WHITEPAPER

Optimized Camera Integration in IP-based Workflows and Infrastructures

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This paper first appeared in the ***Proceedings of the NAB 2022 Broadcast Engineering and Information Technology (BEIT) Conference****. Reprinted here with permission of the author.*

Abstract

The increasing availability of powerful IP infrastructures opens up new application possibilities for system cameras in media and entertainment applications. Additional IP interfaces on camera base stations have enabled initial applications to be covered and experience to be gained in a first step. However, the question arises as to how the integration of cameras in IP infrastructures can be optimized in such a way that an improved workflow can be achieved for almost all use cases. This includes the possibility to adapt the bandwidth requirements of the cameras to the existing IP bandwidths, but also the possibility to do all this without external conversion of the video signals to IP signals. The paper will highlight the various challenges and present possible solutions based on camera systems with fully integrated IP connectivity.

Camera connectivity

From baseband to IP

Signal transmission between camera heads and camera base stations or camera control units (CCUs) has continuously evolved **[1]**. In the 1970s, multicore cables were replaced by triax cables, and more recently, with the introduction of UHD-1 standards, SMPTE hybrid fiber cables and connectors, where all signals except power are connected via two fiber cables, have become the de facto standard for most applications.

At the same time, signals transmitted over camera cables have been converted from analogue to digital, and the most advanced media and entertainment cameras now use IP.

Connectivity between the camera base stations and the rest of the infrastructure was based on multiple baseband signals, and IP interfaces are often used for this in the latest installations. Two different solutions have been developed and specified for the IP signals, one is the SMPTE 2022 standard as a way to use serial digital video signals including embedded audio and ANC data over an IP link, and the other is the SMPTE 2110 standard where all signals are delivered as single essence streams.

Many installations that primarily use IP connectivity still require a certain number of baseband signals to be provided in addition to the IP connection.

An example of a camera base station that provides only baseband signals and a version that provides a combination of baseband and IP connectivity is shown in **Figure 1**. In the version that provides both baseband and IP connectivity, there is no compromise on the baseband connections and the IP connectivity is provided in addition, allowing the user to choose which of the signals to use and in what format.

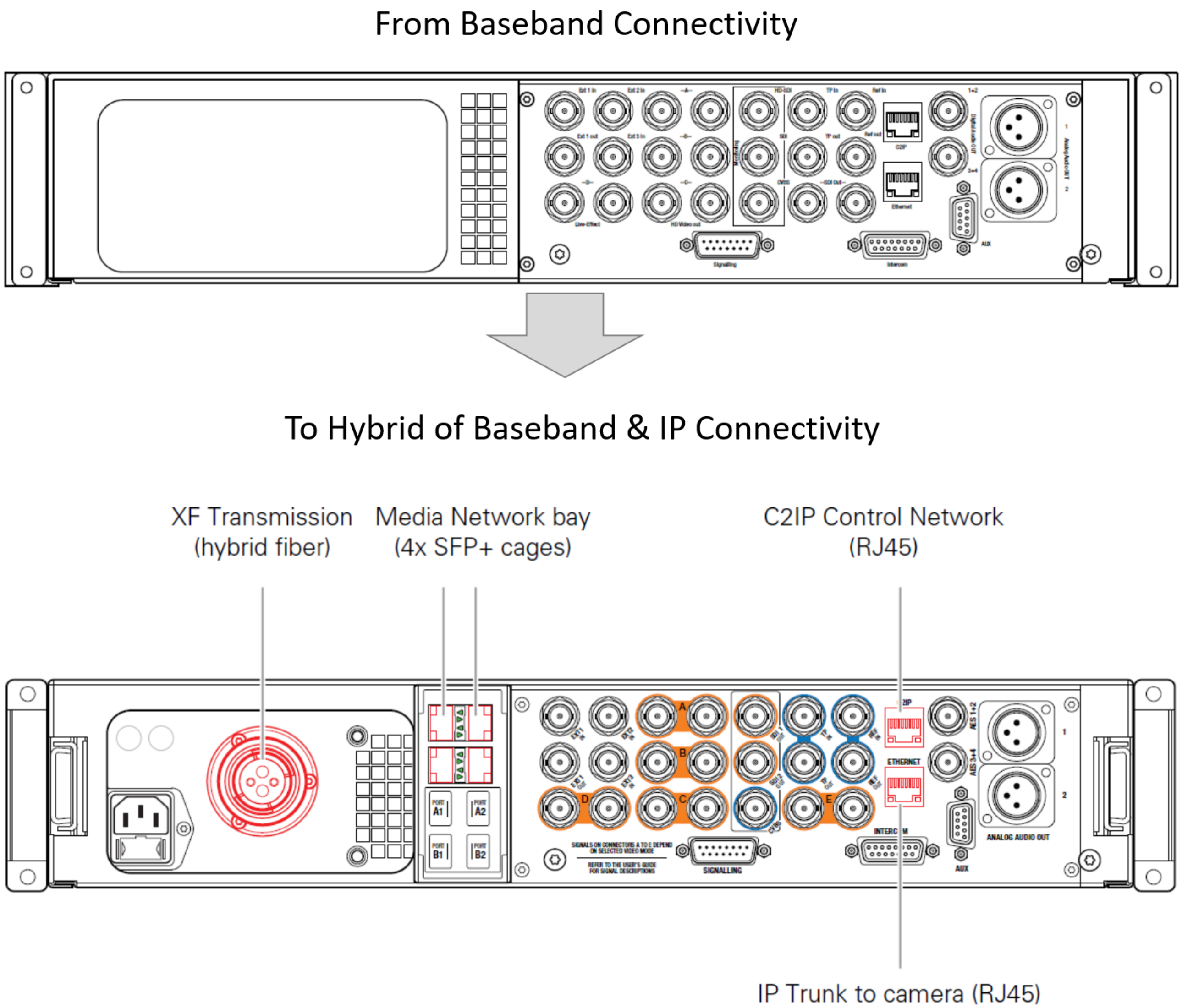

Figure 1 — From baseband to the hybrid of baseband and IP connectivity.

Why using IP

SDI video, with its recent developments around 12G SDI for single-speed UHD-1 operation, has served the broadcast market well for many years, but more and more limitations are becoming apparent. When moving to full UHD-1 operation, high-speed cameras must also be converted to UHD-1 operation; this requires three or even six times the bandwidth of single-speed operation. In addition, high frame rate (HFR) operation is required for some applications, just as there are initial discussions about 8K UHD operation. 12G SDI would require multiple connections per camera there, which also only support a relatively short cable length. It is clear that the bandwidth requirements for UHD-1 operation beyond single-speed require a more flexible and future-proof solution.

Developments in IP technology have far outpaced developments in broadcast video for many years. Moreover, IP costs per Gbit typically halve every 14 months across all components — for serial digital video they are stagnant at best. And the increasing choice of formats such as 4K, HFR, high-speed operation and the associated requirements to support all these different formats as efficiently as possible are much better managed with format-independent IP solutions. So it is not a question of whether IP will replace SDI video in broadcast applications, but rather when this will happen. It is fair to say that most new broadcast installations are already using IP infrastructures in some form and that the use of SDI will decline significantly.

Camera IP-based workflows

Using IP for signal transmission

With the introduction of the first HD camera systems with 6x speed in 2014, the first IP-based fiber transmission solution based on 10 GigE **(Fig. 2)** became available.

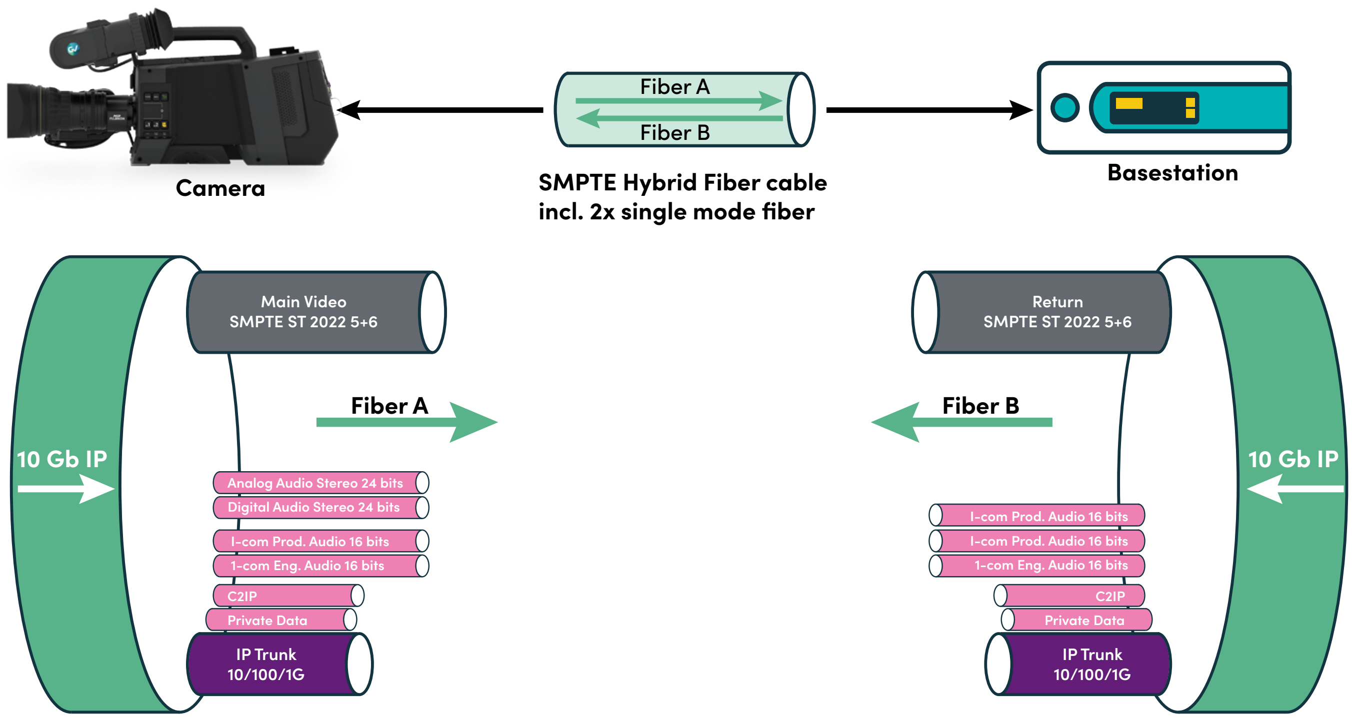

Figure 2 — Camera signal transmission over IP.

The use of standard IP technology made it possible for the first time to use IP infrastructures to connect camera heads and base stations via DirectIP operation **(Fig. 3)**.

Figure 3 — DirectIP connection of camera and base station.

In DirectIP operation, the camera head is given a unique IP address and all signals are routed to a specific camera base station via an IP network. When setting up the connection, it is not necessary to know to which physical port the devices are connected, as long as they use the same IP domain. For a number of years, there have been several fixed installations worldwide that use this flexible connection of camera systems via IP networks, and the benefits have been proven **[2]**.

In fact, DirectIP was the first application of its kind to utilize existing IP infrastructures for fully integrated remote productions in some of the most demanding broadcast applications.

Since all signals between cameras and base stations are transmitted either uncompressed or visibly lossless compressed with low latency, there is no degradation of image quality or limitation of functionality.

When this IP-based fiber solution was developed, SMPTE ST 2022-6 or AVB were the two options available on the market to provide the required functionality. SMPTE ST 2022-6 was selected as the best solution for the specific requirements and still provides an excellent solution for point-to-point connectivity between cameras and base stations.

The interim introduction of the SMPTE ST 2110 standard now provides a more efficient workflow solution for IP broadcast infrastructures. The camera base station, which receives the camera signals as 2022-6 streams, can now convert them into the new SMPTE ST 2110 compliant streams. In addition to this IP conversion, the base station continues to provide all baseband connectivity, manages the synchronization of all signals and powers the camera in all applications via an SMPTE hybrid fiber cable between the camera head and the base station.

Next steps to further integrate broadcast cameras into IP infrastructures

In a full IP broadcast infrastructure, baseband signals are usually not needed or can be generated via IP gateways if needed. So why still use a camera base station or other hardware to convert the signals from the camera to the required IP standards and not connect the camera directly to the IP infrastructure via commercial-off-the-shelf (COTS) IP hardware **(Fig.4).**

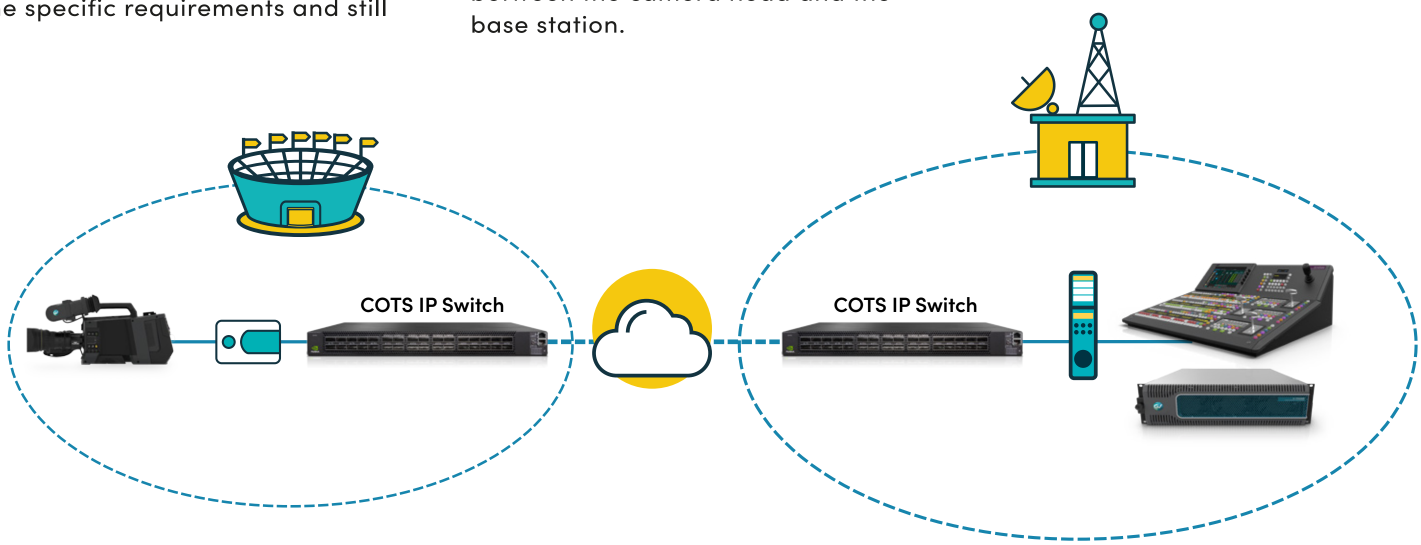

Figure 4 — NativeIP camera connection to IP networks.

One of the advantages of an IP infrastructure is that it does not matter where a device is physically located, as long as other devices can identify it by its unique IP address. In a typical broadcast production, the cameras and cameramen need to be in a specific location, such as a stadium or production studio, but the rest of the equipment and operations staff can be anywhere — not even close to the production site. With a native IP connection of the cameras to the IP infrastructure, the camera manages all outgoing and incoming IP streams itself, so no additional active hardware is required other than a local power supply. This drastically reduces potential sources of error and also reduces set-up time.

Another important advantage is that only one interface needs to be upgraded or changed when the bandwidth requirements of the video format or COTS IP infrastructure change. For example, while UHD-1 Single Speed or even UHD-1 HFR can fit into a single 25 Gb/s connection, all UHD-1 High Speed formats would require multiple 25 Gb/s connections or a 40 Gb/s or even 100 Gb/s connection.

Interfacing

The camera's interface to the COTS switch must support the different bandwidth requirements of today's standards, and to be future-proof, the interface must also be flexible to upgrade as requirements change. To meet these requirements, field upgradeable Small Form Factor Pluggable (SFP) or Quad Small Form Factor Pluggable (QSFP) could be used on the camera side, supporting 25 Gb/s, Dual 25 Gb/s or even 100 Gb/s.

An example of such a field upgradeable SFP solution is shown in **Figure 5**.

A 10G SFP provides backward compatible operation with a camera base station, a 25G SFP supports uncompressed UHD-1 operation even with HFR and a 100G QSFP even supports high-speed operation in native UHD-1 resolution. And by using two bidirectional (BiDi) 25G SFPs, redundant operation from the camera to the IP infrastructure can be realized for all incoming and outgoing IP streams.

Improved bandwidth efficiency

Since the bandwidth requirements for uncompressed operation are quite demanding, there will be cases where the available bandwidth does not support uncompressed operation.

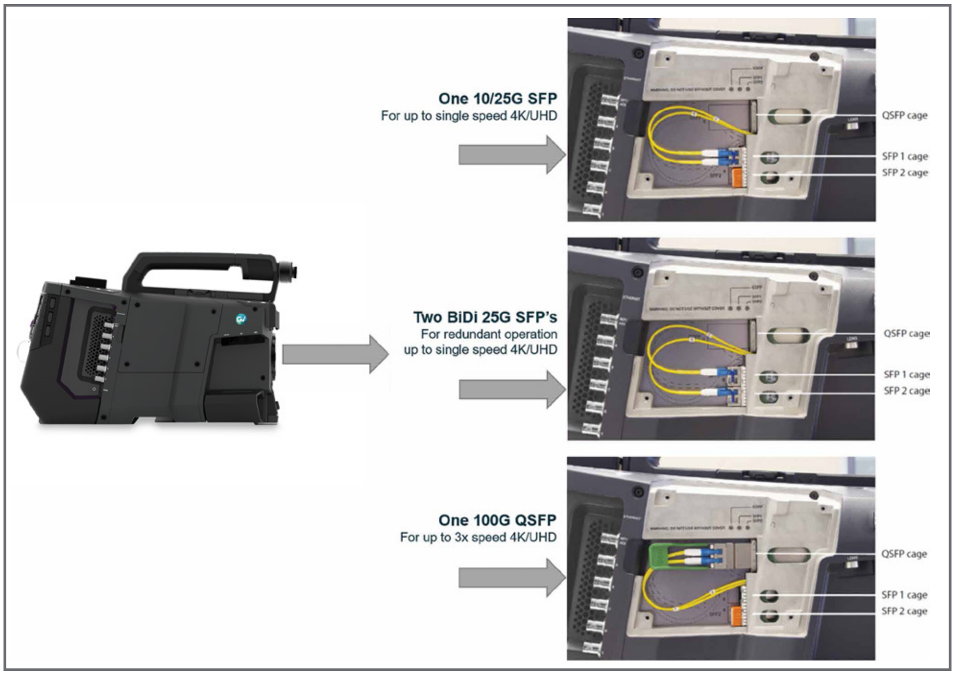

Figure 5 — Solution for an upgradable SFP solution.

However, for live applications, JPEG XS is a widely accepted low-latency video compression codec that delivers visibly lossless image performance up to compression ratios of about 1:8 to 1:10. Multiple in- camera JPEG XS encoders for all outgoing streams and multiple JPEG XS decoders for all incoming streams, without the need for external hardware devices, provide the most flexible and reliable solution for a compressed workflow in live applications.

A signal block diagram of a solution based on JPEG XS compression is shown in **Figure 6**.

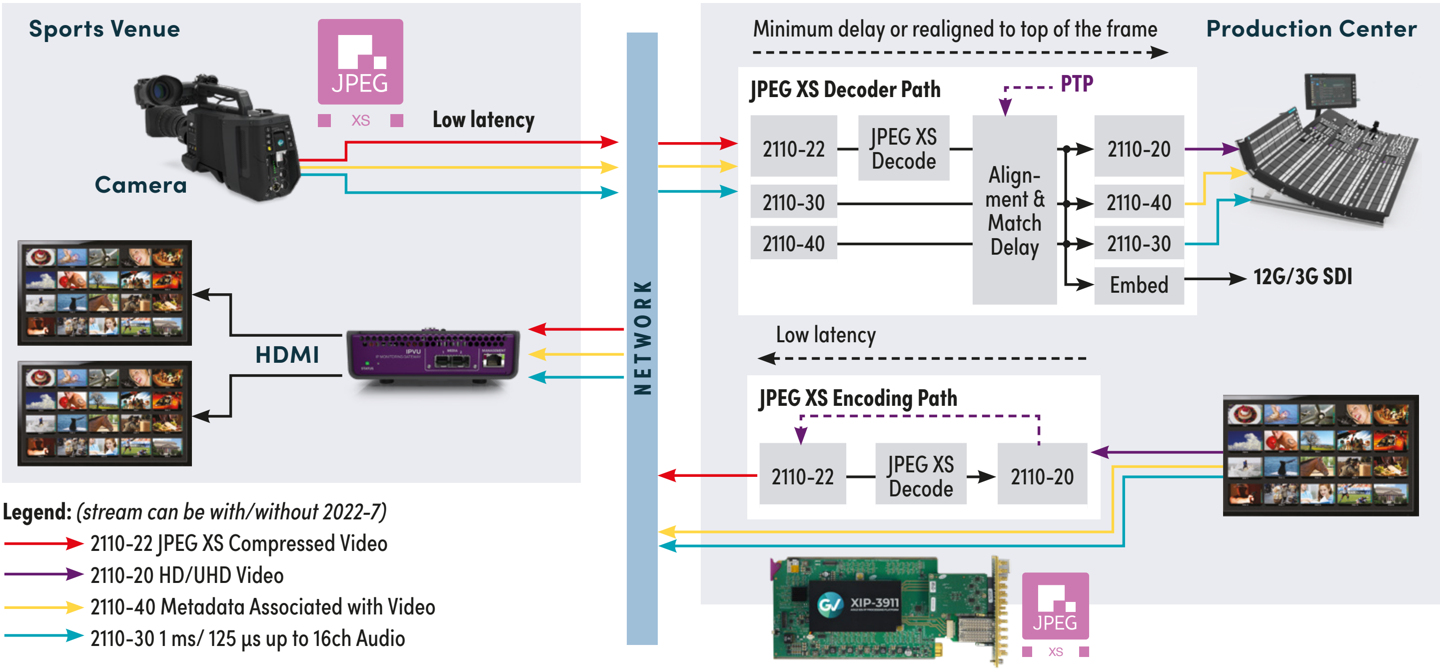

Figure 6 — JPEG XS based workflow for optimized bandwidth efficiency.

Workflows with integrated proxy video streams

In a full IP infrastructure, it may be necessary to use camera signals with an even lower bandwidth than JPEG XS can provide. In most cases, these low-bandwidth proxy video streams are not used to generate the main video signal, but for setup, preview and monitoring purposes. The very low bandwidth of these signals allows them to be distributed not only over the high bandwidth media network, but also over the low bandwidth control network. This allows users to set up, configure and prepare cameras for a production even when the high bandwidth media network is not available. It is important that the proxy videos are generated within the camera head so that they are available without having to pre-configure several different devices with each other first. A typical solution for proxy video is to use H.264 as the compression method, and there are several hardware and software decoders available for these signals from different vendors.

Camera control through the cloud

IP based camera control

Fully IP-based camera control solutions such as the C2IP camera control system, which use TCP/IP and Ethernet as a basis, have been available for many years. For ease of configuration, these systems are typically based on Layer 2 technology, which does not allow the devices to be interconnected over wide area networks as required for remote production applications **[3]**.

To provide a solution for remote connectivity over a wide area network, name server functionality was developed several years ago. This allows the various components to be connected to each other, even if they are not on the same local network, but are distributed over several different networks. An overview of such a solution is shown in **Figure 7**.

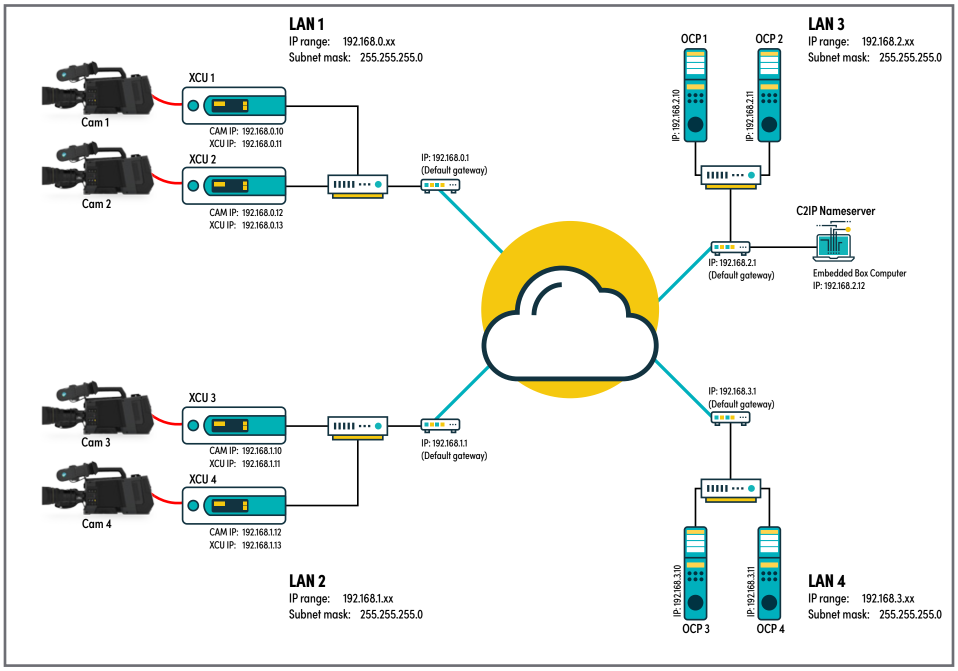

Figure 7 — Camera control solution over distributed IP networks.

The control connection can be managed by these systems with reasonable effort, but many additional signals and connections are still required for a true remote shading application. Providing these represents an effort that should not be underestimated and typically requires a large lead time, which therefore tends to make flexible use impossible.

Cloud-based camera control

Recent developments in cloud-based applications allow for further integration of the camera control solution not only for the control signals, but also for all other signals required for a full remote camera shading application.

An overview of such a potential solution is shown in **Figure 8**, where cloud services manage and provide not only the control connection, but also all other signals required for the camera shader. These additional signals include a multi-viewer tile with all cameras to be adjusted, but also a selection via the preview function of the camera control panels for a selected high-quality signal. Shading requires not only a video monitor but also a meter that displays luminance video level, RGB color signals, etc.

To avoid additional hardware at the remote camera shading location, this “videoscope” functionality should also be a micro-service provided by the cloud solution.

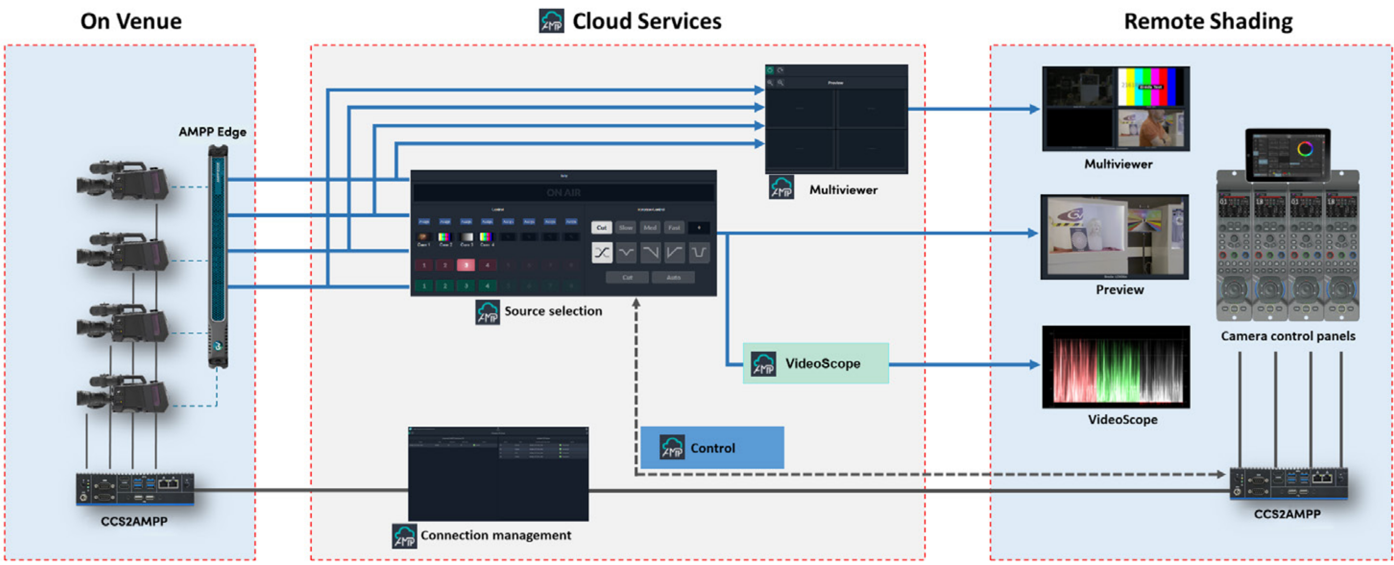

Figure 8 — Camera control through cloud services.

Summary

The way cameras are connected to the rest of the infrastructure has constantly evolved. Most of today's camera base stations offer an optional IP interface to the transmission infrastructure, but still uses a physical connection between the camera head and the dedicated hardware.

A camera system with NativeIP connectivity to IP infrastructures, offering optional low-latency signal compression and requiring no dedicated hardware other than a local power supply, offers a more flexible and future-proof solution.

The availability of additional proxy video signals with low bandwidth requirements offer enhanced possibilities especially for the configuration and diagnostics of IP infrastructures.

The camera control that is always necessary for live production cameras can be realized very flexibly and completely independent of location using IP network technology in combination with cloud applications.

By combining the various new possibilities offered by IP infrastructures and applications, cameras can be used much more efficiently and effectively in live media and entertainment productions.

References

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