
# Asymmetric Networks (xPON etc.) – Timing Solutions

# Topics

- Timing Overview
- Phase and ToD Requirements
- Asymmetric Networks and the Problem of Phase
- IEEE 1588v2 and ToD Transfer
- Asymmetry of Multipoint to Point Networks
- Solution A - Transparent Clock
- Solution B - The Boundary Clock
- Solution C - The PTP Delay Equalizer
- And the winner is……

# *Who is Calix Networks?*

**Not to be confused with Calnex ☺**

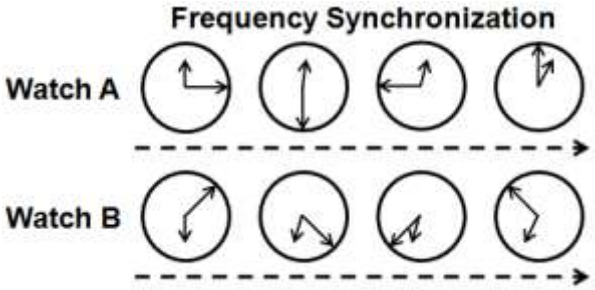
**Equipment supplier of access network solutions**

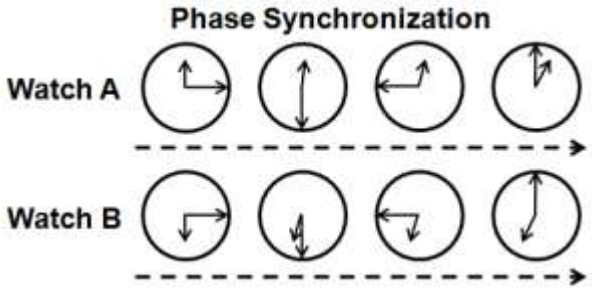
- GPON
- Point to point Ethernet
- DSL
- For residential, business and mobile backhaul

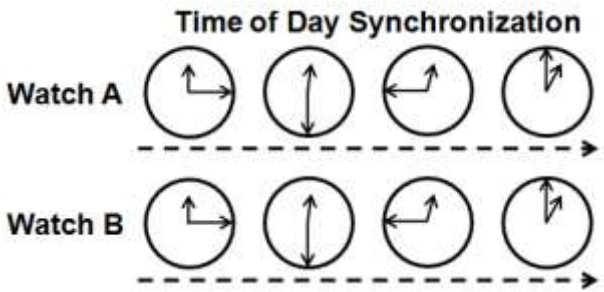
# Timing Overview

## Elements of Timing and Synchronization

- The concept of network timing contains multiple elements
- *Frequency* across an infrastructure may need to be synchronized, this is called “Syntonization”
- *Phase* may need to be synchronized – e.g. 1 pulse per second signals may need to be aligned in phase across a network. If phase is synchronized, then frequency is necessarily also synchronized
- *Time of Day* traceable to Coordinated Universal Time (UTC) may be required at certain points in a network. Frequency and phase sync may be obtained from ToD
- *We will focus on Phase and ToD synchronization in this presentation*



# Topics

- Timing Overview
- Phase and ToD Requirements
- Asymmetric Networks and the Problem of Phase
- IEEE 1588v2 and ToD Transfer
- Asymmetry of Multipoint to Point Networks
- Solution A - Transparent Clock
- Solution B - The Boundary Clock
- Solution C - The PTP Delay Equalizer
- And the winner is……

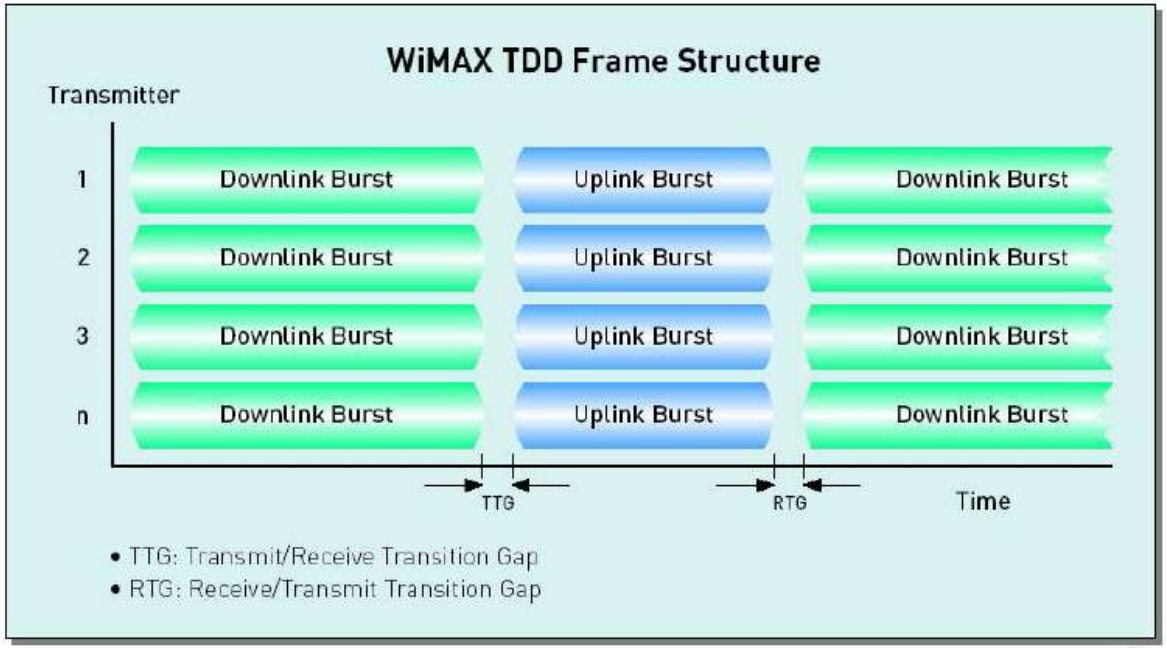
# *Why is Phase Synchronization Important?*

**Sometimes phase sync is *critical*…….**

# Why is Phase Synchronization Important?

**4G Wireless using Time Division Duplexing (TDD) requires phase synchronization**

- WiMAX TDD and LTE TDD (as well as location based services in FDD)
- TDD must be synchronized so all basestations transmit downlink bursts simultaneously to handsets, then all handsets transmit uplink bursts simultaneously to the basestations
- *Otherwise, basestations and handsets will interfere with each other*



# Timing Requirements? Mobile Backhaul is the toughest Telecom requirement

**Phase sync is needed to <1.5us (as low as 0.1us for E911 location).**

**ToD is useful for Ethernet OAM One-way delay measurements**

| Layer | Sub Items | Frequency Accuracy | Phase Accuracy |
|---|---|---|---|
| **Network Sync** | E1 | 50ppm | - |
| | STM-N | 4.6ppm | - |
| | PTN | Not so strict | - |
| **Node Sync** | Controller-Base station | If provide location service, 500ns | If provide location service, 500ns |
| | | 50ppb | 1.5us |
| | Inter-Base station | 50ppb | 3us(TD-SCDMA&TDD LTE) |
| | BS-Reference clock | 50ppb | 1.5us(TD-SCDMA&TDD LTE) |
| **Radio Interface** | GSM | 50ppb | - |
| | TD-SCDMA | 50ppb | 3us |
| | TDD LTE | 50ppb | 3us |

# Topics

- Timing Overview
- Phase and ToD Requirements
- Asymmetric Networks and the Problem of Phase
- IEEE 1588v2 and ToD Transfer
- Asymmetry of Multipoint to Point Networks
- Solution A - Transparent Clock
- Solution B - The Boundary Clock
- Solution C - The PTP Delay Equalizer
- And the winner is……

# How can Phase and Time of Day be recovered over a network?

## Round Trip Delay Measurement (RTD)

- To transfer synchronized phase or Time of Day to a remote location, we must know how long the signal takes to get to the remote
- Therefore, even if an accurate ToD is sent from A to B, the ToD at point B will be off by an amount equal the *one-way transmission delay*
- One-way delay may be obtained by measuring the round trip delay (RTD) and dividing by 2 to get the one-way delay


**One Way DELAY = RTD/2**

- If the network is *asymmetrical*, this approach does not work


**One Way DELAY ≠RTD/2**

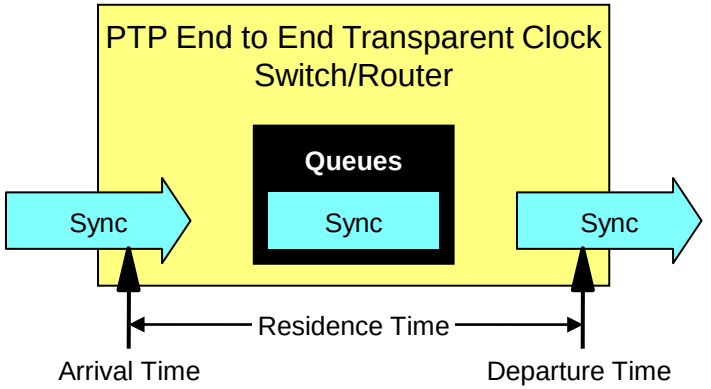
# Topics

- Timing Overview
- Phase and ToD Requirements
- Asymmetric Networks and the Problem of Phase
- IEEE 1588v2 and ToD Transfer
- Asymmetry of Multipoint to Point Networks
- Solution A - Transparent Clock
- Solution B - The Boundary Clock
- Solution C - The PTP Delay Equalizer
- And the winner is……

# How does IEEE 1588v2 handle delay asymmetry?

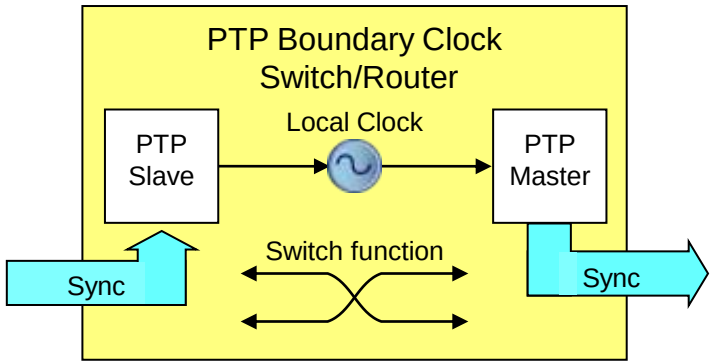
## The 1588 Transparent Clock

- IEEE 1588v2 has created a solution for the asymmetry problem called the Transparent Clock (TC)
- The TC is an Ethernet device (bridge/router/repeater) which measures the *residence time* and applies it to the **correctionField** in the PTP Sync message
- *The TC allows multiple time domains on the same network*




## The 1588 Boundary Clock

- Consists of a PTP slave to obtain the ToD and a PTP master to send the ToD to the basestion
- *Only one time domain*




***Graphics courtesy of Tim Frost of Symmetricom***

# Topics

- Timing Overview
- Phase and ToD Requirements
- Asymmetric Networks and the Problem of Phase
- IEEE 1588v2 and ToD Transfer
- Asymmetry of Multipoint to Point Networks
- Solution A - Transparent Clock
- Solution B - The Boundary Clock
- Solution C - The PTP Delay Equalizer
- And the winner is……

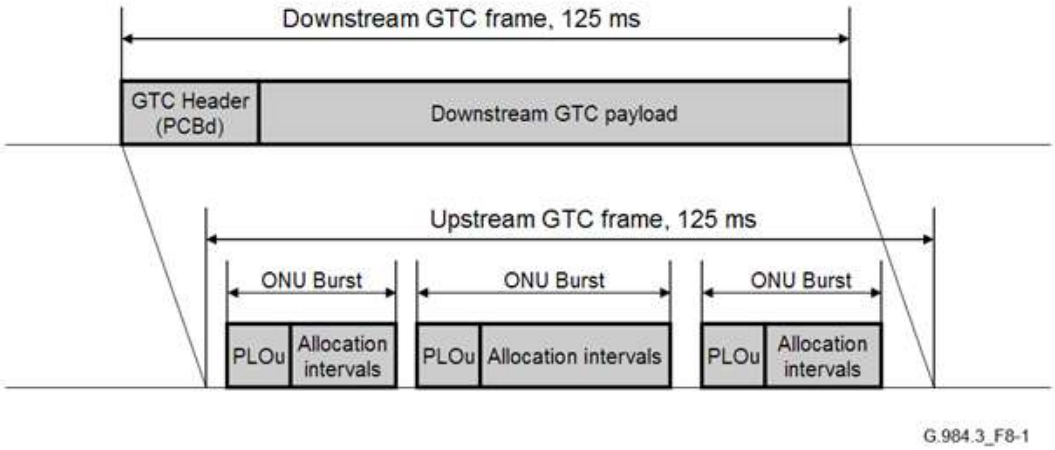
# PONs (and DSL, DOCSIS and Wireless) are Asymmetrical Access Systems

## A fundamental characteristic of Multipoint-to-Point Access Systems is Delay Asymmetry

- This is not simply due to asymmetrical bandwidth, it is mainly due to upstream scheduling protocols

## Example: Upstream GPON Scheduling

- The ONU is dependent  upon grants from the OLT to send packets US
- The OLT issues regular grants on 125us cycles
- Packets arriving too late for one grant must await the next, introducing delay and jitter

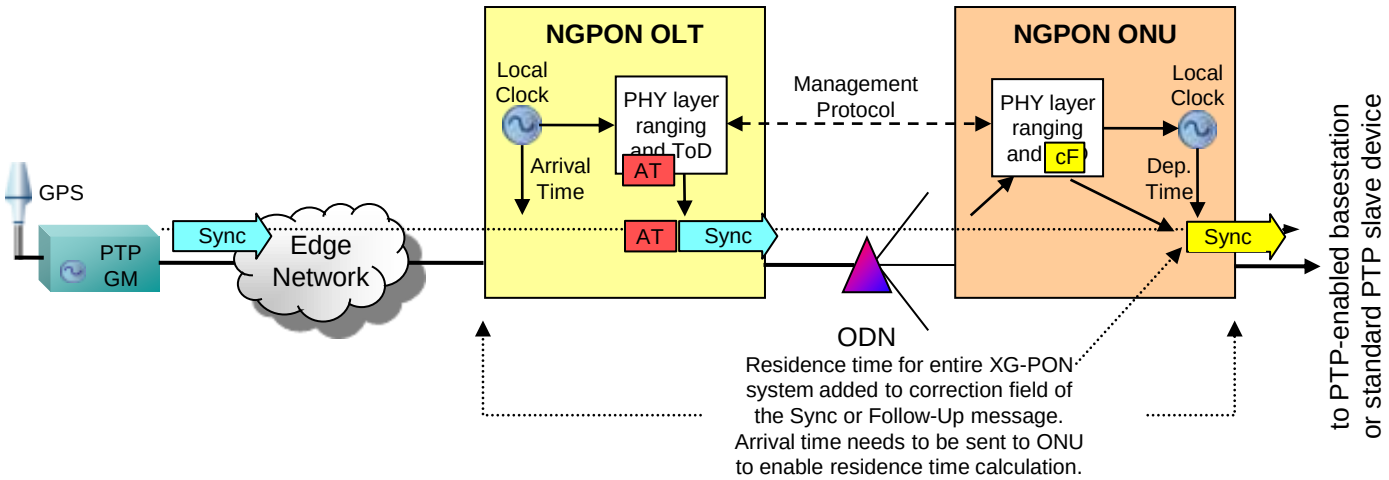


# Topics

- Timing Overview
- Phase and ToD Requirements
- Asymmetric Networks and the Problem of Phase
- IEEE 1588v2 and ToD Transfer
- Asymmetry of Multipoint to Point Networks
- Solution A - Transparent Clock
- Solution B - The Boundary Clock
- Solution C - The PTP Delay Equalizer
- And the winner is……

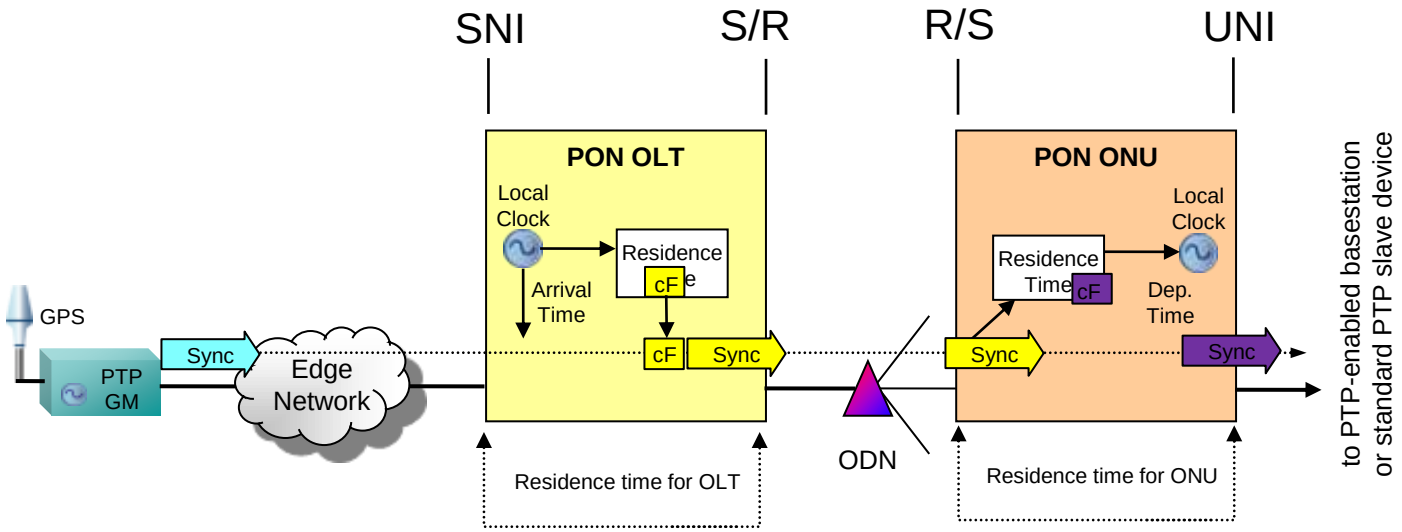
# Asymmetric Delay Solution – Distributed Transparent Clock

- GPON is not an Ethernet device, it is a distributed access system.
- We can consider making the GPON system a ***Distributed Transparent Clock***
- FSAN has added an amendment to G.984.3 that allows the OLT and ONU to synchronize a local Time of Day
- If the OLT stamps the PTP message with the Arrival Time 'AT' at the OLT then the ONU can use that along with the ToD to determine the residence time and adjust the time stamp corrrectionField
- Same is done in reverse in the upstream.



# Asymmetric Delay Solution – Discrete Transparent Clocks

- We can break the PON system into two ***Discrete Transparent Clocks***
- ***However*** we must define precisely the point over which the **PTP Sync** residence time is measured at the *OLT/ODN* and *ODN/ONU* interface
- The Ethernet PTP timestamp points are already defined in 1588; the S/R and R/S PTP timestamp points must be defined



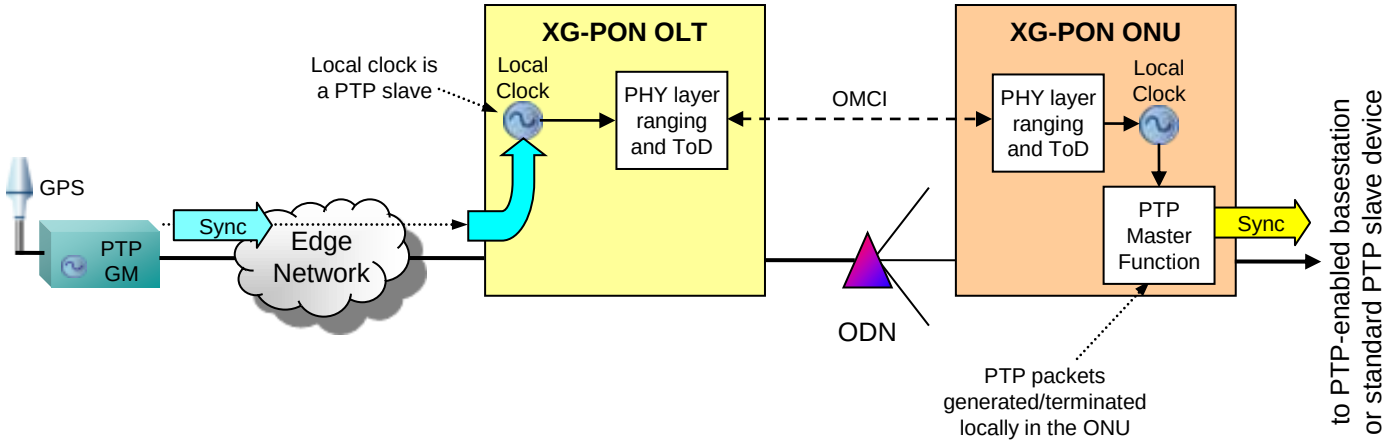
# Topics

- Timing Overview
- Phase and ToD Requirements
- Asymmetric Networks and the Problem of Phase
- IEEE 1588v2 and ToD Transfer
- Asymmetry of Multipoint to Point Networks
- Solution A - Transparent Clock
- Solution B - The Boundary Clock
- Solution C - The PTP Delay Equalizer
- And the winner is……

# Asymmetric Delay Solution – Distributed "Boundary Clock"

## Alternative approach – use ToD Sync to create a new Master at the ONU

- If the OLT has the true traceable ToD from the Grand Master (via 1588) then the ONU also has the true ToD
- The GPON system can now act as a *Distributed Boundary Clock*
- The internal GPON system asymmetries are no longer relevant by using the true ToD and *regenerating* PTP packets locally and acting as a PTP master



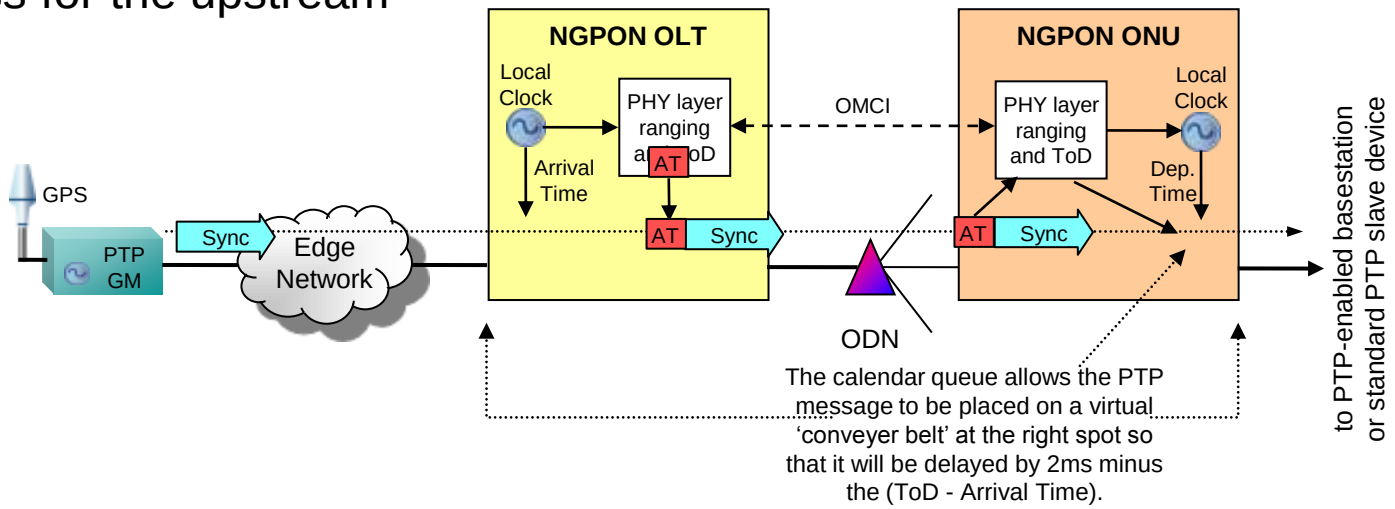
# Topics

- Timing Overview
- Phase and ToD Requirements
- Asymmetric Networks and the Problem of Phase
- IEEE 1588v2 and ToD Transfer
- Asymmetry of Multipoint to Point Networks
- Solution A - Transparent Clock
- Solution B - The Boundary Clock
- Solution C - The PTP Delay Equalizer
- And the winner is……

# Asymmetric Delay Solution – "PTP Delay Equalizer"

## How else can we solve the problem of GPON asymmetric delay?

- First disclosed as '*Controlled Delay*' by Stefano Ruffini of Ericsson, at June 2010 Plenary ITU meeting in Geneva
- Fix the problem at its source, *eliminate the system asymmetry for PTP Sync messages*
- The delay of all PTP packets are adjusted to a precise fixed delay
- The OLT stamps the PTP message with the Arrival Time as before
- The ONU reads the timestamp and places the PTP message into a *calendar queue* to achieve a specific delay
- Same process for the upstream



# Topics

- Timing Overview
- Phase and ToD Requirements
- Asymmetric Networks and the Problem of Phase
- IEEE 1588v2 and ToD Transfer
- Asymmetry of Multipoint to Point Networks
- Solution A - Transparent Clock
- Solution B - The Boundary Clock
- Solution C - The PTP Delay Equalizer
- And the winner is……

# *FSAN chose the Discrete TC for XG-PON*

**This October FSAN agreed to include the *Discrete TC* approach as per Adtran, Calix, PMC-Sierra joint contribution as a solution to asymmetry for XG-PON.**

- The discrete TC had the least impact on G.987, no new messages, simply a definition of where residence time is measured
- The definition will go into an *appendix*
- At least two PON silicon vendors will be adding this to upcoming XG-PON chips
- The Discrete TC may also be used for EPON, GPON and 10G-EPON
- As mentioned previously, the TC allows the use of multiple time domains

***Other methods such as the Boundary Clock, the PTP Equalizer and the Distributed TC may still be used.***

**ITU-T Q13/15 may define one or more *technology independent approaches***


# Thank you

# Message Timestamp Point for Ethernet Frame mapped into XGEM Frame

**For XG-PON it was important to define clearly how to measure residence time when Ethernet frame are encapsulated into the XGEM Frame**