Implementing 10G+ Ethernet in Motion Imaging Workflows:
Practical Considerations and Roadmap for the Future

Welcome!

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Implementing 10G+ Ethernet in Motion Imaging Workflows

Today's Speaker

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Agenda

• Historical perspective
  – too many solutions
• Ethernet: the good, the bad, and the ugly
  – the basic technology is ready,
  – but it can’t be used
• The state of the art
  – Ethernet 10G
  – IEEE 802.3ba: 40G and 100G Ethernet
  – IEEE 802.1 Audio Video Bridging
• Using the new technology
  – An Ethernet Studio

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Historical perspective

- Each generation of content technology added new infrastructure
  - with all new wires, switches, processors, storage
  - interconnect frequently based on proprietary solutions
  - usually done from the point of view of the endpoint equipment designer
  - … so there are lots of different connections

- Computer/IT networks
  - much more evolutionary, good growth with incremental addition of infrastructure
  - but performance was inadequate

Studio infrastructure now
Wouldn’t it be nicer if…

The good: Ethernet technology

- Speeds are finally there:
  - 10 Gbit/s is shipping in quantity - uncompressed HD streams, single stream 4k raw
  - 1 Gbit/s is commodity – digital cinema to 4K, uncompressed SD
  - 100 Mbit/s is “free” – uncompressed audio, management

- Management services are there:
  - built-in cable diagnostics, error logging
  - auto-failover, redundant wiring
  - both automatic and managed routing services

- Security and authentication
  - link encryption, authorized connection

- In continuous development
  - in virtually all markets from consumer to industrial to telecom to …
The bad: no thought for studio A/V

- 10G is still too slow for some applications
  - Backbone needs multistream support: uncompressed HD, 4K raw
- QoS is “statistical”
  - can be made to work, but requires almost as much configuration engineering as existing studio interconnects
- Timing is “statistical”
  - Genlock extremely hard
- Multistream synchronization requires big buffers
  - acquiring synchronization can take a long time, and there are no guarantees it will stick

The ugly: we have what we have
10G Ethernet Overview

- Point-to-point media and port classes***
  - SMF: 10GBASE-LR, 10GBASE-ER, 10GBASE-LW, 10GBASE-EW, 10GBASE-LX4
  - MMF: 10GBASE-SR, 10GBASE-SW, 10GBASE-LX4, 10GBASE-LRM
  - Twisted pair structured cabling (TP): 10GBASE-T
  - Twinaxial/Controlled Impedance: 10GBASE-CX4
  - Backplane (FR4): 10GBASE-KX4, 10GBASE-KR

*** -W indicates a WAN PHY. All others are LAN based

- Point-to-multi-point media and port classes:
  - SMF: 10GBASE-PR

10G “Point-to-Point” Architecture

![Diagram of 10G Ethernet architecture](attachment:image.png)

Figure 44-1—Architectural positioning of 10 Gigabit Ethernet
10G Point-to-multipoint Architecture (PON)

- Used for “fiber to the home” or similar
- 10G bandwidth is shared
  - but less expensive than full point-to-point
- Particularly useful for asymmetric applications
  - faster “down” than “up”

Common 10G Interfaces

- Single Mode Fiber
  - 10GBASE-LR: 2m to 10km at 1310nm wavelength
  - 10GBASE-ER: 2m to 30km (up to 40km when engineered link) at 1550nm wavelength
- Multi Mode Fiber (OM3/50µm core)
  - 10GBASE-LRM: 0.5m to 220m at 1310nm wavelength with EDC
- Twisted pair structured cabling
  - 10GBASE-T: 55m over Cat 6 / Class E; 100m over Cat 6A / Class EA / Class F
- Other interfaces
  - SFP+ Direct Attach Copper: System to system link based on 10GBASE-KR in SFP – very short range, for rack-based systems
New Stuff (1): Energy Efficient Ethernet

- Energy Efficient Ethernet: Ethernet’s “green” project for the physical layer
  - Interest from regulatory bodies. E.g. EPA’s future Energy Star specifications
  - Low Power Idle (LPI) – PHY powers down during idle periods
  - PHY power in LPI mode ~20-40% of normal (depends on type and implementation)

```
assert LPI

low-power

deassert LPI

hold

Active

Data/IDLE

sleep

quiet

refresh

quiet

wait a minimum of Tw_Sys before sending data (Tw_sys >= Tw_PHY)
```

New Stuff (2): 40G and 100G Ethernet

- 40Gbit/sec and 100Gbit/sec MAC data rate
- Similar connection choices, same media:
  - 100m OM3 (50 um) multi-mode fiber @ 40G & 100G
    - parallel ribbon fiber
    - n x 10G, short wavelength, Vertical Cavity Surface Emitting Laser (VCSEL)
  - 100G single mode fiber @ 10 km and 40 km
    - 4 x 25G Wavelength Division Multiplexing (2nm spacing)
  - 40G single mode fiber @ 10 km
    - 4 x 10G Coarse Wavelength Division Multiplexing (13 nm spacing)
  - 1 m backplane @ 40G
    - based on 10GBASE-KR (40GBASE-KR4)
  - 10 m copper @ 40G
    - based on 10GBASE-KR
New Stuff (3): QoS and Timing

• The IEEE 802.1 AVB Task Group is responsible for developing standards that enable time-sensitive applications over IEEE 802 networks
  – part of the IEEE 802.1 Working Group that is responsible for bridging (Ethernet “switches”)
• The primary projects include:
  – queuing and forwarding of time-sensitive streams (P802.1Qav)
  – registration and reservation of time-sensitive streams (P802.1Qat), and
  – time synchronization (P802.1AS)

Audio Video Bridging + Ethernet

• < 2ms guaranteed latency through 7 Ethernet bridges
  – and that’s using 100 Mbit/sec; much less at 1 Gbit/sec, and much, much less at 10 Gbit/sec
• Admission controls (reservations) for guaranteed bandwidth
• Precise timing and synchronization services for timestamps and media coordination
  – < 1µs instantaneous synchronization between devices
  – delivered clock can meet the jitter and wander requirements (MTIE mask) for HD-SDI
A word on time synch

- 802.1AS is strongly related with IEEE 1588
  - very tightly defined subset of 1588 for Ethernet
  - simpler to implement, defined performance, fast to converge
  - superset of 1588 to support WiFi and other “coordinated shared media” LANs
- 802.1AS runs directly on Ethernet
  - not on top of UDP/IP as most 1588 systems do
AVB Grand Master clock

- There is a single device within an AV cloud that provides a master timing signal.
  - All other devices ("ordinary clocks") synchronize their clocks with this master.

When?

- IEEE standardization process well under way
  - All 802.1 and 802.3 docs of interest in "working group ballot", final standards in 2010
- Wireless (802.11) support coming later
  - Time sync (802.1AS) in 2010, but
  - QoS/Reservation enhancements (802.11aa) in two-four years
- Will follow Ethernet-type product curve
  - 10G now, 40G in one/two years, 100G in four/six
  - AVB services automatically take advantage of improvements in PHY and MAC speeds and capabilities
**Studio services and AVB**

- Several technical challenges to take up
  - Genlock
    - Synchronization in frequency and phase of all connected devices
  - Virtual Audio/Video matrix
    - Switch from one group of sources and/or destinations to another in respect of synchronous event (e.g. frame basis).
  - Resource allocation
    - Appropriate class-based treatment of dataflow
  - Wired and Wireless continuity
    - Ensure the service’s continuity between wired and wireless parts of the infrastructure (Emerging HD wireless equipment, like camera)
  - Control and monitoring
    - Provide a complete network supervision in accordance with the TV studio usage (Device control, stream naming, dataflow, alarm designation, automation, etc.)
    - Support current communication features (Intercom, tally, etc.)
    - Dynamic and exhaustive view of the network’s topology including connected devices

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**Layered concept for Genlock**

- Genlock
  - Synchronization in frequency and phase of all connected devices from the cameras to the video switcher (scale of tens of nanosecond)
    - Support switching between different video sources in Vertical Blanking
    - System wide synchronization for low latency (small buffer, no over or under flow)

* SMPTE/EBU Joint Task Force on Timing & Synchronization
Virtual matrix & A/V streaming

- Audio/Video switching done at strict temporal events (SMPTE RP168)
- Ethernet A/V streams are self-addressed (in-band routing)
  - virtual switching matrix is scalable: adding more capability just by adding the equipment, engineering is much less
- Ethernet A/V streams are time-tagged
  - Derived from the accurate wall clock (genlock/802.1AS), uses existing standardized protocol like RTP or IEC 61883 (IEEE 1733 and 1722)
  - New devices (at least new I/Os and protocol handling)

Motion imaging deployment

- Switches, infrastructure, computers …
  - they will all be ready
- Cameras? Legacy converters? Genlock adapters? Things I don’t even know the names for?
  - Broadcom makes commodity ICs …
  - Xilinx and XMOS have programmable AVB devices …
  - What endpoint devices are needed? What kind of interfaces are needed?
Conclusion

- Ethernet will be ready for initial deployment in motion imaging very soon …
  - NOW for 1G applications
  - next year for 10G, three years for 40G
- Physical plant is already well defined
  - unshielded twisted pair AND fiber choices
  - 10G/40G ready, useful NOW
- Question is …
  - will the motion imaging endpoints be ready?

Questions

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