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Connecting IT to Broadcast

IP for Mobile Production

Essential Guide

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Essential Guide to IP for Mobile Production

Match director Jamie Oakford in Arena TV's OBX IP truck.

By David Austerberry

IP networks have been at the heart of many broadcast operations for two decades and more. Editing uses commodity workstations and IP networks, as do playout operations. But live production has, until recently, been the preserve of SDI.

The advances in IT, driven by the data centers that power the cloud, and the general move to virtualization, brings benefits that now make live, real-time broadcast operations possible in an all-IP environment.

There is gathering momentum to consider IP-connected broadcast equipment instead of the tried and tested SDI, which has served the industry well since the introduction of digital video.

The outside broadcast vehicle is an ideal place to start with IP operations.

For one, they are a manageable scale when compared with the rebuild of an entire broadcasting center.

For another, the mobile production sector is often at the vanguard of technical change. Prestigious live events are starting to be covered at UHD resolution, with sports—as ever—leading the field. IP can accommodate new formats, and give the flexibility needed for mobile.

Audio over IP is now commonplace, with AES67, Dante and Ravenna. Video over IP standards are advancing at a pace, such that the construction of interoperable, vendor neutral, all-IP broadcast system is now a viable proposition.

Mobile units have advantages for trialing new technologies in that they are compact and self-contained, but the nature of the events they cover means that reliability is paramount. Add to that, running a mobile fleet is a business and any major technical changes must make business sense.

For a good return on investment, the trucks must be as future proof as possible to ensure a long working life. This dictates a flexible design philosophy that can adapt to future production requirements and to new technical standards. It is in this area that IP can help, with a flexibility that is not possible with SDI systems.

Forward to UHD

The broadcast sector is embarking on a step change not unlike the move from standard to high definition. UHD brings higher frame rates, higher dynamic range and a larger color volume as well as the increased resolution. All combine to make sports, as well as other genres, a more immersive experience. New-build trucks need to be sufficiently adaptable to be capable of covering events in SD or HD and now UHD.

Legacy outside broadcast (OB) trucks have relied on a combination of SDI connections for video and AES3, MADI and SDI-embedded signals for audio. SDI has evolved to meet HD and UHD formats, from 270Mb/s to 1.5Gb/s, then 3, 6 and 12Gb/s, some in dual and quad-link configurations.

Moving forward needs a flexible design philosophy, one that doesn't require re-cabling or the swapping out of hardware to upgrade to a new format. This can be more easily implemented in an all-IP infrastructure than in a legacy SDI system. One advantage of IP is that the video and audio formats are abstracted from the physical connection layer.

Design Goals

The design of mobile units is of course constrained. The weight and dimensions of the vehicle are limited by regulations.

A production unit can be a single vehicle, or two or more linked together. These could be production, record/replay, graphics and engineering. The more flexible and configurable the engineering systems, the easier it is for a facilities provider to match their resources to events. The design should facilitate fast rigging and derigging.

Multi-format equipment has to be transparent to the operators. They want the same functionality and facilities whatever the video format.

In addition, technical details about the infrastructure—whether it is SDI or IP—should not impact on their work.

Production companies are always looking to improve the working environment, to approach the comfort of a fixed studio. Within the constraints of the regulations for the size and weight of a vehicle, the companies want space to work, at a comfortable temperature, and with minimal noise from fans and air conditioning. This indicates that equipment should use less power and occupy less space.

One way to meet the requirements for an improved production environment is to move all the heavy racks to an engineering

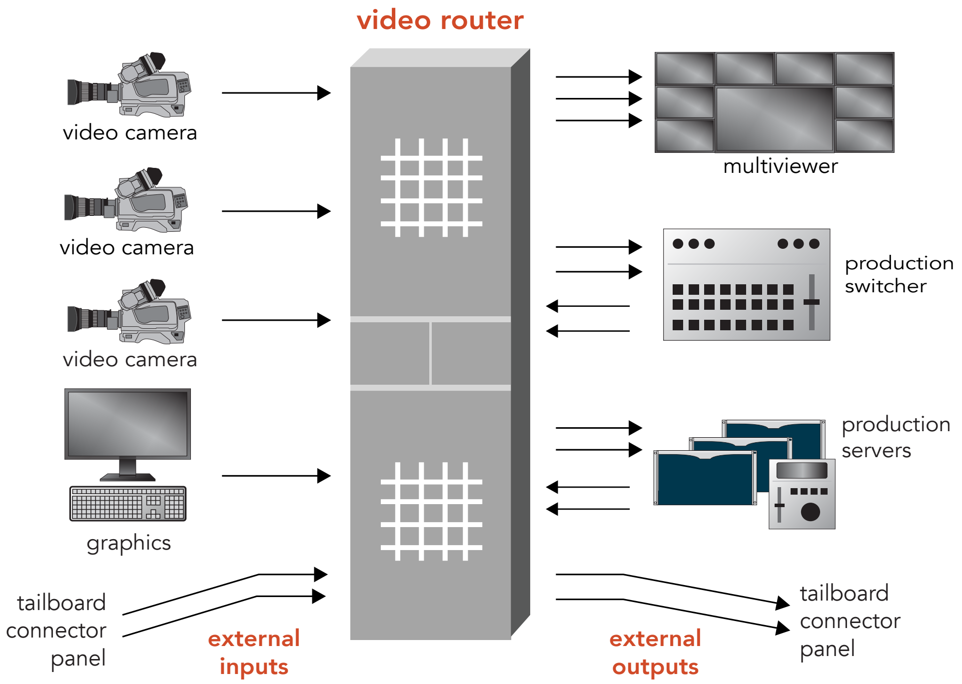

Figure 1. Legacy SDI systems are based around a core SDI router.

Mobile operators are at the vanguard of UHD coverage, with sports being the driver.

vehicle, with the production vehicle carrying just controls panel and monitoring. This does of course mean a large number of interconnecting cables carrying audio, video, comms, and control.

IP systems can take up less space, and IP can carry a multitude of signals over a single Ethernet fiber, simplifying interconnects between vehicles.

The Future Is 4K

Live UHD broadcasts are already a reality for some OTT providers. Over-the-air broadcast will follow, once all the transmission issues have been resolved.

Mobile operators are at the vanguard of UHD coverage, with sports being the driver.

Current UHD production systems are predominately quad 3G-SDI as opposed to 12G-SDI. There is 12G equipment, but it is hardly universal in the way that 3G-SDI has become. So for now, quad 3G is the way to go for UHD. This adds four-fold to the number of cables and connector panels, as well as increasing the size of the core router to as large as four racks for a large truck.

The alternative is to use mezzanine compression for UHD. 4:1 compression allows 3Gb circuits to be used, with the downside being the code/decode for each interconnection. Compression like TICO can be mapped to either SDI or IP, making it an option for both interconnection schemes.

3G or 12G?

Most existing video equipment supports the 3G-SDI standard. Moving to UHD resolution, with its 12Gb data rate, can be achieved by a number of methods.

1. Use 12G-SDI.
2. Use four 3G-SDI circuits in a quad-link configuration:
   a. Square division.
   b. Two Sample Interleave (2SI).
3. Use 4:1 compression and 3G-SDI.

Each has advantages and disadvantages. As of 2016, there is very little support for 12G-SDI. That means severely limiting the choice of equipment. Most routers, for example, support 4K via quad-link 3G-SDI

Quad-link SDI can fill the truck with cable, and needs four times the number of connectors, with the resultant larger termination panels.

Compression is popular, with Intopix's TICO or Sony's Low Latency Video Codec (LLVC) being examples. Both these codecs have low latency, important for viable systems, and low processing overhead. They are typically implemented in FPGA chips adjacent to the connectors or in software.

IP systems also have the option of native or compressed using the same TICO and LLVC codecs. Using compression, a 12G video signal can be carried on a 10Gb Ethernet cable.

Some parties have expressed a dislike of compression. However, 4:2:2 color sub-sampling is compression, 10-bit gamma is compression (over linear light coding). The question is "what data can be removed without causing unacceptable artifacts?" What is considered 'unacceptable' depends on the context.

Standards Development

Any vendor-neutral interoperable system will be based around standards. In the past these have taken years to agree, then an even longer time to implement as working solutions (MXF comes to mind). Rather than existing in a technological bubble, where every standard for broadcast is developed from scratch, the working groups formulating IP standards for broadcast are leveraging existing standards. This should speed the time to release of viable operating standards.

Much work has been undertaken by the Video Services Forum (VSF), with formats like TR04 and TR03, with the SMPTE as

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IP routing

An IP switch is very different from an SDI router. The SDI device is essentially dumb; the route is set by an external control system, choosing the source for a destination. In an IP system, the data packets contain a header with the source and destination IP addresses. Multi-layer switches and routers forward data to the destination using the IP addresses. In a network of many switches and routers, algorithms are used to determine the best path.

An SDI router is defined by the number of inputs and outputs, with the full specified SDI data rate (1.5G, 3G etc.) being available between any input and output. The routers are non-blocking, that is all the inputs are always available to a given output (unless the control system bars a connection).

In contrast Ethernet switches are specified by bandwidth. A port can connect to several sources and destinations. A low-cost switch for office applications may not have the bandwidth to allow all the ports to operate at line speed, being more suited to the bursty data of email, web browsing and file exchange.

Enterprise switches for the data center market have much higher performance, and are generally non-blocking. Selected models can run at line speed, so for example, a 10Gb port can carry 3 x 3Gb/s continuous video data streams. These characteristics mean that such a switch can be used to carry packetized video data streams.

The market for enterprise Ethernet routing and switching is an order of magnitude larger that the video SDI market. This means economies of scale in manufacture, and lower prices. Cloud services drive performance to higher and higher levels, which can be leveraged for the video market.

Do you need clean switching for every route?

One of the characteristics of SDI routers is that they switch in the vertical interval. Ethernet switches are routing packets, and a video frame comprises many packets. To switch program video streams, some means must be found to seamlessly switch at the frame boundary. Several techniques have been developed to achieve this.

However, most video routing is source and destination assignment—an ‘electronic jackfield’. Clean switching is only essential in the program path, which is production switcher busses, emergency bypass router, and any other routing in the transmission path.

The straight assignment switching can be performed by the Ethernet switch, without the complexity of achieving a clean switch.

The Cisco Nexus 9272Q Ethernet switch has a bandwidth of over 5Tb/s in only 2RU.

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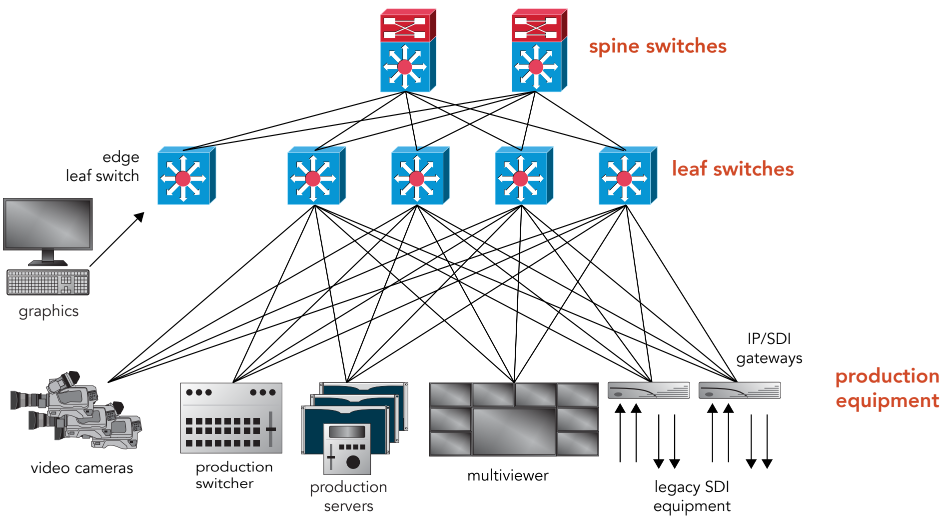

Figure 2. IP routing uses a data center architecture. The leaf-and-spine topology is shown here.

the standards body. These are based on existing standards like IETF RFC 4175 "RTP Payload Format for Uncompressed Video". This example describes a packetization scheme for encapsulating uncompressed video into a payload format for the Real-time Transport Protocol (RTP). Note that the RFC 4175 format only transports active video pixels, the horizontal and vertical blanking are not transported.

The original standard CCIR601, which laid the foundations for digital video, encoded the old analog waveform including the horizontal and vertical blanking intervals. These allowed time for the electron beams in the camera and receiver tubes to fly back to the start of the next line/field. Although they have proved handy for embedded digital audio signals and keeping them synchronized to the video, we no longer use tubes.

Where to Next?

A key part of the move to UHD and 'better' pixels is the introduction of high dynamic range (HDR) services. In order that viewers don't see artifacts from quantisation, the bit depth for program delivery must be increased beyond the current eight bits. Rec 2020 describes 10 and 12-bit coding.

The SMPTE 2084 standard for an electro-optical transfer function (EOTF) is based on the concept of perceptual quantisation (PQ). PQ requires 10-bit coding for minimal visibility, and ideally 12 bits for a better image quality.

High frame rate (HFR) is important, especially for sports, with 50 and 60 fps part of the 2020 standard, and 120fps coming in the future.

SDI is a 10-bit format. 12-bit or higher coding is accommodated by carrying data across two cables. UHD, 12-bit, 4:4:4 coding would need compression or dual-link 12G-SDI to carry the 17.9Gb/s video data. At 60fps, 12-bit, 4:2:2 has a video data rate of 11.9Gb/s, which would exclude any ancillary data.

The next big step in interconnection formats is to carry the signal as elementary streams, rather than being multiplexed together.

Moving from SDI to IP offers an alternative which decouples the intimate connection between coding systems and the electrical interface that we have with SDI standards. IP can carry multiplexed video and audio or elemental streams, it's all just data packets.

Looking to the future, what resolutions will be needed for VR? Will 8K become commonplace?

All-IP systems

Moving to all-IP radically changes the landscape. IP switches are a fraction of the size of SDI routers

The number of interconnecting cables is reduced. One 10G Ethernet connection can carry three 3G-SDI circuits, HD or compressed UHD.

Multi-channel audio, communications and control can share Ethernet connections, simplifying connections to remote commentary boxes and the like.

IP connections are duplex (bidirectional). Stage boxes can use a single Ethernet fiber to carry the inputs and outputs.

The physical layer carrying the IP data is generally Ethernet. This can be twisted cable pairs, or fiber for higher data rates (10Gb and more) and long cable runs.

Ideally, the move to IP should lower costs, provide same facilities as SDI systems, and offer new possibilities.

Moving to all-IP radically changes the landscape.

The IT world has developed quite separately from broadcast engineering, so it's not surprising the language is different. Network engineers talk about 'top-of-the-rack', 'east-west', 'leaf-and-spine'. Part of this stems from the different applications: a remote client communicating with a data center in a query-response manner. Contrast a broadcast system that is essentially linear, camera to final delivery encoder.

That said, both have processing connected to a core switching or routing fabric. IT engineers have moved from a large switch at the system core to a distributed architecture that is more suited to virtualization and cloud applications. One implementation is called 'leaf and spine' (see figure 2).

Advantages for mobile

An IP infrastructure brings a scalability and flexibility to a truck that is not possible with an SDI system. Scale means IP can be used to build a large 32-camera truck.

Flexibility means a truck can be used for an HD production one day, and UHD the next without the need for time-consuming reconfiguration. For mobile operators, reconfiguration time is down time.

Format and standards upgrades can be made through software changes rather than re-cabling. As standards evolve, the operator can move from embedded audio to elemental streams without major hardware changes.

IP is On-air

IP trucks are on-air now, they are field-proven and being used to cover prestigious sporting events, where gear failure is not an option.

IP infrastructure has been demonstrated to be a lighter weight, especially when compared with a quad-link UHD system. The commodity Ethernet switches and routers are designed for the high performance demands of today's enterprise data centers. The scale of manufacture, and the pace of change means 40Gb and 100Gb equipment is becoming more affordable, with 10Gb being a step on the road.

As an example, a 40Gb fiber connection can carry ten or more 1080P video signals in each direction, so the potential to simplify rigging for a production is huge. A future all-IP sports graphics truck can be attached to the main production unit with a single Ethernet connection.

IP in broadcast is no longer a science experiment. It offers real advantages, without necessitating changes to the operators' familiar facilities and control surfaces.

The Broadcast Bridge 11/2016

The Challenge of Building a Multiformat (HD, 4K & HFR) Truck and the Technologies that Solve the Problem

grass valley
A BELDEN BRAND

By Sam Peterson, Sr. Segment Manager, Live Production, Grass Valley, a Belden Brand

Arena TV's UHD mobile unit OB X is based on an IP infrastructure,

As the transition time between new formats continues to shorten, the task of keeping a production facility up-to-date has become increasingly difficult. Never before have so many new potential signal types created such difficulty in managing signal paths, maintaining configuration of user interfaces and control systems and creating the new infrastructures required to handle them.

With this accelerated rate of change, outside broadcasting (OB) truck providers aren't always able to reach a full return on investment if they only choose one production format. Today, operators are looking for a way to be agile enough to accommodate multiple formats with one facility (or truck). The industry needs an approach that protects investments by using technologies that enable flexibility and scalability.

Standards-Based IP

Using standards-based IP interconnects and an accompanying distributed architecture is a technological solution to a very real business problem — the ability to react to the changing requirements of the production marketplace.

Today's 10 GigE IP technology provides the bandwidth required for a broadcast interconnect and allows for a common physical interconnect to provide transport for a varied array of data stream types. The IT industry demonstrated the superior potential for migrations and augmentations as the Ethernet market progressed from 10 to 100 Mb to 1 Gb to 10 Gb. By using a standard encapsulation such as RFC 4175, the medium and the stream can be decoupled and either simultaneously or separately transitioned to the next capability.

Standards-based IP makes this approach valuable beyond 10 Gb. As the industry moves towards 2160p120 or 8K UHD, the same recommended system design can continue to scale as higher speed interfaces become available to the market.

The broadcast industry can help itself by quickly adopting a common standard to use as a long-term, IP-based replacement for the long- standing video interface, SDI.

ROI / Flexibility

Any implementation developed today should provide the flexibility for all contributors in the production chain — including acquisition (cameras), graphics, replay operations, switching and effects, audio, processing and transmission — to easily join streams, combine components of streams and provide those produced streams back into the system with efficiency. In addition, the signal format should not be tied to a physical wire.

In today's production market, particularly in OB trucks, the potential for building a system that allows for easy reconfiguration and deployment for HD/3G/4K UHD or

The Challenge of Building a Multiformat (HD, 4K & HFR) Truck and the Technologies that Solve the Problem

HFR sources is attractive. Being able to pull a truck up to an event and know that the infrastructure is capable of supporting any production format through software configuration, without moving any interconnects, could mean the difference between maximizing the utilization of a mobile asset and losing out on revenue due to time required to reconfigure from event to event.

Customers do not want dedicated wiring based on the type of traffic. In addition, some devices that provide, produce or manipulate live video streams in a production environment no longer rely on a dedicated "video" interface but instead use only standard 10 GigE. Many anticipate their future IP infrastructures can and should accommodate a mixture of traffic via Quality of Service (QoS).

By utilizing standard methods of encapsulation — such as RFC 4175 for RTP — and allowing for multiple raster formats, frame rates and more to be carried in the same way, the concept of one wire for all signals can be achieved. The promise of using a single physical interface type for 4K UHD, or for HFR HD/3G content is well at hand. Utilizing standard methods of transport that allow for easy separation of video, audio, and metadata essence means that all potential users of these streams can be assured their needs are met.

Distributed Architecture

Data centers pioneered the distributed IP architecture model, creating a topology where groups of processing devices or servers are managed through a top-of-rack switch. Switches are then aggregated to provide system-wide access across the enterprise.

Using a similar model for OB trucks — particularly trucks with multiformat requirements — can provide many of the same benefits, including: scalability, options for redundancy and ease of migration, or addition of future services or capabilities. Furthermore, in many cases, by leveraging the pace of development of commercial-off-the-shelf (COTS) IP switching for the core and aggregation layers of a distributed broadcast IP fabric, broadcast-centric devices can concentrate innovation at the edge to address our industry's specific I/O and processing requirements.

Conclusion

IP-based connectivity, when combined with extensible protocols, allows for fast implementation of new signal types without changing the transmission mechanism. With continuous innovation from broadcast manufacturers, additional functionality such as low latency, programmable processing and vertically accurate switching can be added to the scalability, flexibility and fault tolerance afforded by this new IP core. By embracing open standards, the industry can be assured of a common, ubiquitous set of protocols for broadcast and media companies to transition from SDI to IP. When combined with a distributed architecture, production facilities are easily extended to meet the fast-changing requirements of today's broadcast production market.

In addition to benefits in the market overall, the ability for a single system (or truck) to accommodate multiple production types, with practically no downtime beyond a software configuration change, would provide broadcasters with two big advantages — enhanced revenue-generating capabilities from taking on additional jobs and reduced operational costs from not having to change over a system.

The demand to deploy a multiformat, flexible OB truck is upon us. A standards-based IP interconnected infrastructure utilizing a distributed architecture can pave the way to meeting that requirement and allowing for those formats to come as the industry continues to progress.

Grass Valley is a full member of the Alliance for IP Media Solutions

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11/2016