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Session Control and Management

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Abstract

This Deliverable describes the 5G-Xcast Session(s) and the Session initiation call flows that the Multicast/Broadcast mechanisms use.

The Session management described in this Deliverable enables the architectural alternatives described in the Deliverable D4.1 on 5G-Xcast mobile core network. It details the call flows for the use cases described in the Deliverable D2.1 on Definition of Use Cases, Requirements and KPIs, being Media and Entertainment (M&E) and Public Warning System (PW). These call flows support the initiation of Multicast/Broadcast Sessions for media delivery to mass, in an efficient manner.

This Deliverable also provides a baseline for the 3GPP standardization of multicast/broadcast standardization in 5G.

Keywords

5G, architecture, broadcast, MBMS, Multi-access edge computing, mobile network, MooD, multicast, Multilink, point-to-multipoint, Session, PDU, PW, mABR, call flow, core network, dynamic delivery mode

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[1] CO = Confidential, only members of the consortium (including the Commission Services)

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Executive Summary

This document describes how the 5G-Xcast mobile core network can be enabled to provide multicast and broadcast services in a scalable, efficient and seamless way to its end users. This is done in tight alignment to 3GPP 5G Release 15 so that it may be used in the standardization process. It is achieved through defining of the 5G-Xcast Multicast and Broadcast Sessions and their main call flows for the 5G-Xcast media and Public Warning System use cases described earlier by WP2 D2.2 and using the 5G-Xcast principle architecture alternatives developed in WP4 D4.2.

Defined is an enhanced PDU session modification which can be initiated by the UE or the UPF upon the event of UE joining a multicast group. Once the multicast context is established and network resources are allocated, the transport of multicast data from an application to UEs receiving the same multicast data with UPF being the ingress point is possible.

The dynamic delivery mode selection is a key functionality in the 5G-Xcast content delivery framework. The deliverable outlines how this functionality can be achieved with HTTP/2 over multicast QUIC and with the point-to-multipoint.

The call flow for Public Warning System Session illustrates how multimedia content of public warning message can be received via broadcast or multicast using point-to-multipoint service session or the transparent multicast transport triggered by a cell broadcast.

An important call flow of multicast ABR Session shows the interactions and integration at layers that are above mobile network or the converged core, between the 5G-Xcast and the content provider network (CDN and even multi-CDN). Such interaction with/for DVB multicast ABR architecture is studied as one example for mABR.

Yet another session is defined for point-to-multipoint services. It is established in the 3GPP domain of 5GS upon the desire and readiness of content provider to deliver content in certain geographical areas covered by access networks. Terrestrial Broadcast service is briefly referred to as a sub-case of the point-to-multipoint service and call flow, while its full session details shall be given in another WP4 specially designated document.

This document also describes how 3GPP and non-3GPP access networks can be used in Multilink-enhanced Sessions. The Multilink-enhanced Sessions address the use case of user at the edge of multicast/broadcast area of an access network and the use case of insufficient multicast/broadcast capacity of an access network.

All of these 5G-Xcast WP4 call flows are managed within the Core network, preserving the RAN autonomous management of its own resources transparently to the Core, and vice versa.

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List of Acronyms and Abbreviations

5GC	5G Core Network
5GS	5G System
ABR	Adaptive Bit Rate
AF	Application Function
AMBR	Aggregate Maximum Bit Rate
AMF	Access and Mobility Management Function
API	Application Programming Interface
AR/VR	Augmented Reality / Virtual Reality
AS	Application Server
ASM	Any-Source Multicast
ATC	Ancillary Terrestrial Component
AUSF	Authentication Server Function
BC	Broadcast
BM-SC	Broadcast Multicast Service Centre
BNO	Broadcast Network Operator
CAPEX	Capital Expenditure
CBC	Cell Broadcast Centre
CBE	Cell Broadcast Entity
CDN	Content Delivery Network
CGI	Cell Global Identifier
CSP	Content Service Provider
DN	Data Network
DNN	Data Network Name
DSL	Digital Subscriber Line
EC	European Commission
FEC	Forward Error Correction
FQDN	Fully Qualified Domain Name
GCS	Group Communication System
GERAN	GSM EDGE Radio Access Network
GSM	Global System for Mobile Communications
GTP	GPRS Tunnelling Protocol
HTTP	Hypertext Transfer Protocol
IE	Information Element
IGMP	Internet Group Management Protocol
IoT	Internet of Things
ISD	Inter-Site Distance
ISI	Inter-Symbol Interference
JSON	JavaScript Object Notation
LADN	Local Area Data Network
LTE	Long-Term Evolution
MBMS	Multimedia Broadcast Multicast Service
MBMS-GW	MBMS Gateway
MBSFN	Multicast Broadcast Single Frequency Network
MC	Multicast
MCE	Multi-cell/multicast Coordination Entity
MCPTT	Mission-critical push-to-talk
MC	Multicast
MEC	Multi-access Edge Computing
ML	Multilink
MLD	Multicast Listener Discovery
MLPPP	Multi-Link Point-To-Point Protocol
MLR	Multicast Listener Report
MME	Mobility Management Entity
MNO	Mobile Network Operator
mABR	Multicast Adaptive Bit Rate
NEF	Network Exposure Function
NF	Network Function

NRF	NF Repository Function
N3IWF	Non-3GPP Interworking Function
NSP	Network Service Provider
NSSF	Network Slice Selection Function
OFDM	Orthogonal frequency-division multiplexing
PCC	Policy and Charging Control
PCF	Policy Control Function
PDSCH	Physical Downlink Shared Channel
PDU	Protocol Data Unit
PIM	Protocol Independent Multicast
PTM	Point to Multipoint
PW	Public Warning
PW	Public Warning System
QFI	Quality of service Flow Identifier
QoE	Quality of Experience
QoS	Quality of Service
RAB	Radio Access Bearer
RAN	Radio Access Network
REST	Representational State Transfer
RMA	RAN Multicast Area
SACH	Service Announcement Channel
SAI	Service Area Identifier
SC-PTM	Single Cell Point to Multipoint
SDF	Service Data Flow
SDP	Session Description Protocol
SFN	Single Frequency Network
SIB	System Information Block
SINR	Signal-to-Interference-plus-Noise Ratio
SLA	Service Level Agreement
S-NSSAI	Single Network Slice Selection Assistance Information
SMF	Session Management Function
SSC	Session Service Continuity
SSM	Source Specific Multicast
SUPI	Subscription Permanent Identifier
TAC	Tracking Area Code
TAI	Tracking Area Identity
TBC	Terrestrial Broadcast
TMGI	Temporary Mobile Group Identity
UC	Unicast
UDM	Unified Data Management
UDR	Unified Data Repository
UDSF	Unstructured Data Storage network Function
UE	User Equipment
UL CL	Up Link Classifier
UPF	User Plane Function
XCF	5G-Xcast Control plane Function
XUF	5G-Xcast User plane Function

1 Introduction

5G-Xcast examines how to effectively add Multicast (MC) and Broadcast (BC) into a predominantly Unicast (UC) 5G Core Network defined in 3GPP from Release 15 [1]. Apparently, BC-based services have not picked up as expected in LTE/4G with MBMS as the main mechanism. Mass media delivery is seen as having a great business potential in 5G. 5G-Xcast, with its WP4 Core mobile network, has undertaken to bridge this gap. This deliverable examines the call flows within the Core Network that support the identified mechanisms. It offers flexible session management where resource, target geographic area, QoS and other parameters can be dynamically changed during the session lifetime, for both ad-hoc and scheduled multicast/broadcast Sessions.

One guiding line in designing the two architecture alternatives (in WP4 Deliverable D4.1 [2]), was to try and maintain logical functional split between the Core and the other layers such as RAN or the application layer. All potential intra-layer requirements have been considered and it was possible to design the call flows so to achieve this goal. The call flows are self-contained within the Core and no RAN or higher layer resources were identified as requiring the Core call flows control and management. Therefore, the reader is encouraged to first get acquainted with the WP4 architectures by reading document WP4 Deliverable D4.1 [2] before examining in detail the present document.

Further, this Deliverable lays out a strong and efficient baseline for 3GPP standardization of BC/MC in the 5G Core, over the 5G-Xcast architecture alternatives.

The main Session elements are: PDU Session, Point to Multipoint (PTM) services Session, Public Warning (PW) Session, mABR Session and Multilink-enhanced Session. These call flows cover 5G-Xcast use cases (M&E, PW) and their requirements as identified in WP2.

Terrestrial Broadcast, or stand-alone broadcast, has also been considered by Task 4.3. It is referred to under the Point-to-Multipoint services call flow (see Chapter 5), while the full reference architecture and description of this service will be detailed in its own dedicated separate document that will be released after the published date of the present document.

This document starts by explaining the goals and methodology used, followed by a short overview of the current situation for the PDU Session in 3GPP Release 15. From there it continues to specify each of the main call flows: PDU session, Dynamic delivery mode selection for PTM services, mABR, PW and Multilink-enhanced sessions. These chapters analyse the Session initiation call flow in detail. This level of evaluation and detail may be used as a solid basis for further 3GPP design and standardization. The document ends with the conclusions.

2 What is a 5G-XCast Session?

2.1 Relevant Session definitions

This section reviews definitions and scope of relevant “Sessions” as done in the standard and industry bodies. This is done in order to:

1. Keep aligned with these bodies
2. Efficiently learn and adapt as needed rather than invent from scratch

The 5G-Xcast WP4 Core Network Session is actually a collection of Sessions. Each one is relevant to a different technology. Implementing all of these technologies is not required and in some cases is contradictory. The Sessions enable a certain functionality in a certain way, for one or two of the architectures defined in Deliverable D4.1 [2]. The Sessions are self-contained within the core network.

2.2 Methodology

In order to cope with the different components and segments of the various Session types and use cases, the chosen methodology was to develop the architectures and the call flows in parallel. 5G-Xcast uses the same methodology as in 3GPP to describe the session management: via call flows diagrams and a textual description.

The document also reflects an examination that was done to determine whether the RAN or the application layer in 5G-Xcast requires any intervention of the Core Network and whether there are any resources that require inter-layer management. After a discussion with the relevant 5G-Xcast working groups (WP3 on Radio Access Network and WP5 on Converged Content Distribution Framework respectively), the conclusion of this analysis was that no such cross-layer dependencies exist, hence the guideline that each layer is independent, and the Core Sessions are managed separately between the lower and higher layer, has been achieved.

The Sessions in this document support two architecture alternatives specified in Deliverable D4.1 [2] – Alternative 1 and Alternative 2, unless otherwise mentioned. Deliverable D4.1 described in brief also a third alternative, which is considered an implementation option derived from Alternative 1. Hence, the present document focuses on Alternative 1 and Alternative 2.

The following sessions are described in this document: A session in the 3GPP domain of 5GS is established after the UE registers to the core network. 5G-Xcast solution enhances the session to support exchange of multicast packet data units through the 5GS by modifying PDU session modification procedure. Another session is for point-to-multipoint services. It is established in the 3GPP domain of 5GS upon the desire and readiness of content provider to deliver content in certain geographical areas covered by access networks. Another session is the Public Warning Systems (PW) session. It is similar to the session for point-to-multipoint services. Then, a multicast ABR (mABR) session, which establishment is triggered based on configuration and analytics, is above the 3GPP domain. A multilink-enhanced session comes next. It is above the 3GPP domain and uses combinations of the 5G ML, the 5G UC and the fixed network connection are used to enhance service continuity and performance for seamless transition when moving between coverage areas of ML service or enhance mobility within the 5G network. Finally, is the of terrestrial broadcast session where the network is designed to support only broadcast without a return channel, is regarded as a special case of the point-to-multipoint services. The specific details of this terrestrial broadcast session will be detailed in a separate 5G-Xcast document that will be published at a later stage.

In some cases, when a MC/BC group or a terrestrial broadcast transmission already exists for the requested content, the UE may learn of that when listening on the BC system channel.

3 Release 15 PDU Unicast Session overview

A PDU Session in 5G System (5GS) represents an association between the UE and a data network (see 3GPP TS 23.501 [3]). The 5G Core Network (5GC) uses the PDU Session to support a PDU connectivity service providing the exchange of PDUs between the UE and the Data Network (DN). The 5GS supports three PDU Session types: IP PDU Session type, Ethernet PDU Session type and Unstructured PDU Session type. There are specific operation and management aspects for each PDU Session type which need to be considered by the 5GS, however most of the procedures defined in the 3GPP specifications are common for all PDU Session types. It is assumed that services using IP connectivity are relevant to all use cases defined in the 5G-Xcast project and therefore the remainder of this section as well as the Chapter 4 focuses mainly on the IP PDU Session type. However, it is also acknowledged that the Ethernet PDU Session type and the Unstructured PDU Session type may be relevant for some 5G-Xcast use cases such as the Auto 1 use case described in Deliverable D2.1 [4] depending on V2X system architecture and its protocols.

The PDU Session is managed through Session management procedures including PDU Session establishment, modification and release (see 3GPP TS 23.502 [5]). Only the UE initiates PDU Session establishment. However, the network can trigger the UE to initiate the procedure via a device trigger message sent to an application on the UE. On the other hand, the PDU Session modification and release can be requested by the UE or by the network. The PDU Session has the following attributes: S-NSSAI, DNN, SSC mode, PDU Session ID, and user plane security enforcement information.

The PDU Session model provides a lot of flexibility regarding UE's operation and 5GS deployments. The UE may establish multiple PDU Sessions to the same data network or a single PDU Session can have multiple anchors, which are the UPFs terminating N6 interfaces. This functionality can be used to support service continuity where the UE establishes a new PDU Session via a new anchor to the same data network before the previous PDU Session is released. For example, the possibility to establish multiple PDU Sessions is also important for the connectivity to a local area data network (LADN) when the UE may establish PDU Session using a specific LADN data network name (DNN). The UE may also establish concurrent PDU Sessions for 3GPP and non-3GPP access. The 5GS supports handover of PDU Session between 3GPP and non-3GPP access which relies on the fact that for each UE the PDU Session ID identifies a PDU Session uniquely.

4 PDU Session with Multicast

Transparent multicast transport is one of the design principles and building blocks of mobile core network in 5G-Xcast [2]. Transparent multicast transport provides the exchange of multicast PDUs between a UE and a data network in a way that network can apply its own internal optimizations of the multicast transport. The optimizations comprise, but are not limited to, RAN's (e.g. NR or a further evolved LTE (eLTE) connected to 5GC) of dynamic unicast and multicast bearer selection for multicast data transmission for efficient radio resource management regardless whether multicast data should be transmitted to one UE or many UEs. The term multicast in the remaining of this section refers to the exchange of multicast PDUs between a UE and a data network via UPF without involving the XCF and XUF functions.

The 5GS in Release 15 does not support multicast but the support of multicast can be introduced by building on the existing concept of PDU Session and creating a new concept of multicast context which is shared by PDU Sessions of UEs interested in receiving data from a multicast group. In the case of the IP PDU Session type, this means that the UE joins the multicast group using IGMP or MLD signalling. The UE may receive information about a multicast Session and the associated IP multicast address by various means. For example, the UE receives an IP multicast address in an advertisement of a QUIC multicast Session, see Appendix A.5 of Deliverable D5.2 [4] on Content Distribution Framework. In the example of point-to-multipoint services in architecture alternative 1 (see Deliverable D4.1 [2]), the UE could receive the information about a multicast Session from the XCF via the interactive announcement or point-to-point push bearers (see 3GPP TS 26.346 [6], section 5.2.4). The multicast context holds the information about a multicast group, UEs interested in receiving content from the multicast group, and core network resources such as tunnels and network functions serving the multicast traffic for the group. Network functions such as UPF may be instantiated to serve multicast traffic exclusively or an already instantiated UPF may be configured to serve both unicast and multicast traffic.

Neither Ethernet PDU Session type nor Unstructured PDU Session type are considered in this document. The following assumptions are made. For Ethernet PDU session type, it is assumed that the procedures may be adopted to certain Ethernet standards such as audio video bridging where stream reservation protocols would be used instead of IGMP or MLD. Unstructured PDU Session type encapsulates user plane in tunnels. This means that the user plane should not be used to trigger the procedure and that unstructured PDU session type need not be supported unless the 3GPP 5GS is required to interpret protocols in the tunnels.

The multicast context or its parts can be stored in the network, for example if UDSF is present in the 5GC, either as a stand-alone function or collocated with UDR, then the multicast context can be stored in the UDSF. As will be shown later in the PDU Session modification procedure, the ability to retrieve information about a multicast context is important as it is needed for finding firstly whether a multicast context for the multicast group exists and secondly what the network functions currently serving the multicast group are. For example, it should be possible to find the UPFs that are currently serving the multicast group. The information about the serving UPFs is then used to decide whether new UPFs should be instantiated. The system should use the information to ensure that only one N3 tunnel is used to deliver data to each required (R)AN node as well.

The multicast context creation procedure, when the first UE joins a multicast group, or the multicast context update procedure, when a subsequent UE joins a multicast group, can be integrated in the PDU Session modification procedure (see DVB Reference

Architecture for IP Multicast [7] in which 3GPP 5GS provides multicast enabled communication between the multicast server (also referred as Function X [3]) and the multicast gateway (also referred as Function X [3]) as follows. The PDU Session modification procedure for the creation/modification of one or more multicast contexts is initiated by the UE or the UPF based on a user plane event, which is a transmission of IGMP or MLDP message for IP PDU Session type. The Session modification procedure is triggered for each UE joining a multicast group. When the PDU Session modification procedure is triggered, the triggering entity may postpone IGMP, MLD or PIM signalling until the PDU Session modification procedure completes successfully or it may proceed with IGMP, MLD or PIM signalling causing a parallel execution. The modified call flow of PDU Session modification procedure is shown in. Figure 1 The new steps are shown in red colour.

Table 1 describes the PDU Session modification in detail and shows required changes to the PDU Session modification procedure standardized in 3GPP TS 23.502 [5] version 15.0.3 (**marked in red color in** Figure 1 and **marked in blue colour in Table 1** (Please note the black colour text in Table 1 is the original text from [5] including references). Upon successful completion of the procedure, the user plane path(s) is established, the UPF interfacing with DN is configured to classify and route the multicast traffic, (R)AN nodes configure resources and have the information about UEs which shall receive the data. The state of 5GS assuming the IP PDU Session type is illustrated on Figure 2.

In the flows below:

- In the flows below, it is assumed that assumed that all SMFs and UPFs Support this procedure. If not, the procedure fails and consequently, UE cannot join multicast group.
- The 5G-Xcast functionalities of network functions are discussed in D4.1 [2].

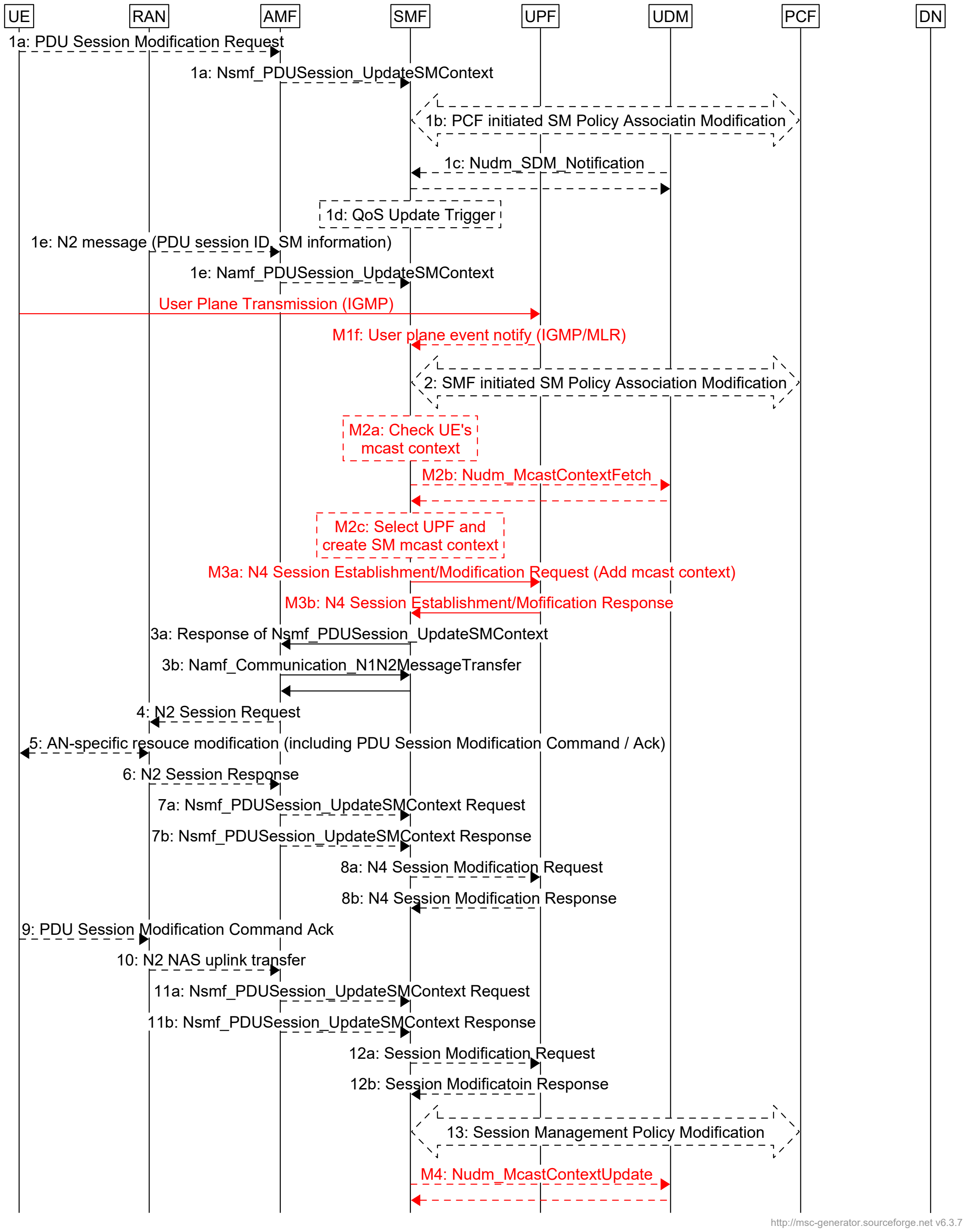

Figure 1 PDU Session Modification with multicast context creation/modification

Table 1 - Required changes to the PDU Session modification procedure TS 23.502 [5]

1. The procedure may be triggered by following events:

 1a. (UE initiated modification) The UE initiates the PDU Session Modification procedure by the transmission of an NAS message (N1 SM container (PDU Session Modification Request (PDU session ID, Packet Filters, Operation, Requested QoS, Segregation, 5GSM Core Network Capability)), PDU Session ID) message. Depending on the Access Type, if the UE was in CM-IDLE state, this SM-NAS message is preceded by the Service Request procedure. The NAS message is forwarded by the (R)AN to the AMF with an indication of User location Information. The AMF invokes Nsmf_PDUSession_UpdateSMContext (PDU Session ID, N1 SM container (PDU Session Modification Request)).

 When the UE requests specific QoS handling for selected SDF(s), the PDU Session Modification Request includes Packet Filters describing the SDF(s), the requested Packet Filter Operation (add, modify, delete) on the indicated Packet Filters, the Requested QoS and optionally a Segregation indication. The Segregation indication is included when the UE recommends to the network to bind the applicable SDF(s) on a distinct and dedicated QoS Flow e.g. even if an existing QoS Flow can support the requested QoS. The network should abide by the UE request, but is allowed to proceed instead with binding the selected SDF(s) on an existing QoS Flow.

NOTE 1: Only one QoS Flow is used for traffic segregation. If UE makes subsequent requests for segregation of additional SDF(s), the additional SDF(s) are multiplexed on the existing QoS Flow that is used for segregation.

 The UE shall not trigger a PDU Session Modification procedure for a PDU Session corresponding to a LADN when the UE is outside the area of availability of the LADN.

 The PS Data Off status, if changed, shall be included in the PCO in the PDU Session Modification Request message.

 When PCF is deployed, the SMF shall further report thePS Data Off status to PCF if the PS Data Off event trigger is provisioned, the additional behaviour of SMF and PCF for 3GPP PS Data Off is defined in TS 23.503 [20].

 The 5GSM Core Network Capability is provided by the UE and handled by SMF as defined in TS 23.501 [2] clause 5.4.4b.

 1b. (SMF requested modification) The PCF performs a PCF initiated SM Policy Association Modification procedure as defined in clause 4.16.5.2 to notify SMF about the modification of policies. This may e.g.; have been triggered by a policy decision or upon AF requests, e.g. Application Function influence on traffic routing as described in step 5 in clause 4.3.6.2.

 1c. (SMF requested modification) The UDM updates the subscription data of SMF by Nudm_SDM_Notification (SUPI, Session Management Subscription Data). The SMF updates the Session Management Subscription Data and acknowledges the UDM by returning an Ack with (SUPI).

 1d. (SMF requested modification) The SMF may decide to modify PDU Session. This procedure also may be triggered based on locally configured policy or triggered from the (R)AN (see clause 4.2.6).

 If the SMF receives one of the triggers in step 1b ~ 1d, the SMF starts SMF requested PDU Session Modification procedure.

 1e. (AN initiated modification) (R)AN shall indicate to the SMF when the AN resources onto which a QoS Flow is mapped are released irrespective of whether notification control is configured. (R)AN sends the N2 message (PDU Session ID, N2 SM information) to the AMF. The N2 SM information includes the QFI, User location Information and an indication that the QoS Flow is released. The AMF invokes Nsmf_PDUSession_UpdateSMContext (N2 SM information).

(AN initiated notification control) In case notification control is configured for a GBR Flow, (R)AN sends a N2 message (PDU Session ID, N2 SM information) to SMF when the (R)AN decides the QoS targets of the QoS Flow cannot be fulfilled or can be fulfilled again, respectively. The N2 SM information includes the QFI and an indication that the QoS targets for that QoS Flow cannot be fulfilled or can be fulfilled again, respectively. The AMF invokes Nsmf_PDUSession_UpdateSMContext (N2 SM information). If the PCF has subscribed to the event, SMF reports this event to the PCF for each PCC Rule for which notification control is set, see step 2. Alternatively, if dynamic PCC does not apply for this DNN, and dependent on locally configured policy, the SMF may start SMF requested PDU Session Modification procedure, see step 3b.

M1f. (SMF requested modification based on UPF trigger) The UPF may inform SMF about a user event, e.g. reception of MLR. The UPF sends the notification if it receives MLR in PDU Session for which UE does not have the multicast context for a multicast group. The UPF may not send the notification to the SMF for subsequent retransmissions of the MRL by UE.

2. The SMF may need to report some subscribed event to the PCF by performing an SMF initiated SM Policy Association Modification procedure as defined in clause 4.16.5.1. This step may be skipped if PDU Session Modification procedure is triggered by step 1b or 1d. If dynamic PCC is not deployed, the SMF may apply local policy to decide whether to change the QoS profile.

Steps 3 to 7 are not invoked when the PDU Session Modification requires only action at a UPF (e.g. gating).

M2. SMF searches for the existence of multicast context in the network. The multicast context can be stored locally in SMF, or in more centralized manner by, for example, UDM or UDSF. If the multicast contexts are stored locally, then NRF could store information about SMFs handling multicast traffic (i.e. such SMFs store the multicast context locally). The SMF initiating the PDU Session modification needs to communicate with SMFs indicated in NRF to check whether the multicast context associated with SSM or ASM addresses already exists. The reason is to avoid a situation in which RAN receives the same multicast traffic from multiple UPFs, which would lead to either multiple transmission of the same data over the air or more complex RAN implementation performing duplication detection.

M2a. SMF checks whether it has a multicast context for the multicast group (e.g. identified by SSM, ASM).

M2b. SMF attempts to fetch the multicast subscription data from UDM and the multicast context from UDSF.

M2c. If the multicast context does not exist in the network, SMF creates the SM multicast context. This step may involve also: PCF selection, communication with PCF for policy control and event exposure similar to PDU Session creation (section 4.3.2 of 3GPP TS 23.502 [5].

M3. N4 Session Establishment/Modification Request towards the selected UPF, which may be different that the UPF which sent the notification in step M1f. If a different UPF is used to handle the multicast traffic, then both UPFs need to be updated (not shown in Figure 1). The UPF, which receives the notification, needs to be updated with UE's context including the multicast context part.

M3a. SMF sends an N4 Session Establishment/Modification Request to SMF and provides Packet detection, enforcement and reporting rules to be installed on the UPF for this PDU Session. If CN Tunnel Info is allocated by the SMF, the CN Tunnel Info is provided to UPF in this step.

M3b. UPF acknowledges by sending an N4 Session Establishment/Modification Response. If CN Tunnel Info is allocated by the UPF, the CN Tunnel Info is provided to SMF in this step.

3a. For UE or AN initiated modification, the SMF responds to the AMF through Nsmf_PDUSession_UpdateSMContext (N2 SM information (PDU Session ID, QFI(s), QoS Profile(s), Session-AMBR), N1 SM container (PDU Session Modification Command (PDU Session ID, QoS rule(s), QoS rule operation, QoS Flow level QoS parameters if needed for the QoS Flow(s) associated with the QoS rule(s), Session-AMBR))). See TS 23.501 [2] clause 5.7 for the QoS Profile, and QoS rule and QoS Flow level QoS parameters.

The N2 SM information carries information that the AMF shall provide to the (R)AN. It may include the QoS profiles and the corresponding QFIs to notify the (R)AN that one or more QoS flows were added, or modified. It may include only QFI(s) to notify the (R)AN that one or more QoS flows were removed. If the PDU Session Modification was triggered by the (R)AN Release in step 1e the N2 SM information carries an acknowledgement of the (R)AN Release. If the PDU Session Modification was requested by the UE for a PDU Session that has no established User Plane resources, the N2 SM information provided to the (R)AN includes information for establishment of User Plane resources.

The N1 SM container carries the PDU Session Modification Command that the AMF shall provide to the UE. It may include the QoS rules, QoS Flow level QoS parameters if needed for the QoS Flow(s) associated with the QoS rule(s) and corresponding QoS rule operation and QoS Flow level QoS parameters operation to notify the UE that one or more QoS rules were added, removed or modified.

The PDU Session Modification Command includes PDU Session ID and information related to multicast context such as N3 tunnel end-point information, QoS rules for multicast, multicast-AMBR, etc.

3b. For SMF requested modification, the SMF invokes Namf_Communication_N1N2MessageTransfer (N2 SM information (PDU Session ID, QFI(s), QoS Profile(s), Session-AMBR), N1 SM container (PDU Session Modification Command (PDU Session ID, QoS rule(s), QoS Flow level QoS parameters if needed for the QoS Flow(s) associated with the QoS rule(s), QoS rule operationand QoS Flow level QoS parameters operation, Session-AMBR))).

If the UE is in CM-IDLE state and an ATC is activated, the AMF updates and stores the UE context based on the Namf_Communication_N1N2MessageTransfer and steps 4, 5, 6 and 7 are skipped. When the UE is reachable e.g. when the UE enters CM-CONNECTED state, the AMF forwards the N1 message to synchronize the UE context with the UE.

The PDU Session Modification Command includes PDU Session ID and information related to multicast context such as N3 tunnel end-point information, QoS rules for multicast, multicast-AMBR, etc.

4. The AMF may send N2 PDU Session Request (N2 SM information received from SMF, NAS message (PDU Session ID, N1 SM container (PDU Session Modification Command))) Message to the (R)AN.

   (R)AN allocates resources for the multicast context. If multicast context already exists in (R)AN, i.e. there are other UEs receiving multicast content associated with the multicast context in (R)AN, UE's context in (R)AN is updated but the N3 tunnel should remain the same.

5. The (R)AN may issue AN specific signalling exchange with the UE that is related with the information received from SMF. For example, in case of a NG-RAN, an RRC Connection Reconfiguration may take place with the UE modifying the necessary (R)AN resources related to the PDU Session.

For the case when the PDU Session is updated due to the multicast context addition/creation, (R)AN configures UE with a set of unicast and multicast bearers used to transfer data over the air for the multicast context. Multicast bearers may be received by multiple UEs.

6. The (R)AN may acknowledge N2 PDU Session Request by sending a N2 PDU Session Ack (N2 SM information (List of accepted/rejected QFI(s), AN Tunnel Info, PDU Session ID), User location Information) Message to the AMF. In case of Dual Connectivity, if one or more QFIs were added to the PDU Session, the Master RAN node may assign one or more of these QFIs to a NG-RAN node which was not involved in the PDU Session earlier. In this case the AN Tunnel Info includes a new N3 tunnel endpoint for QFIs assigned to the new NG-RAN node. Correspondingly, if one or more QFIs were removed from the PDU Session, a (R)AN node may no longer be involved in the PDU Session anymore, and the corresponding tunnel endpoint is removed from the AN Tunnel Info. The NG-RAN may reject QFI(s) if it cannot fulfill the User Plane Security Enforcement information for a corresponding QoS Profile, e.g. due to the UE Integrity Protection Maximum Data Rate being exceeded.

   In case when the PDU Session update is used to add/create multicast context, (R)AN may need to (re)allocate N3 tunnel end-point information and send the information in N2 PDU Session Ack message. For example, the allocation of N3 tunnel end-point information is needed when unicast tunnel is used on N3 for the multicast context. The allocation of N3 tunnel end-point information is not necessary if N3 is using multicast tunnelling, in which case (R)AN joins IP multicast group based on the information received in step 4.

7. The AMF forwards the N2 SM information and the User location Information received from the AN to the SMF via Nsmf_PDUSession_UpdateSMContext service operation. The SMF replies with a Nsmf_PDUSession_UpdateSMContext Response.

   If the (R)AN rejects QFI(s) the SMF is responsible of updating the QoS rules and QoS Flow level QoS parameters if needed for the QoS Flow(s) associated with the QoS rule(s) in the UE accordingly.

8. The SMF may update N4 session of the UPF(s) that are involved by the PDU Session Modification by sending N4 Session Modification Request message to the UPF. (see NOTE 2)

9. The UE acknowledges the PDU Session Modification Command by sending a NAS message (PDU Session ID, N1 SM container (PDU Session Modification Command Ack)) message.

10. The (R)AN forwards the NAS message to the AMF.

11. The AMF forwards the N1 SM container (PDU Session Modification Command Ack) and User Location Information received from the AN to the SMF via Nsmf_PDUSession_UpdateSMContext service operation. The SMF replies with a Nsmf_PDUSession_UpdateSMContext Response.

12. The SMF may update N4 session of the UPF(s) that are involved by the PDU Session Modification by sending N4 Session Modification Request (N4 Session ID) message to the UPF. For a PDU Session of Ethernet PDU Session Type, the SMF may notify the UPF to add or remove Ethernet Packet Filter Set(s) and forwarding rule(s).

NOTE 2: The UPFs that are impacted in the PDU Session Modification procedure depends on the modified QoS parameters and on the deployment. For example in case of the session AMBR of a PDU Session with an UL CL changes, only the UL CL is involved. This note also applies to the step 8.

13. If the SMF interacted with the PCF in step 1b or 2, the SMF notifies the PCF whether the PCC decision could be enforced or not by performing an SMF initiated SM Policy Association Modification procedure as defined in clause 4.16.5.1.

    SMF notifies any entity that has subscribed to User Location Information related with PDU Session change.

If step 1b is triggered to perform Application Function influence on traffic routing by step 5 in clause 4.3.6.2, the SMF may reconfigure the User Plane of the PDU Session as described in step 6 in clause 4.3.6.2.

M4. SMF stores the multicast context in UDM. Other SMFs can fetch it in step M2b.

Figure 2 illustrates the concept of multicast context and depicts the system state after the PDU Session modification of two UEs was successfully completed.

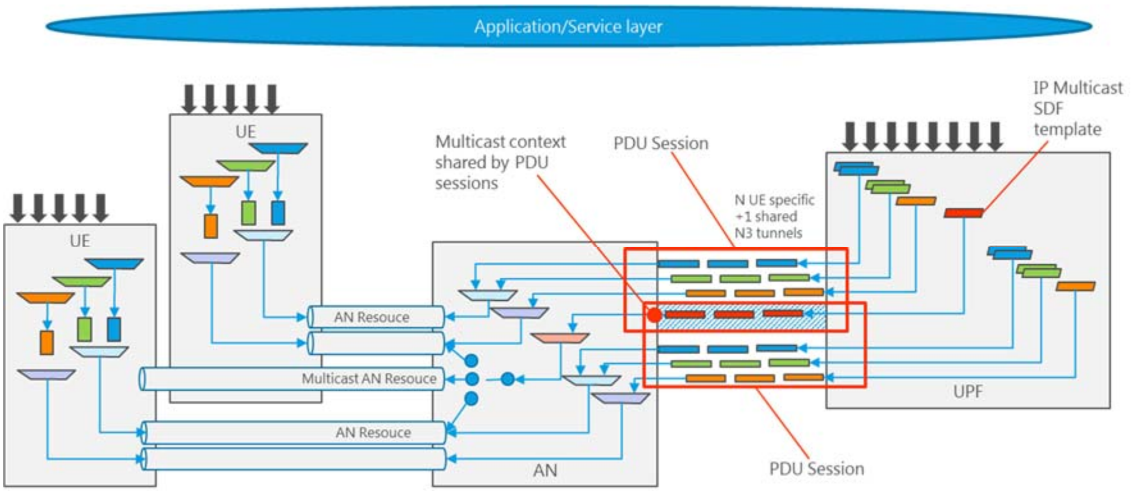

Figure 2 PDU Sessions and multicast context in 5G System

5 Resource management for point-to-multipoint services

Point-to-multipoint services offered by the 5G system over the xMB interface discussed in Deliverable D4.1 [2] use the geographical-area attribute associated with each Session to define a geographical area where a service should be provided by broadcast. The geographical-area attribute contains a list of strings formatted according to an agreement between the content provider and the operator. The system then broadcasts Session content in the geographical area. The reliability of content delivery can be improved by broadcasting the content more than once, application of FEC and – if applicable – allowing unicast repair via an associated delivery procedure as described in Deliverable D4.1.

The resource management for multicast transport within PDU Session is designed around the paradigm that the network resources are managed based on the interest indication from UEs. The same paradigm cannot be applied to the broadcast required by point-to-multipoint services, which shall support also receive-only UEs, i.e. terrestrial broadcast. The broadcast needs a new set of resource management procedures in 5GC allowing to allocate, modify and release network resources for broadcast based on information provided over xMB interface when xMB Session is created, modified or terminated. The resource allocation procedure for broadcast is shown in Figure 3. The procedure does not include related interaction with PCF for policy and charging control for simplicity. The modification and release procedures are not presented in the document as they can be devised from the allocation procedure. However, a few messages in Figure 3 indicate in their names the intention of being used for an initial resource allocation and also for a modification of allocated resources.

It is worth noting that no similar procedure exists in 23.502 [5]. Most of the messages below are new and developed in the 5G-Xcast project. However, the 5GS procedures are considered as background.

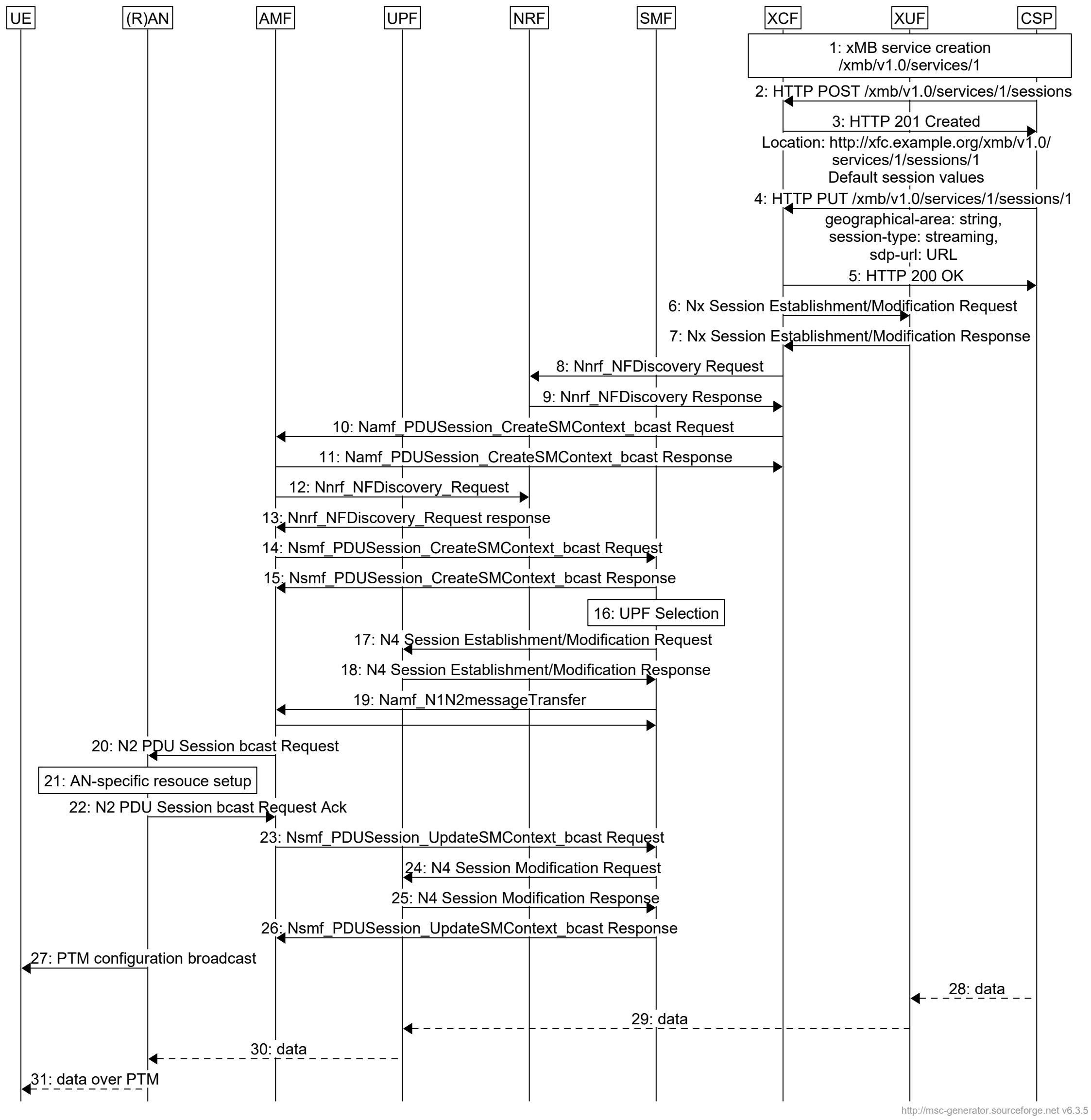

Figure 3 Network resource allocation for broadcast

1. The CSP creates a service with the XCF. The service resource is created in the XCF and the service resource location is returned to the CSP.
2. The CSP requests the XCF to create a Session resource using the service resource.
3. The XCF returns the Session resource to the CSP. The Session is created with default parameters.
4. The CSP updates the Session to provide geographical area where the Session should be provided. The CSP also modifies other parameters of the Session depending on the Session type. For media streaming, the CSP modifies the Session-type and provides a URL to the SDP describing the streaming Session for media ingress.
5. Upon successful update, the XCF responds with HTTP status code 200 or 204 (see 3GPP TS 29.116 [11] for details of steps 1 to 5).
6. The XCF selects a XUF for the Session and requests the XUF to create a Session providing the SDP of streaming Session for media ingress, an FEC layer configuration and, if allocated by the XCF, multicast IP address.

7. The XUF responds to the request and provides transport parameters (e.g. port numbers) to the XCF. If IP multicast address is allocated by the XUF, then it is provided to the XCF in this step. Upon reception of the transport parameters from the XUF, the XCF can create the user service description, which then needs to be provisioned to the converged middleware (not shown in the flow).
8. If XCF does not store AMF information, XCF discovers AMF(s) by sending Nnrf_NFDiscoveryRequest to NRF, which can be configured to the XCF. XCF may be configured with AMF Region IDs, AMF Set ID and mapping of geographical area to these parameters. XCF may include network slice information, NF type of the NF consumer set to XCF, AMF Region IDs, AMF Set IDs.
9. The NRF checks whether the request is authorized (not shown in Figure 3). The NRF determines the discovered AMF instance(s) and replies with the list of AMF(s) with their capabilities. The information provided by NRF about the AMF may contain FQDN, IP address, or end-point addresses (i.e. URLs), TAI(s).
10. The XCF maps the geographical area to a list of cells using cell location and/or cell coverage information, which may be preconfigured in the XCF along with tracking area information of the cell. The XCF then selects AMF(s) from the list of discovered AMF(s) based on TAI(s) received from the NRF and the TAI(s) of the cells. The XCF sends Namf_PDUSession_CreateSMContext_bcast Request to create a broadcast context. The message may contain multicast address used for the xMB Session (used in step 29), a temporary multicast group identifier allocated by XCF, broadcast area information (TAI(s), NR CGI(s)), data network name (DNN).
11. The AMF confirms the reception of the request.
12. If SMF information is not available in AMF, the AMF performs SMF selection. The AMF queries the NRF providing network slice information, DNN.
13. The NRF replies with a set of discovered SMF instance(s) including, e.g. FQDN, IP addresses.
14. The AMF has no association with an SMF to support the xMB Session. The AMF creates such association by Nsmf_PDUSession_CreateSMContext_bcast.

The AMF sends Nsmf_PDUSession_CreateSMContext_bcast containing multicast address, multicast address, a temporary multicast group identifier allocated by XCF, broadcast area information (TAI(s), NR CGI(s)), DNN. The SMF creates a Session management context for the broadcast Session.

The AMF may store the tracking area information for the AMF-SMF association for routing Session management messages later.

15. The SMF sends the response to the AMF.
16. The SMF creates a broadcast context stored either locally or in UDR. The SMF selects the UPF based on the DNN so that the XUF can send multicast data to the UPF.
17. The SMF initiates an N4 Session Establishment/Modification procedure with the UPF. The SMF provides forwarding rules to the UPF, i.e. it provides multicast address used by the XUF for data transmission. The UPF may provide DL tunnel information if multicast tunnelling in the core network is used.
18. The UPF provides an N4 Session Establishment/Modification response. The UPF may provide the SMF with the DL tunnel information if multicast tunnelling in the core network is used and the SMF did not allocate the DL tunnel. The UPF performs necessary signalling to join the multicast tree and be able to receive data from the XUF.
19. The SMF initiates N1N2 message transfer procedure with the AMF to send the PDU Session bcast Request to (R)AN.

20. The AMF sends the N2 PDU Session bcast Request to (R)AN node(s) based on the tracking area information. The AMF can store the tracking area information received in step 10 in a context.
21. The (R)AN allocates broadcast resources in the cells indicated in the N2 PDU Session broadcast request, which may also contain QoS information (interaction with PCF and QoS related signalling is not shown in the figure).
22. The (R)AN sends an acknowledgment. The (R)AN may also provide DL tunnel information in case unicast tunnelling is used in the network.
23. The AMF sends Nsmf_PDUSesssion_UpdateSMContext_bcast Request containing the response from RAN (e.g. the DL tunnel information).
24. If the DL tunnel information needs to be updated in the UPF, the SMF initiates the N4 Session modification procedure.
25. The UPF modifies the Session parameters and responses to the SMF.
26. The reception of Nsmf_PDUSession_UpdateSMContext_bcast Response completes the procedure at the AMF.
27. The (R)AN broadcast the radio resource configuration information for the Session identified by TMGI.
28. Session data is received by the XUF.
29. The XUF processes the received data, e.g. applies FEC, and sends the data using IP multicast to UPF.
30. UPF forwards the data to (R)AN nodes via the allocated tunnel.
31. (R)AN broadcasts the data over the air using point-to-multipoint radio bearer.

The signalling flow shows a sequential execution. A parallel execution of procedures from the XCF towards the XUF and SMF is possible, e.g. for an early resource allocation in the core network or (R)AN. However, this would lead necessarily to at least a Session update procedure from the XCF to the SMF to provision the UPF with the transport parameters so that the UPF can classify the ingress traffic of the Session. For IP multicast, the classification is based on Any-Source Multicast (ASM) or Source-Specify Multicast (SSM) addresses, whichever is used, port numbers and transport protocol.

The signalling flow does not show the handling of erroneous cases. For example, the AMF responses to the Namf_PDUSession_CreateSMContext_bcast Request before the outcome of the subsequent request to the SMF is known. The Namf_PDUSession_CreateSMContext_bcast and other services of the flow are request-response NF services (see 3GPP TS 23.501 [3] and 3GPP TS 23.502 [5]). The AMF can offer a subscribe-notify service through which it can notify other NF such as the XCF in this example about successful or unsuccessful completion of the context creation procedure for broadcast. The paradigm of a request-response NF service in conjunction with a subscribe-notify NF service is an alternative to a request-response NF service with long polling known from RESTful API design. In the long polling paradigm, the connection to a server is open until the server sends data. If underlaying transport connection drops due to a time-out, the client reconnects. The long polling may have a significant impact on number of threads and influence server's performance negatively. 3GPP CT4 acknowledged the drawbacks of polling and recommends the subscribe-notify model in API design (see section 6.2.2.2.1.5.3 in 3GPP TR 29.891 [15]).

The network resource allocation procedure for broadcast relies on the tracking area information to determine by an XCF target AMFs. It is possible to introduce the concept of MBMS service areas known from eMBMS in LTE but there is no additional benefit of doing so because the broadcast area is defined by a list of cells and the tracking area information is used only for discovery of appropriate AMFs and routing of Session management message to (R)AN.

The allocation, modification and release procedures described for broadcast are applicable to terrestrial broadcast according to the definitions of these terms in the terminology section of Deliverable D2.1 [5] with the exception that the associated delivery procedures cannot be supported (see Deliverable D4.1 [2]).

6 Dynamic delivery mode selection

The content delivery framework presented in Deliverable D5.2 [4] includes a mechanism to dynamically switch from unicast to multicast, which allows that multicast can be treated as internal network optimization. The actual mechanism used in solutions following the content delivery framework will depend on technologies selected. This section discusses the mechanisms of dynamic delivery mode selection for HTTP/2 over multicast QUIC utilizing networks capability of transparent multicast transport and multicasting/broadcasting content using the point-to-multipoint services. In comparison to 3GPP MBMS operation on demand (MooD) which is originally specified in 3GPP Release 12, multicast source and multicast termination points are not fixed in the content delivery framework. The switching of unicast to multicast or more precisely enabling multicast in addition to unicast can be done within or outside of mobile/converged core in the content delivery framework. Similarly, multicast may be terminated in a network or a UE. Dynamic delivery mode selection refers to different technological solutions some of which are described in this section. The dynamic delivery mode selection with PTM services for architecture alternative 2 resembles 3GPP MooD very closely.

6.1 HTTP/2 over multicast QUIC

The overview of QUIC protocol is provided in appendix A.5 of Deliverable D5.2 [4]. The appendix also describes HTTP delivery over multicast QUIC from the HTTP layer perspective. The call flow in Figure 4 shows the delivery mode selection by CDN, advertisement of multicast QUIC Session and the relation to the PDU Session modification for enabling multicast transport over 5G network presented in section 4. It is assumed that the CDN node is deployed at edge cloud and an interconnection between 5GC and CDN's edge cloud is multicast enabled. The call flow is applicable to both architecture alternatives.

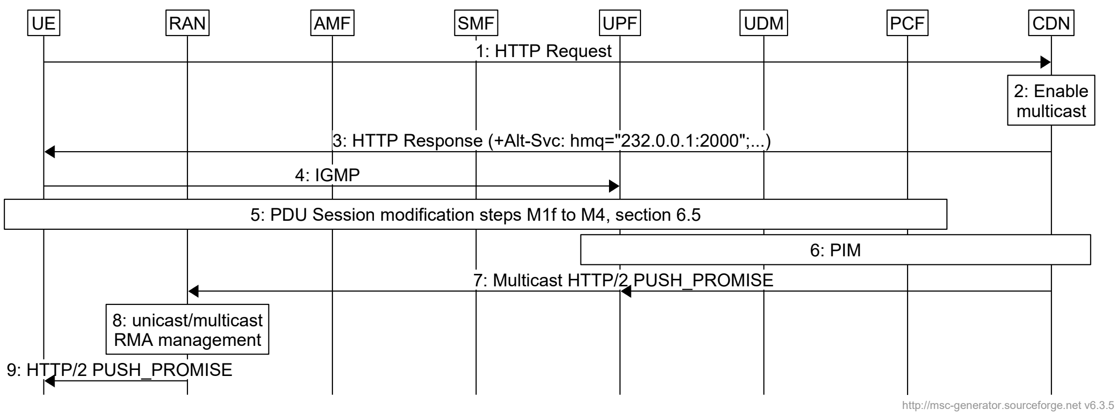

Figure 4 Dynamic delivery mode with multicast QUIC

1. The UE sends an HTTP request for a resource (e.g. media segments) to the CDN.
2. The CDN decides to offer multicast delivery. The decision can be made based on the number of UEs requesting the same content, UEs' IP address range. The CDN can be proactive and offer the multicast delivery quite early depending on the demand because the content delivery framework introduces the possibility for RAN to deliver multicast data over unicast bearers for better spectral efficiency, see step 8.
3. The response from the CDN advertises a multicast Session in the Alt-Svc HTTP header field.

4. Upon the reception of the advertisement, the UE (e.g. an HTTP client library) joints multicast group.
5. The reception of IGMP message by the UPF triggers a user plane event, which initiates the PDU Session modification procedure, see step M1f in Chapter 4.
6. PIM signalling illustrates an establishment of multicast tree towards the CDN. There may be other options how to establish multicast routing between the CDN and the UPF depending on physical and/or virtual infrastructure between the entities.
7. The CDN sends multicast data (e.g. media segments). The data is delivered through the core network from the UPF to the RAN.
8. The RAN knows through the PDU Session modification procedures the set of UEs that joined the multicast and the RAN is also aware of UEs location with cell or RAN multicast area granularity, see Deliverable D3.3 [16]. The RAN determines dynamically on the set of radio bearers used for the transmission of multicast data over the air.
9. The RAN transmits multicast data to the UE.

6.2 Dynamic delivery mode selection with PTM services for architecture alternative 1

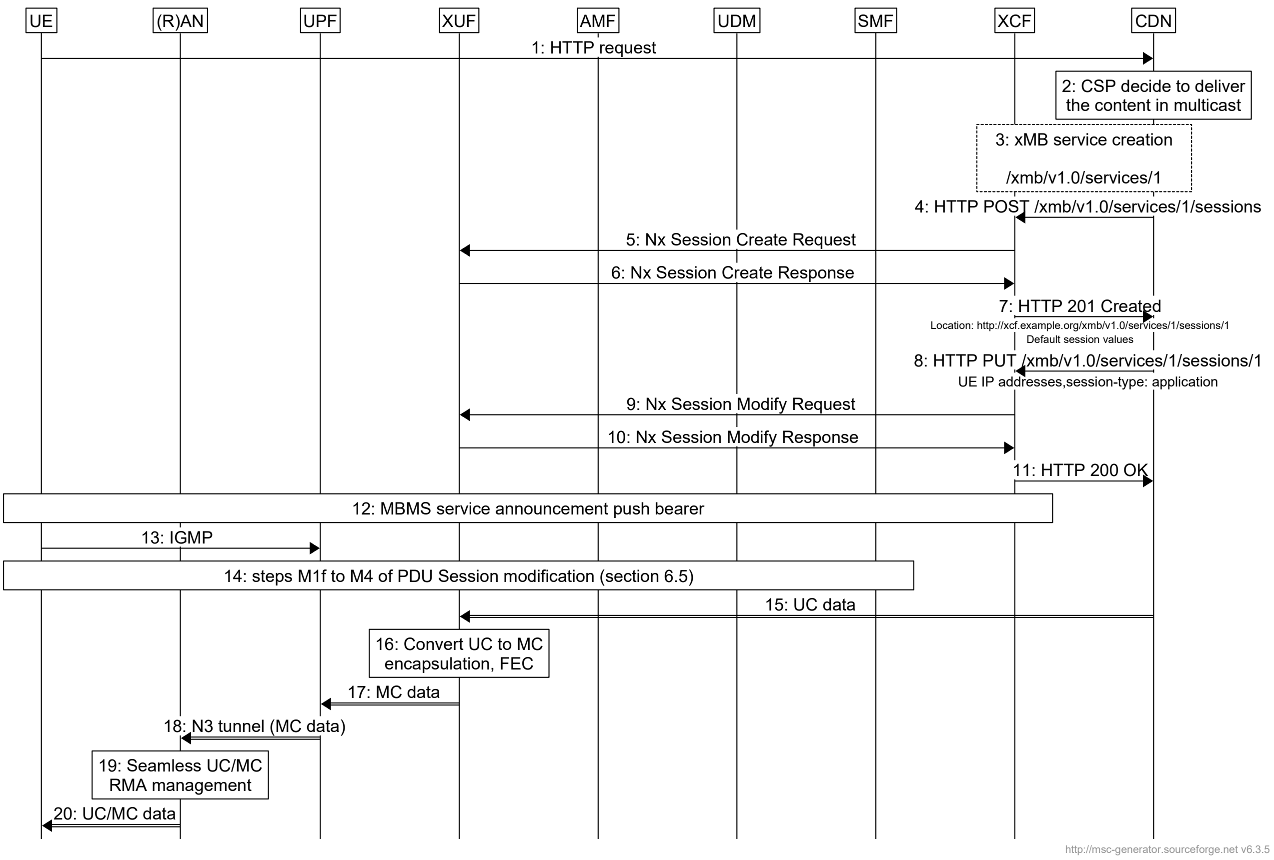

Figure 5 Dynamic delivery mode selection with point-to-multipoint services for architecture alternative 1

The dynamic delivery mode selection described in this section utilizes the transparent multicast transport functionality of 5GC and the RAN capability of unicast/multicast switching with RAN multicast area (RMA) management while offering the possibility to use the point-to-multipoint interface (xMB) for content ingestion [16].

1. The UE sends an HTTP request to the CDN. The request may contain NCGI(s) as UE's location as specified for MooD (see 3GPP TS 26.346 [2]). Alternatively, the request may include URL of xMB-C end-point because the CDN does not need the UE's location for Session creation, see below.
2. The CDN decides to offer multicast delivery. The decision can be made based on the number of UEs requesting the same content, UEs' IP address range, a common xMB-C URL, NCGI(s). The NCGI includes PLMN identity, which can be used by the CDN to discover the entry point to the xMB interface via DNS resolution of FQDN formatted as http://mbmsbs.mnc<MNC>.mcc<MCC>.pub.3gppnetwork.org.
3. The CDN creates a service with the XCF. The service resource is created in the XCF and the service resource location is returned to the CDN.
4. The CDN requests the XCF to create a Session resource using the service resource.
5. The XCF selects the XUF for the Session and sends Nx Session Create Request.
6. The XUF provides Session parameters under its control in Nx Session Create response.
7. The XCF returns the Session resource to the CDN. The Session is created with default parameters.
8. The CDN updates the Session with a list of UE IP addresses. The CDN also modifies other parameters of the Session depending on the Session type. For DASH service, the CDN modifies the Session-type so that a push interface like WebDAV is used as the ingestion method (see 3GPP TS 29.116 [3]).
9. The XCF requests the XUF to modify the Session if necessary.
10. The XUF responses to the XCF.
11. Upon successful update, the XCF responds with HTTP status code 200 or 204 (see 3GPP TS 29.116 [3] for details of steps 1 to 5).
12. The XCF announces the Session availability using the MBMS service announcement with push bearers method (see 3GPP TS 26.346 [2]).
13. Upon the reception of the announcement, the UE discovers the IP multicast address(es) and joins multicast groups.
14. The reception of IGMP message by UPF triggers a user plane event, which initiates the PDU Session modification procedure, see step M1f in section 4.
15. The CDN ingests data to the XUF.
16. The XUF encapsulates the data for multicast delivery.
17. The XUF sends the encapsulated data to the UPF as IP multicast datagrams.
18. The encapsulated data is delivered through the core network from the UPF to the RAN.
19. The RAN knows the set of UEs that joined the multicast and the RAN is also aware of UEs location with cell or RAN multicast area granularity. The RAN determines dynamically on the set of radio bearers used for the transmission of multicast data over the air.
20. The RAN transmits multicast data to the UE.

6.3 Dynamic delivery mode selection with PTM services for architecture alternative 2

This procedure follows the principles of 3GPP MooD operation (see 3GPP TS 26.346 [6]). The UE consumes the data in unicast. The unicast PDU Session between the UE and DN (e.g. CSP) exists. The UE periodically sends the consumption report to the application server. The network and/or CSP decide to deliver the content in PTM services.

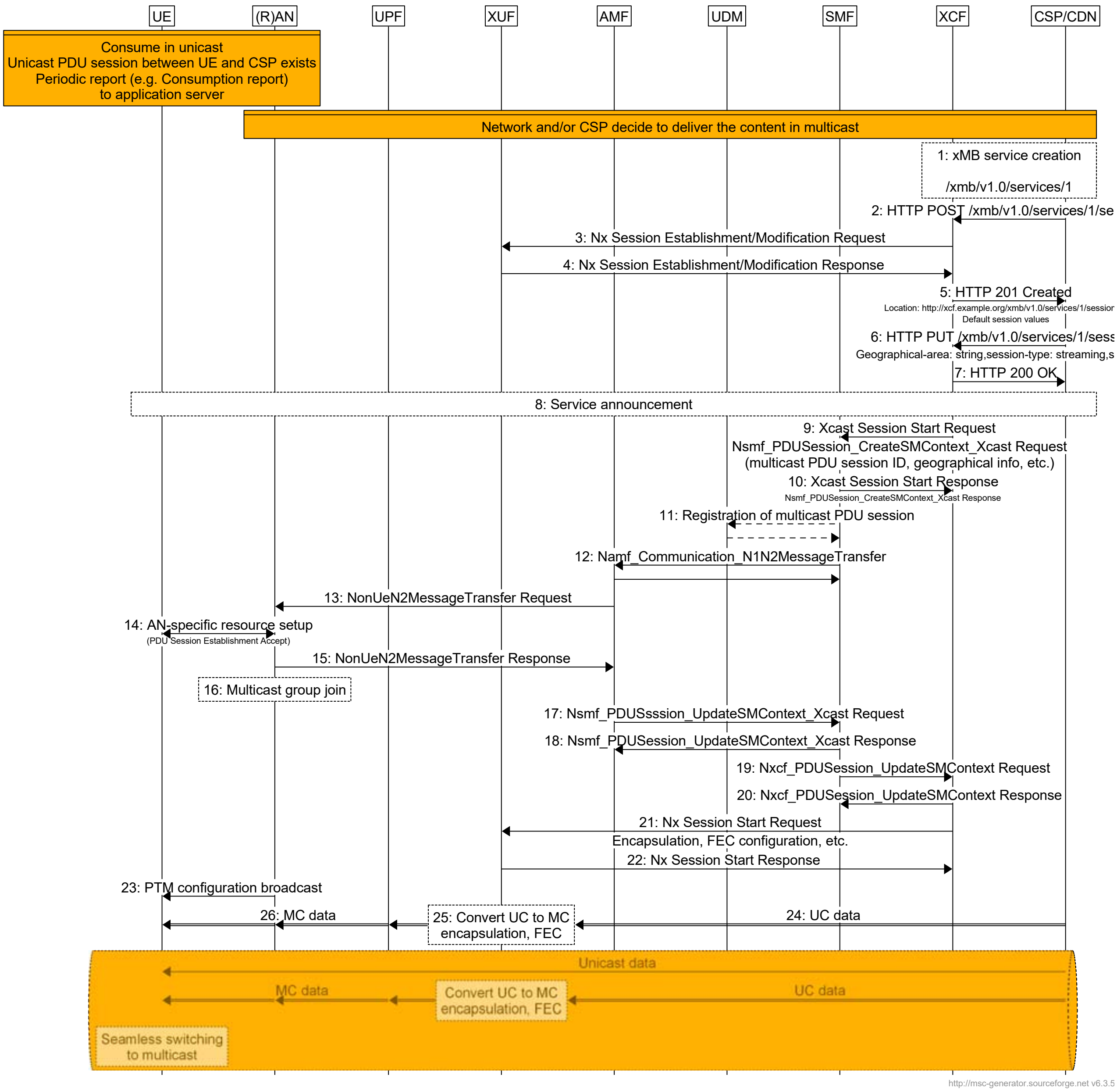

Figure 6 Dynamic delivery mode selection with point-to-multipoint services for architecture alternative 2

1. CSP creates a service with the XCF. The service resource is created in the XCF and the service resource location is returned to the CSP.
2. The CSP requests the XCF to create a Session resource using the service resource.
3. The XCF selects a XUF for the Session and requests the XUF to create a Session providing the SDP of streaming Session for media ingress, an FEC layer configuration and multicast IP address and port.
4. The XUF responds to the request and provides transport parameters to the XCF.
5. The XCF returns the Session resource to the CSP. The Session is created with default parameters.
6. The CSP updates the Session to provide geographical area where the Session should be provided. The CSP also modifies other parameters of the Session depending on the Session type. For media streaming, the CSP modifies the

Session-type and provides a URL to the SDP describing the streaming Session for media ingress.

7. Upon successful update, the XCF responds with HTTP status code 200 or 204 (see 3GPP TS 29.116 [11] for details of steps 1 to 5).
8. Upon reception of the transport parameters from the XUF, the XCF can create user service description to be included in the service announcement. The service announcement data is provisioned to the converged middleware in the UE. The service announcement provisioning can be based on any mechanisms described in clause 5.2 of 3GPP TS 26.346 [6]. It can be a service announcement channel (SACH) such as described in clause L2 of 3GPP TS 26.346 [6], interactive announcement or point-to-point push bearer.
9. The XCF maps the geographical area to a list of cells using cell location information, which may be preconfigured in the XCF along with tracking area information of the cell. Then, XCF sends a Nxmf_PDUSession_CreateSMContext_Xcast request to the SMF to establish a PTM context. The message may contain multicast address, a temporary multicast group identifier (TMGI) allocated by XCF, broadcast area information (TAI(s), NR CGI(s)), data network name (DNN)).
10. The SMF confirms the reception of the request.
11. [Optional] The SMF may register multicast PDU Session to the UDM.
12. The SMF initiates N1N2 message transfer procedure with the AMF to send the PDU Session Xcast Request to (R)AN.
13. The AMF sends the NonUeN2MessageTransfer to Request to (R)AN node(s) as defined in 3GPP TS 29.518 [13].
14. in the cells indicated in the N2 PDU Session Xcast request, which may also contain QoS information (interaction with PCF and QoS related signalling is not shown in the figure). The information may be contained in SIB messages that the UE periodically looks at.
15. The (R)AN sends an acknowledgment.
16. RAN joins multicast group to the XUF.
17. The AMF sends Nsmf_PDUSesssion_UpdateSMContext_Xcast Request containing the response from RAN (e.g. the DL tunnel information).
18. SMF responds to the AMF.
19. The SMF sends a Nxcf_PDUSession_UpdateSMContext request to the XCF to notify the Session establishment is completed.
20. The XCF acknowledges with the response.
21. The XCF send a Nx Session Start Request to the XUF to finalize the PTM Session establishment.
22. The XUF sends a response to the XCF.
23. The (R)AN broadcast the radio resource configuration information for the Session identified by TMGI.
24. Session data is received by the XUF.
25. The XUF processes the received data, e.g. applies FEC, and sends the data using IP multicast to (R)AN nodes.
26. (R)AN broadcasts the data over the air using point-to-multipoint radio bearer.

To seamlessly switch from unicast to broadcast delivery, the metadata included in the service announcement contains the information that allows the converged middleware to fetch the data (e.g. media segments) from either unicast or multicast. For example, with DASH content, 3GPP TS 26.346 [6] defines the unified MPD which describes DASH representations available for both broadcast and unicast reception. The converged middleware acts as a local HTTP proxy viewed from the application. The application is not aware whether the content is delivered in unicast or broadcast, thus, it’s transparent to the application.

7 Multicast ABR (mABR) / Session

In a fixed broadband network, this Session is generated in order to serve a lot of viewers in multicast, in the same area and using mABR to accommodate multiple types of devices and network performance changes.

The call flow presented hereafter is simplified and does not reflect the whole mABR design. Some entities of the mABR reference architecture (as described in 3GPP TS 23.502 [5]) like Content Preparation have been omitted and entities dedicated to Multicast management have been grouped and are referred to as Analytics. DVB architecture is provided below:

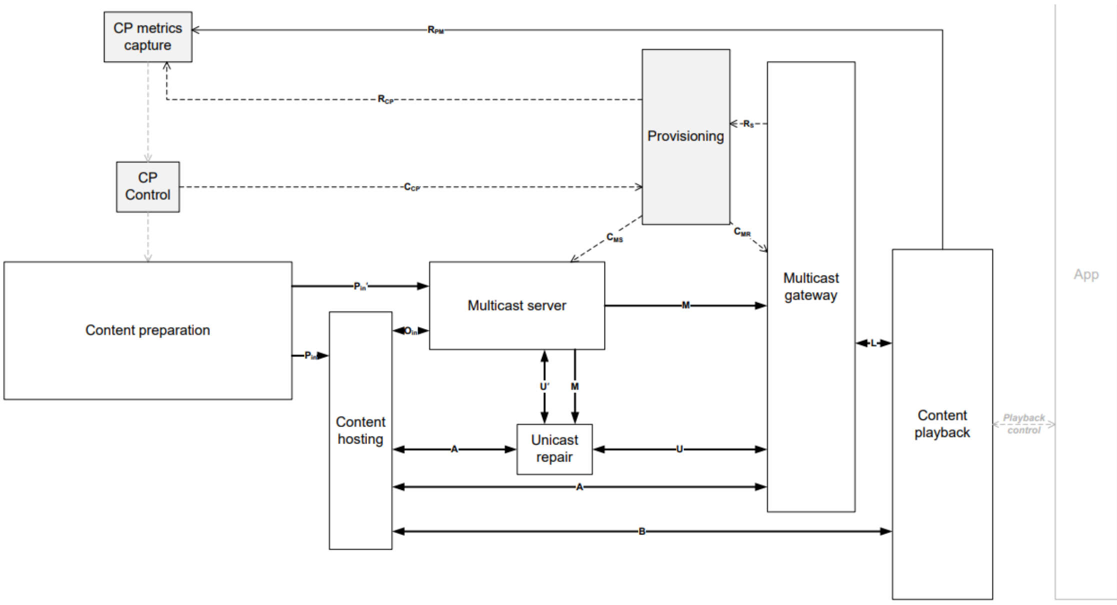

Figure 7 DVB Multicast ABR reference architecture

The main purpose of the call flow is to provide a high-level view of the main mABR principles; mABR is studied further in WP5. For each message exchanged, the next figure shows in square brackets the associated mABR interface.

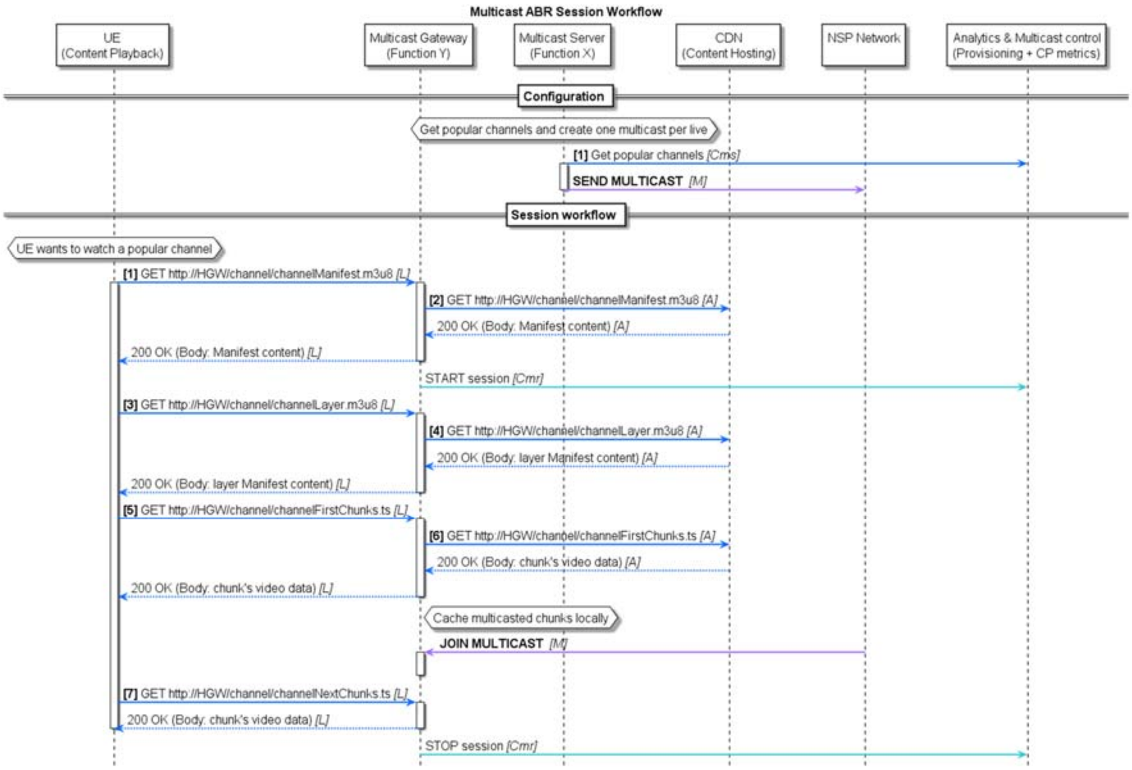

Figure 8 Multicast ABR call flow

7.1 Description

In the above sequence diagram, the HomeGateway (Function Y) acts as a **reverse proxy** forwarding received requests to the CDN if necessary or serving them from its local cache. While this option is the simplest to implement, other solutions are possible:

- **HTTP Redirects**: The video player contacts the CDN which in turn redirects it to the HomeGateway. This type of solution is more Content Service Provider friendly: the CDN continues to receive the unicast Session initiation request, thus not disrupting its internal operations (redirections, authentication & authorization, analytics…). Deliverable D5.2 [4] focuses on this solution and further details the associated call flow.
- **Middleware**: Application Middleware has been informed (through static configuration or dynamically via an API) of the fact that HomeGateway should be used for this channel

The workflow presented above is separated in two distinct unsynchronized parts: Multicast configuration and Session Workflow.

7.2 Configuration

***Note**: Configuration is updated dynamically and is not synced with the Session workflow*

1. Get the popular lives: mABR server (function X) retrieves periodically the list of popular lives. Based on this information, function X starts multicasting the live in the NSP Network (purple arrow). Two options are here offered to the mABR server: stream all channel layers (one multicast per layer) or stream only a subset of the layers. The two options have their pros and cons; this is discussed in Deliverable D5.3 where the impact of mABR over the ABR algorithms dedicated to layer selection is presented. The popular lives can be determined:

   a. Statically thanks to an API (the channel streaming the football match may have been set to popular in advance)
   b. Dynamically thanks to an Analytics server which would count the number of same Sessions per region, user profile etc.

7.3 Session workflow

The two flows START Session and STOP Session serve as containers for any unicast CDN specific operations. There are many possible operations: analytics, authentication and authorization etc.

1. The UE starts a streaming Session and initiates a connection to the HomeGateway (Function Y) to retrieve the manifest file. Depending on the implementation, the way how the video player retrieves the manifest differs
   a. Reverse proxy: the video player contacts the HomeGateway which forwards the request to the CDN. This is the case described in the message flow
   b. HTTP Redirects: the video player contacts the CDN which redirects to the HomeGateway
   c. Middleware: The middleware contacts directly the HomeGateway for this specific channel.
2. The HomeGateway forwards the request to the CDN and answers to the UE
3. As any regular Session the UE then asks for the layer manifest
4. The HomeGateway asks the CDN for this manifest and returns it back to the UE
5. UE asks for the first chunks
6. The HomeGateway retrieves the chunks from the CDN then joins the multicast on this live if necessary (HomeGateway may have already joined this multicast)
7. The HomeGateway caches the chunks from the multicast and forwards them to the UE on request

It is worth noting that first steps are handled using a unicast transport. We use unicast at the initial stage in order to improve QoE when switching between channels. Indeed, joining a multicast can take up to a few seconds.

In case of a multiscreen scenario (TV, smartphone, tablet …) the unicast steps may be skipped if the chunks are already cached in the HomeGateway

7.4 Trigger

As described in the workflow, there are two main sections:

- Configuration and analytics phase. This is where the decision to switch to Multicast ABR is done. The mABR server is driven by an analytics server which determines the currently popular channel.
- Session phase. This describes the mABR session workflow.

In the previous figure this is shown by message (see 3GPP TS 36.300 [10]). Regularly, the mABR server retrieves the popular channels from the Analytics server and updates its multicasted channel accordingly.

Of course, this is completely implementation dependent and therefore not standardized. We could think of other solutions, like pushing a popular channel file to the mABR server, sending events when a new channel becomes popular etc.For this, the Analytics server can use several inputs:

- Sessions creation/destruction: based on this the Analytics increments/decrements an internal counter for the associated channel
- UE location: Analytics may count Sessions per geographical areas

- “Forced” popularity for a channel in prevision of a popular event.

8 Public Warning Session

The PW Session is created to allow an Emergency Agency to quickly send a warning message using multimedia content to a large number of users in a particular area.

Two flows are presented below:

- The 5GC initiates an MBMS broadcast Session and the RAN triggers the UEs in the area to start receiving the multimedia content
- Cell Broadcast is used to send a message to the UEs in the area which contains a URL to retrieve multimedia content via transparent multicast (section 4) or via point-to-multipoint services (section 1)

A notable difference between the two broadcast methods is how the UEs are triggered to receive multimedia content via broadcast. One method is through the Cell Broadcast message itself and in the other case the RAN notifies UEs about the scheduled broadcast. PW Session with RAN triggered broadcast

8.1 PW procedure with RAN triggered MBMS broadcast

The flow for the network resource allocation for broadcast is shown in Figure 3 PW procedure requires one additional step that is needed to notify the UE that alert content is available for reception:

Before step 27 step 27a needs to occur in which the RAN sends the notification to the UEs in the broadcast area, in order to notify the UEs to start receiving the multimedia content.

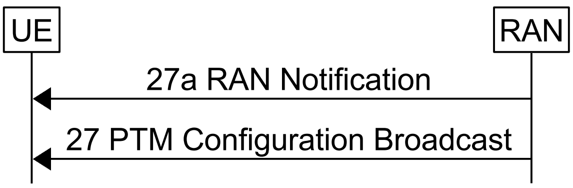

Figure 9 Point-to-Multipoint for PW call flow

8.1.1 PW Session with Cell Broadcast

The below call flow is based on Cell Broadcast (CB) and on alternative 2 from Deliverable D4.1 [2] and uses transparent multicast mode as described in Chapter 4. PW needs to reach as many users in the affected area with free-of-charge information when live and property is at stake; hence there is no need for multicast and broadcast over non-3GPP access which is not in the scope of 5G-Xcast.

8.1.2 PW procedure with Cell Broadcast

The below call flow is based on Cell Broadcast and on alternative 2 from Deliverable D4.1 [2] and uses transparent multicast mode.

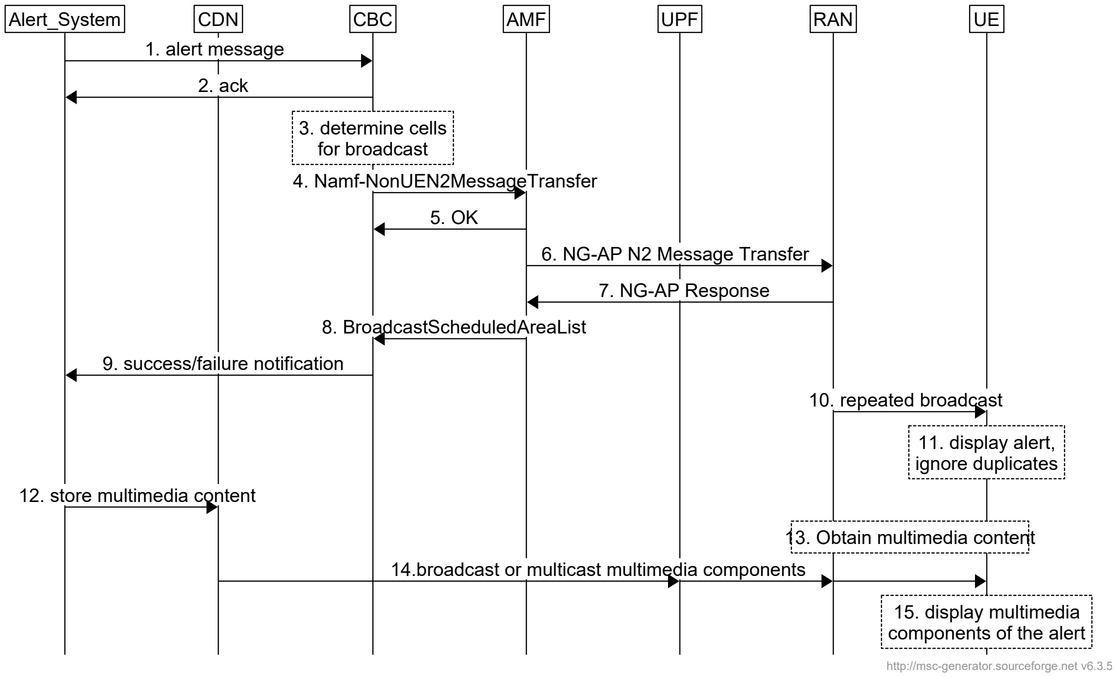

Figure 10 PW call flow

Steps 3 – 11 are based on Cell Broadcast technology which is specified in 3GPP TS 23.041 [5] and for which the protocols are specified in 3GPP TS 29.518 [13] (steps 4 - 5) and 3GPP TS 38.413 [14] (steps 6 – 8).

1. The Alert System sends an alert message to the CBC, which contains, amongst others, the textual information about the alert, the target area information and the information for the UE to receive the multimedia components.
2. The CBC acknowledges the alert message has been received.
3. The CBC determines from the target area information in the alert message which cells need to broadcast the message.
4. The CBC uses the Namf_NonUeN2MessageTransfer procedure to send the Write Replace Warning Request in the N2 message container to the AMF.
5. The AMF acknowledges the message transfer.
6. The AMF sends the N2 message container to the appropriate RAN nodes.
7. The RAN nodes confirm the reception of the message and the response contains the Broadcast Completed Area List with the cells that have scheduled resources for the broadcast successfully.
8. The AMF aggregates the Broadcast Completed Area Lists it has received from the RAN nodes and forwards that in a Broadcast Scheduled Area List to the CBC.
9. The CBC notifies the Alert system of the success or failure of the allocation of resources for broadcast.
10. The RAN nodes repeatedly broadcast the message to the UEs in the area until the message expires or is cancelled (cancellation not shown in figure).
11. The UE receives the broadcast and displays the message if the UE is configured to do so.
12. The Alert System stores the multimedia components of the alert in the CDN.

13. The UE (automatically) initiates the reception of the multimedia components, based on the URL that is provided in the message.
14. The UE obtains the multimedia components via transparent multicast or via broadcast:
    a. If the URL is HTTP-based then transparent multicast is used as detailed in section 4. The procedure as described in section 4 is not repeated here.
    b. If the URL is MBMS-based then broadcast is used as detailed in section 1. The procedure where the application on the UE uses the MBMS URL towards the converged middleware which will trigger the middleware to receive the broadcast is not shown in the figure.
15. The UE displays the multimedia components as per user request/preference.

9 Multilink-Enhanced Session

9.1 Use case: On the edge of PTM area

9.1.1 Description

Mobile device (user equipment) is on the edge of the broadcast/multicast (BC/MC) area (Figure 11). It's noted that the "edge area" means the edge in terms of service level (underground etc.).

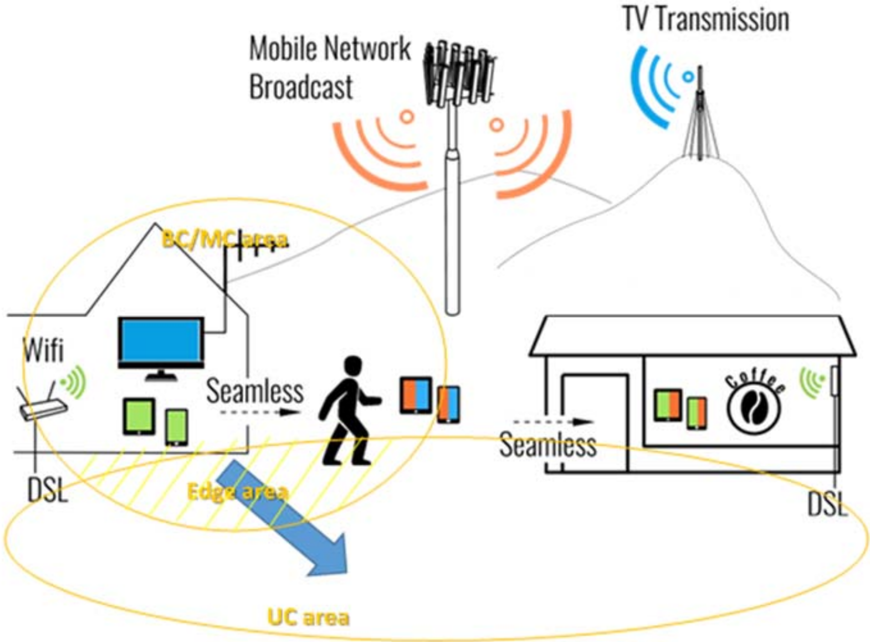

Figure 11 Multilink implementation on the edge of the MC/BC and UC areas

In this case, the following conditions and limitations are taking place:

- Poor BC/MC service or a mobile user going in and out of that BC/MC coverage area;
- The content is also transmitted to that user in unicast (UC);
- This UC content is the same content as the BC/BC content;

The user can watch a high quality and continuous video reliably delivered to him, if he receives it via multiple channels using ML (main stream via multicast 3GPP access and duplicate stream via unicast non-3GPP access). It will allow the user to get better quality video over UC, allow seamless and quick transition between BC/MC and UC, including during mobility and in the house.

Multilink can potentially have advantages for many users for:

- Huge file transfer;
- High/very high definition video streaming;
- Object based content delivery.

Switching from multicast to unicast (multilink) for this use case can be beneficial in terms of seamless transition between different areas.

One actor will benefit from this scenario:

- End User: improved QoE

9.1.2 Call flow

The following diagram (Figure 12) depicts a typical multilink call flow according to the above scenario for both alternatives.

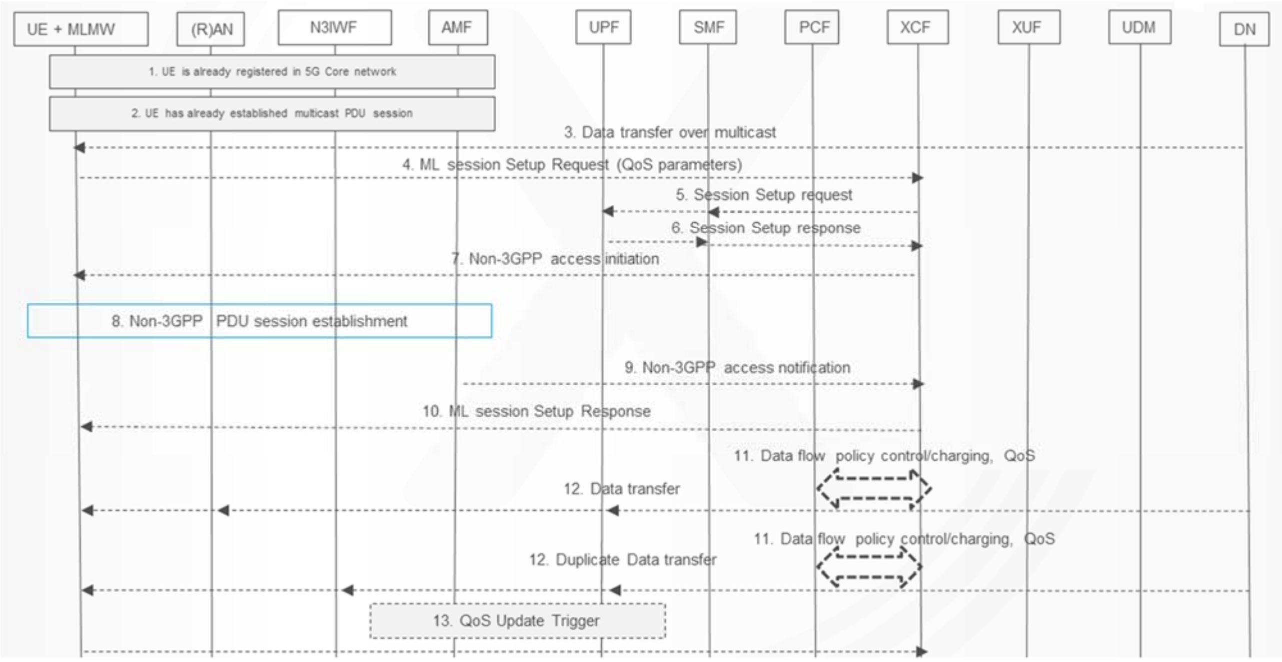

Figure 12 Multilink call flow

9.1.3 Configuration

According to the above diagrams (Figure 12) it is assumed that UE is already registered to the 5G Core network. UE receives data stream over MC. Later, the user is moving from BC/MC to UC area, the UE estimates each available channel (NR, LTE, Wi-Fi etc.) quality information (e.g. available bandwidth, average delay etc.). During this process, multilink middleware for improving data delivery may decide to create multilink Session (data duplication).

9.1.4 Session setup

Session setup process shown in Figure 12 is described below.

1. The UE initiates a multilink connection (ML Session Setup Request).
2. XCF forwards the Session Setup request to the SMF and UPF.
3. UPF sends Session Setup response to the SMF and XCF.
4. XCF sends Non-3GPP access initiation to the UE.
5. UE establishes new non-3GPP PDU Session. This process is described in [5].
6. AMF sends Non-3GPP access notification to the XCF.
7. XCF sends ML Session Setup Response to the UE.
8. PCF and XCF provide policy control/charging information about each channel (3GPP and non-3GPP) exchange.
9. DN provides data delivery directly to the UPF. UPF provides duplicate data delivery to the subscriber via two available 3GPP and not-3GPP links.
10. UE sends QoS Update Trigger to the XCF.

9.2 Use case: UE needs increased bandwidth

9.2.1 Use case description

To provide better QoE to the user, the mobile device (user equipment) needs increased channel bandwidth. The possibility to deliver content that would otherwise be impossible to deliver over a single link. For example, if a certain video stream needs 15 Mb/s and the single link is capable to deliver only 10 Mb/s, then this content could not be delivered over a single link. However, when bonding and aggregating at the application layer at least two such links, the total available bandwidth becomes 20 Mb/s which makes this delivery possible. This process is shown in (Figure 13).

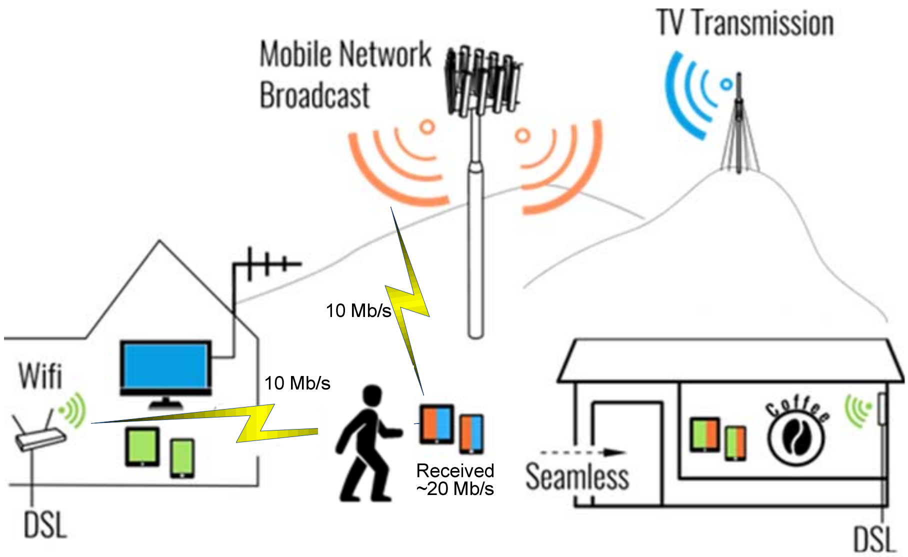

Figure 13 Multilink implementation for the bandwidth increasing

In this case the following conditions and limitations are taking place:

- Low bandwidth on each available channel (at least less than necessary for requested QoE);
- The content is transmitted to that user in unicast (UC);
- The UC content transmitted to the user is just a partial subset of the BC/MC content.

The user can watch a full quality and reliable video only if it is received via multiple channels using ML. It will allow the user to get the best quality video over UC.

Multilink can potentially attract many users for:

- Huge file transfer;
- High/very high definition video streaming;
- Object based content delivery.

Two actors will benefit from this scenario:

- End User: improved QoE
- Network Operator: load balancing between different available links

Due to the expected number of Sessions on this channel, low quality level of each channel, UE decides to optimize its network resources and the overall QoE by using of multiple available links.

9.2.2 Call flow

The following diagram (Figure 14) depicts a typical multilink call flow according to the above scenario for both alternatives.

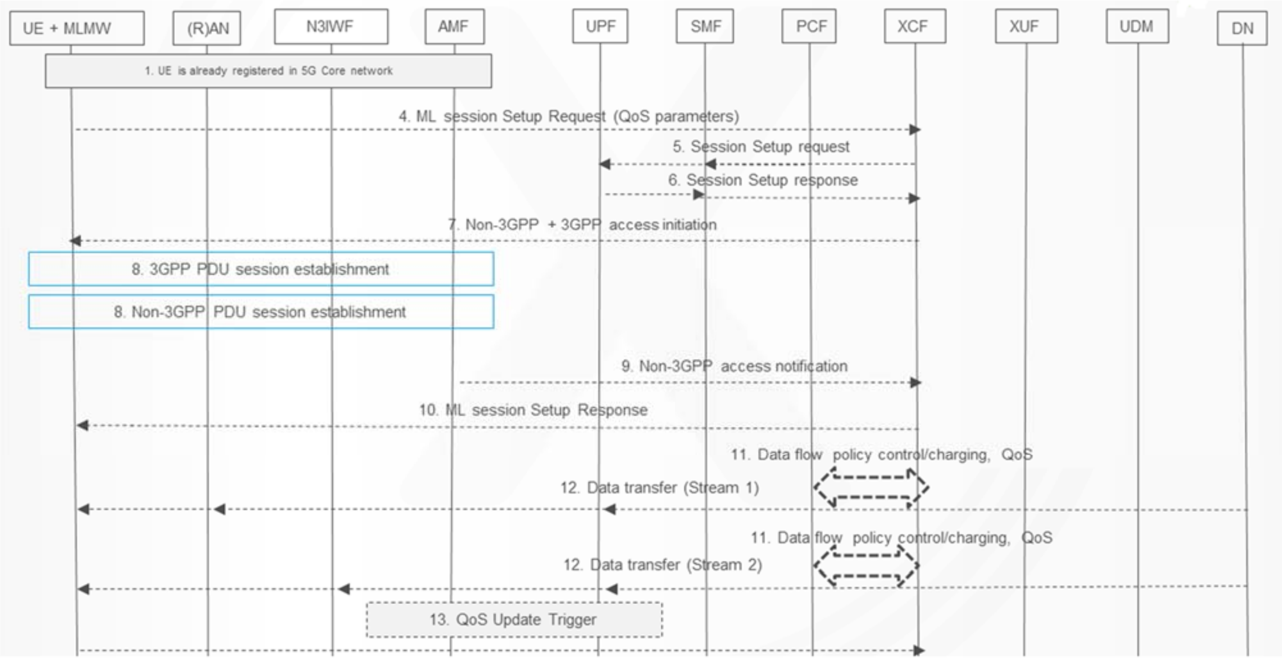

Figure 14 MuliLink call flow

9.2.3 Configuration

According to the above diagram, it is assumed that UE is already registered in 5G Core network. UE estimates each available channel (NR, LTE, Wi-Fi etc.) quality information (available bandwidth, average delay etc.). During this process multilink middleware may decide to create multilink Session (data splitting) for improving data delivery.

9.2.4 Session setup

Session setup process shown in (Figure 14) is described hereafter.

4. The UE initiates a multilink connection (ML Session Setup Request).
5. XCF forwards the Session Setup request to the SMF and UPF.
6. UPF sends Session Setup response to the SMF and XCF.
7. XCF sends Non-3GPP access initiation to the UE.
8. UE establishes new Non-3GPP and 3GPP PDU Sessions. These two processes are described in [5].
9. AMF sends Non-3GPP access notification to the XCF.
10. XCF sends ML Session Setup Response to the UE.
11. PCF and XCF provide policy control/charging information about each channel (3GPP and non-3GPP) exchange.
12. DN provides data delivery directly to the UPF. UPF provides data delivery to the subscriber via two available 3GPP (Stream 1) and not-3GPP (Stream 2) links.
13. UE sends QoS Update Trigger to the XCF.

10 Conclusion

This Deliverable summarizing the work of Task 4.3 for 5G-Xcast core network Session management, showed and specified the main media and PW initiation call flows that can be used for establishing a Multicast/Broadcast Session for each of the technologies and data flows described in Deliverable D4.1 [2].

Specifically, this document presented the concept of multicast context for the management of network resources associated with the transfer of multicast data (PDUs) through 5G system between a data network and UEs with multicast ingress point at UPF. A method of the multicast context establishment by enhancing already standardized PDU session modification procedure for unicast was devised. The enhanced PDU session modification procedure can be initiated by the UE or the UPF upon the event of UE joining a multicast group. Once the multicast context is established and network resources comprising network functions, transport tunnels, etc. are allocated, the transport of multicast data from an application to UEs receiving the same multicast data with UPF being the ingress point is possible. The resource management for point-to-multipoint services in the alternative 1 and related Sessions for point-to-multipoint services build on top of this new network's capability to transport multicast from UPF to UE.

The dynamic delivery mode selection is a key functionality in the 5G-Xcast content delivery framework. This Deliverable showed in detail how this functionality can be achieved with HTTP/2 over multicast QUIC and with the point-to-multipoint services over both architectural alternatives defined in Deliverable D4.1 [2].

The call flows for PW Session illustrated how multimedia content of public warning message can be received via broadcast or multicast using point-to-multipoint service session or the transparent multicast transport triggered by a cell broadcast. The call flow of multicast ABR Session showed the interactions at layers above mobile/converged core among the entities of the 5G-Xcast content distribution framework with the exemplary case of DVB multicast ABR architecture.

This document also described how 3GPP and non-3GPP access networks can be used in Multilink-enhanced Sessions. The Multilink-enhanced Sessions addressed the use case of user at the edge of multicast/broadcast area of an access network and the use case of insufficient multicast/broadcast capacity of an access network.

These call flows are managed within the Core network. There is no cross-layer management interaction with the lower RAN layer nor with the higher application layer. In line with the important 3GPP context, the session management maintains the logical split between Core network, RAN and application layers. The BC/MC are managed within the core network, preserving the RAN autonomous management of its own resources transparently to the Core, and vice versa.

Further, these detailed call flows are described in such details and with the necessary alignment to the 3GPP core architecture and flows that they may be easily used as a baseline for standardization in 3GPP for the 5G MC/BC support.

A Requirements

Following are the main requirements that the Sessions and resource management need to address. These requirements were analysed from the work of WP2 T2.1 and documented in Deliverable D2.1 on “Definition of Use Cases, Requirements and KPIs [5] and Deliverable D4.2 on “Converged Core Network” [12].

Requirement ID	Description	WP4.3 Impact
M&E1_R1	End users have seamless access to audio-visual content both at home and on the move including seamless mobility between access networks, and across different types of devices (stationary, portable/ mobile, mounted in a vehicle). • The user’s device is able to automatically connect to the best available network/s to give the highest QoE to the user, including simultaneous access to multiple networks. • It is desirable to allow using multiple network types together to increase QoS/QoE to any segment of the population that can support this.	* A logic in the UE to handle the complexities seen by UE's application due to mobility, access network switching, simultaneous network handling * Use of multiple network types at the same time (e.g. multilink)
M&E1_R2	End users have a single set of credentials (e.g. single user name and password) in order to access a consistent set of content, services and policies across different access networks.	* Maybe impact on Session control as a Session may relate to specific users
M&E1_R3	The network resources required to deliver the service to a given audience should grow much less than linearly with audience size, particularly for large audiences of very popular content. • An audience may be concentrated in a limited geographical area or distributed • Minimising the distribution costs for the content service provider	* Support multicast/broadcast capability inside the core network * Deliver multicast/broadcast traffic to flexible geographical area * Optimize network resource allocation and management
M&E1_R4	It should be possible for different network types to carry different content elements that constitute the user experience. • It is desirable that networks operated by different operators can carry different content elements that constitute the user experience.	* Deliver all content's elements to the UE in only one network type * Deliver part of content's elements on a given network type
M&E1_R5	If multiple networks are used it should be possible to offload the traffic between them. • e.g. fixed, mobile and/or broadcast networks	* Support traffic offloading between network types
Requirement ID	Description	WP4.3 Impact
M&E1_R6	• It is desirable that content delivery can use multiple networks at the same time and	* Use of multiple network at the same time (e.g. multilink) * Switch between networks; either

	switch between networks including when operated by different operators.	by the an entity in the infrastructure aware of all such networks and connections, or by the UE
M&E1_R7	It is desirable that the network supports dynamic optimisation of resource allocation based on individual operators' policies, e.g. automatically initiating the switching between unicast, multicast and broadcast. • Means should be given to allow implementation of various deployment and optimization policies of network resources vs QoE of the population as a whole or segments of.	* Flexible and optimised resource allocation * Switch from unicast to multicast/broadcast according to policies and vice versa * Support local operator QoS policies & global QoS policies across operators
M&E1_R11	Parallel delivery of a given content at different QoS/QoE levels to different portions of the population in the same geographical area should be supported.	* Dynamic and flexible QoS policies for the same geographical area
M&E1_R12	Transition between unicast and broadcast and multicast should be allowed during service, without impact on viewers and other users, and within a minimized transition time (in the order of seconds).	* Service continuity and seamless transition
M&E1_R16	The system should be scalable to serve very large concurrent audiences while maintaining the required Quality of Service for each user irrespective of the size of the audience. The number of concurrent users can be very high, i.e. >106 for the most popular content. The system should support variations in the number of concurrent users (e.g. driven by the changing popularity of content).	* Use of multicast/broadcast capability as a scalable solution * Guarantee QoS * Switch from unicast to multicast/broadcast on demand and vice versa (probably make before break ?)
M&E1_R20	End-to-end (i.e. from content service provider to end user) transport layer security of multicast traffic must be equivalent to that of unicast traffic. • Content integrity, confidentiality, availability and non-repudiation should be ensured in transit.	* Support secured data delivery for both unicast, multicast/broadcast traffic (e.g. IPSec)
M&E1_R22	The 5G-Xcast solution should support authentication and authorisation of the user, where required.	* Support user identification and authentication
Requirement ID	Description	WP4.3 Impact
M&E1_R27	Content should be delivered to the user device as designed by the content service provider, i.e. without undesired alterations (e.g. interruptions, overlays, distortions, reduced image quality).	* Support data protection and recovery mechanism (e.g. retransmission, AL-FEC) * Guarantee QoS

M&E1_R28	Geographical availability - the service provider should be able to define in which territory the content / service should be made available, i.e.: • globally • in one or more individual countries • regional • local • one or more specific venues	* Scalable and dynamic geographical area
M&E1_R32	The interface between the content provider and different networks should be as simple as possible and it should be consistent across different network types.	* Expose simple and unified interfaces to the content provider
M&E1_R33	The system should have the possibility to provide audience metrics (e.g. number of users, duration, location, QoS experienced), including behavioural and QoE reporting in real-time. • The system should enable monitoring of the performance of the service (Session established, content flow as expected) • It should be possible to report audience metrics anonymised or non-anonymised.	* Logics or network functions for audience measurements (number of users, duration, location, QoS experienced) * Apply for both fixed and mobile network types
M&E1_R34	The 5G-Xcast solution should be designed in a way as to minimise the need to avoid excessive updates to the hardware capabilities of consumer equipment, including UEs. • Support of the 5G-Xcast solution can be different in different types of UEs. • The UEs should also be able to use the capabilities used for unicast for broadcast / multicast such as existing media player components.	* Prefer softwarerization and NFV/SDN solutions * Logic in UE to handle different delivery modes (e.g. unicast, multicast/broadcast)
M&E1_R35	It is desirable that the networks support different business arrangements (e.g. free-to-air, subscription, pay-per-view, usage deducted from a subscriber's data allowance) including both OTT and managed services with guaranteed QoS. • Whilst 5G-Xcast would not develop a billing mechanism, the solution should provide sufficient information to feed a billing system.	* Customized QoS for different subscription models
Requirement ID	Description	WP4.3 Impact
PW1_R1	The system shall support ad-hoc (unplanned) Alerts that must be sent as soon as possible once executed and typically within 10s from the issue of the alert.	

PW1_R2	It shall be possible to send multiple types of content, including: • Pictures; • Text; • URLs; • Videos; • Audios; and • Geographical information	
PW1_R3	Only designated authorities shall be allowed to send the Alert. • Requiring authentication and authorization	
PW1_R4	It shall be possible to target messages to groups of users with a cell granularity	
PW1_R6	The Alert shall be automatically received by each device for which the user has opted-in within the target area and the message is reproduced immediately without any manual user intervention	
PW1_R7	In-bound roamers who opt-in for the service shall also be capable of receiving the Alert	
PW1_R10	The internal components of the alert message can be delivered separately, in order to speed up its diffusion (e.g. textual components before additional geographical information). • Multimedia components such as videos and audios conveying messages to disabled people have the same priority of textual information for able-bodied persons	
PW1_R11	The system shall support multimedia components of an alert according to the modality (priority) specified by the user	
PW1_R12	The system shall deliver multimedia components according to the priority levels defined by the Public authority. Is shall be possible for Public authority to set the priority for delivering alert content that is higher than other types of content to increase the probability that Public Warning content will arrive without undue delay to the end-users	

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