Installing AV in New Age Collaboration Spaces
“How do I install a Collaboration Space”
Many Questions

- What TV?
- HDMI or VGA?
- USB?
- Control?
- Cables?
- Wireless?
- Do we dig a trench?
- Furniture?
- Room scheduling

- Audio
- Microphones
- Speakers
- Amplifiers
- Motion sensors
- Lights
- Cable paths
- Mounting Hardware
- VTC?
Collaboration Space Considerations
Keys to success in this Collaboration arena (three C’s)

- **Connectivity**
  - Cable Access
  - CATx, AV, Wireless, and USB

- **Conferencing Interface**
  - Zoom..Skype...your laptops or phones
  - Phone interface
  - VOIP

- **Control**
  - Simple
  - Push button
  - Motion sensor
  - Touchpanel with Interface
Basics of Installing

- Signal Integrity
  - Using Shielded CATx cable
  - HDMI and USB
- Table Power
- Conferencing Interface
  - ZOOM / Skype
- Wireless Video
- Audio
  - Usually using Speakers on Display
- Control
  - “people forget this all the time”
- Room Scheduling
Classrooms are Changing
Classroom
Classroom Equipment List

- Projectors /Displays
- Switchers
- Cables/UTP
- Wall Plates
- Audio /MICS /Speakers
- Control
- Wireless
Boardrooms are Changing
Huddle Room
Huddle Room Equipment List

- Cable Access Enclosure
- Two input HDMI Switcher
- Power and Device Control Processor
Huddle Room with Soft VTC
Huddle Room with VTC Equipment List

- Cable Access Enclosure
  - HDMI Male to Male
  - USB C Male to Male
  - Network Cable
- Workspace Controller
- Occupancy Sensor
- Video Conferencing Solutions
AV Technology Deployment

4 types
Hard Wired AV Infrastructure using CATx

- Wired AV connections offer benefits related to reliability
Wireless AV

- Wireless AV offers flexibility, mobility, and benefits for installations that have architectural challenges
AV Streaming

- Multiple platforms available for greater exposure
  - YouTube
  - Panopto
  - LMS

- Highly scalable with most AV and control signals existing on the same cable
AV over IP

- Audio
  - AES67
- Video
  - Codec
  - Compression
- Network
  - Layer 3 Protocols
  - Security
Agenda

- Displays
- Mounting Hardware
- Connectivity
  - HDMI
  - USB
- Source to Display
  - EDID
  - HDCP
- Cables and Cabling Standards
- Wireless
- Cable Paths
- Furniture
- Audio
- Room Automation
- Conference Room Interfaces
- Control
- Room Scheduling
- Designs
- AV over IP
Displays
Resolutions

- Old Resolutions
- New standard 1080p
- Headed to 4K/UHD and 8K
4K and Ultra HD Resolution Comparison

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>HD</td>
<td>1920x1080</td>
</tr>
<tr>
<td>UHD</td>
<td>3840x2160</td>
</tr>
<tr>
<td>4K</td>
<td>4096x2160</td>
</tr>
<tr>
<td>5K</td>
<td>5120x2880</td>
</tr>
<tr>
<td>8K</td>
<td>7680x4320</td>
</tr>
</tbody>
</table>
4K Signal Parameters

○ 4K DCI is 4096x2160
  — Four times the resolution of 2K DCI
  — Targeted towards digital cinema

○ 4K refresh rates
  — Varies – 24 Hz up to 60 Hz

○ Color bit depth
  — 8-Bit, 10-bit, and 12-bit

○ Aspect Ratio
  — 17:9 – same as 2K
Ultra HD Video Signal Parameters

○ Ultra HD is 3840x2160
  – Four times the resolution of 1080p
  – Targeted towards consumer and broadcast markets

○ Ultra HD refresh rates
  – Varies – 24 Hz up to 60 Hz

○ Color bit depth
  – 8-Bit, 10-bit, and 12-bit

○ Aspect Ratio
  – 16:9 – same as 1080p
HDMI 2.0 and HDMI 2.1

○ New functionality includes
  – Enables transmission of HDR – High Dynamic Range video
  – Signaling speed to 18 Gbps
  – 4K@50Hz/60Hz, (2160p)
    › 4 times the clarity of 1080p/60 video resolution
  – Up to 32 audio channels with up to 1536 kHz audio sample frequency
    › 32 channels @ 48kHz each
  – Dual video streams on same screen, 4 audio streams
  – Support widescreen 21:9 format
  – Dynamic sync of audio/video
  – CEC extensions with expanded control via single point

○ Backwards compatible
Mounting Hardware
4. Insert the tab of the cable shield into the groove behind the SMB.

5. Secure the cable shield to the clamp using the included rivet.
Connectivity
Connectivity

- Digital Video Characteristics
- HDMI
- Fiber Optic HDMI
- HDMI to USB
- USB
Digital Video Characteristics – Loss

- Digital video signals consist of high speed transitions
- Very susceptible to degradation from:
  - Cable attenuation
  - Cable capacitance
  - Cable resistance
  - Impedance mismatch
  - Noise coupling
  - Crosstalk
  - Jitter
- All factors that Affect the receiver’s ability to distinguish high and low transitions
Digital Video Characteristics – Loss

○ Difficult to anticipate
  – Image quality does not degrade like analog

○ Cliff effect
  – Occurs when the receiver can no longer distinguish high and low values
    › Too many bit errors have occurred
Digital Video Characteristics – Variables

- Cables can vary widely in performance
  - Adapters are useful but may affect signal quality

Damage caused by faulty HDMI connector
Digital Signals – HDMI

- HDMI is an uncompressed digital video signal
  - Designed for the consumer market

<table>
<thead>
<tr>
<th>Standard</th>
<th>Data Rate</th>
<th>Chroma Sampling</th>
<th>4K/UHD @ 30 Hz</th>
<th>4K/UHD @ 60 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDMI 1.4a</td>
<td>10.2 Gbps</td>
<td>4:4:4</td>
<td>1 cable, 8-bit</td>
<td>2 cables, 8-bit</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4 cables, 16-bit</td>
</tr>
<tr>
<td>HDMI 2.0/a/b</td>
<td>18.0 Gbps</td>
<td>4:4:4</td>
<td>1 cable, 16-bit</td>
<td>1 cable, 8-bit</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2 cables, 16-bit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4:2:0</td>
<td>n/a</td>
<td>1 cable, 16-bit</td>
</tr>
<tr>
<td>HDMI 2.1</td>
<td>48.0 Gbps</td>
<td>4:4:4</td>
<td>1 cable, 16-bit</td>
<td>1 cable, 16-bit</td>
</tr>
</tbody>
</table>
Fiber Optic HDMI

○ Hardwired

○ Adapters
HDMI to USB

- Supports all HDMI 1.4
- Video resolutions up to Ultra HD @ 30 Hz
Digital Signals – USB

- A standard for communication protocols that includes cables and connectors
- Historically used for attaching peripheral devices to computers
- Maximum length of USB 2.0 cable: The 2.0 specification limits the length of a cable between USB 2.0 devices (Full Speed or Hi-Speed) to 5 meters (or about 16 feet and 5 inches).
USB Interface Connectors

- Type-A
- Type-B
- USB Mini
- USB Micro
- USB-C
USB Type-A

- Standard connector found on most computer and USB devices
USB Type-B

- An upstream interface used to receive data or power
- Mostly used in printers and peripheral devices
USB Mini

- Developed to provide data and power for smaller devices
- USB 2.0 capable and support USB OTG
USB Micro

- USB 2.0 capable
- Slimmer interfaces that easily integrate into thinner devices
USB Type-C

- Send Data, Video, Audio, and Power
- Latest, high speed, reversible USB
- Deliver up to 100 watts! Devices negotiate...
- Supports “alternate modes”... like DisplayPort and HDMI
Digital Signals – USB

- Over the years, speeds have increased, providing additional options for transporting video and audio.

<table>
<thead>
<tr>
<th>Standard</th>
<th>Data Rate</th>
<th>Maximum Output Power</th>
<th>Power Direction</th>
<th>Cable Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>USB 1.1</td>
<td>12 Mbps Full Speed</td>
<td>2.5V, 500mA</td>
<td>Host to peripheral</td>
<td>Type-A to Type-B</td>
</tr>
<tr>
<td>USB 2.0</td>
<td>480 Mbps High Speed</td>
<td>2.5V, 1.8A</td>
<td>Host to peripheral</td>
<td>Type-A to Type-B</td>
</tr>
<tr>
<td>USB 3.0</td>
<td>SuperSpeed USB (5 Gbps)</td>
<td>5V, 1.8A</td>
<td>Host to peripheral</td>
<td>Type-A to Type-B</td>
</tr>
<tr>
<td>USB 3.1</td>
<td>SuperSpeed USB 10 Gbps</td>
<td>20V, 5A</td>
<td>Bi-directional</td>
<td>Type A or Type B to Type-C, Type-C both ends</td>
</tr>
<tr>
<td>USB 3.2</td>
<td>SuperSpeed USB 20 Gbps</td>
<td>20V, 5A</td>
<td>Bi-directional</td>
<td>Type-C both ends</td>
</tr>
<tr>
<td>USB 4</td>
<td>SuperSpeed USB 40 Gbps</td>
<td>20V, 5A</td>
<td>Bi-directional</td>
<td>Type-C both ends</td>
</tr>
</tbody>
</table>
USB over distance?
USB Hubs

- Connects upstream port and multiple downstream ports
- Port sharing bandwidth among all connected devices
- Provides status and control information
USB Tiered Star Topology

- Broken down into Tiers
- USB cable length is limited by the speed of electrical signals
- Tiered star topology has a max of seven tiers of communication
- Compound vs composite devices
USB Cascading Hub Limits
Source to Display

EDID and HDCP
EDID – Extended Display Identification Data

○ EDID contains the following information:
  – Sink identity – device type, model number, etc.
  – Sink capability – video/audio
    › Video timing parameters, color space, audio formats, etc.
EDID – Sequence

1. Power on PC or activate external graphics card
2. Computer requests EDID data from display
3. Display sends EDID data to computer
4. Computer attempts to match display parameters
AV System Disparities

- BYOD equipment
  - How do they respond to EDID?

Portable devices:
- iPad may only output 1080p if audio is requested in EDID
- Other devices may not offer/support requested resolution

EDID set to:
- 1280x720@60
- RGB
- 2-ch audio
AV System Disparities

- Display’s native resolution versus other equipment
  - How to choose?

- [Image of AV System diagram with devices and resolutions]
HDCP – High-bandwidth Digital Content Protection

- HDCP protocol is a 3-phase process
  - Authentication
  - Content encryption
  - Renewability
- This can take a few moments depending on the number of downstream devices
HDCP

- Most collaboration spaces don’t have Blu-Rays or Cable Tuners
- You will have to worry about Apple, Recording, and VTC products
HDCP Handshakes

- I/O authentication

```
  PC with DVI output  Authenticated  4K Display
  |                   | Authenticated | HDCP compliant |
  |                   | Authenticated | 4K Display     |
  | 4K Blu-ray with HDMI | Authenticated | HDCP compliant |
  
  4K Blu-ray with HDMI

  Digital Matrix Switcher

  Matrix Input
  - HDCP Source
  - Non-HDCP Source

  Matrix Output
  - HDCP Sink
  - Non-HDCP Sink

  4K Blu-ray with HDMI
  4K Display
```

- PC with DVI output
- 4K Display
- 4K Blu-ray with HDMI
HDCP Handshakes – Not HDCP Compliant

○ Visual confirmation
Cables and Cable Standards
HDBaseT

- HDBaseT Alliance, is a consumer electronic (CE) and commercial connectivity standard for transmission of uncompressed high-definition video (HD), audio, power, home networking.
Twisted Pair Transmission

- Distance
  - 328 feet (100 meters) between endpoints
Why Use Twisted Pair?

- One twisted pair cable can carry multiple signals
  - Video
  - Audio
  - Bidirectional RS-232 control and IR
  - Ethernet
  - Remote Power
Twisted Pair Transmission

○ Cable
  – Supports CATx cable
  – Solid conductor, shielded twisted pair cable with shielded connectors should always be used
  – Skew-free cable *should not* be used with XTP Systems
Twisted Pair Signal Transmission

- Shielded cable protects against outside interference from:
  - Air conditioning units
  - Power from adjacent cabling
  - Crosstalk from other cables or within the same cable
  - Radio interference from walkie-talkies

- Symptoms of noisy environments
  - Image drop-out or flashing
  - No image at all
Twisted Pair Shielding

- Different types of twisted pair shielding

<table>
<thead>
<tr>
<th>Cable Name</th>
<th>Outer Shielding</th>
<th>Individual Pair Shielding</th>
</tr>
</thead>
<tbody>
<tr>
<td>U/UTP</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>F/UTP</td>
<td>Foil</td>
<td>None</td>
</tr>
<tr>
<td>U/FTP</td>
<td>None</td>
<td>Foil</td>
</tr>
<tr>
<td>S/FTP</td>
<td>Braided</td>
<td>Foil</td>
</tr>
<tr>
<td>SF/UTP</td>
<td>Braided &amp; Foil</td>
<td>None</td>
</tr>
</tbody>
</table>
### Twisted Pair Signal Transmission

- **Types of Category cable**

<table>
<thead>
<tr>
<th>Cable</th>
<th>Gauge</th>
<th>Conductor</th>
<th>Outer Shield</th>
<th>Outer Shielding</th>
<th>Required Bandwidth</th>
<th>Crosstalk Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAT 5e (U/UTP)</td>
<td>24</td>
<td>Solid</td>
<td>None</td>
<td>None</td>
<td>100 MHz</td>
<td>~27dB</td>
</tr>
<tr>
<td>CAT 5e (F/UTP)</td>
<td>24</td>
<td>Solid</td>
<td>Foil</td>
<td>None</td>
<td>100 MHz</td>
<td>~27dB</td>
</tr>
<tr>
<td>CAT 6 (U/UTP)</td>
<td>24-23</td>
<td>Solid</td>
<td>None</td>
<td>None</td>
<td>250 MHz</td>
<td>~37dB</td>
</tr>
<tr>
<td>CAT 6 (STP)</td>
<td>24-23</td>
<td>Solid</td>
<td>Foil</td>
<td>None</td>
<td>250 MHz</td>
<td>~37dB</td>
</tr>
<tr>
<td>CAT 6a (U/UTP)</td>
<td>24-23</td>
<td>Solid</td>
<td>None</td>
<td>None</td>
<td>500 MHz</td>
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<tr>
<td>CAT 6a (F/UTP)</td>
<td>24-23</td>
<td>Solid</td>
<td>Foil</td>
<td>None</td>
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</tr>
<tr>
<td>CAT 6a (U/FTP)</td>
<td>24-23</td>
<td>Solid</td>
<td>None</td>
<td>Foil</td>
<td>500 MHz</td>
<td>~37dB</td>
</tr>
<tr>
<td>CAT 6a (SF/UTP)</td>
<td>24</td>
<td>Solid</td>
<td>Braid and Foil</td>
<td>None</td>
<td>500 MHz</td>
<td>~37dB</td>
</tr>
<tr>
<td>CAT 7 (S/FTP)</td>
<td>24</td>
<td>Solid</td>
<td>Braid and Foil</td>
<td>Foil</td>
<td>600 MHz</td>
<td>~60dB</td>
</tr>
<tr>
<td>CAT 7a (S/FTP)</td>
<td>24</td>
<td>Solid</td>
<td>Braid and Foil</td>
<td>Foil</td>
<td>1 GHz</td>
<td>~60dB</td>
</tr>
</tbody>
</table>
Twisted Pair Installation

- Cable infrastructure and patch points
  - Up to 2 patch points recommended
Wireless
Wireless Video Applications

- Point-to-point applications where source video signal is converted to a modulated RF signal for wireless transmission to a receiver connected to a display

- BYOD applications where computing device encodes and transmits video content over a Wi-Fi network to a receiver connected to a display
Collaboration with their WAP

TCP/IP Network

Rx with HDMI
Radio Frequency Spectrum

- 500MHz to 5GHz balances capacity and range
- Transmits through common obstacles, such as walls, with low to moderate loss
Radio Frequency Spectrum

- 60 GHz used for higher data carrying capacity
  - Cannot penetrate solid objects
  - Short range
## Proprietary Wireless Protocols

<table>
<thead>
<tr>
<th>Wireless Interface</th>
<th>Frequency Band</th>
<th>Computing Hardware Required</th>
<th>Uncompressed Video</th>
</tr>
</thead>
<tbody>
<tr>
<td>AirPlay</td>
<td>Wi-Fi</td>
<td>Apple Products</td>
<td>No</td>
</tr>
<tr>
<td>Chromecast</td>
<td>Wi-Fi</td>
<td>PC, tablet, smartphone</td>
<td>No</td>
</tr>
<tr>
<td>Miracast</td>
<td>Wi-Fi</td>
<td>PC, tablet, smartphone</td>
<td>No</td>
</tr>
<tr>
<td>WiDi</td>
<td>Wi-Fi</td>
<td>Intel Products</td>
<td>Yes</td>
</tr>
<tr>
<td>WiGig</td>
<td>Wi-Fi, 60 GHz</td>
<td>PC, tablet, smartphone</td>
<td>Yes</td>
</tr>
<tr>
<td>UWB</td>
<td>3.1 – 10.6 GHz</td>
<td>None</td>
<td>Yes</td>
</tr>
<tr>
<td>WHDI</td>
<td>5 GHz</td>
<td>None</td>
<td>Yes</td>
</tr>
<tr>
<td>WirelessHD</td>
<td>60 GHz</td>
<td>None</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Using Your Own WAP
Using Their WAP
Key Features to have in a Wireless Video Platform

○ Easy Wireless and Wired Collaboration
  – Wireless connections via OS mirroring or app
  – Wired connections via HDMI Input
  – Contact/Tally I/O ports
    › Add Motion Sensor
    › Add Button control

○ Multi-Platform Support
  – Mac / Windows runtime or installed app
  – Android / iOS app
  – Apple & Android mirroring
Cable Paths
The Wrong Way
With Core Drilling
With Cable Runway
On Cement
Furniture

“Techniture, Learnature,” and Power
Techniture vs Learnature
Cable Management
Table connectivity including Power and USB charging
Audio
Microphones

- Boundary Mics
- Ceiling Mics
New Types of MICS

- Ceiling Arrays
- CATx Cable
- POE and POE+
- Steerable Lobes
Speakers

- In Ceiling
- Wall Mounted
- Pendant
- Blends into Environment
Amplifiers

- Impedance – 4Ω/8Ω, 70V, 100V
- Channel Number – 1, 2, 3, 4, 8
- Power Output per channel – < 100 watts, 100-200 watts, > 200 watts
- Networked Audio – Dante, AES67
Room Automation
**Simple Motion Sensor**

- Motion Sensor wiring

![Motion Sensor wiring diagram](image)

- Control system module for Motion Sensor configuration

![Control system module](image)
How a timer works
Occupancy Sensor and Collaboration Technology

1. Enters the meeting room

2. Connects laptop
   - Presses Connect Button

3. Connects laptop
   - Presses Connect Button

4. Press Connect Button
   - Input switches

5. After a configured period of inactivity the system automatically shuts down

CATx Cable up to 230' (70m)

Occupancy Sensor

HDMI/CEC
Upgrade Options – Wireless Connectivity

Wireless Devices

Occupancy Sensor

HDMI/CEC

CATx Cable up to 230’ (70m)

Upgrade Options – Wireless Connectivity
Upgrade Options – TouchPanel Control

- HDMI/CEC
- Occupancy Sensor
- CATx Cable up to 230’ (70m)
- Ethernet
- LAN
- Touchpanel
- Ethernet
- LAN
- HDMI
- LAN
- CATx Cable up to 230’ (70m)
Lighting
Sensor Dimmer Coverage Area

NEMA WD7 Test Grid Coverage (High Sensitivity Setting)
- Major motion coverage: 900 ft² (81 m²)
- Minor motion coverage: 400 ft² (36 m²)

Horizontal Beam Diagram

Vertical Beam Diagram

Rolling switch
Conect el sensor con interruptor
Conecter le détecteur interrupteur

Serial communication:
- Port Type: RS-232
- Band Rate: 9600
- Data Bits: 8
- Parity: None
- Stop Bits: 1
- Flow Control: None

Pin Assignments Diagram:

General Notes:
Conference Room Interfaces
Multiple Types of Devices

- Networks need to be capable of handling multiple types of devices and environments where BYOD is common
Seamless Conference Experiences
Control and Zoom Room

TouchPanel

Wireless Meeting Participation

USB Table Mic

Wired Content Sharing

Network

WAP

Control Processor

Control

Display

USB Web Cam

USB

USB to HDMI

HDMI to USB Capture

USB

USB

2020 BICSI WINTER Conference & Exhibition
Control
Push Button Controllers

These do NOT count!
Push Button Controllers

These do!
Single Display Application

- **PC**
  - Ethernet
  - HDMI with embedded audio

- **Blu-ray Player**
  - IR to Blu-ray

- **Projector with internal speakers**
  - Ethernet/PoE
  - Ethernet

- **Screen Control**
  - Ethernet

- **TCP/IP Network**: Ethernet connection between PC and Projector, with HDMI signals.
Features of PUSH – Button controllers

- Manage, monitor, and control AV devices using a standard Ethernet network
- Fully configurable ...NO Programming
- Two bidirectional RS-232 ports
- Two relays for controlling room functions
- One IR port for connecting up to two emitters
- Remote volume control port for external third-party AMPS
Room Scheduling
Scheduling – How it used to be
Room Scheduling Panels
Room Scheduling

TCP/IP Network

Room Scheduling Devices
Open Meeting Space – Capabilities

- Wirelessly share content from personal mobile devices
- Display content simultaneously from multiple different devices
- Play content from media player internal memory, USB/SD card, or network shares
Open Meeting Space - Capabilities

- Wirelessly share content from personal mobile devices
- Display content simultaneously from multiple different devices
- Play content from media player internal memory, USB/SD card, or network shares
Huddle Room with Video Conferencing – Capabilities

- Connect with team members using business collaboration software
- Access to cables and AC power
- Wirelessly share content from personal and mobile devices
- Occupancy sensor activity will start up room
Huddle Room with Video Conferencing – Capabilities

- Connect with team members using business collaboration software
- Access to cables and AC power
- Wirelessly share content from personal and mobile devices
- Occupancy sensor activity will start up room
Equipment
Equipment

- Shielded CAT x cables
- HDMI switcher
- Four Input HDMI Switcher
- HDMI and Audio to USB Scaling
- Wireless Collaboration Gateway
- Tabletop Touch Panel
- Control Processor
- Stereo Amplifier - 100 Watts/Channel
- Speakers
AV over IP Considerations

New Technology
AV over IP – AES 67 Audio Distribution

- AES 67 Standard allows audio transportation over IP based systems
- Interoperability between network audio over IP protocols
- Adds audio networking technology into a variety of applications
- Supports both multicasting and unicasting
AV over IP – Compression

Compression – Three factors

- Bit Rate
- Image Quality
- Latency

<table>
<thead>
<tr>
<th>Video Rate</th>
<th>Uncompressed Bit Rate @ 24 bpp</th>
<th>1G Compression @ 880 Mbps</th>
<th>10G Compression @ 4 Gbps</th>
</tr>
</thead>
<tbody>
<tr>
<td>480p60 (SD)</td>
<td>422</td>
<td>1:1</td>
<td>1:1</td>
</tr>
<tr>
<td>720p60 (HD)</td>
<td>1,330</td>
<td>2:1</td>
<td>1:1</td>
</tr>
<tr>
<td>1080p60 (HD)</td>
<td>2,990</td>
<td>3:1</td>
<td>1:1</td>
</tr>
<tr>
<td>2160p60 (UHD)</td>
<td>11,940</td>
<td>14:1</td>
<td>3:1</td>
</tr>
<tr>
<td>4096x2160 @ 30 (4K/30)</td>
<td>6,370</td>
<td>7:1</td>
<td>2:1</td>
</tr>
<tr>
<td>4096x2160 @ 60 (4K/60)</td>
<td>12,740</td>
<td>14:1</td>
<td>3:1</td>
</tr>
</tbody>
</table>
AV over IP – Compression Ratios

- Mathematically Lossless
- Visually Lossless
- Visually Lossy
  - H.265
  - VP9
  - H.264

- DSC
- JPEG 2000
- VC-2

Based on encoding 4K60:
- <10GBPS
- <1GBPS
- <100MBPS
AV over IP – Network

- Layer 3 Protocols
  - Multicasting
  - IGMP Snooping
- Client Network?
- Private Network?