Adaptive Hybrid Transmission Mechanism for On-Demand Mobile IPTV Over WiMAX

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***Abstract*—In this paper, we propose an Adaptive Hybrid Transmission (AHT) scheme for on-demand mobile IPTV service over broadband wireless access network (i.e. mobile WiMAX, 802.16e). Proposed algorithm utilizes hybrid mechanism which combines multi-channel multicasting and unicast scheme to enhance not only service blocking probability but also reduce overall bandwidth consumption of the wireless system which has very limited resources compared to wired networks. An adaptive resource allocation algorithm is also proposed, and is shown to achieve minimum blocking probability. In order to evaluate the performance, we compare proposed algorithm against traditional unicast and multicast schemes.**

***Index Terms*—Adaptive, IPTV, mobile, multicast, on-demand, WiMAX.**

I. Introduction

As the demand for Internet and Internet-based applications grows around the world, Internet Protocol Television (IPTV) has been becoming popular as it promises to deliver multimedia contents to users whenever they want and wherever they are. At the same time, with the creation of new applications and contents growing exponentially, multimedia streaming over wireless networks has emerged as an important technology and has attracted much attention.

Recently, the IEEE 802.16 working group developed the mobile Worldwide Interoperability for Microwave Access (mobile WiMAX) which provides a wireless solution in the metropolitan area access networks [1]. The WiMAX is capable of wide range coverage, high data rates, secured transmission and mobility supported at vehicular speeds. Moreover, installation and maintenance costs of WiMAX systems are at a fraction of the costs of wired access networks. The high data rate and QoS assurance features of WiMAX make it commercially viable to support multimedia applications, such as mobile IPTV, video gaming, and video telephony services. Therefore, taking advantage of these features, mobile IPTV services can be designed, delivered, and managed effectively without compromising the video and audio quality.

Among the various IPTV services, the Video-on-demand (VoD) service, which offers watching a selected video at any time and any where through the wireless access network, is taking the major service portion. Since users prefer to access content on-demand, rather than following a fixed schedule, most of the Video-on-Demand service system is designed to deliver their video by unicast manner to meet the 'any time', 'on-demand' characteristics. From the network control perspective, it is simple and works fine when there is enough capacity and the service request rate is moderately low. However, if video requests are highly skewed, for example, the famous sports game or popular movies, then, large number of the unicast streams for the same content would be established and transmitted over the network. These results cause huge inefficiency of both media server and bandwidth consumption of wireless system which has very limited resources compared to wired networks. In case of mobile VoD services, the bottleneck has been observed in wireless access network rather than multimedia server. In order to support a large population of clients in WiMAX hot zone, we therefore need new solutions that efficiently utilize the WiMAX downlink resources. The proposed Multi-channel Multicasting scheme was originally motivated from the Fast Broadcasting (FB) [2], which is implemented over cable TV environment as a Near-VoD service. Unlike TV broadcasting, IPTV stream cannot broadcast into all over the internet, therefore we modified to multi-channel concept for serving the highly request contents within the fixed number of wireless channels by using MBS—The IEEE 802.16e standard defined Multicast Broadcast Service (MBS) to provide an efficient way to transmit diverse multimedia stream to multiple users through a shared radio resource.

The decision of which contents are going to be transmitted by the multi-channel multicasting is decided by proposed adaptive resource allocation method that results in the lowest blocking probability.

This paper is organized as follows. In the next 2 sections, we briefly introduce about existing VoD systems and WiMAX basics for Multicast and Broadcast Service (MBS) support. And in Section IV, the mobile IPTV VoD service scenarios are introduced. In Section V, we explain a proposed AHT algorithm over end to end WiMAX system. The implementation considerations are provided in Section VI and performance analysis and results are presented in Section VII. Finally, we conclude this paper in Section VIII.

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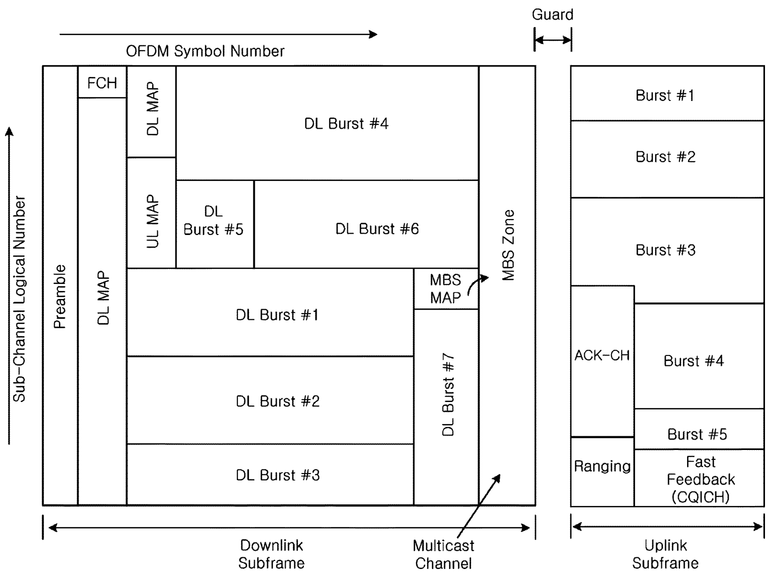

Fig. 1. WiMAX OFDMA frame structure.

II. Related Works

In this section, we briefly review the existing VoD systems. Generally, VoD systems can be categorized into True-VoD (TVoD), which is based on unicast transmission, [3] and Near-VoD (NVoD), which is based on broadcast or multicast transmission, [4]–[12] how videos are delivered [13]. In TVoD, the system reserves dedicated transmission channels from server resources to each client so that clients can receive video data without any delay via dedicated transmission channels as if they use their own VCR. However, may easily run out of the channels because the channels can never keep up with the growth in the number of clients. On the other hand, in NVoD, clients have to wait by some delay time because content is multicasted over several channels with a periodical cycle. The number of broadcasting channels is due to the allowable viewer's waiting time, not the number of requests. Thus, this approach is more appropriate for popular videos that may interest many viewers at a certain period of time. Clearly, the popularity of access pattern of video objects plays an important role in determining the effectiveness of a video delivery technique. Because different videos are requested at different rates and at different times, videos are usually divided into hot (popular) and cold (less popular), and requests for the top 10$\sim$20 videos are known to constitute 60$\sim$80% of the total demand [11], [12]. So, it is crucial to improve the service efficiency of hot videos. Until now, many NVoD methods have been proposed, such as the staggered broadcasting [4], pyramid broadcasting [5], fast broadcasting [2], staircase broadcasting [7], harmonic broadcasting [8] and etc. These methods can classified into three main approaches to provide NVoD services, as batching [9], patching [10], and broadcasting [8]. The batching approach collects a group requests that arrive close in time, and serves them all together with one channel. In patching, video request is firstly served by unicast stream and then joined back to a multicast stream. In broadcasting, the video is periodically broadcast into dedicated channel with pre-defined schedule.

Most of VoD systems aim to improve the overall service transmission efficiency, addressing the concentrated request and abnormal burst request problems. As a result, due to their transmission characteristics, the NVoD is more capable for adopting unlimited clients access with broadcasting environment and the on-demand multicasting is applicable for the IP based network with high performance servers with good controllability over the wireless environment.

The proposed AHT scheme is combined with TVoD, which is based on unicast transmission, and NVoD, which is based on multicast transmission, and it more focused on the decision of which contents are going to be transmitted by the NVOD within limited resource in WiMAX MBS zone that is decided by proposed adoptive resource allocation scheme that results in the lowest service blocking probability.

III. WiMAX for MBS Support [14]–[16]

A. WiMAX OFDMA Frame Structure

According to the IEEE 802.16e standard, PHY supports Time Division Duplex (TDD), Frequency Division Duplex (FDD), and Half-Duplex FDD operation. Fig. 1 shows the OFDM frame structure for a TDD implementation. Each frame is divided into Down Link (DL) and Up Link (UL) sub-frames separated by Transmit/Receive and Receive/Transmit Transition Gaps (TTG and RTG, respectively) to prevent DL and UL transmission collisions. In a frame, the following control information is used to ensure optimal system operation:

- Preamble: The preamble, used for synchronization, is the first OFDM symbol of the frame.
- Frame Control Head (FCH): The FCH follows the preamble. It provides the frame configuration information such as MAP message length and coding scheme and usable sub-channels.
- DL-MAP and UL-MAP: The DL-MAP and UL-MAP provide the sub channel and slot allocation and other control information for the DL and UL sub-frames respectively.

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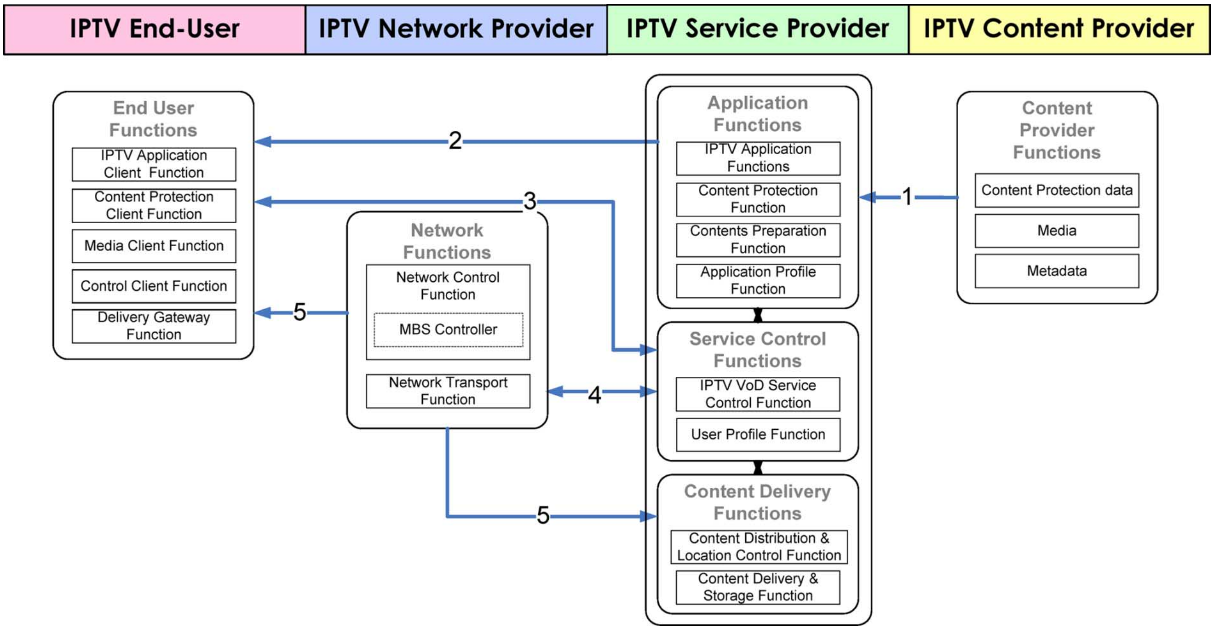

Fig. 2. Service scenario for mobile IPTV VoD.

- UL Ranging: The UL ranging sub-channel is allocated for mobile stations (MS) to perform closed-loop time, frequency, and power adjustment as well as bandwidth requests.
- MBS MAP: The MBS MAP specifies MBS zone PHY configuration and defines the location of each MBS zone via the OFDMA Symbol Offset parameter.
- UL CQICH: The UL CQICH channel is allocated for the MS to feedback channel state information.
- UL ACK: The UL ACK is allocated for the MS to feedback DL HARQ acknowledge.

B. MBS Support of PHY and MAC

The IEEE 802.16e standard defined Multicast Broadcast Service (MBS) to provide an efficient way to transmit diverse multimedia stream to multiple users through a shared radio resource.

The MBS service can be supported by either constructing a separate MBS OFDMA zone in the DL frame along with unicast service (as shown in Fig. 1) or the whole OFDMA frame can be dedicated to MBS (DL only) for standalone broadcast service. Fig. 1 shows the DL/UL zone construction when a mix of unicast and broadcast service is supported. It may be noted that multiple MBS OFDMA zones are also feasible. There is one MBS MAP Information Element (IE) descriptor per MBS zone to be included in DL-MAP. The MBS MAP IE specifies MBS zone PHY configuration and defines the location of each MBS zone via the OFDMA Symbol Offset parameter. The MBS MAP is located at the 1st sub-channel of the 1st OFDM symbol over the associated MBS zone. One MBS MAP contains multiple MAP DATA IEs. One MAP DATA IE specifies the connection ID, the location and the PHY configuration (e.g., modulation coding scheme, abbreviated as MCS) of one MBS burst. One MBS burst consists of one or more than one MAC PDU(s).

An MS (Mobile Station) accesses the DL-MAP to initially identify MBS OFDMA zones and locations of the associated MBS MAPs in each zone. Then the MS can subsequently read the MBS MAPs via MBS MAP redirection without reference to DL-MAP unless synchronization to MBS MAP is lost.

In addition, WiMAX can support both single-BS (Base station) mode and multi-BS MBS mode. The multi-BS mode uses Single Frequency Network (SFN) operation. The multi-BS MBS does not require the MS to be registered to any base station. MBS can be accessed when MS is in the idle mode to allow low MS power consumption.

IV. Mobile IPTV VoD Service Scenarios

According to ITU-T IPTV service scenarios [17], VoD service is defined that "VoD is a video service which allows the end-users to select and watch video content at any point of time. The end-user has full control over choosing which program or clips to watch and when starting to watch." A proposed service scenario for on-demand mobile IPTV is shown in Figs. 2 and 3

1) Video content with its metadata and Content Protection data that are produced and managed by the content provider are delivered to the service provider.
2) The service provider prepares the content as per the agreement between the content provider and the service provider.
3) As shown in Fig. 3, when an end-user selects a VoD content, the request(s) is sent to the service provider and checks that the requested content already sending by multicasting or not. If there already exist multicast stream for the V_i, then the server let the client know the video's multicast group address and then the client can join the multicast stream. This procedure may include service negotiation (e.g., QoS, price, packaging option, etc.).
4) On the other hand, if there is no multicast stream for the video, the service provider interacts with the network provider checks within some threshold—by newly updated arrival rate from IPTV VoD service control function—to

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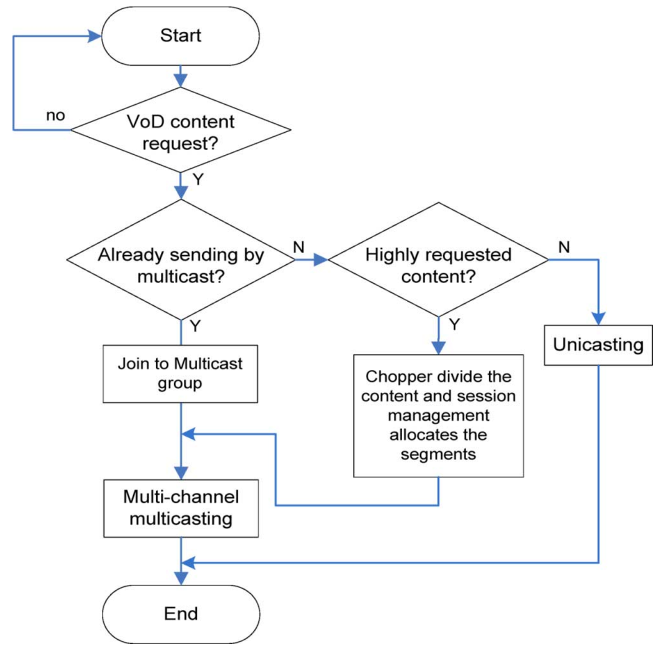

Fig. 3. Proposed service procedures for mobile IPTV VoD.

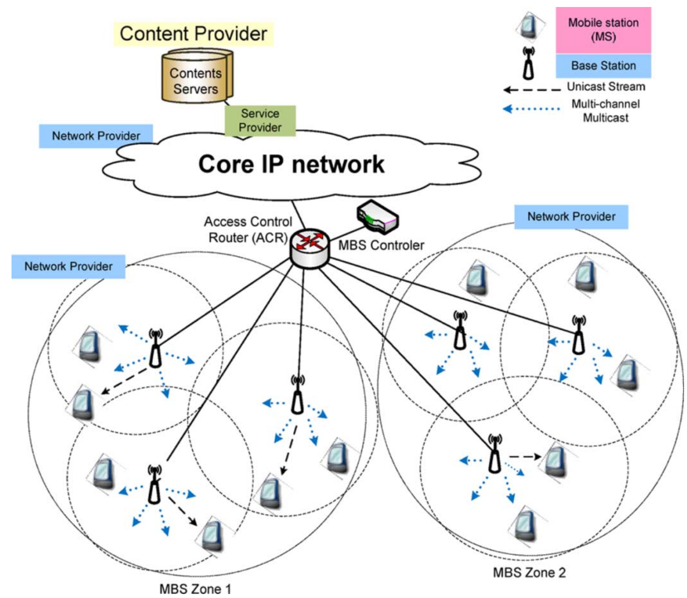

Fig. 4. Network architecture for MBS over multi-BSs.

decide this content is highly requested content or not. In this time, if it is not highly requested contents, it delivered by unicast manner. However, if it is highly requested contents, MBS controller starts multi-channel multicast algorithm for content then to possibly negotiate the conditions of forwarding the content to the end-user. This procedure may include the network resource reservation to guarantee the contracted service level.

5) Upon completion of the above step 4, the service provider supplies the content access information (e.g., the multi-channel multicast address that will be used to forward the content) and the end-user can then receive the video.

V. The Proposed AHT Algorithm

The overall network architecture of mobile IPTV VoD service over multi-BS is shown in Fig. 4. The WiMAX standard defines two types of MBS: single-BS access and multi-BS access. In general, multiple BS composes an MBS zone in mobile WiMAX. The BS can send multicast data synchronously through the same connection identifier (CID) and security association (SA) carrying MBS data in the same MBS zone.

Note that when all BS are in the same MBS zone, they have the same Multicast CID (MCID) for the same MBS multimedia stream transmission. Therefore, the multi-BS MBS does not require the MS to be registered to any BS. Moreover, multi-BS access allows all MS to use the same multicast connection ID during handover within a single MBS zone, such that the MS can receive the MBS packets while moving within the MBS zone.

Since the IEEE 802.16e standard defined criteria only for the PHY and MAC layers, we need to propose a model for the end-to-end which use IP data cast of video over mobile WiMAX as shown in Fig. 5. In order to efficiently manage mobile VoD services, we have added one additional functional entity namely an MBS controller and the proposed AHT scheme is exploited here for the suitably control the system. The functions of each entity in the proposed architecture are described in detail as follows [18]:

A. MBS Controller

The MBS controller performs seven functions: service announcement, membership management, MBS zone management, MCID and IP address management, security management, session management/transmission, and content chopping as described in the following.

- Service Announcements: This function provides potential MBS users with descriptions of the MBS channels and programs available. The popular content, such as a famous sport game or movie, is normally mapped to shared multicast channels. The MBS channels and programs are distinguished by the logical channel ID and the MBS contents ID, respectively, which also are defined in the IEEE 802.16e [1]. Various service mechanisms (e.g., HTTP and push service) also can be used for the service announcement.
- Membership Management: This function authorizes a user who requests to activate an MBS service. A subscription is normally associated with MBS channels or programs. This function must look up the subscription data of the MBS users.
- MBS Zone Management: The MBS controller delivers an MBS program to one or more MBS zones, each of which consists of multiple BS of a WiMAX network. MS that access the same MBS channel in the same zone share a single 802.16 multicast connection. Therefore, the MBS controller must be aware of which BS constitute each MBS zone.
- MCID and IP Address Management: This function performs mapping between an 802.16 MCID and an IP multicast address. To correctly classify IP packets of MBS programs into 802.16 multicast connections, each BS requires

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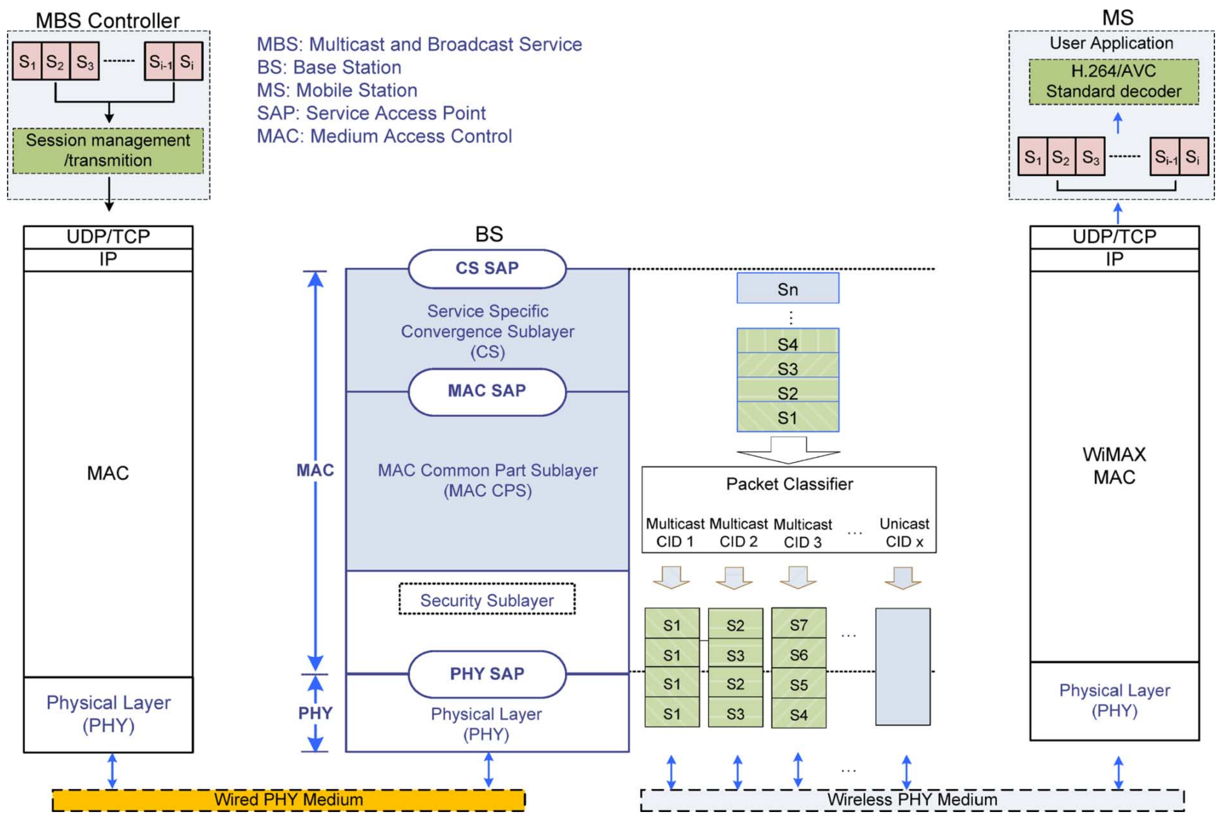

Fig. 5. Proposed end-to-end MBS solution over WiMAX.

the mapping information of the MCID and the IP multicast address when the MBS controller creates a new MBS connection.

- Security: This function provides key management, and thus, the IEEE 802.16 MAC privacy layer performs an integrity and confidentiality check of the MBS packets over the air interface. MS that access the same program in the same zone use the same cryptographic key for data decryption regardless of BS.
- Session Management/Transmission: An MBS session refers to a logical connection, established between an MS and the MBS controller, on which an MBS program is delivered to the users. An MS identifies each session by the tuple of a channel identifier, namely logical channel ID, and an MBS content ID. The MBS controller creates and maintains session information. It also transmits the packets from the content chopper.
- Content chopping—In order to deliver the multicast VoD contents as if it is unicast transmission and satisfy the start up delay requirement, the content is needed to be chopped. According to ITU-T recommendation G.1010 [19], the start-up delay for VoD is less than 10 seconds. Therefore the maximum start-up delay in our proposed VoD system is less than 10 seconds. Suppose there is a i_{th} movie with length L_i. In multi-channel multicast, the number of channel, n_i, required for the i_{th} video, with length L_i that meets the requirement for the VoD start-up delay, $sd < 10$ sec by following equation:

$$n_i = \left\lfloor Log_2 \left(\frac{L_i}{sd} + 1 \right) \right\rfloor \qquad \text{where} \quad L_i : \text{video length} \quad (1)$$

This equation was originally from the Fast Broadcasting (FB) [2] and modified to adopt minimum start-up delay requirement. After calculate the number of channels, chopper divide the content equally into N segments.

$$N = \sum_{j=0}^{n_i} 2^j = 2^{n_i} - 1 \qquad \text{where} \quad n_i : \text{number of channel} \quad (2)$$

Then session management allocates the segments to proper channels and segments are streamed continuously and periodically to its channel by geometrical series of $1, 2, 4, \ldots, N$. The example of allocation is shown in the Fig. 6. Some examples of the number of sessions that is required for multi-channel multicasting is shown in Table I.

B. Base Station

The base station (BS) is a generalized equipment set providing connectivity, management, and control of the subscriber station. In our proposed model the BS maps segmented contents to dedicated MCID for transmission over WiMAX PHY/MAC and then WiMAX PHY allocates burst scheduling and OFDMA data region for each MBS MAC PDU [1].

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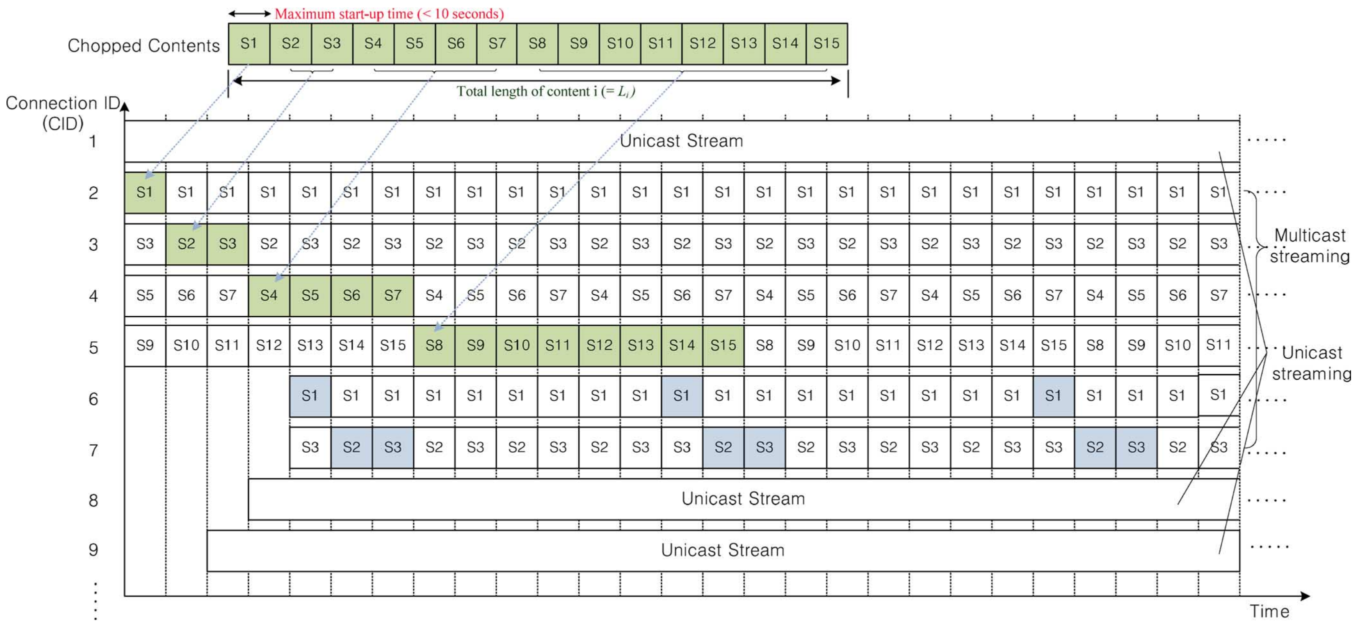

Fig. 6. Contents allocation for multi-channel multicasting.

TABLE I
AN EXAMPLE OF REQUIRED NUMBER OF CHANNELS

Video length (L_i)	Number of channel required (n_i)	Maximum start-up delay (sd)
5400 sec	9	10.5
300 sec	5	9.6

C. Mobile Station

The MS is generalized equipment set providing wireless connectivity between subscriber equipment and a base station. For the MS, it is assumed that the client's device has enough storage to buffer the streaming, channel switcher and standard decoder.

With the session information of the multicasting from the MBS controller, clients can start to receive the multicast stream and select channels via logical channel switcher. After then, the channel switcher determines MCID according to the selected content and indicates WiMAX PHY/MAC to decode only those MBS MAC PDUs associated with the selected MCID. After begin to receive the first segment from the channel, S1, at its first occurrence, it also receives other related segments from the rest of the channels concurrently. Finally user application decrypts and constructs content packets according to standard H.264/AVC video decoding.

VI. IMPLEMENTATION CONSIDERATIONS

In this section, we briefly introduce about implementation concerns which mainly focused on VCR functions and transmission protocols.

A. VCR Functionality

According to the definition of VOD, the VCR function such as fast forward or fast backward to VoD services is an another important factor for consideration in design. In the TVOD system, which is based on unicast transmission, it is relatively easy to provide such VCR functions since it allocates a channel to each client. However, in NVOD, which is based on multicast transmission, it is not as easy to provide VCR functions due to the characteristics of the multicast. In recent years, an increasing number of researchers have gone into this area of research as a basis, proposing ways to support VCR functions more completely to achieve a more interactive VOD system. Several schemes have been proposed to deal with the problem of providing VCR functions in NVOD systems [20].

Since proposed AHT scheme utilizes hybrid mechanism which combines multi-channel multicasting and unicast scheme. We need to adopt both TVoD and NVoD mechanisms for VCR functions. The [21] is one of candidate scheme for our proposed multi-channel multicast to achieve support for VCR functions. On the same basis that storage mediums like hard disks are increasingly affordable, that the user already has enough temporary storage to store the whole content is also assumed.

B. Transmission Protocols

In proposed multi-channel multicast scheme, contents are divided in N segments of equal size and then sent to each segment with carousel manner through its dedicated multicast channels. Each of terminals will receive data packets from multicast channels with several segments. After the client receives the segments, ordering is an important task in the client side.

The File Delivery over Unidirectional Transport (FLUTE) file delivery application (RFC 3926 [22]) is increasingly used to this purpose, and they are included in the technical specifications of the 3GPP MBMS service and of the DVB-H IP Datacast service [23]. By using this mechanism, content can easily be delivered to several millions of clients, through a carousel: the content is continuously broadcast or multicast, and interested clients can join the session, download the content and leave the session whenever they want. The same approach should be used in the Internet (or any multicast capable routed network, e.g. within a

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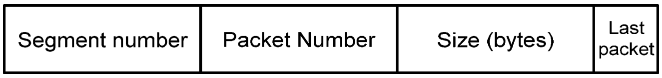

Fig. 7. Application data unit format.

site) when a content has to be broadcast to a large number of receivers. Content delivery systems using FLUTE are already deployed (e.g. within the M6BONE network) and we can expect it to continue.

For another approach, we define the Application Data Unit (ADU) as the minimum data unit for our application. Each UDP packet is formed by an UDP header and an ADU. Each ADU is formed by an ADU header and ADU utile data. For us, the ADU header is the way by which we can order the data inside a segment, or we can decide at which segment the data belongs to, etc. Fig. 7 shows the ADU header. Segment number permits us to classify the content in function of the segment it belongs. Packet number is used for ordering the data that arrives through the multicast channels. Remember that we use UDP transmission and it's not sure that the packets arrive in the same order they were sent. Size is the size in bytes of ADU data. And last packet is a boolean (one bit) to know if the packet is the last of the segment or not [24].

While the development of enhancements and new features for VoD application, related standards will continue. Currently IETF Audio/Video Transport (AVT) working group consider the extension of Real-time Transport Protocol (RTP) for the multi-session transmission [25]. The major step forward for the next generation could be the combination of more than 2 transmission technologies such as TVoD and NVoD.

VII. System Model and Numerical Analysis

In order to analyze the proposed mechanism, we consider a group of K videos $V_1, \ldots V_K$ each of length L with arrival rates $\lambda_1, \ldots, \lambda_K$ respectively that are being transmitted using C channels. In addition, we assumed that $\lambda_i < \lambda_j$ for $1 \leq i < j \leq K$, i.e., popularity of these videos increases gradually with the index so that V_1 and V_K be the least- and the most-popular content respectively. The content's popularity (=request frequency) ranking is calculated and given by the service provider based on their statistical data and their own service policy. For the numerical analysis, we assumed that request arrival for each video follow Zipf distribution [26]. Based on the assumptions and video request model, we calculate the blocking probability by Erlang's loss formula with the state space S and M/M/C/C model [27].

$$S = \{x | 0 \leq x \leq C\} \tag{3}$$

Fig. 8 indicates the state transition diagram for the proposed scheme. The detailed notations used in this diagram are shown in Table II.

First of all, based on this model, we will develop the formulas for steady state probability and blocking probability.

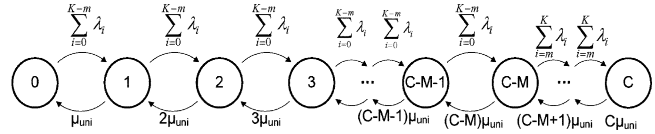

Fig. 8. Transition diagram for the proposed algorithm.

TABLE II
Notations for Numerical Analysis

Notation	Explanation
C	System capacity (The maximum number of concurrent stream)
K	Total number of contents
m	Total number of multicasted contents.
M	Total number of reserved channel for multicast stream.
x	Number of connections in the coverage
L_i	length of content i.
λ_i	Request rate of content i
μ_i	Service rate of stream i (= residual life of Li)
μ_{uni}	Average service rate of unicast stream
P_uni_i	Probability that the unicasted video V_i is being served

Let P_x denote the steady-state probability that there are unicast streams, we can obtain

$$p_x = \begin{cases} p_0 \prod_{j=0}^{x-1} \frac{\sum_{i=1}^{K-m} \lambda_i}{(j+1)\mu_{uni}} = p_0 \left(\frac{\sum_{i=1}^{K-m} \lambda_i}{\mu_{uni}} \right)^{x} \cdot \frac{1}{x!} & \text{for } 0 \leq x \leq C-M \\ p_0 \left(\frac{\sum_{i=1}^{K-m} \lambda_i}{\mu_{uni}} \right)^{x} \left(\frac{\sum_{i=m}^{K} \lambda_i}{\mu_{uni}} \right)^{C-x} \cdot \frac{1}{x!} & \text{for } C-M < x \leq C \\ 0 & \text{for } C < x \end{cases} \tag{4}$$

Since the steady state probability is not dependent on the service time distribution, but dependent on the mean service time, we calculate average service rate as follows:

$$\mu_{uni} = \sum_{i=1}^{K-m} P\_uni_i \cdot \mu_i$$

$$Where \quad P\_uni_i = \frac{\lambda_i}{\sum_{j=1}^{K} \lambda_j}, \quad \mu_i = \frac{1}{L_i} \tag{5}$$

From the normalization equation, we also obtain

$$p_0 = \left[\sum_{j=0}^{C} \left(\frac{\sum_{i=0}^{C} \lambda_i}{\mu_{uni}} \right)^{j} \frac{1}{j!} \right]^{-1} \tag{6}$$

As a result, we can obtain the formulas for service blocking probability as follows:

$$P_{blocking} = \frac{\frac{\rho^{C-M}}{(C-M)!}}{\sum_{i=0}^{C-M} \frac{\rho^i}{i!}}, \qquad where\ \rho = \frac{\sum_{i=1}^{K-m} (\lambda_i \cdot P\_uni_i)}{\sum_{i=1}^{K-m} (\mu_i \cdot P\_uni_i)} \tag{7}$$

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Since the proposed on-demand system divides contents into two subgroups—popular contents and others—such that the former subgroup is assigned M channels for multi-channel multicasting and the latter subgroup is assigned the remaining C–M channels for unicasting. Equation (8) shows minimum blocking probability of mobile wireless system and optimal multicast resource allocation can be determined by this formula. This formula tries to adaptively search the optimal number of channel assigned to the video by the newly updated arrival rate so as to minimize the bandwidth requirement.

$$P_{\min}(C,M) = \min_{0\leq M<C}\left(\frac{\rho^{C-M}}{(C-M)!}\cdot\frac{1}{\sum_{i=0}^{C-M}\frac{\rho^i}{i!}}\right) \quad (8)$$

Next, we introduce the service provider's reward/penalty cost model to expect IPTV service providers' revenue. We assumed that when the base station successfully serves the IPTV VoD without blocking, the service provider receives a reward value of R. On the other hand, if a user is rejected, we assume that the service provider loses a value of L immediately [28].

In prior art under the resource allocation policy, for example, if the system on average services N clients per unit time and rejects M clients per unit time, then the system revenue is

$$\sum N\cdot R - \sum M\cdot L \quad (9)$$

Finally, we define the total system revenue as follow:

$$\text{revenue} = \sum_{i=1}^{C} i\mu\times R\times\frac{\frac{\rho^i}{i!}}{\sum_{j=0}^{C}\frac{\rho^j}{j!}} - L\times\lambda\times\frac{\frac{\rho^C}{C!}}{\sum_{j=0}^{C}\frac{\rho^j}{j!}} \quad (10)$$

VIII. Performance Analysis

For the performance evaluation, we assumed some parameters with specific values. The MBS server can serve 300 concurrent channels, and there are 100 contents that their lengths are average 90 minutes (5400 seconds). The request arrival ratio λ varies from 5/60 to 20/60, and λ is calculated by Zipf distribution with skew factor 0.271 [26].

We applied our adaptive resource allocation method to find the best resource allocation that minimizes service blocking probability. Fig. 9 depicts the blocking probability with different request rates where the number of multicasted contents varies from 1 to 25 that mean the total number of multi-channel multicasted contents (m) in previous analysis model is changed 1 to 25. Under our environment, the results show that when we serve top 8 popular videos with multi-session multicasting, then we can have the best performance. This result shows how many contents need to be delivered by multi-channel multicast to achieve the best performance.

Based on the previous contents allocation, we show the performance of blocking probability of proposed mechanism compared with the existing mechanisms.

As we can see from Fig. 10, the VoD service blocking probability increases as the total service request rate increases. It is observed that when service request rate is lower than 3/min, customers cannot recognize the difference. However, as service request rate increases, their blocking probabilities become different. In such case, our proposed algorithm can offer the low blocking probability.

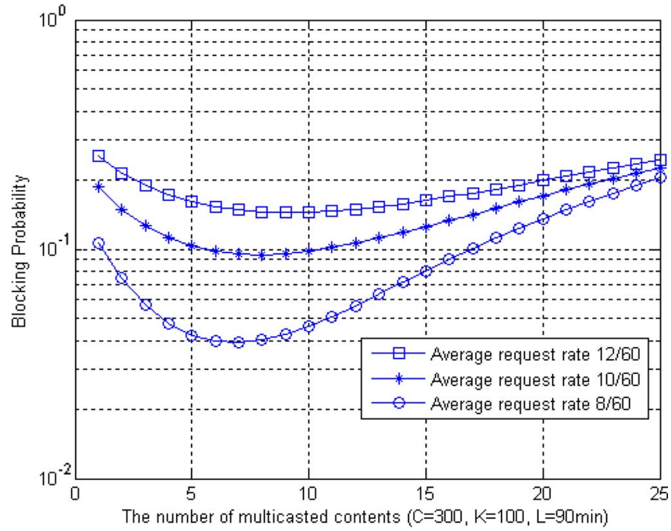

Fig. 9. Contents allocation for multi-channel multicasting.

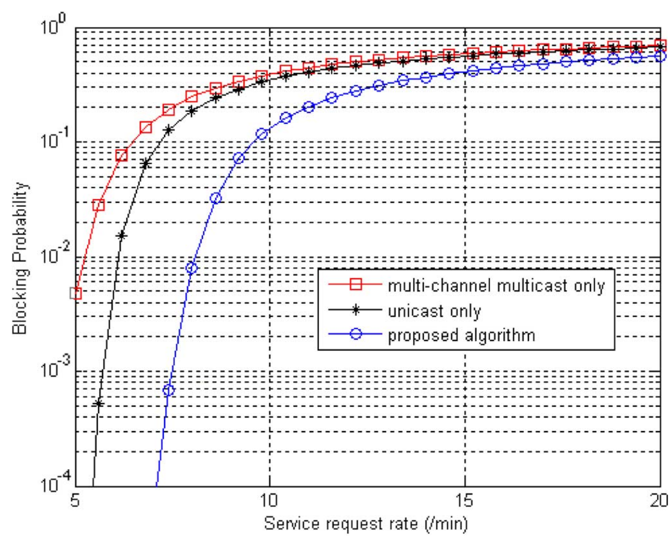

Fig. 10. Blocking probability of VoD services.

Now we evaluate the revenue of each scheme in the aspect of IPTV service provider. Fig. 11 shows the results obtained by service providers' reward/penalty cost model. We assumed that if the base station successfully serves the IPTV VoD without blocking, the system receives a reward value of $\mathrm{R}(=\$10)$. On the other hand, if a user is rejected, we assume that the service provider loses a value of $\mathrm{L}(=\$5)$ immediately.

This figure shows that as the traffic load increases, the revenue of each algorithm is slightly decreasing because of its blocking probability of services. As we mentioned before, this is the case that contents are highly requested, for example, the famous sports game or the popular movies. In such case, our proposed algorithm can offer the higher revenue.

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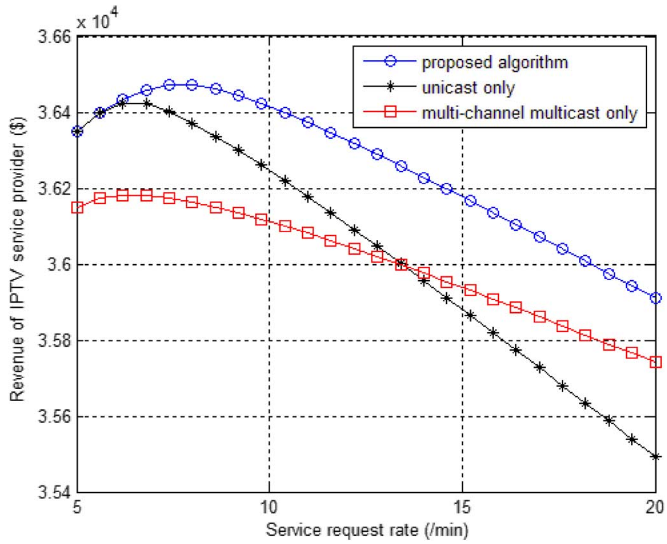

Fig. 11. Revenue analysis of IPTV service provider.

IX. Conclusion

In this paper, we have addressed the AHT algorithm that can efficiently provide mobile IPTV service over broadband wireless access network. Proposed algorithm combined unicast and multi-channel multicast mechanism that enhances not only service blocking probability but also reduces overall bandwidth consumption of the system. In order to analyze the performance of proposed algorithm, we use the one-dimensional Markov chain model. From the numerical analysis, we compared proposed algorithm against traditional unicast and multicast schemes. As a result, proposed scheme is able to improve IPTV service blocking probability over WiMAX. In addition, by reducing the blocking probability, we can also achieve the higher revenue of IPTV service providers. Future work needs to analyze the optimized resource allocation based on test-bed implementation.

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