HDBASET RESIDENTIAL INSTALLATION TRENDS

HDBaseT Alliance
3855 SW 153rd Drive, Beaverton, OR 97006
Tel +1 (503) 619-3007 | Fax (503) 619-6708
admin@hdbaset.org | www.hdbaset.org

CONTENTS

INTRODUCTION

Over the last several years AV media has evolved considerably, not only in terms of quality and quantity of content, but also in the ways in which users access it. Over-the-top (OTT) streaming services now commonly augment traditional broadcast and packaged media, or in a growing number of households, replaces them entirely. The abundance of 4K UHD media grows on a daily basis, with or without HDR, while high frame rate RGB content from state-of-the-art gaming consoles represent the most technically demanding of video sources available today. These combine with the needs for bi-directional audio, unified control, and the ubiquity of network connectivity to heavily influence the installation trends for residential AV systems.

These trends can be categorized into four key areas:

1. AV performance — namely compression, HDR, gaming, and eARC
2. AV distribution — matrix switching or IP network delivery
3. Control — integrating third-party control systems
4. Cabling infrastructure — standards and applications driving higher bandwidth

This paper explores each of these categories, and what they mean for the installation of HDBaseT systems in maximizing interoperability, reliability, and a future upgrade path.

AV PERFORMANCE TRENDS

The vast majority of 4K UHD movies and television— including sports— be it via broadcast, cable/satellite, streaming, or on disc, is limited to 24-30 frames per second (fps). The main exception is gaming, where 60 fps or higher is preferred, irrespective of resolution. Also, the marketing of 8K video has been trending upwards, but support in products other than displays is more an expression of HDMI 2.1 compatibility and bandwidth capacity than it is about practical applications or availability of 8K media.

With typical screen sizes and viewing distances, the most compelling viewing experience can be achieved not necessarily with more pixels (that is, resolution), but better pixels, core to which is HDR. But this in turn increases the interoperability challenges, particularly with some instances of using compression from the source. In fact, these combine to represent the leading trends in video, that in turn influence installation requirements for compatibility. Additionally, such premium video is best complemented by an immersive audio soundtrack, often originating from a smart TV and delivered to an AV receiver via HDMI ARC or eARC.

Compression

Digital AV media delivered into the home is invariably compressed, using high-ratio codecs that can retain excellent quality. The content is then decompressed in the source device and output uncompressed through HDMI. The main reasons for this are to maximize interoperability between devices, and to ensure zero latency. Jonathan Regalado-Hawkey, Business Development Director at Pulse Eight, an HDBase Alliance member, says that zero latency is “crucial for not just gaming but also for usability – nothing is more frustrating than scrolling up/down a menu and overshooting your selection due to a slight picture delay.”

With the continuing upward pressure on bandwidth, compression is now making its way into some transports between the source and display. “Mezzanine” compression with very low ratios up to 3:1 can lighten the load without impacting picture quality or introducing latency. The best example of this is Display Stream Compression (DSC), as used in some applications of DisplayPort 1.4 and 2.0, HDMI 2.1, and HDBaseT. Other transports such as AV-over-IP may require higher compression ratios, thereby adding latency. For more on this topic, see the HDBaseT Alliance white paper **Compression: The Good, the Bad and the Ugly.**

In general, any application of compression adds extra complexity that can risk interoperability. It also creates implications with HDR video, gaming, AV distribution, and control, all of which are discussed in turn throughout this paper.

HDR Video

Historically, the capabilities of display technologies were limited and could not produce the extent of deep blacks, bright whites, or color range that our eyes are capable of seeing. But even if they could, bandwidth was also relatively limited and restrictive. This traditional video is retrospectively and informally referred to as Standard Dynamic Range (SDR), and is delivered in an 8-bit signal.
In recent years, significant developments in technology from content creation right through to the display in peoples' homes have enabled the new era of High Dynamic Range (HDR) video. HDR supports a significantly extended dark-to-bright (contrast) and color range, delivering video that is closer to the capabilities of human vision for more realistic vibrancy and shadow detail. Joel Silver of Imaging Science Foundation (ISF) describes HDR as "the biggest change to video since the introduction of color."

Crucially, HDR requires two key ingredients to work:

1. Minimum **10-bit** signal
   The number of bits in a video signal determines how many shades of gray and tones of color can be reproduced. An 8-bit signal (24 bits total across its three channels per pixel) is adequate for SDR with minimal banding, but only numbers about one-third of the shades required for HDR. As such, a 10-bit signal (30 bits per pixel) is essential.

2. Accompanying **Metadata**
   Metadata are very small (typically kilobytes) packets of information contained in the video signal at the beginning of a program or video frame. Metadata can be likened to an instruction sheet to enable receiving devices to know what to do with the data payload. There are several applications for metadata in an HDMI signal, but in the case of HDR it contains formatting and crucial tone mapping information, so the display knows how to render the picture properly. If the metadata is lost or corrupted, HDR will either fail to engage or will present incorrectly — for example, it might look far too dark.

These attributes must be supported by the end-to-end signal chain, including through the HDBaseT link.

HDR Formats

As HDR evolved it resulted in the development of several different formats. These include:

- **HDR10** —the default that all consumer HDR systems must support, based on 10-bit with static metadata (one setting for an entire program).
- **HLG** — for broadcasters, being a hybrid system to support SDR and HDR in a single stream.
- **Dolby Vision** — premium format with dynamic metadata that can optimize the picture on a scene-by-scene basis. The best is Dolby Vision Standard mode that requires Dolby licensed devices and can't be decoded midstream, and Low-latency mode which is closer to regular HDR methods.
- **HDR10+** — alternative premium format with dynamic HDR.
- **Technicolor HDR** — another premium approach that has both static and dynamic versions.

Which (if any) HDR format is used at any given time depends on the media, its source, and the compatibility of the display and signal path. No AV system should be expected to support just one HDR format, but more commonly at least three, largely dependent on the display's compatibility. For example, one display might support HDR10, HLG, and Dolby Vision, while another supports HDR10, HLG, and HDR10+. The system can change between formats based on the source media, so when the system is installed it should be properly equipped to handle all expected formats.
Jonathan at Pulse Eight points out that "while HDR10 and HLG are now widely used, OTT services with their own content, such as Netflix, Disney+, etc., are starting to push and make accessible dynamic HDR formats— namely Dolby Vision— for their premium services." It is therefore increasingly important to ensure that any end users wanting to watch these premium services at their best should have a system installed that can ensure end-to-end compatibility without undue limitations.

HDR Compatibility Through HDBaseT

One of the most compelling benefits of HDBaseT is its ability to remain transparent to the HDMI devices at either end. Yaki Sfadya, Director of Product Management at Valens, says that "the HDMI stream is transferred as bit-exact passthrough over the HDBaseT link. Uncompressed, no manipulation, no decoding." This is the case at two bandwidth tiers:

- 8 Gbps (equivalent to 10 Gbps in HDMI) with HDBaseT versions 1.0 and 2.0
- 16 Gbps (equivalent to 18 Gbps in HDMI) with HDBaseT version 3.0

Any HDR format that fits within these bandwidth limits will be passed without any need to decode the HDMI, therefore inherently leaving the video composition and metadata intact for maximum performance and interoperability.

This includes all formats up to 4K UHD at 30 fps with 4:2:0 or 4:2:2 chroma. When stepping the chroma up to 4:4:4, or the frame rate to 48-60 fps, the data rate for HDR can then range between 11.14 and 17.82 Gbps, requiring an 18 Gbps HDMI output. With HDBaseT, this leads to one of the following options:

- Adding compression to versions 1.0 or 2.0, but this can complicate interoperability, in some cases may compromise picture quality, and in all cases requires appropriate metadata handling. It is important to check with the manufacturer of any such devices for HDR compatibility.
- The best solution is to upgrade to HDBaseT version 3.0 for native uncompressed transport of ALL formats of HDR up to 4K/60.

The table below depicts the HDR compatibility by HDBaseT version:

HDBaseT Link	HDBaseT Link Rate	HDMI® Data Rate	HDR Formats Supported
1.0/2.0 uncompressed	8 Gbps	10 Gbps	4K UHD 24-30 fps 4:2:0/4:2:2 ✓ HDR10 ✓ HLG ✓ Dolby Vision Standard mode ✓ Dolby Vision Low-latency mode ✓ HDR10+ ✓ Technicolor HDR
1.0/2.0 with DSC (compressed)	8 Gbps	11-18 Gbps	4K UHD 24-30 fps 4:4:4 4K UHD 48-60 fps 4:2:0/4:2:2 (* must maintain 10-bit signal with special metadata handling) ✓ HDR10* ✓ HLG* ✗ Dolby Vision Standard mode ✓ Dolby Vision Low-latency mode* ✓ HDR10+* ✓ Technicolor HDR*
3.0 uncompressed	16 Gbps	18 Gbps	4K UHD 24-30 fps 4:4:4 4K UHD 48-60 fps 4:2:0/4:2:2 ✓ HDR10 ✓ HLG ✓ Dolby Vision Standard mode ✓ Dolby Vision Low-latency mode ✓ HDR10+ ✓ Technicolor HDR

In the table you will note that the combination of HDBaseT version 1.0/2.0 with DSC (compression) is the only one to preclude Dolby Vision Standard mode, even though HDBaseT has always supported it at 24 fps— the frame rate of most streaming media— without DSC. Such compromise might not be desirable, creating a system where Dolby Vision may not work, or have to revert to Low-latency mode. The solution to unlocking all capabilities is to have enough native bandwidth to not need to decode the 18Gbps HDMI stream; that's what HDBaseT 3.0 is designed to deliver.

Gaming

Gaming has long been a staple in many households, but in recent years has seen a meteoric rise not only in engagement, but also in its astonishing AV performance. In fact, high-end gaming represents the most technically demanding of all residential AV sources. It is therefore imperative that the connectivity between a gaming console or PC and the display be capable of sufficient bandwidth with zero latency.

Where TV and movie content is typically 24-30 fps with 4:2:0 chroma, gaming is typically 50-60 fps with native RGB video generated on-the-fly by its internal graphics processing unit (GPU). Some even offer HDR and immersive audio! This all adds up to the need for an 18 Gbps HDMI connection. But even so, it can still be necessary for the gaming console to be set to down-sample the video to 4:2:2 to enable 4K/60 with 10-bit HDR.

Where the console-to-display connection in only short length from an Xbox One/Series X or PS4/PS5, then a Premium High Speed HDMI cable will be required. But if long length is needed then the options are for active HDMI (e.g., active optical cable) or HDBaseT 3.0. The significant benefits of the latter, especially if connecting via an AV receiver, is not only the ability to provision an upgrade path with site-terminable cable, but also the ability to include other features in the same cable: Ethernet to provision the smart TV content, and eARC for the upstream audio path to the AVR.

Internet Connectivity

The need for internet connectivity has long been ubiquitous in AV devices, but the need for capacity and speed has steadily increased over time. This is especially so for OTT streaming services, along with online gaming and downloadable content (DLC).

Many residential installations utilize a rack or cabinet to mount the AV and network equipment, ideally with network cabling in a star configuration to various points around the home. If this is not the case, some source devices and displays may instead rely on Wi-Fi for connectivity, even though wireless communication is half-duplex (one way at a time), often operates in congested RF spectrum, and yields a relatively high “ping” rate (connection reaction time) — not ideal for online gamers! Powerline Ethernet is a popular alternative, but can exhibit even higher latency than Wi-Fi. By comparison, a wired Ethernet connection is higher effective bandwidth, full-duplex (send and receive simultaneously), low-noise, and with the lowest possible latency. In short, it’s the best way to connect all stationary devices, with Wi-Fi reserved for portable.

HDBaseT supports full-duplex wired Ethernet capability shared over the same link as the AV, as part of its 5Play feature set. HDBaseT versions 1.0 and 2.0 can support 100 Mbps Ethernet (100 MbE), while version 3.0 offers the considerable upgrade to gigabit (1 GbE) connectivity. This can optimize the internet connection for the display and a direct-connected gaming console for the best AV performance and user experience, particularly with gigabit for sharing across devices.

eARC

The increasing use of streaming apps in smart TVs and direct-connecting devices to the display, such as gaming consoles, has also increased the need for installers to get the audio back to an AV receiver. When using HDBaseT to enable this over a long distance, installers need to specify products that are compatible, for which there are two main approaches:

- Use an HDBaseT 2.0 product to send a S/PDIF audio signal upstream to the transmitter, either from a TOSlink/coax input or extracted from the HDMI audio return channel (ARC) from the display, or
- Use an HDBaseT 3.0 product with native HDMI enhanced ARC (eARC) capability — these are typically also backward-compatible with HDMI ARC.

	HDMI® ARC	HDMI® eARC
Introduced	HDMI specification 1.4	HDMI specification 2.1
Wires used	Single	Twisted pair
Signalling	Single Mode	Differential
Discovery + setup	HDMI-CEC	Self-discovery
Data rate	Approx. 3 Mbps	up to 100 Mbps
Formats supported	Uncompressed PCM 2.0 Compressed surround formats: Dolby Digital 5.1/7.1 DTS 5.1/6.1 (incl. some Dolby Digital+)	Uncompressed immersive audio: Object-based or up to 32 channels of 24-bit 192 kHz Dolby Atmos / DTS:X / Auro3D
HDBaseT support (dependant on manufacturer implementation)	Version 2.0 via upstream S/PDIF	Version 3.0

There are some limitations with using S/PDIF audio in today's residential custom installations, namely the lack of support for high-resolution immersive audio formats. Furthermore, blending this with the original HDMI ARC introduces some other challenges. For one thing, it relies on HDMI-CEC for discovery and setup, something that many installers like to turn off to not conflict with third-party control systems, though many displays have the option to isolate this. Secondly, Jonathan from Pulse Eight advises that "ARC continues to be an ever-important feature but there are some constraints with standard AV matrices where you are limited by the hardware, such as having to manually configure the audio extraction settings depending on whether video content is coming from an external source or streamed directly to the TV… not the best end-user experience!" To help make the most of ARC, Pulse-Eight NeoX matrices are able to support audio always follows the video mode, regardless of whether video is being routed through the matrix or the video content is being streamed directly to the TV, the matrix will automatically extract the correct audio (either through audio de-embedding or HDMI ARC) to always match the video on the display.

Trends are now moving towards greater adoption of HDMI eARC as it supports the full complement of audio formats right up to 32-channel immersive soundtracks, utilizing an autonomous self-discovery and setup without needing CEC. Notably, as eARC is natively supported by HDBaseT 3.0, it simplifies implementations, and improves performance and interoperability.

Summary of how HDBaseT can facilitate AV Performance Trends

When HDBaseT technology debuted in 2010, the market had not yet evolved to 4K video, and consumer HDR had not yet been invented. But HDBaseT was ready from the outset, and adapted to them seamlessly as consumer and installation trends evolved.

HDBaseT version 1.0 continues to offer uncompressed support for all formats of 4K/30 HDR, while the addition of compression may be used to also include 4K/60 HDR, albeit at the expense of Dolby Vision Standard mode. Some products may also implement 100 Mbps Ethernet to help optimize and simplify connectivity.

Upgrading to HDBaseT version 2.0 can add support for S/PDIF audio, which manufacturers may implement as an upstream TOSlink or coaxial digital link, or adapt it for HDMI ARC.

Flagship performance comes with HDBaseT version 3.0 at double the native bandwidth, enabling uncompressed support for all formats of 4K/60 HDR (including Dolby Vision Standard mode) programs and gaming, gigabit Ethernet for multiple high-bitrate streams and real-time gaming, and HDMI eARC for an immersive audio path back to the AVR.

AV DISTRIBUTION TRENDS

Matrix Switch vs AV-over-IP

Many residential subsystems have evolved to utilize the home network, including AV distribution with AV-over-IP systems. However, according to David Meyer, Technical Knowledge Manager at CEDIA, this places exponentially more pressure on the network to perform. “This is why some AV-over-IP manufacturers go as far as recommending a separate, parallel network for their system, to assure bandwidth availability.” That of course means a duplication of infrastructure. Furthermore, David advises that the vast majority— over 95%— of residential network installations are 1 gigabit Ethernet (1GbE). He says “this is perfectly adequate for most households, and not anticipated to change for the foreseeable future. Some high-end residential installers do occasionally work with 2.5G/5G NBASE-T or 10GbE, but they’re more common in commercial and industrial settings.” As such, 1GbE remains the recommendation for residential networks.

When used for AV distribution of video up to 4K, 1GbE necessitates compression ratios ranging from 8:1 up to 20:1. The picture quality can be excellent, though HDR support is product-specific and cannot be assumed. Either way it does inevitably introduce some latency. As mentioned earlier in this paper, this can frustrate the user experience to some degree, complicate interoperability, and be generally unsuitable for real-time applications like gaming. Also, the lack of inter-brand standards for 1G AV-over-IP solutions means that manufacturers are left to innovate, and many do that very well, but it is important for installers to always be cognizant of the pros and cons of any system.

By comparison, the long-established HDBaseT matrix switch can offer uncompressed 10G or 18G HDMI crosspoint switching with HDBaseT versions 1.0/2.0 and 3.0 respectively, and with very high interoperability and native feature support. Toby Leader, Product Manager at Blustream, states that “uncompressed video keeps installers excited, not to mention retaining the top-end features like Dolby Vision. That’s the main reason for installers to gravitate to HDBaseT version 3.0.”

Jonathan Regalado-Hawkey at Pulse Eight also points out the importance of cross-point speed, saying that the “18G crosspoint switch inside the matrix is crucial in supporting a full uncompressed HDMI 2.0 signal.”

Hybrid Systems

The designer of any distributed AV system may consider some displays as primary and others secondary. For example, the large flat panel display in the living room with the full complement of features including 4K HDR, and an assortment of gaming consoles attached, may have performance considered of primary importance. Meanwhile, the smaller displays in bedrooms are probably more concerned with the three c's— convenience, control, and content— than they are about having the latest features and best possible performance.

As such, some installers will prefer direct uncompressed connections for the primary display, including HDBaseT for the long lengths. They may then tolerate some modest compromise in performance for the sake of simplicity and economy for the secondary zones, with the simplicity of an HDBaseT matrix or the scalability of an AV-over-IP system.

Alternatively, Jonathan at Pulse Eight points out that there is an upsell opportunity on the entire system when the correct hardware is in place. For example, a high-end matrix switch with the aforementioned 18G crosspoint speed means that all zones can be integrated through the same switch: the installer may use zoned 18G HDMI outputs for the primary display and AV receiver to enable 4K/60 Dolby Vision and gaming content with immersive audio, while all other displays in the home are delivered content via HDBaseT links, either full capabilities with HDBaseT 3.0 or up to 4K/30 HDR with HDBaseT version 1.0/2.0.

Figure 1 The combination of 18G backplane and zoned HDMI outputs can enable the use of HDBaseT version 3.0 extenders to the highest performance displays for 4K/60 HDR and gaming

Usability can be made even simpler by this method too. For instance, Pulse-Eight HDBaseT matrices allow access and control of all sources attached the matrix from a standard TV remote control. As Jonathan said, “there’s no need for an expensive remote in the kids’ bedrooms! And the installer can also implement the system to block certain sources to certain rooms (that is, parental control), and add voice-command control with Amazon Alexa integration.” These are all features that can improve the user experience across the entire home, regardless of the performance or priority of each display.

Summary of how HDBaseT can facilitate AV Distribution Trends

A distribution system composed of centralized matrix switch provides choice and simplicity. It enables the best of both worlds: native high-bandwidth HDMI where you need it, and long-length HDBaseT everywhere else, all with the same access and control of sources. The benefits are only heightened when this is combine with 5Play features including Power-over-HDBaseT (PoH), RS232/IR control, audio return, and Ethernet.

Installer tip: If a matrix switch is not equipped with HDBaseT version 3.0 outputs but it does have an 18G backplane and zoned HDMI outputs, simply connect an HDBaseT 3.0 extender as required for even more flexibility and performance options.

CONTROL TRENDS

Ease and effectiveness of control is key to a satisfied user experience, making it a very important consideration in residential installations. HDBaseT is incredibly versatile on this front, offering support for RS232, HDMI-CEC, USB 2.0, and even IP (using 100MbE with HDBaseT 1.0/2.0 or 1GbE with HDBaseT 3.0), all in a unified signal over the HDBaseT link without the need for extra parallel cables. Manufacturers can choose to implement any combination of control interfaces, giving installers unparalleled choice and versatility.

Pulse Eight advises that "bidirectional communication between the AV matrix and the control system offers best possible end user experience and can also reduce service calls. The control system is generally designed to control its environment by issuing commands (change channels, route video, etc.) but it is important that the AV matrix is not just a 'dumb box' – it should inform the control system of any changes to the connectivity status. An example would be replacing video sources that are connected to a matrix (for example, the end-user upgrades an old player to a brand-new media streamer/player); the matrix recognizes that a new source has been connected through HDMI-CEC and automatically updates the control system of the changes. Pulse-Eight matrices do this today."

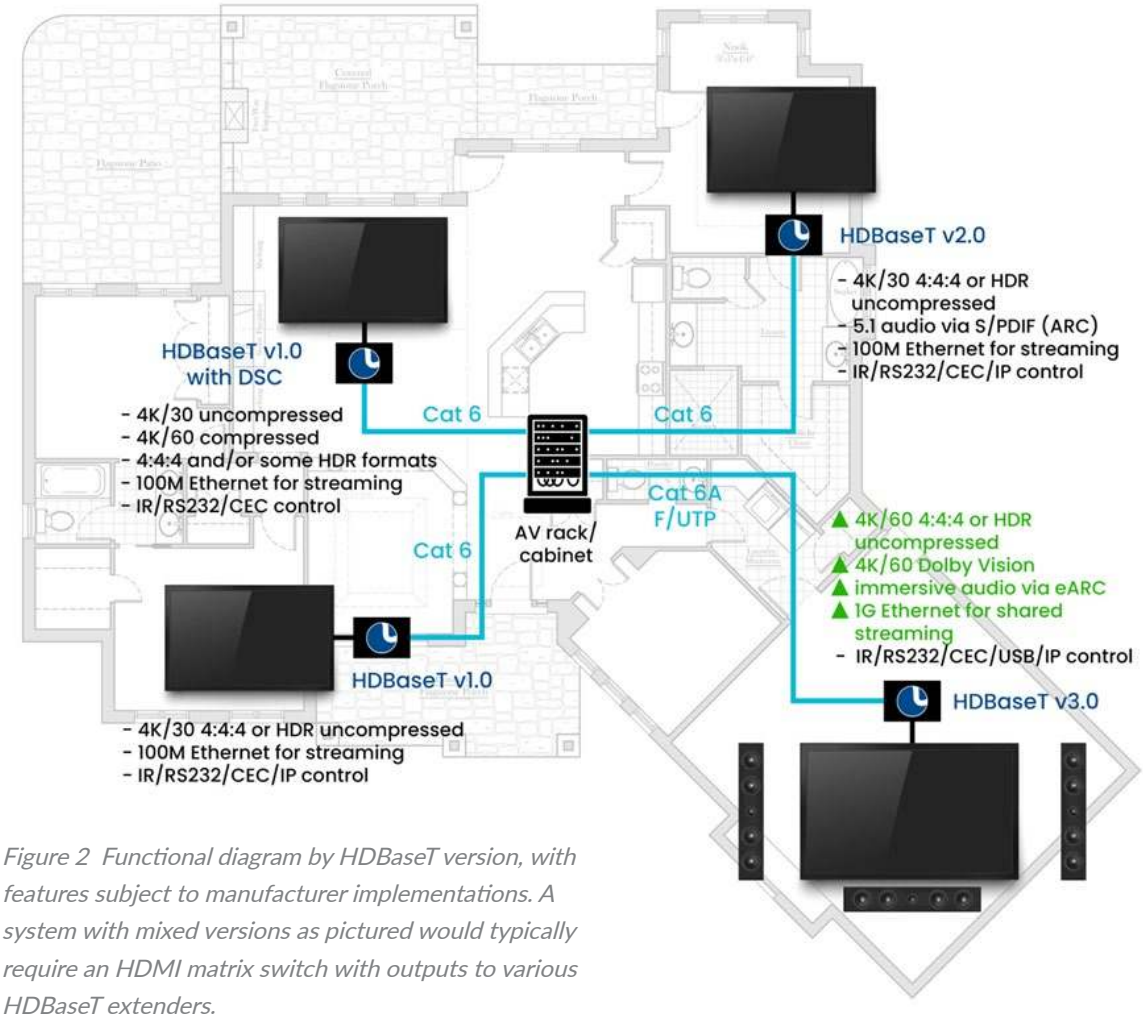

Figure 2 Functional diagram by HDBaseT version, with features subject to manufacturer implementations. A system with mixed versions as pictured would typically require an HDMI matrix switch with outputs to various HDBaseT extenders.

CABLING INFRASTRUCTURE AND UPGRADE POTENTIAL

A longstanding trend in residential technology has been use of the term “future proof.” But this a flawed concept as it can be very limited in scope and, ironically, time validity. An arguably more appropriate approach is to consider a future upgrade path.
Upgrading devices in a system is generally quite straight-forward; a simple swap-out may enable new features or capabilities, but it’s a different story for the cabling infrastructure.

Any cable installed today should conform to the expectations of standards and/or recommended practices and be suitable for the best application for which it may foreseeably be used in future.

The leading standard for global residential cabling infrastructure requirements is TIA-570-D, published in 2018. This document nominates Cat 6A as the minimum category cable grade for communications, effectively outmoding Cat 5e and Cat 6. Even if recommendations and code requirements differ in your region, keep in mind that the Telecommunications Industry Association (TIA) is the body that defines category cables (except Cat 7) through the TIA-568 series of standards. What they say does carry weight.

The TIA’s recommendation aligns with that of the HDBaseT Alliance in that Cat 6A is also the recommendation for HDBaseT 3.0. Where the TIA don’t nominate shielding requirements, the HDBaseT Alliance does recommend U/FTP to ensure the minimum possible near-end and far-end crosstalk, in turn permitting the unprecedented uncompressed 16 Gbps data rate of HDBaseT 3.0.

For deeper insight, see the HDBaseT Alliance white paper **‘Optimizing Cabling for HDBaseT 3.0’ .**

CONCLUSION

The performance and features of AV media have evolved over the last several years, along with way people access and interact with it. Installers need to facilitate this access and ease of control for a home's occupants, regardless of whether the media is centrally sourced for distribution around the home, streamed directly to a smart TV or direct-connected streaming box, or the most technically demanding of gaming content. Residential installation trends have needed to adapt accordingly.

While compression is a viable option to enable higher video resolutions over a bandwidth-limited link, uncompressed is invariably the best for maximum performance and interoperability. Downstream links should be able to support up to 4K/60 HDR, the pinnacle of which is Dolby Vision Standard mode, while any content directly to a display can be enhanced by HDMI eARC to get the immersive audio soundtrack back to an AV receiver. The provision of a wired Ethernet connection is an important complement to this, enabling the most robust connectivity for streaming content or low-ping online gaming.

HDBaseT Alliance member manufacturers have innovated many product solutions to facilitate such capabilities, along with simplified control and power-over-HDBaseT (PoH), all over a single cable up to 100m (328ft) to simplify the infrastructure. While many products available today utilize HDBaseT versions 1.0 or 2.0 to facilitate many of these features, the step up to HDBaseT version 3.0 ushers in a new era for unprecedented performance of uncompressed 4K/60 HDR, HDMI eARC, and gigabit Ethernet for the ultimate user experience.

HDBASET

www.hdbaset.org