ITU-T Q13/15, Network synchronization and time distribution performance

Supporting 5G mobile transport and fronthaul

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- Current and new Sync Requirements
- Synchronous Ethernet; Enhanced Synchronous Ethernet
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Q13, Introduction

- SG15 Question 13 addresses Network Synchronization performance specifications, Equipment synchronization specifications, etc. (https://www.itu.int/en/ITU-T/studygroups/2017-2020/15/Pages/q13.aspx)
- Study of synchronization issues in tdm and packet based networks
- Requirements for the related OAM and Management functions
- Requirements from new network architectures and applications (e.g. as related to the IoT, IMT2020 (5G), etc.)
- Robust and reliable network synchronization solutions (e.g. as related to GNSS (Global Navigation Satellite System) backup)
- SDN/NFV implications on the synchronization networks
- Test equipment specification

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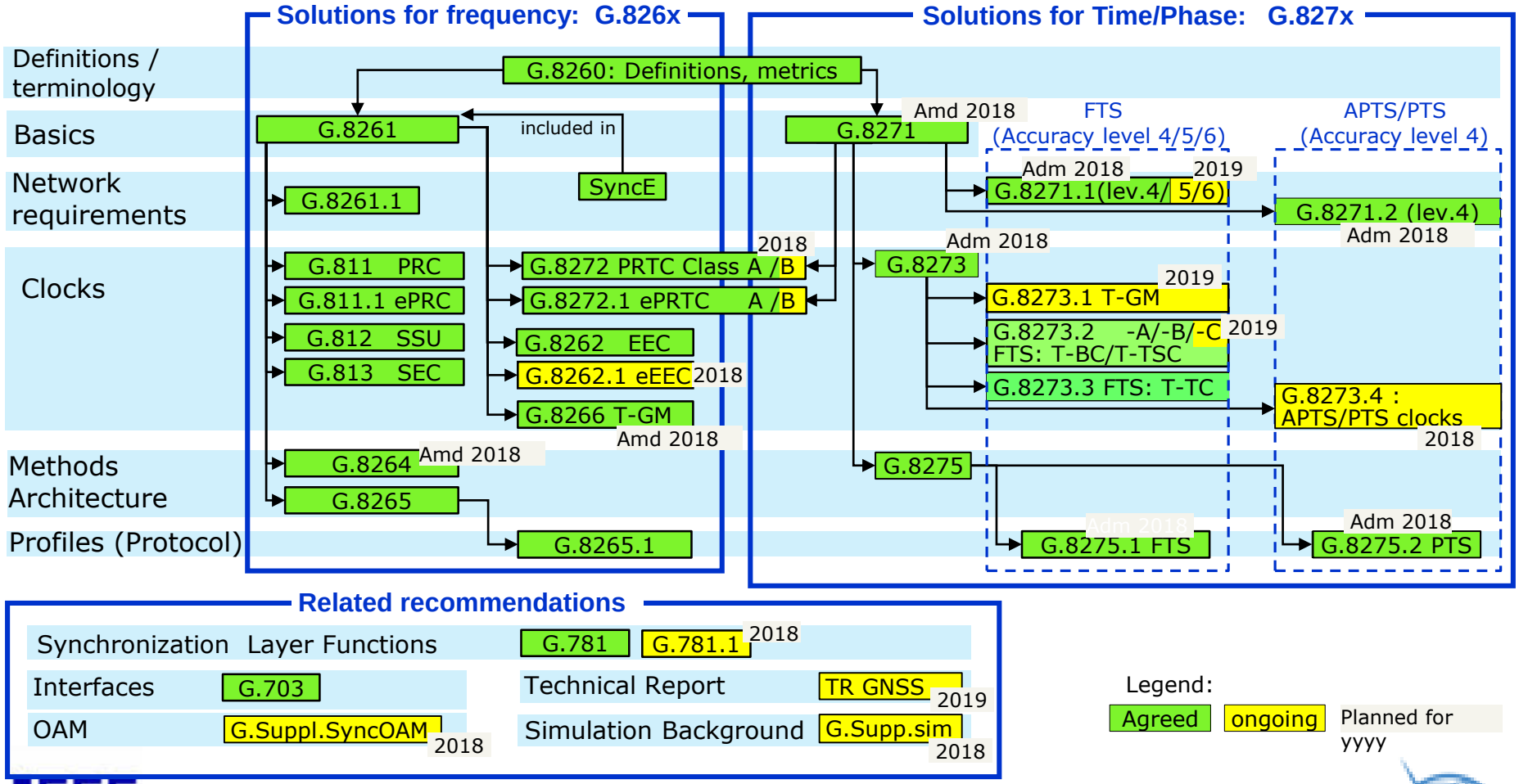
Q13 Recommendations



Related recommendations

Synchronization Layer Functions	G.781 G.781.1 2018		
Interfaces	G.703	Technical Report	TR GNSS 2019
OAM	G.Suppl.SyncOAM 2018	Simulation Background	G.Supp.sim 2018

Legend:

Agreed | ongoing | Planned for yyyy

Requirements

Level of accuracy	Time error requirements (Note 1)	Typical applications (for information)
1	500 ms	Billing, alarms
2	100 µs	IP Delay monitoring Asynchronous Dual Connectivity
3	5 µs	LTE TDD (large cell) Synchronous Dual Connectivity (for up to 7 km propagation difference between eNodeBs)
4	1.5 µs	UTRA-TDD, LTE-TDD (small cell) Wimax-TDD (some configurations) Synchronous Dual Connectivity (for up to 9 km propagation difference between eNodeBs)
5	1 µs	Wimax-TDD (some configurations)
6	x ns (Note 3)	Various applications, including Location based services and some LTE-A features (Note 2)

NOTE 1 – The requirement is expressed in terms of error with respect to a common reference.

NOTE 2 – The performance requireme
purposes only, values between 500 ns
Depending on the final specifications
different level of accuracy.

NOTE 3 – For the value x, refer to Tabl

Level of accuracy	Maximum Relative Time error requirements (Note 1)	Typical applications (for information)
6A	260ns	Intra-band non-contiguous carrier aggregation with or without MIMO or TX diversity, and inter-band carrier aggregation with or without MIMO or TX diversity
6B	130ns	Intra-band contiguous carrier aggregation, with or without MIMO or TX diversity
6C	65ns	MIMO or TX diversity transmissions, at each carrier frequency

NOTE 1 – The maximum relative time error requirements represent the peak-to-peak time difference measured between the elements in the cluster only. See Appendix VII of [ITU-T G.8271.1] for illustration of how requirements are specified in a cluster. In 3GPP terminology this is equivalent to time alignment error (TAE), which is defined as the largest timing difference between any two signals.

- Based on Existing Standards (e.g., 3GPP)

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Moving towards 5G; New Fronthaul Demands

- Sync Requirement analysis in cooperation with 3GPP
- New sync requirements for NR («New Radio»)?
  - TDD currently still satisfied by 3 microseconds (+/- 1.5 microseconds)
  - Ongoing discussion in 3GPP on Carrier Aggregation, CoMP, etc.
- Fronthaul moving towards Ethernet (e.g., legacy requirement of 260 ns, i.e. +/-130 ns)
- Strict requirements to support OTDOA (Observed Time Difference of Arrival)-based positioning (100 ns)

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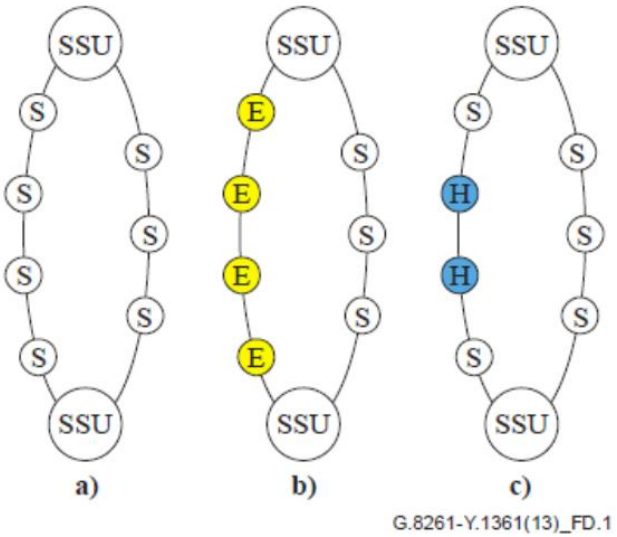
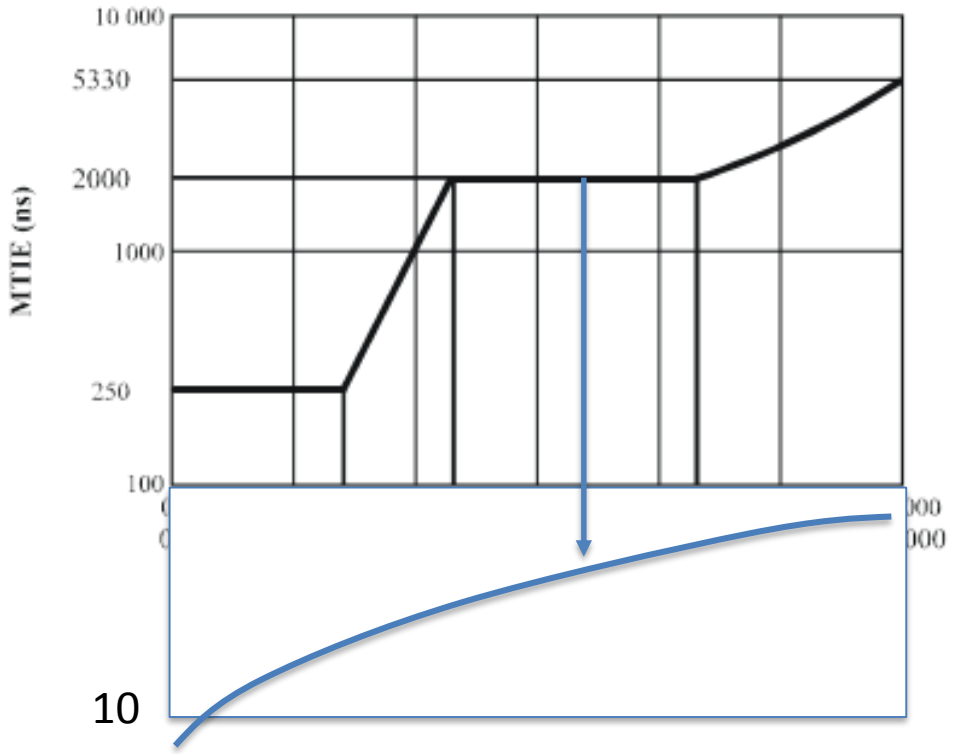
Synchronous Ethernet

- Several applications which require accurate frequency now reached by Ethernet
  - Since the very start of timing over packet network activities, it was proposed to use a synchronous Ethernet physical layer
  - Work done in coordination with IEEE 802.3
  - Compatible with IEEE 802 standards
  - Only in full duplex mode (continuous signal required)
- Based on SDH specification (for interoperability and simplifying the standardization efforts)
  - Ethernet equipment with a synchronous Ethernet Equipment Clock – EEC (G.8262).
  - Synchronous Ethernet interfaces extract the received clock and pass it to the system clock.
  - Synchronization Status Message as per G.8264
  - It does not transport Time (but it has been proposed)
- All nodes must support SyncE: sync chain as per G.803
  - Cannot be transported transparently across network boundaries
- Ongoing work to define an enhanced SyncE (G.8262.1 and revised G.8261)

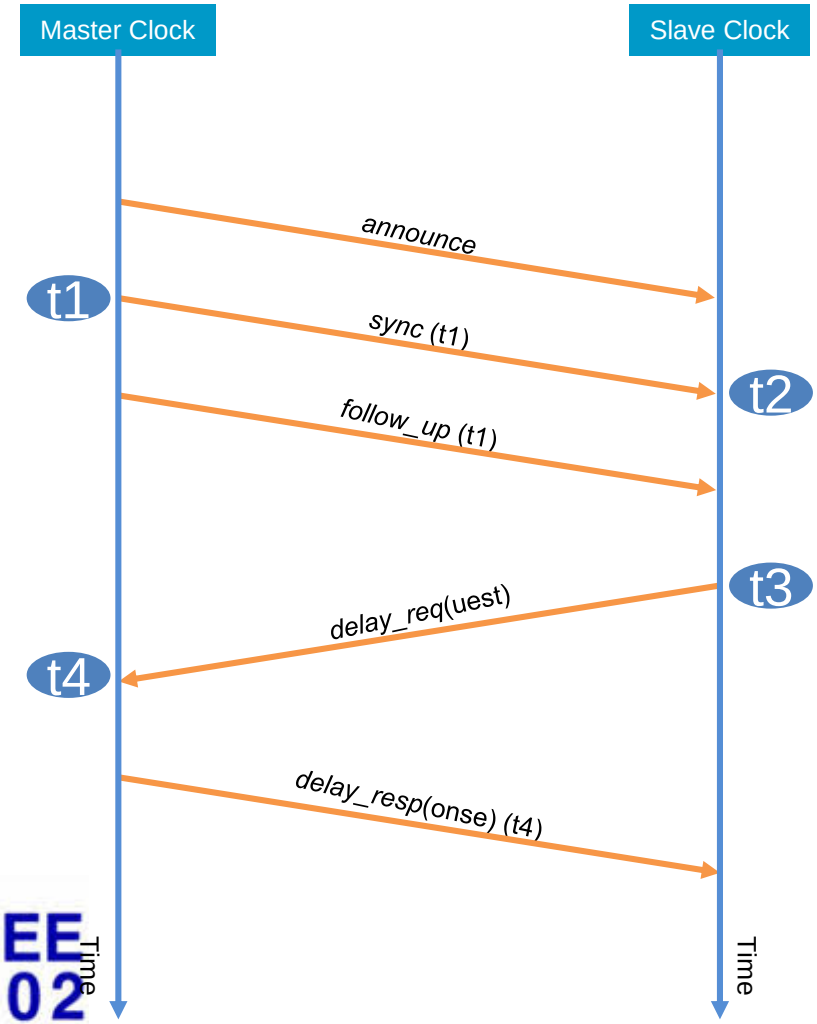


SyncE: Next Steps

- New Interfaces: jitter generation and tolerance for Synchronous Ethernet interfaces based on 50Gb/s and 100Gb/s PAM4 lanes, as defined in IEEE 802.3bs
- «Enhanced SyncE» for more accurate timing



IEEE1588 and Telecom Profile(s)



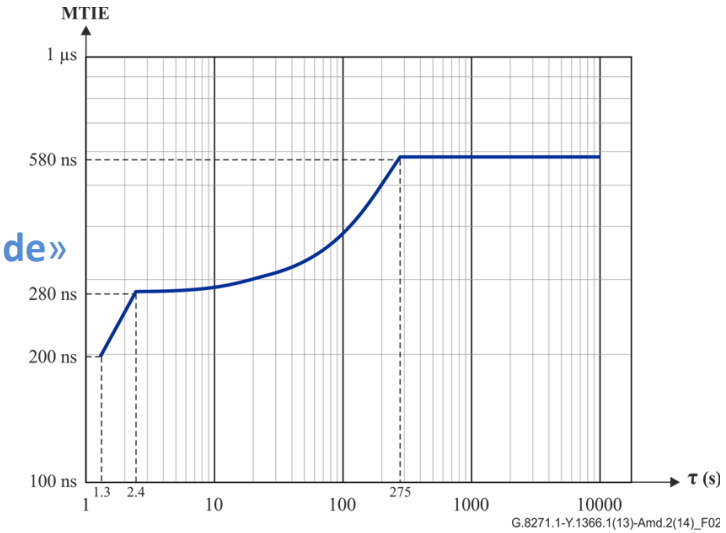
- IEEE1588 (PPT, Precision Time Protocol) is the protocol of choice for accurate time synchronization
- Need to develop specific «profile» for Telecom Application,
  - *A profile is a subset of required options, prohibited options, and the ranges and defaults of configurable attributes*
- Time sync: G.8275.1 and G.8275.2
- Companion Recommendations on performance(clock, network performance, etc.): G.8271.1, G.8273.2/3/4, ..

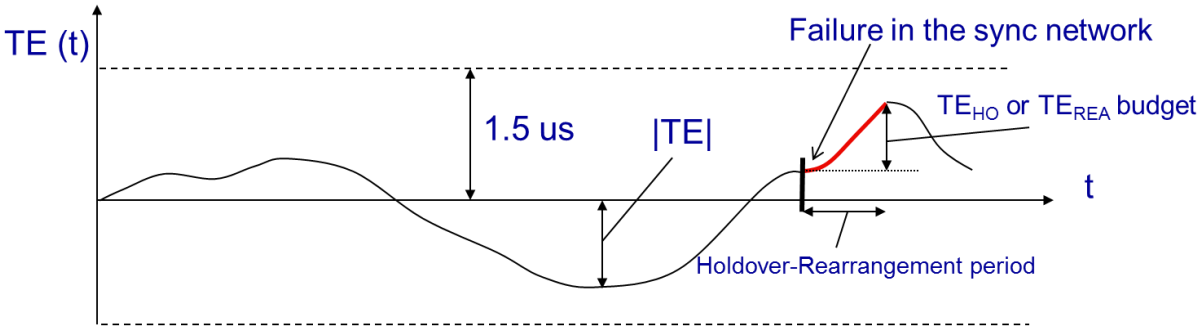
G.8275.1: Telecom profile for full timing support

- Assumes Boundary Clocks or Transparent Clocks in every node
- 16 packets per seconds
- Delay request/delay response mechanism
- VLAN Tagged frames only between Transparent clocks
- Both the non-forwardable multicast address 01-80-C2-00-00-0E and forwardable multicast address 01-1B-19-00-00-00 can be used.
  - The default Ethernet multicast address to be used depends on the operator policy

Time Sync:
Initial focus on +/-1.5 microsecond

- ITU-T Recc. G.8271 , identifies main application areas. E.g., TDD (+/- 1.5 microseconds)
- G.8271.1 provides the related network performance requirements
- **Max abs(TE)** for combined dynamic and constant time error
- **MTIE** («low-frequency») and «**peak-to-peak TE amplitude**» («high frequency») for dynamic time error

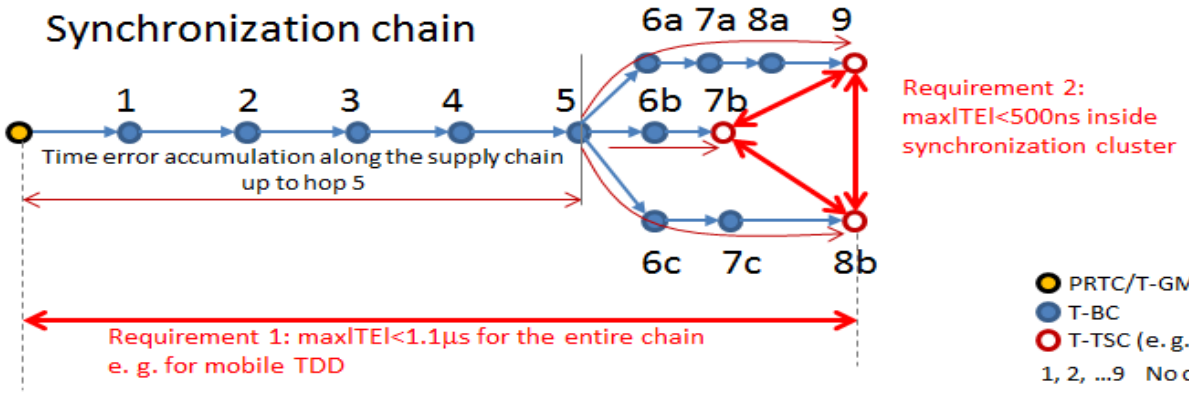




TE_{HO} applicable to the network (End Application continues to be locked to the external reference)
TE_{REA} applicable to the End Application (End Application handles short rearrangement periods)

Time Sync: Next Steps

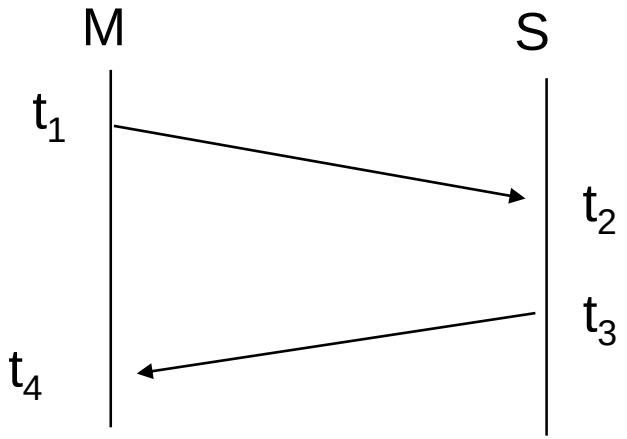
- From PRTC (100 ns) to ePRTC (30 ns) and PRTC-B (40 ns)
- From SyncE to eSyncE
- New T-BC/ T-TSC Type C (10 ns?)
- Looking at 5G (with 3GPP) and Fronthaul needs (with IEEE802.1CM)
- End-to-end requirements in terms of «absolute» phase sync (i.e., error vs. a PRTC) and/or «relative» phase sync



Time Sync via PTP: Asymmetry related impairments

- Basic principle: distribute Time sync reference by means of two-way time stamps exchange
- Time Offset= $t_2 - t_1$ – Mean path delay

  Mean path delay = $((t_2 - t_1) + (t_4 - t_3)) /2$



- As for NTP, also in case of PTP, symmetric paths are required:
  - Basic assumption: $t_2 - t_1 = t_4 - t_3$
  - Any asymmetry will contribute with half of that to the error in the time offset calculation (e.g. 3 µs asymmetry would exceed the target requirement of 1.5 µs)

Accurate timestamping and Asymmetries

- Liaison exchanged with IEEE 802.3 on the need for accurate timestamping (impact on timing performance due to Ethernet PHY)
- E.g., FEC may have to be implemented and it could be a source of impairments during the PTP timestamping process (e.g., codeword insertion)
  - Forward delay (df) and reverse Delay (dr) must be symmetric (within x ns tolerance)

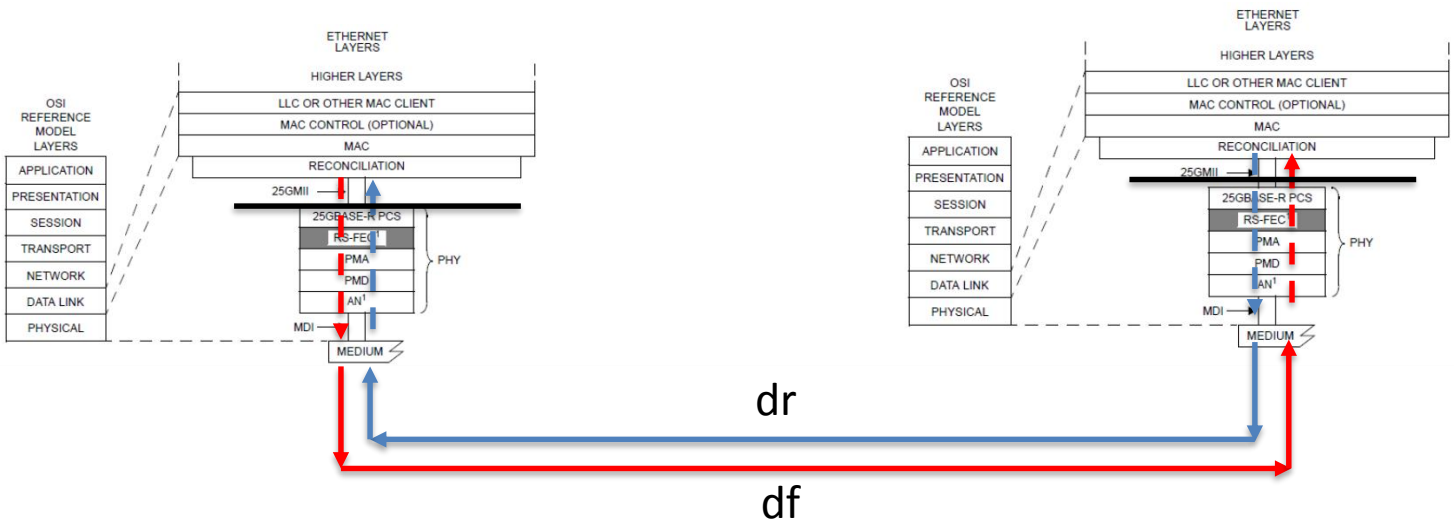


Figure 108-1 from IEEE Std 802.3by™-2016, Amendment to IEEE Std 802.3™-2015,

Summary

- Time sync is a key topic in the area of 5G mobile transport and fronthaul
- Requirements being defined; working in cooperation with 3GPP
- Cooperation with IEEE 802.1 concerning Fronthaul solutions (IEEE 802.1CM)
- Among Key aspects and challenges to address
  - Control of asymmetries in the network
  - Accurate timestamping
  - New more accurate clock types