Timing in Industry Segments

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WSTS 2023

Agenda

1. The need for packet timing in industry
2. Power grid
3. Broadcast (media)
4. Finance
5. Data centers
6. Industrial Automation
7. Automotive

Every technical industry

- Timing is always needed in distributed control systems and/or communication systems
- Moving to datacom/telecom networks for cost reasons

Past

- Industry specific network technology
- Industry specific timing signals, usually in dedicated timing networks

Present

- Mixture of past and future
- Datacom networks with legacy timing signals

Future

- Ethernet, WIFI, IP, 5G
- NTP and PTP for timing
- Driven by cost

Power grid substation equipment

SCADA system

Supervisory **C**ontrol **A**nd **D**ata **A**cquisition

Grid wide monitoring and control system

Protection Relays

Open these to prevent or contain electrical failures

Merging units

Digitize and timestamp analog measurements

Phase Measurement Units (PMUs)

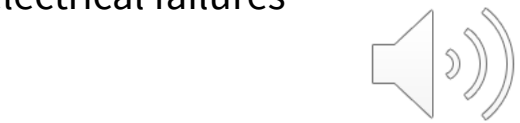
Also called Synchrophasors

Measure amplitude and phase of voltages and currents

Intelligent Electronic Devices (IEDs)

SCADA nodes

May include merging unit and or PMU functions



Station Bus

Top level of substation network

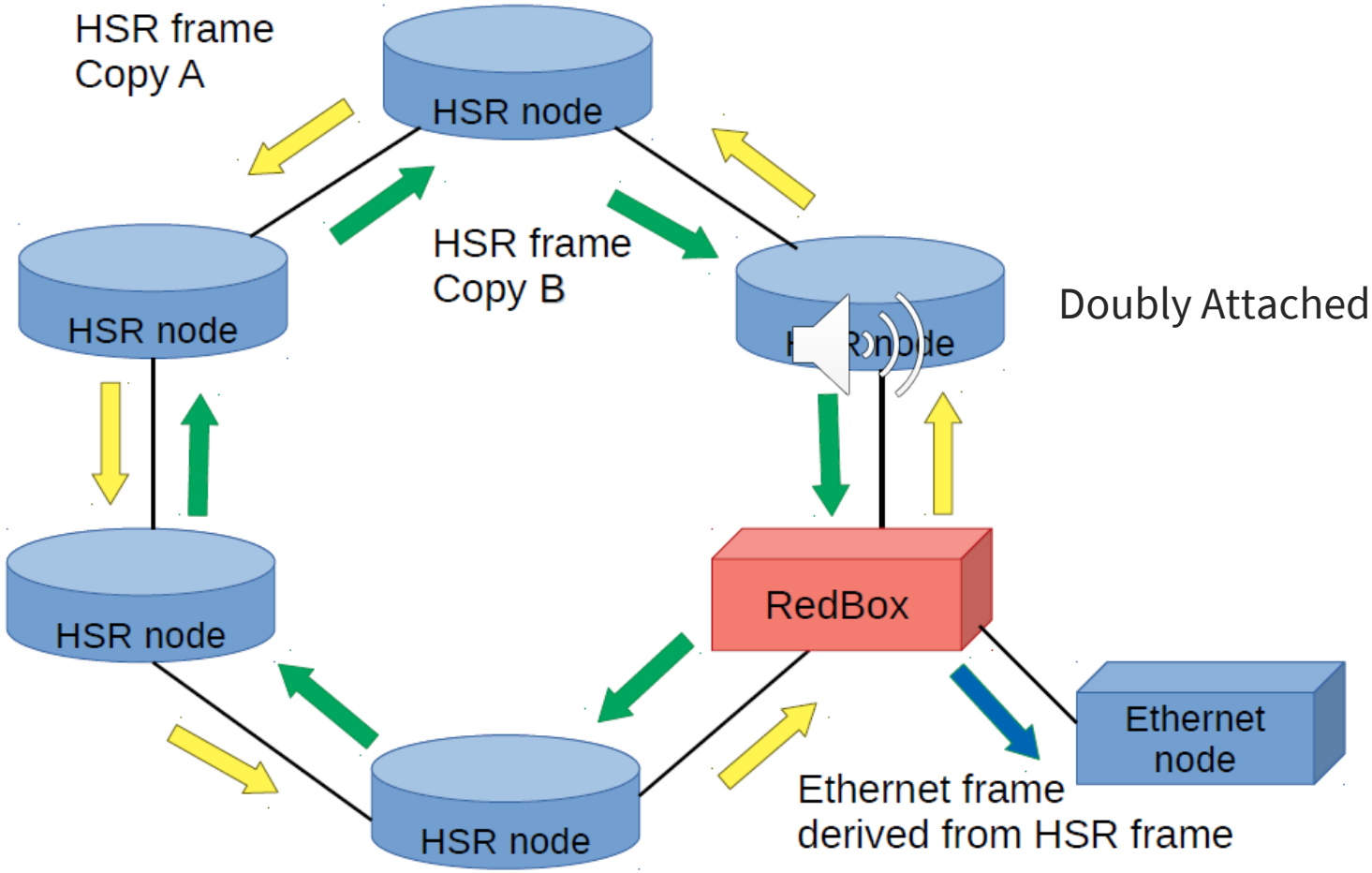
Connects to inter substation network

Process Bus

Data acquisition

Protective relays

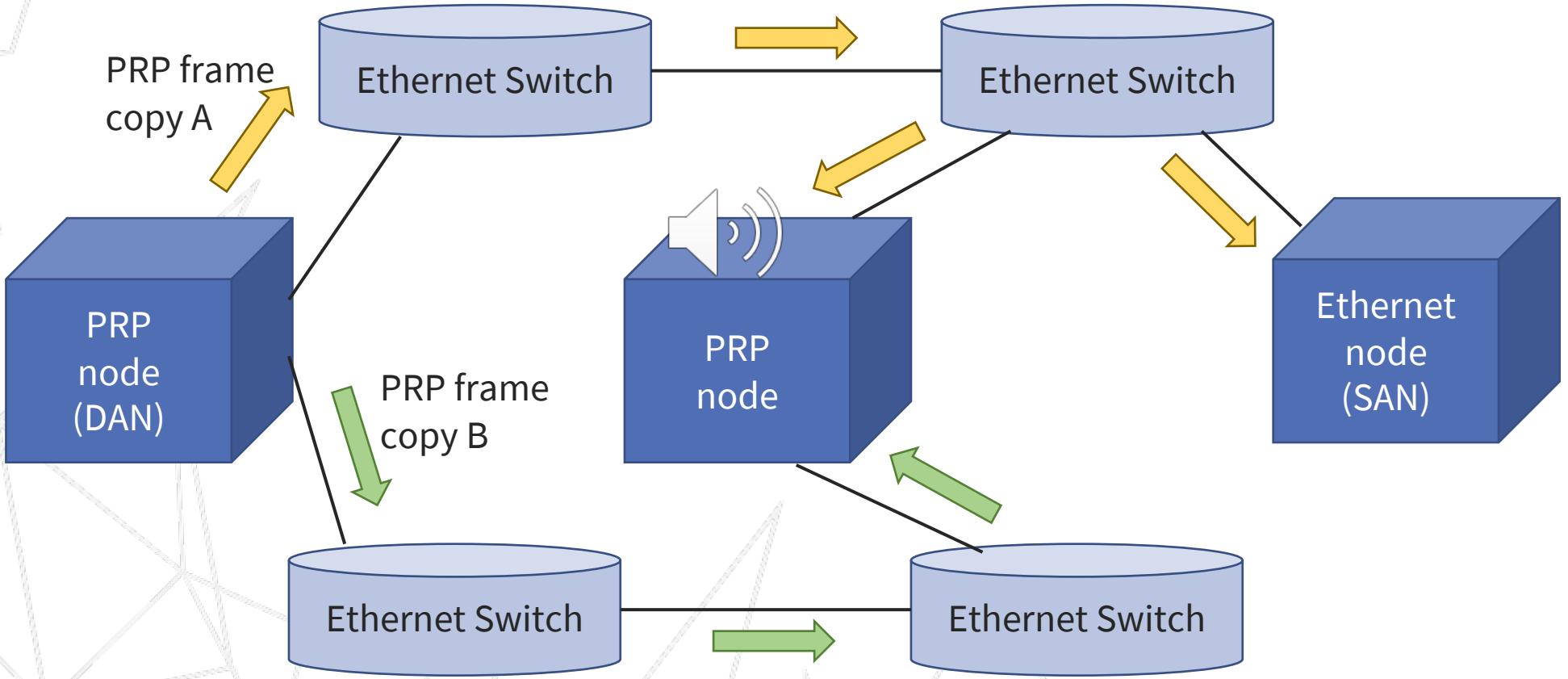
High availability Seamless Redundancy (HSR)



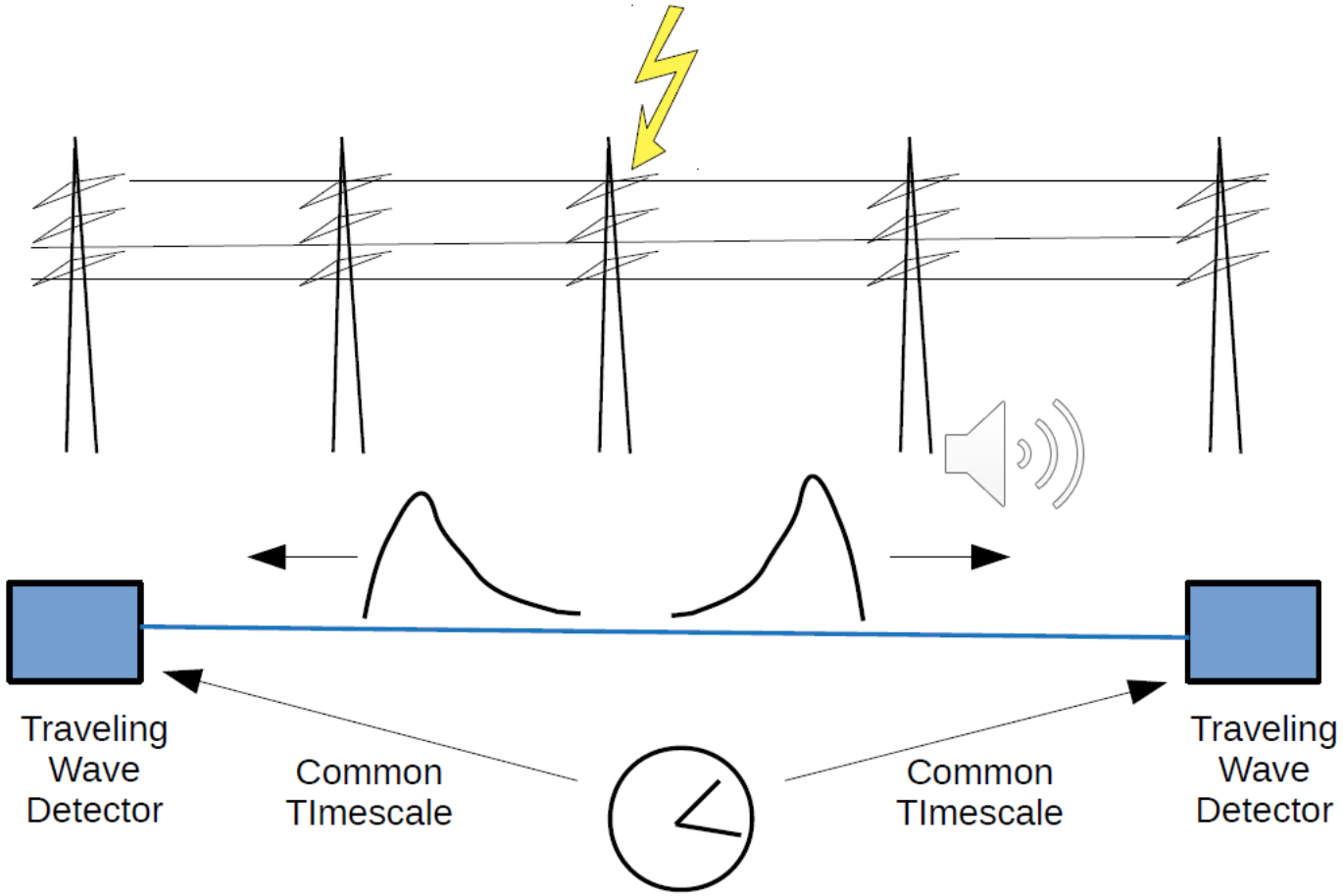
Doubly Attached Node (DAN)

Singly Attached Node (SAN)

Parallel Redundancy Protocol (PRP)



Travelling Wave Fault Detection



- 300 ns precision ~ 100 m location error
- Repair crews can spend less time finding the damaged equipment

Power Grid Standards

International Electrotechnical Commission (IEC)

Standards body for power grid industry

IEC 61850: suite of protocols for SCADA system

IEC 61588: republished IEEE 1588

IEC 61850-9-3: Utility Profile for PTP

Layer 2, P2P, all switches TCs or BCs

IEC 62439-3: PRP and HSR

IEEE

IEEE C37.118: Synchrophasor standard

1 μs time synchronization required

IEEE C37.238:

IEC 61850-9-3

+ reserved PTP domain (PTPv2 only)

Not allowed in PTPv2.1 (IEEE 1588-2019)

+Inaccuracy TLV

estimate maximum accumulated time error

only works if all switches support, but support is optional

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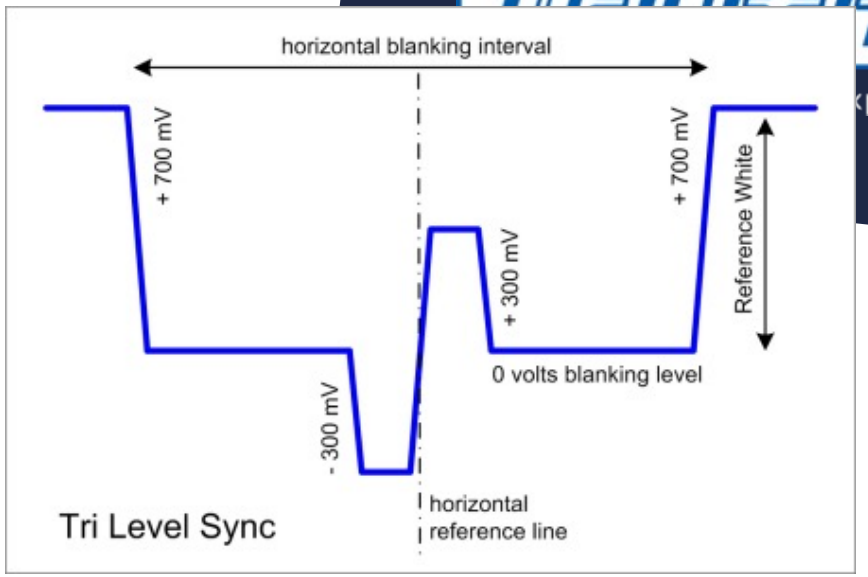
Why time is essential in Broadcast and Media

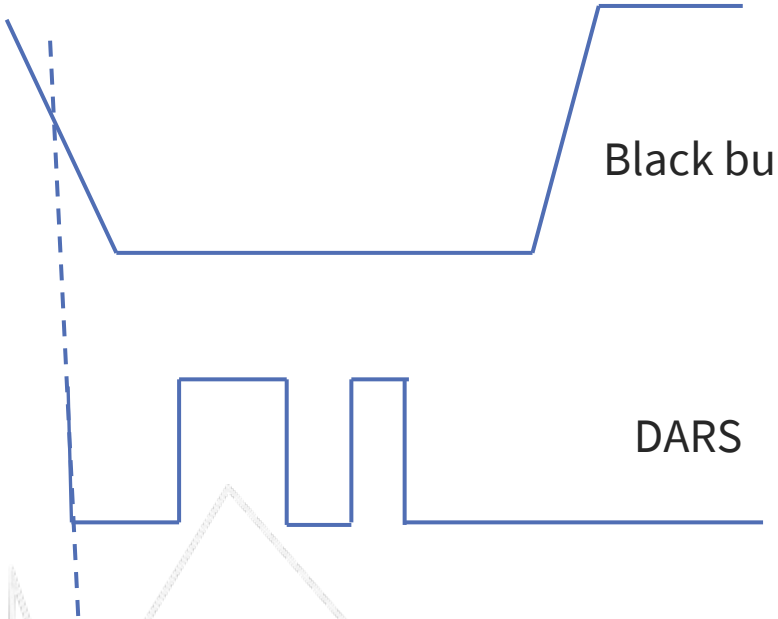
- Multiple audio and video files captured on separate equipment
  - Must be recombined for broadcast or steaming based on audio/visual file timestamps
  - Need smooth transitions among cameras, playback devices and other audio-visual sources
  - Color accuracy
  - Prevent jitter and artifacts
- Timing requirements
  - For video and mono audio: ~10 ms
  - For stereo audio: ~10 μs
  - Error budgeted to network time distribution is typically 1 μs.

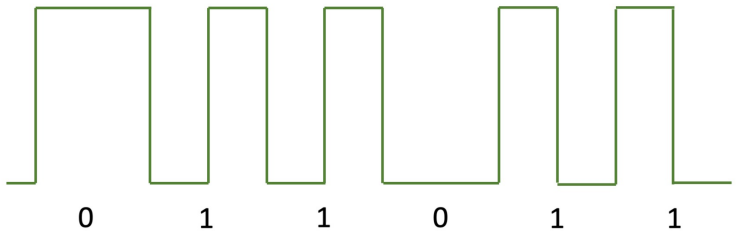
NBC Nightly News. Photo by Jeff Maurone

Legacy Broadcast timing signals

- Video signals **Genlock**
  - Black burst
  - Tri-level sync (supports HDTV)
- Audio signals
  - Word clock (square wave)
  - Digital Audio Reference Signal (DARS)
- Linear time code
  - Used to insert timestamps in captured media







Linear timecode

Broadcast standards

SMPTE

Society of Motion Picture and Television Engineers

ST2059-2: PTP Profile

Layer 3, E2E

Special signaling message sent by GMs with timing metadata

Master/slave replaced by Leader/Follower, Grandmaster still Grandmaster

AES

Audio Engineering Society

AES67: includes PTP Profile

Layer 3, E2E

Can be compatible with SMPTE ST2059-2

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IT in Finance Industry

- Enterprise IT technical viewpoint
  - IETF is where standards come from
  - Comfortable with non-standard approaches (Especially HFT firms)
  - Sometimes use non-standard NTP rather than PTP
- Regulatory compliance is mission critical
- Need time at software layer in standard hardware
  - PCIe cards
  - Software slaves/clients
- HFT algorithms often implemented in FPGAs on PCIe cards

Timing Requirements in Finance

- To trade in the United States (Consolidated Audit Trail)
  - Financial transactions need to be timestamped to 50 ms by traders
  - 100 µs by exchanges
  - To UTC:NIST
- To trade in the Europe (MiFID II)
  - Financial transactions need to be timestamped to 100 µs
  - To UTC
  - Most trading firms do business all over the world, so they will need to meet the strictest time accuracy for
- HFT
  - To measure network performance, not for regulation
  - 1-50 ns

Image from QuoteInspector.com

Timing Protocols in Finance

- Default PTP Profile
- Enterprise PTP Profile
  - Draft RFC in IETF
  - Mixed multicast/unicast operation (hybrid mode)
- Specialized NTP
  - High message rates
  - Lucky packet filters
  - Hardware timestamping

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Timing Requirements in Data Centers

- To make data synchronization in distributed databases more efficient
  - Fewer messages needed required to harmonize DB copies if time sync < latencies between copies
  - Typically want ~ 10 µs
- Cloud vendors starting to host infrastructure for finance
  - Must meet CAT and MiFID II requirements

Image by cloudwatt

Timing technology in Data Centers

- PTP or NTP
  - PTP without on path support common
  - Often engage in leap smeared NTP
    - Add inserted second gradually by slowing down clocks for a period of time
    - Easier to mess up time then change DB software to handle leap seconds
- Strong preference for open software and hardware
  - Open Compute Project (OCP)
    - Industry consortium for sharing open software, hardware and best practices
    - OCP-TAP: time appliance project (open timecard design)

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Industrial Automation

- Timing needed to coordinate cyber physical system
  - Sensors -> Controller -> Actuators
  - For example, assembly line robots
- Networks
  - Legacy CAN bus, RS45
  - Ethernet
  - Order of 1000 nodes
  - Many sensors and actuators are integrated with simple two port switches
  - Up time critical
  - Integration with 5G networks in near future

Industrial Automation requirements

- Timing agreement ~ 1 us
  - Often no need for standard time (no GNSS!)
  - Redundant PTP domains
- Standards
  - IEEE 802.1AS PTP Profile
    - Layer 2, peer delay, Non filtering BCs with cumulative rate ratio
  - IEC/IEEE P60802
    - Time sensitive network profile for Industrial Automation
    - Profile of IEEE 802.1 TSN standards

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Automotive

- Timing needed to coordinate ~ 100 controllers in car
- Networks
  - Moving away from CAN bus and flexRay to Ethernet
  - Moving away from multiple networks to one network
  - Interact with 5G in future
- Timing
  - No need for standard time until 5G communications added
  - Discussing simplified PTP
    - No BMCA
    - Fixed port states
- Standards
  - 802.1DG PTP Profile and traffic shaping

Thank you for your attention

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