WORK

Several references have examined real time applications and more precisely IPTV in WiMax networks. For example in [7], an IGMP proxy is proposed to send Leave/Join/Report to the upstream router on behalf of the wireless sub-network. The proposal can save power

consumption caused by asynchronous IGMP Query messages and improves the uplink throughput. In [4], the authors propose a SLA negotiation procedure for mobile IPTV users over mobile WiMAX networks. The Bandwidth Broker controls the allocated bandwidth for IPTV and non-IPTV users. The proposal dynamically reserves bandwidth for the IPTV services and increases the IPTV user’s satisfaction level.

In [9], He et al. have proposed a standard-based cost-effective solution in order to support MBS services in WiMAX multi-hop relay network. They define a BS-oriented source-routing protocol to automatically discover relay network topology where the mobile relay station forms an ad hoc topology. They have used IGMP snooping protocol on the BS to automatically track the MBS group membership and service activation.

To address the optimal routing and bandwidth provisioning problems for survivable multicast in networks supporting IPTV services. Network-coding-based approaches and two tree-based approaches are formulated by integer linear programming in [10].

In [11], the invention relates to a multicast router of a content distribution system and a associated method adapted for receiving an upper level of a network multiplexed; in scalable video compression encoded and television video stream ,this in hand . On the other hand, it adapts the output video content to the allowed bandwidth of the lower level of the network. The authors in [11], do not take into account the constraints of QoS required by users. However, in our proposal we adapt the video stream to the user’s requests while reducing bandwidth.

IV. PROPOSED IPTV MULTICAST MECHANISM

A. Scalable Video Coding

D Traditional digital video transmission is based on H.222.0 MPEG-2 systems for broadcasting services over satellite, cable, and wireless transmission channels, or on H.320 for conversational video conferencing services. These channels are typically characterized by a fixed spatio-temporal format of the video signal (SDTV or HDTV or CIF for H.320 video telephone) [12].

Scalable video coding (SVC) allows a single data stream to contain multiple speeds and resolutions. Solving the problem with applications that stutter, skip and crash when they cannot keep up with bit rates. SVC enables a single encoder to create a video bitstream that contains several bitstreams which can be separately decoded by dropping packets to down-sample for lower spatial resolution, lower temporal resolution or a lower quality, or a combination of the three, as required for specific client viewing hardware [13].

In the proposed mechanism, we use Scalable Video Coding to adapt the data size to the changes in video stream parameters. SVC is a highly attractive solution to the problems posed by the characteristics of modern video transmission systems [12]. In our solution, we integrate SVC functionalities for each RS in order to extract IPTV video stream to various format (e.g., HD-TV, SD-TV, etc).

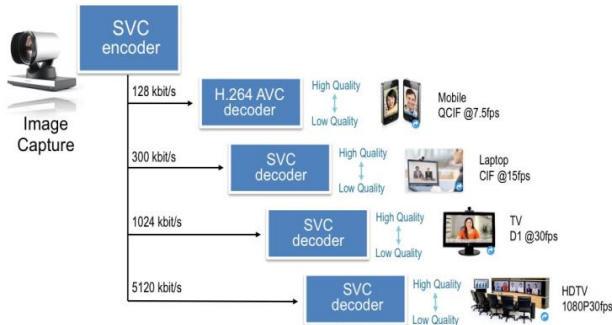


Figure 3. The Scalable Video Coding (SVC) principle [13].

B. Multicast in WiMAX Multihop Relay

MBS (Multicast Broadcast Service) in WiMAX is based on the ability of the WiMAX network to provide flexible and efficient mechanisms to send common content to multiple users sharing the same radio resources [9]. To support consumer’s heterogeneity in WiMAX multihop relay technology, we propose a new multicast solution which is based on SVC and Transmission Identity. We attribute a Transmission Identity (TxId) for each IPTV service, as it is shown in the Table I. TxId enables BS and RS to transfer only one copy of IPTV video stream with high quality.

TABLE I. IPTV SERVICE TRANSMISSION IDENTITY MAPPING

IPTV Service	Transmission Identity
High definition (HD-TV)	TxId=1
Standard definition (SD-TV)	TxId=2
Web-TV	TxId=3
Mobile-TV	TxId=4

In this context, our intention is to propose a new multicast tree construction strategy that reduces bandwidth consumption by sending only one copy of IPTV video stream, supporting various IPTV services through the use of SVC and TxId.

C. Multicast Tree Construction

As mentioned on IEEE 802.16j standards, the multicast traffic will be transmitted from the MAC layer. Since, the multicast traffic will have been transmitted from the ASN-GW or other multicast [9]. A capable network which uses the IP network layer must use a mapping table to address the traffic transmission problem. Table II shows an example of mapping tables.

TABLE II. IP MULTICAST ADDRESS TO MULTICAST CID MAPPING

IP Multicast Address	MCID
224.0.0.100	MCID1
224.0.0.200	MCID2

In WiMAX MR Networks, it is necessary for MR-BS to control and manage all RSs at the same time. Compared to unicasting identical control messages are required for every RS, the use of multicasting control message by MR-BS to RSs is more efficient. In the proposed mechanism, we perform multicasting along a tunnel by using the MT-

CID (Multicast Tunnel CID) which allows identifying a single link between two RS’s or an RS and the MR-BS. With this solution, we can achieve multicasting for IPTV delivery along tunnel connection with less bandwidth consumption.

As 802.16j networks are comprised of multihop paths between the MR-BS and MS, routing and path management issues then arise. Although routing in such systems is tree based, there can be decisions to be made regarding which RS a particular MS should be associated with. To create paths, MR-BS makes centralized computation for the path between the MR-BS and an access RSs for both the uplink and downlink direction. After building up the path information to the destination MS, MR-BS create or update an information table that contains the mapping between a MCID and one given path. The MR-BS selects a path to carry the traffic for the new connection, and informs all the RSs on the path of the binding between the path-ID and the supported CIDs by sending a DSA-REQ message to all the RSs on the specified path [2]. Fig. 4 shows an example of Multihop relay WiMAX network by introducing MT-CID, when we have one MR-BS and five RSs.

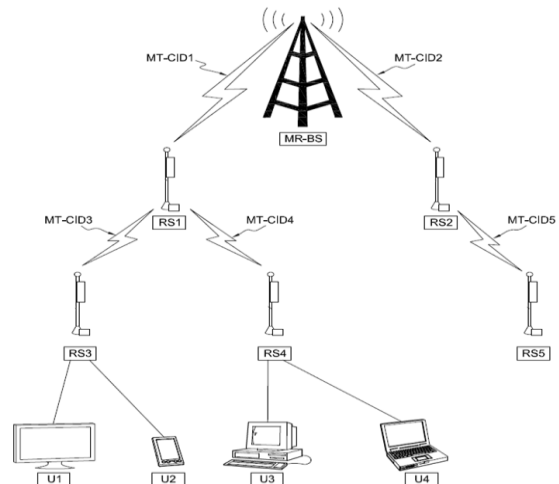


Figure 4. Multihop relay WiMAX network example

For MBS (Multicast Broadcast Service), MR-BS may initiate a multicast tree construction. When a MS wants to demand a MBS, it sends a DSA-REQ message to MR-BS to specify that it wants the MBS [14]. The procedures for establishing multicast tree are below.

When a MR-BS initiates a MBS or receives a MBS request from a MS, it verifies whether the requested MBS has been created. If not, the MR-BS creates a multicast tree for this MBS and allocates a multicast CID (MCID) to it. The MR-BS also determines the path(s) to carry this multicast service flow, attributes the adequate Transmission Identity (TxId) for each MS IPTV video stream request. In the case of our network example shown in Fig. 4, MR-BS creates paths as is illustrated in Table III, thereafter it creates the mapping between the determined path and the MT-CID like is shown in Table IV.

TABLE III. RELAYS BELONGING TO A PATH

Path-ID	Relay
Path-ID1	RS1, RS3
Path-ID2	RS1, RS4
Path-ID3	RS2, RS5

TABLE IV. MULTICAST TUNNEL CID WITH PATH-ID MAPPING

MT-CID	Path-ID
MT-CID1	Path-ID1, Path-ID2
MT-CID2	Path-ID3
MT-CID3	Path-ID1
MT-CID4	Path-ID2
MT-CID5	Path-ID3

The MR-BS saves all information in its diffusion table. To inform all RSs with which quality (TxId), they must extract and transfer video steam content. However, MR-BS sends a DSA-REQ to indicate to RSs on the path of the binding between the path-ID, MCID and the TxId. Each RS along the path stores this information for sending multicast video stream with the appropriate quality (TxId). The MR-BS adds this path to the multicast tree that may consist of multiple paths.

If the multicast tree has been created and an MCID has been allocated to this MBS, the MR-BS would determine the path to carry this multicast service flow. Also, if the path is already in the multicast tree, the MR-BS updates its diffusion table and informs all RSs of accomplishing this change. When the parameters for a multicast service flow change, an MR-BS or MS may also send a DSC-REQ message to update these changes. All the RSs in the multicast tree of the MBS are informed of these changes.

When an MS needs to leave the multicast service, the MS sends a DSD-REQ to the MR-BS to request deleting it from the MBS. MR-BS may remove the path from a multicast tree. When an MS needs to leave the MBS, the MR-BS determines whether the path can be removed from the multicast tree. If no more MSs use this path for the MBS, the path may be removed from the multicast tree. Otherwise, the path would not be removed from the multicast tree. If the path is removed from the multicast tree, the MR-BS removes the binding between the path-ID and the MCID, it updates its diffusion table and informs all RSs in the correspond path.

In WiMAX IPTV system, when the MS selects a TV program, in addition to sending IGMP join message, it must establish a multicast connection with a MCID. However, MR-BS determines the various parameters of the requested TV flow. In order to attribute the adequate Transmission Identity to this video flow which will be used during forwarding process when a RS will send the same video stream via the same MT-CID, it would be based on the TxId. In this case, the RS sends only one copy of the video stream with the highest quality (TxId) requested by the neighbors RS's. We apply this procedure for all IPTV multicast sessions, so to support consumers' heterogeneity and to better manage the consumption of resources. Taking this into consideration, RS ensures video extraction towards all required qualities by using SVC (Scalable Video Coding).

To better understand the proposed solution, we use the topology shown in Fig. 4 for an example application. If we assume that, initially, MR-BS diffusion table is empty and the user U1 request MCID1 video stream with HD quality (TxId=1), MR-BS creates a first line:

TABLE V. DIFFUSION TABLE (A)

Path-ID	MCID	MR-BS & Relays
Path-ID1	MCID1	MR-BS(1), RS1(1), RS3 (1)

In the diffusion table above, the number in parenthesis reflects the quality of the stream (TxId) to be transmitted to the next RS in the list (or broadcast to the terminals in the case of access relay).

If afterwards the user U2 requests MCID2 video stream flow with Mobile-TV quality (TxId=4), MR-BS adds a second row to its diffusion table which is then:

TABLE VI. DIFFUSION TABLE (B)

Path-ID	MCID	MR-BS & Relays
Path-ID1	MCID1	MR-BS(3), RS1(3), RS3 (3)
Path-ID1	MCID2	MR-BS(4), RS1(4), RS3 (4)

Then, if the user U3 requests MCID1 video stream with SD quality (TxId=2), MR-BS notes from the first row of the diffusion table, the flow MCID1 is already transmitted in HD quality from MR-BS to RS1 via MT-CID1 tunnel. At the same time as shown in Table IV, the path to the user U4 borrows also MT-CID1 tunnel. Thus, it is not necessary to send MCID1 video stream flow also with SD quality via MT-CID1. The MR-BS adds a third row to diffusion table, indicating the highest quality to MCID1 flow between MR-BS and RS1, which is to say the Transmission Identity TxId = 1. The diffusion table therefore reads as follows:

TABLE VII. DIFFUSION TABLE (C)

Path-ID	MCID	MR-BS & Relays
Path-ID1	MCID1	MR-BS(1), RS1(1), RS3 (1)
Path-ID1	MCID2	MR-BS(4), RS1(4), RS3 (4)
Path-ID2	MCID1	MR-BS(1), RS1(2), RS4(2)

In the diffusion table above, the TxId indicates the transmission quality of MCID1 stream to U3 user, the MT-CID1 tunnel is listed in bold to highlight this factor.

Similarly, if the user U4 requests MCID2 video stream flows with Web-TV quality (TxId=3), MR-BS finds that MCID2 flow has already transmitted with Mobile-TV quality from MR-BS to RS1. Thus, MR-BS updates the diffusion table by adding a new line to requested flow and changing the second line to indicate the highest quality:

TABLE VIII. DIFFUSION TABLE (D)

Path-ID	MCID	MR-BS & Relays
Path-ID1	MCID1	MR-BS(1), RS1(1), RS3 (1)
Path-ID1	MCID2	MR-BS(3), RS1(4), RS3 (4)
Path-ID2	MCID1	MR-BS(1), RS1(2), RS4(2)
Path-ID2	MCID2	MR-BS(3), RS1(3), RS4 (3)

Finally, after each, diffusion table update, MR-BS informs RSs to update their forwarding table.

D. Forwarding Process

In our mechanism, the RS forwarding table contains three columns, the multicast flow identifier (MCID), the transmission identity (TxId) that represents transmission quality (ITPV service) and the tunnel MT-CID in which the identified flow must be sent. For the above example application, RS1 relay create its forwarding table as shown in Table IX.

In general, the forwarding table contains p entries, where p is the number of multicast sessions (MCID). When an intermediate RS receives a multicast packet, it first extracts a multicast session address (MCID), then the corresponding transmission identity from its forwarding table. Second, for each entry in the forwarding table, the algorithm F is executed to decide via which MT-CID tunnel video stream packets will then be transmitted.

Algorithm F

```

Begin
for (i=1; i < p; i++)
    if ( RS forwarding table TxId = Packet header TxId) then
        Send packets;
    else
        SVC extraction;
        Send packets;
    endif
end
end
    
```

TABLE IX. RS1 FORWARDING TABLE

MCID	TxId	MT-CID
MCID1	1	MT-CID3
MCID1	2	MT-CID4
MCID2	4	MT-CID3
MCID2	3	MT-CID4

V. SIMULATION RESULT

We performed simulations to evaluate the performance of the proposed multicast mechanism using Matlab, and compared it with the traditional mechanism of sending one copy of each video stream service, which requires four IPTV video servers. Contrary to our solution, we used a single IPTV streaming video server. We assume that the number of subscribers and IPTV channel requests are assigned randomly. We suppose that multihop WiMAX network capacity is greater than 256 Mbps. Table X recapitulates the simulation configurations.

TABLE X. SIMULATION PARAMETERS

Parameter	value	
Subscriber IPTV services request	Random	
Maximum number of IPTV channels	60	
Channels request	Random	
Maximum allowable bandwidth for the IPTV services [Mbps]	256	
IPTV services	Random [1, 4]	
Requested bandwidth by a IPTV service [Mbps]	HD-TV	6
	SD-TV	2.5
	Web-TV	0.650
	Mobile-TV	0.350

To compare the proposed mechanism with the traditional approach, we developed several scenarios based on bandwidth metrics.

Fig. 5 compares bandwidth consumption for the proposed mechanism and traditional mechanism. We assume that subscribers request IPTV channels until maximum allowable bandwidth. Fig. 5 shows that, the proposed mechanism can reduce bandwidth consumption by sending only one copy of video stream. Hence, our solution can provide the same services but it requires less bandwidth and only a single video server. When the number of subscribers or the number of IPTV channels increased the proposed mechanism gives the best performance.

Fig. 6 shows that when all IPTV channels are requested with all qualities (60 in our simulation), with the proposed mechanism there is no more bandwidth consumption. This means that we do not need the use of more bandwidth. However, in the traditional mechanism the bandwidth consumption continues to increase to provide all IPTV services.

In Fig. 7, we change the maximum number of IPTV channels to 20, in order to show that with the proposed mechanism bandwidth consumption quickly becomes constant due to all IPTV services requested and served before. On the other hand, bandwidth consumption of the traditional mechanism always increases.

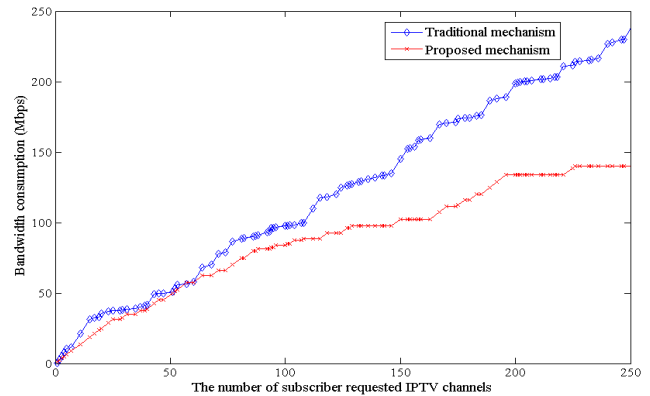


Figure 5. Average bandwidth consumption in 802.16j zone when the maximum number of IPTV channels = 60

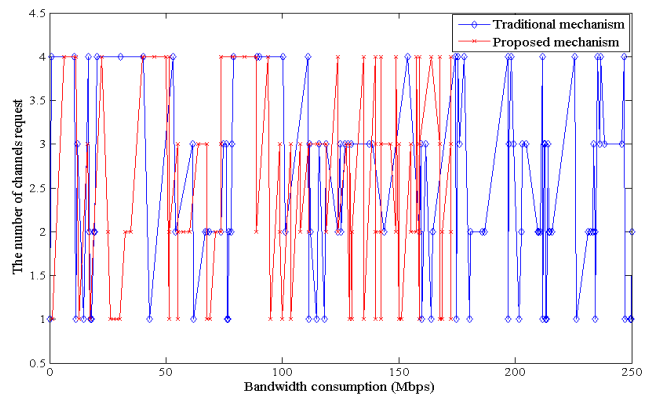


Figure 6. Average subscriber bandwidth consumption

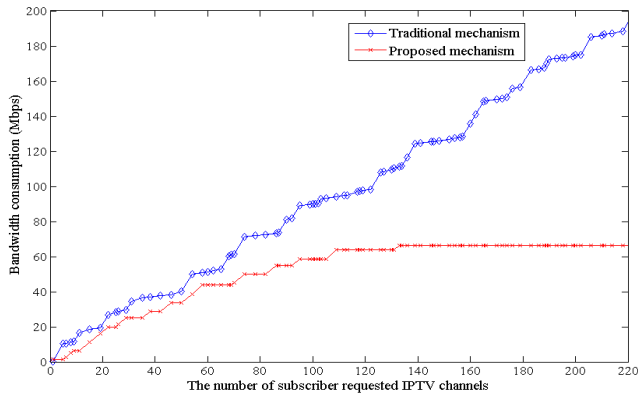


Figure 7. Average bandwidth consumption in 802.16j zone when the maximum number of IPTV channels = 20.

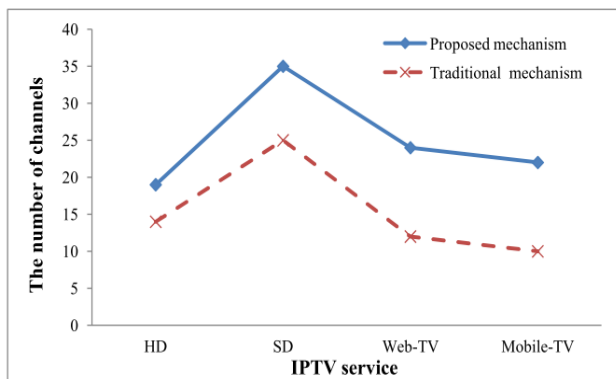


Figure 8. The average number of IPTV channels.

In Fig. 8, we further compare the number of IPTV channels that the provider could offer with the same allowable bandwidth (512 Mbps). Results show that the number of channels provided by the proposed mechanism is greater than those with the traditional mechanism for each IPTV service. This means that we have more bandwidth, so providers can offer more IPTV channels.

VI. CONCLUSION

In this work, we have addressed bandwidth consumption problems for IPTV applications. Also, we have proposed a new multicast mechanism to support several IPTV services in WiMAX multihop relay networks. Results have shown that with the proposed mechanism significant gains can be made to enhance the multicast data routing, in particular bandwidth consumption. For construction of trees, our solution has introduced MT-CID (Multicast Tunnel CID) which maps the relay paths to form a MBS tree in 802.16j MAC layer to support MBS services. By using MT-CID approach and Scalable Video Coding, RSs will only need to transfer one copy of video stream content through each tunnel which reduces network load. In addition our solution, supports various IPTV video stream services while reducing bandwidth consumption. Furthermore, it allows providers to offer more IPTV channels, rather than with only a single video server. The next challenge will be to adapt our

solution to a new scheduling algorithm. We will also propose a connection admission control (CAC) mechanism to efficiently manage the resources among existing and new flows.

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REFERENCES

- [1] Chung-Wei Lin, Yu-Cheng Chen and Ai-Chun Pang, "A New Resource Allocation Scheme for IEEE 802.16-based Networks", 3rd IEEE VTS Asia Pacific Wireless Communications Symposium (AWPCS 2006), Aug, 2006.
- [2] IEEE Std 802.16j™-2009 Part 16: "Air Interface for Fixed and Mobile Broadband Wireless Access Systems", Multihop Relay Specification, 13 May 2009.
- [3] F. E. Retnasothie, M. K. Ozdemir, T. Yiicekt, H. Celebitt, J. Zhang, and R. Muththaiah, "Wireless IPTV over WiMAX: Challenges and Applications", In Proc. of Wireless and Microwave Technology Conference (WAMICON), Dec, 2006, Pp. 1-5.
- [4] M.Z. Chowdhury, B.M. Trung, Y.M. Jang, Y. Kim, and W. Ryu, "Service Level Agreement for the QoS Guaranteed Mobile IPTV Services over Mobile WiMAX Networks", journal CoRR, May, 2011, abs/1105.4431.
- [5] D. C. Verma, "Service Level Agreements on IP Networks", In Proc. of the IEEE, Sept, 2004, pp. 1382 - 1388.
- [6] J. Sommers, P. Barford, N.G. Duffield, and A. Ron, "Multiobjective monitoring for SLA compliance", presented at IEEE/ACM Trans. Netw., 2010, pp.652-665.
- [7] Ning Liao, Yuntao Shi, Jianfeng Chen and Jun Li, "Optimized Multicast Service Management in a Mobile WiMAX TV System", Consumer Communications and Networking Conference, Jan, 2009, pp. 1 - 5.
- [8] International Television Expert Group, http://www.international-television.org/tv_market_data/global-iptv-forecast-2009-2013.html
- [9] Chengxuan He, Oliver Yang and GuoQiang Wang, "Performance Evaluation of Multicast Routing Protocol and MBS Service Architecture in WiMAX Multi-Hop Relay Environment", Future Networks: Cross-Layer design, April, 2008, Ottawa, Ontario, Canada.
- [10] Lee S.S.W, Chen A and Po-Kai Tseng, "Optimal routing and bandwidth provisioning for survivable IPTV multicasting using network coding", Consumer Communications and Networking Conference (CCNC), Jan, 2011 IEEE, pp. 771 - 775.
- [11] Leprovost Yann and Sayadi Bessem, "Multicast router, distribution system, network and method of a content distribution", European Patent Application, Alcatel Lucent April 2009: EP2046041.
- [12] Heiko Schwarz, Detlev Marpe and Thomas Wiegand, "Overview of the Scalable Video Coding Extension of the H.264/AVC Standard", IEEE Transactions On Circuits And Systems For Video Technology, VOL. 17, NO. 9, Sept, 2007, pp. 1103 - 1120.
- [13] <http://nextgenlog.blogspot.com/2010/09/freescale-dsp-tackles-scalable-video.html>
- [14] Hang Liu and Mingquan Wu, "Connection Management for Multicast and Broadcast Services (MBS)", IEEE C802.16j-07/272, 2007-04-05.