IP Video
(uncompressed)
Basics

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PRINT VERSION
Best efforts have been made to modify this presentation for print. The original presentation includes many animations and was not designed to be viewed stand-alone.

- Broadcast Consultancy
- System Design & Delivery
- Training & Support

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IP SHOWCASE THEATRE AT IBC – SEPT. 14-18, 2018

What will this session cover?

- Video Basics
  - Understand where we came from to understand now!
- Networking Basics
  - What you really need to know
- Sending uncompressed video over IP
  - SMPTE 2022-6
  - SMPTE 2110

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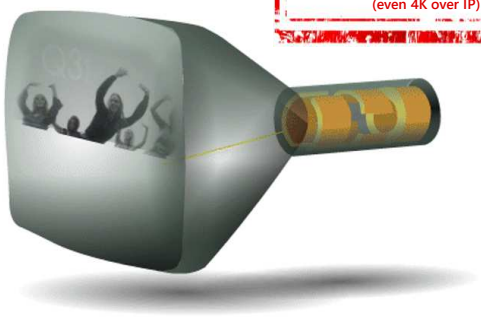
In the beginning…



PRINT NOTE

Television technology is an evolution with many esoteric properties as a result of constraints from technology at different steps of that evolution.
The time taken to reverse the electromagnetic fields in CRT displays gave rise to the analogue timing raster which is still seen in video today
(even 4K over IP)

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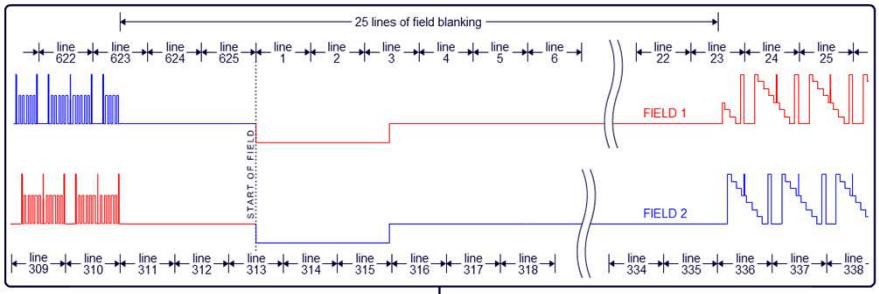
The Analogue Raster Still Persists



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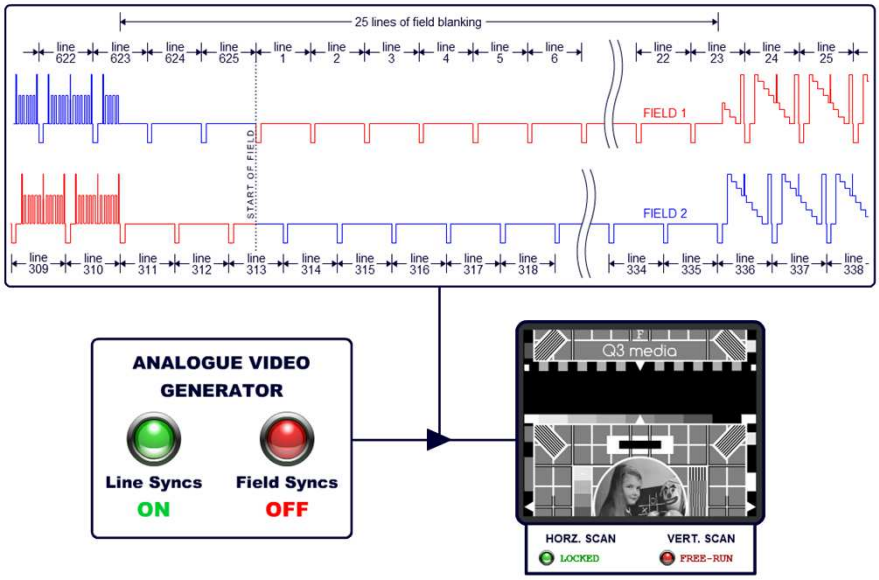
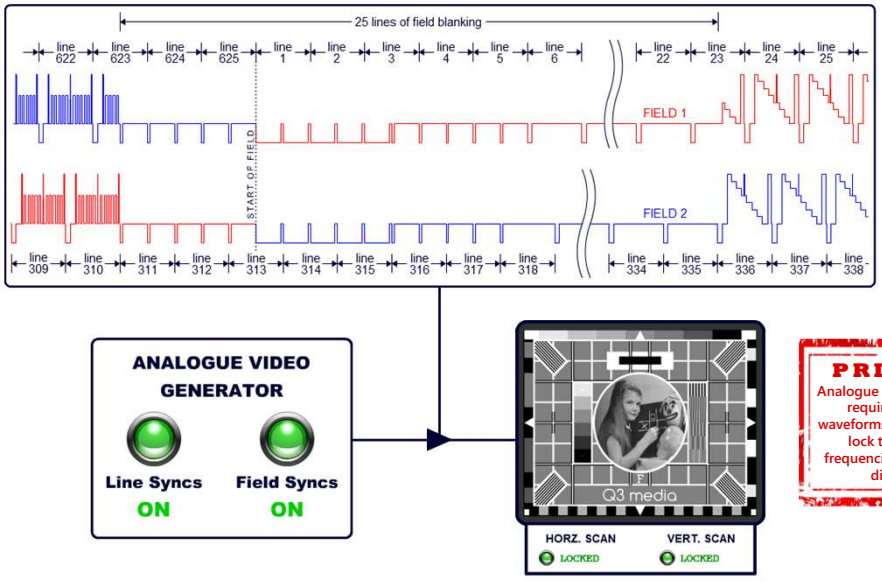
The Analogue Raster Still Persists



5

The Analogue Raster Still Persists

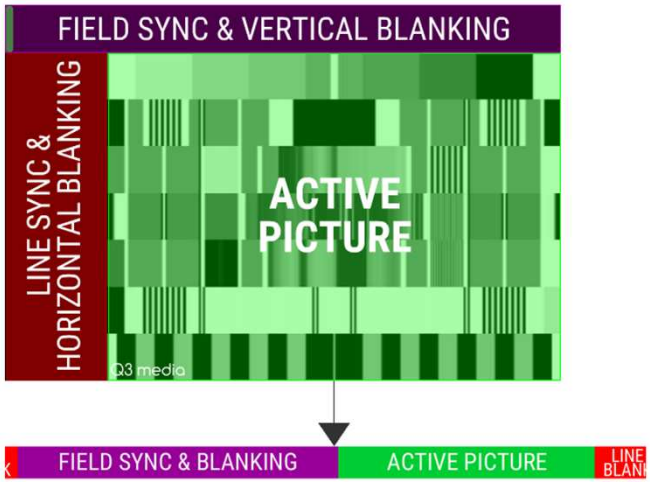


PRINT NOTE

Analogue electronics of the 1930's required specific voltage waveforms allowing televisions to lock to the line and field frequencies needed to drive the display scanning.

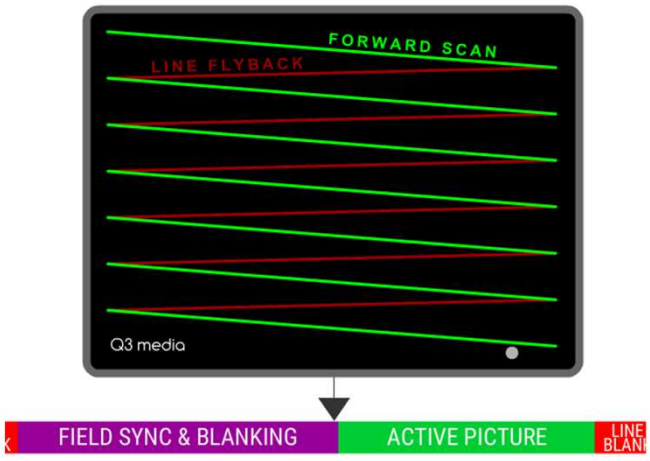
6

Analogue video – what a waste of time?



7

Analogue video – what a waste of time?



PRINT NOTE
The time when the analogue video signal is not carrying active picture is known as 'blanking' as the electron beam would need to be 'blanked' (i.e. turned-off).

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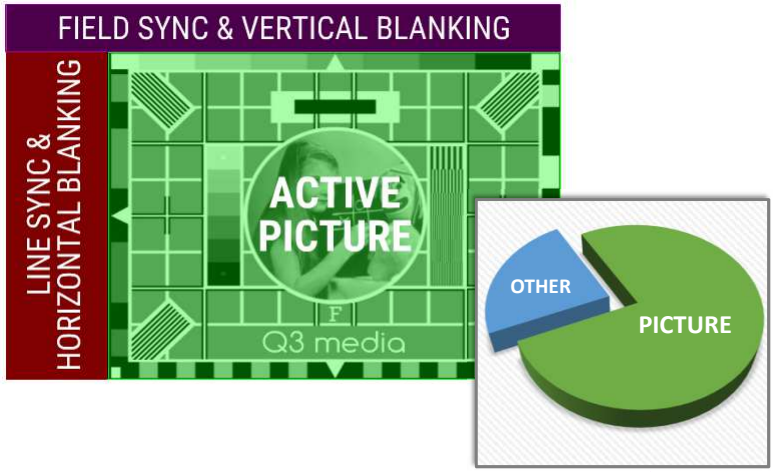
Analogue video – what a waste of time?

PRINT NOTE
The video signal only carries active picture information about 75% of the time. As well a synchronisation pulses it is common to use this wasted time for carrying timecode (VITC) and/or teletext/subtitles as well as other signalling.



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SDI > Fill the void with something useful!

PRINT NOTE
With the analogue syncs replaced by simple digital codes (TRS) the rest of the space is free to be used for carrying digital data.

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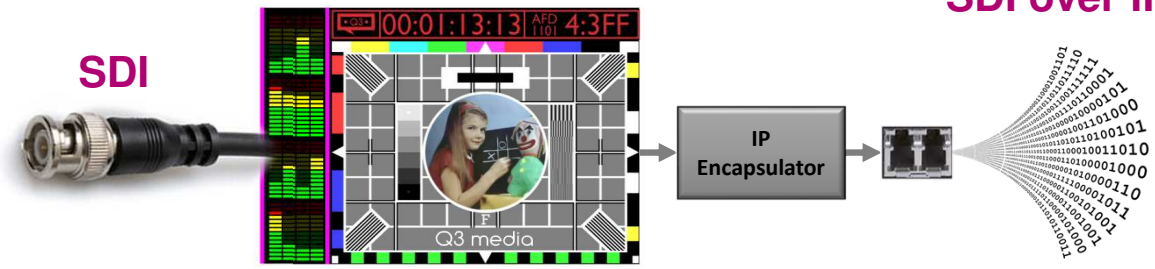
SDI > Let's just send it over IP!

SMPTE ST-2022-6

"SDI over IP"

SDI



Everything in 1 RTP flow sent over UDP Unicast or Multicast

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Everything
in 1 RTP flow
sent over
UDP Unicast or Multicast

IP - Let's start at the beginning…

1974: Transmission Control Program introduced

Vinton Gray Cerf ForMemRS, is an American Internet pioneer, who is recognized as one of "the fathers of the Internet", sharing this title with TCP/IP co-inventor Bob Kahn. His contributions have been acknowledged

Robert Ell

net Protocol

fundamental communication protocols at the heart of the Internet.

>> Let's Fast-Forward at least 25 years… >>

PRINT NOTE
Beware online learning about Ethernet – there is lots of old and irrelevant information out there that you don't need to know.

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Sending Data Over an IP Network

- Prepare Data
- Chose Protocol
  - UDP
  - TCP
- Address it
- Send It

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Sending Data Over an IP Network

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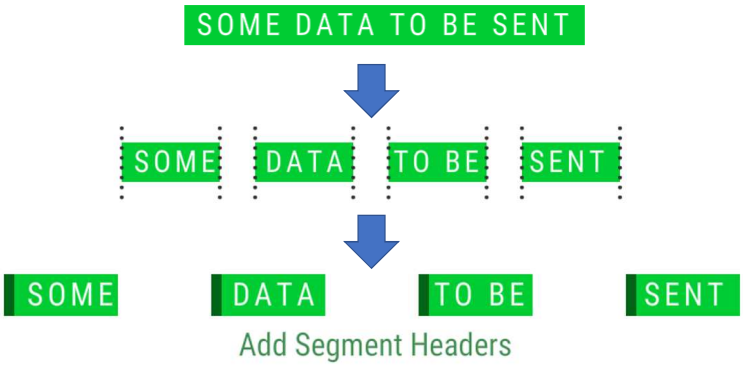

PRINT NOTE
IP networks send data in packets which have a limit to their size. Data we need to sent therefore has to be chopped up into segments. When sending video a common protocol for segmentation is RTP or MPEG-Transport Stream – appropriate headers are added to each segment of data depending on the application layer protocol used.

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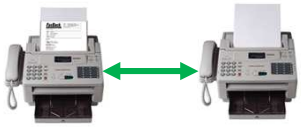
Sending Data Sending Data Over an IP Network

- Prepare Data
- Chose Protocol
  - UDP
  - TCP
- Address it
- Send It

TCP Header

Source Port			Destination Port
Sequence Number			
Acknowledgement Number			
Data Offset	Reserved	Flags (Control Bits)	Window Size
Checksum			Urgent Pointer
Options			Padding



- Link Handshaking
- Transmission Acknowledgments
- Automatic resend on packet loss
- Perfect for FILES

UDP Header

Source Port	Destination Port
Length	Checksum

PRINT NOTE
We typically use UDP for video streaming for real-time video streaming.

- 'Fire & Forget'
- Minimal Data Overhead
- Simple error detection
- Perfect for REAL-TIME STREAMS

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Sending Data Over an IP Network

- Prepare Data
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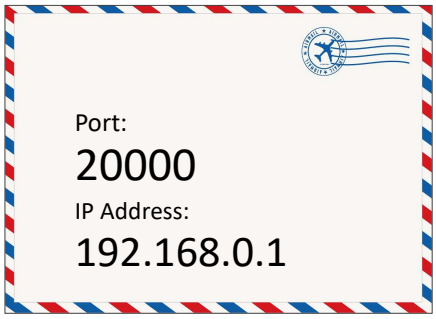
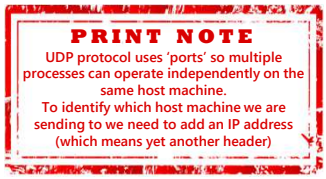
  - UDP
  - TCP
- Address it
- Send It





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Sending Data Over an IP Network

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18

Sending Data Over an IP Network

- Prepare Data
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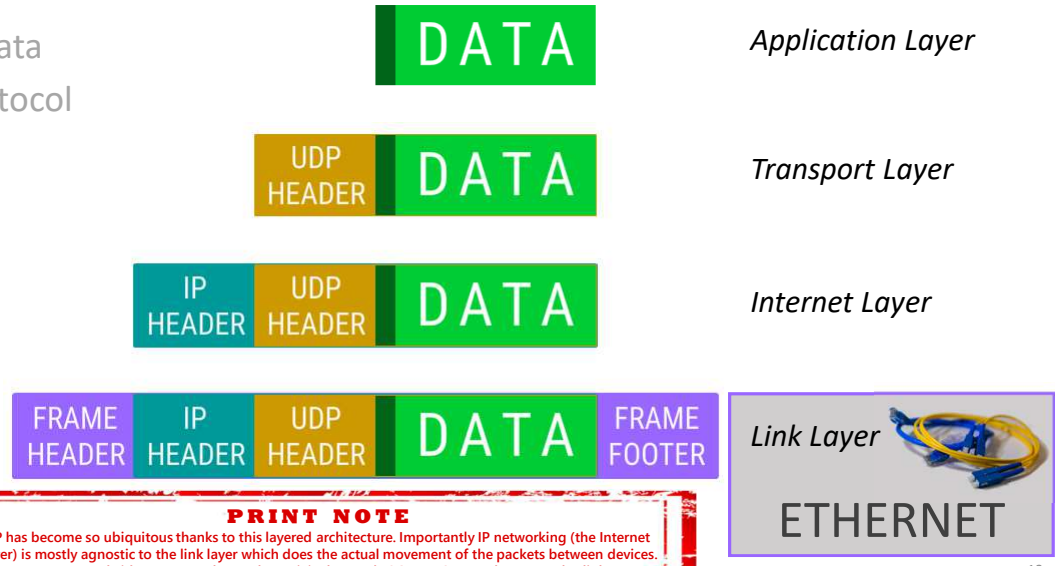

PRINT NOTE

IP has become so ubiquitous thanks to this layered architecture. Importantly IP networking (the Internet layer) is mostly agnostic to the link layer which does the actual movement of the packets between devices. For uncompressed video we use Ethernet but WiFi, Bluetooth, 3G(UMTS) are other examples link types.

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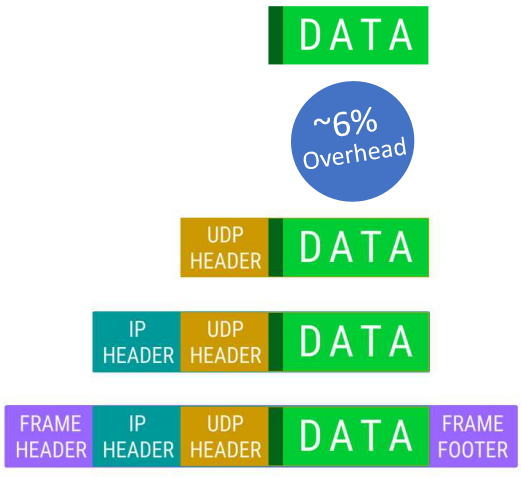
Sending SDI Over an IP Network (SMPTE ST 2022-6)



Name		Standard	Length
Application Layer			
SDI	Serial Digital Interface	SMPTE 259M, 292M, 424M	1376 Bytes
HBRMT	High Bitrate Media Transport	SMPTE 2022-6	8-16 Bytes
RTP	Reat-Time Transport Protocol	RFC 3550	12 Bytes
Transport Layer			
UDP	User Datagram Protocol	RFC 768	8 Bytes
Internet Layer			
IP	Internet Protocol (v4/v6)	RFC 791 / RFC 2460	20 / 40 Bytes
Link Layer			
MAC	Media Access Control (e.g. Ethernet)	IEEE 802.3	42 Bytes

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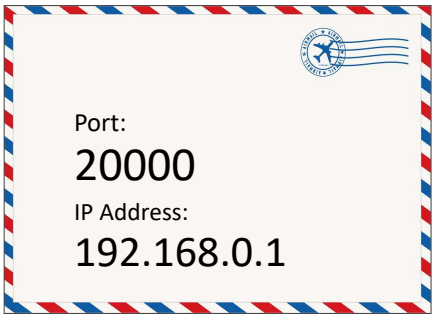
IP Addresses & Unicast / Multicast



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IP Addresses & Unicast / Multicast

192.168.0.1

IPv4 Address: 11000000.10101000.00000000.00000001

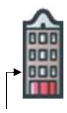
Network Address = 192.168.0.0/24

Host Address

Subnet Mask: 11111111.11111111.11111111.00000000

255.255.255.0

A1 Hotel, Amsterdam, NL



Room 1

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IP Addresses & Unicast / Multicast

Bit → 0		31
0	Class A Address	0.0.0.0 – 127.255.255.255
1 0	Class B Address	128.0.0.0 – 191.255.255.255
1 1 0	Class C Address	192.0.0.0 – 223.255.255.255
1 1 1 0	Class D Multicast Address	224.0.0.0 – 239.255.255.255
1 1 1 1 0	Reserved	240.0.0.0 – 247.255.255.255

PRINT NOTE
Network classes are an old (non-longer used) concept but often still get referred to when discussing subnet masks. The IP addresses reserved for Class D were defined to allow MULTICAST (as opposed to UNICAST where an address for a single specific host machine is used).

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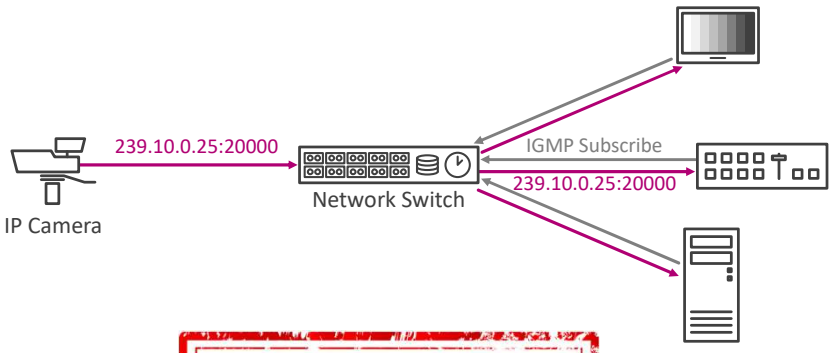
IP Addresses & Unicast / Multicast

1 1 1 0	Class D Multicast Address	224.0.0.0 – 239.255.255.255



PRINT NOTE
Multicast allows multiple devices to receive the same data WITHOUT any additional load on the sending machine. If the above example was a file server with 3 edit workstations loading the same file it would require 3 separate TCP/IP connections (i.e. 3x the work for the file server compared to serving a single workstation)

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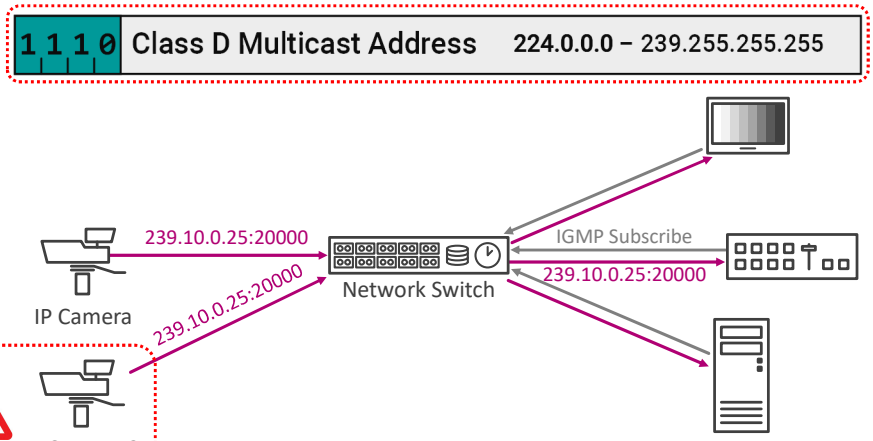
IP Addresses & Unicast / Multicast



Simple multicast does not protect against a second device sending on the same address/port

IGMP v2 >> Join / Leave

IGMP v3 >> Subscribe / Unsubscribe

IGMPv3 Introduced Source Specific Multicast (SSM) which ensures only multicast packets from a specific source address are received

Multicast address typically in range 232.0.0.1/8 to use SSM

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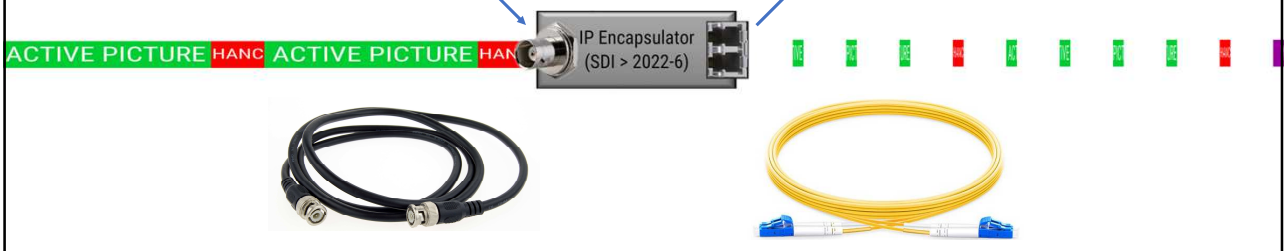
Packetising SDI

SDI is a dedicated link with constant data rate
SD-SDI: 270Mb/s
HD-SDI: 1.5Gb/s
3G-SDI: 3Gb/s

Ethernet links can have higher data rate so more data can be carried in the same time
10GE: 10Gb/s
25GE: 25Gb/s



PRINT NOTE

People talk about IP connections being 'Faster' meaning data is encoded on the connection at a higher frequency (i.e. the transition time between 1's and 0's is faster). The signal itself doesn't move across a connection any faster.

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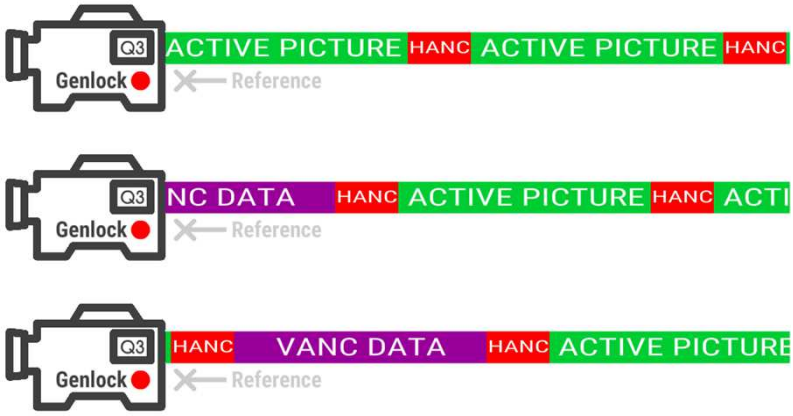
Reference Timing in SDI



PRINT NOTE
3 cameras not referenced will each generate video based on their internal concept of time (i.e. no two will be the same just like 2 people's watches never stay in perfect sync).

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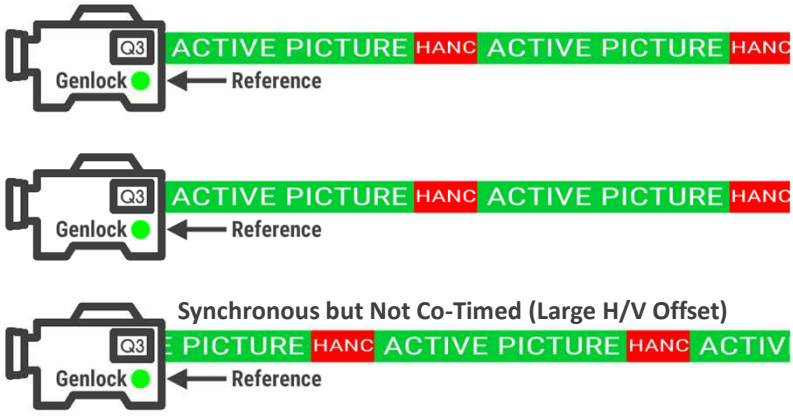
Reference Timing in SDI



PRINT NOTE
Due to the nature of analogue ref cabling & signal distribution adjustment of relative phase was common (also known as horizontal/ vertical timing offset).

Dedicated (Single BNC) connection to equipment with upstream distribution & changeover

- Analogue-SD (Bi-Level Sync / a.k.a "B&B" or "BlackBurst")
- Analogue-HD (Tri-Level Sync)
- SDI Reference

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Reference Timing in IP > PTP (SMPTE ST 2059)

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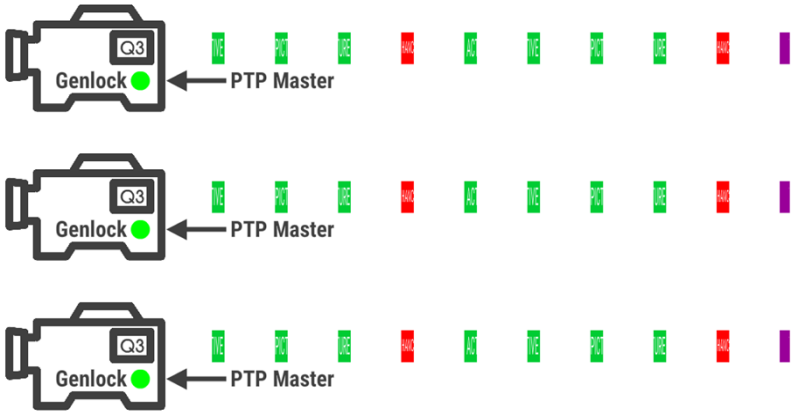
Reference Timing in IP > PTP (SMPTE ST 2059)



PRINT NOTE
PTP automatically compensates for the connection distance (latency) so H/V (phase) adjustment is rarely needed.

Dedicated or shared IP connection over IP switch architecture with automatic failover between masters.

- IEEE 1588-2008 Precision Time Protocol
- SMPTE ST 2059-1 - PTP Alignment to SMPTE Epoc
- SMPTE ST 2059-2 – PTP Operating Profile for Broadcast Use

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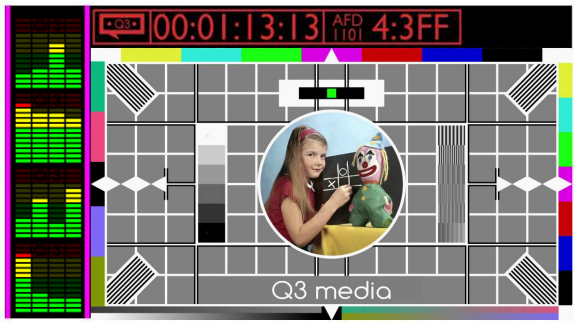
SMPTE 2022-6 > Just a stepping stone?



PRINT NOTE
Remember that SDI contained a lot of empty space (null data). And why send all this data to a device that just wanted the audio or caption data?

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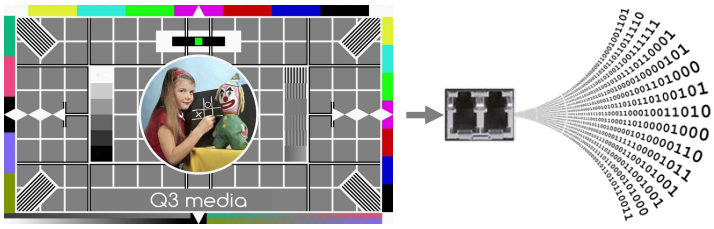
SMPTE ST 2110

"Essence-based flows"

2110-20 : Video



2110-30 : Audio

2110-40 : Data

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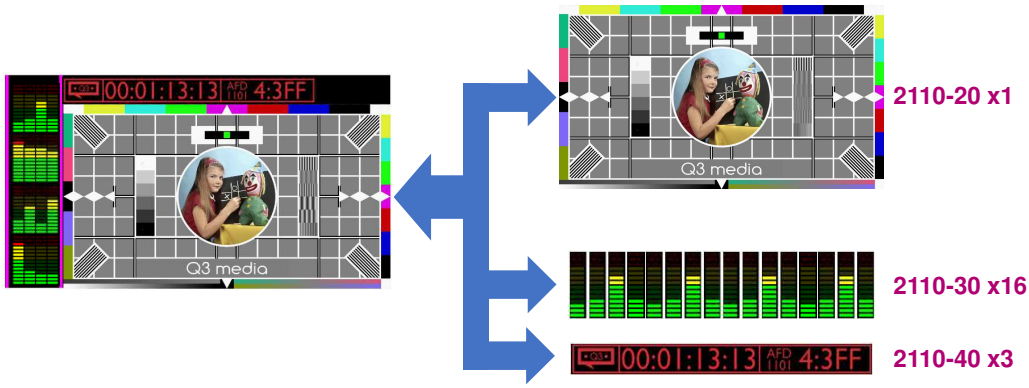
That's a lot more flows!

SMPTE ST 2022-6

SMPTE ST 2110



All contained within 1 RTP Flow

Potentially ~20 flows

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NMOS IS-04 (Discovery & Registration)

Keeping track of all the flows, what is generating them, and what can consume them

AMWA Advanced Media Workflow Association → networked media NMOS open specifications

- Protocols defined for Peer-to-Peer discovery and discovery via central Registry
- mDNS discovery
- HTTP-based protocols for Node/Registration/Query API's (JSON payload)
- Flow properties/parameters via SDP file (RFC 4566)

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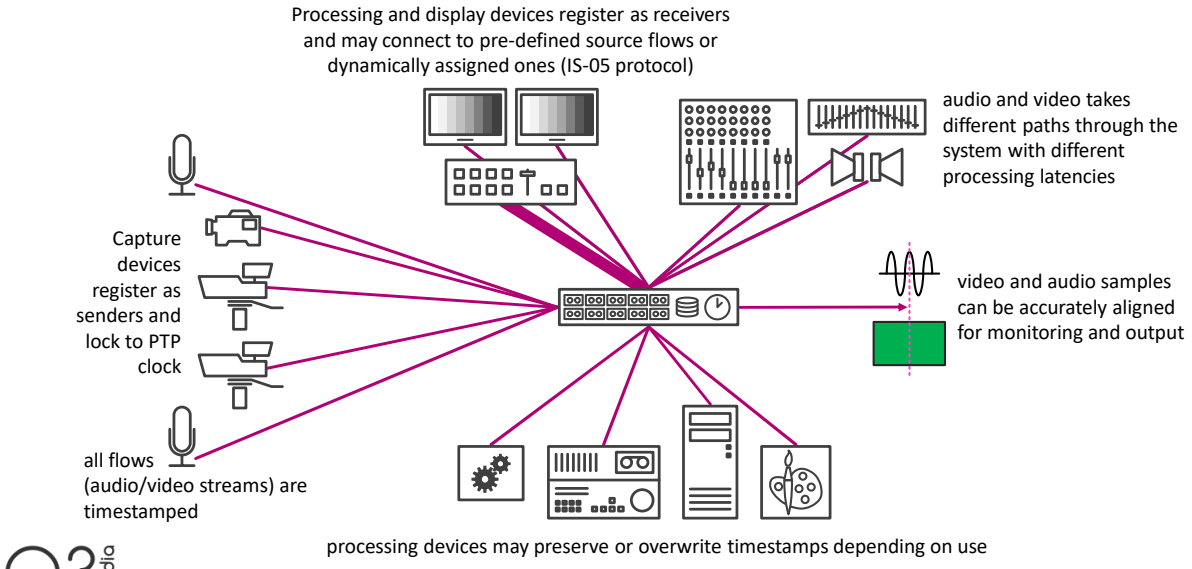
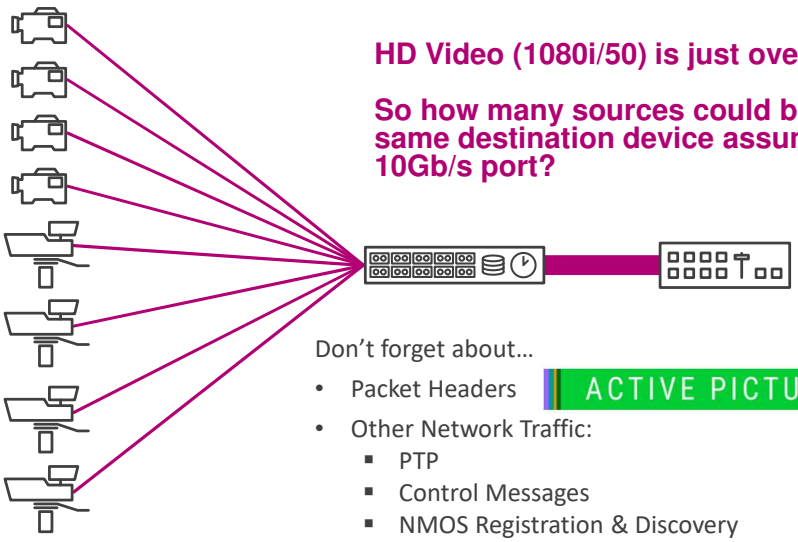
IP-Based Production using 2110 & NMOS (IS-04)



In the IP world we rely on the IP Switch to manage the signal routing



HD Video (1080i/50) is just over 1Gb/s

So how many sources could be fed to the same destination device assuming a 10Gb/s port?

Don't forget about…

- Packet Headers — ACTIVE PICTURE DATA
- Other Network Traffic:
  - PTP
  - Control Messages
  - NMOS Registration & Discovery
  - etc.

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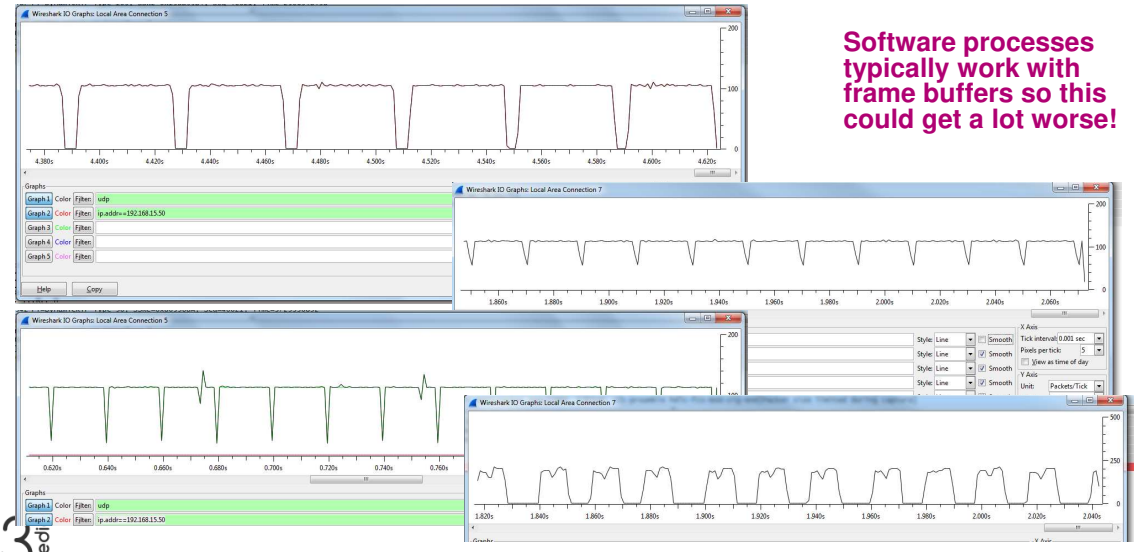
Wireshark captures showing some 2110-20 flows from different hardware devices



Software processes typically work with frame buffers so this could get a lot worse!

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How to send video…

- Hardware processing in real-time (e.g. Camera/Packetiser)
  - Send it as soon as you can (i.e. lowest latency)
- Software generally works with full frames
  - Send all the packets as fast as possible?
    - i.e. Burst at 10Gb/s then wait for next frame
  - Space out all the packets evenly over the time of each frame (drip-feed)
    - i.e. Smooth transmission to give constant rate (e.g. ~1Gb/s for 1080i/50)

This decision significantly impacts the ability for the receiving equipment to successfully receive

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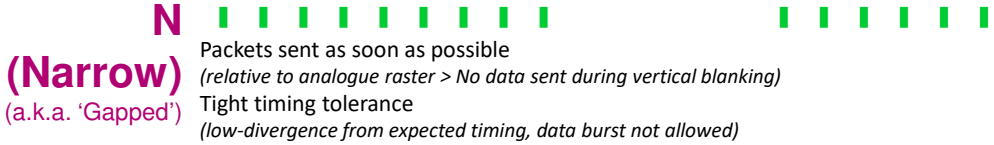
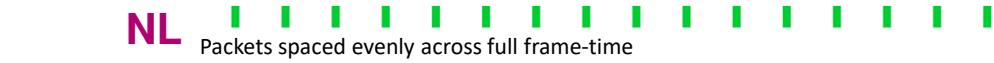
IP SHOWCASE THEATRE

SMPTE ST 2110-21
Traffic Shaping and Delivery Timing for Video



N (Narrow) (a.k.a. 'Gapped')

Packets sent as soon as possible
(relative to analogue raster > No data sent during vertical blanking)
Tight timing tolerance
(low-divergence from expected timing, data burst not allowed)



NL (Narrow Linear)

Packets spaced evenly across full frame-time
Tight timing tolerance
(low-divergence from expected timing, data burst not allowed)

W (Wide)

Packets spaced evenly across full frame-time
Relaxed timing tolerance
(timing variability and data bursts allowed within set limits)
Assumes receiver has a buffer capable of holding at least 720 packets

Q3 media

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IP SHOWCASE THEATRE

SMPTE ST 2110-21
Traffic Shaping and Delivery Timing for Video

N (Narrow) (a.k.a. 'Gapped')

NL (Narrow Linear)

W (Wide)

PRINT NOTE
It is becoming common practice on projects for IP video installations to ensure the widest interoperability by requesting all sending devices adhere to N/NL profile and all receivers are able to support Wide profile.

HARDER	***EASIER***
EASIER	***HARDER***
SENDER	**RECEIVER**

Q3 media

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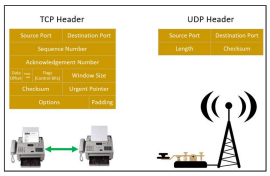
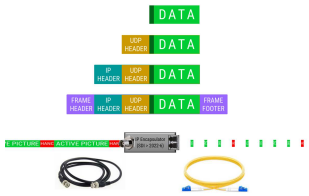
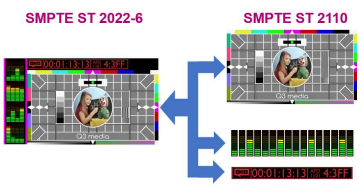
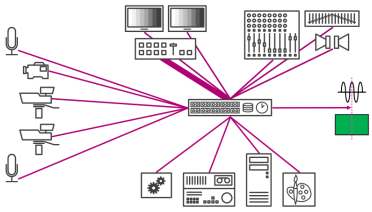
IP SHOWCASE THEATRE Summary









Q3 media

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Pacing of packets is important

Video courtesy of Cargospotter Aviation youtube.com/Cargospotter
Thanks to Andy Rayner for the original idea for this analogy

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