>BUSINESS MADE **SIMPLE**

# Investigation and testing of Layer 2 Timing Distribution using Ethernet Provider Backbone Transport (PBT)

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Prague, November 14-16, 2006

NORTEL

# Overview

> Investigation's goals

> Wireless backhaul reference and performance requirements

> Provider Backbone Transport (PBT) attributes

> Test results (IEEE1588, ACR) in a PBT reference network

- Immunity to low priority background step loads
- Immunity to high priority CES load
- PBT failover and restoration
- Fibre ring failover and restoration

> How PBT addresses concerns about Layer 2 Timing Distribution

> Further engineering considerations

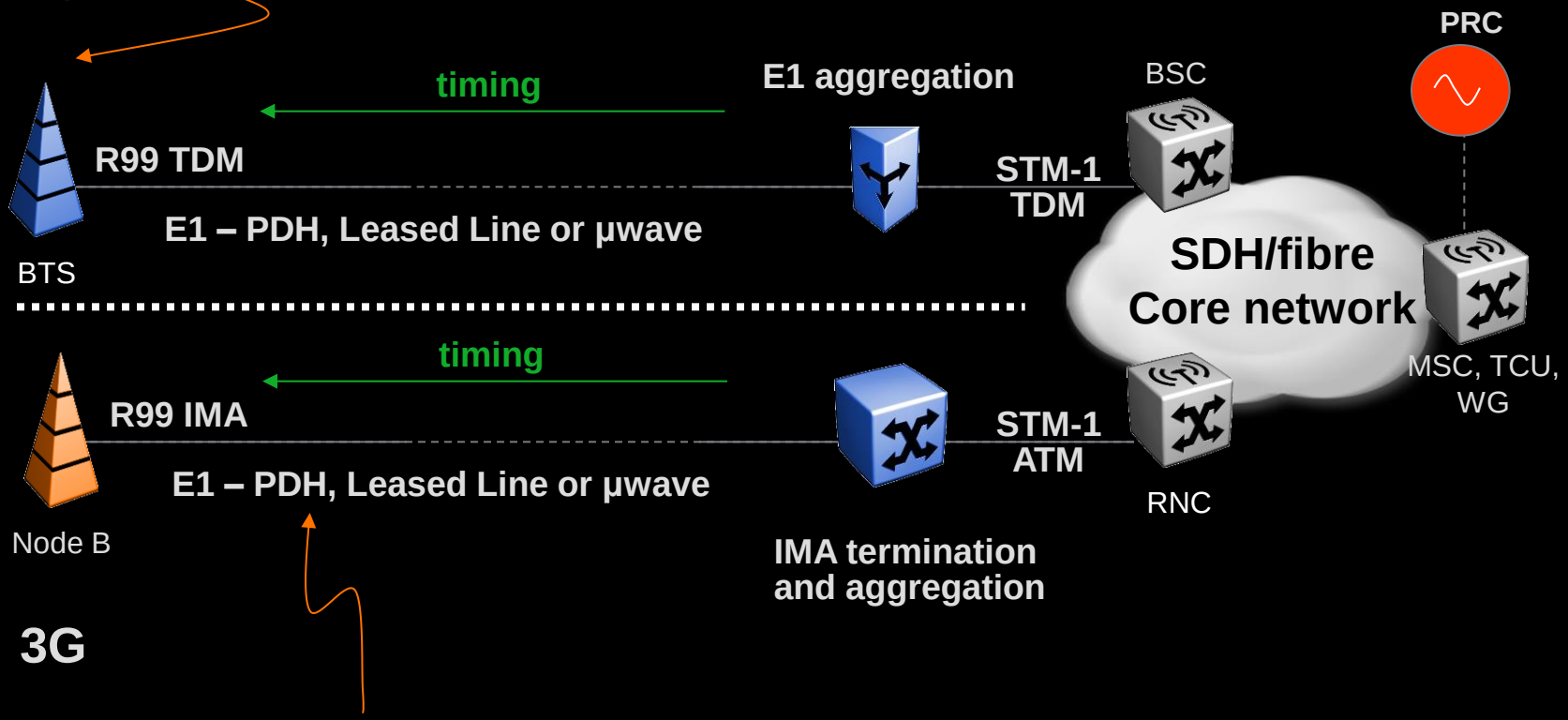
> Conclusions

# Goals

- To test the state-of-the-art in packet based layer 2 timing distribution over carrier grade Ethernet network
  - Engineered with Provider Backbone Transport (PBT)
- To establish acceptable performance to meet the demands of wireless backhaul
- To verify solution's completeness
  - Synchronisation performance alongside challenging impairments
  - Meet or exceed availability targets of PDH and SDH networks
  - Ease of implementation: simple network engineering and operation

# Current Wireless Backhaul Deployment

**Traceability to PRC per ITU-T G.811**
**To meet 3GPP TS 25.104, 25.402 and GSM 05.02**
**frequency accuracy of ± 50ppb @ RF interface**

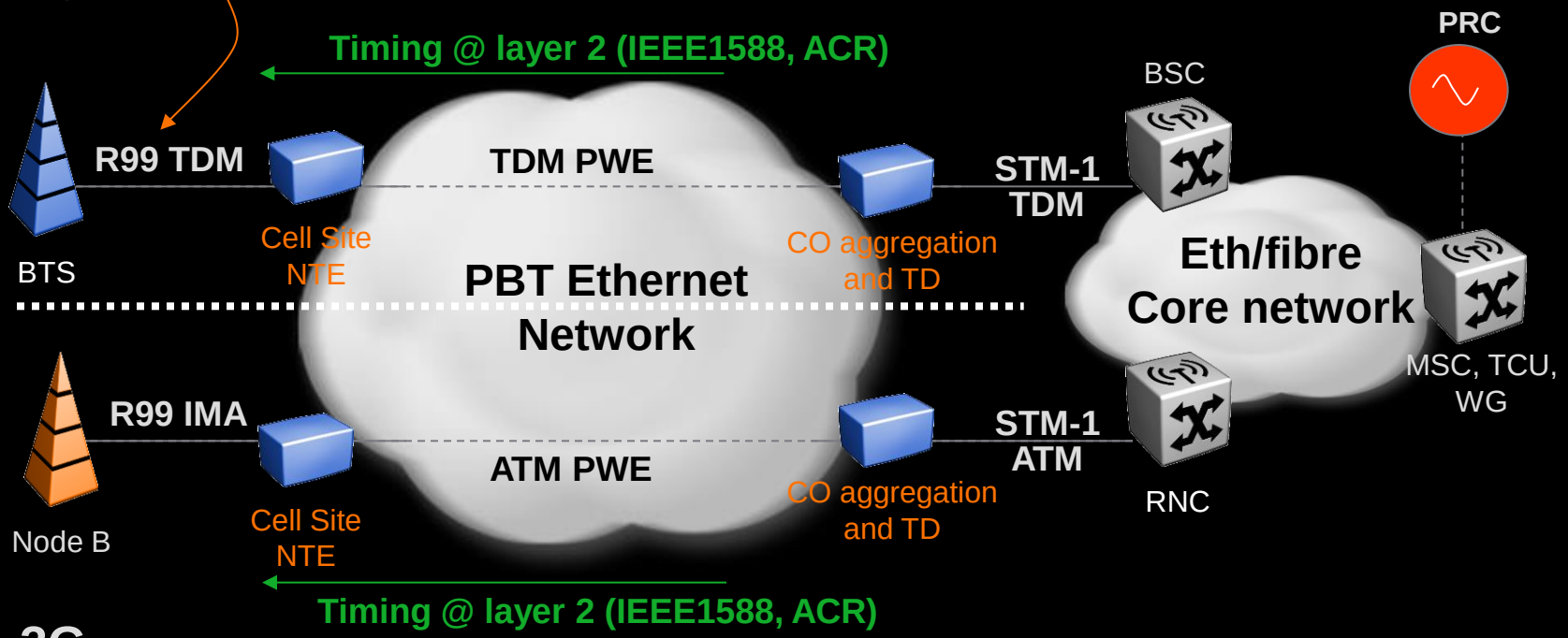



**To be better than ITU-T G.823* MTIE traffic interface**

***Similar requirements exist for T1 interfaces**

# Future Wireless Backhaul Deployment

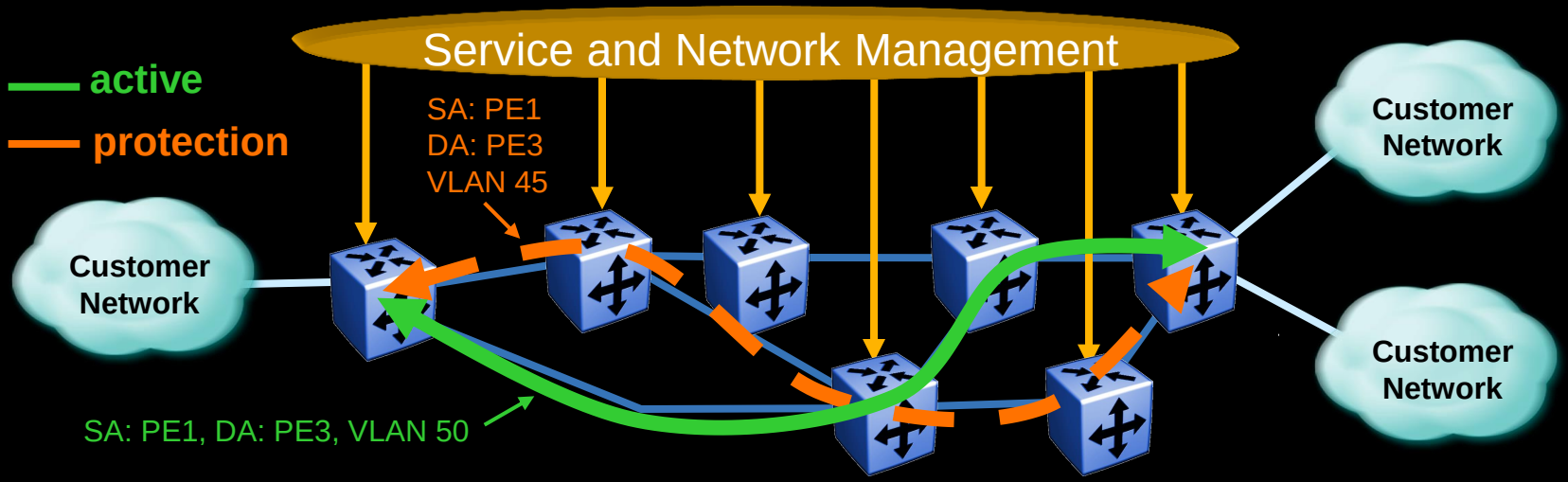
**To meet all current requirements (previous slide) and requirements being established in ITU-T G.8261**




**Ethernet metro and core can be built using PBT to carry all service (not just wireless backhaul) over one network**
**Ethernet network can optionally provide Layer 1 synchronisation**

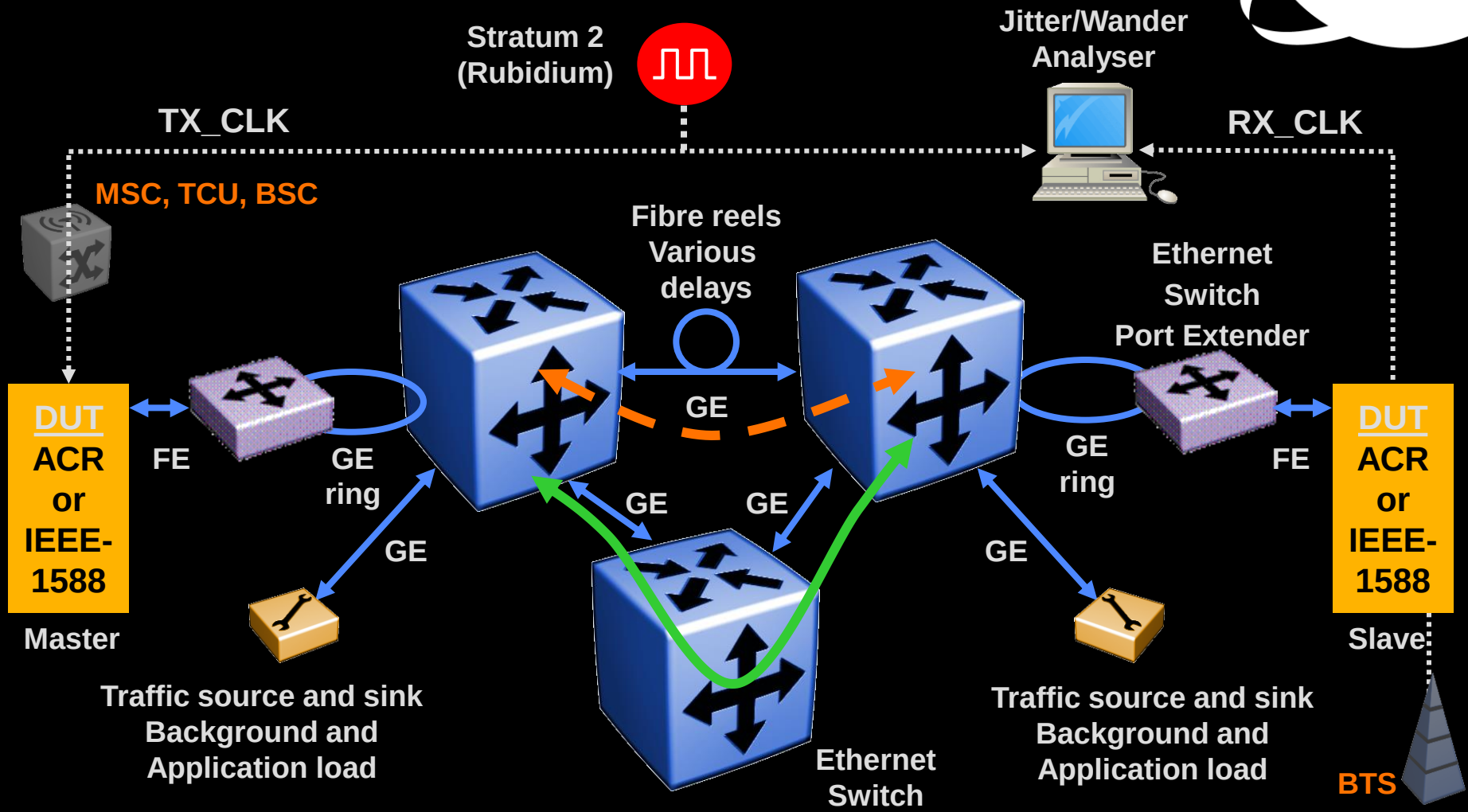
# Provider Backbone Transport (PBT)

- > PBT engineers protected point-to-point Ethernet connections
  - Management and Network Admission Control sets up active and protected connections
  - Both paths (active, protection) are monitored by control frames: 35 to 50ms switchover
- > PBT ensures tight resource control of the Ethernet network
  - Forwarding, Scheduling, Policing in switch assures Network Admission Control (NAC)
- > PBT secures the network by frame encapsulation at edge
  - Carrier addresses isolated from customer prevents eavesdropping and DoS



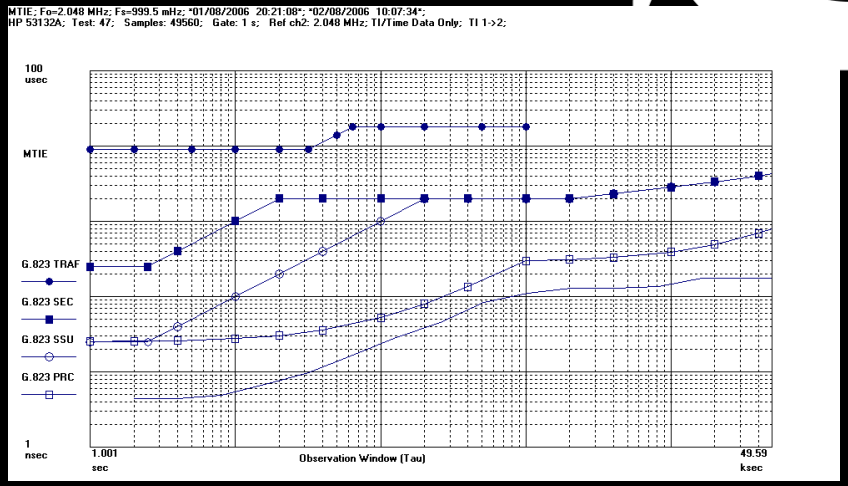

**PBT provides a deterministic environment for multiple services on the same network, and is a standard in ITU, IETF, IEEE, DSL Forum and TMF**

# PBT Layer 2 Timing Distribution Test Bed



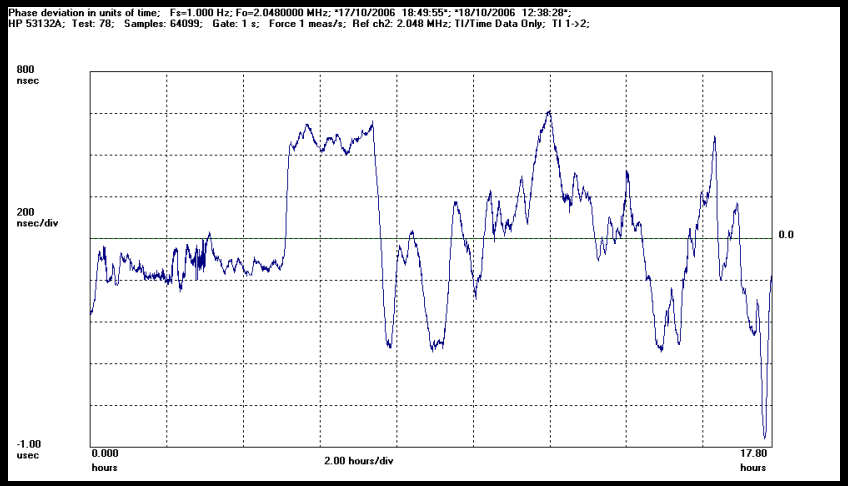
# DUT (Back-to-back) Baseline Performance

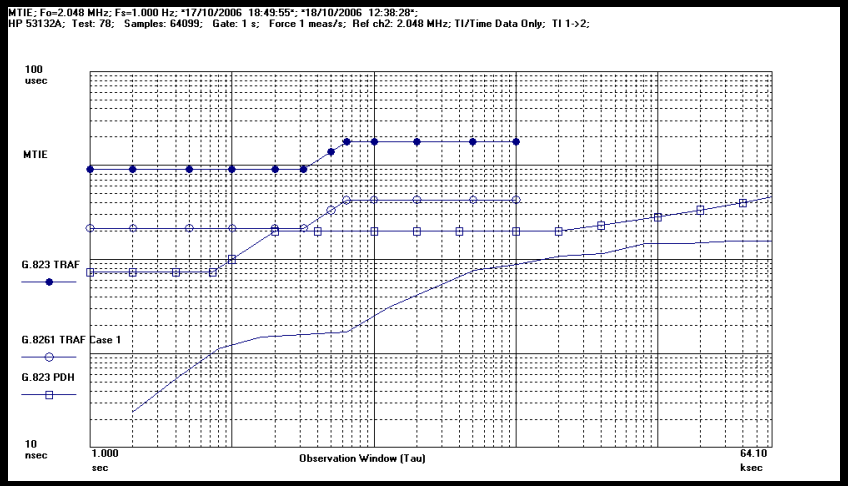
*Fs = 1Hz; Fdev = TIE/s; FFoFF = Fdev/Fo with no filtering


**IEEE1588: FFoFF* ± 3 to 4ppb; MTIE 100ns/1000s (180ns ref. T1)**

Providing time and frequency synchronisation




**ACR/CES: FFoFF* ± 12 to 16ppb; MTIE 900ns/1000s (1.6µs ref. T1)**

# Disciplined IEEE and ACR/CES
## PBT with low priority traffic overloads

> IEEE1588 and ACR/CES traffic marked priority 6 (strict-sense)

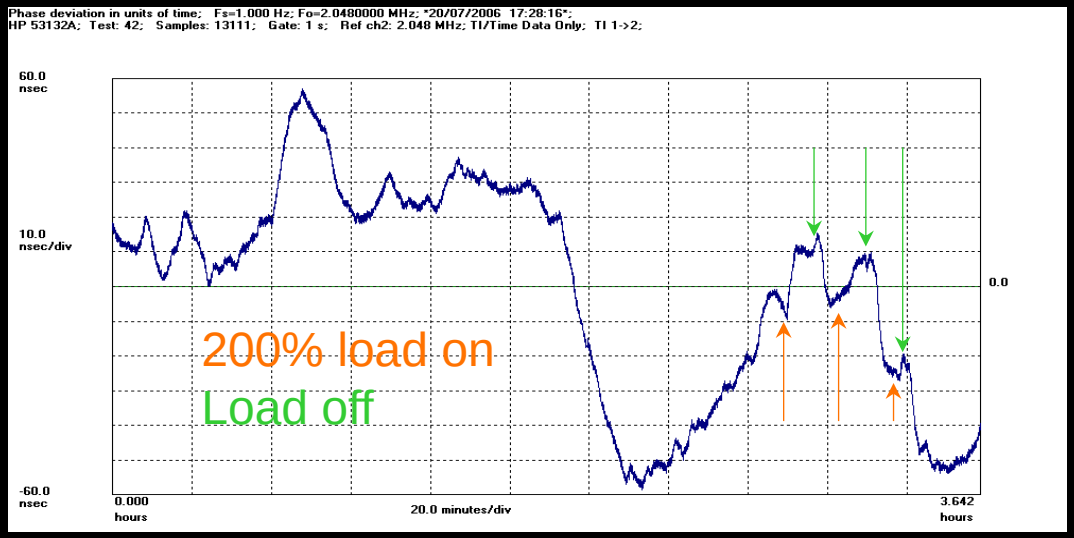
> Background load traffic priority 0 (best effort – preemptable)

> Load applied/removed

- 5 to 10 minute intervals
- 100% and 200% overload GE port rate
- Load fixed packet size = 64 octets (IEEE1588 = 64 octets)
  - Quiescent delay = 51µs, PDV spread = 3µs, PLR = 0%
  - 200% loaded delay = 115µs, PDV spread = 20µs, PLR = 0%
- Load fixed packet size = 1500 octets (ACR/CES = 318 octets)
  - Quiescent delay = 42µs, PDV spread = 3µs, PLR = 0%
  - 100% loaded delay = 97µs, PDV spread = 10µs, PLR = 0%
  - 200% loaded delay = 105µs, PDV spread = 20µs, PLR = 0%

**Investigates how well the PDV is attenuated by the application**

# Disciplined IEEE and ACR/CES
## PBT with low priority traffic overloads




TIE

## IEEE1588

MTIE

80ns/1000s (115ns ref. T1)
≈ back-to-back

FFoFF

± 3ppb ≈ back-to-back

## ACR

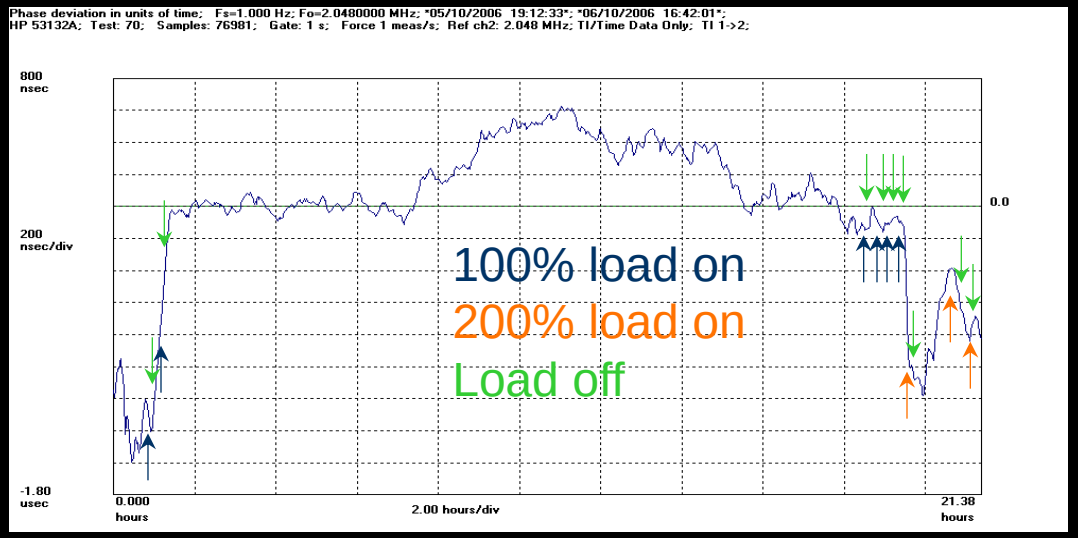
TIE

MTIE

1µs/1000s (2.2µs ref. T1)
≈ back-to-back

FFoFF

± 12ppb ≈ back-to-back



# Disciplined IEEE1588
## PBT with high priority CES traffic load

> IEEE1588 traffic marked priority 6 (strict-sense)

> CES load traffic marked priority 6 (strict-sense)
- CES traffic is bidirectional

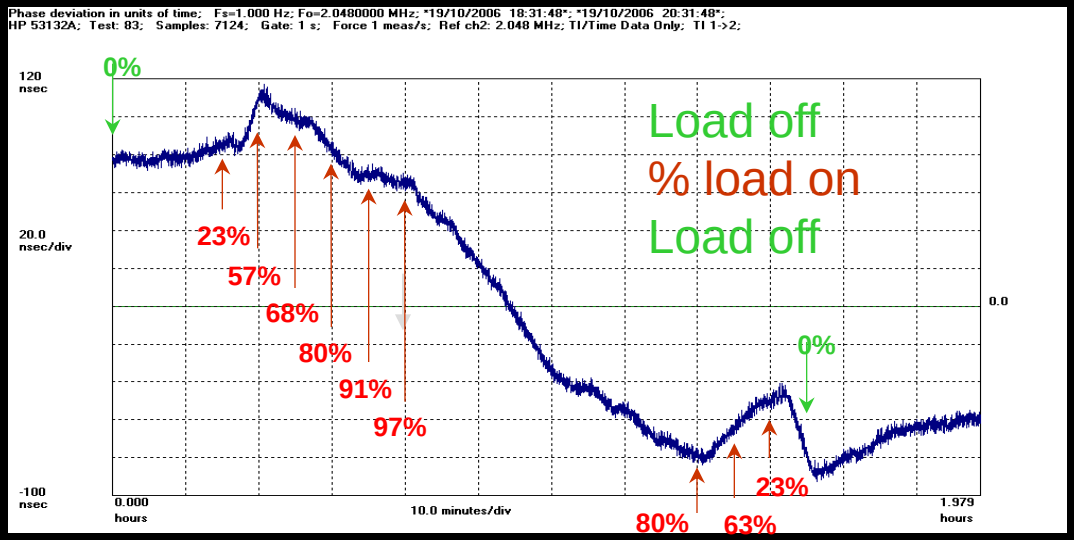
> Load applied, and stepped up/down
- 5 minute intervals
- 5 – 57% steps, between 0% and 97% of GE port rate
- 97% load held for 40 minutes, and also 9 hours
- Load fixed packet size = 318 octets (SAToP)

> IEEE1588 traffic impairment
- Quiescent delay = 51µs, PDV spread = 3µs, PLR = 0%
- 97% loaded delay = 62µs, PDV spread = 5µs, PLR = 0%

**Investigates how well IEEE1588 timing distribution will operate with large amounts of CES traffic, in medium/large switched steps**

# Disciplined IEEE1588

## PBT with high priority CES traffic load




TIE

**Medium step load**

**1h40mins**

MTIE

**90ns/1000s (205ns ref. T1)**

**≈ back-to-back**

FFoFF

**± 11ppb > back-to-back**

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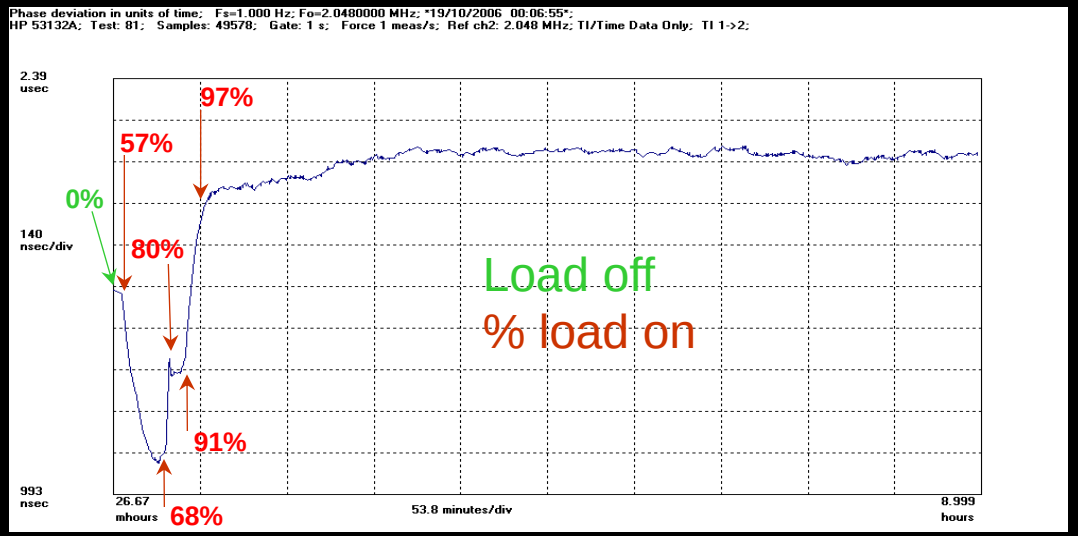
**Large step load**

**Held 9 hours**

TIE




MTIE

**600ns/1000s (1µs ref. T1)**

**> back-to-back**

**Still under G.8261 mask**

FFoFF

**± 11ppb > back-to-back**

# Disciplined ACR/CES
## PBT with high priority CES traffic (over)load

> ACR/CES traffic marked priority 6 (strict-sense)
- CES traffic is bidirectional

> Load applied, and stepped up/down
- 2 – 5 minute intervals
- 10 – 50% steps, between 0% and 97% of GE port rate
- Load fixed packet size = 318 octets (SAToP)

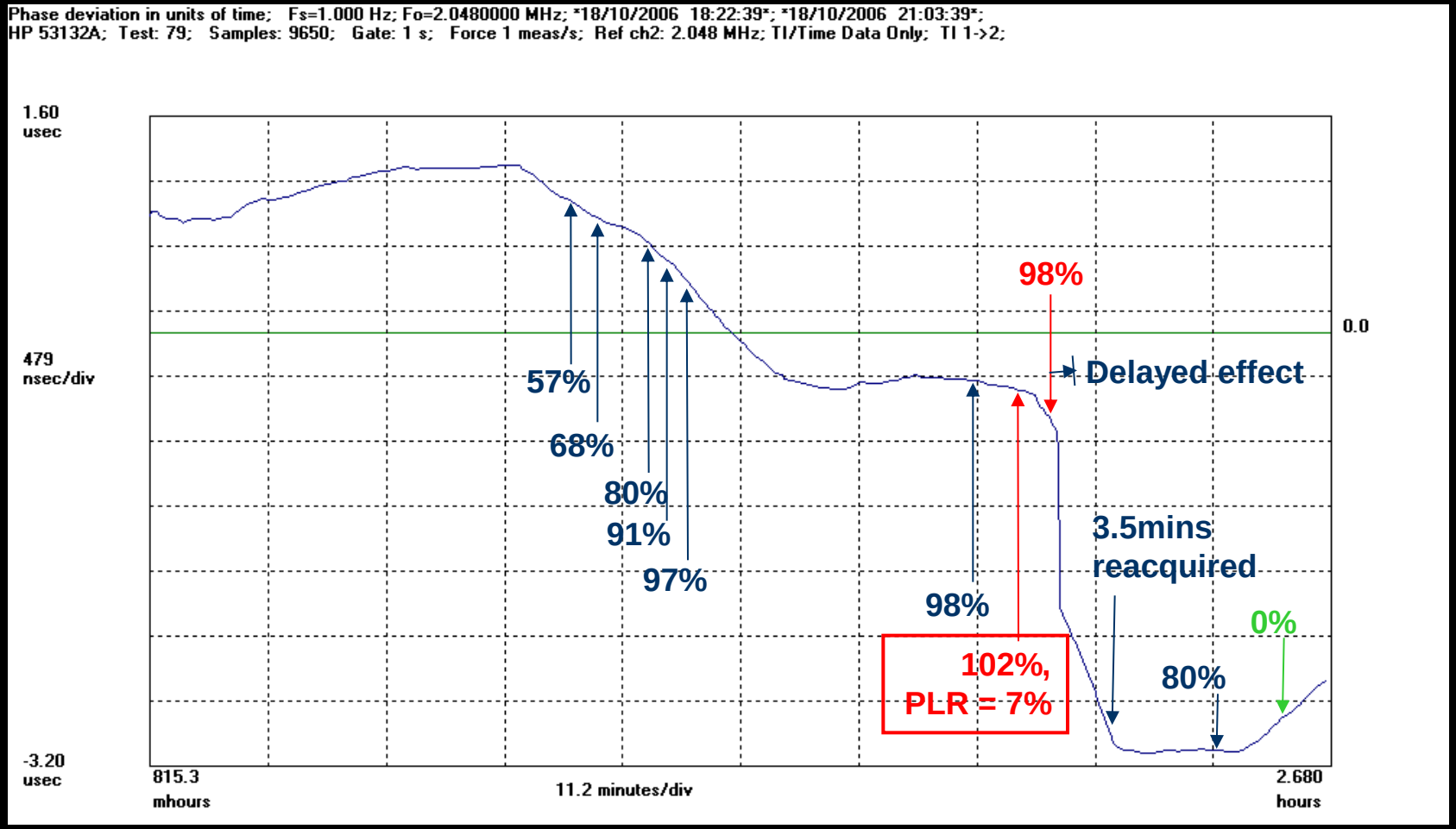
> ACR/CES traffic impairment
- Quiescent delay = 42µs, PDV spread = 3µs, PLR = 0%
- 97% loaded delay = 51µs, PDV spread = 5µs, PLR = 0%

> Deliberate overload of 102%, PLR = 7%
- Reversion to 97%, demonstrating re-acquisition under load conditions

**Investigates how well ACR/CES timing recovery will operate normally**
**Overload demonstrates why Network Admission Control is essential**

# Disciplined ACR/CES

## PBT with high priority CES, and a deliberate overload




**System goes into holdover on overload, i.e. when Packet Loss Ratio rises above nominal**

# Disciplined ACR/CES
## PBT failover with various path delay changes

> Failover to a back-up route within 35-50ms

> Delay on back-up route set between 300µs and 6600µs (1300km), steps of 260µs

> Successive failover and restoration at 10 minute intervals, 5 minutes in failover

> After restoration at each interval the back-up route delay was incremented

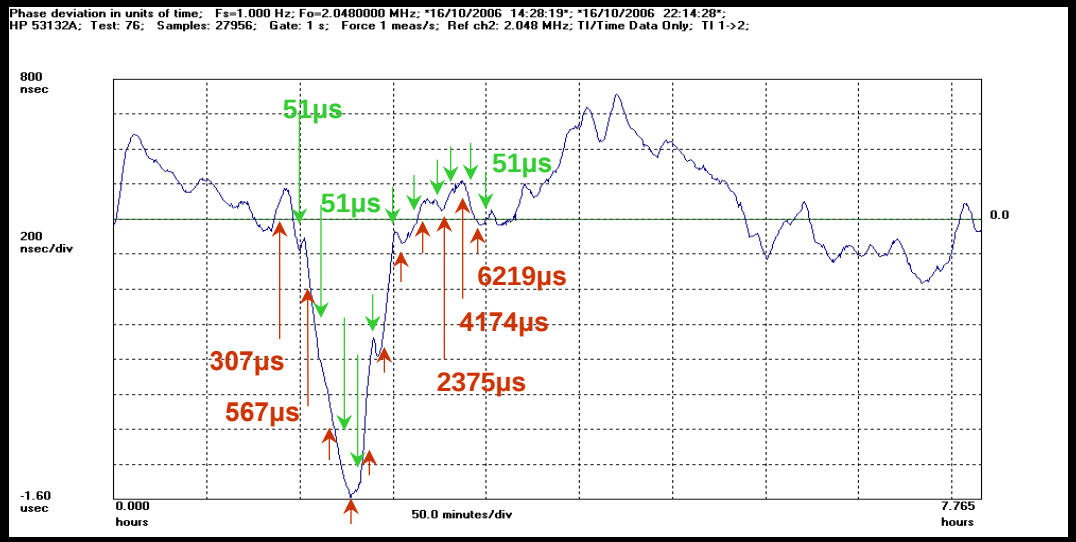
**Investigates how well ACR/CES timing recovery will operate when failover occurs and the path delay changes**

# Disciplined ACR/CES

## PBT failover with various path delay changes

Failover – to delay path (300µs to 6600µs, steps of 260µs or greater)

Restoration to direct path (51µs)




TIE

FFoFF

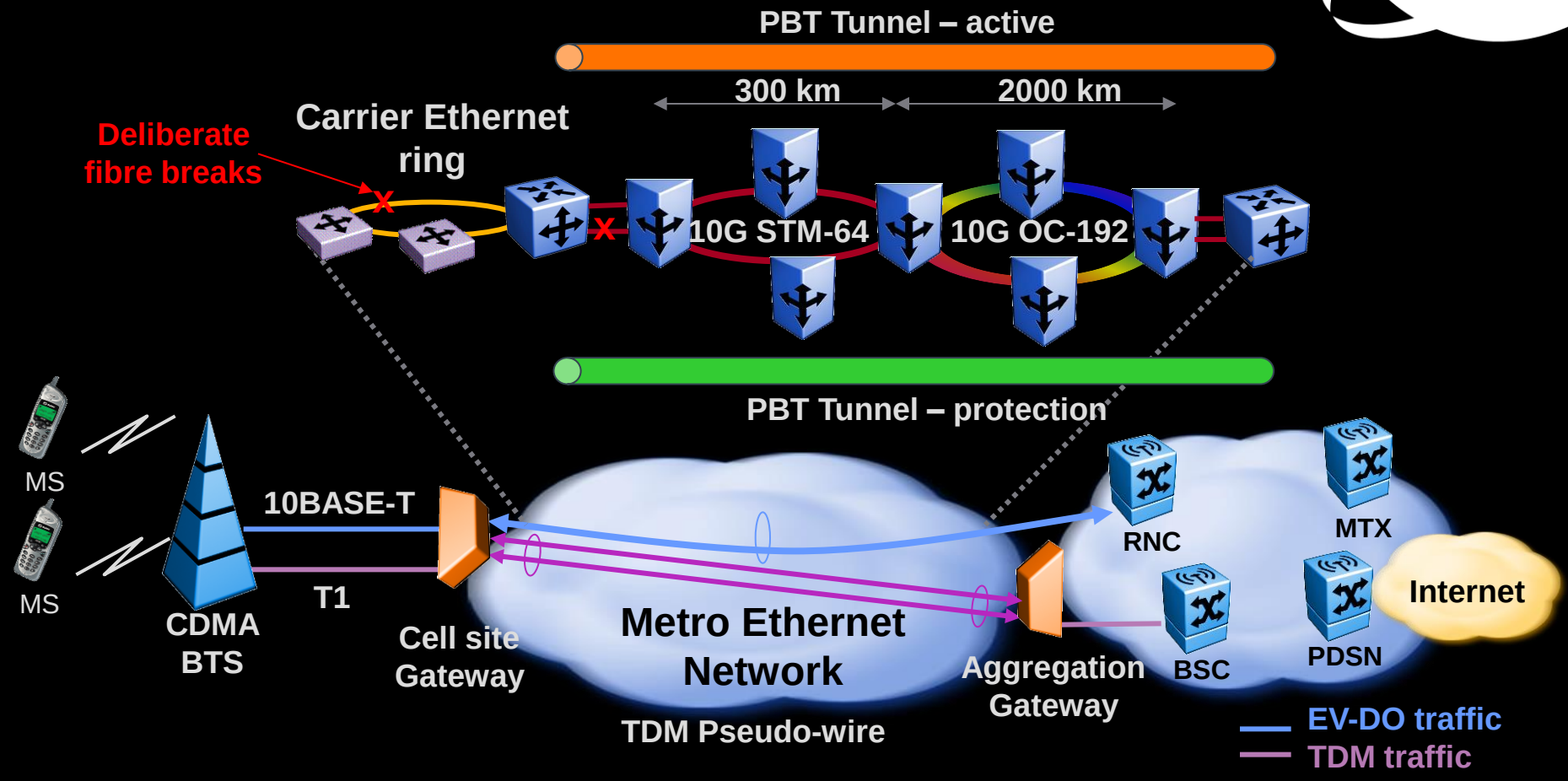
± 18ppb ≈ back-to-back

MTIE

1.5µs/1000s (2.2µs ref. T1)
≈ back-to-back

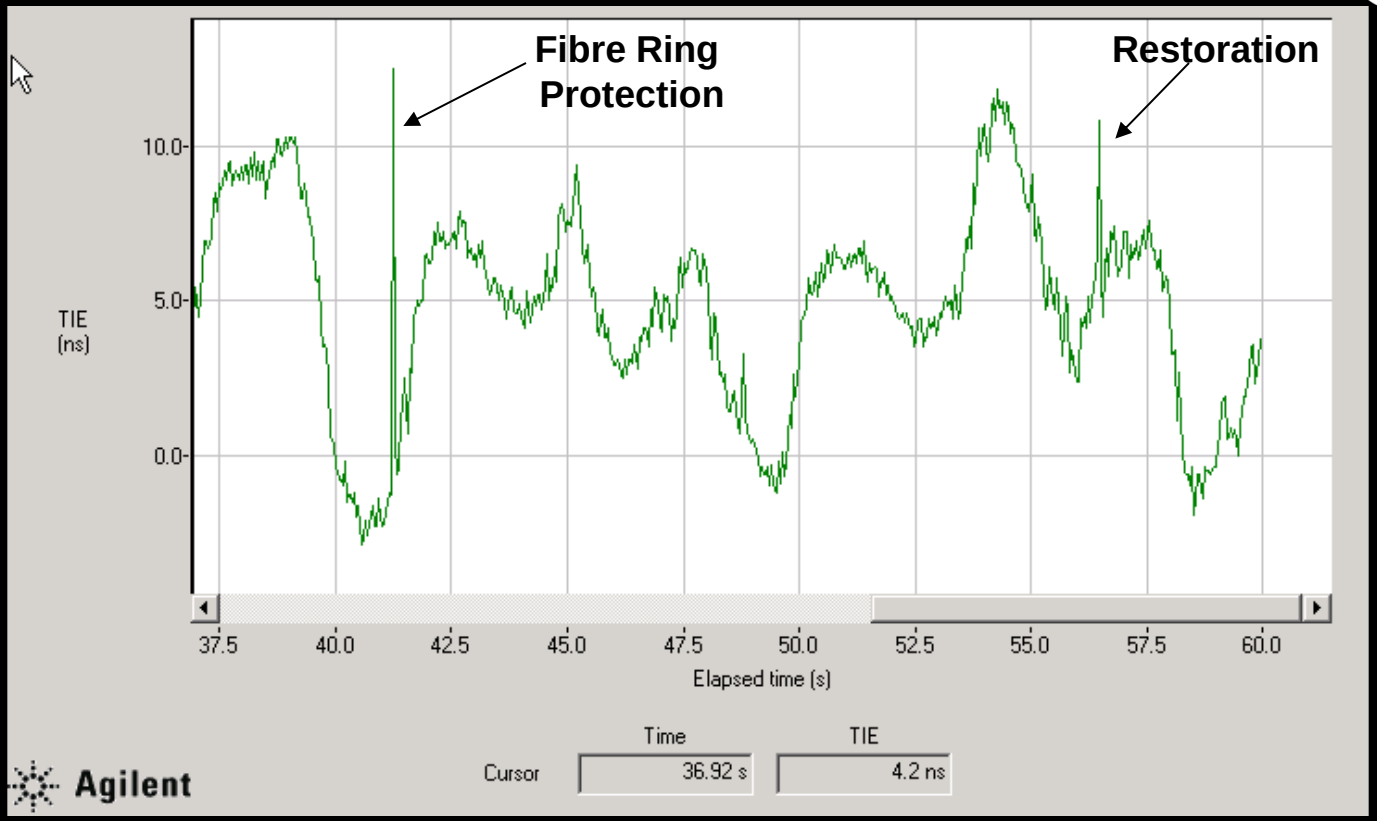
**Failover and restoration has been successfully achieved carrying live GSM calls, with no call drop or loss of synchronisation**

# CDMA BTS Backhaul
## Live PBT Network




**No slips reported for over 1 week duration in CDMA BTS backhaul**
**T1 jitter & wander within interface specification network limits**

# CDMA BTS Backhaul
## Fibre Ring Resiliency




**Protection & restoration switch on Carrier Ethernet ring did not impact wander generation at the cell-site gateway**

# Layer 2 Timing Distribution
## PBT is necessary to address impairments

- Load and PDV
  - PBT guards all service routes against overload
  - Can maintain service route utilisation at any desired operating maximum via NAC
  - Layer 2 timing distribution is marked Highest Priority, minimising PDV to just µs
- Low-frequency wander
  - Only CES or other uniform bidirectional traffic shares same route at same priority
  - Other traffic of bursty or varying profile (mobile data) restricted to lower priorities
- Stabilisation period
  - No overload or service interruption means no loss of synchronisation in service
- Changes in end-to-end delay
  - PBT guarantees symmetrical delay (normal/failover) – both ways are co-routed
  - Back-up path meets same criteria for load and PDV as primary path
  - Contributes considerably towards Layer 2 timing distribution
- Security
  - PBB address encapsulation at edge of PBT guarantees no eavesdropping or DoS

PBB: Provider Backbone Bridging (aka MAC-in-MAC)

# Further Engineering Considerations

- > Each switch model has idiosyncrasies, e.g.
  - Higher PDV than theory predicts
    - Software based scheduling may introduce delay artefacts
  - PDV may be a skewed distribution: mean close to maximum delay
  - Load direct A – B can also affect PDV in direction B – A
    - Most switches have a common fabric for both directions
- > Different vendor's switches yield different results
- > Standards must go further than specifying load tests alone
- > Network Impairment Emulators are now available that can establish the operating limits of Layer 2 timing
- > Tests specified in absolute terms of path delay changes and PDV limits (min, max, mean and sigma)
  - Repeatable
  - Transferable targets between labs
    - Layer 2 timing vendors, switch vendors, and network engineers

# Conclusions

> PBT provides an ideal environment to ensure the performance of Layer 2 Timing Distribution technologies
  - Management layer Network Admission Control prevents overload
  - Uniform traffic (ACR/CES, IEEE1588+CES) can be as high as 97% load
  - Non-uniform traffic sent at lower priorities minimises interference
  - Failover switching times as fast as SONET, SDH, and WDM fibre
  - Security via flexible VPN model with edge carrier address isolation

> Tests conducted so far with ACR and IEEE1588 over PBT show that both can achieve wireless backhaul synchronisation requirements

> Further soak tests are planned in the coming months, including failover tests with IEEE1588

**Live calls and data download have been successfully made over PBT on GSM and CDMA networks, using Layer 2 Timing Distribution and CES**
**All equipment worked in specification**