

Technology Guide

v2.0 — Updated May 2019

IP Standards – Video over IP Networks

The AIMS Roadmap is based on open standards and specifications established by SMPTE, AMWA, AES, the IETF and other recognized bodies. It is aligned with the JT-NM Roadmap, developed by the AMWA, EBU, SMPTE and VSF in order to provide guidelines for broadcast operations to adopt IP technology. AIMS' own membership participates in these organizations. It is precisely because our industry enjoys a robust set of standards bodies that AIMS seeks to foster the adoption of this work as best practice for the industry.

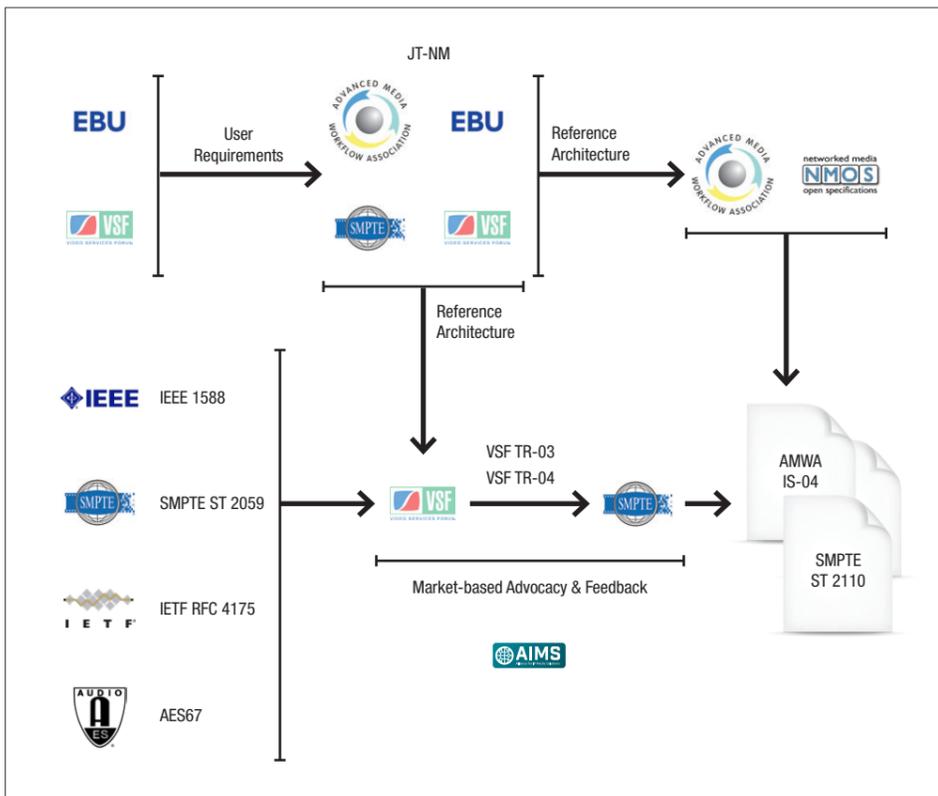


VSF TR-03

An early standard for audio, video and metadata over IP, TR-03 has been largely superseded by SMPTE ST 2110.

JT-NM (Joint Task Force on Networked Media) – AMWA/EBU/SMPTE/VSF

The Joint Task Force on Networked Media (JT-NM) was formed by the European Broadcasting Union, the Society of Motion Picture and Television Engineers and the Video Services Forum in the context of the transition from purpose-built broadcast equipment and interfaces (SDI, AES, cross point switcher, etc.) to IT-based packet networks (Ethernet, IP, servers, storage, cloud, etc.) that is currently taking place in the professional media industry. The JT-NM Tested program offers prospective purchasers of IP-based equipment greater, more documented insight into how vendor equipment aligns with the SMPTE ST 2110 and SMPTE ST 2059 standards.



AMWA / NMOS (Advanced Media Workflow Association / Networked Media Open Specifications)



The NMOS Discovery and Registration API is documented in AMWA Specification IS-04 providing a way for network-connected devices to become listed on a shared registry, and it provides a uniform way to query the registry. It also describes a method for peer-to-peer discovery in order to permit operation on a link-local only or smaller network deployment.

IS-04 NMOS Discovery & Registration.

Defines a methodology to register a device's services (available outputs and inputs and configuration) and discover other devices on a network that it is compatible with and can connect to. IS-04 is part of the Network Media Open Specification (NMOS) project within AMWA.

- HTTP Registration API that Nodes use to register their resources with a Registry.
- HTTP Query API that applications use to find a list of available resources of a particular type (Device, Sender, Rec.) in the Registry.
- HTTP Node API that applications use to find further resources on the Node.
- How to announce the APIs using DNS-SD, so the API endpoints don't have to be known by Nodes or Applications.
- How to achieve "peer-to-peer" discovery using DNS-SD and the Node API, where no Registry is available.

IS-05 NMOS Device Connection Management.

Enables a client or controller application to create or remove media stream connections between sending and receiving devices including:

- Configuration of parameters relating to transport protocols
- Support for immediate or scheduled parameter changes
- Hosting of transport files which are used to connect to a given transport
- Support for bulk changes to senders and receivers
- Support for redundant media streaming (i.e., SMPTE ST 2022-7)
- Support for flagging parameter constraints
- Support for staging and activation of parameters
- Use of IS-04 with IS-05

IS-07 NMOS Event and Tally

Mechanism to emit and consume states and state changes issued by sources.

- Message types
- Event types
- Core models
- Transports
- REST API

IS-08 NMOS Audio Channel Mapping

Set channel mapping/selecting/shuffling settings for use with NMOS APIs

- Client side implementation
- Server side implementation
- Interoperability including IS-04
- Upgrade path

JT-NM Technical Recommendations

TR-1001-1:2018 v1.0

Recommendations for SMPTE ST 2110 Media Nodes in Engineered Networks that easily integrate equipment from multiple vendors with a minimum of human interaction.

- Networks
- Registration
- Connection Management

SMPTE Standards ST 2022

MPEG-2 Transport stream over IP

- ST 2022-1: 2007 - Forward Error Correction for Real-Time Video/Audio Transport Over IP Networks
- ST 2022-2: 2007 - Unidirectional Transport of Constant Bit Rate MPEG-2 Transport Streams on IP Networks
- ST 2022-3: 2010 - Unidirectional Transport of Variable Bit Rate MPEG-2 Transport Streams on IP Networks
- ST 2022-4: 2011 - Unidirectional Transport of Non-Piecewise Constant Variable Bit Rate MPEG-2 Streams on IP Networks

SDI over IP

- ST 2022-5: 2013 - Forward Error Correction for Transport of High Bit Rate Media Signals over IP Networks
- ST 2022-6: 2012 - Transport of High Bit Rate Media Signals over IP Networks (HBRMT)
- ST 2022-7: 2017 - Seamless Protection Switching of RTP Datagrams
- ST 2022-8: draft - Integration with 2110 (rename of 2110-50) proposed

SMPTE Standards ST 2110

ST 2110-10:2017 System Timing and Definitions

- ST 2059 (PTP) is used to distribute time and timebase to every device in the system
- Senders mark each packet of video, audio, or ANC with an "RTP Timestamp" that indicates the "sampling time"
- Receivers compare these timestamps in order to properly align the different essence parts to each other
- Specifies how SMPTE 2059 PTP timing is used for ST2110
- Specifies how the RTP timestamps are calculated for Video, Audio, and ANC signals
- Specifies general requirements of the IP streams
- Specifies using the Session Description Protocol (SDP)
- The actual stream formats are in the other parts of the standard

ST 2110-20:2017 Uncompressed active Video (RFC 4175)

- Only the "Active" image area is sent –no blanking. - See table below.
- Supports image sizes up to 32k x 32k pixels
- Supports Y'Cb'Cr', RGB, XYZ, I'Ct' Cp'
- Supports 4:1:1, 4:2:2/10, 4:2:2/12, 4:4:4/16, and more (8- to 16-bit)
- Supports HDR (e.g., PQ & HLG etc)

Bandwidth Savings				
Format	F/rate	2022-6	2110-20	difference
2160p	@ 59.94	12282.2	10279.6	-16.3%
1080p	@ 59.94	3070.7	2570.1	-16.3%
1080i	@ 29.97	1535.4	1285.0	-16.3%
720p	@ 59.94	1535.4	1142.5	-25.6%
2160p	@ 50	12294.8	8754.9	-30.3%
1080p	@ 50	3074.1	2143.9	-30.3%
1080i	@ 25	1537.4	1071.9	-30.3%
720p	@ 50	1537.4	953.0	-39.9%

ST 2110-21:2017 Traffic Shaping and Delivery Timing of Uncompressed Video

- Standard for timing sets criteria for the sender profile.
- There are three profiles: Narrow (N), Narrow Linear (NL) and Wide (W).
- N and NL provide for a nearly smooth transmission of packets with the ideal spacing.
- N is used to transmit the video packets as soon as possible from a rasterized source where there is blanking.
- NL is used to transmit video packets as soon as possible from a source that is not rasterized.
- W transmitters, allow for a longer burst of data. This profile is desired by software product developers to enable a wider range of SMPTE ST 2110-20 senders. W transmitters need only be accurate to about 100 μsec and can be useful in playout where the server needs to run at real time, although some latency is tolerable.
- Ref GV Whitepaper (auth Chuck Meyer CTO Production)

ST 2110-30:2017 PCM Digital Audio Built On AES67 -2015 --PCM Audio (only),

- Level A: 48 kHz streams from 1 to 8 channels at packet times of 1 ms
- Level B: 48 kHz streams from 1 to 8 channels at packet times of 1 ms or 1 to 8 channels at packet times of 125 μs
- Level C: 48 kHz streams from 1 to 8 channels at packet times of 1 ms or 1 to 64 channels at packet times of 125 μs
- Other - AX, BX, CX

Stream bandwidth audio	
(2 channels) * (24 bits) * (48,000 samples) * (1.08 RTP) =	2.5 Mb/s
(8 channels) * (24 bits) * (48,000 samples) * (1.05 RTP) =	9.7 Mb/s

ST 2110-31: AES3 Compressed Audio Transparent Transport (2018)

- Provides bit-transparent AES3 over IP
- Can handle non-PCM audio (like Dolby AC3/E)
- Can handle AES3 applications that use the user bits
- Can handle AES3 applications that use the C or V bits
- Always supports a pair of AES3 sub-frames

ST 2110-40: 2018 Ancillary Data (ref IETF 8331: 2018)

VANC data routing. (Breakaway routing)

ST 2110-50: (see SMPTE standard ST 2022-8 2022-6 integration)

SMPTE Standards Various

ST 2059-1:2015

- Generation and Alignment of Interface Signals to the SMPTE Epoch
- Provided parameter and required calculation for audio and video format alignment



ST 2059-2:2015 (IEEE1588-2008)

- SMPTE Profile for use of IEEE-1588 Precision Time Protocol (PTP) in Professional Broadcast Applications
- Defines profile, clocks, transport and performance for both unicast and multicast
- Enable any slave introduced into a network to become synchronized and maintain network-based time accuracy

ST 2082-xx 12 Gb/s (Note that the "M" designator was originally introduced to signify metric dimensions. Units of the International System of Units (SI) are the preferred units of measurement in all current SMPTE Engineering Documents.)

- HD SDI defines the mapping of various source image formats onto a single-link, dual-link and quad-link serial digital interface operating at a nominal rate of 12 Gb/s.
- SMPTE 259M describes a 10-bit serial digital interface operating at 143/270/360 Mb/s
- SMPTE 274M defines the 1080 line HD video formats including 1080p25 and 1080p30
- SMPTE 291-1 2011 Anc data packet and Space Formatting
- SMPTE 292-1 expands on 259M nominally 1.5 Gb/s interface. defined; 1.485 Gb/s, and 1.485/1.001 Gb/s
- SMPTE 296M defines 720 line HD video format
- SMPTE 304M defines LEMO Hybrid Fiber connector standard (3K.93C connector)
- SMPTE 311M-2009 defines camera to CCU Cable and connects to SMPTE 304M connector
- SMPTE 344M expands on 259M
- SMPTE 356M MPEG2 compression I frame 4:2:2, AES3 24-bit PCM
- SMPTE 367M HDCAM standard
- SMPTE 372M Dual link HD SDI
- SMPTE 424:2012 3 Gb/s HD SDI, Physical layer, expands on 259M, 344M, 292M
- SMPTE 425:2011 3 Gb/s HD SDI. Video, audio and ancillary data mapping for the 3G interface. Level A Direct Image Mapping, Level B-DL Dual Link mapping, Level B-DS Dual Stream mapping

IETF Standards (Internet Engineering Task Force)

RFC 3550 Real-time Transport Protocol (RTP)

Provides end-to-end delivery services for data with real-time characteristics, such as interactive audio and video. Those services include payload type identification, sequence numbering, timestamping and delivery monitoring



RFC 4175 Payload Format for Uncompressed Video

Defines a scheme to packetize uncompressed, studio-quality video streams for transport using RTP. It supports a range of standard and highdefinition video formats, including ITU-R BT.601, SMPTE 274M and SMPTE 296M.

RFC 4566 Session Description (SDP)

The SDP (RFC4566) tells the Receiver what it needs to know. Senders expose an SDP for every stream they make. The control system (out of scope) conveys the SDP information to the receiver

RFC 8331: 2018 Ancillary Data (RTP Payload for SMPTE ST 291-1)

RTP Payload for SMPTE ST 291-1 Ancillary Data (incl Timecode, Closed Captioning and Active Format Description) SMPTE Ancillary data is generally used along with professional video formats to carry a range of ancillary data types, including timecode, Closed Captioning, and the Active Format Description (AFD).

AES67 (Audio Engineering Society) AES67-2015

Is a standard (published 2013) to enable interoperable streaming of high-performance audio-over-IP between various IP based audio networking products currently based on existing standards such as Dante, Livewire, Q-LAN and Ravenna. It is not a new technology but a bridging compliance mode compatible with all IP-Networks; offering interoperability over standard layer 3 Ethernet networks. As such, is routable and fully scalable across any common modern IT network.



DANTE (Digital Audio Network Through Ethernet)

Created by Audinate 2006. Licensed to Shure, Allen & Heath and Yamaha.

Proprietary system improves on audio-over-Ethernet technologies such as CobraNet and EtherSound



- Dante currently uses UDP for audio distribution, both unicast and multicast.
- Bandwidth usage is about 6 Mb/s per typical unicast audio flow (containing 4 channels and 16 audio samples per channel). Flows are pre-allocated a capacity of 4 channels. The samples-per-channel can vary between 4 and 64, depending on the latency setting of the device.
- Multicast audio is always on UDP port 4321. Unicast audio ports come from a range: 14336 - 14600.
- Audio traffic should not take up more than 70% of the bandwidth of any network link.

IT Networks: Switches and Layers

Layer 4 switch – (a.k.a. session switch)

A network device that integrates routing and switching by forwarding traffic at layer 2 speed using layer 4 and layer 3 information. When packets are inspected at layer 4, the sockets can be analysed and decisions can be made based on the type of application being serviced. Policy based switching. Is an enhancement to the layer 3 switch that uses hardware based switching techniques

Layer 3 switch – (a.k.a. multilayer switch)

Is a specialized hardware device used in network routing. Inspects incoming packets and makes dynamic routing decisions based on the source and destination IP addresses Intranet use (no WAN port). VLAN support.

Layer 2 switch – (a.k.a. Network Switch).

Layer 2 (OSI) switching (or Data Link layer switching) packets are sent to a specific switch port based on destination MAC addresses. Switches and bridges are used for Layer 2 switching. They break up one large collision domain into multiple smaller ones. Supports routing protocols.

Layer 1 switch – (physical layer)

Layer-1 non-blocking switching (also called crosspoint, matrix, or crossbar switching) is roughly analogous to the old circuit-switched phone networks, where operators would manually patch calls end-to-end. It provides clock and data recovery (CDR).

Internet Protocol

Application layer protocols (#7 OSI)

BGP, DHCP, DNS, FTP, HTTP, IMAP, LDAP, MGCP, NNTP, NTP, POP, ONC/RPC, RTP, RTSP, RIP, SIP, SMTP, SNMP, SSH, Telnet, TLS/SSL, XMPP.

Transport layer protocols (#4 OSI)

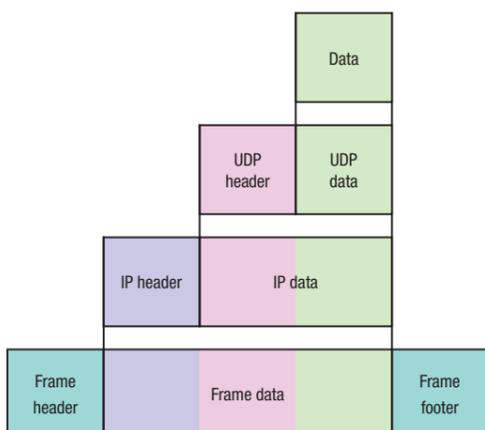
TCP, UDP, DCCP, SCTP, RSVP, PTP.

Network Layer Protocols (#3 OSI)

IP, IPv4, IPv6, SNMP, ICMP, ICMPv6, ECN, IGMP, IPsec, IGMPv2.

Data Link Layer (#2 OSI)

ARP, NDP, OSPF, Tunnels, L2TP, PPP, MAC, Ethernet, DSL, ISDN, FDDI.



UHD Video Standards

4K UHD Phase A ref UHD Forum

(Covers broadcasting services as of early 2017 updated V1.4 Sept 2017)

- Number of pixels 3840x2160, display resolution of 1080p or 2160p (progressive video only);
- Wide Color Gamut – (wider than Rec. 709) Rec. 2020 must be supported; HDR (high dynamic range) SDR (standard dynamic range), PQ/10, HLG/10.
- Bit depth of 10-bits per sample; frame rate of up to 60 fps (integer frame rates preferred);
- Audio; 5.1 channel audio or immersive audio. Audio Codec AC-3, EAC-3, HE-ACC, AAC-LC,
- Closed captions/subtitles CTA-608/708, ETSI 300 743, ETSI 300 472, SCTE-27, IMSC1

UHD TV1 consumer devices should be able to decode the High Efficiency Video Coding (HEVC) Main 10 profile Level 5.1 and process Hybrid Log-Gamma (HLG10) or Perceptual Quantizer (PQ10)/HDR10 content using Rec. 2020 color space. The guidelines consider Rec. 2100 1080p content with wide color gamut (BT.2020) and high dynamic range as Ultra HD service.

The guidelines also document live and pre-recorded production, as well as the combination of HDR and SDR video content and conversion between BT.709 and BT.2020 color spaces and different HDR metadata formats. Broadcasters are advised to provide backward compatibility by using HLG10 with BT.2020 color space, or simulcasting PQ10 or HDR10 streams.

4K UHD Phase B

Candidate technologies to be included in UHD Phase B, which is targeting UHD services launching in 2018-2020, include:

- Next Generation audio codecs supporting multiple audio objects (Dolby AC-4, DTS:X, MPEG-H 3D Audio);
- Scalable Video Coding to encode spatial (resolutions 1080p and 2160p), temporal (different frame rates), color gamut (BT.709 and BT.2020), and dynamic range (SDR and HDR) differences to provide backward-compatible video signal within a single program stream;
- 12-bit color depth;
- High Frame Rates greater than 50/60 fps;
- 8K UHD resolution;
- Dynamic HDR metadata for per-scene coding (SMPTE ST 2094 Dynamic Metadata for Color Volume Transform);
- Single-layer HDR (SL-HDR1);
- Dual-layer HDR (Dolby Vision);
- ICTp color encoding;
- Color Remapping Information (CRI).

8K UHD (Japan: Super Hi-Vision)

- Number of pixels: 7680x4320, uncompressed video bit rate: 144 Gb/s,
- Aspect ratio: 16:9, Viewing distance: 0.75 H, Viewing angle: 100°
- Colorimetry: Rec. 2020, Frame rate: 120 Hz progressive, Bit depth: 12-bits per color RGB
- Audio system: 22.2 surround sound, Sampling rate: 48/96 kHz, Bit length: 16/20/24-bit, Number of channels: 24 ch
- Upper layer: 9 ch, Middle layer: 10 ch, Lower layer: 3 ch, LFE: 2 ch

High Dynamic Range

ITU-R Recommendation BT.2100, more commonly known Rec. 2100 or BT.2100, defines various aspects of high dynamic range (HDR) video such as display resolution (HDTV and UHDTV), frame rate, chroma subsampling, bit depth, color-space, and optical transfer function. It was posted on the International Telecommunication Union (ITU) website on July 4, 2016 (HDR video) describing video having a dynamic range greater than that of standard dynamic range video (SDR video), which uses a conventional gamma curve. SDR video, when using a conventional gamma curve and a bit depth of 8-bits per sample, has a dynamic range of about 6 F-stops (64:1). When HDR content is displayed on a 2,000 cd/m2 display with a bit depth of 10-bits per sample it has a dynamic range of 200,000:1 or 17.6 F-stops, a range not offered by the majority of current displays.

Perceptual Quantizer (PQ), SMPTE ST 2084

is a transfer function that allows for the display of high dynamic range (HDR) video with a luminance level of up to 10,000 cd/m2 and can be used with the Rec. 2020 color space. PQ is a nonlinear electro-optical transfer function (EOTF). On April 18, 2016, the Ultra HD Forum announced industry guidelines for UHD Phase A which uses Hybrid Log-Gamma (HLG) and PQ transfer functions with a bit depth of 10-bits and the Rec. 2020 color space.] On July 6, 2016, the ITU announced Rec. 2100 which uses HLG or PQ as transfer functions with a Rec. 2020 color space.

HDR10 Media Profile

More commonly known as HDR10, was announced on August 27, 2015, by the Consumer Technology Association and which uses the wide-gamut Rec. 2020 color space, a bit depth of 10-bits, and the SMPTE ST 2084 (PQ) transfer function – a combination later also standardized in ITU-R BT.2100. It also uses SMPTE ST 2086 "Mastering Display Color Volume" static metadata to send color calibration data of the mastering display, as well as MaxFALL (Maximum Frame Average Light Level) and MaxCLL (Maximum Content Light Level) static values, encoded as SEI messages within the video stream. HDR10 is an open standard supported by a wide variety of companies, which includes monitor and TV manufacturers such as Dell, LG, Samsung, Sharp, Sony and Vizio, as well as Microsoft and Sony Interactive Entertainment, which support HDR10 on their PlayStation 4 and Xbox One S video game console platforms.

HDR10+

Also known as HDR10 Plus, was announced on April 20, 2017, by Samsung and Amazon Video. HDR10+ updates HDR10 by adding dynamic metadata which is based on Samsung application SMPTE ST 2094-40. The dynamic metadata is additional data that can be used to more accurately adjust brightness levels on a scene-by-scene or frame-by-frame basis. HDR10+ is an open standard and is royalty-free; it is supported by Colorfront's Transcoder and MulticoreWare's x265. HDR10+ video will be offered by Amazon Video later in 2017.



Dolby Vision

Is an HDR format from Dolby Laboratories that can be optionally supported by Ultra HD Blu-ray discs and streaming video services. Dolby Vision is a proprietary format and Dolby SVP of Business Giles Baker has stated that the royalty cost for Dolby Vision is less than \$3 per TV. Dolby Vision includes the Perceptual Quantizer (SMPTE ST 2084) electro-optical transfer function, up to 4K resolution, and a wide-gamut color space (ITU-R Rec. 2020). The main two differences from HDR10 are that Dolby Vision has a 12-bit color depth and dynamic metadata. The color depth allows up to 10,000-nit maximum brightness (mastered to 4,000-nit in practice). It can encode mastering display colorimetry information using static metadata (SMPTE ST 2086) but also provide dynamic metadata (SMPTE ST 2094-10, Dolby format) for each scene. Examples of Ultra HD (UHD) TVs that support Dolby Vision include LG TCL, and Vizio, although their displays are only capable of 10-bit color and 800 to 1000 nits (800 – 1000 cd/m2) luminance.

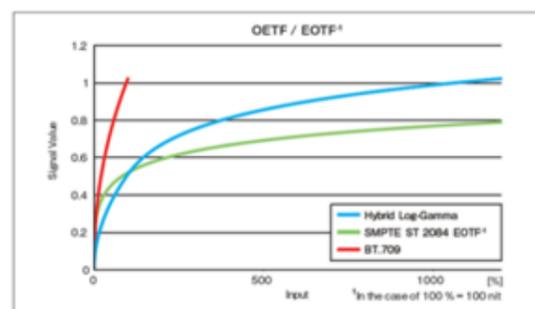
DMCVT (Dynamic Metadata for Color Volume Transform) SMPTE ST 2094-1:2016

DYNAMIC TONE MAPPING - Six parts. Carried in HEVC SEI, ETSI TS 103 433, CTA 861-G.

Standardizes HDR color transform technologies from Dolby (Parametric Tone Mapping), Philips (Parameter-based Color Volume Reconstruction), Technicolor (Reference-based Color Volume Remapping), Samsung (Scene-based Color Volume Mapping), and 80 other participating companies. Can preserve the creative intent in HDR media across a variety of displays, carried in files, video streams, packaged media. Standardized in SMPTE ST 2094.

Hybrid Log-Gamma (HLG)

Is an HDR standard that was jointly developed by the BBC and NHK. HLG defines a nonlinear electro-optical transfer function (EOTF) in which the lower half of the signal values use a gamma curve and the upper half of the signal values use a logarithmic curve. The HLG standard is royalty-free and is compatible with SDR displays. HLG is supported by ATSC 3.0, Digital Video Broadcasting (DVB) UHD-1 Phase 2, HDMI 2.0b, HEVC, and VP9. HLG is supported by video services such as Freeview Play and YouTube.



SL HDR-1

Is an HDR standard that was jointly developed by STMicroelectronics, Philips International B.V., CableLabs and Technicolor R&D France. It was standardized as ETSI TS 103 433 in August 2016. [64] SL-HDR1 provides direct backwards compatibility by using static (SMPTE ST 2086) and dynamic metadata (using SMPTE ST 2094-20 Philips and ST 2094-30 Technicolor formats) to reconstruct a HDR signal from a SDR video stream which can be delivered using SDR distribution networks and services already in place. SL-HDR1 allows for HDR rendering on HDR devices and SDR rendering on SDR devices using a single layer video stream.

Wide Color Gamut ITU-R Recommendation

BT.2020/BT.2100

More commonly known by the abbreviations Rec. 2020 or BT.2020, defines various aspects of ultra-high-definition television (UHDTV) with standard dynamic range (SDR) and wide color gamut (WCG), including picture resolutions, frame rates with progressive scan, bit depths, color primaries, RGB and luma-chroma color representations, chroma subsamplings, and an opto-electronic transfer function.

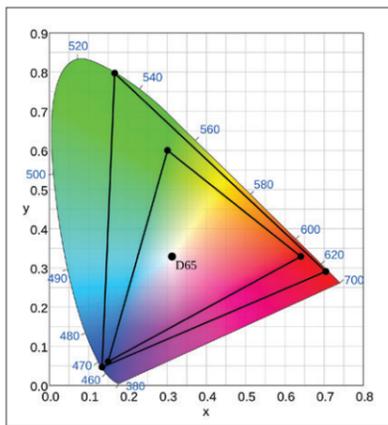
The first version of Rec. 2020 was posted on the ITU website on August 23, 2012.

REC 2100 has same color space as REC2020

- It defines three resolutions 1080p, 3840x2160 (4K UHD) and 7680x4320 (8K UHD).
- Only progressive frame rates from 25p/24/23.976p through 120p/119.88p.
- Color Depth of 10 or 12 bits per sample

Illuminant D65

- Represents a black body radiator at 6500 degrees Kelvin. It is a careful approximation of daylight with an overcast sky.



4K UHD Video Compression

H.265 / MPEG-HEVC

High Efficiency Video Coding (HEVC), also known as H.265, is a new video compression standard, developed by the Joint Collaborative Team on Video Coding (JCT-VC). The JCT-VC is a single standard that is approved by two standards bodies;

- ITU-T Study Group 16 – Video Coding Experts Group (VCEG) – publishes the H.265 standard as ITU-T H.265 ; and
- ISO/IEC JTC 1/SC 29/WG 11 Motion Picture Experts Group (MPEG) – publishes the HEVC standard as ISO/IEC 23008-2.

The initial version of the H.265/HEVC standard was ratified in January, 2013. HEVC was developed with the goal of providing twice the compression efficiency of the previous standard, H.264 / AVC. Although compression efficiency results vary depending on the type of content and the encoder settings, at typical consumer video distribution bit rates HEVC is typically able to compress video twice as efficiently as AVC. Endusers can take advantage of improved compression efficiency in one of two ways (or some combination of both).

At an identical level of visual quality, HEVC enables video to be compressed to a file that is about half the size (or half the bit rate) of AVC, or when compressed to the same file size or bit rate as AVC, HEVC delivers significantly better visual quality. See also SHVC

H.264 / MPEG-4 Part 10, Advanced Video Coding (MPEG-4 AVC)

This is a block-oriented motion-compensation-based video compression standard. As of 2014 it is one of the most commonly used formats for the recording, compression and distribution of video content. It supports resolutions up to 4096x2304, including 4K UHD and 4K DCI.

H.264 was developed by the ITU-T Video Coding Experts Group (VCEG) together with the ISO/IEC JTC1 Moving Picture Experts Group (MPEG). The project partnership effort is known as the Joint Video Team (JVT). The ITU-T H.264 standard and the ISO/IEC MPEG-4 AVC standard (formally, ISO/IEC 14496-10 – MPEG-4 Part 10, Advanced Video Coding) are jointly maintained so that they have identical technical content.

The final drafting work on the first version of the standard was completed in May 2003, and various extensions of its capabilities have been added in subsequent editions. High Efficiency Video Coding (HEVC), a.k.a. H.265 and MPEG-H Part 2 is a successor to H.264/MPEG-4 AVC developed by the same organizations, while earlier standards are still in common use.

The intent of the H.264/AVC project was to create a standard capable of providing good video quality at substantially lower bit rates than previous standards (i.e., half or less the bit rate of MPEG-2, H.263, or MPEG-4 Part 2), without increasing the complexity of design so much that it would be impractical or excessively expensive to implement. An additional goal was to provide enough flexibility to allow the standard to be applied to a wide variety of applications on a wide variety of networks and systems, including low and high bit rates, low and high resolution video, broadcast, DVD storage, RTP/IP packet networks and ITU-T multimedia telephony systems.

TICO (Tiny COdec) compression – SMPTE:RDD 35:2016

Visually lossless light-weight compression. This technology uses minimal hardware (FPGA, ASIC) , software (CPU), robust for real-time operation with low latency.



- Mapped onto RTP
- Visually lossless up to 4:1.
- Latency: Few microseconds – very few lines of pixels (selectable from 1 to x)
- Small complexity and ultra-compact codec: easy to implement in low-cost FPGA or ASIC.
- Powerful, real-time or faster than real-time in CPU
- Compatible with different resolutions, from mobile to 4K/8K UHD, via multiple usual transport schemes.
- Code, hardware IP-cores and software libraries are licensable from intoPIX

JPEG 2000 (JP2K) ISO/IEC 15444-1:2016 MIME types are defined in ietf RFC 3745

Created by the Joint Photographic Experts Group committee in 2000 with the intention of superseding their original discrete cosine transform-based JPEG standard (created in 1992) with a newly designed, wavelet-based method.



License-free, improved compression efficiency, mathematically lossless compression, graceful degradation, scalability, robust transmission, easy post-production, region of interest (ROI), low latency, constant quality through multiple generations. Available in FPGA - intoPIX JPEG 2000 encoding and decoding IP-cores

NDI (Network Device Interface)

(NDI®) is a royalty-free compression system developed by NewTek to enable video-compatible products to communicate, deliver and receive broadcast quality video in a high quality, low latency manner that is frame-accurate and suitable for switching in a live production environment. A free code library and examples available for Windows, Linux and macOS. NDI has also been ported to iOS, Android, Raspberry Pi, and FPGA. There is also a range of free NDI tools for end users provided by NewTek, Sienna, VMix and others

VC2 (Dirac) SMPTE 2042-1:2012 (-2:2017, -3:2010, -4:2016)

Dirac is an open and royalty-free video compression format, specification and system developed by BBC Research & Development, Schrödinger and Dirac-research (formerly just called "Dirac") are open and royalty-free software implementations of Dirac. This format aims to provide high-quality video compression for Ultra HDTV and beyond, and as such competes with existing formats such as H.264 and VC-1. The specification was finalized in January 2008, and further developments are only bug fixes and constraints. In September of that year, version 1.0.0 of an I-frame only subset known as Dirac Pro was released

Future Standards

JPEG XS – project ISO/IEC 21122-(1,2,3,4,5). (JPEG XS)

A low-latency lightweight image coding system allows for an increased resolution and frame rate, while offering visually lossless quality with reduced amount of resources such as power and bandwidth at a reasonable level. The upcoming JPEG XS standard will offer a low-latency lightweight image coding system that is able to support increasing resolution (such as 8K UHD) and frame rate in a cost effective manner



- Pt1 Core coding system
- Pt2 Profiles and buffer models
- Pt3 Transport and container formats
- Pt4 Conformance testing
- Pt5 Reference software

AV1 (AOMedia Video 1)

An open, royalty-free video coding format designed for video transmissions over the Internet. It is being developed by the Alliance for Open Media (AOMedia), a consortium of firms from the semiconductor industry and video-on-demand providers. Extended from VP9/Daala/Thor. Containers Matroska, WebM, ISO BMFF, RTP (WebRTC). Intent that AV1 to be released late 2017 and will only be released when it can demonstrate a 20% improvement over HEVC. Founding members are Amazon, Apple, ARM, Cisco, Facebook, Google, IBM, Intel, Microsoft, Mozilla, Netflix and NVIDIA



Streaming Protocols

RTSP, RTP, RTCP

Were specifically designed to stream media over networks. RTSP runs over a variety of transport protocols, while the latter two are built on top of UDP. All operate on different ports. Usually when RTP is on port N, RTCP is on port N+1. An RTP session may contain multiple streams to be combined at the receiver's end; for example, audio and video may be on separate channels. UDP URLs aren't widely supported by browsers, so a plug-in is needed to do RTP/UDP streaming to a browser. Flash is the one that's most commonly used. RTP is also used by standalone players such as RealPlayer, Windows Media Player and QuickTime Player.

HDS (HTTP Dynamic Streaming)

Adobe's method for adaptive bitrate streaming for Flash Video. This method enables on-demand and live adaptive bitrate video delivery of MP4 media over regular HTTP connections.

HLS – (HTTP Live Steaming). (Used in Apple QT)

Is an HTTP-based media streaming communications protocol implemented by Apple Inc. as part of its QuickTime, Safari, OS X and iOS software.

MPEG DASH – (Dynamic Adaptive Streaming over HTTP) – using TCP

Is an adaptive bitrate streaming technique that enables high quality streaming of media content over the Internet delivered from conventional HTTP web servers. MPEG-DASH client can seamlessly adapt to changing network conditions and provide high quality playback with fewer stalls or re-buffering events.

RTMP (not supported on iOS)

Real Time Messaging Protocol (RTMP) is a proprietary protocol used primarily by Flash, but implemented by some other software as well. Adobe has released a specification for it, but it's incomplete in some important respects. It's usually used over TCP, though this isn't a requirement.

HTML5

HTML5 provides the <audio> and <video> tags, along with DOM properties that allow JavaScript to control the playing of the content that these elements specify. This is an application-layer protocol only, with no definition of the lower layers. HTML5 implementations can specify formats which they process. The server is expected to download the content progressively, and it will keep downloading it completely even if paused, unless the browser completely eliminates the element. The Web Audio API allows detailed programmatic control of playback.

Containers (wrappers)

A metafile format whose specification describes how different elements of data and metadata coexist in a computer file:

- AIFF (IFF file format, widely used on Mac OS platform)
- ASF (container for Microsoft WMA and WMV, which today usually do not use a container)
- AVI (the standard Microsoft Windows container, also based on RIFF)
- Flash Video (FLV, F4V) (container for video and audio from Adobe Systems)
- IFF (first platform-independent container format)
- MJ2 - Motion JPEG 2000 file format, based on the ISO base media file format which is defined in MPEG-4 Part 12 and JPEG 2000 Part 12
- MOV QuickTime File Format (standard QuickTime video container from Apple Inc.)
- MPEG-2 transport stream (a.k.a. MPEG-TS) (standard container for digital broadcasting)
- MP4 (standard audio and video container for the MPEG-4 multimedia portfolio, based on the ISO base media file format defined in MPEG-4 Part 12 and JPEG 2000 Part 12) which in turn was based on the QuickTime file format.
- MXF SMPTE 377M, SMPTE 390M: OP-Atom, SMPTE 378M: OP-1a
 - SMPTE 383M: GC-DV (how to store DV essence data in MXF using the Generic Container)
 - SMPTE 385M: GC-CP (how to store SDTI-CP essence data in MXF using the Generic Container)
 - SMPTE 386M: GC-D10 (how to store SMPTE D10 essence data in MXF using the Generic Container)
 - SMPTE 387M: GC-D11 (how to store SMPTE D11 essence data in MXF using the Generic Container)
 - SMPTE 382M: GC-AESBWF (how to store AES/EBU and Broadcast Wave audio essence data in MXF using Generic Container)
 - SMPTE 384M: GC-UP (how to store Uncompressed Picture essence data in MXF using the Generic Container)
- GXF SMPTE 360M. extended SMPTE RDD 14-2007 (HD resolutions) A simple data model (compared with MXF) primarily used for file transfers.
- XMF (Extensible Music Format) 3GP (used by many mobile phones; based on the ISO base media file format)
- WAV (RIFF file format, widely used on Windows platform)

Interfaces

12 Gb 4K UHD Coax

Belden 4794R (type7) 0.32" dia, RL 15db, 64 db/100m
Belden 4855R (RG-59) 0.159" dia, RL 15 db, 135 db/100m (mini)



Formula	-30 dB at 1/2 clock	-20 dB at 1/2 clock	-40 dB at 1/2 clock	-40 dB at 1/2 clock	-40 dB at 1/2 clock
Data Rate	270 Mb/s	3.0 Gb/s	3.0 Gb/s	6.0 Gb/s	12.0 Gb/s
SMPTE Spec	ST 259	ST 424	ST 425	ST 2081-1	ST 2082-1
Application	Component SD-SDI	HD 3G-SDI	UHDTV1	UHDTV1, UHDTV2	UHDTV1, UHDTV2
Cable Part #	4794R	4794R	4794R	4794R	4794R
Feet (meters)	1.716 (523)	329 (100)	659 (201)	449 (137)	306 (93)

IC Drivers – Cable Length (Semtech GS12241 driver specification)

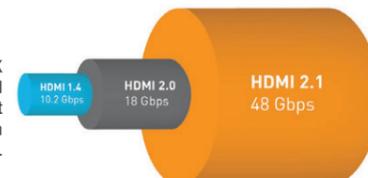
12 Gb ~ 80m. 6 Gb ~ 100m. 3 Gb ~ 200m. 1.5 Gb ~ 200m. 270 Mb ~ 400m.

Connectors BNC 12 GHz

Belden 4794RBUHD1 Series7 (1 piece compression) 75 ohm 4794R
Belden 4794RBUHD3 Series7 (3 piece crimp) 75 ohm 4794R
Cambridge XBT-1068-RGBD 75 ohm optimized 4K UHD Belden 4694R, 4794R
Amphenol 031-70534 75 ohm optimized 4K UHD Belden 1794A, 4794R
Amphenol 031-70537 75 ohm optimized 12G Belden 4855R, 1855A

HDMI 1.4 (High-Definition Multimedia Interface)

Is used on 4K UHD television sets and is the closest thing to a consumer standard for 4K UHD signals available right now. The main limitation of HDMI 1.4 is bandwidth, as HDMI 1.4 is only able to handle 8-bit color at 24p or 30p. This is suitable for most situations, but 8-bit color is limiting for proper color correction. Also, HDMI is notoriously finicky when being used with switchers, distribution amplifiers, or any other similar types of devices. For this reason, there are no converter boxes that convert HDMI 1.4 to other signals.



HDMI 2.0

New HDMI standard. It supports up to 18 Gb/s of bandwidth and allows for higher frame rates and bit depths than HDMI 1.4. HDMI 2.0 supports 12-bit color at up to a 60p. It is also backwards compatible with HDMI 1.4 cables. HDMI 2.0 4K UHD TV sets aren't on the market yet, but some current HDMI 1.4 4K UHD sets should receive a firmware update to support HDMI 2.0. Like HDMI 1.4, HDMI 2.0 will most likely be hard to use with switchers and other forms of signal distribution, but could be a good option for post equipment since it supports a higher bandwidth than even Quad-Link 3G-SDI.

HDMI 2.1

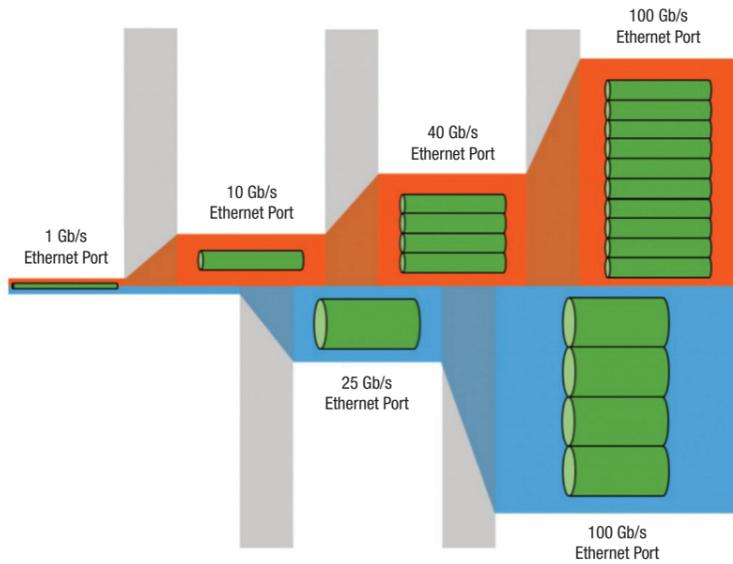
It supports a range of higher video resolutions and refresh rates including 8Kp60 and 4Kp120, dynamic HDR, and increased bandwidth with a new 48G cable. Version 2.1 of the HDMI specification is backward compatible with earlier versions of the specification.

- Higher video resolution 4K120p & 8K60p
- HDR and wide color gamut
- 48 Gb support backward compatible
- eARC advanced audio formats (object based audio), device audio detect
- Game mode VPR features (variable refresh rate/3D graphics)

HDBaseT (IEEE 1911)

A consumer electronic (CE) and commercial connectivity standard for transmission of uncompressed high-definition video (HD), audio, power (up to 100W/100m), home networking, Ethernet, USB, and some control signals, over a common category cable (Cat5e or above) using the same 8P8C modular connectors used by Ethernet. The five elements also known as "5Play." Ref HDBT Alliance www.hdbaset.org.

IP Connectivity "25 is the new 10, 100 is the new 40"



40 GbE and 100 GbE Optics

The IEEE introduced the 802.3ba Ethernet standard in June 2010 in response to the increasing bandwidth demands facing data centers, paving the way for the introduction of 40 Gb/s and 100 Gb/s Ethernet operations. Just a few years later, users of this technology are still relatively isolated but continue to increase as network operators need the highest data rates over a single connection. As you begin to think about the future of your network, understanding all the 40 GbE and 100 GbE optical components can be confusing. Curvature has put together a brief overview of the current 40 GbE and 100 GbE optics types and form factors to aid in planning for future high-performance Ethernet needs.

40GBase-SR4

40GBase-SR4 optics use a single MPO ribbon cable for both transmit and receive, as SR4 uses four strands for transmit and four strands for receive. Maximum distance depends on the type of multimode fiber used. 850 nm MMF (OM3) 30m, MMF (OM4) 100m.

100GBase-SR10

100GBase-SR10 optics use a 24 strand MPO cable for connectivity: ten strands for transmit and ten strands for receive. Because each individual lane uses the same laser type as 40GBase-SR4, maximum distances are identical. MMF/OM3 100m. MMF/OM4 150m.

100GBase-SR4

100GBase-SR4 optics use 4 fibers for transmit and 4 for receive, with each lane providing 25 Gb/s of throughput. 100GBase-SR4, like 40GBase-SR4, uses a 12 fiber MPO cable with 4 strands for transmit and 4 for receive, allowing for existing 40GBase-SR4 fiber assemblies to be reused when higher performance is needed. This interface standard has been introduced alongside the 100 Gb/s QSFP offerings now arriving on the market in order to make any 40 GbE to 100 GbE upgrade as seamless as possible.

40GBase-LR4

40GBase-LR4 optics uses the same multilane technology as SR4 optics, with one exception. Instead of using a single fiber strand for each lane, WDM technology is used to multiplex all four transmit lanes onto one strand of fiber and all four receive lanes onto another single strand of fiber, allowing any existing single-mode fiber installation to be used. Because of this, standard LC (for QSFP modules) or SC (for CFP modules) connections are used, allowing for an easy upgrade from a 10 GbE connection. Typ 4lanes 1271, 1291, 1311, 1331 nm. Tx 2.3 dBm, Rx -13.7 dBm min. SMF 10km

100GBase-LR4

Like 40GBase-LR4, the 100GBase-LR4 is a multilane optic. However, each lane's data rate is increased to 25 Gb/s to achieve the full 100 Gb/s data rate. Typ 4lanes, 1295.6, 1300.1, 1304.6, 1309.1 nm. Tx 4.5 dBm max, Rx -10.5 dBm min. SMF 10 km.

Module Types

AOC (active optical cables)

Plugs into standard optical module sockets. They have the optical electronics already connected eliminating the connectors between the cable and the optical module. They are lower cost than other optical solutions because the manufacturer can match the electronics to the required length and type of cable.

SFP "Small Form-factor Pluggable"

A compact hot-pluggable optical module transceiver supporting communication over optical cabling up to 4.25 Gb/s (depending on model).

SFP+

Enhanced version of the SFP that supports data rates up to 16 Gb/s.



SFP28 Support for 25G Gigabit Ethernet or 25GBASE-T standard

Before the 25GBASE-T standard, the Ethernet speed upgrade path was defined as 10G - 40G - 100G. The advent of SFP28 provides a new way for server connections: 10G - 25G - 40G - 100G.

QSFP+ 4x10 Gb/s

Cable is electrically compliant with the SFP+ interface supporting InfiniBand, Ethernet, Fiber Channel and other applications. The QSFP+ connector includes 4-Channel full-duplex active optical cable transceiver. Min bend radius (typ) 15xDIA - Dynamic 10xDIA - Static, 4Lanes bidi, 10.5 Gb/s / ch max, 850nm wavelength. Ethernet 40G Base SR4. Multimode up to 300m (LR ~10 km).

QSFP28 4x28 Gb/s

Used with direct-attach breakout cables to adapt a single 100 GbE port to four independent 25 gigabit Ethernet ports (QSFP28-to-4x-SFP28). Sometimes this transceiver type is also referred to as "QSFP100" or "100G QSFP"

QSFP56 200 Gb 4x50 Gb/s

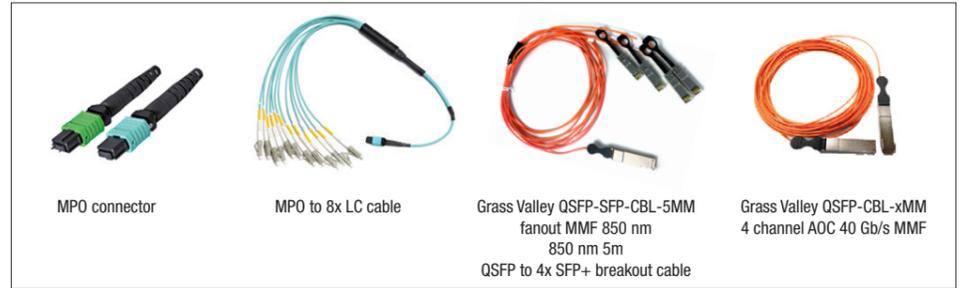
QSFP56 family will initially include an FR4 version supporting 2 km reaches and an LR4 version for 10 km reaches, both operating over single-mode fiber. Initial 4x50G PAM4 electrical and optical interfaces, and is intended to work in conjunction with the next generation of switching silicon, enabling 6.4 Tb/s in single rack unit (RU) configuration. Initial demo to feature an LR4 module designed for 10 km reaches per the IEEE's 200GBASE-LR4 standard (Ref Finstar.)

QSFP-DD 200 Gb/400 Gb

Double density QSFP optical transceiver. The new QSFP-DD group plans to specify eight lanes that operate at up to 25 Gb/s via NRZ modulation or 50 Gb/s via PAM4 modulation, which would support optical transmission of 200 Gb/s or 400 Gb/s aggregate. (group = Broadcom, Brocade, Cisco, Finisar, Foxconn Interconnect Technology, Intel, Juniper Networks, Lumentum, Luxtera, Mellanox Technologies, Molex, Oclaro and TE Connectivity).

Converters and Breakout Cables

Most 40 GbE ports are capable of running in a 4x 10 GbE mode, allowing for easy 10 GbE/40 GbE mixed media deployments. These ports can also provide the option of ultra-high 10 GbE port density (for example, a Nexus 3016 can be configured to present 64 total 10 GbE ports, which is more than what can fit in 1 RU when presented as SFP+ ports). For QSFP based systems, this is accomplished using either a special direct attach cable with 1x QSFP on one end and 4x SFP+ on the other end, or an SR4 optic with a custom MPO to 8x LC cable. For Cisco products that use CFP-based 40 GbE, such as the WS-X6904-40G parts, Cisco makes the CVR-CFP-4SFP10G converter that changes the CFP slot into four SFP+ slots.

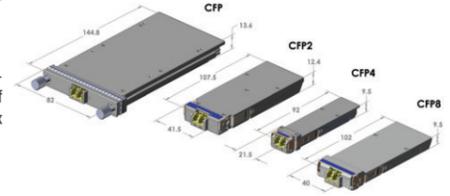


CFP

CFP form factor optics is available in 40 GbE and 100 GbE varieties. These present MPO connectors for multi-mode optics or SC connectors for singlemode optics. The CFP Multi-Source Agreement (MSA) defines hot-pluggable optical transceiver form factors to enable 40 Gb/s, 100 Gb/s and 400 Gb/s applications, including next-generation High Speed Ethernet (40 GbE, 100 GbE and 400 GbE)

CFP2, 4, 8

The CFP2,4,8 is an evolution of the existing CFP form factor, using manufacturing and optics advances to reduce the size of the module to approximately half that of the original CFP, allowing for higher interface density. CFP2 16 lanes x 25 Gb, 8x 50 Gb, 4x 100 Gb.



CPAK

The CPAK is a Cisco-proprietary form factor developed in order to provide a more power and space-efficient 100 GbE optic compared to the CFP or CFP2 modules, especially for long reach optics such as 100GBase-LR4.

Cabling Considerations

Current multimode optics standards for 40 GbE and 100 GbE optics use multiple 10 Gb/s lasers, simultaneously transmitting across multiple fiber strands to achieve high data rates. Because of the multilane nature of these optics, both 40 GbE and 100 GbE multi-mode optics use a different style of fiber cabling, known as MPO or MTP cabling. An MPO/MTP cable presents 12 separate strands of multimode fiber in a single ribbon cable. As with 10 GbE optics over multimode fiber, an OM3 or OM4 grade MMF is needed to be able to cover longer distances (up to 150m). Typical distances @ 10GBase-SR OM1=33m, OM2=82m, OM3=300m, OM4=400m / @ 40GBase-SR4 OM1=NA, OM2=NA, OM3=100m, OM4=150m.

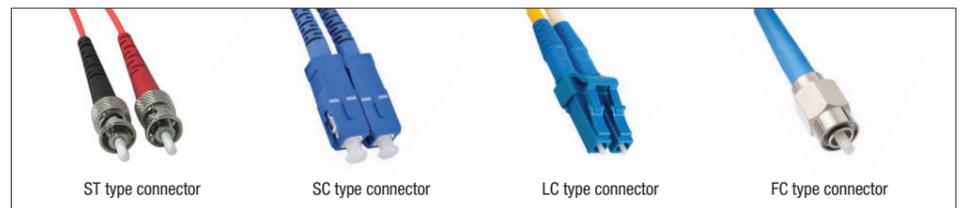
Multimode Optics

Multimode fiber gives you high bandwidth at high speeds (100 Mbit/s for distances up to 2 km (100BASE-FX), 1 Gb/s up to 1 km and 10 Gb/s up to 550m). Light waves are dispersed into numerous paths, or modes, as they travel through the cable's core typically 850 or 1300 nm. Typical multimode fiber core diameters are 50, 62.5 and 100 micrometers. However, in long cable runs (greater than 914.4 meters (3,000 feet), there is a potential for signal distortion at the receiving end.

Single-mode Optics

A single strand (most applications use 2 fibers) of glass fiber with a diameter of 8.3 to 10 microns that has one mode of transmission. Single mode fiber with a relatively narrow diameter, through which only one mode will propagate typically 1310 or 1550 nm. Single-mode carries higher bandwidth than multimode fiber, but requires a light source with a narrow spectral width. Also called mono-mode optical fiber, single-mode fiber, uni-mode fiber.

Fiber Connectors



Terminology – Networks

Boundary Clock

Terminates the PTP connection from the Master/Server and creates a new PTP connection towards the Slave Client.

Datagram

A self-contained, independent entity of data carrying sufficient information to be routed from the source to the destination computer without reliance on earlier exchanges between this source and destination computer and the transporting network.

HBRMT

High Bitrate Media Transport. Typically uncompressed video streams.

HTML5 Hypertext Markup Language (Fifth and current version of HTML standard – pub 2014/W3C)

Is the code that describes web pages. Typically, three kinds of code: HTML, which provides the structure; Cascading Style Sheets (CSS), which take care of presentation; and JavaScript, which makes things happen. HTML5 includes HTML 4, XHTML 1 and DOM Level 2 HTML

IGMP Internet Group Management Protocol

A communications protocol used by hosts and adjacent routers on IPv4 networks to establish multicast group memberships. IGMP is an integral part of IP multicast. IGMP can be used for one-to-many networking applications such as online streaming video and gaming, and allows more efficient use of resources when supporting these types of applications. IGMP is used on IPv4 networks. Multicast management on IPv6 networks is handled by Multicast Listener Discovery (MLD) which is a part of ICMPv6 in contrast to IGMP's bare IP encapsulation.

IGMP V3

Internet Group Management Protocol communications protocol used by clients & adjacent routers on IPv4 networks to establish multicast group memberships.

IGMP Snooping

The process of listening to Internet Group Management Protocol (IGMP) network traffic. The feature allows a network switch to listen in on the IGMP conversation between hosts and routers. By listening to these conversations the switch maintains a map of which links need which IP multicast streams. Multicasts may be filtered from the links which do not need them and thus controls which ports receive specific multicast traffic. IGMP snooping is a layer 2 optimization for the layer 3 IGMP.

IP Flow

These attributes are the IP packet identity or fingerprint of the packet and determine if the packet is unique or similar to other packets. Traditionally, an IP flow is based on a set of 5 and up to 7 IP packet attributes. IP Packet attributes used by NetFlow: • IP source address.

IP Multicast

Provides a means to send a single media stream to a group of recipients on a computer network. A multicast protocol, usually Internet Group Management Protocol, is used to manage delivery of multicast streams to the groups of recipients on a LAN. One of the challenges in deploying IP multicast is that routers and firewalls between LANs must allow the passage of packets destined to multicast groups.

IP Stream

An individual flow of media and/or FEC datagrams on an IP network.

Media Datagram

RTP Datagram consisting of the RTP header and the media data payload. The media data payload is composed of a Payload Header and a Media Payload.

Media Payload

Raw data (video, audio, anc data) that are transmitted from the sender. The payload header and the media payload are placed inside of a media datagram.

MPLS

Multiprotocol Label Switching is a protocol for speeding up and shaping network traffic flows. MPLS allows most packets to be forwarded at Layer 2 (the switching level) rather than having to be passed up to Layer 3 (the routing level).

Netflow/IPFIX

A flow is any number of packets observed in a specific timeslot and sharing a number of properties, e.g., "same source, same destination, same protocol." Using IPFIX, devices like routers can inform a central monitoring station about their view of a potentially larger network. IPFIX is a push protocol, i.e., each sender will periodically send IPFIX messages to configured receivers without any interaction by the receiver.

PIM-SSM. (Protocol Independent Multicast – Source Specific Multicast)

PIM source-specific multicast (SSM) uses a subset of PIM sparse mode and IGMP version 3 (IGMPv3) to allow a client to receive multicast traffic directly from the source. By default, the SSM group multicast address is limited to the IP address range from 232.0.0.0 through 232.255.255.255.

PTP. (Precision Time Protocol) IEEE 1588-2008

A protocol used to synchronize clocks throughout a computer network. It can achieve clock accuracy in the submicrosecond range, making it suitable for measurement and control systems.

TCP/IP

(Transmission Control Protocol / Internet Protocol), is the suite of communications protocols used to connect hosts on the internet. TCP/IP uses several protocols, the two main ones being TCP and IP. TCP provides a bidirectional connection and a guarantee of delivery.

Transparent Clock

Does not terminate the PTP connection. Minimize the information degradation (e.g., PDV) that its own network element causes (by modifying the PTP packet as it flows through the network element).

UDP (User Datagram Protocol)

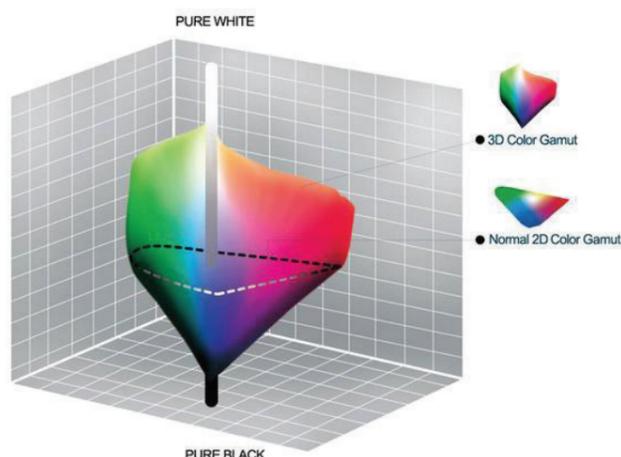
A connection-less protocol without a guarantee of delivery. Used primarily for establishing low-latency and loss tolerating connections between applications on the Internet.

Terminology Optical**Color Volume**

Includes all colors throughout the entire luminosity range - not just at one specifically defined level of luminance. It is represented by a three-dimensional graph (sometimes referred to as a "3D Color Gamut").

Color Depth

Also known as bit depth, is the number of total bits used to indicate the color of a single pixel (bpp), in a bit-mapped image or the number of bits used for each of the red, green and blue color components that make up a single pixel.

**Color Space**

Also referred as Color Model is a specific organization and representation of colors. The Color Model is an abstract mathematical model which simply describes the range of colors and represents them as tuples of numbers or color components (e.g., RGB).

Content-Dependent Metadata

Metadata that can vary dynamically throughout the source content.

Electro-Optical Transfer Function (EOTF)

A function that maps digital code value to displayed luminance (see also OETF).

High Dynamic Range System (HDR System)

System specified and designed for capturing, processing, and reproducing a scene, conveying the full range of perceptible shadow and highlight detail, with sufficient precision and acceptable artifacts, including sufficient separation of diffuse white and specular highlights

Luminance

Luminous intensity of a surface in a given direction, divided by the projected area of the surface element as viewed from that direction. Unit is candela per square meter (cd/m²). This is a simplified version of the SI definition. It is not to be confused with the term "luminance" in television and video to represent a quantity which may more precisely be referred to as "luma". 1 lx = 1 lm/m² = 1 cd-sr/m²

nit

A unit of visible-light intensity, commonly used to specify the brightness of a cathode ray tube or liquid crystal display computer display. One nit is equivalent to one candela per square meter. 1 nit = 1 cd/m²

Opto-Electronic Transfer Function (OETF)

A function that maps scene luminance to digital code value (see also EOTF).

Optical-Optical Transfer Function (OOTF)

A function that maps scene luminance to displayed luminance.

Peak Display Luminance

The highest luminance that a display can produce.

Scene-Referred

An attribute indicating that the image data represent the colorimetry of the elements of a scene.

Standard Dynamic Range (SDR)

A reference reproduction using a luminance range constrained by Recommendation ITU-R BT.2035 § 3.2 for video applications, or SMPTE RP 431 for cinema applications.

Tone Mapping

The mapping luminance values in one color volume to luminance values in another color volume.

Transfer Function

Is a single variable, monotonic, mathematical function applied individually to one or more color channels of a color space.

Wide Color Gamut (WCG)

Chromaticity gamut significantly larger than the chromaticity gamut defined by Recommendation ITU-R BT.709.

Terminology Digital Audio**AAC**

Advanced Audio Coding is a standardized, lossy compression and encoding scheme for digital audio. Designed to be the successor of the MP3 format, AAC generally achieves better sound quality than MP3 at similar bit rates.

AC-3

Audio Coding 3 is a 6-channel, audio file format by Dolby Laboratories that usually accompanies DVD viewing. It operates 5 channels for normal range speakers (20 to 20,000 Hz) and the 6th channel reserved for low-frequency (20 to 120 Hz) sub-woofer operation. AC3 increases fidelity over its previous surround sound standard, Pro-logic, with independent tracks for each of the 6 speakers, a 16-bit depth at 48 kHz sampling rate with a maximum bit rate of 640 Kb/s.

AES3

A digital audio interface which passes two digital audio channels, plus embedded clocking data, with up to 24 bits per sample and sample rates up to 384 kHz. Developed by the Audio Engineering Society and the European Broadcasting Union, it is often known as the AES-EBU interface. Standard AES3 is connected using 3-pin XLRs with a balanced cable of nominal 110 ohm impedance and with a signal voltage of up to 7V pk-pk. The related AES3-id format uses BNC connectors with unbalanced 75 ohm coaxial cables and a 1V pk-pk signal. In both cases the data stream is structured identically to S/PDIF, although some of the channel status codes are used differently.

AES10

An AES standard which defines the MAD1 interface (serial Multichannel Audio Digital Interface). MAD1 can convey either 56 or 64 channels via single coaxial or optical connections.

AES11

An AES standard that defines the use of a specific form of AES3 signal for clocking purposes. Also known as DARS (Digital Audio Reference Signal).

AES17

And AES standard that defines a method of evaluating the dynamic range performance of A-D and D-A converters.

AES42

An AES standard which defines the connectivity, powering, remote control and audio format of "digital microphones." The audio information is conveyed as AES3 data, while a bespoke modulated 10V phantom power supply conveys remote control and clocking information.

AES59

An AES standard which defines the use and pin-outs of 25-pin D-sub connectors for eight-channel balanced analogue audio and bidirectional eight-channel digital interfacing. It conforms fully with the established Tascam interface standard.

AES67 (Audio Engineering Society) AES67-2015

A standard (published 2013) to enable interoperable streaming of high-performance audio-over-IP between various IP based audio networking products currently based on existing standards such as Dante, Livewire, Q-LAN and Ravenna.

A-Weighting

An electrical filter which is designed to mimic the relative sensitivity of the human ear to different frequencies at low sound pressure levels (about 30 dBA SPL). Essentially, the filter rolls-off the low frequencies below about 700 Hz and the highs above about 10 kHz. This filtering is often used when making measurements of low-level sounds, like the noise floor of a device. (See also C-Weighting and K-Weighting.)

C-Weighting

An electrical filter which is designed to mimic the relative sensitivity of the human ear to different frequencies at high sound pressure levels (about 87 dBA SPL). The filter rolls-off the low frequencies below about 20 Hz and the highs above about 10 kHz. Typically used when making measurements of high-level sounds, such as when calibrating loudspeaker reference levels.

K-Weighting

An electrical filter which is designed to mimic the relative sensitivity of the human ear to different frequencies in terms of perceived loudness. It is broadly similar to the A-Weighting curve, except that it adds a shelf boost above 2 kHz. This filter is an integral element of the ITU-R BS.1770 loudness measurement algorithm. (See also A-Weighting and C-Weighting.)

DANTE

A form of audio-over-IP (layer 3) created by Australian company Audinate in 2006.

DAT

An abbreviation of Digital Audio Tape, but often used to refer to DAT recorders (more correctly known as R-DAT because they use a rotating head similar to a video recorder).

dB

The decibel is a method of expressing the ratio between two quantities in a logarithmic fashion. When one signal is being compared to a standard reference level the term is supplemented with a suffix letter representing the specific reference. 0 dBu implies a reference voltage of 0.775V rms, while 0dBV relates a reference voltage of 1.0V RMS.

DSDIFF

Direct Stream Digital Interchange File Format) - Format for the storage or exchange of one-bit delta sigma modulated audio, often called Direct Stream Digital, or for the lossless compressed version called Direct Stream Transfer (DST).

DST

Direct Stream Transfer is lossless compression; part of MPEG-4; used for SACD.

DTS

A series of multichannel audio technologies owned by DTS, Inc. (formerly known as Digital Theater Systems, Inc.). DTS supports bit rates up to 1534 Kb/s, sampling rates up to 48.0 KHz and bit depths up to 24 bits.

Dynamic Range

The ratio of the amplitude of the loudest possible undistorted sine wave to the root mean square (RMS) noise amplitude. The 16-bit compact disc has a theoretical dynamic range of about 96 dB (or about 98 dB for sinusoidal signals, per the formula). Digital audio with 20-bit digitization is theoretically capable of 120 dB dynamic range; similarly, 24-bit digital audio calculates to 144 dB dynamic range.

FLAC

Free Lossless Audio Codec is a codec (compressor-decompressor) which allows digital audio to be lossless compressed such that file size is reduced without any information being lost.

LPCM

Linear PCM is pulse-code modulation (PCM) with linear quantization.

LUFS

The standard measurement of loudness, as used on loudness meters corresponding to the ITU-TR BS1770 specification. The acronym stands for Loudness Units (relative to) Full Scale. Earlier versions of the specification used LKFS instead, and this label remains in use in America. The K refers to the "K-Weighting" filter used in the signal measurement process.

MADI

Multichannel Audio Digital Interface. Originally specified by the Audio Engineering Society (AES) as AES10 in 1991. This unidirectional digital audio interface shares the same core 24-bit audio and status data format as AES3, but with different "wrapping" to contain 56 or 64 synchronous channels at base sample rates, or 28 channels at 96 kHz. It can be conveyed over unbalanced coaxial cables, or via optical fibers.

MP3

MPEG-1 or MPEG-2 Audio Layer III is a patented encoding format for digital audio which uses a form of lossy data compression.

PCM

Pulse-code modulation is a method used to digitally represent sampled analog signals. It is the standard method of storing audio in computers and various Blu-ray, DVD and compact disc formats. PCM supports bit rates up to 1534 Kb/s, sampling rates up to 48.0 KHz, and bit depths up to 24 bits.

SPDIF

Sony/Philips Digital Interface. A stereo or dual-channel self-clocking digital interfacing standard employed by Sony and Philips in consumer digital hi-fi products. The S/PDIF signal is essentially identical in data format to the professional AES3 interface, and is available as either an unbalanced electrical interface (using phono connectors and 75 ohm coaxial cable), or as an optical interface called Toslink.

SPL

Sound pressure level. A measure of the intensity of an acoustic sound wave. Normally specified in terms of Pascals for an absolute value, or relative to the typical sensitivity of human hearing. One Pascal is 94 dB SPL, or to relate it to atmospheric pressures, 0.0001 Bar or 0.000145PSI.

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