# 802.1AS Clause 13 Overview

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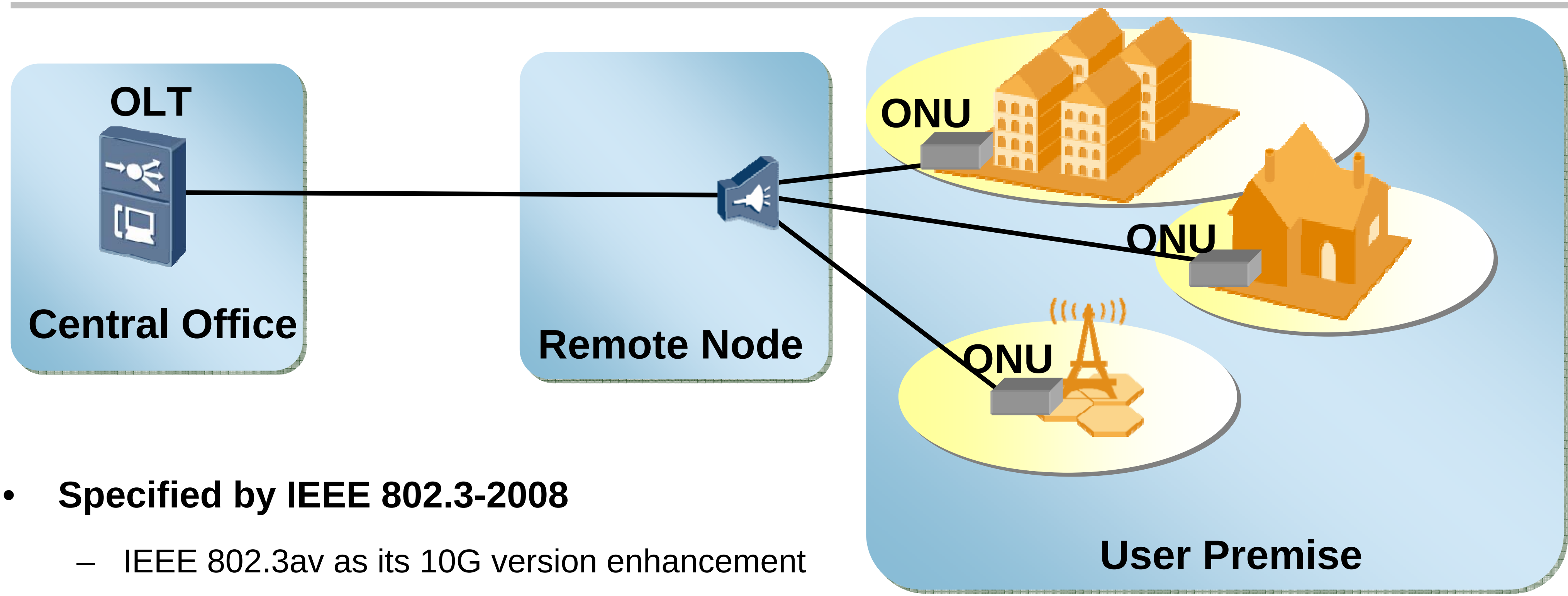
# Agenda

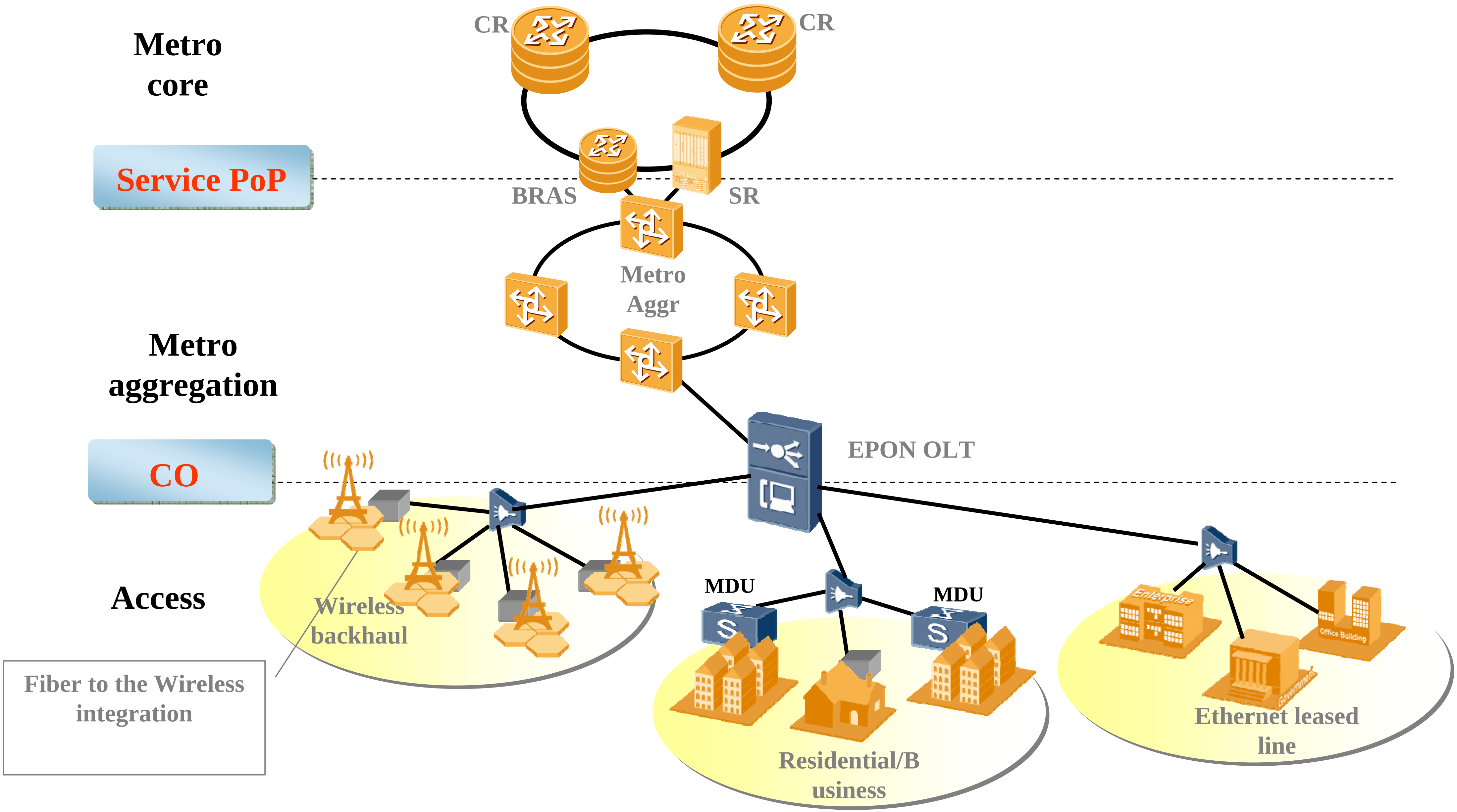
- **What is EPON**
- **Why time sync over EPON**
- **What challenges**
- **How to sync time over EPON**
- **What performance**
- **Clause 13 structure and status**

# EPON




- **Specified by IEEE 802.3-2008**
  - IEEE 802.3av as its 10G version enhancement
- **FTTx broadband access**
  - 1G symmetric, 10G symmetric, 10G/1G asymmetric
- **Management and control**
  - TDM (downstream), TDMA (upstream)
  - MPCP
  - Slow Protocol (Eth OAM, OSSP)

# EPON for full service access



# EPON as wireless backhaul

- Efficient and cost-effective in carrying cellular data to remote BS
- Challenge: providing time synchronization over EPON
  - **ToD accuracy in microseconds is the mainstream time sync requirement of wireless technologies**
  - **EPON Std does not specify time sync issue**

**Table 1: ToD requirements of wireless technologies** [1]

| Wireless technologies | Time-of-day requirement |
|---|---|
| CDMA2000 | 3us |
| TD-SCDMA | 3us |
| WiMAX TDD | 1us |
| FDD LTE | 4us |

[1] ITU-T G.987.1 Recommendation, *10-Gigabit-capable passive optical networks (XG-PON): General requirements*, ITU-T, 2009.

# EPON time sync: Why not IEEE 1588?

- IEEE 1588 performs perfectly in some systems. However, in the case of EPON, delays in downstream and upstream are asymmetric
  - Frame queuing (on the order of 100 microseconds)
  - DBA cycle (on the order of milliseconds)
  - PHY link asymmetry (different wavelengths)
  - Transparent delivery of 1588 cannot distribute precise time

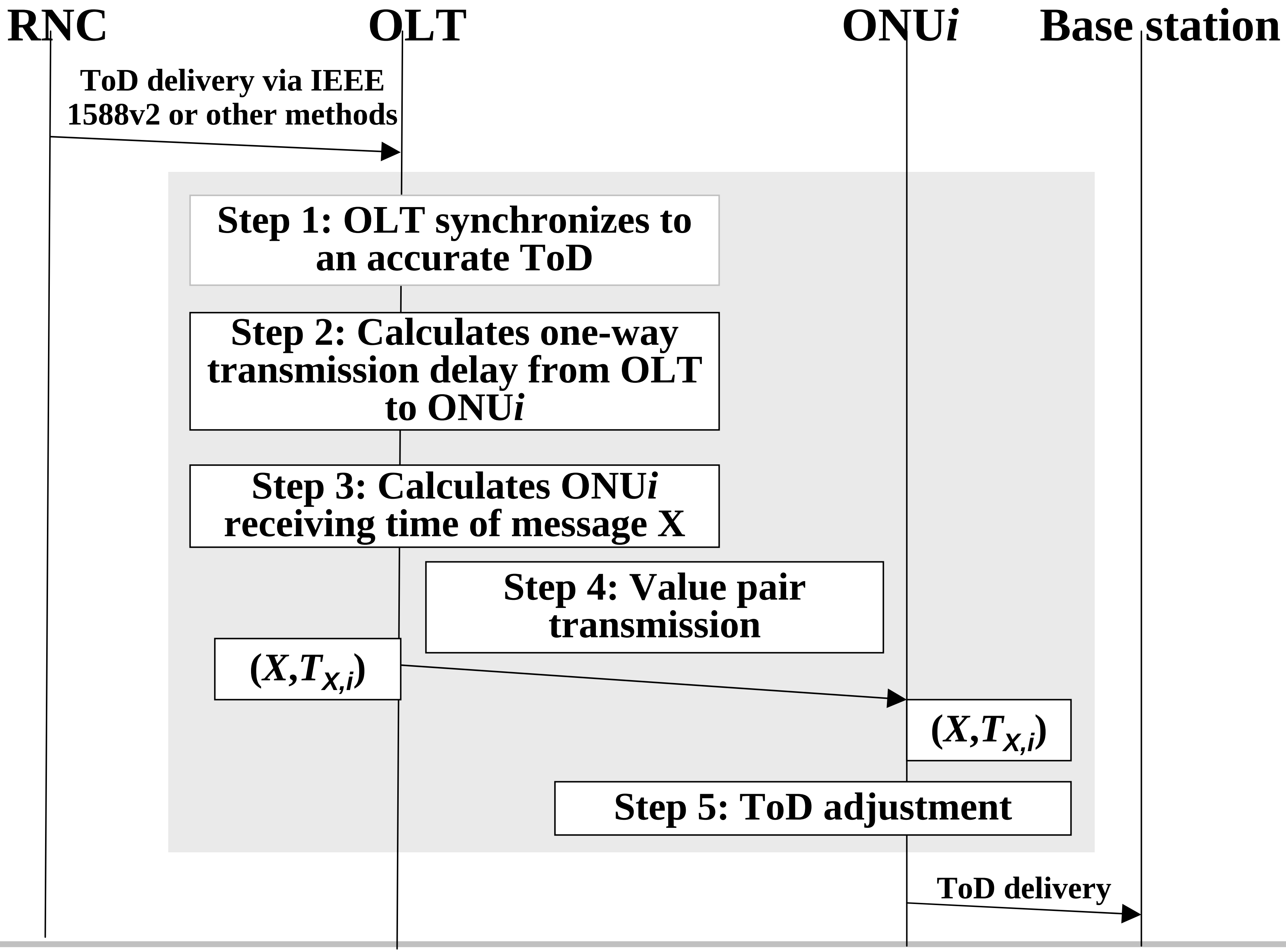
# EPON time management: MPCP counter

- **MPCP has its own time management facility**
  - Both the OLT and ONT have a local MPCP counter
    - 32 bits long
    - 16ns granularity
    - Roll over every ~68.72 seconds
  - Measured by the OLT’s line clock
  - This counter is the reference for the EPON timestamps
    - MPCP message timestamp
    - Registration, ranging, RTT measurement and update
  - This counter is the reference for the EPON upstream grants
    - ONU reports upstream bandwidth requirement
    - OLT generates collision-free grants of upstream time

# EPON time sync: How

- **OLT (clock master), ONUs (clock slaves)**
- **Relate OLT MPCP counter with synced time**
- **Compensate DS/US link asymmetry**
- **Relate ONU MPCP counter with synced time**

# EPON time sync: Steps



# Timing reference

- **The OLT selects an MPCP timestamp value, X, that will be used as a reference**
  - Any timestamp value may be chosen, provided it is relative to the current epoch of the MPCP counter
  - An MPCP message with timestamp X may or may not be transmitted
- **All of the time values correspond to timestamps are referenced to the MAC control sublayer**
  - MAC control sublayer is where the MPCP counter locates

# Link asymmetry compensation

- **OLT (clock master) calculates the $ToD_{X,i}$ based on $ToD_{X,o}$ using**

$$ToD_{X,i} = ToD_{X,o} + \frac{RTT_i}{rateRatio} \cdot \frac{n_{down}}{(n_{up} + n_{down})},$$

  – $ToD_{X,i}$ : time-of-day at which a downstream MPCP message that would carry the timestamp X would have arrived at the clock slave

  – $ToD_{X,o}$ : time-of-day at which a downstream MPCP message that would carry the timestamp X would have departed the clock master

  – $RTT_i$ : round-trip time measured by the clock master (OLT) for clock slave *I* (ONU $_I$)

  – $n_{up}$ : effective index of refraction for upstream wavelength light of the optical path

  – $n_{down}$ : effective index of refraction for downstream wavelength light of the optical path

  – *rateRatio* : rateRatio member of the most recently recevied MDSyncSend structure

# Value pair delivery

- **OLT can send value (*X*, $ToD_{X,i}$) to ONU*i* via**
  - Slow Protocol
    - OSSP (organization-specific slow protocol) message
    - Info to be carried
      - (*X*, $ToD_{X,i}$), sourcePortIdentity, logMessageInterval, rateRatio, gmTimeBaseIndicator, lastGmPhaseChange, scaledLastGmFreqChange
    - Message size 75 bytes
    - Up to 10 messages per second
      - 8 messages per second is required

# Time adjustment at clock slave

- **After clock slave (ONU) receives the value pair, it can compute the grandmaster time,*To*D, at its local counter time *S*; *ToD* is given by**

$$ToD = ToD_{X,i} + \frac{[(S - X) \bmod (2^{32})](16 \text{ ns})}{rateRatio},$$

- **Clock slave could adjust the grandmaster time**
  – Immediately when receiving the value pair
  – Or a while after receiving the value pair

# Performance analysis

- **MPCP counter inaccuracy**
  - **With 16ns granularity, counter offset is up to ±8ns**
- **RTT drift tolerance**
  - **TDMA scheme tolerence is specified as 12 Time_quanta, which is equal to 192ns**
  - **This means up to 96ns tolerance to RTT drift**
  - **and typically much better!**

# Performance analysis

- **Assume $n_{down}=N$ and $\Delta N= n_{up} - n_{down}$, the index correction factor is** 

$$\frac{n_{down}}{n_{up}+n_{down}} = \frac{n_{down}}{2n_{down}+(n_{up}-n_{down})}$$
$$= \frac{N}{2N+\Delta N}$$
$$\approx \frac{2N^2 - N\Delta N}{4N^2}$$
$$= \frac{1}{2} - \frac{\Delta N}{4N}.$$

  - **Zero order analysis results in the index correction factor of 0.5 [2]**
  - **1st order analysis gives an index correction factor of 0.500085, which is equivalent to 17ns propagation difference [2]**
  - **In 2nd order analysis, the index correction factor varies from 0.500041 to 0.500090, meaning up to 5ns propagation difference [2]**
  - **Therefore, 1st order analysis dominates propagation difference [2]**

[2] ITU-T G.984.3 Recommendation Amendment 2, *Gigabit-capable Passive Optical Networks (G-PON): Transmission convergence layer specification*, ITU-T, 2009

# Performance analysis summary

**Table 2: EPON time sync performance**

| Item | Impact |
|---|---|
| MPCP counter | ⩽ 8ns |
| RTT drif | ⩽ 96ns |
| Fiber propagation difference | ⩽ 17ns |

- **EPON time sync supports accuracy on the order of 100 nanoseconds**

# Clause 13 structure

- 13. Media-dependent layer specification for interface to IEEE 802.3 Ethernet passive optical network (EPON) link
  - 13.1 Overview
    - 13.1.1 General
    - 13.1.2 Description of the EPON timing process
    - 13.1.3 Best master selection
    - 13.1.4 Clock synchronization in EPON
  - 13.2 Message attributes
    - 13.2.1 Message class
  - 13.3 Message format
    - 13.3.1 TIMESYNC message
  - 13.4 Layering for IEEE 802.3 EPON links
  - 13.5 Service interface definitions
    - 13.5.1 OSSPDU.request
    - 13.5.2 OSSPDU.indication
  - 13.6 MD entity global variables
  - 13.7 State machines
    - 13.7.1 Requester state machine
    - 13.7.2 Responder state machine
  - 13.8 Message transmission intervals
    - 13.8.1 General interval specification.
    - 13.8.2 TIMESYNC message transmission interval default value and default range
  - 13.9 Determination of asCapable

MPCP counter

Clock master/slave

Time sync steps

Slow Protocol message to carry value pair

EPON interface model

Service primitives

Global variable

State machones

# Clause 13 status

- **Current Clause 13 in 802.1AS was drafted in May 2009**
- **Context was well cooked in working group ballot and recirc**
- **Commenters**
  - Geoffrey Garner (Samsung)
  - Ryan Hirth (Teknovus)
  - Yuanqiu Luo (Huawei)
  - Dave Olsen (Harman)
  - Bob Sultan (Huawei)
  - Yuehua Wei (ZTE)

**Table 3: Clause 13 comments**

| Ballot | Total comments | Serious comments |
|---|---|---|
| Working group, D6.1 | 27 | 10 |
| 1st recirc, D6.2 | 92* | 6 |
| 2nd recirc, D6.6 | 49 | 3 |
| 3rd recirc, D6.7 | 0 | 0 |

* Most comments are due to the information loss when converting WORD file into FrameMaker file