Standards-based Audio Networks Using IEEE 802.1 AVB

Michael Johas Teener

Robert Boatright

Matthew Xavier Mora

What we are going to do …

- Technical justification and summary description:
  - "Ethernet AV and Audio Video Bridging"
- Streaming audio with AVB:
  - "IEEE 1722"
- Fitting AVB into the existing infrastructure:
  - "Bridging IEEE 1394 and Ethernet AV"
- Q&A

EthernetAV™ and AV Bridging

Michael Johas Teener

Technical Director & Plumbing Architect

mikejt@broadcom.com

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Agenda

- Ethernet 101
  - Ethernet as it really is
  - Ethernet as it is coming to be
  - Ethernet synergies
- IEEE 802.1 AV Bridging and Ethernet AV
  - Technical summary
  - Bringing it all together
- Real devices for Ethernet AV
  - Ethernet AV ready devices and switches

What am I trying to show?

- Ethernet already has the fundamental technology in place
  - and there is a huge market and technology momentum
- New work is demonstrating 1394-like QoS guarantees at Ethernet cost points
- Adapting Ethernet for professional live audio transport is straight forward
  - and has significant fundamental advantages over the alternatives

Ethernet 101:
The way it really is

- All links run at 100 Mb/s or faster
  - 1 Gb/s links are now outselling 100 Mb/s
  - 100 Mb/s is “free” (included in most CE-based SoC’s)
- Ethernet is a switched network
  - There are no hubs
  - There is no shared media
  - “CSMA/CD” is dead, there is no media access protocol
- Ethernet switches are really smart
  - Priorities, virtual LANs, QoS by deep packet inspection
  - “Spanning tree” eliminates loops
  - “Link aggregation” takes advantage of redundant paths

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Ethernet 101:
The way it really is (cont.)

- Ethernet PHYs are really smart
  - Cable diagnostics (impairment measurement and location)
- Ethernet runs on all kinds of media
  - UTP (Cat 5 for 10/100, Cat 5e for 1G, Cat 6a for 10G)
  - STP (Cat 7 for RJ45 connectors, “infiniband” for 10G short range)
  - Fiber (multimode, single mode)
- Ethernet does not have to run at “decade” rates
  - 2.5G widely deployed in data centers, 40G is next standardized speed
  - “SONET” infrastructure used for Ethernet links as well
- Strong security
  - link encryption, link login, strong ID

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Ethernet 101:
The way it is coming to be

- 10 Gb/s deployment is ramping up
  - currently data center and telecom / short range copper / long range fiber
  - UTP (four pair Cat 6a) just starting
- 40 and 100 Gb/s standardization starting
- “Energy Efficient Ethernet” starting
  - automatic and very fast power scaling with traffic requirements
- “FireWire”-type QoS services coming soon
  - IEEE 802.1 Audio Video Bridging
- Congestion management
  - “no dropped packets” IEEE 802.1au, 802.1bb

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Ethernet 101:
Synergies

- Almost all networked devices have an Ethernet port
  - least common denominator
- Baseline assumption for IP networking
  - must work on Ethernet
- Baseline network for DLNA
  - along with WiFi
- Market volumes are **huge**
  - Broadcom alone shipped over a billion ports by 2004
  - Technology and production investment continues

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AV Bridging and Ethernet AV

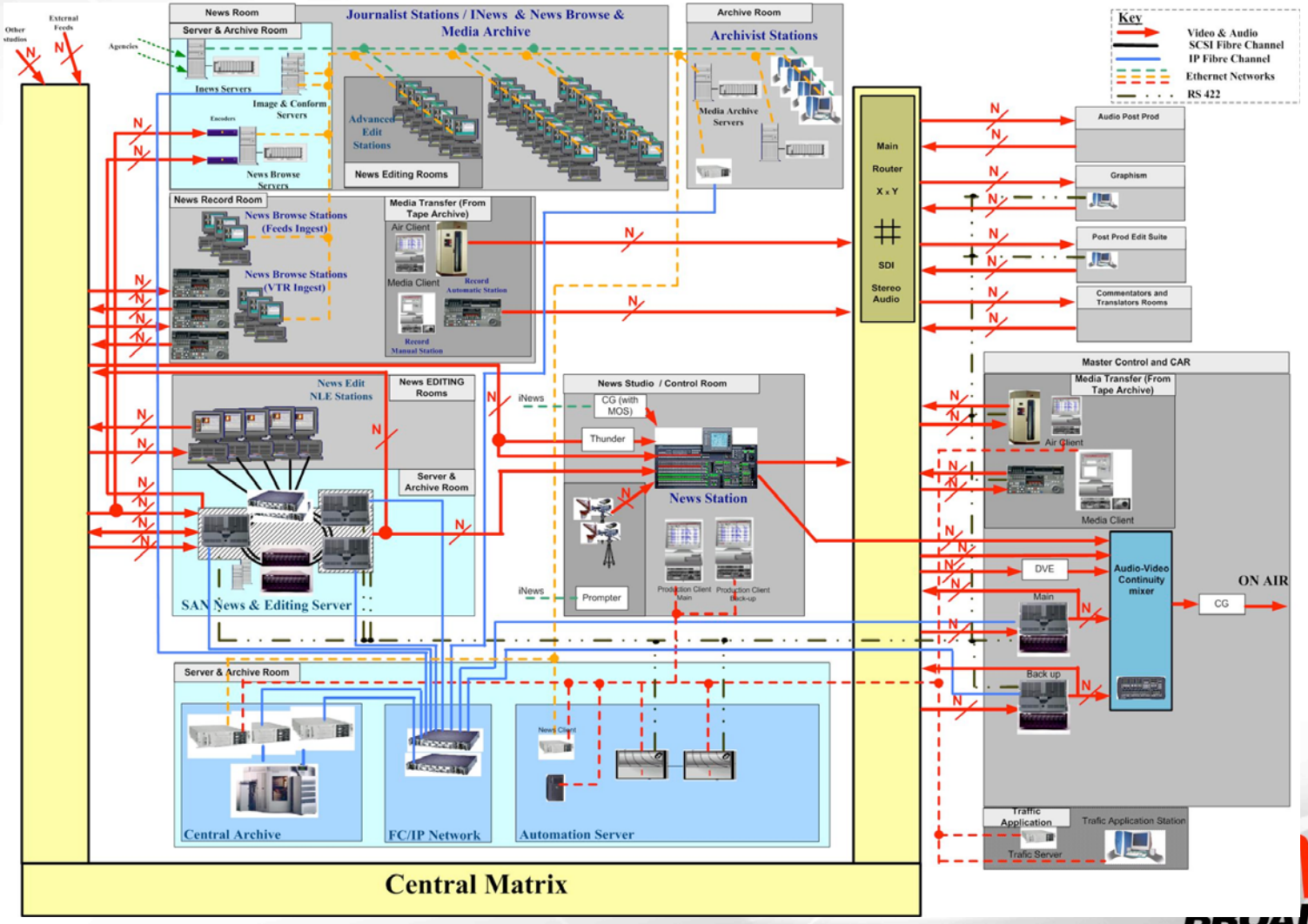
Agenda

- Historical perspective
  - too many solutions
  - can there be a simpler way?
- Ethernet for HD: the good, the bad, and the ugly
  - the basic technology is ready,
  - but it can't be used,
  - so we have what we have
- Fixing the problems
  - IEEE 802.1 Audio Video Bridging

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

Digital Studio Distribution Now



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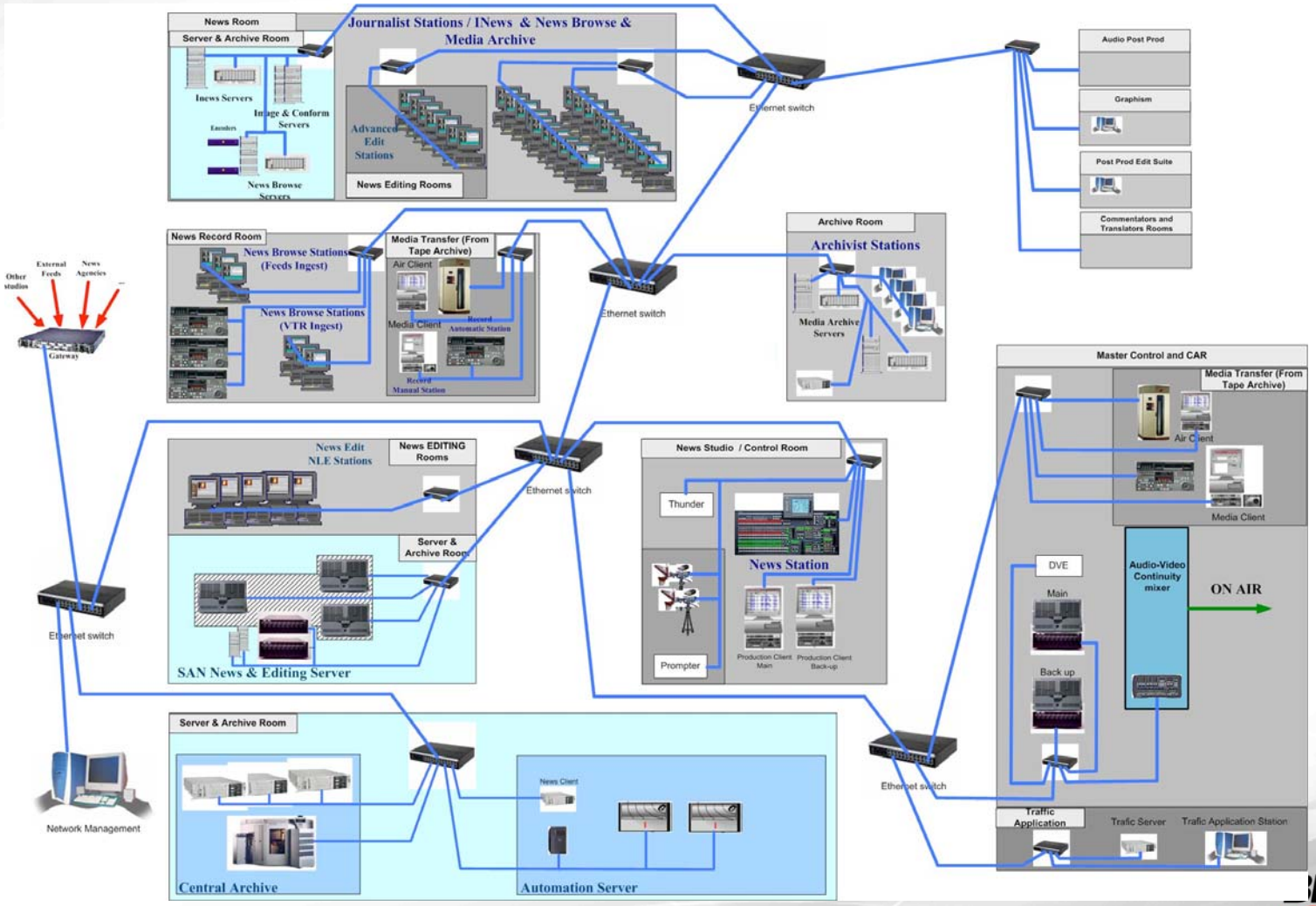
Wouldn't this be better?



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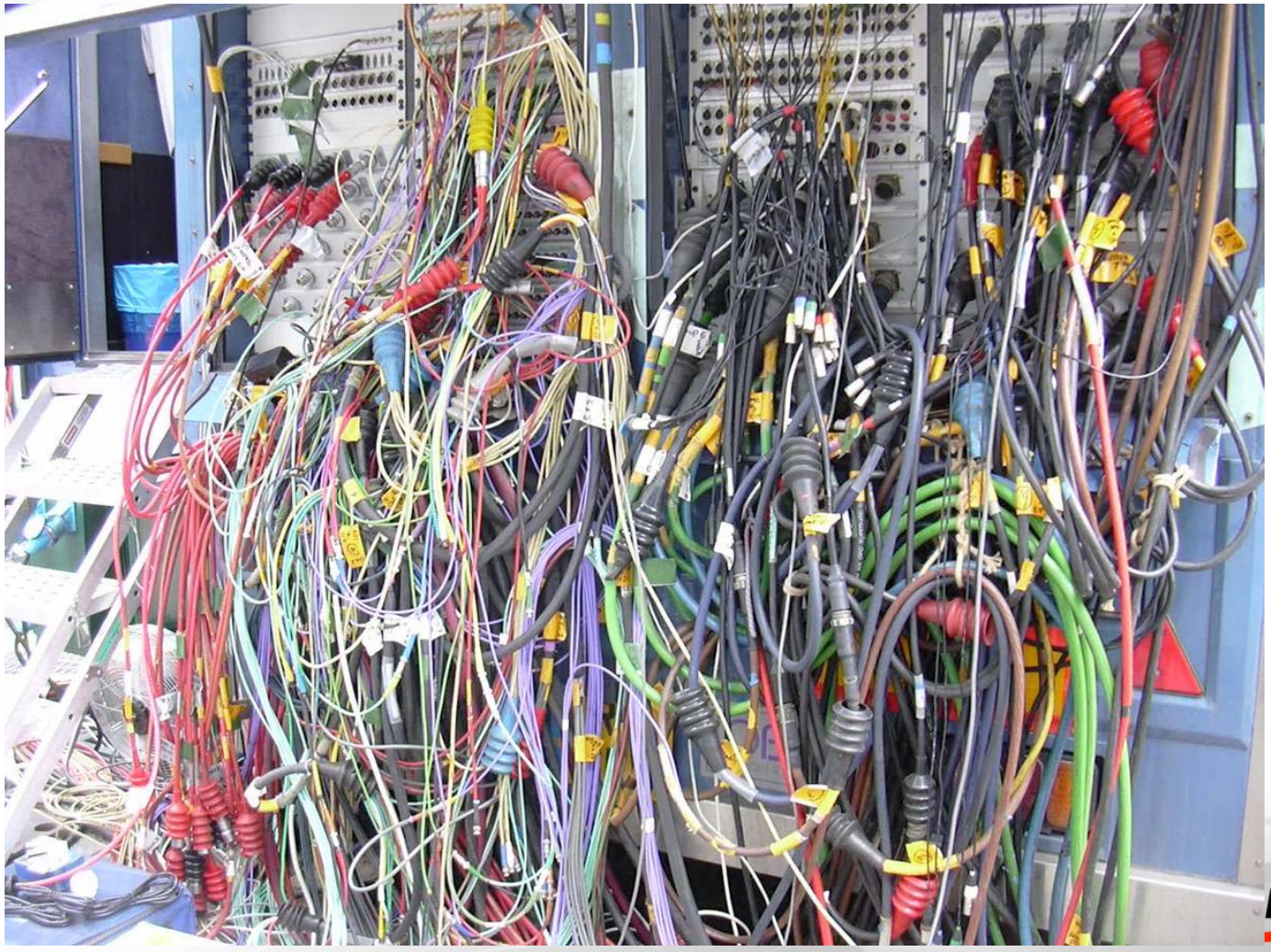
The good:
Ethernet technology should work

- Speeds are finally there:
  - 10 Gbit/s is shipping in quantity - uncompressed HD/hundreds of audio streams
  - 1 Gbit/s is commodity and 100 Mbit/s is “free”
- 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:
it wasn't intended for studio A/V

- QoS is "statistical"
  - almost always works, but no guarantees
  - can be made to work, but requires almost as much configuration engineering as existing studio interconnects
- Timing is "statistical"
  - Genlock/house clock extremely hard
- Multi-stream 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



Fixing it: IEEE 802.1 Audio Video Bridging

- 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

- 2 ms 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 exceed the jitter and wander requirements (MTIE mask) for HD-SDI and AES audio streams

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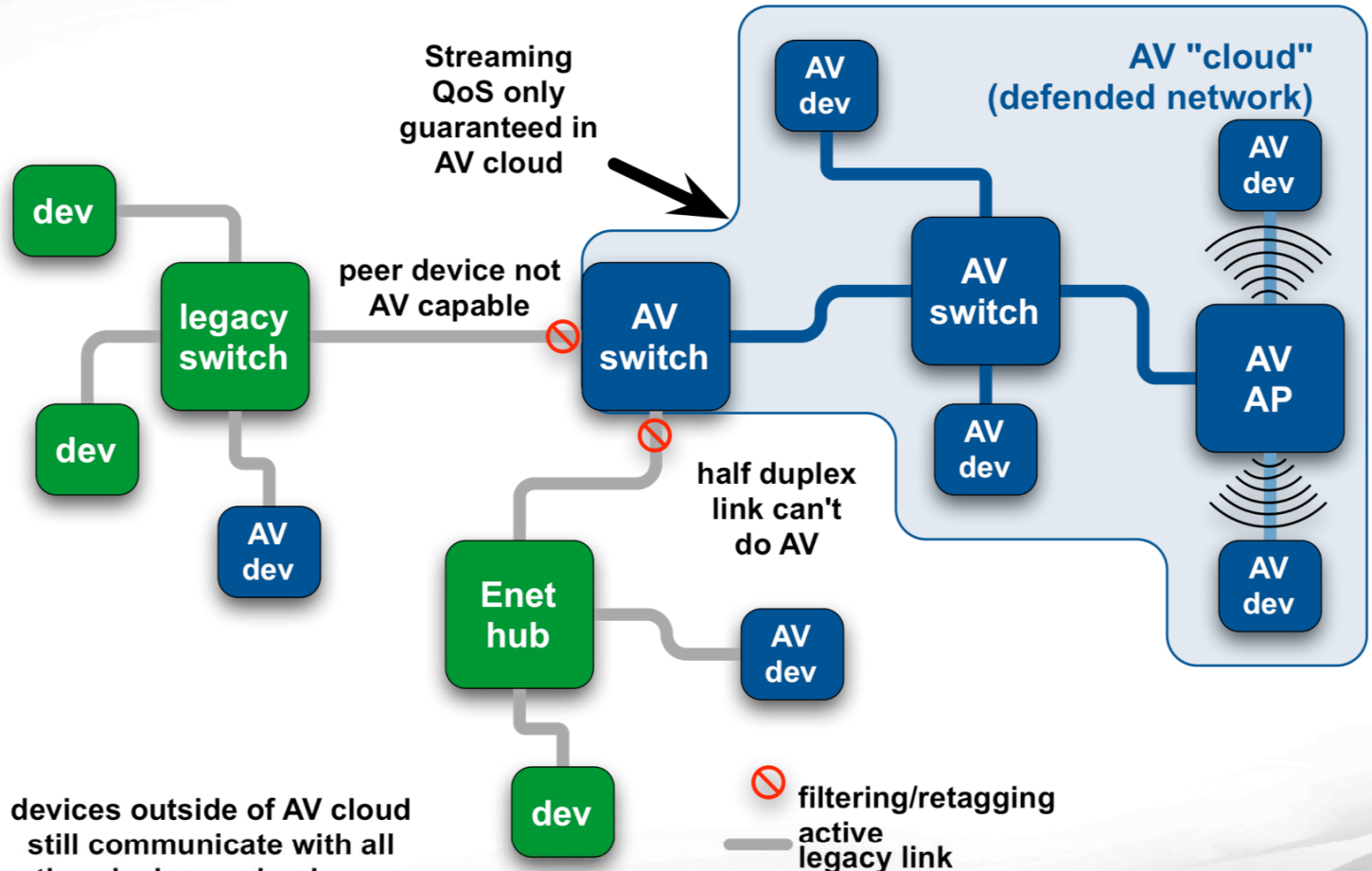
AVB architecture

- Changes to both IEEE 802.1Q ("bridge") and MAC (media-specific)
  - 802.1Q - bridges/switches - most of work
  - 802.3 - Ethernet MAC/PHY - possible small change to MAC *definition*, not implementations
  - 802.11n - WiFi - more work, but basic tools in place
  - MoCA – Multimedia over Coax – intermediate effort
- Three basic additions to 802.1/802.3
  - Traffic shaping and prioritizing,
  - Admission controls, and
  - Precise synchronization

Topology & connectivity



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Establishing the AV cloud

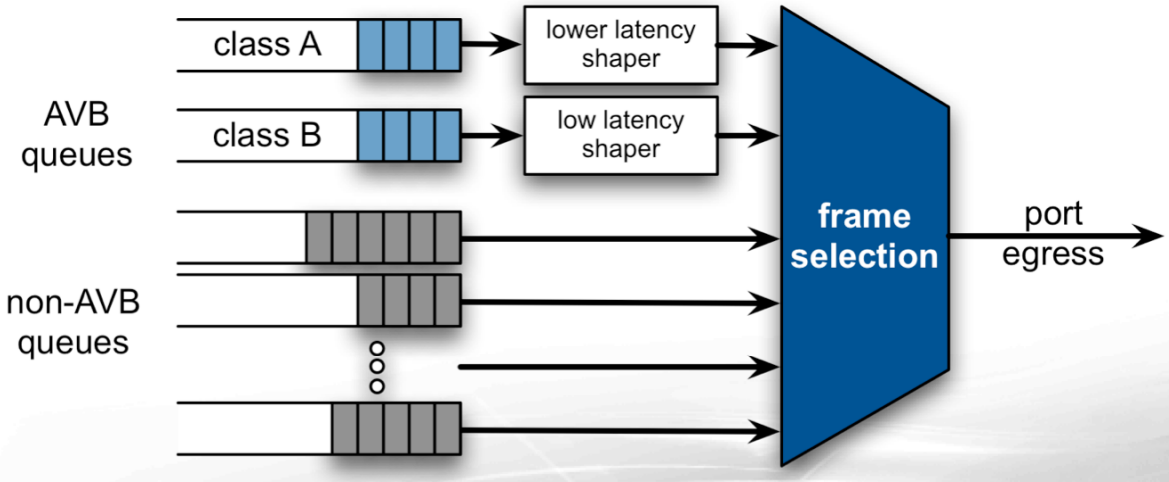
- IEEE Std 802.1AB defines “LLDP”: Logical Link Discovery Protocol
  - allows link peers to determine each other’s characteristics
  - may not be needed
    - used for sharing certain non-standard parameters
- Will be enhanced with P802.1AS service that gives a relatively precise round trip delay to a peer
  - allows link peers to discover if any unmanaged bridges or other buffering devices are present on link

Traffic Shaping and Priorities
(p802.1Qav - rev to 802.1Q)

- Endpoints of Ethernet AV network must “shape traffic”
  - Schedule transmissions of streams to prevent bunching, which causes overloading of network resources
  - Shaping by simple credit-based methods with parameters that depend *only* on aggregated traffic class requirements (diffserv-like)
  - Traffic shaping in bridges as well as source devices
- Mapping between traffic class and priorities

Traffic Class?

- 802.1p introduced 8 different traffic classes
  - Highest (6 & 7) reserved for network management
  - Next two for streaming video and voice (4 & 5)
  - Lowest four for “best effort”
- AV bridging:
  - Class A is for lowest latency streaming (2ms through 7 hops), Class B is for moderate latency streaming
    - by default, Class A is mapped to priority 5, and B to 4, but can be changed



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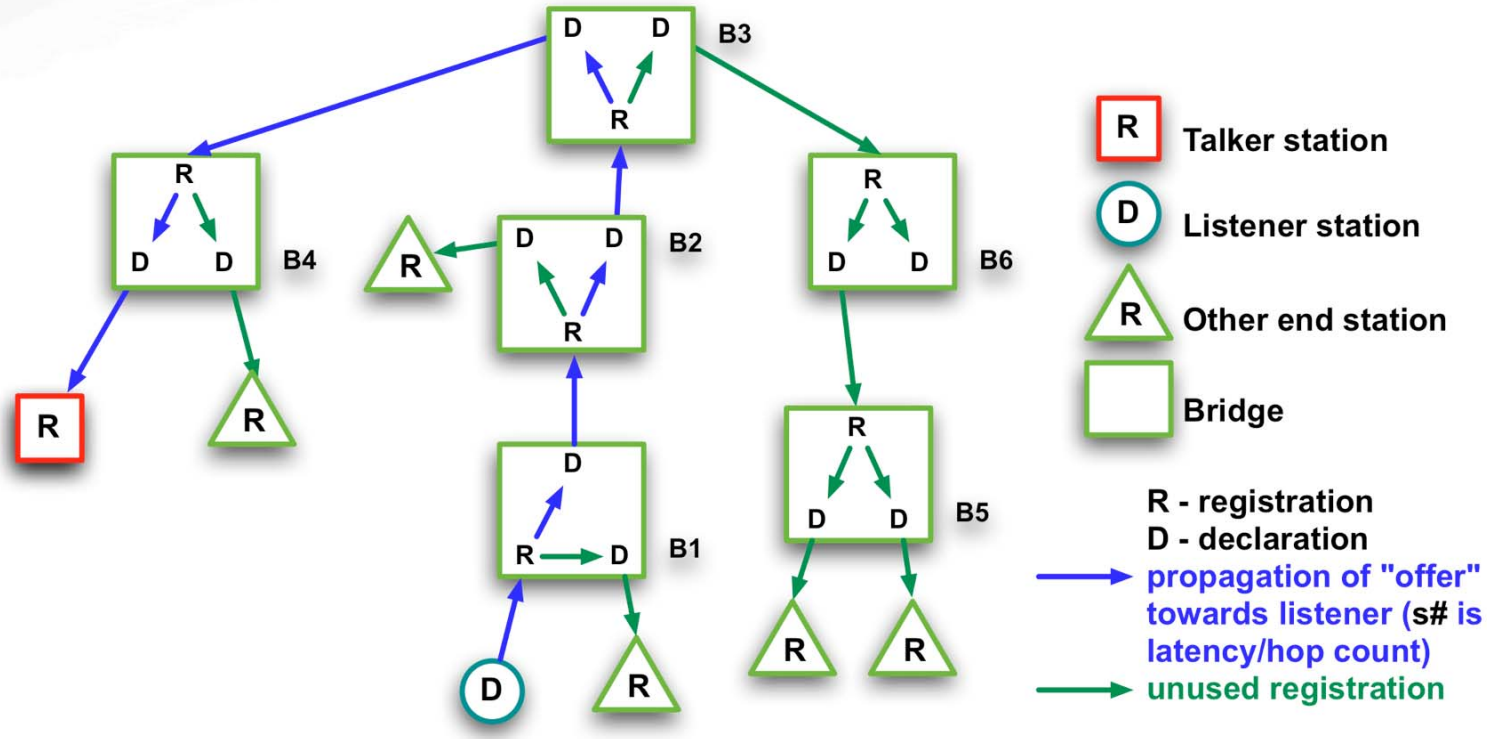
Admission controls (p802.1Qat - added to 802.1Q)

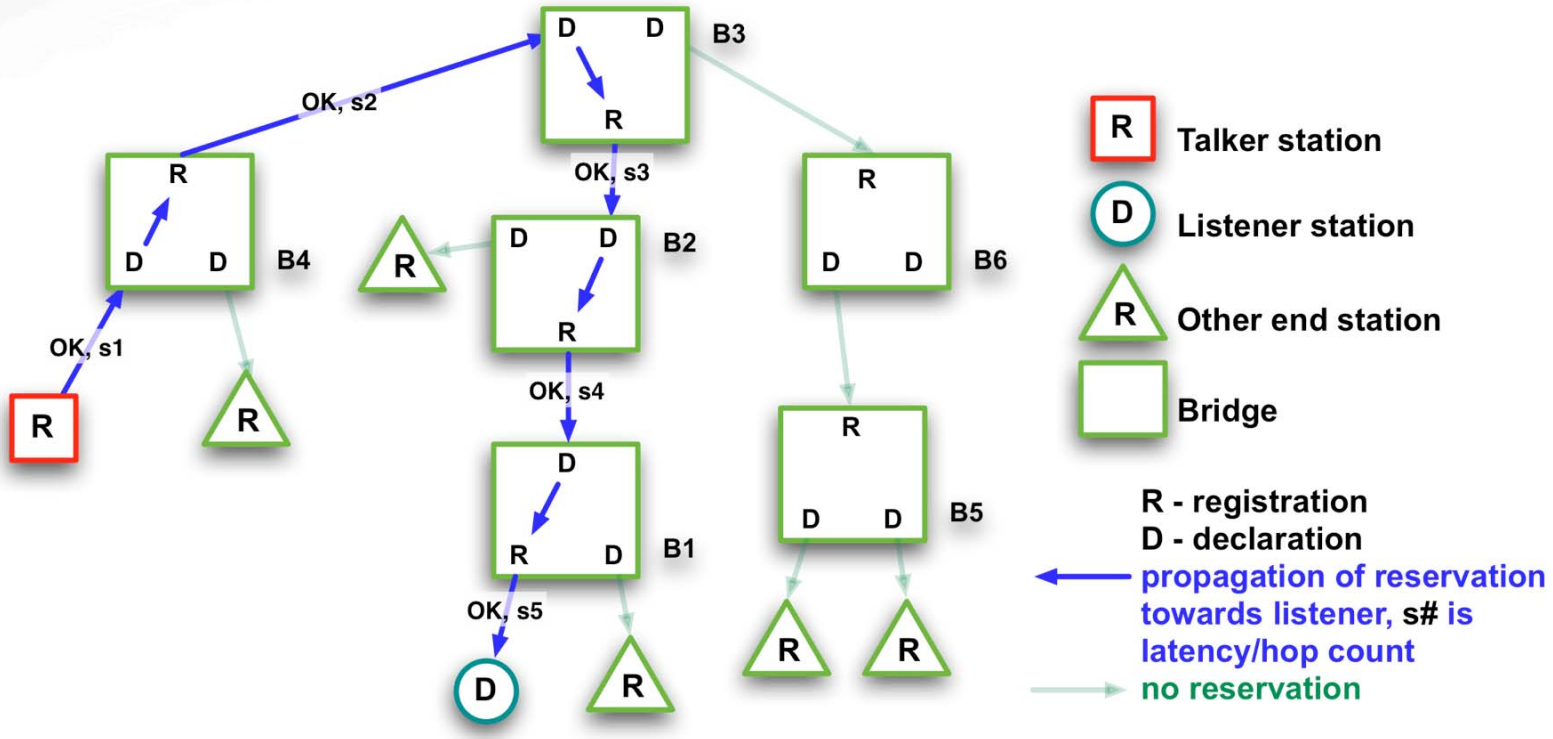
- Priorities and shaping work only if the network resources are available along the entire path from the talker to the listener(s).
  - AVB “listeners” register for a stream
    - not required in small networks, such as home nets
  - AVB “talkers” guarantee the path to the listener is available and reserve the resources
- Done via two 802.1ak “Multiple Registration Protocol” applications: MMRP (“Multiple MAC Registration Protocol”) and SRP (“Stream Reservation Protocol”)
  - Registers listeners as a MAC address using MMRP
  - Registers streams as a source MAC address combined with a higher level ID (frequently the IP port address)
  - Reserves resources for streams based on bandwidth requirements and latency class

Admission Control (1)
(optional registration)



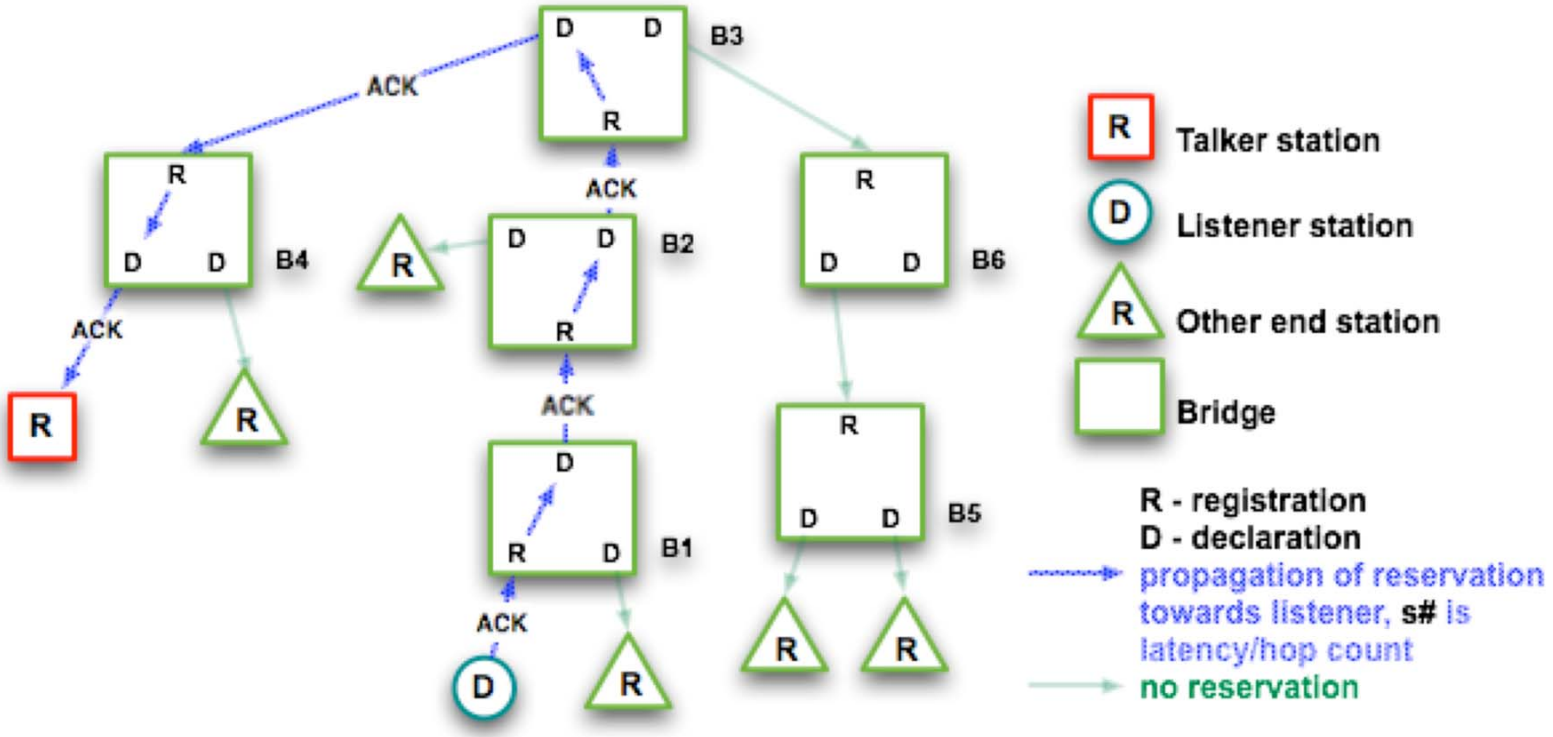
- With MMRP registration, the talker and intermediate bridges know the location of potential listeners and how to get to them

Admission Control (2)
(successful reservation)



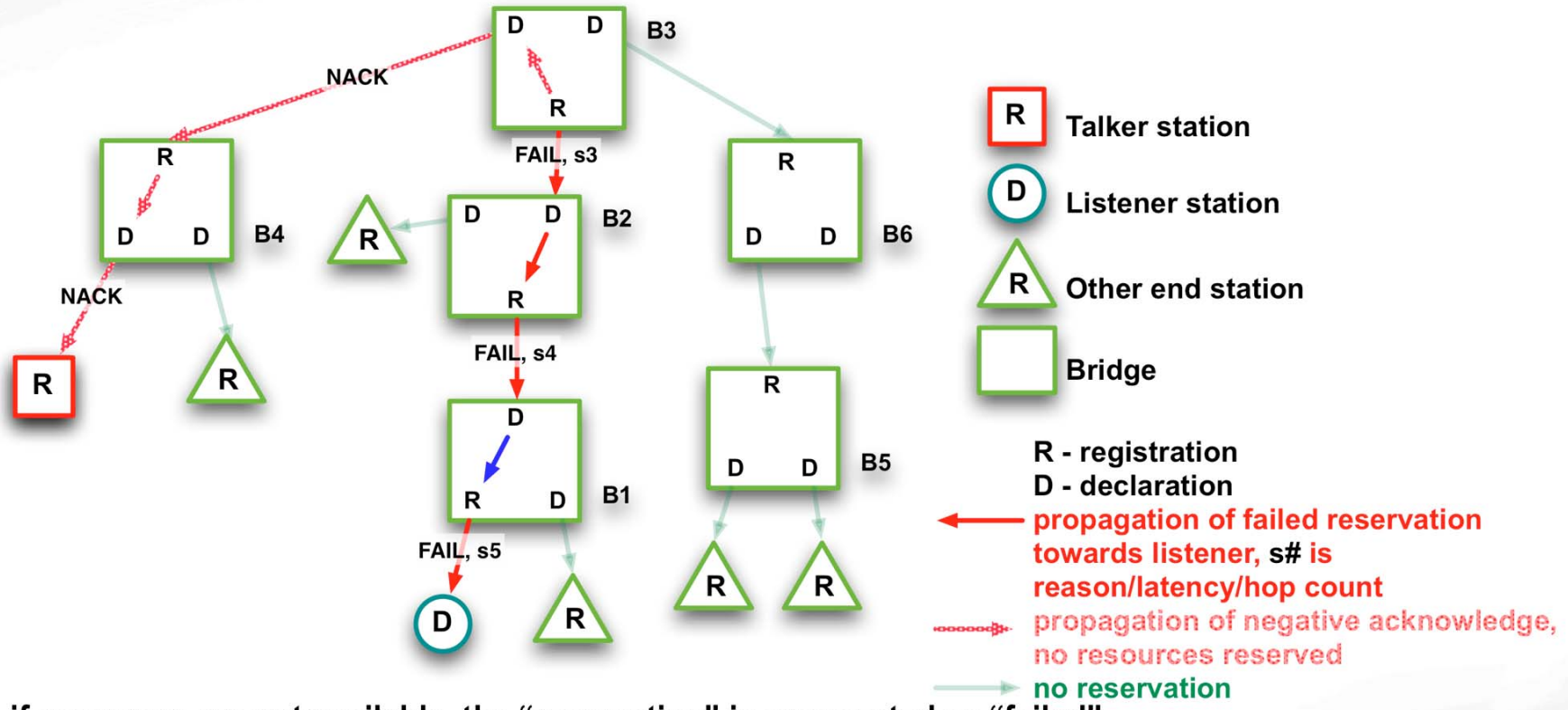
- phase one of a reservation is an “reservation” that tests the path and leaves behind a “breadcrumb” trail to the talker

Admission Control (3)
(reservation acknowledge)



- phase two of a successful reservation actually locks down the needed resources

Admission Control (4)
(failed reservation)



- if resources are not available, the "reservation" is propagated as "failed"
  - no reservation is made, this is done to allow a listener to know that a reservation is not possible now
- a "negative acknowledge" is propagated back towards the talker from the bridge that is first unable to make the reservation
  - the talker knows that at least one listener cannot get the reservation

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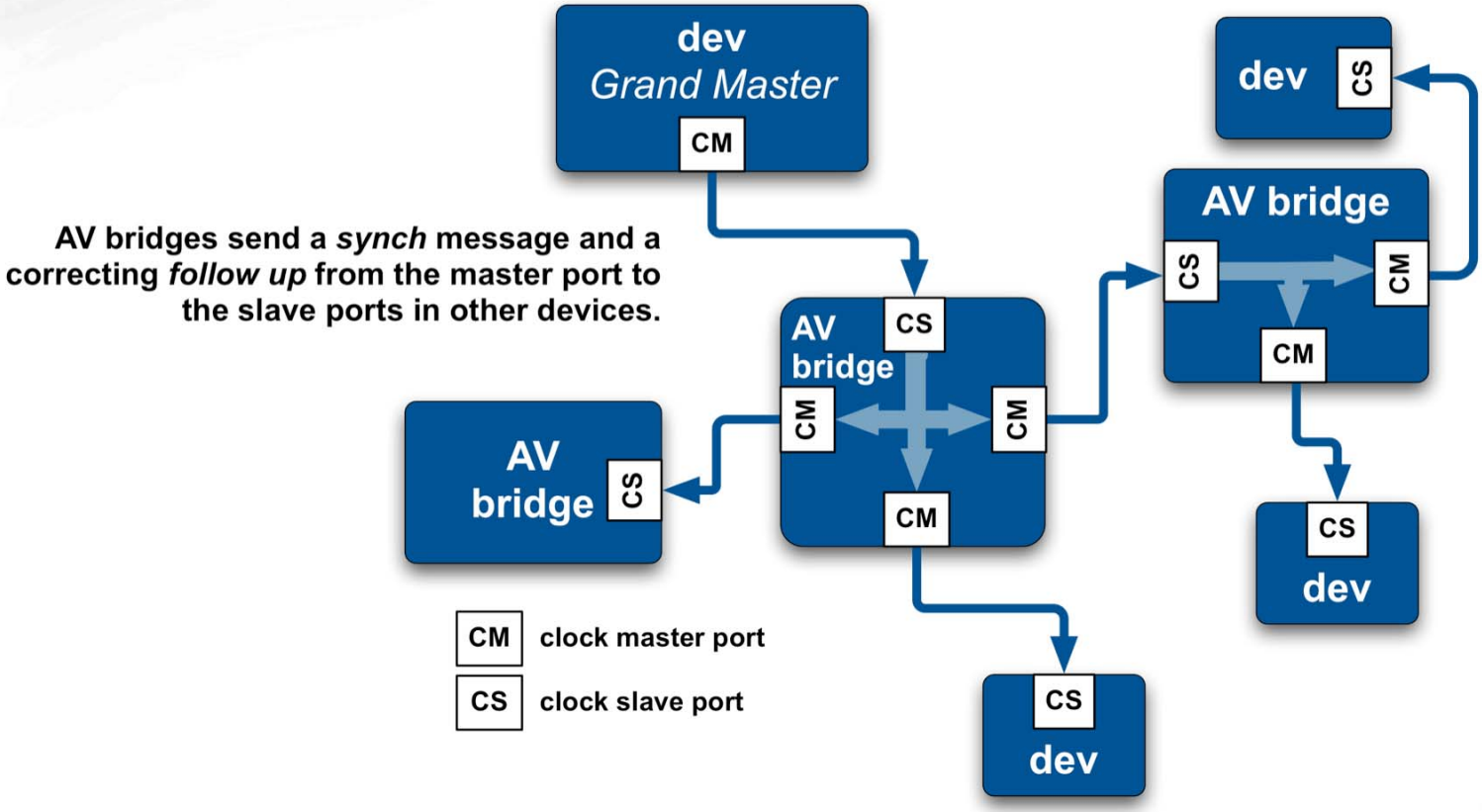
Precise synchronization (p802.1AS)

- All AV devices participate in a “native IEEE 802 layer 2 profile” of IEEE 1588v2 “Precision Time Protocol”
  - subset of standard 1588v2 for Ethernet
  - superset of 1588v2 to support 802.11 WiFi and MoCA
- This precise synchronization has two primary purposes:
  - allow multiple streams to be synchronized and
  - provide a common time base for sampling data streams at a source device and presenting those streams at the destination device with the same relative timing

AVB (1588) 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.

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Master clock selection

- Selection of the master is arbitrary for most applications, but can be overridden if the network is used in an environment that already has a “house clock”.
  - Professional A/V studios
  - Carrier networks
- Selection algorithm and clock attributes are the same as IEEE 1588
  - Typically, fully automatic and transparent to the end user
  - Clock quality hierarchy well defined

When?

- IEEE standardization process well under way
  - Early drafts already available
  - Technical closure already for 802.1AS, 802.1Qat/av almost ready, final draft standards in 2009
  - WiFi version (802.11aa) just started
- MoCA interface to AVB also making fast progress
- Will follow Ethernet/WiFi-type product curve
  - AVB services automatically take advantage of improvements in PHY and MAC speeds and capabilities
  - 100M/1G/10G NIC/Switch all have markets for Ethernet AV

End-to-end EAV: switches

- The BCM5395 was the first switch with pre-standard EAV technology on the market
  - Broadcom's lowest cost 1G 5 port switch, introduced in 2006
  - Demonstrated QoS features privately throughout 2007
  - Public demonstration of time-synch (802.1AS) features at 2007 International IEEE Symposium on Precision Clock Synchronization for Measurement, Control and Communication
  - Better than 500ns synchronization through 6 hops
- Newer versions with better performance available now
  - BCM53115 (5 port), BCM53118 (8 port), BCM53314 (24 port)

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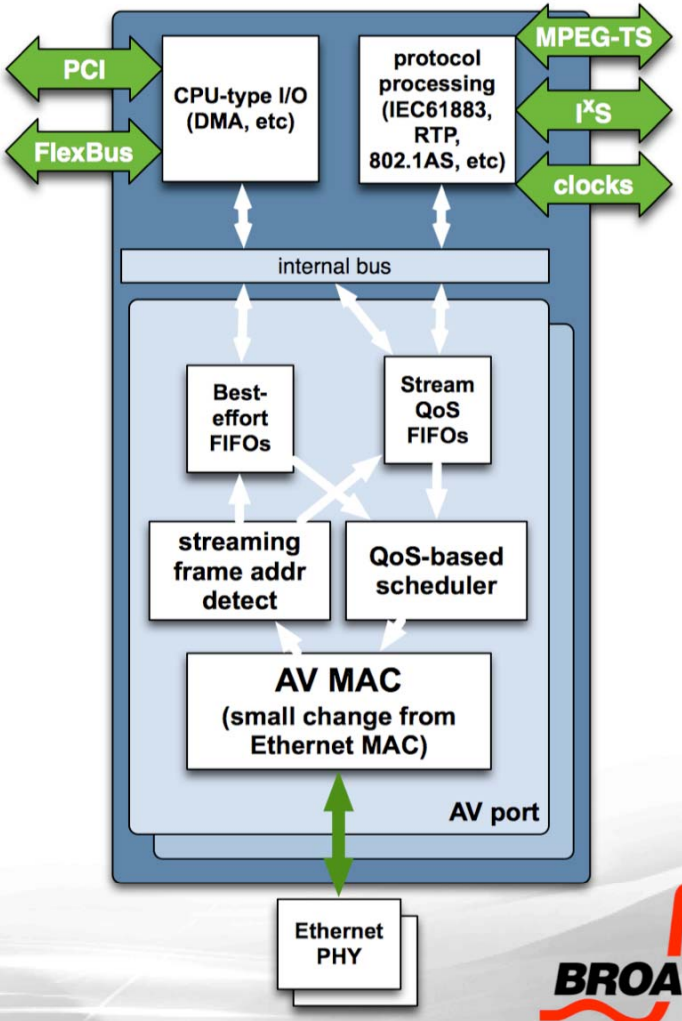
End-to-end EAV: endpoint

- PHY(s) are 100Mbit/sec or better
  - 1G for professional, 10G for backbone or uncompressed video
- CPU interface for higher level management
  - Integrated processor for 802.1 and 1722 acceleration
- Streaming I/O
  - MPEG transport stream
  - I²S serial audio
  - Clock I/O



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Key points

- Ethernet is the best technology base for professional audio networks
- New AVB features fully enable those networks
- Real devices, real protocols are coming on line soon
- It's time to integrate them into the AES infrastructure

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Thank you!

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