Infinera

# Key Enablers for Migration to Timing Cloud Synchronization Distribution in Optical Transport Networks

Jon Baldry

2nd November 2021

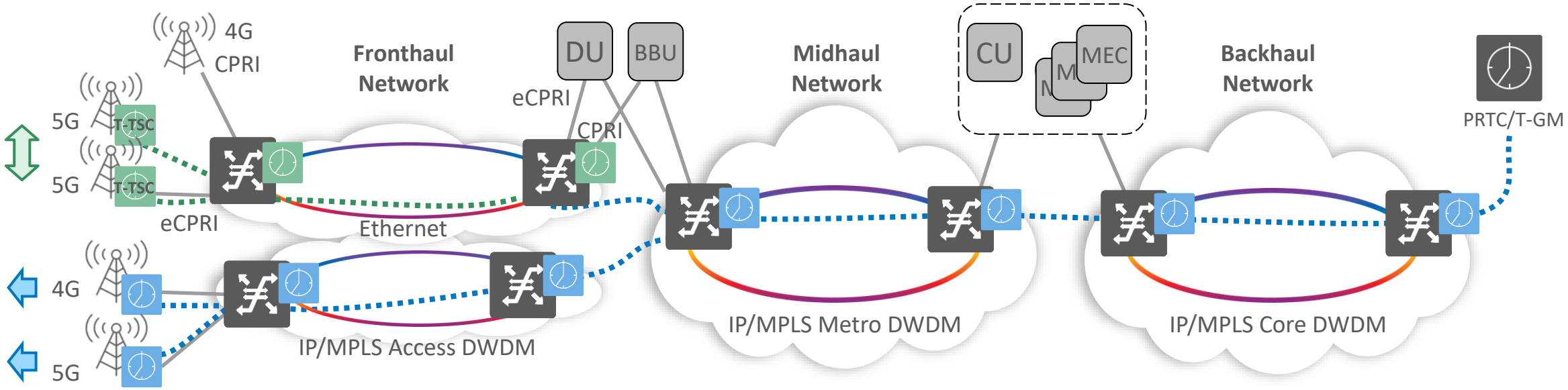
# 5G Drives High Accuracy Synchronization Requirements

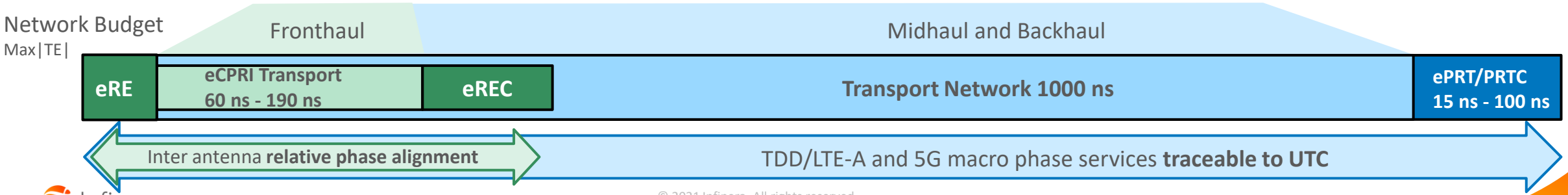
See Sync e-book in ITSF website downloads section

3GPP TS 38.104 Time Alignment Error
ITU-T G.8273.2 PTP T-BC Class C
ITU-T G.8275.1 Full Onpath Support
ITU-T G.8262.1 eEEC Synchronous Ethernet

ITU-T G.8271.1 Network Limits
ITU-T G.8273.2 PTP T-BC Class B/C
ITU-T G.8275.1 Full Onpath Support
ITU-T G.8262.1 eEEC Synchronous Ethernet

IP Router or Ethernet Switch with inbuilt T-BC

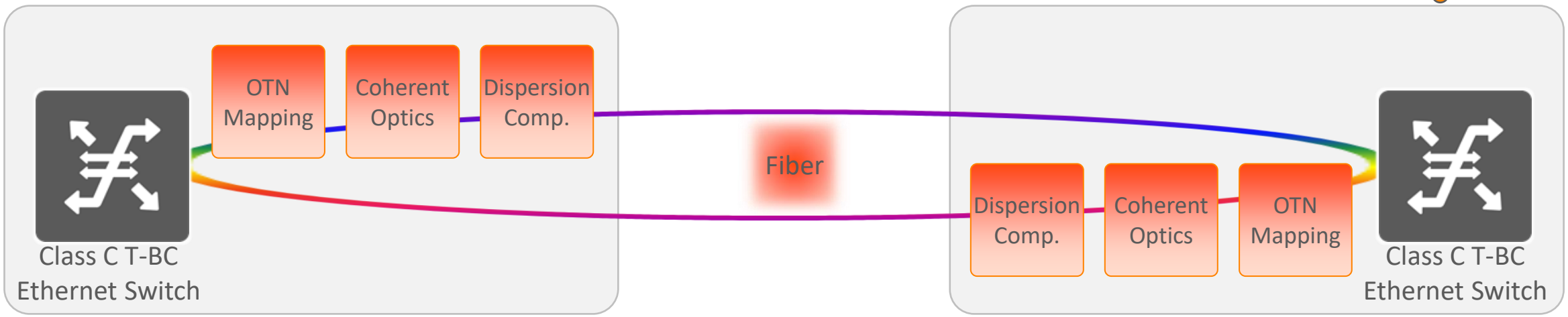



Infinera

# Example Causes of Asymmetry in Optical Transport

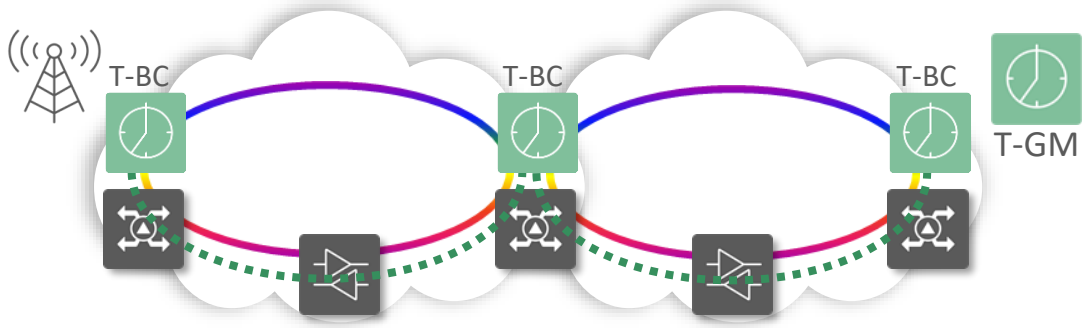
See Sync e-book in ITSF website downloads section




| Contributor | Fiber | Dispersion Compensation | Coherent Optics | OTN Mapping | IP Routing and Ethernet Switching |
|---|---|---|---|---|---|
| **Source** | Asymmetry in fiber lengths, jumper cables, etc. 2.5 ns/m (vs 5 ns/m latency) | Random asymmetry in DCF used in each direction | FIFO buffers in DSP<br>Varies on restarts | Deep FIFO buffers in OTN mapping<br>Varies on restarts | Traffic/buffering asymmetry and timestamping inaccuracy |
| **Impact** | Large but static | Very large but static | Varying and random | Large and random | Tight requirements to control impact |
| **Range** | Fixed cTE of ±5 to 1000+ ns | Fixed cTE of ±5 to 20,000 ns | Random cTE of ±20 to 130 ns on restart | Random cTE of ±20 to 1000 ns on restart | Class A/B/C specifications<br>Max(TE) of 30 to 100 ns<br>cTE of 10 to 50 ns<br>dTE (low-pass filtered) of 10 to 40 ns |

# Sychronization Distribution Strategies for 5G

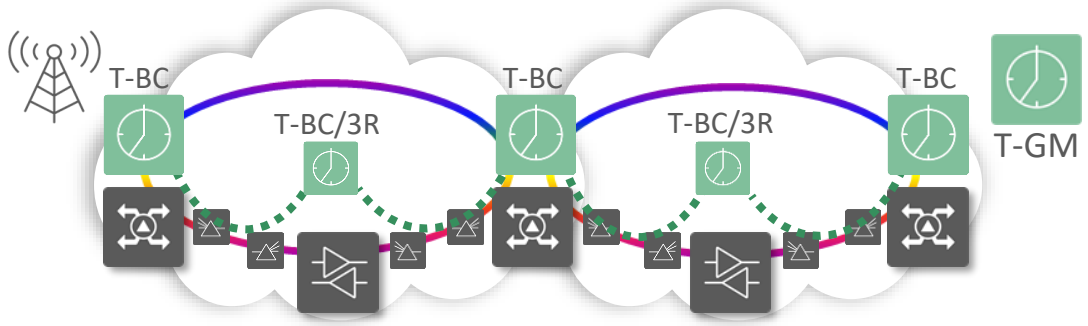
1. In-band Delivery




**In-band delivery of synchronization**

- Transponder synchronization performance
- Coherent synchronization performance
- High-performance PTP 1588 and SyncE delivery

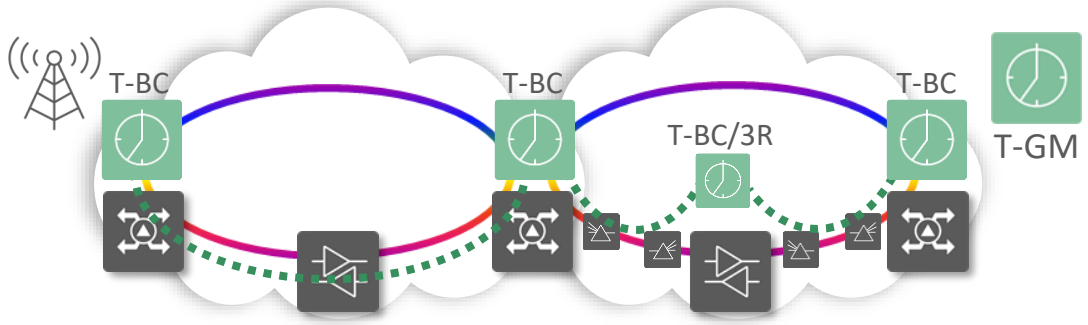
2. Optical Timing Channel




**Out-of-band delivery of synchronization**

- Very high-performance PTP 1588 and SyncE
- Single-fiber CWDM and O/E/L-band overlay
- OTC network elements:
  - T-BC Class D boundary clocks
  - Optical 3R regeneration

3. Hybrid Sync Distribution

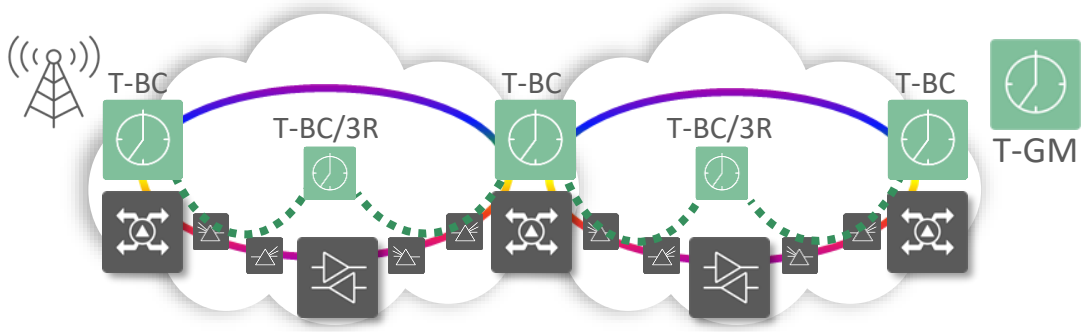


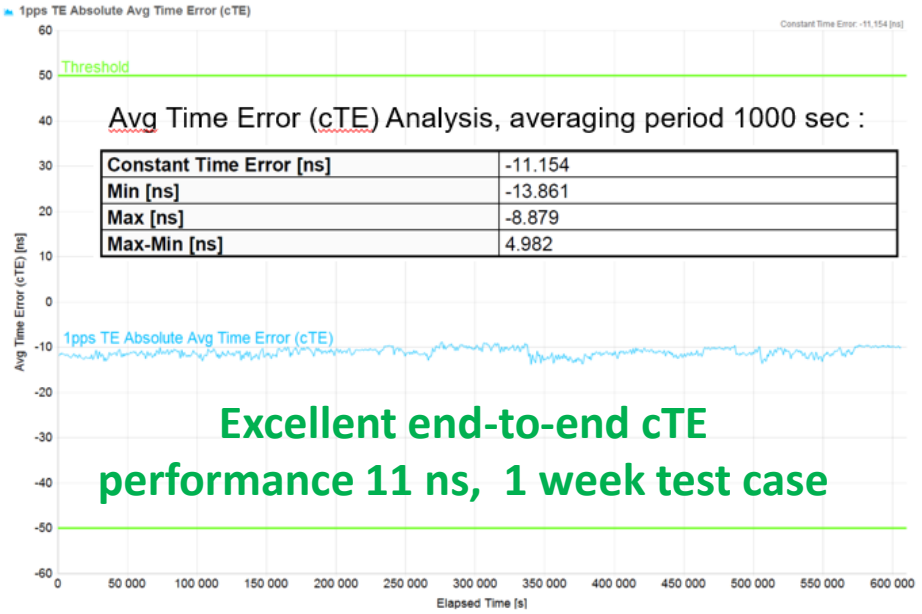

**Hybrid use of in-band and OTC mechanisms**

- Interoperable and interchangeable
- All high-performance 1588 PTP, not proprietary
- Use the appropriate solution for the best fit
  - In-band delivery perfect for metro-access
  - OTC widely used as core distribution

Infinera

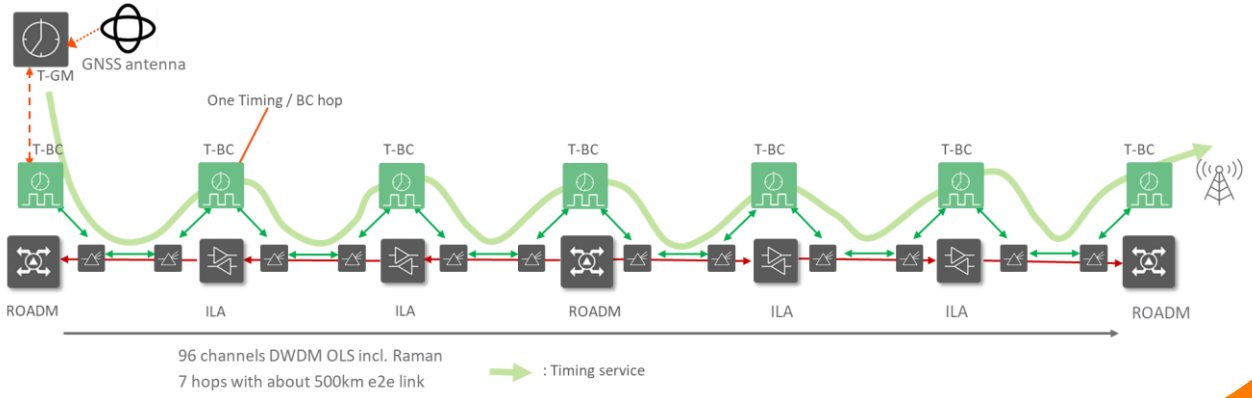
# Optical Timing Channel-based Synchronization Distribution



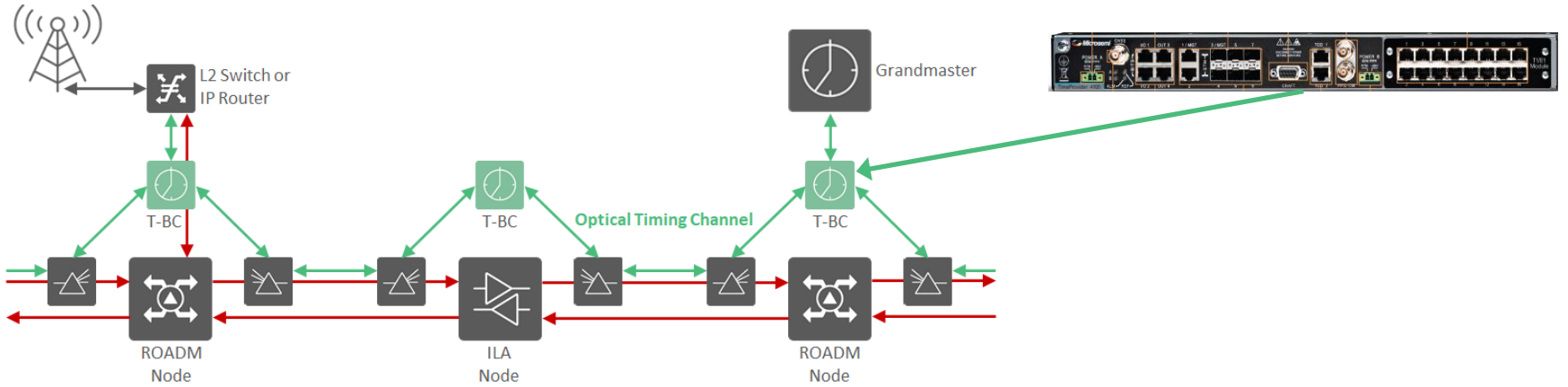




## KEY ATTRIBUTES/FEATURES:

- Supports nanosecond-level 5G sync distribution in challenging transport networks
- Class D sync distribution performance over transport networks
- Highly reliable and robust timing distribution with advanced resiliency mechanisms
- Extensive range of sync features and functionality
- Broad range of optical layer capabilities
- Broad range of supported network architectures and timing service delivery



# Building High-Performance Optical Timing Channels




## OPTICAL LAYER CONSIDERATIONS:

- Fiber topology and resiliency – Ring, Linear, Tree, Mesh
- Analogue domain – many factors to balance:
  - Managing fiber effects – asymmetry, non-linear effects, dispersion etc.
  - Optical add/drop – ROADM / Fixed add/drop
  - Amplification options – EDFA / Raman
  - Bandwidth – C Band / C+L Bands
- Optical Timing Channel Toolkit:
  - Timing channel options – O/E/L-band
  - Sync/Retiming options – High performance T-BC, Integrated T-BC (Router) or optical 3R

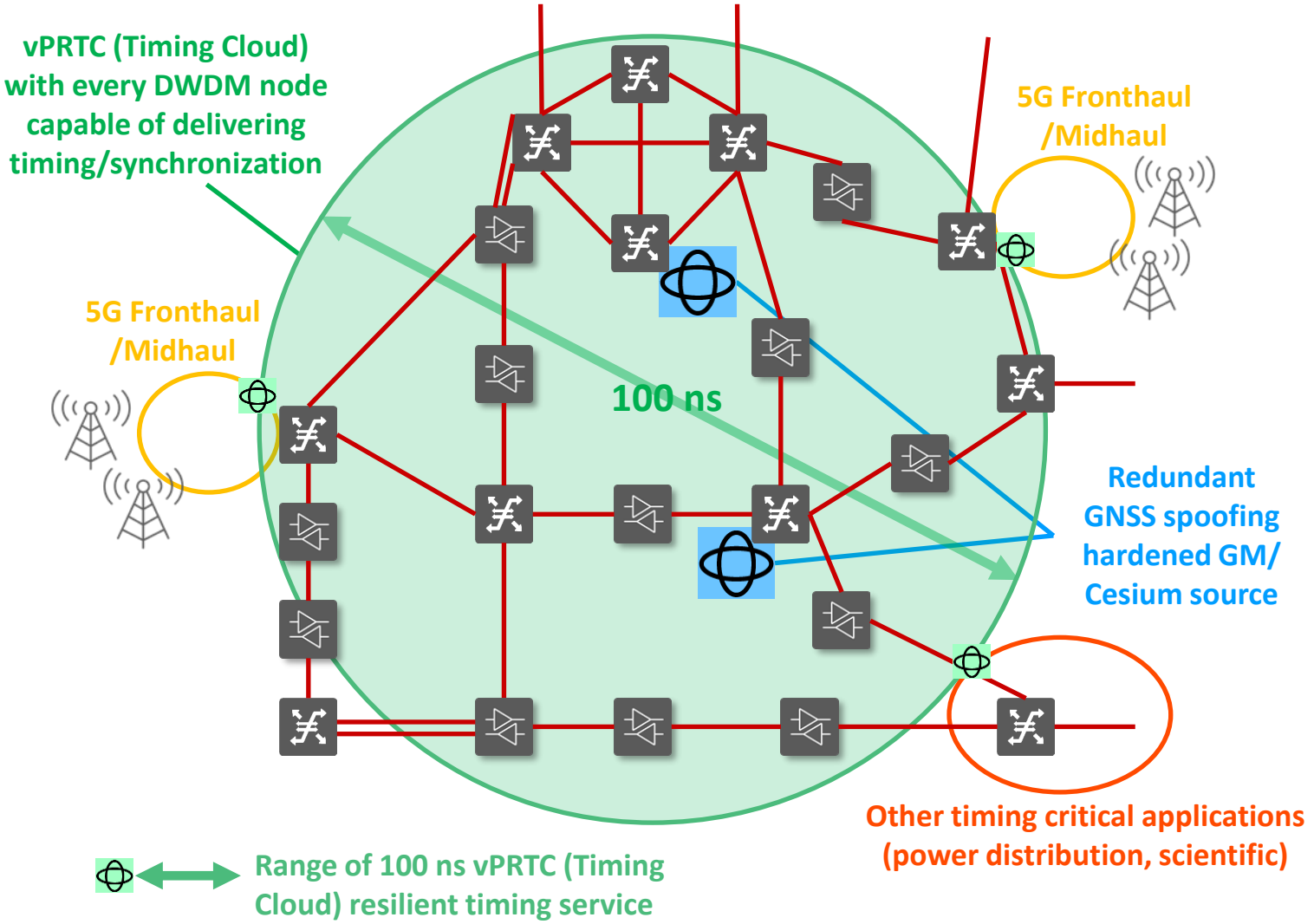
Optical Layer Foundation

## SYNC LAYER CONSIDERATIONS:

- High performance boundary clock operation
- vPRTC / Timing cloud architecture
- Demanding performance/feature requirements:
  - Class D cTE within ± 5 ns, max. |TE| <5 ns
  - Hop-by-hop local clock recovery, OCXO holdover
  - Resiliency mechanisms
  - GNSS/Grandmaster options
- Supporting optical layer interoperability:
  - BiDi single fiber working optics
  - Large (up to 14) number of degrees/directions

Infinera

# Creating an OTC2.0-enabled vPRTC/Timing Cloud

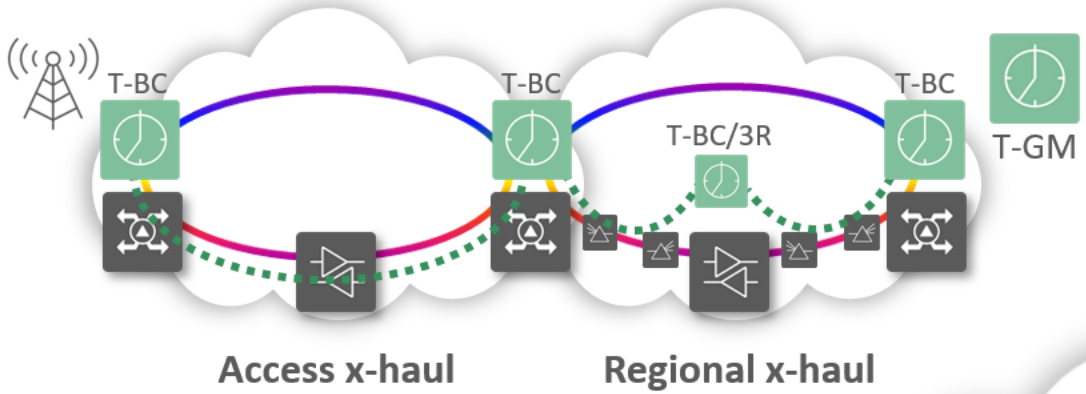



## OTC2.0-ENABLED vPRTC:

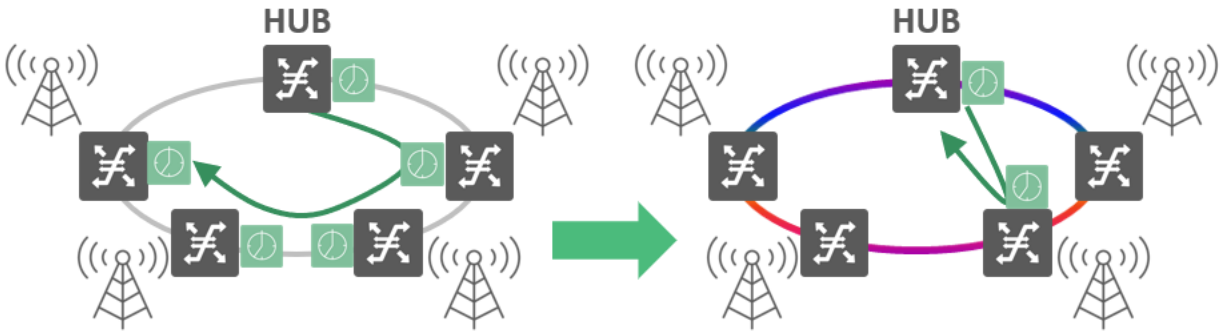
- Provides GNSS-like omnipresent timing, overcoming GNSS security/reliability/accessibility issues
- Uses secure and reliable optical network to deliver highly-accurate timing/synchronization:
  - Predictable, traceability to UTC and PRC
  - Reliable, resilient and secure
  - Highly-accurate
- Flexible and independent
- Every DWDM node capable of delivering timing/synchronization
- Preserves timing budget for access/aggregation networks
- Simplifies timing/synchronization planning and ongoing operations

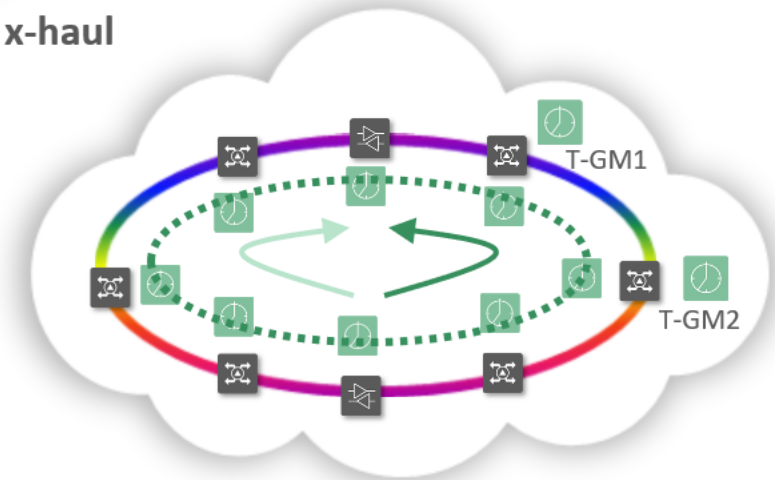
# Key Trends in Sync/Timing Distribution Networks

DEDICATED λ




TIMING CLOUD




## DWDM ACCESS RINGS:

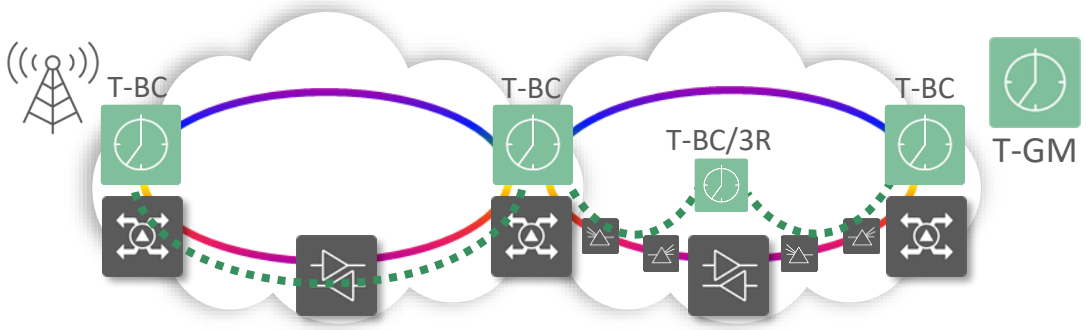
- 5G driving dedicated wavelength per node
- From hop-by-hop to DWDM sync engineering
- Can deliver 50% improvement in Timing Error

## RESILIENT TIMING CLOUD:

- vPRTC performance to all nodes
- Resilient and robust architecture
- Single OTC provides ***bidirectional timing service***

# Key Trends in Sync/Timing Distribution Networks

DEDICATED λ



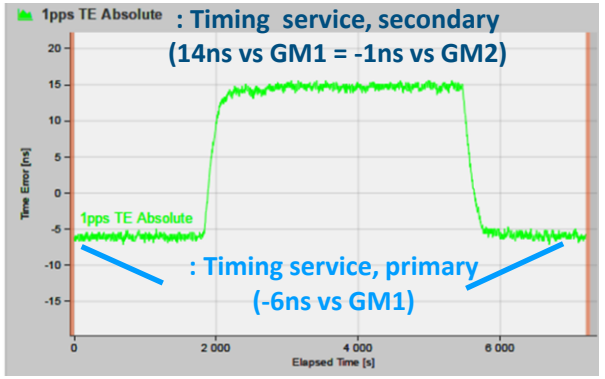

TIMING CLOUD

9 node pt-pt grey optics access ring:

$$\max|TE_9| \le \sum_{i=1}^{9}|20ns| + \sqrt{\{\sum_{i=1}^{9}[40ns]^2\} + [70\text{ns}]^2} = 180\text{ ns} + 138\text{ ns}$$ **~ 320 ns**

Vs dedicated DWDM access wavelength:

$$\max|TE_2| = 10\text{ ns} + 40\text{ ns} + \sqrt{\{\sum_{i=1}^{2}[40ns]^2\} + [70\text{ns}]^2} = 50\text{ ns} + 90\text{ ns}$$ **~140 ns**




## DWDM ACCESS RINGS:

- Sample 9 node access ring, a very typical customer case
- G.8271.1 calculation using G.8273.2 Class B T-BC and optimized DWDM elements with 10 ns cTE
- Max|TE| reduced from ~320ns to ~140ns

## RESILIENT TIMING CLOUD:

- No loss of synchronization, PTP slave is always locked
- Smooth and hitless switch-over between timing masters
- Reverts to same cTE as before incidence

Infinera


# Thank You