# Access network systems for future mobile backhaul networks

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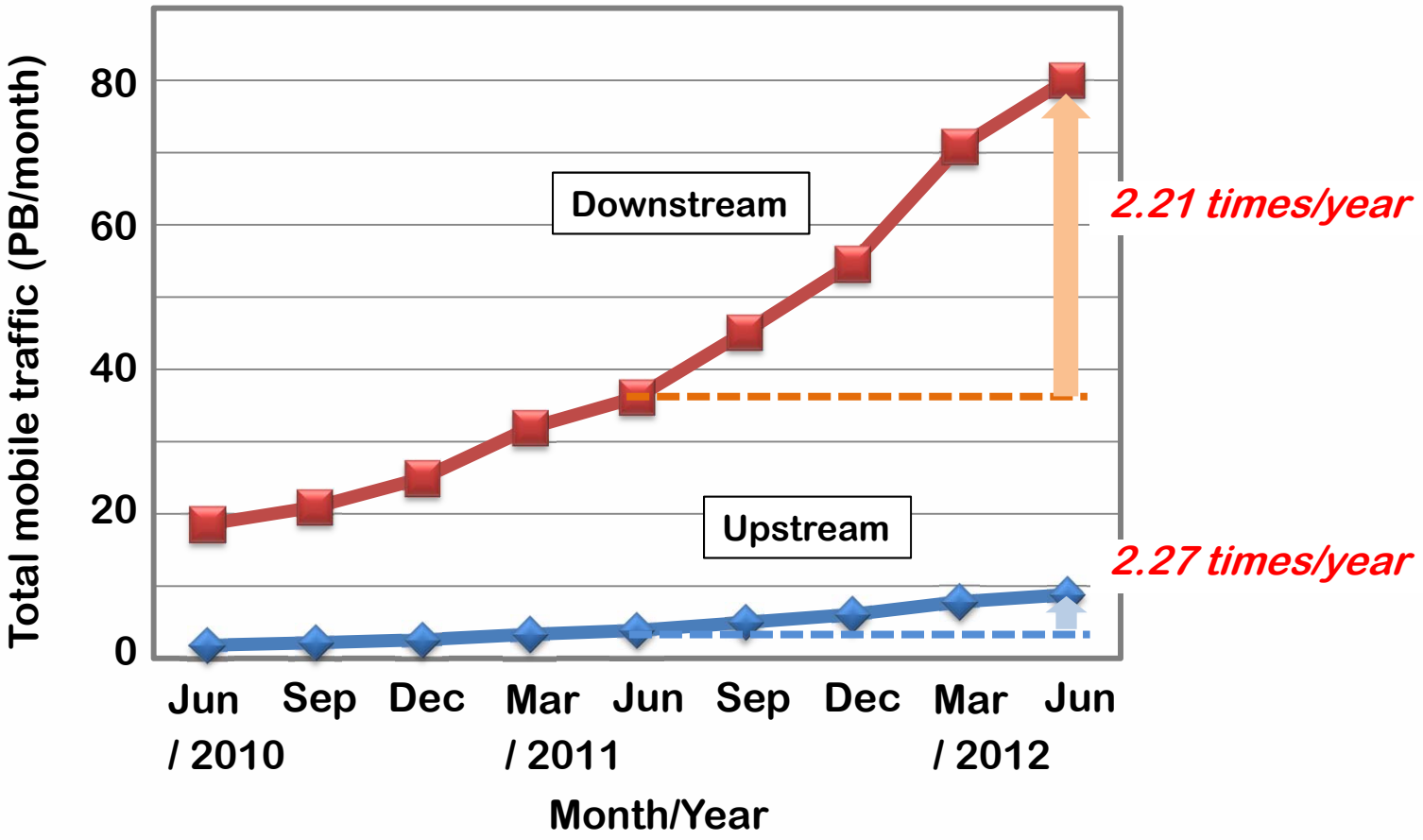
# Outline

- Mobile Traffic Growth in Japan
- Future Mobile Base Station Configurations
- Development of Synchronous Access Network Systems
  - 10G-EPON
  - Aggregated Media Converters
  - Frequency Synchronization Characteristics
  - Temperature Cycling Test
  - Time/Phase Synchronization Characteristics
- Summary

# Mobile traffic growth in Japan

**Launches of LTE services and rapid spread of smart phones and tablet devices have accelerated mobile traffic growth in Japan.**



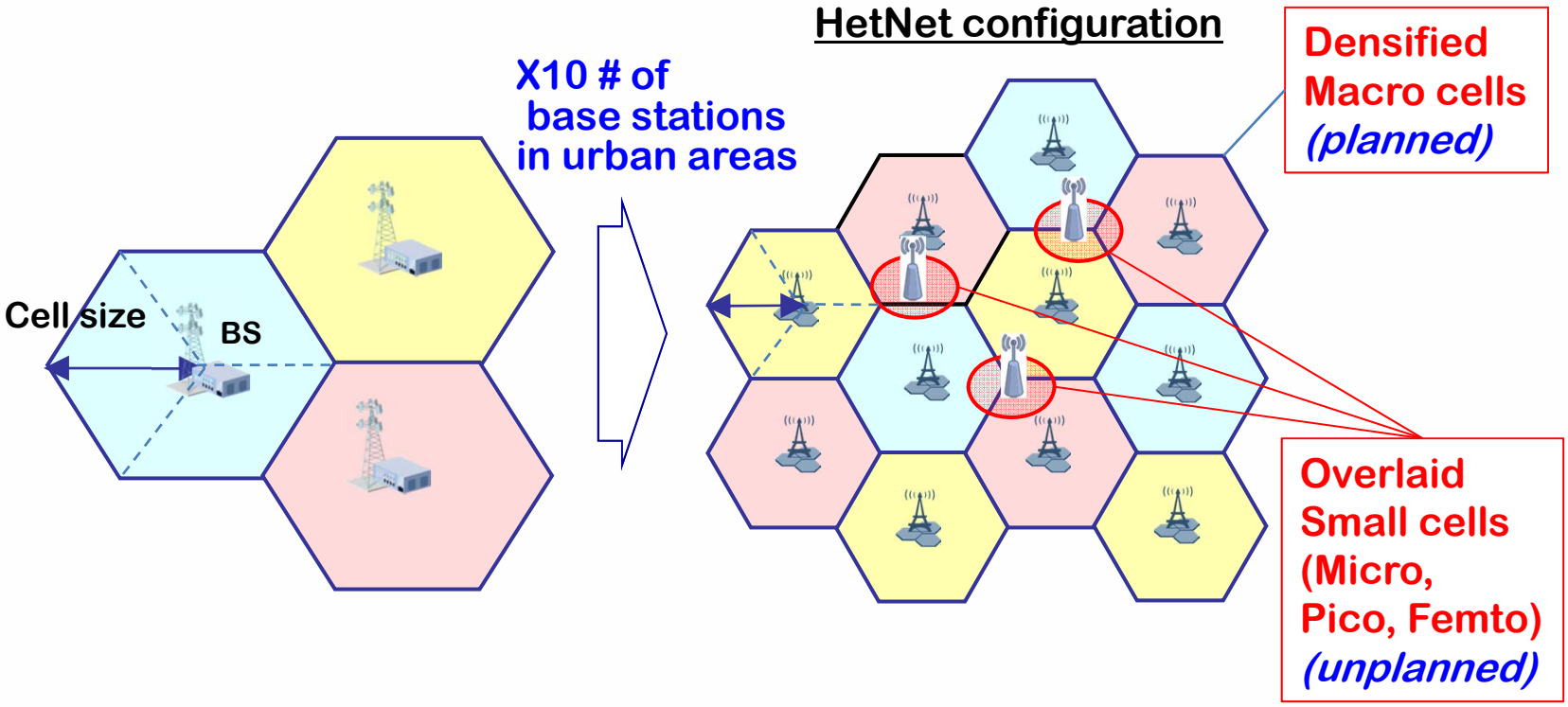

*Data from information & communications Statistics database*
*By Ministry of Internal Affairs and Communications in Japan*

# Future mobile base station configuration

**To increase spatial capacity, planned cell size will decrease along with small cells over-laid on traffic "hot spot" areas.**

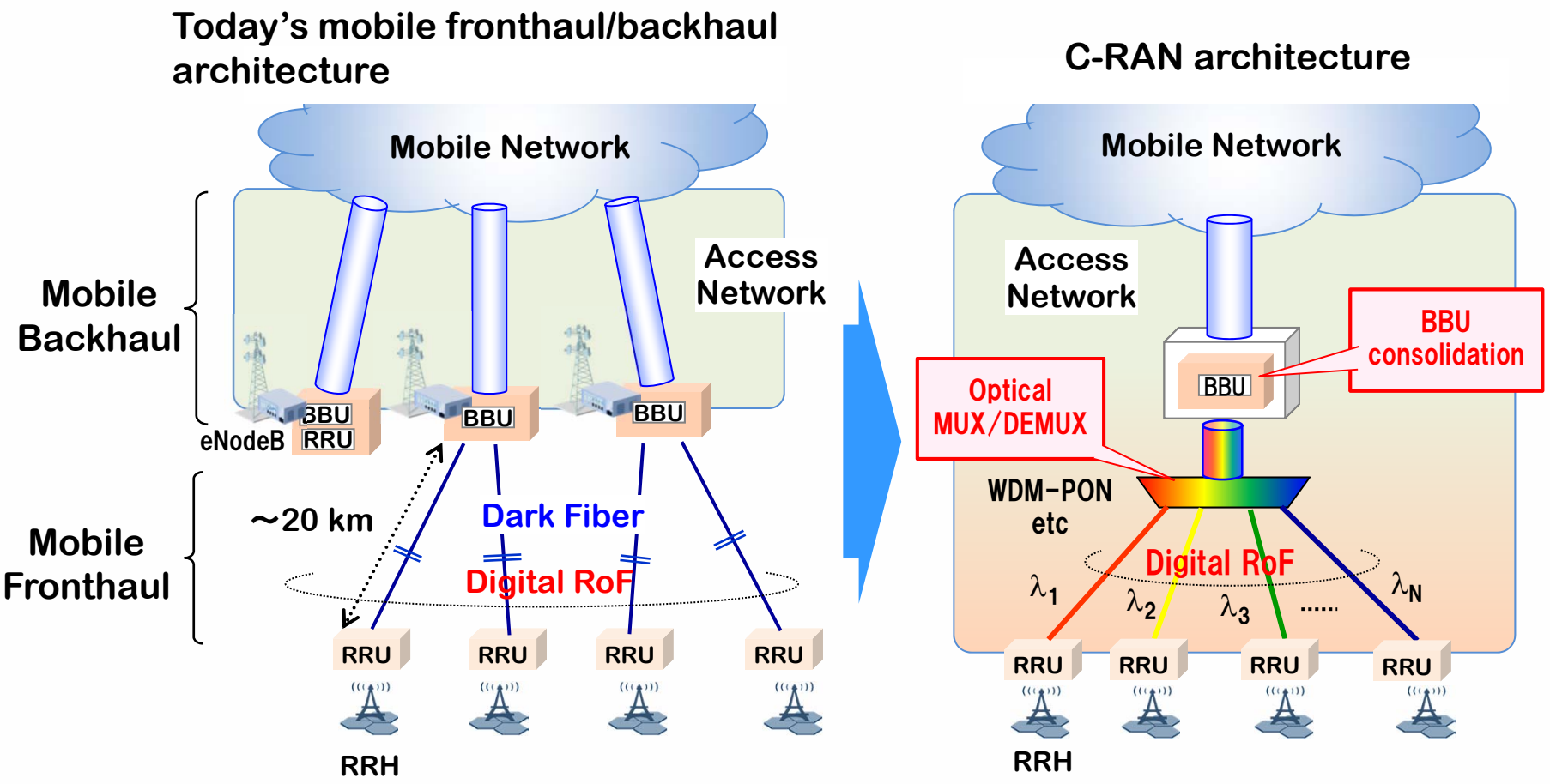
**Today's mobile base station configuration**

**Future mobile base station configuration**



# Cloud RAN (C-RAN)

**C-RAN is architectural goal towards BBU consolidation, which could effectively reduce CAPEX/OPEX and power consumption.**



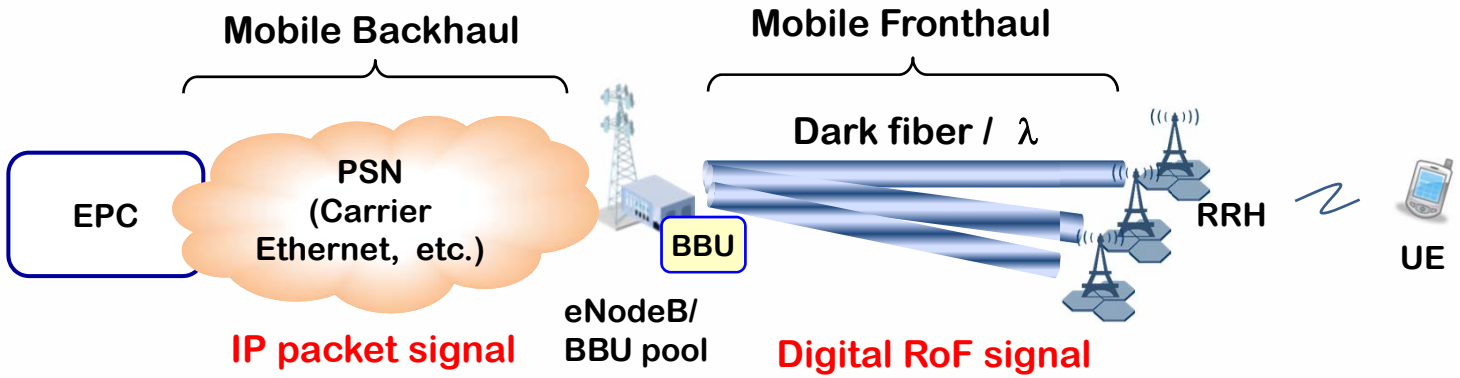

RRH: Remote Radio Head
RRU: Remote Radio Unit

BBU: Baseband Unit
RoF: Radio over Fiber

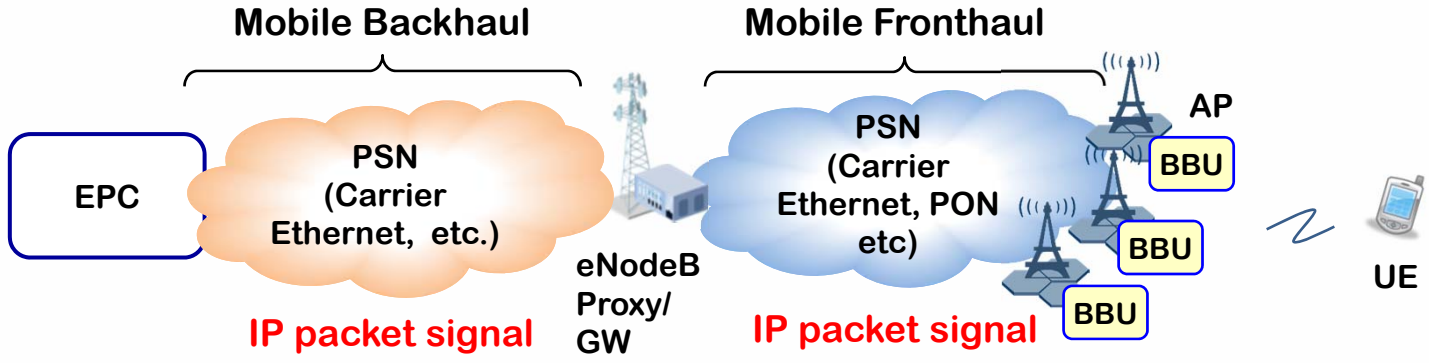
# Access network for small cell base stations

**Requirements for future mobile fronthaul will be different for different types of base station architecture.**

## Type (A): C-RAN




## Type (B): Distributed APs (antennas) with BBU




PSN: Packet Switched Network
PON: Passive Optical Network
EPC: Evolved Packet Core

Act as proxy in place of APs against EPC

AP: Access Point
GW: Gateway

# Mobile fronthaul for small cell base stations

| | Type (A)<br>C-RAN | Type (B)<br>Distributed APs with BBUs |
|---|---|---|
| Mainly applicable cell type | Macro Cell | Small Cell |
| Signal type | Digital RoF<br>(CPRI/OBSAI) | Packet-based signal<br>(IP, Ethernet) |
| Architecture<br>(toady's technologies) | • Dark fiber<br>• WDM-PON<br>• OTN, etc | PSN<br>(Ethernet, TDM-PON, etc) |
| Requirement for transmission delay | Severe both in delay and delay variation | relaxed |
| Effectiveness of BBU consolidation | High | Low |
| CoMP Options | NW-MIMO<br>Joint Transmission, etc | Joint Transmission, etc |
| Cost challenge | CPRI transceiver | SoC (MPU&DSP) |

CPRI: Common Public Radio Interface
OBSAI: Open Base Station Architecture Initiative
CoMP: Coordinated Multi-Point transmission and reception

# Technical Challenges

## C-RAN

- Increasing bandwidth of digital RoF segments in accordance with wireless bandwidth increment towards LTE-advanced.
  e.g. LTE 10MHz 2x2 MIMO →1.2 Gbps DRoF signal
- Bandwidth compression of CPRI signal.
- Limitation of distance between BBU and RRHs.
- CPRI transmission over public networks.
  - CPRI could not be electrically multiplexed as in PSN.
- Redundancy of CPRI transmission path.

## Distributed APs

- Distribution of time/frequency to APs over PSN.
- Transmission latency reduction.
- Enhancement of cost effectiveness.
  - SoCs will be key devices for cost reduction.
- Vendor lock-in.

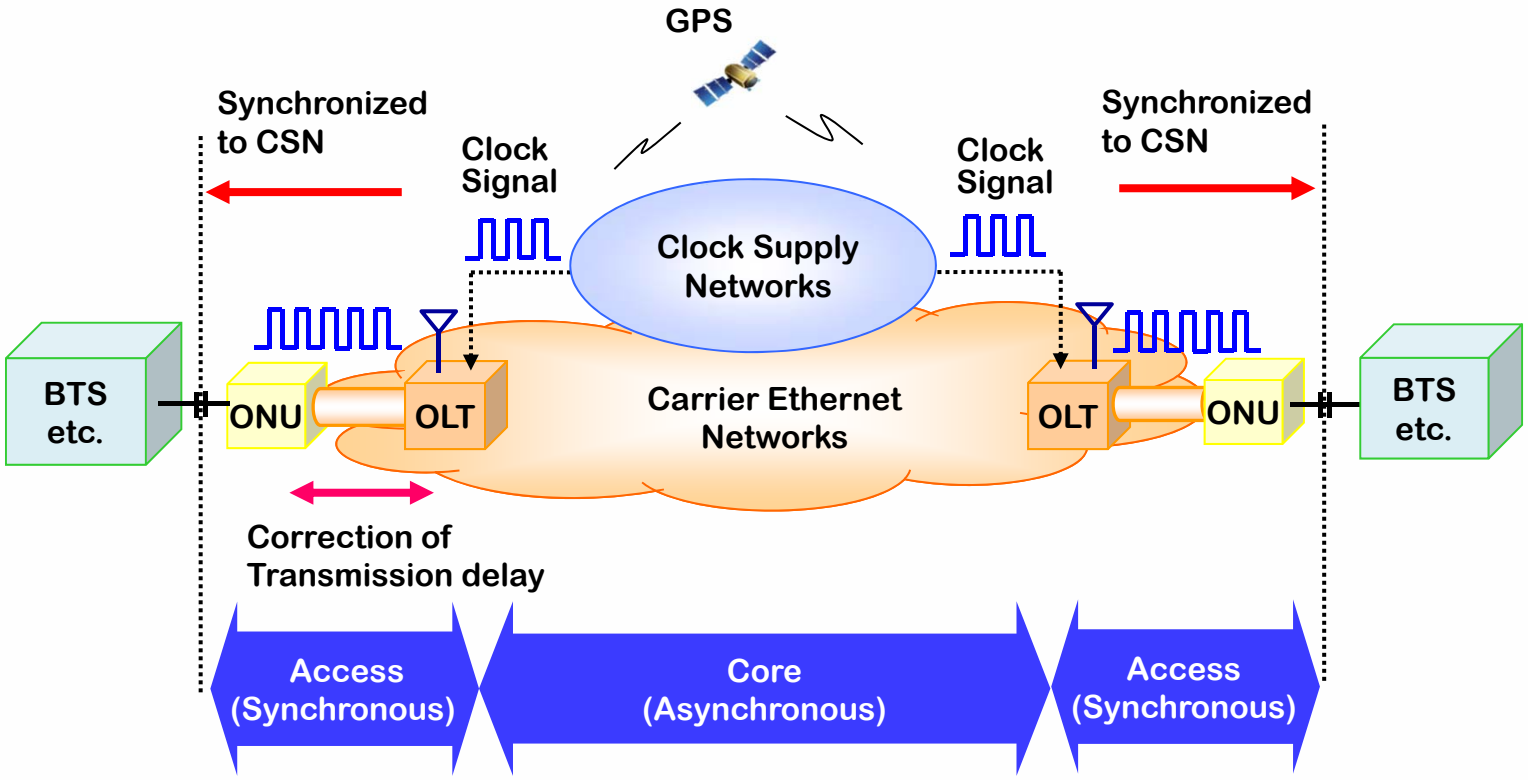
# Our Scope

- We expect future mobile fronthaul/backhaul architecture will be a mixture of Types (A) & (B).
- Applying synchronous Ethernet technologies (Sync-E & PTP) to access network systems as short-term (STEP-1) solutions to provide phase/time & frequency synchronization to mobile base stations for PSN-based mobile fronthaul/backhaul architecture.
- In C-RAN, transmitting DRoF signals from each RRH to BBU might be important issue.
  Cost-effective measures other than using dark fibers require further study.

Sync-E: Synchronous Ethernet PTP: Precision Time Protocol (IEEE1588v2) PSN: Packet Switched Network

# Synchronous Access Network Systems

**Sync-E and PTP are applied only for access networks in first stage, while core network infrastructures remain unchanged.**



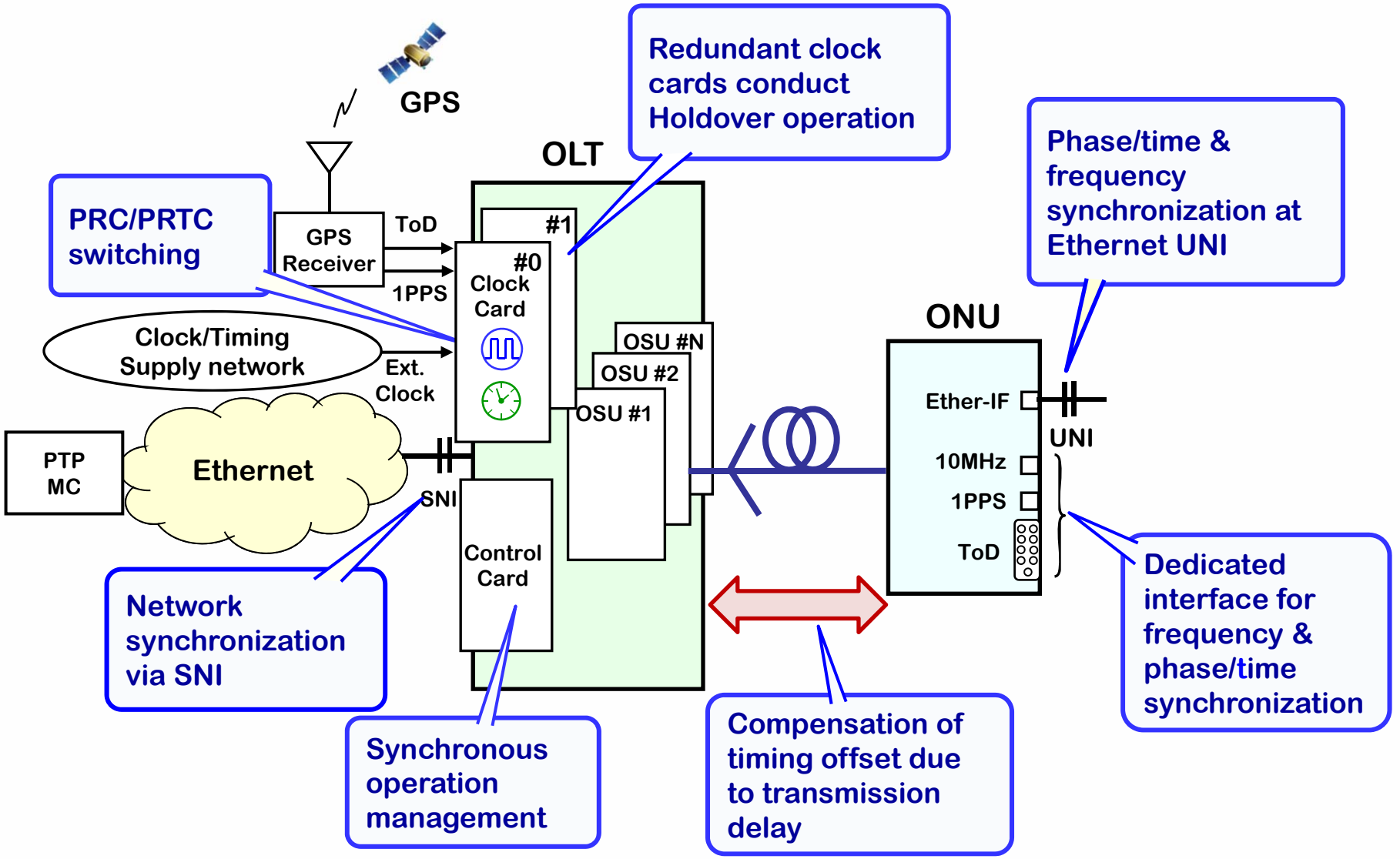

GPS: Global Positioning System
BTS: Base Transceiver Station
OLT: Optical Line Terminal
ONU: Optical Network Unit

# Synchronous Access Network Systems

- We have developed two types of synchronous access systems (10G-EPON and aggregated media converters), which can be applied for both consumer and enterprise network services.
- Coherent/Incoherent hybrid sync operation (Sync-E / PTP, Sync-E / 802.1AS) used to achieve highly precise time/phase sync.
- Support of multiple reference clock/timing sources. (PRC/PRTC, GPS, and Ether-IF)
- Target accuracy is ±100 ns for phase/time synchronization.
  - Assuming application for LTE-advanced CoMP (co-operative multi-cell multiuser MIMO).
- Clock card redundancy.
- Holdover capability for both time/phase & frequency.
- UNI for providing frequency and phase/time synchronization to CPEs.
  - Ethernet-IF (Sync-E, PTP) and 1PPS/ToD/Clock interface.
- SSM (ESMC) is supported at UNI as well as inside access systems.

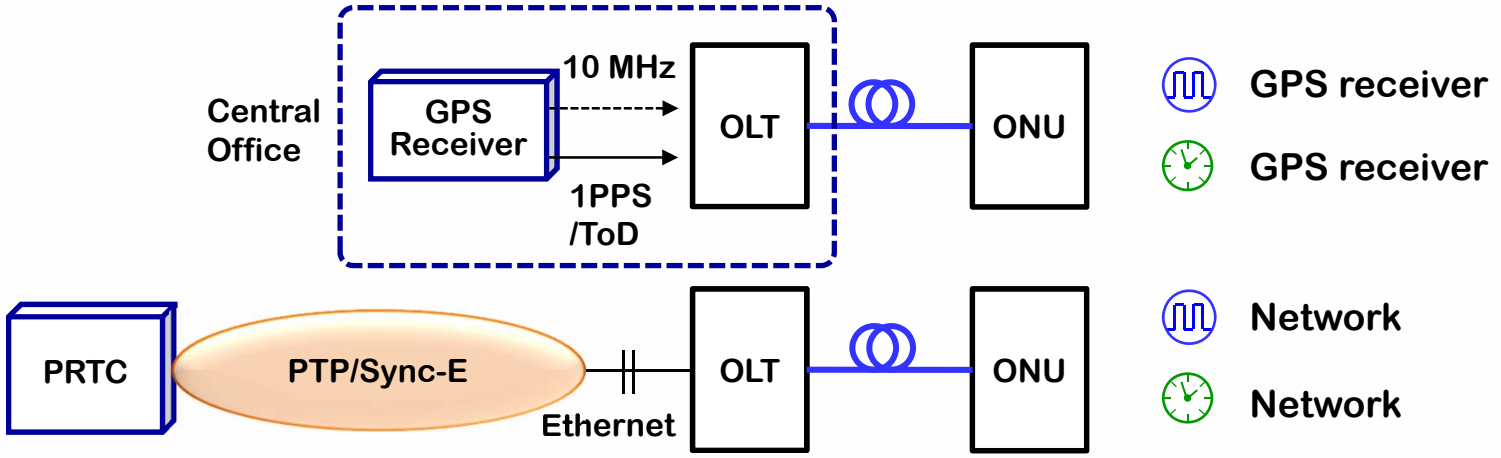
PRC: Primary Reference Clock PRTC: Primary Reference Time Clock PPS: Pulse per second
ToD: Time of day ESMC: Ethernet Synchronization Message Channel

# Overview of Synchronous Access Network Systems

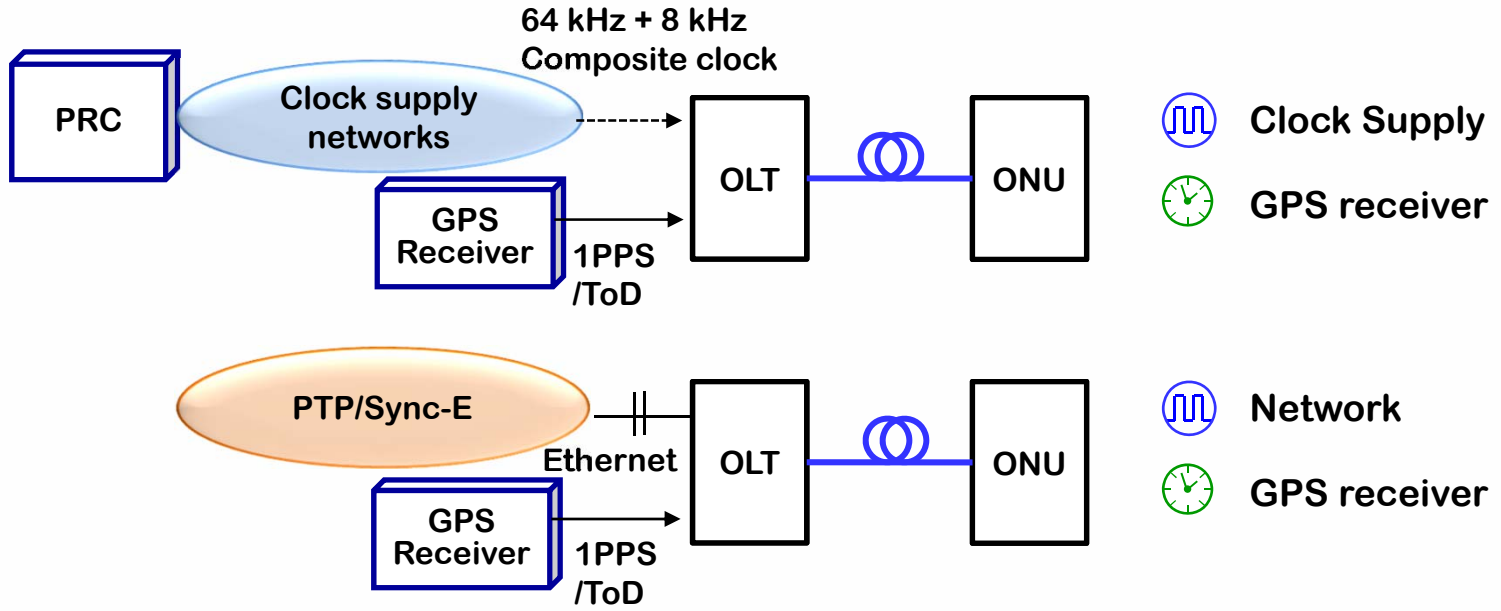


# Hybrid sync operation of Sync-E & PTP/802.1AS

## Coherent Hybrid Operation

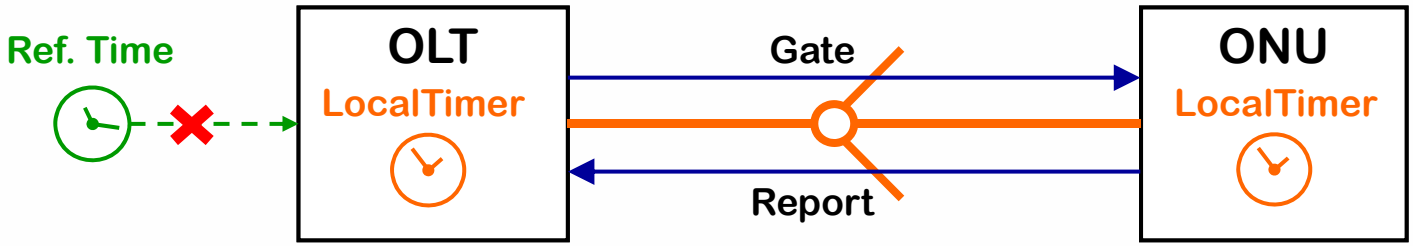



## Incoherent Hybrid Operation

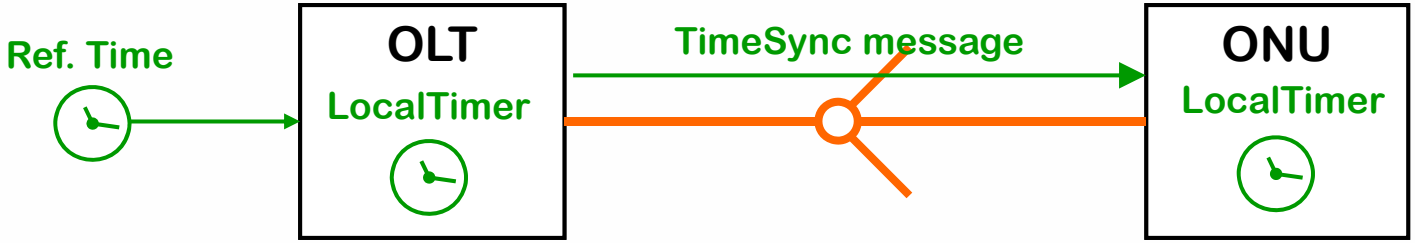


# Correction of timing offset in access line

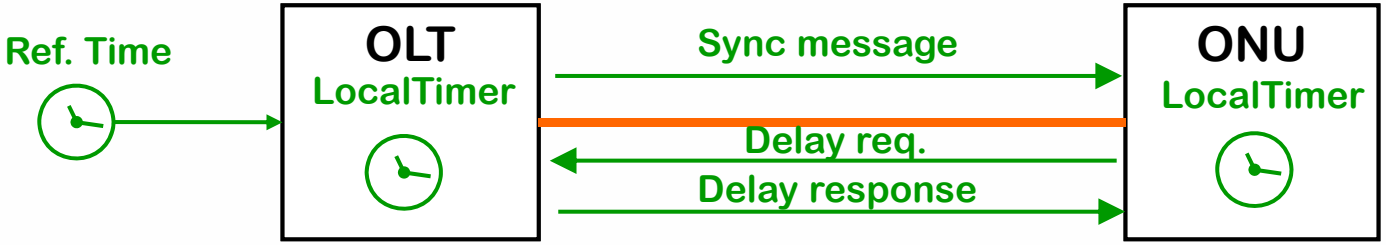
- 10G-EPON
  - Multi-Point Control Protocol (MPCP)




  - IEEE802.1AS



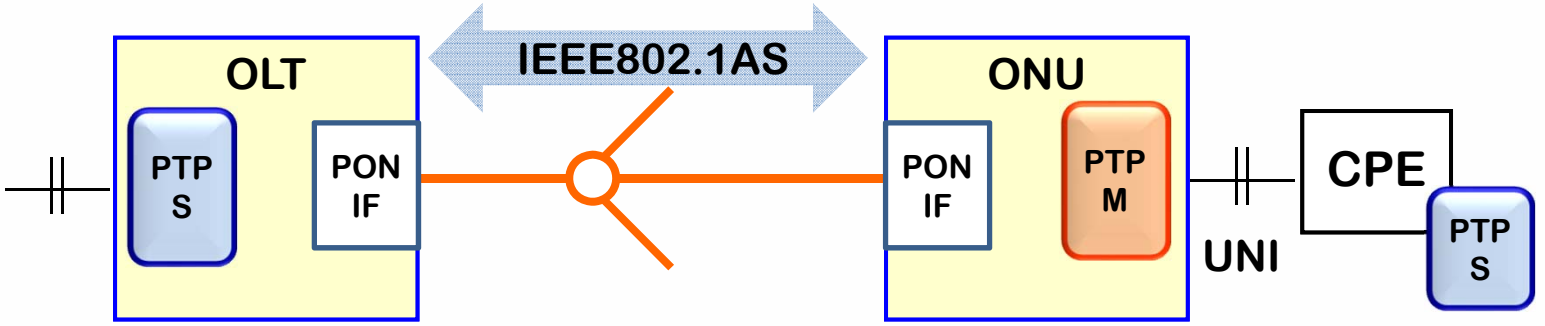

- Aggregated media converter
  - Precision Time Protocol (PTP)



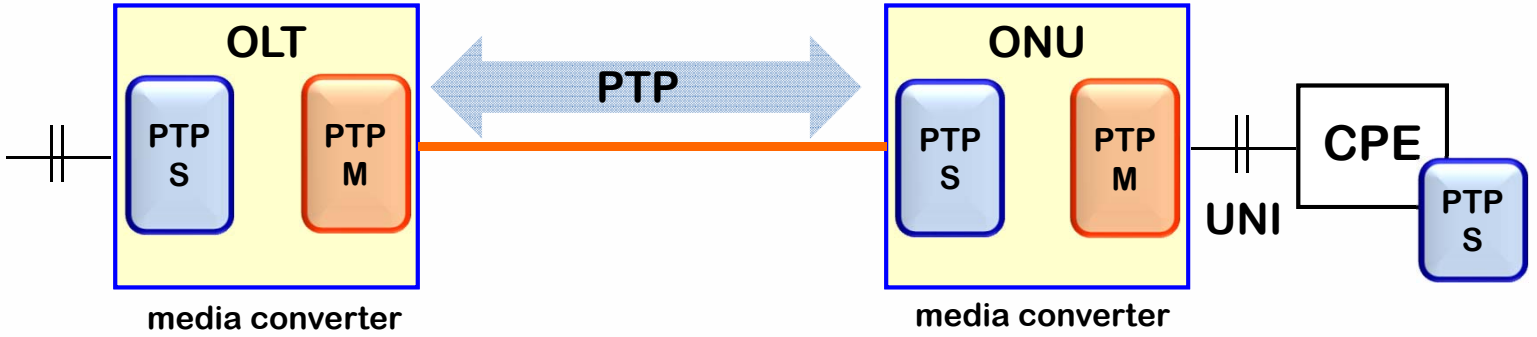
# PTP Implementation

**Synchronous access network systems works as PTP boundary clock. In aggregated media converters, PTP is also used for timing offset correction in access line.**

- 10G-EPON

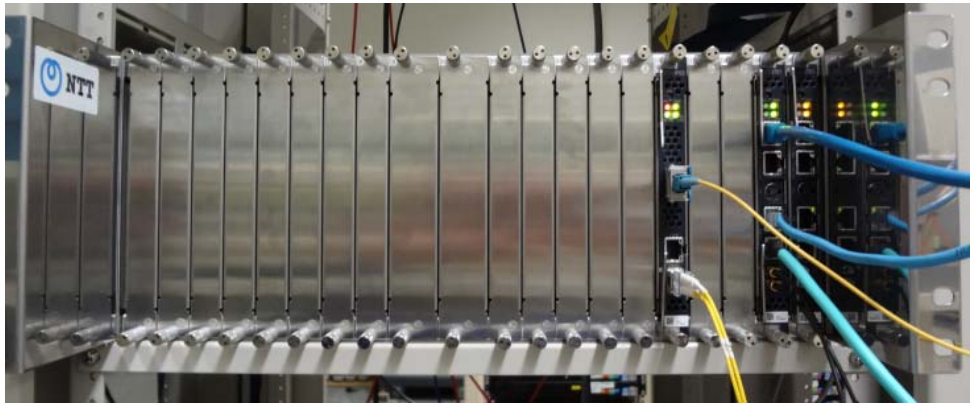



- Aggregated media converters



# 10G-EPON Access Systems

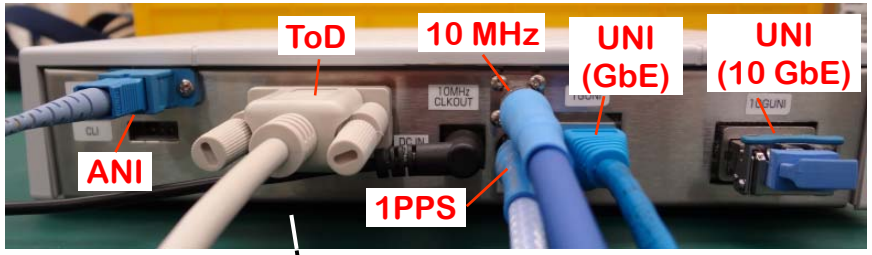
10G-EPON OLT




10G-EPON ONU

Front view

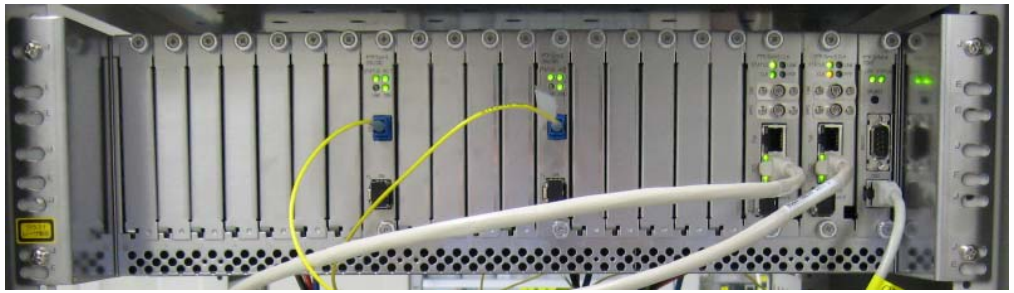

Rear view



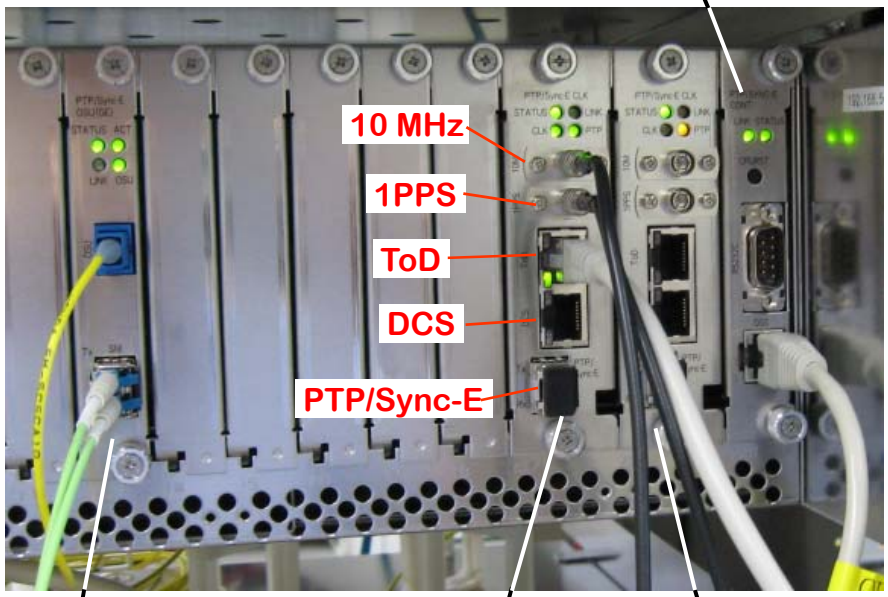

D-sub 9pin (NMEA-0183)

# Aggregated media converters access systems

OLT



Control card

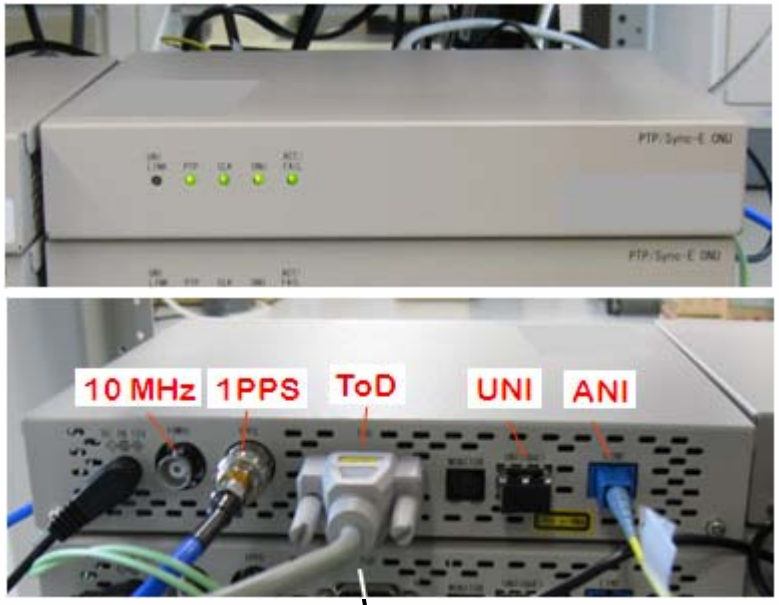



OSU card

Clock Card #0

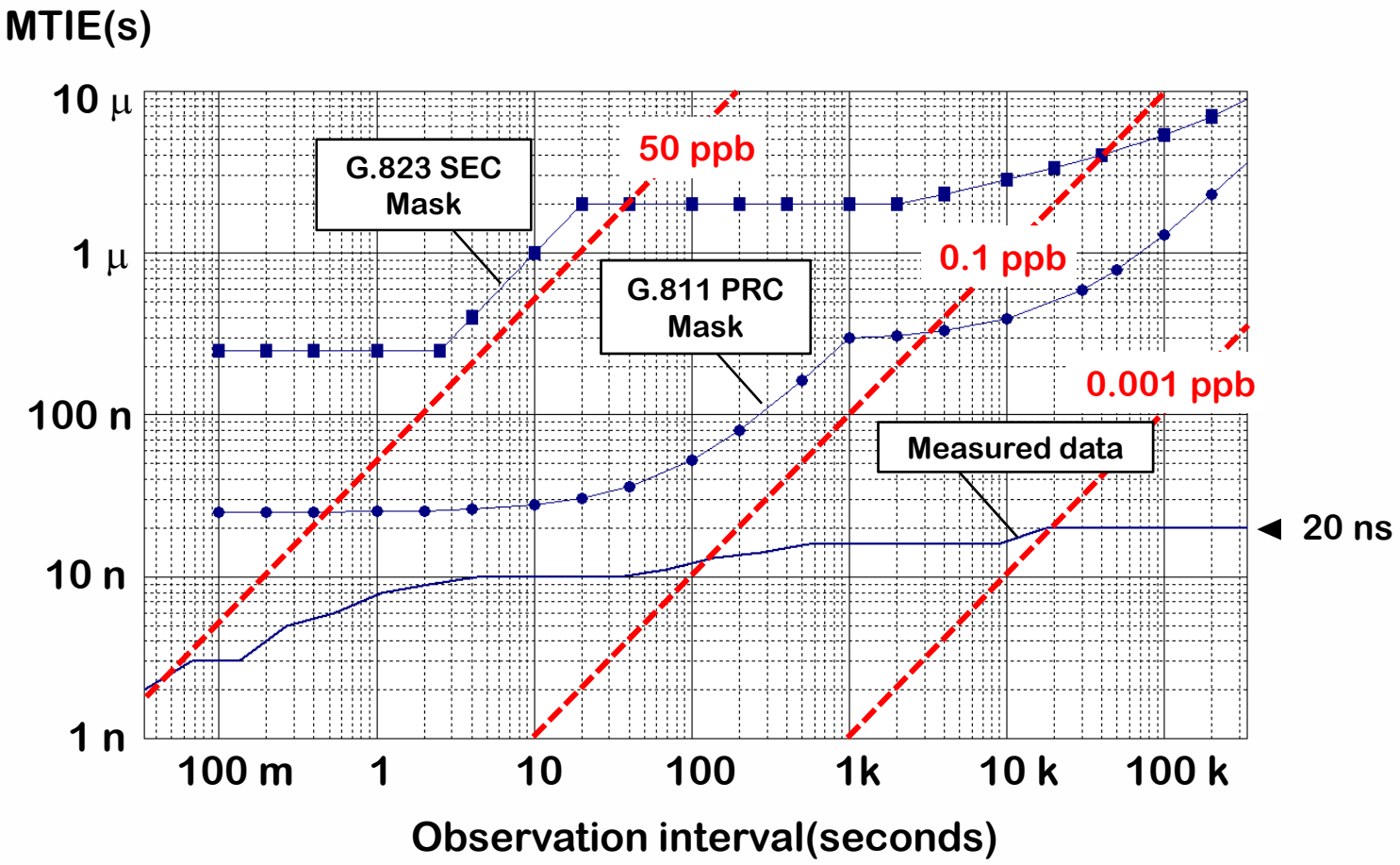
Clock Card #1

ONU




D-sub 9pin (NMEA-0183)

# Frequency Synchronization Characteristics

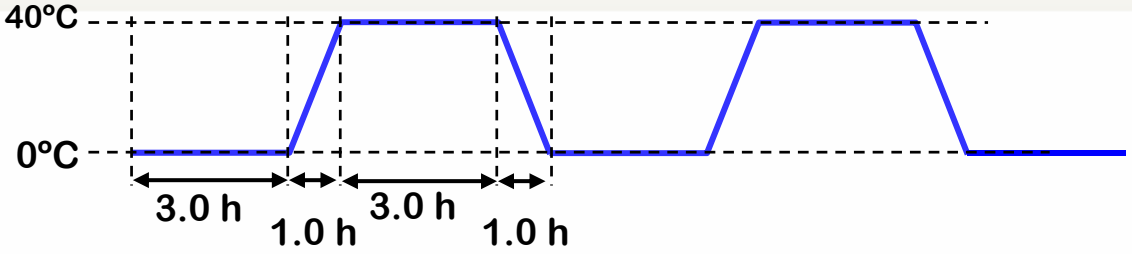



- Long-term TIE is around 20 ns and FFO is < 0.001 ppb.
- PTP sync messages need to be exchanged only once in $10^5$ seconds to achieve +-100-ns phase/time accuracy in hybrid operation.

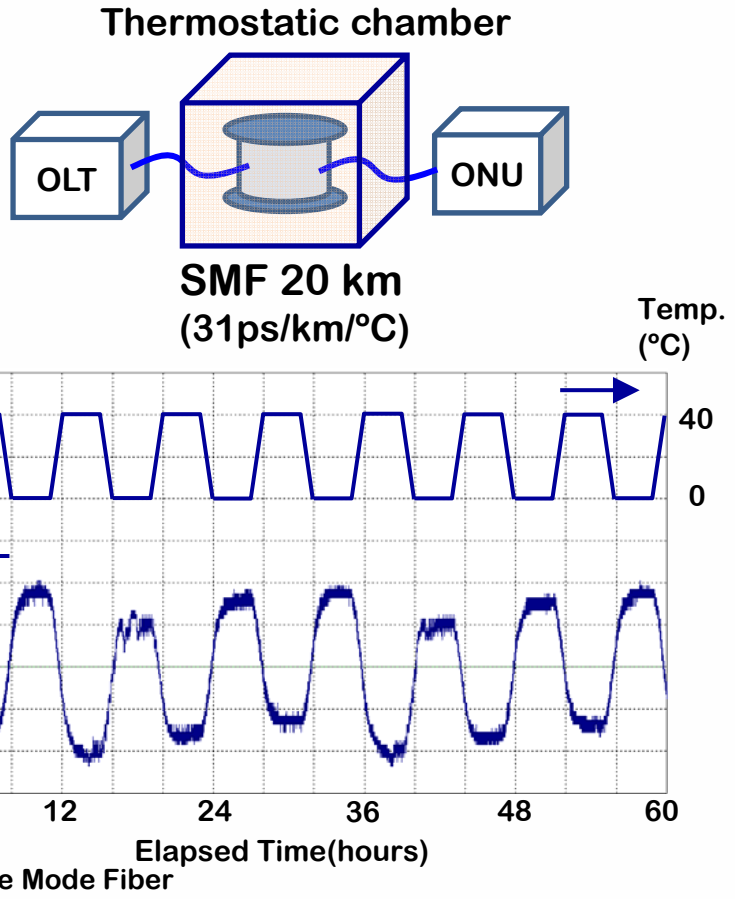
FFO: Fractional Frequency Offset TIE: Time Interval Error MTIE: Maximum Time Interval Error

# Temperature cycling test

Temp. cycling pattern

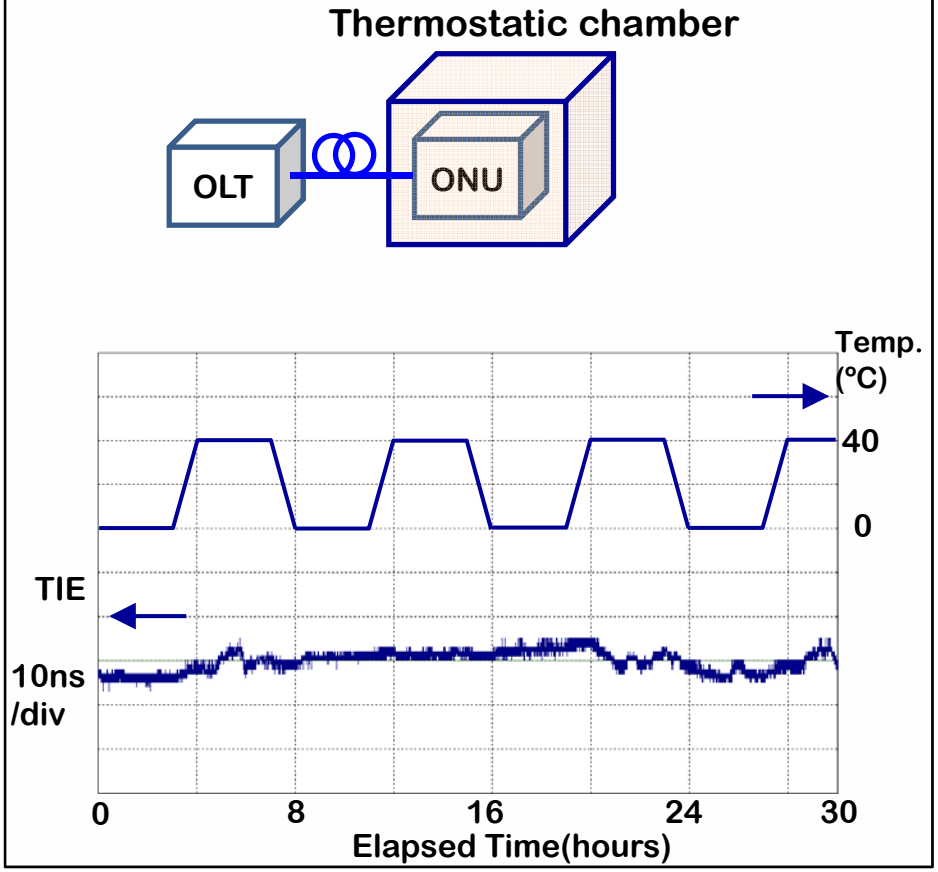



## (1) Access transmission line(optical fiber)



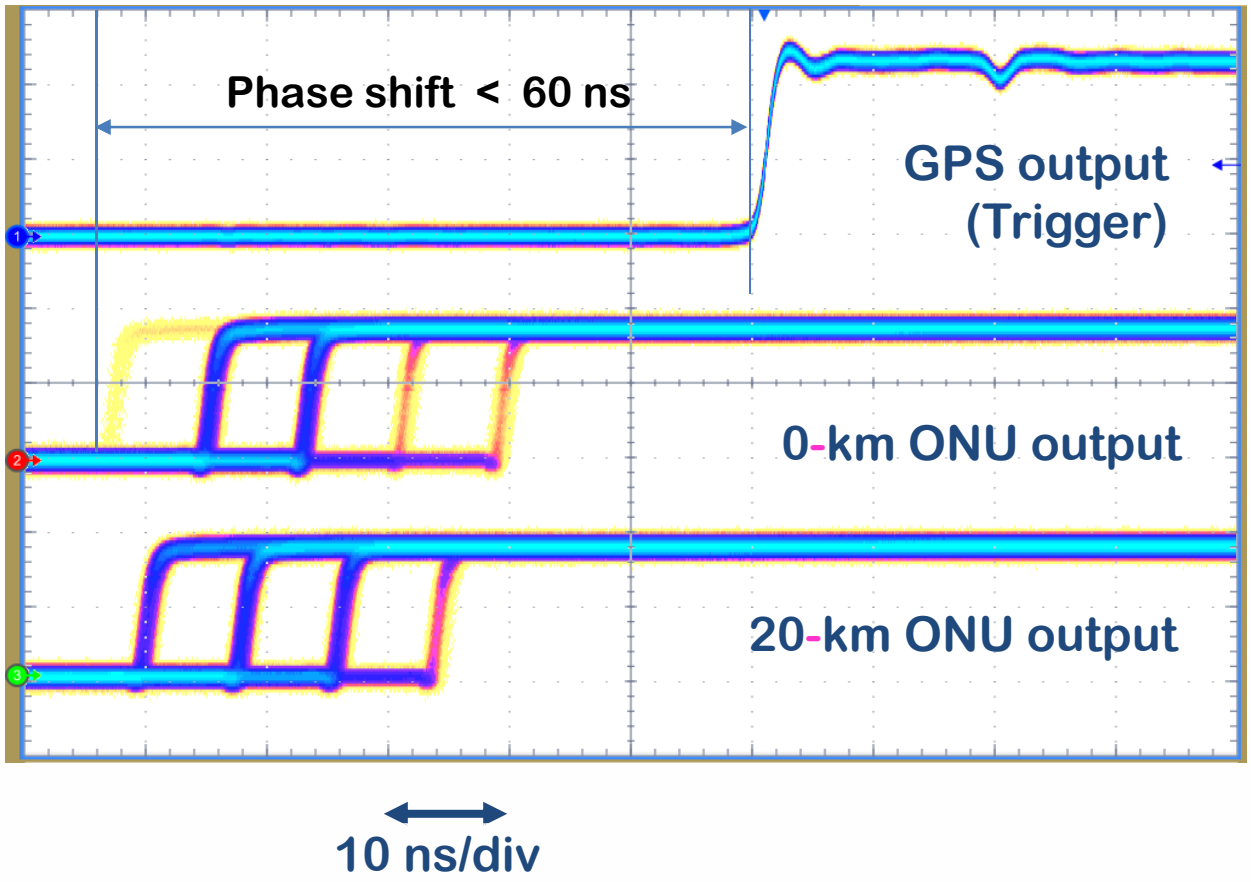

SMF: Single Mode Fiber

## (2) ONU

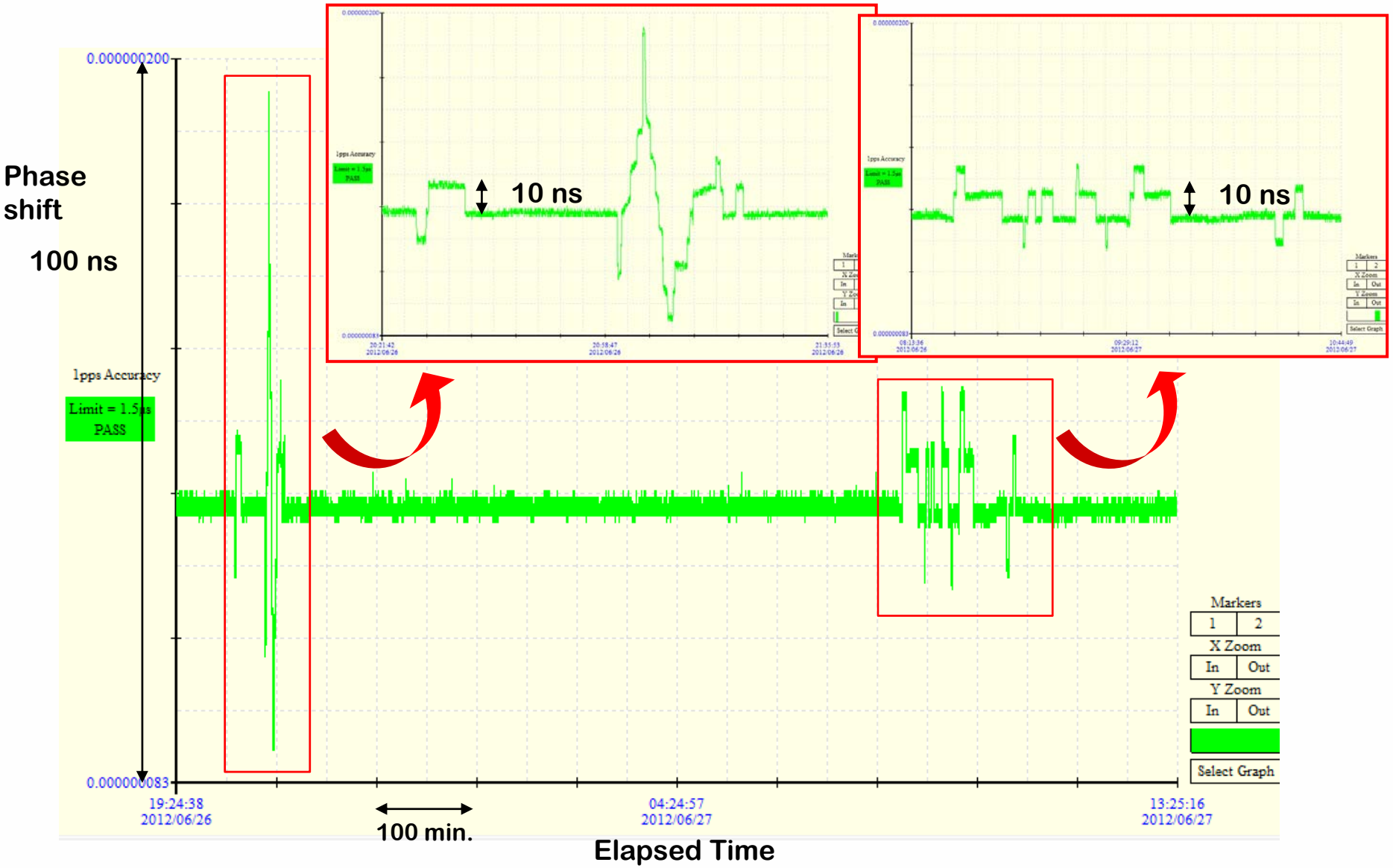


# Time/Phase Synchronization Characteristics [10G-EPON/802.1AS]

*$10^5$ times overwriting



# Time Synchronization Characteristics [Media converter/PTP]



# Summary

- Issues to be considered in future mobile networks were discussed.
- We developed two types of synchronous access network systems,10G-EPON and aggregated media converters.
- Sync-E/PTP and Sync-E/802.1AS hybrid operation was implemented and highly accurate phase/time synchronization (<100 ns) was achieved.