How Ethernet Is Shaping the Future of Real-Time Applications

- and What We’ve Learned in Professional Audio

JOYNED | AUDIO. NETWORK. TECHNOLOGY.

Fabian Braun

CO-FOUNDER / CEO

What is “REALTIME”?


CLOCK
INFO

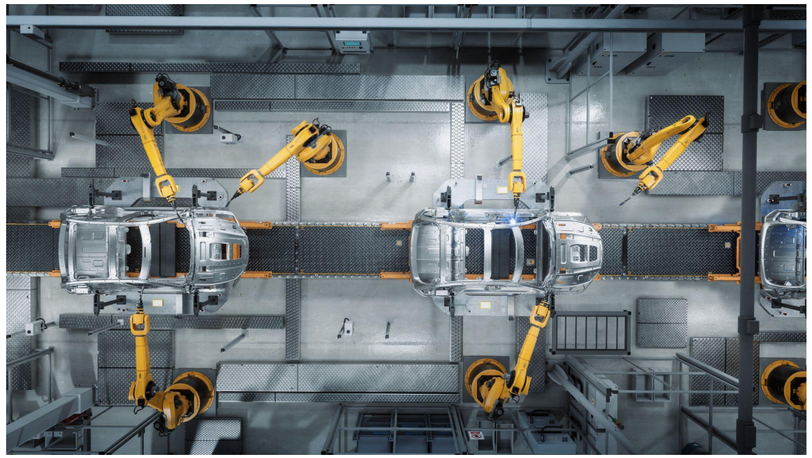
Credits: L-Acoustics, Milan Presentation - 2023-01-27 - ISE2023

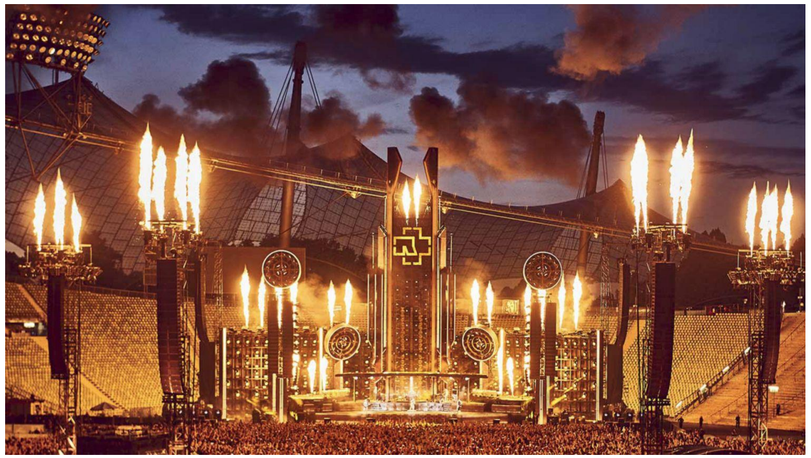
Credits: Meyersound, Milan Presentation - 2023-01-27 - ISE2023

ABBA Voyage

Credits: L-Acoustics, Milan Presentation - 2023-01-27 - ISE2023

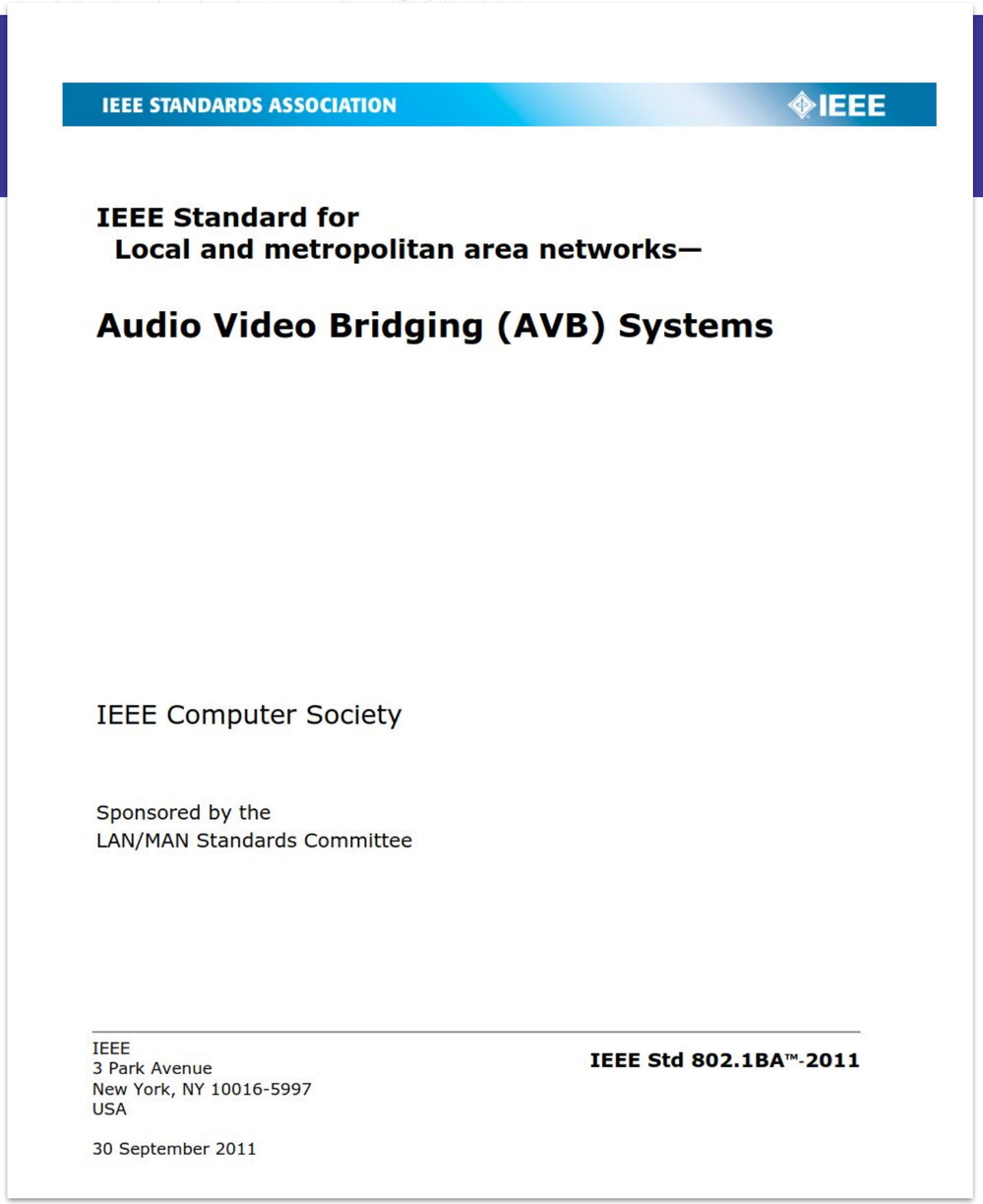
Commonalities and differences





Advancing Technology for Humanity

Youtube Tip:
https://youtu.be/JgGuRKgvWQ4?si=Cphx9q3B0xoC9Zsh



IEEE STANDARDS ASSOCIATION IEEE

IEEE Standard for
Local and metropolitan area networks—

Audio Video Bridging (AVB) Systems

IEEE Computer Society

Sponsored by the
LAN/MAN Standards Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 802.1BA™-2011

30 September 2011

A list of standards with maaaaany options:

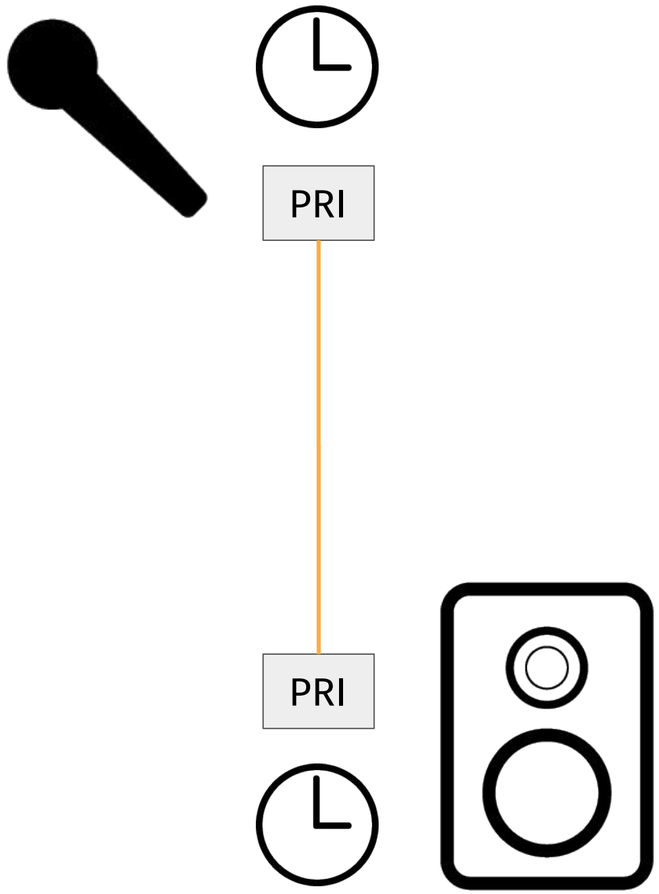
- **IEEE802.3**
- **IEEE802.1BA**
- **IEEE802.1AS**
- **IEEE802.1Q**
- **IEEE1722**
- **IEEE1722.1**

“AVB” workgroup renamed to “TSN” - maintaining and enhancing the same set of standards

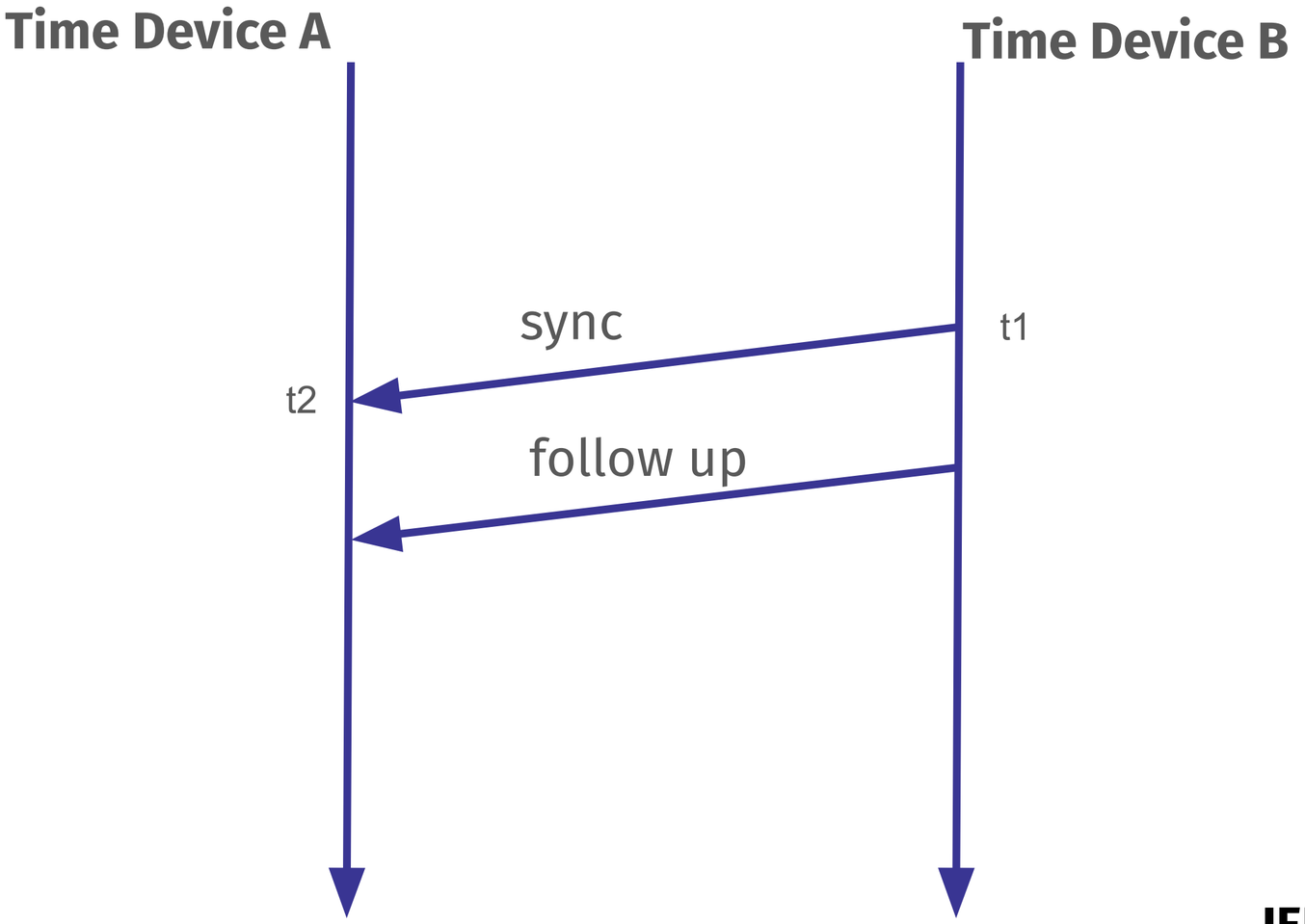
JOYNED AUDIO. NETWORK. TECHNOLOGY.

Synchronization with (g)PTP

Live Experiment



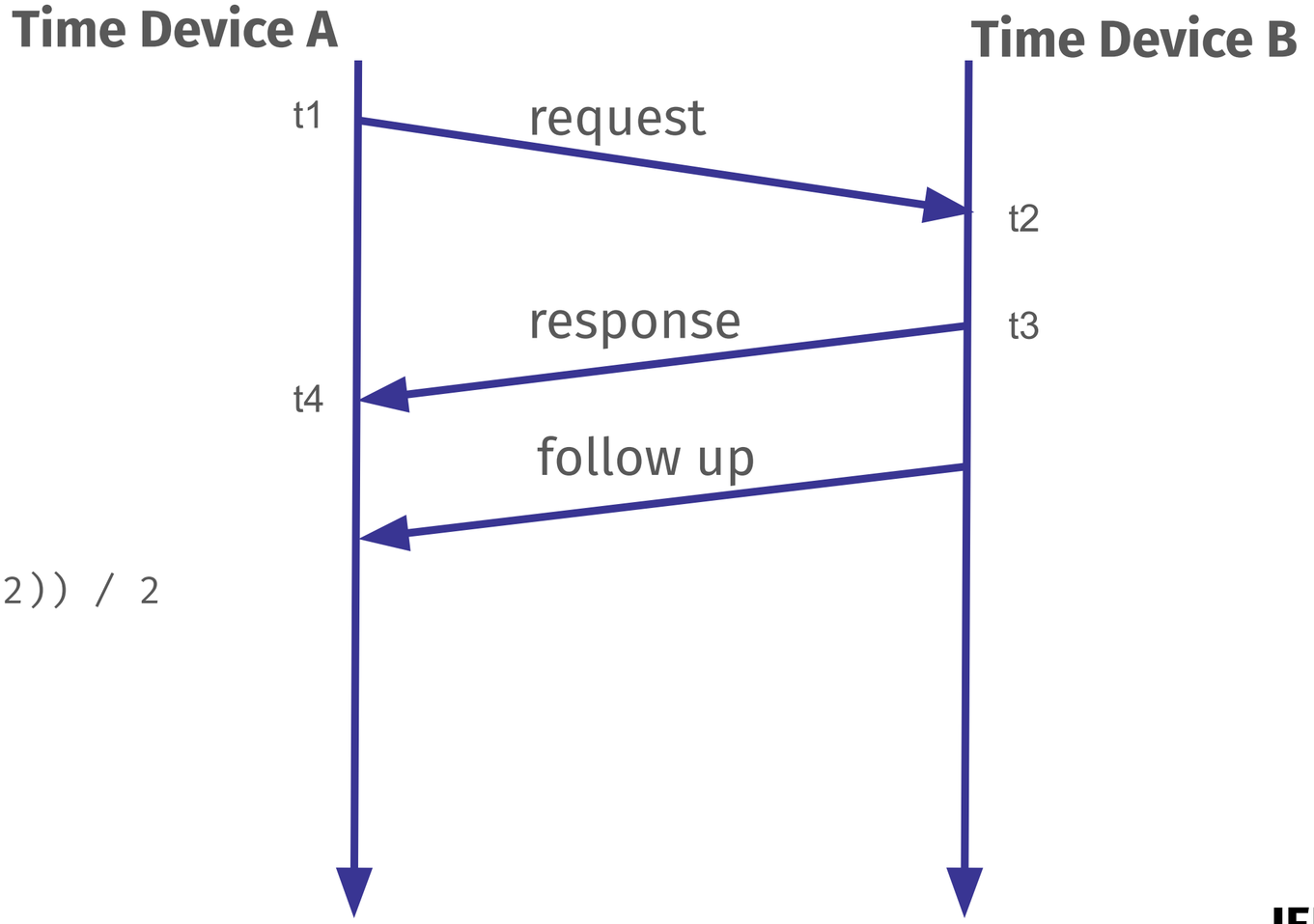
The gPTP Protocol



IEEE 802.1AS gPTP

JOYNED AUDIO. NETWORK. TECHNOLOGY.

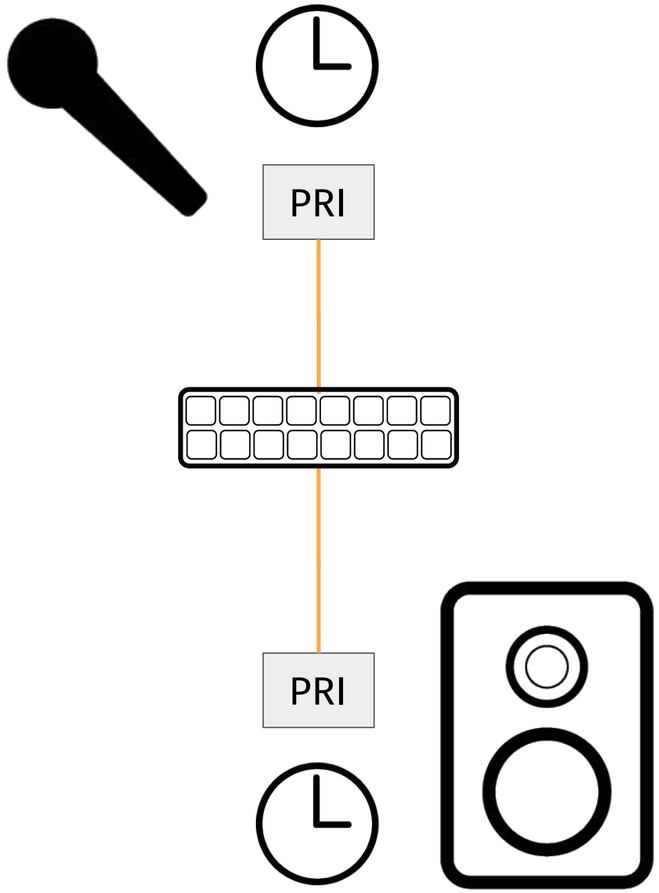
The gPTP Protocol




```
pdelay =
   ((t4 - t1) - (t3 - t2)) / 2
```

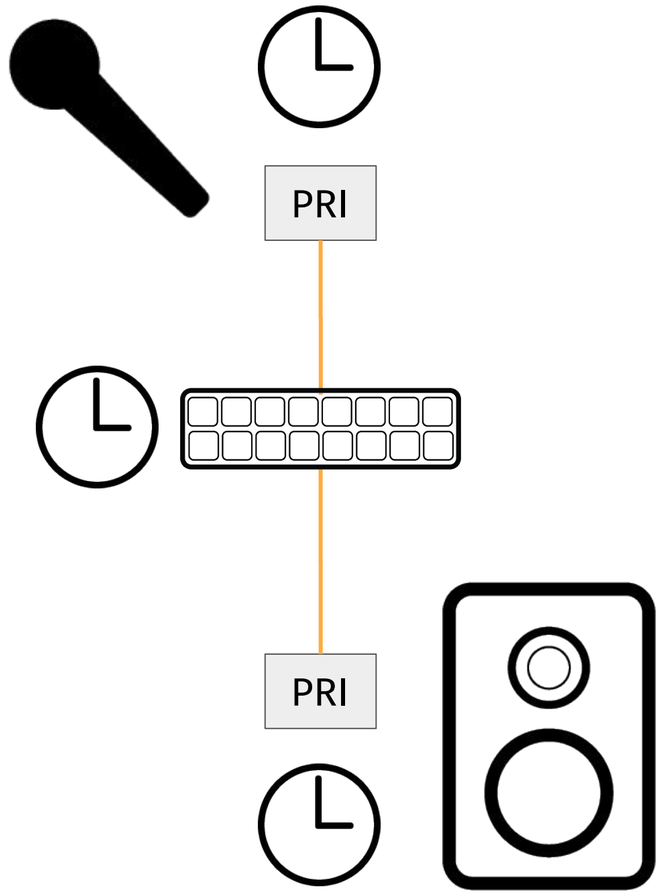
IEEE 802.1AS gPTP

Precision Time Protocol - PTPv1



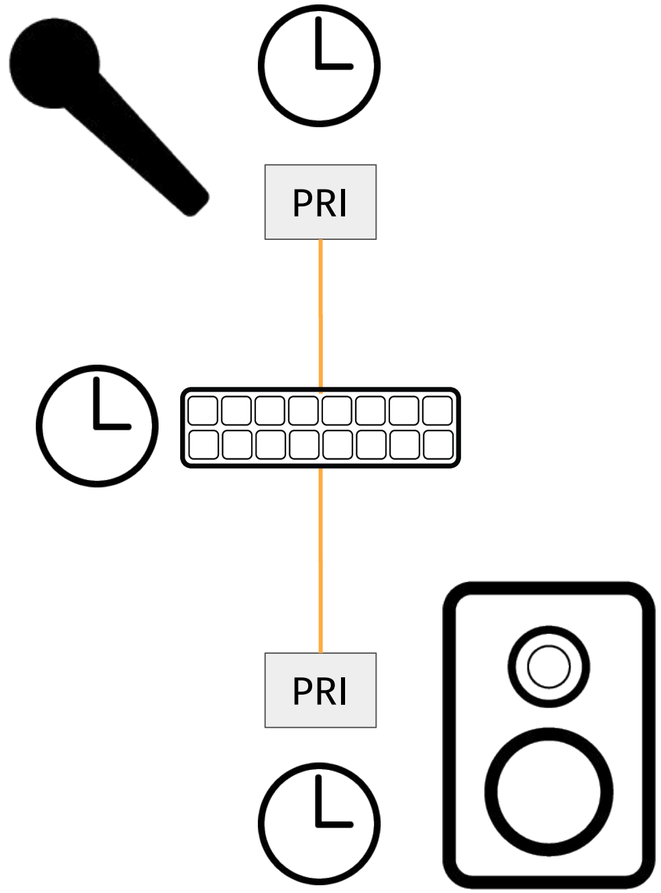
- Timestamping in Software
- Only endpoints - no switches - involved
- IP headers

Precision Time Protocol - PTPv2



- Timestamping in Hardware
- All endpoints and switches involved
- Various profiles
- IP headers

All network devices are getting synchronized per gPTP



- Timestamping in Hardware
- All endpoints and switches involved
- Harmonized profile across all devices
- Ethernet Layer 2 - no IP - headers

JOYNED AUDIO. NETWORK. TECHNOLOGY.

Precision Time Protocol - Performance comparison

Max Time Error	1st hop	6th hop
PTP V1, heavy traffic	N/A	±2500µs
PTP V2, transparent clocks	±0.024µs	±4.5µs
PTP V2, boundary clocks	±1µs	±4µs
gPTP	±0.035µs	±0.063µs

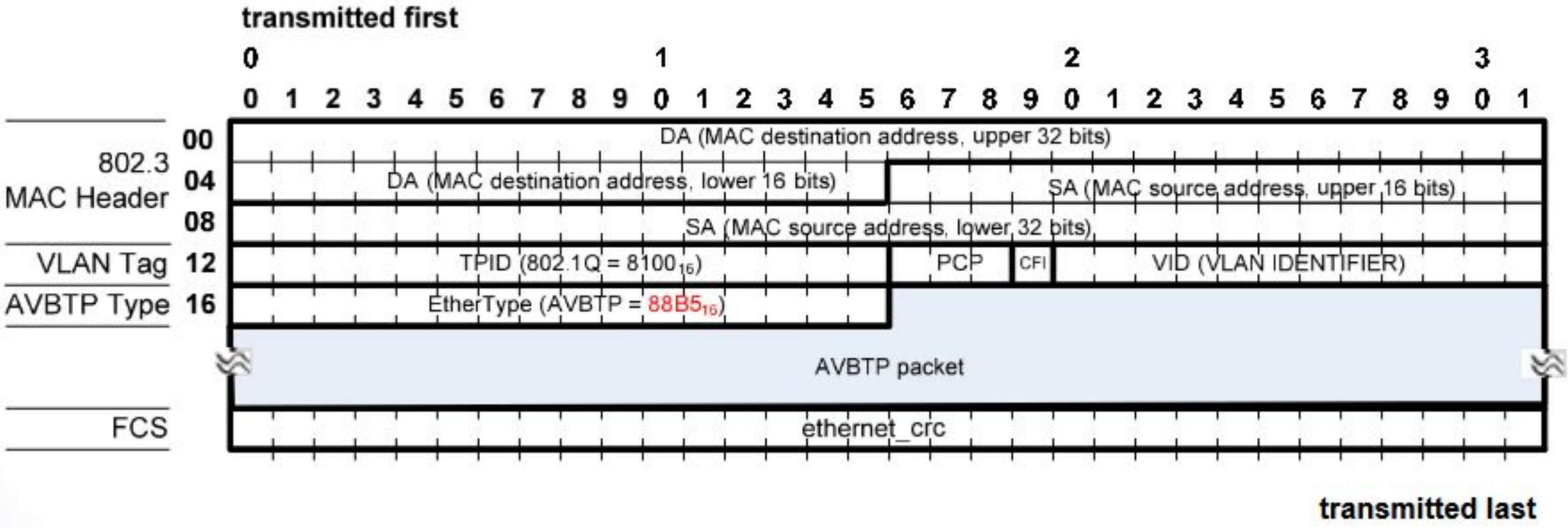
Kaltheuner, Henning / Kronauer, Genio / Lave, Morten / Corteel, Etienne: Requirements and Solutions for Audio Networking in Sound Reinforcement Systems. Conference Paper 18: AES 2024 International Conference on Acoustics & Sound Reinforcement (January 2024), 1-10. https://www.aes.org/tmpFiles/elib/20251007/22356.pdf

JOYNED AUDIO. NETWORK. TECHNOLOGY.

Stream Reservation

JOYNED AUDIO. NETWORK. TECHNOLOGY.

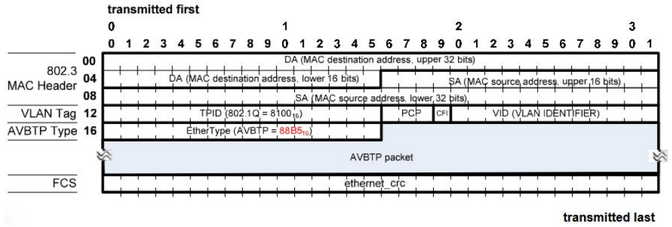
What is an ethernet packet?

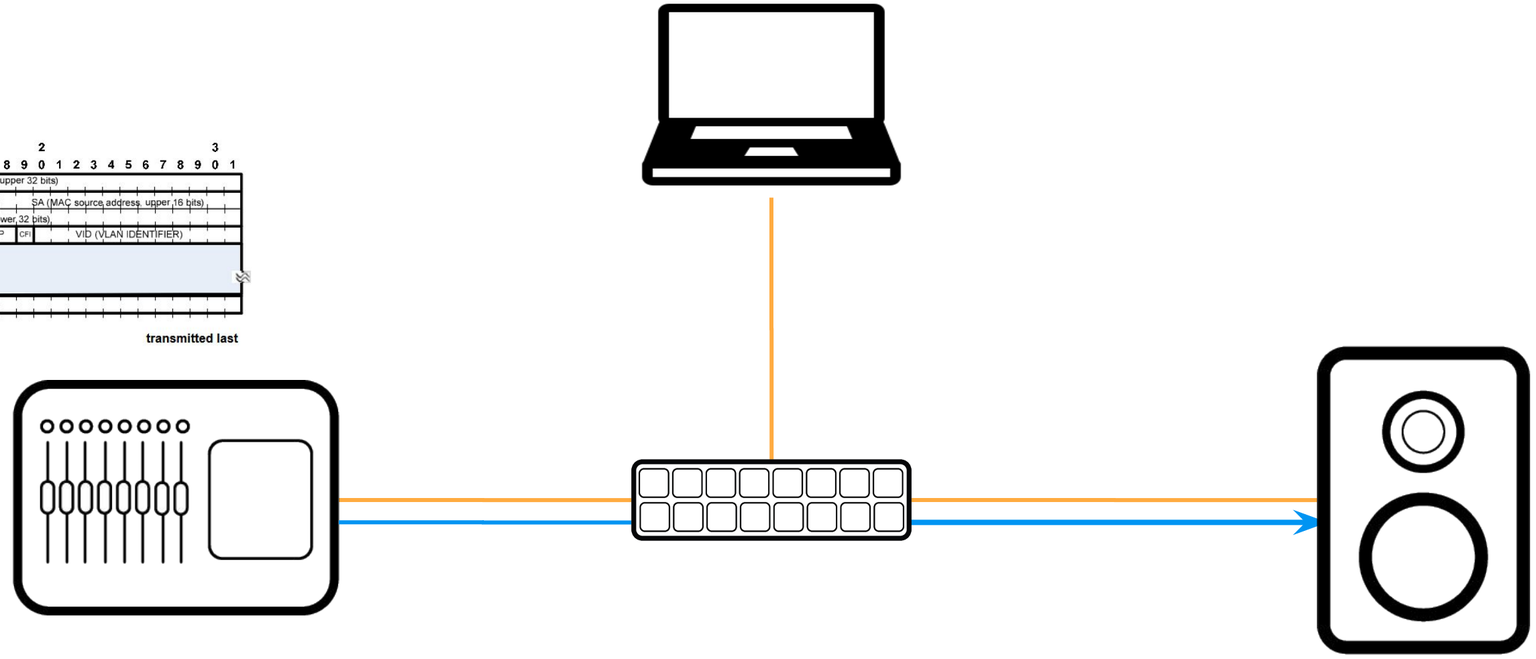


Source: https://www.ieee802.org/1/files/public/docs2009/avb-rboatright-p1722-explained-0903.pdf

JOYNED AUDIO. NETWORK. TECHNOLOGY.

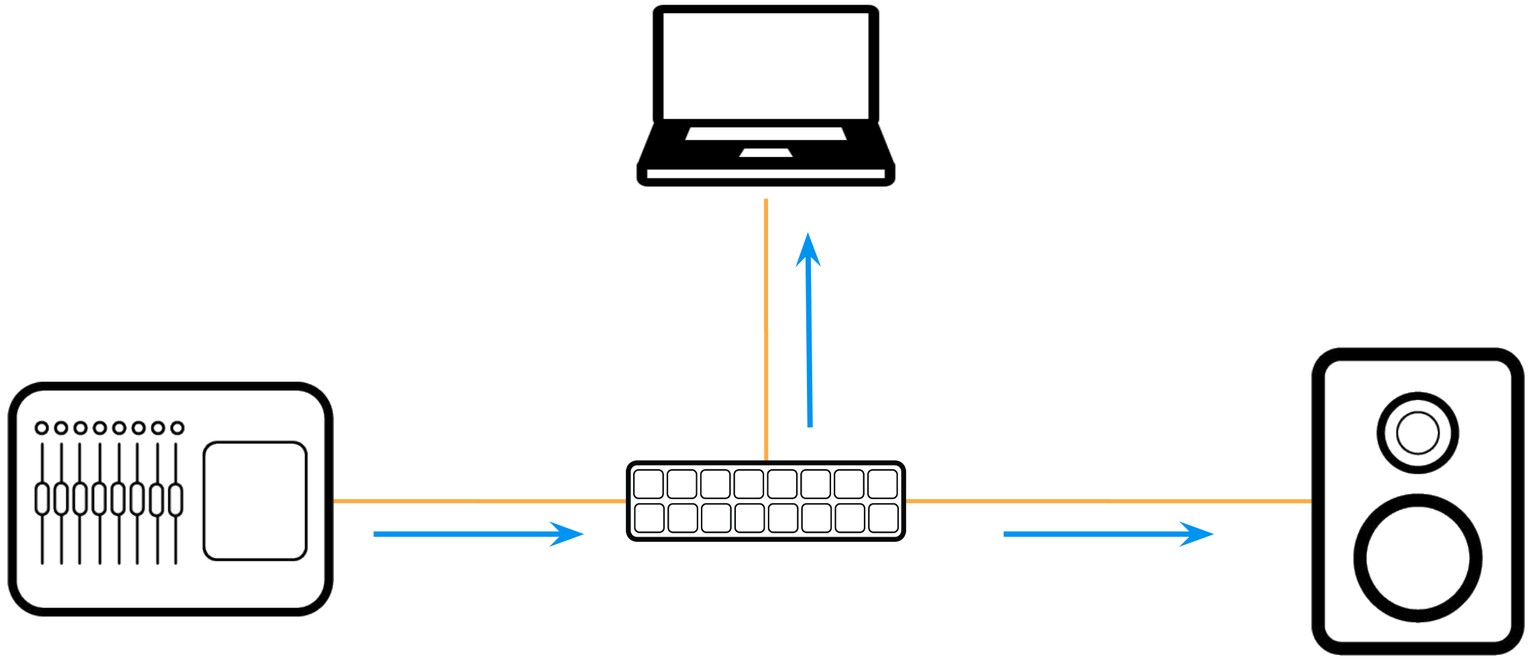
What is a stream?



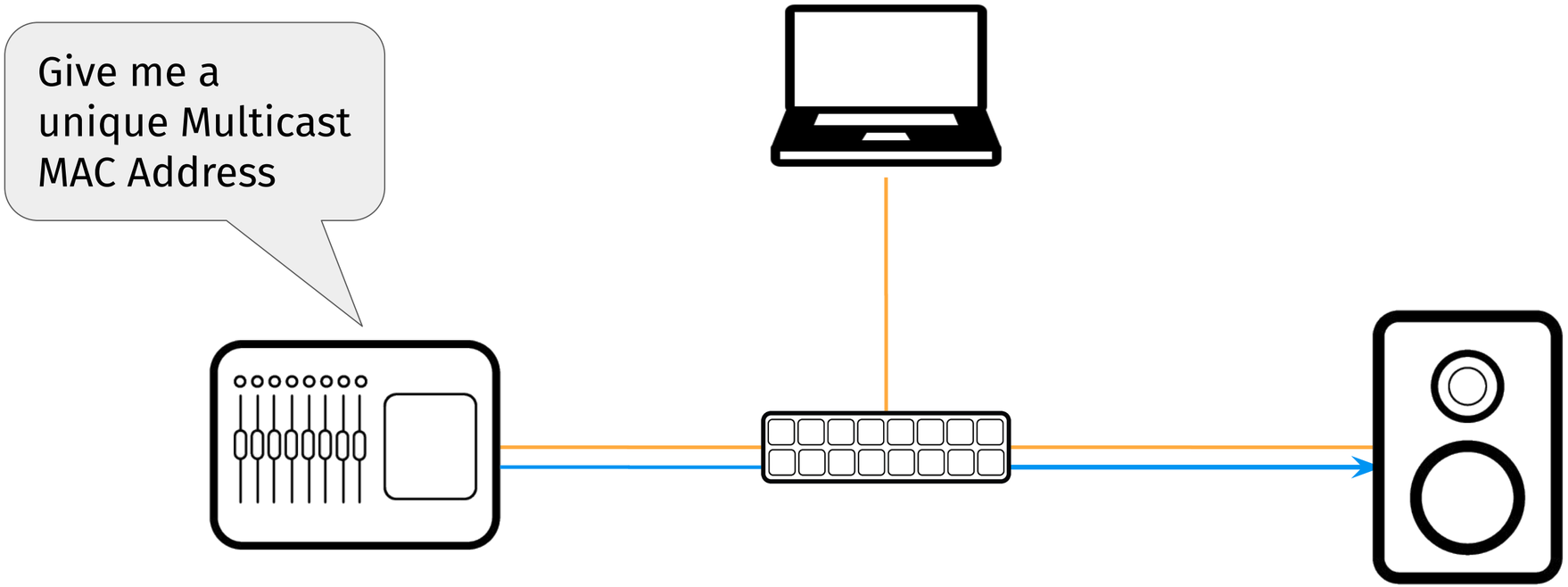


Continuous transmission of ethernet packets. 8000x per second!

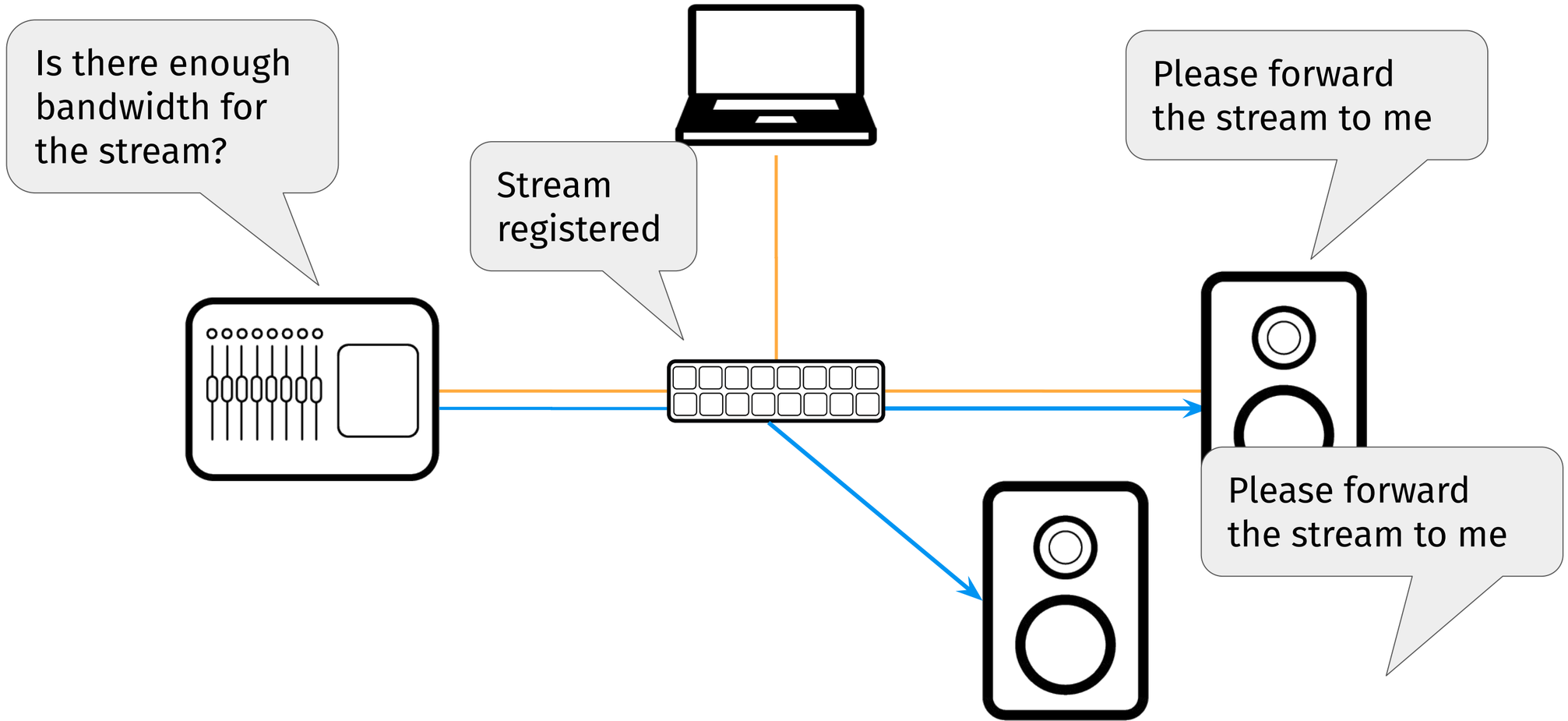
Recap: Regular Multicast



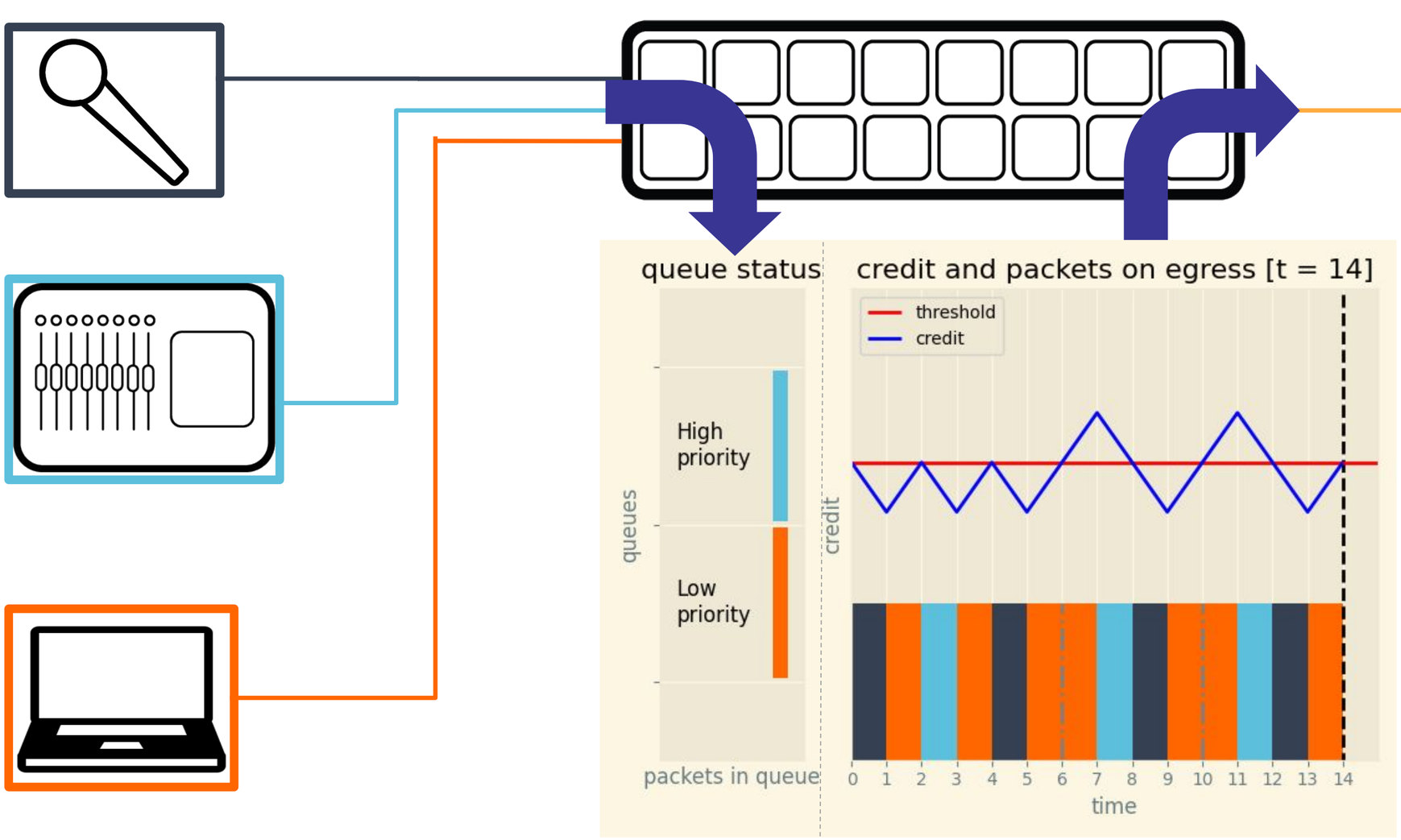
Multicast Address Allocation Protocol



Stream Reservation Protocol



Queueing and shaping - Qav - The credit based shaper



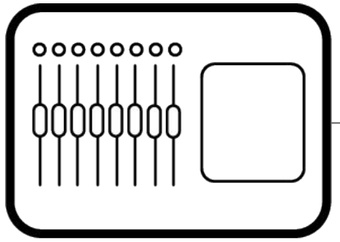
2 devices sending at the same time with interfering traffic

So what’s special about Pro Audio Applications?

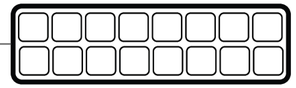
JOYNED AUDIO. NETWORK. TECHNOLOGY.

The audio market situation in 2016 and before - Example

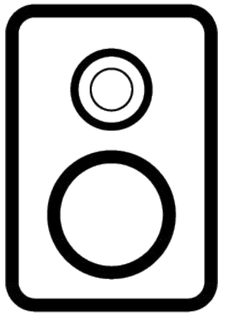
Manufacturer A



IEEE1722
AM824
48kHz
24Bit
8 channels



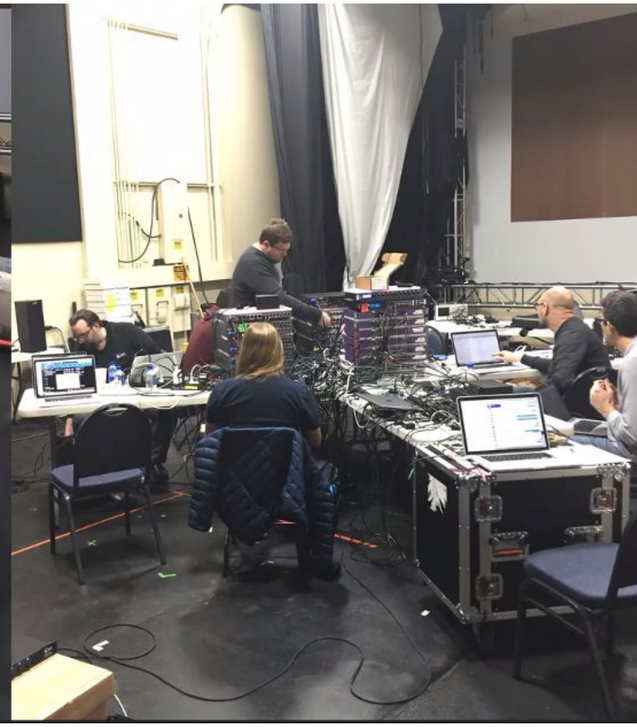
Manufacturer B



IEEE1722
AM824
48kHz
24Bit
1 channel

JOYNED AUDIO. NETWORK. TECHNOLOGY.

So we had to work this out...



Who supports Milan?

JOYNED | AUDIO. NETWORK. TECHNOLOGY.

Milan Baseline

Milan defines <u>interoperable</u> subset of the standards:

- Media clocking
- Common Stream Formats
- Enumeration, Connection Management, (basic) Control

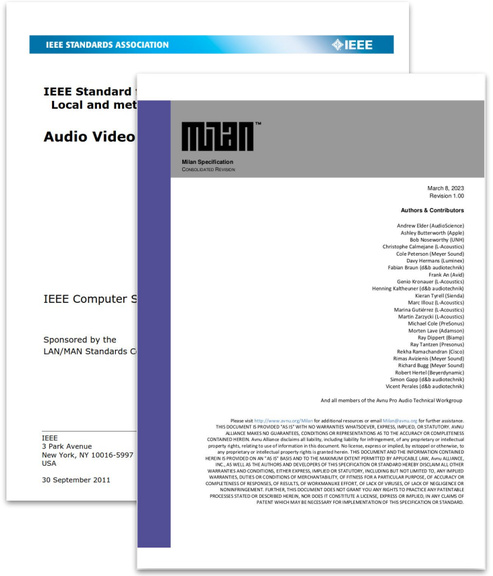
Clarifies ambiguities

Adds redundancy scheme (optional)

IEEE Advancing Technology for Humanity

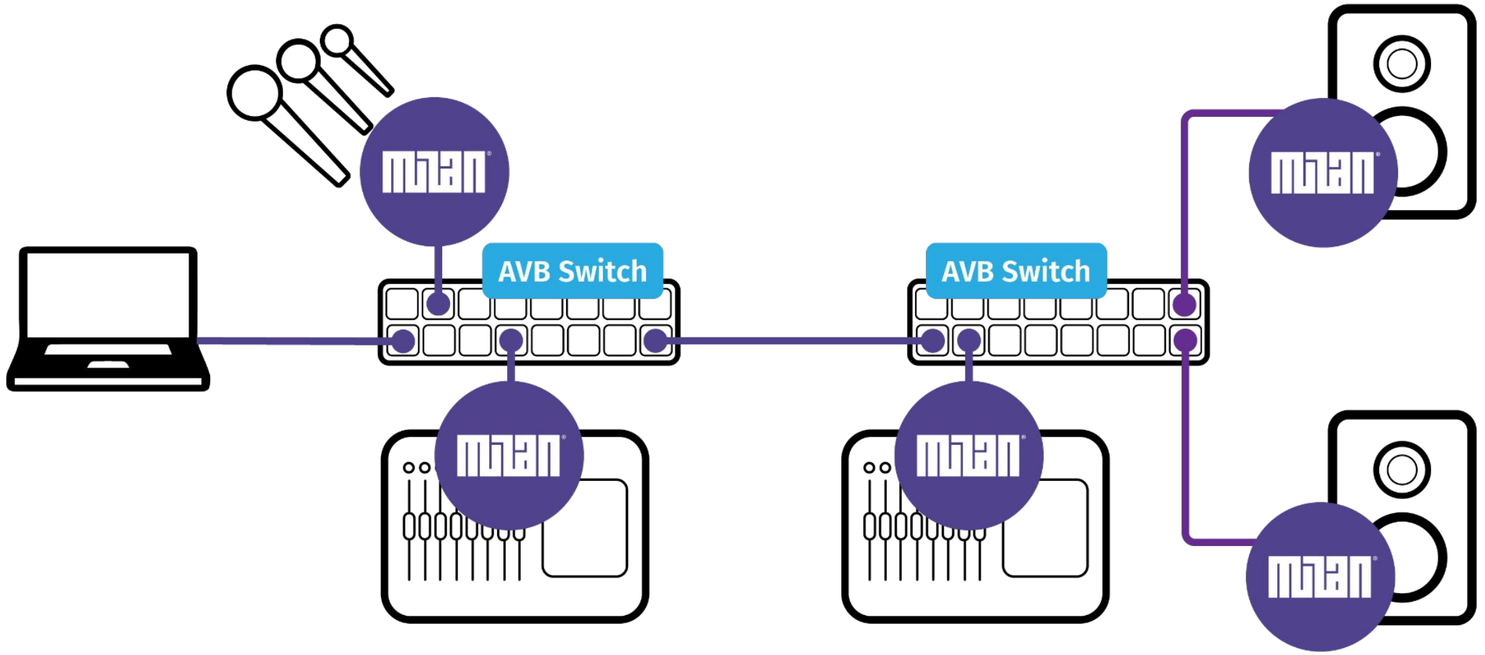
AVNU

Milan



JOYNED | AUDIO. NETWORK. TECHNOLOGY.

What is AVB/TSN and Milan?



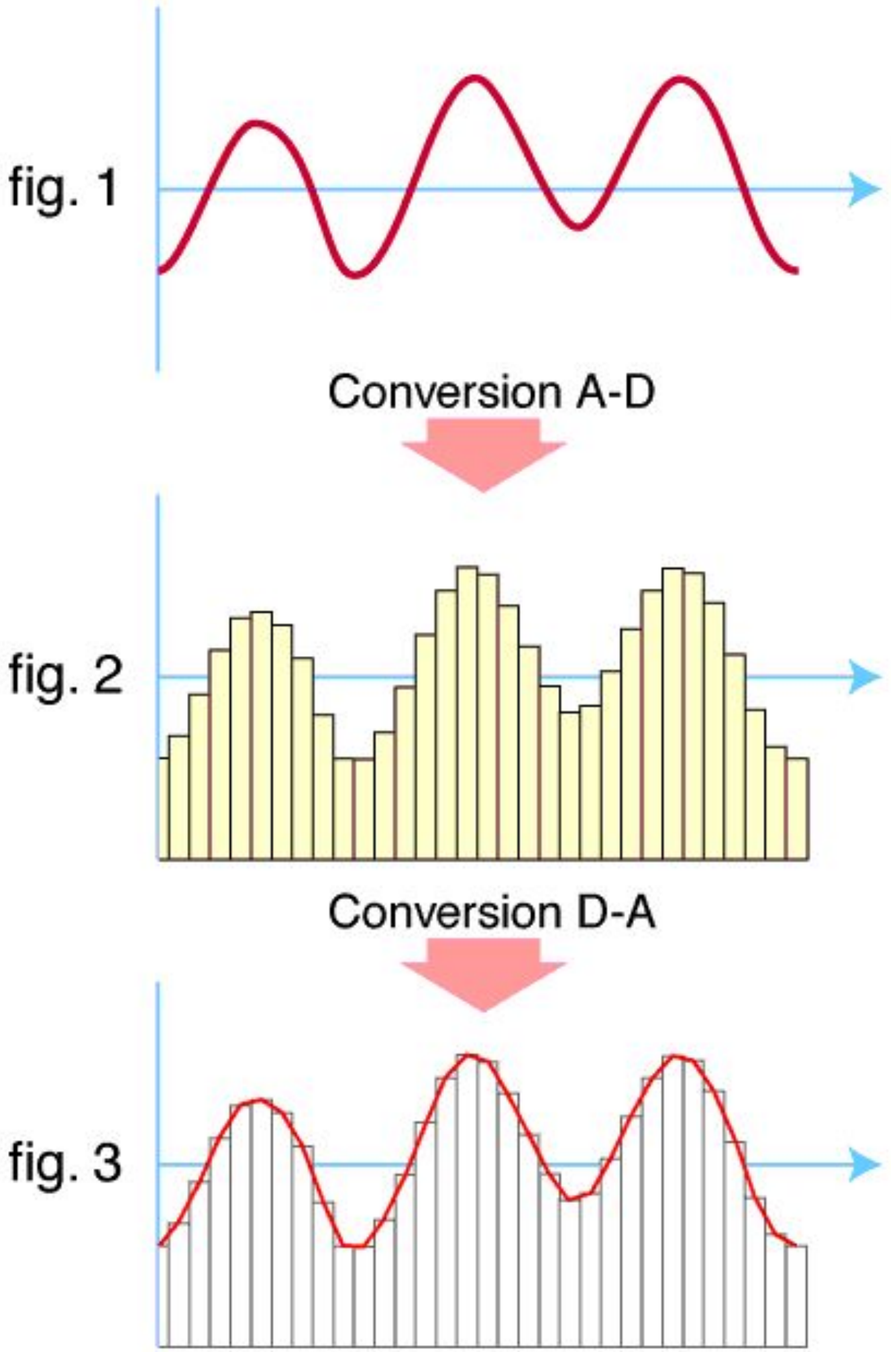

Enjoy your next concert!
JOYNED
AUDIO.
NETWORK.
TECHNOLOGY.

JOYNED | AUDIO. NETWORK. TECHNOLOGY.

Can Milan really sound better?

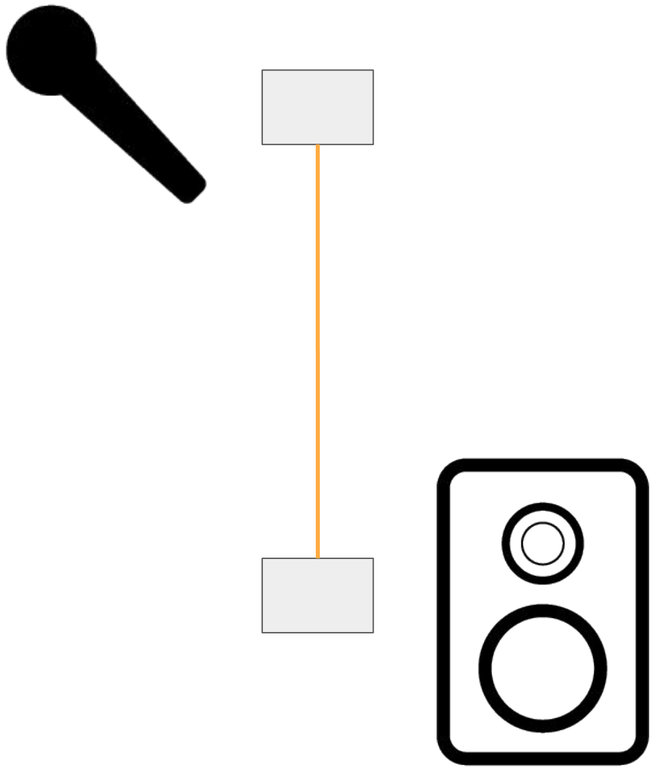
JOYNED AUDIO. NETWORK. TECHNOLOGY.

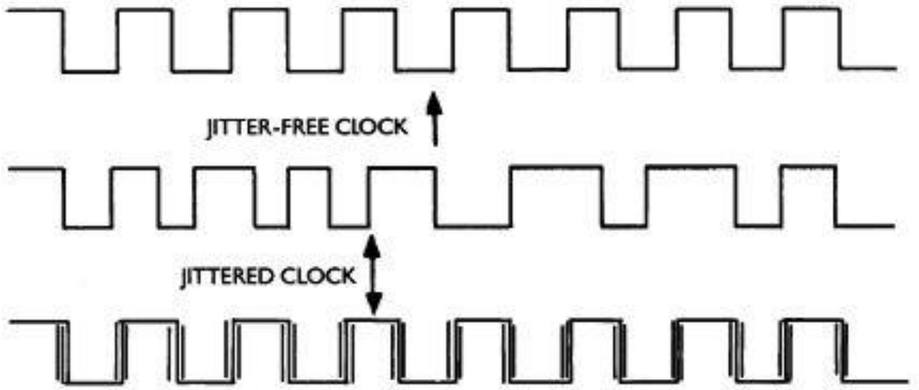
Basics: Analog-Digital-Conversion



Visual source: https://commons.wikimedia.org/wiki/File:Conversion_AD_DA.png

Basics: Jitter in a Digital system





Basics: The effect of Jitter in Digital-Analog-Conversion

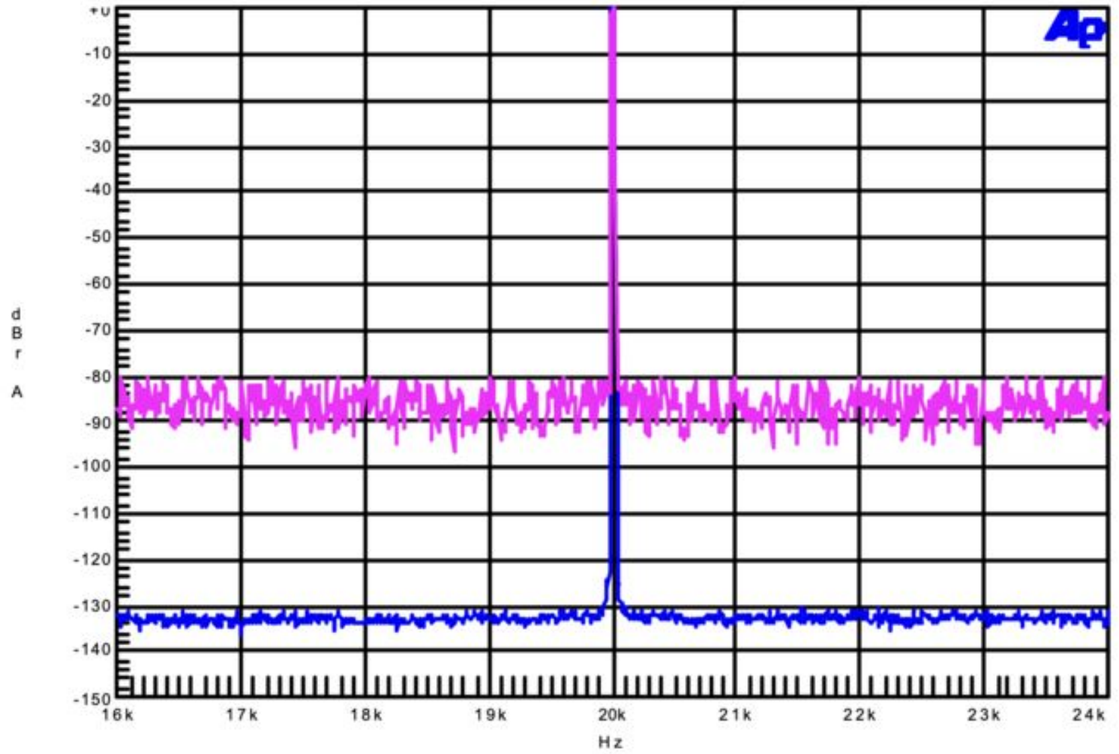


Figure 1 DAC in clock master mode (lower trace) and in clock slave mode with 25 ns peak wide band jitter applied (upper trace).

Audio Networking in Sound Reinforcement Systems

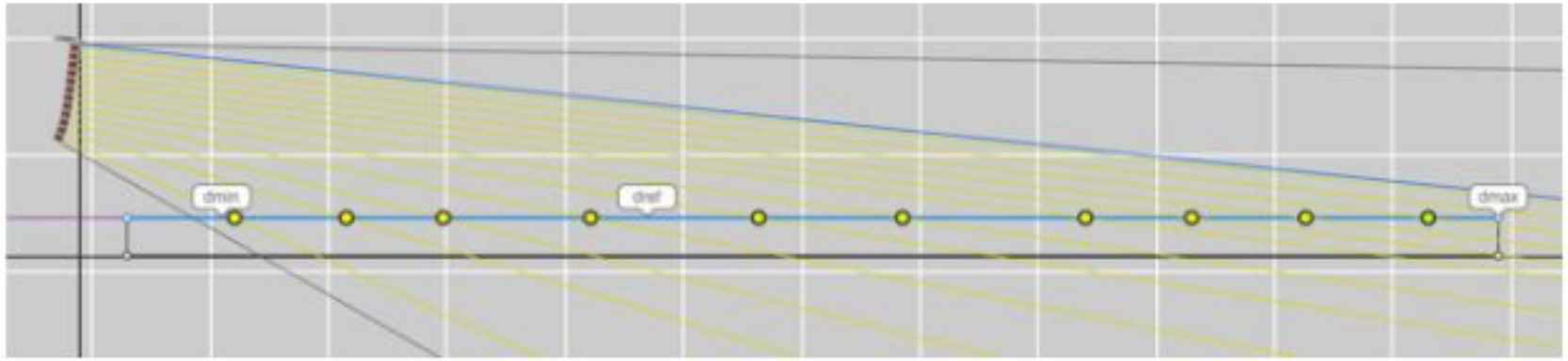


Figure 2: loudspeaker system and audience area used for synchronization evaluation tests

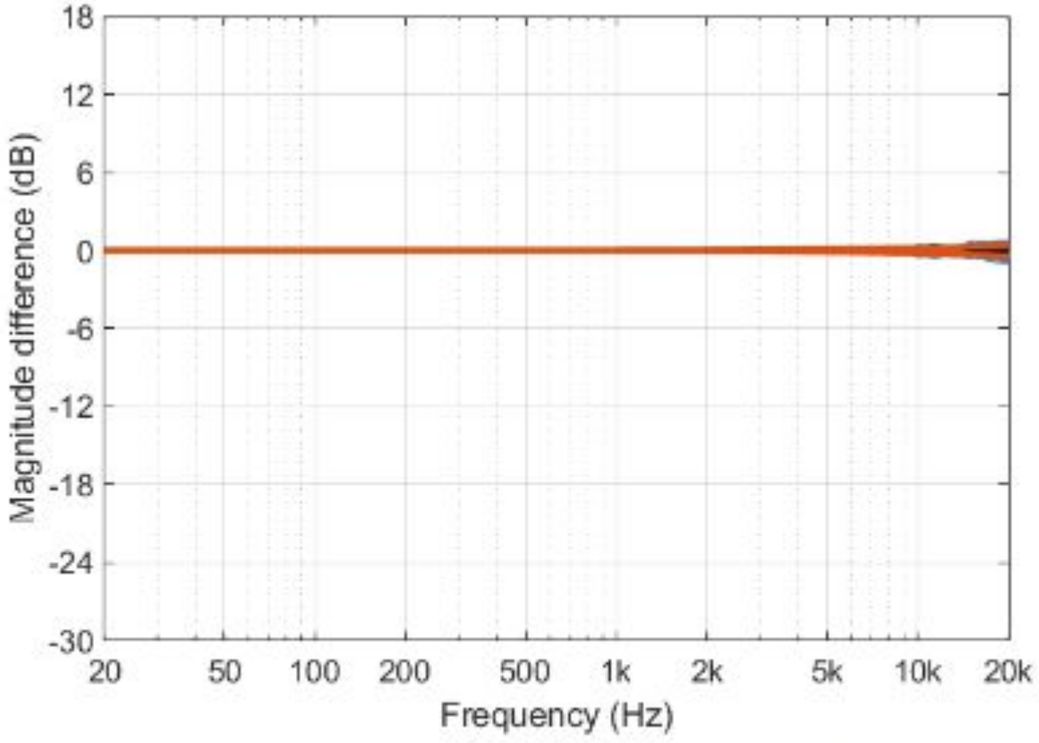


Figure 3: frequency response variations between unsynchronized and synchronized according to Figure 2 (blue: individual curves, black, median, red: 2.5 and 97.5 percentile), third octave smoothing, ±**0.5µs** timing offset (uniform random distribution)

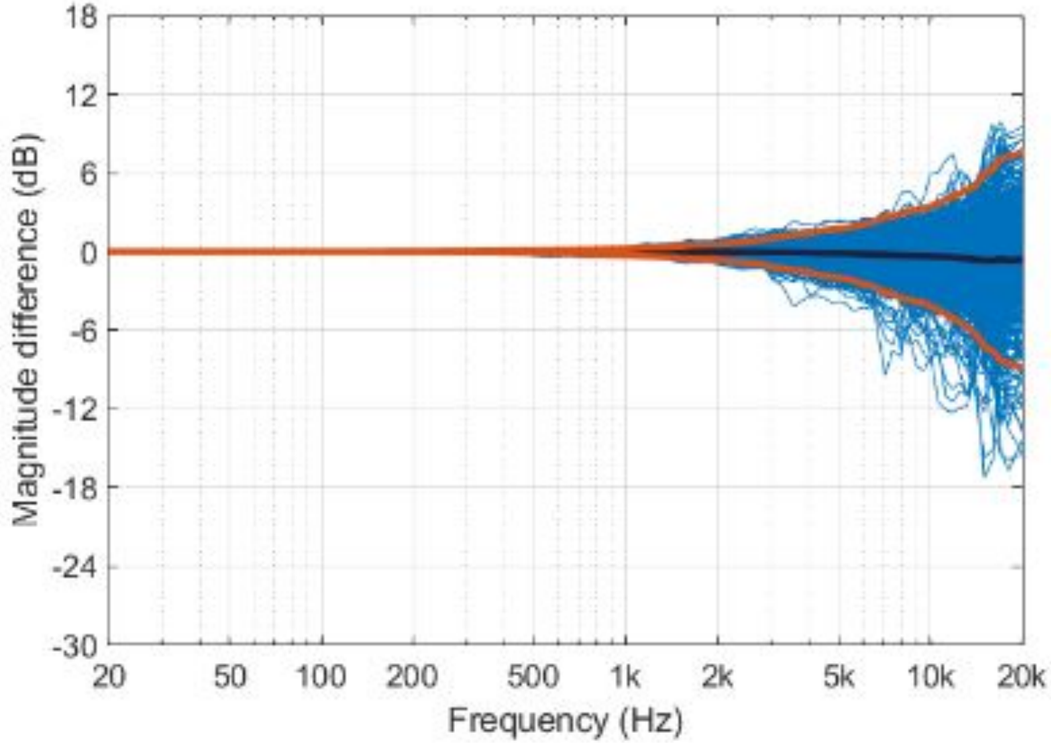


Figure 4: frequency response variations between unsynchronized and synchronized according to Figure 2 (blue: individual curves, black, median, red: 2.5 and 97.5 percentile), third octave smoothing, +/- **10µs** timing offset (uniform random distribution)

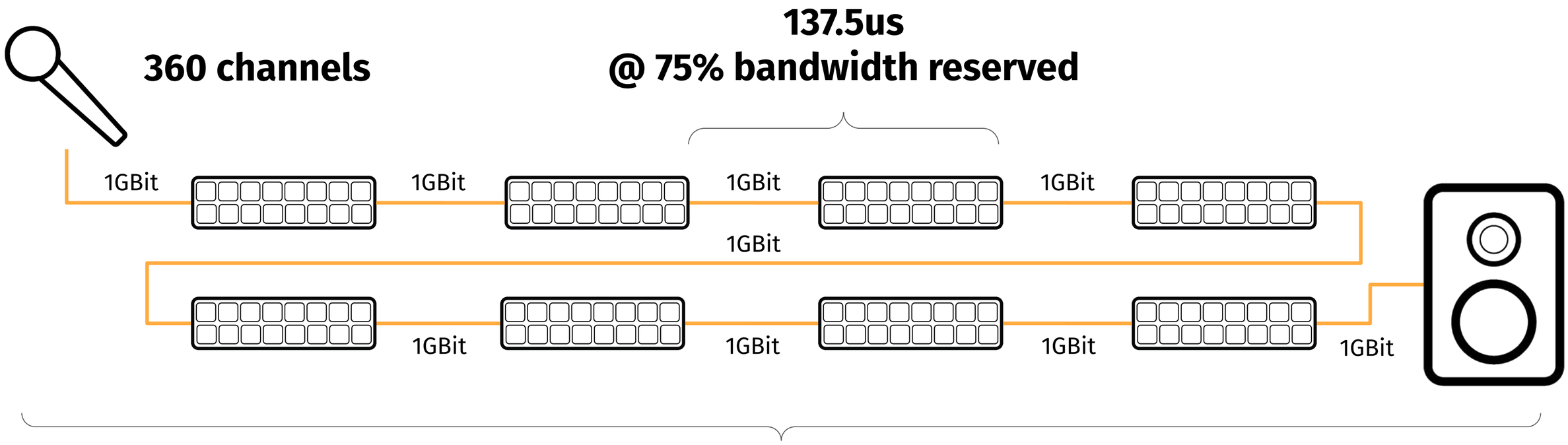
BACKUP SLIDES

JOYNED AUDIO. NETWORK. TECHNOLOGY.

Latencies in Milan networks

JOYNED AUDIO. NETWORK. TECHNOLOGY.

Latency in AVB networks



Latency in AVB networks

Hops	Worst Case Latency	Link Speed
2	0.5ms	100 MBit
7	2ms	100 MBit
2	0.275ms	GBit
14	2ms	GBit

75% bandwidth for AVB reserved