White Paper

The Death of Dedicated AV Distribution

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By

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**Introduction**

This white paper will describe a new and emerging class of distribution service that we are calling “4K-Multimedia-over-IP” and its potentially disruptive impact on the current distributed AV solutions that are sold today. We use the term multimedia, as the capabilities go beyond the distribution of just video and audio. For example, solutions are now available that offer various combinations of these additional capabilities: Ethernet, USB, keyboard and mouse, control signals and even power.

In fact, two major transitions are underway right now. One is from 1080p resolution content to 4K and UHD resolution content. But in addition to expanded resolution, many applications will soon embrace higher dynamic range, expanded color gamuts and higher bit-depth processing.

The other transition is the type of information being distributed and the way it is being distributed. We are moving from a model of dedicated and often proprietary AV distribution to a more IP-centric approach that includes control and signaling in addition to audio and video.

We are also changing from a model of separate and dedicated networks or proprietary switching solutions to a converged distribution model. The new 4K Multimedia-over-IP paradigm is changing the options available to end users and integrators, not only from the perspective of lower hardware costs, but it is simultaneously creating new opportunities. This can include additional functionality, easier management, and the ability to change the use models and applications without major hardware or software upgrades. In other words, it allows easy reconfiguration of systems where there are multiple sources of content in different formats that need to be distributed to many displays of various configurations, resolutions and locations.

This capability is now fundamentally changing the way AV and other signals in professional applications are being routed and distributed. We believe it is essentially a new paradigm, but it is still in the emerging phase so there are many variations. How the market will evolve is always hard to predict, but if we look at the lessons of history, it is more likely than not that the final solution will involve the use of standard packet-switched IT equipment. This will allow networks to expand from the distribution of Ethernet and web content to become the main standard for all aspects of professional signal distribution.

While the traditional approach of using both analog and proprietary circuit-based protocols are popular today, emerging silicon chip sets are now driving innovation in converting uncompressed high quality content to IP packets at a rapid pace. As displays transition from 1080p to low cost Ultra HD / 4K versions, and mainstream 1Gb migrates to 10Gb data networks, there will be a need for affordable video distribution at extremely high data rates for uncompressed or visually lossless compression to support these new products.

In a nutshell, the packet-switch multimedia-over-IP solution that ZeeVee offers allows all kinds of digital signals, including uncompressed Ultra HD / 4K video to be encoded to IP protocols using dedicated encoder boxes at the source and dedicated decoder boxes at the destination. In the middle is a standard 10 Gigabit Ethernet (10 GbE) switch powered by the same hardware and protocols that now drive all Ethernet and web networks.

But what is unique about the ZeeVee solution is the ability to multiplex and independently route multiple signals over the network with minimal latency – even with visually lossless light
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compression (if needed). Such a capability allows for the distribution and pixel for pixel reproduction of uncompressed 4K video at 60 frames per second (fps) with 4:4:4 color sampling within the 10 GbE pipe.

All this means that end users deploying such solutions will significantly reduce costs of cabling, equipment, programming, management and maintenance. And, management of AV and other signals will consolidate under internal or outsourced IT departments.

In this white paper, we will first take a look at major technology transitions before discussing circuit-switched and packet-switched networks and the solutions that are available today. Then, we will dig more deeply into the packet-switched 4K multimedia-over-IP solution that ZeeVee offers to let you judge its strengths vs. competitive solutions.

**The Power of Convergence**

In the IT industry, convergence has been underway for some time. Consider a school that was built 20 years ago. This facility had a dedicated network for the phone lines, a dedicated network for the Public Address (PA) system, a dedicated network for data and a separate and dedicated network for TV. Today, that school can install a single Ethernet-based network that can manage the distribution of all of these functions using a common protocol – IP.

Clearly, such converged networks eliminate duplicative networks along with the equipment, installation, programming and maintenance that goes with each. And, many of these previous dedicated systems were often expensive because they served dedicated purposes and had a limited scale from a mass production point of view.

All that changes when this traffic can be converged on a packet-switched IP network where there are huge economies of scale that can bring down costs for equipment, installation, management and maintenance.

The same is true in many professional AV applications. For example, a corporate campus has the need to distribute data, video, and perhaps digital signage video, but often does this on separate networks. In a broadcast facility, there are separate networks for video, audio, data and keyboard/mouse operations. A government facility might have similar needs. Up until now, the traditional 1Gb network infrastructure handled voice and data well, but the bandwidth requirements of high resolution streaming video typically required tradeoffs in image quality or speed.

**The Disruptive Nature of IP**

The introduction of the Ethernet data structure, or Internet Protocol (IP), has been (depending on your viewpoint) one of the most creative or destructive forces in technology to existing product paradigms. Whatever your view, there is no denying it is disruptive. While we understand the use of IP for traditional desktop and notebook computing, the actual impact to companies in traditional analog or circuit-based technology markets represents one of the biggest technology transitions, shifting both the market landscape and market capitalizations of billion-dollar industries – including the segments of AV, broadcast and cinema. Essentially, IP
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represents a giant amoeba that, as it extends to new product categories and problems, slowly digests the category to be absorbed into the overall corporate network.

By protecting legacy investments and traditional approaches to solving problems, often the market leaders in traditional circuit based platforms do not wholeheartedly embrace the capabilities, synergies, and opportunities that are created by IP based platforms. They become bound by their traditional single-vendor approach to solving the problem rather than partnering within the data ecosystem opened up by the IP transition.

History is full of examples where companies who had market dominance of circuit-based technology could not adapt to new paradigm of native architecture. One of the first examples of this is the rapid transition from circuit-based telephones to Voice Over Internet Protocol (VOIP), and the respective impacts it had on Nortel and Cisco.

**PBX vs. Voice over IP**

In 1975 Nortel Networks launched the Meridian PBX phone system, and grew their share by strong marketing, high quality reliable products, and aggressive innovation. After launching a digital PBX, the Meridian became the de-facto standard for most medium-sized and large business in North America. During 1997, Nortel shipped 2.09 million lines of its Meridian 1 and SL-100 PBXs for a 30.7 percent share of the U.S. market, according to Eastern Management Group. Nortel stock was peaking at over US$100 per share, and the future looked bright for the company.

While Nortel was dominating the phone business that year, in November of 1997, a small company named Selsius launched the first commercially available IP phone. A year later the company was acquired by Cisco – a company with virtually no background in telephony but a revolutionary concept of Unified Communications using Voice over IP (VOIP).

This technology extended the existing data networks to handle voice applications using high grade routers, switches, and software to enable a seamless phone call using data, not circuits, to connect handsets with each other throughout the world. While Nortel was capable of duplicating the technology and leveraging its strong position in the market, it continued to push the concept of a separate network for phones and data. However, by 2010, Voice over IP had toppled the existing paradigm of the circuit-based PBX and sold over 30 million handsets, with Nortel’s stock price dropping from a peak of US$850 per share in 2000 to less than US$0.05 in 2010.

**IP Based Feature Phones vs. Smartphones**

A more recent example can be found in a product that we all have used every day for the last two decades. In 2007, the digital cell phone was one of the hottest items in the world with over one billion handsets sold (http://www.gartner.com/newsroom/id/612207). According to Gartner Inc., Nokia was dominating the market, growing their market share to over 37% - twice the share of rival Motorola. That year Nokia shipped over 400 thousand digital handsets, and achieved 40% share in the last quarter of the year. The popular N series had a web browser, Microsoft Office Viewer, contact manager, messaging and even a music player. At the end of 2007, Nokia stock was in record territory after the 2001 market crash, and boasted a market capitalization over $150 billion dollars at the close of the year.

While Nokia was dominating the market, a new competitor broke into the phone business with virtually no experience in handsets, voice quality, cellular networks or any other traditional cell phone ecosystem partner. That January, Steve Jobs pulled the first iPhone out of his pocket, announcing his intention to “reinvent the phone”. When the product shipped in June, it became one of the most popular phones, and by the end of the year, Apple was in the top ten handset manufacturers in the world.

One of the key elements that made the iPhone different was that it was not oriented around voice as its primary function, but data. AT&T had upgraded their network, enabling easy access to high speed data via a phone, just like on your computer. Even though the Nokia phones had similar features on paper as the Apple, and could be used on the same data network, the iPhone’s use of IP infrastructure to view web pages, check email, and listen to music was light years ahead because it was designed around the IP architecture, not voice. Phone “apps” became a common term (something that never existed on a Nokia phone), and the voice functionality was taken for granted.

Nokia eventually sold the handset division to Microsoft, and in July of 2015 Microsoft announced the layoffs of 7800 employees, and wrote off US$7.6 billion in charges related to the Nokia handset operations. Also, according to NPD, the IP based smartphones from Apple, Samsung, LG, and others have a higher household penetration rate than notebook computers in the United States, and is generating so much of the internet traffic that Google explicitly downgrades the ranking if a website is not mobile phone friendly.

The Next Shift – HD and 1Gb to 4K and 10Gb

Much of the current infrastructure and products toady are built around circuit-switched HD (720 or 1080p) video and data networks that can support voice over IP and compressed HD video. But now, the TV and display market is rapidly moving to 4K and 1GbE networks are not going to be sufficient. 10Gb networks have been in existence for some time, but now the convergence of 4K video and ever increasing data and video traffic is pushing the IT community to rapidly deploy and lower the cost of 10Gb infrastructure. The combination of these two major market drivers are converging at just the right time to enable the emergence of 4K over standard packet-switched networks.

Let’s consider some trend data. Network data continues to grow exponentially for virtually every organization, driving demand for increased infrastructure upgrades. According to IDC, in the fourth quarter of 2014, the worldwide demand for network switching hit a record US$6.2 billion. One of the fastest growing network switching categories is the 10Gb switch segment, which accounted for $2.3 billion of the market, with over 24% year-over-year growth last year. Looking forward, Netgear and Infonetics Research predict that worldwide 10Gb network ports sales will grow to over 100 million installed ports by 2017 (see Figure 1).

One other element that also reduces the overall cost is the reduction in the expense for single and multimode fiber cables and CAT6a cable. Today, the cost for bulk multimode fiber cable is about the same as CATx cable, and significantly less than brand-certified twisted pair cable that is designed for circuit-based AV switching. This lowers the overall project cost and increases functionality. 4K Multimedia over IP can leverage these cost reductions for both installation and long term maintenance cost reductions.
The other convergence point is 4K display adoption. Like the growth of the smartphone, the consumer segment is leading the way in driving the transition from 1080p to 4K screens. The transition is happening faster than ever before. According to IHS, worldwide shipments of 4K displays increased 400% on a year over year basis, shipping over 4.7 million units in Q1 of 2015.

Regionally, 4K-UHD TV shipments in China now account for over half of global demand. But in the North American market, we are seeing similar exponential growth. In June of 2014, 4K-UHD televisions represented under 10% of the dollar share of the television market, but by June of 2015, it is estimated that 4K-UHD televisions generated 35% of all television revenue.

The impact of this convergence will be that circuit-based AV distribution system will not be competitive with packet-switched distribution systems, leading to a major technology and infrastructure change in many markets. That is why we have written this white paper – to help you better understand the dynamics underway and adjust your business as needed.

**Circuit vs. Packet Switching**

So why was the introduction of the IP-based architecture so disruptive to Nortel and Nokia, and so beneficial to their competitors? And why do we believe that history will repeat itself in the move from HD and 1Gb infrastructure to 4K and 10 Gb infrastructure?

To understand, let’s start by explaining the difference between circuit-based and packet-based switching.

A useful way to think about circuit-based switching is the way that older telephone systems operated. When you made a call to someone, a temporary connection was opened on the phone lines between you and the destination phone. This was a dedicated connection that used up a certain amount of bandwidth - irrespective of whether you were talking or not.
These calls went through a series of switches that routed the call. This path through the switches was fixed as well. If a faster path suddenly was available, you could not just change to this new path – you had to disconnect and reconnect along the new path making it impractical to consider.

In addition, since each call requires a dedicated amount of bandwidth, the circuits could “fill up” meaning you got a busy signal. The only way to scale was to add more lines and more switches.

Packet-switched networks are more flexible and are the de-facto standard architecture used for the delivery of data and web traffic. The first difference is that the communication message is broken into segments (or packets) for communication. Data is then sent out in bursts that require momentary bandwidth, not dedicated circuits with fixed bandwidth.

The second main difference is that the path the data travels can be different with each burst as well, meaning that the optimal path for those packets is determined at the time of transmission. In other words, an email sent from New York to San Francisco might travel via Chicago for the first part; via St. Louis for the second part and via New Orleans for the third part.

The advantage of this is network efficiency but the downside can be latency and lost pieces of data. That is why Internet delivery of information or internal LANs often have buffering built in so the destination can require a resend of lost data and there is time to reassemble the data in the proper order.

This is fine when small delays or lost data can be tolerated. An example might be the playback of YouTube videos which can clearly have playback issues, but this is not considered a mission critical application.

But many professional applications involving the distribution of audio, video and other traffic cannot tolerate delays and loss of data. This is one of the key reasons why many of the historical AV distribution architectures are essentially circuit-based solutions. They are not the most effective or efficient from a bandwidth point of view, but they offer fast and reliable delivery. Such solutions will be discussed below in the circuit-based section.

But professional packet-based solutions for AV distribution exist as well. These have been developed to leverage the low-latency and high reliability of conventional IT data networks and are discussed below as well. But as we will see, some solutions use dedicated or purpose-built AV distribution equipment that can’t use standard IT equipment and infrastructure, so they may not be the best long term solution.

The new packet-based multimedia-over-IP solutions from ZeeVee address these shortcomings, as we will explain later.

Common AV Signals

Before we talk about distributing multimedia, let’s talk about the features, strengths and weaknesses of the most common AV signals in professional use today: HDMI and SDI. While other signal types like VGA, DVI, DisplayPort and more may also be used, VGA and DVI are legacy solutions that are not likely to be supported with IP transport, while DisplayPort has not made much headway yet in professional applications.
HDMI

Features

The High Definition Multimedia Interface (HDMI) technology was developed by Silicon Image, who then assembled a series of founding companies (Hitachi, Panasonic, Philips, Sony, and Toshiba) to form HDMI to license and commercialize the connection interface. HDMI has become the de-facto standard for the connection of consumer electronics, digital signage, and other audio video applications such as video conferencing.

The HDMI standard has been continually upgraded over time to support new features, such as 3D video, increased bit depth, and more recently, 4K content. The most commonly supported version of HDMI 1.4 can support 4K content up to 30 fps, and HDMI 2.0 will support 60 fps output with higher color bit depth and sampling (Table 1).

<table>
<thead>
<tr>
<th>Maximum total TMDS throughput</th>
<th>Signal</th>
<th>Color Depth</th>
<th>Bit Depth</th>
<th>HDMI 1.4</th>
<th>HDMI 2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>18G</td>
<td>4096/60p 3840/60p 4096/50p 3850/50p</td>
<td>YUV 4:2:2</td>
<td>12-bit</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>4096/44p 3840/44p 4096/50p 3850/50p</td>
<td>YUV 4:4:4</td>
<td>8-bit</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>4096/30p 3840/30p 4096/44p 3850/44p</td>
<td>YUV 4:4:4</td>
<td>12-bit</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>10.2G</td>
<td>4096/60p 3840/60p 4096/50p 3850/50p</td>
<td>YUV 4:2:0</td>
<td>8-bit</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>4096/24p 3840/24p 4096/50p 3850/50p</td>
<td>YUV 4:2:0</td>
<td>10-bit</td>
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<td>10-bit</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 1: Frame Rate, Bit Depth and Color Sampling Support for HDMI 1.4 and 2.0

HDMI 2.0 uses the same connector, but a new transceiver must be integrated into the source and destination device. These will be backward compatible to older versions of HDMI, but older versions of HDMI cannot be upgraded to support 2.0 functionality. HDMI says all existing high speed HDMI cable can be used for HDMI 2.0, but common sense says to test the cable’s response over the desired path length and desired 4K signal.
Strengths

HDMI offers the delivery of uncompressed video and audio with low latency and high reliability. It is ubiquitous and can be switched and extended with repeaters. It does offer HDCP content protection for encrypted content, such as movies from Hollywood.

There is also support for 3D content and a limited (100 Mbps) Ethernet mode that is rarely used.

Weaknesses

One of the main drawbacks of the HDMI connection is the limited cable length. While there is no specification for how long an HDMI cable can be, most AV experts are hesitant to extend beyond 20-30 meters without adding third party equipment to extend the signal – and certainly not this far for a 4K signal. Compared to traditional coax or analog cables, which can go very long distances, the cable length limitation has been one of the reasons circuit switched networks have grown over the last few years.

Also, while there is a data component to HDMI, the 100Mbps Ethernet mode is insufficient to be used for any mainstream networking function.

SDI

Features

SDI or Serial Digital Interface is a connection standard used mostly in the broadcast and post production industries. It is a point-to-point connection standard developed by SMPTE (Society for Motion Pictures and Television) to allow the movement of audio and video in the digital domain in a professional environment.

There have been several “generations” of SDI with increasing bandwidth to support the ever increasing resolution and data needs of broadcast video. For example, HD-SDI supports a data rate of 1.485 Gbps, 3G-SDI supports 2.97 Gbps, 6G-SDI operates at 5.94 Gbps, while 12G-SDI runs at 11.88 Gbps.

The SDI standard also allows for the inclusion of ancillary data which can include embedded audio, closed captions, timecode and other metadata. Bit depth support for 3G-SDI and higher is 8-, 10- and 12-bit, but not 16-bit. Neither the 6G nor 12G standard can support 4K/UHD at 120 fps.

The data format consists of two streams: Y and \( C_bC_r \) – meaning the luminance (Y) and two color difference signals \((C_bC_r)\). HD-SDI does not transmit 4:4:4 color – only 4:2:2 color samples. However, 3G-SDI does allow expanded color sampling and color encoding using the alpha or data channel.

The SDI interface is realized as a BNC connector with a coax cable. It is therefore a single lane connection standard. Several dual link and quad link standards have also been specified, but these merely use two or four BNC cables to complete the connection. 4K content today is
typically routed using the quad 3G-SDI format. Dual-link and quad-link 3G standards (ST 425-2, ST 425-3, ST 425-4, ST 425-5, and ST 425-6) have now published and there are dual-link and quad-link 6G and 12G standards in the works taking the total payload up to 48Gbps. By the time SMPTE is done with the ST 208x standards there will also be an octa-link 24G mapping standard for a total payload of 192Gbps!

The coax cable is a legacy of the analog days when good isolation and shielding was needed to achieve decent cable runs. There remain distance limitations, especially for 6G and 12G. SDI signals can also run over fiber cables to eliminate the length limitations.

SDI is a point-to-point distribution standard but can also be switched using dedicated hardware. However, SDI is not IP routable and therefore will not run on standard IP switches.

**Strengths**

SDI is the backbone of the broadcast and movie industry as it has proved to offer very high reliability and minimal latency for the distribution and switching of uncompressed digital audio and video. Many facilities have extensive coax installations that they can leverage, to a certain degree, for advancements in the standards.

**Weaknesses**

SDI is a single lane solution that has severe distance limitations as resolution, bit depth, frame rate increase. This is solved with multiple cables, but this adds complexity and cost.

Dedicated, purpose-built hardware is needed to encode/decode and switch SDI signals, meaning costs will be much higher than a solution that uses standard IT equipment.

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**Circuit-Switched AV Distribution Options for 4K Content**

**HDBaseT**

**Features**

HDBaseT is an alliance of companies formed around key signaling IP developed by Israeli-based Valens Semiconductor. Incorporated in 2010, the HDBaseT Alliances was founded by Valens, Samsung, LG and Sony Pictures Entertainment to promote and standardize the protocol.

HDBaseT is based upon using standard LAN cables (CAT 5e/6) to deliver uncompressed video, audio, 100 Mbps Ethernet data, power and control (RS232, IR or proprietary signals) over a single cable from source to destination.

HDBaseT can be used in its native state to connect a source and destination device using appropriate chip sets that are embedded in encode/decode boxes that sit at the source and destination, or which are embedded directly into the source or destination device.

HDBaseT also supports HDMI (1.3-2.0) and DVI protocols, so it is a popular way to extend the distance between a source and destination. HDBaseT switchers can also direct signals from multiple sources to any destination.
HDBaseT 1.0 defined a point-to-point connectivity standard, while HDBaseT 2.0 defines point-to-multi point connectivity, thereby providing multi-stream support. That means the ability to daisy-chain displays using simple CAT5/6 cable.

Figure 2: HDBaseT 2.0 Features

The HDBaseT 2.0 spec also adds inherent support for USB 2.0, which allows keyboard and mouse extension and operation while streaming 4K video. Also new is support for fiber connectivity for increased bandwidth and distance.

HDBaseT uses an asymmetric transmission method, which means it can send and receive data, but not at equal data rates. HDBaseT transmits a wideband 8 Gbps channel from source to display, sending video, audio, Ethernet and controls. On the way back, it transmits a narrower band of 300Mbps channel from the display back to the source, returning only audio, Ethernet and control signals.

So far, most HDBaseT products are used to extend HDMI signaling (audio and video), with announced plans to bring out USB extension products and higher data rate chipsets.

**Strengths**

HDBaseT was the first real solution to share and distribute HDCP copy protected content among multiple screens, and, until recently has been the only true platform to offer this capability. The alliance has many members such as Crestron, AMX, and Extron who provide products with the features and options that are popular with traditional AV integrators. And since it uses some common components such as standard CAT cable and connectors, cost savings can be achieved compared to expensive traditional analog/digital cabling and connectors.

Because it is a separate circuit-switched solution, it has the benefits of dedicated bandwidth, reliability and low latency for point-to-point or switched applications. In addition, some of the higher end projectors and displays are now including the chipset within the display itself, reducing the cost of the initial installation.
Weaknesses

While the HDBaseT protocol uses Ethernet cable as the delivery medium, it is not running standard IP protocols on this network. As a result, the circuit-based switches are not off-the-shelf Ethernet gear, but rather dedicated implementations. Also, while the HDBaseT signaling protocols are standardized, each company within the ecosystem develops their own proprietary products. This means that, in many cases, common network components such as transmitters, receivers, and software all have to be from the same vendor. This increases the cost – and risk of sunken cost for the end user if they need to switch brands for any reason.

One of the biggest costs of the HDBaseT solution is the AV matrix switcher. Unlike port neutral IP switches these switchers use the same chassis based architecture of traditional analog switchers, which have fixed limitations on number of inputs and outputs. For example – a 16 port chassis has 8 inputs and 8 outputs. If only two sources are needed to be sent to ten screens, the user must purchase a bigger switcher chassis.

Another weakness of the HDBaseT switchers is the cost of programming, installation and on-going maintenance. Typically, each port has to be programmed with the specific product information and control codes for the controller to be able to identify the source or display. In addition, if the ports need to be changed, or equipment substituted (such as upgrading a projector to a different model), the system typically has to be reprogrammed.

Each brand has their own software platform to program the system, and these are complex programs that most end users do not have the resources to support in-house. Most AV dealers provide these services, but it is difficult for an end user to estimate both the initial cost and ongoing costs from third party sources. A standard IP-based solution would allow the IT department to manage all these functions at much lower cost.

For video and mainstream data applications, HDBaseT is not an IP routable solution, and requires dedicated network cabling, equipment, and software support as described above. The architecture does support a 100 Mbps Ethernet connection to off-the-shelf Ethernet LAN switches to enable devices connected to a HDBaseT network to access the IP network, such as transporting control data or updating digital signage media players, but it not a enough bandwidth for mainstream applications such as Video over IP.

HDBaseT is currently limited to a data rate of 8 Gbps, which means it can support 4K/60 at 4:2:0 if the bandwidth is fully dedicated to the video. One drawback is that if other features are added, the user has to reduce the frame rate, bit depth, color sampling or resolution since HDBaseT does not support compression.

Finally, the cost of an HDBaseT matrix switcher is usually much more expensive than IP switches with similar bandwidth. While most major brand HDBaseT switchers are not sold on the Internet where easy price comparisons can be made, both the MSRP and “street” prices for HDBaseT can be up to 40% higher than similar port / bandwidth IP network switches. Furthermore, because the HDBaseT switches are designed around each brand’s product line and software, they are not interchangeable if a user wants to switch vendors, or if one goes out of business.
Packet-Switched 4K Distribution Options

SMPTE 2022

Features

The SMPTE 2022 standard is designed to allow transport of broadcast video signals over an Ethernet (IP) network. There are seven parts. Parts 1-4 focus on MPEG2 streams for HD and SD content. Part 5 specifies forward error correction (FEC) for high bit rate applications for signals running at 270 Mbps and higher. Part 6 specifies the encapsulation method, while Part 7 specifies the timing and characteristics of the 2022 streams so receivers can switch seamlessly between the streams.

2022 allows SGI, HD-SD, and 3G-SDI (but not UHD or 4K) payloads to be encapsulated into an Ethernet IP stream. This basically means adding an IPv4, UDP, RTP and media payload headers. The SMPTE payload is also processed to include forward error correction to help recover lost packets. This, along with the headers, is shown in Figure 3.

![Figure 3: Data Structure of the SMPTE 2022 Encapsulation](image)

IP networks also have large latency variations, which require a means of synchronizing and switching between video streams. The IEEE 1588 (Precision Time Protocol) standard allows for precise clock synchronization over local area networks (LANs) and wide area networks (WANs). A derivative of this protocol (SMPTE 2059) is used to generate clocks and time-stamps for remote video sources, and for those sources to be aligned and edited at a central location.

The issue of packet loss is addressed by adding Forward Error Correction (FEC). The scheme used by SMPTE is Row/Column which simply adds extra FEC packets in a separate stream (which may be lost along with the payload packets).

SMPTE 2022 is often used as a Contribution broadcast transport mechanism – that is, when sending a high quality uncompressed video feed from a remote location to a production studio. It is not yet widely used to replace the routing of baseband SDI signals over coax within a facility, however. There are two capabilities that still need work: routing of 4K signals and clean switching.

Because of the emerging need to transport 4K signals in a broadcast environment and the prevalence of 3G-SDI infrastructure, SMPTE is looking to develop compression solutions that...
work with 3G-SDI and 2022 signals over IP networks. The leading proponent is TICO, a visually lossless 4:1 compression technology that features very low encoding/decoding latency of 10 ms (milliseconds). This is less than a frame and acceptable for broadcast and many demanding applications. TICO allows 2160p/60 video to be transported over 3G-SDI infrastructure or 3 streams of 2160p/60 over an 10 GbE IP infrastructure using 2022. The development of a SMPTE standard to allow this is on-going at this time.

The other on-going issue in the use of 2022 in the facility is the ability to switch video streams without picture disruption. So called “clean switching” means you change the picture at the end of the frame. But in an IP-based environment, an IP router or switch may re-route packets in the middle of a frame. 2022-7 can clean switch between identical streams generated by the same source, which is helpful, but not a total broadcast solution yet. Solutions like dual transmission of the streams or switching using SDN technology are also being proposed and demonstrated today, but additional standards are not yet available or ratified by SMPTE.

**Strengths**

SMPTE 2022 signals are IP routable over standard Ethernet equipment. It allows for real time operation with minimal latency and synchronous processing (genlocking of sources). Compression can support multiple 4K/60 streams over a 10 GbE network as well, making this an attractive solution for the broadcast and post-production community – so far.

**Weaknesses**

Using 2022 in a ProAV or non-broadcast application is problematic as it does not support the signals that are common in these applications and SDI equipment is not widely deployed outside of the broadcast industry. The structure calls for the encapsulation of SDI signals in an IP wrapper, and it is geared to deliver audio, video and some broadcast-specific data like embedded audio, closed captions, timecode and other metadata.

2022 also is limited to 4:2:2 color sampling that is designed for broadcasting and television. This may not be acceptable to higher end applications such as medical environments, digital signage, and other applications where higher color sampling is needed.

**AVB/TSN**

**Features**

Audio Video Bridging (AVB), Ethernet AVB (eAVB) or Time Sensitive Networking (TSN) are all common names for an emerging standard to deliver audio and video signals over an Ethernet network. Going forward, the TSN name will be used as this better reflects what the standard does. The AVnu Alliance was developed to help commercialize the technology and to develop a certification process for devices that serve a diverse set of markets.

Like HDBaseT, TSN uses an RJ-45 connector and CAT cable. Both however, require modifications to traditional IT Ethernet gear to operate. TSN is a true network protocol allowing one-to-one or one-to-many connections. HDBaseT, SDI and HDMI are point-to-point connection standards.

TSN is based upon the IEEE 802.1 standard, which has a number of subcomponents specifying time, queuing, etc. This group has developed the specifications to allow time-
synchronized low latency streaming services on Ethernet (IEEE 802.1) networks. It is an open standard with no royalties.

As discussed in the SMPTE 2022 section, sending audio and video over Ethernet networks will not produce a quality viewing experience because of the unsynchronized packet distribution nature of Ethernet networks. TSN adds precise synchronization, traffic shaping for media streams, admission controls and identification of non-participating devices. The idea is to reserve a portion of the network bandwidth to assure there is enough for the video delivery (admission control and traffic sharing) and the use of new timing-based frames.

TSN adds a “grandmaster” timer (based on the IEEE 1588 Precision Time Protocol standard used in SMPTE 2022) and a way for devices to exchange timing information for synchronization of multiple streams and to deliver video from the source (Talker in TSN parlance) to the sink (Listener) with the same relative timing. Multiple clocks are supported for video and audio, for example, to travel different path from talker to listener. This is good for sending video at its native rate instead of retiming it.

As shown in Figure 4, AVB-based and non-AVB devices can interoperate on the same network, but to send synchronized audio or video from a talker to a listener requires all TSN/AVB capable bridges in between. As a result, you can’t use off-the-shelf Ethernet gear – it must be modified to be TSN compliant.

Figure 4: AVB Connection on an Ethernet Network (source: AVnu Alliance White Paper: No-excuses Audio/Video Networking: the Technology Behind AVnu)
Management of the video packets are also different in TSN vs. a standard Ethernet network. In an Ethernet network, the packets are sent in “bursts”, but in an TSN network, the packets are sent at regular intervals to help ensure they can pass through the allocated bandwidth without bunching or packet losses.

Think of TSN as the dedicated commuter lane on a highway with the cars (packets) spaced at regular intervals. This can result in delivery of video with low latency and low jitter as long as resources are properly allocated along the full path. TSN allows the operator to specify a Quality of Service (QoS) level and worse case latency to facilitate the process. Regular traffic can also flow on the network independent of the TSN component (the rest of the highway with start and stop traffic at times).

With conventional Ethernet networks, designers often built in large amounts of buffering at the listener end to ensure all packets got delivered. That means latency, which is usually not tolerable in many AV applications. TSN reduces this latency to less than 2 ms (milliseconds) on a typical seven hop network.

**Strengths**

TSN addresses the issues of latency and timing for the delivery of audio and video over an IP network. It reserves bandwidth and manages the IP traffic to provide a quality of service. And, it is flexible in the ability to scale to higher bandwidth networks depending upon the needed data rate. TSN can simultaneously support non-time sensitive Ethernet traffic (typically up to 25% of the total bandwidth).

Commercially modified switches are available from companies like Evertz, Arista, Cisco, Extreme and Axon.

**Weaknesses**

TSN product and standard development is still in the early stages and behind the efforts of SMPTE with 2022. While TSN compliant switches and routers are now being offered, development of smaller scale converters and nodes points still needs work.

When bandwidth in a TSN network is allocated to a specific AVB flow, that bandwidth is dedicated to that flow and is no longer available to any other signals on the network. That is why flow setup and tear-down is such a software-intensive process, and not implemented on a lot of off-the-shelf high-bandwidth switches.

In addition, roll out of audio solutions are well ahead of video solutions. ESPN’s new Digital Center 2, which came on line in the summer of 2014, features a full TSN Ethernet network with fiberoptics running everywhere. This is currently supporting only audio distribution, but is planned to support video and control signals in the future.

The AVnU Alliance is also looking at multiple industries to adopt the technology. Its use in automotive is gaining a lot of attention, so the focus on AV applications seems to have slipped in priority. This was reflected by the lack of news in this area at the 2015 InfoComm show.

**Internet/Cable**

Video is delivered to our PCs, phones, tablets and TVs every day over IP networks, so why is this technology not suitable for the distribution of AV in professional markets? The main reason it is not suitable are the reasons we discussed above including:
The Death of Dedicated AV Distribution

- Latency in delivery
- High compression
- No bandwidth reservation
- No quality of service
- No clean switching capability

As a consumer, it may be acceptable to see delays in delivery, to have pauses and poor to moderate image quality. Professional applications cannot tolerate this, which is why the alternatives in this paper are being developed.

4K Multimedia Over Standard IP

So far, we have seen examples of point-to-point or circuit-based multi-point distribution schemes like HDBaseT, HDMI or SDI. These all require specialized equipment and only HDBaseT uses Ethernet style CAT cable (or fiber) for distribution.

For true packet-based IP distribution, TSN (AVB) and SMPTE 2022 are being developed for professional applications, while highly compressed, non-time-sensitive video over IP solutions are available for consumer and some non-critical professional applications.

Only SMPTE 2022 uses off-the-shelf Ethernet IP hardware whereas TSN requires some modifications. But 2022 is very much focused on broadcast and post-production and not the needs of mainstream ProAV markets.

A new solution focused on these markets is called “4K Multimedia Over Standard IP.” This means the ability to deliver uncompressed or visually lossless 1080p, Ultra HD/4K video, audio, USB and more on conventional IP networks using unmodified off-the-shelf Ethernet hardware from traditional suppliers.

Basic Architecture

Just as the transceiver chips from Valens enables HDBaseT products and transceiver chips from Silicon Image enables HDMI and MHL connectivity, a new silicon chip set from AptoVision is now enabling 4K Multimedia Over Standard IP connectivity. The chips form the basis of new product offerings from companies like ZeeVee.

Figure 5 shows the general architecture from ZeeVee, which offers encode/decode modules called ZyPer4K. At the center is a standard, off-the-shelf 10GbE switch from mainstream players like Cisco, HP, Arista, Extreme Networks and Netgear. On the left side are multiple sources of video such as digital signage players, laptops, rack-mount PCs, set top boxes, Blu-ray players and cameras, like PTZ models for security applications.

Note that all of these sources output over HDMI to the ZyPer4K encoder and also support a dedicated, guaranteed 1Gb Ethernet connection (for mainstream data applications such as IP based cameras), as well as legacy control methods, such as dual band infrared and RS-232. The output of the ZyPer4K encoder is an Ethernet stream that flows over either fiber (multi- or single-mode) or soon over CAT6a to the 10GbE switch.
Unlike circuit-based platforms such as HDBaseT that need to be programmed to identify the sources and outputs, the ZeeVee software can automatically assign an IP address to each device, so the IP switch software automatically recognizes the incoming streams routing audio, video and control to output devices based upon their unique IP addressing. 4K video, audio, and control information can all be sent to one output device or multiple output devices depending upon the desires of the operator.

Note that management of the signal flow occurs at the switch, which can be located anywhere with access from any location offering great flexibility.

Signals leaving the switch are then directed to various display devices. Each display has a corresponding ZyPer4K decoder that converts the IP stream back to an HDMI data stream for delivery to the display. Such display devices can consist of TVs, Smart TVs, Video Walls, projectors and more.

ZeeVee’s architecture of Figure 5 is typical of functionality available today and uses fiber network cable to extend the HDMI signal up to 80 kilometers, and new products available later this year will offer support for CAT6a copper cable.

Figure 6 shows the ZyPer4K Encoder (Input) and Decoder (Output) modules.
Features

Signal Conversion and IP Multiplexing

At the encoder, the uncompressed HDMI video and audio streams are reformatted into IP packets with proper headers and payloads to be recognized by standard IT Ethernet equipment. By having a decoder at each destination display device, the encoder can use the IP address of that decoder to route signals to the correct display.

The 4K Multimedia Over Standard IP approach addresses the need for synchronization of the various sources using a scheme called “adaptive clock re-synchronization”. This is essentially a multiplexing technique that weaves in the audio, video, 1Gb Ethernet and other signals, along with an embedded clocking mechanism into the IP stream. This scheme can recover the clocks for both audio and video at the decoder end with only a few lines of latency while remaining fully genlocked (synchronized to the source clock across the entire network – even through an IP switch.

Quality of Service

To deliver pixel for pixel reproduction of 1080p, UHD, and 4K video, audio, and data to each device, the ZeeVee solution leverages the high data rates and fast switching speeds of the 10 Gb Ethernet switch to deliver high quality of service.

While the bandwidth and network traffic generated by converting these high resolution signals is higher than normal, most 10Gb IP switches have multiple tools to manage this level of traffic effectively at various layers of the network, ranging from Quality of Service (QoS) traffic prioritization software and simple VLAN tools that can be configured within the switch, to other more sophisticated tools such as as dynamic VLAN assignment, double VLAN tagging, ACL binding, and static routing where network administrators can fine tune traffic flow and optimize network performance for each installation. These tools are commonplace in the data world, and the 4K over Multimedia concept now enables these techniques to be applied to mainstream audio video signals at virtually no incremental cost.

Support for High Bandwidth Signals—Distribution of 4K or UHD signals is a growing concern in all ProAV applications. The implementations of Multimedia Over Standard IP today feature a 10 Gbps transport rate. But as Table 2 shows, many configurations of 4K signals can exceed 10 Gbps. For example, a 4K signal at 60 fps, 10 bits and 4:4:4 color sampling requires about 16 Gbps to transport (before any schemes to reduce errors in transmission).

To address this scenario, the AptoVision chip set includes two types of manipulation of the signal. The first one is mathematically lossless decoding from HDMI format to uncompressed—
raw video format. For the signal mentioned above, this brings the data rate down to 13.8 Gbps. The second part is a light, zero-frame latency compression codec developed by AptoVision to bring the data rate down to 9.1 Gbps. This processing only adds 7 lines of latency – well within the needs of the ProAV community.

![Image](Image1.png)

**Table 2: Various Uncompressed Data Rates for 4K Video Signals**

**Auto Device Discovery**

The ZeeVee encoders and decoders are IT devices. As a result, they are automatically recognized when connected to a network. This makes the set up and configuration of the solution quite simple since dedicated encoder devices are assigned to all signal sources and dedicated decoder devices are mated to each destination device.
For example, if you want to add a display to your network, you simply connect the decoder to the fiber network and then use an HDMI cable from the decoder to the display. Using the ZeeVee management tool the decoder/display pair will be automatically recognized. Now, you simply need to select which source of content you want to route to the display.

**Universal Port Use**

One of the big advantages of the Multimedia over Standard IP solution is the ability to use off the shelf network switches. These are general nxn matrix switches that allow any combination of inputs to outputs. Have 10 sources and 2 displays – no problem. Have 2 sources and 10 displays – no problem – the same switch can accommodate either configuration.

This is a problem for circuit-based AV switches from companies like Extron, AMX or Crestron. These are typically sold in 4x4 or 8x8 or 16x16 I/O configurations meaning there are fixed I/O configurations. e.g. 4 input and 4 output connections.

In our above example, one would have to source a 16x16 switch for either scenario, whereas just a 12 port 10Gb Ethernet switch is fine with the Multimedia over IP solution.

Finally, if more ports are needed on an IP network switch, the end user can purchase an additional switch and interconnect them, preserving the initial investment. In most cases, a circuit-based AV switcher must be completely replaced with a larger chassis.

**Unique IP Addressing**

Regardless of the source or display type, brand, or model, 4K Multimedia over IP encoders and decoders create unique addresses for each device, eliminating the need for custom programming for setup and maintenance that is common in traditional circuit-based devices. One significant benefit is that this also enables each device to be able to be seen and monitored by standard network monitoring tools such as BNC Remedy and Zendesk, two popular programs to monitor and maintain network and IP devices using the corporate network. This potentially eliminates the cost for separate AV-specific monitoring software such as the Resource Management System (RMS) by AMX or Crestron Fusion or RoomView that are required to actively monitor circuit-based AV networks.

**Integration with Third Party Control Software**

One common AV application is the use of control devices from Crestron, AMX, Extron, Control 4, SAVI, and others to provide customized user interfaces to the end user. These controllers are often custom programmed and used in environments such as home installations, board room control panels and university lecture auditoriums to provide a custom front end so that changing a source or turning on/off the display can be accomplished with the touch of a button.

ZeeVee has integrated support of these controllers using a three layer approach. First, the encoders and decoders can pass through dual band infrared data from any source to any display. This is ideal for a residential installation where custom remotes are programmed and modified to address multiple devices through infrared signals. Secondly, ZyPer4k also transmits RS-232 control information across the network, which is ideal for legacy displays such as large screen projectors. Finally, due to its native IP structure, the system can transmit IP control information to both sources and smart displays, and has a built in API to enable controllers such as Crestron or AMX to talk directly to the device over the network using a custom interface.
Strengths

4K Multimedia Over Standard IP offers the ability to route uncompressed video at 4K resolution, Dolby Digital 7.1 audio, control, and other signals using standard off-the-shelf IP switches and related gear for time-sensitive applications. Each signal can be separately encoded and routed – all using software control tools that are familiar to IT personnel. This offers a lot of flexibility in how you configure and manage the AV solution.

Compression and processing can allow higher data rate signals to fit within the 10 GbE pipeline with no visual loss. The solution will also support the new Blu-Ray 4K standard which calls for 4K/60 at 10 bit and 4:2:0 color sub-sampling.

Most importantly, there will be substantial cost savings compared to other solutions. For example, when comparing to an HDBaseT solution, the initial cost of the hardware from companies like Crestron, AMX, Lightware or Extron can be up to twice the cost of similar density Ethernet switches, routers and other IT gear. In addition, the ports on these switches can be used for either input or output.

While cabling costs may be similar, the costs to program and maintain the system are likely to be higher with an HDBaseT solution. Why? Because unless you have in house experts on staff for the AV brand you are using, you will have to rely on the integrator or the supplier to do the programming and maintenance. Furthermore, if you switch brands from one HDBaseT supplier to another, it is likely that you not be able to use any of your previous software and start over with new programming. With the 4K Multimedia Over Standard IP solution, the system standard IT software that is used to switch data packets, so either in-house personnel or external contractors, can set up and manage an installation at a fraction of the cost.

The ability to use the same hardware and software for a video wall, use existing network infrastructure software such as Remedy to monitor the devices, and the fixed price per port of a network based solution can positively impact the overall Total Cost of Ownership (TCO) evaluations all network managers perform as part of their evaluation process. This evaluation not only includes hardware costs but it identifies and measures other indirect costs of operating a network, which Gartner estimates at over 50% of the total cost of maintaining a network. These costs can be reduced by extending existing network monitoring tools instead of licensing new monitoring tools that work on only one brand of circuit-based AV networks. This saves administration costs for multiple brands and types of switches, and operational costs by eliminating programming resources and certification requirements commonly needed for circuit-based AV solutions. For more detail on calculating the comparative cost of these two approaches, you can learn more at http://www.networkalliance.com/your-advantage/understanding-technology-costs

Weaknesses

The introduction of 4K Multimedia Over Standard IP is just beginning now. As a result, products and capabilities remain a bit limited in terms of the number of formats supported and transport media.

While the light compression and processing can fit higher bandwidth signals available today into a 10GbE pipe, new displays and infrastructure are being developed at even higher resolutions such as the Samsung 8K 3D television or video walls feed with data that exceeds 4K.
In this case, multiple-link 10 GbE or single-link 25 GbE or 40 GbE solutions will be needed. The capabilities to do this are still in development.

Current solutions rely on using an FPGA as the heart of the encode/decode process, which is more expensive than an ASIC. However, this is right approach for this stage of development. Once a larger market is established, ASICs could come and the encode/decode functionality will move from discrete boxes on the input and output devices to integration within these devices.

While 10 GbE equipment is less expensive than circuit-based AV matrix switchers, they are costlier than 1 GbE equipment today. However, over the last two years, prices on this equipment have dropped significantly, and industry expectations are that 10 GbE switches will cost about 40% less by 2016 and drop to today’s price of 1 GbE devices by 2017. While these cost declines are typical in the IT space, we do not to see this level of price decline in the current dedicated AV transport solutions.

Implementation Examples

4K Multimedia Over Standard IP can address point-to-point connections without a switch in the middle as well, as shown in Figure 7. This shows a digital signage example, but it can be used for many dedicated ProAV solutions.

![Figure 7: Point-to-Point Connection without a Switch](image)

Figure 8 shows the configuration for a video wall demonstration done at Display Summit 2015. In one mode, the laptop output the 4K signal over HDMI to the ZeeVee encoder, which provided an IP signal to the Netgear switch. The switch was also managed by the same laptop over an Ethernet connection to route the 4K signal to the decoder, sitting next to the 4K LCD video wall. Note that only a single decoder is needed in this application compared to the 4 decoders shown in Figure 5. That is because the video wall (from NEC) can accept the 4K signal in the first display, then redistributes the correct pieces of the image to the other displays using a daisy chain connection.

The switch was included in this demo as a second mode allowed a 1080p signal to be distributed to both the LCD video wall (with internal scaling to 4K resolution) and to an LED wall with native 1080 resolution. Note that there is no dedicated video wall controller in either of these scenarios.

ZeeVee’s ZyPer4K’s encoders and decoders also support the creation of small and midsize video walls of up to 25 screens. By connecting each display to a ZyPer4K decoder, the total system can create a video with nearly 23 feet of diagonal surface area using commonly available 55” screens available from NEC, Samsung, LG, BenQ, Viewsonic and others vendors. The ZeeVee software will accept content up to 4K resolution, and process the image across the appropriate number of screens. This can eliminate the need for expensive video wall processors in many cases.
Another very popular application in ProAV is KVM (keyboard, video and mouse). This means that the servers are located in a secure location that is remote from where a person may need to access this information. The application runs on the server, so mouse and keyboard commands need to flow from the remote location to the server, while the requested information – graphics or video – needs to flow back to remote user.

Many of these applications are in government, military, post production, utilities and other applications where security of the data is paramount. The ZeeVee solution using a fiber-based switch solution meets these needs – especially if the switch can be located next to the secure servers.

**The Right Side of History**

Both 4K televisions and high speed 10Gbe IT equipment are manufactured on a mass scale – a scale much larger than the sub-segments of the ProAV, broadcast and cinema industries. That means any approach that can leverage this capability will have a long term cost and service advantage.

It is well know that the demands for data have been growing exponentially – driven lately by huge growth in video consumption. The needed industry bandwidth is currently doubling every two years with no let up in sight.
To meet this demand, 10 GbE switches serve many key data transfer needs, with 25 GbE and 40 GbE capabilities coming on quickly. This speed increase starts in the critical highest traffic regions and adoption spreads out from there. 10G was rare 10 years ago but is quickly becoming a mainstream solution.

For example, it is estimated that approximately 90% of servers will ship with 10G copper adapter connectivity options and many servers are incorporating 10G directly on the motherboard (LoM). In addition, power consumption has dropped and advances in reducing latency have resulted in 10GbE copper and fiber switches delivering between 2 and 4 microseconds delay compared to 1 Gigabit switches with a which range of between 1 and 12 microseconds. This technology is exponentially faster than traditional AV circuit-switching solutions.

We mentioned the price advantage of IT equipment over circuit-switched equipment above, but let’s be more specific. The cost per port of a HDBaseT matrix switcher can range from $400 – $1200 depending on the brand and configuration, while the cost per port on a 10Gb switch in 2014 ranged between $250 - $500 per port. We expect major brands to drive this price down to $100-200 per port in the next 12-24 months for entry level 10Gb switches. This enables 10G to move from beyond the core of the network into the aggregation / distribution layer which has significantly higher volume and larger scale.

The move from proprietary AV distribution systems is already underway. 4K Multimedia Over Standard IP is a new approach that makes sense, and if successful, can potentially transform the AV industry bringing in better video quality, improved audio, easier to use features, and lower cost. While potentially disruptive to some AV technologies, it will enable the market for these types of systems to potentially increase dramatically due to the ease of deployment and lower costs. Combined with the rapid adoption of 4K televisions and commercial displays, 4K Multimedia over IP seems to be a natural fit for the next generation of display deployment. Which side of history will your company be on?