

SONY

Technical White Paper

Sony's IP Live Production Technology

Version 1.0

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1. Introduction

Sony has developed an AV over IP interface that will contribute to better efficiency and lower system costs for live productions by creating new capabilities and workflows beyond those currently provided by conventional SDI-based environments. These technologies are extensions to those used in our first-generation AV over IP interface, the NXL-IP55, with much more sophisticated signal processing thereby enabling wider applications. Among others, one possible application of this new technology is an IP-based A/V routing system.

These new network-related technologies include synchronization, network management, and security; while new technologies related to audio and video processing include SDI-IP mapping, a low-delay video codec, overall low end-to-end system latency, and seamless video switching. These are based on existing and draft standards complemented by a number of dedicated technologies.

To create new systems and products that can incorporate these technologies, the AV over IP Interface combines the benefits of each of the above technologies to produce an optimized production environment. Sony considers the following two issues to be fundamentally important in the successful use of IP-based technologies for broadcast and non-broadcast applications.

- To maintain current workflows while keeping operational practices intact.
- To ensure interoperability in the connection of systems and products.

It is worth emphasizing that the adoption of IP-based technologies has the potential to bring about a number of significant benefits only if it does not lose the advantages and user experience of current SDI-based systems; in particular, in terms of familiar workflow, operational practice and interoperability.

Unless these are maintained, the widely promoted benefits of IP-based technologies will have reduced value or will not be adopted by the marketplace altogether. Sony's AV over IP Interface maximizes these benefits, while carefully ensuring that nothing is lost by their adoption.

This document describes major technologies used in IP Live production as well as Sony's thoughts in advancing the use of IP-based technologies.

1.1 Benefits of IP Live Production

The benefits of IP Live Production are wide-ranging. Currently, different types of cables have been used for video, audio, and control in existing content creation and production systems. With the proliferation of file-based systems, IP-based networks have become commonplace in the production industry. For facilities which have to employ both SDI and IT infrastructures, considerable expense and resources are used to manage them due to the complex wiring required for installation of multiple transmission systems.

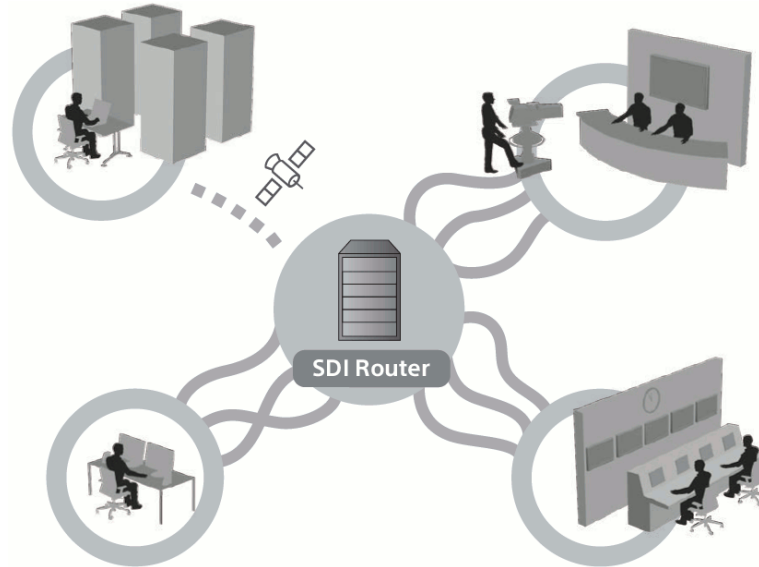


Figure 1: Conventional SDI System

To solve this problem, Sony's new AV over IP interface integrates video, audio, control signals, and the existing file-based system for transmission over an IP network. This provides a number of significant benefits to the end user that includes:

- Use of Standard IT Technologies
 - Take advantage of so-called COTS (Commercial Off-The-Shelf) products available in the market at reasonable prices.
 - Ability to improve system performance as standard IT technologies evolve.
- Reduction of Total Cost
 - Reduction of total system cost by reducing size and weight, device cost, number of cables, and management overhead.
- Agile, Flexible and Scalable Operation Workflow
 - Manage and integrate different types of operations and/or data; for example, stream-based operations vs. file-based operations, and A/V essence vs. control data.
 - Deal agnostically with a multitude of formats, streams and file types in use today, and new types as they are introduced in the future.
 - Facilitate the creation of IP-based A/V systems that can be altered or expanded from any point within the architecture.
- Ubiquitous Accessibility
 - Use resources as if they are all in the same place regardless of actual location of either the resources or the operators.
- Collective Intelligence
 - Additional system value and user benefits by gathering and analyzing a variety of information available on the network in real-time.

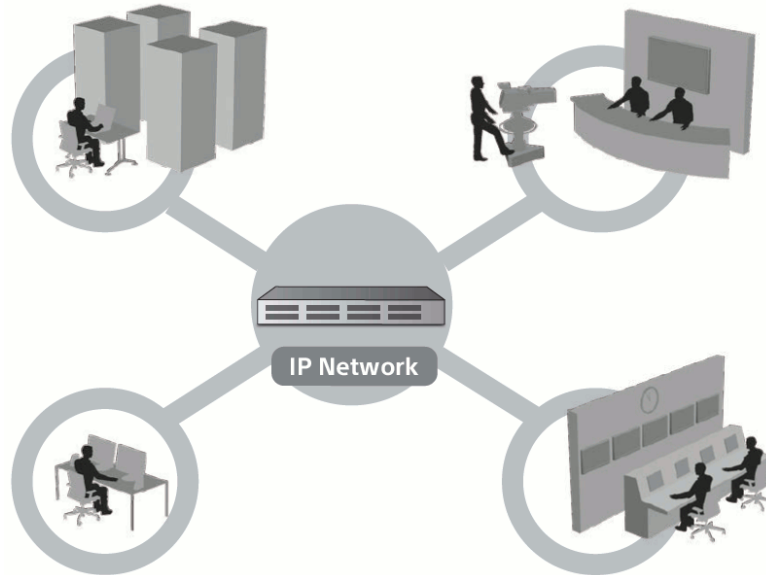


Figure 2: IP Live Production System

2. Sony's AV over IP Interface

The AV over IP interface is made possible by using the following standardized technologies in the IT and A/V industries. Their use makes long-term stable management of the entire system possible together with significant improvement of expandability of the system.

- IP Multicast Routing
- QoS (Quality of Service)
- Network time and synchronization
- SNMP (Simple Network Management Protocol)
Syslog (the standard protocol to send log messages over an IP network)

In addition to these standard technologies, the AV over IP interface introduces some unique operational functionality:

- Reliable A/V stream transmission
- Clean video switching

Moreover, an intelligent application software layer is implemented by the control software called the IP Live System Manager by accommodating the various control specifications and configuration for the various network devices in the marketplace. This upper layer application permits the acquisition of network resources and information on the state of the network regardless of the model of the network switch. Sony has developed AV over IP interface by taking into consideration the use of software-defined networking (SDN) for controlling the switch.

2.1 Audio and Video Processing over IP

2.1.1 Synchronization

One of the most important technologies in the current workflow and operational practices of SDI-based systems is synchronization. All devices in the system are synchronized with each other using a common synchronization signal. This guarantees equal phasing for all output signals of the various devices in the system. SMPTE is developing a set of standards in Technology Committee 33TS for time and frequency synchronization over an IP network in a professional broadcast environment.

Sony's AV over IP interface uses network synchronization technology from the draft standard SMPTE ST2059-2 (the SMPTE Profile of IEEE 1588), in conjunction with SMPTE ST 2059-1 which defines an epoch (or reference time) and A/V signal alignments to the epoch. Sony AV over IP interface focuses on the following two issues:

1. Having sufficient synchronization accuracy using generic Network Switches. One of the major reasons of adopting IP technology is the use of standard IT technologies. However, when seeking high accuracy synchronization under high network load, the use of specialized time-aware network devices such as Transparent Clock Switches is commonly considered to be necessary. The synchronization implemented in Sony's AV over IP interface achieves synchronization accuracy under high network load using generic Network switches equal to that exhibited by current SDI-based synchronization systems.
2. The migration from current synchronization systems. **Figure 3** shows an idealized IEEE 1588-based synchronization system in which a global time reference, such as GPS, is used as the time source. By sharing a reference time, synchronization can be achieved between PTP slaves that are even not necessarily connected to the same PTP (grand) master. While this could be the optimum solution for new facilities, it does not consider migration from a legacy synchronization system.

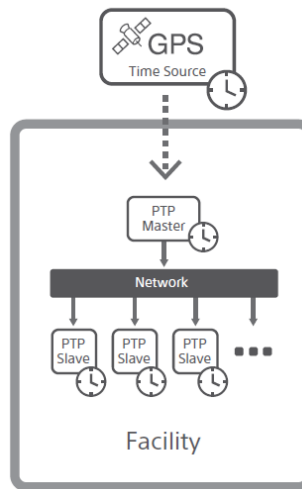


Figure 3: Idealized use case of PTP for a 'Green Field' Facility

Sony's AV over IP interface provides an option to use a legacy synchronization signal, such as black burst, as the master time source generator for the PTP system. This could be an optimum solution to an IP infrastructure when replacing a part of an established SDI-based system as illustrated in **Figure 4**.

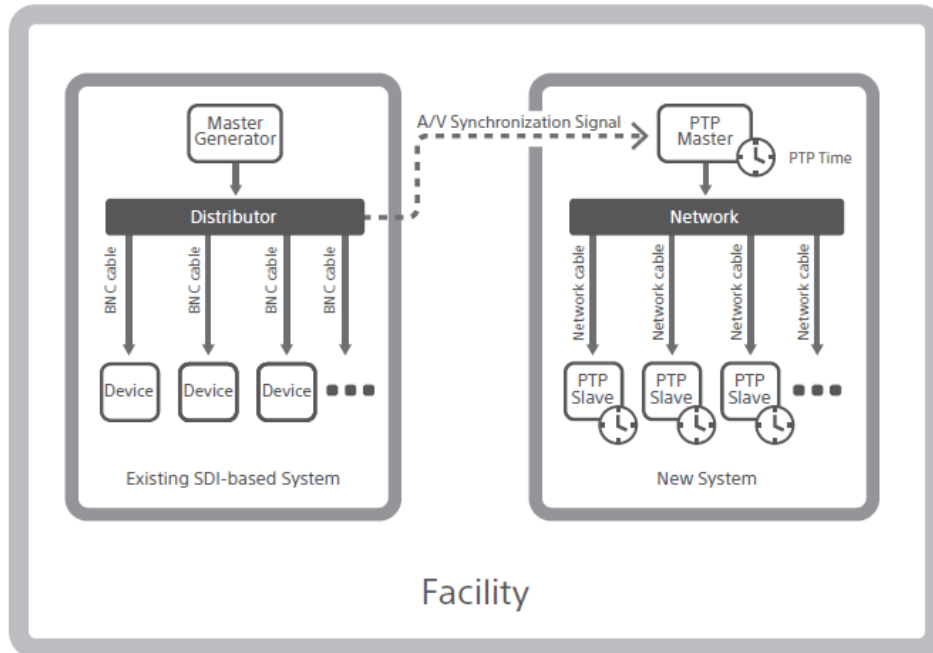


Figure 4: Migration Use Case within a Facility

2.1.1.1 IEEE 1588: Precision Time Protocol

IEEE 1588 PTP (Precision Time Protocol) is one of time synchronization protocols used over IP network. Unlike other time synchronization protocols, PTP is capable of synchronizing devices on the network in sub-nanosecond granularity.

PTP achieves time synchronization by exchanging messages between a (grand) master and slaves across the network as described in **Figure 5**. The followings are typical PTP messages:

- Sync
- Delay_Req
- Delay_Res

First a (grand) master sends Sync message to a slave with t_1 of when the message is sent. The slave holds the time when the message is received as t_2 .

Then the slave sends Delay_Req message to the (grand) master with holding the time when the message is sent as t_3 . The (grand) master holds the time when the message is received as t_4

and sends Delay_Res message with t4 to the slave. This message exchange cycle is repeated periodically and the slave obtains set of timestamps t1, t2, t3, and t4 in each cycle with which can be used for synchronizing its time with that of the (grand) master.

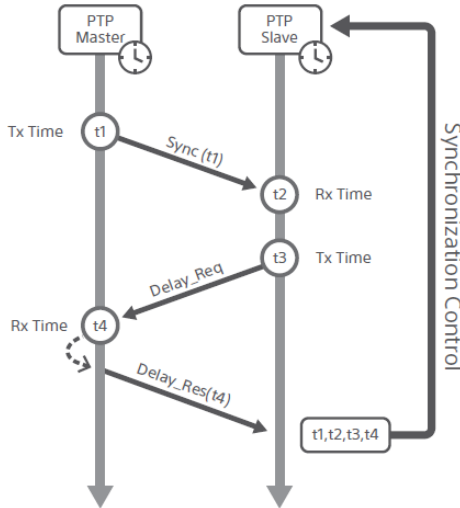


Figure 5: Precision Time Protocol

2.1.2 Video Switching

Another important technology in the current workflow and operational practice of SDI-based systems is video switching. In an IP-based system, this technology is closely related to synchronization. It is the ability to accurately select between multiple IP-based input video streams at the defined video signal switching point, outputting the result as a single synchronized video packet stream.

In conventional IP networks, multicast IGMP function is used for the stream switching. When "join" command is issued from a device to an Ethernet switch, the Ethernet switch starts sending the correspondent stream while "leave" command is issued, it stops sending the correspondent stream. However the response to the command has a certain delay and the strict specification cannot be met.

The AV over IP interface has realized IP-based video switching with identical functionality to that of current SDI-based systems by combining existing IP functions such as multicast IGMP with a number of dedicated technologies

2.1.3 Low Latency Video Codec

The required video bitrates increase rapidly at higher video resolutions. For example, HD 1080i requires an HD-SDI connection with a bitrate of 1.5Gbps., while for a 1080p signal, a 3G-SDI connection requires a bitrate of 3Gbps. In the case of 4K video signals, data rates

ranging from 6Gbs, 12Gbps, or more are required. These very large data rates can easily exceed the data capacity capabilities of today's commercially available 10GbE fiber optic transports. Hence, there is a need for the use of high-quality video compression with extreme low latency.

Sony has developed a suitable codec for the AV over IP interface that minimizes encoding and decoding process latency within several milliseconds. Using this compression technology, the required network bandwidth can be reduced while maintaining the high levels of picture quality required in broadcast applications. For example, the AV over IP interface can transmit up to four 1080i HD signals using a single gigabit Ethernet cable, or two 4K signals using a single 10-gigabit Ethernet cable.

Resolution	bit-depth	Frame Rate (Maximum)	Compression	Non-compression
720 x 480	10	59.94i	-	✓
720 x 576	10	50i	-	✓
1280 x 720	10	60p	✓	✓
1920 x 1080	10	60p	✓	✓
2048 x 1080	10	60p	✓	✓
3840 x 2160	10	60p	✓	✓
4096 x 2160	10	60p	✓	✓

Figure 6: Supported video format (YCbCr 4:2:2)

Resolution	bit-depth	Frame Rate (Maximum)	Compression	Non-compression
1920 x 1080	10/12	60p	✓	✓
2048 x 1080	10/12	30p	✓	✓
3840 x 2160	10/12	30p	✓	✓
4096 x 2160	10/12	30p	✓	✓

Figure 7: Supported video format (RGB 4:4:4)

2.2 High-Reliability Transmission

2.2.1 Admission Control

Proper network management is indispensable for maintaining a good operational environment in an IP-based system. This is because the network contains a complex, time-varying mix of different types of data such as A/V essence, control data, synchronization data, and management data, as well traditional network traffic.

Sony has developed a suite of network management tools that manage the network session and resources. This is called the Network System Manager.

When the Network System Manager configures a system, a bandwidth reservation process is carried out by calculating the capacity required for transmitting the content based on the type of signal transmitted by each device, the available capacity reported by the network, and other parameters.

The highest transmission priority is given to video, audio, and control signals guaranteeing their unimpeded transmission because other network traffic cannot utilize that reserved bandwidth.

2.2.2 FEC (Forward Error Correction)

With the AV over IP interface, the bandwidth reservation method prevents packet loss caused by network congestion. Nevertheless, signal quality deterioration, such as packet loss caused by electrostatic noise generated on a physical line of Ethernet cable, can occur. To avoid this, a data stream is encoded with additional data protection offered by an FEC (Forward Error Correction) in order to restore the packet loss on the physical line. By using a special FEC encoding method that takes into account the information contained within a single video frame, the FEC-encoded stream can be simultaneously protected and switched within picture boundaries.

2.2.3 SDI-IP Mapping

The first issue to be considered when converting SDI-based environment to IT-based environment is mapping SDI payload information into IP datagram payload.

SMPTE ST 2022-6 defines the IP mapping of SD-SDI, HD-SDI and 3G-SDI and the AV over IP interface adopts this standard for a packaged transfer of uncompressed SDI signals.

As SMPTE ST 2022-6 defines a video frame boundary on a datagram basis, video switching equivalent to that of the traditional SDI-based system can be realized in the AV over IP interface at datagram level.

At the same time, as SMPTE ST 2022-6 is a standard that maps the whole SDI payload information including video, audio and metadata as a package, it cannot deal with video, audio, metadata independently at datagram level.

In addition to the SMPTE ST 2022-6 mapping, the AV over IP interface supports SDI-IP mapping in which video, audio, and metadata are placed in separate datagrams so that they can be dealt with independently. This mapping, for example, supports a use case where the video signal is compressed in order to save network bandwidth.

2.2.4 IP Multicast

Using IP multicast, the AV over IP interface can deliver high-quality content to multiple receiver devices, as if they were connected to a traditional A/V router (a matrix switcher). This provides multi-point transmission without unnecessarily consuming network resources. In addition, the Network System Manager manages bandwidth reservation for each stream in accordance with the IP multicast path in order to maintain stable transmission of the

stream(s). In traditional IP networks, when switching multiple IP multicast streams, speed can be negatively affected. However, the AV over IP interface offers quick and effective synchronized switching.

2.2.5 Redundancy

Network Redundancy Technology, which is generally used in the IT industry, is usually implemented by deploying at least two sets of IP Switches. The first set of switches acts as the primary transmission path for data exchange between connected devices, while the second set acts as a backup to the primary switches.

In the event of a critical error or failure, network traffic is automatically transitioned from the primary set of switches to the backup set. However, due to the time it takes for the new network linkages and data re-transfer to occur, a temporary disturbance of data is likely.

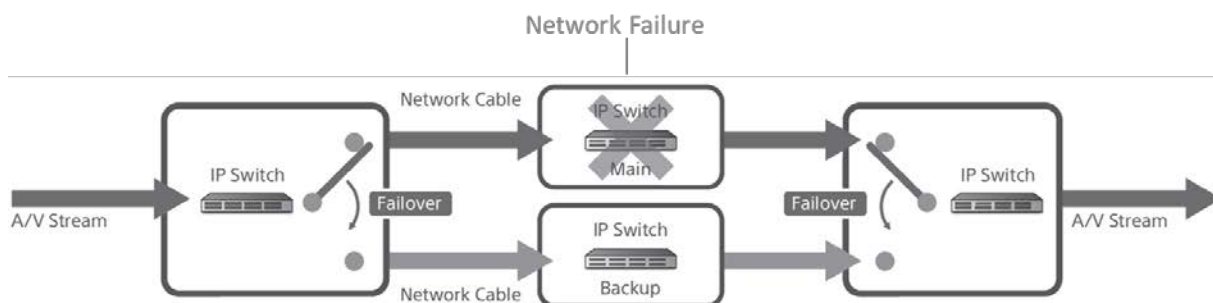


Figure 8: Example of basic IT Network Redundancy

With Sony's AV over IP interface, the sender transmits duplicated media datagrams and the receiver chooses datagrams from both the primary and secondary network paths. When one is lost, a hitless failover complied with SMPTE ST2022-7 occurs, and there is no loss in data or disturbance in the stream.

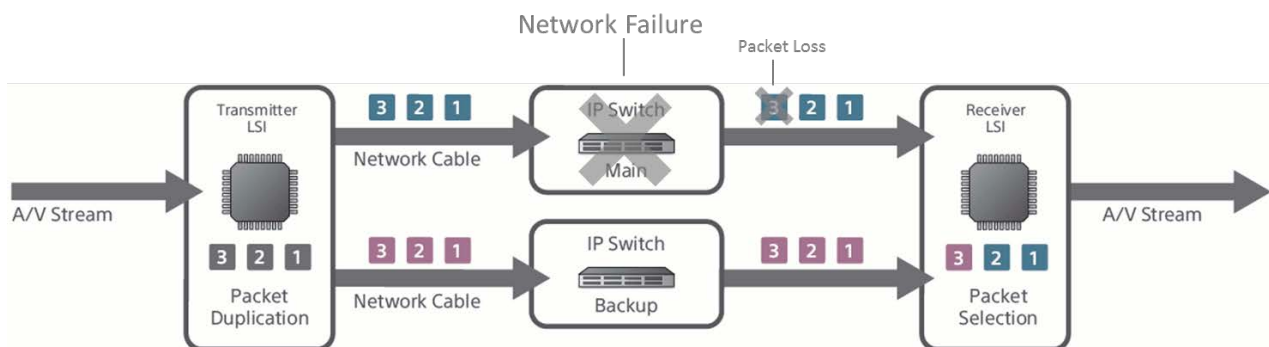


Figure 9: Hitless Failover Using the AV over IP interface

2.2.6 Security

Compared to a traditional SDI-based system, an IP-based system has the potential to allow access to any device regardless of its location. It is therefore vital to be able to protect against unauthorized access.

Sony has developed a network security suite that combines a number of standard technologies such as network authentication, device authentication, and user authentication. This makes it possible to realize the considerable benefits of IP technologies while maintaining system security.

- User Authentication

The user authentication function eliminates operations from illegal or unauthorized users. While operating equipment over a network is very convenient, it can be risky not knowing who is operating the equipment. The equipment is exposed to the possible threat of operation by a malicious user. By implementing a user authentication function to protect from this threat, network administrators can assign available functions for each specific user so that unauthorized access is not possible.

- Device Authentication

The device authentication function verifies the identity of the device to be connected to the network. Even if an illegal device is connected, the Network System Manager can control the device's access so as not to permit its use of the system.

- Network Authentication

The network authentication function provides secure network environment by preventing unauthorized devices from gaining access to the network. The unauthorized devices are not even allowed to communicate with other devices on layer-2.

2.2.7 System Maintenance

Sony's AV over IP interface is capable of monitoring equipment by utilizing the Simple Network Management Protocol, or SNMP, and Syslog on the integrated IP network for easy, detailed status monitoring (**Figure 10**). This is not possible with existing broadcast and production equipment. These protocols are widely used in the IT industry, thus allowing easy construction of monitoring and maintenance systems.

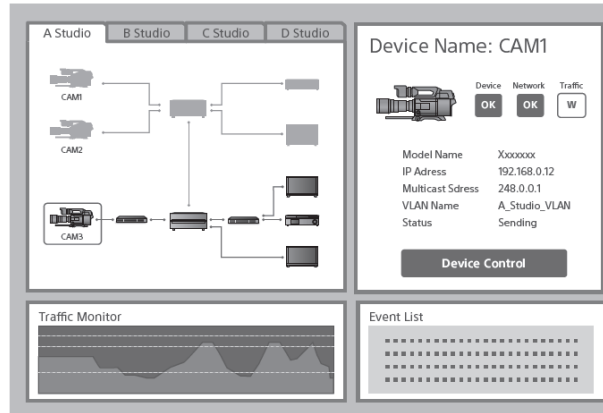


Figure 10: Image of System Maintenance UI

2.3 Applications

Sony's AV over IP interface can be applied to product groups designed to process high picture quality and audio applications—from a core router for broadcasting stations to that of xxx for a studio, a production truck, a stadium, or a performance hall.

The Sony's AV over IP interface architecture can also be utilized in non-broadcast applications, such as education and medical markets, as a next generation interconnect system.

2.3.1 Centralized IP-based AV Router

The centralize AV Router using conventional HD-SDI technology results in complicated main & sub configurations to connect many rooms and studios in and outside of the building. And the need of high-reliability and 24/7 operation results in the high-cost facility.

Figure 11 shows the AV over IP interface in Centralized AV Router. This solution can provide simple wiring between rooms and studios in and outside of the building by using network cables. And this solution provides easy format and size expansion by adding IP Switches to add more bandwidth and ports.

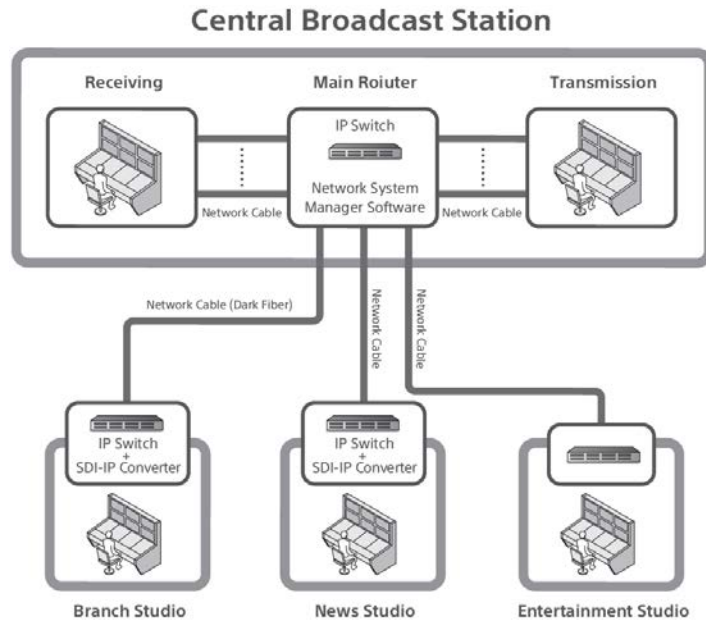


Figure 11: 2 IP-based AV Router Solution

2.3.2 Remote Production

Figure 12 shows the AV over IP interface in a remote production environment. Please note, that only a minimal amount of media acquisition equipment and personnel need to be deployed at event venue since all of the media processing takes place at the broadcast production center. Hence, the overall project results in significant operational expense reduction while still maintaining bi-directional, low-latency, high-quality A/V communication between endpoints.

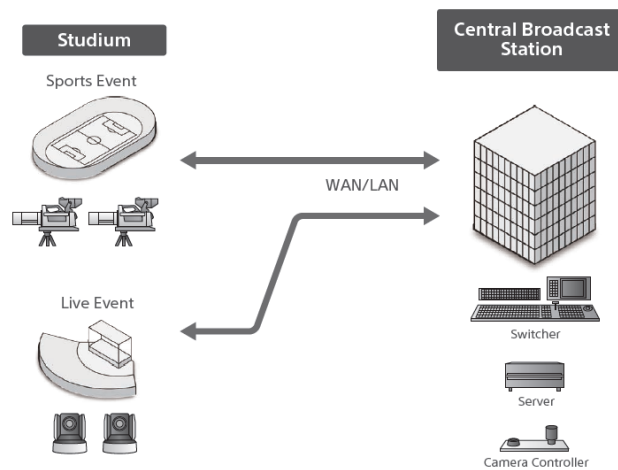


Figure 12: Remote Production Solution

2.3.3 Production Vehicles

The design of production vehicles using conventional HD-SDI technology results in the high-cost of wiring and space consideration as well as excess weight for the vehicle. This situation only worsens as we transition to the construction of production vehicles designed to handle UHD signals since each UHD 4K signal requires four 3G HD-SDI cables.

The AV over IP technology represents a dramatic savings in wiring complexity and overall weight of the production vehicle since the 4K signal can now be transmitted by using a single fiber interconnect. An example of this cost reduction in wiring is shown in **Figure 13**.

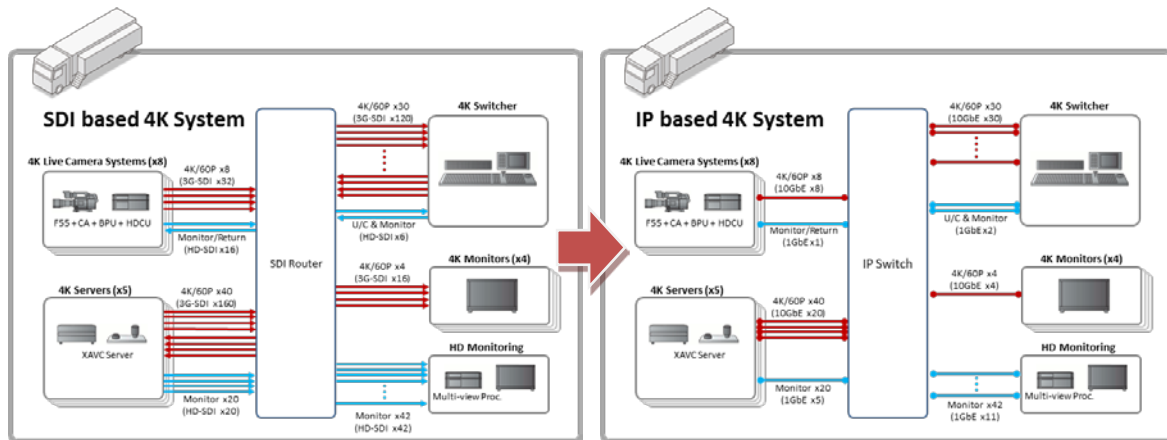


Figure 13: Production Vehicle Solution

3. IP Live Production System

An IP Live Production System is composed:

- Network System Manager software
- an aggregate of general-purpose IP switches
- A variety of audio and video equipment with equipped with the AV over IP Interface.
- SDI-IP converter for legacy SDI-based equipment

See picture below.

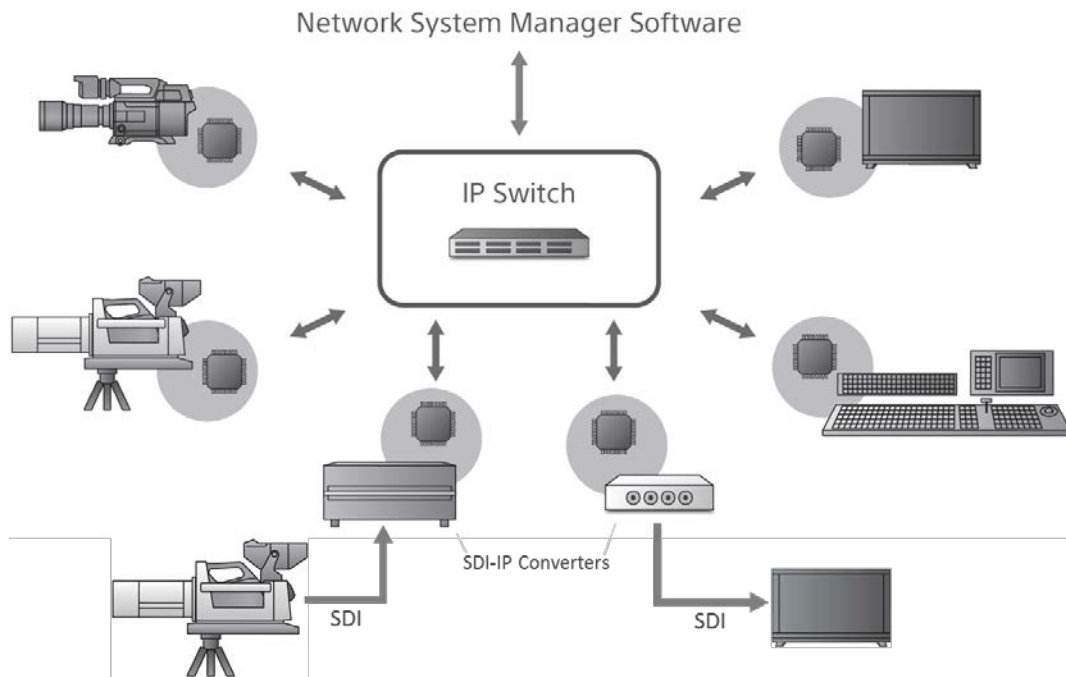


Figure 14: Overall View of an IP Production System

3.1 Network System Manager Software

The Network System Manager software suite is the cornerstone of the Sony IP Live Production system. It runs on a centralized control server and manages communications between devices connected on a Sony IP Live Production network. It uses Sony's unique algorithm for optimal network resource management which helps stabilize IP video transmissions to ensure broadcast quality. Using Quality of Service (QoS) technology to prioritize transmitted video data or to reserve the required network bandwidth, the Network System Manager ensures that the required communication speed is always provided.

The Network System Manager is also responsible for the following functions:

- System Administration
- Setup functionality for AV over IP interface devices and network equipment
 - Device settings
 - IT related configurations

- A/V related configurations
- Matrix configuration and cross-point switching functionality
 - Core functions for A/V router (Name/Level/Status/Tally/etc.)
- System Maintenance
 - Collect status logs from AV over IP interface devices
 - Remote firmware update
 - Communication functionality for the Remote Maintenance System

3.2 AV over IP Interface Installed Equipment

To fully utilize the benefits of Sony AV over IP technology, Sony is developing a network LSI as a SoC (System-on-a-chip) which integrates the main components of the required hardware. This LSI is equipped with such functions as A/V IF, Encoder/Decoder of Low Latency Codec, FEC, Network Packetizing and Network Synchronization.

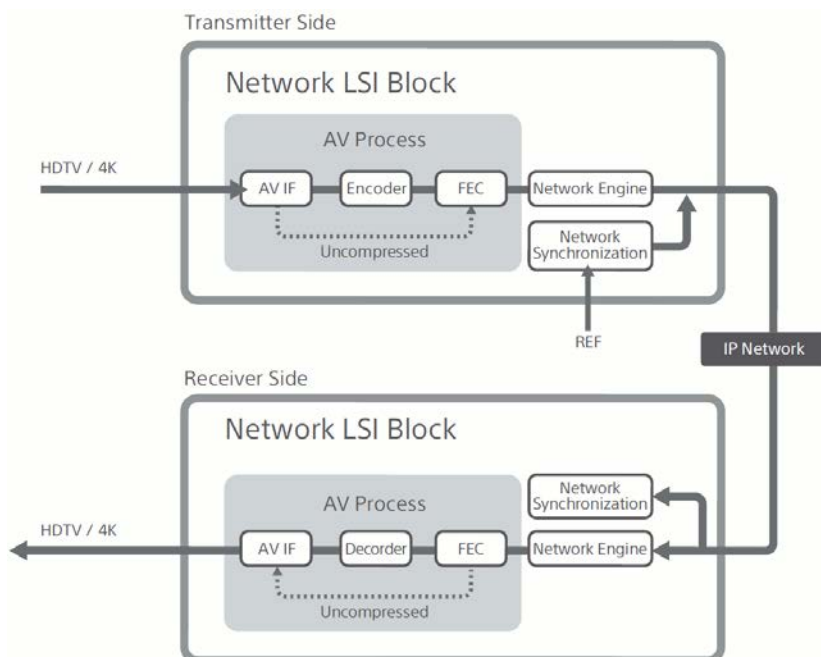


Figure 15: Network LSI Blocks

Sony plans to embed the AV over IP interface LSI into a variety of A/V production equipment in order to enable the networking capability for a full IP broadcast production workflow.

3.3 SDI-IP Converter

For interoperability with legacy devices that only feature an SDI interface, Sony has developed external conversion hardware that can support up to 4K signals. By transporting SDI streams over IP packets, the external converter adds IP interface functionality to conventional broadcasting equipment and can be used for network connections with existing SDI products during the period of transition.

This external converter hardware works with legacy devices that only feature an SDI interface. By converting SDI to IP, the external converter adds IP interface functionality to conventional broadcasting equipment and can be used for network connections with existing SDI products during the period of transition.



Figure 36 SDI-IP Converter and option board

4. Products to be provided to Alliance Partners

Sony will openly provide AV over IP interface to our alliance partners.

To adopt the AV over IP interface on various equipment effectively, Sony provides LSI of the developed SoC. Furthermore, taking the variation of implementation into account, Sony will offer solutions by IP Core and Software for FPGA (Field Programmable Gate Array).

5. Conclusion

The adoption of IP-based technologies has the potential to bring about a number of significant benefits. However, it is important only if it does not lose the advantages and user experience of current SDI-based systems; in particular, in terms of familiar workflow, operational practice and interoperability.

Sony has developed AV over IP interface in such a way as to maximize these benefits, while carefully ensuring that nothing is lost by their adoption.

Sony will continue to provide additional benefits for live production workflow with these cutting edge technologies.

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