5G-MAG REFERENCE TOOLS: DYNAMIC CONTENT DELIVERY SWITCHING BETWEEN 5G BROADCAST AND OTT STREAMING

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ABSTRACT

The increasing consumption of high-quality mobile video over 5G networks demands for sophisticated and robust streaming service architectures and implementations ready to cope with traffic loads and meet requirements and expectations from content providers. To support media and content providers in getting access to the powerful, but complex 5G media distribution platform, 5G-MAG has started the 5G-MAG Reference Tools development program. Its goal is to develop common open-source reference tools that serve as a reference implementation and help catalyze the interoperability and adoption of the 5G Media technology ecosystem.

In this paper, we provide an overview of the 3GPP Release 16 5G Media Streaming and LTE-based 5G Terrestrial Broadcast architectures and present the corresponding implementations in the 5G-MAG Reference Tools. Focusing on the client-side components, we discuss three different use-cases: “TV and Radio services over LTE-based 5G Terrestrial Broadcast”, “Broadband-Broadcast seamless switching” and “Broadcast-on-Demand”. Moreover, we show how the 5G-MAG Reference Tools can serve as a reference or integration platform for traditional broadcast standards and services including a DVB-I service layer or the alignment with the service layer of ATSC3.0.

INTRODUCTION

The internet, together with the global introduction of 5G, enables media content providers to have access to a universal, ubiquitous, and future-proof distribution platform. The media industry can reach users everywhere, anytime and on any device creating tremendous opportunities for new service propositions, more personalized experiences, and a fast lane for innovation for service providers and content creators. The trend to consume media content on mobile devices is reflected in the numbers: Forecasts predict that by 2023 69% of the total smartphone shipments will be 5G-enabled [1]. By 2027 5G networks will carry 62 percent of the world's smartphone traffic. Specifically, the delivery of video content is expected to account for 79 percent of the mobile data traffic in 2027 [2].

To support media and content providers in getting access to the powerful, but complex 5G distribution platform, simplifications, support, and proof of concept implementations are required. In the dynamic world of apps, software-centric solutions and agile developments, access to open-source tools to support prototyping, trials and possibly even deployments are of utmost relevance. 5G-MAG has taken on the duty and mandate to fill the role of bringing together the media and the ICT industries to support deployment of media services on 5G systems.

As a concrete action, the 5G-MAG Reference Tools project [3] has been established to respond to the need for an open reference software implementation. The overall goal of the project is to provide an end-to-end platform enabling the implementation and experimentation of media players and clients, service layers and applications, developed by the media industry as well as relevant standardization organizations, and the integration of third-party functions in the 5G system.

In this paper, we present the current architecture of the 5G-MAG Reference Tools, implementing client components in the context of 3GPP Release 16 5G Media Streaming and LTE-based 5G Terrestrial Broadcast. We focus on the use-cases “TV and Radio services over LTE-based 5G Terrestrial Broadcast“, Broadband-Broadcast seamless switching” and “Broadcast-on-Demand” (BoD). These three use cases highlight the opportunities for delivering TV and Radio services to 3GPP-enabled devices, therefore expanding the reach beyond traditional devices. At the same time new ways of distribution are introduced including a static provisioning and the dynamic switching of users between broadcast and unicast delivery according to channel conditions or users’ demand.

THE 5G MEDIA DELIVERY PLATFORM IN 3GPP RELEASE 16

3GPP is the global standardization organization defining core elements of the 5G system, including those that constitute the 5G media distribution platform. Such standardization effort is leading to the support of different deployment and collaboration models among service providers, media companies and network operators to enable the creation of new services and user experiences.

The first releases of 5G specifications, with Rel-16 completed in mid-2020, include the definition of the 5G Media Streaming (5GMS) architecture and LTE-based 5G Terrestrial Broadcast. 3GPP Rel-16 has been taken as the starting point for the implementation of the 5G-MAG Reference Tools. As a live and evolving project, the latest status of the 5G-MAG Reference Tools can be found in [https://www.5g-mag.com/blueprints].

Standardization continues in Rel-17 and Rel-18 with several extensions to 5G Media Streaming, including edge capabilities, the introduction of 5G Multicast Broadcast Services (5MBS) and the evolution of LTE-based 5G Terrestrial Broadcast, among others. These are part of the future roadmap of the 5G-MAG Reference Tools.

5G Media Streaming

5G Media Streaming responds to the growing consumption of multimedia services, and the need to open the 5G System capabilities to content providers. A range of collaboration

models are enabled focused on improving QoE for end users, optimizing delivery across the network, monetizing traffic or monitoring QoS and consumption.
3GPP has defined the 5G Media Streaming architecture and its basic procedures together with a series of protocols, codecs and functionalities well aligned with current over-the-top distribution models and applications [4].

The main components of 5G Media Streaming are the following:

- 5GMS Application Function (AF): provides management functions for the 5GMS system (control plane), including provisioning and configuration (offered to the service provider) and reporting (from the user equipment). Depending on the collaboration model, the 5GMS AF can be deployed within the mobile network or in an external data Network (e.g. in the domain of the service provider).
- 5GMS Application Server (AS): provides data and content functionalities (data plane) including ingest functionalities (towards service providers) and the delivery to the 5GMS clients.
- 5GMS Client, containing the Media Session Handler (MSH), which receives the configuration information from the AF and handles the relevant 5GMS features, and the Media Player which obtains media content from the AS.

LTE-based 5G Terrestrial Broadcast

3GPP specified the first global broadcast standard to address 5G-enabled devices. LTE-based 5G Terrestrial Broadcast, widely known as 5G Broadcast[1], allows linear TV and radio to be broadcasted to compatible 3GPP-based devices like smartphones, tablets, home gateways and connected cars. Rel-16 extended the capabilities of Multimedia Broadcast Multicast Service (MBMS) to support dedicated broadcast networks for the transmission of linear television and radio services. Among others, the standard supports the following key features:

- Support of Free-to-Air (FTA) services
- Broadcast-only service for UEs with no MNO broadcast subscription
- Decoupling of content, MBMS service and MBMS transport functions
- Exposure of eMBMS service and transport capabilities to third parties.
- Single Frequency Network (SFN) deployments with Inter-Site Distance (ISD) significantly larger than a typical ISD associated with typical cellular deployments
- Support for Receive-Only Mode (ROM) services and devices

Rel-17 has addressed additional functionalities such as the support of 6/7/8 MHz carrier bandwidths, which will be completed in Rel-18 with the support of the sub-700 UHF band. The connection of LTE-based 5G Terrestrial Broadcast to 5G Media Streaming has also been addressed in Rel-17, so the latter serves as the entry point for service providers to the complete 5G media distribution platform.

[1] Note that parts of this paper use the short form « 5G Broadcast » to refer to « LTE-based 5G Terrestrial Broadcast »

A profile of the 3GPP specifications that constitute LTE-based 5G Terrestrial Broadcast can be found in ETSI TS 103 720 [5].

Hybrid Services and Broadcast-on-Demand

5G Media Streaming incorporate advanced features for streaming and broadcasting, enabling building hybrid services where broadcast can be enhanced by means of unicast and vice-versa [4].

As for the architecture and components described above, the application at the user device can interact with the different client components. The 5GMS Client, in particular the Media Player in collaboration with the Media Session Handler, and the MBMS Client dynamically select the delivery path from which to acquire media content according to reception conditions, user preferences or other policies. Content is provisioned such that the 5GMS Client can provide a seamless user experience when switching between different delivery networks.

These operations can fulfil a series of scenarios such as the service continuity between broadcast and unicast, when the user equipment may be out of service on one of the networks; time-shifted viewing; content replacement and ad-insertion; dynamic provisioning of broadcast or unicast services on-demand; augmented quality to the broadcast service through unicast, etc.

RELATED WORK

For further reference, this section captures related articles to the 3GPP Rel-16 identified architectures and previous trials and demonstrations.

In “5G Media Streaming Architecture” [6] Gabin et al. outline the basic 5G downlink and uplink streaming architecture developed by 3GPP in Rel-16 with a focus on the relationship between the different components, interfaces, and APIs to support 5G Media Streaming.

In “3GPP Enhancements for Television Services: LTE-based 5G Terrestrial Broadcast” [7], “Overview of Physical Layer Enhancement for 5G Broadcast in Release 16” [8] and "Cellular Terrestrial Broadcast—Physical Layer Evolution From 3GPP Release 9 to Release 16" [9], the authors provide a comprehensive overview of the architecture for LTE-based 5G Terrestrial Broadcast services and features and enhancements included in the different 3GPP releases up to Rel-16.

In “Demonstrating Immersive Media Delivery on 5G Broadcast and Multicast Testing Networks” [10] the authors provide insight into demonstrations around Media & Entertainment and Public Warning, with a highlight on hybrid broadcast and unicast distribution, broadcast delivery on demand or multimedia public warning messages.

In “Multimedia Public Warning Alert Trials using eMBMS Broadcast, Dynamic Spectrum Allocation and Connection Bonding” [11] the authors discuss requirements that need to be fulfilled to support multimedia warning message delivery in the 5G systems. Moreover, the paper demonstrates the delivery of multimedia public warning messages using eMBMS, dynamic spectrum management, and bonded connections.

THE 5G-MAG REFERENCE TOOLS

The 5G-MAG Reference Tools development program was established in mid 2021 with the goal to create common open-source reference tools to support implementation and interoperability of 5G Media technologies.

The initial focus of the 5G-MAG Reference Tools project is the development of Rel-16 5G Media Streaming and LTE-based 5G Terrestrial Broadcast client components and corresponding 5G unicast and broadcast radio emulators. For that reason, the steadily growing developer community has implemented multiple software components that are publicly available on Github[2]. The overall architecture of the 5G-MAG Reference Tools is depicted in Figure 1. The main components are the rt-mbms-modem (MBMS Modem), the rt-mbms-mw (MBMS Client) and the rt-wui (Webinterface). In addition, supporting components for FLUTE encoding/decoding (rt-libflute) and a modified version of srsRAN are used.

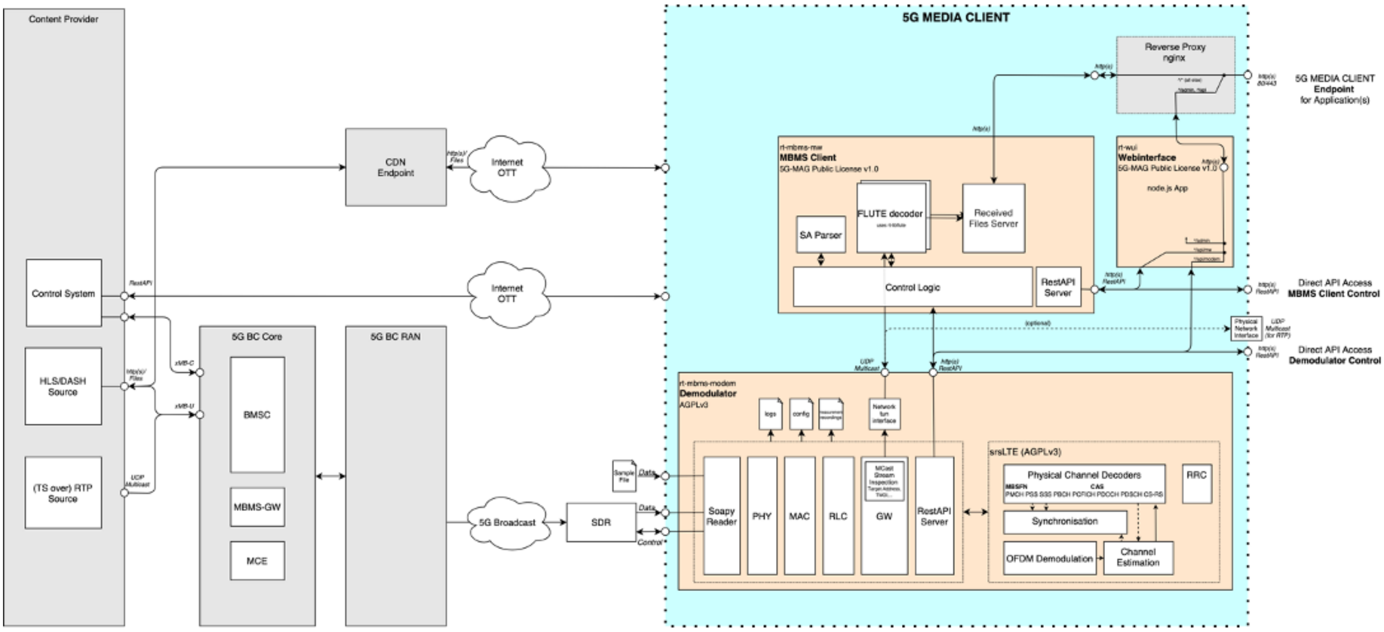

Figure 1: The architecture of the 5G-MAG Reference Tools

MBMS Modem

The MBMS Modem builds the lower part of the 5G-MAG Reference Tools. Its main task is to extract multicast IP packets from the radio layer. The MBMS Modem is implemented as a standalone C++ application using a modified version of the srsRAN library[3] for physical layer decoding and demodulation. The main components of the MBMS Modem are implemented as modules for a better structure and easier improvement of specific parts.

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[2] https://github.com/5G-MAG
[3] https://github.com/srsran/srsRAN

The Soapy Reader module processes the input signal that can either be received as I/Q raw data from a Software Defined Radio (SDR) or as a prerecorded sample file. The usage of sample files provides a convenient way to implement and test new features and to showcase specific functionality of the MBMS Modem.
The Physical Layer module (PHY) is responsible for synchronization, OFDM demodulation, channel estimation, decoding of the physical control and user data channels.
The Medium Access Control (MAC) module evaluates the Downlink Control Information (DCI) and the Control Format Indicator (CFI), as well as the System Information Block (SIB) and the Master Information Block (MIB). Moreover, a decoding of the Multicast Control Channel (MCCH) and Multicast Traffic Channel (MTCH) is performed.
Additionally, the MBMS Modem uses the Radio Link Control (RLC) and Gateway (GW) module to output MTCH data on a tun network interface. The output of the MBMS Modem is a UDP multicast that can be further processed by the MBMS Client or directly be accessed by an external application or media player.

The MBMS Modem can be configured via a configuration file and writes important status messages to a log file. In addition, it exposes a RESTful API for dynamic configuration and querying status information.

MBMS Client

The MBMS Client is responsible for providing the content in the best available path to the (internal or external) application at any time. When available, it combines content from the (mobile) broadband, WiFi and broadcast (MBMS modem) interfaces using an advanced decision logic. The content is presented to the applications in the form of an intelligent edge cache ready for pick up via http(s).

The MBMS Client uses the UDP multicast IP packets from the MBMS Modem. If the payload contains File Delivery over Unidirectional Transport (FLUTE) encoded content files, like the service announcement or DASH and HLS files, the MBMS Client decodes the packets with its FLUTE/ALC decoder into files. The MBMS Client includes a web-cache server and each service is available like an CDN publishing point including manifest and segment files.

Like the MBMS Modem, the MBMS Client can be configured via a configuration file and writes important status messages to a log file. In addition, it exposes a RESTful API for dynamic configuration and querying status information. The RESTful API is used by the Web-User Interface to query the location of the FLUTE decoded manifest and segment files.

Webinterface

The Webinterface as depicted in Figure 2 provides a graphical interface with a control display. Its main purpose is to collect and display useful information from the MBMS Modem and the MBMS Client. For that reason, it uses the RESTful APIs provided by both processes. It also enables use cases where the 5G-MAG Reference Tools can be used for simple measurements (e.g., mobile measurements) or as a standalone device (e.g., set-top box, mobile phone/tablet showcase). The interface consists of three tabs, one for each process. In addition, the Webinterface works as a media player using dash.js and hls.js as external dependencies for the playback of the FLUTE decoded DASH and HLS streams provided via the MBMS Client.

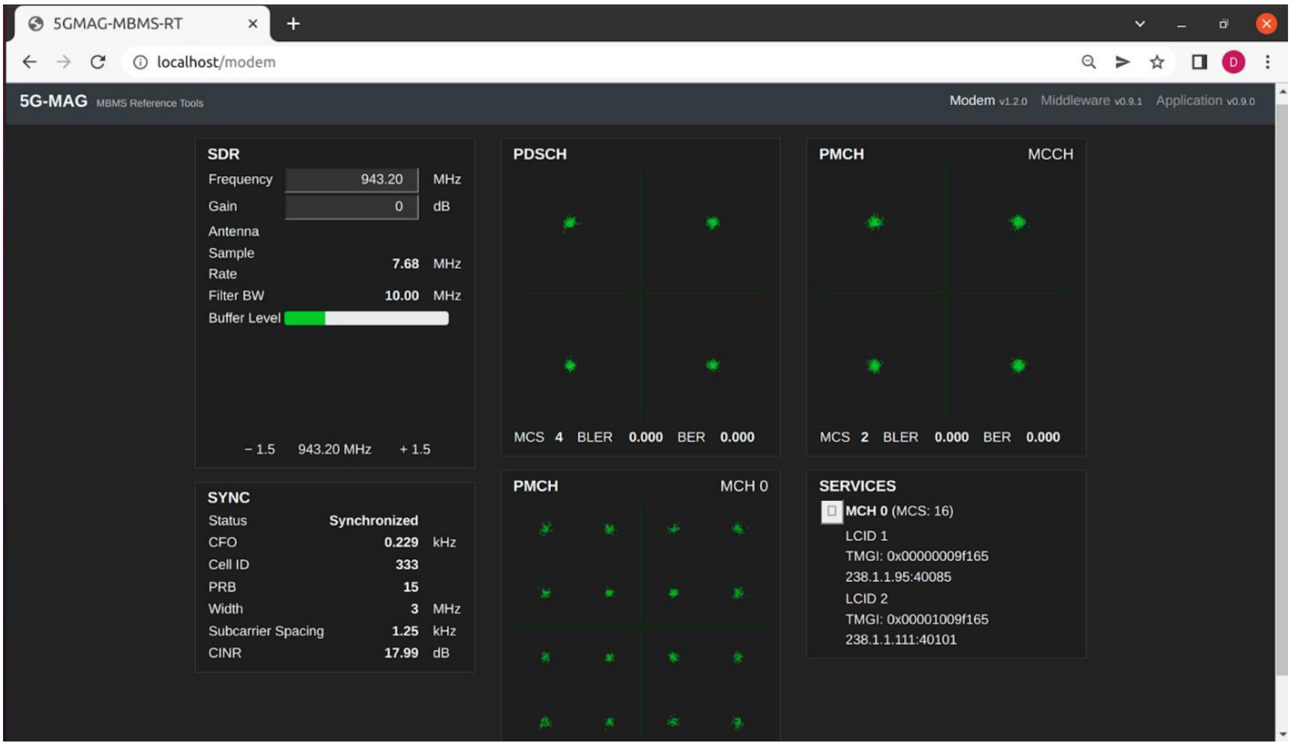

Figure 2: The webinterface to collect and display information from the MBMS Modem and the MBMS Client

USE CASE: TV AND RADIO SERVICES OVER LTE-BASED 5G TERRESTRIAL BROADCAST

This first use case focuses on the reception of broadcast services such as public or commercial linear TV and radio services, which can be delivered free-to-air or encrypted to devices such as smartphones, smart TVs, or car infotainment systems. Well-defined 3GPP APIs (TS 26.346, 26.347, 23.246, TR 36.976) enable its distribution and integration into existing media applications in a standard compliant way. The service may be extended by combining linear broadcast content and personalized content delivered via unicast using 3GPP as the common family of standards.

A simplified illustration of the basic is depicted in Figure 3. The MBMS Modem outputs a UDP multicast output for further handling. When the broadcast signal contains an RTP media stream the output of the MBMS modem can directly be played in a third-party media player such as VLC or ffplay. When it contains FLUTE encoded DASH and HLS files the output of the MBMS Modem is further processed in the MBMS Client. The MBMS Client uses the Service Announcement (SA Parser) to set up a FLUTE decoder and saves the FLUTE decoded media files on a file server. Compared to the unicast delivery of manifest files and media segments the broadcast delivery can introduce a small delay. To account for such delays the MBMS Client modifies timing specific values in the DASH and HLS manifests. As a result, the client will not attempt to request files that have not yet been received by the MBMS Modem.

Once the media files have been cached in the MBMS Client they can be accessed by DASH and HLS media players. A Reverse nginx Proxy performs an internal mapping of specific ports and routes to the standard ports used for http(80) and https (443). The Webinterface itself integrates dash.js and hls.js for playback of the DASH and HLS streams directly in the browser.

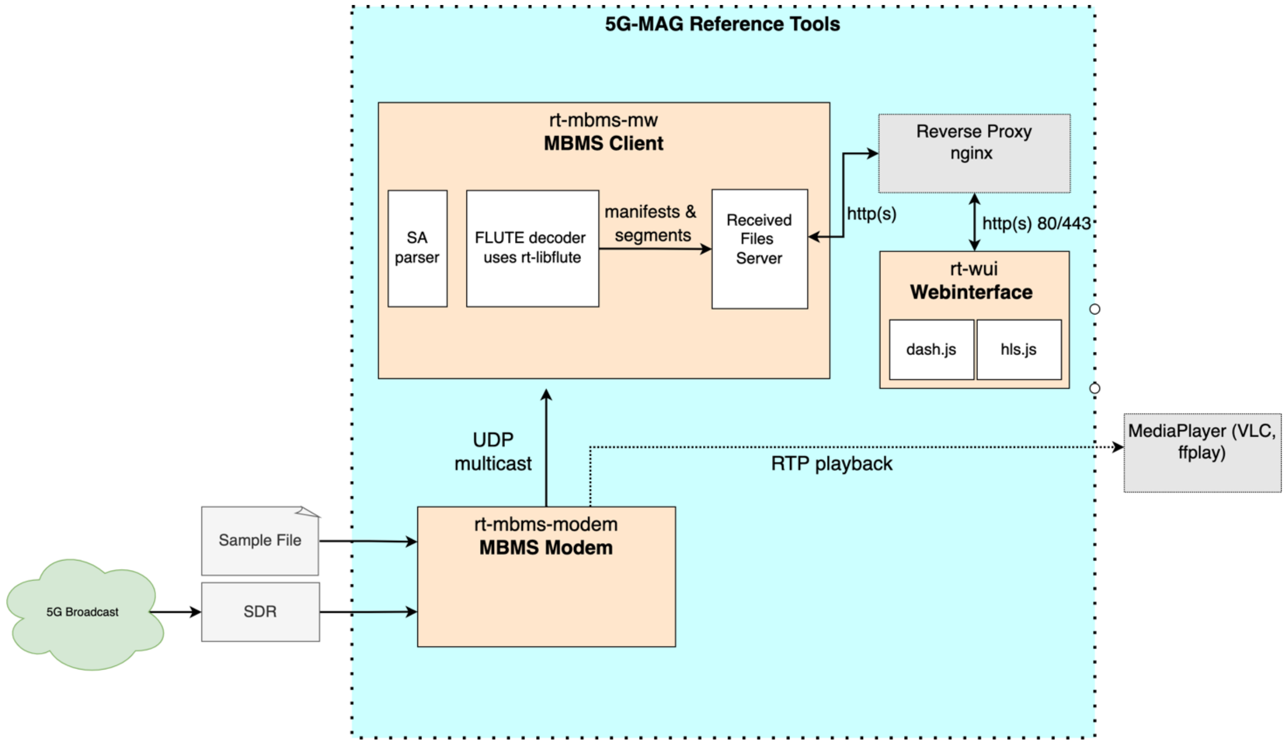

Figure 3: The workflow of the 5G-MAG Reference Tools to process an LTE-based 5G Terrestrial Broadcast

USE CASE: BROADBAND-BROADCAST SEAMLESS SWITCHING

With seamless switching, universal service coverage can be provided by the complementarity of different networks and delivery mechanisms. In cases in which certain users are out of 5G Broadcast coverage, the service continues to operate with unicast fallback from the 5G broadband network. In this way, the media playback is not disrupted, and the quality of service can be maintained at an exceptionally high level. Moreover, the technology behind seamless switching enables other use cases such as personalized ad-insertion and offering additional audio (languages) and video (viewports and angles) tracks alongside the standard tracks that are delivered via broadcast.

Technically, the requirements for broadband-broadcast seamless switching present two main challenges: push vs. pull availability of the data, and an availability time offset introduced by the latency experienced in the processing of the broadcast path components.

Playlists, video, and audio segments are provisioned by the content provider to the 5G Broadcast core network. The MBMS Client receives the broadcast content in the form of segments which can also be pulled from a CDN individually after having provisioned the appropriate playlists/manifests. Delays must be adequately handled in the manifests.

To enable seamless switching of the video playback, the MBMS Client must ensure that every audio and video segment has been received either by 5G Broadcast or should be fetched from the CDN in time for the player's request of this segment. This effectively precludes using the manifests from CDN directly, as the latency experienced in the broadcast path means they present segment availability too close to the live edge. This becomes apparent in cases where a client can receive a particular stream only from the CDN, and then either enters an area where such stream can also be received through 5G Broadcast; or when this stream becomes available through 5G BC by scheduling or by a dynamic provisioning mechanism.

In the reference implementation of this use case, we demonstrate a simplified first approach for these challenges constrained to HLS streaming. For that reason, the architecture of the 5G-MAG Reference Tools is extended by additional components as illustrated in Figure 4. The handling of audio/video segments and playlists/manifests is split up into different components:

The “Cache Management” component handles the segment data, which is stored when received through 5G Broadcast. A request from the player for a segment that has not yet been received triggers a cache miss, causing this segment to be immediately fetched from the CDN. In the current implementation, a 404 status is returned to the player's request, mimicking a request too close to the live edge and causing the player to retry with progressive intervals.

The playlists/manifests are handled by “Playlist Management”, which creates them dynamically when requested by the player. This component also receives playlists incoming on 5G BC, and periodically requests playlists from CDN. From these two sources, the content of the playlists that are created and presented to the media player is determined: for 5G BC playlists, it is assumed that the latest contained file should be available on 5G BC, and hence can be presented as such to the player; whereas for CDN playlists, a configurable number of segments is stripped out of the playlist to offset the expected 5G BC delay. For the media player itself it is not visible whether the manifests and segments originated from 5G BC or from a CDN.

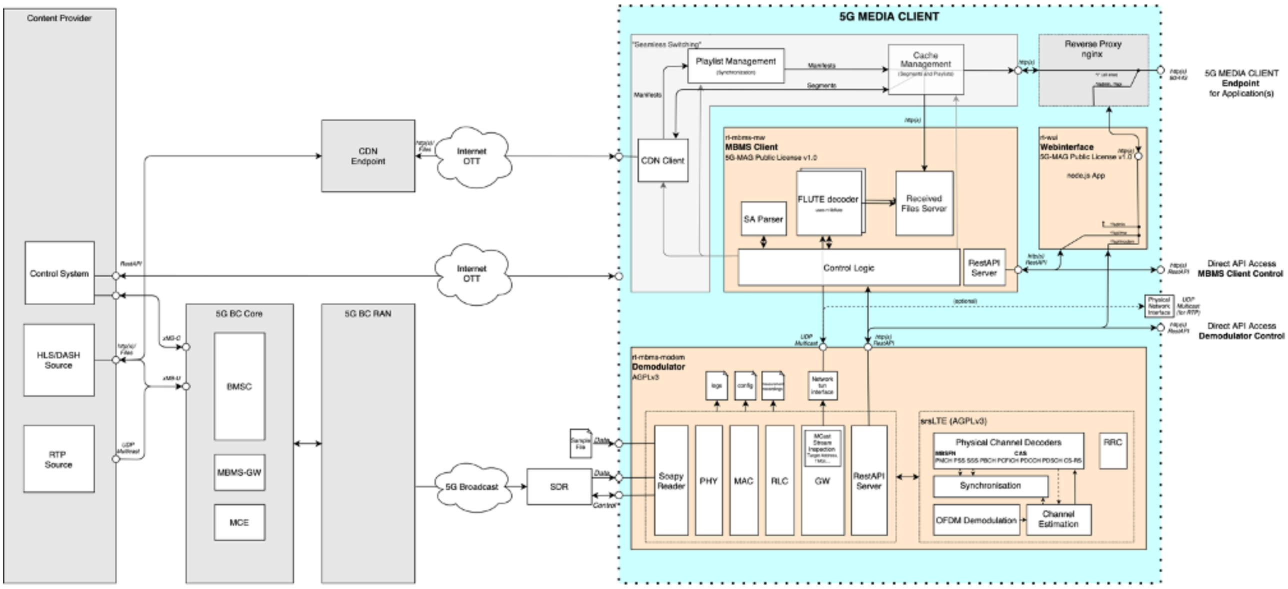

Figure 4: Extension of the 5G-MAG Reference Tools for supporting a seamless switch between broadband and broadcast content

USE CASE: BROADCAST-ON-DEMAND

Broadcast on demand refers to a scenario in which the content (or parts of the content) is initially distributed via 5G Media Streaming. The decision whether to provision the files via broadcast is done dynamically based on metrics such as the current consumption and the available resources.

To support this use case the 5G-MAG Reference Tools are extended by an additional component namely the “5G Media Streaming Client (5GMS Client)” as depicted in Figure 5.

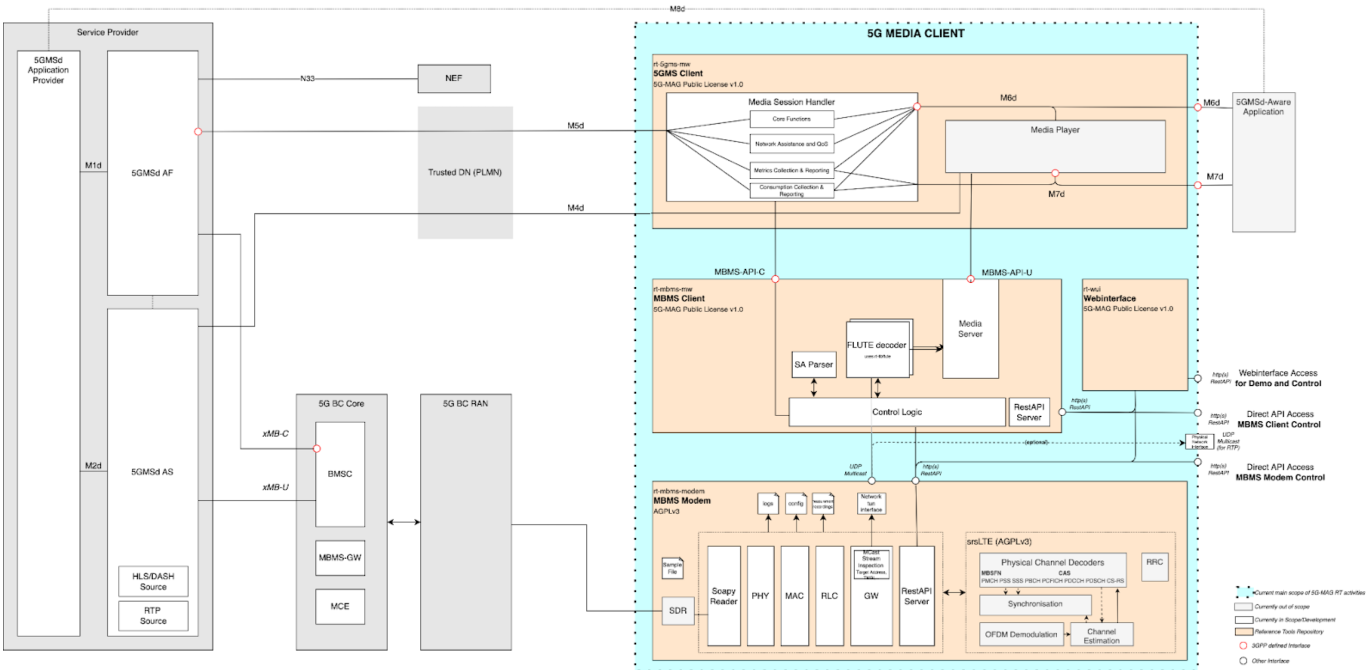

Figure 5: Extension of the 5G-MAG Reference Tools to support broadcast on demand

The 5GMS Client consists of a Media Session Handler which is connected to the MBMS Client using MBMS-API-C and via M5d with the 5GMSd AF. The 5GMS Client periodically sends consumption reports including information about consumed content, location et cetera to the 5GMSd AF using the M5d interface ("Media Session Handling API," specified in TS 26.501). Specifically, the API calls for consumption reporting and metrics reporting are periodically called by the Media Session Handler portion of the 5GMS Client, which in turn interfaces with the media player to retrieve information on the current stream.

Based on a decision logic, the 5GMSd AF decides to provision a 5G Broadcast service using the xMB interface between 5GMSd AF and BMSC to provide the same content over 5G Broadcast as over 5GMSd AS to the client.

Clients capable of receiving the same content over 5G Broadcast should then switch from 5GMS to 5G Broadcast when providing the content to the Media Player.

Note: The decision logic for 5G BC5G-BC provisioning is part of the 5G Media Streaming Application Function (5GMSd AF) on the Service Provider side, and out of scope for this paper. Nevertheless, it might be useful to provision a 5G Broadcast service for content which is watched simultaneously in a certain area to decrease the (unicast) load (on Content Delivery Networks) over 5GMS and potentially significantly decrease CDN costs.

EXPANDING THE 5G-MAG REFERENCE TOOLS TO SUPPORT DVB and ATSC3.0 SERVICE LAYERS

A full-IP stack for media distribution allows to decorrelate the service layers from the underneath layers. The service layer's role generally includes the specification of discovery and announcement mechanisms, and the media protocol stack for distribution of DASH/HLS services over multicast to serve native players of connected devices.

The Transparent (or transport-only) Delivery Method [12] offered by LTE-based 5G Terrestrial Broadcast, where the multicast streams are transparently forwarded, allows operating any IP multicast services and non-3GPP service layers as the ones specified by ATSC or DVB, over 5G Broadcast, making it easily adaptable for deployments in different ecosystems or regions, with potential different regulation requirements

For ATSC 3.0, the transport of DASH services relies on the ROUTE protocol, an evolution from the FLUTE protocol, optimized for delivery of DASH services. ROUTE is more robust and allows low latency (delivery of segment chunks before the full segment generation to reach the same latency as traditional broadcast). A ROUTE implementation is available in the GPAC open-source project [12] and as a pull-request to the 5G MAG reference tools[4]. ROUTE has been selected by the SBTVD Forum (Sistema Brasileiro de TV Digital, the Brazilian organization responsible for development of digital television in Brazil) for the Transport Layer component, while 5G Broadcast is a candidate for the physical layer.

DVB-I, specified by DVB, is a universal, access network agnostic service layer over IP for linear TV. It includes DVB-I Service Discovery and Programme Metadata, a profile of DASH and DVB multicast ABR (DVB-MABR), which specifies how ABR segment-based services such as DASH or HLS can be delivered over IP multicast. DVB-MABR allows two

[4] https://github.com/5G-MAG/rt-mbms-mw/pull/18

protocols: the ROUTE protocol from ATSC 3.0 or the 3GPP FLUTE stack, enhanced for low latency support. After an initial study and the publication of commercial requirements for DVB-I services over 5G is now leading a joint effort with 5G-MAG to produce guidelines and enrich the reference tools. The target is to add 5G delivery systems as new additional pipes for the delivery of DVB-I services. The first considered scenario is the delivery of standalone DVB-I over 5G Broadcast, for which several architectures are considered, depending on the selected multicast stack (3GPP or DVB-MABR). To implement this, several additions to the reference tools will be considered, for the delivery of the service discovery metadata and its integration with the DVB-I reference client.

CONCLUSION

The global introduction of 5G and the trend to consume high-quality videos over mobile networks lead to a high demand for robust streaming service architectures on top of the complex 5G distribution platform. The 5G-MAG Reference Tools project has been established to provide an open-source end-to-end platform to support implementation and interoperability of 5G Media technologies.

In this paper we presented the 5G-MAG Reference Tools focusing on three specific use cases "TV and Radio services over LTE-based 5G Terrestrial Broadcast", Broadband-Broadcast seamless switching" and "Broadcast-on-Demand" (BoD).

LTE-based 5G Terrestrial Broadcast can be used to distribute public and commercial linear TV and radio services, free-to-air or encrypted, to 3GPP-compatible devices such as smartphones, smart TVs, or car infotainment systems. The two main components of the 5G-MAG Reference Tools, namely the MBMS Modem and MBMS Client enable the reception and the processing of a 5G Broadcast signal. The media data transmitted via 5G Broadcast e.g., FLUTE encoded DASH and HLS files are provisioned to external mediaplayers such as dash.js or hls.js using a reverse proxy and a dedicated web interface.

With broadband-broadcast seamless switching, universal service coverage can be provided by the complementarity of different networks and delivery mechanisms. In cases in which certain users are out of 5G Broadcast coverage, the media playback is not disrupted, and the service continues to operate with unicast fallback from the 5G broadband network. For that reason, the 5G-MAG Reference were extended by additional components to enable intelligent caching of files coming either from the 5G Broadcast or via unicast directly from a CDN.

Broadcast-on-demand refers to a scenario in which the content (or parts of the content) is initially distributed via a 5G media streaming system. The decision whether to provision the files via broadcast is done dynamically based on metrics such as the current consumption and the available resources. To support this use case a 5G Media Streaming Client (5GMS Client)" was added to the 5G-MAG Reference Tools. They key component of the 5GMS Client is the Media Session Handler that periodically sends consumption reports to the 5GMS AF using standard compliant interfaces. Based on the consumption reports a service provider can dynamically enable and disable a 5G Broadcast Service.

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