PTP Implementation and Experience for Synchronization at PG&E

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IEEE/NIST Timing Challenges in the Smart Grid Workshop

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Why PTP?

STANDARDS BASED

ACCURATE

- Great than 1 μSec Accuracy
- Lengthy Holdover
- Quantifiable Performance

DISTRIBUTABLE

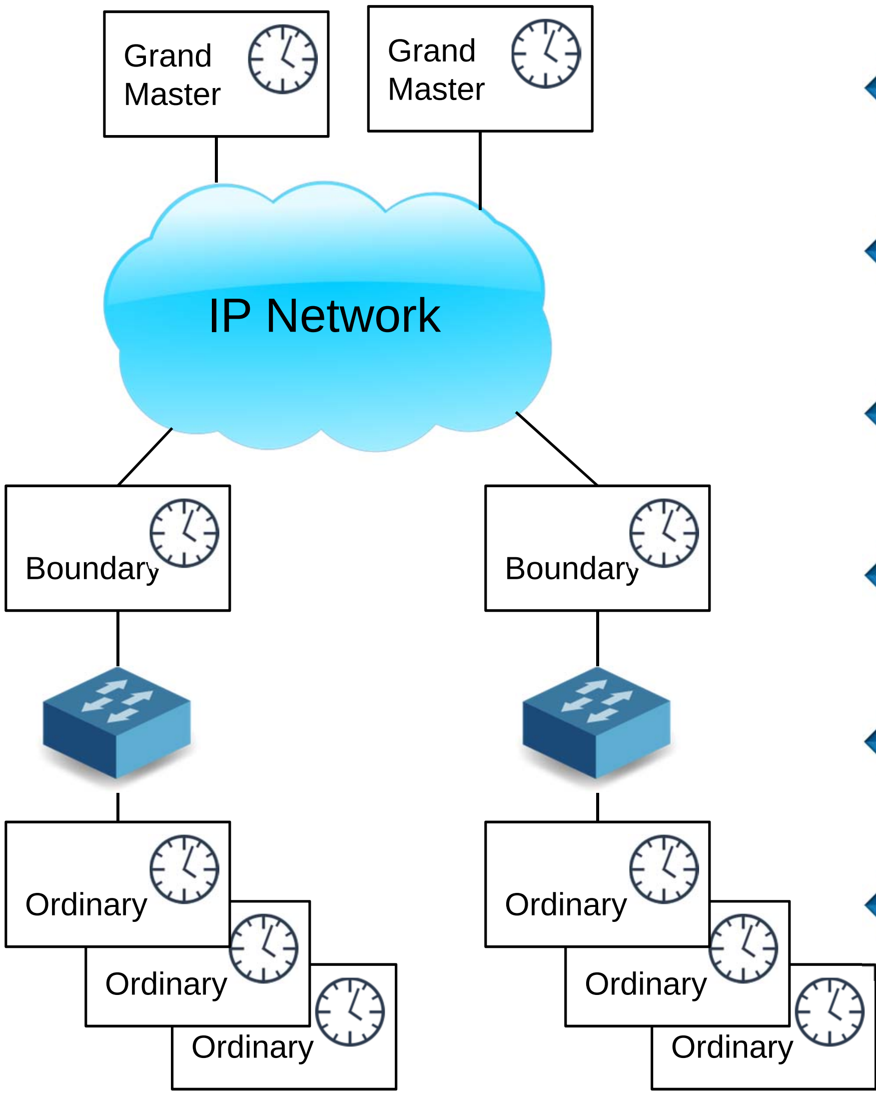
- Ethernet Based
- No Special Cabling
- Simple Deployment for any Environment

SECURE

- Defined Fail Over Parameters
- Alarming on Errors
- Substation Hardened

Synchrophasor Clocking Source & Evolution for Other Substation Devices

Types of PTP Clocks



- Master Time Source for All Clocks
- Best Master Clock Algorithm Allows Grand Master Redundancy
- Clock Distribution Over WAN (Typically End to End)
- Local Master for Ordinary Clocks
- Transparent Clocks Distribute Clock Signal and Correct Time Stamps
- Synchronized End Devices (Typically Peer to Peer)

PG&E Deployment

Remote Synchronization Source

Hub to Sub - Standards Based
1588 Telecom Profile Distribution

Local Source
Substation Hardened – Rb Holdover

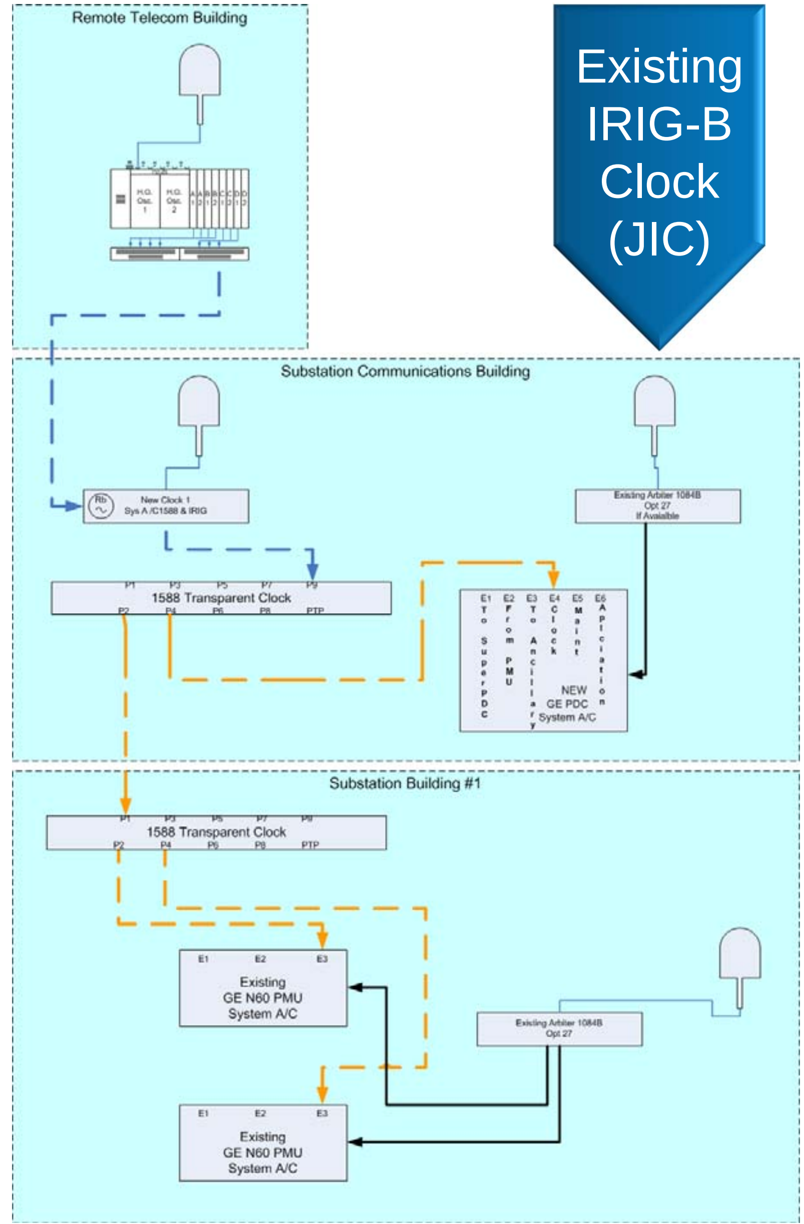
Transparent Clock
Distribution to All Devices

Sub to Device - Standards Based
1588 Power Profile Distribution

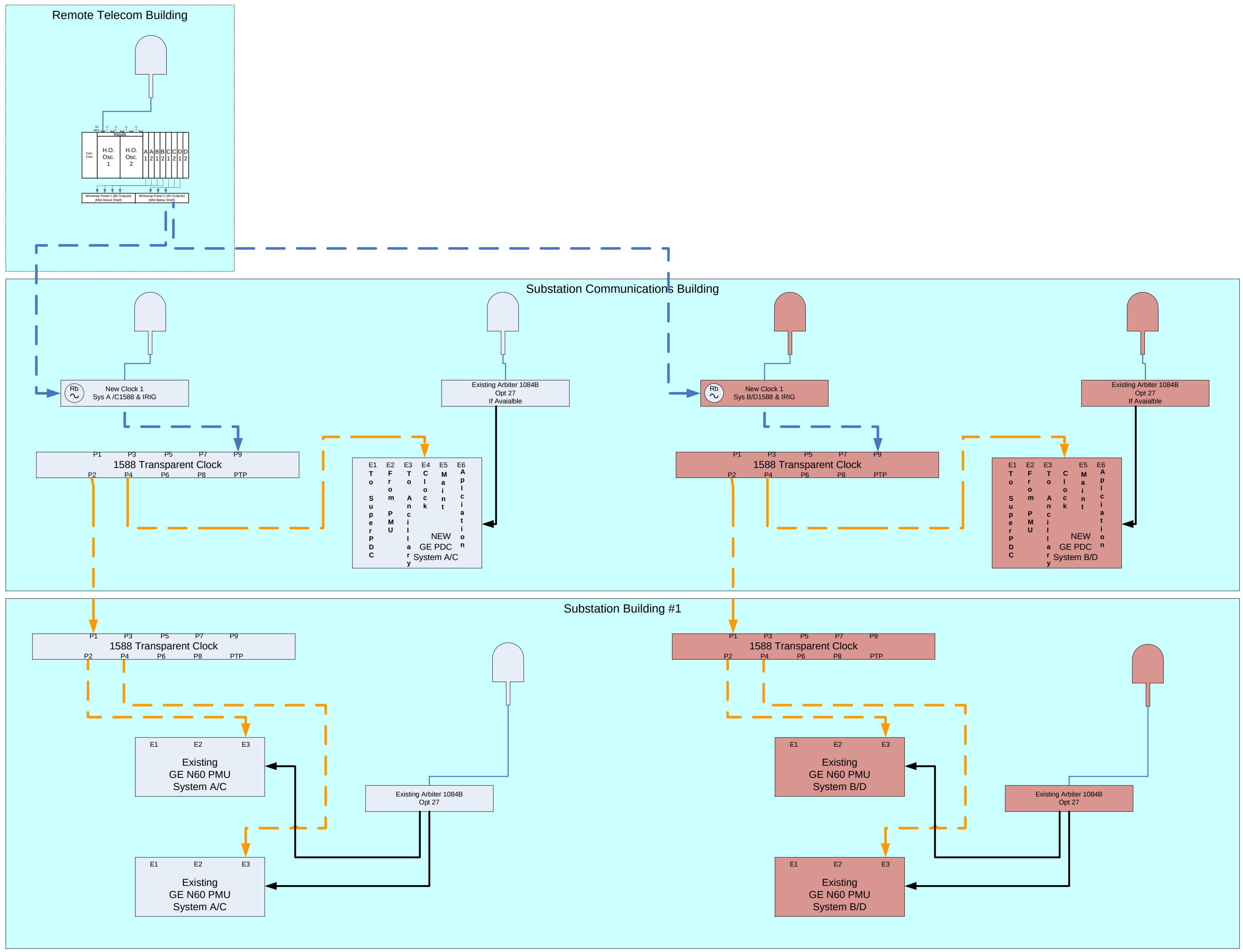
Fiber Based Ethernet Cabling
Whenever Possible

Full Redundancy
This is only half of the picture!

Existing IRIG-B Clock (JIC)



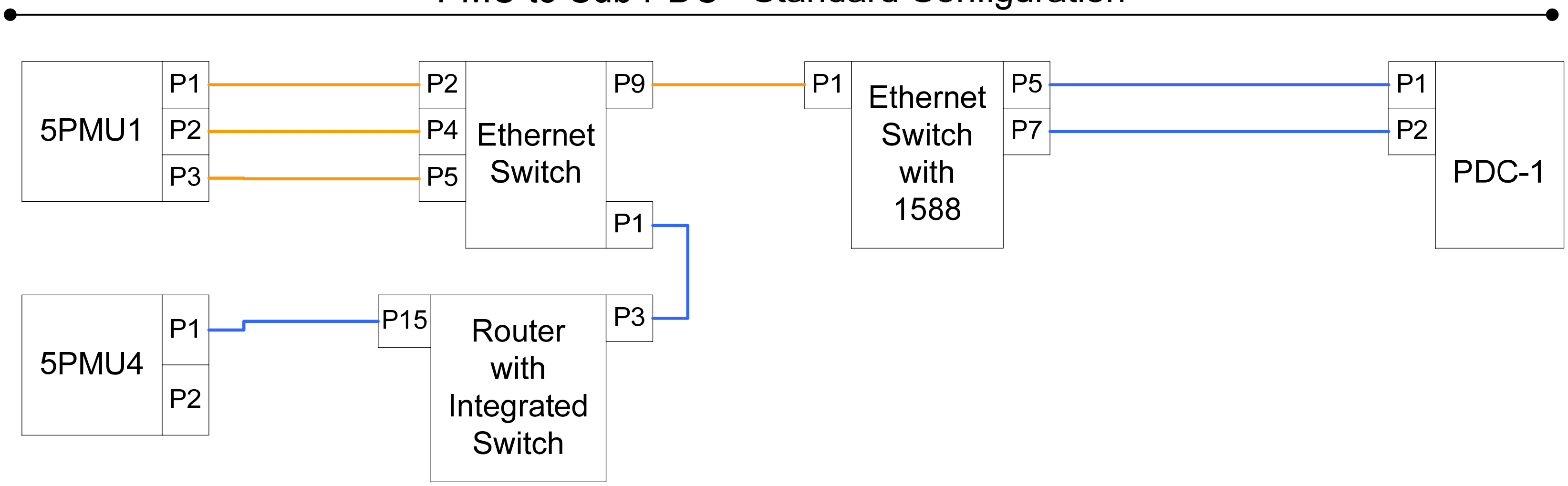
Typical Substation Clocking Distribution with Redundancy



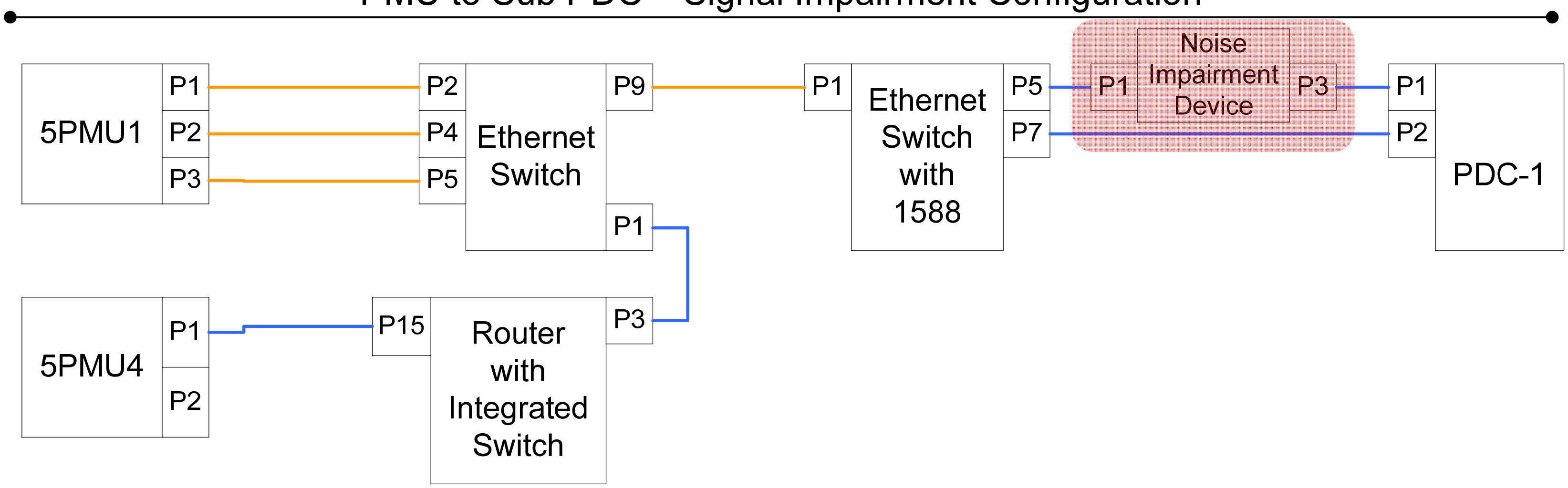
Noise Impairment Tests

- Noise Injection / IP Packet interference

PMU to Sub PDC - Standard Configuration

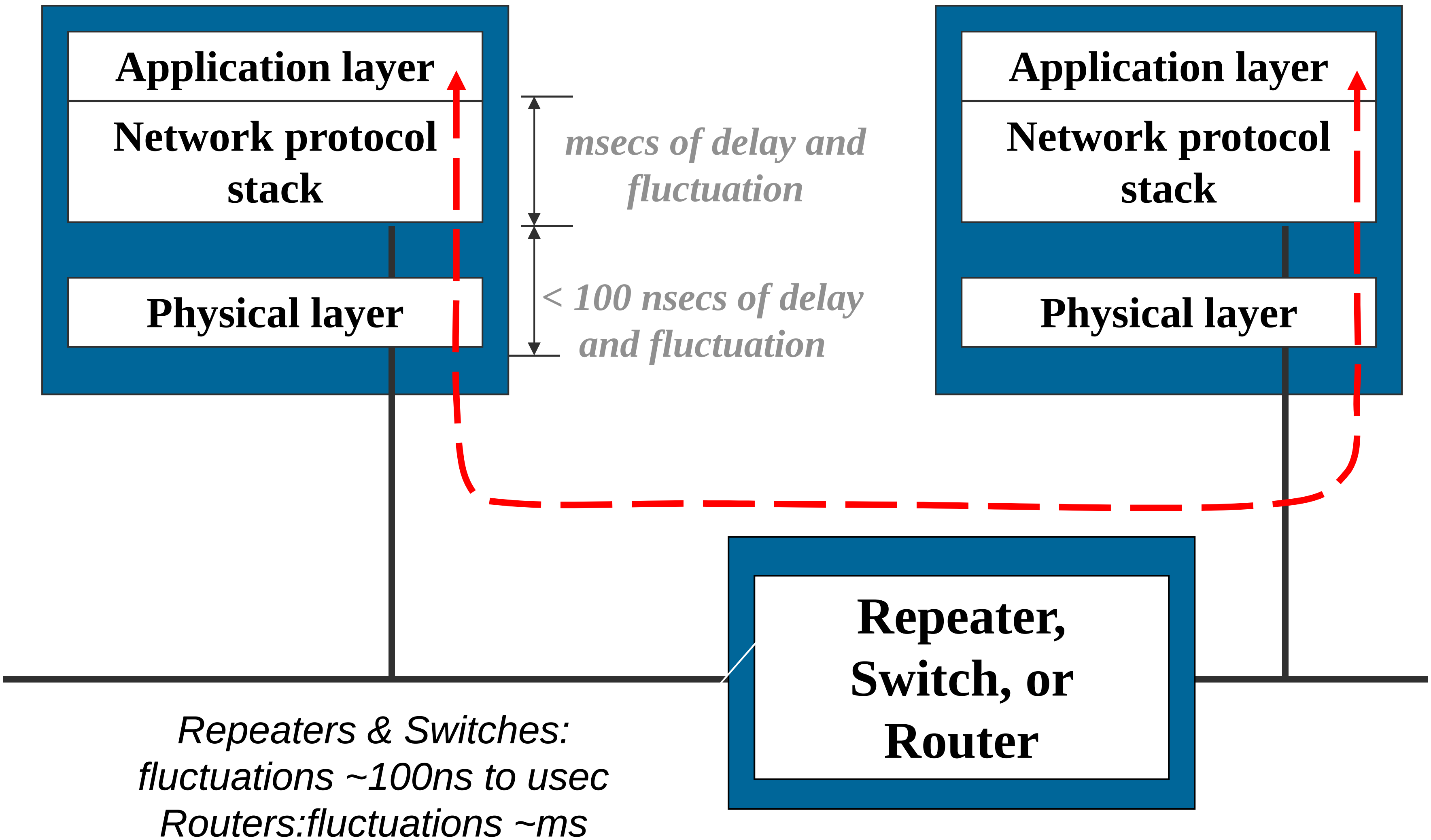


PMU to Sub PDC – Signal Impairment Configuration

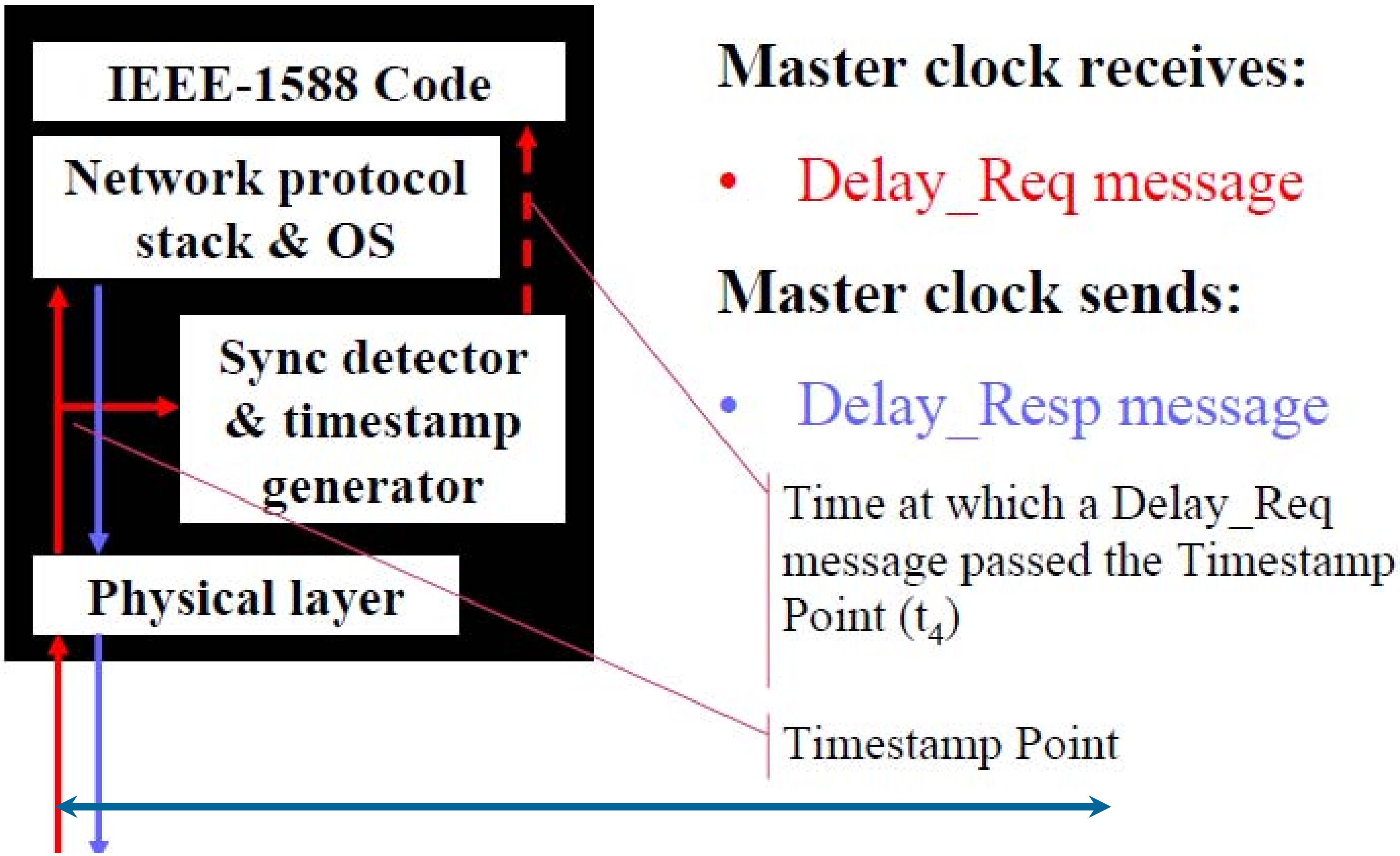


Observations – Timing functions (GPS, IRIG-B, and IEEE 1588)

- Several GPS-synchronized clocks providing timing accuracy better than 1 us (mostly on the order of 0.1 us)
- Some clocks did not update time-quality bits in IRIG-B timing data after loss of GPS input. Similarly, for IEEE 1588 PTP.
- In the absence of GPS input, clock drifts on the order of 10^{-7} to 10^{-9} were observed from different clocks.
    - Typical commercial products
        - 10^{-9} is a drift of 4 us in about an hour
        - 10^{-7} is a drift of 26 us in about 4 minutes (Bad Time)
            - Synchrophasor permissible TVE of 1% ~ 26.5 us
- Other 1588 PTP (precision time protocol) test results
    - Typical accuracy of 0.1 to 0.5 us has been observed.
    - Any delay in network communication can translate to delay in Transparent Clock when not compensated.
    - Some Slave clocks assume transmission delay is the same in both directions (usually OK, but not always)


Application layer
Network protocol stack
Physical layer
msecs of delay and fluctuation
< 100 nsecs of delay and fluctuation
Application layer
Network protocol stack
Physical layer
Repeater, Switch, or Router
Repeaters & Switches:
fluctuations ~100ns to usec
Routers:fluctuations ~ms

Synchronization Details (continued)



Master clock receives:

- Delay_Req message

Master clock sends:

- Delay_Resp message

LN – STIM identified to set time and provide time synchronization in a substation

Class	Accuracy	Function/phase error
T1	± 1 ms	Event timing
T2	± 0.1 ms	Zero Crossing / Sync Check
T3	± 25 μs	32’ at 60Hz / 27’ at 50 Hz
T4	± 4 μs	5’ at 60Hz / 4’ at 50 Hz
T5	± 1 μs	1’ - Synchrophasors
T6	± 0.1 μs	Available, but not defined yet