Audio/Video Bridging on Local Area Networks

Ilya Dmitrichenko <errordeveloper@gmail.com>

Outline

1. Motivation
   - Overview
   - Other Technologies
   - Introducing A/V Bridging
2. Implementation Overview
   - Layers and Protocols
   - Audio in The Network
3. Outlook on Design Perspectives
   - New Hardware!
   - What AVB can do?
   - . . . More Information

Outline

1. Motivation
   - Overview
   - Other Technologies
   - Introducing A/V Bridging
2. Implementation Overview
   - Layers and Protocols
   - Audio in The Network
3. Outlook on Design Perspectives
   - New Hardware!
   - What AVB can do?
   - ...More Information

Outline

Why AVB is needed?

- Designed for real-time streaming of audio and video data
- Common standard approved by joint group of manufacturers as part of `IEEE P802`
- Cost-effective cabling and hardware technology
- Simple to use and and set-up
- Robust operation achieved by a combination of specifically designed protocols

AVB addresses multiple market segments, including professional A/V and consumer entertainment.

Background Overview I

Point-to-Point Links:

- *MADI and AES/EBU*
- *SDI and HDMI*
- *OptoCore*
- *I2S and USB*
- *IEEE P1394*

A/V equipment manufacturers have already developed their own approaches to achieve similar capabilities and a number of standards exist using specific serial data protocols with specialized cabling and hardware. However, these cannot be combined with each other!

Background Overview II

Proprietary Solutions:

- *CobraNet*
- *EtherSound*
- *Aviom*
- *REAC*
- *AES50*

These audio networking systems are already using Ethernet.
The approach is not uniformal and cross-compatibility
of these systems is a major issue for field engineers!

Background Overview III

- Networking protocols *(such as TCP, UDP and IP)*
  - do not implement time synchronization
  - were designed for more general data transmission
  - applied on a different scale of deployment
- It has been generally proven that *Ethernet is capable to handle high definition A/V with reasonable quality of service (QoS)*
- Some technologies listed above achieved it with various approaches (mostly proprietary)

Background Overview IV

There certainly is a way of fine-tuning off-the-shelf networking equipment and software to provide reliable performance for streaming audio from one computer to another using cross-over *CAT5* connection or a single switch. Applying a set of fine-tunned *QoS* and *traffic shaping* rules on commodity equipment may in theory provide reasonable performance in a larger *LAN*, assuming there is no other traffic.

Another set of approaches exists using *RTP* and *RTSP* combined with *multicasting*, however these are used for *compressed latency-tolerant media streaming* in conferencing and entertainment.

How AVB uses the Ethernet network?

- No IP addresses and ports, use streams instead
- Distributed precise clocking hierarchy
- Pre-allocated resources for streams
- Monitoring of throughput and latency

Underlining Base Standards

IEEE 802.1 - Network Layer 1:

- `802.1Q` - *Virtual Bridged Local Area Network (VLAN)*
- `802.1Qav` - *Time-Sensitive Forwarding and Queuing*
- `802.1ak` - *Multiple Registration Protocol*
- `802.1Qat` - *Stream Reservation Protocol (SRP)*
- `802.1AS` - *Timing and Synchronization* `(P1588-2008)`
- `802.1BA` - *Audio Video Bridging Systems*

Network Layers 2 and 3:

- `P1723` - *Encapsulation Format for A/V Transport (AVBTP)*
- `P1733` - *Correlation of RTP timestamps with PTP*

Other:

- `P1588` - *Precision Time Protocol (PTP)*
- *...digital media format standards*

Clock Synchronization I

- *PTP version 2 is an IEEE standard* `P1588-2008`
- *For AVB use, a subset has been defined under* `802.1AS`
  Unlike other new protocols,
  PTP is already used in other application areas:
  - Industrial Control
  - Test and Measurement Equipment
  - A/V Streaming and Control
  - Telecommunications

Clock Synchronization II

PTP defines a number of algorithms to *find the delay times* on the network and *adjust the clock* on all devices to *the same time base*. This clock is then used to re-align audio and video frames received in data packets. This functionality needs to be implemented in *physical layer* hardware and sync precision of *tens of nano seconds* is achievable on a network that fully implements *PTP* in *switches* and *end-points*.
A clock hierarchy of *master* and *slave* devices, including *boundary* and *transparent* clocks applies no such network.

Virtual Networks (VLANs)

`802.1Q` is a base for *Virtual Bridged Local Area Networks*. Fallowing two amendments were made for *A/V Bridging*:

- `802.Qat` - *Stream Reservation Protocol*
- `802.1Qav` - *Time-Sensitive Forwarding and Queuing*

Combination of this two protocols allows allows traffic with AVB tag to take 75% of total LAN bandwidth and also make sure the buffered packets are synchronized with PTP clock.

Stream Reservation and Traffic Shaping I

`802.1Qat` and `802.1Qav` introduce the concepts of

- *streams* and *slots* or *channels*
- *talkers* and *listeners*

- Provide special *admission control* and *priority tagging*
- Talkers advertise their stream
  - *(64-bit ID) = (48-bit MAC address) + (16-bit stream ID)*
  - *QoS requirements*
- Listeners request to register for streams
- `802.1Qat` is a software protocol

Stream Reservation and Traffic Shaping II

`802.1Qav` is designed to:

- *prevent packet loss in buffers*
- *synchronize queued packets with PTP clock*

It defines flow control algorithms to provide:

- *predictable latency of the path and lower the jitter*
- *synchronized forwarding of buffer queues*
- *prevention of packet "bunching"*

Stream Reservation and Traffic Shaping III

- All *A/V Bridges* are required to
  - *verify the bandwidth availability (between the end-points)*
  - *propagate the advertise message (to and from end-points)*
- If the bandwidth is insufficient
  $\longrightarrow$ *the failure is reported*
- When a listener registers a stream
  $\longrightarrow$ *the resources are locked down*
- The resources are *unlocked when it de-registers*

Channels and Devices I

On AVB network end-point devices are classified as

- `talkers` - advertise streams
- `listeners` - subscribe to receive streams

Then the set of first layer protocols ensure

- best-effort traffic throughput
- synchronization *in transmission* and *on end-points*

Channels and Devices II

- Audio channels are grouped into *streams*
- Video or audio channels are referred to as *slots*
- Stream originates from *one talker* and shares *one clock*
- Routed on second layer in *unicast* or *multicast* mode
- The channels are not split out of the stream in the network
- From the network level only the *unique stream ID* is known
- Higher channel count in one stream reduces the bandwidth

Media Formats and Control

AVBTP - the Transport Protocol (P1722)

- Various media formats can be used
  (such as MPEG/ISO, PCM or AM824 and others)
- Allows for bridging of `P802` and `P1394` networks
- Compatibility with IP streaming is facilitated by `P1733`

DECC - the higher layer protocol (P1722.1)

- Discovery
- Enumeration
- Connection
- Control

Design Solutions

- National Semiconductors DP83640
  Ethernet Physical Layer Chip with P1588
- XMOS AVB Reference Design Software
  for XS1 Processor Architecture
- Marvell Kirwood ARM SoC
  and 88E0000 Yukon & LinkStreet Ethernet ICs
- Freescale MPC831X PPC SoC
- Lab-X and Xilinx FPGA cores

Performance Metrics

Source: XMOS reference design documentation

- Network: 100MB Ethernet
  - Channels: 32x32 and 16x16
  - Audio Quality: 48kHz/24-bit and 96kHz/24-bit
- Network: 1GB Ethernet
  - Channels: 72x72 and 36x36
  - Audio Quality: 48kHz/24-bit and 96kHz/24-bit

Source: Harman product presentation

- Network: 1GB Ethernet
- Latency: <2ms
- Channels: 300 x 300
- Audio Quality: 48kHz/24-bit

More Data : Bandwidth of channels per stream

Table: *Source: XMOS reference design documentation*

$\frac{kHz}{Mbps}$	*48*	*96*	*192*
7.81	2 or 1	-	-
10.88	4	2 or 1	-
17.02	8	4	2 or 1
29.31	16	8	4
53.89	32	16	8

On-line Reference

- AVnu Alliance
  Homepage:
  http://avnu.org/
- IEEE Task Group
  Homepage:
  http://ieee802.org/1/pages/avbridges.html
- Xilinx Ethernet AVB Endpoint IP LogiCORE
  Product Page:
  http://xilinx.com/products/ipcenter/DO-DI-EAVB-EPT.htm
- XMOS AVB Reffeerece Desgin
  Application Design for XS1 Processor:
  http://xmos.com/applications/avb