

**TR-459.3**  
**Multi-Service Disaggregated BNG with CUPS: IPTV  
Multicast function - Reference Architecture,  
Deployment Models, Interface and Protocol  
Specifications**

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## Executive Summary

This Technical Report extends the TR-459: Multi-Service Disaggregated BNG with CUPS - Reference Architecture, Deployment Models, Interface and Protocol Specification to cover the IPTV Multicast function.

# 1 Purpose and Scope

## 1.1 Purpose

TR-459: Multi-Service Disaggregated BNG with CUPS - Reference Architecture, Deployment Models, Interface and Protocol Specification serves as a baseline document for implementing the core BNG functions. In this document, the MS-DBNG solution is further extended to incorporate the IPTV Multicast function.

TR-459.3 specifies architecture, call flows, technical requirements, and PFCP protocol to cover IPTV use cases using the interfaces introduced in TR-459.

## 1.2 Scope

TR-459 introduces the IPTV Multicast as a DBNG-UP function:

IPTV Multicast: IGMP and MLD request are processed locally to provide the fastest channel change time.

Building on the scope specified in TR-459, the following are specified in this document:

- IGMP/ MLD protocol standards that are applicable
- Details on the Multicast management function in DBNG-CP to enable IPTV Multicast function in the DBNG-UP
- IPTV Functional Requirements on the DBNG-CP and DBNG-UP in terms of Mi, CPRi and SCi interfaces
- IPTV Call flows
- PFCP IE extensions to support IPTV.

## 2 References and Terminology

### 2.1 Conventions

In this Technical Report, several words are used to signify the requirements of the specification. These words are always capitalized. More information can be found in RFC 2119 [4].

MUST	This word, or the term “REQUIRED”, means that the definition is an absolute requirement of the specification.
MUST NOT	This phrase means that the definition is an absolute prohibition of the specification.
SHOULD	This word, or the term “RECOMMENDED”, means that there could exist valid reasons in particular circumstances to ignore this item, but the full implications need to be understood and carefully weighed before choosing a different course.
SHOULD NOT	This phrase, or the phrase “NOT RECOMMENDED” means that there could exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications need to be understood and the case carefully weighed before implementing any behavior described with this label.
MAY	This word, or the term “OPTIONAL”, means that this item is one of an allowed set of alternatives. An implementation that does not include this option MUST be prepared to inter-operate with another implementation that does include the option.

### 2.2 References

The following references are of relevance to this Technical Report. At the time of publication, the editions indicated were valid. All references are subject to revision; users of this Technical Report are therefore encouraged to investigate the possibility of applying the most recent edition of the references listed below.

A list of currently valid Broadband Forum Technical Reports is published at [www.broadband-forum.org](http://www.broadband-forum.org).

Document	Title	Source	Year
[1] <a href="#">TR-145</a>	Multi-service Broadband Network Functional Modules and Architecture	BBF	2012
[2] <a href="#">TR-178 Issue 2</a>	Multi-service Broadband Network Architecture and Nodal Requirements	BBF	2017
[3] <a href="#">TR-459</a>	Control and User Plane Separation for a Disaggregated BNG	BBF	2020
[4] <a href="#">RFC 2119</a>	Key words for use in RFCs to Indicate Requirement Levels	IETF	1997
[5] <a href="#">RFC 2236</a>	Internet Group Management Protocol, Version 2	IETF	1997
[6] <a href="#">RFC 2710</a>	Multicast Listener Discovery (MLD) for IPv6	IETF	1999
[7] <a href="#">RFC 4604</a>	Using Internet Group Management Protocol Version 3 (IGMPv3) and Multicast Listener Discovery Protocol Version 2 (MLDv2) for Source-Specific Multicast	IETF	2006
[8] <a href="#">3GPP TS 29.244 V16.5.0</a>	Interface between the Control and User Plane Nodes	3GPP	Sep 2020



## 2.3 Definitions

The following terminology is used throughout this Technical Report.

**MS-BNG** TR-178 introduces the Multi-Service BNG (MS-BNG), which extends the capabilities of a traditional BNG to offer services to both residential and business customers as well as to allow mobile backhaul deployments. To achieve this, it performs Ethernet Aggregation and can either forward packets via MPLS or through IP Aggregation/routing. A MS-BNG is part of a TR-145 network architecture and can be deployed in a hierarchical BNG architecture.

## 2.4 Abbreviations

This Technical Report uses the following abbreviations:

3GPP	3rd Generation Partnership Project
AAA	Authentication, Authorization & Accounting
BBF	Broadband Forum
BNG	Broadband Network Gateway
BIER	Bit Index Explicit Replication
CPRi	Control Packet Redirect interface
DBNG	Disaggregated BNG
DBNG-CP	DBNG Control Plane
DBNG-UP	DBNG User Plane
DHCP	Dynamic Host Configuration Protocol
FAR	Forwarding Action Rule
ID	Identifier
IE	Information Element
IETF	Internet Engineering Task Force
IGMP	Internet Group Management Protocol
IP	Internet Protocol
IPMA	IP Multicast Accept
IPMD	IP Multicast Deny
IPv4	Internet Protocol Version 4
IPv6	Internet Protocol Version 6
IPTV	Internet Protocol Television
LAN	Local Area Network
LNS	L2TP Network Server
MC	Multicast
MCAC	Multicast Call Admission Control
Mi	Management interface
MLD	Multicast Listener Discovery

PDI	Packet Detection Information
PDR	Packet Detection Rule
PFCP	Packet Forwarding Control Protocol
PIM	Protocol Independent Multicast
QER	QoS Enforcement Rule
QoS	Quality of Service
RFC	Request For Comments
RG	Residential gateway
Sci	State Control interface
TR	Technical Report
UP	User Plane
URR	Usage Reporting Rule
VLAN	Virtual Local Area Network
VSA	Vendor Specific Attribute
WA	Work Area
WT	Working Text

### 3 IP Multicast Overview

IPTV is part of the traditional triple play service, where the BNG plays an important role in managing the service. The BNG in general is required to tailor the multicast service for each subscriber individually. This requires the BNG to receive a list of channel requests, process them and to either accept or deny each request. In the case where the channel request is allowed, the BNG will retrieve the multicast traffic from the network using a multicast routing protocol such as PIM, BIER, etc. The multicast traffic is then distributed to each subscriber. There are variations of the multicast distribution model from the BNG depending on the operator preference to place the replication within BNG or at different aggregation points of the access network.

#### 3.1 IGMP/ MLD Concepts

IPTV service is requested by the subscribers utilizing Layer 3 multicast signaling protocols. Options available for IPv4 subscribers are IGMPv2 (see IETF RFC 2236) or IGMPv3 (see IETF RFC 4604). IPv6 subscribers utilize MLD (see IETF RFC 2710) or MLD2 (see IETF RFC 4604) signaling.

#### 3.2 DBNG Functional Architecture

TR-459 mentions “IPTV Multicast” as a DBNG-UP function with the below description:

**IPTV Multicast:** IGMP and MLD request are processed locally to provide the fastest channel change time.

We also require a DBNG-CP function for IPTV Multicast. Figure 1 adds a “MCAST Mgmt” control function in the DBNG-CP.

**MCAST Mgmt:** Responsible for managing multicast functionality for each subscriber session.

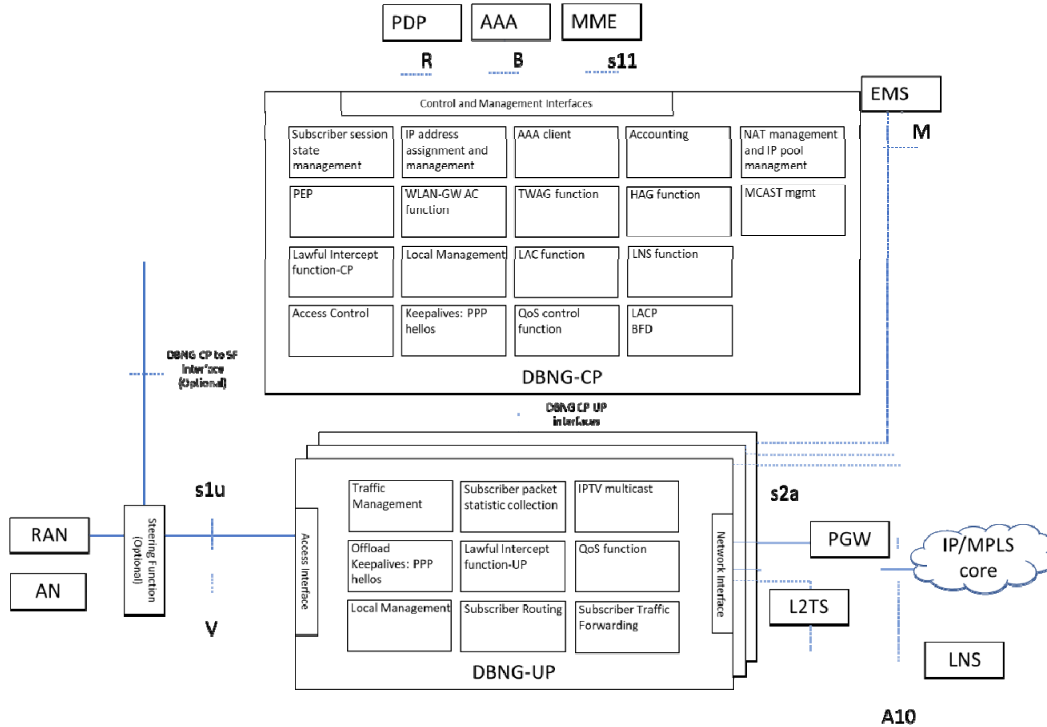


Figure 1: DBNG functions (IPTV Multicast)

Concepts or Definition:

For multicast service, there are typically several multicast (S,G) lists that subscribers will reference:

- Static join list – a (S,G) list that specifies multicast group(s) that must be delivered to the subscriber regardless of an IGMP/MLD request being initiated.
- Channel list – a list with (S,G) entries that either allow or deny specific (S,G)s. This is typically the channel package that the subscriber has ordered.
- Channel bandwidth info list – a list that contains the bandwidth information of individual channels. This is typically utilized to adjust the QoS scheduler to ensure the subscriber access bandwidth is not over-saturated. It is also used to ensure that accepting the next IGMP message will not result in over-subscription of the access line.

Replication models:

- Subscriber replication – The multicast is replicated to each subscriber individually in the DBNG-UP.
- Multicast redirected VLAN model – The multicast is delivered for a group of subscribers by utilizing a separate logical interface.

Multicast is a data plane service, requiring immediate processing and response to guarantee the best user experience. In a typical scenario, the multicast request from the subscriber in the form of IGMP/MLD would result in an immediate PIM join for the multicast source. In the DBNG CUPS architecture, this immediate response must be maintained. Therefore:

- IGMP/MLD messages are never relayed to the DBNG-CP which would delay the processing, rather all IGMP/MLD messages are processed locally on the DBNG-UP.
- The DBNG-CP will enforce per subscriber multicast policies through the DBNG-UP. The policies can be applied at authentication or through an update during the subscriber session.
- The DBNG-UP may inform DBNG-CP per subscriber IGMP/MLD (S,G) joins. This can help update policies and for failover scenarios.

### 3.2.1 Control Plane Function

The DBNG-CP is a centralized location to manage multicast service for all subscribers. During authentication, the policy server would provide a list of multicast attributes to tailor each subscriber IPTV service. Per subscriber multicast attributes are:

- IGMP/MLD protocol related:
  - Router-alert
  - Fast-leave
  - IGMP/MLD version
- Channel related:
  - Maximum (\*,\*), (S,\*), (\*,G), and/or (S,G)
  - Permit/Deny channel list
  - Static join lists (i.e., TV guide, weather programs)
- Bandwidth related:
  - Egress rate adjustment
  - IGMP/MLD rejects based on bandwidth consumption.

### 3.2.2 User Plane Function

To provide the best and most responsive experience for the subscriber, IP Multicast requires the DBNG-UP to support:

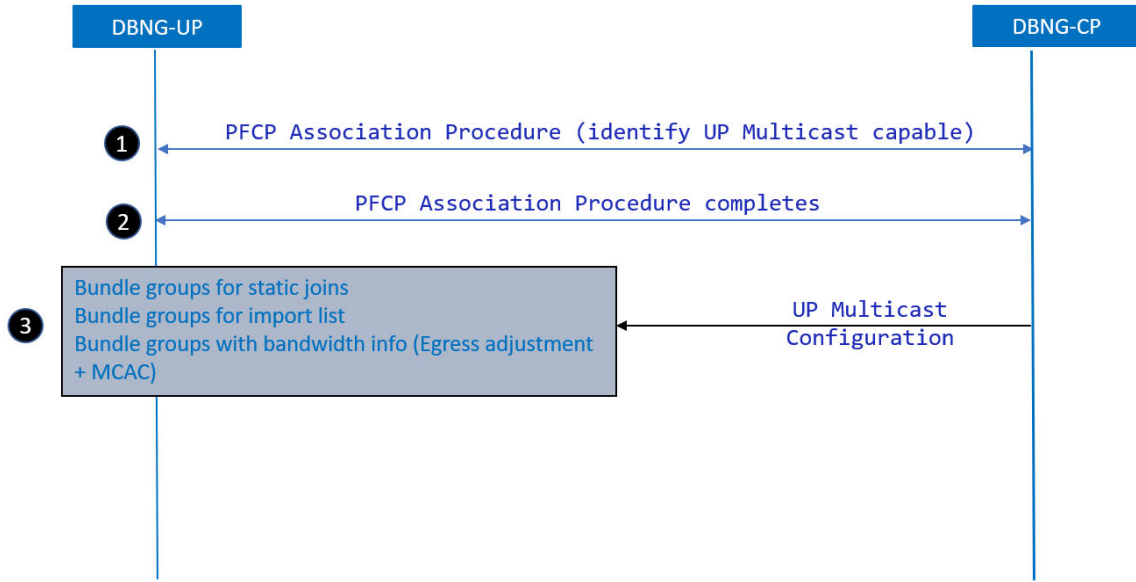
- Terminating and managing IGMP or MLD messages received from the Residential Gateway (RG);
- Acting as a Multicast Router as defined in IETF RFC 2236 and IETF RFC 3376;
- Replicating IP multicast traffic received from the A10 interface for subscriber sessions having joined the corresponding IP multicast group;

- Notifying the DBNG-CP when a subscriber session has joined or left a multicast group, if so requested by the DBNG-CP.

## 4 Call Flows

### 4.1 DBNG-UP Association for IP Multicast

DBNG-UP bootup:



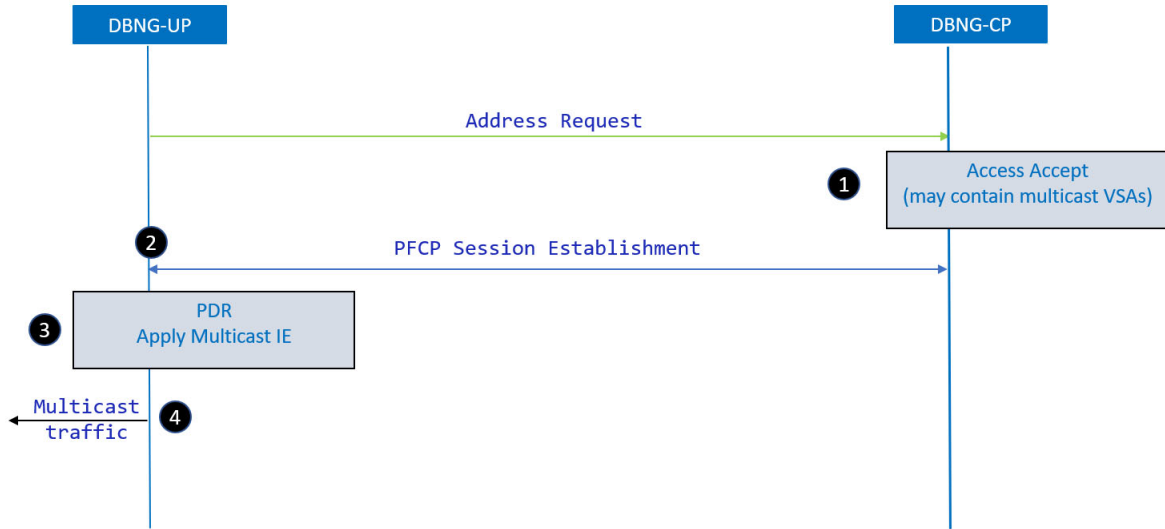
**Figure 2: DBNG-UP association for IP multicast**

Steps:

1. A new DBNG-UP is initialized in the network. DBNG-UP informs DBNG-CP about its multicast function capabilities.
2. DBNG PFCP association completes.
3. DBNG-CP through the management interface updates DBNG-UP with:
  - IGMP/MLD policies
  - IGMP/MLD channel list
  - (S,G) channel and associated bandwidth.

## 4.2 Multicast Activation During Login

Simplified login call flow:



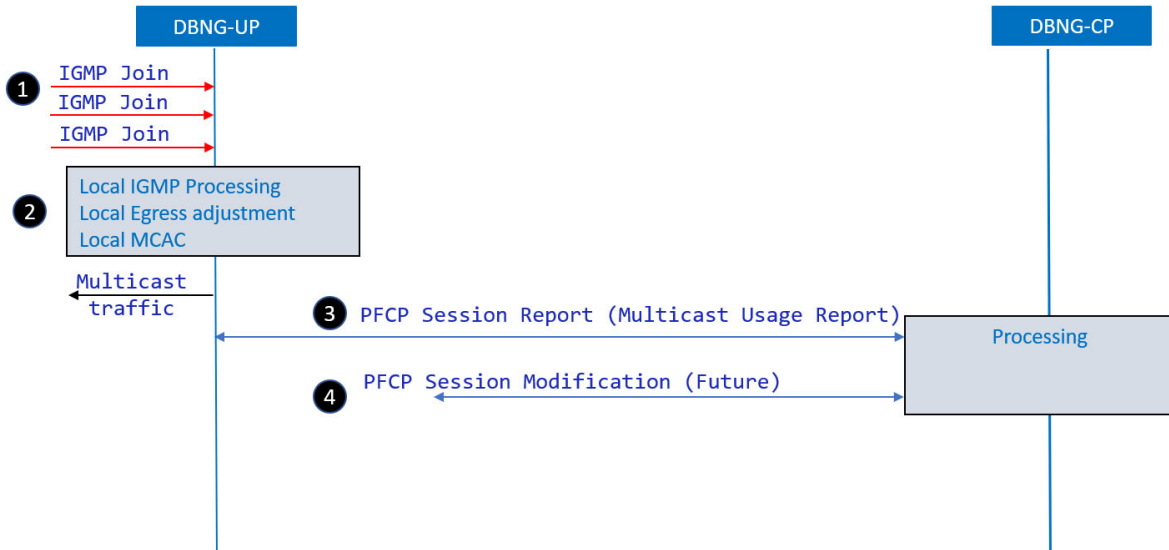
**Figure 3: Multicast activation during login**

Steps:

1. Subscriber logs onto the network via an address request message. The DBNG-CP gets a list of multicast attributes from the AAA server.
2. The DBNG-CP sends a Session Establishment request to enforce IGMP/MLD policies and channel lineup.
3. The PDRs activate predefined rules and policies that are already configured on the DBNG-UP.
4. Depending on the policy, multicast traffic (e.g. TV Guide) may immediately be forwarded to the subscriber.

## 4.3 Multicast JOIN Processing

IGMP join request:



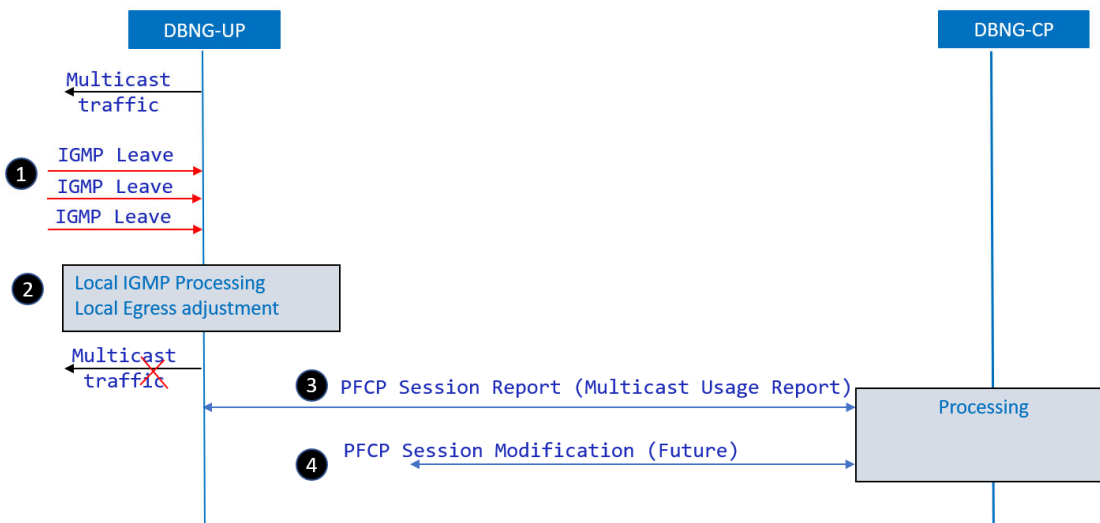
**Figure 4: Multicast join**

Steps:

1. The subscriber begins sending IGMP/MLD JOIN requests to the DBNG-UP
2. The DBNG-UP will perform local IGMP processing and start the multicast traffic for the channel joined
3. The DBNG-UP will notify the channels being watched to the DBNG-CP via URR messages (Refer Appendix I for more details). The DBNG-CP will store the list of channels being watched by the subscriber for accounting, QoS, or logging purposes.
4. It is possible for the DBNG-CP to update the subscriber session based on the URR information.

## 4.4 Multicast LEAVE Processing

IGMP leave request:





### **Figure 5: Multicast leave**

Steps:

1. The subscriber sends IGMP/MLD LEAVE requests to the DBNG-UP
2. The DBNG-UP will perform local IGMP processing and stop the multicast traffic for the channel left
3. The DBNG-UP will notify the channels being watched to the DBNG-CP via URR messages (Refer Appendix I for more details). The DBNG-CP will store the list of channels being watched by the subscriber for accounting, QoS, or logging purposes.
4. It is possible for the DBNG-CP to update the subscriber session based on the URR information.

## 5 Technical Requirements

Below is a list of key requirements to support the IP Multicast function on DBNG.

### 5.1 General IP Multicast Requirements on DBNG

This section describes the SCi and Mi requirements for IP Multicast. There are no CPRi requirements.

### 5.2 DBNG-CP Requirements

DBNG-CP SCi requirements:

1. The DBNG-CP MUST be able to send PFCP rules to the DBNG-UP based on the IGMP/MLD protocol attributes received from AAA server.
2. The DBNG-CP MUST be able to send PFCP rules to the DBNG-UP based on the IGMP/MLD policies received from AAA server.
3. The DBNG-CP MUST support two replication modes. For each PFCP session, the DBNG-CP must use only one replication mode, either “BBF Outer Header Creation” IE or the “Forwarding Policy” IE.
4. The DBNG-CP MAY request the DBNG-UP to report IGMP/MLD JOIN and LEAVE information in PFCP Session Report Request.

### 5.3 DBNG-UP Requirements

DBNG-UP SCi requirements:

1. During PFCP association, the DBNG-UP MUST utilize BBF UP feature function flag to inform the DBNG-CP of broadband IPTV multicast support.
2. The DBNG-UP MUST support multicast parameters listed below either using Activate Predefined Rules IE or per-subscriber IGMP/MLD protocol IE:
  - Fast Leave
  - Router Alert
  - Query interval
  - Query Response interval
  - Group-specific query interval
  - Maximum concurrent Source Groups
3. The DBNG-UP MUST enforce multicast policies based on PFCP rules from DBNG-CP.
4. The DBNG-UP MUST report IGMP/MLD JOIN and LEAVE information in PFCP Session Report Request if requested by DBNG-CP.

Multicast signaling and routing protocol requirements:

1. The DBNG-UP MUST process IGMP and MLD messages locally.
2. The DBNG-UP MUST be able to source multicast streams from the core network.

### 5.4 Management Interface Requirements

DBNG-UP requirements:

1. The DBNG-UP MUST be able to store IGMP and MLD policies and templates.

## 6 PFCP CUPS Protocol

### 6.1 PFCP Use Case and Information Exchanges

IP Multicast requires the DBNG-UP to support:

- terminating and managing IGMP or MLD messages received from the Residential Gateway (RG);
- acting as a Multicast Router as defined in IETF RFC 2236 and IETF RFC 3376;
- replicating IP multicast traffic received from the A10 interface for PFCP sessions having joined the corresponding IP multicast group;
- notifying the DBNG-CP when a PFCP session has joined or left a multicast group, if so requested by the DBNG-CP.

Refer Appendix I for 3GPP IPTV PFCP IEs. The 3GPP PFCP IEs though usable for IP Multicast are not sufficient for the wireline use cases and below enhancements to PFCP are proposed.

For DBNG, a new bit in BBF UP Function Features IE is introduced for IP Multicast support by the DBNG-UP function as follows.

**Table 1: BBF UP Function Features for Multicast**

Feature Octet / Bit	Feature	Interface	Description
7/6	IPTV	SCi	DBNG-UP support of IP Multicast

The BBF IPTV bit is mandatory for IPTV support requiring BBF Multicast extensions. The 3GPP IPTV bit is required (see Appendix I) in addition to the BBF IPTV bit.

The DBNG-UP runs multicast protocol towards the subscriber and the following protocol parameters are typically applied for individual subscribers to manage the multicast control traffic.

- Protocol query timers
- Maximum concurrent channel limit
- Protocol control flags - Fast leave, Router alert check

It is proposed to introduce a new optional BBF Multicast Protocol Control IE for this purpose. The BBF Multicast Protocol Control IE is defined in Section 6.3.1. The PFCP rule for upstream PDR will use the new IE as follows:

**Table 2: Example PDR for specifying multicast protocol in upstream direction**

Direction	PDR	FAR
Upstream	PDR ID IP Multicast Addressing Info (Optional) BBF Multicast Protocol Control PDI: Source Interface = access Traffic-Endpoint SDF match (IGMPv2/v3, MLDv1/v2) FAR ID URR ID Reporting trigger IPMJL -IP Multicast Join/Leave	FAR ID Apply Action: IPMA/        IPMD        (IP Multicast Accept/Deny)

Channel List is the channel lineup that the subscriber has paid for. In wireline, the channel lineups are in the range of hundreds. The 3GPP PFCP IE, IP Multicast Addressing Info, takes a minimum of 4 bytes per IPv4 channel i.e., 400 bytes for 100 channels and 4,000 bytes for 1,000 channels. This list is repeated per

direction. With 100,000 subscribers on the DBNG-UP, the PFCP will need to transfer multiple megabytes of control data just for multicast channel lineup alone from the DBNG-CP. With (S,G) and IPv6 in IP Multicast Addressing Info, the control data increases even more. Any channel updates or subscriber changes by the subscriber can increase the byte transfer further. Therefore, the proposal is to use one or more pre-defined channel listing names using Activate Predefined Rules IE (3GPP TS 29.244[8] section 8.2.72) instead of using the 3GPP method to express combination of channel listing. The channel packages will be predefined in the DBNG-UP. The PFCP PDR rules for upstream will be used as follows:

**Table 3: Example PDR for specifying pre-defined rules in upstream direction**

Direction	PDR	FAR*
Upstream	PDR ID Activate Predefined Rules (Pre-joined channel list, Group list/filter, Source-specific group list/filter, allow/ reject based on multicast bandwidth) PDI: Source Interface = access Traffic-Endpoint SDF match (IGMPv2/v3, MLDv1/v2) URR ID Reporting trigger IPMJL -IP Multicast Join/Leave	

\*: FAR is not required when there is a predefined rule per 3GPP TS 29.244[8]

The downstream traffic when replicated for each subscriber requires the BBF Outer Header to be created. This is addressed as follows:

**Table 4: Example PDR for specifying per-subscriber replication**

Direction	PDR	FAR
Downstream	PDR ID IP Multicast Addressing Info PDI: Source Interface = network FAR ID QER ID: MBR/GBR	FAR ID Apply Action: Forward Forwarding Parameters: Destination Interface <b>BBF Outer Header Creation</b>

In the downstream direction, the replication may be done once into a Multicast virtual LAN terminating on an Access Node on which multiple subscribers are connected. The Access Node snoops into the Multicast JOINS and does replication for each subscriber only in the last mile. This use case is not covered by any existing 3GPP IE. To provide flexibility in supporting different replication modes, we propose the Forwarding Policy IE be supported for downstream traffic.

**Table 5: Example PDR for specifying replication using multicast vlan**

Direction	PDR	FAR
Downstream	PDR ID IP Multicast Addressing Info PDI: Source Interface = network FAR ID QER ID: MBR/GBR	FAR ID Apply Action: Forward Forwarding Parameters: Destination Interface <b>Forwarding Policy (replication mode)</b>

**Note:** If the BBF Outer Header Creation and Forwarding Policy(Replication mode) are present, the DBNG-UP function shall treat this as an error. The DBNG-UP shall reject the Session Establishment Request/ Session Modification Request by responding with Cause IE as “Request Rejected” and Forwarding Parameters IE as Offending IE in the Session Establishment response/ Session Modification Response if this is violated.

## 6.2 PFCP IE summary

This section describes the Multicast related IE summary.

PFCP Association - BBF UP Function Features:

**Table 6: Multicast association Information Elements**

IE Type Value	Information Elements	Use Case			
		CP and UP Association	DHCP Multicast	PPPoE Multicast	LNS Multicast
32768	BBF UP Function Features	Yes	No	No	No

PFCP Session Establishment/ Modification - Create PDR (Upstream):

**Table 7: Multicast upstream PDR Information Elements**

IE Type Value	Information Elements	Use Case			
		CP and UP Association	DHCP Multicast	PPPoE Multicast	LNS Multicast
20	Source Interface	No	Yes	Yes	Yes
32785	BBF Multicast Protocol Control	No	Yes	Yes	Yes
188	IP Multicast Addressing Info	No	Yes	Yes	Yes
106	Activate Predefined Rules	No	Yes	Yes	Yes

PFCP Session Establishment/ Modification - Create PDR (Downstream):

**Table 8: Multicast downstream PDR Information Elements**

IE Type Value	Information Elements	Use Case			
		CP and UP Association	DHCP Multicast	PPPoE Multicast	LNS Multicast
20	Source Interface	No	Yes	Yes	Yes
188	IP Multicast Addressing Info	No	Yes	Yes	Yes
32770	BBF Outer Header Creation	No	Yes	Yes	Yes
41	Forwarding Policy	No	Yes	Yes	Yes

Table 9 provides a list of BBF PFCP IEs introduced by TR-459.3.

**Table 9: List of BBF PFCP IEs for TR-459.3**

IE Type Value	Information Elements	CP and UP Association	DHCP Multicast	PPPoE Multicast	LNS Multicast
32785	BBF Multicast Protocol Control	No	Yes	Yes	Yes

Table 10 provides a list of 3GPP IEs from TS 29.244[8] that MUST be supported for TR-459.3.

**Table 10: List of 3GPP PFCP IEs for TR-459.3**

IE Type Value	Information Elements	Additional Remarks	3GPP UP function feature flag	BBF UP function feature flag
188	IP Multicast Addressing Info			
189	Join IP Multicast Information			
190	Leave IP Multicast Information			

## 6.3 PFCP Grouped IE Extensions

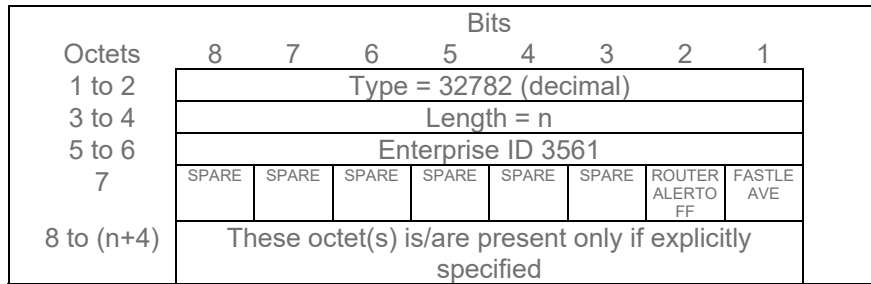
This section describes the Multicast-specific BBF IE extensions to PFCP.

### 6.3.1 BBF Multicast Protocol Control

The BBF Multicast Protocol Control IE type shall be encoded as shown below.

**Table 11: Information Elements in BBF Multicast Protocol Control**

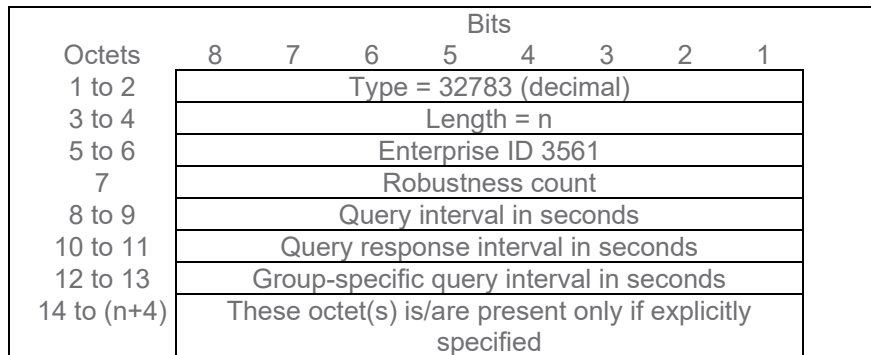
Octet 1 and 2	BBF Multicast Protocol Control IE Type = 32785 (decimal)			
Octets 3 and 4	Length = n			
Octets 5 and 6	Enterprise ID 3561			
Information elements	P	Condition / Comment	Appl.	IE Type
			Sci	
BBF Multicast Flags	M	This IE shall contain multicast protocol related flags	X	BBF Multicast Flags
BBF Multicast Query Parameters	O	This IE shall contain multicast protocol query intervals	X	BBF Multicast Query Parameters
BBF Multicast Group Limit	O	This IE shall contain maximum concurrent groups allowed	X	BBF Multicast Group Limit



**Figure 6: BBF Multicast Flags Information Element**

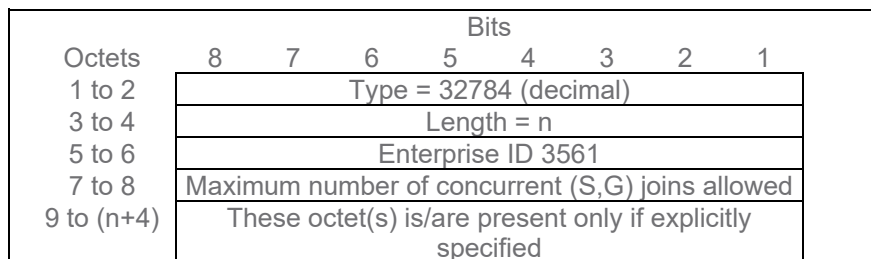
The following flags are coded within Octet 5:

- Bit 1 – FASTLEAVE: If this bit is set to "1", then Fast Leave/ Immediate Leave is supported.
- Bit 2 – ROUTERALERTOFF: If this bit is set to "1", then Router Alert Off is supported.
- Bit 3 to 8 Spare, for future use and set to "0".



**Figure 7: BBF Multicast Query Parameters Information Element**

- "Robustness count" field shall have a value from 2-255.
- "Query interval in seconds" field shall have a value from 60 to 65535.
- "Query response interval in seconds" field shall have a value from 10 to 65535.
- "Group-specific query interval in seconds" field shall have a value from 1 to 65535.



**Figure 8: BBF Multicast Group Limit Information Element**

- "Maximum number of concurrent (S,G) joins allowed" field shall have a value from 1 to 65535.

## Appendix I. PFCP for IPTV in 3GPP TS 29.244

3GPP 29.244[8] defines PFCP Information Elements for IPTV to address the multicast requirements.

In section “8.2.25 UP Function Features”, the UP Function Features IE defines a bit for IPTV.

Feature Octet / Bit	Feature	Interface	Description
8/5	IPTV	N4	UPF support of IPTV service (see clause 5.25)

The PFCP PDR, FAR, QER, URR rules for upstream and downstream are defined in section “5.25 Support for IPTV (for 5GC)”.

Direction	PDR	FAR
Upstream	PDR ID IP Multicast Addressing Info PDI: Source Interface = access Traffic-Endpoint SDF match (IGMPv2/v3, MLDv1/v2) FAR ID URR ID: Reporting trigger IPMJL -IP Multicast Join/Leave	FAR ID Apply Action: IPMA/    IPMD    (IP Multicast Accept/Deny)

Direction	PDR	FAR
Downstream	PDR ID IP Multicast Addressing Info PDI: Source Interface = network FAR ID QER ID: MBR/GBR	FAR ID Apply Action: Forward Forwarding Parameters: Destination Interface Outer Header Creation

For JOIN/ LEAVE reporting using URR, refer the 3GPP TS 29.244[8] Section 5.25.

End of Broadband Forum Technical Report TR-459.3