IP Multicast Transmission Technology and Technical Issues

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Abstract

IP (Internet protocol) multicast is one of the key technologies for providing IP broadcasting, which is a major component of next-generation-network services. This article describes the background of recent IP multicast deployment, gives a brief overview of current IP multicast technologies, and discusses some technical issues related to applying IP multicast to IP broadcasting. Finally, it introduces new technologies for solving the issues.

1. Introduction

Broadcasting by IP (Internet protocol) multicast is expected to be at the heart of Triple Play services for the Next Generation Network (NGN), and it is an important technology within the convergence of telecommunications and broadcasting. As clearly stated in the mid-term findings of the Telecommunications Commission of the Ministry of Internal Affairs and Communications, "IP Multicast using communications infrastructure such as optical fiber should be actively applied, ... if it satisfies the requirements to realize equivalent services to terrestrial broadcasting." Recent advances in the technology and the infrastructure have fueled these expectations for the potential of IP multicast. Stable packet transfer suitable for broadcasting has become possible because of the penetration of fiber-to-the-home (FTTH), and further developments in multicast support for routers make it easier to build multicast networks. For example, multicast routers capable of carrying over 1000 channels are currently available on the market.

2. Differences between unicast and multicast

The differences between unicast transmission, which is currently the most commonly used method of video distribution on the Internet, and multicast transmission applied to IP broadcasting are shown in **Fig. 1**. With unicast, the receiving device (receiver) connects directly to the streaming server containing the video data. The streaming server recognizes the accessing receiver and transmits the video data packets directly to it. With multicast, streaming servers do not transmit data directly to receivers. The receivers send a multicast request containing the desired channel ID to the nearest router (user edge). For example, the user might acquire the channel ID beforehand from the program schedule webpage of the content provider.

In multicast, the channel is identified by the (S,G) pair, where S (source) is the IP address of the streaming server and G (group) is the multicast address. In the example in Fig. 1(b), the receiver requests multicast address 233.0.0.1 from streaming server 3.3.3.3. The multicast address is within a range of assigned IP addresses. Specifically, in IPv4 that range is from 224.0.0.0 to 239.255.255.255; in IPv6 the range includes all address that begin with 0xFF. These address ranges are used only for forwarding multicast traffic, and may not be assigned as the IP addresses of personal computers, etc. Routers can automatically recognize packets in this address range as multicast packets.

The streaming server sends the broadcasting video data to the nearest router (server edge) as multicast (S,G) packets where G is destination address and S is source address. Within the IP network, each router between a user edge and a server edge relays the mul-

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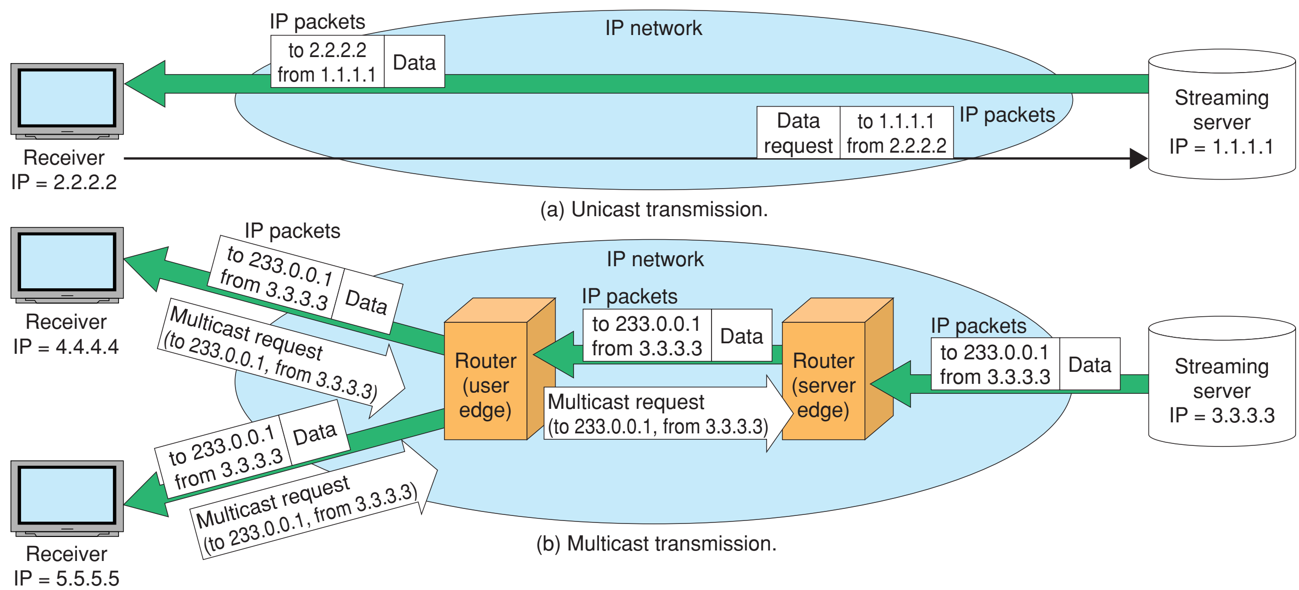

Fig. 1. Unicast versus multicast.

ticast request towards the streaming server of address S according to the channel ID. When the multicast request finally arrives at the router receiving the (S,G) packets (in the worst case, the request will reach the server edge if it traces the route shown in Fig.1(b)), that router copies and sends them in the opposite direction along the path that the multicast request traveled. This mechanism enables broadcasting video data to reach the receiver as (S,G) packets.

Unicast and multicast differ in terms of their suitability to applications as a result of the differences in flow described above. For example, unicast is suitable for video-on-demand type services. The direct control between the receiver and streaming server makes possible special play control features such as fast forwarding, rewinding, and pausing: the types of features that are attractive for video-on-demand. However, one limitation of unicast is that extremely powerful streaming resources are necessary to handle streaming to many receivers simultaneously.

In multicast, because there is no direct control between the receiver and the streaming server, it is difficult to implement special play control capabilities. However, because it is only necessary to send a single packet stream, multicast is well suited to broadcast applications. Therefore, from the streaming server's perspective, there are no limitations on the number of possible receivers, and the streaming load is extremely low.

3. Existing multicast technologies

The standard multicast protocols are: i) IGMP (Internet group management protocol) [1] and MLD (Multicast Listener Discovery) [2] used between the receiver and a user edge and ii) PIM (Protocol-independent multicast) used between routers on IP networks. Although PIM has a number of modes, we introduce PIM-SSM (source-specific multicast) [3] here because it is expected to be the mainstream mode in the foreseeable future. IGMP and MLD are IPv4 and IPv6 protocols, respectively: while the IP versions may differ, their behavior is the same. PIM-SSM supports both IPv6 and IPv4.

As shown in **Fig. 2**, IGMP/MLD and PIM-SSM are similar in the way they send a Join message as a multicast request to the adjacent router in the direction of the streaming server. However, the inter-router protocol PIM-SSM includes a function for confirming the existence of an adjacent router running the PIM protocol by a Hello message. This function makes it possible to control multicast bypassing routers that are not running the PIM protocol.

On the other hand, IGMP/MLD, the protocol between the receiver and router, has a function that periodically confirms the existence of receivers that desire multicast data. Specifically, as shown in Fig. 2, the router sends a query message, and if there is no Join message response, the server determines that there are no receivers wishing to receive multicast

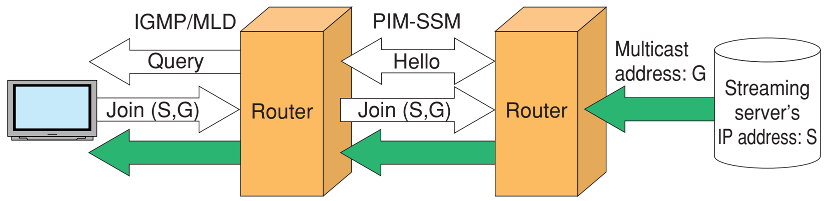

Fig. 2. Message flow of existing multicast protocols.

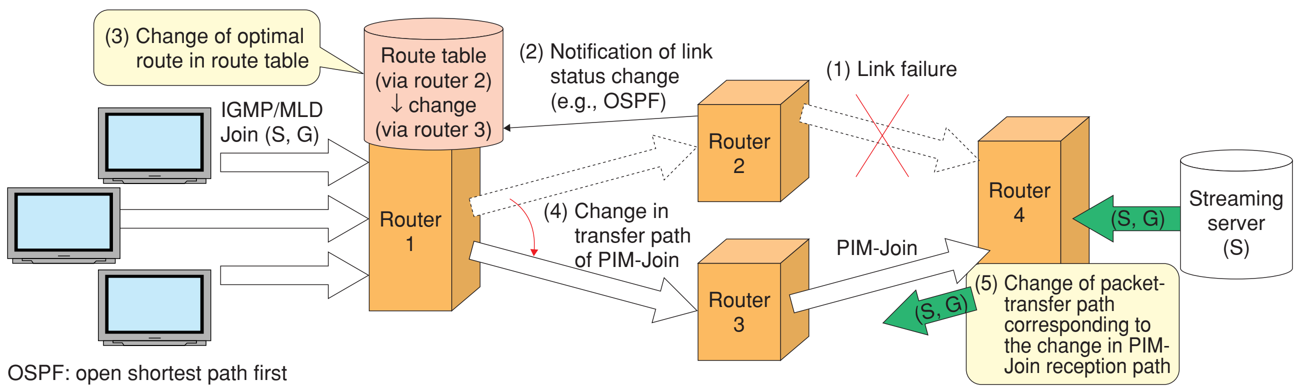

Fig. 3. Issues in highly reliable transfer.

data. The purpose for this is to prevent wasteful transfers of multicast packets when multicast data has become unnecessary, for example, because the receiver has been restarted or powered off.

4. Requirements and issues

This section overviews the major network requirements for IP broadcasting and issues related to applying IP multicast. The network is required to support services equivalent to current broadcasting.

4.1 High quality transfer

The network should reserve link bandwidth so that the receiver can view contents stably. Moreover, for NGN, the reserved bandwidth should be sufficient to handle HDTV (high-definition television) video rates (10 Mbit/s or more). With the current best-effort packet transfer, however, it is difficult to assign routes according to channel bandwidth to achieve stable packet transfer for 10 Mbit/s or higher rates. In particular, it is difficult to specify multicast routers and reserve bandwidth for redundant routes because multicast routes set by PIM depend on the result of transmission using unicast routing protocols.

4.2 Highly reliable transfer

The requirement for a highly reliable network is especially important. It is shown in detail in **Fig. 3**. From the perspective of transfer reliability, route switchover must be performed as quickly as possible when a network failure occurs. The network should have an extremely short downtime for a network failure (e.g., less than 1 s). With PIM, route switchover takes a long time because it is executed after the convergence of unicast routes. As a result, the number of routes is larger, that is the network is larger, so switchover takes longer. In some cases, PIM route switching takes several tens of seconds. Furthermore with PIM, because the router manages the transfer status of each channel, the switchover time increases when more channels are provided.

4.3 Fast channel switching

To support TV channel surfing, the network should have an extremely short response time between a channel change request and the display of video on screen. With IGMP/MLD, it takes a few seconds to confirm the status of the other receivers by Query messages when the current channel is terminated before switching to the new channel.

4.4 Limited area of delivery

The network must be able to limit the geographical area over which content is broadcast because the broadcasting license covers a limited area. It is functionally possible to configure IGMP/MLD filtering on routers. However, it is difficult to administer distribution policies distributed across routers.

4.5 Maintain operability

The network should provide easy failure analysis and preventative maintenance using route redundancy. Because route control is in the opposite direction to the data flow for PIM, it is difficult to analyze failures. With PIM, it is difficult to confirm the state of non-ultimate redundant routes.

5. Conclusion

New technologies for solving the above-mentioned multicasting problems are described in other articles in this issue. Multicast AAA (Authentication, Authorization, and Accounting) and Multicast MPLS (multiprotocol label switching) are key technologies. For example, the use of i) path assignment by Multicast MPLS traffic engineering and ii) coordination with admission control using Multicast AAA leads to high quality transfers. Network reliability is improved by fast route switchover by Multicast MPLS just like point-to-point MPLS. Aggregated administration of distribution policies using Multicast AAA simplifies the management of router configurations. MPLS-OAM of Multicast MPLS achieves advanced management of current and redundant multicast paths (OAM: operation, administration, and maintenance).

References

[1] "Internet Group Management Protocol, Version 3," RFC3376.
[2] "Multicast Listener Discovery Version 2 (MLDv2)," RFC3810.
[3] "Protocol Independent Multicast - Sparse Mode (PIM-SM)," RFC4601.

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