5G Phase 3 – Media Pilots

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by NEM 5G joint Working Group with Networld2020 ETP

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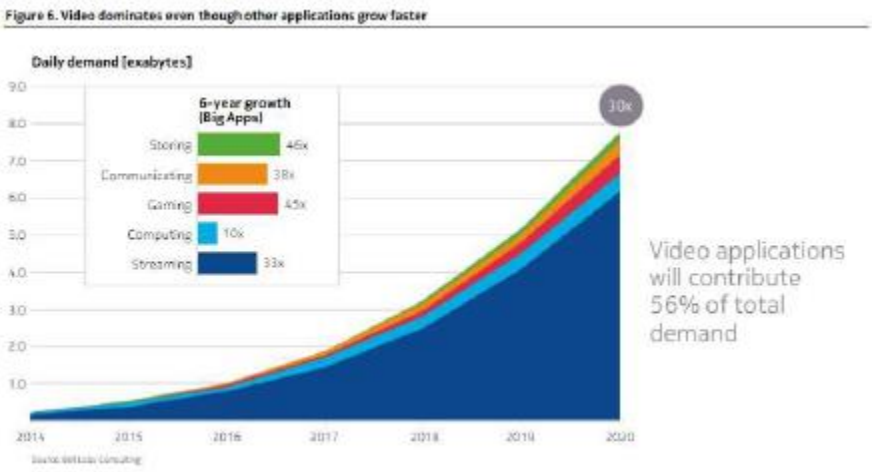
Executive Summary

This paper has the objective to describe potential pilots from the Media & Content domain that can be developed to take advantage of the future 5G networks.

Media & Content are one of the most important consumer of network capacities "Streaming and cloud-based services and applications are the biggest demand drivers. They are enabled by better devices and richer applications and reinforced by trends to higher resolution screens and the availability of lower latency, higher performance networks. The younger generation's unprecedented consumption of data anywhere and on any device becomes the de facto behaviour in the larger populous" - *Bell Labs Consulting report 2016.*



Given these trends, it is key that the future 5G networks will be able to support requirements from Media & Content applications and services, mainly bandwidth, latency and security.

5G PPP IA has identified 6 KPIs that 5G should reach:

1. 1000 times higher mobile data volume per geographical area.
2. 10 to 100 times more connected devices.
3. 10 times to 100 times higher typical user data rate.
4. 10 times lower energy consumption.
5. End-to-End latency of < 1ms.
6. Ubiquitous 5G access including in low density areas.

There are many use cases that could be developed in the Media & Content sector able to validate these 5G KPIs. The working group, mixing experts from Network (Networld2020 members) and Media (NEM members) collected those potential use cases and ranked them according to the coverage of the KPIs (bandwidth, latency, security,…).

The working group identified ten potential pilots suitable to verify the 5G KPIs but should also show case realistic use cases that could be conducted all around Europe during the experimental phase of 5G.

1. NREN for education
2. Next Generation media over 5G enabled cities
3. Large events remote visualization experience
4. Cooperative designing platform
5. Public Protection and Disaster Relief
6. Remote medicine
7. Remote education
8. VR with multiplayer interactions
9. Mixed reality experience
10. Real time video analysis

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1. Context

5G promises a wide range of extra features compared to the currently available communication systems. 5GPPP has already identified a list of high level 5G Key Performance Indicators (KPI) which includes: 1000 times higher mobile data volume per geographical area, 10 to 100 times more connected devices, 10 times to 100 times higher typical user data rate, 10 times lower energy consumption, End-to-End latency of < 1ms and Ubiquitous 5G access including in low density areas.

Multi-access Edge Computing (MEC) capabilities enabled by Network Functions Virtualization (NFV) and Software Defined Networking (SDN) are fundamental to realize 5G PPP vision. With the help of NFV and SDN, the embedded resources at the multi-access network edge are employed to offer added value services, improve quality of experience by moving intelligence at the edge and create new business opportunities.

In particular, for next generation media services the virtualization capability offered by NFV and SDN will help media service provides to exploit resources (network and IT) from a central point, without being worried about where the actual hardware is located, how it is maintained, who is the vendor, etc. Moreover, the unified management of computing, networking and storage will significantly reduce media service provisioning time. For example, instead of spending hours to set up a service, it will happen in order of minutes (5G PPP KPI: reduce serviced provisioning time from 90 days to 90 minutes). Orchestration capacity makes it possible to coordinate thousands of devices, thus media service providers can utilize unconventional hardware, e.g. GPUs, in fly and on demand (5G PPP KPI: more connected devices). Programmability and automation are two important features which change the overall media service behaviour towards more automated/intelligent systems able to guarantee QoS and SLA compliance with minimum human intervention and error. Dynamic scaling is another important advantage enabled by SDN/NFV to optimize resource utilization and reduce OPEX (5G PPP KPI: 10 times lower energy consumption). Furthermore, sharing expensive infrastructure among serves tenants/service provides, so called 5G multi tenancy feature, will significantly reduce the required CAPEX for service offering. Last but not least, SDN/NFV create an open ecosystem where a full choice of modular plug-ins can be easily adapted to customize service offering according to the user needs.

After 5G technologies have reached a maturity level beyond pure lab experiments, trials and pilots at local as well as Pan-European level will play a key role to accelerate the deployment of these new technologies. The main target of such trials is the validation of 5G technologies in multi-vendor and multi-user environments. Verifying the stability and advantages in this environment will be an important step in moving 5G technologies from the R&D laboratories into the market. In addition such trials will serve the validation of the technology as well as the identification of further features to serve the needs of specific industry segments and user groups. A secondary and equally important

goal is to increase the understanding of the new possibilities 5G technologies offer in industry segments which are less ICT focused and thereby help to jump start 5G adoption across a broad range of industries.

The ambition and the reality of actual demonstrations coming from vertical trials should be considered as with a strong dependency on underlying platform capabilities. Without discussing detailed technical features, one should take into account the platform interoperability issues at least from following different angles:

- Verticals should benefit from a meaningful (representing 5G services offer) common and standard interface, such as APIs, that will allow discovering, triggering, negotiating and controlling the platform capabilities through this vertical interaction.
- Since many Verticals should involve several platforms to demonstrate end-to-end capabilities, interoperability between platforms is becoming a must.
- Platforms should serve for actual KPI validation, benchmarking including vertical missions.
- Platforms should also be repeatable and deployed where the vertical stands.

Thanks to the work done together with Networld2020 and NEM in 2015, Media & Content has been identified as one of the potential vertical sector that should take part in these pilots. However several other domains have been also selected such as Health, Logistics, Smart cities, Automotive, Agriculture, … There is a need to demonstrate Media & Content as really a key sector that 5G pilots should take advantage to validate the technology KPIs but also to get relevant feedback from end users.

2. Potential Media & Content use cases

Ideas regarding use cases, coming from NEM members as well as from 5G Media project, have been identified and listed in this chapter This list is not exhaustive and can be extended if needed.

2.1. Ultrahigh fidelity imaging for medical applications

2.1.1. Description

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.

2.1.2. Technical requirements

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 the lossless coding, the reliability of the connectivity is a must for this kind of applications.

In addition, near real time data transmission is crucial under critical conditions, while mobile communication can highly extend the availability of these services, for example where xDSL or fiber connections are not available or in mobility, for instance inside an ambulance or an helicopter.

To achieve this it may also be needed to use "bonding", splitting the video over multiple connections from the same or different technologies or operators, including for example 5G bonded with satellite connection, or 5G from two different operators.

To provide 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 case of mass events and/or accidents and disasters, network must provide appropriate mechanisms to prevent denial of service for first responders, medical personnel and similar units' devices.

2.2. On site live event experience

2.2.1. Description

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 use case concerns with augmenting the experience of the onsite visitors, for example by means of augmented reality, by 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 in certain area of the location which would otherwise be too far away or not visible from their current location, or view re-plays 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,…).

Scheduled events are planned by TV organizations employing professional equipment like 360 degrees cameras and UHD video streams. Additionally, video streaming produced 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.
Unpredictable/unexpected events cannot be planned in advance and need to be streamed at unpredictable time, from both TVs and users in the area of the event.
The fundamental difference between the two kind of events is related to the time available for infrastructure setup, being the second one possibly critical also for environmental aspects.
Both cases requires to setup media delivery and the related communication support for a limited period of time, i.e. the duration of the event.
eMBMS, 5G broadcast and multicast and seamless transition to unicast, can also enable delivery of high quality video to many users without consuming more bandwidth.

2.2.2. Technical requirements

Onsite live event experiences have to cater for several (hundreds or thousands) users. This means that these use cases will demand large data rates and are characterized by a high number of devices simultaneously active onsite. Additionally, there will be stringent requirements in terms of latency, due to the live and real-time nature of the use cases (especially for the augmented onsite live event experience). A further requirement relating to experience personalization will be the availability of different types, or versions, of content, where therefore caching (both for what concerns capacity and efficiency / management) will play an important role.
The communication support for onsite live event experience calls for dynamic setup capability characterized by different KPIs in scheduled or unpredicted events, even with 'on the fly' service deployment time. Network resources require to be flexibly assigned to the media sources depending on the traffic and device capacity. In fact streaming can be generated by different devices and video formats. Reliable connectivity between the "event site" and the final users should be provided to deliver contents with guaranteed QoS and service continuity. In addition, smart caching techniques should be available for the network to reduce its load.
The above requirements can be met by exploiting the cloud RAN design principle and network slicing. Distributed content caching can be developed accordingly (e.g., placing the cache where some baseband processing functions are placed).
3D Sound should also be a potential interested technology for such a use case.
Low latency, ultra high data rates and high performance compression technologies, capabilities to geo-position sound within video content.
Adding more viewers to the same content without linear increase in bandwidth consumption is required as well as managing several broadcasts at the same

location (e.g. transmitting different views of the same event or different events), using 5G broadcast and multicast technologies.

2.3. User generated and machine generated content

2.3.1. Description

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. Incident commander is therefore better informed about the situation in the field which could be crucial in making decisions.

Smart City: Mobile web cam 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

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 the 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.

2.3.2. Technical requirements

The connected drones used for Infrastructure or Environmental monitoring, requires very low latency for their remote operation and high bandwidth per sending high quality images. In addition the network should be able to operate with systems moving at a speed up to 70 km/h

For mobile surveillance, high throughput is essential for the reliability of the service in addition to a secure management of the data both in the phase of sending to the network and in the storage in the cloud.
The speed (60 km/h), in some cases the availability of an ad-hoc network

Public Protection and Disaster Relief: To provide expected level of service, PPDR devices should have guaranteed quality of service level within the network. Since network overloads are common in case of incidents, network must provide appropriate mechanisms to pre-emptively allocate and preserve level of communication quality and prevent denial of service for those devices.

For **Smart City**, given the potentially high number of devices, the requirements fall in the area of Enhanced Mobile BB and massive IoT.

Smart Agriculture, , the bandwidth requirement is high for the tasks based on high quality videos, while the speed of the transmitter and receiver usually is not an issue because these robots move slowly (around 3 m/h) around the fields

2.4. Immersive and Integrated Media

2.4.1. Description

Virtual Reality

The users, wearing a VR headset replacing his whole field of view, will be able to experience 360 videos, lightfields and 3D contents (e.g. 3D reconstructions of environments captured through photogrammetry o laser scan technologies). The user can experience the visit of specific locations of interest, downloading at very high speed all the related content, realizing a virtual reality experience.

This can be exploited to make remotely available specific contents, but also to integrate the existing contents with additional information. Main areas of exploitation could be tourism and education.

2.4.2. Technical requirements

Virtual Reality will require extremely high data rates, in order to transmit 4K, 8K and even 16K video resolutions. WebVR applications will need to dynamically download all the 3D assets and media contents needed to build the VR experience requiring both very high data rates and low latency. Additionally, ultra-low latency (<20ms) will be needed, to avoid motion sickness. Similarly, reliability and video continuity without perceived interruptions are needed, otherwise the VR will not succeed. Delivery into vehicles, such as trains (300 km/hr) or infotainment in vehicles (70 km/hr) is also a technical requirement, at a lower priority than other services in cases of insufficient networks performance.

2.5. Cooperative media production

2.5.1. Description

Immersive videoconferencing and collaborative designing environment will enable 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 audiovisual feed of all other participants and be able to smoothly interact with them, both verbally (e.g. speaking or in terms of other environment noises) and visually (e.g. body language, shared document, artifact and/or activity). The experience will be so compelling that the need of physical meetings among distant / international parties will be drastically reduced and possibly no longer required.

2.5.2. Technical requirements

In order to achieve the ambitions of this use case, a combination of networks, 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 audiovisual 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 realtime experience
- solutions shall take device requirements into account, in fact the ability of devices to decode different audiovisual 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

2.6. Collaborative gaming

2.6.1. Description

Including immersive gaming (AR, VR)

2.6.2. Technical requirements

The requirements include very low latency, certainly including dynamic path adaptation based on geo-localised and physical network architecture.
Also high resolution video transfer that includes enriched content, multi-users, multi-sites, multi-data streams independent of video content streams.

2.7. Immersive Applications and Virtual Reality

2.7.1. Description

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.

2.7.2. Technical requirements

For Interactive Virtual Reality, the technical requirements fall in the area of Enhanced Mobile BB and Low Latency.

2.8. Remote and Smart Media Production Incorporating User-Generated Content

2.8.1. Description

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 created, breaking news, Sports events including lower ranking and even local events, reality shows, faith TV and other professional and semiprofessional content which the new technologies in cellular, video compression and editing, cloud editing and social networks distribution, have been enabling. 5G can bring high uplink and downlink bandwidth to support such volumes of content and high resolutions (full HD and 4K), improved congestion handling for multiple transmission from the same area, lower latencies (though of less importance than in other use cases), and mobility – even from/to moving vehicles. Multiple video feeds form 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 very much 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 the 5G in order to split the load, reduce congestion, increase video quality and number of feeds.

2.8.2. Technical requirements

Synchronization: between the professional content and user-generated content

Dynamic network resource allocation: for example to allocate more upload bandwidth to the user devices currently filming the user-generated content; or caching capacity at the edge, where the user-generated content may be further processed (re-encoded, synchronized, integrated with other streams, multicast redistributed), ensure sufficient bandwidth (>12 mbps per a 4K stream, at least 5 streams) using network slicing and multi-link technologies; Be able to use simultaneously any type of other networks together with the 5G connection (satellite, fiber, LAN, WiFi, LTE).

2.9. Dynamic and Flexible UHD Content Distribution over 5G CDNs

2.9.1. Description

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 forms of adaptive coding. Low latency requirements will require adaptation 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 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 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.

2.9.2. Technical requirements

For such a purpose, the testbed should comprise

- a properly populated content distribution service
- a resource orchestrator to match content characteristics with available resources
- a descriptor (and/or) a model of the rate-quality characteristics of the content to be made available to the orchestrator
- a set of heterogeneous radio interfaces with cells of different sizes
- an analysis of the handoff delay characteristics and the time margin
- user devices capable to actually deal with multiple interfaces at the same time
- modified decoders capable to exploit diversity and scalability
- resource orchestration and cache placement close to the edge with clustered small cells coordinated by an edge controller or being based on distributed computation algorithms
- KPIs to be addressed: reduced latency (<1ms), increased spectral efficiency (x1000), reduced service setup time (order of seconds)

2.10. 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 the 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 us 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.

New mobile technology and connected devices will give students the opportunity to learn with minimal intervention from teachers and mostly through exploration, discovery and peer coaching. Telcos could provide the connectivity and platforms to enable these use cases out of campus and leverage the existing infrastructures, such as the network to supporting the needs of the research and education communities within a country (i.e., National Research and Education Network) and confederation-based Wi-Fi roaming access service (eduroam[1]) for in-campus services . The wired and wireless systems in the education sector are increasingly diverse with continuously changing experience. Seamless integration of different technologies would be needed to facilitate communication between

[1] www.eduroam.org

different organizations and easy roaming procedures. The lack of technical expertise in schools requires plug-and-play and self-organising/ optimising devices that can sense and learn from their environment and autonomously adapt. The applications for education are very diverse with varying requirements. For instance, applications that need Tactile Interaction through the Internet would require extremely low latency, while other use cases can leverage their delay-tolerant nature and ease off on latency requirement significantly.

2.11. Professional content production

2.11.1. Description

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 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, splitting the content over the multiplicity of these links … Highly reliable bandwidth is even more needed in higher quality video formats such as UHD and AR/VR.

The newest trend in remote production is what 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 in the stadium only the cameras, send the video from each camera back to the production studio which is then fixed rather than field-deployed and can be located either at the studio or even in the cloud, and do all the production there. The benefits are huge in cost savings, ease of operation, enabling production of more and smaller-scaled and localized events etc.

2.11.2. Technical requirements

For these use cases, most demanding as they require ongoing continuous video stream, reliability and quality video uplink connectivity is required from anywhere, again supported by "bonding", involving heterogeneous networks and multi-RAT connections such as cellular+cellular, cellular+satellite, cellular+xDSL/fiber.

Sufficient bandwidth for single or multiple HD to 4K video feeds (cameras), high reliability of this stream, back channel audio and video. Latency should be minimal yet not mandatory for ms-level. Synch of the multiple camera transmissions is required in <200 msec deviation.

3. 5G features needed by Media & Content use cases

There are several important features needed by Media&Content use cases such as “mobile edge computing”, “specific media SDN slice” so Media & Content applications should communicate their requirements (bandwidth, latency, edge service, …) to the network and the network should be able to satisfy these requirements, which may be dynamic in time.

Worth noting that adaptive coding and transmission is used mostly by Media&Content applications, therefore the KPIs should be described as such:

- The network must be capable to modify and adapt its heterogeneous being according to the timings of the different media applications (frame by frame? segment by segment?) under constraints that quality cannot be changed too much but considering that codecs allow several degrees of freedom (“handoff” latency)
- Proactively estimate along the end-to-end path the actual bandwidth/quality trade-off to avoid bandwidth and energy waste (needs to inspect media or signalling media-network).

This is somewhat a second level KPI, but for 5G use cases related to Media & Content it will be relevant reaching very low times to deploy new services.
For example, a VR or AR application may require a video rendering service deployed at the edge, and in case it was not already running (e.g. because it was not being requested by other users), it should be deployed very quickly, in the order of seconds.
In alternative, this requirement may be achieved in the way in which network slices will be designed in 5G: a VR/AR application will be using the “VR/AR slice”, which already runs the edge services that may be needed by the application.
In view of this, the requirements should be something like: “the Media & Content vertical will require 5G networks to be able to carry out 5G application functions, needed by the Media & Content services and available to them in the order of Milliseconds”. It is up to the 5G network to decide whether this means low times for deploying new services or instantiating all possible services in a particular slice beforehand.

4. 5G KPIs

Extract from the 5GP PPP Association contract[2]:

The development of new communication networks is dependent on the emergence of globally accepted standards in order to ensure interoperability, economies of scale with affordable cost for system deployment and end users. This partnership aims to have European industry driving the development of 5G standards and to develop and exploit at least 20% of the 5G SEP (standards essential patents).

The following parameters are indicative new network characteristics to be achieved at an operational level:

1. *1000 times higher mobile data volume per geographical area.*
2. *10 to 100 times more connected devices.*
3. *10 times to 100 times higher typical user data rate.*
4. *10 times lower energy consumption.*
5. *End-to-End latency of < 1ms.*
6. *Ubiquitous 5G access including in low density areas.*

This new high-performance network will be operated via a scalable management framework enabling fast deployment of novel applications, including sensor based applications, with reduction of the network management opex by at least 20% compared to today.

In addition, new lightweight but robust security and authentication metrics suitable for a new era of pervasive multi domain virtualized networks and services will have to be provided.

Looking to these KPIs, it is obvious that Media&Content applications should be able to validate a number of them. They are:

1. 1000 times higher mobile data volume per geographical area ➔ High quality video, pictures, music, … are needed such feature in order to allow users to experience entertainment services wherever they are.
2. 10 to 100 times more connected devices ➔ this features is not really needed for Media&Content sector, however there will be more and more Media devices such as cameras, smart phones and other displays.
3. 10 times to 100 times higher typical user data rate. ➔ obviously such a feature is key for Media&content applications
4. 10 times lower energy consumption ➔ due to the fact that Media&content are high consumer of storage and computing capacity, it should be an indirect important feature

[2] https://5g-ppp.eu/kpis/

5. End-to-End latency of < 1ms ➔ this feature is key for gaming applications but also in other sectors using Media&Content technologies such as eHealth
6. Ubiquitous 5G access including in low density areas ➔ Due to high consumption of bandwidth, Media&content applications are easily experienced in high density areas and it is key for the sector to offer access everywhere as far as the ATAWAD concept is central.

5. Potential pilots

5.1. Description

5.1.1. NREN for education

Recent developments in mobile access technologies have provided the possibility of having higher availability of the rich digital resources beyond the physical confines of the classroom and in the hands of learners. However, unlimited access to information is only the steppingstone for ubiquitous learning and effective teaching and learning is still required. Advances in mobile technology, IoT and the Tactile Internet, can open a new chapter in Education. NRENs (National Research & Education Network) with their dedicated network for research and education community, e.g., Janet [3] can provide a significant role in coordinating such trials. Jisc as the UK NREN is happy to collaborate in holding any pilot in the UK Education Sector. 5G trial in Education can provide the following services:

- **Tactile Internet & Skillset communication** : manual skillset delivery Internet will create new ways of Tele-teaching and Tele-mentoring especially for manual training and skill development, bringing new definition& experience for distance learning, distance team-working, etc. ;
- **Virtual Reality & education** : VR has ever increasing relevance in education and training & will have a big role in providing quality education& improving understanding-based learning;
- **Augmented Reality & education** : AR is an efficient way of providing the right amount of information at the right time to the right audience (contextualised learning). Also, immersive AR can enable new services such as mobile cloud classroom and Virtual Presence.
- **Walled-off classroom:** combination of Tactile Internet & VR can remove the physical location constraint for experimental practices, and facilitate and enable the sharing of resources between larger numbers of students irrespective of their location.
- **Student wireless backpack**: it enables single device content access anywhere by using distributed cloud and mobile edge computing. All the user needs is a device to access any of his personal content and stored files to resume his work with the experience of immediacy.

[3] https://www.jisc.ac.uk/janet

Use Case	Latency	Throughput
Tactile Internet & Skillset communication	1ms RTT	Medium-High
Virtual Reality & education	2-4ms*	High
Augmented Reality & education	2-4ms	Medium-High
Walled-off classroom	1ms	High
Student wireless backpack	Order of 10ms	Low-Medium

*3GPP SA1, TR22.891 Document

5.1.2. Next generation media over 5G enabled cities

Aligned with the 5G Action Plan from the European Commission, the 5G technology is first expected to be deployed in urban scenarios. It is therefore of high interest to investigate, develop, and validate media applications that benefit from 5G infrastructure deployed in European cities.

5G trial requirements in future European 5G cities are expected to provide the following services:

- Mobile edge computing facilities, allowing the deployment of media functions close to the end user.
- Network slicing, in order to provide virtual networks that are customized for specific usage
- Guaranteed service delivery even in the presence of heavy background traffic. For example in crowded events, or demonstrations.
- Broadcasting/Multicasting capabilities to minimize network traffic.
- Delivery of a common time reference to selected points of attachment.
- Real-time APIs providing network status information to the media services, including location, coverage or capacity.
- APIs allowing the media service to request an expected SLA.

Envisioned media applications to be trialled in city environments, may include among others:

- Remote content production, such as providing real-time coverage to crowded events, to localized events in rural areas and inner-city areas,

- Collaborative user based content creation,
- “Follow me” media delivery, where media content moves to the optimal location following a user on the go,
- Advanced gaming applications requiring AR and VR support,
- [OTHER use cases described above]

KPI:

- High bandwidth
- Low latency / jitter
- High network flexibility (realtime network reconfigurations to support use cases dynamicity)
- Localization
- Reliability
- Privacy

5.1.3. Large event immersive remote experience

5G will allow the possibility to transmit a high number of parallel communications and large event should take advantage of such capabilities. Stadium could be equipped with several 360° cameras that provide “basic” video that could be enriched by video taken by mobile phones of participants. Immersive sound should also be taken into account.

With such a number of video sources, remote users should be able to select one or several sources to better experience the event.

For professionals, it should also be possible to manipulate these sources in order to provide enriched immersive TV events mixing all these inputs together with augmented realty information.

So end users could subscribe to a professional TV show or could manage by their own the navigation into the multiple sources.

Use heterogenous networks, multi-RAT and multi-operators technologies to support such transmissions at any conditions.

KPI:

- Very high bandwidth
- Ultra-low latency / jitter
- Network scalability (to support many concurrent users)
- Localization

- Reliability
- Privacy

5.1.4. Cooperative industrial designing platform

In many vertical sectors, there is a need to cooperate with a number of competencies to design a product or a service. The objective of such a pilot is to develop an environment facilitating remote cooperative design taking advantage of 5G capabilities.

Several sectors should take advantage of such a tool, we can see car design, home design, fashion design, or any object design that should be made by teams localized in several remote locations.

Several local designing environment exist, the pilot should use one of them and install 3 of them in different locations connected through 5G networks.

Such pilot could experiment co-design of products as well as co-design of services.

KPIs:

- Very high bandwidth
- Ultra-low latency / jitter
- Network scalability (to support many concurrent users)
- Privacy

5.1.5. Public Protection and Disaster Relief

With 10 to 100 times higher user data rates, 10 to 100 times more connected devices and minimal end-to-end latency, 5G will become very promising environment for Public Protection and Disaster Relief communications, operational services and critical applications. Also, according to the EU Commision's 5G Action Plan, the Commission encourages Member States to consider using the future 5G infrastructure to improve the performance of communications services used for public safety and security, including shared approaches in view of the future procurement of advanced broadband public protection and disaster relief systems.
Basic requirement for the network in terms of PPDR is to provide guaranteed service delivery even in the presence of heavy background traffic as load in public networks typically increases in case of accidents, disasters, large events, demonstrations, etc. As described in use cases chapter, 5G will therefore enable flying drones, real-time video streaming from cameras, collecting data from body-worn devices, etc. Devices will be through mobile network connected to Intelligent and Advanced Operational Center and data feed to platform where functions for data storing and processing, data and video analytics, machine learning, predictions will be implemented. Besides

data, PPDR services should include voice communications where interoperability with existing PPDR infrastructure (eg. TETRA) might be needed in first 5G PPDR deployments.
5G Action plan also proposes, that such role of 5G network could involve migrating public safety and security services from existing proprietary communications platforms to commercial 5G platforms which will be even more secure, resilient and reliable.
Such pilot could serve for several real situations: maintaining security at large event, supervising country border, firefighting large wildfire, firefighting fire in fire-hazardous environment

KPIs:

- Network scalability (to support many concurrent users)
- Localization
- Reliability

5.1.6. Remote medicine

Remote Medicine Service was designed to serve clients charged with the welfare of those working in extreme environments with limited healthcare but also for people far from specialists to investigate specific diseases.

Rural and remote medicine describes general practice at its full scope. It refers to the professional values, skills and competencies necessary for providing high quality, safe and appropriate care to a rural or remote community.

In situations where patients do not have easy access to a full suite of specialist services and resources the medical practitioner has a heightened level of responsibility to meet community needs. Rural and Remote Medicine encompasses the best models of care for these contexts.

It is typically delivered through private community-based practices and hospitals but also on roadsides, in remote clinics, prisons, Aboriginal Medical Services, military front lines or via telephone or digital health systems.

Remote medicine applies also to exchanges between hospital services that need to cross-check diagnostics before giving a treatment.

There are already a number of examples of applications serving remote medicine and they often use leased line in order to have a good service quality because most of the data exchanged are video and/or high quality pictures. Now, with 5G, it should

be possible to get a similar quality of service but is has to be verified through such a pilot.

KPI:

- Very high bandwidth
- Ultra-low latency / jitter
- Network scalability (to support many concurrent users)
- Reliability
- Privacy

5.1.7. Remote education

Remote educations services give the possibility to perform both synchronous and asynchronous teaching for chidlren far from their teachers. The system should provide also monitor of the activities . Functionnalities as videoconferencing and live communication should be real time monitored in order to tune them on the fly for an effectiveness behaviour. The 5G performances as large bandwidth, low latency, slicing and reliability are key enablers of these services.
Pilots could be done in different areas:

- In suburban areas where children living in small villages spread on a vast region could be gathered in a single virtual class. Nowaday, in these kind of villages, schools gather in one class children with different ages in order to reach the minimal number to form a single class. This means that a single teacher needs to address different level of education in the same class reducing effectiveness and efficiency. The remote education service may be used to create homogenous classes with children of the same age living in different places. In such a way it's possible to create homogenous classes as happens in large cities where a great number of children of the same ages live close to each other and go physically in the same school.
- The same requirement applies to children that are hospitalized for long periods. Nowadays dedicated teachers move to the hospital increasing costs and reducing effectiveness of the education. Through a remote education service hospitalized children may participate to classes with other children augmenting the inclusion.

KPIs:

- High definition videoconference
- Low latency for direct human interaction
- Reliability
- User satisfactions

5.1.8. VR with multi-person interaction

Virtual Reality experiences including interaction with remote real people inside the VR world could enrich the touristic appeal of many sites. Pilot could be done in particular with the following objectives:

- Visit places that are not physically accessible for any reason (danger, need to preserve the site etc …)
- Visit places that are far from main touristic sites (e.g. small villages quite far from large cities). In this case it could be a good way to allow people to virtually discover new places and push them to go physically there
- Create thematic visits that link together different sites

In all cases it should be possible to interact through VR with people living in those places that have a strong link with the visited site.
Such a service may help the inclusion of small sites and their growth in terms of touristic and economical opportunities.
Key enablers are the possibility to quickly interact with remote people through VR experience as well as the possibility to quickly and dynamically download contents through the experience providing the feel of being in a real environment.

KPIs:

- Large bandwith
- Low latency
- Numbers of people involved in the multiplayer interaction

5.1.9. Mixed reality experiences

Mixed reality experience allows the visualization of virtual objects over a real video live stream. This could be done with dedicated devices, like smart glasses, or even with smartphone using their cameras.
There's a number of application fields relevant for pilots:

- Tourism. It could be possible to see a monument as it was originally built. For instance a broken statue or an ancient building.
- Industry. Modelling and prototyping objects, maintenance
- Command and control. Operations in emergency situations or control of risky operations (e.g. load and unload of goods in a port)

In all cases in order to allow a rich experience, dinamycally adapted to context and users, processing should be performed at the server side. This implies that a continous and reliable communication must be available for the devices. Low latency is important in order to track position and movement of users and instantly react. Bandwith is important to download virtual content as well as upstream video that in some cases must be processed at server side in order to produce relevant virtual content.

KPIs:

- Low latency
- Large bandwith
- Numbers of people involved in the multiplayer interaction

5.1.10. Real time video analysis

Video stream analysis could be performed for a number of applications and services. In all cases there's a strong requirements in terms of real time video upstream towards server applications for video analysis. Pilots could be done in the following applications domain:

- Public safety. Face and body recognition for access control and suspicious people detection.
- Mobility. Automatic recognition of people flows and vehicle traffic, parking, people counting
- Envrinoment control. Water level, rain detection, landslides monitoring etc ...

KPIs are:

- Large bandwith
- Number of devices

5.2. Trial technical requirements

With regards to the above pilots proposals, the key technologies needed are the following:

- Multiple technologies (native 5G, 4G, WIFI, satellite ? …) and/or multiple operators to demonstrate seamless behavior and the multi-link behaviour Multiple cell size large to small with hand over, simulated international roaming to check E2E QoE.
- Multiple locations
- Several CDN location: centralized, distributed
- Several RAN cloud location: distributed, centralized
- Several mobility schemes including High speed train
- Several devices: mobile phones, (VR and professional) cameras, VR/AR headsets
- Cyber security capabilities (attacks…)
- Virtualization in the Cloud of any existing game. (including 4k games)

5.3. Supporting organisations

Aviwest, Orange, Technicolor, Harmonic, Ericsson Envivio, Broadpeak, TDF, Eureva, JISC, ATOS, BBC, Comcast, CWI, Digital Catapult, DTG, Engineering, ESA, Eurescom, Eureva, Eutelsat, FEUGA, I2Cat, Images&Réseaux, IMEC, Intel, Interinnov, IRT, Iskratel, JISC, LiveU, Martel, Netas, Nokia, Quobis, SES, Telecom Italia, Telekom Slovenije, TNO, Ubiwhere, UCL (5G-MEDIA), University Bologna, University Cataluna, University Kent, University Malaga,

University of Hertfordshire, University of Pavia, University Politecnic Madrid, University Valencia, University Vigo, Wings ICT Solutions

6. Conclusions & recommendations

This paper is proposing the vision from two European Technology Platforms, Networld2020 and NEM,) which represent more than 2000 experts in the domains of Network and Media & Content.

The 10 pilots described above should be suitable to verify the 5G KPIs but should also show case realistic use cases that could be conducted all around Europe during the experimental phase of 5G.

There is no priority in these pilots but all of them have their specific advantage in term of KPIs coverage.