Time Sensitive Networking (TSN)
Also known as “Ethernet”

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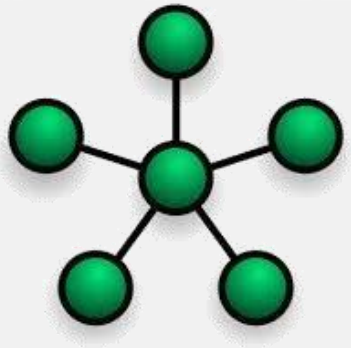
Abstract: Standard Ethernet is becoming inherently time-capable. In this talk we provide an overview of the multiple standards and amendments under development in IEEE 802 TSN and elsewhere that promise guaranteed, robust delivery of time-sensitive streams over local area networks, expanded to routed networks by IETF DetNet.

TSN (Time Sensitive Networking)
TCC (Time Coordinated Computing)

Time Sync

Timeliness

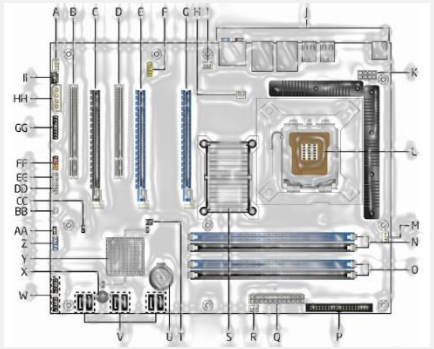


TSN

Between Systems

PTP
IEEE 802.1AS profile of IEEE 1588

"TSN"
IEEE 802.1Q
IETF DetNet
Latency Guarantees, Seamless Redundancy, Ingress Policing, Ethernet Preemption, etc.



TCC

Within The System

System Timekeeping

Traditional Realtime

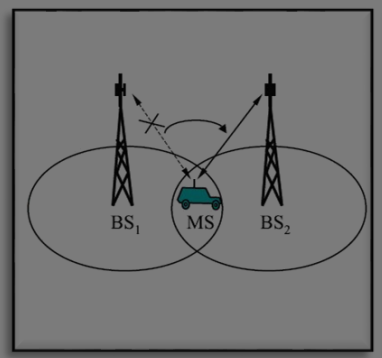
Application Domains for TSN

Automotive

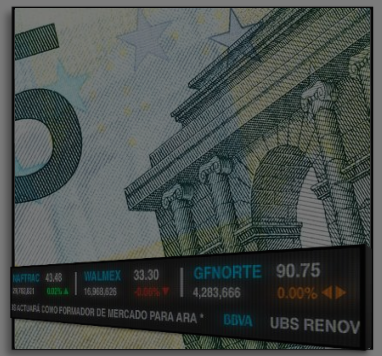
Conferencing

Realtime A/V

Industrial/
Energy



Cellular/Telco



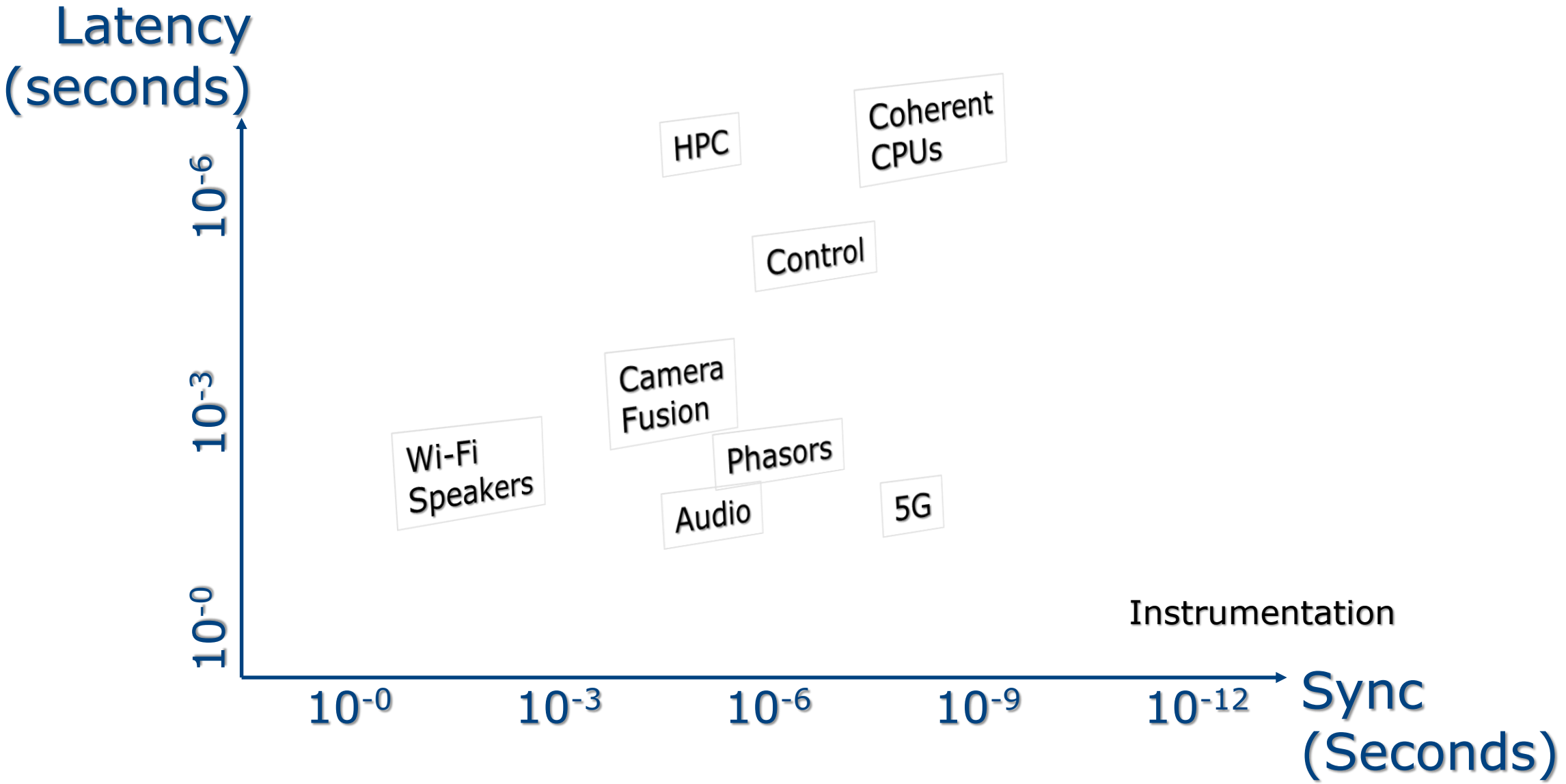
Financial

Cloud/HPC

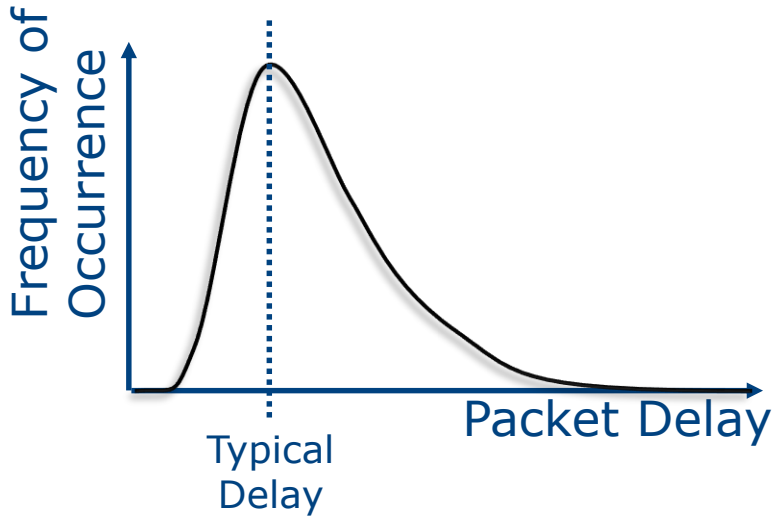
Latency Guarantees Needed?

Some Apps Require UTC Traceability
…Some Do Not

Application Requirements



Network Latency

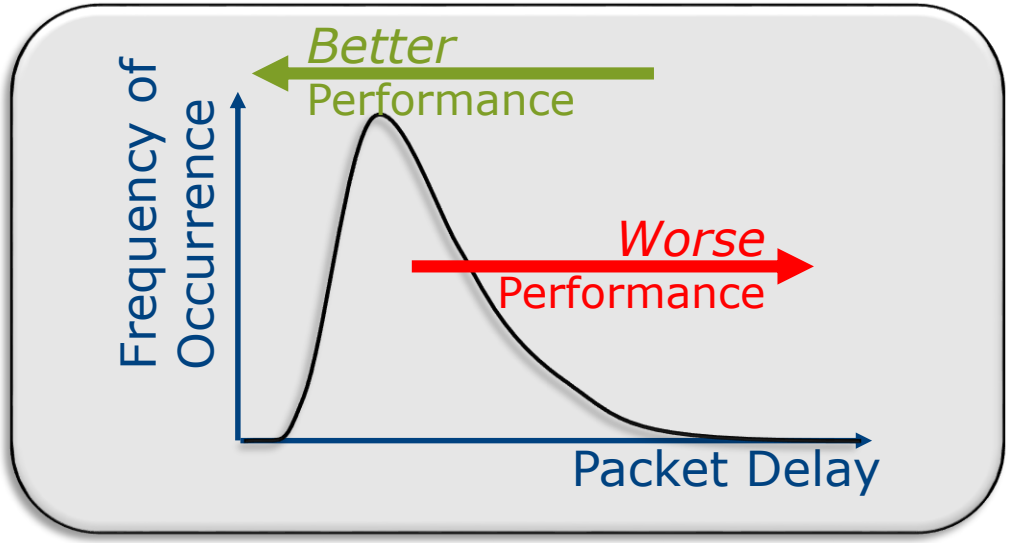


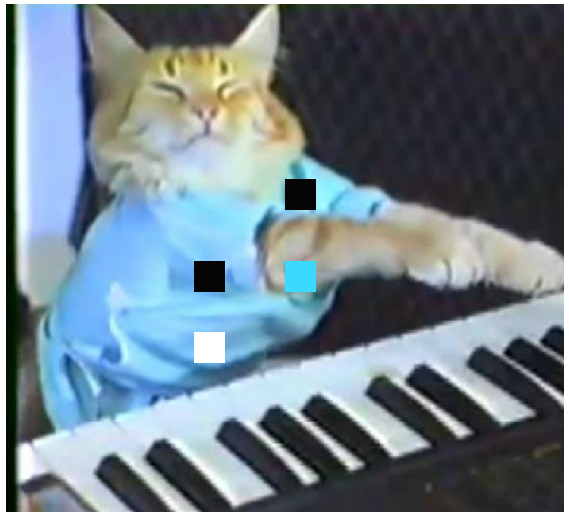
Even High Priority Traffic Experiences PDV (Packet Delay Variation)

Most Applications Perform Fine with Large PDV

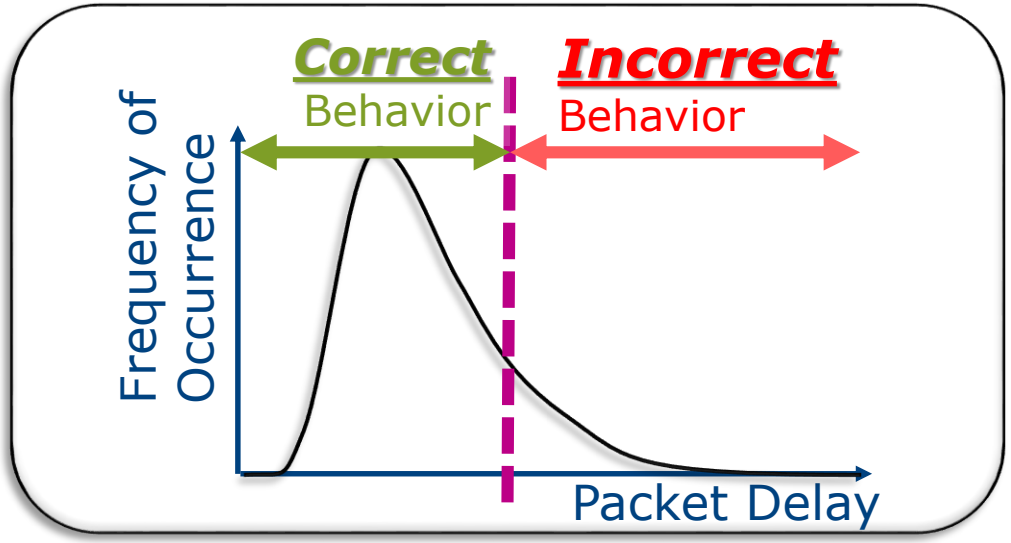
For Some Applications, Latency has Hard Limits

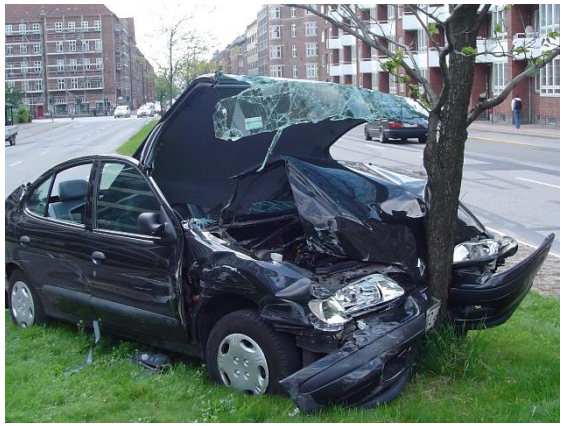
Typical Data Traffic





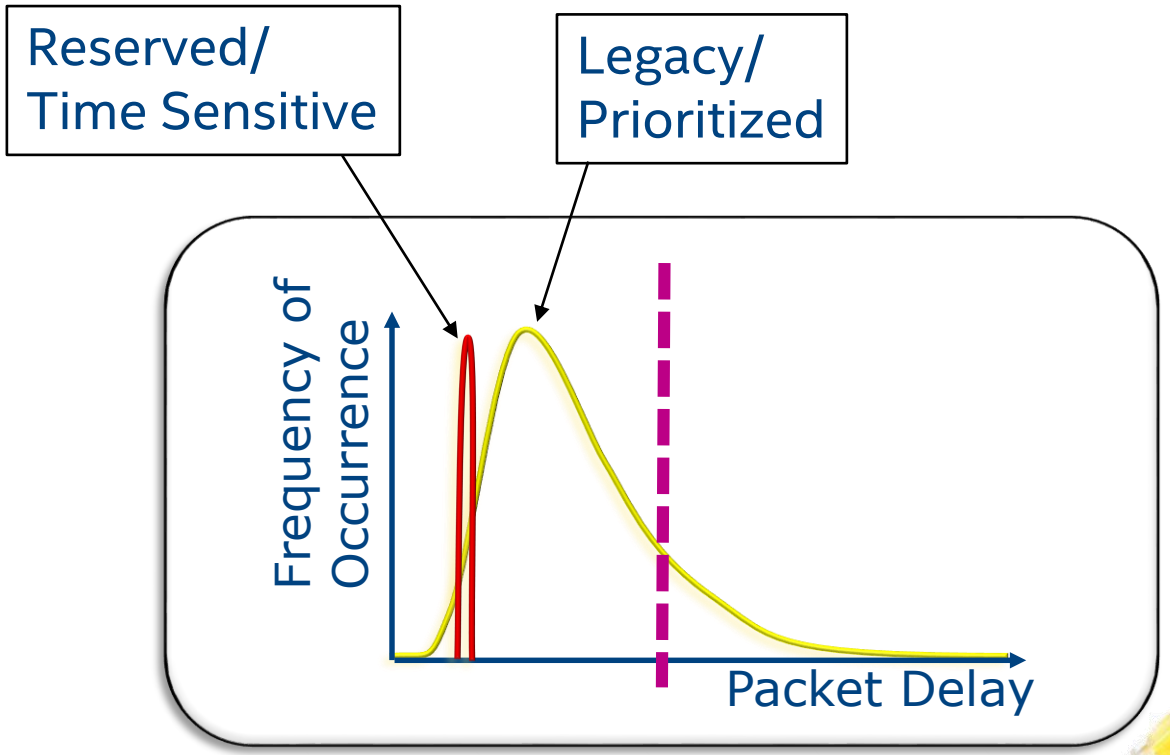
Cyber-Physical System (CPS)

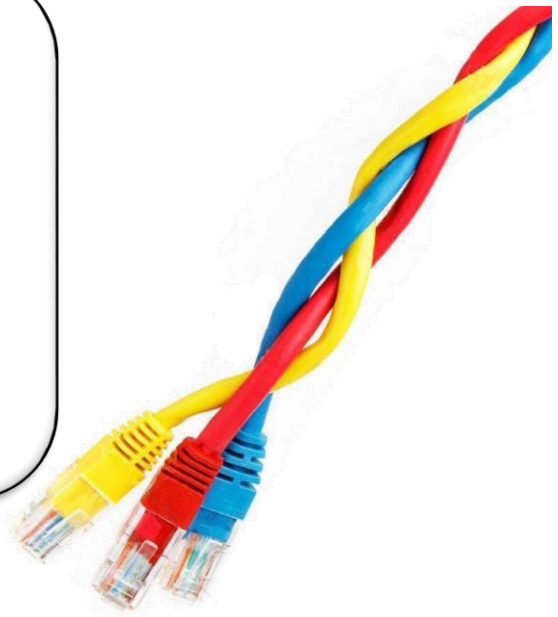




For Cyber-Physical Systems, *Only* Worst Case Delay Matters

Latency of Time Sensitive Streams Must be Constant and/or Bounded (and small)





Simultaneously Support Time-Sensitive and Legacy/Best-Effort Simultaneously

TSN Miniminizes Packet Latency (and PDV)

Also Delivers Robust, Deterministic Time Accuracy via PTP Profile

The Challenge	A Solution	The Standard
Need guaranteed time accuracy with redundancy	IEEE 1588 profile optimized for deterministic accuracy & redundancy	IEEE 802.1AS-Rev
Packet Delay Variation (and long tail)	Globally time-scheduled slots for Time-Sensitive Flows only [+Cut-through]	IEEE 802.1Qbv
Interfering long frames	Preempt (& then resume) interfering frames, insert time-sensitive frame	802.1Qbu/802.3br
Dropped frame (e.g., CRC error or network reconfig)	Replicate frames on ‘n’ maximally disjoint paths, remove duplicates	802.1CB
“Babbling Idiot” Problem	“Police” traffic on switch ingress	802.1Qci
How to configure the above	Path Control and Reservations	802.1Qca/802.1Qcc
Need guarantees across IP routers	Scale Determinism to Routed Networks	IETF DetNet

TIME SYNC UPDATES

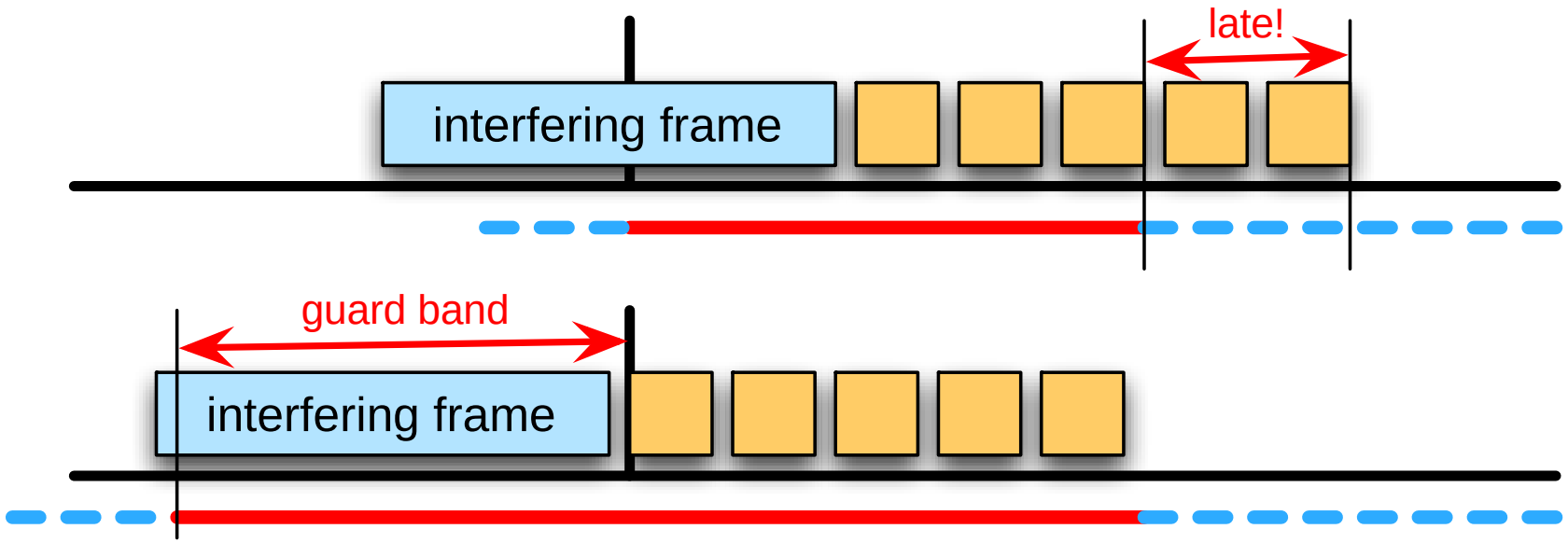
IEEE 802.1AS-revision is an update to 802.1AS for

- **Enhanced link support**
  - Support for *all* of Ethernet, including link aggregation
  - Probable support for 802.11 “fine timing measurement”
  - Other layer 2 links of interest
- **Improve performance and usability**
  - Responsiveness and reliability, support for “one step” links
  - Scalable to larger / more difficult topologies
  - Timing path selection for maximum accuracy
  - Explicit support for centrally-managed systems
- **Start the process towards protocol unification**
  - End the 1588 vs 802.1AS vs NTP confusion
  - 802.1 is coordinating with the 1588 revision project
  - “High accuracy” modes (working with IEEE 802.3 and 802.11) to support single digit nanosecond synchronization (with architecture to support better in the future).

802.1Qbv Time Aware Shaper

Schedule Time-Sensitive Frames, Eliminate Interference with Guardband

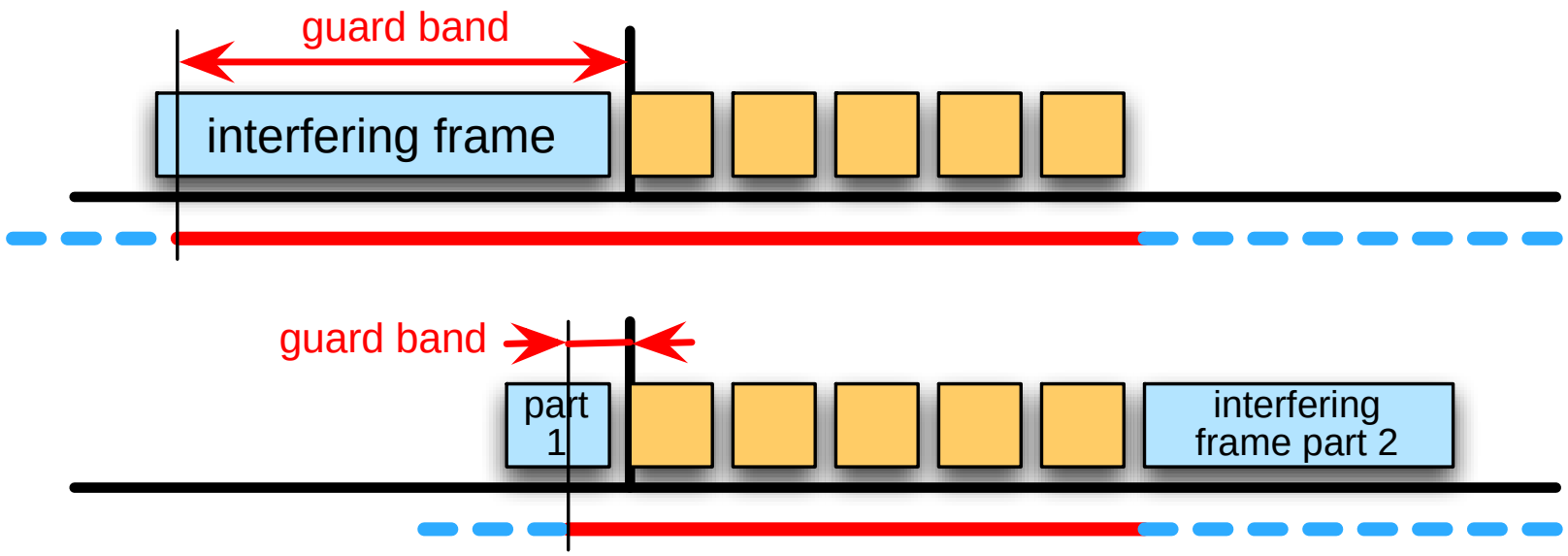
- **If an interfering frame begins transmission just before the start of a reserved time period, it can extend critical transmissions outside the window.**
- **Therefore a guard band equal in size to the largest possible interfering frame is required before the window starts.**



Preemption Reduces the Guard Band

Preemption (802.1Qbu/802.3br) is a solution

- **If preemption is used, the guard band needs to be only as large as the largest possible interfering fragment instead of the largest possible interfering frame.**



802.1CB: SEAMLESS REDUNDANCY

- **Identify and Replicate Packets of Certain Flows**
- **Duplicate frame elimination based on address/traffic class and timing**
- **Compatible with existing industrial architectures**
  - E.g., HSR, PRP
- **NOT TRIVIAL!**
- **IP Flows (Octuple) Defined**

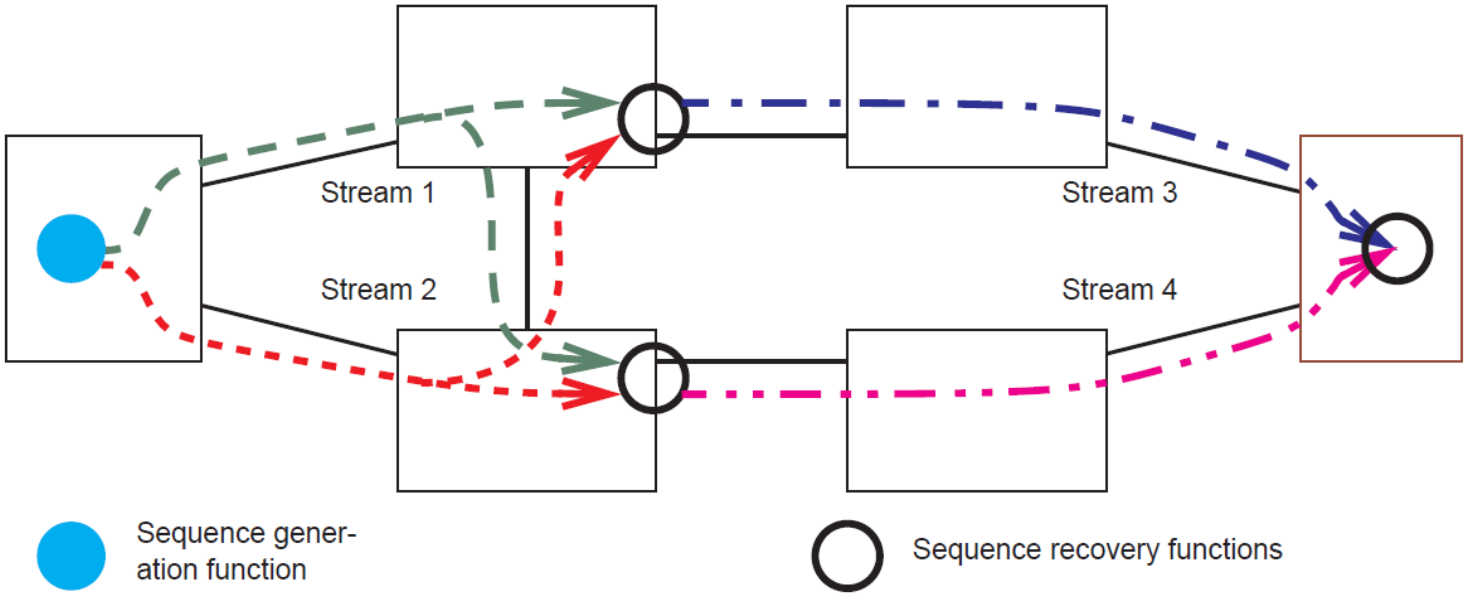


Figure 7-1—Compound Stream built from four Member Streams

SDN-style Configuration of Schedules, Redundancy

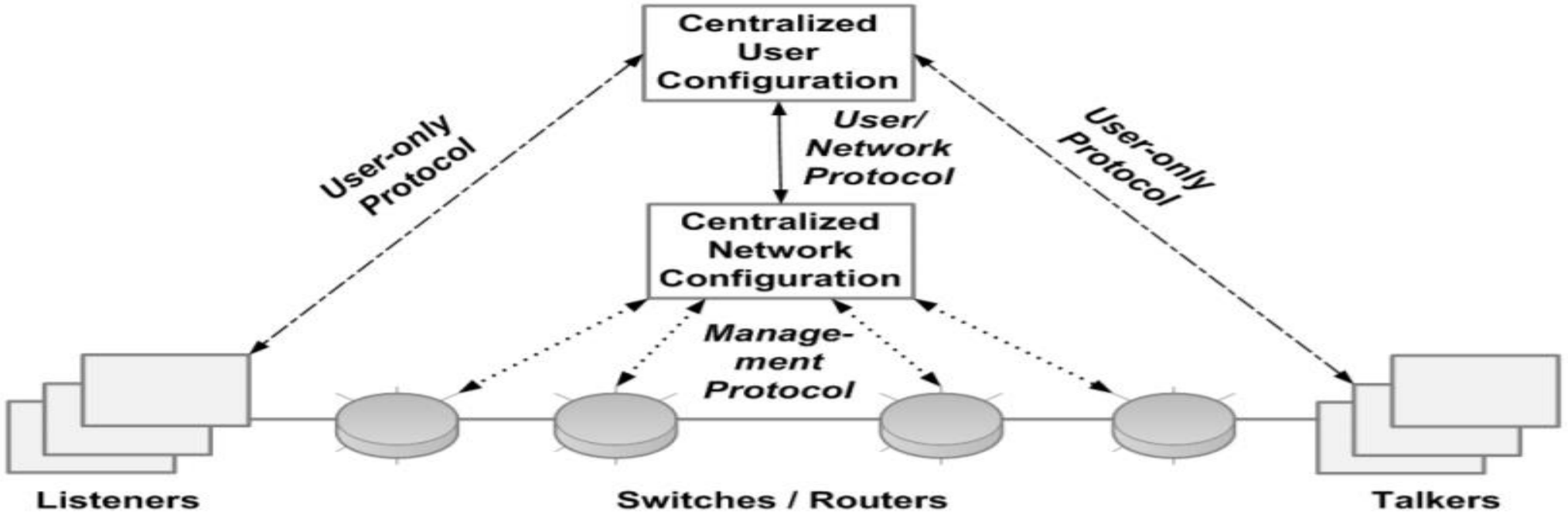
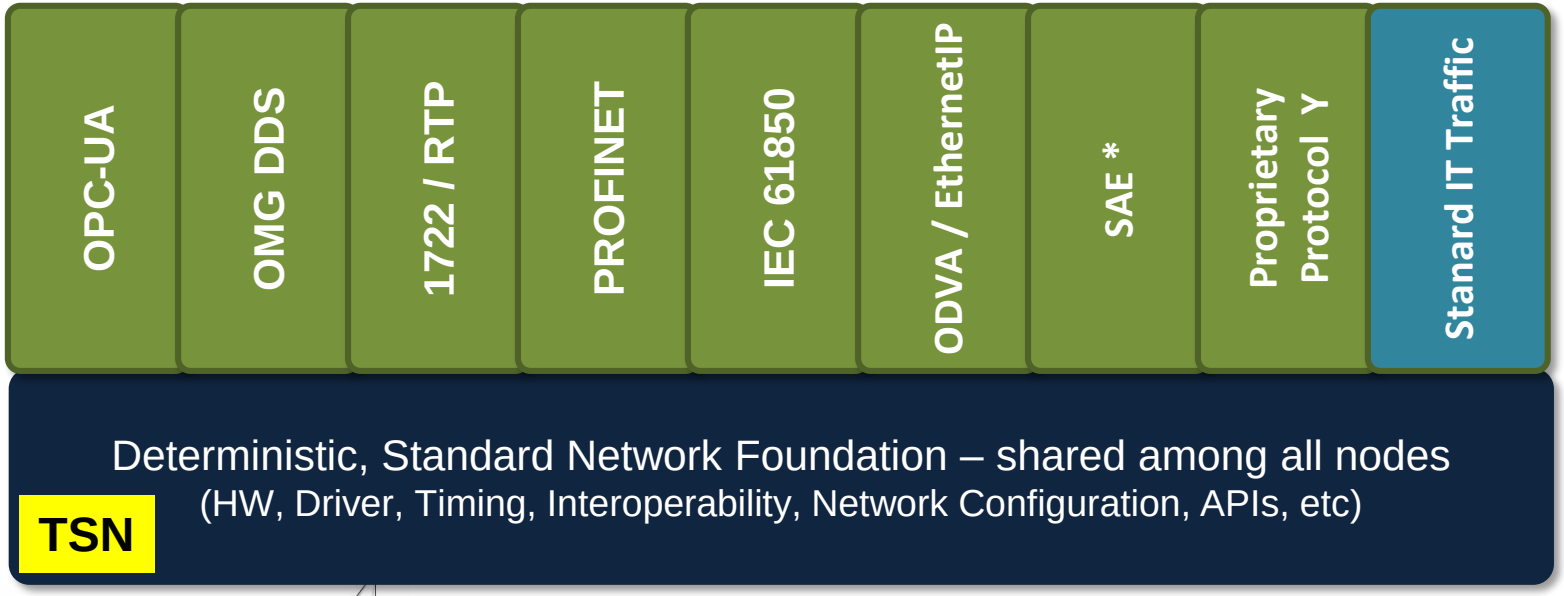
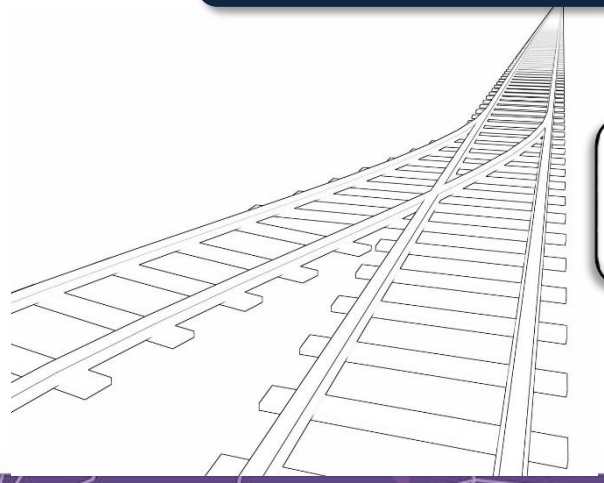


Image source: P802.1Qcc/D0.3

Realtime Application Protocols Can Share the Wire With Standard IT Traffic





Avnu Drives Standard Foundation APIs to Application Protocols

NOTE: This represent the view of Avnu, not necessarily the plans or views of other organizations, e.g., OPC Foundation, OMG, ODVA, PI, and SAE

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Summary

TSN builds on 1588 and 802.1 AVB, adds tools for

1. Redundancy
2. Fault Tolerance
3. Zero Packet Loss
4. Fixed (and low Latency)

Deployment led in Automobiles and Industrial Applications