September 2019

5G Media slice definition
(version 1.2)

Executive Summary

This document is the outcome of a joined working group setup between the two European Technology Platforms, New European Media (NEM) and Networld2020. The objective was to combine expertise from the media sector which brought application requirements and the network domain which brought expertise in 5G.

Nine media&content use cases have been identified by the group that cover most of the common media&content situations from production to consumption.

From these 9 use cases the group has identified 12 parameters that should be used to adapt the network to the application requirements, such as: Latency, Reliability, Data rate, Mobility, User density, Positioning, User Equipment speed.

Looking to the 5G network capabilities and parameters that could be activated, the last section provides a description of 5G Media Slices. There is a "s" because one of the main conclusions of the paper is that the media chain encompasses a number of functionalities and operations such as content creation, service composition, service aggregation, content distribution, devices, user interaction and interfaces, which requires different slices. Additionally, 5G requirements will be different for production which needs mostly uplink capacities and distribution which needs mostly downlink capacities.

For each of the 9 use cases, there is a proposal to allocate 1 or 2 slices, detailed in the conclusion of this paper.

The objective of this paper is to provide proposals and reference material to standardisation organisations in order to contribute to the design and specification of 5G Media Slices.

Table of Content

Abbreviations

5GIA: 5G Infrastructure Association
API: Application Programing Interface
AR: Augmented Reality
CDN: Content Delivery Network
ETP: European Technology Platform
HD: High Definition
IEM: In-Ear-Monitoring system
IP: Internet Protocol
LAN: Local Area Network
M&C: Media and Content
MNO: Mobile and Network Operator
MTC: Machine Type Communication
NFV: Network Function Virtualisation
PMSE: Programme Making and Special Events
PPP: Public Private Partnership
QoS: Quality Of Service
SDN: Software Defined Network
UGC: User Generated Content
UHD: Ultra High Definition
VNF: Virtual Network Function
VR: Virtual Reality

Contributors :

Contributor name	Organisation
Francesco D'ANDRIA	ATOS
Alex BUCHAN	DTG (3GPP SA1/SA2)
Pasquale ANDRIANI	Engineering (5G Media)
Francesco NUCCI	Engineering
Maria GUTA	ESA (SATis5, SHINE, ViBES)
Elisabeth WELLER	Eutelsat
Carolyn TAYLOR	Hepta7291
Michael BONIFACE	University of Southampton, IT Innovation Centre (FLAME)
Valerio FRASCOLLA	Intel Deutschland GmbH (5GENESIS)
Baruch ALTMAN	LiveU (5GXcast)
Josephus VAN SAS	Nokia
Pierre-Yves DANET	Orange labs (GSMA, NGMN)
Volcy LESCA	Orange
Axel SCHMIDT/ Jan DUERRE	Sennheiser
Matina RIZOU	Singular Logic
Jovanka ADZIC	Telecom Italia (GSMA, NGMN)
Lucia D'ACUNTO	TNO (3GPP SA4)
Carla RAFFAELLI	University Bologna
Almudena DIAZ ZAYAS	University Malaga
Lorenzo FAVALLI	University of Pavia
Felipe GIL-CASTINEIRA	University Vigo
Kieran SULLIVAN	Waterford Institute of Technology

1. Context

The mandate of the working group in charge of this paper, which is supported by Networld2020 and NEM ETPs, as well as by the 5GIA, is to provide a high level description of what a 5G Media&content (M&C) slice is. The work started with taking the most relevant Media&content use cases requirements provided by participants, 5G PPP projects and standardisation bodies. From this, the group identified which 5G network parameters are the most suitable in order to satisfy the requirements of all Media&content use cases, both in the uplink and downlink, for all stakeholders such as end-users, production houses and Mobile Network Operators (MNOs).5G is not only about a faster network access, but marks a transition from a rather static network to a much more dynamic one.

Network slicing is becoming one of the key concepts in 5G with development driven by the ambition to better utilise future 5G networks. While some are excited about the opportunities slicing provides, others doubt that slicing is really that new and revolutionary.

The basic motivation for slicing is to increase the usage of network resources and to enable its shared use for multiple applications posing very diverging requirements on the network and to add the required flexibility and scalability to meet these requirements.

Network slicing is one of the main concepts in 5G, it was first formulated by the NGMN Alliance in the context of future networks. Slicing was originally defined as a set of run-time network functions, and resources to run these network functions, forming complete instantiated logical network to meet certain network characteristics required by the service.

In the course of identifying the requirements for the 5G networks, a large number of use cases have been described and analysed by standardisation bodies. These different requirements have been agreed and consolidated in three main classes:
- Enhanced Mobile Broadband (eMBB) - also called Extreme Mobile Broadband
- Ultra-Reliable and Low Latency Communications (URLLC) and
- Massive Machine Type Communication (mMTC).

This paper is about exploring if there is a requirement for a specific slice for Media&content applications and then proposing a possible design and recommendations.
From a business point of view, a slice includes a combination of all relevant network resources, network functions, service functions and enablers required to fulfil a specific business case or service, including the functions of an Operation Support System (OSS) and Business Support System (BSS).

The behaviour of a network slice is realized via a network slice instance. From the network point of view, network slice instances require the partitioning and assignment of a set of resources that can be used in an isolated, disjunctive or non-disjunctive manner for that slice.

Network slicing transforms the networking perspective by abstracting, isolating, orchestrating, software defining and separating logical network functions from the underlying physical network resources.
The methodology used to define a Media&content slice was based on:
1/ Identification of the most relevant use cases
2/ Identification of the technical requirements of such use cases
3/ Mapping with the 5G network resources and capabilities

A number of projects and organisations are already addressing parts of this question, we shall obviously liaise with them in order to share a common understanding and facilitate adoption of the paper.

- *3GPP standardisation*

- *GSMA industry specification*
- *NGMN industry specification*
- *5G-MEDIA project: use cases & requirement*
- *FLAME project: use case & requirements*
- *Matilda project: 5G*
- *5GXcast project: focussing on broadcast and multicast*
- *SATis5 project: Satellite*
- *5GENESIS project: 5G KPIs validation on media sector*

2. Potential Media&Content use cases and application requirements

This section has the objective to give a number of relevant Media&content use cases that will be used to study the requirements that the future 5G media slice will be able to support. Nine use cases covering a large part of Media&content domain have been described below in Section 2.2. The application requirements depend on parameters as described in Section 2.1.

Media production and consumption models have evolved considerably: they are more collaborative, more social, and more personal. Broadcasting and telecommunications industries have to establish viable models for future networks that will benefit all stakeholders, considering the scale, assets and cost-effective solutions provided for various Media&content service scenarios.

2.1 Parameters description

This section provides a description of parameters that are used to translate use case requirements to 5G System.

Parameter	Description
Experience data rate	It means the minimum data rate required to achieve a sufficient quality experience, with the exception of the scenario for broadcast like services where the given value is the maximum that is needed
Application Latency	It means the duration between the transmission of a data packet from the application layer and successful reception at the application layer of the destination node Note: This parameter is different from the transmission latency
Reliability (IP packet within the latency bound)	It means the target rate required for the data packet dropping, throughput, and latency in order to achieve successful reception of the IP packet within the latency bound.
#devices	It means the number of devices (density)
Broadcast/Multicast	It means the delivery of identical content to users simultaneously.
Battery	It means the life cycle of the battery and the device battery life requirement with respect to the use case scenario.
Coverage	It means the geographical area covered criteria required to achieve a sufficient quality of service. Within this area, the application will be accessible.
Mobility	It means the movement of user/devices with respect to location, velocity and direction over a period of time required for reception.
Interwork/roaming	It means the criteria for interworking/roaming agreements among network operators..

Security	It means the security requirement for the application.
Positioning	It means the required location based service and location data criteria for the application.
External dependencies	It means there are other dependencies not covered in the list of attributes.

2.2 Use cases descriptions

Ultrahigh fidelity Imaging for Medical Applications

In events such as disaster relief and first-response triage, technologies such as mobile X-ray radiography, mobile medical ultrasound or even mobile computed tomography can enable onsite medical personnel to receive assistance with diagnostic decisions by remote medical experts. This could also be applied to distant medical centers where medical experts are scarce. Concerning the mobile diagnostic imaging, the ultrahigh fidelity imaging is fundamental to guarantee the diagnostic value of the received data. Therefore, besides the source quality and lossless coding, the reliability of the connectivity is a must for this kind of application. In addition, near real-time data transmission is crucial under critical conditions, for example where xDSL or fiber connections are not available or in mobility scenarios, e.g. inside an ambulance or a helicopter. To achieve this it may also be needed to use "bonding", video is split over multiple connections from the same or different technologies or operators, including for example 5G bonded with satellite connection, 5G from two different operators or 5G combined with 4G to ensure service continuity, this will obviously need consideration of throughput and latency synchronisation.

To provide the expected level of diagnostic imaging service in case of first-response and disaster relief, devices intended for diagnostic imaging should have guaranteed priorities within the network. Since network overloads are common in the case of mass events and/or accidents and disasters, networks must provide appropriate mechanisms to prevent denial of service for first responders, medical personnel and similar units' devices considering alignment with Net neutrality regulation.

The use cases described here are relevant for the health and wellness industry that tries to increase human wellbeing, including medical equipment integration with live video feed (i.e., 4K, 8K) and real-time imaging (i.e., X-ray, Magnetic resonance imaging (MRI), computed tomography (CT), ultrasound, etc.) delivery. The imaging for medical applications requires ultra-reliability (i.e., 99.999%) and low latency (i.e., some scenarios require 20 ms).

The capabilities in Table 1 are relevant for imaging for medical applications.

Table 1: Capabilities required for imaging for medical applications use cases

Use case attribute	Low-latency services for imaging for medical applications
Description	Real-time peer-to-peer or server-client sharing of data (object information, live video feeds, etc.) for imaging for medical applications
Experience data rate	– Up to 1 Mb/s for object data – 4K (2160/60/P) H.265/HEVC: 30~40 Mb/s – 8K (4320/60/P) H.265/HEVC: 80~100 Mb/s – HD H.265/HEVC: ~10 Mb/s
Application Latency	20 ms
Reliability (IP packet within latency bound)	Critical for object data, important for video feeds
#devices	Up to 100/km^2
Battery	Important
Coverage	Important
Mobility	500 km/h (a customer can be sitting on a high speed train, but the user would be stationary/nomadic relative to the train due to the customer engagement)
Interwork/roaming	Needed
Security	Critical (identity, authentication, data integrity, privacy)
Positioning	– Location data (30 cm – 1 m) could help create new imaging for medical applications experiences utilising location information – Indoor positioning may also be useful
External dependencies	Digital rights management

Immersive and Interactive Media

Virtual Reality: Users, wearing a VR headset replacing their whole field of view, will be able to experience 360 videos, lightfields and 3D contents (e.g. 3D reconstructions of environments captured through photogrammetry of laser scan technologies). The user can experience the visit of specific locations of interest; with high-speed downloads of all the related content in order to realize a virtual reality experience.
This can be exploited to make specific content available remotely, but also to integrate existing content with additional information. Main areas of exploitation could be tourism and education.

Interactive Virtual Reality: Virtual and mixed reality technologies are going to have an increasingly important role in the next few years. Through appropriate mobile devices, two or more people interact in a virtual space, experiencing physical interaction even if they are not in the same location.

Advanced and photorealistic avatars will replicate eye movements, subtle facial expressions and the movement of the whole body of the user, further enriching the communication. This can be exploited in the area of entertainment, but also in the area of business/enterprise services.

Social VR is possibly the killer application for immersive technologies to succeed, and it likely represents the natural evolution of today's social networks.

Collaborative gaming will allow two or more individuals to exchange information through interaction and to work together to complete the task. Compared to single-player games, multiplayer games are more engaging because each individual experience is directly influenced by the other individuals. It includes a task beings divided into subtasks, with the performance of one player being influenced by the others. When two or more individuals contribute equally to achieving the task, it enhances positive social interaction. 5G networks can support collaborative gaming requirements of ultra-reliability, low latency and security.

The use cases described for immersive and interactive media, such as collaborative gaming and VR/AR, are relevant for the gaming and VR/AR retail industries and can revolutionize the world of gaming and shopping through its enhanced support for VR/AR since low latency with live video feed (i.e., 4K, 8K, HD) can contribute greatly in making VR/AR experience seamless. The gaming and retail industries requires ultra-reliability (i.e., 99.999%) and low latency (i.e., some scenarios require 20ms).

The capabilities in Table 2 are relevant for immersive and interactive media such as collaborative gaming and virtual & augmented reality.

Table 2: Capabilities required for immersive and interactive media use cases

Use case attribute	Low-latency services for collaborative gaming	Low-latency services for VR/AR shopping	Broadband services for live streaming in crowded areas
Description	Real-time peer-to-peer or server-client sharing of data (object information, live video feeds, etc.) for collaborative gaming	Real-time peer-to-peer or server-client sharing of data (object information, live video feeds, etc.) for VR/AR shopping	Live streaming of various angle views and replays at large mall or city centre for shoppers
Experience data rate	– Up to 1 Mb/s for object data – 4K (2160/60/P): 30~40 Mb/s – 8K (4320/60/P): 80~100 Mb/s – HD H.265/HEVC: ~10 Mb/s	– Up to 1 Mb/s for object data – 4K (2160/60/P): 30~40 Mb/s – 8K (4320/60/P): 80~100 Mb/s – HD H.265/HEVC: ~10 Mb/s	– 4K (2160/60/P): 30~40 Mb/s – 8K (4320/60/P): 80~100 Mb/s – HD H.265/HEVC: ~10 Mb/s
Application Latency	20 ms	20 ms	20 ms
Reliability (IP packet within latency bound)	Critical for object data, important for video feeds	Critical for object data, important for video feeds	Important
#devices	Up to 100/km^2	Up to 100/km^2	Up to 25,000 /km^2 (activity factor = 10%)

Broadcast/Multicast	No	No	Yes
Battery	Important	Important	Important
Coverage	Important	Important	Important for the place/venue where service is provisioned
Mobility	500 km/h (a gamer can be sitting on a high speed train, but the user would be stationary/nomadic relative to the train due to the game engagement)	Nomadic	Nomadic
Interwork/roaming	Needed	Needed	Needed
Security	Critical (identity, authentication, data integrity, privacy)	Critical (identity, authentication, data integrity, privacy)	Critical (identity, authentication, data integrity, privacy)
Positi oning	– Location data (30 cm – 1m) could help create new gaming applications utilising location information – Indoor positioning may also be useful	– Location data (30 cm – 1m) could help create new shopping experiences utilising location information – Indoor positioning may also be useful	– Location data (30 cm – 1m) could help create new shopping experiences utilising location information – Indoor positioning may also be useful
External dependencies	Digital rights management	Digital rights management	Digital rights management

Audio Streaming in Live Productions

This use case combines different professional scenarios in which audio PMSE (Programme Making and Special Events) equipment is used for live audio capturing and playback, such as presentation, musicals, concerts, studio recording, etc.. Common to all scenarios is that audio source and audio sink are very close together or often served by a single user, which leads to very stringent latency requirements.

Considering, for example, a live audio production with an artist singing on stage, who is equipped with an in-ear-monitoring system (IEM) to receive an individualized audio mix. Due to the particularity that the singer hears himself twice via the bone conducted sound propagation and via the IEM, the time difference between both signals will cause comb filter effects. The intensity of the effects may be off-putting causing them not be able to perform accordingly. Similar observations can be made with all kind of musicians, for whom physical coupling with the audio source is perceived in combination with the corresponding IEM signal. In practice, the round-trip time, defined from analogue input (the microphone) to analogue output (the IEM), must not exceed 4 ms. In a presentation scenario the round-trip time limit can be relaxed to a maximum of 20 ms before speakers get in trouble when hearing themselves via the loudspeaker standing next to them. In addition to the latency requirement of the communication service, synchronicity of the mobile terminal is also important to make future stereo and beamforming applications wireless. Here, synchronicity describes the maximum allowed time offset at application layer within the synchronized system between all device clocks and a reference signal. Third stringent requirement is reliability because in a live scenario there is often no

opportunity to repeat the audio capturing. Therefore, it must be processed without any audible disturbance.

This use case supports stringent requirements in terms of latency, reliability, and synchronicity.

The capabilities in Table 3 are relevant for audio streaming in live productions.

Table 3: Capabilities required for audio streaming in live productions use cases

Use case attribute	Low latency service for presentation	Very low-latency service for live audio streaming at big events	Very low-latency service for live audio streaming at AV productions	Very low-latency service for live audio streaming at audio studios
Description	Campus scenario with guaranteed QoS (data rate, latency, reliability, etc.) services to support microphones (UL)	Festival scenario with guaranteed QoS (data rate, latency, reliability, etc.) services to support microphones (UL) and in-ear monitors (DL)	AV production scenario with guaranteed QoS (data rate, latency, reliability, etc.) services to support microphones (UL) and in-ear monitors (DL)	Audio studio scenario with guaranteed QoS (data rate, latency, reliability, etc.) services to support microphones (UL) with high definition audio and in-ear monitors (DL)
Experience data rate	Up to 200 kbit/s per UE in UL	– Up to 500 kbit/s per UE in UL – up to 1 Mbit/s per UE in DL	– Up to 1.5 Mbit/s per UE in UL – up to 3 Mbit/s per UE in DL	– Up to 5 Mbit/s per UE in UL – up to 1 Mbit/s per UE in DL
Application Latency	5 ms	4 ms	4 ms	4 ms
Reliability (IP packet within latency bound)	Critical	Critical	Critical	Critical
#devices	Up to 1000	Up to 300	Up to 30	Up to 40
Broadcast/Multicast	Yes	Yes	No	No
Battery	Important	Important	Important	Important
Coverage	Important 1.5 km^2	Important 0.2 km^2	Important 1000 m^2	Important 100 m^2
Mobility	5 km/h (UE speed)	10 km/h (UE speed)	5 km/h (UE speed)	5 km/h (UE speed)

Interwork/ roaming	Not needed	Not needed	Not needed	Not needed
Security	Critical (identity, authentication, data integrity, privacy)	Critical (identity, authentication, data integrity, privacy)	Critical (identity, authentication, data integrity, privacy)	Critical (identity, authentication, data integrity, privacy)
Positioning	Not needed	Not needed	Not needed	Not needed
External dependencies	None	None	None	None

Remote, Cooperative and Smart Media Production incorporating UGC

More and more media content is being produced daily. It includes real time video, e.g, very highly promoted on social networks like Facebook or Whatsapp or WeChat, or non-real time – uploaded and shared. More and more professional content is also being created such as breaking news, sports events including lower ranking and even local events, reality shows, faith TV and other professional and semi-professional content. The production of this content has been facilitated by new technologies in cellular, video compression and editing, cloud editing and social networks distribution.. Multiple video feeds from the same content owner or from different ones may be transmitted to the cloud or to the professional studio (like TV), potentially in different qualities yet with more or less the same latency. Networks, technologies and links other than 5G cellular that may be available in some locations or venues (e.g. WiFi, fiber, LAN, 4G LTE) should be used seamlessly together with 5G in order to split the load, reduce congestion, increase video quality and number of feeds.

Cooperative media production integrates media from a variety of sources, e.g., professional production teams, drone cameras, and even user generated content (UGC). Remotely controlled 4K cameras as well as drone cameras may be used e.g. to closely track athletes, and wearable devices on athletes can collect vital/ meta-data (e.g. heartbeat, fatigue, location, temperature, etc.) for value adds on sports scenes. 5G can bring high uplink bandwidth to support such volumes of content and high resolutions, improved congestion handling for multiple transmission from the same area, lower latencies, and mobility – even from/to moving vehicles.

Media production firms and broadcasters traditionally relied heavily on dedicated, proprietary solutions to collect media inputs (e.g., live video feeds) from various sources and to process them at centralized production studios. Data analytics (e.g. video analytics and object recognition) could help to correlate and detect related media, for production and consumption efficiency. Content authentication, licensing and accessibility management are required together with guaranteed QoS for certain media/applications. 5G networks can support such media contribution / production if stringent bandwidth, latency, reliability and security requirements can be guaranteed.

The capabilities in Table 4 are relevant for remote & smart media production.

Table 4: Capabilities required for remote & smart media production use case

Use case attribute	Low latency service for remote & smart media production for real-time video or non-real-time videos updated and shared
Description	Remote & smart media production scenario with real-time video, e.g., very highly promoted on social networks or non-real-time uploaded & shared
Experience data rate	– Up to 1 Mb/s for object data – 4K (2160/60/P): 30~40 Mb/s – 8K (4320/60/P): 80~100 Mb/s – HD H.265/HEVC: ~10 Mb/s
Application Latency	20 ms
Reliability (IP packet within latency bound)	Critical
#devices	Up to 100/km^2
Broadcast/Multicast	No
Battery	Important
Coverage	Important
Mobility	500 km/h
Interwork/ roaming	Critical
Security	Critical (identity, authentication, data integrity, privacy)
Positioning	Not critical
External dependencies	None

Professional Content Production

TV and other professional media organizations have already been using cellular networks as their prime vehicle to transmit live video from the field, and also non-live. This has been used for news coverage, sports coverage, events coverage etc. It has been replacing traditional satellite trucks as well as enriching the professional content generation with a myriad of new applications, like live video from indoors, underground, tunnels, the air, moving vehicles, no-time to going live, etc.

One of the prime technologies to enable this is sometimes referred to as "bonding" – using multiple links/connections/modems/operators simultaneously together and splitting the content across these links. High reliability, high bandwidth links are even more of a requirement for uplinking higher quality live video formats such as UHD and AR/VR. Bonding may be done of multiple 5G operators, 5G with the venue fiber or DSL, 5G with 4G considering synchronisation between the different links.

The newest trend in remote production is what is sometimes referred to as "at home production". The idea is to minimize the cost of such field production by sending and deploying the minimal set of equipment and personnel and doing as much as possible of the production in fixed locations. For example, deploying only cameras in a stadium then sending the video from each camera back to the fixed production studio or even the cloud, where all the production will then be done. The benefits are huge in cost savings, ease of operation, enabling the production of more and smaller-scaled and localized events etc. In these cases the desire is to send in the uplink several (2-10) uncompressed video streams from the cameras in the event. The bandwidth for each uncompressed IP video (SMPTE 2110 or similar) may be 200-300 mbps and they should also be synchronized.

The capabilities in Table 5 are relevant for professional content production.

The use cases described for professional content production is for the media and entertainment industry, where media is with the ultimate quality anywhere, along with professional content production supporting low latency with live streaming and media production (i.e., 4K, 8K, HD) to meet consumers experience expectations. The professional content production use cases require ultra-reliability (i.e., 99.999%) and low latency (i.e., some scenarios require 20 ms).

The figures in Table 5 for Experience data rate show production requirements when uncompressed as well as when compression has been used. The exact bitrate needed varies between broadcasters, formats, use cases and the type of compression that is used. In some use cases a compressed HEVC video may be used, for example for HD news gathering. In other cases, uncompressed video is desired, for example for sports "at home" production (away from the venue of action). In some cases 4K sports is enough, in others 8K is expected. Additional parameters of the incoming feeds further impact the required bandwidth. The bitrate range is therefore quite broad, with the lowest being HEVC compressed (~80mbps) and the highest as much as 12gbps (uncompressed).

Table 5: Capabilities required for relevant professional content production use cases

Use case attribute	Guaranteed QoS broadband services for media production	Low-latency services
Description	Guaranteed QoS (data rate, latency, reliability, etc.) services to aggregate various media feeds at servers	Real-time peer-to-peer or server-client sharing of data (object information, live video feeds, etc.)
Experience data rate	- uncompressed video, HD to 4K: 2Gbps - 12 Gbps - "slightly compressed" IP video stream 200-300 Mb/s – 4K (2160/60/P): 30~40 Mb/s – 8K (4320/60/P): 80~100 Mb/s – HD H.265/HEVC: ~10 Mb/s	– Up to 1 Mb/s for object data – 4K (2160/60/P): 30~40 Mb/s – 8K (4320/60/P): 80~100 Mb/s – HD H.265/HEVC: ~10 Mb/s
Application Latency	20 ms	20 ms
Reliability (IP packet within latency bound)	Critical	Critical for object data, important for video feeds

#devices	– Up to 100 /km^2 for professional media feeds – Larger for consumer media feeds	Up to 100 /km^2
Broadcast/Multicast	No	No
Battery	Important	Important
Coverage	Important	Important
Mobility	500 km/h (media feeds may be from drones, helicopters, etc.)	500 km/h (a customer can be sitting on a high speed train, but the user would be stationary/nomadic relative to the train due to customer engagement)
Interwork/roaming	Needed	Needed
Security	Critical (identity, authentication, data integrity, privacy)	Critical (identity, authentication, data integrity, privacy)
Positioning	– Location data (30 cm – 1m) could help media production process – Indoor positioning may also be useful	– Location data (30 cm – 1m) could help create new media and entertainment applications utilising location information – Indoor positioning may also be useful
External dependencies	Digital rights management	Digital rights management

Machine Generated Content

This chapter encompass a number of use cases showing usage of machine generated content. It is not an exhaustive list but some examples.

Connected Drones for Infrastructure or Environmental monitoring: 3D mapping in various industries, such as oil & gas, agriculture, and logistics, Public safety and surveillance are just a few examples of the services that can be offered through UHD and 360° camera mounted on remotely operated drones. Beside remotely operated drones a large number of drones carrying cameras within a geographic area will:
- navigate themselves automatically,
- taking care of obstacles, weather, charged batteries,
- exchanging each other
Collaborate to cover a specified area with video feed + ad hoc BS

Mobile Video Surveillance: Public Safety Operators can wear connected camera while they are in action and send through the mobile network their video feed to a Video/Management/Localisation Platform that handles the registration and the coordination with the Operation Center. The Video Surveillance could be provided in conjunction with communication push to talk, to guarantee coordination among operators. Some of the most important use cases are:
1. Support to operational services for mass events (heads of state visits, parades, football games, concerts, ...)
2. Additional tool for managing critical situations in real time by the central from field
3. Surveillance access and sensitive areas on mobility
4. Video surveillance from helicopter.

Public Protection and Disaster Relief: body-worn devices, surveillance cameras, sensors may collect and send various parameters regarding environmental conditions (temperature, presence of toxic gases, water level, seismic activity, location of crowds, etc.), vehicular installed sensors (including autonomous driving public safety related vehicles) and responder's physical conditions (position, body temperature, heartbeat, air consumption, etc.) to the Operation Centre where data could be further analysed. This will enable the Incident commander to be better informed about the situation in the field which could be crucial in making decisions.

Smart City: Mobile webcam can be installed in the smart city. The images/streams acquired can be remotely processed to enable a variety of applications in different service areas:
- Monitoring parking areas: to determine the availability of parking slots, to verify the appropriate use, etc.
- Security reasons: biometric recognition, video surveillance, etc
- Monitoring the environment for safety reasons: management of emergency conditions. Etc.

Smart Agriculture: robots with advanced functionalities related to guidance, detection, action and mapping may be employed in agriculture to better monitor the environmental conditions and increase production.
These robots do not need guides on the floor, and avoid collisions with people and objects thanks to remote real-time processing of sensor data and images.

This use case described for machine generated content includes connected drones for infrastructure or environmental monitoring, mobile video surveillance, public protection & disaster relief, smart city and smart agriculture support stringent requirements in terms of latency, reliability, and synchronicity.

The capabilities in Table 6 are relevant for machine generated content.

Table 6: Capabilities required for user generated and machine generated content use cases

Use case attribute	Low latency service for connected drones for infrastructure or environmental monitoring	Low latency service for mobile video surveillance	Low latency service for public protection & disaster relief	Low latency service for smart city & smart agriculture, etc.
Description	Connected drones scenario with guaranteed QoS (data rate, latency, reliability, etc.) services to support video feeds, etc.	Mobile video surveillance scenario with guaranteed QoS (data rate, latency, reliability, etc.) services to support video surveillance and video feeds, etc.	Public safety and disaster relief with guaranteed QoS (data rate, latency, reliability, etc.) services to support body worn devices, surveillance cameras, sensors to collect & send information	Remote real-time processing of sensor data and images with guaranteed QoS (data rate, latency, reliability, etc.) services to support video feeds, etc.
Experience data rate	– Up to 1 Mb/s for object data – 4K (2160/60/P): 30~40 Mb/s – 8K (4320/60/P): 80~100 Mb/s – HD H.265/HEVC: ~10 Mb/s	– Up to 1 Mb/s for object data – 4K (2160/60/P): 30~40 Mb/s – 8K (4320/60/P): 80~100 Mb/s – HD H.265/HEVC: ~10 Mb/s	– Up to 1 Mb/s for object data – 4K (2160/60/P): 30~40 Mb/s – 8K (4320/60/P): 80~100 Mb/s – HD H.265/HEVC: ~10 Mb/s	– Up to 1 Mb/s for object data – 4K (2160/60/P): 30~40 Mb/s – 8K (4320/60/P): 80~100 Mb/s – HD

				H.265/HEVC: ~10 Mb/s
Application Latency	20 ms	20 ms	20 ms	20 ms
Reliability (IP packet within latency bound)	Critical	Critical	Critical	Critical
#devices	Up to 1000	Up to 1000	Up to 1000	Up to 1000
Broadcast/Multicast	No	No	No	No
Battery	Important	Important	Important	Important
Coverage	Important	Important	Important	Important
Mobility	500 km/h	500 km/h	500 km/h	500 km/h
Interwork/ roaming	Needed	Needed	Needed	Needed
Security	Critical (identity, authentication, data integrity, privacy)	Critical (identity, authentication, data integrity, privacy)	Critical (identity, authentication, data integrity, privacy)	Critical (identity, authentication, data integrity, privacy)
Positioning	– Location data (30 cm – 1m) could help connected drones process – Indoor positioning may also be useful	– Location data (30 cm – 1m) could help mobile video surveillance process – Indoor positioning may also be useful	– Location data (30 cm – 1m) could help public protection & disaster relief process – Indoor positioning may also be useful	– Location data (30 cm – 1m) could help smart city and smart agriculture process – Indoor positioning may also be useful
External dependencies	None	None	None	None

Collaborative Design including Immersive Communication

Immersive videoconferencing and collaborative designing environment could also be considered, aggregating media feeds from all participants in real time, and enabling people to meet, discuss and collaborate in a virtual location, while having the experience of being in the same physical room or

space. To make this possible each participant needs to be able to receive, in real time, the audio-visual feed of all other participants so they can smoothly interact with them, both verbally (e.g. speaking) and visually (e.g. body language, shared document, artefact and/or activity).

To achieve this a combination of network processing and device requirements need to be met. Specifically:

- the network shall be capable to transmit, both in uplink and downlink, a large amount of bandwidth at a very low latency
- the audio-visual feeds generated at different locations shall be synchronized before being displayed to the end user, however the introduction of too much additional delay due to synchronization should be limited or avoided, to enable a real-time experience
- solutions shall take device requirements into account, in fact the ability of devices to decode different audio-visual streams may be limited
- scalability, the above properties should scale well for a large and a dynamic number of participants
- dynamic path adaptation based geo-located and physical network architecture
- high resolution video transfer that includes enriched content, multi-users, multi-sites

The capabilities in Table 7 are relevant for immersive videoconferencing and collaborative design.

Table 7: Capabilities required for collaborative design including immersive communication use case

Use case attribute	Low latency service with a large amount of bandwidth for immersive videoconferencing and collaborative designing environment
Description	Real-time peer-to-peer or server-client sharing of data (audio-visual feeds of all other participants and can smoothly interact with them, both verbally e.g. speaking and visually e.g. body language, shared document, artefact and/or activity, etc.)

Experience data rate	– Up to 1 Mb/s for object data
	  – 4K (2160/60/P): 30~40 Mb/s
	  – 8K (4320/60/P): 80~100 Mb/s
	– HD H.265/HEVC: ~10 Mb/s

Application Latency	750 µs (E2E latency)
Reliability (IP packet within latency bound)	Critical
#devices	Up to 100/km^2
Broadcast/Multicast	Yes
Battery	Important
Coverage	Important
Mobility	500 km/h (a designer can be sitting on a high speed train, but the user would be stationary/nomadic relative to the train due to the designer engagement)
Interwork/ roaming	Needed

Security	Critical (identity, authentication, data integrity, privacy)
Positioning	- Location data (30 cm – 1 m) could help create new gaming applications utilising location information - Indoor positioning may also be useful
External dependencies	None

Dynamic and Flexible UHD Content Distribution over 5G CDNs

In 5G CDNs will heavily rely on virtualization techniques even in the mobile edge segment. With the high reconfigurability and heterogeneity of the network, we can expect novel forms of exploiting traditional adaptive coding. Low latency requirements will mean adaptation has to be performed in the network, limiting the applicability of pure adaptive streaming protocols such as DASH. For this purpose we can foresee a DASH streaming service to be constructed fewer descriptions per segment and being based on scalable coding techniques that can allow exploitation of adaptive modulation and coding (AMC) techniques as well as adaptive scheduling algorithms.

Eventually also multiple description coding could be exploited providing multipath (and multi-radio interface) capabilities. Other techniques potentially useful could be related to join handover indications with prefetching content to the new site. Also, device mobility information could be used for selecting the most appropriate edge cache holding a copy of the sought content. The testbed could be extended to include a "follow me" feature to allow the user to set requests and the network to comply with them while the user moves. At the same time, novel network and coding features should also be future proof and be designed keeping the abilities of (legacy) end user devices into account, which should still be able to obtain at least a (basic) version of the content.

To support efficient multi-viewer delivery of live content in this use case and any other, broadcast and multicast capabilities are needed, such as designed by the 5G-Xcast project.

TV and radio are consumed on many different devices and in many different usage scenarios. A traditional, linear service is understood as a curated integrated service, which could be a 24/7 linear live channel but could also be complemented by on-demand elements. For a 5G network iteration there should also be considerations for future types of "linear" such as skipping songs, shows, replacing (parts of) programme items.

Linear is downlink only in broadcast mode, i.e. a certain portion of spectrum is permanently consumed by TV/Radio services - independently from the number of viewers. This can then be combined with on-demand elements obtained in unicast mode known as "hybrid applications" (e.g. as is the case with HbbTV).The use of on-demand apps (Video on Demand, Audio on Demand) is by nature an individual affair and requires bi-directional communications and unicast mode.

Places such as stadiums, cinemas and hall parks are becoming increasingly connected to the digital world, with the purpose of further engaging their users.

Augmented onsite live event experience: this means enhancing the experience of the onsite visitors, for example by means of augmented reality, providing them with additional information relating to the live event. Such information may be previously available or be created in real-time.

Personalised onsite live event experience: this use case caters for personalizing the visitors' experience, for example allowing them to select (additional) camera angles to view, zoom in certain areas of the location which would otherwise be too far away or not visible from their current location, or view replays of the just played content or view related content.

On site live events can be classified into scheduled (e.g. sport matches, music concerts, festivals) and unpredictable/unexpected events (e.g live news, emergency support).

<u>Scheduled events</u> are planned by TV organizations employing professional equipment like 360° degree cameras, 4K cameras that are controlled remotely, and UHD video streams. Additionally, video streaming produced for users attending the event could be properly conveyed by professional equipment to enhance media fruition or delivered directly to final users as direct video communications.

<u>Unpredictable/unexpected events that cannot be planned in advance and</u> need to be streamed at unpredictable time, from both TVs and users in the area of the event.

The fundamental difference between the two kinds of events is related to the time available for infrastructure setup, with the second scenario possibly critical also for environmental aspects.

Both cases require setup of the media delivery and the related communication support for a limited period of time, i.e. the duration of the event.

Broadcasting and multicasting via eMBMS, 5G broadcast and multicast and seamless transition to unicast, can also enable the delivery of high quality video to many users without consuming more bandwidth.

The capabilities in Table 8 are relevant for dynamic and flexible UHD content distribution.

The use case described for dynamic and flexible UHD content distribution allows high reconfigurability and heterogeneity of the network, in which broadcast and multicast capabilities are required along with linear TV and radio.

Table 8 Capabilities required for dynamic and flexible UHD content distribution use case

Use case attribute	Low latency service with high reconfigurability and heterogeneity of the network	Live event experiences
Description	Dynamic and flexible UHD content distribution scenario that support the applicability of pure adaptive streaming protocols such as DASH, in which a DASH streaming service can be constructed by not having as many descriptions per segment as allowed qualities but rather being based on scalable coding techniques that can allow exploitation of adaptive modulation and coding (AMC) techniques.	AV production for live event experiences with guaranteed QoS (data rate, latency, reliability, etc.). On site live events can be classified into scheduled (e.g. sport matches, music concerts, festivals) and unpredictable/unexpected events (e.g live news, emergency support,…).
Experience data rate	– 4K (2160/60/P): 30~40 Mb/s – 8K (4320/60/P): 80~100 Mb/s – HD H.265/HEVC: ~10 Mb/s	– Up to 500 kbit/s per UE in UL – Up to 1 Mbit/s per UE in DL
Application Latency	20 ms	750 µs (E2E latency)

Reliability (IP packet within latency bound)	Critical	Critical
#devices	Up to 100/km^2	Up to 100/km^2
Broadcast/Multicast	Yes	Yes
Battery	Important	Important
Coverage	Important	Important
Mobility	Nomadic	10 km/h (UE speed)
Interwork/ roaming	Needed	Not Needed
Security	Critical (identity, authentication, data integrity, privacy)	Critical (identity, authentication, data integrity, privacy)
Positioning	- Location data (30 cm – 1m) could help create new experiences utilising location information - Indoor positioning may also be useful	Not needed
External dependencies	Digital rights management	Digital rights management

Smart Education

The future learning model will be an immediate, virtual, and interactive environment which enables students to learn and interact in different ways than they do today.

This can be envisaged as follows: by using distributed cloud and mobile edge computing to support such learning models, future mobile technology will enable single device content access anywhere, empowering students to resume their work at a convenient time and place through different devices, with an impression of immediate response time.

The advent of the tactile internet in 5G will help us to move from today's content and information delivery Internet to a skillset delivery internet. This will create new ways of tele-teaching and tele-mentoring especially for training and skill development, bringing a new experience for distance learning and distance team-working. It can provide the possibility of removing the physical location constraint for experimental practices, and facilitate the sharing of resources between larger numbers of students irrespective of their physical location.

VR, and AR apart from their expected promising future in gaming and entertainment industry will play a big role in providing quality education and improving understanding-based learning and "reversed classroom" techniques among students and teachers. The nature of these services can make learning much more interesting and fun, and therefore persuading students to spend more time on their subjects. These services will also enable us to provide the right amount of information at the right time to the right users; Context Sensitive Training.

Combination of tactile internet with VR and AR will add a new dimension to tele-teaching, tele-mentoring, virtual university, virtual classroom, virtual team-working, etc., helping to provide more personalised vs. one-size-fits-all, problem-solving and question-asking vs. learning facts and figures, practical application vs. theory, and on-demand vs. time-specific based learning.

The use case described for smart education is relevant for the education sector and can transform our teaching and learning experience making it personalized by combining education and VR/AR since low latency with live video feed (i.e., 4K, 8K, HD) can contribute greatly in making VR/AR experience seamless. The education industry requires ultra-reliability (i.e., 90%) and low latency (i.e., some scenarios require 20 ms).

The capabilities in Table 9 are relevant for smart education.

Table 9: Capabilities required for relevant smart education use cases

Use case attribute	Low-latency services for smart education
Description	Real-time peer-to-peer or server-client sharing of data (object information, live video feeds, etc.) for smart education
Experience data rate	– Up to 1 Mb/s for object data – 4K (2160/60/P): 30~40 Mb/s – 8K (4320/60/P): 80~100 Mb/s – HD H.265/HEVC: ~10 Mb/s
Application Latency	20 ms
Reliability (IP packet within latency bound)	Critical for object data, important for video feeds
#devices	Up to 100/km^2
Broadcast/Multicast	No
Battery	Important
Coverage	Important
Mobility	500 km/h (a learner can be sitting on a high speed train, but the user would be stationary/nomadic relative to the train due to the learner engagement)
Interwork/roaming	Needed
Security	Critical (identity, authentication, data integrity, privacy)
Positioning	- Location data (30 cm – 1m) could help create new gaming applications utilising location information - Indoor positioning may also be useful
External	Digital rights management

dependencies	

2.3 Media&content application requirements

5G slicing for vertical industries is foreseen as being the building block for growth opportunities in this 5G digital transformation era, especially the media and entertainment and automotive industries. These vertical industries capabilities are diverse and can be clustered into 9 key categories which cover most of the situations from production to consumption:
- Ultrahigh fidelity imaging for medical applications
- Immersive and Interactive Media
- Audio Streaming in Live Productions
- Remote, Cooperative and Smart Media Production incorporating UGC
- Professional Content Production
- Machine generated content
- Collaborative design including immersive communication
- Dynamic and Flexible UHD Content Distribution over 5G CDNs
- Smart Education

There can be different requirements on functionality for all the different services/applications. Moreover, use case requirements may be mapped to particular services based on capabilities and performance (QoS) level parameter settings. As each use case is defined to meet different service/application requirements, which can be represented by a certain capabilities and performance (QoS) level. Table 10 provides a mapping of service/application requirements based on capabilities and performance (QoS) level parameter settings.

Table 10: Feature list of services/application requirements and QoS level (c.f. note at the end of the Table)

Parameter / requirement	1	2	3	4	5	6	7	8	9
1- Latency									
Metric 1 – up to 3ms			x				x		
Metric 2 – 10ms									
Metric 3 – 20ms	x	x		x	x	x		x	x
Metric 4 – >20ms									
2- Reliability									
Metric 1 –									

<90%									
Metric 2 – 90%			x						
Metric 3 – 99.99%		x		x	x	x	x	x	x
Metric 4 – 99.999%	x								
3- Data Rate									
Metric 1 – up to 10Mbps		x	x						
Metric 2 – 30-100Mbps		x	x						
Metric 3 – 200-500Mbps									
Metric 4 - >1 Gbps	x	x		x	x	x	x	x	x
4- Mobility									
Metric 1 – 60 km/h Low)			x						
Metric 2 – 130 km/h (Medium)									
Metric 3 – 250 km/h(high)									
Metric 4 – 500 km/h (very high)	x	x		x	x	x	x	x	x
Metric 5 – no mobility									
Metric 6 – nomadic			x		x				
Metric 7 – stationary		x							
5- User Density									
Metric 1 – 4000/km	x								
Metric 2 – 10000/km									

	1	2	3	4	5	6	7	8	9
Metric 3 – 250000/km		x							
Metric 4 – 500000/km			x						
6- Positioning									
Metric 1 – <30cm									
Metric 2 – 30cm-1m	x	x			x	x	x	x	x
Metric 3 – >1m									
7- UE Speed									
Metric 1 - up to 60 km/h									
Metric 2 - up to 130 km/h	x						x	x	
Metric 3 - up to 250 km/h									
Metric 4 - up to 500 km/h		x		x		x			x

Note: The 9 key categories listed above represents the following: 1) imaging for medical applications, 2) Immersive and Interactive Media, 3) audio streaming in live productions, 4) remote & smart media production, 5) professional content production, 6) machine generated content, 7) collaborative design including immersive videoconferencing, 8) dynamic and flexible UHD content distribution along with linear TV & radio, and 9) smart education,.

3. 5G Capabilities and Parameters

This section provides a short description of 5G network capabilities which will be used to describe the functionality of the 5G media slices.

3.2 5G Capabilities

The concept of slicing is posing several challenges to network providers to support and operate the different kinds of 5G services and related requirements, with one main issue to solve whether slice control will be kept fully or partially by tenants or by the providers.

Slicing is a functional partitioning of resources, either physical or virtual, available in network infrastructures and configured according to service requirements. Different kind of services and needs can be provided on the same infrastructure by applying resource slicing and maintaining their requirements by static or dynamic segregation. This concept is coming from and in agreement with the definition of slice given by the Next Generation Mobile Network Alliance (NGMN) as a means to run multiple logical networks on a common physical infrastructure [4.1].

5G enabling infrastructure is the result of a concatenation of the radio section, transport section and cloud section, controlled by SDN orchestration to support and operate different services according to their requirements. In particular, each segment contributes to latency in terms of propagation and processing delay which directly impacts on the concept of media slicing. Providing end-to-end slicing in 5G networks presents several design challenges both in terms of latency, bandwidth and timing [4.2]. The emerging e-CPRI standard based on packet transport is introducing enhanced network flexibility while giving the opportunity to adopt Ethernet/IP networking, synchronization and security relying on existing standards.

Cloud like facilities to support Network Function Virtualization (NFV) and Software Defined Network (SDN) management are increasingly being introduced for efficient and flexible slice support. Anyway, architectures for slice operation and orchestration are still a relevant area of research.

As far as orchestration is concerned, it is introduced to support end-to-end instantiation and configuration of network service, possibly across multiple domains and multi-service scenarios. The concept of dynamic orchestration is emerging as a solution based on existing products that are pre-integrated with each other to support specific business use cases and exploit the most of network function virtualization [4.3].

As far as slice implementation is concerned, an edge or remote cloud approach can be adopted, depending on whether either latency or centralization gain are dominant requirements. Different approaches can be found mostly with reference to the degree of flexibility of the slice itself. While in principle a flexible slice management is envisaged as desirable, this conflicts with complexity and latency constraints. Current implementations tend to divide the task between what can be defined as "core slices" which will then be able to interface different "edge slices" in the access section through proper interface APIs. These slices are "application aware" so that vertical applications can be easily matched to the most appropriate slice. As an example, in the MATILDA project the slice can be logically divided in a core component and an edge component with the first exposing to the second one a user model through a RESTful API. The QoS parameters are managed according to the 5G definition of bearer which automatically represents the access part as a virtual link between UE and 5G core. This currently limits the reconfigurability and the ability to allow using different bearers with different SQIs. The reference scenario for the demonstrator is specifically for the 'video sharing' use

case being part of a recommendation system. In their approach, the requirements set for the slice sets a limit to delay and jitter to 100ms and a packet loss probability not greater than 0.001%. Bandwidth, CPU, memory scale depending on the actual request [4.6].

Different network architectures need to be chosen in relation to application requirements in particular with respect to latency while achieving trade-off between centralization and latency. Mobile edge computing solutions must be adopted when service latency requirements are lower than 10 ms. When service requirements go down even further, i. e. latency in the range of 1 ms, the application must be placed as close as possible to the user.
A slice manager is needed in each entity involved as a part of the slice, i.e. application entity, distributed unit (DU), centralized unit (CU). Enhanced flexibility can be supported by the RAN NG paradigm in slice configuration.

For example eMBB services typically benefit from centralization gain with latency requirements typically not so stringent, i.e. greater than 20 ms.
Multiple media slices can be configured on the same infrastructure depending on QoS targets and tenants. To achieve good efficiency dynamic resource allocation among slices is recommended.

Another important capability is the enhanced support of multicast and broadcast, being under process in the upcoming 3GPP releases (Rel 16 and 17), and as developed and demonstrated in the 5G-Xcast project. The relevant capabilities are designed into the standalone 5G New Radio and the 5G Core Network, via flexible session control and resource management functions and having network functions in both user and control planes. This results in a network-agnostic content distribution framework to optimise network resources dynamically, agnostic of the slice being used. The underlying capabilities include:
- Broadcast and multicast point to multipoint (PTM) capabilities for 5G considering M&E, automotive, IoT and PWS use cases.
- Dynamically adaptable 5G network architecture with layer independent network interfaces to dynamically and seamlessly switch between unicast, multicast and broadcast modes or use them in parallel and exploit built-in caching capabilities.
- Broadcast/Multicast in specific geographical areas.

3.2 5G Parameters

GSMA has defined how network slices can be characterized in relation to service needs by introducing the concept of Generic Slice Template (GST). The GST is a set of common slice attributes that can be used to define the network slice type. By filling values into GST the NEST (NEtwork Slice Type) is obtained that can be used by vendor to feature their products or by the customers to understand what operators are offering in a vertical sector. The service requirements must be identified in advance in order to obtain the corresponding NEST.

In 3GPP TS 23.501, the Slice/Service Type (SST) is used to refer to an expected network slice behaviour in terms of features and services (eMBB,URLLC and MMTC). No values are specified for these SSTs. This task can be completed by the association of standardized NESTs (S-NESTs) with one or more SSTs.

Some performance indicator parameters have been defined and related to the different media services as described in [4.4] and that must be taken into account in the design of different media slices. Each Network Slice Instance (NSI) needs to be designed to meet different service/application

requirements, which can be represented by a certain level of capabilities and performance requirements (QoS).

The emerging e-CPRI standard introduces transport network parameters and requirements in relation to a few classes of services (CoS) [4.5]. Bandwidth requirements are reduced with the adoption of higher layer functional splits. Per flow requirements are classified into low, medium and high with respect to user and control/management plane frames taking into account delay and packet loss parameters. Maximum one way frame delay performance results, as a consequence, can be reduced to a few tens of microseconds for the more stringent latency class.

Mapping of service parameters into slice parameters is nowadays considered of particular importance not only to properly run the slice itself, but also to create a methodology to communicate network capability to customers and facilitate network interoperability with multiple operators.

To map a service into a slice, In practice, the GST reports the attributes used by an operator to characterize an application. Starting from a general service description, a customer driven description is obtained in terms of class of service (e.g. URLLC, capacity, number of connections, latency, reliability, location...) as reported in tables of section 2. This GST is connected with a NEST provided by the operator, which satisfies the service requirements. These information are used to configure a Network Service Template that will be used for slice deployment within the cloud.

As an example, for multicast and broadcast distribution requirements could include the configuration of an feMBMS system to deliver TV services with parameters such as
• Free-to-air and receive-only mode i.e. free-to-air reception without SIM Card and without contractual obligation with a network operator;
• The possibility to dedicate 100% of the available radio resources to broadcast;
• The definition of a longer cyclic prefix (CP) of 200 μs, to cover Inter Site Distances (ISD) up to about 60 km in a Single Frequency Network (SFN) scenario.

This information could be provided in the NEST in response to a GST from a broadcaster. This functionality together with NFV could offer many co-operative models for delivering the required slice type such as a service being provided from a broadcast owned and operated core network using shared transport and RAN resources of an MNO. The other way round, a broadcast managed Radio Access network could offer excess capacity not required for linear content in form of network slices for eMBB unicast to MNOs' core networks. Similar co-operative models based on different entities managing their respective network slices can be imagined for a range of business cases.

4. 5G Media Slice Description

One of the fundamental questions regarding slicing for media and entertainment is whether there will be one slice for all services and use cases, or whether there would be multiple media slices. In the scenario of multiple media slices, important sub-questions are what type of slices they will be and how many there will be. This chapter provides an initial direction to answer these questions.

4.1 5G Media Slice Properties

To be useful to vertical sector users, a slice instance needs to have certain characteristics, enabled by the slice capabilities mentioned in Section 3.

Relevant characteristics for a media slice are: the RAN bandwidth (both in uplink and downlink), the bandwidth on the DN (Data Network) interface(s), the latency experienced by the delivered service, the VNFs (Virtual Network Functions) running in the network. Examples of VNFs that are useful in the media and entertainment sections are, for example, network assistance (communication to the end user application with respect to bandwidth available / expected latency), in-network cache, media ingest, transcoding, processing, image recognition, rendering. A Media slice intended for downstreaming needs to support multicast/broadcast in order to efficiently serve large numbers of viewers of the same live content. Unless for the case of traditional linear distribution, a desirable feature for the slice would be the ability to cope with different UE constraints therefore introducing scalable and/or multiple (sub)stream options to take advantage of transmission over multiple links, and eventually technologies, (*bonding*) wherever possible.

4.2 5G Media Slice APIs

Once slice instances or slice instance templates are created, Media Service Providers (MSP) need to be provided with mechanisms to monitor and control the slice(s) where their services are deployed, as per 3GPP requirements (3GPP TS 22.261).

In order to enable this, monitoring and control APIs may be offered by the 5G network operator, for example to:
- request a list of available slices for the service
- instantiate a slice instance, with certain properties
- remove a slice instance
- request a modification of a slice property
- request addition of a property (e.g. a new function)
- request status of slice and its properties
- measure the provided QoS
- request one or more (edge) media VNF(s)
- request the use of Broadcast/Multicast

4.3 5G Media Slice Architecture

One fundamental question regarding the 5G Media slice architecture is whether there will be one media slice for all media use cases and applications. As observed in Section 2, the media and entertainment use cases are quite varied, with different requirements and tolerance to requirement fulfilment. It would therefore make sense to have several 5G media slices, perhaps grouped in categories with similar requirements, or perhaps even for each application use case. For example for linear TV and radio applications it may be desirable that a separate slice is used, which may be provisioned similarly to DVB standards today. In this scenario, virtual channels (known as physical layer pipes in DVB-T2) could be used to reserve a certain amount of capacity for TV and radio services at a physical layer and above layers would then rely on eMBMS/enTV specifications for broadcast delivery. Other video services, e.g. on-demand streaming from online platforms such as youtube and facebook, have less stringent requirements than live TV and may be delivered within the same (shared) media slice.

The need to differentiate among different media slices has been recognized by 3GPP, which is currently defining the 5G Media Streaming (5GMS) architecture (3GPP TS 26.501). At present, the 5GMS architecture distinguishes between two types of slices, one for downlink streaming services and one for uplink streaming services. It should be noted that a slice for downlink streaming services is designed to support the bulk of traffic in downlink, but also permits traffic in uplink, e.g. for control messages. The same principle also holds for the slice targeted at uplink streaming services.

To enable MNOs as well as broadcasters and online media content providers to offer high quality downlink streaming services to mobile users, the 5GMS architecture introduces the so called *trusted media functions*. Trusted media functions are deployed both in the network and on the UE, and interface with external media application servers and media functions via APIs, that guarantee access control and authorization, as well as differentiation among collaboration models between the operator and the media content providers. Trusted media functions located in the mobile network include Application Functions (AFs - which are VNFs capable of influencing traffic routing and policy management for a specific application) as well as Application Servers (ASs - which are VNFs that interact with the media content itself, such as a cache or a transcoder). Beyond executing control actions on behalf of the UE or external media application servers, media AFs also control and configure the usage of the ASs deployed in the mobile network itself, e.g. selecting the closest AS to a specific user.
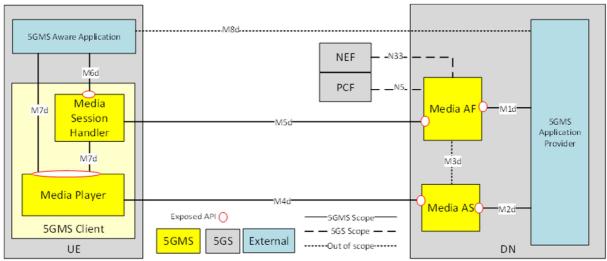

Figure 01 : High-level view of 5GMS downlink architecture

Figure 01 shows a high-level view of the 5GMS downlink architecture, with the trusted functions highlighted in yellow. Following the 5G approach of separating control plane from user plane, the 5G media downlink streaming architecture defines «media control interfaces» M5d/6d/7d between the UE and the AFs in the 5G network, in order to carry signalling parameters and media configuration information. Conversely, the media user interface M4d between the UE and the AS's is used to carry the media content itself. A similar separation is carried out in the exposure of AFs' and ASs' APIs towards external media application servers (interfaces M1d and M2d respectively).
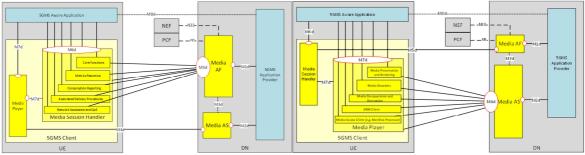

Figure 02 : View of UE performing downlink streaming

Figure 02 shows a close-up view of a UE performing downlink streaming, with the trusted media functions located below the horizontal dashed lines. The Operator App and the Third-party App, located above the horizontal dashed line, will use APIs M8d/9d/10d to access the UE media trusted functions. Several UE media trusted functions may communicate to the AF(s) located in the mobile network in order to use 5G capabilities to improve the delivery of the service. Specifically, the Media Session Handler may receive help in the establishment of the session. Consumption reporting may provide information on the currently consumed media, on the UE capabilities and on the environment of the media session which in turn may be used by the AF for potential transport optimization within the mobile network. The Media Access client receives the media data from the AS, which can be either located within the mobile network (among the trusted media functions) or outside of it (external media application server).
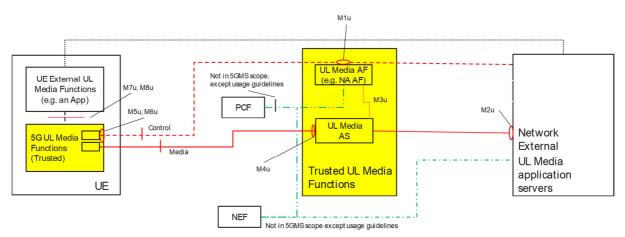

Figure 03 High-level view of 5GMS uplink architecture

Figure 03 depicts the high-level functional architecture for the 5GMS uplink architecture. Any media function can use network services, which are exposed by an MNO using exposure APIs. The UL Media AS receives media content from the UE(s) via the M4u interface and can then forward the content to an External application server, using the M2u interface. Depending on the configuration of the M1u API, the UL Media AS may do additional processing.
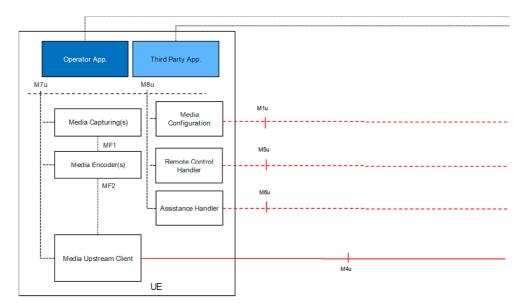
Figure 04 UE model for Uplink Media Streaming

Figure 04 depicts the UE model for Uplink Media Streaming. Operator and third party apps may access the trusted UL media functions using APIs (M7u and M8u). APIs on the M7u are used to manage aspects of the media content that is being recorded, e.g. influencing the media capturing, encoding and upstreaming processes. The Media Upstream Client is responsible for streaming media content to the UL Media AS. APIs on the M8u interface are used for signalling and session configuration.

The Media Configuration function is used to configure (via the UL Media AF), the UL Media AS, which acts as a sink for the uplink streaming. The configuration procedure can include media processing and media forwarding from the UL Media AS to other functions as well as session specific QoS or charging configuration. The Remote Control Handler offers Remote Control capabilities to authorized UL Media AFs. This allows remote controlling of e.g. drone mounted cameras. Remote control is also widely used within professional media production cases. The Assistance Handler is used for any sort of network assistance. Applications may use only a subset of the functions or all functions, depending on the application needs.

4.4 5G Media Slice Usage Models and number of media slices

The 5G media slices can be defined as subtypes of the eMBB slice type, which is meant for applications requiring large amount of bandwidth. Additionally, elements of the other two types of slices (latency from URLLC and density from mMTC) should also be taken into account, when needed by the specific media use cases requirements.
Some of the use cases identified in Chapter 2 use only one of the slice types defined above, as exemplified in the table below.

Table 11: List of Use Cases using one slice type

Use Case	UpLink slice	DownLink slice
Ultrahigh fidelity Imaging for Medical Applications	✓	
Remote, Cooperative and Smart Media Production incorporating UGC	✓	
Professional Content Production	✓	
Machine Generated Content	✓	
Dynamic and Flexible UHD Content Distribution over 5G CDNs		✓

Other use cases, identified in Chapter 2, requiring a combination of both uplink and downlink traffic, often with strong latency requirements, are the following:
- Immersive and Interactive media
- Audio Streaming in Live productions
- Collaborative Design including Immersive Communication
- Smart Education

For these use cases the uplink traffic needs to be synchronised or correlated to the downlink traffic. In order to support these use cases, the 5G system should provide one of the following:
- a new type of slice with support for downlink and uplink at the same time
- the ability to link an uplink slice to a downlink slice in order to synchronise or correlate the uplink traffic and the downlink traffic running through them, respectively.

Finally, a design choice which remains still largely unexplored today is that of the number of media slices that a 5G system should support. Different possibilities, or perhaps a combination of those, exist, such as:
- just one media slice for all media services
- just one media slice for all downlink media service and one media slice for all uplink media services
- one personalized media slice for each media service provider
- hybrid (one shared downlink slice + one shared uplink slice + personalized media slices for requesting MSPs).

4.5 Collaboration scenarios

A key objective of 5G media slicing should be the ability to enable collaboration scenarios between a third-party content and service provider and an MNO, for potentially mutual benefits. Ideally, the 5G system should be designed in a way that allows an external provider to access a subset of functions in the 5GMS system to generate complex workflows, but at the same time leave certain control within its own domain.

A few examples of collaboration scenarios envisioned by 3GPP within the context of the 5GMS architecture are provided below:
- MNO CDN: the MNO acts as a CDN for the third-party provider. The third-party provider uses well-defined interfaces to upload streaming content to the MNO and also uses a subset of the

3GPP defined 5GMS functions (e.g., Content delivery protocol, Network Assistance, Session Management, Metrics collection) for optimized delivery. Codecs, DRM, Manifest format, etc. are all under the control of the third-party provider.

- Live Broadcast: The third-party provider pushes a live service into the network in a proprietary format. The MNO transcodes that content into 5GMS compatible formats and the 5G Aware application uses the 5G MS Player for playback of the content. Codecs, DRM, Manifest format, etc. are all under the control of the MNO. The MNO also ensures timely delivery of the service.

Media Processing: The third-party provider uploads the content in a defined format as done for an origin server, but the MNO adds additional functionality, for example it provides targeted and regional ad insertion, it does automatic captioning of the content by using network internal AI functions.

5. Conclusions & recommendations

This paper provides an in-depth complete description of the needs of 5G for media&content use cases and applications. Looking at the media chain, 5G would be used in both content production and content distribution, and therefore we foresee a significant impact on the media services delivery and user devices. Production and distribution requirements are substantially different and must be considered separately.

We have considered the requirements of 9 use cases, covering a broad spectrum of existing and expected media services, from which we have identified 12 parameters that should be used to adapt the network to the following application requirements, such as: latency, reliability, data rate, mobility, user density, positioning, user equipment speed.

Looking to the 5G network capabilities and parameters that could be activated, the previous section provides a description of the 5G Media Slice**s**. There is a "s" because one of the main conclusions of the paper is that, looking to the media chain - which encompasses a number of functionalities and operations such as content creation, service composition, service aggregation, distribution, use device, user interaction and interface - 5G should be used differently for production, which needs mostly uplink capacities, and distribution, which needs mostly downlink capacities.

There are many different production use cases such as news gathering, broadcast live events, on-site live events, audience services in a venue, wireless studio, media files transfer which have an impact on the 5G network (network availability, reliability, bandwidth, guaranteed QoS, latency, synchronisation, redundancy).

On another hand, there are also different use cases in the distribution chain such as live/linear TV & radio, on demand TV & radio, hybrid radio & TV, UGC, VR/AR, … which required specific network capacities such as bandwidth, reliability, resilience, security, coverage.

The next step is to push this paper to standardisation organisations in order to bring recommendations for the definition and description on the 5G Media slices. In addition, we recommend that at least one of the ICT-19 5GPPP projects implements an example of media slicing as described in this paper in order to validate the pertinence of current definitions and to bring additional recommendations.

This paper is not providing any technical description of the 5G Media Slice, there is still a need for such a specification work.

References:

[4.1] NGMN Alliance, NGMN Network Slicing "Description of Network Slicing Concepts"
[4.2] P. Rost et al., "Network Slicing to Enable Scalability and Flexibility in 5G Mobile Networks"
[4.3] https://www.ericsson.com/en/press-releases/2017/5/ericsson-introduces-dynamic-orchestration
[4.4] NGMN 5G White Paper
[4.5] e-CPRI specification v 1.2 - 2018 - www.cpri.info.
[4.6] http://www.matilda-5g.eu/index.php/outcomes