5G RECORDS

5G KEY TECHNOLOGY ENABLERS FOR EMERGING MEDIA CONTENT PRODUCTION SERVICES

NEWSLETTER

ISSUE | 03 | DECEMBER 2022

5G RECORDS

5G KEY TECHNOLOGY ENABLERS FOR EMERGING MEDIA CONTENT PRODUCTION SERVICES

TABLE OF CONTENTS

1. A message from David Gómez-Barquero (5G-RECORDS Coordinator).
2. Use Case 1 Trial: Live audio production.
3. Use Case 2 Trial: Multiple camera wireless studio.
4. Use Case 3 Trial: Live inmersive content production.
5. Frequency Asked Questions on Non-Public Network (NPN)

A MESSAGE FROM
DAVID GÓMEZ-BARQUERO
5G-RECORDS COORDINATOR

5G KEY TECHNOLOGY ENABLERS FOR EMERGING MEDIA CONTENT PRODUCTION SERVICES

Hola there!

Time flies, and 5G-RECORDS finished last October 2022. Unfortunately, due to the pandemic the first face-to-face meeting took place when the project was about to end.
However, the last months of the project were extremely productive, and all the good work that the consortium was doing in an online and relatively quiet way (except for our rock-and-roll videos) manifest itself and gathered huge attention.

In June 2022, the final trial of the multiple camera wireless studio use case took place at the landmark Tivoli gardens in Copenhagen (Denmark), hosted by TV2, just before the kick-off of the Tour de France! This trial also included professional audio equipment provided by the live audio production use case. For the first time, it was shown that professional audio and video can be transported over the same private 5G network for local TV production and that with specifically developed gateways, it is possible to use 5G in professional content production workflows.

In July 2022, the live immersive media production use case organized a live music performance by professional artists in Madrid (Spain), hosted by Nokia, using millimetre-wave 5G transmissions to transport video and depth information from many cameras, integrating a Free Viewpoint Video (FVV) system with edge/cloud computing.

Both trials successfully demonstrated different key technology enablers developed by the consortium and had a big impact. The components were also tested in the 5G-RECORDS test-beds in Sophia-Antipolis (Eurecom), Aachen (Ericsson), and Segovia (Nokia), capturing state-of-the-art results in terms of 5G performance, such as reduction of the overall latency and uplink throughput at millimetre-wave frequencies.

The interest of the audiovisual production sector in 5G for content production, and the possibility of using dedicated private 5G networks, is gaining more and more momentum, and the results of 5G-RECORDS will help the industry to understand the potential benefits and current challenges.

David Gómez-Barquero
PROJECT COORDINATOR

Website: www.5grecords.eu
5GPPP: https://5g-ppp.eu/5g-records/
Contact: 5G-RECORDS-Contact@5g-ppp.eu

5G RECORDS

USE CASE 1 TRIAL: LIVE AUDIO PRODUCTION

UC1 5G disaggregated infrastructure was used to (i) study the performance of the E2E system when using a single UE, (ii) measure deterministic audio streams through multiple 5G modems and (iii) conduct mobility tests to better understand the use-case KPIs in a more realistic environment, i.e., when musicians are moving around the stage.

Even if the UC1 network has evolved gradually during the project to reduce latency, UC1 requirements for local audio production applications, e.g., 1 ms one-way network latency, are still not met. After multiple iterations, UC1 partners were able to reduce the one-way network latency in the disaggregated 5G testbed to about 10 ms for a single audio UE and about 20 ms for up to three audio UEs. However, the availability and maturity of available 5G components remained a major issue until the end of the project. For instance, the COTS 5G modem used in UC1 had major influence on the support for specific features and achievable KPIs.

During the trials, UC1 partners identified that some components introduced significant latency jitter into processing and forwarding of audio IP packets in the 5G system. This is the case of the 5G UPF deployment and the parametrization of the CU. Also, while the latency in the UL is determined by 5GS timing and jitter, the latency in DL is determined by asynchronous processing and the USB connection. This means that, not only is the finally achieved latency dependent on the 5G radio timing grid (e.g., slot-length), but it is also significantly defined by implementation of interfaces and processing functions, and types of deployments.

Another important outcome of 5G-RECORDS was the collaboration between UC1 partners and components within the UC2 trial in Tivoli Garden in order to explore the possibility of using 5G in a local TV production to also deliver wireless audio. The goal was to demonstrate the delivery of audio and video over the same 5G network, as well as to conduct latency measurement as part of the evaluation of the state-of-the-art 5G components. Test results showed that packets were faster than 75 ms.

All in all, it can be stated that significant effort is still needed to finally achieve the full set of requirements for live audio production scenarios. Low latency must be considered end-to-end. All components and interfaces on all layers in the full signal path need to be designed with low latency paradigms. This remains especially challenging in complex wireless connectivity systems with many individual components and standardized interfaces. Since the latency requirement was not met yet, it remains an open question in what way the trade-off between latency, reliability and (spectral) efficiency can result in valid operation points in this use case context. Also, state-of-the-art 5G components do not yet support sufficient time synchronization or provide corresponding interfaces on application level.

Nonetheless, 5G-RECORDS has shown that it was possible to integrate live audio production on network layer into multiple 5G testbeds and that the latency in a state-of the-art 5G system can be reduced significantly with extensive optimizations.

More info: https://www.5g-records.eu/Deliverables/5G-RECORDS_D5.3_v1.0_web.pdf

5G KEY TECHNOLOGY ENABLERS FOR EMERGING MEDIA CONTENT PRODUCTION SERVICES

USE CASE 2 TRIAL:
MULTIPLE CAMERA WIRELESS STUDIO

Several tests were performed by UC2 towards the technology validation and execution of the final trial at Tivoli Garden. Despite several setbacks due to development and integration delays and partners leaving the consortium, it was possible to perform the desired tests and trials in the second phase of the project. Following, conclusions about the last tests and trials performed are presented.

The PTP performance tests were initially envisioned to decide if PTP over 5G networks could provide enough time synchronization precision for 2 purposes: first, so PTP could be used by the IM encoder board to extract genlock signals from the PTP synchronization and to use the synchronization for frame timestamping (on RTP streams). Genlock extraction was not possible, as IM, the partner responsible to implement it, left the consortium. The PTP tests were successful in demonstrating that PTP over 5G is sufficient for frame-level synchronization. It was also demonstrated that the basic PTP performance can be greatly enhanced by client tweaking and using advanced TSN features (from about 117 µs to 3,6 µs median offset).

Regarding the local and remote production, several tests have been performed to test the complete production chain to prepare it for the trial in Tivoli. In these last tests performed in Aachen, UC2 team was able to integrate the media gateway into the infrastructure. The tests allowed to study the traffic behavior and extract different KPIs (frame delay, interarrival, packet latency, etc.) In summary, the most important KPIs such as E2E latency and uplink throughput have been achieved with a glass-glass latency around 200ms and 50 Mbps per video stream.

For the remote production scenario, tests were also conducted to assess the performance of uplink video transmission using different combination of parameters, including the use of network slices in Aachen. The use of network slicing proved to be beneficial, as the devices using the guaranteed performance slice did not have their throughput affected by the best-effort devices. Additionally, remote production tests were performed at UPV campus, focusing on bonding, comparing 2 different modems and network configurations. Tests were successful, as they allowed to discover performance differences between modems and network configurations.

The final trial in Tivoli aimed to perform a real-world scenario with the components and architecture designed and developed within the project. Both local production and remote production scenarios were tested successfully since a live event could be covered via 5G private network-enabled content production with low latency (200 ms) and sufficient quality. The integration of the encoder and the 5G modem in a single box allowed for seamless integration with the TV cameras, as this unit could be docked to the back of them, providing low latency encoding and 5G connectivity. Remote production scenario was made connecting 2 facilities: Tivoli and Turin via 5G network and also using the MCR (GV AMPP) that proved to be suitable for content production with 2 second G2G latency.

More info: https://www.5g-records.eu/Deliverables/5G-RECORDS_D5.3_v1.0_web.pdf

USE CASE 3 TRIAL:
LIVE IMMERSIVE MEDIA PRODUCTION

During the final UC3 field trial, the viability of a full end-to-end FVV Live deployment to stream and record an event over a 5G network was demonstrated. The trial was chiefly intended to bring the use case into a real environment and validate each of the modules and components. This final trial was successful and provided relevant information as a result of all the work carried out during the project.

The event consisted in a live music performance by professional artists which was produced as a FVV service in real time and streamed to the final user. The event took
place in Nokia premises in Madrid (Spain), and the FVV content was also recorded to demonstrate the FVV playback functionality of the system. Furthermore, Grafana dashboards were shown and monitored during the whole session.

Specifically, two traffic slices were configured (Multimedia Gold and Best Effort) in two different network segments (5G RAN and Transport Network), covering the delivery of the produced video from the Media Delivery VNF in the Delivery Edge Cloud to the end user in the trial site. The Gold QoS improves the video delivery in heavy traffic conditions, while in low traffic conditions, the results are similar.

Since only 5G NSA is available for mmWave frequencies, QoS slicing in the RAN is implemented by giving different QoS parameters to different users. Various tests have been run using the Web Player and playing content from a media player under different conditions. In all the scenarios, content has been played in different resolutions, introducing noise (traffic) in the radio network which has been generated using iperf3 to produce downlink traffic to 3 additional UEs.

The status of the radio cells was monitored at Nokia AirScale system and reported in the Grafana dashboard. The incoming and outcoming traffic was monitored in all the network interfaces of the 5G core. Due to the characteristics of the trial, uplink traffic from the 5G-enabled capture server was the dominant contributor to the total traffic, both at input (coming from the 5G gNB) and at output (going to the MEC). It is worth noting that the traffic was very stable during the whole trial session.

The results collected provide useful insights on options to reduce, if necessary, the amount of data to deliver FVV providing the highest possible quality to the end users.

Also, they can help define trajectories that can be appealing for the users. Regarding metrics, both capture servers 1 and 2 were connected by cable, so their losses are negligible. Capture server 3 used a 5G link, and their cameras suffered from some losses due to the radio access, although the average value remained within a reasonably range. Also, RTT has experienced no significant variations during the measurement for the different video qualities tested as well as jitter and initial load time.

USE CASE 3 TRIAL: **LIVE IMMERSIVE MEDIA PRODUCTION**

Additionally, selected KPIs were measured and validated. In general, as expected, the higher the QP (Quantization Parameters) the lower the perceived quality with all HRTs (Hypothetical Rendering Trajectories). Also, HRT1 offers the highest quality. Results for all the SRC contents, evidence the perceptual quality reduction when the framerate is reduced from 30 to 15 fps, besides, the effect of the framerate is highly dependent on the content. It is worth noting that the target motion-to-photon latency under 170 ms was not fully achieved with the existing FVV + 5G network configuration. However, the obtained result is close enough (25% higher) so that the effective QoE is not affected significantly. Regarding the critical uplink bitrate, some tests have been conducted to test the overall capacity of the uplink. Regarding the delivery network, with the results obtained during the final trial for UC3, we can certify that the expected KPIs have been met for four different scenarios and the whole setup is working as expected with two QoS slices.

More info: https://www.5g-records.eu/Deliverables/5G-RECORDS_D5.3_v1.0_web.pdf

Introduction

Audio and video productions – such as television and radio studios, live news gathering, sports events or music festivals – typically require numerous wireless devices. These include wireless microphones, in-ear monitoring systems and cameras. Traditionally, media production teams have used specialist radio services. In the future, the wireless communication service for such devices could potentially be provided by a 5G system. What are the requirements of such systems for professional AV productions? In this FAQ, we aim to provide information derived from the 5G RECORDS project, focusing in particular on 5G NPN (Non-Public Network): What is this NPN? Why is it interesting in the context of professional media production? How can it be deployed for media production?

Q1 – Why look into 5G?

Because 5G supports natively IP communication and media productions are moving towards IP production (local, in the cloud). 5G will allow also to multiplex different types of signals (e.g., audio, video, return video, talkback and command controls) in one single infrastructure instead of using different radio links as it happens today.

Q2 – What does 5G have over 4G?

The capabilities of the 5G components have improved compared to 4G components:

- Support for much larger bandwidth, allowing for higher bitrates.
- Dedicated support for private network by means of NPN support
- Support for IP native deployments, allowing for more flexible, agile, and distributed deployments.
- Support for time-synchronization over 5G
- Network slicing and QoS support in 5G is more flexible than 4G,
- More flexible uplink/downlink ratio

Q3 – Public versus non-public networks: What's the difference?

A Public Land Mobile Network (PLMN) is a mobile network operated by a Mobile Network Operator (MNO) in a specific country intended for telecommunication services. They are the most prevalent mobile networks today and have wide area coverage. The spectrum regulation typically assigns several obligations to be provided by public networks, most importantly the capability of supporting emergency call services. The spectrum regulation typically assigns several obligations to be provided by public networks, most important the capability of supporting emergency call services. A Non-Public Network (NPN) - sometimes referred to as a private network - is a network that is dedicated to a specific set of devices within a dedicated area.

These networks can potentially be tuned for performance or uplink vs. downlink balance if the regulation permits it (e.g., interferences generation) NPNs are often local and cover a small service area, but they can also be deployed over a wider area, which offers the possibility to support nomadic and ad-hoc audiovisual content production applications and workflows, independently of PLMN coverage availability. Media producers will need to determine the type of network they need depending on the individual scenario, including the redundancy required to run the equipment smoothly and without interruption.

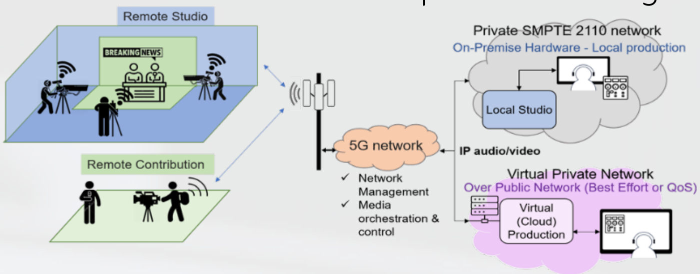
Q4 - How can a 5G network be deployed?

5G non-public networks (see Q3) can be deployed in several ways:

• As a PNI-NPN, they can be Integrated into a PLMN (Public Land Mobile Network) and connected to an MNO (Mobile Network Operator) network,

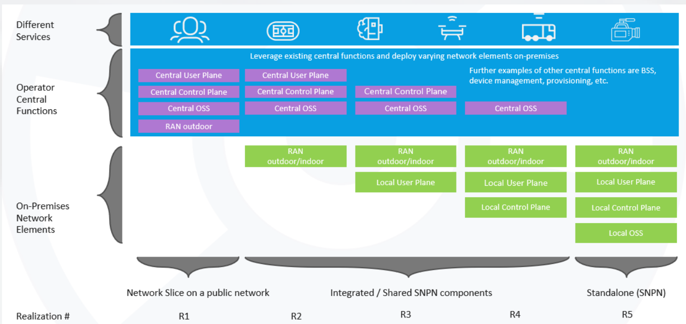
• As as a Standalone Non-Public Network (SNPN), they are deployed independently of any other network known.

PNI-NPN and SNPNs are useful as they allow dedicated 5G connectivity for a restricted number of users in a more secure environment but also allow those users to tune a network to their own requirements. An example of media production that rely on PLMN for the remote contribution link and on 5G standalone network for the multi-cam production in the remote studio is reported in this figure:



Q5 - What are the basic S-NPN (Non-Public Network) deployment models?

The deployment of a Standalone NPNs (S-NPN) (see Q4) requires dedicated spectrum access and management. Some regulatory authorities have reserved specific spectrum for the purpose of S-NPNs (e.g. 3.7 - 3.8 GHz in Germany). S-NPNs potentially offer the most flexibility and performance since dedicated optimisations for specific use cases are possible. they support the wireless connectivity of a constrained set of several devices separate to any public network that may be in the area. They are likely to be deployed and managed by specialist engineers, similarly to how we manage our existing radio cameras and microphones. This other figure shows the different level of integration with the operator: from a slice on a public network (PNI-NPN) to a private standalone network.



Q6 – What are the main technical and operational attributes and considerations that are relevant for standalone NPNs deployment?

In order to deploy a standalone NPN, there are a number of factors and requirements that need to be considered. As with traditional radio equipment used on production, it is necessary to gain the relevant spectrum licence for use of for use of spectrum at the correct power levels in the target area. The ability to do this will often be dictated by local regulations and may be constrained for indoor or outdoor use only. Depending on the type of application there may be advantages to use different spectrum bands for different applications with higher frequencies providing more bandwidth, but they also have less range and may not be as robust. The next consideration is the amount of bandwidth required on both the uplink and downlink.

Cameras will require a larger share of the bandwidth than audio, and the higher quality needed, the more bandwidth required. Other factors in this equation include latency and robustness. A high quality, low latency, robust connection used for programme output will require more bandwidth per device than a lower quality signal that could be used for a reverse video or audio stream. Uplink vs. downlink balance is also a critical aspect as media production requires both to be the same but downlink is generally prioritized in telecom networks.

As 5G is a 2-way IP-based network, it is possible to include all traffic, not only audio and video, within a single connection. This data can be used to carry control, timing or other ancillary data that may be required by the end user device. Some additional attributes that are relevant to the deployment of standalone NPNs include:

• Autonomy and control
• Isolation
• Security
• Deployment flexibility

Q7 – How do 3GPP specification releases relate to NPN features?

For shorter definitions of Non-Public Networks (NPN), Standalone Non-Public Networks (S-NPN), and Public Network Integrated NPN networks (PNI-NPN), see Q3 and Q4. 3GPP defines the concept of a NPN in Release 16. NPNs refer to a 5G System (5GS) deployed for private use. The requirements to enable NPNs for video, imaging and audio for professional applications are described in 3GPP TS 22.261 with additional media production requirements detailed in 3GPP TS 22.287. An S-NPN is identified by a combination of a PLMN ID and Network identifier (NID).

At the UE (user equipment), these two parameters need to be configured to access the S-NPN. The PLMN ID may be one assigned in the range of PLMN IDs for private networks (e.g. based on MCC 999, as assigned by the ITU). Note that a UE connected to an S-NPN may also be able to access services from a PLMN where available. In such case, the UE is required to authenticate in both networks. Release 16 specifications do not include support for roaming, handover between S-NPNs not interworking with Evolved Packet Core (EPC). Such networks can be tailored to support specific requirements such as increased uplink / downlink (see Q6), which is beneficial for high uplink scenarios such as cameras and microphones. It is unlikely that such a network would be used for contribution workflows but are more likely to deployed in small, controlled areas with limited coverage areas.
They are completely isolated from other networks and therefore are unlikely to suffer from congestion or contention if properly designed. 3GPP Release 16 also defines a PNI-NPN as an NPN deployed with the support of at least one PLMN. Two deployment solutions are normative:

• PNI-NPN deployment by means of dedicated Data Network Names (DNNs). The DNN defines a dedicated gateway (UPF) in the PLMN to/from which NPN traffic is conveyed and dispatched to the NPN local area network.

FAQs

• PNI-NPN deployment by means of network slicing. The PLMN provisions a dedicated slice of the PLMN comprising a set of resources allocated for the exclusive use of the NPN.

This type of network will rely on the provision of some shared services and so it may not be possible to adjust uplink/downlink balance or other QoS metrics as they will be dependent on the host network. They will therefore depend on the agreement with the host network to ensure the QoS.

The NPN architecture has been enhanced in Release 17, including the following:
• Enable support for SNPN along with subscription/credentials owned by an entity separate from the SNPN operator.
• Support UE onboarding and provisioning for NPNs.
• Support audio-visual content production service requirements, e.g. for service continuity
• Support voice/IMS emergency services for SNPN.

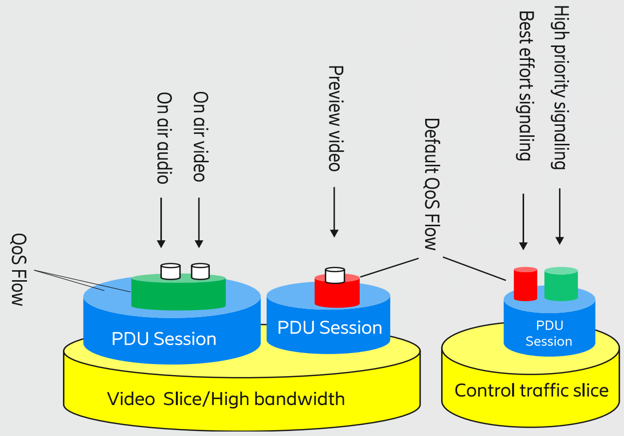
Q8 – How do Network Slicing and QoS work?

The 3GPP system offers different solutions to separate and prioritize traffic. Since early releases, 3GPP offers the capability to allow a UE (user equipment) to connect to one or more data network (DN), like different Virtual Private Networks (VPN). The UE establishes one or more PDU Sessions to (typically) different Data Networks.

In 5G, this capability is extended by Network Slicing. Network slicing enables the virtualization of the network resources in both radio and core. It gives the flexibility for the network operator to create multiple separate virtual networks on top of the physical network resources. A separate slice allows the network operator to tailor the network characteristics to fulfill the requirements needed per use case i.e., slice users. Slice separation also allows the Edge cloud to be only accessible by the slice users. There are two basic realization alternatives with Network Slices:

(1) Using a single Network Slice in combination with multiple QoS Flow. The Network Slice separates the traffic of a Media Producer from other eMBB (enhanced mobile broadband) traffic and provides a defined capacity for the media producer. QoS is used within the Network Slice, in order to prioritise the different Media Production related flows against each other.
(2) Using multiple Network Slices. For example, Slice A is used for media streaming, where the slice can be optimized to provide high capacity. Slice B is used for control signal which can be optimized for low latency. Slice C can be used for any other non-critical traffic.

QoS plays an important role in prioritising streams within the same slice. The usage of QoS is essential to ensure that the radio scheduler assigns the needed resources to a given flow. For example, two video streams can compete on resources within the media slice. If one stream is considered by the production facility more important than the other stream, the network operator can assign a QoS value to that stream. QoS assignment can be modified dynamically using APIs that can be triggered from the media orchestrator towards the Network Exposure Function (NEF). Therefore, the priority of a certain stream can change according to the production process requirements. The concept of using network slicing in combination with QoS is depicted in this figure.



Q10 – What competences are needed to set up a 5G S-NPN?

The list below is not exhaustive:

• Secure spectrum planning and reservation.
• Radio planning: This often includes a terrain scan. Sector positions and sector sizes need to be planned, based on the terrain information.
• Power and connectivity planning: Power Generators may be used outdoors. Connectivity planning includes the deployment of e.g. fiber networks (when not available at the event site)
• Setup execution: Starting from basic hardware installation (radios, switches, different compute units), and including connectivity establishment (putting the plugs into the right sockets).
• System planning: IP address plans, QoS rules, like VLAN QoS or DiffServ, security zones, 5G System configuration
• Radio performance optimization.

Q11 – How is spectrum licensed?

Radio spectrum is, necessarily, a highly regulated area. Spectrum availability remains essential for conventional wireless production equipment as well as for 5G-based solutions. Certain spectrum bands are more technically suitable for specific PMSE (Programme Making and Special Events) applications. Furthermore, licensing models should be suitable for different operational needs, including permanent and temporary, stationary and nomadic production use cases.

Spectrum licensing can take a number of different forms. For conventional PMSE services some possibilities include:

• Long term fixed site licensing, suitable for a location where productions are continuous and can demonstrate regular demand, perhaps a film or TV production center with multiple stages or studios, it may be appropriate to authorize long-term spectrum access.
• Short-term temporary licensing, suitable for short-term events there is a requirement for temporary spectrum access in some specific locations (e.g. sports venues, festivals and other outdoors events) over flexible periods of time, which could be as short as few hours or as long as several weeks. The amount of spectrum required can vary depending on the nature of the production; the duration for which it is needed can be from a few hours to many days, or permanently.

In contrast, the way spectrum is currently allocated to 5G services means that access is provided on a long-term basis (e.g. several years). With regard to spectrum access for 5G NPNs, there is a substantial difference between Public Network Integrated NPNs (PNI-NPNs) and Standalone NPNs (S-NPNs) (see Q3 and Q7):

• PNI-NPNs are provided by mobile network operators and operate in the spectrum the same way as the public mobile networks (PLMNs).

• For SNPNs, spectrum is licensed on specific permanent locations (e.g. a factory or a studio) but the options for temporary deployments are limited. This is not optimal for those PMSE applications that require spectrum only temporarily over short periods of time and at non-permanent locations.

For the content production sector, it is important that spectrum access for PMSE services, whether conventional or 5G-based, remains easy, affordable and timely. Another important requirement is long term access to internationally harmonized spectrum bands. Furthermore, spectrum allocations for NPNs ideally should be defined in such a way as to allow the same hardware to operate in both public and non-public 5G networks (see Q3).

A detailed treatment of spectrum licensing options for 5G NPNs is provided in the 5G-RECORDS deliverable D2.2 5G regulatory framework for content production [Link]

Q12 – Can NPN be implemented using technologies different from 5G?

The concept of NPN (see Q3) could be applied using other technologies such as 4G, by ensuring that the company has exclusive access and control over the different network components. This is not limited only to computational resources but also to the transport medium (e.g., radio resources and backhaul). Note, one benefit of using 5G networking technology is the reuse of radio equipment for different deployments. For example, a Device, which is used for a 5G SNPN during a first production, can be used within a 5G PNI-NPN for another production.

The guaranteed resources can be utilized either using physical resources or using virtualization such as network slicing in 5G.

The usage of a licensed band guarantees that the radio resources are secured and not prone to interference from unexpected users of the same radio frequency used by the company. For instance, Because WIFI Access Points operate in the unlicensed band 2.5GHz,5GHz and 6GHz for WiFi6E, the media production facility cannot guarantee that the radio resources are not shared with other users. For example, a neighboring WIFI Access Point (AP) can operate on the same frequency band used by the media production facility, causing interference which will result in unexpected behavior.