The Test of Time

Testing the Functionality, Timing Accuracy, Performance, and Scalability of IP/Ethernet Networks

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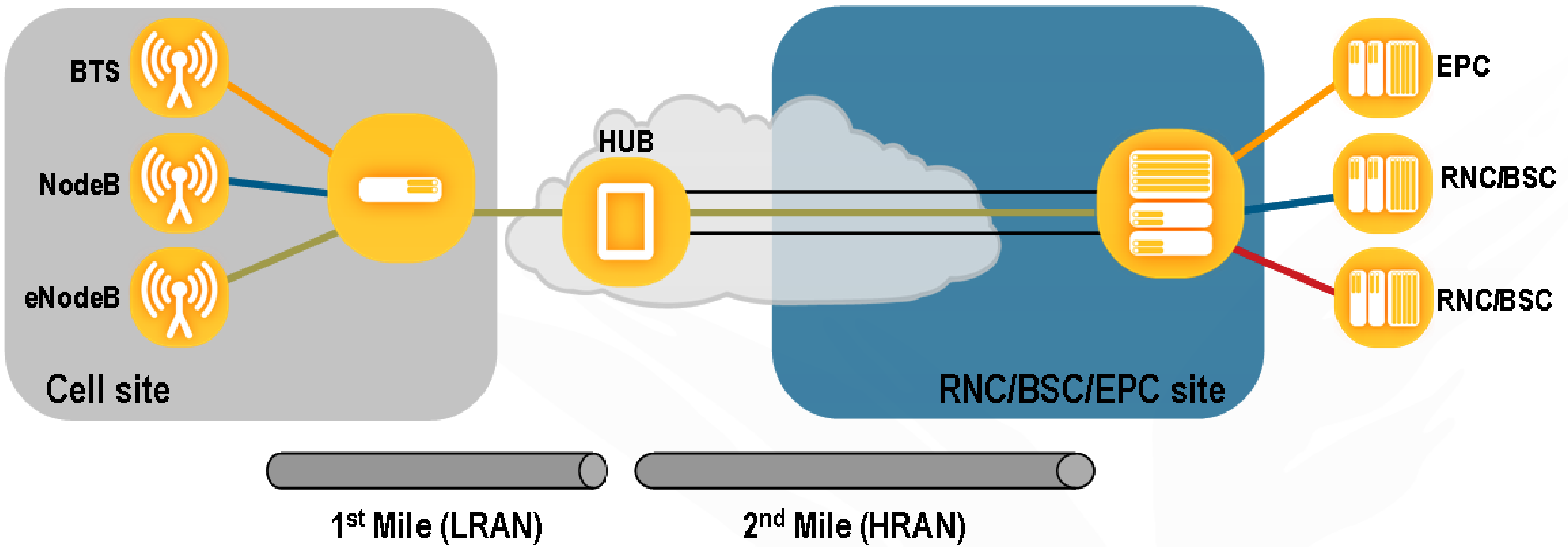
Mobile Backhaul is a Key Application for 1588v2

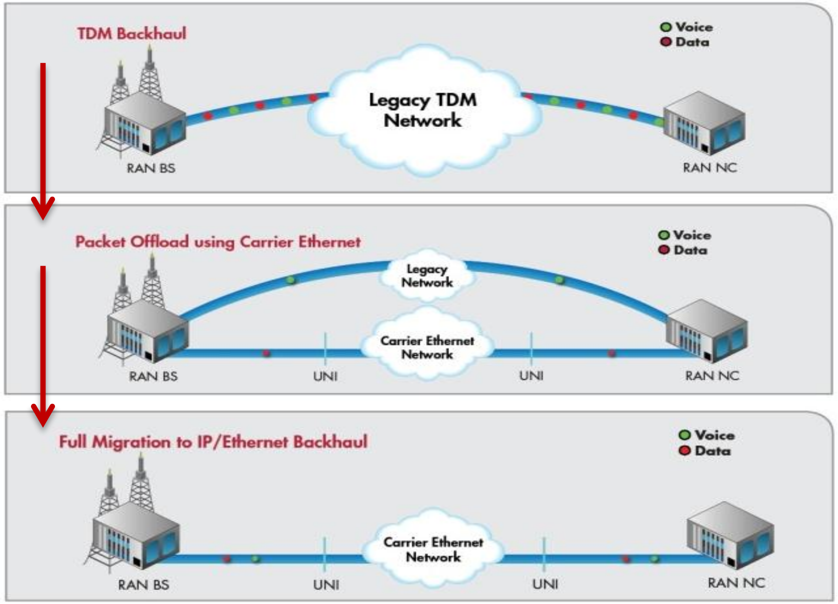


- **Mobile backhaul** is used for transporting mobile traffic between the macro BTS/NodeB and BSC/RNC or the eNodeB and the EPC site, including equipment used in hub points in the metro network
- IP/Ethernet equipment is over 90% of mobile backhaul equipment spending
- Global mobile backhaul equipment hit $7.5B in 2011, forecast steady, slow growth in 2012, up 3% to $7.7B. MBH eqpt. = $9.7B in 2016

Source: Infonetics Research, Oct 2012

IP/Ethernet Mobile Backhaul Deployment

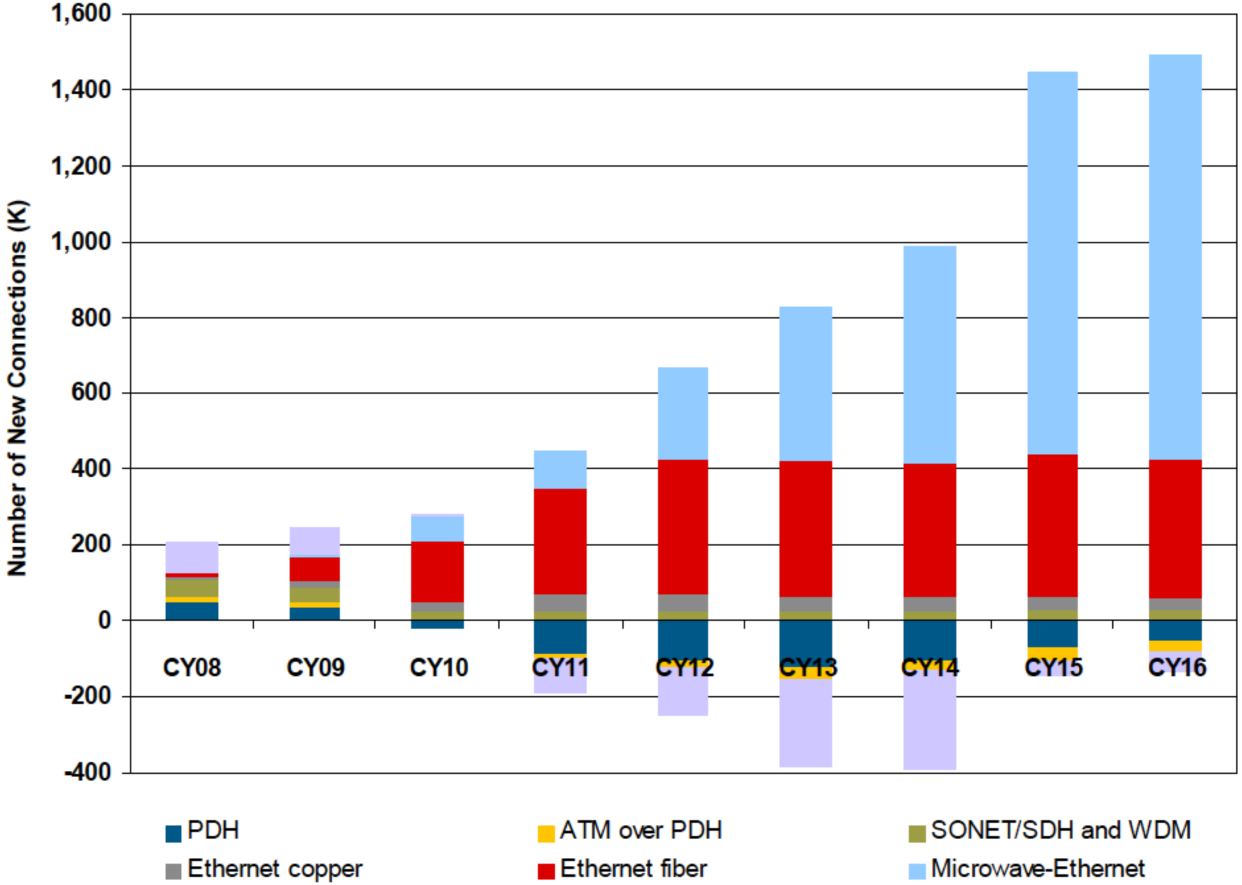
- Drivers
  - Lower the costs of growing mobile data traffic
  - Accommodate the 3G mobile broadband data transition
  - Move to IP as the basic technology of LTE (and WiMAX)
- IP/Ethernet growth
  - 94% of 2012 MBH equipment spending is IP/Ethernet gear, and 58% of that is packet microwave
  - ~200 mobile operators are actively deploying IP/Ethernet backhaul in 2012, up from 150 in 2011, 100 in 2010, and 25 in 2009
- Most carriers aggressively deploying 1588v2, others using TDM and or GPS to provide timing while not fully migrated



MEF: Migration to IP/Ethernet

Source: Infonetics Research, Oct 2012

Mobile Backhaul key application of timing over packet



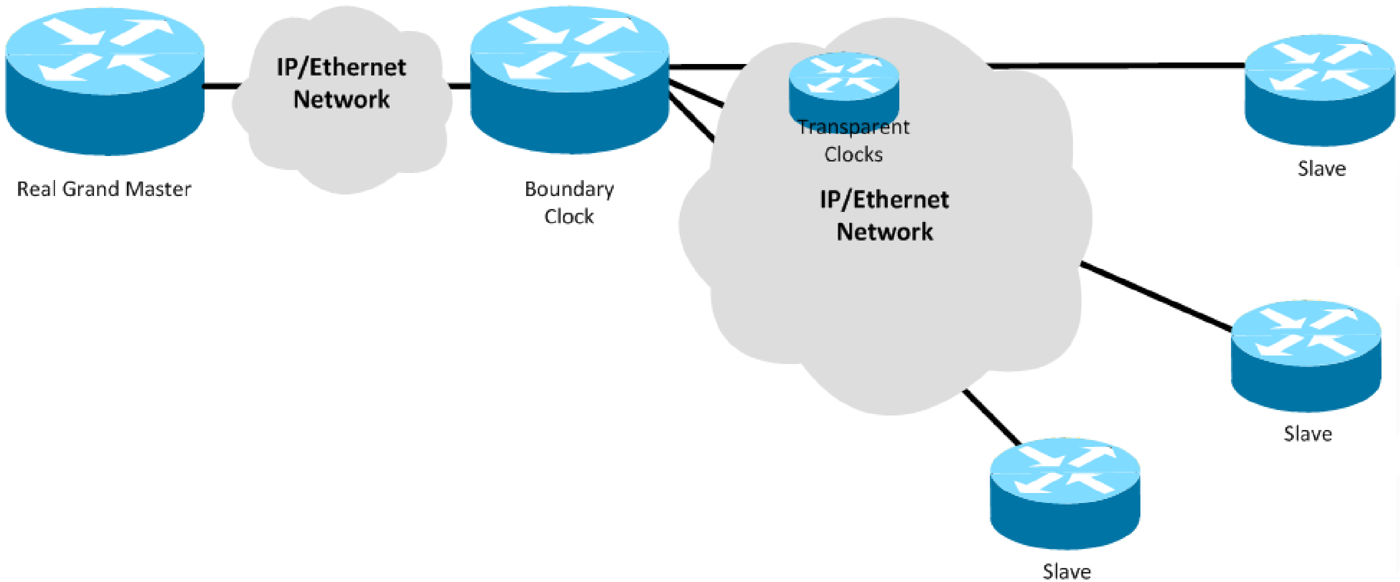
Source: Infonetics Mobile Backhaul Equipment and Services (2012)

Ethernet Synchronization Solutions

- Physical layer (SyncE)
  - Use a synchronized clock for Ethernet PCS
- Packet layer for frequency
  - CES, SAToP, Pseudo-wire
- Packet layer for time & frequency
  - PTP, NTP
- Focus here is mainly on **PTP (1588v2)**

XIXIA Anue

Ixia 1588v2/PTP Emulation



- 1588v2 device types: Master, Boundary, Transparent and Slave

Testing distribution of timing on IP/Ethernet Networks

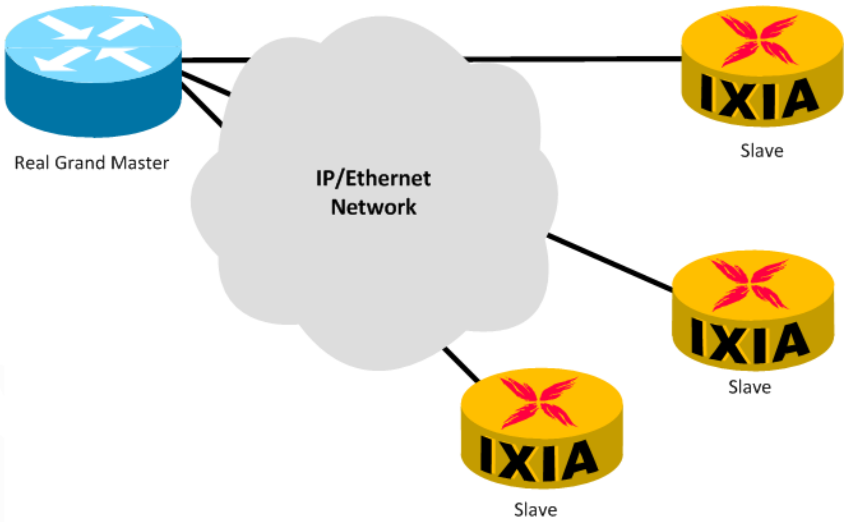
Real-world testing – multi-protocol networks with realistic network conditions

Clock quality testing – test accuracy and resiliency of clock

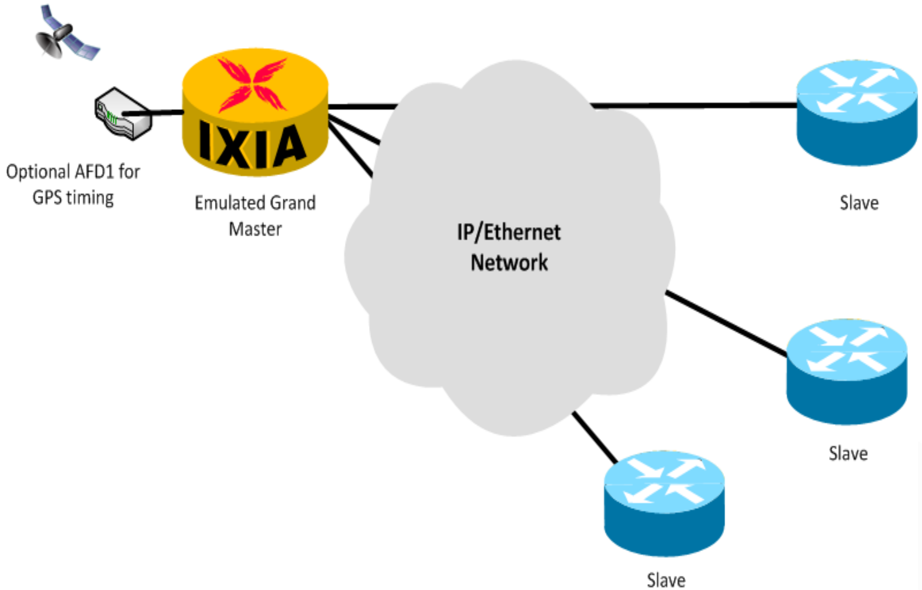
Protocol testing – verify functionality, performance and scale

1588v2 Protocol Testing - Master

- **Testing a Grand Master Clock**
  - 1588v2 is a “tool box” with many options
  - Ethernet, IPv4 or IPv6
  - Multicast or Unicast
  - Delay-Request/Response, Peer Delay or One-way
  - Priority: 802.3P, IP ToS or DiffServ
  - clock parameters
  - Configurable message rates
    - Sync @ 1/32s vs Sync @ 1/128 = message rates 4x faster per slave if unicast
  - Becoming more common to require a profile like Telecom Profile G.8265.1 for frequency
  - Need to make key measurements: min/max/ave offset, path delay, all message counters and rates
  - Slave scalability – need to be able to capacity plan

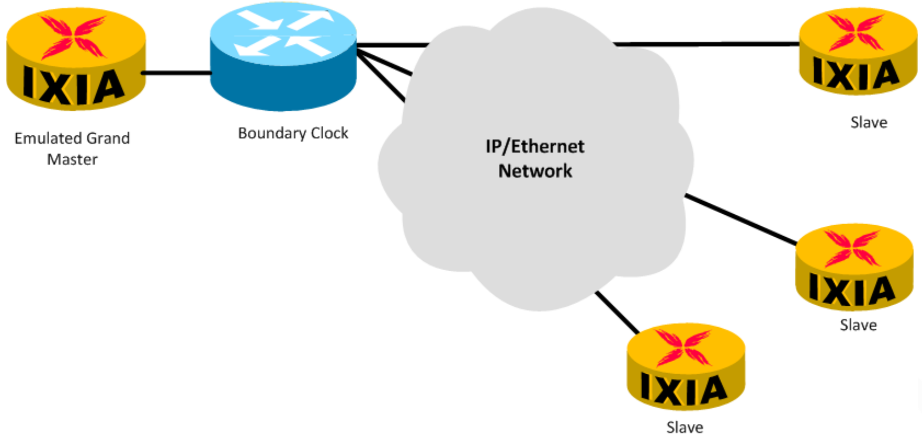


1588v2 Protocol Testing - Slave

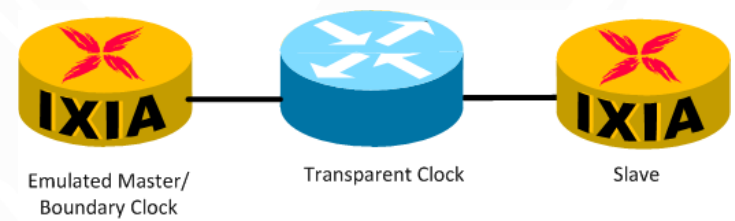


- **Testing Slave Clocks**
  - Ethernet, IPv4 or IPv6
  - Multicast or Unicast
  - One-step or Two-step
  - Delay-Request/Response, Peer Delay or One-way
  - Priority: 802.3P, IP ToS or DiffServ
  - All clock parameters including BMC
  - Messages rates:
    - Sync Interval Log -9 (512/s) to Log 9 (1 per 512s)
    - Announce Interval Log -9 (512/s) to Log 9 (1 per 512s)
    - Delay Request Interval Log -9 (512/s) to Log 9 (1 per 512s)
  - Telecom Profile G.8265.1 parameters
  - Key measurements: min/max/ave offset, path delay, all message counters and rates
  - Test Best Master Clock algorithm

1588v2 Protocol Testing – Boundary and Transparent

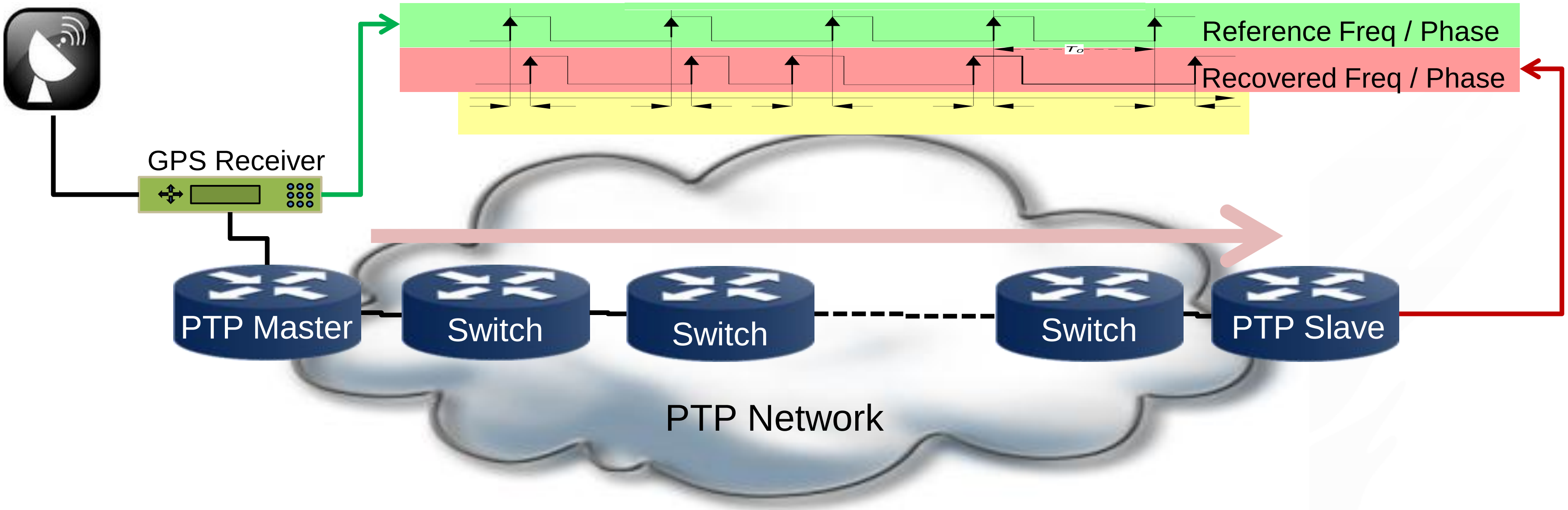


- Test **boundary clock** ability to be slave to the master and master to connected slaves



- Test **transparent clock** ability to accurately modify the correction field (CF) of each PTP packet

Clock Quality in a 1588v2 Network



- Time (frequency, phase, ToD) is distributed from PTP Master, and recovered at the slave device for use by remote network equipment
- Packet network between master and slave includes a number of switches or routers
  - Causes non-linear timing impairment, known as PDV, due to traffic congestion, queuing, etc.
  - Boundary Clocks and Transparent Clocks are PTP-aware switches with on-path support that can reduce the effect of PDV on a synchronization network

Synchronization Networks – Wander

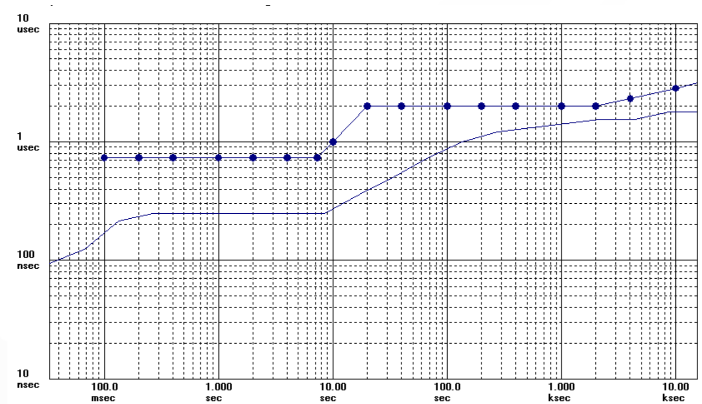
- Wander
  - Physical-layer deviation of a clock signal compared with a reference
    - If linear, indicates an offset; If time-varying, viewed in terms of frequency
  - Measured with Time Interval Error (TIE)
    - MTIE & TDEV are calculated from TIE data
  - **Wander is a property of a *physical clock***
  - Clocks recovered from Ethernet packet network may have wander
    - Must be evaluated using TIE, MTIE and TDEV
    - Limits and masks defined by ITU-T standards
- Wander of the recovered clock is often **caused by PDV**
  - Use of boundary clocks & transparent clocks reduces the effect of PDV

Clock Quality - MTIE & TDEV

- Wander is evaluated using two metrics: MTIE and TDEV
  - Amplitude is in units of time (ns), against an observation interval “tau”
    - The TIE data is analyzed in progressively larger windows or intervals of time, which are plotted on the X axis
    - “Tau” is the width (in time) of this window from which the value of MTIE or TDEV is calculated
    - Tau is related to time, but is not the same as time!
  - MTIE – Maximum Time Interval Error
    - Maximum difference of any two data points within the given value of tau
    - Useful indicator of buffer size, cumulative frequency offsets
  - TDEV – Time Deviation
    - Represents the spectral content of the TIE data
    - Useful indicator of periodic effects
  - ITU-T standards specify masks for testing MTIE and TDEV

What To Test for PTP Equipment

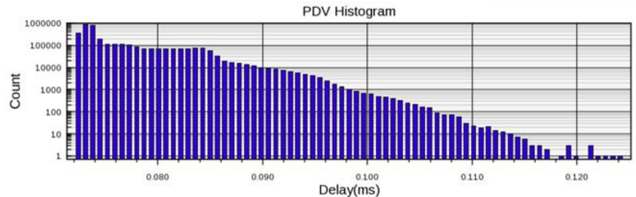
- G.8261 Test Cases
  - PDV of network emulated using precise profiles with Anue 3500
  - Wander on the recovered clock of slave is evaluated according to the ITU-T standards (MTIE & TDEV)
- Time Error & Phase
  - Compare 1PPS of master with slave
    - LTE requirement: <1.5us
  - Measure PTP packet time error
    - Boundary Clock timestamp accuracy (time error)
    - Grandmaster Clock timestamp accuracy (time error)
  - Transparent Clock correction field accuracy



MTIE Plot example
- Top line is mask
- Bottom line is measured TIE
- Staying below the mask indicates a “pass”

Slave Clock – Testing to G.8261

- Slave Clock (aka Ordinary Clock) Functionality
  - Receives timestamps from sync and follow-up packets from master
  - Calculates network delay using delay request, delay response sequence
    - Time at the slave is compensated using this calculated one-way delay
    - Asymmetry due to rate adaptation, load balancing, etc. can cause time/phase error
  - Delivers the recovered clock to the host or network
    - Traditional slave clock delivers synchronization
      - Frequency – 2.048MHz, T1, E1
      - Phase – 1PPS aligns “top of the second” for time synchronization
    - Embedded slave may deliver time to the host such as a switch/router or server
  - PDV in the network affects recovered clock accuracy
    - Slave clocks are normally tested using G.8261 test cases
    - PDV is added according to G.8261 test case between master and slave
    - Recovered clock interface is measured for accuracy and compared to a mask



Delay Stats (ms)		
	Delay	Time
Minimum	0.072	00:07:38
Maximum	0.124	00:16:02
Average	0.076	

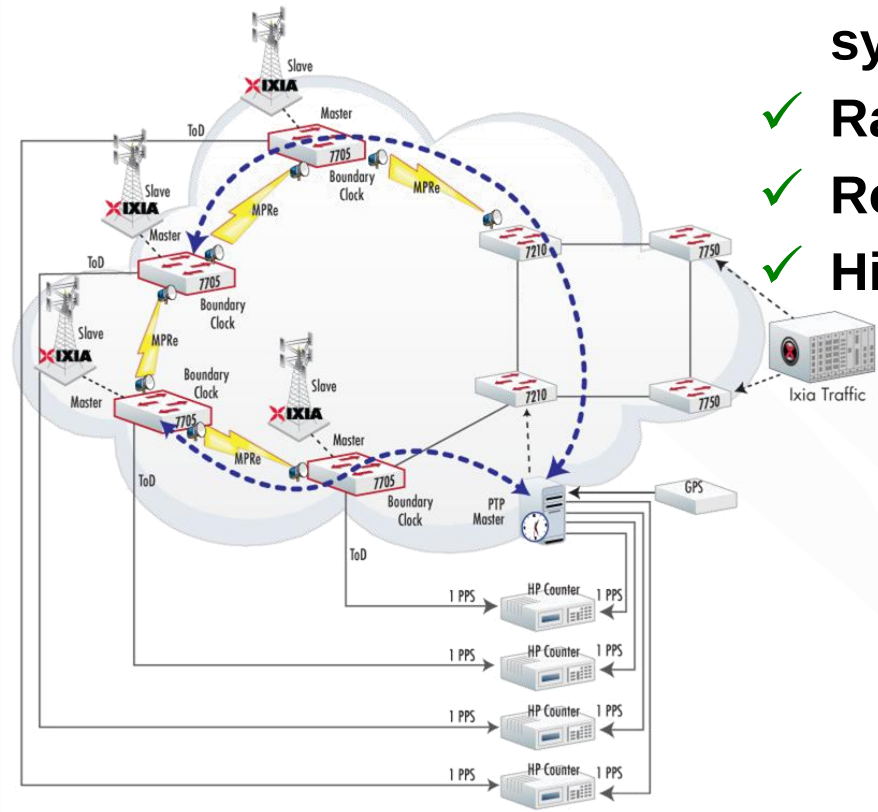
Boundary Clock – Testing Timestamp Error

- Boundary Clock Functionality
  - Switch or router at network boundary (subnet, provider edge, etc.)
  - Derives frequency and time from slave port connected to a Grand Master clock through the network
  - Provides sync (frequency & time) on one or more master ports connected to slaves downstream
    - Time stamps in outgoing sync/followup packets are generated by the BC using its PTP implementation.
- Potential for timestamp error – same effect as PDV
  - Caused by: queuing delays, inaccurate clock recovery, network congestion, etc.
  - These non-linear timing errors that cannot be distinguished from PDV and have the same effect at slave device as PDV (causes wander)
  - Timestamp error of Boundary Clocks must be evaluated

Transparent Clock – Testing Correction Field Accuracy

- Transparent Clock Functionality
  - Ethernet switch positioned between PTP devices
  - Transparent Clock calculates the ***residence time***, amount of time a PTP packet is delayed as it is forwarded through the switch
  - Residence time is added to the PTP packet's ***correction field***
    - Multiple TCs in a network may each increment the correction field as a PTP packet makes its way through the network
  - Correction field of PTP packet is used by slave to compensate for PDV
- Potential for correction field error
  - Inaccuracy in the correction field can reduce the effectiveness of the transparent clock to remove the cumulative effects of PDV
  - Correction Field accuracy must be evaluated

MWC 2012 Demo of 1588v2



- ✓ Scalable frequency and phase synchronization
- ✓ Rapid clock re-alignment after failover
- ✓ Robust under real-world conditions
- ✓ High performance under heavy traffic

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Barcelona | 27 February - 1 March 2012

Video: http://www.ixiacom.com/ixiatv/customer_testimonials/index.php

- Test Case this year included
  - Testing Boundary Clocks
  - Testing Transparent Clocks
  - Testing hybrid mode (PTP and SyncE)
  - Testing Ethernet Microwave transport
  - Tested best master selection
  - New measurement metrics and impairment profiles
  - G.8265.1 Telecom Profile was tested but did not have wide vendor support
  - G.8275.1 for Phase was not yet ratified
- Issues
  - Boundary clocks did not have compatible feature set (one had one-step only, the other had two-step clock)
  - Limited support for G.8265.1 Telecom Profile
  - Transparent Clock inserted a constant value for correction factor
- Successes
  - Several transparent clocks tested successfully
  - PTP and SyncE hybrid tested successfully
  - PTP over Ethernet Microwave tested successfully

- Many participating vendors requesting testing of basic Master and Slave clock implementations
- IxNetwork was used to run slave scalability tests for master clocks
- Both IxNetwork and Anue 3500 were used to test accuracy of transparent clocks
- Tested PTP over Ethernet/VLAN, IPv4 and IPv6 – found issues with IPv6
- Only a few Boundary clock implementations
- Significant interest in the Power Profile
- Interest in AVB(802.1AS) using PTP for Audio-Video bridging

Thank You!

Questions?

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