Broadcast and Multicast Communication Enablers for the Fifth-Generation of Wireless Systems

Deliverable D4.3
Session Control and Management

Version v2.0

Date: 2019/05/30

Document properties:

Grant Number:	761498
Document Number:	D4.3
Document Title:	Session Control and Management
Editor(s):	Baruch Altman (LiveU)
Authors:	David Navratil (NOK); Jon Hart (BT); Maël Boutin (Broadpeak); Roman Odarchenko, Rui Andrade Aguiar (Bundeslab); Tuan Tran (Expway); Christian Menzel (IRT), Baruch Altman (LiveU); Peter Sanders, Menno Bot (one2many), Mauro Castagno (TIM)
Reviewers	Hannu Hietalahti, Devaki Chandramouli (Nokia).
Contractual Date of Delivery:	2019/05/30
Dissemination level:	PU[1]
Status:	Final - updated
Version:	2.0
File Name:	5G-Xcast_D4.3_v2.0

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 [2[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), Public Warning System (PW), Mission Critical Communications (MCC), Cellular-to-Vehicle (C-V2X) and Internet of Things (IoT). 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, MCC, IoT, V2X, C-V2X

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

PU = Public

Revision History

Revision	Date	Issued by	Description
1.0	2018/05/31	Baruch Altman)	First public version May 2018.
2.0	2019/06/04	Baruch Altman	Second public version July 2019.

Disclaimer

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, Public Warning System, IoT, C-V2X Automotive and Mission Critical Communications (MCC) use cases described earlier by WP2 D2.2 and using the 5G-Xcast principle architecture alternatives developed in WP4 D4.2 [12].

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.

Table of Contents

List of Figures

List of Tables

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
C-V2X Cellular V2X
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
SCS Service Capability Server
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
V2X Vehicle-to-Everything
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 two main 5G-Xcast architecture alternatives.

The main Session elements are: PDU Session, Point to Multipoint (PTM) services Session, Public Warning (PW) Session, IoT Session, C-V2X automotive Session, Mission Critical Communications 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 is detailed in its own dedicated separate document (see Deliverable D2.4 [38]).

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, Multilink-enhanced, IoT, C-V2X Automotive and MCC 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 describes 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 the 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 providers 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 outside the 3GPP domain. A multilink-enhanced session comes next. It is outside the 3GPP domain and uses combinations of the 5G ML, the 5G UC and the fixed network connection and 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. The sessions of MC/BC in IoT, in C-V2X automotive and in MCC are then analysed and their basic call flows described. 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 is published separately (see Deliverable D-something [38].

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 could 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 focus 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 (see Deliverable 4.1 [2]. Transparent multicast transport provides the exchange of multicast PDUs between a UE and a Data Network in a way that the 5GS 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. The multicast context is created or updated when UE's interest in receiving multicast content changes. In the case of the IP PDU Session type, this means that the UE joins or leaves the multicast group by means of 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. The same principle of multicast context applies also to the dynamic delivery mode selection with point-to-multipoint services in architecture alternative 1 as described in section 6.2 (see Deliverable D4.1 [2] for architecture description). The point-to-multipoint services relies on deployment of XCF, which could send the information about a multicast session via the interactive announcement or point-to-point push bearers to the UEs (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 needs 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 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 colour 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 3GPP TS 23.502 [5] including the 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].

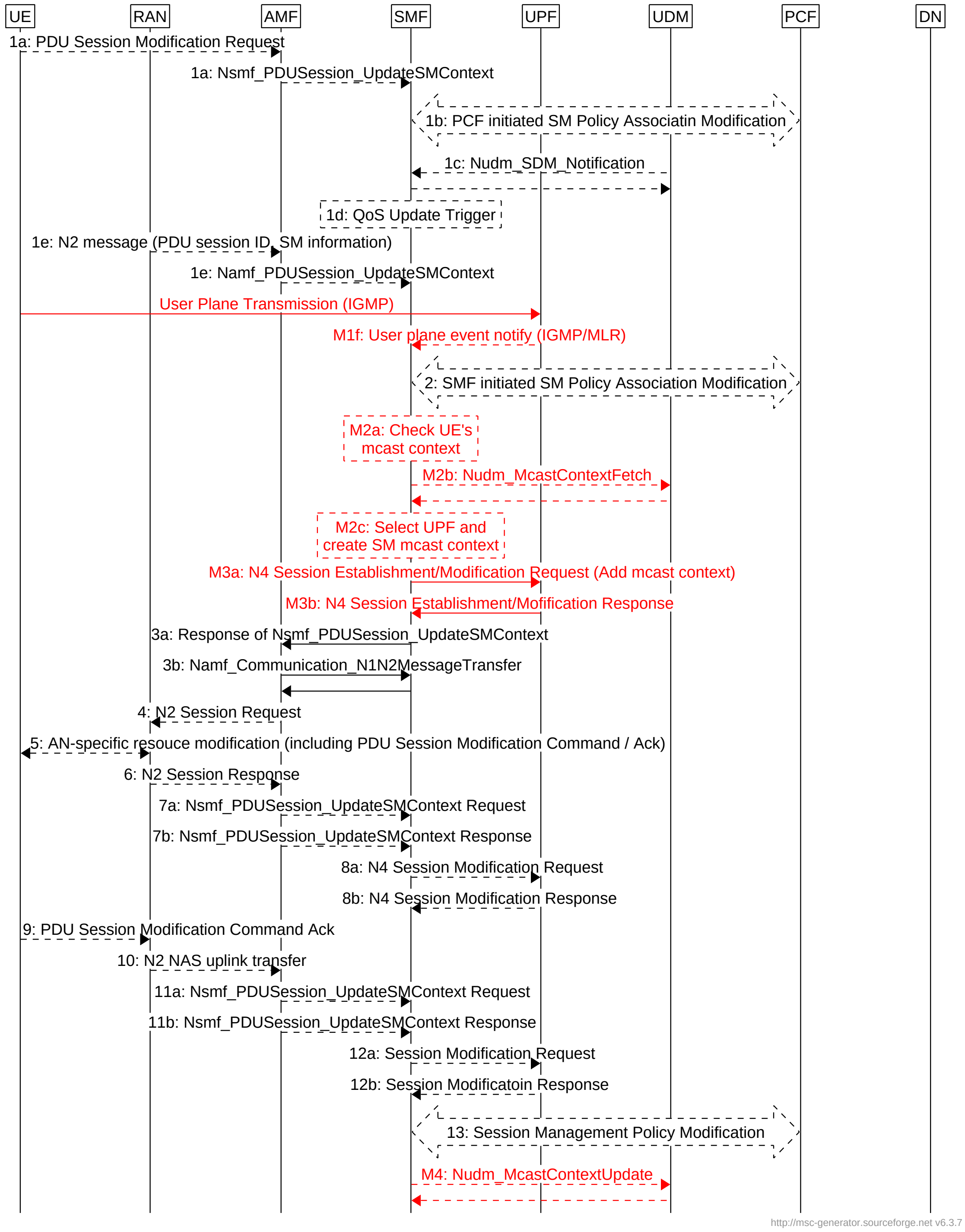

Figure 1 PDU Session Modification with multicast context creation/modification

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 the PS 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 [3] 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 [3] 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 operation and 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 fulfil 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.

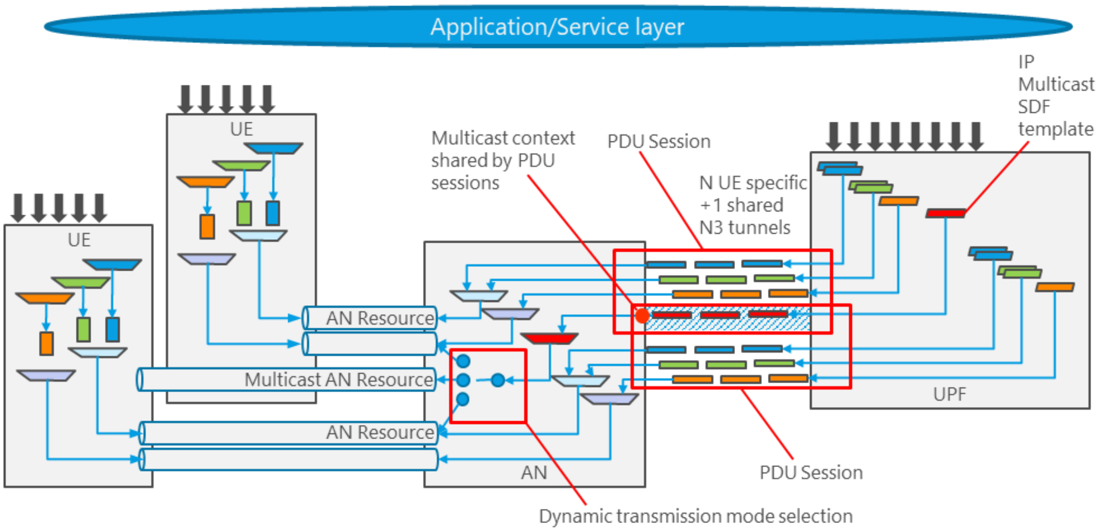

Figure 2 PDU Sessions and multicast context in 5G System

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 [2].

5.1 Core network architecture alternative 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 using architecture alternative 1 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 TS 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.

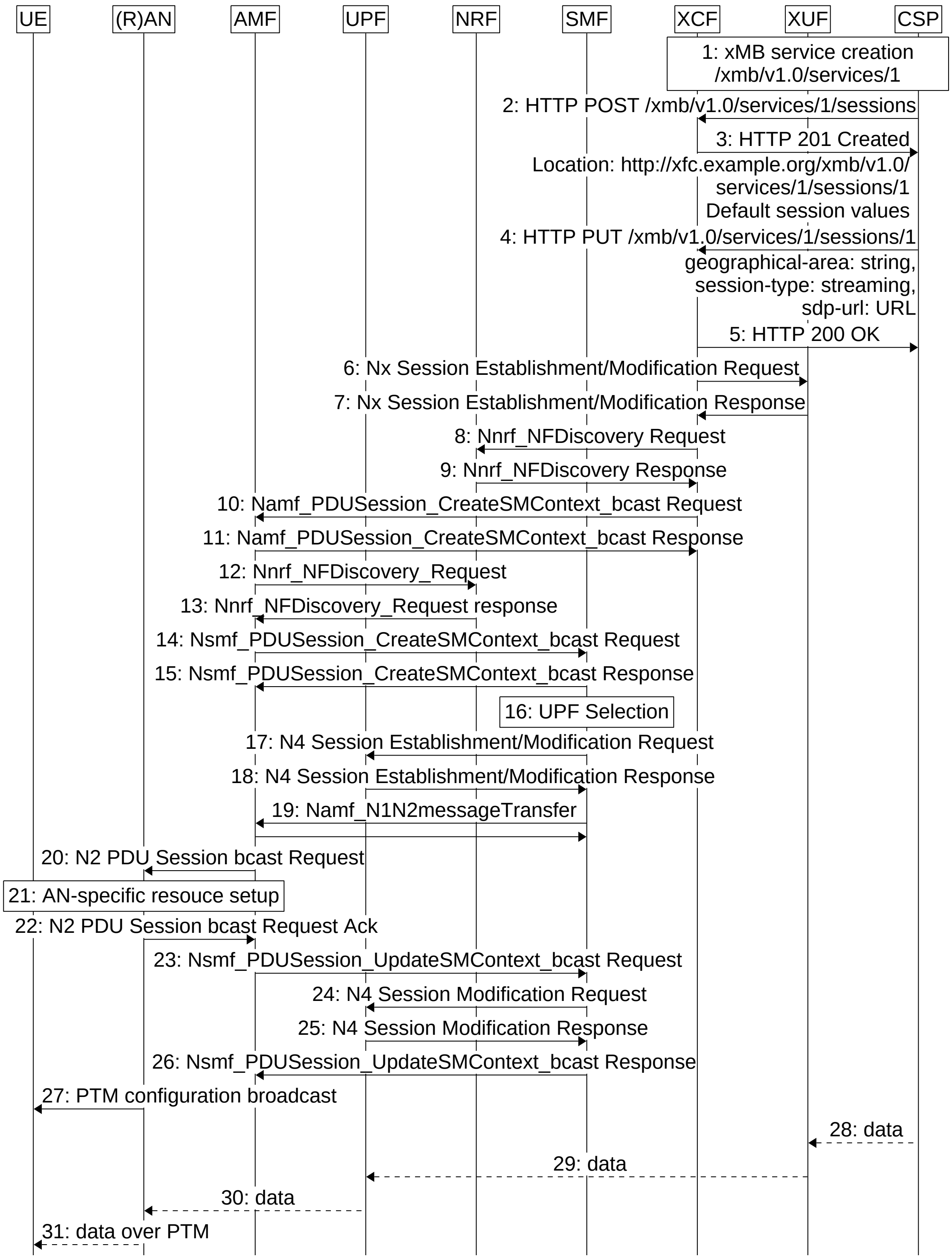

Figure 3 Network resource allocation for broadcast (architecture alternative 1)

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]).

5.2 Core network architecture alternative 2

The resource allocation procedure for broadcast using architecture alternative 2 is shown in Figure 4.

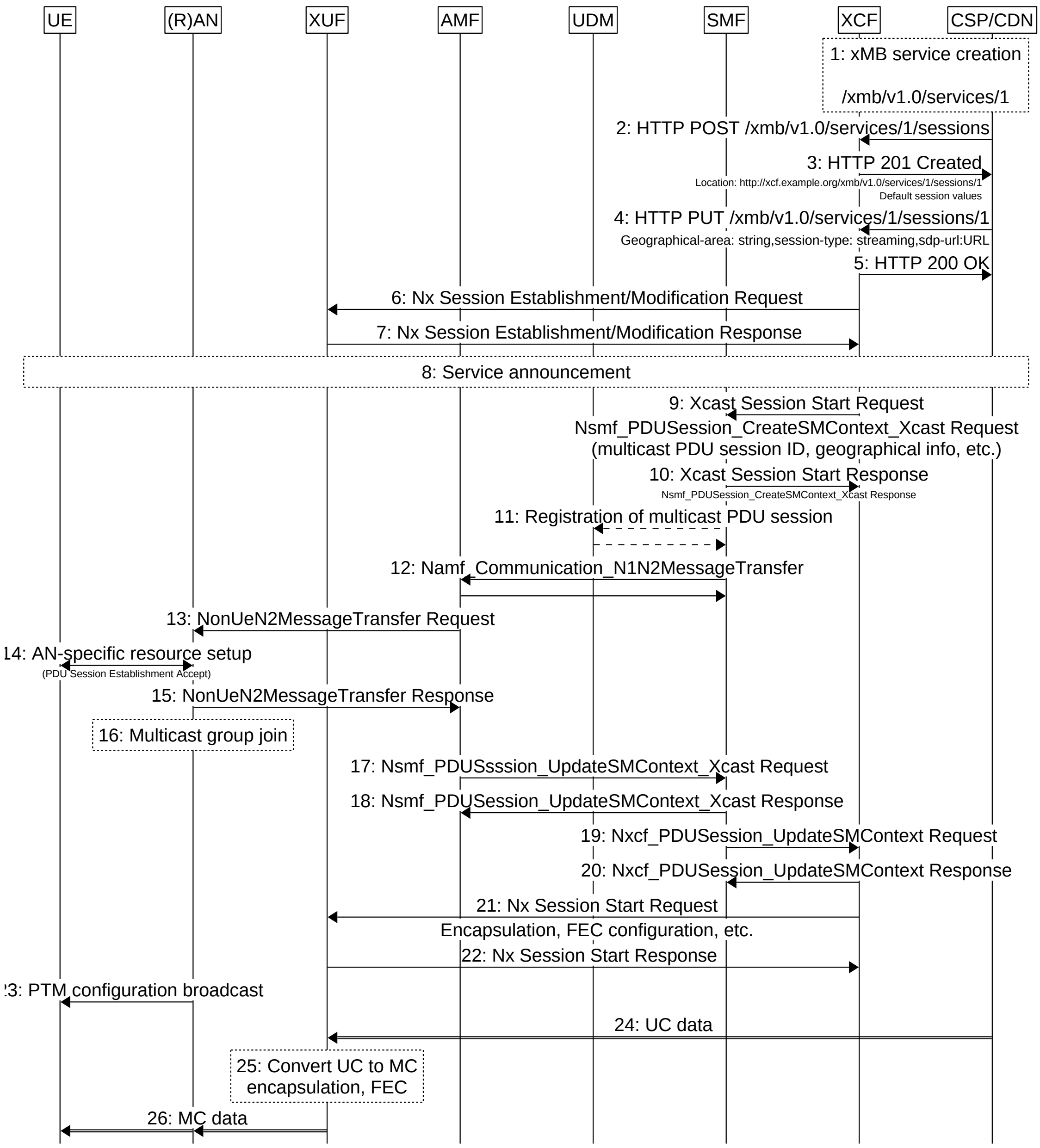

Figure 4 Network resource allocation for broadcast (architecture alternative 2)

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.

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 **¡Error! No se encuentra el origen de la referencia.** 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.

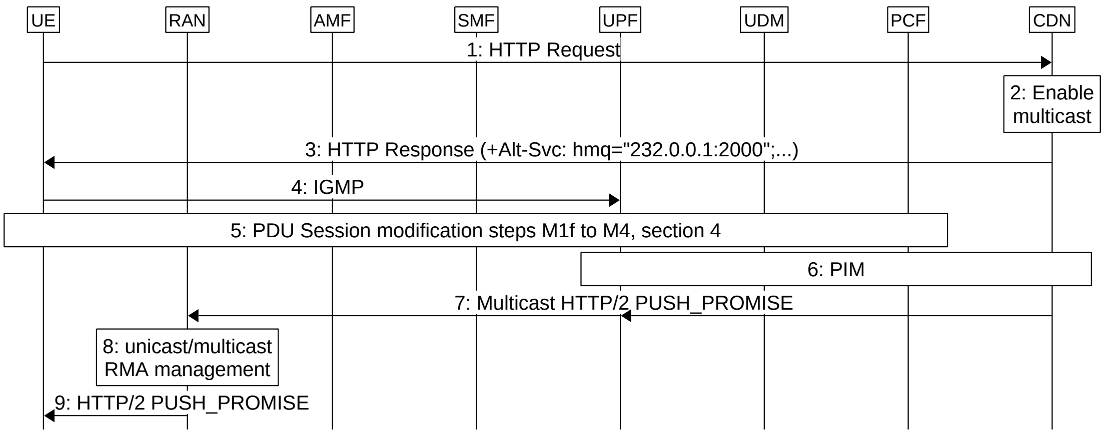

Figure 5 Dynamic delivery mode with multicast QUIC

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

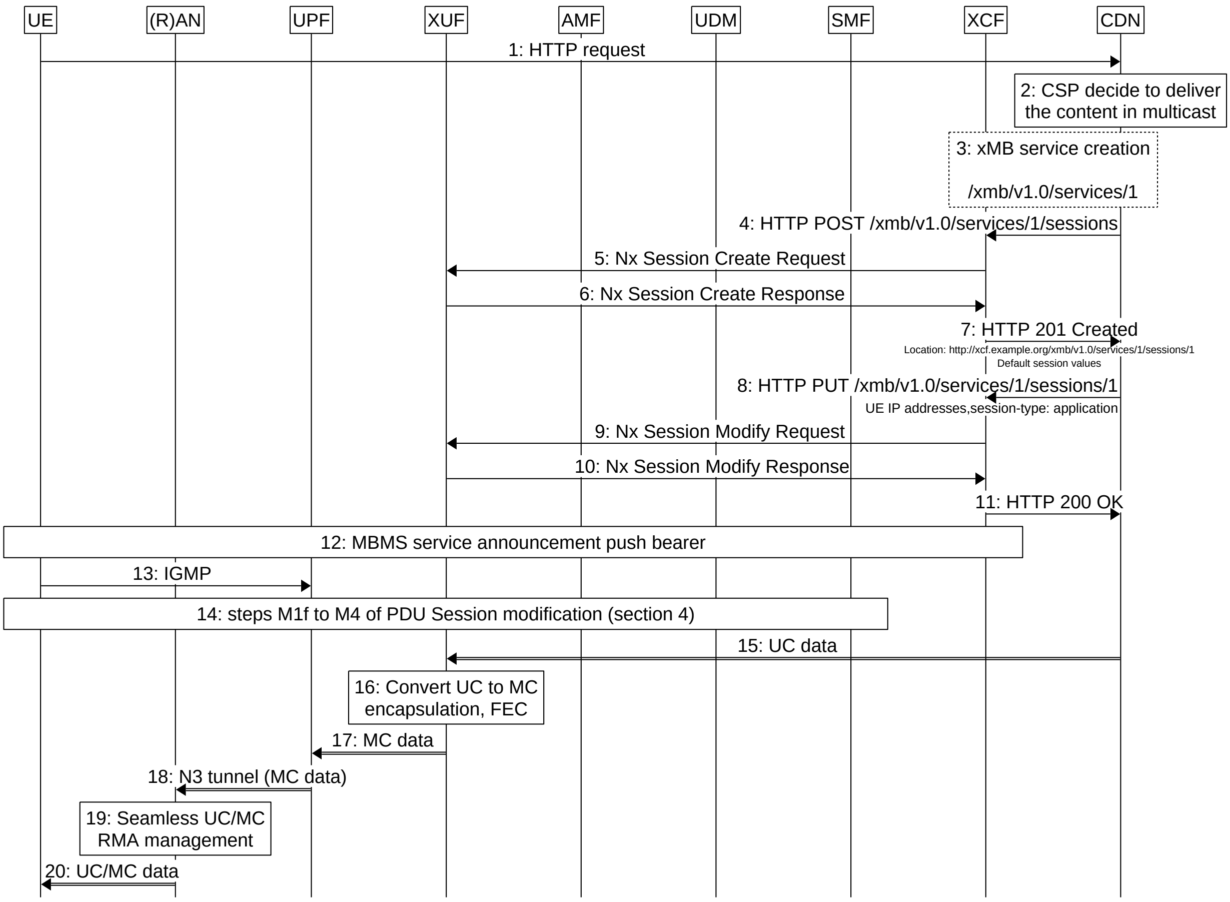

Figure 5 Dynamic delivery mode selection with point-to-multipoint services for architecture alternative 1

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 [6]). 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 [11]).
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 [11] 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 [6]).
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. 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/broadcast. 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.

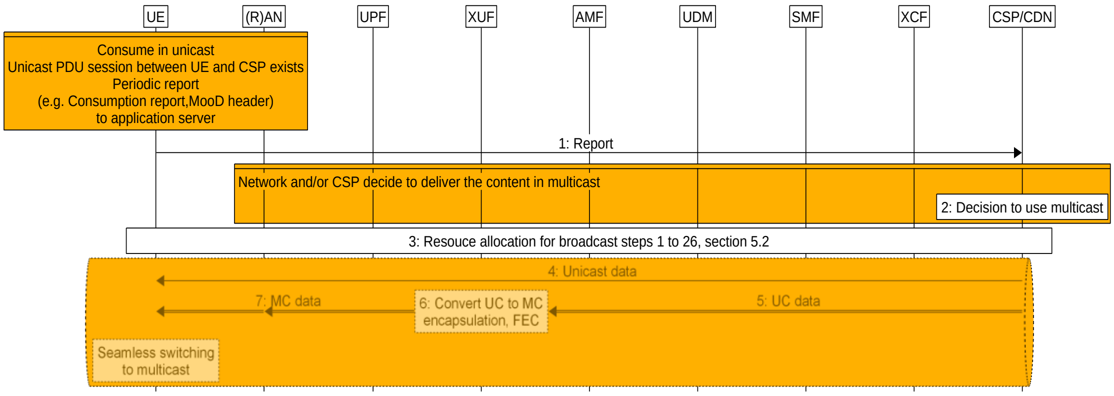

Figure 6 Dynamic delivery mode selection with point-to-multipoint services for architecture alternative 2

Figure 6 describes the workflow for dynamic delivery mode selection based on consumption report messages sent from the UEs to the network (e.g. consumption report server). Although possible, the solution using MooD header field is not considered in the present document.

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:

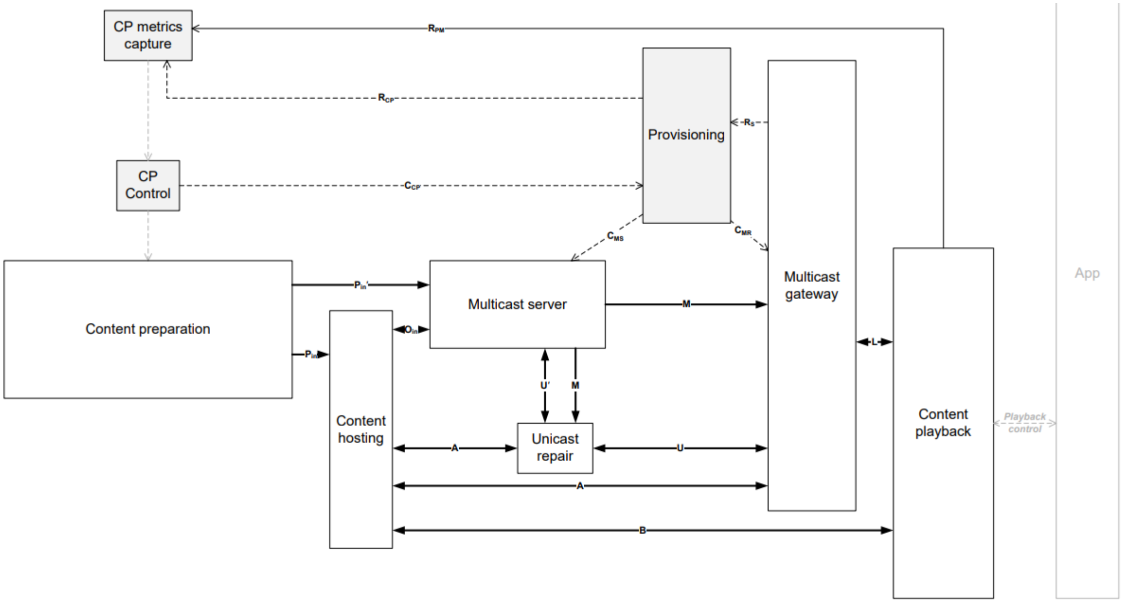

Figure 7 DVB Multicast ABR reference architecture

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.

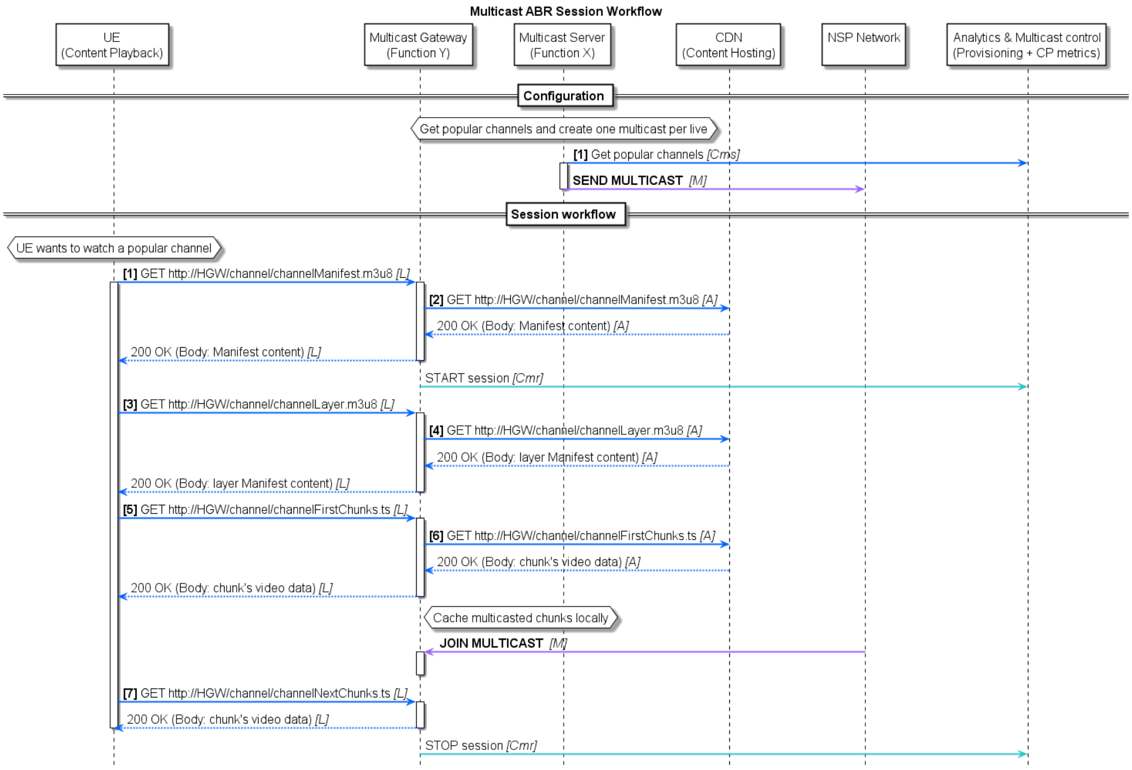

Figure 8 Multicast ABR call flow

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 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. Other solutions could be considered, 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 (section 5)
- 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 5)

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.

8.1 PW Session with RAN triggered 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.

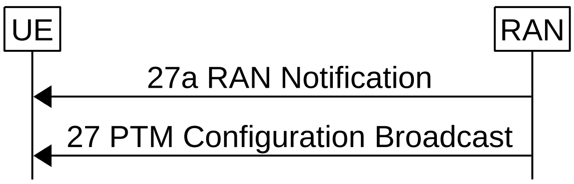

Figure 9 Point-to-Multipoint for PW call flow

8.2 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 section 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.

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

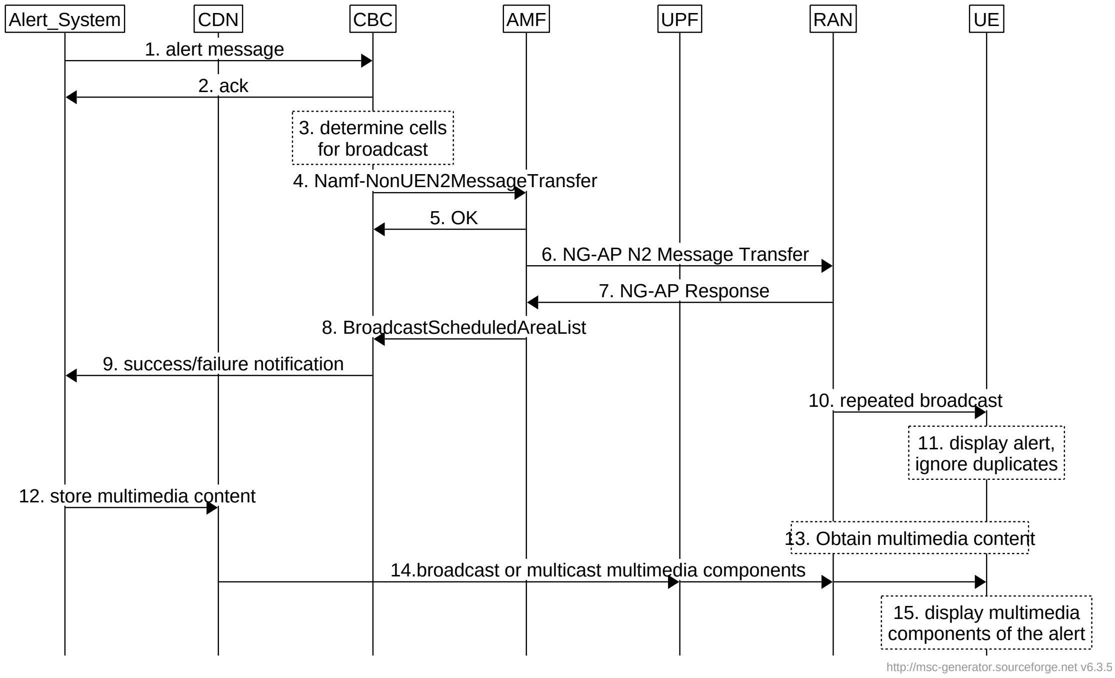

Figure 10 PW call flow

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.).

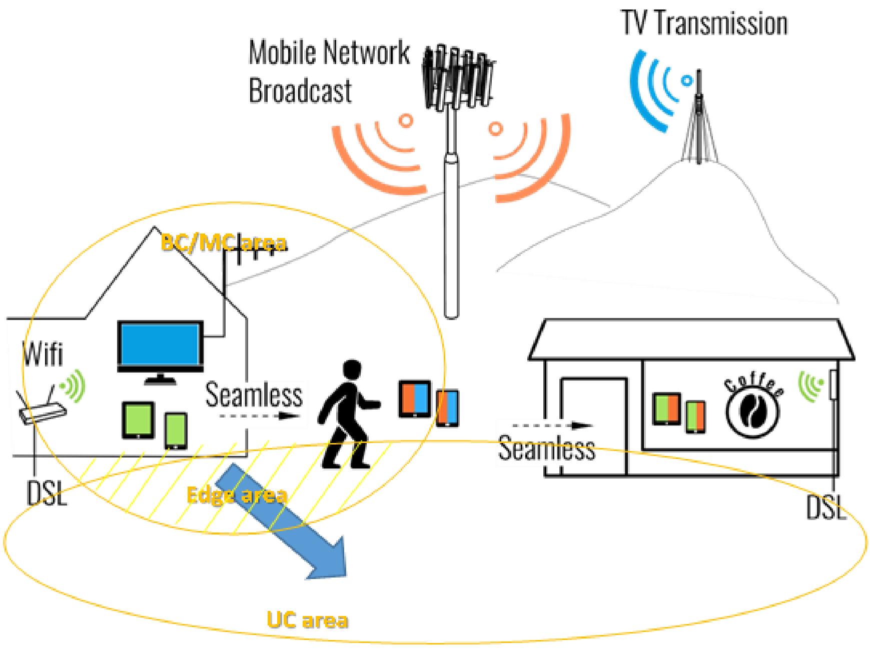

Figure 11 Multilink implementation on the edge of the MC/BC and UC areas

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.

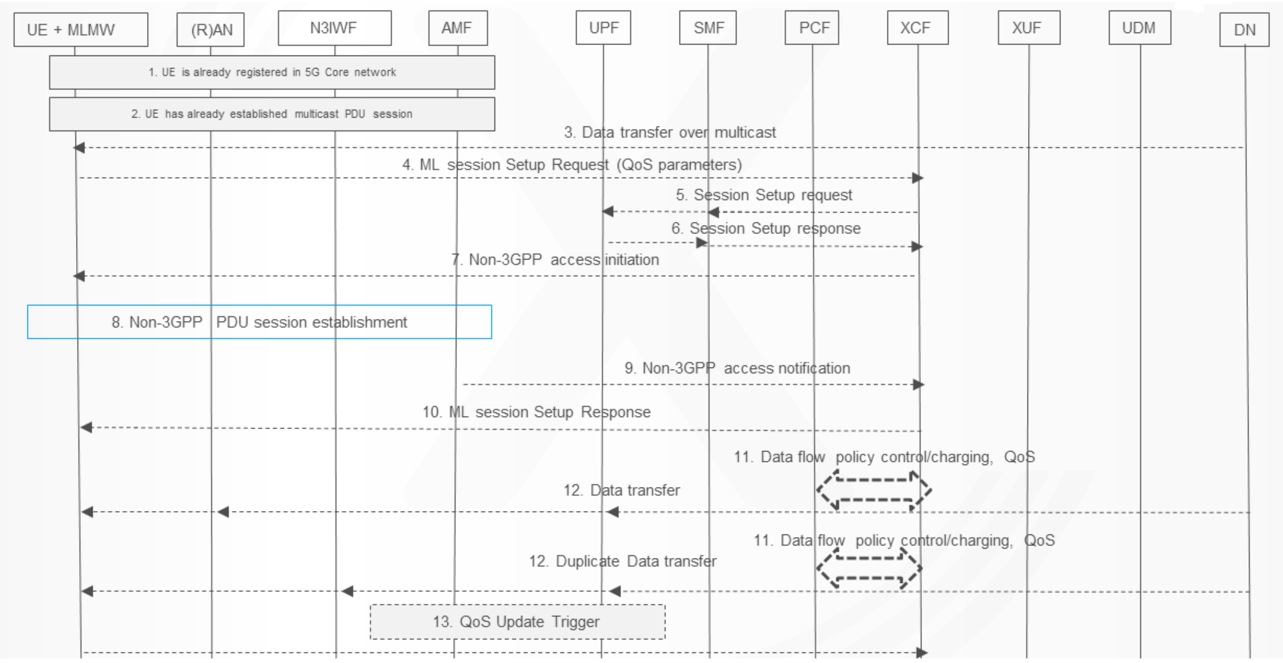

Figure 12 Multilink call flow

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 3GPP TS 23.502 [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).

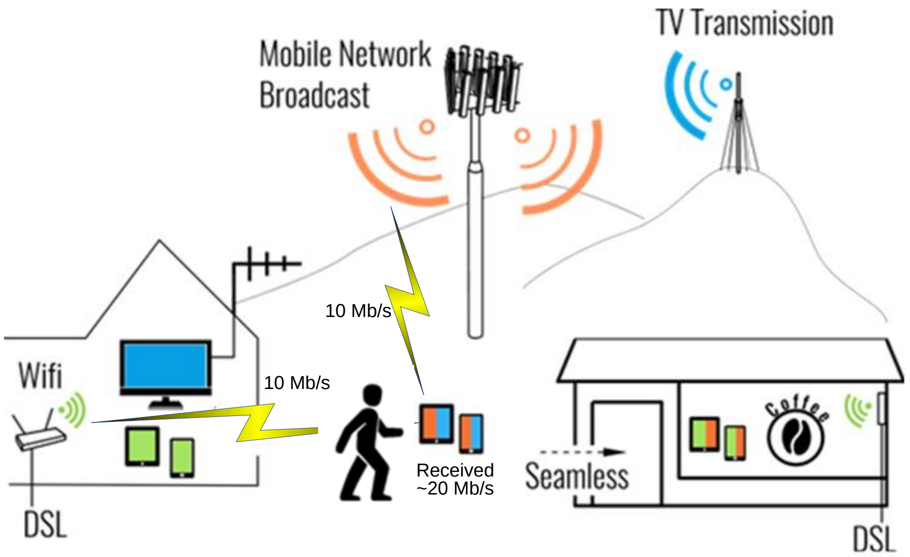

Figure 13 Multilink implementation for the bandwidth increasing

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.

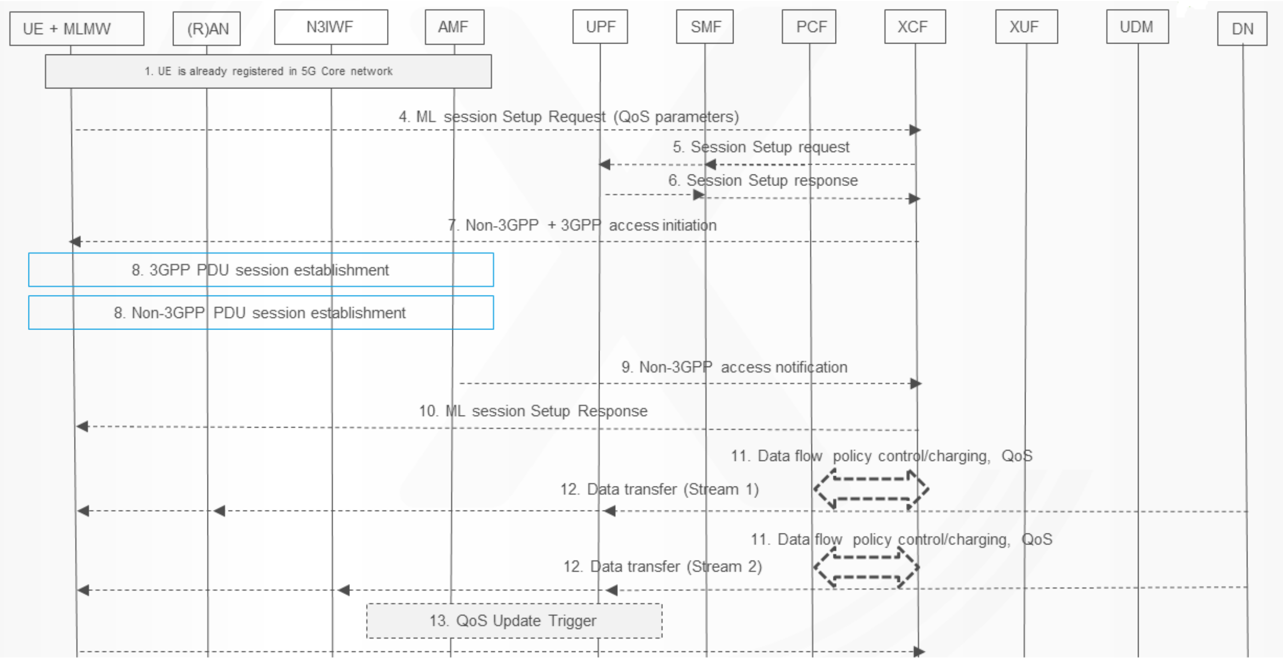

Figure 14 MuliLink call flow

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 3GP TS 23.502 [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 Group message delivery for IoT devices

10.1 Summary of IoT in 3GPP

The concept of Internet of Things (IoT) first appeared in 3GPP Rel-12 as part of the Technical Report (TR) 36.888 [25]. The document provided a careful study on the provision of low-cost Machine-Type Communications (MTC) UEs based on LTE. The proposed technology was designed to use LTE technology and allocated frequencies.

In 3GPP Rel-13, the IoT technology was further improved and labelled as LTE enhanced MTC (eMTC). In this release, a new UE category was defined, i.e. Cat-M. In addition to eMTC, NB-IoT was specified in Rel-13 along with a new UE category Cat-NB1.

3GPP Rel-14 introduced RAN enhancements in terms of mobility, power consumption, positioning and tracking as well as data rates both for eMTC and NB-IoT leading to new UE categories Cat-M2 and Cat-NB2, respectively. In addition, it included the support of SC-PTM for both eMTC and NB-IoT specifications. The concept of eMBMS for IoT was introduced for the first time.

3GPP Rel-15 addressed the use of MBMS for the potential data delivery to a large number of IoT devices. The considered requirements are the support of reliable delivery, acknowledgements on successful reception, eMBMS delivery procedures for devices with limited capabilities (e.g. limited battery life of 15 years). Furthermore, Rel-15 brought further improvements in terms of power consumption, mobility support, latency, coverage, etc.

Recently, within the scope of 3GPP Rel-16 the first study on the support and evolution of Cellular IoT (CIoT) functionalities for the 5G system was performed. The main objective was the study and evaluation of the following network architecture enhancements: (i) CIoT/MTC functionalities in 5GC, (ii) coexistence and migration from EPC-based eMTC/NB-IoT to 5GC and (iii) 5G system enhancements to address 5G requirements. For that purpose, 3GPP TR 23.724 [26] identified 17 key issues on the 5G system and 52 possible architectures as potential solutions of the identified issues. The key issue of interest in the present document is the support of group communication and messaging. In the TR 23.724, group message delivery can be supported by unicast MT NIDD (Mobile Terminated Non-IP Data Delivery) between the NEF and UE. However, this solution is based on unicast approach which is not efficient. The following section provides a more efficient solution using broadcast approach.

10.2 5G-Xcast solution for group message delivery for IoT devices

The communication between the IoT Application hosted by an Application Server (AS) in the external network and the IoT Application in the UE uses services provided by the 4G system, and optionally services provided by a Services Capability Server (SCS) for value-added services. In particular, 3GPP TS 23.682 clause 5.5 [24] provides a solution for the group message delivery service is offered by SCEF (Service Capability Exposure Function). The SCS/AS delivers a message through the SCEF using T8 reference point to the LTE EPC with eMBMS capability enabled and then to a group of IoT UEs.

In the context of 5GC, if the SCS/AS is trusted by 5GC, the SCS/AS can use directly the interface to ask for a group message delivery using xMB interface. In this case, the work flow is similar to the section 6.3 (see Figure 6). If the SCS/AS is not trusted by 5GC, then the SCS/AS access services offered by 5GC via the Network Exposure Function (NEF) using the NEF Northbound interface specified in 3GPP TS 29.522 [27]. The 5G-Xcast solution proposes to introduce an API for group message delivery to the NEF Northbound interface similar to APIs for group message delivery via MBMS specified for the interface

T8, see 3GPP TS 29.122 [28]. Figure 15 describes the call flow for IoT group message delivery using this new API for alternative 2.

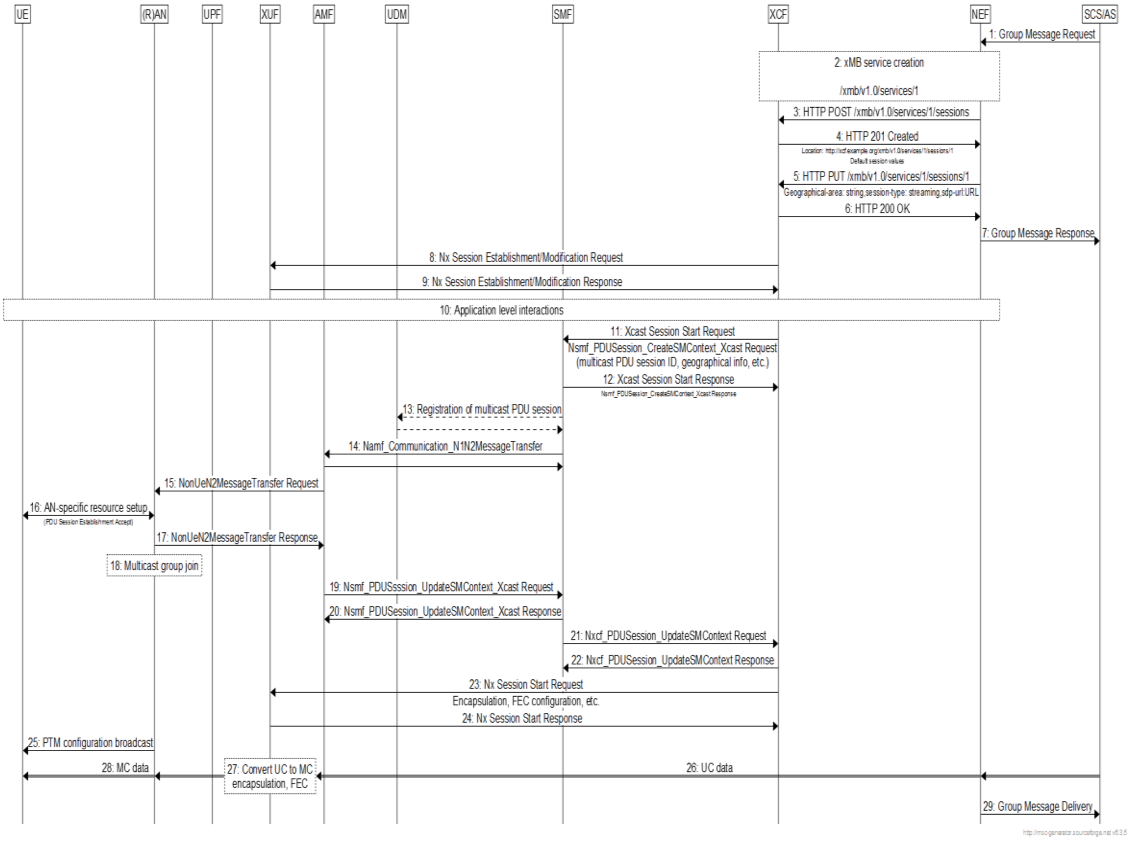

Figure 15 Group message delivery for IoT devices

1. The SCS/AS sends the Group Message Request (External group Identifier, SCS Identifier, Message Delivery Stop Time, optional (Group Message Payload, location information, Accuracy, Message Delivery Start Time) message to the NEF. The NEF identifies the associated PTM Service using the external Group Identifier. The NEF assigns a TLTRI that identifies this group message delivery request. The location/area information is included to identify the location over which group message is to be sent. It takes the format indicated in Accuracy parameter which can be either a list of cell IDs, or a list of PTM Service Areas, or civic addresses, or a geographic area, or a combination of any of the above. The Message Delivery Start Time indicates the time at which the group message is to be sent by the network on the PTM bearer(s). If not included, the group message is expected to be sent immediately. The Message Delivery Stop Time indicates the time at which the group message delivery is expected to be completed. When included, Group Message Payload indicates the payload the SCS/AS intends to deliver to UEs. Absence of Group Message Payload is indicative of the SCS/AS using delivery of group message in step 13a.
2. NEF then creates a service with the XCF. The service resource is created in the XCF and the service resource location is returned to the NEF.
3. The NEF requests the XCF to create a session resource using the service resource.
4. The XCF returns the session resource to the NEF. The session is created with default parameters.

5. The NEF updates the session to provide geographical area provided by the SCS/AS in step 1. The NEF also modifies other parameters of the session depending on the session type.
6. Upon successful update, the XCF responds with HTTP status code 200 or 204 (see 3GPP TS 29.116 for details of steps 1 to 5).
7. The NEF sends a Group Message Response (TLTRI, Acceptance Status, (optional) NEF Message Delivery IP address/port) message to the SCS/AS to indicate whether the Request has been accepted for delivery to the group. The NEF sends Acceptance Status of TMGI to indicate whether activation of PTM bearer corresponding to the TMGI was accepted or rejected. If Group Message Payload was not included in step 6, then the NEF also sends NEF Message Delivery IP address and port number to the SCS/AS.
8. 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.
9. The XUF responds to the request and provides transport parameters to the XCF.
10. 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 announcement is described in the Annex A.3.
11. 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)).
12. The SMF confirms the reception of the request.
13. [Optional] The SMF may register multicast PDU session to the UDM.
14. The SMF initiates N1N2 message transfer procedure with the AMF to send the PDU Session Xcast Request to (R)AN.
15. The AMF sends the NonUeN2MessageTransfer t Request to (R)AN node(s) as defined in 3GPP TS 29.518.
16. The (R)AN allocates broadcast resources 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 look at.
17. The (R)AN sends an acknowledgment.
18. RAN joins multicast group to the XUF.
19. The AMF sends Nsmf_PDUSesssion_UpdateSMContext_Xcast Request containing the response from RAN (e.g. the DL tunnel information).
20. SMF responds to the AMF.
21. The SMF sends a Nxcf_PDUSession_UpdateSMContext request to the XCF to notify the session establishment is completed.
22. The XCF acknowledges with the response.
23. The XCF send a Nx Session Start Request to the XUF to finalize the PTM session establishment.
24. The XUF sends a response to the XCF.
25. The (R)AN broadcast the radio resource configuration information for the session identified by TMGI.
26. Session data is received by the XUF.
27. The XUF processes the received data, e.g. applies FEC, and sends the data using IP multicast to (R)AN nodes.
28. (R)AN broadcasts the data over the air using point-to-multipoint radio bearer.

29. Upon execution of group message delivery, the NEF sends a Group Message Delivery (TLTRI, TMGI, Delivery Trigger Status) message to the SCS/AS to indicate whether group message delivery was triggered successful. TLTRI refers to the transaction identified by TLTRI in step 1. For the TMGI, the NEF sends Delivery Trigger Status to indicate whether delivery of Group Message Payload corresponding to the TMGI was successful or not.

It's noted that the solution for alternative 1 can be derived easily based on the workflow above. Hence, it's not described in the present document.

11 Communication in Automotive C-V2X

11.1 Overview of V2X Communication and Use Cases Analysis

Communication in automotive industry relates to exchanging various types of information not only between vehicles themselves but also between vehicles and other objects including infrastructure, pedestrians and network. Therefore, this type of communication is referred to as vehicle-to-everything (V2X) communication. The V2X communication can be enabled by different technologies such as IEEE 803.11p, ITS-G5, LTE and 5G. However, it is envisioned that only the capabilities of 5G system will enable advanced use cases in automotive field. It is many times termed as Cellular V2X (C-V2X).

V2X broadcast service has been defined as the automotive use case of 5G-Xcast project (see Deliverable D2.1 [9]). In this use case, C-V2X broadcast service is used to deliver information from the Intelligent Transport System (ITS) infrastructure, which is assumed to be located in the Data Network of 5GS architecture, to vehicle UEs. The broadcast information may comprise of various type of alerts, digital signage information, HD mapping data, and vehicle and objects location.

The 5GCAR project is a 5G-PPP project with the objective to develop an overall 5G system architecture providing optimized end-to-end C-V2X network connectivity for C-V2X services. The 5GCAR project classifies use cases into five use case classes: cooperative manoeuvre, cooperative perception, cooperative safety, autonomous navigation and remote driving [29]. An exemplary use case is defined in each use case class. High Definition (HD) local map acquisition is similar to mapping data broadcast in the C-V2X broadcast service use case of 5G-Xcast. Line merge and see-through are example use cases for cooperative manoeuvre and cooperative perception, respectively. These use cases may be realized by vehicle-to-vehicle (V2V) communication but also by a combination of vehicle-to-infrastructure (V2I) and infrastructure-to-vehicle communication. It can be observed from the use cases that in general vehicles form a group and communicate within the group to complete a task regardless whether V2V or V2I communication is used. If fact, 5GAA presents V2I communication and edge computing as key supporting technologies for advance driving assistance with use cases similar to the ones defined by 5GCAR (see the 5GAA white paper [30] for details).

5G-Xcast can contribute to the efficient, economical delivery of content, including high volume such as HD maps and continuously so, to vehicles by replacing the huge continuous usage of wasteful unicasts. 5G-Xcast supports all the required ingredients: broadcasting in specific geographical areas (such as junctions), delivering the content from edge computing (e.g. cache at the edge) or from the service provider and multicasting to identified vehicles.

From the perspective of 5G-Xcast project, C-V2X use cases can be classified based on whether a use case requires multicast or broadcast communication. More specifically, the broadcast communication refers to information dissemination in a geographical area such as described in the C-V2X broadcast service use case of 5G-Xcast project (see Deliverable D2.1 [9]). It is assumed that a C-V2X system may not be aware of all vehicles in a target area. On the other hand, use cases in the domain of cooperative driving assistance are expected to involve vehicles that are known to a C-V2X system and thus multicast communication may be more suitable for such use cases.

11.2 LTE eMBMS Solution

3GPP system architecture for PC5 and LTE-Uu based C-V2X communication was first standardized in Release 14. Multicast/broadcast for LTE-Uu based C-V2X communication is supported using MBMS via MB2 or xMB interface, see Figure 16. The reference point V1 is used for the following functions among others:

- To provide UE with C-V2X USDs for reception of MBMS based C-V2X traffic. It's noted that alternative methods such as MBMS bearer announcement are also available.
- To provide C-V2X Application Server with UE's geographical location or network cell identities.

A C-V2X Application Server initiates the dissemination of information by requesting a service from BM-SC. A C-V2X application server must provide location information over xMB or MB2 interface. In case of xMB interface, a C-V2X server shall define a geographical area property of xMB session. A geographical area property is formatted as a string array, which format is defined as part of a business agreement between a mobile network operator and a C-V2X service provider. A geographical area property could contain radio access identifiers (i.e. MBMS SAI(s) and/or ECGI(s)) or a description of geographical area (e.g. a polygon). If MBMS SAI is not provided over xMB interface, BM-SC must determine MBMS SAI(s) from EGCI(s) or a description of geographical area. In case of MB2 interface, a C-V2X application server is required to provide radio access network identifiers to BM-SC. As can be seen, LTE MBMS supports broadcast in geographical area without any significant drawbacks. Perhaps, the most challenging task is how to maintain or automate the determination of MBMS SAI(s)/ECGI(s) in BM-SC.

In use cases when a C-V2X application server needs to send information to a group of vehicles, multicast is a natural choice for such group communication. However, LTE MBMS supports only the broadcast mode (see 3GPP TS 23.246 [32]). The way around is such that a C-V2X server receives vehicle UE's location, or a serving cell ID or both via V1 reference point. It is noted that the V1 reference point is not standardized. A C-V2X server then based on the received information determines whether it should use MBMS services. The problem is that a C-V2X application server doesn't have a detail knowledge about radio access network. Even if multiple vehicle UEs are served by the same cell, report the same serving cell identity to the server and the server decides to use MBMS, it may happen that unicast communication would be more efficient from RAN perspective. Another problem with this work-around solution is that mobility is very poorly supported. Mobility support is critical for advance cooperative driving such as in vehicle platooning and lane change use cases. Mobility should be supported seamlessly and efficiently. In principle, a UE moving from a cell where the service is provided using MBMS should switch to unicast transmission before it leaves the cell. When more UEs move to a new cell and report this even to a C-V2X application server, then the server may modify MBMS service, e.g. to include a new cell in MBMS session. Again, the C-V2X application server would do so only based on serving cell identities.

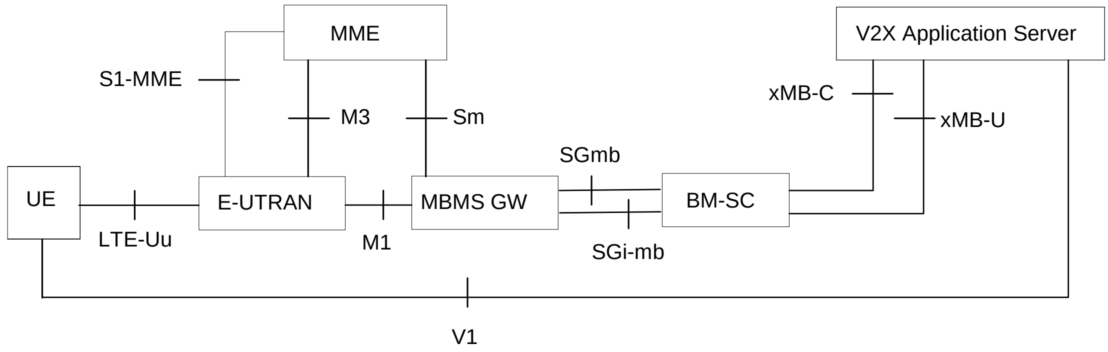

Figure 16 Reference architecture for MBMS for LTE-Uu based C-V2X communication via xMB

11.3 5G-Xcast Solution

5G-Xcast architecture supports transparent multicast transport and point-to-multipoint services. Point-to-multipoint services offer the same broadcast functionality to a C-V2X application server as LTE MBMS. The split of control plane and user plane of MB-SC between XCF and XUF has no impacts on a C-V2X server because xMB interface already supports separation of control and user plane. This means that a dissemination of information to vehicles and other objects in a geographical area using 5G-Xcast solution does not require any changes in a C-V2X application server if the server utilizes xMB interface and uses geographical location over xMB instead of MBMS SAI(s) and ECGI(s) (i.e. a C-V2X application server is not aware of RAN identities).

The transparent multicast transport and the dynamic delivery mode selection with point-to-multipoint services together with mixed-mode single-cell transmission, multi-cell transmission modes and dynamic RAN multicast area management offer new innovative multicast solutions for C-V2X communication. Benefits of these innovative solutions are described with a reference to an exemplary use case of a vehicle (UE1 in Figure 17) merging into a middle of a platoon comprising of two or more vehicles (UE2 and UE3 in Figure 17) with a centralized controller located in network (C-V2X App server).

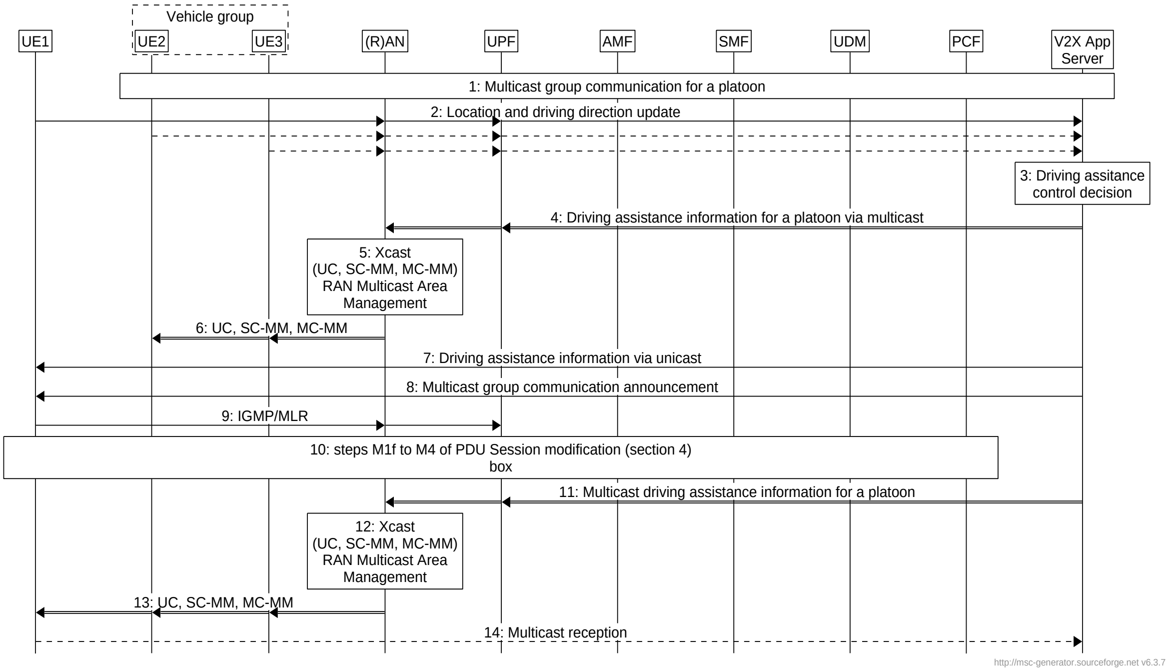

Figure 17 Call flow for UE joining a C-V2X group communication using transparent multicast transport

The procedure of UE joining a multicast communication group of a platoon using transparent multicast transport is shown in Figure 17.

1. A C-V2X application server provides driving assistance control information to a group of UEs that form a platoon. Driving assistance information is delivered from the C-V2X application server to the UEs via multicast. The C-V2X application server is responsible for group management.
2. UE1 updates its location and driving direction with the V C-2X application server. It is assumed that UE1 successfully discovered a C-V2X application server and established unicast communication with the server. Example solutions of C-V2X application server discovery are described in 3GPP TS 23.285 [31]. The UEs in the platoon may also provide updates to the C-V2X application server, for example if a UE cannot follow given control information due to an unexpected event or road conditions detected by on-board sensory systems.
3. The C-V2X application analyses received information and decides that UE1 should join the platoon control process. The C-V2X application server determines driving assistance control information such as vehicle paths and timing that shall be provisioned to UEs.
4. The C-V2X application sends driving assistance control information to the UEs that already joined a multicast group, which is used for communication within the platoon via multicast.
5. (R)AN knows the group of UEs to which it shall transmit the multicast data received in step 4 based on transparent multicast transport operation (i.e. PDU session modification with multicast context creation/modification procedure was successfully completed for each UE in the group, see section 4). The (R)AN may use combination of unicast (UC), single-cell mixed mode (SC-MM) or multi-cell mixed mode (MC-MM) multicast. The (R)AN may configure a RAN multicast area (RMA) for the group and manged the cells comprising the RMA dynamically based on UE mobility. This simplifies greatly the functionality of C-V2X application server because unlike in the case of LTE MBMS solution the V2X application server does not need to update MBMS broadcast area. Moreover,

RAN provides service continuity for multicast during UE mobility and UE does not need to switch to unicast communication with C-V2X server. Please note that (R)AN may use unicast internally. **¡Error! No se encuentra el origen de la referencia.**

6. The multicast data is delivered to the UEs in the group.
7. The C-V2X application server must provide driving assistance information to UE1 via unicast until UE1 joins the multicast group and 5GS modifies its resource allocation accordingly.
8. The C-V2X application server made the decision that UE1 should join the platoon. The V2X application server announces the availability of the multicast group session to UE1. The multicast group communication announcement consists at least multicast IP address but other parameters needed for reception of driving assistance information may need to be provided as well, e.g. in form of SDP. Step 7 and step 8 may be implemented as transmission of single message.
9. UE1 joins IP multicast group.
10. A UPF detects the reception of IGMP/MLR that initiates PDU session modification with multicast context modification procedure (see section 4). It is assumed that 5GC decides to use the same UPF that is already serving the multicast for the platoon and thus there is no need for signalling (e.g. PIM) in data network between the UPF and the C-V2X application server because the multicast routing in the data network is established already.
11. The C-V2X application server retransmits or sends updated driving assistance control information to the platoon via multicast only.
12. The (R)AN knows that multicast data needs to be delivered to the group of UEs now also including UE1 because the (R)AN received the PDU session update for UE1 in step 10. The (R)AN decides on a set of UC, SC-MM, and MC-MM bearers and possibly updates RMA.
13. The (R)AN delivers multicast data to the UEs in the group.
14. UE1 may notify the C-V2X application server about successful reception of multicast data so that the C-V2X application server may stop sending driving assistance information via unicast.

12 Mission Critical Communications

12.1 Introduction

Mission critical (MC) communications refer to communications meeting the requirements and needs of public safety organizations such as police, firefighters, and ambulances. Mission critical communication services include push-to-talk, mission critical video and data. 3GPP has been committed to developing solutions for mission critical services since Rel-13. The requirements for mission critical push-to-talk, video and data area defined in 3GPP TS 22.179 [33], TS 22.281 [34], TS 22.282 [35]. In addition to private communication between two parties, the key requirement for mission critical services is group communication (i.e. audio, video and data group calls). The group communication makes use of MBMS in LTE. The mission critical service architecture on LTE network shown in Figure 18 is common for all mission critical services as defined in 3GPP TS 23.280 [36].

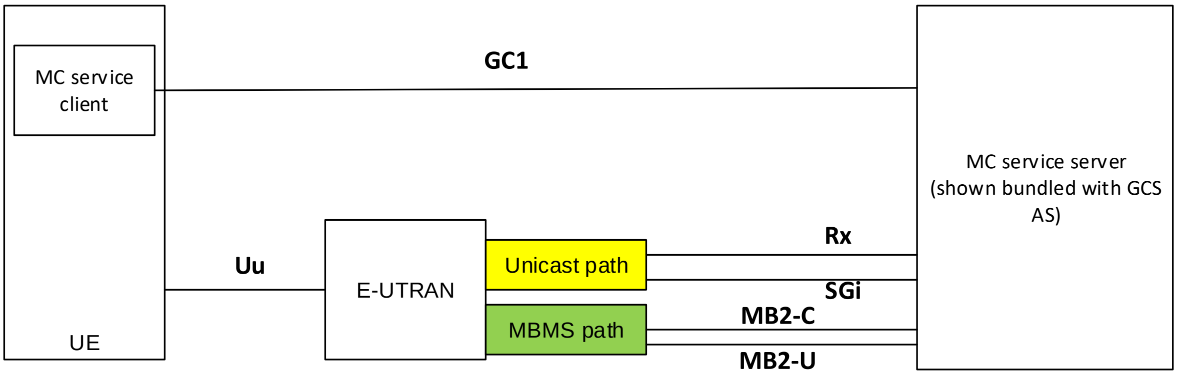

Figure 18 Mission critical architecture in LTE

MC service server is an instantiation of group communication service application server (GCS AS) that is responsible for control of unicast and multicast operations for group communications. The control of multicast operation comprises of receiving over GC1 reference point cell identities of cells serving UEs affiliated with a group. MC service server determines based on the received information whether to use unicast path or multicast path. It is easily understandable that the decision based on cell identities is very coarse and may result in suboptimal operation of radio access network.

When MC service server chooses MBMS path, then it uses the control plane of MB2 interface (see 3GPP TS 23.280 [36]) for TMGI management and MBMS bearer control. Once MBMS bearers are set, user plane data are transparently transported from MC service server to MC service client. Optionally, MC service server may request BM-SC to apply FEC and/or robust header compression.

UE mobility causes switching from MBMS bearer to unicast bearer. The switching is initiated by a UE upon detection of bad MBMS bearer condition or that a candidate target cell for reselection does provide the service using SC-PTM, see Deliverable 4.1 **¡Error! No se encuentra el origen de la referencia.** annex A.1.5. The UE sends MBMS listening status report to a MC service server, which then sends the downlink data via unicast path (see 3GPP TS 23.280 [36]). Overlapping MBSFN areas were documented as a solution that can improve the mobility and avoid frequent switching to unicast delivery. However, the SC-PTM and MBSFN mobility solutions do not solve the mobility problem because they do not address the root cause of the problem that is the architecture of MBMS in LTE was designed for broadcasting and not group communication with multicast. Consequently, the control over radio resources (i.e. whether unicast or multicast/broadcast transmission is used in radio access network) was placed to an entity that has no knowledge about radio access network operation except the serving cell identities of UEs affiliated with a group.

12.2 5G-Xcast Solution

MC services do not require dissemination of information to any UEs in a geographical area as some of V2X use cases. On the other hand, group communication is a general case that is common to MC services and advanced V2X use cases. In fact, LTE solutions for MC services and V2X communication were specified using the same design principles and suffer from the same problems.

5G-Xcast addresses the problems by new system architecture and RAN design **¡Error! No se encuentra el origen de la referencia.** that

- Supports transparent transport of multicast either as part of PDU session or as a point-to-multipoint service;
- Allows RAN to decide how multicast data are delivered using unicast, single-cell or multi-cell mixed mode transmission;
- Introduces new concept of mobility management with RAN multicast area;
- Transparent multicast transport may use Layer 2 FEC in RAN for improved reliability and QoS in general (see Deliverable D3.4 [37]).

MC service server functionality can be simplified and efficient radio resource management in RAN enabled with 5G-Xcast solution as shown in Figure 19. Please note that the call flow for MC service can be applied to any group communication in other verticals including V2X group communication and there are some similarities with the call flow in Figure 17.

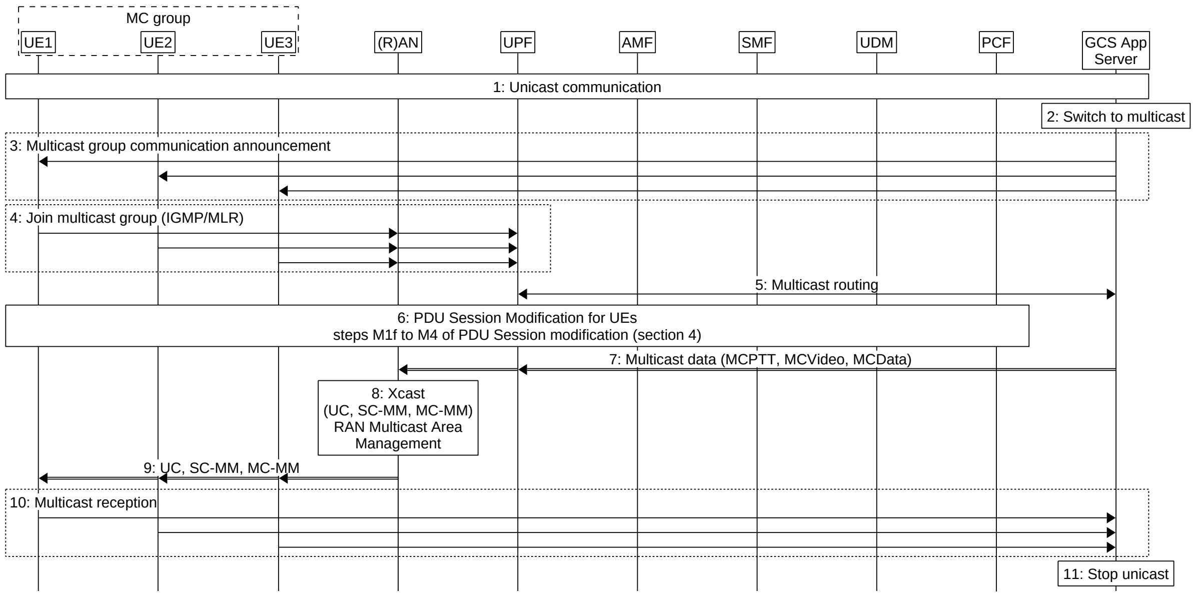

Figure 19 Group communication with multicast for mission critical services

1. A GCS Application Server (GCS AS) communicates with UEs in a group using unicast. Please note, the unicast communication is maintained through this procedure to ensure service continuity.
2. The GCS AS decides to switch to multicast. The GCS AS should consider only the cost of multicast on N6 interface. The GCS AS does not need to be concerned about resource usage in 5G core and RAN as the resource usage when using

multicast should not be larger than multiple unicast connections and RAN can always use unicast if it sees beneficial from radio resource management. Therefore, it is assumed that the GCS AS switches to multicast considerably early from RAN perspective, i.e. before radio resources consumed by multiple unicast connections become a bottleneck.

3. The GCS AS announces multicast session to UEs in the group (e.g. via GC1 reference point using unicast).
4. The UEs join multicast group.
5. This step represents necessary signalling (e.g. PIM) to enable multicast routing between UPF and GCS AS. It is assumed that the interconnection between GCS AS and UPF comprises only of manged networks supporting multicast routing.
6. The reception of IGMP/MLR triggers the PDU Session Update with multicast procedure, see section 4.
7. The GCS AS starts sending data over multicast.
8. The (R)AN knows that multicast data needs to be delivered to the group of UEs because the (R)AN received the PDU session update for the UEs. The (R)AN decides on a set of UC, SC-MM, and MC-MM bearers and possibly updates RMA.
9. The (R)AN delivers multicast data to the UEs in the group.
10. The UEs report the successful reception of multicast data to the GCS AS.
11. When all UEs reported the successful reception of multicast data, the GCS AS stops sending the data over unicast.

13 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.

MC/BC session management is also provided for three additional important verticals that may significantly benefit from these services; C-V2X Automotive communications, MCC and IoT. They all make use of the same basic concepts, entities and capabilities identified for the M&E MC/BC use cases.

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 Optimization of MBMS User Services for IoT

Section 10 describes the work flow that allows the application server to deliver the same message to a group of IoT devices. However, it's required to optimise the service layer for the constrained IoT devices (e.g. CPU, memory, power resources). Group message delivery and software update for IoT devices are the same from the service layer perspective in a sense that the same content (e.g. messages or files) is delivered to multiple devices. This Annex describes the aspects where the optimisation on the service layer can be done. The optimisation at the service layer is independent of the underlying radio technologies (e.g. LTE or 5G), hence the work done in LTE as described in 3GPP TR 26.850 [17] can be applied for the present work in 5G-Xcast project.

A.1 Classification of IoT devices

There are two separate parts in IoT devices: connectivity and application. The connectivity part is responsible for the connectivity between the IoT device and the network (e.g. LTE/5G modem) while the application part is used for a specific application/use case. Each part may have its own software/firmware/OS.

RFC 7228 [18] defines constrained devices as small devices with limited CPU, memory, and power resources applied for the application part. The devices are often used as sensors/actuators, smart objects, or smart devices. RFC 7228 [18] identifies 3 classes of constrained devices as in **¡Error! No se encuentra el origen de la referencia.** to provide rough indications of device capabilities.

3GPP TS 36.306 [19] defines categories for NB-IoT and MTC devices applied for the connectivity part: Cat-NB1, Cat-NB2, Category M1, Category M2. 3GPP TS 36.306 clauses 4.1A and 4.1C specify uplink and downlink capability for MTC and NB-IoT categories, respectively. However, 3GPP TS 36.306 does not specify whether NB-IoT or MTC devices support certain MBMS operations and capabilities (e.g. XML parsing and processing).

The MBMS client is between the applications and the connectivity functions. Classification and dimensioning provided by RFC 7228 [18] and by 3GPP TS 36.306 [19] cannot be applied directly to the MBMS client. Consequently, 2 classification categories are here proposed for the MBMS reception point of view: low-end and high-end; depending on the application and/or use case.

The low-end IoT category represents the devices with limited capabilities such as processing, memory, battery etc. The MBMS User Services for this category have to be simplified as much as possible to address a wide range of devices, applications, and use cases. For example, Class 1 devices do not recommend full XML processing.

The high-end IoT category represents the devices with moderate or good capabilities (e.g., smart endpoints, IoT gateways). This device category may have additional capabilities (e.g. XML parsing/processing) compared to the low-end IoT category.

The low-end IoT category may support reduced MBMS processing (e.g. no XML). The high-end IoT category may support an MBMS profile without requirements for multimedia services (e.g. neither RTP nor DASH).

A.2 Binary data format for IoT

MBMS protocols, codecs and procedures in LTE often use XML as a format for exchanging metadata (e.g. FDT, service announcement). However, the use of XML stack can be costly for IoT devices, especially for low-end IoT profile. Binary data formats may be more appropriate for IoT devices to exchange metadata. One can define a particular binary format for each specific purpose (e.g. FDT, service announcement, reception report). However, it is desirable to have a common binary format for all procedures, formats in the context of MBMS IoT.

There are several well-known binary formats for representing the data such as ASN.1 [20], Thrift [21], Protobuf [22]. In addition, the EXI (Efficient Extensible Interchange or Efficient XML Exchange) [23] is also a candidate to represent the data format exchanged between the network and the IoT devices. According to 3GPP TR 26.850, it is recommended to use ASN.1 PER (Packed Encoding Rules) as basis for binary format for IoT devices. Further study and performance comparison between the binary formats are described in clause 7.4 of 3GPP TR 26.850.

A.3 Announcement about the software update or group message delivery

IoT devices use eDRX (Extended Discontinuous Reception) and PSM (Power Saving Mode) to save battery consumption. When there is a software/firmware update or a group message delivery to the IoT devices, the service announcement using continuous/carousel broadcast delivery of SACH (Service Announcement Channel) may not be efficient from the network perspective since IoT devices are not expected to be awake throughout the day, but only infrequently. Furthermore, they do not wake-up at the same time and more importantly, they are not reachable while being in power saving mode. The details about the announcement for IoT devices are described in 3GPP TR 26.850 [17].

References

[1] D. Gomez-Barquero, D. Navratil, S. Appleby and M. Stagg, “Point-to-Multipoint Communication Enablers for the Fifth-Generation of Wireless Systems”, *IEEE Communications Standards Magazine*, vol. 2, no. 1, March 2018.

[2] T. Tran (Ed.), “Mobile Core Network,” Deliverable D4.1, 5G-PPP 5G-Xcast project, June 2018.

[3] 3GPP TS 23.501, “System Architecture for the 5G System”.

[4] T. Stevens (Ed.), "Content Distribution Framework,” Deliverable D5.2, 5G-PPP 5G-Xcast project, Oct. 2018.

[5] 3GPP TS 23.502, “Procedures for the 5G System,”.

[6] 3GPP TS 26.346, “Multimedia Broadcast/Multicast Service (MBMS); Protocols and codecs,".

[7] DVB Document A176, “Adaptive media streaming over IP multicast,” March 2018.

[8] 3GPP TS 23.041, “Technical realization of Cell Broadcast Service (CBS),”.

[9] D. Ratkaj and A. Murphy, (Eds.), “Definition of Use Cases, Requirements and KPIs,” Deliverable D2.1, 5G-PPP 5G-Xcast project, Oct. 2017.

[10] 3GPP TS 36.300, "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2,”.

[11] 3GPP TS 29.116, “Representational state transfer over xMB reference point between content provider and BM-SC,”.

[12] J. Hart (Ed.), “Converged Core Network,” Deliverable D4.2, 5G-PPP 5G-Xcast project, Oct. 2018.

[13] 3GPP TS 29.518, “5G System; Access and Mobility Management Services; Stage 3,”.

[14] 3GPP TS 38.413, “NG-RAN; NG Application Protocol (NGAP),”.

[15] 3GPP TR 29.891, “5G System – Phase 1; CT WG4 Aspects,”.

[16] M. Säilly and C. Barjau (Eds.), “RAN Logical Architecture and Interfaces for 5G-Xcast,” Deliverable D3.3, 5G-PPP 5G-Xcast project, March 2019.

[17] 3GPP TR 26.850, “MBMS for Internet of Things (IoT)”.

[18] IETF RFC 7228, “Terminology for Constrained-Node Networks”, May 2014.

[19] 3GPP TS 36.306, “Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities”.

[20] https://www.itu.int/en/ITU-T/asn1/Pages/asn1_project.aspx

[21] https://thrift.apache.org/

[22] https://github.com/google/protobuf

[23] https://www.w3.org/XML/EXI/

[24] 3GPP TS 23.682, “Architecture enhancements to facilitate communications with packet data networks and applications”.

[25] 3GPP TR 36.888, “Study on provision of low-cost Machine-Type Communications (MTC) User Equipments (UEs) based on LTE”.

[26] 3GPP TR 23.724, “Study on Cellular Internet of Things (CIoT) support and evolution for the 5G System (5GS)”.

[27] 3GPP TS 29.522, “5G System; Network Exposure Function Northbound APIs; Stage 3”.

[28] 3GPP TS 29.122, “T8 reference point for Northbound APIs”.

[29] Antonio Eduardo Fernandez, Mikael Fallgren, “5GCAR Scenarios, Use Cases, Requirements and KPIs”, Deliverable D2.1 v1.0, 5G-PPP 5GCAR project, Aug. 2017

[30] Dario Sabella, et al., “Toward fully connected vehicles: Edge computing for advance automotive communications”, 5GAA white paper, Dec. 2017

[31] 3GPP TS 23.285, “Architecture enhancements for V2X services”

[32] 3GPP TS 23.246, “Multimedia Broadcast/Multicast Service (MBMS); Architecture and functional description”
[33] 3GPP TS 22.179, “Mission Critical Push To Talk (MCPTT); Stage 1”
[34] 3GPP TS 22.281, “Mission Critical Video services”
[35] 3GPP TS 22.282, “Technical Specification Group Services and System Aspects; Mission Critical Data services”
[36] 3GPP TS 23.280, “Common functional architecture to support mission critical services; Stage 2”
[37] “RAT Protocols and Radio Resource Management in 5G-Xcast”, Deliverable D3.4
[38] “Analysis and Deployment of Terrestrial Broadcast in 5G-Xcast”, Deliverable 2.4