Uplink media delivery in 5G: Architectures & Features

The 5G-MAG report Towards a comprehensive 5G-based toolbox for live media production [1] identified a series of high-level scenarios where 3GPP features can be used for uplink enhancements and traffic management.

This report covers the following aspects:

- Identification of systems and features enabling enhancements for uplink media delivery and traffic management in the content of media production and contribution applications.
- Description of architectures, reference points and relevant procedures in the context of uplink media delivery using 3GPP technology.
- Feasibility analysis of the status of the technology and its potential applicability based on 3GPP Release 17 and Release 18 specifications.
- Identification of possible gaps in existing specifications to support their application for uplink media delivery.

Contents

Uplink media delivery and traffic management: from niche to ubiquitous

Uplink media delivery has evolved from a specialized tool for professional newsgathering to a ubiquitous feature, driven by the rise of user-generated content from smartphones (e.g., Instagram, YouTube, TikTok).

Historically, uplink contribution relied primarily on wireless link-based solutions in licensed spectrum, such as line-of-sight point-to-point microwave links or DVB-T-based COFDM systems. To address the unreliability of general-purpose mobile networks, cellular bonding emerged as a technique that combined multiple modems in parallel to distribute video traffic providing better reliability and throughput, although still on a best-effort basis. Smartphone applications for uplink streaming can exploit bonding technologies. However, video quality can still be unpredictable due to its dependence on best-effort networks.

Coping with best-effort unmanaged networks

5G introduces Non-Public Networks (NPNs) to address specialized connectivity needs. Standalone NPNs mitigate performance variations by reserving spectrum for a dedicated uncongested network Public Network Integrated (PNI-)NPNs, often implemented using network slicing, can offer the flexibility to reserve network resources for temporary events in a public network. However, without proper Quality of Service (QoS) management and as the number of devices connected to the NPN increases, QoS degradation may still occur.

3GPP defines a series of architectures and features applicable to both professional and consumer applications. Some of these are defined in the 5G Media Streaming (5GMS) and Real-time Media Communication (RTC) specifications, alongside a set of functions enabling more reliable video streaming sessions for uplink and downlink scenarios. Aspects covered span from architecture, multimedia profiles, protocols, up to functionalities to support content management (e.g. ingest, hosting and publishing) and traffic management through network assistance and dynamic policies, Quality of Experience (QoE) metrics reporting and support for edge capabilities.

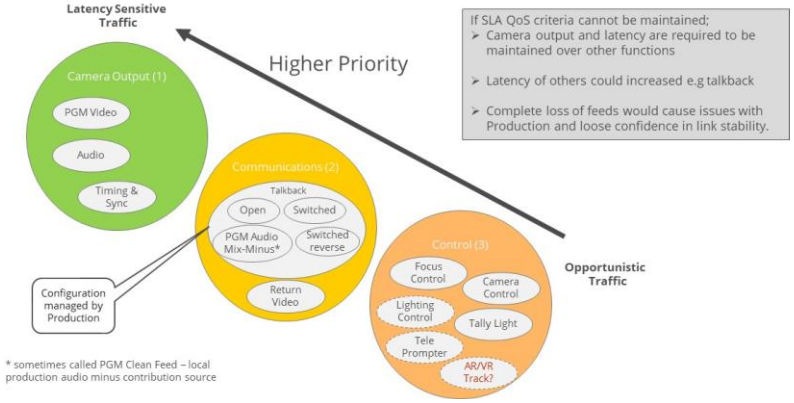
Other tools may also be applied to the network such as ATSSS (Access Traffic Steering, Switching and Splitting) or RAN-related mechanisms.

What's in it for media production and contribution?

In remote production setups, multiple media flows are carried simultaneously over the Radio Access Network (RAN) and core network from a venue to the cloud/studio, and some media flows are sent in the opposite direction. Such flows may be treated differently based on requirements.

The identification and mapping of devices and media flows to network QoS flows is done by hand. The complexity is even higher when wireless production equipment is fitted with multiple SIM cards, enabling it to communicate more reliably by using more than one RAN ("cellular bonding"). Mechanisms to automatically map media flows to the adequate QoS policies would make media production deployments more efficient.

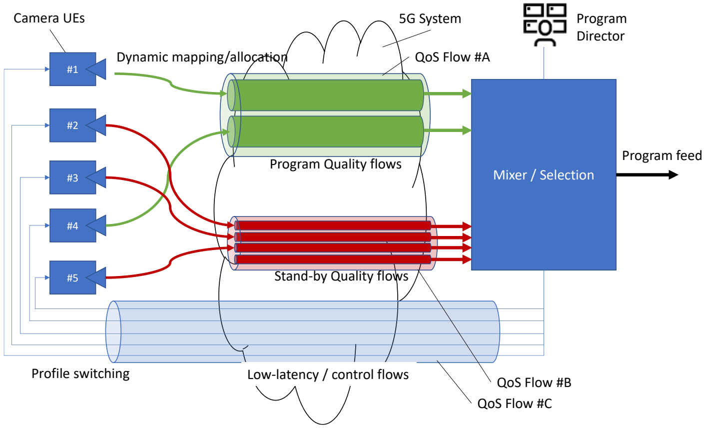
Furthermore, setting the QoS parameters is mainly done manually and statically (e.g., using pre-defined 5QI code points). There is little flexibility in (sub-)slicing deployed in NPNs and no particular mechanism available to manage the fairness between multiple sources in a shared allocated resource. An approach where the network tells the device what to do throughout the production event lifecycle would save time and resources.



Practically, and from a network perspective, allocated QoS levels should be flexible and dynamic enough to support fine-grained media workflow optimization. In particular, the following capabilities are key:

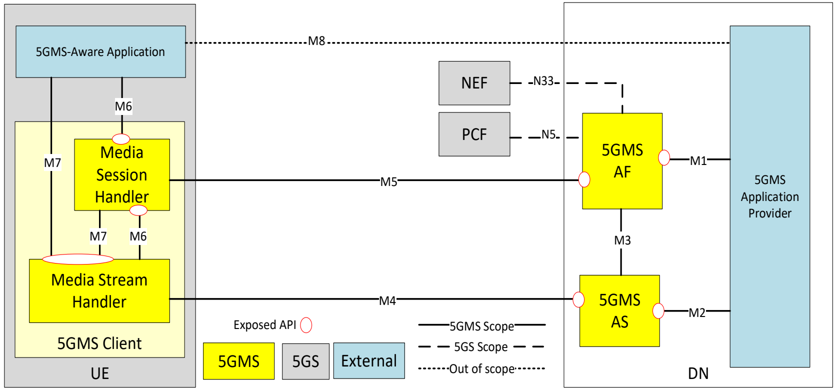
- Setting the relative importance of one data flow compared to another, for example based on a production-oriented decision.
- Dynamic switching between multiple QoS profiles based on media type.
- Automatic identification of which device belongs to each UE, and mapping its data flow(s) automatically to the desired QoS profile(s).
- Obtaining network KPIs and forecasts.
- UE support for elastic media encoding bit rate, coping with media fluctuations (including variable resolution, frame rate, etc.).
- Support for offloading media processing tasks to a server in the network (including AI, editing, etc.), possibly an edge computing resource.

Note that some of these issues were identified as part of TR 26.805 [2], with some of its figures reproduced in this page.



3GPP architectures for uplink media delivery

5G Media Streaming (5GMS) general architecture



From Release 16 onwards, 3GPP TS 26.501 [3] defines a general architecture for media streaming assisted by 5G System network features.

A **5GMS Application Provider** can collaborate with the Mobile Network to achieve improved media streaming Quality of Experience using managed interactions with the 5G System.

A Network Function called the **5GMS Application Function (5GMS AF)** can invoke policy and charging services exposed by the Policy Control Function (PCF) at reference point N5 (or via the NEF at reference point N33) to manipulate network Quality of Service (QoS) parameters and charging policies in either the downlink or uplink direction.

- The 5GMS AF can be deployed either in the 5G Core or in an external Data Network (interacting with 5G Core via Network Exposure Function).
- The 5GMS AF exposes a **provisioning API** at reference point M1 to 5GMS Application Providers that enables QoS **Policy Templates** to be agreed in advance with the 5G System operator.
- The 5GMS AF also offers a **media session handling API** at reference point M5 to a **Media Session Handler** logical function deployed in the 5GMS Client of a UE.

Media content is relayed between a Media Stream Handler at reference point M4 and the 5GMS Application Provider at reference point M2 by a **5GMS Application Server (5GMS AS)**.

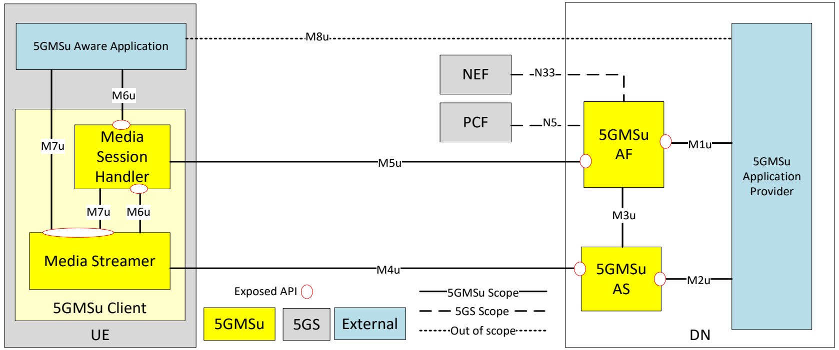
To support operational scalability, the 5GMSu AS logical function may be realised as a set of **Edge Application Servers** in an **Edge Data Network** through suitable provisioning of an **Edge Resources Configuration**.

An instantiation of the **UE data collection, reporting and event exposure architecture** defined in 3GPP TS 26.531 [4] enables the 5GMS System to log data relating to media streaming sessions and to expose this to subscribers in the form of **Events**. Using this, media consumption information and QoE metrics reported by the Media Session Handler to the 5GMS AF can be exposed to the 5GMS Application Provider.

3GPP Release 18 introduces the use of a **3GPP Service URL** to launch media session handling for media streaming sessions by the Media Session Handler. This enables 5GMS services to be announced within a third-party application, a general web page, a messaging service or shared via social messages using a 3GPP Service URL for 5GMS.

Uplink 5G Media Streaming (5GMSu) architecture

Clause 4.3 of 3GPP TS 26.501 [3] defines an instantiation of the generic 5GMS architecture to support media streaming in the uplink direction in which a **5GMSu Client** contributes media content to a **5GMSu Application Server (5GMSu AS)** at reference point M4u and this content is then published to a **5GMSu Application Provider** at reference point M2u.



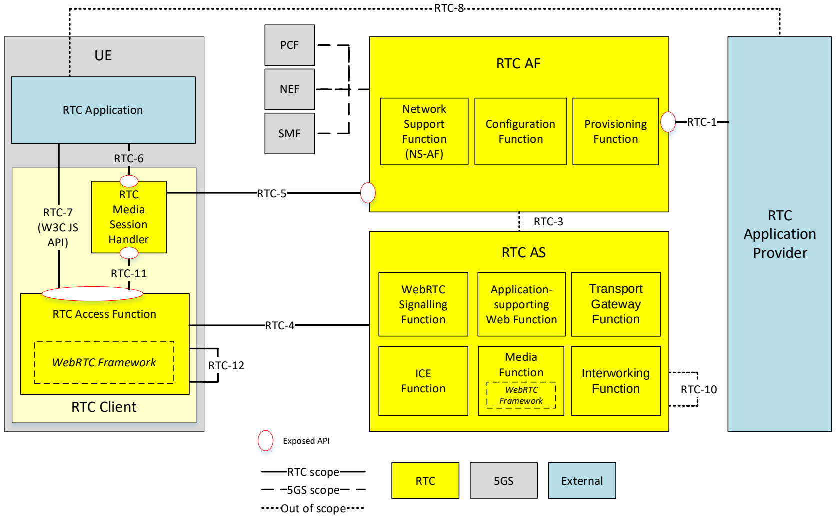
To achieve this, the **5GMSu AS** implements the Content Publishing and/or Content Preparation features and is responsible for relaying media content between 5GMSu Clients (at reference point M4u) and 5GMSu Application Providers (at reference point M2u) as follows:

- Uplink media streaming is provisioned by means of a **Content Publishing Configuration** provided by the 5GMSu Application Provider at reference point M1u.
- Media content is contributed to the 5GMSu AS by a **Media Streamer** in the UE-based 5GMSu Client at reference point M4u, and from there published (referred to in the technical specifications as "content egest") to a 5GMSu Application Provider via reference point M2u. The 5GMSu AS may optionally cache contributed content.
- The 5GMS System may be provisioned to process content as it passes through the 5GMS AS using a **Content Preparation Template**. Examples of the kinds of processing that might be performed by the 5GMSu AS are re-encoding of content or performing object detection.

The **5GMSu-Aware Application** executes on the UE and uses the uplink media streaming functions and APIs provided by the 5GMSu Client. The specifics of the application are out of scope in current specifications.

5G Real-Time media Communication (RTC) architecture

In Release 18, 3GPP developed an architecture for Real-Time media Communication (RTC) in TS 26.506 [5]. This specifies the integration of the RTP-based WebRTC protocol stack [6] into the 5G System, including support for dynamic QoS policies and charging functions, as well as providing a mapping for Interactive Connectivity Establishment (ICE) and WebRTC signalling services into the 5G System.



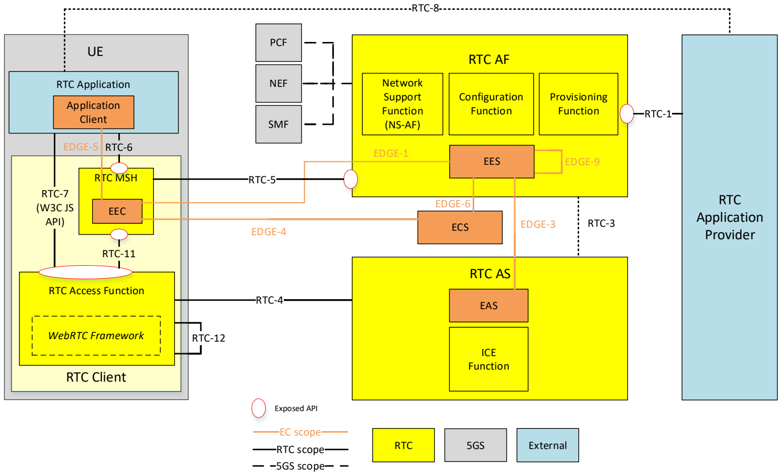
In this context, RTC implies a requirement to support interactive services, such as facilitating live video and audio interaction between geographically diverse participants, and eXtended Reality (XR) [7] use cases.

An **RTC Application Function (RTC AF)** plays a similar role to the 5GMS AF in providing a provisioned application gateway to the trusted PCF services offered by the 5G Core. Features include interacting with the PCF to realise dynamic QoS policies and to obtain bit rate recommendations given prevailing network conditions, among others.

An **RTC Application Server (RTC AS)** relays content between RTC peer UEs in real time using an RTP-based media transport protocol. The RTC AS may be provisioned by the RTC AF to provide the following support services:

- **WebRTC Signalling Function**, supporting RTC session setup.
- **ICE Function**, facilitating RTC session setup between participants separated by firewalls and Network Address Translators.
- **Media Function** that creates or processes one or more RTC sessions.
- **Inter-working Function** and **Transport Gateway Function** that relay WebRTC sessions between different RTC Systems.
- **Application Support Web Function** to deliver web resources and file sharing to support RTC sessions.

An **RTC endpoint** is defined by TS 26.506 [5] as a sending or receiving participant in an RTC session. The RTC endpoint is typically instantiated in a UE, under the control of an application, but may equally be deployed in the RTC AS, which may be deployed as an Edge Application Server for horizontal scalability.



The RTC endpoint is controlled by an RTC Application which can be deployed in two different ways:

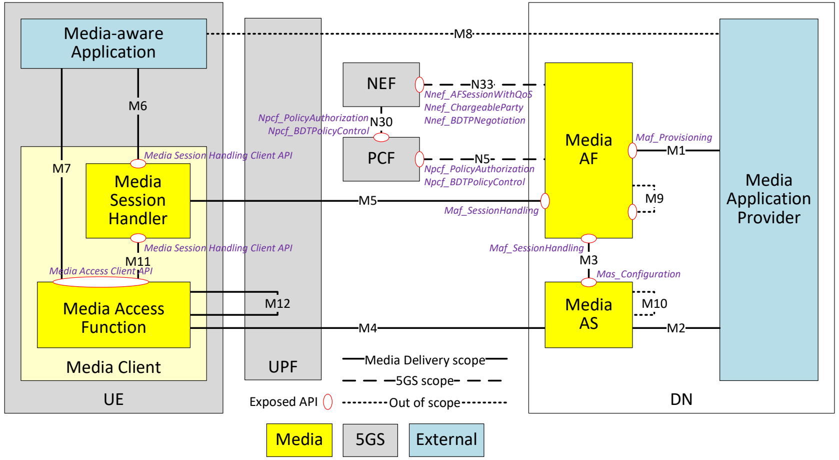
- As a **Web App** deployed within the scope of a standard web browser. In this deployment, the application only has access to the WebRTC JavaScript API [8] defined by W3C via reference point RTC-7, and the RTC Access Function component queries the RTC Media Session Handler (via reference point RTC-11) on behalf of the Web App to discover WebRTC signalling functions and to request QoS allocation for the RTC session.
- As a **Native WebRTC App** that does not use a standard web browser, for example native code compiled against a WebRTC library. A native application additionally has direct access to the RTC Media Session Handler (via reference point RTC-6) and can discover WebRTC signalling functions and request QoS allocation for the RTC session directly, and accesses WebRTC features using the WebRTC Framework (via reference point RTC-7).

In addition to implementing a standard WebRTC framework that interacts with the RTC AS at reference point RTC-4, the RTC Client also incorporates an **RTC Media Session Handler** that interacts with the RTC AF at reference point RTC-5. The Media Session Handler configures the WebRTC framework while abstracting the details of 5GS-specific QoS and network assistance from the RTC application. It also reports QoE metrics of running WebRTC sessions back to the RTC AF.

Converged media session handling

In an attempt to converge object-based and packet-based approaches to media delivery, 3GPP has defined in Release 18 a **generalised media delivery architecture** in TS 26.501 [3] and TS 26.506 [5] that maps respectively to the 5GMS architecture and to the RTC architecture. As can be seen in the figure below:

- The 5GMS AF and RTC AF are generalised to a **Media AF**.
- The 5GMS AS and RTC AS are generalised to a **Media AS**.
- The 5GMS Client and RTC Client are generalised to a **Media Client**.



As a consequence of this generalised architecture, Release 18 factors out the common media session handling services of the 5GMS architecture into a separate technical specification, TS 26.510 [9]. This specification is referenced by both TS 26.512 [10], the stage-3 specification for 5GMS; and by TS 26.113 [11], the stage-3 specification for RTC.

Feature support in 3GPP Release 18

In terms of feature support, the following is a summary of those available under the 5GMSu or RTC architectures based on the 3GPP Release 18 specifications.

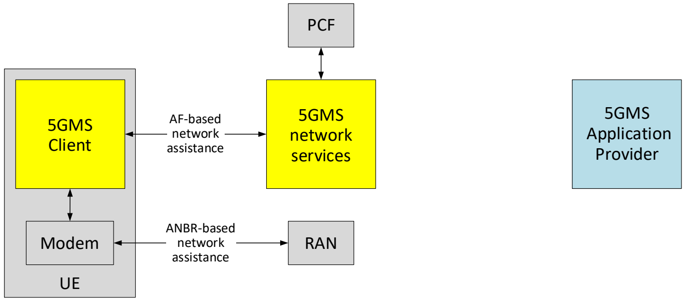
Function		5GMSu	RTC
Content Publishing		Supported	Not applicable
Content Preparation		Supported	Not applicable
Network Assistance	Bit rate Recommendation	Supported	Supported
	Delivery Boost	Supported	Supported
Dynamic QoS Policies		Supported	Supported
	Background Data Transfer	Supported	Not applicable
Edge Processing		Supported	Supported
QoE metrics reporting		Supported	Supported
Consumption reporting		Not applicable	Underspecified
UE data collection, reporting and exposure		Supported	Out of scope
Service URL handling		Supported	Out of scope

Network Assistance

The Network Assistance feature enables the 5GMSu Media Client in the UE to interrogate or manipulate the network Quality of Service for an ongoing media streaming delivery session.

There are two main mechanisms for network assistance in the converged Media Delivery System:

- **AF-based Network Assistance**, where the Media Session Handler makes use of the Network Assistance API exposed by the Media AF at reference point M5, which then interacts with the PCF (via reference point N5 or N33) to authorise dynamic QoS policies for a particular media delivery session.
- **ANBR-based Network Assistance**, with signalling interactions between the UE modem and the RAN. Because it happens at the radio layer, this form of Network Assistance applies to all traffic between the UE and the RAN, and not to a specific media delivery session.



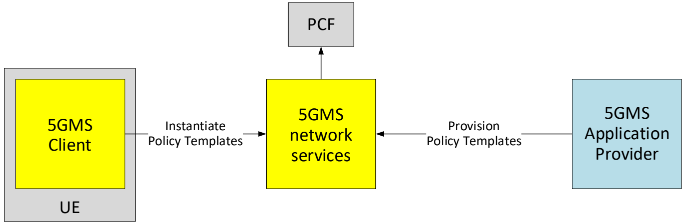
The two Network Assistance features currently supported in Release 18 are:

- **Bit rate Recommendation/Throughput Estimation**: The network analyses network conditions and suggests an optimal bit rate for the streamed content. The Media Client uses this information to adjust its own streaming bit rate to fit within the Quality of Service (QoS) range that the network can offer, for example by adjusting the encoding bit rate for uplink streaming to fit within this bit rate budget.
    - The Media Session Handler may additionally subscribe to an MQTT channel to receive notifications with up-to-date bit rate recommendations whenever the 5G System notices a change in network conditions.
- **Delivery Boost**: In scenarios with congestion or limited bandwidth, the network might employ techniques to prioritise the delivery of streaming data, minimising delays. The Media Client uses this temporary boost to speed up a media data transfer, for example to relieve a congested uplink sending buffer without having to drop frames.

Dynamic QoS policies

Dynamic QoS policies enable the Media Client to request that the 5G System applies particular network traffic handling policies for an ongoing media streaming session. Unlike static QoS settings, these policies can be adjusted dynamically based on real-time network conditions and application needs.

Dynamic QoS policies are established by means of a **Policy Template** which specifies a *Service Operation Point*, an abstract set of requirements that support the media delivery service. A Policy Template may be defined as applicable to a particular Data Network and/or Network Slice.



NOTE: The PCF is accessed via the NEF when the 5GMS network services are deployed outside the Trusted DN.

From Release 18 of 5GMS onwards, the repertoire of QoS policies supported is extended to include **Background Data Transfer (BDT)** which may also be linked to a different charging treatment.

At the start of a media delivery session, the set of available Policy Templates is exposed to the Media Session Handler function on the UE. The Media Client can subscribe to receive real-time notifications e.g. BDT opportunities.

During operation, the Media Client may request a BDT by instantiating a Policy Template including an estimate of the data volume it intends to transfer. If the request is granted, the 5GMS network services apply the appropriate BDT Quality of Service policy to the uplink media streaming session for a limited time. After this time window has expired, the 5GMS network services automatically revert the network QoS back to its state before the grant. The 5GMS network services may reject attempts to provision a Policy Template that specifies Network QoS parameters outside acceptable bounds imposed by local system configuration. Although available in the RTC System, BDTs are not useful in RTC application flows, so this feature is primarily intended for use in 5GMS.

Edge processing

The edge processing feature enables the Media Client in the UE to take advantage of edge computing capabilities in the 5G System to support media delivery. In particular, the capabilities of the Media AS may be scaled horizontally in a real deployment by instantiating multiple Edge Application Server (EAS) instances in an Edge Data Network (EDN). This is expected to be useful for supporting large numbers of concurrent uplink media streaming sessions with complex Content Preparation requirements in the 5GMSu AS.

QoE metrics reporting

The generalised media delivery architecture specified for the 5G System includes a mechanism for reporting QoE metrics for media delivery sessions. The Media Application Provider can provision one or more Metrics Reporting Configurations on the Media AF via reference point M1, which are then reflected in the Service Access Information resource retrieved by the Media Client at reference point M5.

The metrics configuration tells the Media Session Handler what kind of metrics to report, the frequency to both sample and report, details on specific media sessions to report, and the address of the Media AF to submit the metrics to.

Release 18 of 5GMS only specifies QoE metrics for DASH downlink media streaming, with nothing specified for 5GMSu. Conversely, the RTC architecture has a fully specified metrics reporting scheme. Even though WebRTC can be bidirectional, the metrics are all from the perspective of the RTC session receiver, so the RTC AS is also able to submit QoE metrics to the RTC AF from its own perspective at reference point RTC-3 (M3).

The types of metrics that can be reported by the RTC endpoint are as follows:

- Transport protocol metrics.
    - Lost RTP packets.
    - Round-trip time.
- Media presentation metrics.
    - Number of corrupted frames in a picture sequence.
    - Displayed frame rate.
    - Average codec bit rate.
    - Synchronisation loss duration.
    - Jitter duration.

Most of the above metrics only apply for an RTC endpoint *receiving* a media session. Lost RTP packets and the session round-trip time are reported by conventional RTCP signalling and the codec bit rate can be inferred by the sender, but there is no mechanism for a remote receiver to report the other metrics to the sender via RTCP messages. Therefore, where an RTC session is terminated outside of the 5G network the receiving metrics will not be available for the RTC session.

Consumption reporting

Consumption reporting is not applicable for 5GMSu because the Media Client is not downloading content for consumption.

In Release 18, consumption reporting is underspecified for RTC: the data types and API for submitting consumption reports are specified by TS 26.510 [9], but TS 26.113 [11] does not specify how to populate consumption reports for RTC sessions.

Traffic steering and multipath architectures

Multipath architectures: dual-steering & ATSSS

One of the limitations of cellular bonding approaches is that they imply deploying multiple SIM cards (UEs) to access multiple connectivity paths in parallel. Traffic is treated over-the-top and therefore in a best-effort manner because networks are used as a transparent bit-pipe. Recent 3GPP releases introduce tools such as dual-steer and **Access Traffic Steering, Switching and Splitting (ATSSS)** that attempt to alleviate this limitation. This opens the door to the following hybrid access scenarios for a UE (as per 3GPP TR 22.841 [12]):

- UE connected to two independent links over the same PLMN.
- UE connected to a PLMN + a Standalone NPN.
- UE connected to different RAT (e.g. a NR+NTN, NR+LTE, NR+WiFi, …).

These scenarios may replace some of the cases requiring cellular bonding. However, it would be useful to get assistance from the 5G System in order to efficiently split traffic across the multiple available access networks. More specifically, the exposure of the following information would be required:

- Split recommendation based on type of media being sent (e.g. audio on link A, video on link B).
- Split rate recommendation (e.g. 30% of traffic on link A, 70% on link B).
- Split recommendation based on stream priority.
- Support for aggregation of multiple links into a unique media delivery session.

Multi-band traffic steering

Certain scenarios may benefit from the availability of different radio carriers in different frequency bands. A camera may obtain connection from one carrier (e.g. mid-band) but allocate intensive traffic on a carrier with larger capacity (e.g. mmWave). The ability to instruct the camera to make use of such additional capacity exclusively for intensive data traffic could be investigated.

Network Assistance features for multipath

In many uplink media scenarios, devices leveraging cellular bonding introduce redundancy through multiple access networks. Current approaches rely on "trial and error", consisting of empirically finding the optimal delay *versus* capacity trade-off. As those devices embed multiple SIM cards, advanced Network Assistance can be useful to better drive the bit rate allocation across multiple links and avoid retransmission quality degradation. More specifically, exposure of the following information to the Media Client would be required:

- Initial recommended throughput with associated latency.
- Upcoming network conditions.
- Upcoming network handover.

Potential RAN enhancements to support uplink media delivery

The downlink/uplink (DL/UL) throughput requirements for video and the latency requirements for both audio and video may require specific TDD network configurations which differ from the typical configurations in most public network deployments. In addition, in multi-operator environments even when considering non-public networks, interference [15] [16] may prevent the TDD frame structure from being adjusted to the most favourable configuration for uplink streaming. National regulators may also impose a specific TDD structure as part of the licence agreement [17]. The use of guard bands, power limitation or isolation may help in reducing interference. Other current or future RAN features specified by 3GPP may also prove useful in improving throughput.

Numerology and frame structure

TDD carriers, normally deployed in frequency ranges in mid bands and mmWave, combine uplink and downlink subframes (and slots) multiplexed in the time domain. Transmission Time Interval (TTI) and throughput are limited by the amount of available uplink resource and the delay; these are impacted by the frame structure, the RAN scheduler and the number of users competing for transmission opportunities.

According to 3GPP TS 38.213 [13], the most suitable slot formats for uplink transmissions are Format 1, 10 and 34, which maximise uplink slots.

Symbol #	0	1	2	3	4	5	6	7	8	9	10	11	12	13
1	U	U	U	U	U	U	U	U	U	U	U	U	U	U
10	F	U	U	U	U	U	U	U	U	U	U	U	U	U
34	D	F	U	U	U	U	U	U	U	U	U	U	U	U

Delay between slots is inversely proportional to subcarrier spacing (SCS). The 3GPP specifications enable configuring SCS of 15, 30 and 60 kHz for frequency range FR1 (below 6 GHz). For frequency range FR2, 60 and 120 kHz can be used. This results in shorter delays between slots [18].

Slot #	0	1	2	3	4	5	6	7	8	9
Carrier 15 KHz	D	D	D	S	U	D	D	S	U	U

Slot #	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
Carrier 30 KHz	D	D	D	S	U	D	D	S	U	U	D	D	D	S	U	D	D	S	U	U

When using TDD in mmWave frequency bands, e.g. 26 GHz, 28 GHz, and 39 GHz, the TTI can be reduced alongside other potential improvement in terms of beam-forming or higher propagation loss, which reduce potential interference.

Carrier Aggregation

Carrier Aggregation (CA) allows two or more Component Carriers (CCs) to be aggregated to increase throughput. CCs can be contiguous or non-contiguous and even in different frequency bands. When aggregating multiple CCs, different solutions can be applied to increase transmission opportunities and throughput as described in [19] and summarized below.

Frame offset and uplink switching

In Release 16, 3GPP TS 38.211 [14] describes the option to misalign frame boundaries (offset between frames) among different CCs. Transmission switching, see 3GPP TS 38.214 [20], also enables dynamic switching between the frames of two CCs to obtain additional transmission opportunities in the time domain. Offsets between the subframes of each component carrier may also enable more transmission opportunities than when using a single carrier or even when using cellular bonding of two carriers that are frame-aligned. An example with a 3-slot offset is shown in the following figure.

Slot #	0	1	2	3	4	5	6	7	8	9
Carrier A	D	D	D	S	U	D	D	S	U	U

Slot #	0	1	2	3	4	5	6	7	8	9
Carrier B	S	U	D	D	S	U	U	D	D	D

Supplementary Uplink (SUL)

A single TDD carrier in a multi-UE deployment may not be suitable for high uplink throughput applications. Supplementary uplink enables a UE to be scheduled to transmit on a carrier with near 100% uplink resources, in addition to another TDD carrier that may be used for connectivity or for less demanding operations. 3GPP TS 38.101 [21] specifies the frequency bands where the combination of a TDD carrier and a SUL carrier is currently permitted. An example where a regular TDD carrier is complemented by a SUL carrier is shown in the figure below.

Slot #	0	1	2	3	4	5	6	7	8	9
Carrier A	D	D	D	S	D	D	D	S	U	U

Slot #	0	1	2	3	4
SUL Carrier	U	U	U	U	U

Carrier structure and performance degradation

If **Hybrid Automatic Repeat Query (HARQ)** is enabled on a carrier, the loss of an uplink transport block is indicated by signalling in the corresponding downlink, which instructs the UE to re-transmit the transport block with a new scheduling grant by sending a negative acknowledgement (NACK). Re-transmitting a data block adds extra delay, varying the uplink latency. Multiple re-transmissions add more latency variation, increasing the buffering required to prevent dropped video frames or audio samples when decoding media.

The response time and behaviour of the HARQ and re-transmission process are implementation-dependent, but the fastest possible NACK and re-transmit time are determined by available downlink and uplink TDD slots.

A downlink:uplink ratio of 2:7 has a high upstream capacity, but with the increased possibility of larger re-transmission delay due a longer wait for an available downlink slot to signal a re-transmission NACK. A downlink:uplink ratio of 1:2 has less upstream capacity, but has less potential delay to signal a re-transmission. However, the behaviour of the 5G Core and other factors may also have a significant impact on re-transmission delay.

TDD carriers are generally used in mid and high bands. An estimation of available throughput per carrier would allow for better tailoring encoding performance to actual resource availability.

Handover and cell pinning for a UE

Sometimes a static camera encounters handover across multiple local cells, without the UE moving. In ultra-low-latency content production scenarios, this severely impacts the QoE because of the very tight latency requirements (margins to retransmit packets). Therefore, capabilities to configure cell pinning for a UE in a PNI-NPN or an S-NPN could usefully be further studied.

Related documentation

[1] 5G-MAG Report: "Towards a comprehensive 5G-based toolbox for live media production".

[2] 3GPP TS 26.805 "Study on Media Production over 5G NPN Systems" (Release 17).

[3] 3GPP TS 26.501: "5G Media Streaming (5GMS); General description and architecture" (Release 18).

[4] 3GPP TS 26.531: "Data Collection and Reporting; General Description and Architecture" (Release 18).

[5] 3GPP TS 26.506: "5G Real-time Media Communication Architecture (Stage 2)" (Release 18).

[6] IETF RFC 8825: "Overview: Real-Time Protocols for Browser-Based Applications".

[7] 3GPP TR 26.998, "Support of 5G Glass-type Augmented Reality / Mixed Reality (AR/MR) devices" (Release 18).

[8] W3C Recommendation: "WebRTC: Real-Time Communication in Browsers", October 2024.

[9] 3GPP TS 26.510: "Media delivery; interactions and APIs for provisioning and media session handling" (Release 18).

[10] 3GPP TS 26.512: "5G Media Streaming (5GMS); Protocols" (Release 18).

[11] 3GPP TS 26.113: "Real-Time Media Communication; Protocols and APIs" (Release 18).

[12] 3GPP TR 22.841: "Study on Upper layer traffic steering, switching and split over dual 3GPP access" (Release 18).

[13] 3GPP TS 38.213: "NR; Physical layer procedures for control" (Release 18).

[14] 3GPP TS 38.211: "NR; Physical channels and modulation" (Release 18).

[15] Ericsson Blog: "Cross-link interference in TDD networks and what to do about it", 2020.

[16] GSMA Report: "5G TDD Synchronization Q&A; Recommendations for the Coexistence of TDD Networks in the 3.5 GHz range", 2020.

[17] Ofcom document: "Vodafone Limited – Spectrum Access 3.6-3.8 GHz License", 2021.

[18] BBC R&D White Paper WHP410 "5G Standalone Non-Public Networks: Modernising wireless production", October 2023.

[19] NGMN Report: "5G TDD Uplink v1.0", 2021.

[20] 3GPP TS 38.214: "NR; Physical layer procedures for data" (Release 18).

[21] 3GPP TS 38.101-1: "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone" (Release 18)..

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