BLACK BOX WHITEPAPER: VIDEO TRANSMISSION OVER IP: CHALLENGES AND BEST PRACTICES

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INTRODUCTION

Network-based video distribution technology has been going through major evolutions in recent years, which partly originates from the need for better image quality and higher resolutions (4K and 8K), AV systems growing in size and improved connectivity for various distributed devices. The other major driver for development is an increasing number of applications such as high-resolution P2P AV connectivity, digital signage systems, video wall connectivity, or on a larger scale, video distribution networks, CCTV monitoring, AV matrix switching networks, production networks, content playout and delivery for video on demand and more.

The transition from local connections and proprietary AV networks to IP has yielded significant improvements in terms of quality and performance but at the price of increasing bandwidth, new network infrastructures and higher energy consumption. This is because network-based video delivery is associated with several serious challenges such as the demand for high-performance local network infrastructure and content sources (PCs, content players, etc.) on a small scale, and a stable and reliable backbone infrastructure, including new data centers and additional maintenance on a large scale. Since video is a very bandwidth-hungry medium, content streaming demands real-time, consistent network performance, sophisticated distribution schemes and better compression algorithms.

With HD or 1080p resolutions becoming the standard for many applications such as TV broadcast and the video game industry, 4K and 8K resolutions are not expected to be mainstream anytime soon. At the same time, end users expect to be able to send and receive ultra-high resolution 4K/UHD video content across any distance while retaining the image quality of a UHD video system. As technology advances, both end users and business customers have to carefully balance their AV system requirements between cost efficiency and keeping up with the trend of bigger, faster and better. This white paper will help you understand the crucial factors you should consider when selecting and planning a networked AV system, including network components, bandwidth consumption, compression methods and more.
CRITICAL IP INFRASTRUCTURE COMPONENTS

The main advantages of IP-based AV networks are reduced costs and ease of network infrastructure and enhanced compatibility, since IP is a commonly used protocol. Experts are predicting global, IP-based data traffic will grow more than 80% until the year 2021.1

When designing an IP video network and specifying the need for high resolutions, low-latency, real-time bandwidth management and format conversion for multiple file types, the whole situation becomes even more complicated. Careful considerations have to be made when selecting the following components, because they will have a substantial impact on overall performance and quality.

Cables
It is important to select the right cable category (CATx), typically specified by the AV device or software. Benefits of copper cable include reasonable price, its common application and that it can support power distribution via Power-over-Ethernet (PoE) technology. If you are making your infrastructure future-proof and ready for 4K resolutions and beyond, consider 10-Gbps Ethernet or higher to provide enough bandwidth for adding new endpoints and applications that require high color-depth and pixel-perfect video transmission. Depending on the type of cable, required bandwidth and other factors, copper cables typically support distances of up to 100 m, which can be extended using network repeaters or adding additional network switches. You can also extend the reach of your copper network by combining it with fiber media converters.

Fiber cables provide higher bandwidths, are insusceptible to electromagnetic interference, require less maintenance and are less prone to unauthorized access. There's a variety of different types, such as single-mode and multimode cables, and multiple types of connectors including ST, SC, FC, so make sure to pick the right one for your application. The supported IP transmission distance depends on the type of cable (supported wavelength of light); required bandwidth; and type of SFP module (if used), ranging from 220 m up to 70 km. With prices for fiber infrastructure dropping regularly, this is a viable and future-proof option for many applications and industries today.

Switches
A vast number of different managed and unmanaged IP switches are available on the market. When choosing an IP-switch for networked AV, you need to carefully consider your requirements and supported features. Select a switch that supports the right count and types of network ports and keep future system upgrades in mind. The total bandwidth capacity has to meet or exceed the AV network requirement. For multicast, switchable AV connections and large-scale applications, you will need a managed switch with features such as multicast over IGMP, QoS support, IP-address management, bandwidth management and more. To learn about the different types of managed and unmanaged switches, download our free white paper at blackbox.com/switcheswhitepaper.

Video Cables and Converters
Selecting high-quality video cables and converters to connect your IP-AV device with screens or media sources is extremely important because it has a major influence on the video quality of your screen display. Additionally, make sure to select high-end connectors and sufficient shielding for the best user experience.

VIDEO-OVER-IP CHALLENGES
As video resolutions continue to increase and high-resolution 1080p and UHD devices become more affordable, the demand for AV distribution and switching solutions that support these resolutions is growing as well. The limiting factor for AV distribution of high definition and UHD is bandwidth, which can be put into an equation of source content (resolution, frame rate, color depth and scanning), applied compression (transmitted pixels per time interval) and available network infrastructure and management.

Increasing Resolutions and Video Performance over IP
Supported resolutions vary by device and application, with end user technology today typically ranging between 720p (non-HD TV broadcast) and compressed 1080p or 4K at 30 Hz. However, in professional environments such as video production, 5K (5120 x 2160) and 8K (7680 x 4320) cameras and screens are already in use, and 10K (10240 x 4320) devices are already on the horizon. Most of today's high-resolution video distribution requirements exceed 1 Gbps in uncompressed video bandwidth, with 1 Gigabit networks still being a standard for private use and in many organizations. Uncompressed 4K video (2160p60), for example, uses 22 Gbps of bandwidth at 10-bit color and 4:4:4 color scanning. When compared to 1080p60 — only 5.5 Gbps uncompressed at the same image quality — it’s easy to see why 4K, the professional resolution of the near future, is still difficult to implement in professional environments such as TV broadcast and media production.

AV and KVM (keyboard, video and mouse) extenders and switches today are capable of transmitting up to lossless compressed 4096 x 2160 at 60 Hz and 10-bit color depth over IP, using intelligent compression algorithms to keep the required bandwidth at a minimum (10 Gbps) while retaining full image quality and transmitting images pixel by pixel.

1HTTPS://WWW.STATISTA.COM/STATISTICS/499431/GLOBAL-IP-DATA-TRAFFIC-FORECAST/
An exemplary application for this would be post-production facilities, distributing video streams to editing suites. When considering the required bandwidth for transmitting these lossless video signals, it is self-evident that they should not be passed through an existing, in-house LAN. Instead, distinct IP networks serving one purpose should be implemented to not interfere with other applications.

### Table 1: Video Resolutions and Required Bandwidth

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Active Pixels (Horizontal x Vertical)</th>
<th>Refresh Rate, Color Depth</th>
<th>Required Bandwidth (Uncompressed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>576p</td>
<td>720 x 576</td>
<td>60 Hz, 10-bit</td>
<td>0.9 Gbps</td>
</tr>
<tr>
<td>720p</td>
<td>1280 x 720</td>
<td></td>
<td>2.7 Gbps</td>
</tr>
<tr>
<td>1080p</td>
<td>1920 x 1080</td>
<td></td>
<td>5.5 Gbps</td>
</tr>
<tr>
<td>2160p/4K</td>
<td>4096 x 2160</td>
<td></td>
<td>22 Gbps</td>
</tr>
<tr>
<td>8K</td>
<td>7680 x 4320</td>
<td></td>
<td>89 Gbps</td>
</tr>
</tbody>
</table>

**Video Interface Bandwidth Limitations**

End users today expect to be able to send and receive HD and 4K/UHD video that retains full image quality all along the distribution chain. This is forcing industries to produce new or updated interface/cable standards that support higher data rates. Table 2 shows three commonly used types of digital video interfaces and their supported video bandwidths.

Comparing the available video interfaces and their supported bandwidths, and given that commonly used network types today are 1-G and 10-G Ethernet, it becomes evident that most AV-over-IP solutions supporting high resolutions must compress the quantity of data by encoding at the beginning of the distribution chain and decoding at the receiving end. Using the latest DisplayPort 1.4 and HDMI 2.1 interfaces and 40-G Ethernet technology, transmitting and displaying uncompressed Full HD and 4K content over IP is possible already today, yet inefficient and costly.

### Table 2: Video Interfaces and Supported Bandwidth

<table>
<thead>
<tr>
<th>Interface Image</th>
<th>Type of Interface</th>
<th>Supported Resolution</th>
<th>Supported Bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="hdmicon.png" alt="HDMI" /></td>
<td>HDMI 1.0 (2002) “Standard HDMI”</td>
<td>1920 x 1080 @ 60 Hz</td>
<td>3.96 Gbps</td>
</tr>
<tr>
<td></td>
<td>HDMI 2.1 (2017) “Ultra-High Speed”</td>
<td>5120 x 2880 @ 60 Hz or 7680 x 4320 @ 30 Hz</td>
<td>42.6 Gbps</td>
</tr>
<tr>
<td><img src="dpicon.png" alt="DisplayPort" /></td>
<td>DisplayPort 1.1a (2008)</td>
<td>2560 x 1440p @ 60 Hz or up to 3840 x 2160 @ 30 Hz</td>
<td>10.8 Gbps</td>
</tr>
<tr>
<td></td>
<td>DisplayPort 1.4 (2016)</td>
<td>5120 x 2880 @ 60 Hz or 7680 x 4320 @ 30 Hz</td>
<td>32.4 Gbps</td>
</tr>
<tr>
<td><img src="dvicon.png" alt="DVI-D Single Link" /></td>
<td>DVI-D Single Link (1999)</td>
<td>1920 x 1200 @ 60Hz or 2560 x 1600 @ 30Hz</td>
<td>4.95 Gbps</td>
</tr>
<tr>
<td></td>
<td>DVI-D Dual Link</td>
<td>2560 x 1600 @ 60 Hz or 3840 x 2400 @ 30 Hz</td>
<td>9.9 Gbps</td>
</tr>
</tbody>
</table>

**Compression**

Most solutions for distributing high-resolution video need to employ compression prior to distribution due to network and video interface/cable bandwidth limitations. Compression lowers the total amount of signal bandwidth required by reducing the amount of transmitted information. Lossy compression reduces the amount of unnecessary information. Lossless compression eliminates bits that are statistically redundant. High-ratio, lossy compression usually causes signal degradation, which results in poor chroma sharpness and frequency response (horizontal, vertical and diagonal), making the picture appear pixelated and blurred. Whereas, lossless compression allows a perfect reconstruction of the image when decoded.
Network Bandwidth Cost Considerations

Networks speeds have evolved from 10/100/1000 Mbps to premium-priced 10 Gbps, 40 Gbps and 100 Gbps. These speeds are not superfluous, but are needed to lay the foundation for an increasing number of (video) data streams, such as compressed HD and 4K content. Each new video stream or AV source added to the system will inevitably increase bandwidth consumption, which makes it even more important to plan ahead and keep future requirements in mind.

Most network switches, when properly configured, can limit data flow to the ports that are actually being used by video traffic, so the main concerns are where data paths converge, such as links between switches. These links should be capable of carrying the maximum amount of video traffic that is anticipated and can use 10–Gbps network connections for higher bandwidths along shared pathways. However, packet loss may still occur when one or more packets of data travelling across a computer network fail to reach their destination. As video distribution can be very bandwidth hungry, jumbo frames and IGMP snooping activation might be required for perfect service. Dedicated managed network switches and VLAN setups are ideal to distribute full-frame video. You might also want to take advantage of specific IP video routers that can distribute and convert video to IP packets, route it over your existing Ethernet network and convert IP video back to a digital video signal. Additionally, a dedicated server for encoding all the streams and making them available via HTTP can be implemented into your network, helping to improve the quality/bandwidth trade-off.

Video Distribution Latency

Another challenge for some networked video applications is keeping video latency as low as possible. Video latency can be defined as the delay between a video frame leaving a content source (e.g., a computer) and being displayed at the target of the distribution chain (e.g., a screen). Video latency is usually measured in milliseconds.

Latency Depends On Many Factors:

- Color depth and refresh rate of the video content
- Processing time required from the content source
- Number and type of points that are being passed along the distribution chain (hardware or software)
- Degree of video processing that is required (scaling or converting content)
- Type of video compression used
- Network transport process (IP data packeting and negotiation)
Video/audio delays can be very disturbing, so even small amounts of video latency are intolerable.

This is why in most large-scale systems audio signals are usually time-coded to sync with the delay of the video signal.

As a rule of thumb, heavy compression reduces data drastically and results in minimal bandwidth requirements, but the resulting video has the lowest quality and the longest latency. Lighter compression offers better video quality and minimal latency but requires more bandwidth. Depending on all of the above mentioned aspects, image latency can vary from a few milliseconds to half a second of delay, with <30 ms usually being perceived as a good “real-time” video transmission.

THE ROLE OF AV AND KVM EXTENSION TECHNOLOGY

Both AV and KVM extenders/switches have proven to be helpful devices wherever there’s a need for real-time, high-speed, IP-based connectivity to sources like computers, servers and content players “at the edge of the network.” Technology for large-scale applications usually provides options for managing bandwidth requirements and only uses as much of the available network bandwidth as necessary to provide optimal signal quality; typically, AV transmitters will use considerably less bandwidth than the maximum available. Some of these devices come with built-in encoding and decoding and image scaling and conversion. Additionally, some allow you to adjust the level of compression, can be managed from a web-based GUI and overall allow IT staff to control every single step of the AV distribution chain. This is particularly useful for applications that require 24/7 uptime and real-time access to critical servers 365 days a year.

AV and KVM extenders play an important role in overcoming bandwidth and distance limitations of VGA, HDMI and DVI, as well as PS/2 and USB cables. KVM-over-IP devices transmit video and peripheral signals using a standard IP network, providing fast visual access and sharing of peripheral devices such as keyboards, mice, tablets and storage devices. Video signals are typically compressed (lossless) to accommodate for the bandwidth requirements of the application and network infrastructure. When KVM solutions such as Emerald 4K KVM over IP are combined with a virtualized server infrastructure, it provides zero-client-based, real-time access at very high image quality, preserving the desktop experience that users get from a local PC. This helps to increase workflow efficiency, response times and productivity without the expense of consuming more bandwidth.

CONCLUSION: OVERCOMING VIDEO-OVER-IP CHALLENGES

Network-based, high-quality video and audio distribution is becoming a challenge due to increasing bandwidth requirements and end user expectations. New network technologies and standards as well as compression algorithms will help mitigate these challenges, yet there are still additional costs for required infrastructure and migrating legacy components. Nevertheless, current developments in AV and KVM technology allow the transmission of high-quality video that consumes less bandwidth than ever before and make management of small-to-large scale IP-based AV networks both comfortable and future-proof. Here are some takeaways when considering high-resolution image distribution for your project:

- If you want to stream up to HD video, look for products that support resolutions of 1080p60 and 1920 x 1200 only. Support for higher resolutions can mean higher bandwidth consumption and higher costs, although this is not true for all solutions.
- Learn about the type of compression used, since specific codecs strongly vary in price. For example, you might want to consider encoders/decoders utilizing a relatively high-priced H.264/MPEG-4 AVC codec for high-quality, low-bandwidth projects.
- Synchronizing video channels and using optical fiber connectivity enables video extension of resolutions up to 4K and even 8K across very long distances today. This method provides enough bandwidth for uncompressed, high-resolution DisplayPort 1.2 video signals, keyboard/mouse, RS232, USB 2.0 and audio.
- Latest compression technologies allow the lossless transmission of video signals at a resolution of 4K @ 60Hz, 10-bit color depth. Lossless compression requires more bandwidth to transmit video signals but provides crystal-clear images and latency-free operation.

You should ask yourself the following questions before starting your research on components to build-out your AV-related application:

- What is my budget for the project?
- Can the new AV-over-network solution be integrated into my current network topology, even at 1-G Ethernet infrastructure?
- What image quality and resolution will be good enough, and do I need uncompressed video?
- What video inputs and outputs will have to be supported by the AV-over-IP system?
- Do I have to be prepared for the next big video standard?
- What’s your latency tolerance? If you’re planning to distribute video only (no real-time interaction), you may have a high latency tolerance and don’t need to use real-time technology.
- Will I have to support multiple streams for simultaneous on-premises and internet consumption?
- Are there any compatibility issues with existing and/or legacy components?

Black Box can help you design an AV- or KVM-over-IP distribution system tailored to your specific needs. Based on extensive experience and a unique product portfolio, our experts will recommend you the right mix of components. Ask us for a free demonstration of our solutions by calling us at 1.877.877.2269 or visit www.blackbox.com.