Agenda

- What is AV Bridging?
  - and Ethernet AV?
- Why is it needed?
- Where will it be used?
- How does it work?
- How can it be used in carrier networks?
What is AV bridging?

- Add Precise Timing in an 802 network (~100 nS native, ~100 pS achievable)
- Add E2E Bandwidth guarantees using QoS and Admission Control
- Do both with very low cost adder (approaching zero) to meet CE market requirements.
- Ethernet AV is the first wave
  ... but not the last
Gaining Support and Momentum

- Names of the companies who has been supporting the IEEE standard activities.
- Stronger support comes from companies who had had triple play trials.

**Initiators**
Broadcom
Pioneer
Samsung
Nortel
Gibson

**CE Vendors**
Samsung, Pioneer, Panasonic, Phillips, Gibson, etc

**Service Providers**
EchoStar, KDDI, SBC (AT&T), France Telecom, etc

Enhancements
Precise Timing
BW Reservation & Admission Ctrl
Ethernet Switch Enhancements

"WLAN-AV"
MoCA

Ubiquitous “no-excuses” home connectivity

CE + Home Computing Convergence

Connect everything

Broadcom
Why is it needed? (1)

- Common IT-oriented networks have inadequate QoS controls
  - all use 802.1 “priority” (actually, “traffic class”)
  - can work in controlled environments (same higher layer QoS)
  - no guarantees, timing synchronization difficult
- Ethernet is the best
  - but it’s easy for the customer to misconfigure or overload
  - no guarantees, timing synchronization difficult
- Wireless has superior convenience, but inadequate bandwidth and excessive delays for whole-home coverage
  - 802.11n will work for many applications, but ...
  - latencies through multiple A/Ps may be too much for interactive applications
  - difficult environment (interference, variable S/N), so no guarantees
  - and we still need a backbone for the wireless attachment points
Why is it needed? (2)

- Proposed CE-based networks need new media or are expensive
  - MoCA requires coax everywhere, and is not cheap, and does not carry power, and has modest performance
    ... but it’s part of the solution (it’s almost everywhere in NA)
  - Power line is not cheap, has modest performance, is susceptible to interference, and is blocked by protection circuits
    ... but it’s part of the solution (it IS everywhere!)
  - 1394b/c long distance has limited developer base & infrastructure, is not cheap
    ... but even this is part of the solution (has best QoS guarantees)
Digital Home Media Distribution

Satellite Broadband

Over-the-air Broadcast

Content/Services

MSO Broadband

Telco Broadband

Home network backbone

Den

Living Room

Bedroom

Family Room

Kitchen

Security Panel

2nd Wireless AP

802.11 STB

802.11 STB

Residential Gateway(s)

WebPad

802.11

BROADCOM

Connecting everything
Ethernet AV: the Gold Standard

- **Backbone for home**
  - Highest quality/lowest cost way to interconnect networked CE devices
  - “Perfect” QoS, requires the least customer interaction
- **Within the entertainment cluster**
  - Trivial wiring, no configuration, guaranteed 100/1G/2.5G+ per device, not just per room or per house
  - PoE for speakers, extra storage (HD/optical), wireless A/Ps, other lower-power devices
  - Ideal long-term replacement for 1394
- **Numerous non-“residential” applications**
  - Professional audio/video studios, industrial automation, test and measurement, *carrier backbone*
But it’s only part of the solution!

• Ethernet AV is the best backbone for QoS
  – But NOT the most convenient in much of the existing market (e.g., requires Cat5)
• Ethernet AV is the most cost-effective high QoS network for endpoints
  – But only if the endpoints are fixed (e.g., not useful for mobile)
• So we need to enable the heterogeneous network
  – Provide QoS services universally, as well as can be done for the particular layer 2 technology

So …
Unified Layer 2 QoS

• Enhance network bridging
  – Define common QoS services and mapping between different layer 2 technologies
    • E.g., 802.3 Ethernet, 802.11 WiFi, UWB, MoCA, etc
  – IEEE 802.1 is the common technology
    • Ethernet “switches” (IEEE 802.1D/Q bridges)
    • Basis of 802.11 A/P attachment to Ethernet
    • Basis of non-802 network bridging (e.g., FDDI, carrier nets)

• Common endpoint interface for QoS
  – “API” for QoS-related services for ALL layer 2 technologies
  – Toolkit for higher layers
The first step: Ethernet AV™

- Simple enhancement to IEEE 802.1 bridges to support streaming QoS
  - 2 ms guaranteed latency through 7 Ethernet bridges
  - Admission controls (reservations) for guaranteed bandwidth
  - Precise timing and synchronization services for timestamps and media coordination
    - < 1μs absolute synchronization between devices
    - Jitter less than 100ns, filterable down to 100ps (can meet the MTIE mask for professional uncompressed video)

- Trade group to provide trademark “enforcement” of otherwise optional features
  - Require useful bridge performance, network management, PoE management, auto-configuration features
Proposed architecture

• Changes to both IEEE 802.1Q and layer 2
  – 802.1Q - bridges-switches - most of work
  – 802.3 - Ethernet MAC/PHY - possible small change to MAC definition
  – 802.11n - WiFi - more work, but basic tools in place
    • Not discussed in this presentation, but watch this space!

• Three basic additions to 802.1/802.3
  – Traffic shaping and prioritizing,
  – Admission controls, and
  – Precise synchronization
**Topology & connectivity**

- Streaming QoS only guaranteed in AV cloud.
- Peer device not AV capable.
- Half duplex link can't do AV.
- Devices outside of AV cloud still communicate with all other devices using legacy "best effort" QoS.

- Filtering/retagging active.
- Legacy link in gray.
- AV link in blue.
Establishing the AV cloud

• IEEE Std 802.1AB defines “LLDP”: Logical Link Discovery Protocol
  – Allows link peers to determine each other’s characteristics

• 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 streaming data to prevent bunching, which causes overloading of network resources (mainly switch buffers)
  – Shaping by limiting transmission to “x bytes in cycle n” where the cycle length is 125 μs or 1ms depending on traffic class
  – Traffic shaping in bridges will provide scalability
    • without it, all bridges need larger buffers

• Mapping between traffic class and priorities
Traffic Class?

• 802.1p introduced 8 different traffic classes
  – Highest (6 & 7) reserved for network management
    • low utilization, for emergencies
  – Next two for streaming (4 & 5)
  – Lowest four for “best effort”

• AV bridging:
  – Class 5 is for lowest latency streaming
    • Roughly 250 usec per bridge hop for 100baseTX, near 125 usec for 1G or better: interactive audio/video
  – Class 4 is for moderate latency streaming
    • Perhaps 1ms per bridge hop, longer for wireless, MoCA, power line: voice over IP, movies

![Diagram of traffic class queues and priority-based selection](image)
Admission controls
(p802.1Qat - added to 802.1Q)

• Streaming priority mechanism can reliably deliver data with a
deterministic low latency and low jitter
  — but only if the network resources (bandwidth, in particular) are available
  along the entire path from the talker to the listener(s).

• For AV streams it is the listener’s responsibility to guarantee the
  path is available and to reserve the resources.

• Done via 802.1ak “Multiple Multicast Registration Protocol” and
  the new SRP (“Stream Registration Protocol”)
  — Registers streams as multicast addresses using MMRP
  — Reserves resources for streams as bandwidth/traffic class
    • Specifics for “bandwidth” include at least max packet size and number of
      packets per traffic class measurement intervals
  — Perhaps other information useful for stream management such as path
    availability, egress port MAC addresses, etc.
• With MMRP registration, the talker and intermediate bridges know where are potential listeners and how to get to them
• MMRP floods the registration
Admission Control (2) (successful reservation)

- Reservation signaling triggers admission control operations in intermediate bridges. It also locks resources and updates filtering database if the admission control is successful.
- In this example, admission control is successful along the whole path. Reservation signaling serves as the end-to-end explicit ACK signaling to listener.
In this example, admission control fails at B2. The SI (Status Indication) flag of the reservation signaling will be set to FAIL.

The reservation is still forwarded to the listener. However, down-stream bridges (i.e., B1, B2) will not lock resources for the reservation whose SI is set to FAIL.

Listener is noted of the failure since a reservation with FAIL SI serves as an end-to-end explicit NACK.
Precise synchronization (p802.1AS)

- AV devices will periodically exchange timing information
  - both devices synchronize their time-of-day clock very precisely
  - the delay time between devices is very precisely known
- This precise synchronization has two purposes:
  - to enable streaming traffic shaping 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
- Very similar to IEEE std 1588-2004, but much simpler
  - will be an explicit “native IEEE 802 layer 2 profile” of new IEEE 1588v2
There is a single device within an Ethernet AV cloud that provides a master timing signal.

- All other devices ("ordinary clocks") synchronize their clocks with this master.

AV bridges act as "peer-to-peer transparent clocks" repeating the synch message and a correcting follow up from the master to the "ordinary clocks" in other devices.
Master clock selection

• Selection of the master is largely arbitrary (all AV devices that can source data will be master-capable), but can be overridden if the network is used in an environment that already has a “house clock”.
  – Professional A/V studios
  – Homes with provider time-synchronization service
  – Carrier networks

• Selection algorithm and clock attributes are the same as IEEE 1588
  – Typically, fully automatic and transparent to the end user
Changes to Ethernet NIC

• MAC changes
  – Frame Timer – Accurately note time of RX/TX Ctrl Frame
    • Not really a change to “MAC”, but to buffers for the MAC

• Queuing/DMA
  – Separate queues and DMA for class 4/5 frames to provide appropriate traffic shaping (scheduling)
    • One extra queue/DMA channel possible

• Admission Control (driver firmware)
  – Bandwidth allocation database associated with filtering database
  – Management using same methods (MRP) used for multicast addressing

• Real-time clock module
  – Master clock generator
  – Time Sync correction method
Changes to Ethernet Switch

• MAC changes
  – Frame Timer – Accurately note time of RX/TX Ctrl Frame

• Bridging
  – Ingress filtering/shaping at edge of network to ensure proper traffic shaping for class 4/5 (streaming) frames
  – Egress filtering to ensure that streaming CoS not over-utilized

• Admission Control
  – Bandwidth allocation database associated with filtering database
  – Management using same methods (MRP) used for multicast addressing

• Real-time clock module
  – Master clock generator
  – Time Sync correction engine per port - only if wanted to reduce switch CPU processing

• Reasonable Microprocessor Cycles
  – Scales with # of ports similarly.
When?

• IEEE standardization process well under way
  – Originally an 802.3 study group, moved to 802.1 in November 2005 as “Audio/Video Bridging Task Group”
  – Early drafts already available
  – Expect technical closure in 2007, final draft standards in 2008

• First hardware/software soon after stabilization
  – Possibly a number of “pre standard” interactions

• Will follow Ethernet-type product curve
  – 100M/1G/10G NIC/Switch all have markets for Ethernet AV
Example Enet AV NIC

- **PHY** is Fast Ethernet or better
  - 1G for backbone/professional, 10G for uncompressed video
- **CPU interface** is PCI-E
  - Streaming frames on PCI-E use virtual channel
  - Perhaps parallel PCI for CE
- **Streaming I/O acceleration**
  - MPEG transport stream
  - I²S serial audio
  - DVI for uncompressed video
Example Enet AV bridge

- PHYs are Fast Ethernet or better
  - 1G/5 port for first versions
- Separate CPU at first, but moving to integrated processor ASAP
Example multiport Enet AV NIC

- Best product for TVs, STBs, home gateways, media PCs
- Anything that is a “hub” in the cluster
Key Take Away

• Ethernet AV will be the standard interconnect for uncompromised quality of service
  – soon!

• There will be growth in both technology (speeds and feeds) and infrastructure (switches, ICs, intellectual property)
  – The first providers set the real standards, the interoperability requirements
G.8261 (G.pactiming) and 802.1 AV bridging

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Bridging between SDH/SONET (and similar) networks requires carrying both the data with adequate QoS and timing information.

- E.g., an Ethernet network must carry the timing information of one edge SDH/SONET to another.
- It must also emulate the connection-oriented model for data transport (not lose data from established connections in spite of interfering traffic).
G.8261 Differential Method

- Common reference clock available throughout packet network
- Service clock (at packet network ingress) is encoded using a timestamp with respect to the reference clock and included with data
- Service clock at packet network egress is recovered using reference clock and timestamp information in stream
Using the Differential Method

TDM Service Clock

The two PRCs may also originate from the same source
802.1 Audio/Video Bridging

• Provides precise synchronization services
  – 802.1AS - IEEE 1588v2 as applied to 802.1 bridged networks.
  – Probably better MTIE than needed for SDH/SONET
    • (Geoff Garner is currently comparing with TDEV for SDH-1 and -2)
• Provides connection-oriented services
  – 802.1Qat - Stream Reservation Protocol to manage streams
  – 802.1Qav - Guaranteed latency and bandwidth for established streams
• No need to manage PHYs, no need for external PHY-level synchronization
  – Any 802.3 PHY will work, nothing special needed, full configuration flexibility
  – Support for other full-duplex point-to-point PHYs trivial
  – Support for shared media MACs allowed (802.11/16/17) via sublayer definition
Using 802.1 AVB

The two PRCs may also originate from the same source

In addition, TDM stream latency and bandwidth guaranteed by 802.1Qat admission control and 802.1Qav QoS services
Using 802.1 AVB for multiple independent clocked streams
Advantages of 802.1 AVB

• Will be heavily used in consumer electronics and professional AV networks
  – Driven to be a simple and low cost as possible
• Easily scaled to much larger networks
  – Architects of the 802.1 understand and require scaling
• Supports multiple simultaneous TDM streams with different clocks
New work needed

• Telecom core networks must be managed at a high level
  – Limiting automatic switchover of clock sources and routing of packets
  – “protected environment” for management vs. “plug and play” usage models

• Standardized packet format for TDM emulation
  – Mapping/demapping for timing recovery (timestamp usage)

• 802.1 AVB protocols have all the lower layer tools
  – Higher level management interfaces and overrides need to be defined