IMPACT OF MACSEC ON ETHERNET TRAFFIC LATENCY AND PTP TIMESTAMPING ACCURUCY

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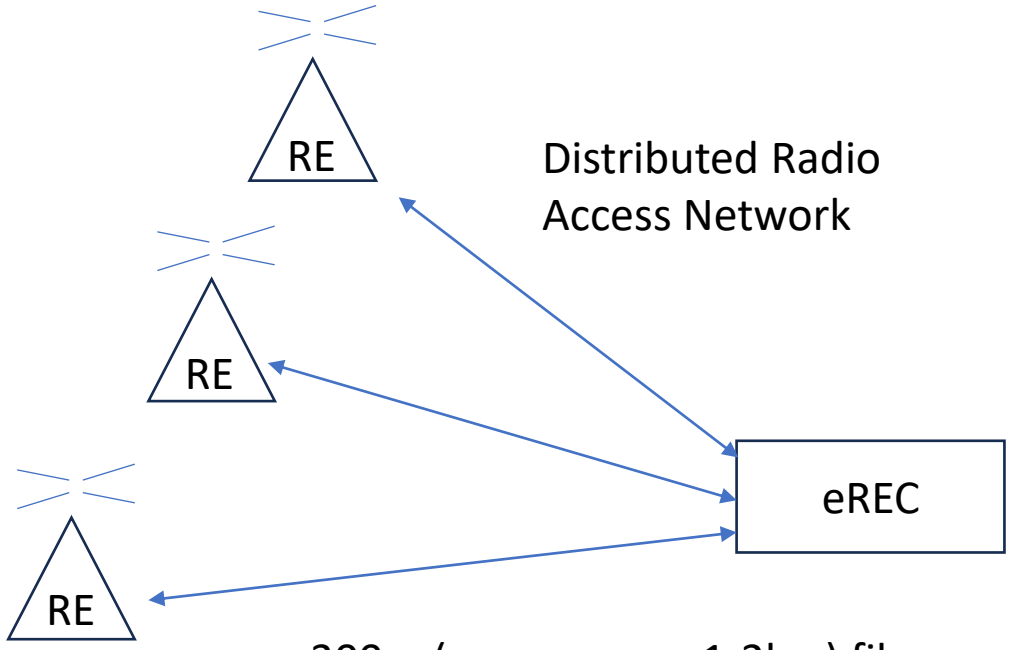
Latency sensitivity of Ethernet traffic in fronthaul

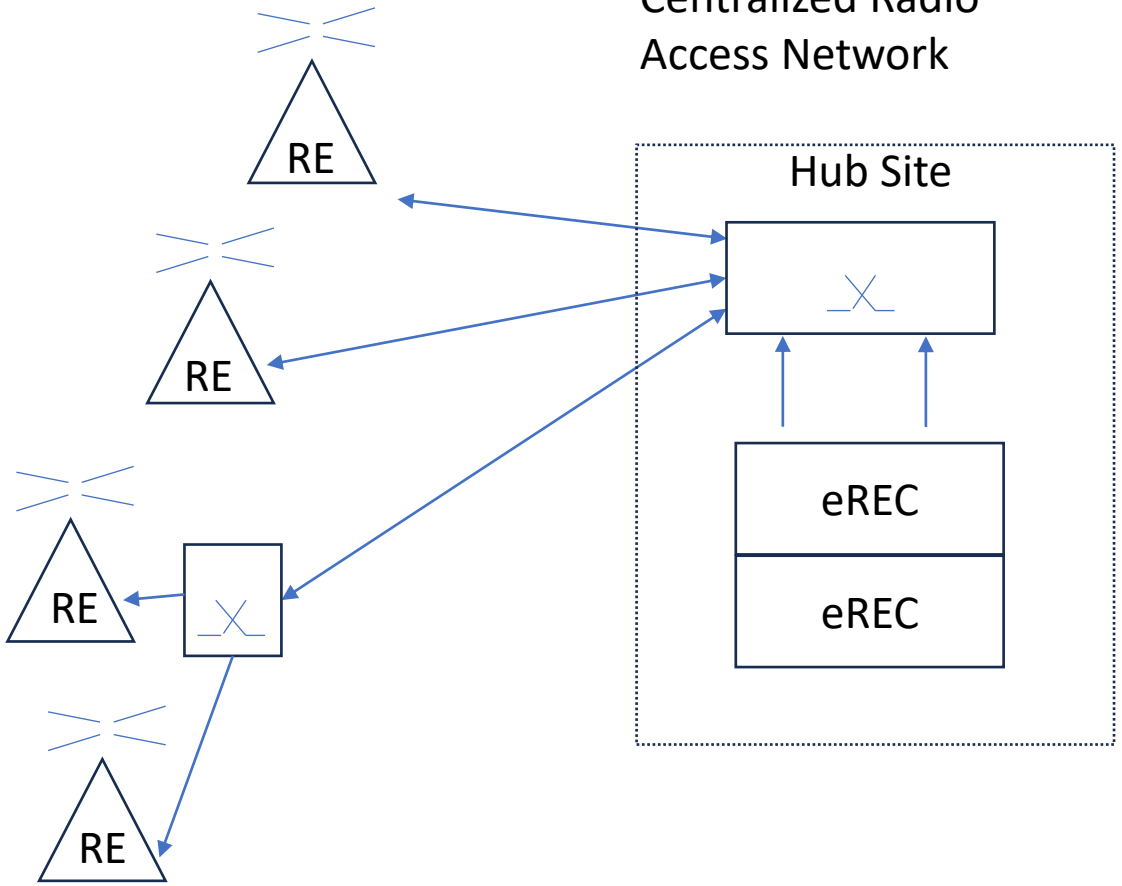
Time constants typically for 3GPP signaling is
Slot level 1 ms, e.g. HARQ-loop



Distributed Radio Access Network

<300m (corner cases 1-2km) fiber

Centralized Radio Access Network



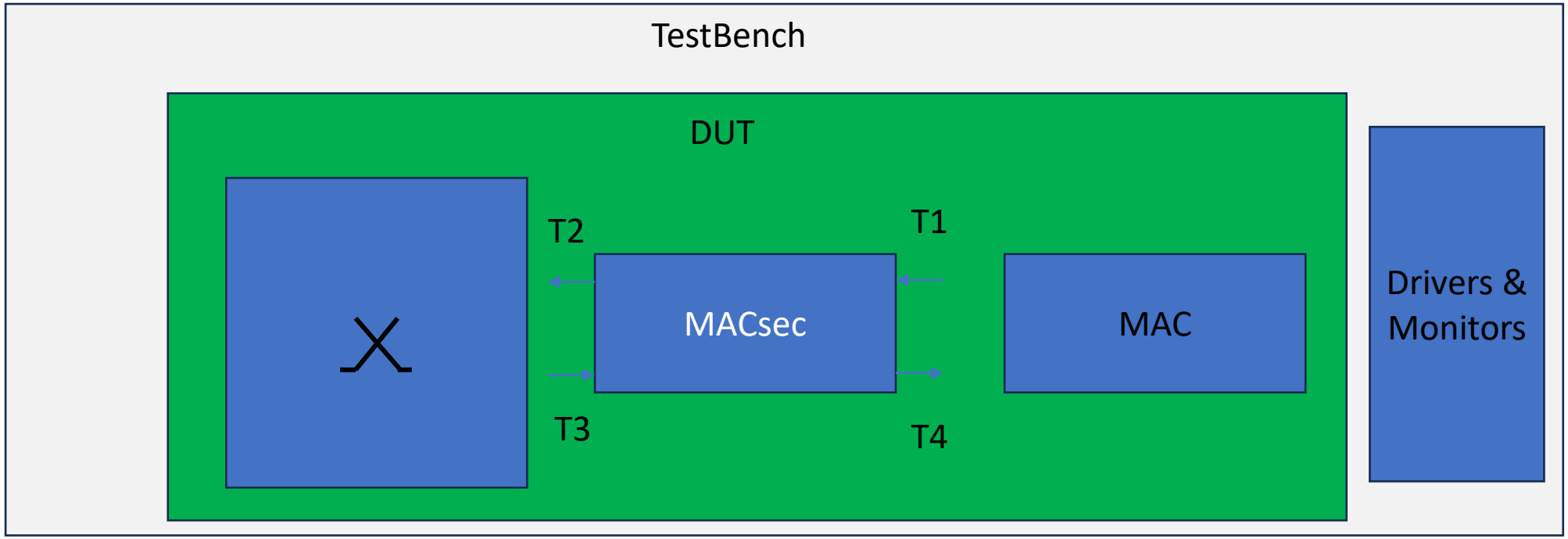
1-15 km fiber (possibly up to 30 km in the future)

* Latency of fiber and intermediate switching infrastructure doesn't impact PTP, only the resulting asymmetries not in scope of contribution

Test setup

- Data collected using RTL (Register-Transfer Level) simulation tool, cycle accurate simulation for ASIC and FPGA, [fs] resolution (result data on page 5 has been rounded to closest 0,5ns)
- Simulation chosen over real-life measurement to allow isolation of MACsec contribution, portability and repeatability of test data collection
- Measurement presented taken from an existing SOC, and is accurate value of an real world delay of a IEEE 802.1AE MACsec implementation
- Test was repeated on multiple SOC and MACsec IP generations with similar or lower result

DUT and TestBench architecture



1500byte Pkt size

Randomized IPG

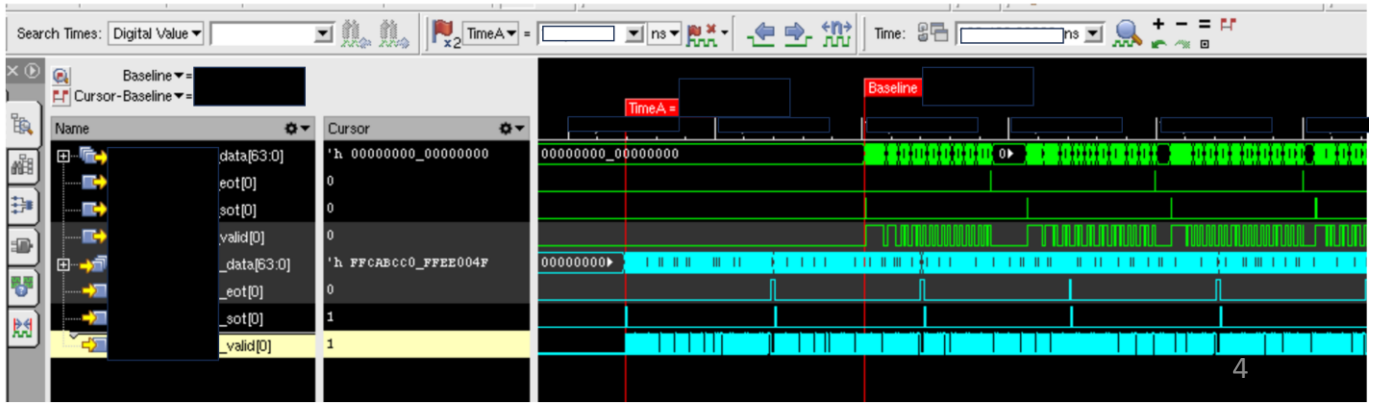
Port Speed 25Gbps

100 frames

Ingress {TimeA = T2 - BaseLine T1}

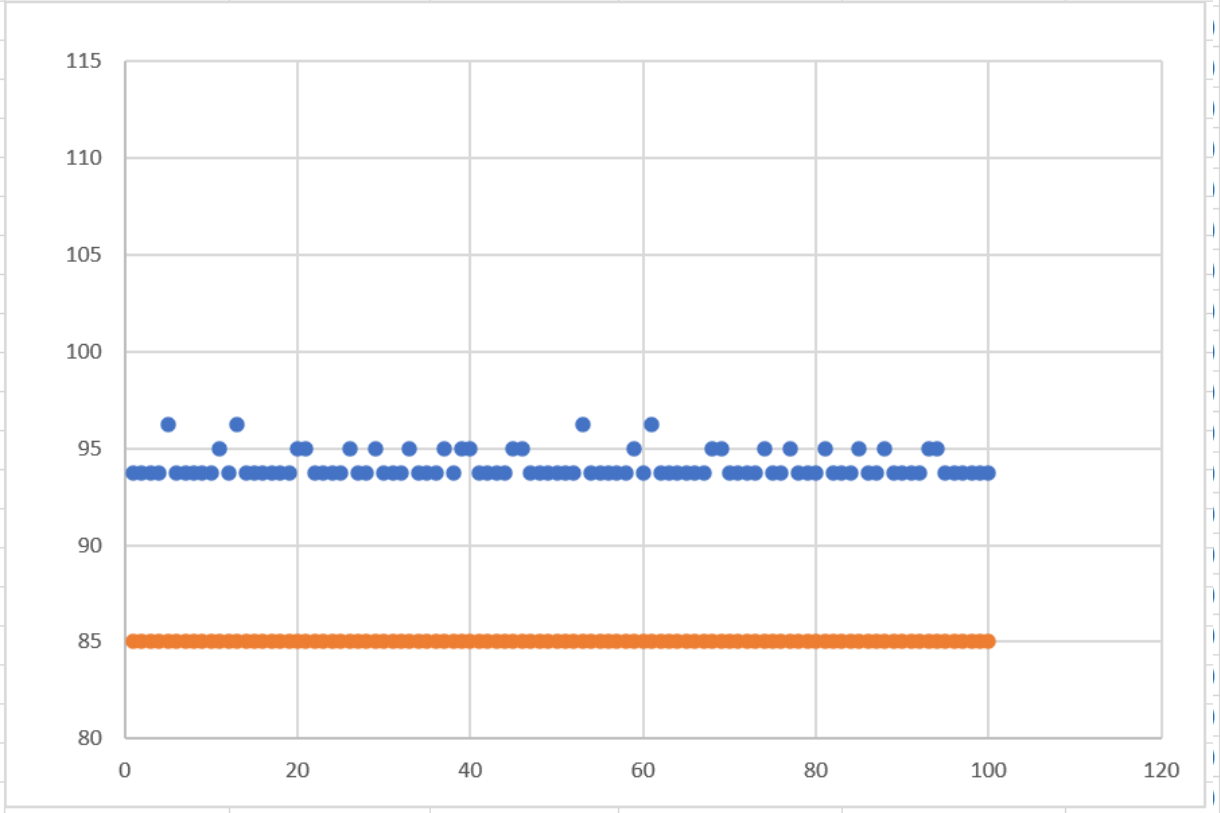
Egress {TimeA = T3 - BaseLine T3}

The applicable Ingress or Egress Tuple of timing data are captured for each Ethernet frame



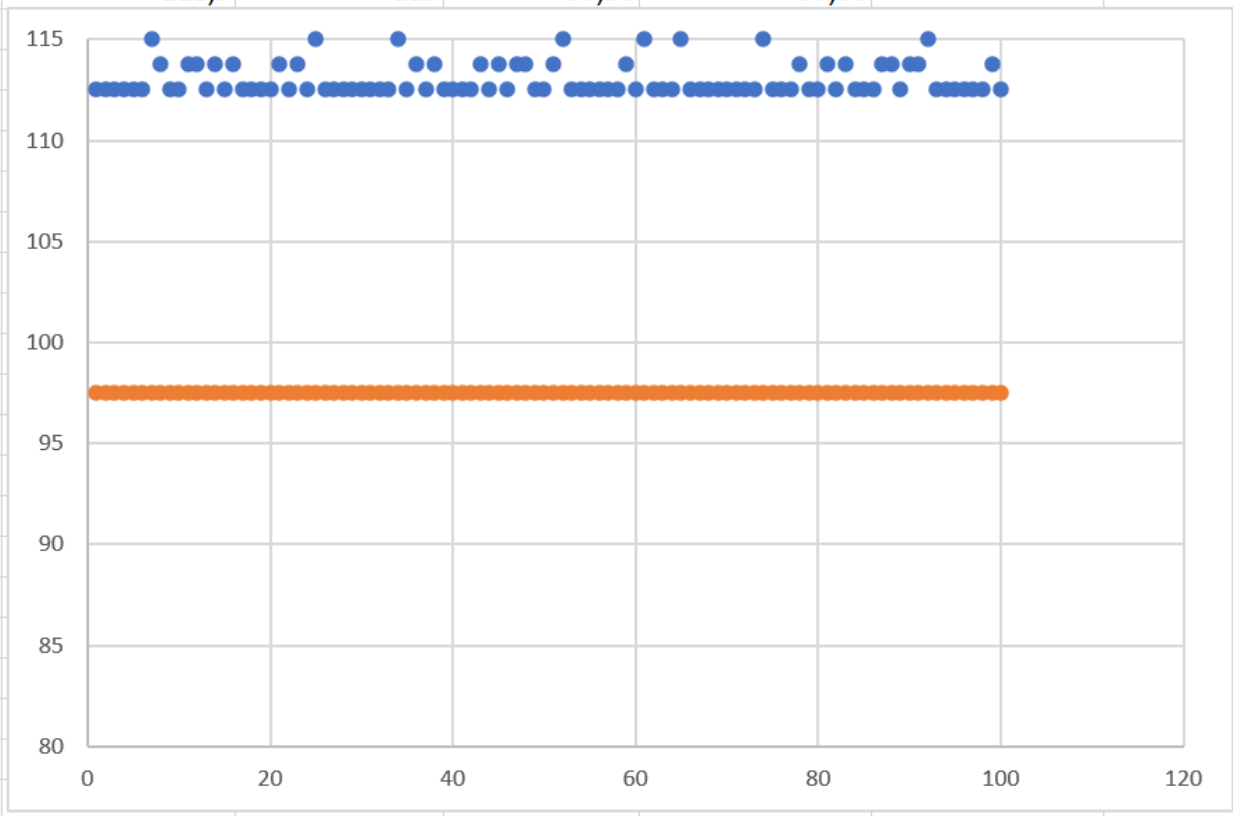
Delay measurement result

Min latency T2-T1 (ns)	Max latency T2-T1 (ns)	Min latency T4-T3 (ns)	Max latency T4-T3 (ns)
93,75	96,25	85,00	85,00



Uncontrolled max Egress(Red) + Ingress(Blue) 181.25ns

Min latency T2-T1 (ns)	Max latency T2-T1 (ns)	Min latency T4-T3 (ns)	Max latency T4-T3 (ns)
112,5	115	97,50	97,50



Controlled max Egress(Red) + Ingress(Blue) 212,5ns

*The delay for no MACsec in above SOC is estimated to be 10ns, due to physical placement of functions in silicon

Conclusion

Delay of fiber is ~5ns / m

Delay of controlled MACsec flow Egress + Ingress 212ns ~42 meter’s of fiber

MACsec delay addition < Fiber distance of Fronthaul

MACsec delay addition <<<< Time constant of 3GPP signaling

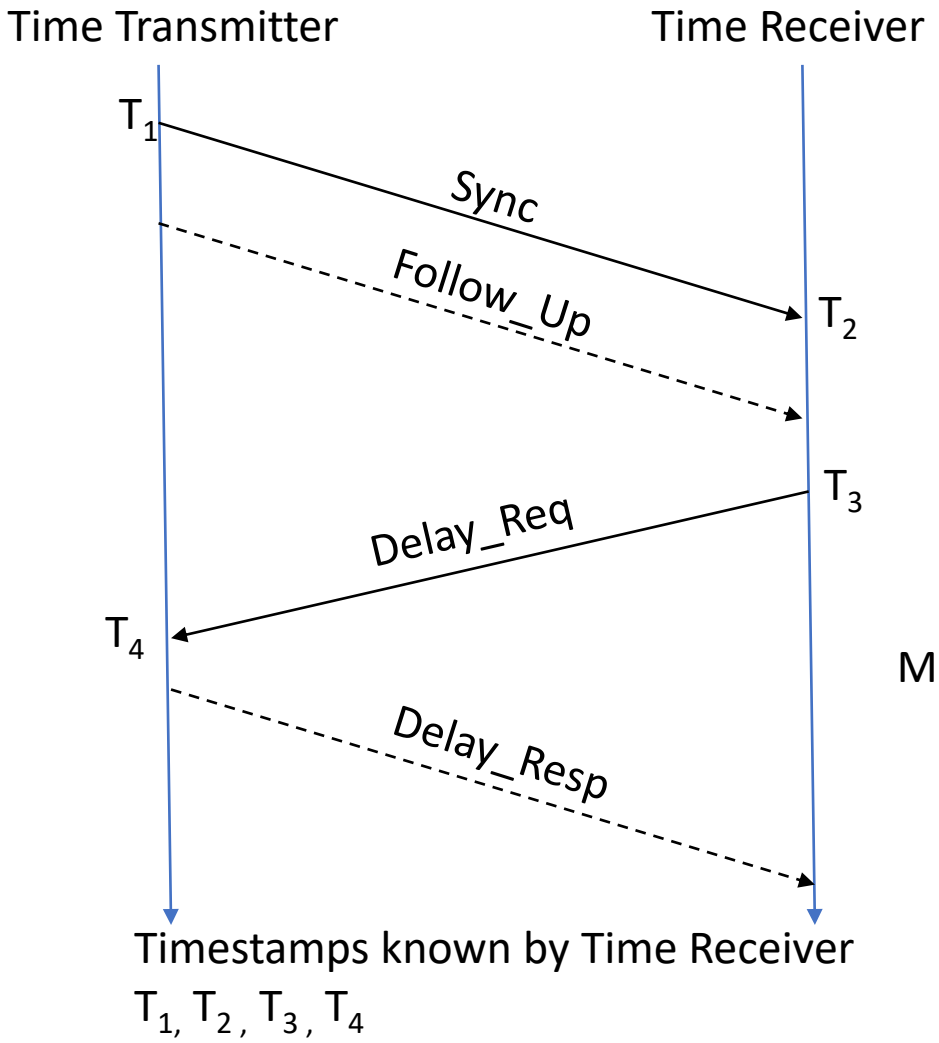
Synchronization Plane

- The synchronization plan implemented with PTP IEEE 1588 is important to distributed phase and time in the fronthaul network

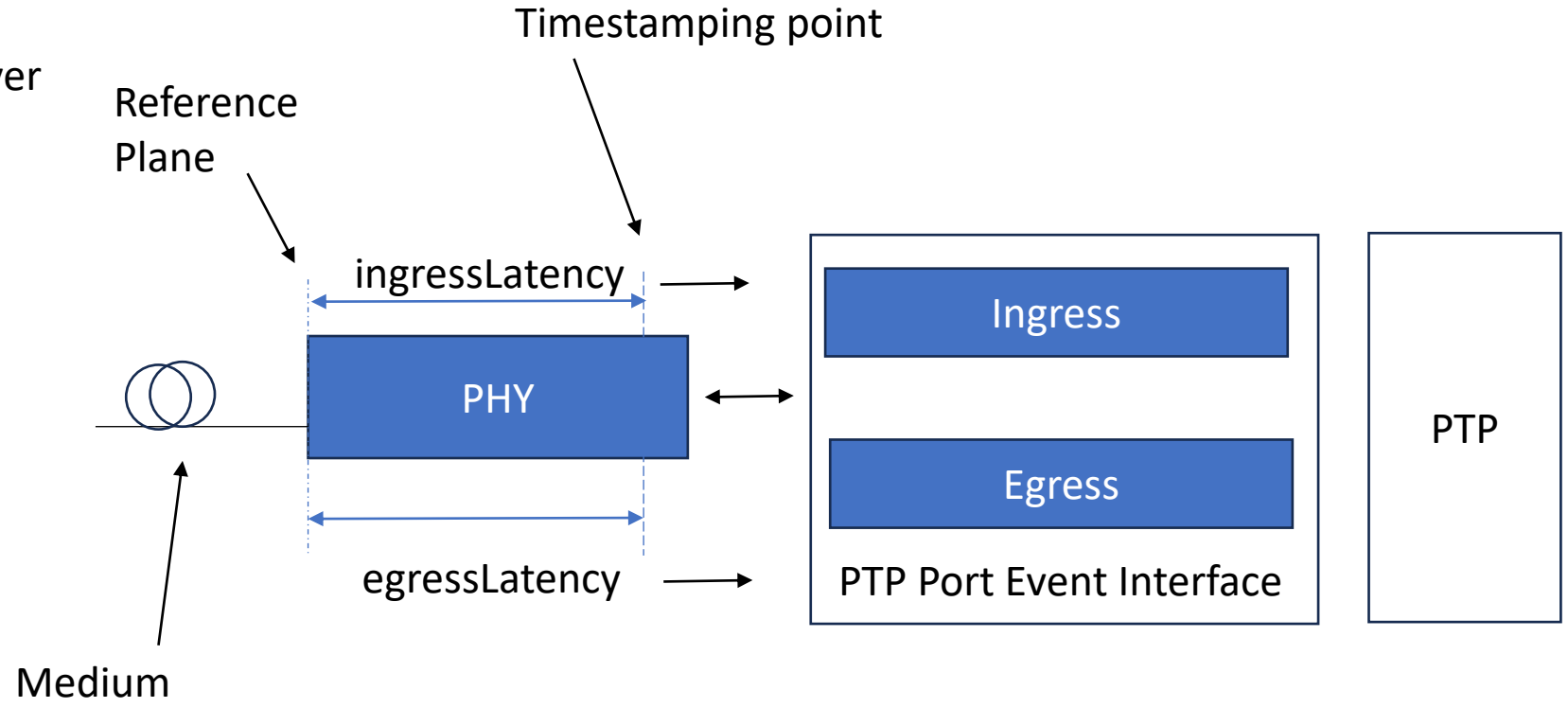
- ITU-T Recommendation G.8273.2, Timing characteristics of telecom boundary clocks and telecom slave clocks.
  - cTE constant time error

- Fronthaul devices target is G.8273.2 Class C +/-10ns cTE for 5G

1588 BASICS



Timestamps known by Time Receiver
T_1, T_2, T_3, T_4



Timestamp shall reflect time when packet traverses the Reference plane

IngressLatency and egressLatency needs to be measured or estimated to maintain a sufficiently low RX and TX asymmetry

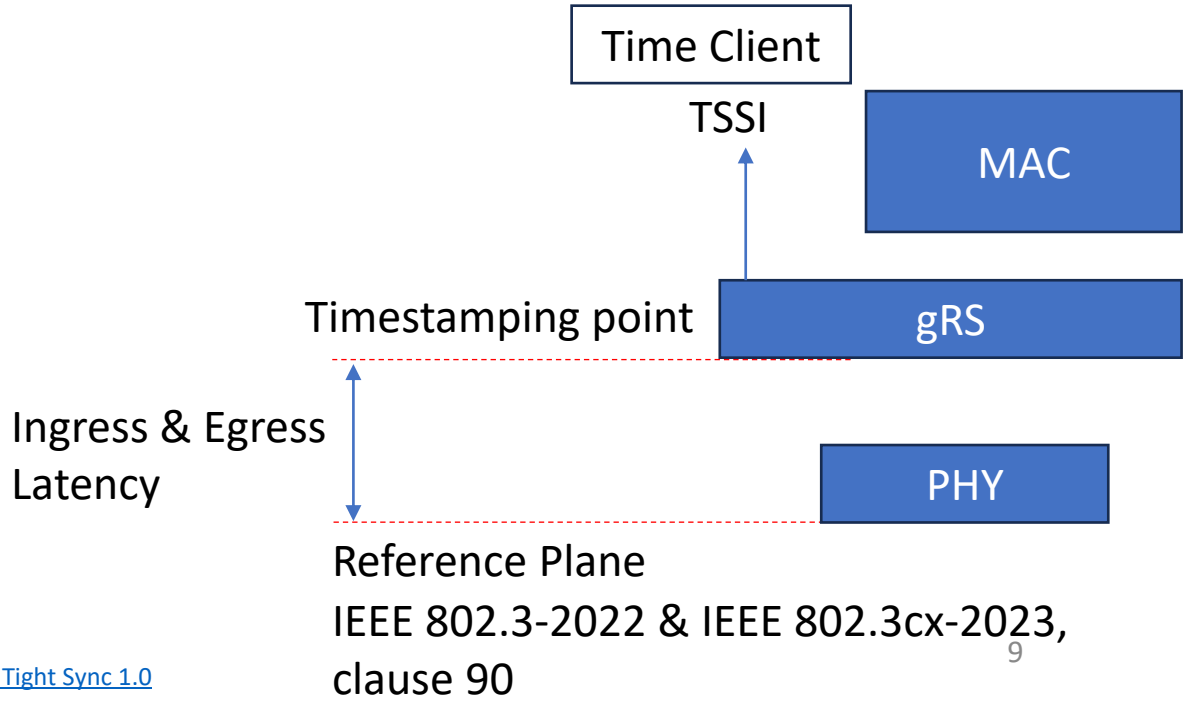
IEEE 802.3 Timestamping

- The optional TSSI interface provides TimeClient with timing information on a per frame

- PHY may be restricted to send Timestamp packets on fixed positions with known TSSI values

Some IEEE 802.3 rates and technologies would fail to meet ITU-T G8273.2 Class C without the TSSI information, see IEEE 802.3CX taskforce CFI

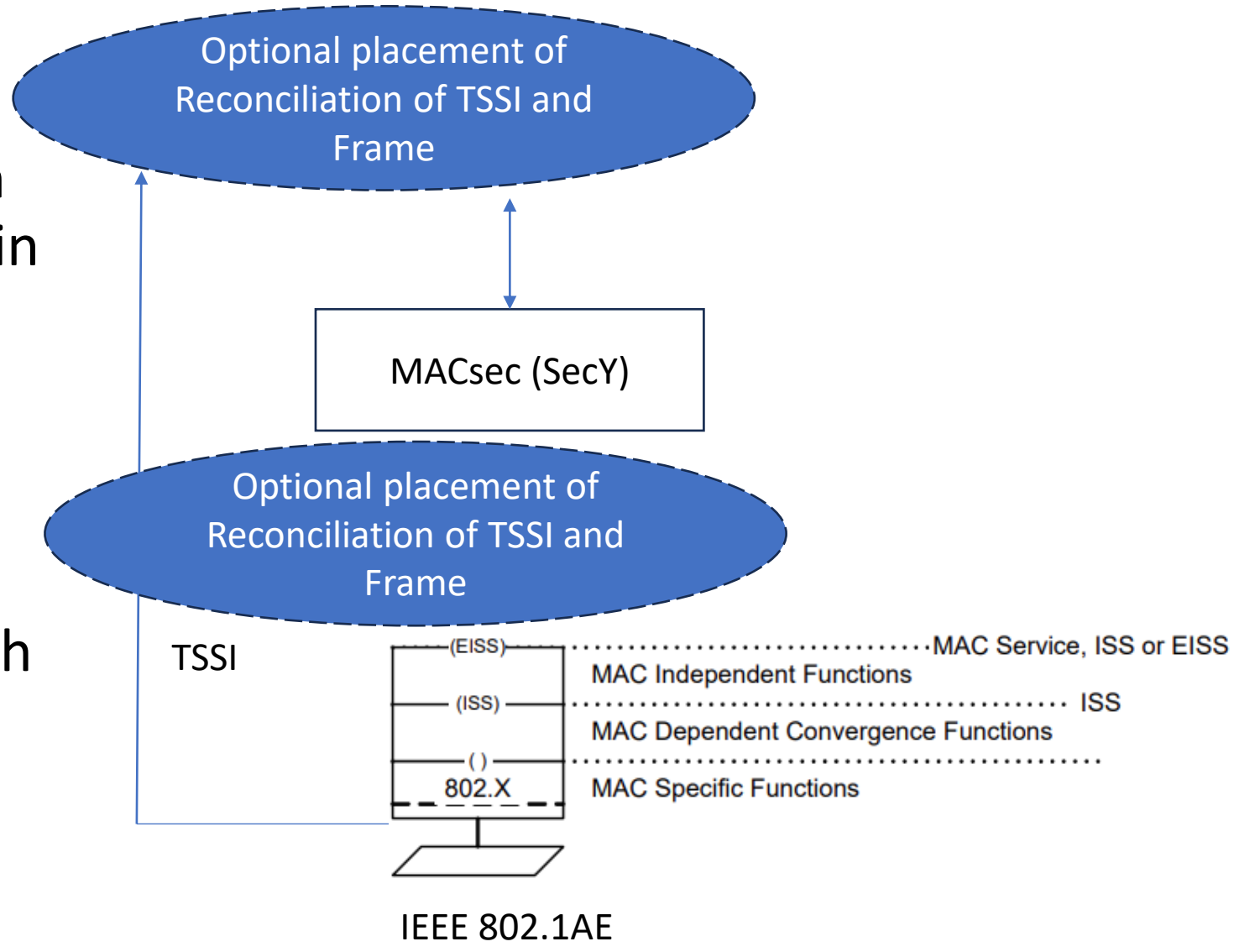
Improving PTP Timestamping Accuracy on Ethernet Interfaces Call For Interest Consensus Presentation (ieee802.org)



*Refer to MOPA tight sync paper for further system level considerations MOPA Tight Sync 1.0

2-step

- TSSI to frame reconciliation and filtering may be done in SW, FW or HW, position is design choice
- Based on recorded TSSI with offline processing for Follow_up and Delay_Responce Frames

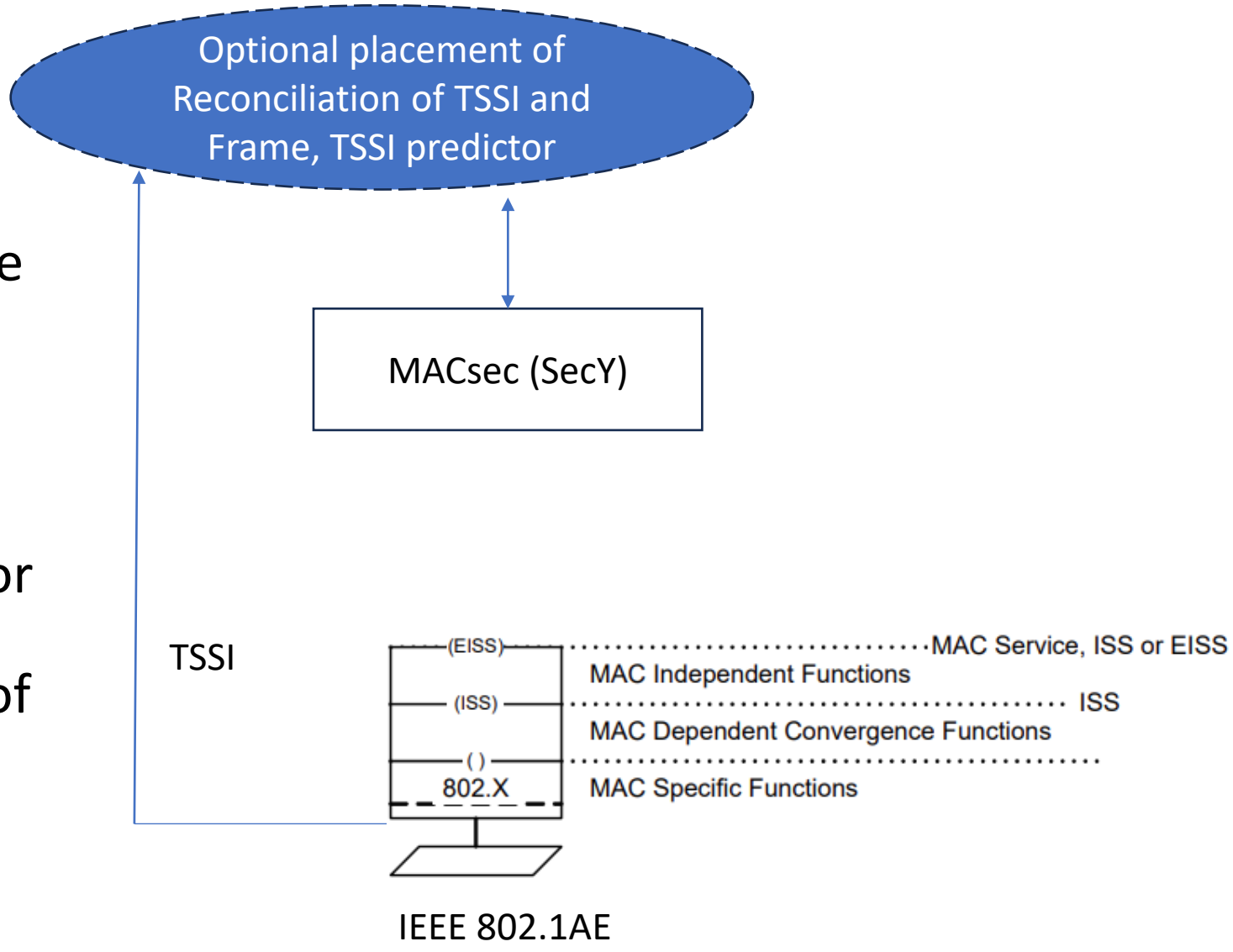


IEEE 802.1AE

1-step

- TSSI to frame reconciliation and filtering may be done in SW, FW or HW, position above SecY

- Ingress: Based on recorded TSSI with offline processing for Sync and Frames
- Egress: Based on estimation of future TSSI for processing of Sync and Delay_Responce Frames



IEEE 802.1AE

Conclusion

IEEE 802.1AE is orthogonal to the needs to support high accuracy PTP with a IEEE 802.3 PHY and MAC

There are multiple implementations to allow propagation and reconciliation of Ethernet frame and TSSI in time sync client

Summary

With correct design and system consideration IEEE 802.3AE MACsec doesn’t impact Ethernet Fronthaul latency

With correct design and system consideration IEEE 802.3 MACsec doesn’t impact PTP accuracy and precision