IEEE 802.1/802.15 Joint Meeting: Time Reference Points in IEEE 802.1 & IEEE 802.15.4

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Overview

Purpose

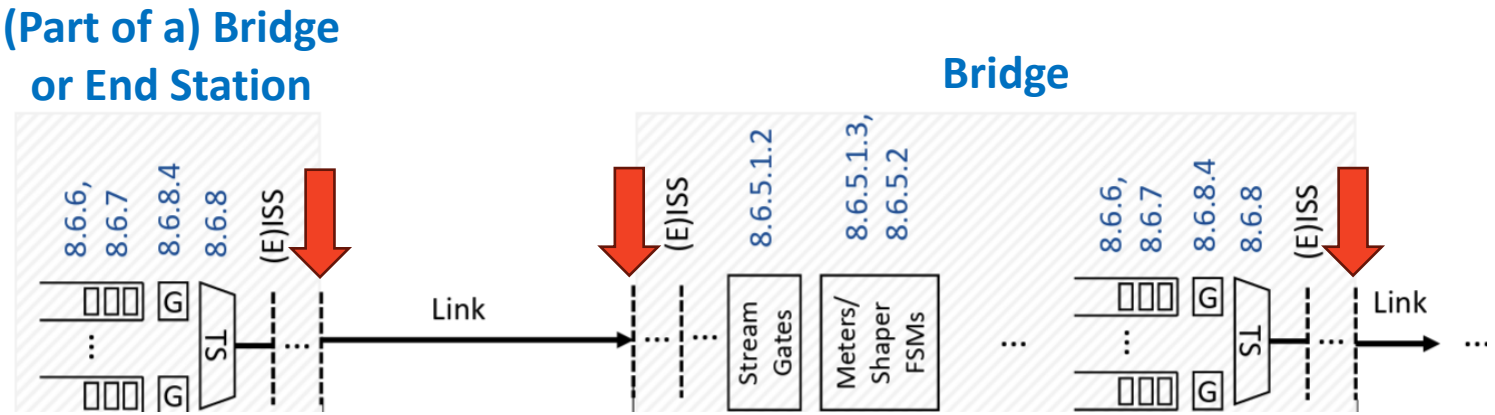
This slide set is intended to encourage discussion between IEEE 802.1 and IEEE 802 MAC/PHY groups on *time measurement reference points* used in IEEE 802.1 protocols and protocol mechanisms (see also https://1.ieee802.org/tsn/) and discussed in IEEE 802.1 Maintenance Item #314.

Contents

- A view on IEEE 802.1 (Specht)
  - What: The reference points
  - Why: Use in IEEE 802.1 Standards
  - Where: Standards Relationships
- A view on IEEE 802.15.4 (Beecher)

What: The reference points

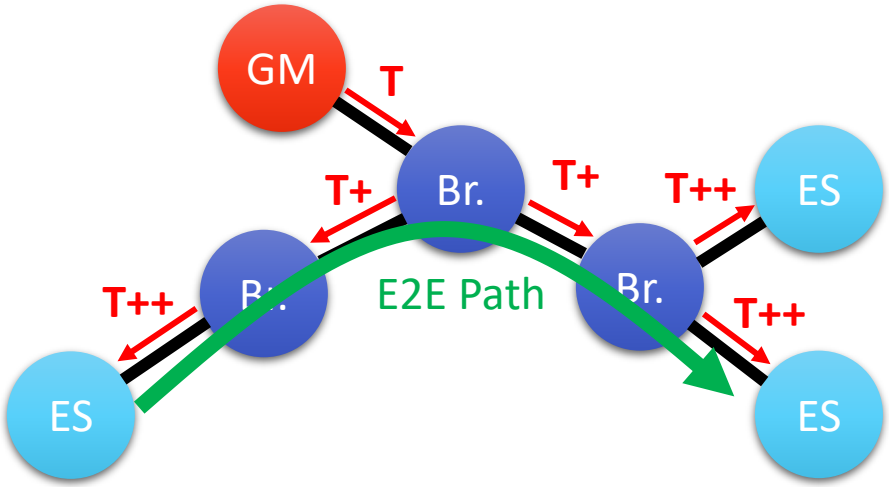
What: The reference points



- **Desire (cmp. IEEE 802.1 Maintenance Item #314)**
  - Definitions of the reference points for the IEEE 802 MAC/PHY stacks, needed for other operations specified in IEEE Stds 802.1AS and 802.1Q.
  - **Current situation:** Defined in IEEE Stds 802.1AS and 802.1Q, but with some issues and not applicable for all IEEE 802 MAC/PHY standards.
  - **Direction:** Pointers into IEEE 802 MAC/PHY Standards from IEEE Std 802.1AC, allowing a single pointer into IEEE Std 802.1AC from other IEEE 802.1 Stds
- **Reference points details**
  - Low delay variation from egress to ingress reference points enhances precision
  - The exact reference point positioning in IEEE 802 MAC/PHY stacks may be flexible to a certain extent (i.e., not necessarily limited to “the boundary between PHY entity and physical medium”), as long as it is defined and delay variation is “sufficiently” low.

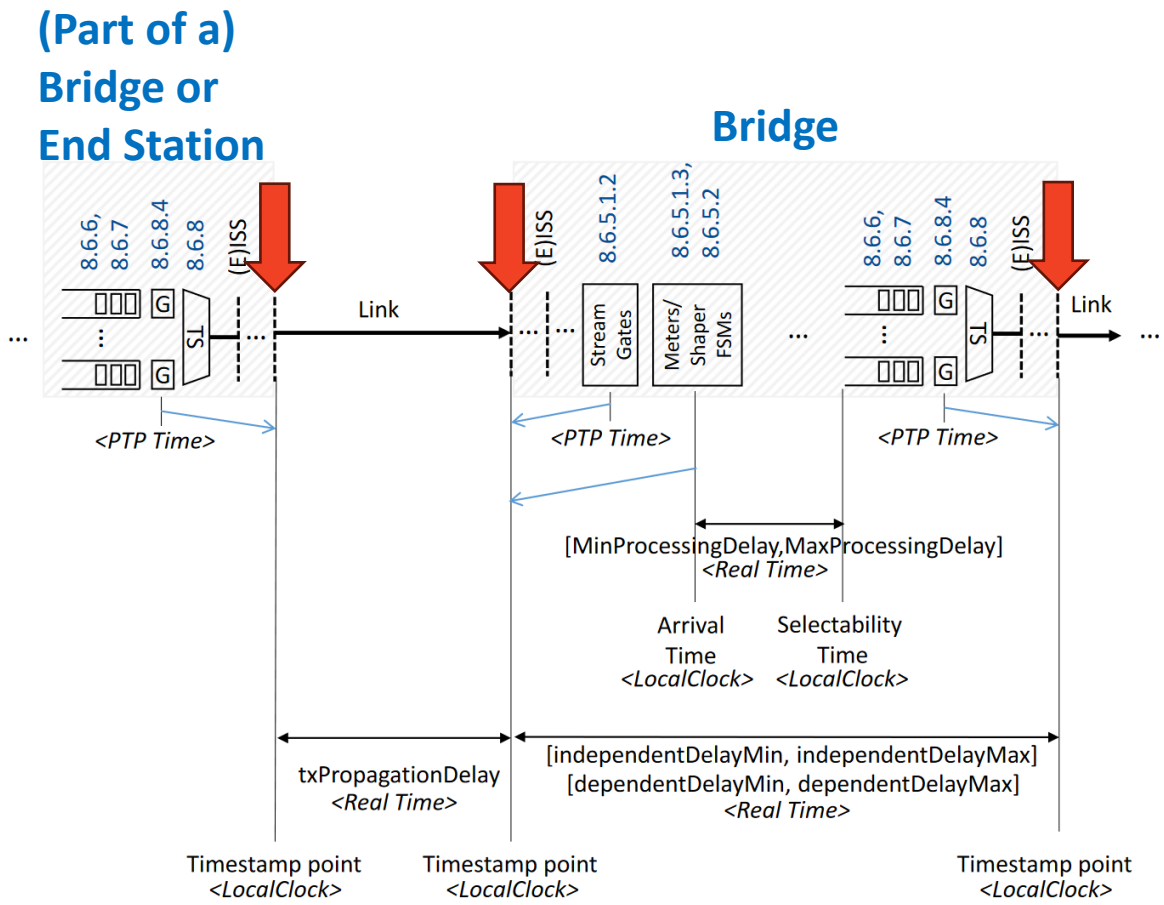
Why: Use in IEEE 802.1 Standards

Reference points in 802.1Q: Delay Calculation



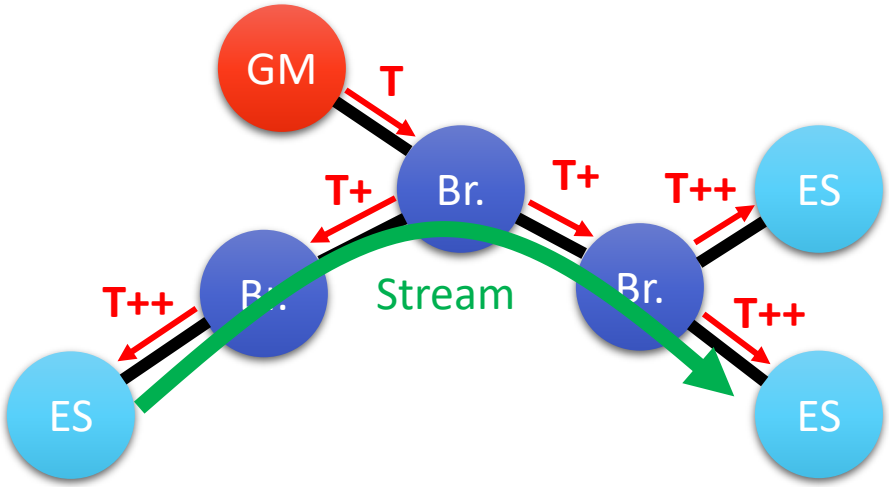
- Environment
  - Typically Static/non-Plug&Play
  - SDN/YANG
- End-2-End Delay =

  … + Bridge delay + Link delay +
  + Bridge delay + Link delay + …
- Link delay is between two subsequent reference points

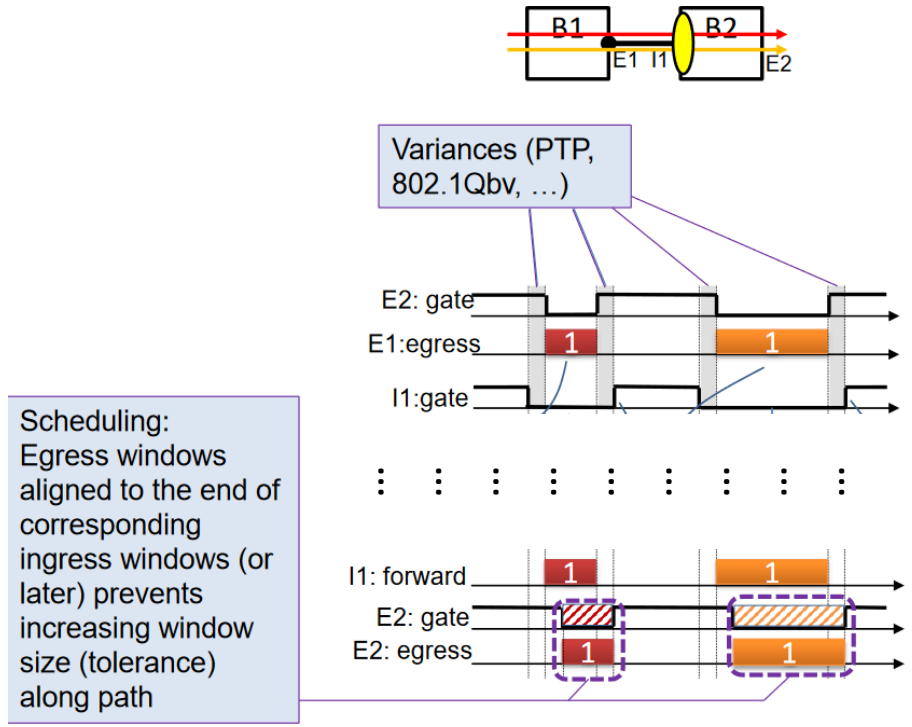


Source: https://www.ieee802.org/1/files/public/docs2017/cr-specht-bridge-timing-0917-v01.pdf

Reference points in 802.1Q: Gate Configuration

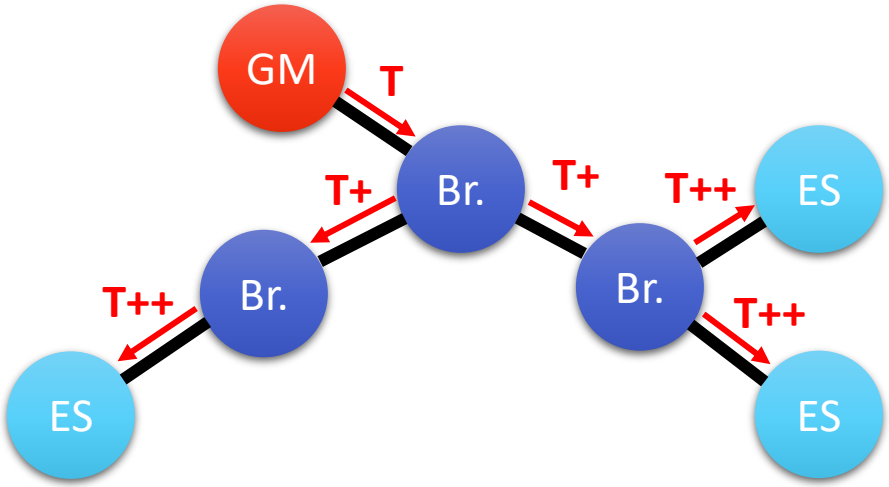


- Ingress and egress gates, configured by periodic open (pass) and close (block) events
- Can synthesize TDMA schemes
- Gates located “somewhere” in the stacks, but …
- … the open/close timing is configured relative to the reference points



Source: https://www.ieee802.org/1/files/public/docs2014/new-tsn-specht-samii-tas-protection-1114-v02.pdf

Reference points in 802.1AS: Time Sync., Link Delays



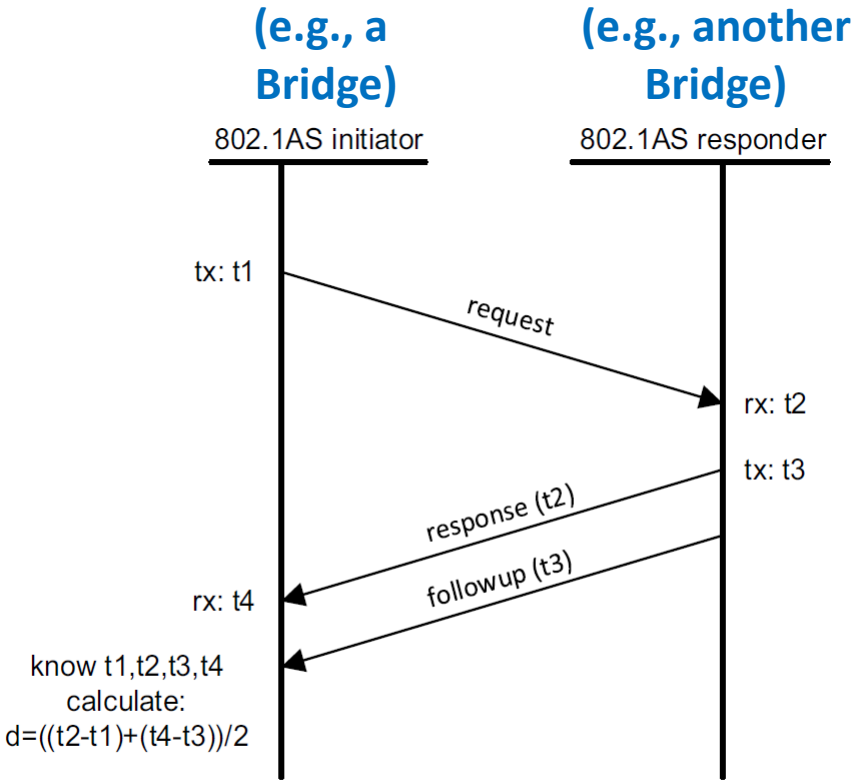


Figure 7-7—Conceptual medium delay measurement

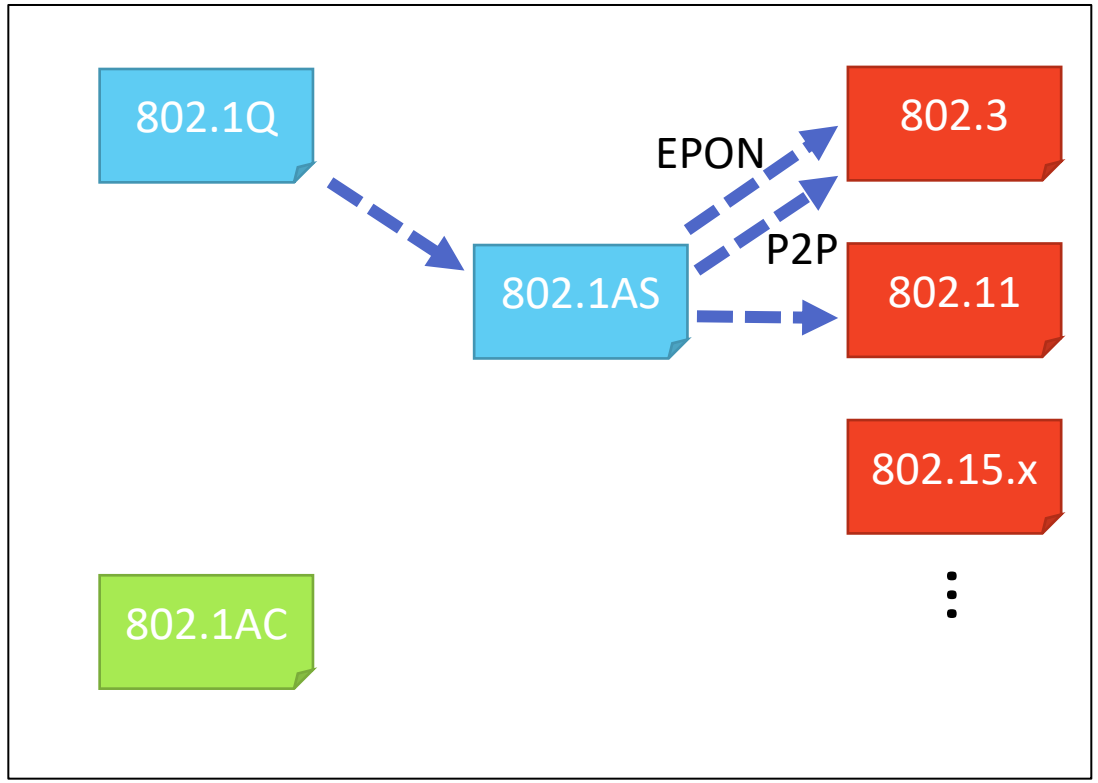
Source: IEEE Std 802.1AS-2020

- Actual time continuously transferred from Grandmasters to clients
- Compensates delays - Device-/Buffer- and Links-Delays
- Lower delay variation (non-compensable):
  → higher precision/less time deviation between clients

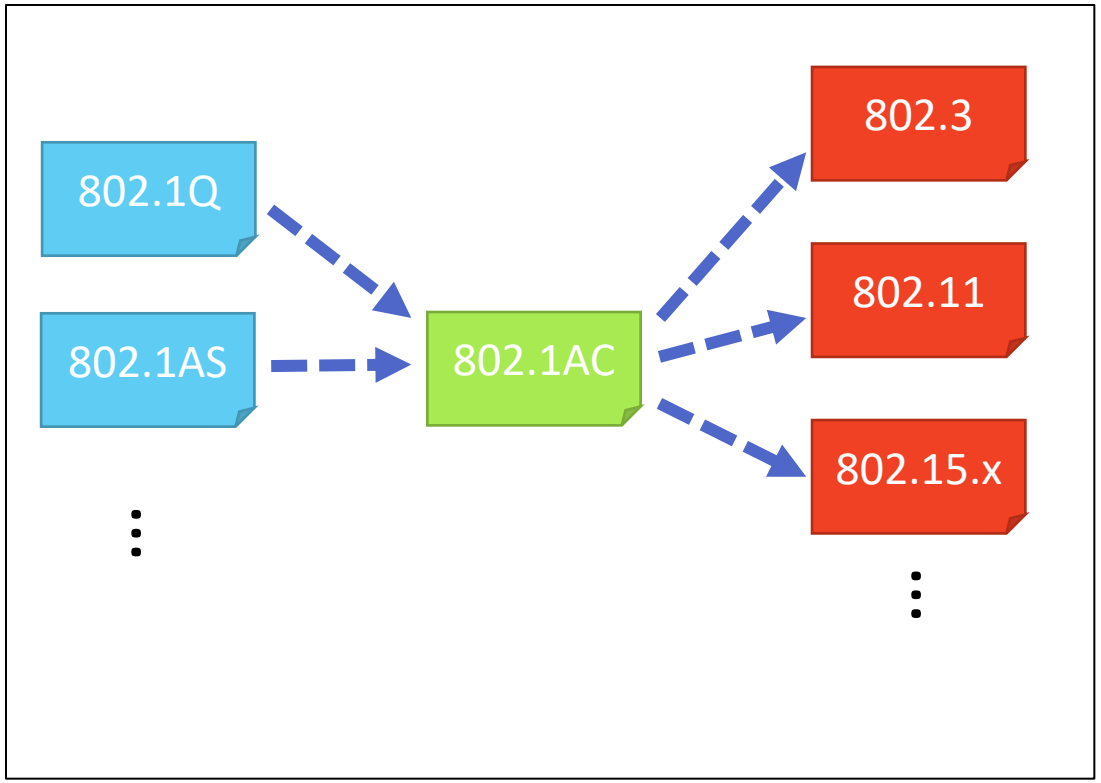
Where: Standards Relationships

Pointers to Reference Points

Current Situation



Future direction (Maintenance Item #314)



A view on IEEE 802.15.4

802.15.4 Frame Timing

- **Two distinct timing schemes**
  - **ERDEV -** enhanced ranging capable device
  - **non-ERDEV -** ranging not supported

This presentation describes Data Frames for non-ERDEV implementation only

- **Summary of IEEE Std 802.15.4-2024 Paragraph 6.5.3 Timestamps**
- Several primitives include a Timestamp parameter to indicate when a frame was transmitted / when a frame was received.
- The timestamp value is that of the local clock of the device at the time of the symbol boundary.
- Note, the timestamp is intended to be a relative time measurement that may or may not be made absolute, at the discretion of the implementer.
- For non-ERDEV, the timestamps will be expressed in symbol periods.
- The symbol boundary is described by *macSyncSymbolOffset*, as described in Table 8-35.
- This is a minimum of 24-bit value, and the precision of this value shall be a minimum of 20 bits, with the lowest 4 bits being the least significant.

For ERDEV, timestamps are expressed as the time in ranging scheduling time units (RSTU), as defined in 10.29.1.5, corresponding to the start of the received packet (preamble) for the frame.

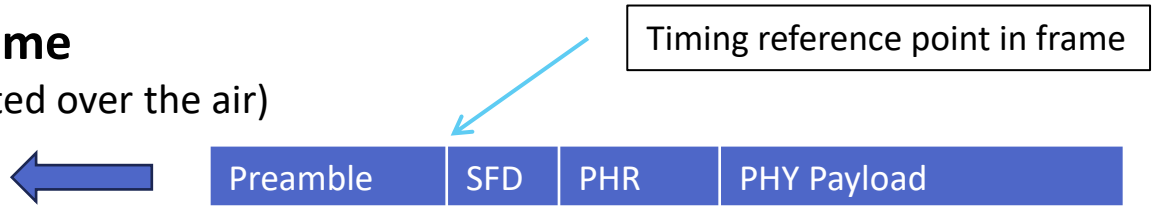
Extract from IEEE Std 802.15.4-2024

802.15.4 Frame Timing

MAC PIB attributes *from* Table 8-36

Attribute	Type	Range	Description	Default
macSyncSymbolOffset	Integer†	0x000–0x100 - for the 2.4 GHz band, 0x000–0x400 for the 868 MHz and 915 MHz bands, and the SUN FSK and SUN OFDM PHYs	The offset, measured in symbols, between the symbol boundary at which the MLME captures the timestamp of each transmitted or received frame, and the onset of the first symbol past the SFD.	
macTimestampSupported	Boolean†	TRUE, FALSE	Indication of whether the MAC sublayer supports the optional timestamping feature for incoming and outgoing Data frames.	

PHY Frame
(transmitted over the air)



Extract from IEEE Std 802.15.4-2024

802.15.4 Frame Timing: non-ERDEV

Sync between PHY layer, MAC layer and NHL.

Data transmission - Transmitting Device

MCPS-DATA.confirm (MsduHandle, **Timestamp**,…) – confirmation to NHL that data was transmitted

Timestamp - Integer 0x000000–0xffffff - The time when the data were transmitted. The format of timestamp is specified in 6.5.3. The value of this parameter will be considered valid only if the value of the Status parameter is SUCCESS.

Data transmission – Receiving Device

MCPS-DATA.indication (…Msdu,…**Timestamp**, …)

The MCPS-DATA.indication primitive indicates the reception of data from another device or, when ranging information is available, upon reception of a packet from another device.

Timestamp - Integer 0x000000–0xffffff -The time at which the data were received. The format of timestamp is specified in 6.5.3.

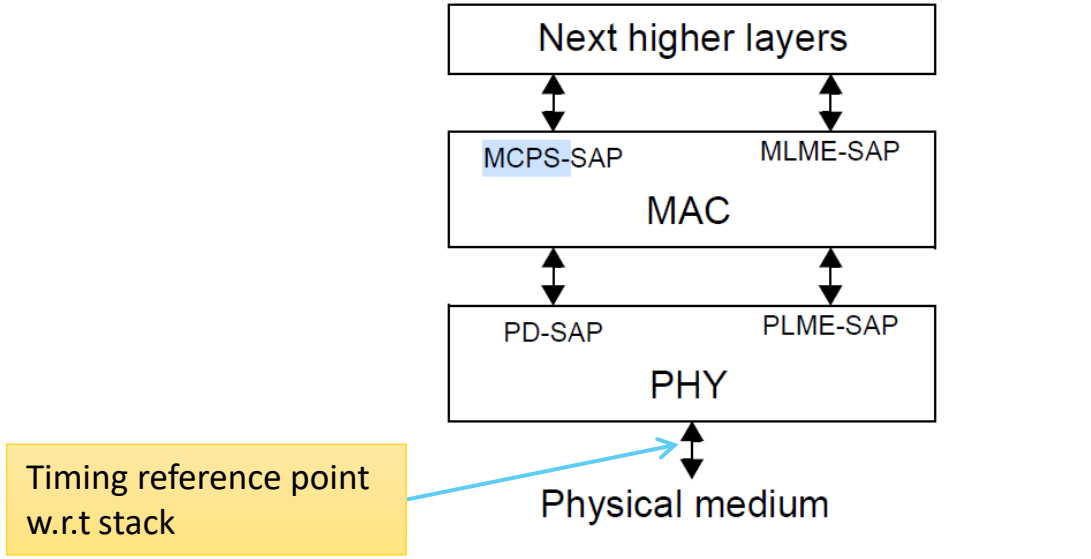


Figure 5-2—LR-WPAN device architecture

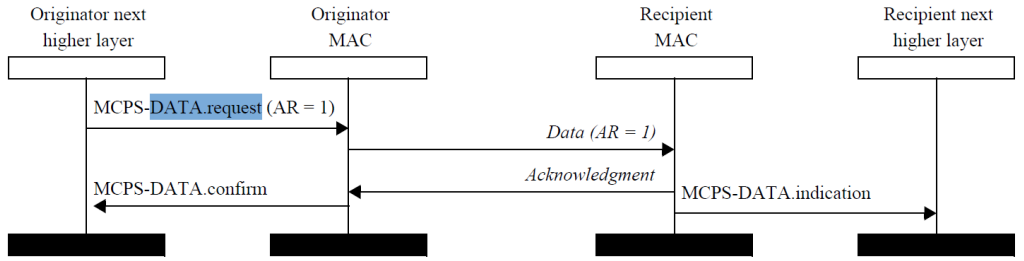


Figure 6-6—Successful data transmission with an acknowledgment

Extract from IEEE Std 802.15.4-2024

Summary

1. 802.15.4 non-Enhanced Ranging Devices - data exchange
   - Implementations can provide sufficient information for NHL to calculate time relationship between any 2 nodes to a resolution of 1 symbol (16 us for OQPSK) , (20 us for SUN-FSK at 50 kbps), (120 us for SUN OFDM)
   - Similar mechanism with MLME commands (beacon scanning and notification) to same resolution.

2. 802.15.4 Enhanced Ranging Devices
   - Additional mechanisms for high accuracy timing between 2 nodes - outsides scope of this presentation

Thank You for Your Attention!

Questions,
Comments,
Ideas?