5G key technology enableRs for Emerging media COntent pRoDuction services

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PU = Public

Abstract

The European H2020 5G-RECORDS Project aims at investigating whether and to what extent the technological improvements introduced by 5G network can be exploited for professional multimedia content production. The MOCG (Media Orchestration Control Gateway) is one of the components deployed in 5G-RECORDS; it acts as an intermediary between the devices on the 5G network and the applications that control and monitor them. For Use Case 2 (multiple camera wireless studio) the MOCG also invokes the Media Gateway (MG) to handle media conversions.

This deliverable includes the following:

- an outline of Media Orchestration and Control functions that have been identified, in particular:
- how the MOC functions are used in a typical media production event
- architecture and implementation of the functions for Use Cases 1 (Live audio production) and 2
- comments on what can be addressed in further work

Keywords

5G, Audio-visual sector, end-to-end infrastructures, Non-public networks, Professional media content production, NMOS, MQTT, AMWA, media gateway, orchestration

Disclaimer

Executive Summary

5G-RECORDS is a European project aiming at investigating some of the relevant business opportunities that 5G brings in the context of the professional multimedia content production. The project is investigating three use cases: live audio production, multiple camera wireless studio and live immersive media production.

As well as specific requirements and components related to streaming live video and audio, the project is also concerned with how wireless video and audio devices become available for use in a production, are configured for use and connected to the production infrastructure in a way that makes suitable use of the available connectivity. We use the term “Media Orchestration and Control” (MOC) to cover this, as well as related requirements such as authentication of devices, monitoring of operation, and automation of all these aspects.

5G-RECORDS has developed the concept of a Media Orchestration and Control Gateway (MOCG) to handle many of the requirements identified by the project’s use cases. The MOCG acts as an intermediary between the devices on the 5G network and the applications that control and monitor them. For Use Case 2 (multiple camera wireless studio) the MOCG also invokes the Media Gateway (MG) to handle media conversions.

This deliverable gives an overview of the MOC requirements and approach that has been identified by the project. Parts that have been implemented are presented in detail; including those related to discovery, connection and camera control, and automation of provisioning. Some of this work builds on the work of the Advanced Media Workflow Association’s Networked Media Open Specifications [1], adapted for the use cases of the project, using a messaging protocol (MQTT, [2]) that is suited to 5G networks. A summary of the project’s findings in other areas such as prioritisation of different flows, authentication and adapting stream bandwidths to operational need, is also presented, together with suggestions for future work.

Table of Contents

List of Figures

List of Acronyms and Abbreviations

The acronyms list has a special style defined as “acronyms”. Each acronym is separated by a tabulation with each definition. As is shown below:

3GPP	3rd Generation Partnership Project
5G	5th Generation of mobile communications systems
5GS	5G System
AMWA	Advanced Media Workflow Association
API	Application Programming Interface
AV	Audio-Visual
AV1	Alliance for Open Media Video (format) 1
CAG	Closed Access Group
CCS	Core Configuration Service
CCU	Camera Control Unit
CH	Content Handler
CIU	Camera Interface Unit
DNN	Data Network Name
EAP-TLS	Extensible Authentication Protocol-Transport Layer Security
EC	European Commission
eSIM	Embedded Subscriber Identification Module
ETSI	European Telecommunications Standards Institute
GDR	Gradual Decoder Refresh
GUI	Graphical User Interface
HEVC	High Efficiency Video Coding (H.265)
IBC	International Broadcasting Convention
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IEM	In-Ear monitoring
IETF	Internet Engineering Task Force
IGMP	Internet Group Management Protocol
IS (AMWA)	Interface Specification
ISO	International Standards Organization
ITU	International Telecommunications Union
JT-NM	Joint Task Force on Networked Media
MG	Media Gateway
MOC	Media Orchestration and Control
MOCG	Media Orchestration and Control Gateway
MPEG	Moving Picture Experts Group (formally, ISO/IEC JTC 1/SC 29/WG 11)
MQTT	Message Queuing Telemetry Transport
NEF	Network Exposure Function
NID	Network Idenitfication
NMOS	Network Media Open Specifications
NPN	Non-Public Network
NSM	Network Slice Manager
NTS	Network Technology Seminar
PCC	Policy and Charging Control
PCF	Policy Control Function
PDU	Protocol Data Unit
PGM	Programme (on a vision mixer)
PLMN	Public Land Mobile Network
PNI-NPN	Public Network Integrated NPN

PTP	Precision Time Protocol
PVW	Preview (on a vision mixer)
QoS	Quality of Service
QER	QoS Enforcement Rule
QFI	QoS Flow Identifier
RAN	Radio Access Network
REST	Representational State Transfer, an architectural style used in APIs
RPC	Remote Procedure Call
SAC	Shared Access Client
SAS	Spectrum Access Server
SDAP	Service Data Application Protoocol
SIM	Subscriber Identification Module
S-NPN	Standalone NPN
SMPTE	Society of Motion Picture and TV Engineers
ST	(SMPTE) Standard
UC	Use Case
UE	User Equipment (the 5G "device”)
VM	Virtual Machine
VPN	Virtual Private Network

1 Introduction

5G-RECORDS is a European project aiming at investigating some of the relevant business opportunities that 5G brings in the context of the professional multimedia content production. The project is investigating three use cases: live audio production, multiple camera wireless studio and live immersive media production.

As well as specific requirements and components related to streaming live video and audio, the project is also concerned with how wireless video and audio devices become available for use in a production, are configured for use and connected to the production infrastructure in a way that makes suitable use of the available connectivity. We use the term “Media Orchestration and Control” (MOC) to cover this, as well as related requirements such as authentication of devices, monitoring of operation, and automation of all these aspects.

5G-RECORDS has developed the Media Orchestration and Control Gateway (MOCG) component to handle many of the requirements identified by the project’s use cases.

The MOCG acts as an intermediary between the devices on the 5G network and the applications that control and monitor them. Use Cases 1 and 2 implemented several MOCG functions, and although resources were not available to do this for Use Case 3, this could be possible in future work.

For Use Case 2 (multiple camera wireless studio) the MOCG also invokes the Media Gateway (MG) to handle media conversions.

1.1 Structure of the document

This deliverable D3.3 includes the following:

- An outline of Media Orchestration and Control functions that have been identified (Section 2)
- How the MOC functions are used in a typical media production event (Section 3).
- Architecture and implementation of the functions for Use Cases 1 and 2 (Sections 4 and 5)
- Comments on what can be addressed in further work (Section 6).

2 Media Orchestration and Control Functions

Successful operation of a Media Network, including a 5G wireless network, depends on several common areas of functionality (see Figure 1). This section outlines the general requirements for each of these areas, and later sections go into more detail for 5G-RECORDS's use cases.

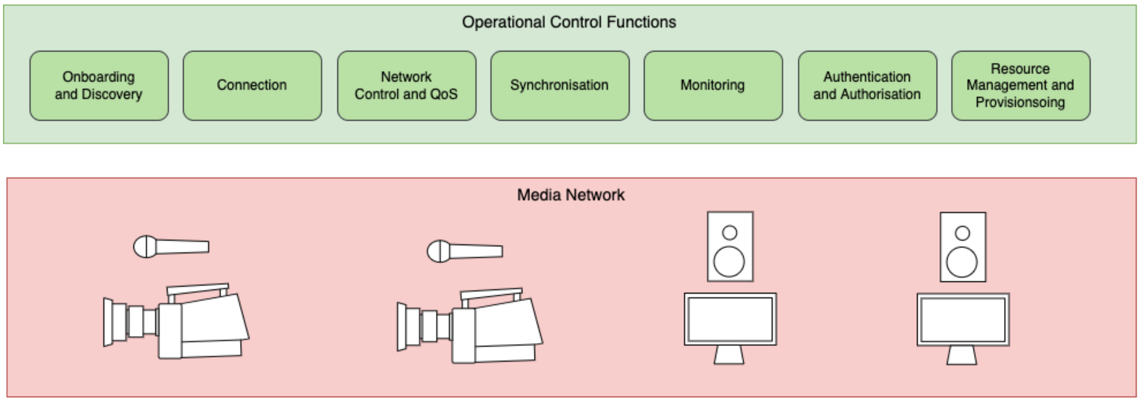


Figure 1: Common Operational Control Functions

These functions are (mostly) consistent with the model presented in the AMWA Network Media Systems Template (Figure 2, [3]). See D3.1 [4] for further discussion on this topic.

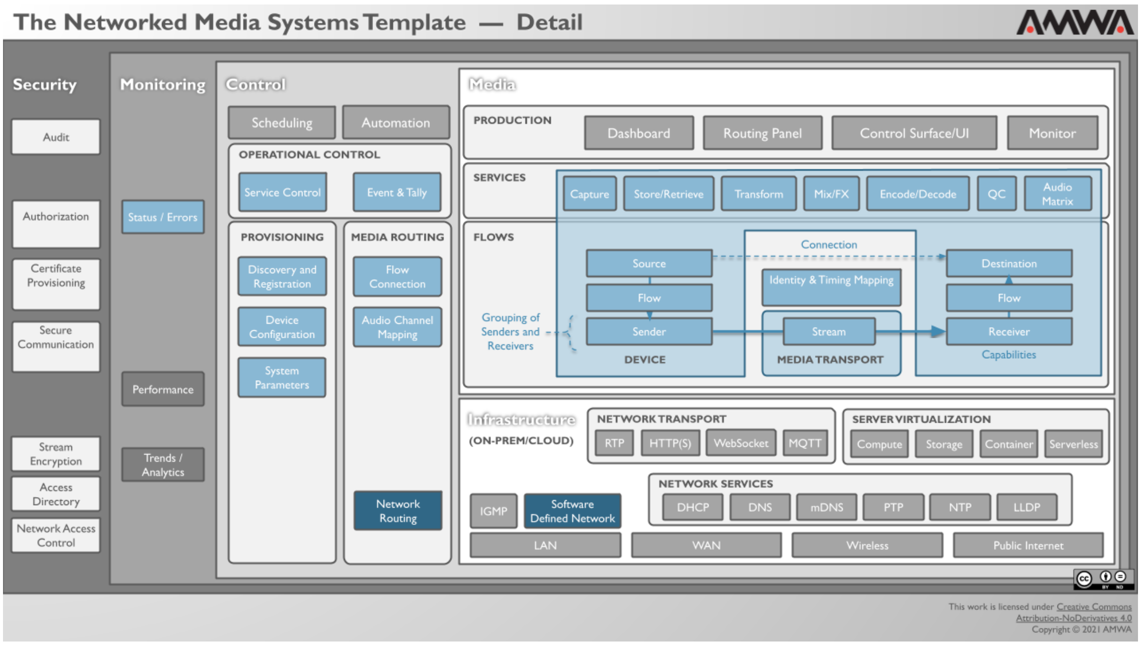


Figure 2: AMWA Network Media Systems Template

2.1 Onboarding and Discovery of Media Devices

When a Media Device (camera, microphone, monitor, etc.) is connected to a network it first needs to access to the network. This is discussed in more detail in section 3.1

Once the Media Device has network access it then needs to register itself with the production so it can be discovered. For broadcast facilities based on SMPTE ST 2110

[5], wired Media Devices register using the Registration API of AMWA NMOS IS-04 [6], and broadcast control applications can then discover them using IS-04's Query API. Use Case 2 has studied how this approach can be extended to the wireless 5G network through the use of a Media Orchestration and Control Gateway (MOCG), described in section 4.2.

2.2 Connection of Media Devices

For broadcast facilities based on SMPTE ST 2110, AMWA NMOS IS-05 Connection API provides an open approach to connecting wired Media Devices (that typically have been discovered with IS-04). The 5G-RECORDS project requires a consistent approach for wireless 5G devices. This is complicated where a Media Gateway (MG) is required to perform format, protocol, and address conversion, as these typically do not happen within a ST 2110 facility. It is required to have an IS-05 capable broadcast controller to connect (or disconnect) a wireless camera, microphone, or other device in the same way as it would connect a wired device.

2.3 Network Control and QoS

Live media production often imposes low latency requirements for video and audio streaming, which can be problematic for shared-use IP networks, and especially wireless networks. Therefore, prioritisation of Quality of Service for different network flows from and to cameras, microphones and other production devices will be vital. Use Case 2 has investigated what this prioritisation should be, how they relate to device discovery and connection and the state of the available 5G APIs (section 4.4). Use Case 1 has developed a Core Configuration Service (CCS) to provide access to relevant APIs to prioritise flows (see section 5.5)

2.4 Configuration and Control of Media Devices

Cameras, microphones, and other media devices have various operational parameters that might be set at the start of production (e.g. colour space, audio sample rate), or changed during production (e.g. camera iris). Ideally there would be a common and open approach to this but the broadcast industry has many ways of configuring and controlling devices, often based on proprietary technologies and protocols. Use Case 1 has investigated the use of a simple web-friendly protocol (MQTT) for some aspects of camera control, and how AMWA NMOS might be extended.

2.5 Synchronisation of Media Devices

A video production might be:

- **Frequency and phase-locked.** This is typical for broadcast facilities. Camera shutters are all synchronised to a system reference, and all cameras' shutters open together. Traditionally this has used a "genlock" signal to each source, which in a ST 2110 wired IP network is replaced with a Precision Time Protocol (PTP) timing reference according to ST 2059 [7] [8].
- **Frequency-locked.** The camera frame rates are the same, so dropped/doubled frames are avoided, and frame synchronisers are used downstream to allow the camera feeds to be mixed correctly
- **Asynchronous.** The camera frame rates may be different and downstream synchronisers are used. Dropped/doubled frames might occasionally occur – this depends on the quality of the cameras' internal clocks.

The MOC layer needs to provide timing information, and if required, manage connection of the timing reference.

2.6 Monitoring of Media Devices

Production and technical staff monitor the video and audio signals. This may include wireless monitoring, so discovery and connection of monitoring equipment is necessary.

The state of networked media devices themselves must also be monitored; at the most basic it is necessary to know when a device has lost power, or connectivity, or suffered some other problem. A typical approach for this (used with IS-04) is for the device to send a regular “heartbeat” message to the network. An implementation of this is covered in section 4.2.

2.7 Authentication and Authorisation

A media device must first be allowed onto the 5G network. The UC1 and UC2 teams have investigated this further as discussed in sections 3.1, 4.2 and 5.2.

Once on the network, the media device needs to be authorised for the production. An approach to this is outlined in section 4.6.

2.8 Resource Management and Provisioning

Many broadcasters are seeking to support a more dynamic approach to how their technical facilities are used, including on-demand provisioning of production resources. This will include on-demand creation and management of the MG and MOCG gateway components, and likely provisioning in “cloud-like” environments. Section 4.7 describes how we used these techniques in the development of the UC2 test environment.

3 Media Production Events

While traditional studio environments have typically had relatively fixed infrastructure and networks, outside the studio, this aspect will often be different. Media production events – especially for outside broadcasts – will require a temporary network to be set up before the event and torn down afterwards, and devices should only have access for a limited time (Figure 3). This is particularly important for rental devices, which are commonly used in broadcast.

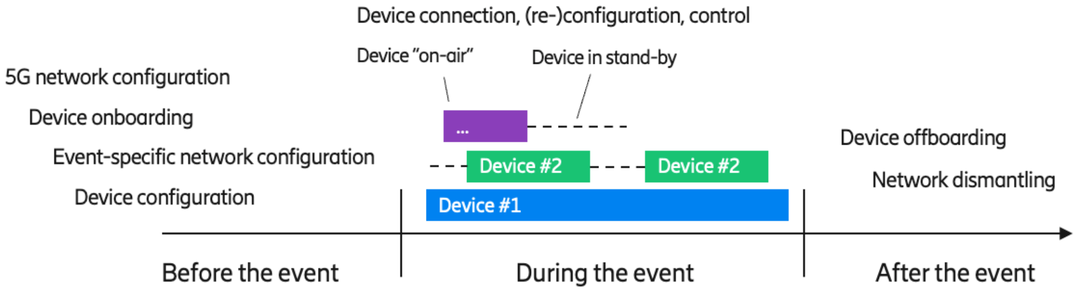


Figure 3: Media Production Event Timeline

For a device to be available for use on such a temporary media production event, it first needs to be "onboarded": granted access to the 5G network and initial configuration. Typically, this happens via a touchscreen or other user interface on the device itself, but could also be automated using provisioning and configuration technologies (see section 2.8). The device might be "on-air" throughout the event, or just from time to time and in "standby" at other times. See section 4.4.1 for a discussion of how to prioritise bandwidth for on-air devices. After the event it needs to be "offboarded", so its access is revoked.

In the following section the three stages are studied in more detail, including how they relate to the MOC functions outlined in section 2.

3.1 Before the event

5G network configuration: perform IP address planning and configuration, data network configurations (including DNN) and provisioning of device authorisation information (including access credentials provisioned on a SIM). For permanent installations (e.g., a media production studio), there is a high degree of re-use across multiple media production events; for temporary setups (e.g., an Outside Broadcast), each production event is unique, and the configuration is therefore bespoke.

Device onboarding: provide basic 5G network access information to devices, such as the Network Id (e.g. PLMN ID or a NID) and the network access credentials. The device then acts as either an SNPN-enabled UE (a UE configured to use standalone Non-Public Networks with PLMN ID and NID – see clause 5.30.2 of TS 23.501 [9]) or a regular UE with the appropriate PLMN subscription for the PNI-NPN acces through e.g. a Closed Access Group (CAG – see clause 5.30.3 of TS 23.501) and needs to connect to the correct network to successfully authenticate itself using the network access credentials provisioned above. The network access credentials are typically stored on a SIM card, which is unlocked using a PIN code, although modern devices may support an embedded SIM (eSIM) solution, which removes the dependency on a physical SIM card. For SNPNs, authentication based on EAP-TLS may instead be used.

Event-specific network configuration: apply additional configurations to devices according to the number used and the respective application. This activity may also include the configuration of different QoS flows and other network services (see sections 4.4 and 5.5).

Device configuration: provide event-specific configuration information to the device. For example, depending on the Radio Access Network used for the production event (e.g. mid-band or high-band), and the uplink bit rate available, the device may use a different codec configuration. Furthermore, the IP senders and receivers may change from one event to another and the device configuration may need to be adjusted accordingly.

3.2 During the event

After a device has been onboarded and had its initial configuration it is made available for use in the production. This may involve authorisation and registration, and then connection to systems used by the production, for example a camera's video output would likely be connected (possibly indirectly) to the production's vision mixer.

Generally, a device's event-specific configuration will stay the same through the event, but there will inevitably be exceptions; for example, it may be necessary to reduce the bandwidth of a video stream as a result of congestion, or to connect to a different system.

During the event camera controls such as iris, zoom, focus may be controlled directly by the camera operator, or may be controlled by a remote operator. The production will monitor the video and audio coming from the event for content and quality.

3.3 After the event

At the end of event (or when it is removed from the event) a device is de-registered from the production and its authorisation removed. It is disconnected from the network and its access to the network may be revoked if it not to be used again.

The following section presents specific aspects of Media Orchestration and Control for 5G-RECORDS Use Cases 2 and 1.

4 Media Orchestration and Control for Use Case 2

For Use Case 2 (Multiple Camera Wireless Studio), the project considered the various types of signals, that are typically produced and consumed by cameras and other media devices and are desirable to carry over a 5G connection. In approximate descending order of bandwidth required these include:

- Video output from camera (also known as programme video).
- Return video to camera viewfinder and/or monitors at the event or in a studio. This can be the programme output or other video useful for the production.
- Audio output from camera or microphone
- Intercom and return audio to help operators
- Teleprompter text signal for news and other studio productions.
- Synchronisation signals. For traditional studio operations this includes a video reference so that all cameras are frequency- and phase-locked (also known as genlocked). However, there are other possibilities including locking only the frequency and running completely asynchronously.
- Live remote control of settings of the camera or other device. For sports production, often the camera iris and colour settings are controlled from the production gallery rather than by the camera operator. Some productions will use follow focus which separates the focus operation from the main camera operation (this is common for film making, where this is the task of the focus puller). Productions also often use remote control of the position and pan, tilt, zoom of cameras without human operators.
- Lighting control, including camera-mounted lights
- Positional tracking data for virtual sets and augmented reality
- Tally signal to display light on camera, in camera viewfinder and on other monitors

Each of these signals will have corresponding control requirements, and an important part of UC2 has been to investigate what is suitable for these signals in the 5G environment, and how to integrate them into a larger production infrastructure. We have primarily concentrated on video, audio and camera control in this project, and for UC2 how the Media Orchestration and Control Gateway (MOCG) and Media Gateway (MG) work together. The MG performs address translation, unicast-multicast conversion, transcoding and stream protocol conversion to interface the 5G network to a wired production network. This has implications for the MOCG's functionality, as is discussed in the following sections.

4.1 Architectural Approach

Figure 4 shows a 5G multicamera wireless studio connecting to a production that also uses a SMPTE ST 2110 [5] media facility wired media facility via a Camera Interface Unit (CIU), Media Gateway (MG) and Media Orchestration and Control Gateway (MOCG).

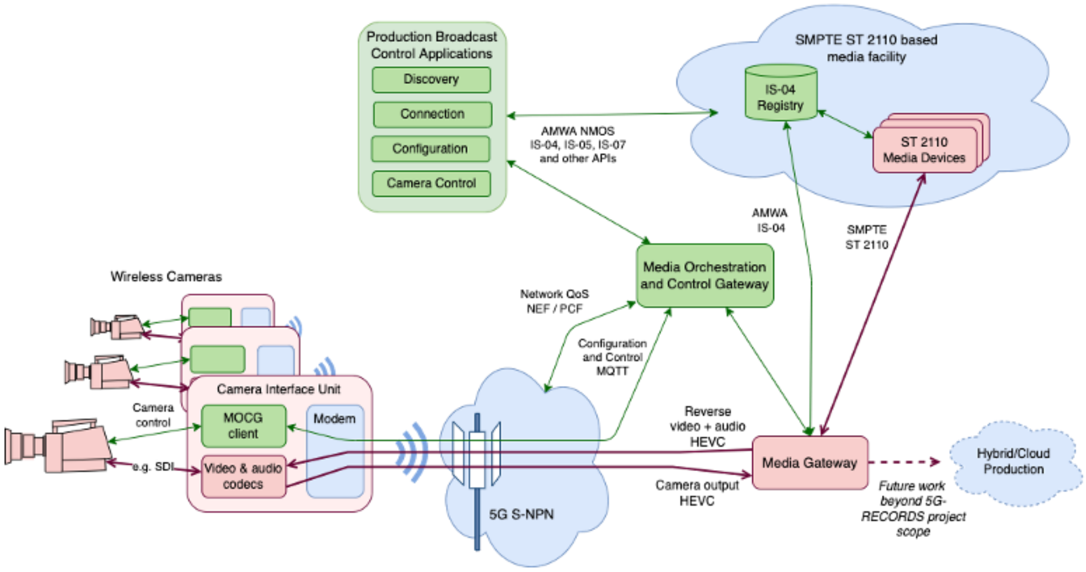


Figure 4: Use Case 2 architectural approach

UC1 (discussed in section 5) does not include a Media Gateway so uses a similar but simpler approach.

Figure 5 shows the relationship between the two gateways; the MG creates Content Handlers (CH) on request from the MOCG.

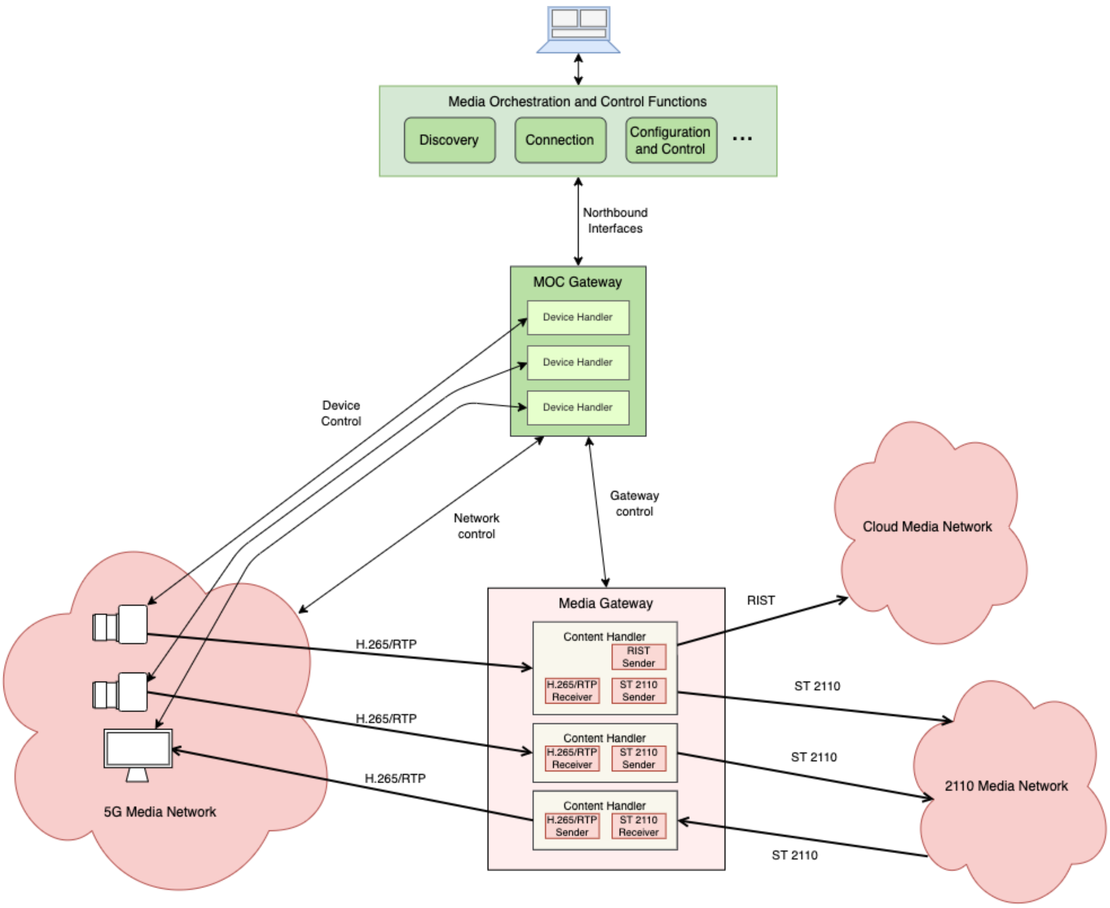


Figure 5: Media Orchestration and Control Gateway interfaces (UC2)

4.2 Registration and Discovery of Media Devices

For UC2, the camera connects via the MG to a ST 2110 network. The Joint Task Force on Networked Media (JT-NM) recommends [10] the use of AMWA IS-04 NMOS Discovery and Registration Specification [6] with ST 2110, and so it is desired for the camera to appear in the NMOS IS-04 registry. However, it might not be possible, or desirable to use IS-04 directly in the device:

- Currently, few cameras support IS-04 directly.
- IS-04 has mostly been used with uncompressed video, rather than the compressed stream formats typically used on wireless networks (although, with input from 5G-RECORDS partners, this is starting to change).
- In its current form, IS-04 requires a media device to expose a Node API. This requires the camera to run an HTTP server, which might not be possible for some implementations or for some network scenarios or might not be permitted by the network operator.

For such cases, the project has developed a simple MQTT protocol to register a camera (or other media device). This is shown in Figure 6 and has been implemented by BBC and Bisect using Node.js (and the Node-RED flow wiring toolset [11]) and GStreamer [12] pipelines for the H.265 RTP streams. This was tested between the partners via a WireGuard VPN [13](see section 4.7) and demonstrated at EBU Network Technology Seminar (NTS) 2022 (Figure 7). It was not possible to run a 5G network at this event, so Ethernet was used instead.

The demonstration is being extended for the International Broadcasting Convention (IBC) in September 2022 in three ways (Figure 8, Figure 9).

- The registration sequence will be initiated automatically on network connection
    - This shows a simplified version of device onboarding
- The CIU sends a “heartbeat” status message every five seconds so the MOCG can de-register it when it becomes unavailable
    - IS-04 uses a similar mechanism and by default devices are removed from the IS-04 registry if they miss two such heartbeats. We will use a shorter time for the IBC demonstration, but in practice the time is likely to be longer to allow for periods of poor 5G connectivity.
- The coding bitrate can be changed on request via a MQTT mechanism
    - This shows a simple use of a config/control change during an event, and demonstrates ideas from 5G-RECORDS camera control (Section 4.5) and standby-vs-programme bitrate (Section 4.4.1)

Again, BBC and Bisect are using the WireGuard VPN [13] for testing to prepare for this.

The project has also proposed a more general approach in which “request” and “response” MQTT topics provide a general mapping of a REST API to MQTT. This could be part of a future proposal to AMWA to enable NMOS to be used with new types of devices.

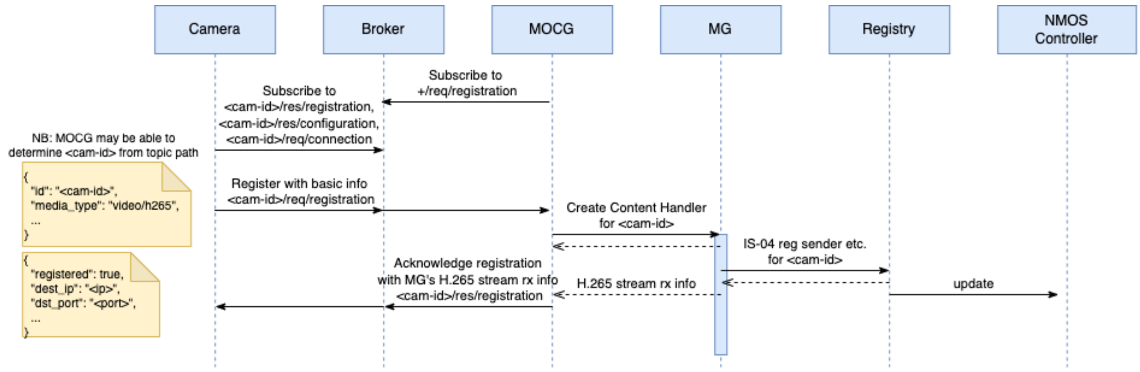
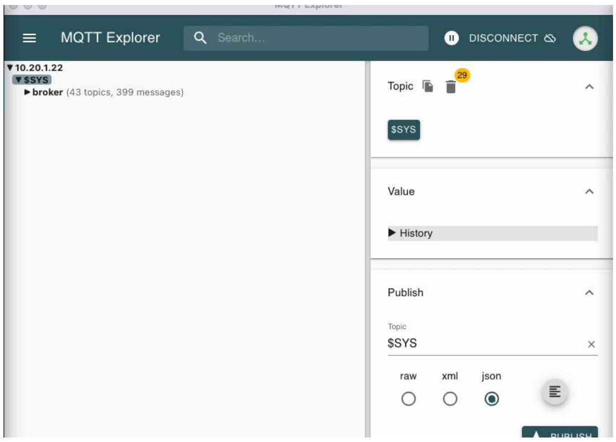
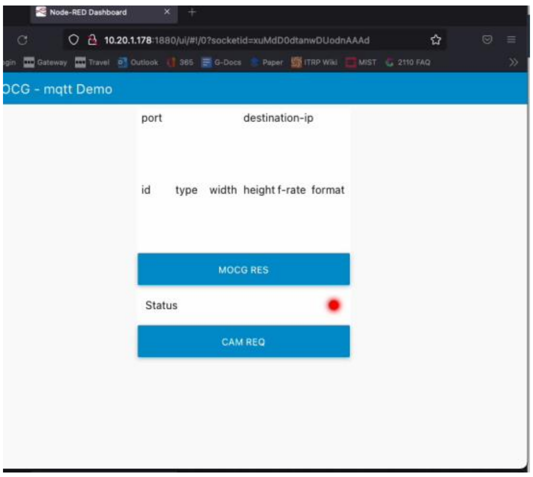
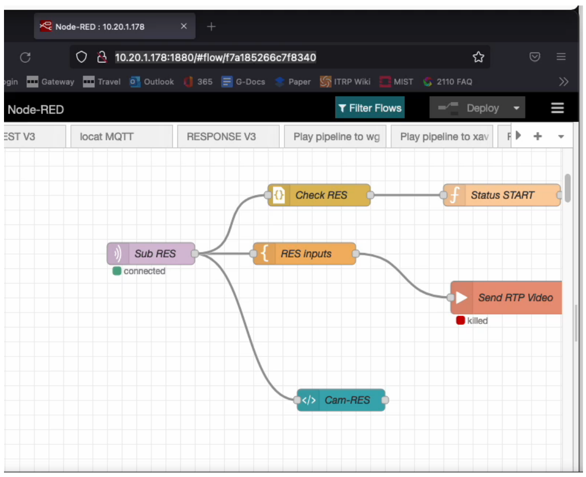


Figure 6: Simple Camera registration using MQTT and IS-04

Note: in the above sequence the MG – which provides an NMOS Node – registers itself using the IS-04 Registration API. This is a more direct approach than previously proposed in 5G-RECORDS D3.1 [4], where the MOG Gateway performed the registration and makes for a cleaner separation of concerns when using a MG. The previous proposal may still be appropriate where is no MG, however.







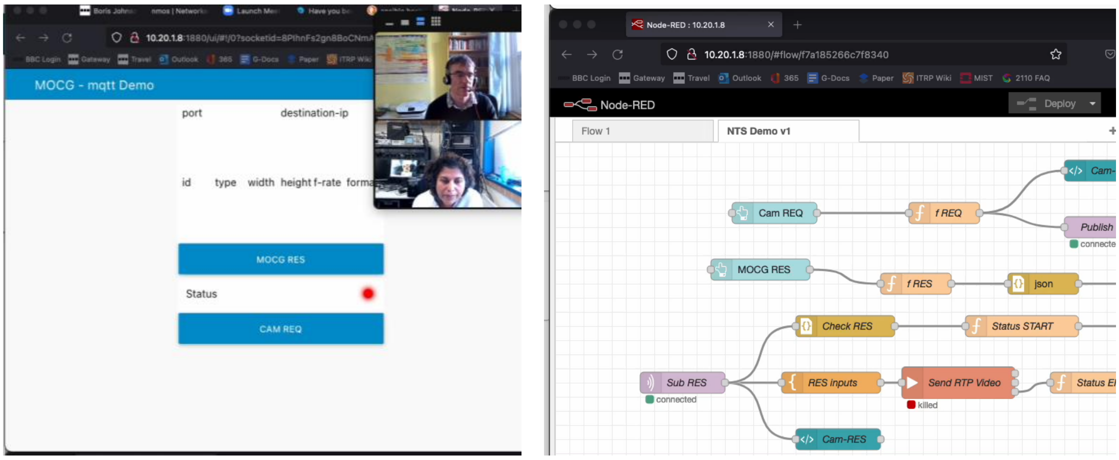


Figure 7: Screenshot from EBU NTS 2022 demonstration

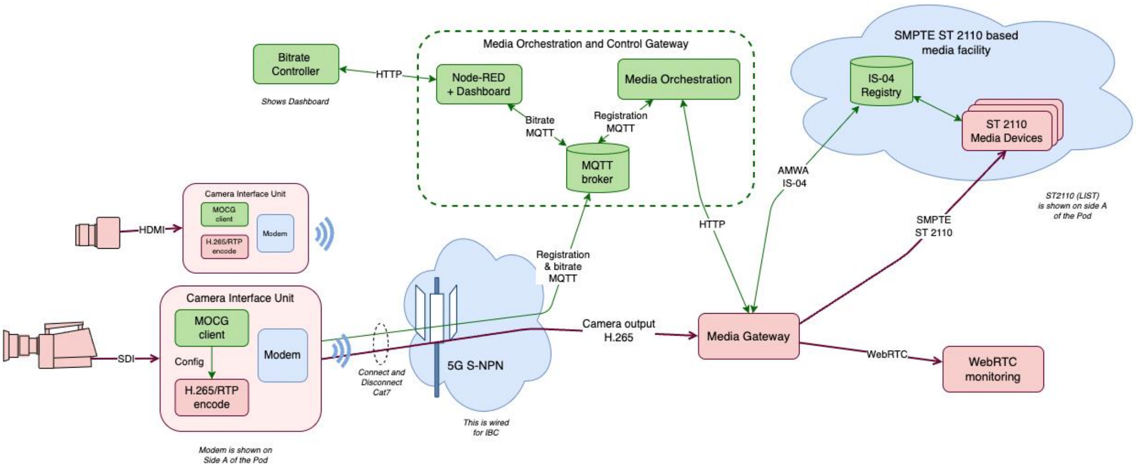


Figure 8: Architecture of IBC 2022 MOC demonstration

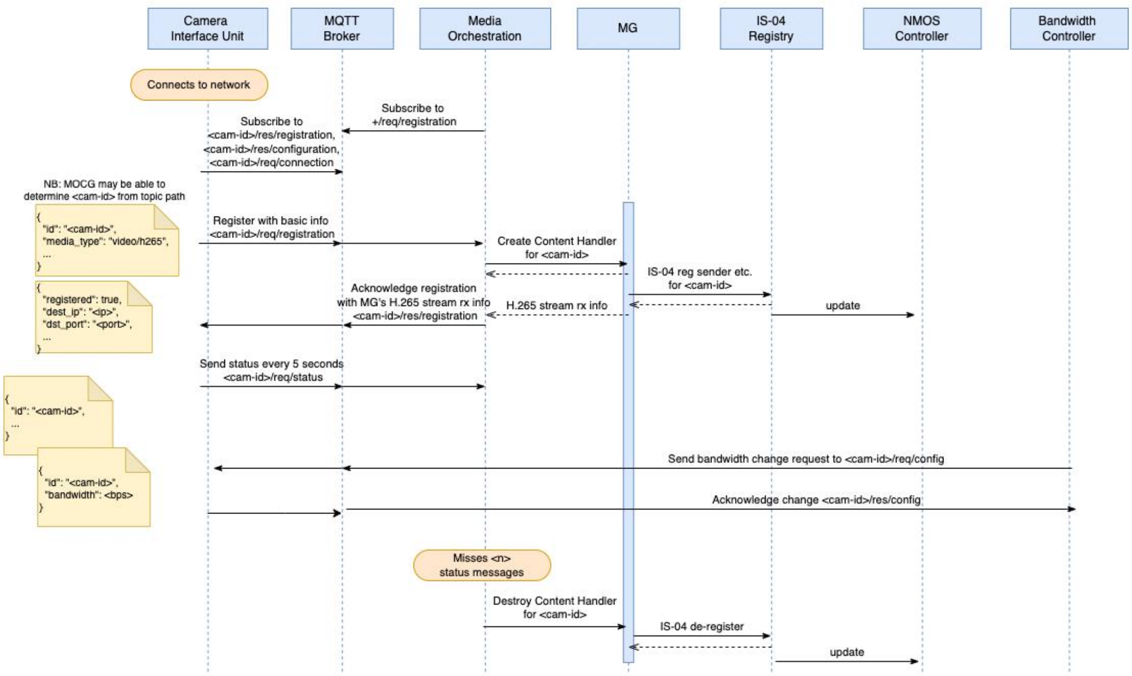


Figure 9: IBC 2022 sequence with registration, heartbeat and bandwidth change

4.3 Connection of Media Devices and Stream Configuration

Once the camera or other media device is registered, a control application can connect it to a destination in the media facility, which in simplified form (Figure 10), involves the following process:

- The MG runs a media pipeline to receive streams from the camera and transform and send them to the ST 2110 wired facility.
- The MOCG uses MQTT to communicate with the camera (see above) to communicate the MG's receive endpoint
- The controller queries the NMOS registry to find information about the camera and the ST 2110 sender on the MG that is handling the (converted) camera streams, and about the ST 2110 receiver in the wired facility.
- The controller invokes AMWA IS-05 NMOS Connection Management [14] to make a connection between the sender and receiver.

A more detailed description of this sequence and the MOCG and MG roles in it is presented in D3.1.

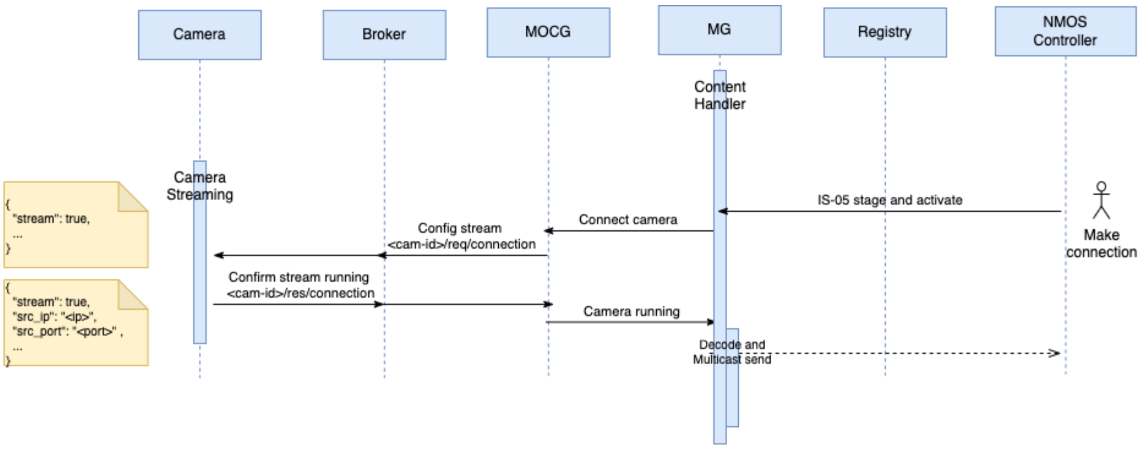


Figure 10: Simple Camera connection using MQTT and IS-05

This approach allows for signalling and setting of configuration information about the media stream to/from the device. For 5G-RECORDS tests we have used H.265 video, Opus audio over RTP. In some cases, MPEG-TS can be configured. The approach can be extended to support specific codec selections (e.g., AV1 or H.266) and parameters, such as use of GDR (Gradual Decoder Refresh), and video/audio settings such as picture dimensions and audio sample rate.

4.4 Network Control and QoS

The project has investigated requirements for prioritisation of different flows used by in production, based on their sensitivity to latency (see figure below) and the available APIs (PCF and NEF) to define QoS flows to meet these requirements in 3GPP releases 15, 16 and 17. While the UC2 tests so far have used default QoS settings, the MOCG architecture can be extended to use the APIs to setup suitable QoS flows, as discussed in D3.1.

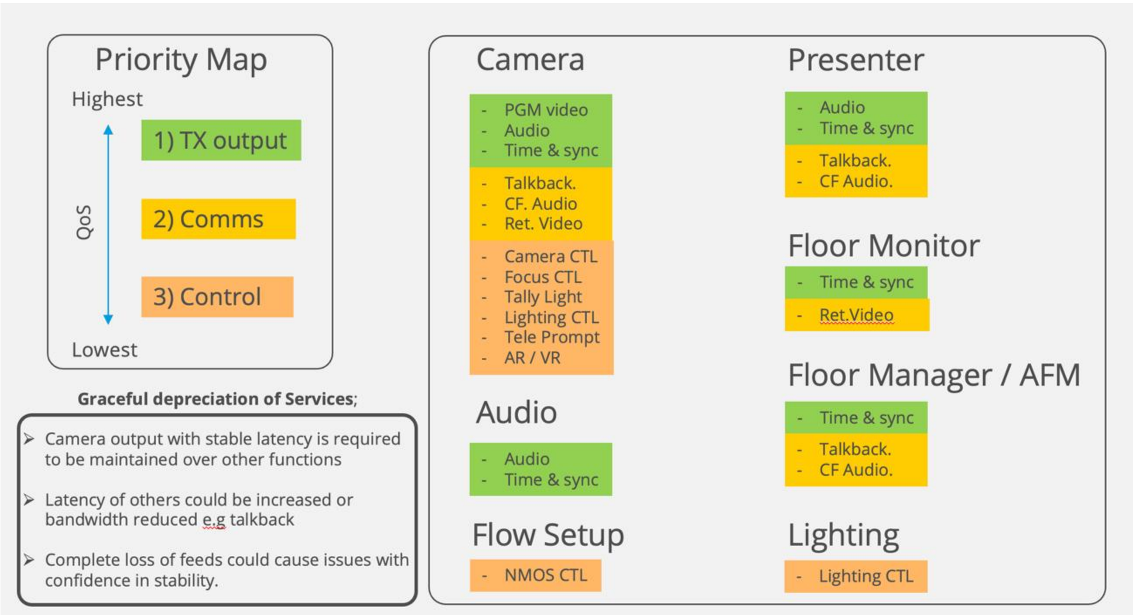


Figure 11: Prioritisation of typical production flows

4.4.1 Different bit rates for Standby vs Programme

The project has considered dynamically changing the bit rate of a camera depending on what it is doing. In professional multi-camera production use-cases, several cameras simultaneously capture an event, with each camera focusing on different parts of the scene, for example close-up shots of certain performers, wide angle shot, audience reaction shot. The video of all cameras is displayed in the production gallery and the programme director or vision mixer selects the “on air” camera, known programme (PGM) camera. A tally light will often be illuminated on the programme camera. Full quality will be needed for this camera, and probably other cameras that will be used soon (often the vision mixer will select a preview (PVM) camera to show next), but if a camera is unlikely to be used soon, its bit rate could be reduced to a “standby” level, but enough to monitor it in the production gallery. This is not done for wired studios, but it could help make best use of bandwidth for a wireless scenario (Figure 12).

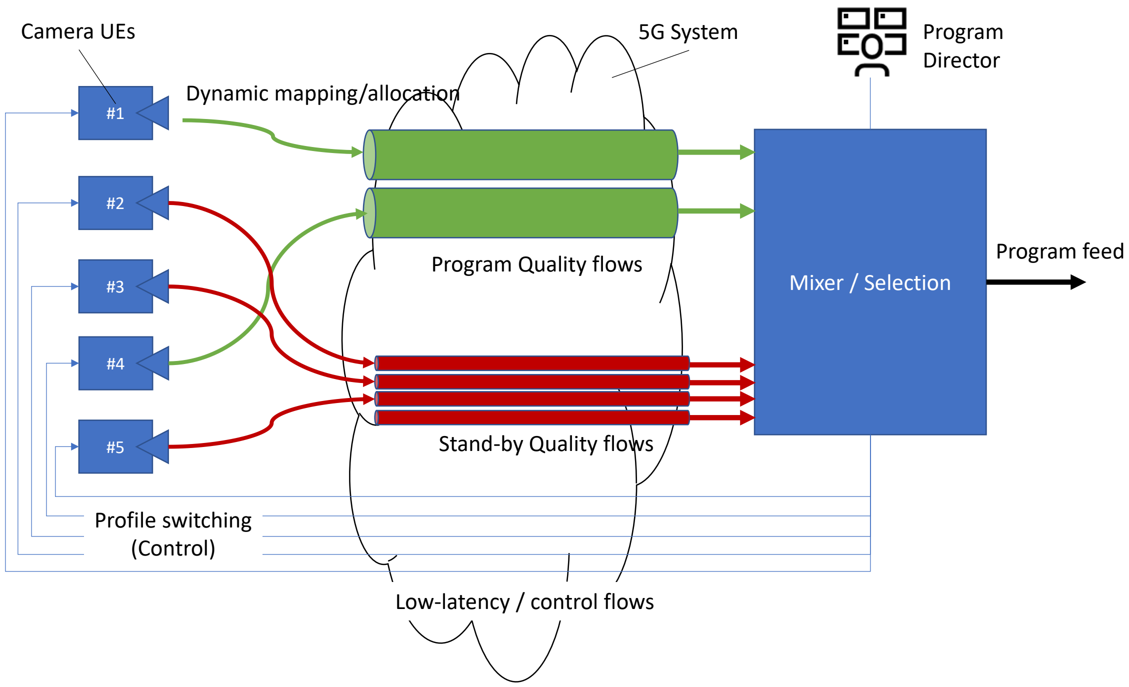


Figure 12: Different quality camera flows

Two methods of achieving the above have been considered:

A) Modify QoS rules on the fly to change between programme and standby profiles (Figure 13). This has the advantage of requiring only one QoS rule but introduces signalling latency and will not be synchronised with the video.
B) Establish programme and standby flows in advance for each camera (Figure 14). This is faster and can be synchronised but doubles the number of QoS rules needed.

These methods have not been implemented in 5G-RECORDS, although the IBC demonstration includes dynamic control of camera bandwidth.

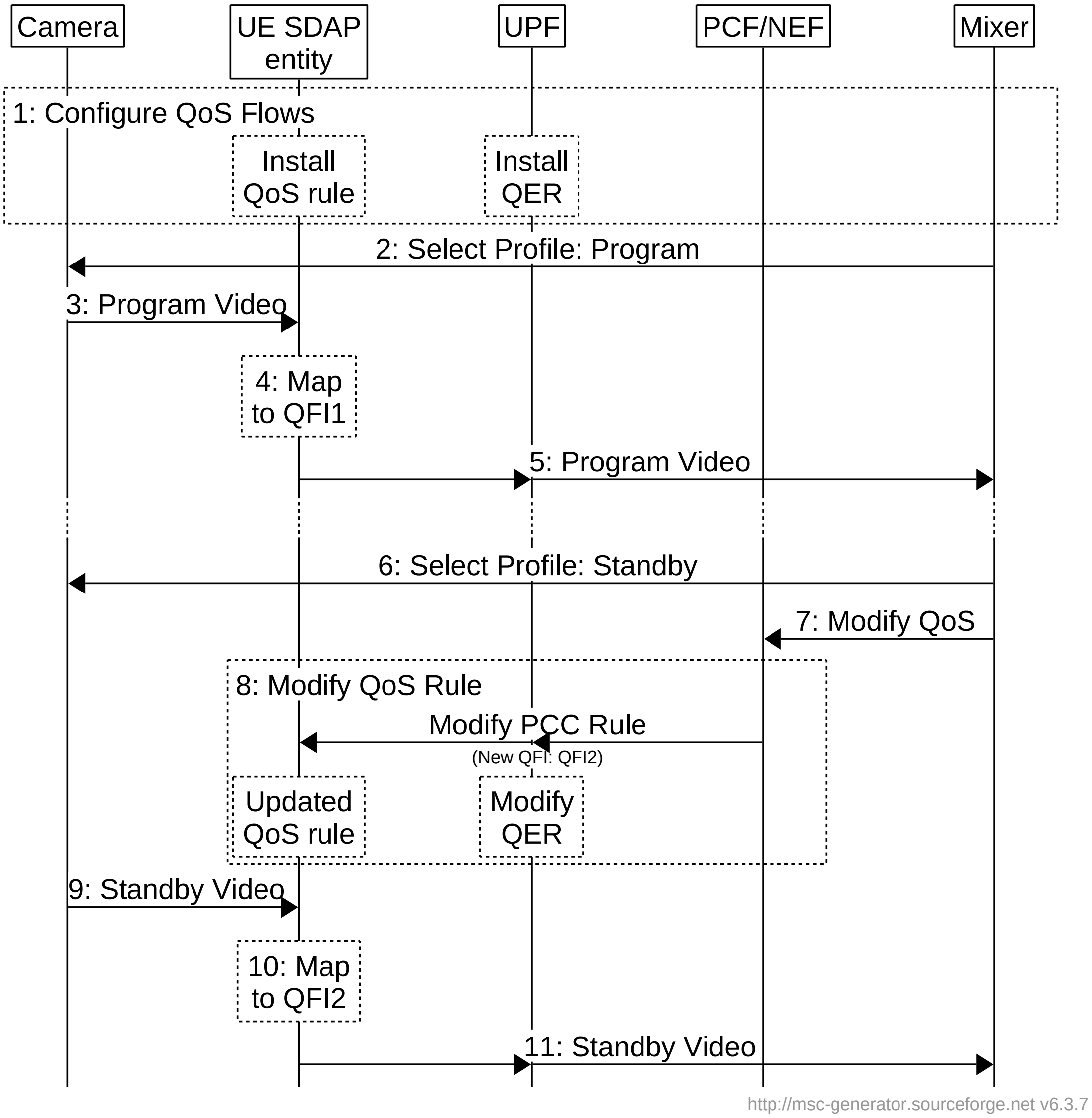


Figure 13: Dynamic modification of QoS rules

While it has not been possible to implement the above during the 5G-RECORDS project timescale, a simple demonstration of changing the bit rate streamed from the camera will be demonstrated at IBC 2022, by changing the H.265 coder parameters under MQTT control.

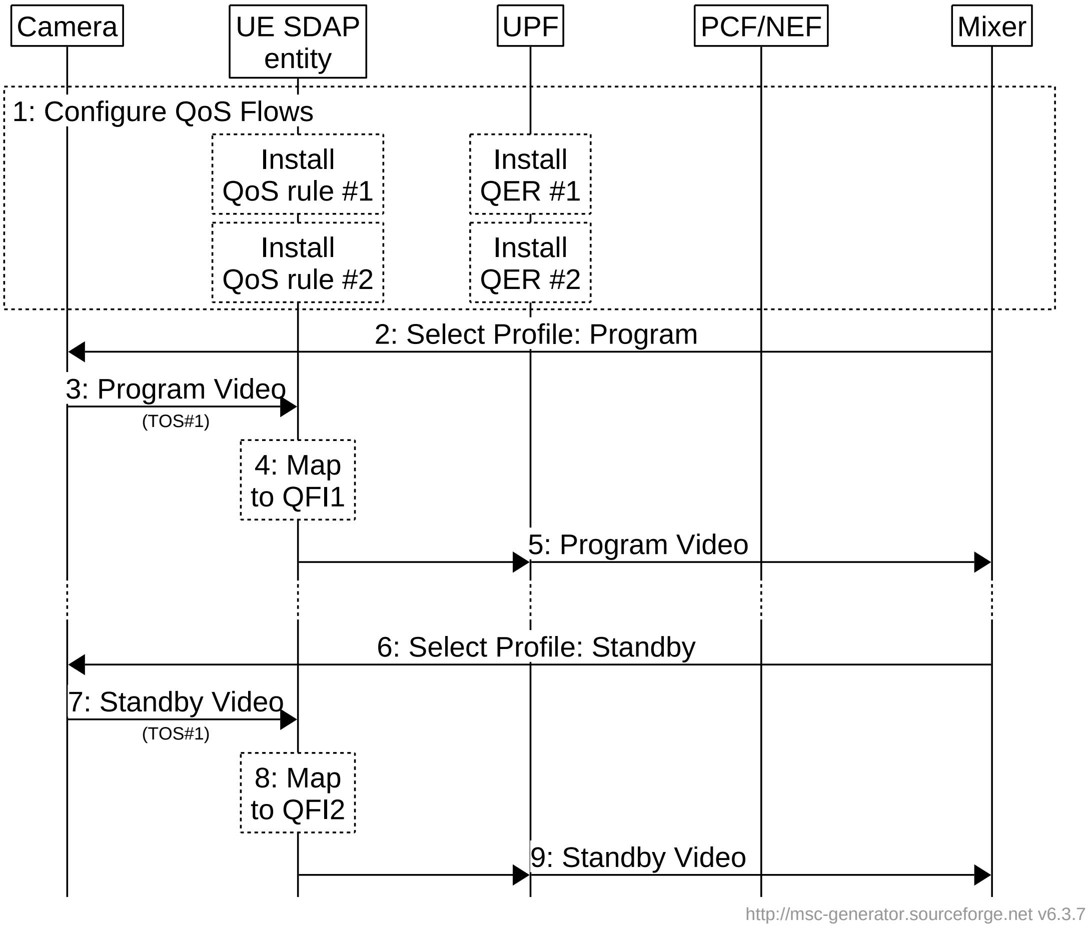


Figure 14: Separate programme and standby flows

The approaches described above have contributed to, and are consistent with, 3GPP's study on TR 26.805 [15].

4.5 Camera Control

As discussed in D3.1, there are many camera control protocols in use today, from simple RS 232 / 422 / 485 serial protocols to Ethernet and IP based protocols. Many are proprietary, although some (for example Sony's VISCA [16], used by multiple manufacturers. The project has met with several camera manufacturers to explore the possibility of a common approach; but it is understandable why all the different solutions have arisen as a result of different technologies and requirements over many years. In many cases, a camera will be controlled by a CCU (Camera Control Unit) from the same manufacturer, and this allows "added value" features to be implemented in the control.

However, some features are common across cameras, and there would be a business benefit to allow a common approach to use these. Therefore 5G-RECORDS has investigated a possible solution to Remote Camera Control and a has implemented a Proof-of-Concept (POC) application to control the camera. Based on what we described in the previous deliverable D3.1 we developed a novel way to send time stamped camera control messages through AMWA IS-07 NMOS Event and Tally Specification [17].

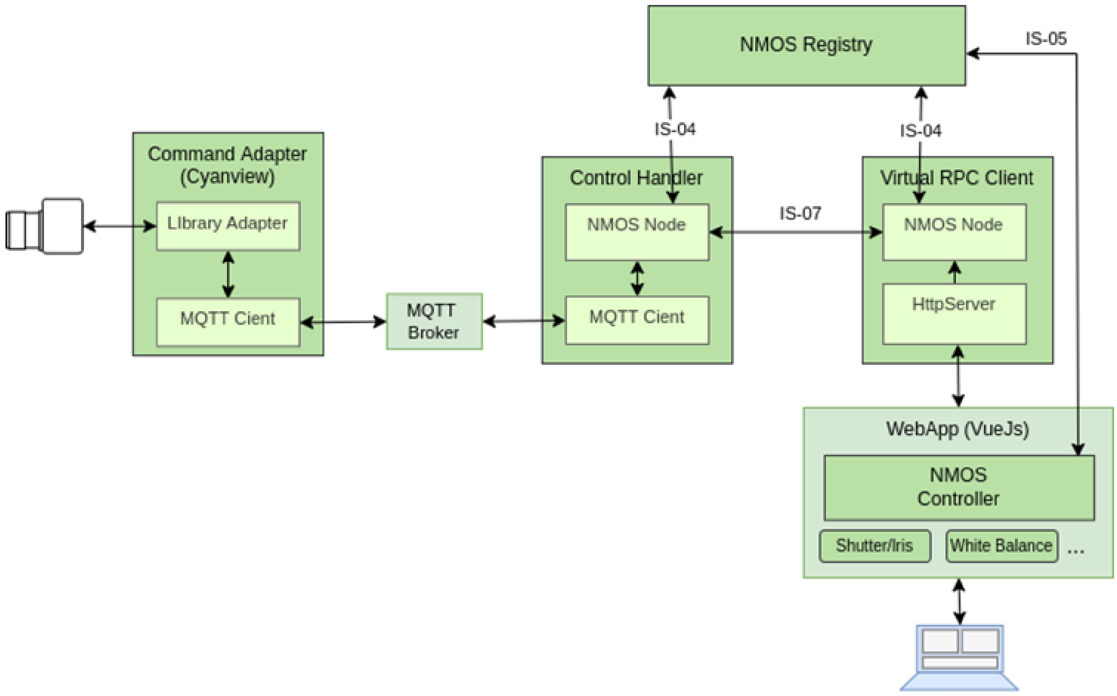


Figure 15: Camera control proposed architecture

The two core components developed by RAI team in the proposed architecture (Figure 15) presented are:

- NMOS-control-sender (i.e., NMOS node in Virtual RPC client): this node has the http endpoints to get the commands from the control WebApp
- NMOS-control-receiver (i.e., NMOS node in Control Handler): this node receives the IS-07 messages and translate it into MQTT messages to forward proper commands to CyanView system

The two NMOS nodes have been adapted for the project's scope. The baseline implementation used for our development was the Sony NMOS open-source implementation [18].

A control WebApp has been developed using VueJS framework [19], starting from a template available on GitHub called Vuestic. In the dashboard panel it is possible to control basic camera parameters like exposure and gain.

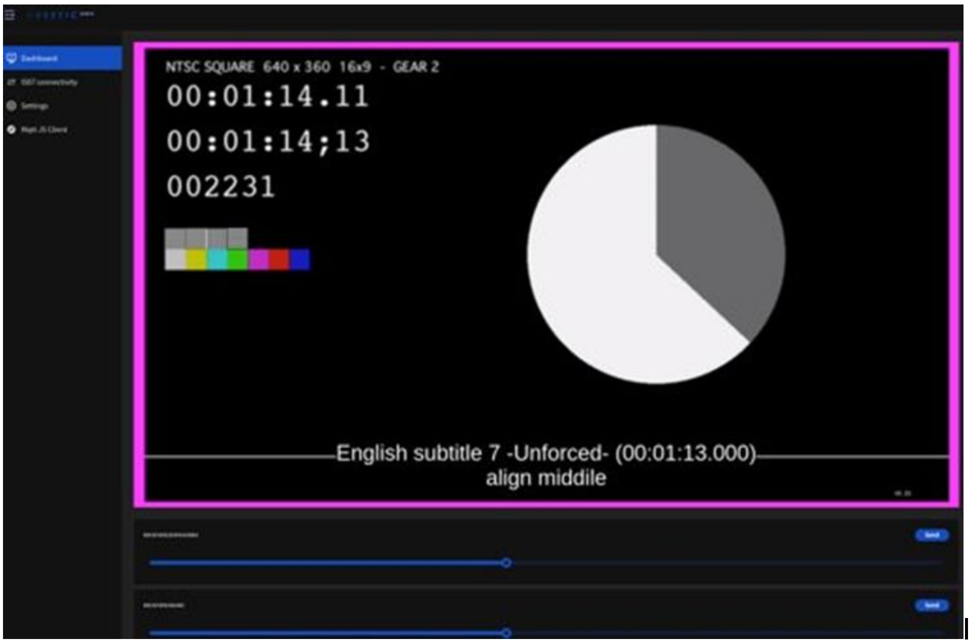


Figure 16: Camera control dashboard

A basic NMOS controller has been implemented. With this simple Web NMOS controller, it is possible to discover every NMOS-control-receiver and NMOS-control-sender registered to the NMOS registry present in the local network. It is also possible to connect an IS-07 receiver to an IS-07 sender (Figure 17). The top right icon updates its state to indicate if the receiver is connected.

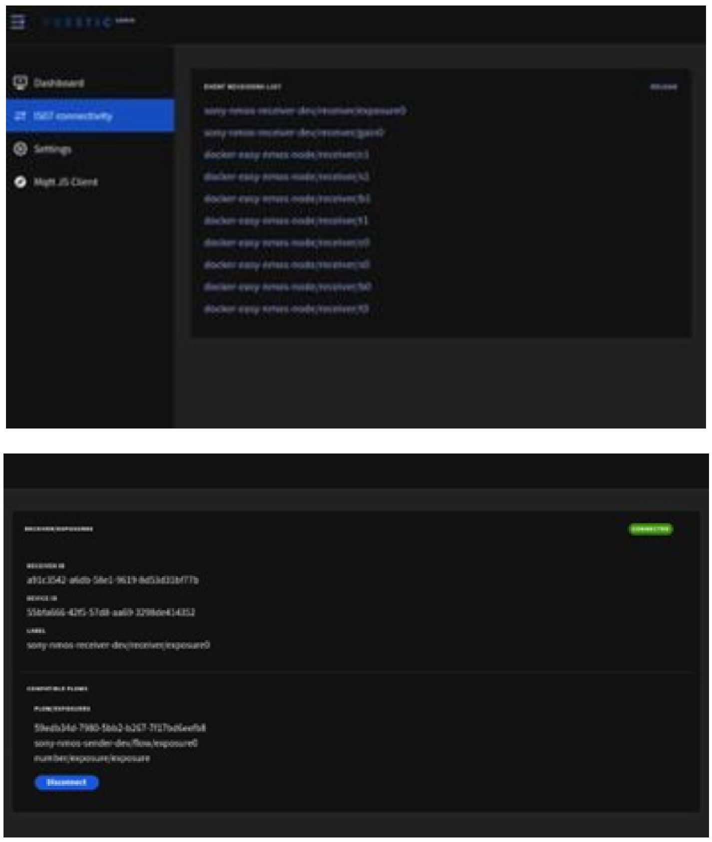


Figure 17: IS-05 connection management view

The settings webpage is where it is possible to set up the web application. It is possible to set up the NMOS registry address and the NMOS-control-sender HTTP endpoints (i.e, gain 10.45.1.12:9999/gain). Lastly, it is possible to set up also the video stream endpoint, if available, coming from the MG developed by project partners, allowing to check directly on screen the result of the remote control.

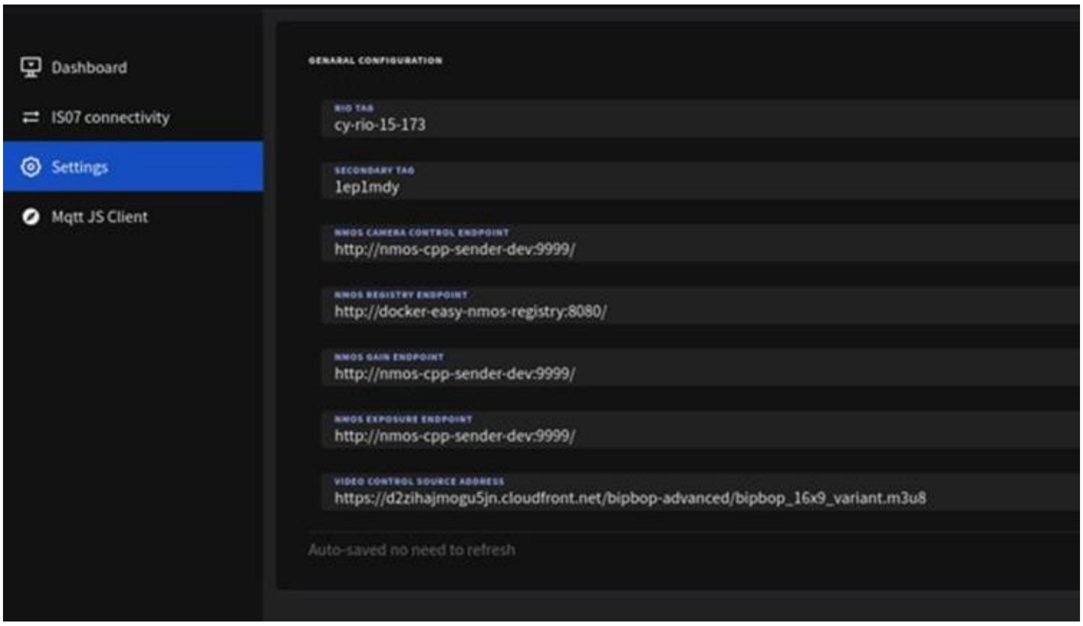


Figure 18: Settings view

The project used products from CyanView [20] to interface to the proprietary protocol of a Sony camera. These are the CyanView RCP, which provides a controller and MQTT broker, and the RI0 which provides the command adaptor.

CyanView has defined a specific MQTT topic hierarchy for the operational control purpose. For example, to control a camera tally, a numeric value is published to an MQTT topic such as the following (simplified) example:

/<id>/camhead/set/tally

where <id> uniquely identifies the camera.

The functions developed are packaged as 3 containers present on docker-hub:

- /nmos-cpp-camera-control:sender (Virtual RCP client in the diagram)
- /nmos-cpp-camera-control:receiver (Control Handler in the diagram)
- /camera-control-gui:latest (WebApp (VueJs) in the diagram)

Thanks to this modular and containerised design, it is possible to deploy these three containers dynamically into a generic remote orchestrator like Kubernetes or Openshift. In the context of the project an OpenStack cluster has been provided by BBC, where the three developed application runs relying on two Virtual Machines (VM).

Using WireGuard (see section 4.7) it has been possible to test the remote deployment at BBC premises with a Sony camera and CyanView devices from Turin at Rai CRITS-Labs premises.

4.5.1 Remote Camera Control POC

A Remote Camera Control POC has been developed. The proposed solution uses the developed components to remote control a camera through this NMOS IS-07 [17] novel approach (Figure 19)

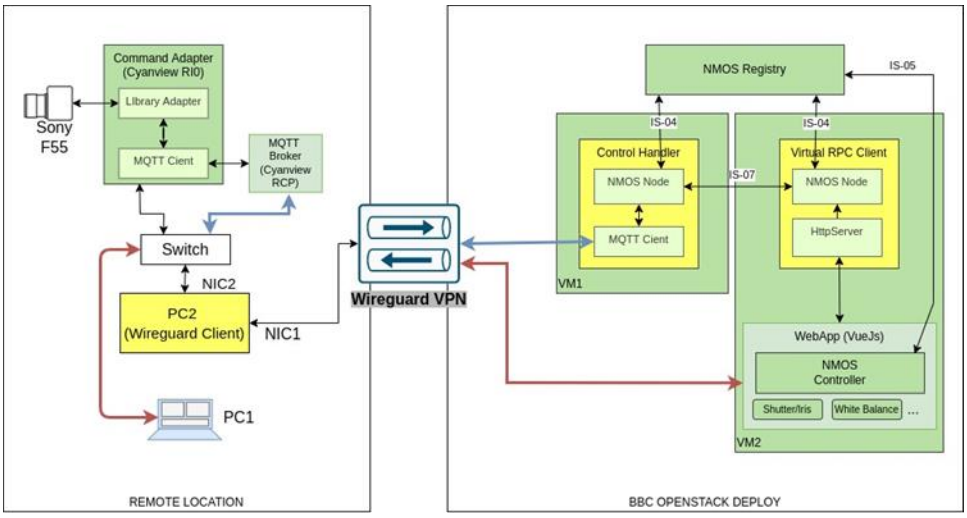


Figure 19: POC architecture

The two VMs (VM1 and VM2) were deployed on BBC's OpenStack (see section 4.7) and accessed via WireGuard VPN [13] by using a PC as a client (PC2). An unmanaged switch for the local remote connection of the devices has been added for convenience. The setup was completed by another PC (PC1) used as access for the remote-control GUI, the red arrow represents the connection to the WebApp through the browser. The MQTT traffic produced by nmos-cpp-camera-control:receiver is represented by the blue arrow in Figure 19.

Figure 20 shows the POC at RAI's CRITS-Lab. We can see the Sony F55 camera [21] with a viewfinder, the two CyanView devices (RCP controller and RI0. Converter (blue)) and the workstation used to route the traffic through the WireGuard VPN (green Ethernet cable).

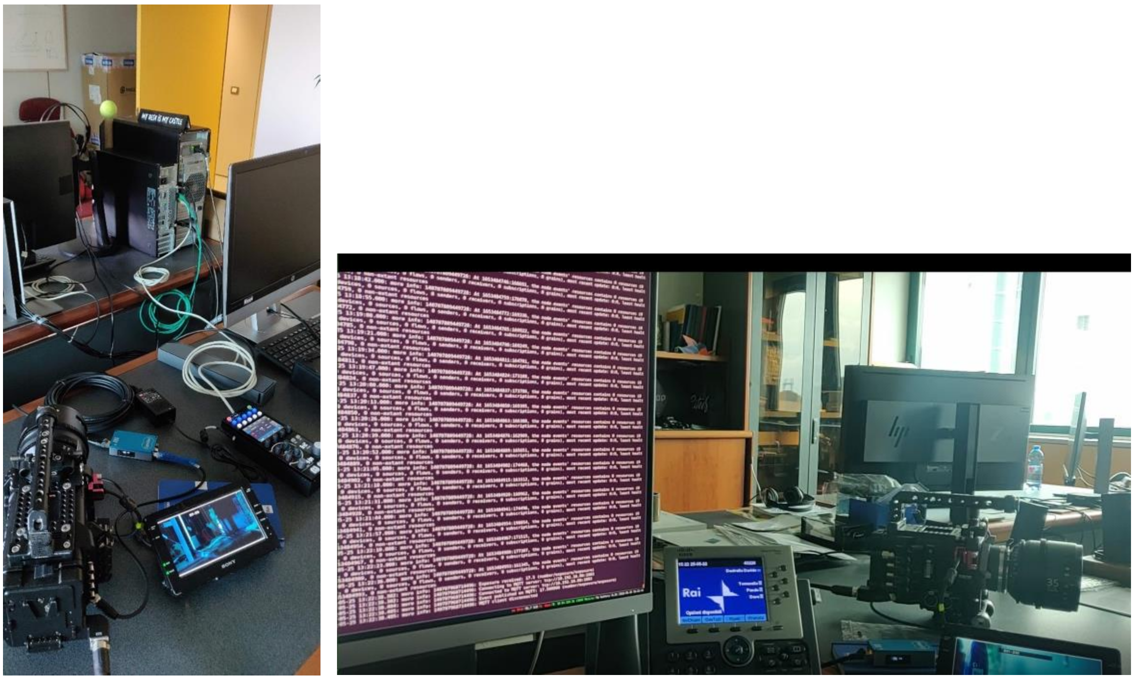


Figure 20: POC at RAI CRITS-Lab

4.6 Authentication and Authorisation

A media device's modem is authorised on the 5G network as part of its initialisation. By their nature, the MOCG and MG provide a mechanism of controlling access beyond the network, and the MOCG could be extended to support the [AMWA IS-10 NMOS Authorisation Specification](), so that it could present credentials when registering the media devices with IS-04.

Authentication should also used to control access to the MQTT broker. The simplest approach is to use a password file, but this will be difficult to manage at scale, and for temporary access. However, MQTT also supports use of external authentication mechanisms, including OAuth 2.0 [22]. Although not investigated by the project, it should be possible to use a similar approach to AMWA IS-10, which uses OAuth 2.0 tokens.

4.7 Provisioning, Resource Management and Monitoring

The project has investigated the use of widely used open-source tools for provisioning and configuration of software components used for typical UC2 scenarios:

- BBC R&D provides the project with an NMOS registry, MQTT broker and GStreamer [12] H.265/RTP endpoints hosted in virtual machine instances on its OpenStack [23] cloud at its London site. A WireGuard VPN [13] provides controlled connection to these from project partners' locations (Figure 21). This enables transport of media flows, MQTT messages, etc. without complications caused by firewalls, NATs etc. For ease of operation and management we used a star topology with VPN traffic routed via a server in London; the throughput was sufficient for the testing required (and there was also the possibility of using a point-to-point topology if required).
- The registry, broker and VPN server are provisioned using the open-source infrastructure-as-code tool Terraform [24] and are configured using the open-

source automation tool Ansible [25]. This provides a high degree of automation, which has been helpful when making changes such as adding new WireGuard clients.

- We have also made use of containerisation: much of the Media Gateway and Media Orchestration and Control Gateway is now containerised, as are parts of the camera control proof-of-concept, and AMWA's NMOS test suite. The project has deployed these containers (using Docker Z), both locally and on BBC's OpenStack cloud.
- BBC has also investigated the use of Ansible for installation of software on Jetson Nano and Xavier devices [26] required for streaming and control.

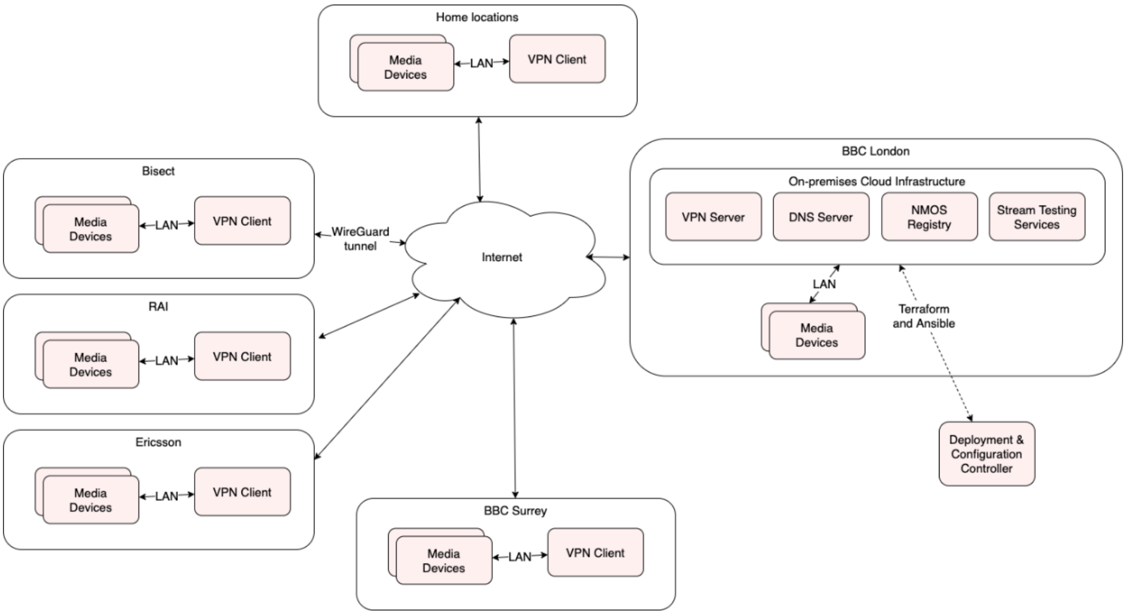


Figure 21: Multi-site working using WireGuard VPN and BBC on-premises cloud

5 Media Orchestration and Control for Use Case 1

In contrast to Use Case 2, this use case does not include remote processing of media in the current state and therefore no MG is used. Nevertheless, both use cases have the basic concept of an MOCG in common.

Figure 22 shows the general architecture used in this project to realise the UC1 scenario. Multiple 5G-enabled microphones and in-ear monitoring receivers are connected to a local 5G network. An in-ear mix for each IEM can be generated in a local audio processing device that is connected via Ethernet cable to the 5G system (5GS). Ultimately all audio devices should be controllable by a user over the Internet.

The controllable parameters of a wireless audio device (mic/IEM) can include:

- Gain of a mic preamp
- Sample rate
- Audio compression rate / codec
- Headphone volume

Additionally, some status parameters should be retrievable from the mobile device to support the operation:

- Battery level
- Audio input level

As well as control of the media devices, the MOCG could also configure the network e.g., by setup of QoS flows in the 5G network to allow best performance for the media devices.

5.1 Architectural Approach

To achieve the necessary device and network control the concept of a MOCG is used like in UC2. The user uses a Media Orchestration Controller application to enter the desired media flows. The MOCG translates these user control inputs to device-specific protocols. The actual protocols can include vendor-independent protocol standards like NMOS or proprietary protocols.

For network control the idea is to achieve this via a Core Configuration Service (CCS) that can access the 5GS flow control through a dedicated application function named Network Slice Manager.

The overall control architecture is shown in Figure 22.

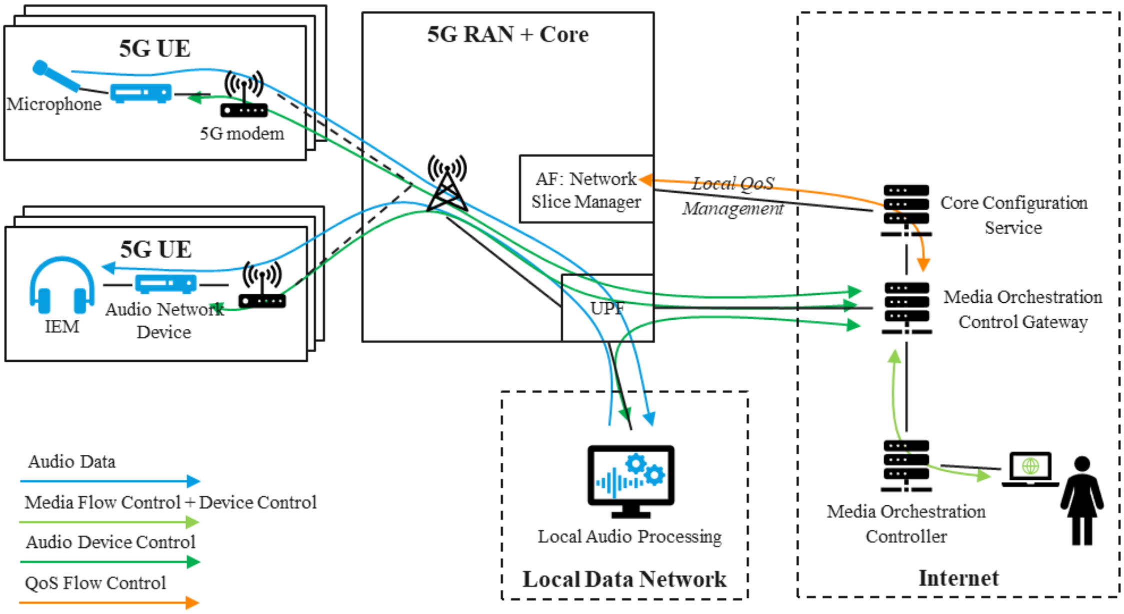


Figure 22: High level control architecture of Use Case 1 (live audio production)

In the UC1 deployment both the media orchestration controller – offering a user interface to input media orchestration requirements – and the MOCG are hosted in a cloud environment and are therefore accessible from anywhere via the Internet. All other devices and functions are located on site.

In typical network setups there are gateways and firewalls in between local and cloud networks, so it is necessary that the protocols used to bridge the two networks can deal with these. In the deployment used for UC1 this is ensured by using a TCP-based protocol where the connection is initiated by the local devices. This typically reduces issues with firewalls – depending on the configuration.

5.2 Setup 5G Network and connect UEs

To connect a UE to the local 5G network first the 5GS itself must be configured properly. Figure 23 shows the necessary steps. A Spectrum Access Server (SAS) gets a frequency lease from the national regulator. When the 5GS powers up a list of channels is negotiated with this SAS. When the RAN is operational the UE can connect and establish the default PDU session for basic connectivity.

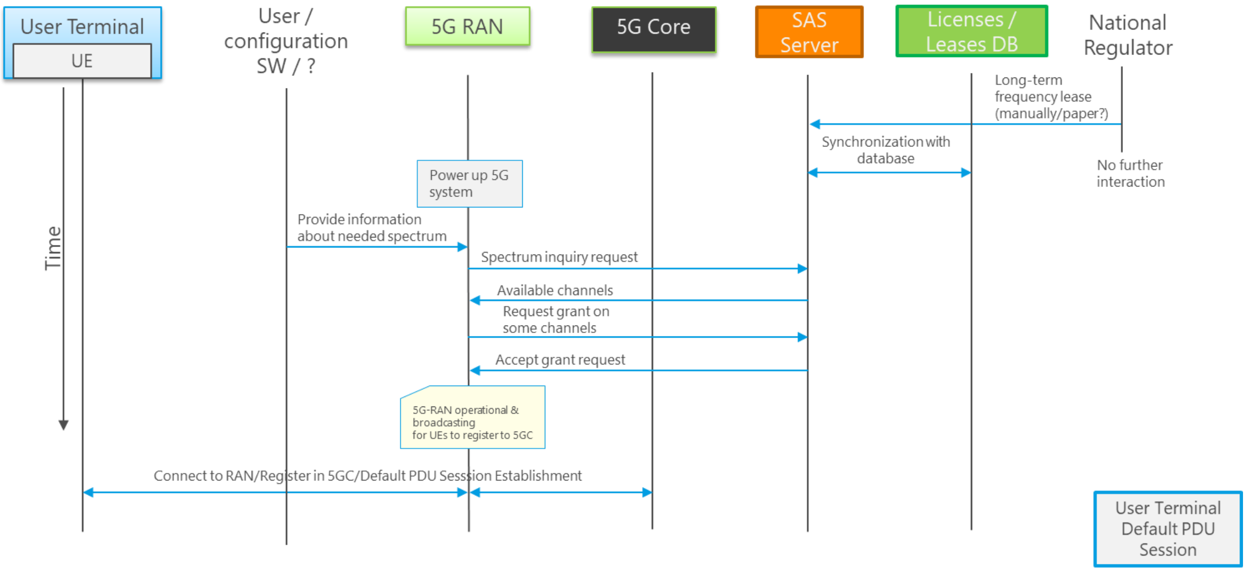


Figure 23: Data flow for setup 5G network and connect UE

This process is independent from the MOCG but creating basic connectivity is a necessary preparation to achieve a remote controllability of the media.

5.3 Registration and Discovery of Media Devices

When audio devices connect to the network, they need to be known to the MOCG. Figure 24 shows this process. The audio devices announce their capabilities to the MOCG which allows the MOC to setup streams. In the current implementation a custom TCP-based protocol is used to connect the media devices to the MOCG. In a potential product a protocol like MQTT as suggested by UC2 could be used. AMWA NMOS IS-04 might also be a good solution for a local network but where it is not possible to run an IS-04 Node API on a media device, for example because of a NAT gateway or firewall between the device and the MOCG, a modified version of IS-04, such as the MQTT mapping proposed in UC2, would be required.

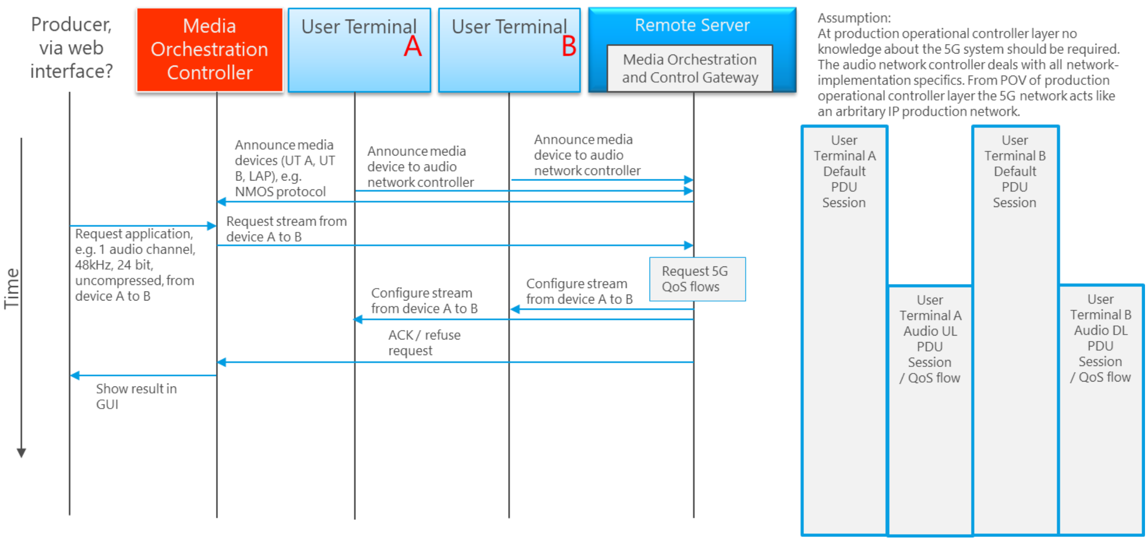


Figure 24: Data flow for device discovery and audio stream establishment

5.4 Connection of Media Devices and Stream Configuration

Once the media devices are connected to the network and are registered with the MOCG the user could request the setup of audio data streams as shown in Figure 24. The system concept in UC1 includes the setup of QoS flows to realise a high priority for media flows in the network. After setup of a QoS flow the MOCG notifies the involved media devices of the audio data stream that should be setup.

5.5 Network Control and QoS

In cases where there are competing devices and competing traffic classes on a network (e.g., audio, video, intercom, control) a congestion based on uncritical data could cause a delay / failure for critical data like live production audio. To overcome this issue, it is possible to make the network aware of the priorities of the different traffic classes. This could avoid blocking of mission critical data while keeping sufficient connectivity for less critical devices.

When the MOCG setup audio data streams, the concept provides for the configuration of QoS flows in the network. Since there are multiple implementation specific ways to achieve QoS in different networks a function called core configuration service (CCS) is defined within this use case.

The concept for QoS requests by MOCG is:

- The MOCG requests QoS flows from the CCS.
- The CCS requests the required QoS flows from the 5G Network Slice Manager (NSM) application function.
- The NSM checks the availability of radio resources with the Shared Access Client (SAC) in the RAN.
- If the 5GS has capacity for these flows a new QoS-PDU session per UE is created to carry the audio payload.
- The MOCG configures the audio devices and the MOC shows the user that everything is up and running.

The process of requesting QoS flows from the 5GS is shown in Figure 25.

More details on the concept of the Network Slice Manager and the used protocols are available in D3.1.

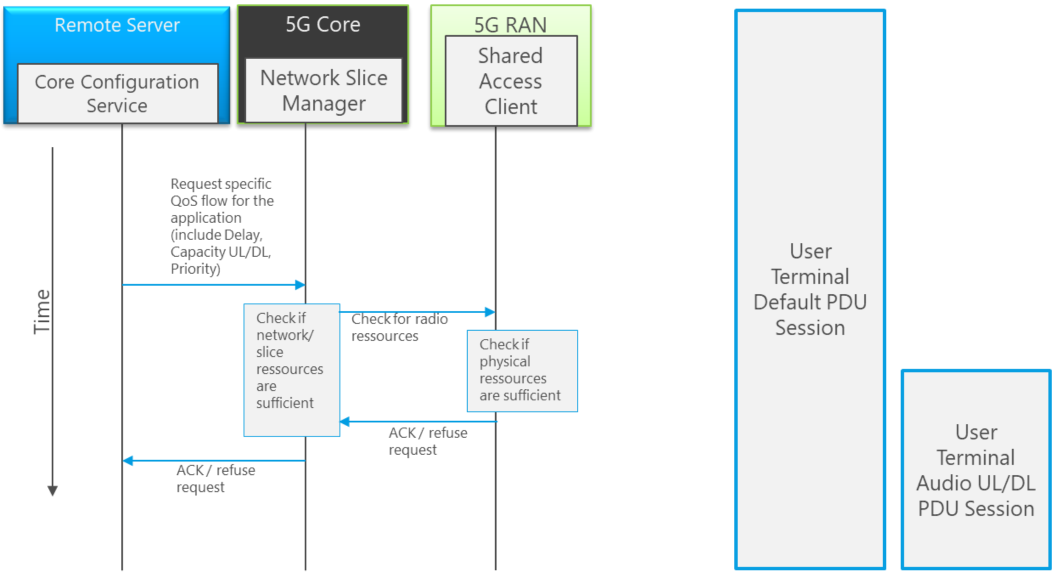


Figure 25: Data flow for requesting a QoS flow from the 5G network

5.6 Media Device Control

Once the audio data flows are setup the user should be able to monitor the status of the media devices but also to control the device parameters.

Figure 26 shows a screen shot of the control web application developed during this project. This application interacts with the MOCG and shows the user the devices that are involved in the production. For each media device several control options and status information are available to the user.

Since this application is deployed in the cloud it can be accessed from every browser via the Internet. The application is designed for a proof-of-concept analysis only and therefore the user interface is not optimised for productive use.

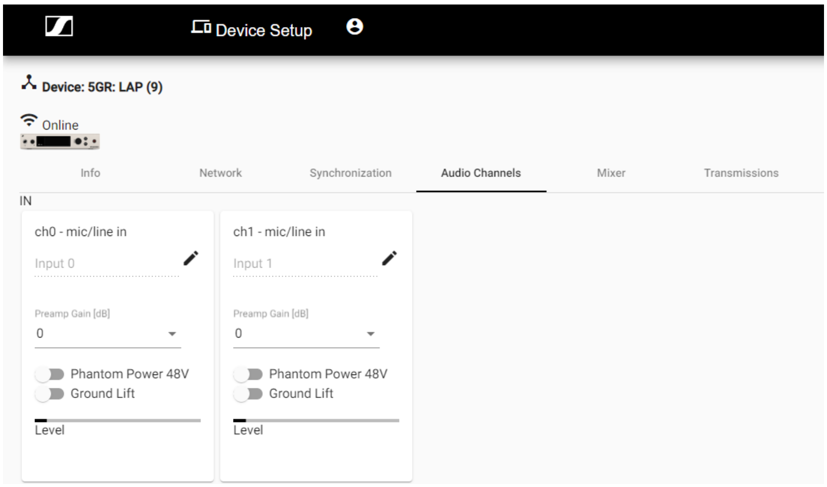


Figure 26: Web-based demonstration control application for media devices

The application allows control of parameters such as the preamp gain and monitoring of the actual volume level of the 5G microphone demonstration system.

For a 5G IEM device this control interface allows setting of the volume of the headphone output.

6 Possible follow-on work

The MOC controller, gateway and camera interface components described above provide a basis for further exploration and development.

- The components could be used in follow-on trials of 5G-RECORDS technology, including deployment in “cloud-based” software infrastructure. BBC is investigating this for its on-premise OpenStack infrastructure, as well as other cloud infrastructures.
- The simple MQTT-based protocol of camera discovery, connection and control is a basis for a more complete approach that could be proposed to AMWA to extend the capabilities of NMOS. This could be a generic mapping of REST commands to MQTT as discussed in section 4.2.
- The project has identified a set of important codec/stream formats, which will feed into future work in AMWA in extending NMOS’s capabilities beyond ST 2110. In particular BBC and Bisect are working with NVIDIA on a proposal for support for H.265 in NMOS.
- Further investigation is needed to explore the proposals of sections 4.4 and 5.5 of QoS management on real-world NPNs.
- The broadcast industry is still coming to terms with how synchronisation will work in IP and software systems (see section 2.5) and this will lead to further requirements for Media Orchestration and Control.
- Further work on authentication and authorisation (section 2.7) should provide a way to control access to a production’s resources based on identity established in the 5G network, and rules provided by the production.
- The provisioning and configuration approach explored within the project (section 2.8 and 4.7) can be extended to provide further automation, of the media devices, the gateways and the services they connect to. This will be an important aspect for effective use of wireless devices in local, edge and cloud-based architectures for the future.
- The techniques and components developed for Use Cases 1 and 2 could be implemented for Use Case 3.

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