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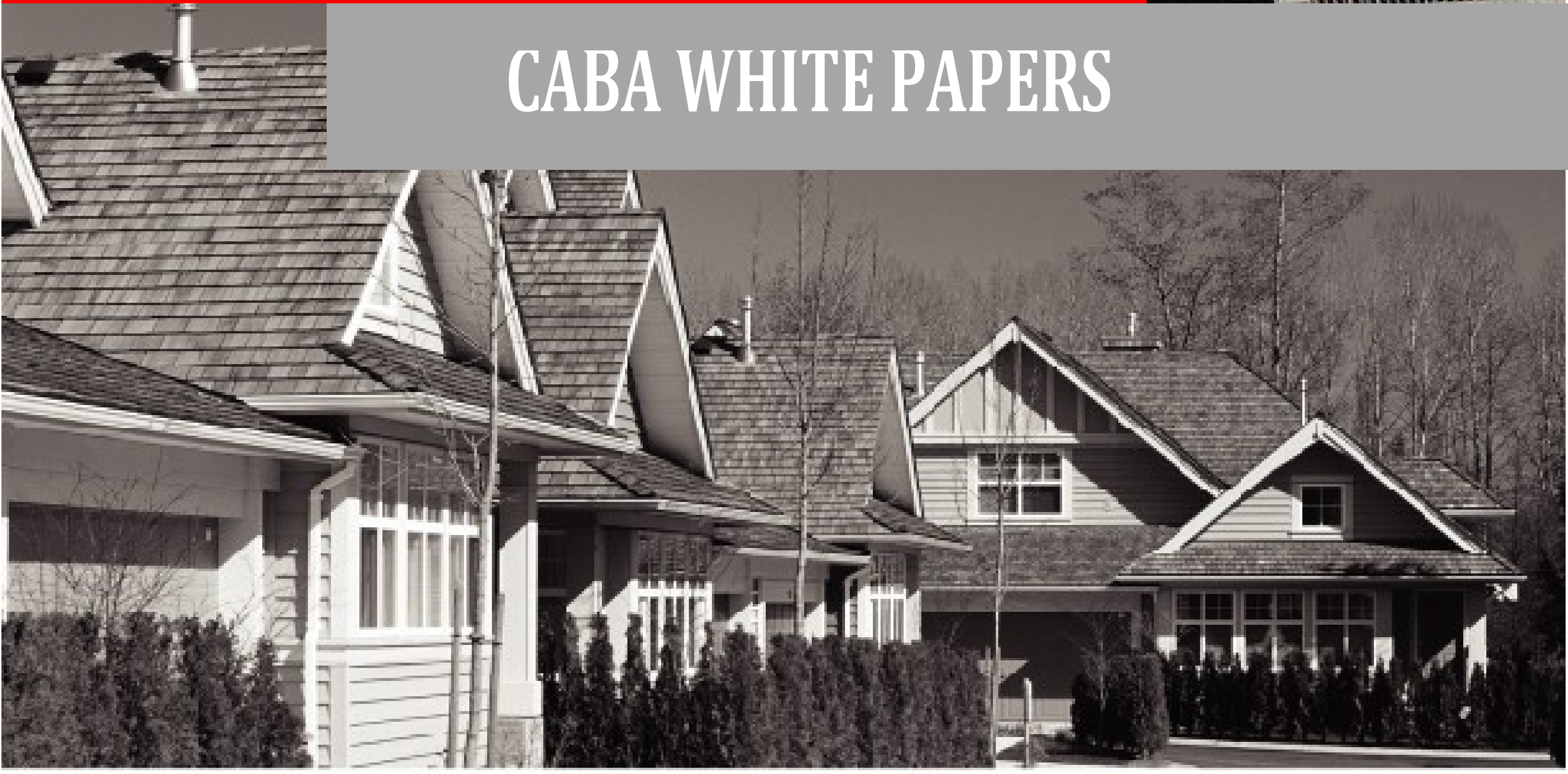

High-Quality Multimedia Distribution in Commercial Buildings

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CABA Intelligent & Integrated Buildings Council

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Abstract

Multimedia is being integrated into a diversity of commercial settings, ranging from corporate offices to education facilities to transportation to government operations. These applications require an integrated infrastructure for distributing audio, video, and control from sources such as videodiscs, media servers, broadcasts, and Internet streams to displays. A high-quality multimedia experience is essential for conveying messages and information effectively to employees, business associates, and customers. Transportation facilities such as ships and airplanes can also benefit from the solutions presented in this paper since they have similar needs for distributing multimedia and data.

Video quality has been evolving from standard definition (SD) to high definition (HD) to ultra high Definition (UHD); audio has added surround sound channels and subwoofers. The technology for high-quality multimedia distribution requires high-resolution source material, high-resolution displays, and a distribution network that can stream high-data-rate audio and video. Our increasing expectations for higher quality multimedia pose challenges for developing technology that can adapt with higher resolutions and faster data-distribution rates with lower latency (delay).

"Building infrastructure cabling" has traditionally meant power wiring and support for building automation services such as environmental control, lighting, and communications. Video distribution cabling has been limited to point-to-point solutions such as coaxial cables and specialty cables for projectors. Extending coaxial cables throughout a commercial building for high-quality multimedia distribution is not a practical option because of costs and content protection agreements. This paper reviews methods for distributing audio and video content in buildings with a focus on an integrated solution that can be installed easily and can operate in parallel with a corporate data network.

The media industry has selected the High-Definition Multimedia Interface (HDMI) as the primary suitable interface between commercial content on media (such as Blu-ray discs) and video displays, including televisions. This interface was designed for the transmission of uncompressed data for high-definition video. HDMI has been implemented in specialized cables

that are typically 10 feet in length (with a limit of 50 feet) and are expensive compared to data cables. Thus, HDMI is not practical for a building infrastructure. To address this distance limitation and yet provide all the features supported by HDMI, a new technology was developed. This technology, called HDBaseT™, converts signals passed via an HDMI interface into a format suitable for transmission via the same type of local area network cabling as used for Ethernet data communications over distances that can span hundreds of feet while maintaining the quality of the source material.

This paper examines the increasing need for high-quality multimedia in commercial buildings and the options for a distribution infrastructure. The building industry has adopted standards for a building data infrastructure that can be extended to multimedia. As we will show, there is a solution using HDBaseT technology that overcomes the limitations of HDMI while carrying all of the HDMI signals, is cost-effective, suitable for content-protected audio and video, and can be integrated with a building data network using established installation skills and tools.

Multimedia applications

Static message boards are giving way to dynamic presentations with graphics and video using high-definition displays. The phenomenal market growth in LCD (liquid crystal display) high-definition (HD) and ultra-high-definition (UHD) displays has resulted in low-cost, high-quality large-format displays for commercial applications. These video displays offer the opportunity for visual information presentation and corporate messaging in public spaces, company lobbies, conference rooms and even office areas.

Digital signage applications that are common in airports, and increasingly in commercial buildings, display data from computers that are typically co-located, such as bolted on the back of the display. For efficient distribution of full-motion high-resolution content, it is usually more cost-effective to supply the source materials to multiple displays from a centralized digital video source (e.g., a digital video recorder (DVR), Blu-ray disc player, or computer acting as a media server). A media room with servers and players affords flexibility for commercial building video applications. However, distributing HD audio and video (A/V) in a building is a challenge.

Structured cabling systems (as specified in North American and international standards) are intended for building automation system operation and for data networks that support local area networks (LANs) for corporate data access, file sharing, Internet access and telephony. Audio and video distribution is usually limited in commercial buildings to localized applications such as conference rooms. Until recently, the distribution medium for video has been coaxial cables. However, there are technical and business reasons for moving to other media:

- Coaxial cables are bulkier than data cables that comprise a local area network in the building. Also, the F connectors that terminate coaxial cables are more complex to install and more fragile than the RJ-45 connectors on LAN cables.

- The content production industry, led by the entertainment industry, decided not use coaxial cables to interconnect video sources (such as Blu-ray players) to displays because of concerns for controlling content distribution. Instead they developed the HDMI specification that includes data encryption capabilities for Digital Rights Management.

With the advent of large-size and low-cost HD displays, new cables and connectors complying with the HDMI specification were introduced to carry the higher bandwidth A/V signals. However, these HDMI cables are even more cumbersome than coaxial cables, expensive, and limited to less than 50 feet (most are about 10 feet) without using additional electronics. In 2010, HDBaseT technology was introduced to overcome these limitations while transmitting audio, video, Ethernet, and control via the standard LAN cables and RJ-45 connectors that are used for Ethernet and data networks.

HDBaseT technology consists of electronics that converts A/V and control signals, including uncompressed high-definition and ultra-high-definition video, into a format suitable for transmission on standard local area networks via RJ-45 connectors. HDBaseT electronics may be externally attached to or embedded inside A/V sources and displays.

Application examples of HDBaseT technology using a multimedia infrastructure include:

– Corporate lobby displays

Figure 1 – Displays in Vertex Pharmaceuticals Lobby

– Corporate conference room support[1]

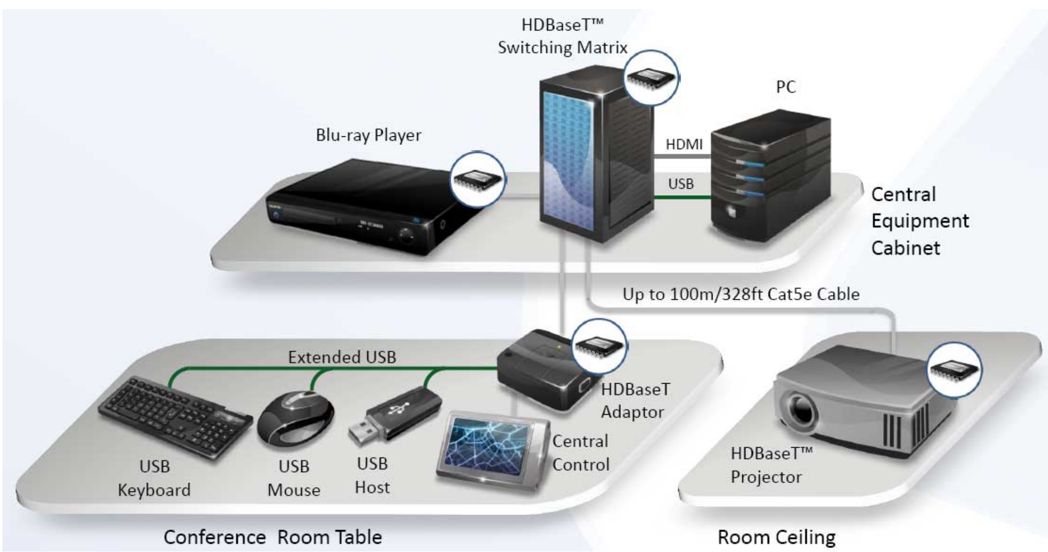

Figure 2 – Multimedia Conference Room

[1] A local PC, media server, or Blu-ray player supplies source material for a projector. The presenter selects the presentation using a keyboard, mouse, display, and USB reader. All these peripherals are linked to remote equipment via a common infrastructure using HDBaseT as shown in Figure 2.

– Airport data and video screen

Figure 3 – Airport Flight Display with Integrated TV Show

– Hotel room video feeds and hotel digital signage

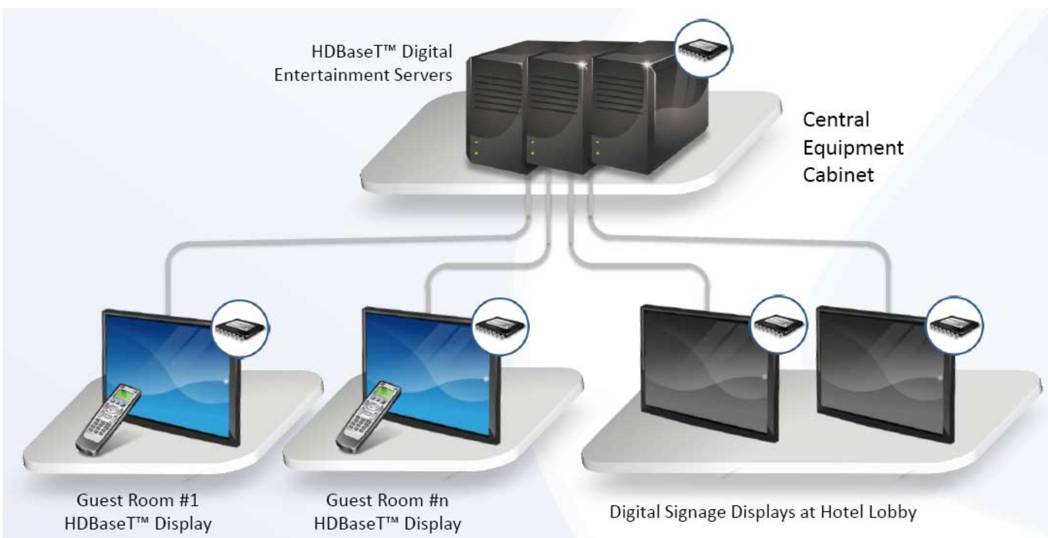

Figure 4 – Supplying Lobby Information and Video-on-Demand in a Hotel

Data infrastructure

The term *structured cabling* refers to an organized installation of wires in a building for data network applications. These wires may be bundled into a common sheath for ease of installation. Structured cabling is specified in the following standards:

- U.S. national standard: TIA-568C[2], *Generic Telecommunications Cabling for Customer Premises*

- International standards:

  - ISO/IEC 11801[3], *Generic cabling for customer premises*

  - ISO/IEC 15018, *Generic cabling for homes [and small offices]*

Before there were standards, the installation of wiring for services such as telephone, data networks, and cable TV was not well organized. Typically, wires were run from device to device in an *ad hoc* fashion for rapid installation and minimum wire usage. This topology would deliver unequal signals to the devices, which would lead to a degradation of data transmissions and video reception.

The structured cabling standards require "star wiring." Star wiring consists of many wires emanating from a single distribution point in the building to each floor in a hierarchy as shown logically in Figure 5 and physically in Figure 6. The connection interfaces in these diagrams include the following:

- CD: Campus Distributor

- BD: Building Distributor

- FD: Floor Distributor (usually in a telecommunications room)

- CP: Consolidation Point[4]

- TO: Telecommunications Outlet

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[2] TIA is the Telecommunications Industry Association.
[3] ISO is the International Organization for Standardization (headquartered in Geneva, Switzerland).
IEC is the International Electrotechnical Commission (headquartered in Geneva, Switzerland).
ISO and IEC collaborate to develop standards for information technology (IT standards).
ISO and IEC member nations develop voluntary industrial standards to promote international trade.
[4] CP is a connection point in the Horizontal Cabling Subsystem at least 15 meters (49 feet) from the Floor Distributor; CP is a passive connector to facilitate administration of open offices where TOs may be moved.

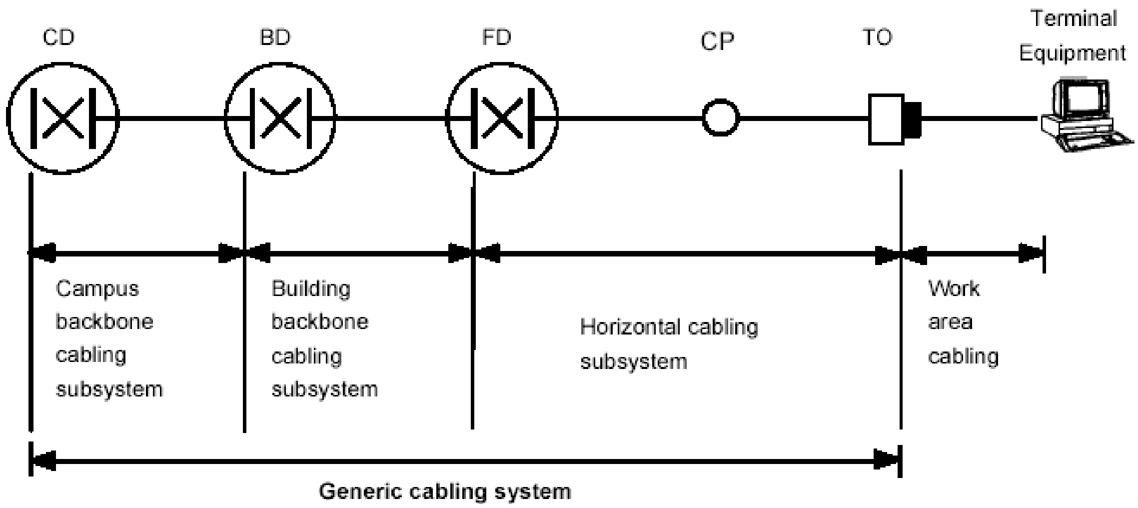

Figure 5 – Structured Cabling Hierarchy (from ISO/IEC 11801)

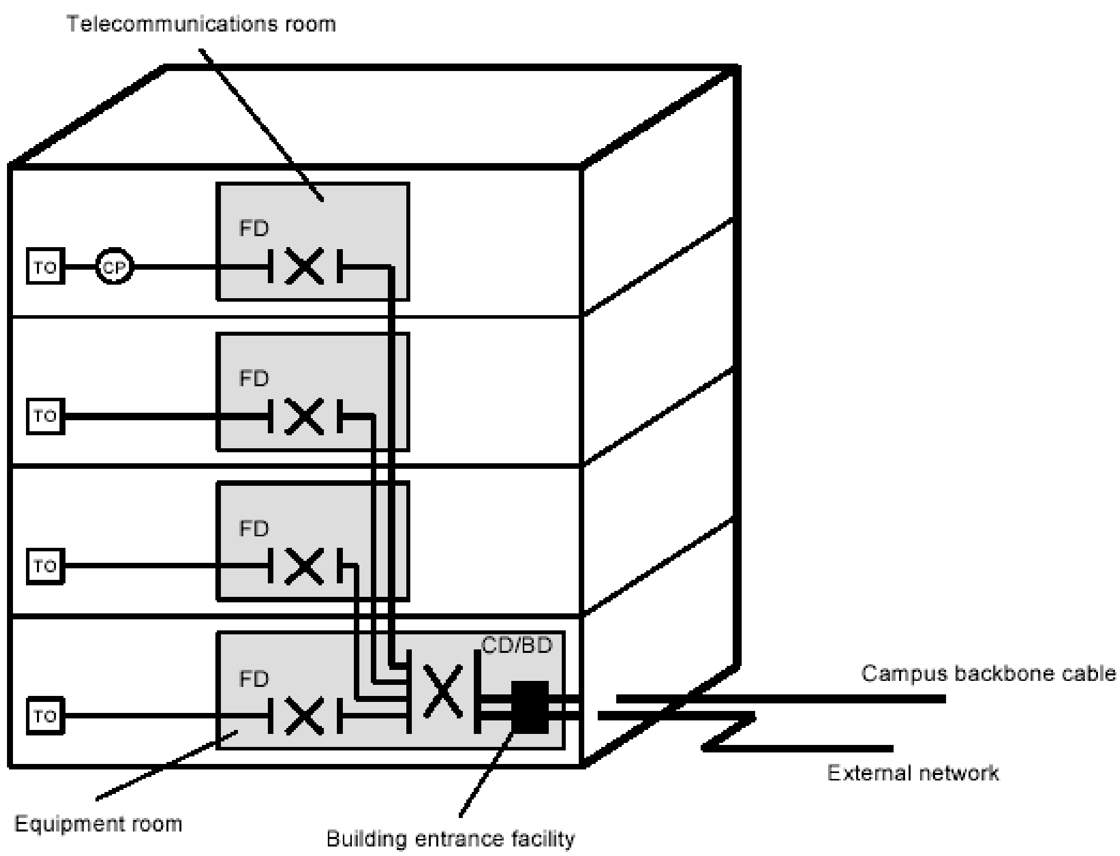

Figure 6 – Physical Arrangement of Structured Cabling (from ISO/IEC 11801)

The existence of a Campus Distributor and the number of Building Distributors depend on the size of the campus and buildings. The interconnections among the three cabling subsystems (Campus, Building, and Horizontal) of the generic cabling system are provided by active or passive elements.

Star wiring, in general, uses more cabling material than bus or device-to-device wiring. However, signal quality is controlled better with star wiring. Also, less drilling through wood studs in the wall is required when installing star wiring. The international standards specify signal quality as a function of the entire communications channel, which includes the wire, connectors, and any patch cords.

Since HDBaseT uses the same type of infrastructure as data LANs, once cable installers are trained for a LAN installation, they will have the skills to install a high-quality A/V network with HDBaseT technology. Skilled installation practices are important for maintaining channel performance. Even with high-quality components, poor installation practices can degrade signals. For example, if twisted-pair wires are pulled too tightly around a corner, the twists will be deformed, reducing performance.

ISO/IEC 15018 specifies structured cabling for small offices and organizes the cabling by categories of applications:

- Control/Command Communications in Buildings (CCCB)

  CCCB cabling consists of low data-rate communications typically for building automation systems. CCCB may be hierarchical, bus, loop, or star wiring within a room for interconnecting sensors, actuators, user interfaces, and similar devices with a building automation controller.

- Information and Communications Technologies (ICT)

  ICT cabling encompasses local area data networks for accessing corporate servers, Internet services, voice-over-IP telephony, and interconnecting building automation systems controllers.

- Broadcast and Communications Technologies (BCT)

BCT cabling includes broadband distribution of multimedia via coaxial cable or high-quality, shielded twisted-pair wiring.

HDBaseT technology enables the consolidation of BCT and ICT into an infrastructure that uses the same components and topology.

High-definition video distribution

High-definition video originated with the upgrade of TV broadcasting from standard definition. High-definition displays using technology developed for the consumer market are being adapted for commercial venues.

Broadcast TV distribution is provided via over-the-air signals from TV towers, satellite, cable, and fiber optics. In 2009 broadcast TV in the U.S. transitioned from analog to digital encoding. Digital technology has the potential to deliver a better TV experience than analog, but is not guaranteed to do so. Digital offers the broadcaster flexibility in controlling what the customer sees and hears. The quality of the image and sound depend on the broadcaster and the customer equipment.

Most digital equipment depends on electronics with processors and memory like a computer. Therefore, it is feasible to design encoders and decoders that are programmable for field upgrades. This makes digital technology more flexible and extensible than analog technology for adding new features.

Much of the content for applications within buildings will be sourced locally from:

- A server containing A/V data
- A DVD or Blu-ray disc player
- A digital video recorder
- A computer that generates video graphics
- A streaming media decoder (Apple TV, Google TV, Roku, etc.) for Internet TV

- HD video cameras capturing and possibly recording live events
- A set-top box (STB) to decode TV from a service provider

Some of this equipment delivers signals to displays and monitors in a variety of formats, both analog and digital, using the connection interfaces shown in Figure 7. Although distribution in buildings is migrating to digital formats, analog systems and connectors are still widely used.

Display/TV ↔ DVR/DVD/Blu-ray Connections		
Connector	**Description**	**Sample Cable**
Coaxial cable	An analog A/V signal viewed on TV channel 3 or 4	
Composite video	An analog video signal on one wire using an RCA connector	
S-video (Super-video)	Separate brightness and color analog signals	
Component video	Separate brightness and two color analog signals on three wires using RCA connectors	
DVI (Digital Visual Interface)	Encoded digital video signal	
HDMI (High-Definition Multimedia Interface)	Encoded digital video plus audio and control signals	
Stereo audio	Two-channel analog audio signals using RCA connectors (not used with coax and HDMI cables)	
S/PDIF (Sony/Philips Digital Interface Format)	Digital audio interconnection cable using a coaxial cable with an RCA connector or a fiber optics connector called TOSLINK (Toshiba Link)	Coax  TOSLINK 

Figure 7 – Connection Options for a Display

Broadcast TV delivery within buildings has been via coaxial cable for more than 50 years. Figure 8 shows a cable bundle for structured cabling that accommodates a LAN and TV distribution via coaxial cable. Coaxial cable is no longer the best choice for video distribution in buildings because of the following factors:

- Physical size of the cables, which creates a bulky package when multiple coaxes and data cables are combined for installing in a building chase.
- Termination with F-connectors, which are easy to damage.
- Bandwidth limitations requiring data compression for video distribution.
- Latency if source material is decoded and re-encoded for carriage on a coaxial cable and then decoded at the display.

Furthermore, distribution via coaxial cables is constrained because of decisions to mandate data protection via encryption. Content producers, led by the entertainment industry, insisted that electronic manufacturers agree to develop interfaces that comply with their demands for content protection. Manufacturers are contractually barred from developing equipment that violates these agreements. Some cabling choices widely used for decades such as coaxial cables and video component cables are no longer allowed to carry high-definition video content if the producer mandates content protection.

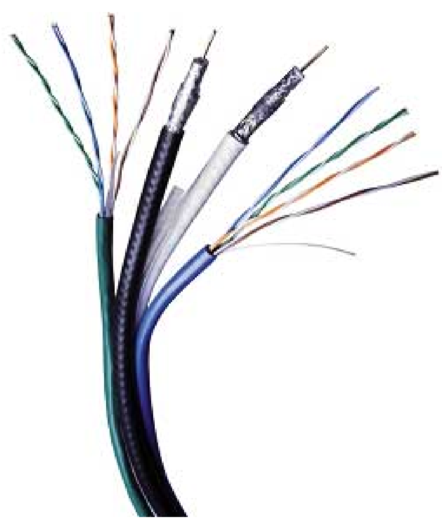

Figure 8 – Wiring for LAN and TV
(Courtesy of Belden, Inc.)

Therefore, the movie and television industries have decided that commercial high-definition video will be available only for distribution via DVI and HDMI interfaces because digital processing methods allow the data to be encrypted in order to control distribution and to reduce copyright violations. Studios are concerned about unauthorized distribution or copying of content. Furthermore, resolutions beyond high-definition (1920x1080 picture elements – pixels), such as Ultra HD (3840x2160) and 4K for digital cinema (4096x2160)[5], and display modes such as 3D are available only in digital format. Coaxial cables can and do carry digitally encoded broadcast video, but often involve compression, degrading quality, and adding latency. Also, encoders for modulating high-resolution digital signals from local (non-broadcast) sources onto coaxial cable are very expensive and do not support the data protection schemes mandated for commercial videos. HDBaseT equipment, on the other hand, is a more cost-effective option, and supports the mandated data protection schemes.

Standard definition (640x480) content is still distributed via coaxial cables and analog connections. However standard definition content does not produce the detail or shape (wide aspect ratio) that viewers have come to expect with the proliferation of HDTVs. Studio equipment is being upgraded to HD, so standard definition content production is on the wane or is derived from HD source material by down-converting the resolution and cropping or shrinking the image.

The distribution of high-definition video from local sources within a building requires digitally formatted video, support for data protection, and high data rates for uncompressed HD video. Until now, the only choices were media that comply with the DVI or HDMI interface specification. The HDMI format has replaced DVI especially since HDMI also carries audio, so the A/V industry migrated to HDMI. As noted, HDMI equipment was intended as a short-range point-to-point interface for connecting a video source to a TV located nearby (typically 10 feet).

HDBaseT technology offers another option for carrying HD A/V content. HDBaseT allows for a much longer range of HD distribution using LAN cabling infrastructure, with the advantage of

[5] On November 11, 2014, the Consumer Electronics Association (CEA) announced that industry, technical, and retail organizations have agreed on common terminology for 4K and UHD, to be called *4K UHD*. CEA is licensing a 4K UHD logo for "the emerging category of display products with more than 8 million pixels – four times the resolution of Full HD."

also distributing Ethernet, control signals, and up to 100 Watts of power. Thus, HDBaseT makes high-quality multimedia distribution feasible and practical.

HDMI

The specifications for HDMI were developed by an industry alliance formed by Hitachi, Panasonic Corporation, Philips, Silicon Image, Sony, Technicolor, and Toshiba. The HDMI specifications are now maintained by the HDMI Forum. The founders established the HDMI Forum in 2011 to encourage other companies to participate in enhancing the specifications. The current version is HDMI 2.0.

HDMI was developed to transport high-resolution video without data compression. Data are optionally encrypted to limit distribution only to authorized receiving devices. The audio, video, and control features of HDMI 2.0 include:

- Audio: 49.152 Mbps maximum
    - High-resolution audio
    - 32-channel audio support
    - Audio Return Channel (ARC)

      ARC enables a TV to supply audio to a sound system when the audio originates from a decoder within the TV. This might occur in a smart TV that is receiving a streaming movie via the Internet, for example, using a Netflix account. The ARC avoids using a dedicated cable for the sound, typically a TOSLINK or analog cables with RCA connectors (as shown in Figure 7).
- Video
    - Encoding as high as 4096×2160 pixels per frame for 4K resolution (4K refers to the 4096 pixels per row)
    - As high as 48 bits per pixel for “deep color”

  - Progressive at 60 frames per second maximum
  - Multiple aspect ratios such as 4:3 (standard definition TV), 16:9 (high-definition TV – HDTV), and 21:9 (approximately the aspect ratio of the CinemaScope wide-screen film format developed by Twentieth Century Fox)
  - Support for 3D TV

- Control channel
  - Consumer Electronic Control (CEC)

    CEC supports remote operation of devices. Some manufacturers use this control channel for applications such as one-touch play and record, timer programming, tuner control, and on-screen menu displays. CEC features are marketed under a variety of trade names.[6]

  - Digital Display Channel (DDC)

    DDC enables display devices to inform source devices which video formats are supported. The formats are encoded using EDID (Extended Display Identification Data). The specifications for EDID formats were developed by the Video Electronics Standards Association (VESA) with extensions published by the Consumer Electronics Association as standard CEA-861-F, *A DTV Profile for Uncompressed High Speed Digital Interfaces*.

    DDC is also used for the exchange of data keys to manage content that is protected with encryption using HDCP (High-bandwidth Digital Copy Protection) to limit distribution and copying.

[6] Examples of CEC trade names are Anynet+ (Samsung), Aquos Link (Sharp), BRAVIA Link and BRAVIA Sync (Sony), HDMI-CEC (Hitachi), E-link (AOC), Kuro Link (Pioneer), INlink (Insignia), CE-Link and Regza Link (Toshiba), RIHD (Remote Interactive over HDMI) (Onkyo), RuncoLink (Runco International), SimpLink (LG), T-Link (ITT), HDAVI Control (Panasonic), EZ-Sync (Panasonic), VIERA Link (Panasonic), and EasyLink (Philips).

The data transport rates for the integrated HDMI signal (video, audio, and control) have been increasing as the HDMI specification has evolved to accommodate higher quality video such as Ultra HD:

- HDMI versions 1.0, 1.1, and 1.2
    - 3.96 Gbps for content
    - 4.95 Gbps for content plus overhead (for managing the data transfer)
- HDMI versions 1.3 and 1.4
    - 8.16 Gbps for content
    - 10.2 Gbps for content plus overhead (for managing the data transfer)
- HDMI version 2.0
    - 14.4 Gbps for content
    - 18 Gbps for content plus overhead (for managing the data transfer)

A common infrastructure for data and A/V

An HDMI cable that uses the connectors shown in Figure 7 contains 19 wires. Twelve of these wires are devoted to carrying the video and audio signals including electromagnetic shields and a clock signal. The other lines carry control signals, an optional audio feed from the display device, and a hot plug detect to determine when an HDMI cord is plugged into a device. One pin carries power (up to 0.25 Watt) that may be used by an extender unit since a single HDMI cable is limited to about 50 feet.

HDMI cable limitations

Distribution in a commercial building is a challenge especially since the HDMI cables are bulky, expensive, and limited in range:

- A 50-foot HDMI cable weighs more than four pounds.
- An HDMI cable is almost a half-inch thick.
- An HDMI cable has a limited bend radius.
- A plenum-rated 50-foot HDMI cable costs about $200-300.
- The HDMI connector assembly is large compared to other connectors.
- The original HDMI connector plug can be easily dislodged from the jack (later versions are sold with latches). Both versions are still being sold.
- HDMI connectors are complex and expensive, as are field termination tools and kits.

HDBaseT cabling

A significant cost for building construction is hiring and scheduling the various skilled trades-people to install infrastructure components such as building wiring. It is very desirable to have one skilled person install integrated cabling rather than separate installations of power, data, and HD A/V cabling. HDBaseT fulfills this goal by using the same infrastructure as an office local area network including cabling and connectors (RJ-45 type), thus requiring no new inventories of cables, connectors, or installation tools and no special training for installers.

HDBaseT is a method for encoding HDMI onto the same type of local area network cabling as used for Ethernet in office buildings. HDBaseT provides a multimedia, control, and power interface suitable for:

- Multipoint-to-multipoint distribution up to 100 meters (328 feet)
- Star-wired distribution via a matrix switch
- Daisy-chain distribution of up to eight HDBaseT links, each up to 100 meters long

Furthermore, the HDBaseT technology can include Ethernet signals in the same stream that is carrying the audio, video, control signals, and power.

HDBaseT can operate over any of the commonly used LAN twisted-pair cabling infrastructures listed below. These LAN cables are becoming ubiquitous in commercial buildings. In the following list cable bandwidths are included, but data rates are not since they depend on the signal coding chosen. HDBaseT data rates exceed Ethernet rates for CAT (Category) 5e, 6, and 6a cables.

Unshielded cabling options include:

- CAT 5e (100 MHz)
- CAT 6 (250 MHz)
- CAT 6a (500 MHz)

HDBaseT will also work on higher bandwidth twisted-pair cabling under development. Each twisted pair of wires in the list of cables below is shielded; the overall cable may be shielded depending on the category. Note that CAT 6a cabling is available unshielded and shielded.

- CAT 7 (600 MHz)
- CAT 7a (1000 MHz)
- CAT 8 (1600-2000 MHz)

Shielded cables offer higher bandwidths. However, unshielded cabling is simpler to install and eliminates possible ground loops, which may cause audio and video interference. Installers are advised to select cables that are certified[7] for performance according to the specifications for the cable category selected. Test parameters are specified for each class of cabling. Cable testing includes the following field test options (listed from the lowest quality testing to the highest):

- Verification
    - Test the network for continuity.

[7] ETL, GHMT, and UL are examples of organizations that test cables for certification to standards.

- No transmission performance is measured.

– Qualification

- Determine that the cabling will support a specific network performance level such as 100-Mbps Ethernet or 1-Gbps Ethernet.
- The accuracy of the test equipment is not traceable to a reference.

– Certification

- Specify conformance to a national or international standard (TIA-568C or ISO/IEC 11801 using the IEC 61935 series of standards, which specify testing of balanced communication cabling[8] in accordance with ISO/IEC 11801).
- Provide confidence that specific applications will work.
- The test equipment accuracy is traceable to a national or international standard.
- Certification testing is usual for commercial and industrial applications.

HDMI signals from a source such as a Blu-ray player are converted to HDBaseT format using an HDBaseT module called an Extender because it extends the reach of HDMI from an average of 10 feet to about 300 feet. Figure 9 shows a typical pair of HDBaseT Extenders. The HDTV source (such as a Blu-ray player) would be plugged into the HDMI transmitter (called an HDMI Sender), shown on the left, using a short HDMI cable. On the backside of the transmitter (not shown) is an RJ-45 jack into which the building LAN cable (such as CAT 6) would be connected to carry the HDBaseT signals. At the display location, the LAN cable would be plugged into the RJ-45 jack of the HDMI Receiver, shown on the right. On the back of this unit (not shown) is an HDMI jack where a short HDMI cable would be connected to the display. Some manufacturers are incorporating HDBaseT Extenders into end products or into wall outlets using convenient RJ-45 jack connectors.

[8] Twisted-pair wiring is an example of a balanced cable with two identical conductors having the same impedance to ground. A coaxial cable is unbalanced since the outside conductor may be grounded.

The receiver is specified for operation up to 100 meters (330 feet) from the sender. This distance can be increased by interposing one or more HDBaseT switches.

Figure 9 – HDMI ↔ HDBaseT Converters

HDBaseT technology

For a building manager seeking high-quality multimedia distribution (HDTV or UHDTV), the choice until now was to bring the source close to the display or to install a network of HDMI cables with repeaters. This is not a practical solution because the cables are bulky and expensive, as are the repeaters. HDBaseT is a technology that combines specialized electronics at the source, the display, and a switch with conventional LAN cabling to distribute high-definition video, audio, Ethernet, power (up to 100 Watts), and controls in parallel with data networks. HDBaseT equipment is a practical solution for building-wide distribution of high quality multimedia including protected (encrypted) content. Thus a unified infrastructure of local area network wiring that is widely deployed for corporate data networks can also support multimedia using HDBaseT technology.

Optional extensions to HDBaseT carry additional signals. The 5Play™ feature set of HDBaseT extends the technology beyond carrying A/V to include controls, Ethernet, USB, and up to 100 Watts of power in a single LAN cable.

In 2010 a consortium of manufacturers formed the HDBaseT Alliance to advance the use of HDBaseT technology in various applications such as enterprise, transportation, digital signage, education, home networking, and more. The HDBaseT Alliance was founded by Samsung, LG, Sony Pictures, and Valens. It now consists of more than 115 members, including the major manufacturers of A/V equipment.

HDBaseT architecture

HDBaseT encodes the HDMI payload onto the four pairs of balanced cables (twisted-pair wires) used for LANs. The application payload throughput rate of HDBaseT is comparable to the HDMI 1.4/2.0 mandatory rates after accounting for differences in overhead data. The data modulation scheme used by HDBaseT is denser than Ethernet (more bits per baud, which means more digital data conveyed per symbol transmitted on the communications medium).

Digital data are encoded on a physical medium with an electric signal such as voltage or current. In a simple digital transmission system the measured signal value is represented by a binary number (1s and 0s), and each binary digit (bit) is sent as a separate signal. For example, a temperature of 50 is sent as a sequence of six electrical pulses representing 110010 (the binary encoding of 50). A 0 might be sent using a 0 ma (milliamps) electric current, while a 1 is 100 ma. The receiver is designed so any signal below 50 ma is interpreted as a binary 0 and any signal above 50 ma is considered a binary 1. Thus, with less than ±50 ma of noise, an error never occurs. This is illustrated in Figure 10 with a noise level of ±10 ma.

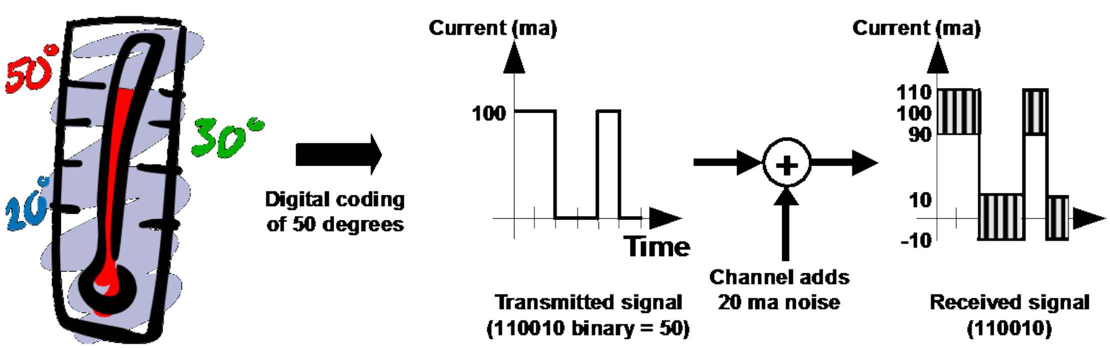

Figure 10 – Digital Encoding using Two Levels

Both Ethernet and HDBaseT encode digital data in this fashion, called pulse amplitude modulation (PAM). The illustration in Figure 10 shows two-level PAM as adopted for an HDMI interface signal. Ethernet and HDBaseT use more discrete levels to achieve a higher density of data throughput. Ethernet uses five discrete levels (PAM 5) on two pairs of wires, while HDBaseT increases this to 16 discrete levels (PAM 16) on all four pairs of wires in the cables.

The increased number of PAM levels could make a transmission system more susceptible to channel noise than Ethernet. However, HDBaseT compensates with a special forward error-correction method that provides improved error resistance as the bit rate is increased. Thus HDBaseT uses a robust transmission method. In contrast, HDMI has no forward error-correction or request–for–re-send provisions to seek lost packets.

The HDBaseT modulation scheme is proprietary using *T-Packets*, which is not IP-based (Internet Protocol). IP packets introduce too much latency and the possibility of dropped packets (with the UDP protocol commonly used for real-time data transmission through the Internet), which makes it unacceptable for high-definition video transmission. HDBaseT adds less than 10 microseconds of latency over 100 meters of cable, a negligible amount.

300 Mbps is allocated in the HDBaseT payload to accommodate control and Ethernet data. HDBaseT expands the control channels that can be carried beyond those in HDMI (CEC and DDC) with the addition of:

- RS-232 (serial point-to-point link)
- USB 2.0
- IR (Infrared)
    - Type A passes only the base-band data.
    - Type B passes through the signal with no demodulation, transferring both base-band and carrier data.
    - Both must use a compatible receiver at the far end.

HDBaseT also includes a hot plug detect circuit to start the process of establishing communications when a device is first connected. This involves exchanging EDID data via the DDC channel to adapt to the display format and any data needed for HDCP to operate. HDCP requires authentication messages to ensure that all devices receiving the content are licensed and authorized to receive the content. Also, encryption keys are exchanged so only authorized devices can decrypt the scrambled A/V stream.

As noted, HDBaseT can carry an Ethernet channel in addition to audio, video, and control. HDBaseT supports a fallback mode to Ethernet. As a result, if an HDBaseT device is connected to an Ethernet switch, the HDBaseT devices will pass the Ethernet packets in conventional form without the audio, video, or control signals that the Ethernet switch cannot handle.

Power over HDBaseT (PoH)

A new technology for delivering power to office equipment over local area network cabling was introduced in 2001. This power delivery system is called Power over Ethernet (PoE). Power is delivered via direct current (DC) using the same wires that carry data. Two standards have been issued for PoE to supply about 13 Watts and PoE+ to supply 25 Watts via office network cabling.

HDBaseT extends PoE to 100 Watts with a feature called PoH (Power over HDBaseT) using four pairs of local area network wires. Examples of office equipment that could use PoE and PoH include:

- Telephones (using Voice over IP (VoIP) technology)
- Control of HVAC systems for heating, ventilation, and air conditioning
- Digital signage displays
- Displays for local video sources and streaming (Internet) TV
- TVs (displays with tuners) for high-definition broadcasts
- Security cameras

The devices connected to office networks for these services need modest amounts of power, typically less than 20 Watts. The powered device identifies the cable length and resistance, and draws increasing amounts of power as long as the overall power consumption does not exceed 100 Watts. If PoH equipment is connected to a PoE line, the maximum common power will be passed between them, i.e., according to whether PoE or PoE+ devices are installed. If the device needs more than 25 Watts in a PoE+ installation, the power sourcing equipment (PSE – the device connected to the power supply) will shut off the power, and the powered device (PD) will not work.

PoH at 100 Watts is enough power for operating most TVs up to 60 inches (diagonal measure). The U.S. EPA (Environmental Protection Agency) Energy Star program for TVs requires consumption for a 60-inch TV to be no more than 98.7 Watts, down to 21.9 Watts for a 20-inch TV.

HDBaseT versions

HDBaseT 1.0

The HDBaseT 1.0 specification, issued in 2010, supports point-to-point distribution of multimedia content for up to 100 meters (328 feet) using an Ethernet-type local area network cabling infrastructure and RJ-45 connectors. The focus of HDBaseT 1.0 was achieving throughput with no errors or latency, no overhead, and asymmetric communications.

HDBaseT 2.0

Version 2.0 of the HDBaseT specification was launched in 2013 with capabilities for networking, switching, and a control point. HDBaseT 2.0 supports star-wired distribution (multipoint-to-multipoint) for multiple streams in a mesh network. It enables an HDBaseT matrix switch using the same topology as an Ethernet switch. Additional HDBaseT 2.0 features include:

- Support for daisy-chain distribution of up to eight HDBaseT links, each up to 100 meters long.
- Integrated control options using USB 2.0, infrared (IR), and UART (serial interface for RS-232 signals). Also, audio can be delivered by an S/PDIF cable (the S/PDIF

connectors are illustrated in Figure 7). These interfaces may be embedded in a single HDBaseT controller for compact devices.

- Specifications across all seven layers of the *OSI [Open Systems Interconnect] Reference Model for Communications* for efficient operation and improved error handling that can support video streams up to UHD (Ultra High Definition).

- Support for fiber optics.

Class A HDBaseT

Class A HDBaseT is the traditional HDBaseT product able to support all 5Play features with transmission up to 100 meters (328 feet).

Class B HDBaseT

Class B HDBaseT is intended as a more cost-effective solution for certain applications. It supports distances of up to 70 meters (230 feet), but does not include Ethernet functionality.

Long-Reach HDBaseT

Long-Reach HDBaseT allows for connectivity up to 150 meters (492 feet) with lower HD display resolutions of up to 720p (720 horizontal lines, progressively scanned).

HDBaseT over Fiber

HDBaseT over Fiber supports applications requiring a much higher distance than 100 meters. Fiber optics capabilities are a feature of HDBaseT version 2.0. Fiber-based applications may include inter-building connectivity, campus connectivity, digital signage, and some vertical markets with infrastructure requirements that demand fiber optics as the transmission medium (such as medical and military).

HDBaseT equipment

A variety of HDBaseT equipment is available for applications in commercial buildings as illustrated in this section. These components and products fulfill the requirements outlined by the HDBaseT Certification Program. The HDBaseT Certification Program (http://hdbaset.org/certification) verifies that products comply with the HDBaseT specifications to promote interoperability among vendors of current and future HDBaseT products. All products must be certified for carrying audio and video with Class A or Class B capabilities. Optional product features include:

- Ethernet
- PoH
- Control features
    - CEC
    - IR
    - RS-232

To be HDBaseT-certified, products are tested in an HDBaseT Alliance Recognized Testing Facility against a Golden Unit to verify proper operation and feature functionality. Hundreds of HDBaseT products have been certified and are available including extenders, matrixes, switchers, AV receivers, displays, and projectors. All certified products are listed on the HDBaseT web site: http://hdbaset.org/products_list. Here is a sampling of HDBaseT components and products:

- HDBaseT components (from Valens)
    - VS100TX (Transmitter): for use inside DVD and Blu-ray players, STBs, and other HD source equipment.
    - VS100SRX (Receiver): for use inside video walls, projectors, and other HD display equipment.
    - Valens VS2K / Colligo family
        - ◊ Support for USB 2.0, audio interfaces, and fiber optics.
        - ◊ Enables the transmission of 4K video over longer distances.

◊ The Colligo product line:

- VS2000: 5Play Gen 2.0.
- VS2310: 5Play Gen 2.0 Plus, a high-end 5Play chipset that includes native USB 2.0 support and inter-device connectivity.
- VS2311: 5Play Gen 2.0 Fiber, which introduces HDBaseT using fiber optics for transmission over longer distances.

– Matrix switches

- All switches accommodate HDMI EDID (Extended Display Identification Data – which data formats are supported by the HDMI sink device) and HDCP (High-bandwidth Digital Copy Protection).
- Video inputs: HDMI.
- Video outputs: HDBaseT.
- Atlona switches: 8x8 and 16x16, with an example shown in Figure 11.

Figure 11 – Atlona HDBaseT 8x8 HDMI Matrix Switcher

- Crestron switches: 6x4, 6x6, 8x8, 16x16, 32x32, 64x64, and 128x128 switches, some of which support UHDTV, with an example shown in Figure

12. Note that the Crestron trade name for HDBaseT is DigitalMedia™, abbreviated DM on the RJ-45 jacks in the figure.

Figure 12 – Crestron HDBaseT 8x8 HDMI Matrix Switcher

– Wall plates from Belkin: HDBT-WP-100M

- Fits in a single-gang box and extends HDMI transmissions to 100 meter (328 feet) with HDBaseT technology (see Figure 13).
- The backside of each box contains an RJ-45 jack for connecting to LAN cabling.

Figure 13 – Wall Plates for HDBaseT Interface

– HDBaseT Extender from Black Box Network Services including an IR pass-through port (see Figure 14)

Front of Sender

Front of Receiver

Back of Sender

Back of Receiver

Figure 14 – HDBaseT Extenders: a Sender and a Receiver

– Projector with HDBaseT port

Figure 15 – Projector with HDBaseT Input

– Displays with HDBaseT ports are offered by popular LCD display makers such as NEC, Panasonic, and Samsung. They feature simple connectivity to a multimedia distribution network, as shown in Figure 16.

Figure 16 – LCD Display with HDBaseT Port

Summary

Multimedia, developed for entertainment, is now being adapted for conveying business information. This will have a profound effect on commercial buildings and transportation facilities with a diversity of applications, as listed in Figure 17.

Multimedia Applications in Commercial Facilities
Corporate information networks for building visitors and employees
Hospitality, such as hotels and cruise ships
In-flight entertainment systems
Fitness centers
Education applications
Conference rooms
Public displays with multiple screens
Government agencies
Power system operators
Healthcare
Digital signage
Interactive kiosks
Commercial showrooms
Movie theaters for digital cinema

Figure 17 – Multimedia Applications Enabled with HDBaseT Technology

HDBaseT has been developed to carry high-quality multimedia including HD and UHD content while simplifying the cabling comprising a building infrastructure. No longer will bulky coaxial cables with fragile connectors be needed for video distribution.

The impact on building infrastructure cabling for accommodating multimedia is minimal because the same cabling components used for data networks can carry high-quality audio and video streams with HDBaseT technology. Thus, HDBaseT technology enables high-definition audio and video, including encrypted commercial videos, to be carried on local area networks that are widely deployed in buildings.

Displays and projectors are being developed with built-in HDBaseT technology. To accommodate these devices wall jacks with RJ-45 connectors for HDBaseT will become as common place in buildings as RJ-45 jacks for data. A single HDBaseT connection can deliver audio, video, Ethernet, control signals, USB 2.0, and up to 100 Watts of power.

Figure 18 shows the diagram for the international structured cabling standard augmented with HDBaseT equipment. Note that the cabling infrastructure is the same as the data cabling of a local area network. The audio/video source equipment may be located in a telecommunications room on each floor or in an equipment room serving the building, as illustrated with a Blu-ray player, an HDBaseT switch, and a server. The telecommunications outlets (TO) on the left side of Figure 18 may be either:

- An HDMI wall plate, as shown in Figure 13, that includes the HDBaseT technology for bi-directional conversion of HDMI signals to and from the HDBaseT format using HDBaseT electronics behind the wall plate.
- An RJ-45 wall plate for connecting devices that have embedded HDBaseT technology. These devices send and receive HDBaseT signals via RJ-45 plugs.

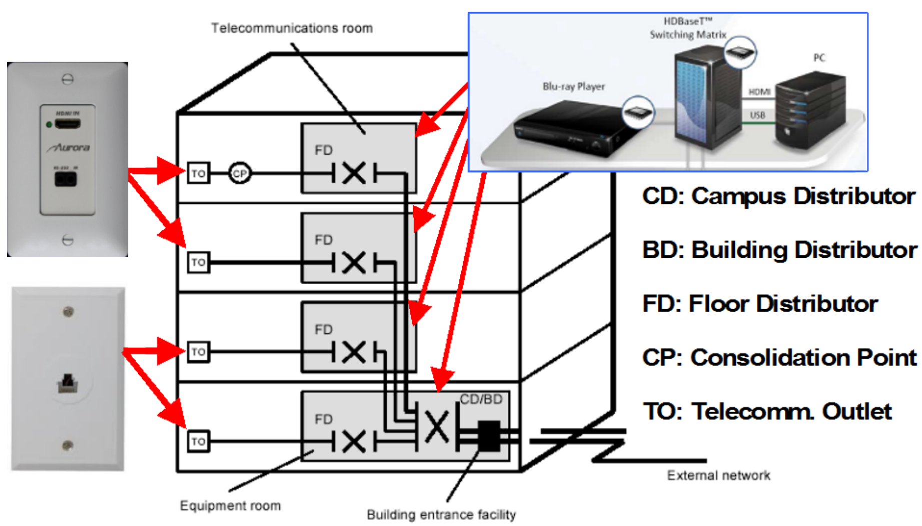

Figure 18 – HDBaseT using the International Standard Structured Cabling

Thus, high-quality multimedia can be distributed on a network that parallels a building data network and uses the same types of cables and the same topology. HDBaseT technology offers a solution for multimedia distribution in commercial buildings that is attractive, cost-effective, and easily installed without special cables, connectors, or additional training.

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