



Key Media & Content use cases in the context of 6G

(December 2021)

Executive summary

This document is the outcome of a joint effort between two European Technology Platforms, i.e., New European Media (NEM) and NetworkEurope. Such a result has been obtained by pulling together expertise from the media sector, which led to the definition of application requirements, and from the network domain, which supported the definition of future 6G technical requirements.

Eight use cases have been identified, covering most of the main Media&Content scenarios from production to consumption, as well as referring to new unforeseen media applications, in which Metavers is a very recent example.

From these eight use cases, twelve *network requirements* were derived and identified as instrumental to provide an enhanced user-experience compared to current standards. Such requirements are: extreme high bandwidth, low latency, Non-Public-Networks (NPN) capabilities, configurability, automation high power edge computing, fast handover capabilities, low jitter, reliability, security, multiple access and infrastructure.

This document also provides six *application requirements* such as: network-aware media, “New” media, AI-based media provisioning and orchestration, distributed, decentralized in cloud/edge architecture/infrastructure, synchronization, energy-efficient media applications/software.

The two main objectives of this document are: i) to identify requirements that are not covered well enough by the Smart Network and Services phase 1 work program and propose them as targets for the next phases; ii) to push research topics proposals to the Next Generation Internet work program 2023-2024.

The Conclusions and recommendations section proposes to address a number of research areas which are not sufficiently taken into account in the work program 2021-2022.

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Abbreviations

ABR: Adaptive Bit Rate
AI: Artificial Intelligence
AMWA: Advanced Media Workflow Association
API: Application Protocol Interface
APN: Access Point Name
AR: Augmented Reality
CDN: Content Delivery Network
CGI: Computer Generated Imagery
CN: Core Network
CNF: Containerised Network Function
CPE: Customer Premise Equipment
DPC: Data Processing Center
DTT: Digital Terrestrial Television
E2E: End to End
EMF: Electro Magnetic Field
FVV: Free Viewpoint Video
GPS: Global Positioning System
GSMA: Group Special Mobile Association
HD: High Definition
HDR: High Dynamic Range
HTTP: HyperText Transfer Protocol
HW: HardWare
eMBB: enhanced Mobile BroadBand
IoT: Internet of Things
KPI: Key Performance Indicator
MEC: Multi-access Edge Computing
MIMO: Multiple Input Multiple Output
ML: Machine Learning
MPTCP: Multi-Path Transmission Control Protocol
MR: Mixed Reality
NEM: New European Media Initiative
NGI: Next Generation Internet
NGN: Next Generation Networks
NMOS: Networked Media Open Specifications
NPN: Non-Public Networks
NTN: Non Terrestrial Networks
NTP: Network Time Protocol
OB Van: Outside Broadcast Van
OTT: Over The Top
PLMN: Public Land Mobile Network

PN: Public Network
PTP: Point To Point
QoE: Quality of Experience
QoI: Quality of Interaction
QoS: Quality of Service
RAN: Radio Access Network
RTP: Real Time Protocol
SDI: Serial Digital Interface
SLA: Service Level Agreement
SMPTE: Society of Motion Picture and Television Engineers
SNS: Smart Network and Services
SW: SoftWare
TSN: Time-Sensitive Network
UC: Use Case
UE: User Equipment
UL/DL: Uplink/Downlink
UHD: Ultra High Definition
URLLC: Ultra Reliable Low Latency Communications
VNF: Virtual Network Function
VOD: Video On Demand
VV: Viewpoint Video
VR: Virtual reality
WP: Work Program
xDSL: x-Digital Subscriber Line
XR: X-Reality

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1. Context

The objective of this document is to promote Media & Content technologies and use cases that could take advantage of 6G technologies and capacities. It is also a way to influence the forthcoming 6G system design with specific requirements that are mandatory to achieve these innovations.

The recent announcement of the Metavers vision, i.e., a fully immersed world of connected people and machines, is just one futuristic example where extreme media communications and other technologies meet. This document takes this into account such innovation in the context of 6G.

The methodology used started from use case description and technical requirements identification, then the list of technical challenges has been developed and finally compared with the ongoing WP 2021-2022.

The European Commission is beginning to work on the definition of the next work program 2023-2024, this document can be considered as an input to contribute to the definition of research topics for the Smart Network & Services partnership regarding the network technical challenges and for the Next Generation Internet (NGI) (Cluster 4) regarding the Media & Content technical challenges.

2. Use cases

This section describes a number of key use cases that could take advantage of the planned 6G network capacities.

Use cases below can be projected in several verticals as explained in the previous section

The eight use cases taken into consideration in this document, which are going to be detailed below, can be projected in several verticals, such as:

- Health: remote surgery, remote consultation, etc.
- Education: remote teaching
- Mobility: video sensing, object detection and tracking, IoT sensing, etc.
- Entertainment: TV, media, gaming, etc.
- Industry: collaborative design, digital twins, IoT sensor-based robotisation, etc.
- Agriculture: Automatic earth analysis and culture
- Tourism: remote visits
- Cultural heritage: preventive conservation, VR recreation, etc.

2.1. Use case 1: Professional Content Production

2.1.1. Description

In a professional production environment, the traditional Serial Digital Interface (SDI) mesh of the production centre, with dedicated point-to-point connections, is progressively being replaced by new IP transport architectures and protocols, typically based on SMPTE ST-2110 and ST-2022 protocols, the AMWA Networked Media Open Specifications (NMOS), or other similar ones, to facilitate the transport of different types of essence between the functional areas of the a production centre. This migration causes important benefits not only for production activities located in the centre itself (e.g., facilitating the reuse of production infrastructure for different sets, depending on which one is in use, or allowing automatic identification of equipment connected to the network), but also for allowing remote or distributed professional productions and remote contribution scenarios, with remotely connected infrastructure making use of the new features of recent networks to reconfigure themselves, facilitate negotiation of the necessary quality of service (QoS), and providing new information transport capabilities. Media productions greatly vary in terms of size, complexity, location, duration, and being live or not. They may include the production of high-value content and unique sports, cultural, political or other events, which may be associated with stringent technical and commercial requirements. Production formats continuously evolve towards better quality and higher immersiveness

2.1.2. Technical requirements

The complete migration from traditional SDI architectures to IP-based networks will offer many advantages to professional production facilities, bringing them closer to the user base. The new 6G networks are expected to offer unprecedented use of Artificial Intelligence (AI) and

the ability to reconfigure as needed, carry any type of signal without the need for signal-specific interfaces, virtualisation of functions, and ease of resource orchestration. The design of the new networks must guarantee sufficient capacity, including large uplink and bandwidth, ultra-low latency where required, highly accurate timing, adequate redundancies and security measures to avoid losing information, absolute flexibility to reconfigure the production infrastructure in such a way that it can meet the daily planning needs of the 24/7 centre, control of latencies and jitters in the transport of the essences and adequate dimensioning to facilitate scalability, operational flexibility and agility in the future. This is all part of the new possibilities of the Next Generation Networks (NGN) to negotiate the offered QoS and to allow resources to be distributed intelligently and appropriately. NGN shall support a range of implementation scenarios, from public networks to stand-alone dedicated networks, and shall facilitate cloud-based production workflows and Multi-Access Edge Computing (MEC) solutions.

To summarize the discussion so far, one can identify the following requirements for the Professional Content Production use case.

Application requirements:

- Work with uncompressed, or slightly compressed, 4K-8K production video
- Allow for distributed production architectures
- Allow for remote production architectures (hybrid: on-site Outside Broadcast (OB) Van; fully remote: cloud or remote studio)
- Allow for multi-source media feed synchronization (various levels of precision, one frame or even lower for some audio productions)
- Ability to seamlessly connect and manage new equipment
- IP-Based
- Support new media paradigms, such as Virtual/Augmented/Mixed Reality (VR/AR/MR) and holographic communications
- Capable of working anywhere, including cell edges.

Network requirements:

- Support for extremely high bandwidth (Gbps) in uplink
- Support for low-latency communications, either for low bandwidth or high bandwidth streams (several level of latency requirements; including sub 1 msec for some very tight audio productions)
- Low jitter in latency and bandwidth
- Non-Public-Networks (NPN) deployment capabilities as well as commercial, PN-based enhanced Mobile BroadBand (eMBB) remote production
- Easily configurable Radio Access Network (RAN) parameters
- Service Level agreement (SLA)-based network slicing for Public Land Mobile Networks (PLMN)
- Very high power edge computing capabilities for some applications.

2.1.3. Stakeholders

To make migration possible, it is necessary to combine the efforts of different actors, such as:

- Professional media producers
- Network infrastructure providers
- Service providers
- Users acting as content producers, either as amateurs or freelance professionals

- Equipment manufacturers (for monitoring, information compression, capture, storage, display, etc.)
- Software developers

2.1.4. Vertical projections

- Entertainment, news: Local, distributed and remote content production.

2.2. Use case 2: Holoconferencing and Social XR

2.2.1. Description

The maturity of immersive and interactive technologies together with the pandemic, have fuelled the development of Social VR, AR and MR platforms that enable users to meet, immersed or not, in 3D environments, to develop a certain task, such as learning and training, designing and engineering, entertaining, etc. These platforms aim to go far beyond the typical mosaic of upper body video representations in video-conferencing platforms. Social XR promises to provide higher levels of realism, immersion and interaction, and steer collaboration through higher levels of (co)presence, thus overcoming current limitations of 2D user representations in multi-party conferencing. Examples of Social XR platforms include Mozilla Hubs, Facebook Spaces / Horizon, AltspaceVR / Mesh, etc. Most of these platforms rely on the use of synthetic avatars, Computer Generated Imagery (CGI)-generated, to represent the participant users. In parallel, the latest volumetric capture developments enable the recreation of photo-realistic volumetric replicas of humans, which can be in turn inserted in such collaborative 3D environments. In addition, volumetric photo-realistic representations have shown higher levels of Quality of the Interaction (QoI) than CGI-based avatars when used for real time volumetric capture.

Holoportation, volumetric video, 3D lightfields, from capture to transmission and display, will enable the deployment of holo-conferencing services. Holoportation is expensive in terms of computational and network needs when Viewpoint Video (VV) capturing technologies are used, and it will be even more expensive as real time volumetric capture systems provide higher qualities thanks to better cameras, capture technologies and deep learning algorithms. Also, beyond point-to-point holoportation, holo-conferencing implies scalability in terms of number of users.

2.2.2. Technical requirements

Holoconferencing presents three main challenges. First, the volumetric capture needs to be photo-realistic, i.e., of great visual quality, comparable to that of High Definition (HD) or Ultra HD (UHD) in the 2D video domain. Second, scalability, i.e., holoconferencing services are expected to provide service to an increasing number of users, just like the latest videoconferencing tools during the pandemic. Third, holoconferencing services will have to deal with legacy formats and multiple 3D representation formats (i.e., users and also objects in the 3D domain can be represented, depending on the use case needs, with a video projection, a 3D mesh, a point cloud, a lightfield, or even Free Viewpoint Video (FVV) user representations).

Application requirements:

- Allow for AI-enabled acquisition and error-resilient scalable compression of HQ multi-sensory XR content including photorealistic VV and 3D light-field, as well as virtual, alongside other sensory modalities (e.g. haptic, 3D audio etc.).
- Allow for multi-user immersive applications with interactive features.
- Use of VR, AR, MR and holoportation with full sensing capabilities.
- Allow for immersive representations in high-detail 360-degree virtual content or highly photorealistic (e.g. VV, 3D lightfields).
- Provide an enhanced experience over current conferencing tools.

Network requirements:

- Enable the deployment of specific computational efforts on edge nodes.
- Ensure high bandwidth capacity among micro services that, in turn, are distributed across the network, between cloud DPCs, edge computation nodes, and the client devices.
- lowest latency, tactile network, specially for collaborative or interactive environments that have a replica in the physical world (e.g., driving a car remotely).
- handover capabilities that include, not only at transmission level, but also to transfer computational efforts that need to be available and continuous in mobility environments (e.g., edge rendering, edge volume reconstruction, AI components based on upload data streams, compression algorithms, distributed volume capture systems, etc.).

2.2.3. Stakeholders

- Software developers
- Telecom operators
- Device manufacturers
- Integrators

2.2.4. Vertical projections

- Any vertical: Teleconference via holographic displays
- Education via VR/MR/XR environments
- Telemedicine, either for training and education or for remote diagnosing and remote surgery
- Industrial applications, such as remote working via VR/MR/XR or digital twinning
- Immersive entertainment

2.3. Use case 3: Multi-source media time synchronization

2.3.1. Description

In several use cases (UC), sharing a common, reliable and accurate time source between components is required in order to optimize service experience and extend usable use cases. This is relevant for local and remote media productions, to vehicular video transmissions, XR, multi-cam robotics, gaming, drone flying and others. Distributing this time source within a network (specially in wireless ones) is a complex matter and can therefore be viewed as a UC

on its own. The leader clock may be co-located with the follower clocks or be remotely distributed to them.

Several video feeds, in a single location and/or multiple locations (multi-sites), close by or remote, using the same network and operator, or different ones, shall need this time source in order to synchronize latencies, video frames, audio inputs, and other key characteristics.

2.3.2. Technical requirements

There are several levels of accuracy, depending on the specific UC. For audio synchronization, such as in HQ audio productions including several microphones, speakers etc, the level of accuracy between devices at the receiving end (e.g., mixer, local production room etc), is preferred at <1 msec; for HQ multi-cam productions, a max 1 frame synch is needed (e.g. at 25fps, 30 fps, 60 fps etc). redundancy, frequency etc; Could potentially include two or more leader clocks being transmitted (in sync), timestamping media and/or packets “out of band” etc.

Sub-frame synchronization is often desired, but perhaps not mandatory. Potentially various “degrees” of accuracy/beet’ may be supported, such that require more or less resources and effort, match specific conditions, architectures and configurations, rather than having the most strict requirement “fit all” approach.

Application requirements:

- Support readily-available time synchronization mechanisms, such as PTP and NTP, GPS-based synch or network-based solutions
- Support media transmission protocols that allow inter-stream synchronization, such as RTP
- Support different type of media essences timestamping (audio, video, 3D video)
- Allow for different time “profiles” or requirements

Network requirements:

- Go beyond current 5G Time-Sensitive Networks (TSN) features, e.g., not only being “sensitive” to time, but also providing accurate time and support/enable “guaranteed” time-based QoS for applications at various tens of msec, msec and sub-msec accuracies.
- Support readily-available time synchronization mechanisms, such as PTP and NTP, specific solutions within the network protocols which are also exposed to external applications on both UE and CN side
- Network needs to be a time-aware component that does not introduce high delay but most importantly, does not introduce any jitter (sub-frame in 60fps).
- Optimized RAN for low jitter and latency
- Optimized CN for low jitter and latency
- Network needs to have a similar UL-DL delay
- Provide high-power edge computing

2.3.3. Stakeholders

- Network providers
- Service providers
- Application developers

2.3.4. Vertical projections

- Media production (especially in the contribution process).
- Entertainment (media delivery to final users such as sports, esports).
- Telemedicine, either for training and education or for remote diagnosing and remote surgery
- Industry: Robotics, e.g. industrial processes, autonomous navigation, etc.

2.4. Use case 4: Ad-hoc local production

2.4.1. Description

In some media productions, a local mesh communication may need to be established, with or without involving a remote side/studio/cloud production. For example, a local production where low-cost, low-power devices (to allow co-location as well as long duration and low cost services), communicate with each other in the same area (e.g. cameras, mics, sensors, etc.) at a very low, fixed and reliable latency, which 6G might be able to provide support for. This allows resources saving (not having to send up and down the packets that anyways are used locally), lower latencies and hence increased use cases, increased reliability (due to the lack of backhauling etc), support of local broadcast/multicast in the production area only, usage of more bandwidth via NPN, etc.

2.4.2. Technical requirements

Ease of rapid deployment of a local NPN or PN. Support multi-“island” deployments. Mesh, UE-UE and UE-multi UEs support. Self-organizing/self-arranging, self-healing, self-adjusting (to various different traffic patterns) networks. Ease of integration with non-terrestrial (satellite) backhauls/networks. Ease of management UEs, authorizations, service assignments. Multiple levels of services, such as a guaranteed low-BW slot-timing for audio delivery, high BW high reliability time-synched service for A/V (audio-video such as from cameras), low-BW, low latency command and control service (to allow remote control of equipment).

Could perhaps consider Sidelink as a candidate basis for the “mesh” deployment.

Application requirements:

- Allow equipment to work with wireless capabilities
- Allow for multi-source feed synchronization
- Ability to seamlessly connect and manage new equipment
- IP-Based

Network requirements:

- Support for extremely high bandwidth (up to Gbps) in uplink

- Support for low-latency communications, either for low bandwidth or high bandwidth streams
- Low jitter in both latency and bandwidth
- Easily configurable RAN parameters

2.4.3. Stakeholders

- Network providers
- Service providers
- Application developers

2.4.4. Vertical projections

- Media production (TV, production houses, at-home studios)
- Entertainment / Live events: Sports, esports

2.5. Use case 5: Network Assisted Bonding Video Uplink Delivery

2.5.1. Description

Application level bonding might be still required in 5G for remote and local production of HQ, reliable and live video. This is the result of the increase in video resolutions (4K and future 8K and even non-compressed or softly compressed with mezzanine coding at > 200 Mbps per stream), new techniques such as HDR, XR streams, multi-camera setups in the same location etc. while coverage, propagation and other issues prevent real life supporting the demand. 6G may be able to support some of these new requirements, but probably not in real life scenarios. Hence, application level bonding of multiple networks, technologies and modems is still envisioned as an important feature for remote production and various other UCs of delivering video in the uplink.

An overall 5G/6G architecture that supports such cross-layer cross-domain communications, could potentially also benefit non-media verticals, UCs and applications such as in mobility (e.g. coordinating with mobile applications an upcoming handoff). A localized solution rather than full architecture, just for this media vertical UC, may also benefit other verticals and UCs.

In order to achieve higher performance, network assisted bonding is foreseen important. In this bonding UC, the network entities will exchange data with the application, allowing for example the bonded transmission to use a different modem (or network) for a specific duration when informed of a coming handover. The bonded video transmission, for these UCs, will become more robust, predictive, lower cost to both application user and the network operator.

2.5.2. Technical requirements

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stream), new techniques such as HDR, XR streams, multi-camera setups in the same location etc. while coverage, propagation and other issues prevent real life supporting the demand. 6G may be able to support some of these new requirements, but probably not in real life scenarios. Hence, application level bonding of multiple networks, technologies and modems is still envisioned as an important feature for remote production and various other UCs of delivering video in the uplink.

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Application requirements:

- Stream multiplexing and de-multiplexing over multiple connections, from different network operators
- Support for multiple types of media essences (video, audio, 3D video, holograms)

Network requirements:

- High-bandwidth, UL focused network (Gbps)
- High-reliability connections

2.5.3. Stakeholders

- Network providers
- Service providers
- Application developers
- Potentially modules vendors

2.5.4. Vertical projections

- Industry
- Public services: Emergencies
- Entertainment: gaming (cars, drones, etc.), Sports, esports
- Media production environments, especially in the contribution process.
- Transportation/mobility applications

2.6. Use case 6: Immersive telecontrol

2.6.1. Description

Traditionally, the remote control of machines has been restricted to emergency situations in dangerous areas where the presence of a human operator is not feasible. For example, areas with high radiation, very high temperatures, etc. In other situations, this alternative was not used because of the limited amount and quality of information that can be provided to the human operator, which was never comparable to the real experience.

The capabilities provided by 5G networks have opened this option to new use cases, and it is not uncommon to hear about remote surgery, remote driving, remote piloting, among others.

The quality of the experience for the remote operator has been incredibly increased, but it is still far from the live operation. 6G networks should be able to provide completely immersive video, for example by streaming 360 8K 3D contents with no or very low perceived latency. Furthermore, information for other senses should also be captured and transmitted, such as high quality 360 audio or haptic information from the control systems.

The pose and actions of the operator also have to be captured and interpreted. 6G networks can also provide the computing power to understand the actions intended by the operator just by analysing the video captured by a camera, complementing the information provided by other sensors.

2.6.2. Technical requirements

Immersive telecontrol systems will have to:

- Capture high resolution, 360, 3D, and high frame rate images and transmit them without noticeable latency or quality loss.
- Provide a high bandwidth and low latency communication channel.
- Provide edge computing power to process video streams, extract analytics, AI/ML provision, orchestration and processing, robot movement or route planning, etc.

These capabilities should work even (and especially) in harsh environments, so features such as robust connections (redundancy) or high quality positioning (especially indoors or in GPS denied areas) will be desirable.

Application requirements:

- 3D displays/headsets, high resolution screens.
- Rich input devices (in terms of sensed interaction, haptic interfaces, etc.).
- High quality audio.
- Edge support (for low latency video processing, AI, etc.).

Network requirements:

- Ultra-reliable low-latency communications.
- High bandwidth UL capabilities.
- Provide high-power edge computing with very low latency.

2.6.3. Stakeholders

- Operators
- Machinery manufacturers
- Emergency agencies
- Camera/sensor/controller manufacturers
- Codec developers/solution providers
- Video analytics developers/solution providers
- AI developers/solution providers

2.6.4. Vertical projections

- Manufacturing: Industrial applications, such as remote working via VR/MR/XR or digital twinning

- Public services: Emergency response situations with telepresence, where human intervention is not feasible
- Army: Remote vehicle/aircraft piloting
- Media production camera operators

2.7. Use case 7: Content storage optimised management

2.7.1. Description

Today, people are shooting pictures/video with their mobile phone and usually publish them on a number of cloud storage services and social networks. Consequently, one content is duplicated in several location which brings 2 main concerns:

1/ Not energy efficient at all, storage in servers and network usage (upload/download) are consuming a lot of energy that could be saved.

2/ No possibility to control the access to a specific content and no possibility to remove exhaustively a content.

A possible solution should be to store one content in one single location and to give access to authorised persons with no possibility to download it or to replicate it. This storage location could be a cloud platform or a specific device totally under the control of the end user owner.

2.7.2. Technical requirements

This use case is needing to use 3 technologies, one is dealing with the storage processing, the second with the access right management and the third one with the network up/down link.

- Storage processing: a location where the content is stored, it could be a cloud server, a home device, a mobile phone, ...
- Access right management: the access to this content is under control of the content owner, no one can download it, only remote access is available with authorisation
- Network up/down link: the access to the content should be easy and with a good QoE

Application requirements:

- remote content visualisation (picture, sound, video, XR, documents, ...)
- access right management by the content owner

Network requirements:

- High uplink bandwidth to upload content on a cloud server or to distribute content to one authorised remote device
- End2end Security to avoid content hacking
- able to take advantage of a network based on multiple access technologies (e.g. cellular, wireless, wireline, satellite,...)
- Multicast, broadcast capabilities

2.7.3. Stakeholders

- Data center host
- Application developer
- Social networks
- Regulatory/policy

2.7.4. Vertical projections

This use case could be easily replicated to any content from any verticals (entertainment, Education, Health, Industry, Tourism, ...).

2.8. Use case 8: CDN orchestration

2.8.1. Description

New generation networks based on 5G evolution and 6G are meant to deliver huge volumes of video, on any screen, ubiquitously. Video streaming, which is currently overtaking broadcast viewing and meant to replace it in the next decade, is one major contributor to that traffic. 5G and 6G are even potential candidates to replace legacy television broadcast systems in the future, like DTT (Digital Terrestrial Television) or satellite television.

With the generalization of ultra-high-definition devices and new, immersive video formats, users have higher expectations for video. While VOD services like Netflix and Disney+ may work, watching live TV over a cellular network is rarely a smooth experience, especially during popular live programs, such as sporting events. These challenges should soon extend to fixed networks users as streaming becomes more and more dominant.

Therefore, video service providers need new solutions to deliver a prime streaming experience to their fixed, fixed wireless and mobile subscribers.

Content Delivery Networks (CDNs) have become a vital function in fixed and mobile internet networks. Without CDNs, transmission networks and content origin servers would be constantly saturated, with a disastrous impact on user experience. However, CDNs must adapt to the new world where HTTP-based streaming, mobile & fixed wireless usage and bandwidth-intensive content are becoming the norm.

One of the most promising technology evolutions for CDNs is to make them fully dynamic and virtualized. To maximise streaming efficiency and QoE while minimising network and infrastructure cost, CDN instances must be orchestrated and placed where and when needed, in a dynamic way, sometimes very close to the users (at the network edge) if necessary.

Some first CDN orchestration prototypes have emerged, but they have limited capabilities and maturity.

The objective of the present proposal is to move CDN orchestration to a new level in the context of 5G evolution and 6G.

2.8.2. Technical requirements

The target CDN orchestration system shall benefit from 5G evolution and 6G through the following aspects:

- Integrate the **new Telco Edge Cloud paradigm**. Abstract and opportunistically use any kind of edge compute infrastructure/models: private cloud, public cloud, device edge, GSMA Operator Platform Telco Edge, etc. Why 6G helps: The edge is a native and preponderant element of new 5G and 6G architectures.
- Leverage 6G as a **multi-access convergent system** – Combine multiple accesses (cellular, Wi-Fi, fiber, xDSL, etc.) at transport layer level (ABR-streaming aware MPTCP algorithms). Why 6G helps: thanks to its performance on par with fiber, 6G is meant to increase the opportunities for dual-connectivity uses, from 3GPP and non-3GPP networks.
- Add **intelligence** – Introduce AI/ML engines and robots to optimize user streaming sessions (re)allocation, CDN instances (re)deployment and system analytics. Why 6G helps: 6G networks are designed to allow AI/ML to be present at all levels (physical, network, applicative layers).
- Enable **deeper dataplane integration** to devise an **environmentally responsible system** – Integrate CDN SW workloads with low-energy HW infrastructures using energy-efficiency techniques, while maximizing processing and throughput efficiency. Why 6G helps: 6G will expose APIs that will allow better integration of the dataplane for reduced power consumption of VNF/CNFs.

Application requirements:

- Energy-efficient application software
- Support for ML/AI, e.g. for dynamic and intelligent VNF/CNF placement

Network requirements:

- Ready for fully virtualized/containerised and orchestrated workloads
- Multi-access Edge Computing (MEC) architecture and framework in place with a rich ecosystem of APIs and services
- Support for a multi-access convergent architecture
- Support for multipath protocols at transport layer (MPTCP/MPQUIC)
- Support for very high DL bandwidth (Gbps)
- Energy-efficient hardware

2.8.3. Stakeholders

- Communication / Internet Service Providers
- Content Providers
- Public Cloud Service Providers
- Network vendors
- CPE and (mobile) device manufacturers
- Application developers

2.8.4. Vertical projections

This use case is primarily intended for

- Entertainment: Video streaming industry (OTT platforms/services, pay-TV service providers, etc.), e-gaming industry, social networks (User Generated Content).

3. Global technical requirements

This section is identifying the technical challenges that need to be addressed in the Work Program 2023-2024 in order to ensure the feasibility of Media&Content use cases.

3.1 Network requirements

3.1.1 Extreme high bandwidth

The challenge is to provide high bandwidth (Up to 1 Tbps) on demand both up and downlink through the development of optimised spectrum management, fixed backhaul, midhaul, fronthaul and long haul networks. It has to cover fixed-line, mobile and NTN networks in order to provide an end-to-end solution.

Note that this is not “peak” bandwidth but a sustainable consistent bandwidth with minimal jittery behaviour.

3.1.2 Low latency

The requirements to benefit from ultra-low-latency (sub-millisecond) connectivity in the RAN, taking into account spectrum re-farming, improvements on millimetre wave technologies such as ultra massive MIMO, unified air interfaces, and continuing improvements on technologies for massive connections (such as random multiple access, broadcast/multicast architectures, and cell free networks).

These technical requirements should also be addressed for all types of networks (satellite, optical, Wifi, ...) and edge computing should also be considered to optimise functional placement and as a consequence latency.

3.1.3 NPN capabilities

Non Public Networks allow users to build, configure and customize the network to specific customer needs (in terms of coverage, security, privacy, latency, reliability, capacity, etc.). Nevertheless, the deployment of NPN might imply a cost that many companies are not able to afford. Thus, it is necessary to create cost-efficient solutions with flexible architectures that can be adapted to the requirements of different customers or applications. In addition, NPNs need to support various deployment scenarios where they can be implemented as standalone end-to-end solutions or by using sharing principles (either in core or RAN segments) over the public network.

3.1.4 Configurability

The challenge is to make the various network segments configurable, while including RAN, core, and transport networks. RAN configurability shall enable the implementation of dynamic RAN sharing service models in order to improve the network capacity, the QoE of users, and energy consumption, as well as the implementation of advanced resource sharing and market

place mechanisms. Auto-reconfigurability is particularly necessary during unexpected service outages (or other forms of hazards, natural or man-made) to guarantee enhanced reliability. Core configurability is necessary to support customized vertical (industry) needs by means of network slicing technologies, by the implementation of dedicated private networks (NPN), or others. Both RAN and Core network functions need to be conceived to enable customizing bandwidth, latency, data rate, number of supported customers, billing, specialized security, resource sharing, etc.

The expectations towards fully configurable network infrastructures are about increased programmability and interoperability (over the corresponding vertical and horizontal interfaces) as well as, zero touch configuration mechanisms (from deployment and during the whole service lifecycle).

3.1.5 High power edge computing

The challenge is to offer an open, secure, distributed, possibly decentralised, edge computing architecture and implementation, optimally integrating heterogeneous communications and networking in edge computing for IoT, with a value chain perspective opening innovative IoT applications and control. The work brings virtualization and disaggregation in different segments (home, edge, datacentre, NTN ground and on-board flying nodes), under the scope of multi-access edge computing concepts, to address functional placement and optimised computing distribution capabilities as a function of requirements emerging from ultra-low latency, ultra-high capacity immersive applications.

3.1.6 Fast Handover capabilities

5G and 6G users expect these technologies to support mobility, allowing UEs to change the location quickly. Not only cars, trains or different kinds of aerial vehicles will require being serviced by a large number of base stations, but also pedestrians in areas covered by small cells will initiate many handovers while connected. Traditionally, a handover only required maintaining the voice or data connection alive, but now the strict requirements in terms of parameters such as latency or bandwidth will also demand rapid relocation of applications or services to an infrastructure close to the user's new location.

3.1.7 Low jitter

Many applications require a very low latency for their operation, but in certain applications, the human user can tolerate the higher latency. Nevertheless, if the latency variation is significant, the experience will be greatly degraded, thus techniques to mitigate its impact or to take action before it becomes too high are necessary. Achieving low jitter communications is a complex task due to the current best-effort model of current, non-specialized networks, interferences, scheduling, etc.

3.1.8 Reliability

The challenge is to address the reliability/trust challenges created by fully virtualized solutions, increased network programmability, extended network exposure and tight integration to service providers and non-public networks. It includes secure and reliable technologies for

efficient containers and smart and secure container orchestration, with reliable software virtualization, with fast instantiations and mobility support seen as promising primitives for supporting these novel security architectures

3.1.9 Security

The target security architecture should be able to support flexible security policies in very distributed (and continuously changing) settings complementing traditional perimeter protection technologies. The scope includes a set of complementary topics which handle the securitisation of 6G technologies, (radio, virtualisation, orchestration, safe code, supply chain), Data centric application for AI usage in 6G, and dynamic E2E security life cycle of 6G systems and services. Also, user personal data protection and privacy must be guaranteed.

3.1.10 Multiple access

The challenge is to provide and improve technologies to support access agnostic and massive connections in any situation. It should cover random multiple access, broadcast/multicast/unicast architectures, and cell free networks. The best network connectivity should take into account application requirements as well as cost and end user preferences.

3.1.11 Infrastructure

5G and 6G network architectures are meant to be ultra flexible, open, automated and energy-efficient. This is the condition for network slicing – one of the most important technology enabler of 5G/6G – to emerge. The first and primary requirement for the infrastructure is to be cloud-ready, if not cloud-native. This means that efficient and resilient virtualisation/containerisation environments have to be devised, deployed and orchestrated. The vertical HW/SW disaggregation of telecom network functions is a challenge in itself, in terms of interoperability and performance. The variety of vendor solutions and systems add complexity, not forgetting the increasing use of public cloud as infrastructure for 5G Core and Radio network functions, that call for multi-cloud capabilities and overlay orchestrators. Moreover, if 5G had defined targets of power-efficiency, 6G makes the environmental and societal responsibility at the very center of its project. 5G and 6G infrastructure will require SW instances and underlying HW platforms to be integrated such a way that network functions and application softwares fully exploit the potential of HW platforms to make the overall system energy-efficient; these HW platforms will also need to be intrinsically low-consumption.

3.1.12 Automation

Fully automated procedures are required to deal with the increasing number of customized networks and advanced features. Service deployment automation is required from the business layers leading to the implementation of AI mechanisms able to translate natural language-based customer requirements into technical and deployable solutions. Thus, zero touch principles need to be proposed at each layer of the network stack while including automated infrastructures (zero touch OS & cloud deployments, resource discovery, auto-sale up/down, auto-scale out/in of cloud native network functions, etc), automated lifecycle management of network functions (onboarding, configuration,

instantiation, activation/deactivation, monitoring, service level enforcement), self-organized service management (end-to-end service level validation, multi-domain support).

3.1.13 Sustainable ICT and CO2 Footprint

The big challenge is to meet all the network requirements from 3.1.1 to 3.1.12 by evaluating the sustainability of the ICT solutions as well as its global CO2 footprint. This means that the whole process, comprising the design of the basic units, devices, infrastructures, etc. of the system must be considered as well as the cost/consumption associated to the system for its working, providing innovative functions and applications and maintenance. Associated with that, new models able to account for these specific sustainability and CO2 features of ICT systems should be introduced.

3.1.14 Coexistence and Interaction between different technologies

Another fundamental technical requirement that has not been sufficiently addressed right now, is the design of specific agnostic mechanism to make different communication technologies coexisting and interacting in order to be able to meet the QoS defined by the underlying applications, with a specific regard to the energy consumption minimization. These approaches should privilege the use of more efficient technologies when the QoS can be met and guarantee a dynamic switching to other technologies when the performance cannot be guaranteed anymore.

3.2 Application requirements

3.2.1 Network-aware media applications

Exchange of information in real time (RT) or near real time (Near-RT) between network entities and application entities/modules at the UE and/or Edge and/or Cloud point needs to be supported, controlled and managed across various network domains (radio, core, ..). Thanks to the RT or Near-RT information coming from the network regarding status and performance, or even predictions about network entities, the network-aware media applications will become more robust, predictive and cost efficient, both for the application user and the network operator.

The challenge here for networks is to collect, process and provide, in RT or Near-RT, meaningful information about the actual and future performances (i.e. predictions) of the network entities to the relevant media applications. The challenge here is also about “observability” and “predictability” of the network entities and network services end-to-end, i.e. across network entities and domains.

3.2.2 “New” media applications

Supporting new kinds of media content is challenging, as it extends beyond the state of the art of traditional media content (2D video and audio) as well as Metaverse concept. The introduction of VR, AR, MR, 360 video, immersive audio, haptics and holograms into media applications for users (such as teleconferencing) requires working with very specialized equipment, not only users but also content producers or application providers, stringent KPIs

have to be met (high bandwidth, low latency) and standardization have to take place to facilitate the growth of this kind of media.

3.2.3 AI-based media applications provisioning and orchestration

There is a need for network architectural and functional extensions so that service providers can leverage the network as the intelligent transmission platform to support media AI/ML-based services, including device-based application AI/ML training or inference services. There is a need to support a media-application layer for AI/ML model distribution and transfer (download, upload, updates, etc.), that can identify and manage specific characteristics of AI/ML model distribution, transfer and training for media applications, e.g. video/speech analytics and recognition. It is important to support and/or assist the media-application layer with training of the AI/ML model (e.g. application client running on the edge or UE), dynamic and intelligent VNF/CNF distribution and update of trained AI/ML models, together with collection of the performance data from the running AI/ML models, that should be provided and analyzed by the media-application provider. Any media-application AI/ML security, privacy and user consent related aspects should be also handled.

The challenge here for the networks is to provide this additional layer for coordination and aggregation that may support media-applications with AI/ML models, up to collaborative AI/ML based Federated Learning (FL) between the media-application clients running on the edge or UEs and the application servers running in the cloud.

AI based quantum computing can solve this challenge. Certainly, the quantum acceleration of a quantum computer allows algorithmic speed and as a result it is therefore possible to represent and handle so many states for solving problems.

3.2.4 Decentralized, distributed in cloud/edge architecture/infrastructure

New media-media applications need decentralized, distributed in cloud/edge multi-tenant architecture enabling efficient production process from multiple remote sites, with ability to easy and seamlessly connect and manage new equipment with wired or wireless capabilities. Multi-user immersive media-applications with interactive features and with multiplexing and de-multiplexing over multiple connections, even from different network operators, are strongly demanding availability of decentralized and distributed architecture.

The challenge here for networks is to look for the most efficient, effective and sustainable way to integrate various networks and business players in such distributed multi-tenant architecture ensuring technical requirements but also security, privacy and business requirements for all players and users. In such decentralized and distributed architecture digital rights management should be also provided.

3.2.5 Synchronization

Current wireless networks can carry out time synchronization application data (such as NTP and PTP), as they provide IP capabilities, but the characteristics of the network make the precision of time synchronization much worse than wired networks. Wireless mobile networks are not aware of the application data carried out and thus, they do not provide optimization for it. The main challenge is to provide network functionalities that allow for optimizations for such kind of time services i.e. a “time-aware” system.

3.2.6 Energy-efficient media applications/software

Media-applications SW instances should fully exploit the virtualized/containerized environments in order to make the overall media-application energy efficient and scalable.

Edge computing and storage could also be a way to optimise Media application energy consumption avoiding long haul transit, CDN are also using these new capacities offered by the 5G/6G networks. Another way is to withdraw duplication of a specific content in several storage locations (see UC 2.7).

4. SNS KPIs and KVLs mapping with network requirements

List of SNS key performance Indicators

Data Rate, Latency, Link Budget, Jitter, Density, Position, Energy Efficiency, Reliability, Capacity, Mobility, Cost, Position Accuracy, Imaging resolution, EMF values, Security metrics, Open Interfaces, Vertical specific metadata, Resource Efficiency, Guaranteed Effort Service deployment, provisioning and resilience in multi- and variable topology networks.

KPI1 : Automated network operation allowing self-operating networks

KPI2: Service deployment time reduced by a factor of 10 compared to similar tasks in 2020

KPI3: Full integration of technical operations and business operations

KPI4: Slice creation on the fly with negligible time across the combined cloud, edge and fog infrastructure

KPI5: Terabits per second will provide seemingly infinite network capacity and multi-core MEC servers will provide required computing power for future digital applications and services

KPI6: Application to application response time in sub-millisecond range (latency)

KPI7: Networks and services have to be trusted, secure and dependable

KPI8: Personalised and perpetual protection and privacy

KPI9: Trillions of things and systems connected in scalable and cost-efficient way

KPI10: High efficiency in energy and natural resources usage to limit impact on climate change and sustain Earth resources

KPI11: Combination of global reach, ubiquitous availability and optimised local service delivery

KPI12: Spectrum efficiency above 256 bps/Hz

KPI13: Means for geographical and social inclusion to allow basic Internet access at minimum cost

KPI14: Infrastructure solutions for efficient deployment capital expenditures (very low-population density areas)

KPI15: Autonomous networks and systems based on Artificial Intelligence and Machine Learning mechanisms combined with cyber physical security

KPI16: EMF-aware networks

Mapping of the SNS KPIs and the Media use case requirements:

Media UC requirements	SNS KPIs	Comments
Extreme high bandwidth	KPI5	In SNS WP 2022
Low Latency	KPI6	In SNS WP 2022
NPN capabilities		
Configurability	KPI1, KPI4	in SNS WP 2022
High power edge computing		in SNS WP 2022
Fast handover capabilities		in SNS WP 2022
Low Jitter		
Reliability		in SNS WP 2022
Security	KPI7, KPI8	in SNS WP 2022
Multiple access	KPI11, KPI14	in SNS WP 2022
Infrastructure	KPI10	in SNS WP 2022
Automation	KPI1, KPI2, KPI3	in SNS WP 2022
Sustainable ICT and CO2 Footprint	KPI10	In SNS WP 2022
Coexistence and Interaction between different technologies		In SNS WP 2022

5. NGI KPIs mapping with Application requirements

Next Generation Internet KPIs

NGI Challenges

<https://digital-strategy.ec.europa.eu/en/library/next-generation-internet-brochure>

- Protect personal data
- Ensure privacy and security
- Combat disinformation online
- Guarantee access and freedom of choice
- Respect fundamental rights
- Enforce ethics and sustainability by design

Ch 1: Language Equality and Web Accessibility in the Digital Age : Natural Language Processing and Understanding; Machine Translation; Automatic Speech Recognition; Multilingual Information Retrieval; Sign Languages; Assistive Technologies and Accessibility solutions addressing diverse types of disability

Ch 2: Interactive Technologies and Immersive Environments: Future Interactive Technologies will allow users to access, process and deliver information more efficiently and less intrusively. There is high potential to transform sectors including education, healthcare, culture, manufacturing, engineering, live events, retail, construction, entertainment and media.

Ch 3: Digital Innovation and Blockchain: Blockchain and Distributed Ledger Technologies can help reduce costs while increasing trust, traceability and security. They have huge potential for making social and economic online transactions more secure by guarding against an attack and removing the need for any middleman

Ch 4: Media Convergence and Social Media: Next generation social networks, media and platforms will define the way we communicate, exchange, do business, create, learn and share knowledge. The challenge is to accompany a positive evolution of Social Media, overcoming issues such as trust, civic engagement, governance and economic sustainability. Social Media Innovation, Fight against disinformation online, Collective and Connected Intelligence (including AI), Media convergence, Immersive technologies, New contents distribution

Next Generation Internet WP2021-2022 call topics

DESTINATION 6 - A HUMAN-CENTRED AND ETHICAL DEVELOPMENT OF DIGITAL AND INDUSTRIAL TECHNOLOGIES

Call 2021

HORIZON-CL4-2021-HUMAN-01-06: Innovation for Media, including eXtended Reality

HORIZON-CL4-2021-HUMAN-01-13: eXtended Reality Modelling

HORIZON-CL4-2021-HUMAN-01-14: eXtended Reality for All - Haptics

HORIZON-CL4-2021-HUMAN-01-21: Art-driven use experiments and design

HORIZON-CL4-2021-HUMAN-01-25: eXtended Collaborative Telepresence

HORIZON-CL4-2021-HUMAN-01-27: AI to fight disinformation

HORIZON-CL4-2021-HUMAN-01-28: eXtended Reality Ethics, Interoperability and Impact

Call 2022

HORIZON-CL4-2022-HUMAN-01-14: eXtended Reality Technologies

HORIZON-CL4-2022-HUMAN-01-19: eXtended Reality Learning - Engage and Interact
eXtended Reality (XR)

Mapping table:

Application requirement	NGI challenges	NGI 2021-2022 WP	SNS KPI
Network-aware media applications	Ch 4		KPI7
“New” media applications	Ch 2	HUMAN-01-06	
AI-based media applications provisioning and orchestration		HUMAN-01-27	KPI3, KPI4, KPI15
Distributed, decentralized, cloud/edge, architecture/infrastructure	Ch 3		KPI3, KPI4
Synchronization			
Energy-efficient media applications/software			KPI10

6. Conclusions & recommendations

This paper is proposing the vision of NetworkEurope and NEM European Technology platforms which represent more than 2000 experts in the domains of network and Media & content

8 innovative use cases have been developed and for each of them, technical requirements have been identified. From these technical requirements which are addressing both network and application domains, a number of technical challenges have been extracted.

Based on these 14 Network oriented technical challenges and 6 Application oriented technical challenges, we have also identified those which are not sufficiently covered in the WP2021-2022:

- Network technical challenges:
 - NPN capabilities
 - Low jitter

- Application technical challenges
 - Synchronisation
 - Energy-efficient media applications/software

In order to be able to develop such innovative use cases by the end of the Horizon Europe program, there is a need to address these technical challenges in the Smart network & Services WP 2023-2024 for the network aspects and in the NGI (Cluster4 Destination 6) WP 2023-2024 for the application aspects