An Extended IGMP Protocol for Mobile IPTV Services in Mobile WiMAX

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Abstract. Mobile WiMAX access network is being developed to support various multimedia services such as mobile Internet Protocol Television (IPTV), mobile Video-on-Demand (VoD), and mobile Internet services. This mobile network is a shared radio medium which utilizes a point-to-multipoint method, where one base station (BS) can be connected to many mobile stations (MS). This environment enables mobile IPTV viewers join a specific multicast group over mobile WiMAX access network while others, at the same time, receive the same program channel even though they do not belong to the same multicast group. This, however, is different from the traditional Internet Group Management Protocol (IGMP) version used for IPTV services in network layer which does not allow immediate program channel sharing. This is because the Connection ID (CID) is required before the Multicast Broadcast Service (MBS) can transmit its service flows in mobile WiMAX. Therefore, in this case, viewers always need to perform two processes before they are able to view the program channels, i.e. performing the IGMP join/leave at network layer and obtaining the CID at Medium Access Control (MAC) layer. This paper propose a new extended IGMP protocol which can be used in mobile WiMAX radio access network especially for mobile IPTV services to reduce the channel change response time on the mobile network.

Keywords: Internet Group Management Protocol, Mobile WiMAX, program channel change.

1 Introduction

Lately, mobile access networks are being developed to support various multimedia services such as mobile Internet Protocol Television (IPTV), mobile Video on Demand (VoD), and mobile high-speed internet services. In particular, Mobile WiMAX defines an IP end-to-end network architecture, which is an integrated telecommunications network architecture that uses IP for the end-to-end transport of all user data and signaling data [1]. This paper extend the application scope to IP multicast services for multimedia program delivery using radio access resources. IP

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multicast delivers a multimedia program to many hosts that belong to the same group and at the same time accompanied by unicast. Therefore, using IP multicast in mobile access networks is highly efficient for multimedia services because it uses a Point-to-multipoint (PMP) method in which one Base Station (BS) could connect to many Mobile Station/Subscriber Stations (MS/SS). In case of providing multimedia services through IP multicast method using radio access resources, some viewers located in the same multicast transmission zone can start receiving both the multicast program channel they requested and the multicast program channels they did not requested. In other words, if a viewer is joining a specific multicast group, other viewers also receive the multicast program channel at the same time, even though they do not belong to the same multicast group.

This is, however, different from the traditional Internet Group Management Protocol (IGMP) as it does not allow immediate multicast program channel sharing as explained above. Moreover, the Connection ID (CID) must be used for transmitting the Multicast Broadcast Service (MBS) service flows in WiMAX. In this case, the viewers always need to perform two processes before they could view the program channels, i.e. performing the IGMP join/leave processes at network layer and obtaining the CID at Medium Access Control (MAC) layer. The mobile IPTV viewers over WiMAX access networks must endure, at least, several milliseconds of the channel change response time when changing program channels, i.e, time for IGMP processing and time for MBS configurations. Channel change response time is considered to be one of the most important parts of IPTV service quality. Particularly, IGMP join and leave delay is the main source of channel changing delay. Therefore, each viewer of the same multicast transmission zone in WiMAX would want to be able to watch immediately the shared IPTV program channels without the channel change response time.

This paper propose a new extended IGMP which can be apply in mobile WiMAX access network especially for mobile IPTV services to dramatically reduce the channel change response time caused by independent processes using the traditional IGMP at network layer and cause by delay during the issuance of CID at MAC layer.

The rest of the paper is organized as follows. In Section 2, we describe channel change response time on IPTV systems and mobile WiMAX protocol structure as the background of this study. In Section 3, details the cross-layer design of the Extended IGMP for mobile IPTV services in WiMAX. Section 4, we propose the extended IGMP protocol architecture for mobile WiMAX and its performance analysis is shown in Section 5. Finally, we conclude this paper in Section 6.

2 Background

2.1 Traditional IGMP Versions

IGMP, a multicasting protocol in the internet protocols family, is used by IP hosts to report their host group memberships to any immediately neighboring multicast routers. IGMP messages are encapsulated in IP datagram, with an IP protocol number of 2. IGMP has versions IGMP v1, v2 and v3 [2-6].

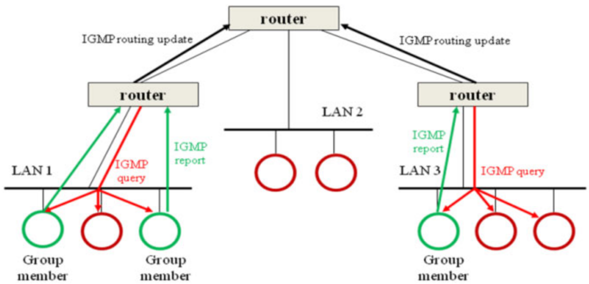

Fig. 1. IGMP basic mechanism

In IGMP version 1, as shown in Figure 1, hosts can join multicast groups. There were no leave messages. Routers were using a time-out based mechanism to discover the groups that are of no interest to its members. In IGMP version 2, leave messages were added to the protocol. It allows group membership termination to be quickly reported to the routing protocol, which is important for high-bandwidth multicast groups and/or subnets with highly volatile group membership. In IGMP version 3, the protocol has several major revisions. It allows hosts to specify the list of secured hosts from which incoming traffic is allowed. Traffic from other hosts is blocked from entering the network. It also allows hosts to block packets from sources that sent un-request traffic inside the network.

2.2 Channel Change Response Time in IPTV Services

The key quality of experience (QoE) element for IPTV is how quickly and correctly the subscribers can change TV channels. Acceptable channel change response time is generally considered to be around 1 second, end-to-end. A channel change response time of 100~200ms is considered, by viewers, to be instantaneous [7]. Sources of channel change response time response include network equipment and IPTV terminals. The IPTV terminals, an IPTV enabler at subscribers' side, add several

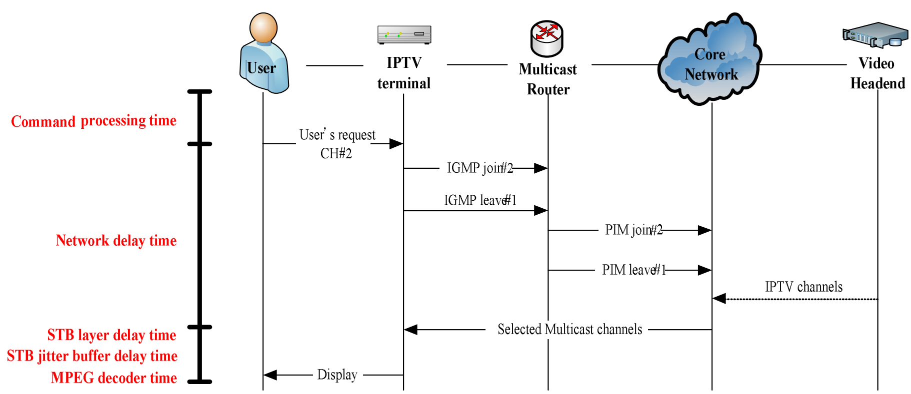

Fig. 2. IPTV channel change flows

hundred milliseconds of delay when changing channels due to command processing, buffer delay, MPEG decoder delay and video buffer delay. Fortunately, each IPTV terminal serves only one user and the main IPTV terminal functions are processed in hardware [8]. Therefore, IPTV terminal performance is relative stable and repeatable. Multicast protocols are used as the technique to enable channel change response time in network infrastructure. IGMP or MLD (Multicast Listener Discovery) leave/join delay is the main source of channel change response time. To keep overall channel change response time within one second, the target multicast leave/join delay of each network component needs to be about 10-200 ms.

3 Multicast Multimedia Delivery in WIMAX MAC Layer

3.1 Downlink MAP Message Monitoring to Receive MBS Data Bursts

The MBS service flows are managed through a DSx messaging procedure used to create, change, and delete a service flow for each MS [9-10]. The DSx message exchange between MS and BS carries important service flow information (SFID) such as quality of service (QoS), service flow identifier, and multicast CID (MCID). DSx messaging also provides an MS with the MBS_ZONE_ID for the subscribed service flows to indicate a service area through which an MCID and security association for a broadcast and multicast service flow are valid.

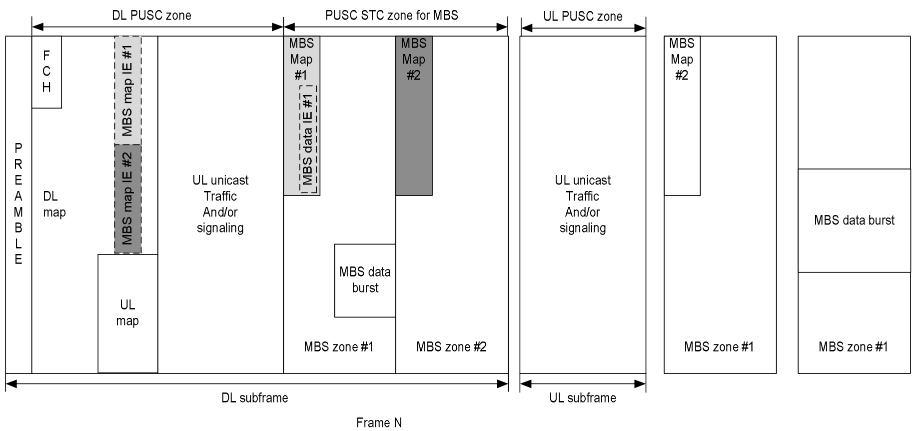

Fig. 3. MBS signaling in IEEE 802.16 MAC [9]

MBS typically involves multiple selectable content channels, the IEEE 802.16 standards [11] also define compound or group DSx, which can activate, delete, or change multiple connections and service flows using a single message exchange to reduce system overhead and latency. A BS supporting MBS includes the list of MBS zone identifier to which it belongs. One BS may belong to multiple MBS zones of the same or different sizes and coverage. From the MS perspective, the SFID assigned by the anchor authenticator is unique, and the MCID is also unique per MBS zone. This

MCID is common to all the MSs for that content in the MBS zone. As shown in Figure 3, the MS continues monitoring the broadcast channels (DL-MAPs) and looks up an information element called MBS-MAP-IE. Once the MS receives the MBS-MAP-IE, it verifies the associated MBS zone ID and, using the pointer within MBS-MAP-IE, locates the corresponding MBS permutation zone and the corresponding physical layer parameters. All MBS transmissions are sent in their designated subcarrier permutation zones. The MBS permutation zone starts with a management message called MBS-MAP, which includes one or more information elements called MBS-DATA-IEs, which list the MCIDs included in the upcoming MBS transmission and its also points to next occurrence of MBS-MAP as well as the location of MBS bursts. These pointers serve as daisy chain allocations allowing the MS to follow the MBS control and data transmissions without reading MAPs in every frame or interacting with the BS. MBS data bursts may contain different content channels, each mapping to different MCIDs. The standard allows parsing and selective discard/processing of content channels based on their corresponding MCIDs.

3.2 MBS Information Element Table Configure

In the future, the BS shall send an MBS_MAP message on the Broadcast CID to specify the location and size of multi-BS MBS data bursts which are located in downlink permutation zones designated for MBS in frames that ranges from two to five frames from a single frame containing the MBS MAP message. Figure 4 is an illustration of MAC service access point (SAP) which provides an MS with MBS information elements to network layer which an MCID and logical channel ID will be shared.

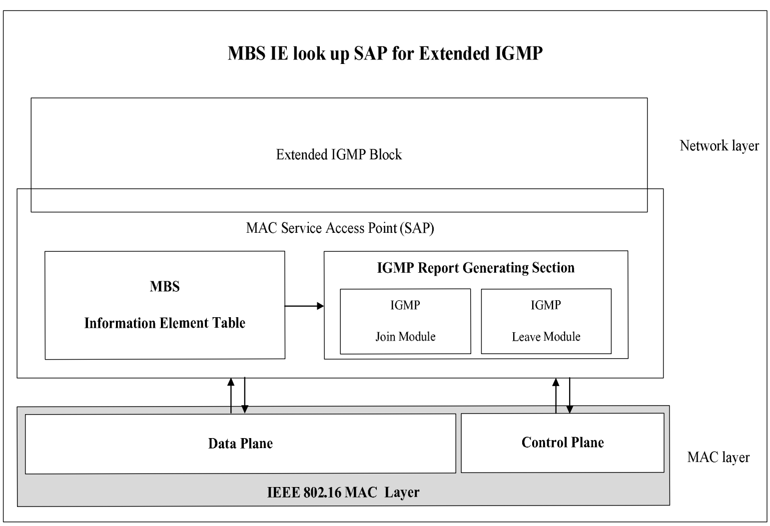

Fig. 4. Basic function blocks with MCIDs mapping SAP for Extended IGMP

4 Extended IGMP Protocol Architecture in Network Layer

The proposed IGMP involves classifying multicast packets, updating the IPTV channel table, and managing channel control in network layer [12].

4.1 Multicast Packet Classifications in Extended IGMP Block

Figure 5 shows the extended IGMP protocol architecture in the network layer. Packet streams from ‘input module’, originated from service interface on mobile access network at the MS of viewer, are delivered to the ‘input packet classification section’. As shown in Figure 6, this section checks each octet and all specific field value in IP header for the packet’s destination IP address in order to classify packets into either general data packet/multicast packet for multimedia contents, or multicast packet for IGMP Group-Specific management. According to the address system of IPv4, the multicast IP is D-class (224.0.0.0~239.255.255.255) and leading 4 bits of uppermost octet is assigned as '1110'. The uppermost 8 bits start with hexadecimal '0xFF' in multicast address of IPv6 system. In this paper, the multicast address at IPv4 will be used for explanation. In other words, if the value of uppermost octet is greater than decimal '223' and less than '240' at the destination IP address of entered packet, the corresponding packet is a multicast packet. Therefore, the entered packet streams can be mainly classified into general data packets and multicast data packets using the method above. The separated general packets are sent to ‘general data packet handling section’. Next, all packets using contents for multimedia transmission (224.0.1.0~239.255.255.255), IGMP query (general query: 224.0.0.1, group-specific query: corresponding multicast address) and reserved address for specific protocol (random value between 224.0.0.2~224.0.0.255) are included in the separated multicast packets.

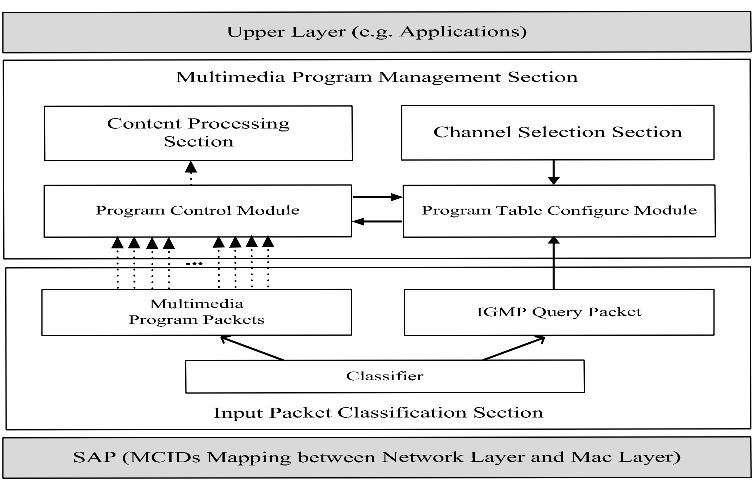

Fig. 5. Extended IGMP protocol architecture in network layer

Therefore, in order to reclassify the multicast packets which is separated initially by usage, the second and third octet values are checked at the destination IP address using the same method as above. If both values are '0' and the value of the fourth octet '1', the corresponding packet is sent to IGMP general query ‘program control module’. This is because all multicast packets, with the value of the fourth octet is not equivalent to '1', are often used by other specific protocol, therefore, they are delivered to the ‘general data packet handling section’.

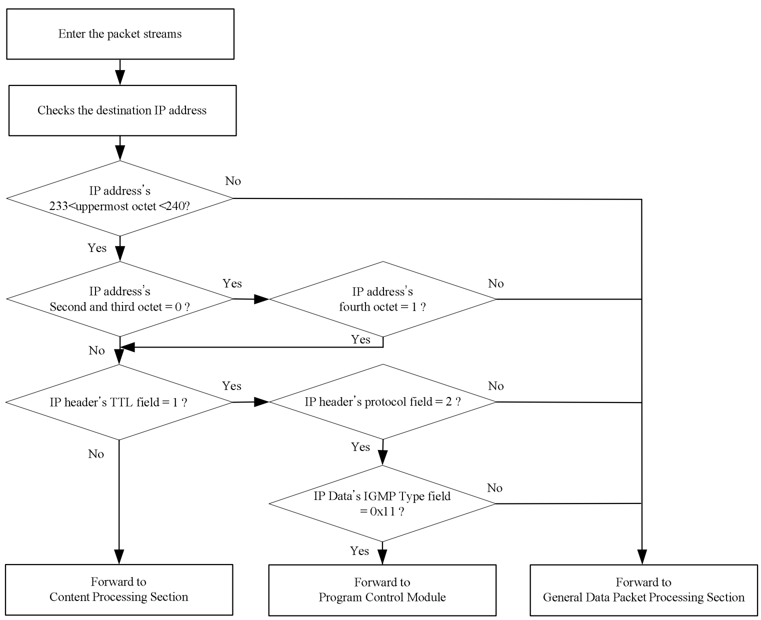

Fig. 6. Flow chart of multicast packet classification

The remaining packets are content packets for multimedia transmission and packets for IGMP group-specific query. Group-specific query is a message inquiring existence of other participants on corresponding group in case multicast router has received IGMP leave report on specific group. Especially, the packets for IGMP group-specific query transmits using multicast address of corresponding group as destination IP address in contrast to the IGMP general query inquiring to all hosts (destination IP address: 224.0.0.1) on the network. Also, the TTL (Time To Live) field value of IP header is assigned as '1' and the value of protocol field is set as '2'. Therefore, in order to reclassify multicast packets other than two remaining types, the value of TTL field is checked at the IP header of corresponding packet. If the corresponding value is not '1', this is sent to ‘program table configuration module’ because the packet is for sending multimedia contents. Next, the remaining packets with TTL field value of '1' are send to ‘program control module’ after being classified as IGMP group-specific packet if the type field value of IGMP frame inserted to IP data field also corresponds to '0x11' specifying membership query after checking whether the protocol field value of IP header corresponds to '2' once again.

4.2 Multicast Program Channel Table Configure

In Figure 5, the ‘program table configure module’ of ‘program management section’ obtains multicast address which is destination address of corresponding packet and source address which is transmitting address once the multimedia content transmission packet is sent to organized this as multimedia program table. Also on the program table, the 'check viewing (CV)' field to check the program that the viewer is currently watching, 'reception time (RT)' field to check the time when program reception was started, 'max response time (MRT)' to check the maximum response time on programs that have IGMP group-specific query and 'waiting time' field to check continuity of program are organized together.

Table 1. IPTV Program table from extended IGMP

Destination IP	Source IP	CV	RT	MRT	WT
224.15.26.100	171.124.56.1	0	45000	45500	500
224.26.37.100	129.197.92.9	0	23000	23000	23500
224.37.48.100	166.214.55.7	1	1100	0	500
…	…	…	…	…	...

The 'check viewing' field value is expressed as 1 bit while being expressed as '1' if viewing is in progress and '0' if not. The 'reception time' field expresses the time from the point of starting program reception at the ‘program table organization module’ by counting as millisecond units. The 'Max Response Time' field is formed by adding the max response time field value of IGMP frame inserted to IP data domain of IGMP group-specific query packet handed over from ‘program control module’ to the 'reception time' field value on the program table. The initial value of 'max response time' is '0' and updated each time new value on group-specific query is handed over from ‘program control module’. While 'waiting time (WT)' field sets 'max response time' as one program receives IGMP group-specific query, a random 'waiting time' is assigned if the 'check viewing' value is maintained as '0' during the time when 'reception time' and 'max response time' becomes the same. This is to prevent immediate viewing until the continuity on multimedia program not participating directly in IGMP group-specific query is confirmed. Table 1 is a simple scenario of an IPTV program table from extended IGMP.

4.3 Multimedia Program Control

The ‘program control module’ receives IGMP query packet from the ‘input packet classification section’. If the received packet is IGMP general query, the ‘IGMP join module’ of ‘IGMP report generating section’ hands over the information of corresponding program to create IGMP join report to report join on the multimedia program with 'check viewing' value of '1' using multimedia program table. If the received packet is IGMP group-specific query, the status on whether multimedia program using multicast address of corresponding query is currently being viewed is checked using the multimedia program table. If the viewer is watching the corresponding program, the ‘IGMP join module’ of ‘IGMP report generating section’ hands over the information of corresponding program to create IGMP join report. If the corresponding program is not being watched, the received IGMP group-specific query is sent to ‘program organization module’ to form a 'max response time' field within the multimedia program table. Also, the response on corresponding query is not performed. Accordingly, the multicast router starts to leave corresponding group completely in case the response does not arrive within max response time of IGMP group-specific query.

4.4 Operations of the Extended IGMP

Figure 7 is an illustration of internet group management method proposed by this paper as sequence figure according to time. As element devices, it is assumed that the 'multimedia server' transmitting multimedia programs, the 'Edge Multicast Router' connecting transport network and access network, the 'Multicast Router' forwarding data according to multicast routing protocol of access network and the 'MS' that are subscriber terminals, exist. At first, the multimedia server transmits 'stream A' which is a multimedia program by multicast method.

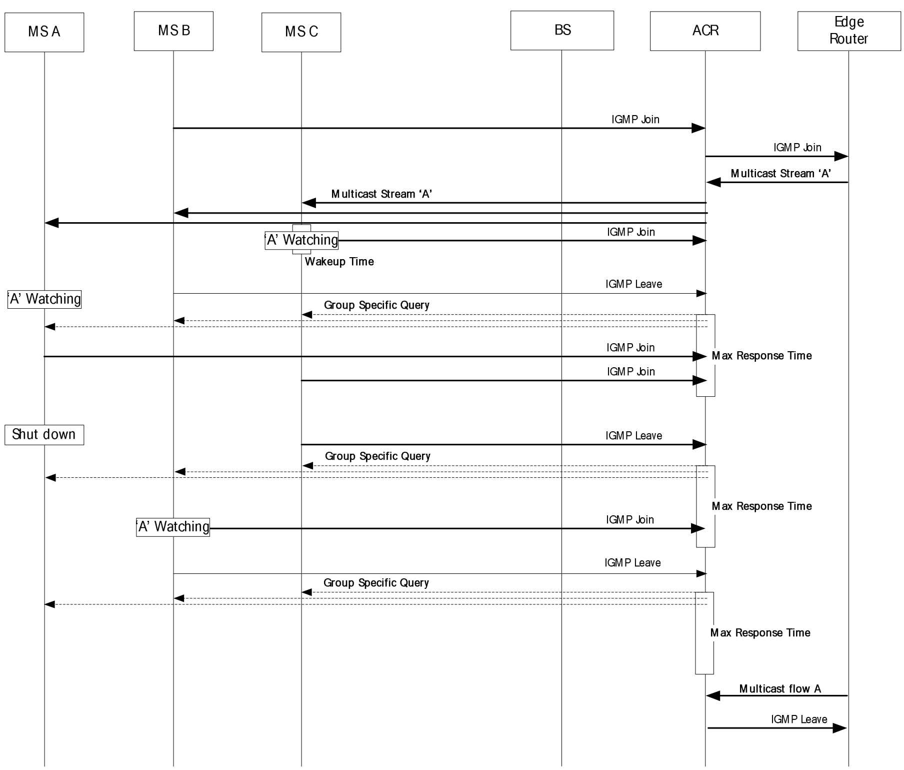

Fig. 7. Sequence diagram of the proposed extended IGMP in mobile WiMAX

The edge multicast router receive the corresponding program through transmission network. At this time, the subscriber terminal MS B sends IGMP join report to multicast router to view 'stream A'. Afterwards, mobile access networks are formed between multicast router and MS so that the 'stream A' requested by MS B is sent to both MS A and MS C existing on the same node. The 'stream A' transmitted this way gets to organize the program table at the MS. If A section is immediately perform after booting the MS or immediately perform after receiving new multimedia program, as shown in Figure 8, the multimedia program table is at an incomplete state. This is a section where the continuity of received program cannot be confirmed. Accordingly, a waiting time is set at the corresponding section and once the program is requested from the waiting time, an explicitly stated IGMP join report must be transmitted. Accordingly, the sequence for transmitting IGMP join report by MS C at the waiting time in order to view 'stream A' is illustrated. Next, once MS B sends IGMP leave report in order to change the multimedia program, the multicast router gets to send IGMP group-specific query. The MS A that had been viewing 'stream A' without explicitly stated IGMP join report at B section and MS C that had been viewing previously as illustrated in Figure 8 get to make a explicitly stated IGMP join report within max response time. Next, in case the MS of MS A that had been viewing 'stream A' becomes in a state of not viewing by being shut down and MS C that had been the last viewer also makes IGMP leave report on corresponding program, the multicast router gets to send a group-specific query.

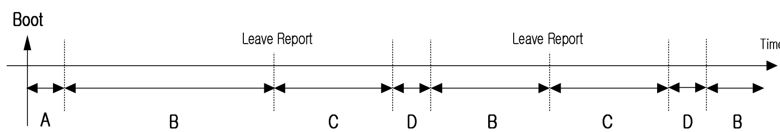

Fig. 8. Requesting sections of an IPTV program

For the MS B to watch the corresponding program once again at C section as illustrated in Figure 8, it gets to participate in viewing after making sure to send an explicitly stated IGMP join report. Next, if the MS B which is the last viewer of 'stream A' makes IGMP leave report, the multicast router gets to send a group-specific query and if the proper IGMP join report is failed to be received with max response time, the IGMP leave message is sent to multicast router that the data on 'stream A' is no longer received.

5 Performance Analysis

In order to analyses the performance of the new extended IGMP, we need analysis of the program popularity. Figure 9 shows the independent popularity change scenario and popularity-oriented change scenario when total numbers of program are 10, 15, and 20. For proper program popularity distribution, TV viewing behavior should be modeled. However, the program popularity is very difficult to be modeled. Therefore, we will model the channel popularity for a period of time.

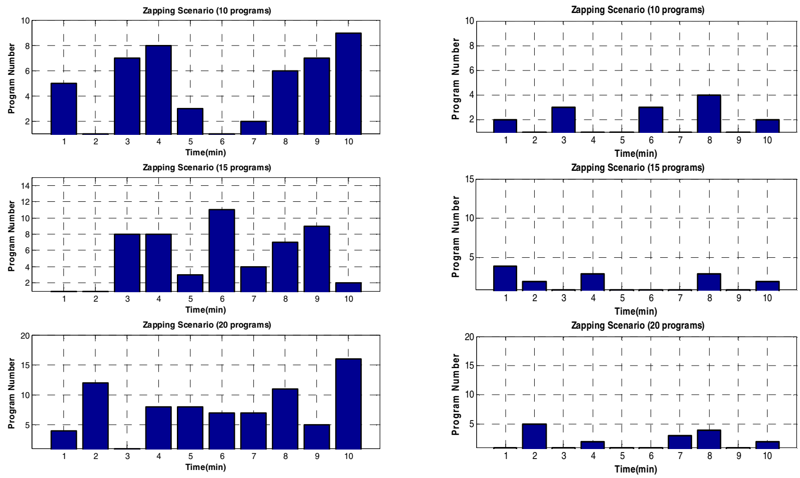

Fig. 9. Independent popularity change and popularity-oriented change scenario

As shown in Figure 10, if $\bar{C}_{select}$ is an element of $\bar{C}_{shared}$, a viewer immediately watches the selecting channel without an IGMP join report.

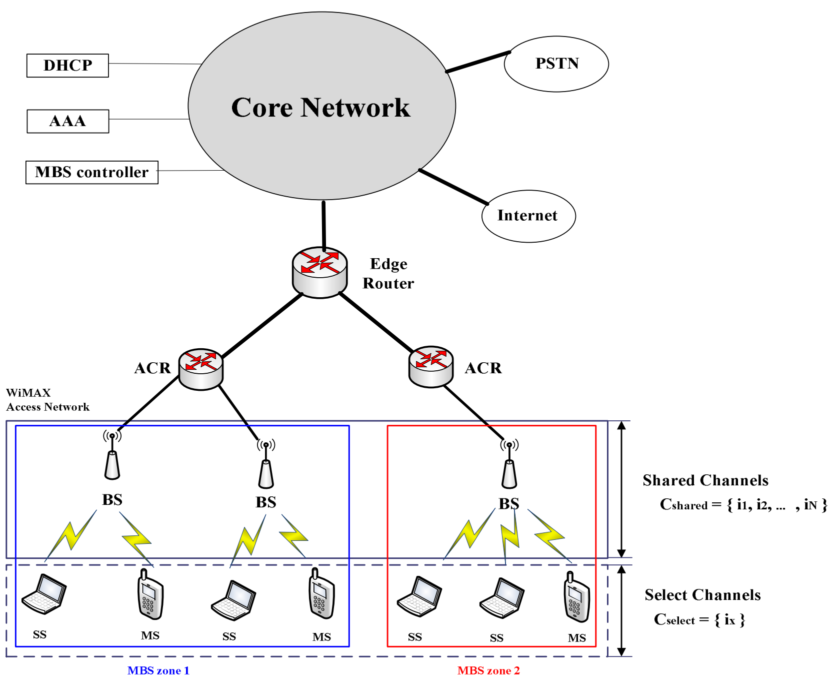

Fig. 10. Shared and select multimedia program channels

Accordingly, we attempt to investigate a channel popularity model in order to analyze the channel sharing. In Figure 11, there are 96 channels which are about Korea TV channel popularity density announced by TNS Media Research in Korea [13].

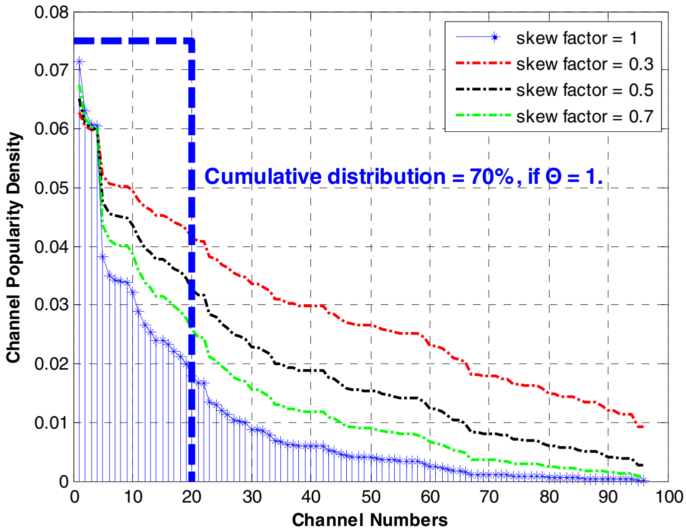

Fig. 11. Channel popularity density

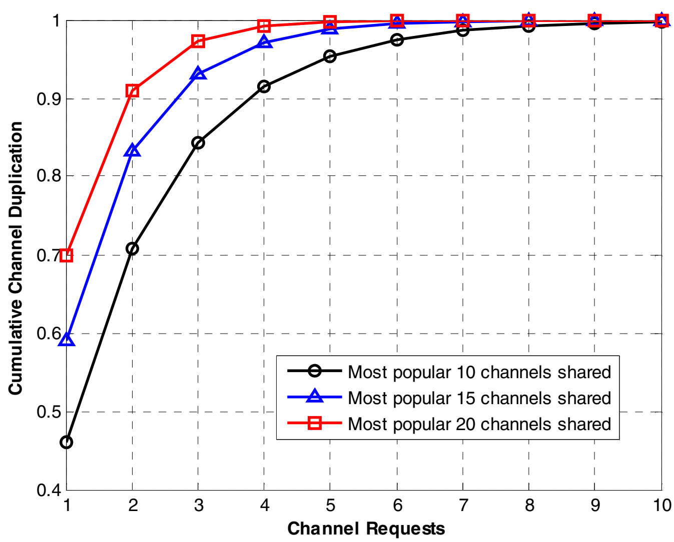

Fig. 12. Cumulative channel duplication probability on a MBS zone

$$p_X(x) = \kappa x^{\Theta}, \quad \text{for } x=1, 2, \ldots, N , \tag{1}$$

where x is the channel's popularity-rank, Θ is the skew factor, κ is a normalization constant, and N is the number of channels [14]. We shall use this probability density to find the probability that X has values from 0 to most popular 10, 15, and 20 channels, respectivly. The probability is

$$P\{0 \le X \le N\} = \int_0^N p_X(x)dx = 1 . \tag{2}$$

Thus, the event $\{0 \le X \le 10\}$ is about 46%, the event $\{0 \le X \le 15\}$ is about 59%, and the event $\{0 \le X \le 20\}$ is about 70%. If the most popular channels are shared respectively in a service node, we can assume a channel duplication probability. The channel duplication probability implies that a viewer's selecting channel, C_{select}, is already included in C_{shared} set. We shall repeat the experiment M times and determine the probability that $C_{select} \in C_{shared}$ is observed exactly r times out of the independent M trails.

$$P\{C_{select} \in C_{shared}\} = \binom{M}{r} p^r (1-p)^{M-r} . \tag{3}$$

If most popular 10 channels are shared in a service node, the probability of a viewer choosing among the channels is 0.46 and M=1. If most popular 10 channels are shared in a service node, the probability of a viewer choosing among the channels is 0.46 and M=1. Figure 12 shows the cumulative channel duplication probability of 10 independent trials when total numbers of most popular shared channels are 10, 15, and 20. Notice that the newly proposed IGMP are able to let viewers immediately watch on the shared IPTV without channel change response time when more than 5 channel.

6 Conclusions

This paper proposes a new extended IGMP for IPTV services provided especially although mobile WiMAX access network. The proposed IGMP architecture includes MAC SAP, input packet classification section, multimedia program management section and IGMP report generation section. The MAC SAP provides downlink MAP information to an extended IGMP which can be allowed immediate channel switching. In the extended IGMP, general unicast packets and multicast packets are classified the packet streams entered to a MS of viewer from the service interface on the shared mobile access networks while classifying the separated multicast packets once again into multicast packets for sending IPTV contents and packets for IGMP query. Otherwise, the new IGMP with MAC SAP allows viewers to switch channels being watched by other viewers without going through complex traditional IGMP processes. In usual TV viewing situations, most popular channels are being watched by some views. Simulation results show that the newly proposed IGMP can immediately watch the shared IPTV channels without the channel change response time using the enhanced group join and leave process for mobile WiMAX, when more than 5 channel requests are made for most popular channels.

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