Navigating the Next Disruption to Video Distribution – Video Over Ethernet

Michael D. Frank, CTS
Biamp
How we got here

Remember 2007?
- Began talk about “Analog Sunset”
- Started to see the first Digital Video Systems
How we got here

Enter HDBaseT (about 2010)

- Single Cable
- 100 Meter Distance
- Supports Almost Everything HDMI 1.4 Supports
Video Distribution

Balun (HDBaseT) Based Video Matrix Switches

- Centralized Setup
- Low Latency
- Easy Setup
Video Distribution

Balun (HDBaseT) Based Video Matrix Switches

- Expansion difficult
- Difficulty traversing long distances
- Non Linear Cost Structure
Video Distribution

Network Based Video Solutions/Advantages

- Ease of Expansion
- Use of Network Infrastructure
- Linear Cost Structure
- Centralized Management
- Access to content from anywhere
- Capture and Content can be Centralized
Video Distribution

Network Based Video Solutions Challenges

- Network Capacity (Bandwidth) is Finite
- Network Bandwidth needs to be considered a resource
  - Same way we consider inputs and outputs on matrix today
**Bandwidth vs Data Rate**

- Bandwidth is generally referred to as the size of the data pipe or network capacity.
- Data Rate is the amount of Bandwidth used up by what you are sending between devices.
Compression

- Compression involves encoding information using fewer bits than the original representation.
- Can be “lossy” or “lossless”
Lossless Compression
Lossy Compression

Original → Compressed Transfer → Sort of Original

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Compression Types

- Spatial Compression
  - Aka intra-fame
  - MJPEG 2000, M-JPEG

- Temporal Compression
  - Aka inter-frame
  - MPEG-4,
    - H.264 and H.265
Compression Types

**Intraframe compression**
Every frame is encoded individually

**Interframe compression**
Only the differences between frames are encoded for each group of frames
Compression Debate

- Which Compression is Best?
- It depends
  - Do you know your available bandwidth?
  - How much latency are you willing to tolerate?
  - Cost Structure Encoder vs Decoder?
Compression Types

- **MJPEG**
  - Supports 12 bit color and **VERY high resolutions** (64,000 X 64,000)
  - Widely used in Broadcast

- **MJPEG-2000**
  - About 10x more processor intense than MJPEG
    - Lots of energy used, lots of heat produced
  - **Sweet spot** – value over 20:1 compression ratios
Compression Types

- MPEG-2 (most widely used temporal compression)
  - Used in early satellite TV broadcasts
  - 8 bit color support
  - Long latency
- MPEG-4 part 10 / H.264
  - Used in Blu-ray discs
  - Capable of up to 14 bit color
  - Capable of resolutions up to UHD
- H.265 (iteration of MPEG-4)
  - Supports very high compression for 4k/UHD content over low bandwidth connections (YouTube)
  - Supports 10 bit color
  - High Latency
## Compression Comparison

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<thead>
<tr>
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<td><strong>Processing</strong></td>
<td>Symmetric</td>
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<td>Processing</td>
<td>Symmetric</td>
<td>Asymmetric</td>
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<tr>
<td>Error Tolerance</td>
<td>High</td>
<td>Low</td>
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Compression

- All Compression has a cost
  - Processing (\$, power and heat)
  - Time (latency)
  - Data (video quality)
- More Compression = Less Bandwidth Use
- More Compression = More Power, More Cost and often More Latency
Compression

- Excessive Compression introduces visible artifacts
  - Blocking – visible structures from block based algorithms
  - Blurring – loss of high frequency detail like smoothing of textures
  - Ringing – present on steep edges in an image
  - Mosquito Noise – time variant edge busyness (prediction errors)
  - Posterization & Solarization – color artifacts introduced by bit depth adjustments
Network Video Design

Video Quality

Latency  Bandwidth
Compression (Natural Video)

- **Compression Ratio**
  - Used to quantify the reduction in data-representation size produced by a data compression algorithm
- **10:1 Compression Ratio**
  - Applied to a 1Gbps stream would produce a 100Mbps stream
- **2:1 Video can be “mathematically lossless”**
- **6:1 Video considered “visually lossless”**
Deciding What Video To Distribute
Refresh Rates

Content Refresh Rates
- 24 Hz (Movies)
- 60 Hz (NTSC)
- 50 Hz (PAL, SECAM)

Display Refresh Rates
- 60 Hz
- 120 Hz
- 240 Hz
- 480 Hz
Refresh Rates

Key Takeaways
- There is no widely available content with refresh greater than 60Hz
- Higher refresh support in displays have nothing to do with transport

Content Refresh Rates
- 24 Hz (Movies)
- 60 Hz (NTSC)
- 50 Hz (PAL, SECAM)

Display Refresh Rates
- 60 Hz
- 120 Hz
- 240 Hz
- 480 Hz
# Video Resolution

## Resolution Marketing Evolution

<table>
<thead>
<tr>
<th>Name</th>
<th>Vertical X Horizontal</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>480i</td>
<td>640 X 480 interlaced</td>
<td>(240 lines)</td>
</tr>
<tr>
<td>480p</td>
<td>640 X 480 progressive</td>
<td>(480 lines)</td>
</tr>
<tr>
<td>720p</td>
<td>1280 X 720 progressive</td>
<td></td>
</tr>
<tr>
<td>1080p</td>
<td>1920 X 1080 progressive</td>
<td></td>
</tr>
<tr>
<td>4K</td>
<td>3840 X 2160 progressive</td>
<td></td>
</tr>
</tbody>
</table>
Resolution vs Viewing Distance

Recommendations vary by industry

- Consumer
- InfoComm (more credible, has well documented math to support it)
Viewing Distance where Resolution Becomes Noticeable

Screen Size vs. Viewing Distance

480p, 720p, 1080p, 4k (2160p) all appear to be equivalent at these “far away” viewing distances.

- Benefit of 4k (2160p) starts to become noticeable
- Full benefit of 4k (2160p) visible
- Benefit of 1080p starts to become noticeable
- Full benefit of 1080p visible
- Benefit of 720p starts to become noticeable
- Full benefit of 720p visible
- Full benefit of 480p visible

Screen Size - Diagonal (inches)

Viewing Distance (feet)
Resolution vs Viewing Distance

Infocomm International Standard “Display Image Size for 2D Content in Audiovisual Systems”

Analytical Decision Making

Minimum Image Height = \[
\frac{\text{Maximum View Distance} \times \#\text{Vertical Pixels}}{3438}
\]

Basic Decision Making

Minimum Image Height = \[
\frac{\text{Maximum View Distance}}{200 \times \%\text{Element}}
\]
Basic Decision Making Example

5% Element Height and 70” Diag. Flat Screen

Minimum Image Height = \frac{\text{Maximum Viewing Distance} \times \text{Element Height}}{\text{Maximum Viewing Distance}}

38” = \frac{\text{Maximum Viewing Distance} \times 0.05}{200 \times 0.05}

Maximum Viewing Distance = 32 feet (380”)

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Basic Decision Making Example

5% Element Height and 5’ Height Proj. Screen

Minimum Image Height = \( \frac{\text{Maximum Viewing Distance}}{200 \times \% \text{Element}} \)

60” = \( \frac{\text{Maximum Viewing Distance}}{200 \times 5\%} \)

Maximum Viewing Distance = 46 feet (600″)
## Practical Application

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Font Sizes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1280 X 720</td>
<td>10 Point Font, 12 Point Font, 14 Point Font, 16 Point Font, 18 Point Font, 20 Point Font, 24 Point Font, 28 Point Font, 36 Point Font, 40 Point Font, 44 Point Font, 54 Point Font</td>
</tr>
<tr>
<td>1920 X 1080</td>
<td>12 Point Font, 14 Point Font, 16 Point Font, 18 Point Font, 20 Point Font, 24 Point Font, 28 Point Font, 36 Point Font, 40 Point Font, 44 Point Font, 54 Point Font</td>
</tr>
<tr>
<td>3840 X 2160</td>
<td>12 Point Font, 14 Point Font, 16 Point Font, 18 Point Font, 20 Point Font, 24 Point Font, 28 Point Font, 36 Point Font, 40 Point Font, 44 Point Font, 54 Point Font</td>
</tr>
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</table>
Analytical Decision Making Example

Analytical Decision Making 20’ Conference Room

Minimum Image Height = \[ \frac{\text{Maximum Viewing Distance} \times \# \text{Vertical Pixels}}{3438} \]

Minimum Image Height = \[ \frac{240 \times 720}{3438} = 50’’ (4’2”, 1.27m) \]

Minimum Image Height = \[ \frac{240 \times 2160}{3438} = 151’’ (12’7”, 3.8m) \]
Resolution

Key Takeaways

- When watching motion video higher resolution won’t matter
- When viewing computer graphics higher resolution is harmful to room function and “health/comfort” of the viewer

Regardless, customers will demand this capacity. 4K doesn’t necessarily mean...better!
Color Space
Chroma Sub Sampling
Chroma Sub Sampling

- Y, Cb, Cr
Chroma Sub Sampling

- Playing with human perception
- Human vision can resolve fine detail spatial differences in luminance to a greater extent than similar detail in chrominance
- Displaying all of the brightness (Luma) information but only some of the color (Chroma) saves us bandwidth but keeps quality very high
Chroma Sub Sampling

- 4:4:4, 4:2:2, 4:2:0
- J:a:b
  - J = Reference Block Size (Width, # of Columns)
    - The Height or # of Rows is fixed
  - a = Number of pixels in 1st row that get a sample
  - b = Number of pixels in the 2nd row that get a sample
Chroma Sub Sampling
Chroma Sub Sampling

4:2:2

1/2 horizontal resolution, full vertical resolution

4:4:4

full horizontal resolution, full vertical resolution
Chroma Sub Sampling

4:2:0

1 2 3 4 J = 4
1 2
a = 2
b = 0
½ horizontal resolution, ½ vertical resolution

4:2:2

1 2 3 4 J = 4
1 2
a = 2
b = 2
½ horizontal resolution, full vertical resolution

4:4:4

1 2 3 4 J = 4
1 2 3 4
a = 4
b = 4
full horizontal resolution, full vertical resolution

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Chroma Sub Sampling

4:1:1  
\[ Y'CrCb = \begin{array}{llll} 1 & 2 & 3 & 4 \\ a = 1 \\ b = 1 \end{array} \]

4:2:0  
\[ Y' = \begin{array}{llll} 1 & 2 & 3 & 4 \\ J = 4 \end{array} \]

4:2:2  
\[ (Cr, Cb) = \begin{array}{llll} 1 & 2 \\ a = 2 \\ b = 2 \end{array} \]

4:4:4  
\[ \begin{array}{llll} 1 & 2 & 3 & 4 \\ J = 4 \end{array} \]

\( \frac{1}{4} \) horizontal resolution, full vertical resolution

\( \frac{1}{2} \) horizontal resolution, \( \frac{1}{2} \) vertical resolution

\( \frac{1}{2} \) horizontal resolution, full vertical resolution

full horizontal resolution, full vertical resolution

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Chroma Sub Sampling – Bandwidth Sampling

4:4:4

4:2:2

4:2:0

Luma

Chroma

30% Savings

50% Savings
Color or Pixel Depth

24-bit “true color” displays

Each screen pixel is represented by three groups of eight pixels, for a total of 24 bits.

Blue: 0 0 0 0 0 0 0 0
Green: 1 1 1 1 1 1 1 1
Red: 1 1 1 1 1 1 1 1

Pixels on the computer screen

Picker

R: 255
G: 255
B: 0

Photoshop color picker shows the R, G, B components that make “yellow.”
Dynamic Range

- **Starlight**
  - $10^{-6}$
- **Moonlight**
  - $10^{-4}$
- **Indoor Lighting**
  - $10^{-2}$
- **Sunlight**
  - $10^{6}$

**Luminance in CD/m²**

- **Rod Function**
  - Images look "real" in HDR
  - Easily seen difference at ANY distance
- **Cone Function**
  - Steady-state HVS
  - LDR Display
  - HDR Display
Chasing the human vision system

SDR

Human Dynamic Range
Color  Contrast  Capture  Post Production  Mastering  Distribution  Display  Color  Contrast

What Viewer Sees
Full Range of Human Eye
0.05-100 cd/m²

HDR

Human Dynamic Range
Color  Contrast  Capture  Post Production  Mastering  Distribution  Display  Color  Contrast

What Viewer Sees
Full Range of Human Eye
0.0005-10,000 cd/m²
Video Design

- All of the aspects of a video signal impact its data rate.
- Impact varies and what aspects are important and depend on your application.
Network Impact

How does Resolution Effect Data Rate?

- 4k (3840x2160) quadruples data rate relative to 1080p (1920x1080)
- No practical application for rooms larger than huddle space

1920 x 1080, 60Hz, 4:2:2, 8bit = 1.99Gbps
3840 x 2160, 60Hz, 4:2:2, 8bit = 7.96Gbps***
Network Impact

How does Color Space Effect Data Rate?

- RGB doesn’t support Chroma Sub Sampling
- YCbCr 4:4:4 Data Rate = RGB Data Rate
Network Impact

How does Chroma Sub Sampling Effect Data Rate?

- YCbCr 4:4:4 Data Rate = RGB Data Rate
- 4:2:2 uses 33% less Data than 4:4:4
- 4:2:2 is basically all video today, including Blu-ray

1920 x 1080, 60Hz, 4:4:4, 8bit = 2.99Gbps
1920 x 1080, 60Hz, 4:2:2, 8bit = 1.99Gbps
Network Impact

How does HDR Effect Data Rate?

- HDR = 10bit Color
- 10bit uses 25% more Data than 8bit
- Real Impact with existing content at any distance

1920 x 1080, 60Hz, 4:2:2, 10bit = 2.49Gbps
1920 x 1080, 60Hz, 4:2:2, 8bit = 1.99Gbps
Today’s Changes to the Network
Today’s Network Changes

- AVB = Audio Video Bridging
- TSN = Time Sensitive Networking
- Deterministic Networking
- IEEE 802.
Today’s Network Changes

IEEE’s AVB Ethernet Additions

- **IEEE 802.1AS**
  - Generalized Precision Time Protocol (gPTP)

- **IEEE 802.Qat**
  - Stream Reservation Protocol (SRP) / Multiple Stream Reservation Protocol (MSRP)

- **IEEE 802.Qav**
  - Forwarding and Queuing for Time-Sensitive Streams (FQTSS)

- **IEEE 802.1BA**
  - An umbrella standard for the three above
Deterministic Networking

- Bounded Latency

Exactly 1.327ms
Deterministic Networking

- Bounded Latency
- Precise Timing / Synchronization
Deterministic Networking

- Bounded Latency
- Precise Timing / Synchronization
- Automatic Setup
  - VLAN
  - QoS
  - Traffic Shaping
  - Bandwidth Management and Guaranteed capacity
AVB – Available Switches

- MOTU
- Netgear
- Extreme Networks
- Cisco
“V” in AVB

- Today…this is possible:
  - Route, combine or separate audio and video signals at will
  - Process them separately and still guarantee lip-sync
  - Doing this all over AVB guarantying network transit time and performance
  - AVB also removes the need for complex manual network setup.
Video Distribution – Traditionally (non-network)
Video Distribution – Natural Evolution (Network based)
Video Distribution – Natural Evolution (Network based)
HDMI 2.0a

- HDMI forum’s official Statement:
  The specification has been updated to enable transmission of HDR formats, which provide enhanced picture quality by simultaneously enabling greater detail for both the dark and bright parts of an image. The HDR-related updates include references to CEA-861.3, CEA's recently published update of HDR Static Metadata Extensions. - **HDMI Forum, Inc.**

- Starting to see support now, many displays late 2016
HDMI 2.0a

- YCbCr 4:2:0 Chroma sub sampling support
- 14.4Gbps data rate (additions in red)

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<th>10bit</th>
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<td>RGB 4:4:4</td>
<td>RGB 4:4:4</td>
</tr>
<tr>
<td>4K@25</td>
<td></td>
<td>RGB 4:4:4</td>
</tr>
<tr>
<td>4K@30</td>
<td>RGB 4:4:4</td>
<td>4:2:2</td>
</tr>
<tr>
<td>4K@50</td>
<td>RGB 4:4:4</td>
<td>4:2:0</td>
</tr>
<tr>
<td>4K@60</td>
<td>4:2:0</td>
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HDCP

High-bandwidth Digital Content Protection

- **HDCP 1.4**
  - Widely deployed legacy version
  - Point to Point solution
  - No Network Support; Wired only connections (HDMI, DVI, DisplayPort)
  - Today, HDCP isn’t deployed correctly in most products
HDCP 2.2

High-bandwidth Digital Content Protection

- **HDCP 2.2**
  - 2.x required for UHD type 1 (High Value Content)
  - Not required for HDR or WCG content (supported with HDMI 2.0a)
  - Required for any Network based distribution
    - TCP/IP, USB, WiFi
    - HDMI, DVI, DisplayPort Support
  - 32 Device Count Limit
HDCP 2.2

OF THE 32 DEVICES ALLOWED BY THE HDCP 2.2 SPECIFICATION, ONLY 15 CAN BE DISPLAYS IN THIS MEDIA NETWORK TOPOLOGY
HDCP 2.2 Pro

High-bandwidth Digital Content Protection

- HDCP 2.2 Pro
  - Issued on May 13, 2016
  - Unlimited Number of Devices Supported
  - White-Listed Site Support
HDCP 2.2 Pro

Preliminary Site White List
- Education facilities (Classrooms, lecture theatres)
- Office buildings
- Share trading floors
- Hospitals & Medical training facilities
- Transport venues (Airports, railway stations etc.)
- Hospitality (Bars, Casinos, Convention centers, Hotel & conference centers)
- Manufacturing facilities
- Houses of Worship
- Broadcast production facilities
- Military installations
- Government / Municipal sites (parliaments, local government, town halls)
- Courts & Justice facilities (Court rooms, detention centers)
- Sporting facilities (Stadiums, arenas, coaching facilities)
- Large Retail outlets, (e.g. Best Buy or Walmart wall of monitors),
- Shopping Malls
- Airports, airlines
- Cruise ships
- Single family dwelling (Bill Gates house)
HDCP 2.2 Pro

Not All Sunshine and Rainbows

- **Current HDCP Pro Draft:**
  - Requires New and Specific Hardware
  - Must not be re-deployed
  - Requires “Licensed Installers” to report hardware location at time of sale
  - Hardware must receive regular updates (quarterly)
# HDCP

<table>
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<tr>
<th>Feature</th>
<th>HDCP 1.x</th>
<th>HDCP 2.2</th>
<th>HDCP 2.2 Professional</th>
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<tbody>
<tr>
<td>Network capable</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Max levels</td>
<td>7</td>
<td>4</td>
<td>unrestricted</td>
</tr>
<tr>
<td>Max devices</td>
<td>128</td>
<td>32</td>
<td>unrestricted</td>
</tr>
<tr>
<td>Leave/join tolerant</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>UHD type 1 support</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>White list sites only</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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Questions

Thank You

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