1588v2 Performance Validation for Mobile Backhaul

May 2011

Executive Summary

Many mobile operators are actively transforming their backhaul networks to a cost-effective IP-over-Ethernet paradigm. One of the last remaining hurdles to widespread acceptance of this transformation is demonstrating that packet networks can address the synchronization requirements for 2G, 3G, and 4G mobile networks.

The IEEE 1588v2 Precision Time Protocol (PTP) standard addresses frequency, phase, and time-of-day synchronization requirements, making it ideal for applications such as LTE TDD.

Ixia and Alcatel-Lucent engaged in a rigorous test exercise to validate the performance and robustness of 1588v2 boundary and transparent clock implementations under traffic load and scaled mobile backhaul network conditions. The demonstration included a state-of-the-art 1588v2 implementation on Alcatel-Lucent's 7705 Service Aggregation Router (SAR). Infonetics' Mobile Backhaul and Services report (October 2010) shows Alcatel-Lucent as the market leader in mobile backhaul router sales for the second year in a row. Ixia's IxNetwork application, running on high-density 1GE load modules, was used to emulate the grandmaster clock and hundreds of 1588v2 slave clocks, and perform traffic generation and analysis.

Test measurements verified that the Alcatel-Lucent 7705 SAR boundary clock (BC) implementation successfully synchronized to the grandmaster clock and 100 slave clocks under real-world traffic load. Synchronization was maintained during negative conditions, including delayed, dropped, and CRC errors on PTP messages. Traffic latency, jitter, loss, and throughput measurements confirmed traffic forwarding performance and QoS. The 7705 SAR transparent clock (TC) implementation successfully modified the *correction* field for all 200 slave clocks in the test bed.

The test results provide an industry-first, proof-of-concept demonstration that a packet-based backhaul network can satisfy both timing synchronization requirements, as well as traffic forwarding performance and QoS guarantees for wireless services.

Introduction

With the next-generation wireless network providing media-intensive data, video, and voice services, one of the major challenges for service providers is provisioning enough mobile backhaul.

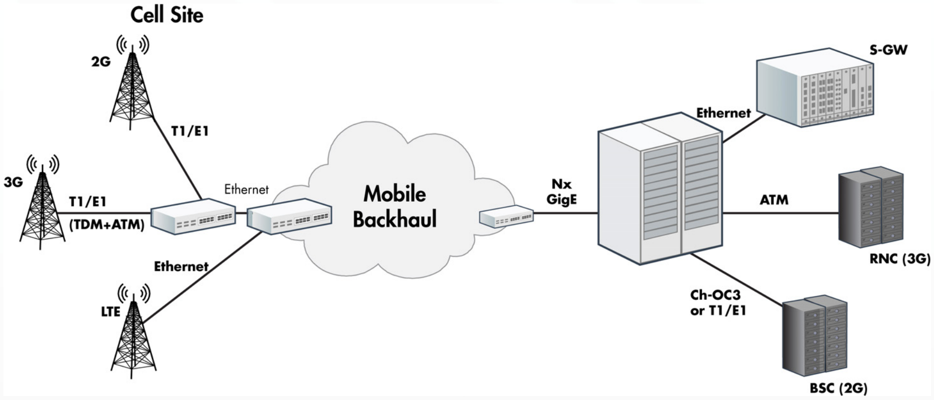

Figure 1. Mobile Backhaul Network

In a recent survey of global service providers by Infonetics, 100% of service provider respondents claimed to be deploying IP/Ethernet somewhere in their backhaul network. However, this will be a "phased" migration due to the fact that unlike TDM, Ethernet was not designed to carry synchronous information and cannot "natively" align clock frequency across devices in the network to the level of accuracy and stability required for the set-up, hand-over, and reliability of mobile phone connections.

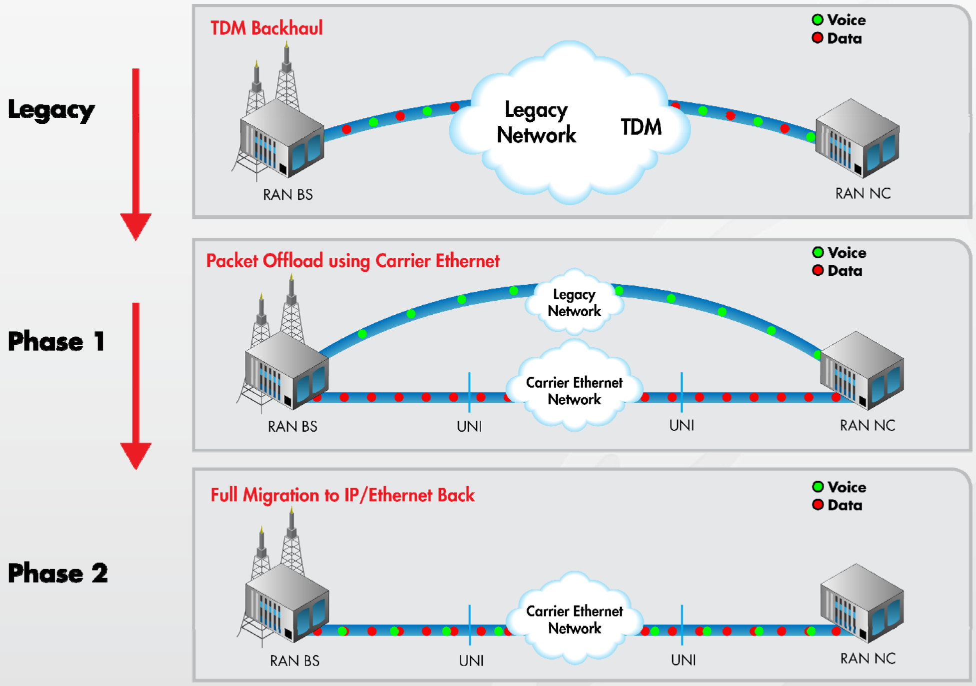

Figure 2. Mobile Backhaul Migration

The first phase is a hybrid implementation where IP/Ethernet backhaul is used for packet offload of data services while TDM is retained for voice. This approach is not an ideal solution as it forces carriers to maintain and pay for two separate networks. The ultimate goal is phase two, in which a single IP/Ethernet network is used to backhaul all services. Infonetics' survey indicated that 65% of service providers plan to eventually move to a single IP/Ethernet backhaul. Before pursuing this final stage of migration, carriers must have confidence that timing over packet (ToP) technologies can satisfy the strict clock synchronization requirements of wireless standards. Timing synchronization is also critical in other network deployments, such as “smart grid” utility infrastructure.

1588v2 Technology Overview

The IEEE 1588v2 PTP standard is used to synchronize clock frequency across network devices and can improve clock accuracy to satisfy wireless standards. It addresses frequency, phase, and time-of-day synchronization requirements, making it ideal for applications such as LTE TDD. It is a purely packet-based solution, with the actual clock values being passed inside the payloads of special packets dedicated to that task.

IEEE-1588v2 establishes a master/slave hierarchy of clocks in a network, where each slave synchronizes to a master clock that acts as the primary time source. Synchronization packets are exchanged between the master and slave, so the slave can continually adjust its own oscillator.

Packet Delay Variation is a key parameter that affects the performance of 1588v2. In order to constrain Packet Delay Variation, version 2 of the IEEE 1588 PTP (IEEE 1588v2) has defined boundary and transparent clocks:

A boundary clock increases system scalability by acting as a slave clock to an upstream master clock, and acting as master to multiple downstream slave clocks. A boundary clock has its own internal oscillator that is disciplined from its upstream master. In large systems, the introduction of boundary clocks can allow many more slave clocks than a single master could handle.

The effects of forwarding delays, such as those caused by packet queuing within a switch, reduce the accuracy of clock recovery. To mitigate these delays, a transparent clock (TC) is typically built into each Ethernet switch that is within a PTP network. The TC measures the forwarding delay of PTP timing packets passing through the switch. This forwarding delay is encoded within a *correction factor* field of certain PTP packets, enabling slave clocks to correct for network delays and, at least in theory, achieve perfect synchronization.

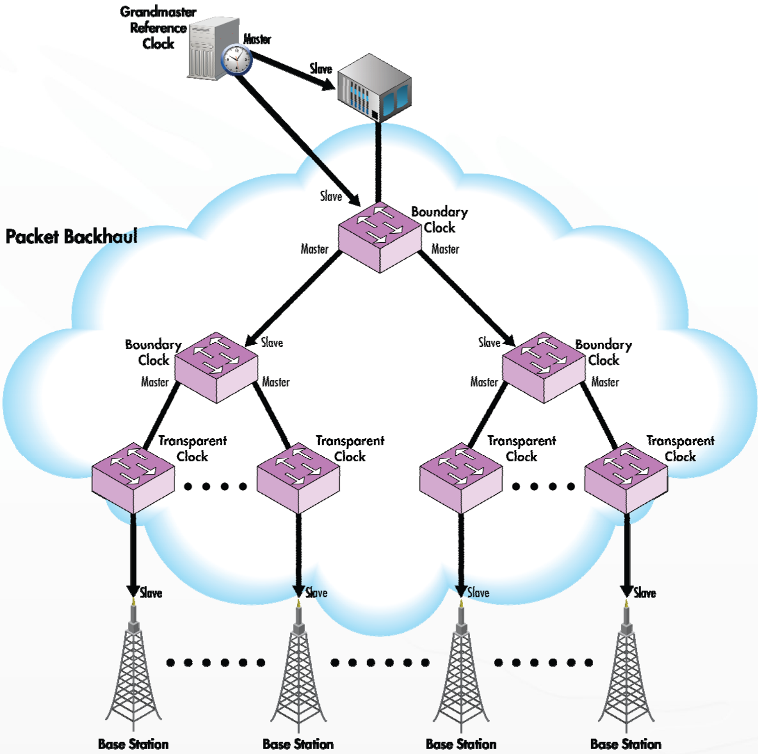

Figure 3. Timing over Packet using 1588v2

Transparent clocks are typically deployed closer to the edge of the network where cost sensitivities are greater and where the need to support multiple neighbors is not required. Boundary clocks can be deployed at higher levels of network aggregation. Hence, both boundary clocks and transparent clocks can be used in a flexible manner to ensure accurate synchronization in the network.

1588v2 Performance Benchmarks

The functionality, performance, and stability of 1588v2 can be compromised under heavy network load. As you scale traffic, number of network hops and devices, there is a potential impact on the operation of 1588v2 that could negatively affect end user Quality of Experience (QoE). It is critical for mobile operators that these factors are addressed as they move towards IP-over-Ethernet backhaul.

Ixia and Alcatel-Lucent engaged in a rigorous test exercise to validate the performance and robustness of 1588v2 boundary and transparent clock implementations under traffic load and scaled mobile backhaul network conditions.

The goal of the test was to provide the industry's first proof-of-concept demonstration that a packet-based backhaul network can satisfy timing synchronization requirement, as well as traffic forwarding performance and QoS guarantees for wireless services.

Test Configuration

The demonstration was achieved using a state-of-the-art 1588v2 implementation on Alcatel-Lucent's 7705 SAR. For the second year in a row, Alcatel-Lucent is the market leader in mobile backhaul router sales (Infonetics' *Mobile Backhaul and Services* report, October 2010).

Figure 4. Alcatel-Lucent 7705 Service Aggregation Router (SAR)

Ixia's IxNetwork application running on high-density 1GE load modules was used to emulate the grandmaster clock and hundreds of 15882 slave clocks, and perform traffic generation and analysis.

Figure 5. Ixia Test System

Test Scenarios

The comprehensive assessment included three main test scenarios with multiple measurements:

1. Boundary clock scalability with 7705 SAR providing grandmaster clock
2. Boundary clock scalability with Ixia test ports providing grandmaster clock
3. Transparent clock correction field validation

Test Scenario #1:
Boundary clock scalability with Alcatel-Lucent 7705 SAR providing grandmaster clock

Test Objective
The objective of this test is to demonstrate the scalability and accuracy of the 7705 SAR boundary clock implementation under network traffic load. The test setup uses both the 7705 SAR and the 9500 MPR-e Ethernet microwave products from Alcatel-Lucent. The 7705 SAR provides grandmaster clock and boundary clock on path support. The Ixia test unit emulates 100 slave clocks and generates a realistic mix of network traffic. The 9500 MPR-e allowed us to test 1588 over microwave links, as may be encountered in a mobile backhaul deployment.

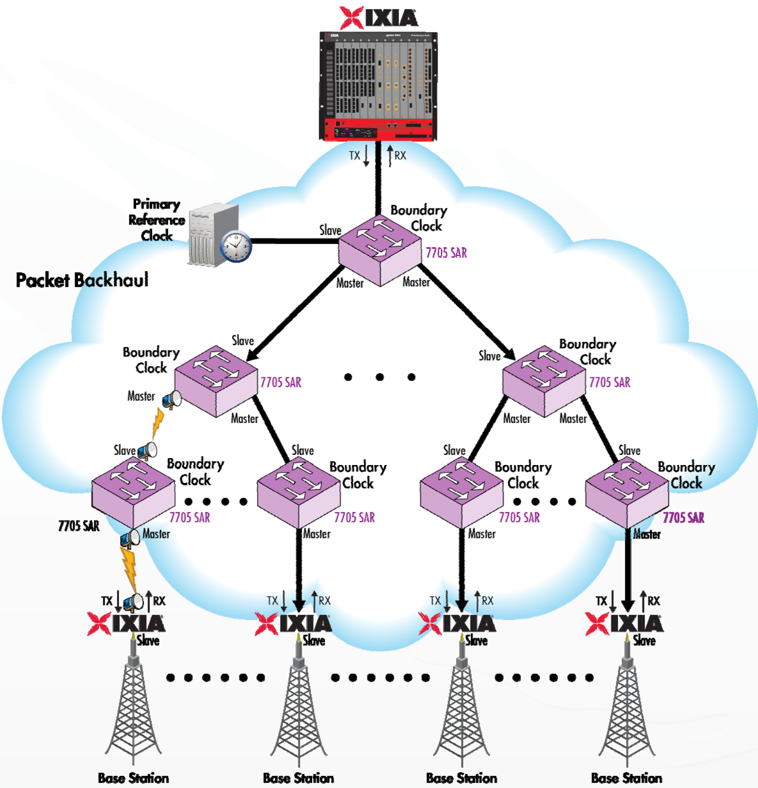

Figure 6. Test Setup: Boundary clock scalability with Alcatel-Lucent 7705 SAR providing grandmaster clock

Test Results

Measurements and observations demonstrated that the Alcatel-Lucent 7705 SAR, in addition to being up and running functionally, scaled to 100 slaves and successfully established and maintained 1588 sessions with the boundary clocks. The test also monitored the message exchange per slave; and the minimum, maximum, and average offset and path delay per slave. Finally, traffic measurements such as latency, jitter, loss and throughput were also gathered. The results showed that under real-world conditions of scaling and traffic load, the 7705 SAR 1588 implementation fully meets the synchronization requirements for mobile backhaul networks.

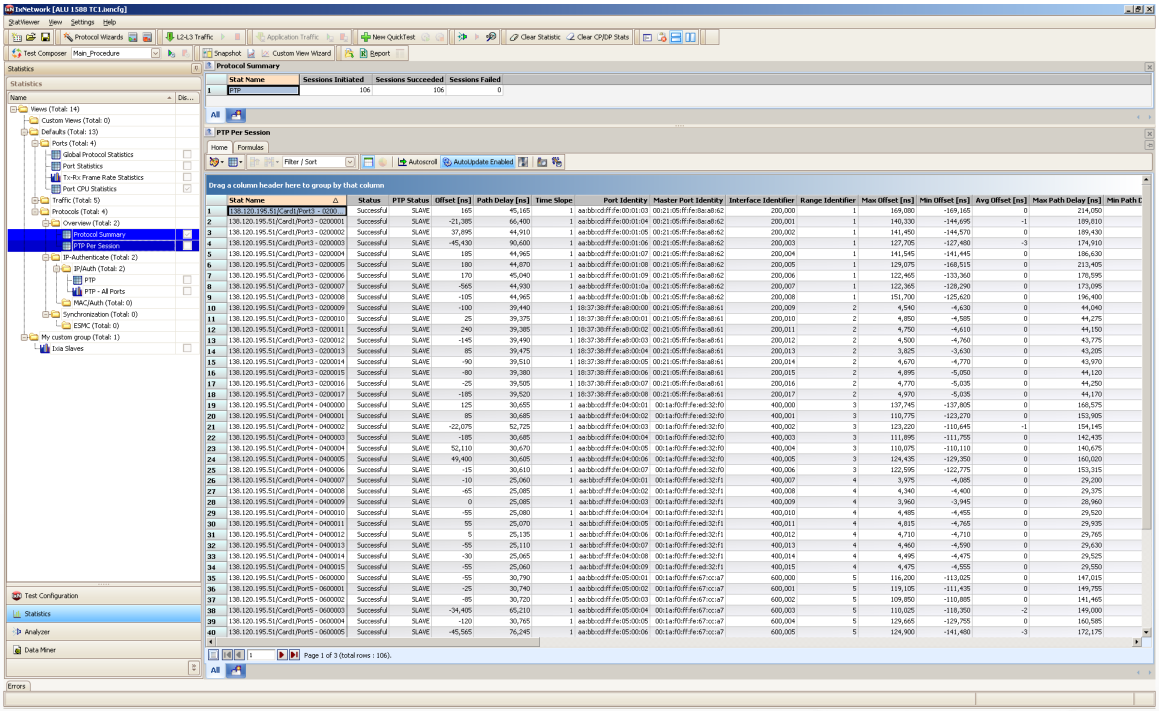

Figure 7. Per slave statistics showing over 100 slaves synchronized

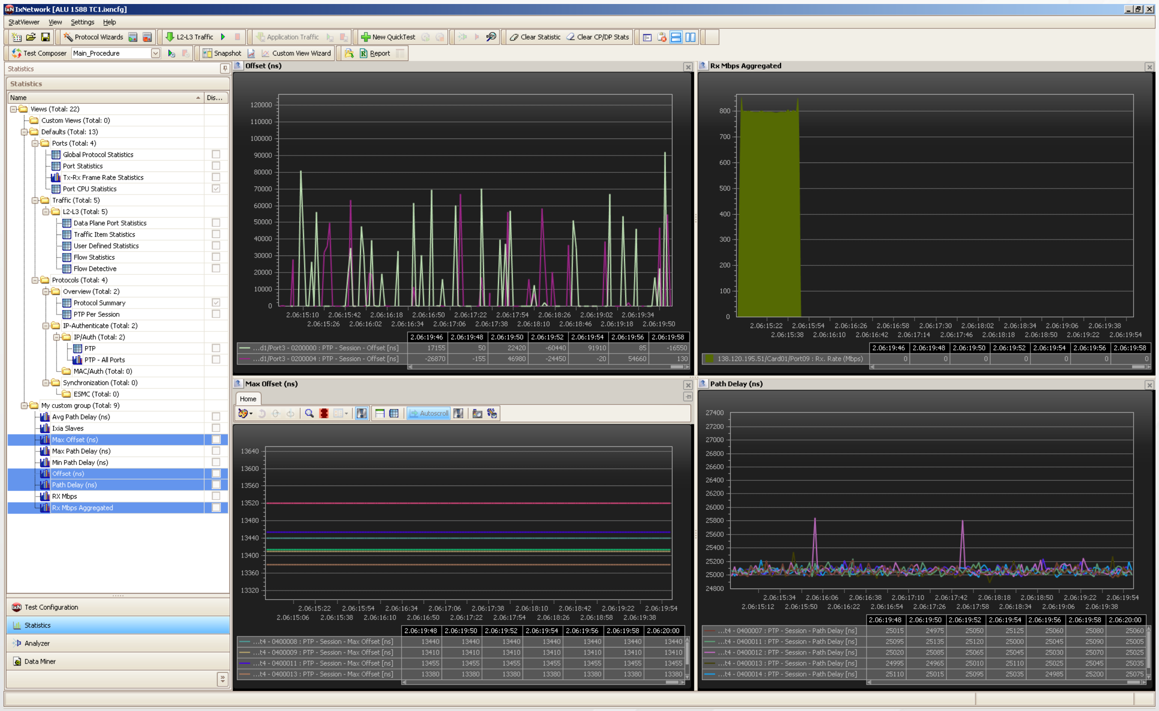

Figure 8. Real-time measurement of offset, path delay, and traffic throughput

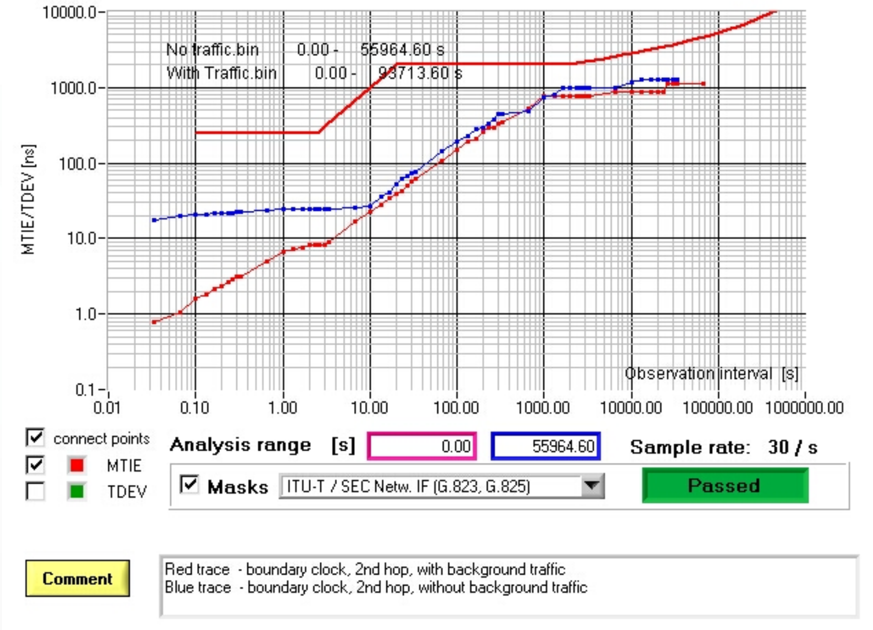

Figure 9. MTIE statistics

Test Scenario #2:
Boundary clock scalability with Ixia test ports providing grandmaster clock

Test Objective

The objective of this test was to demonstrate the scalability and accuracy of the 7705 SAR boundary clock implementation under network traffic load. The test setup used both the 7705 SAR and the 9500 MPR-e Ethernet microwave products from Alcatel-Lucent. The 7705 SAR provided boundary clock on path support. The 9500 MPR-e allowed us to test 1588 over microwave links, as may be encountered in a mobile backhaul deployment. Ixia test ports emulated a grandmaster clock on one side of the 7705, and 100 downstream slave clocks on the other side of the 7705. Ixia also generated a realistic mix of network traffic over this topology.

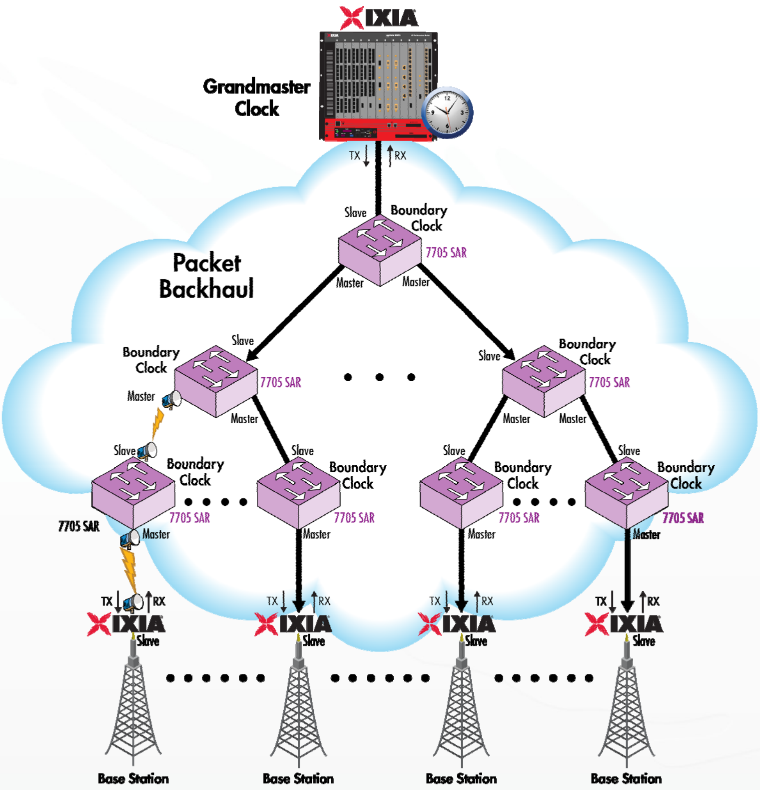

Figure 10. "Test Setup: Boundary clock scalability with Ixia test ports providing grandmaster clock

Test Results

The test configuration achieved several critical measurements. With respect to master clock interaction, we verified that the 7705 boundary clock successfully synchronized to the grandmaster. With respect to slave interaction, we verified the boundary clock established and maintained accurate synchronization with all 100 slaves under real-world traffic load. We monitored the message exchange per slave and measured the minimum, maximum, and average offset and path delay per slave.

By generating negative conditions, including delayed, dropped, and CRC errors on PTP messages, the test validated the robustness of the Alcatel-Lucent 1588v2 implementation. Finally, traffic latency, jitter, loss, and throughput measurements demonstrated that both traffic forwarding and timing synchronization requirements were met at the same time, under real-world network conditions. This provided a very comprehensive validation of the 7705 SAR's boundary clock performance and its ability to meet synchronization requirements for mobile backhauling over packet networks.

Figure 11. Verify upstream and downstream traffic Rx rate as traffic is started and stopped

Figure 12. Measure path delay over time, ensuring it stays under key thresholds

Test Scenario #3:
Transparent clock correction field validation

Test Objective

Transparent clock does not participate in the PTP messages. It is never a master or slave. It does, however, monitor and measure its own residence time. This is the time it takes for a packet to get from the ingress port to the egress port. TC takes that measurement and inserts it into a field in every PTP packet, using the *correction* field. This allows PTP to subtract out the network latency, thus reducing the impact of multiple hops and delivering more accurate timing propagation. The objective of this test is to demonstrate the Alcatel-Lucent 7705 SAR performing the transparent clock function. The test set-up interconnected 7705 SARs in a ring of transparent clocks. Ixia's IxNetwork application emulated both a master clock and 200 slave clocks; and provided measurements per slave, including correction field analysis.

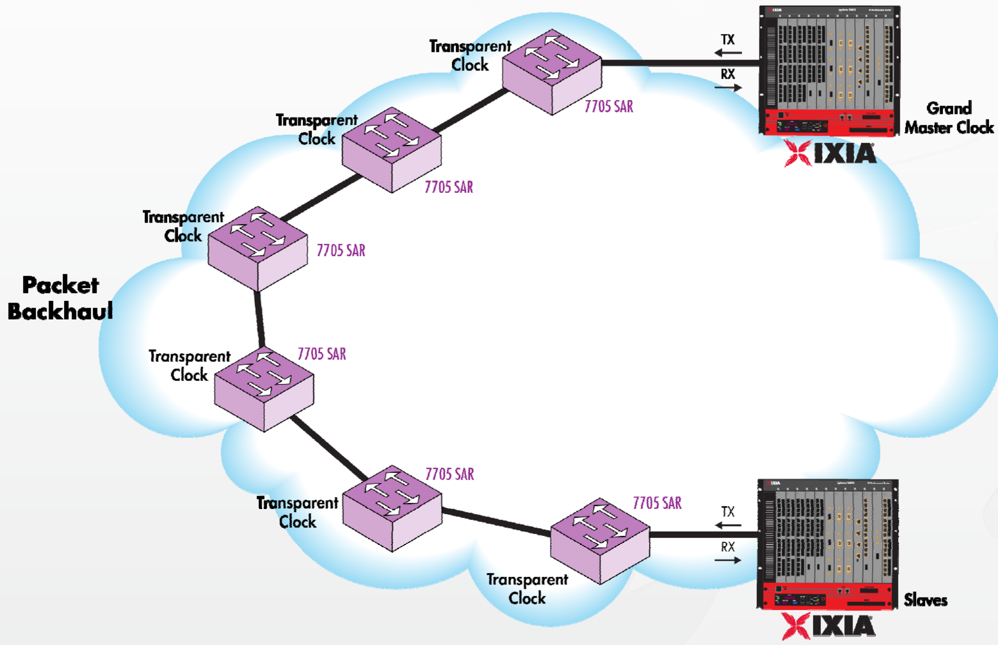

Figure 13. Test Setup: transparent clock correction field validation

Test Results

The tests showed that by changing the load, the 7705 SAR adjusted the correction field accurately. This is important because the *correction field* needs to vary depending on the load. As network load is increased on the device under test (DUT), the time it takes for frames to move through the device will be slower. The test results demonstrate how the 7705 SARs were able to modify the correction field correctly for 200 slave clocks in the test bed. As traffic load is added, the residence time increases and the 7705 SARs correctly increased the correction field values. The correction field values of all relevant 1588 sessions were monitored concurrently and synchronization operation was verified.

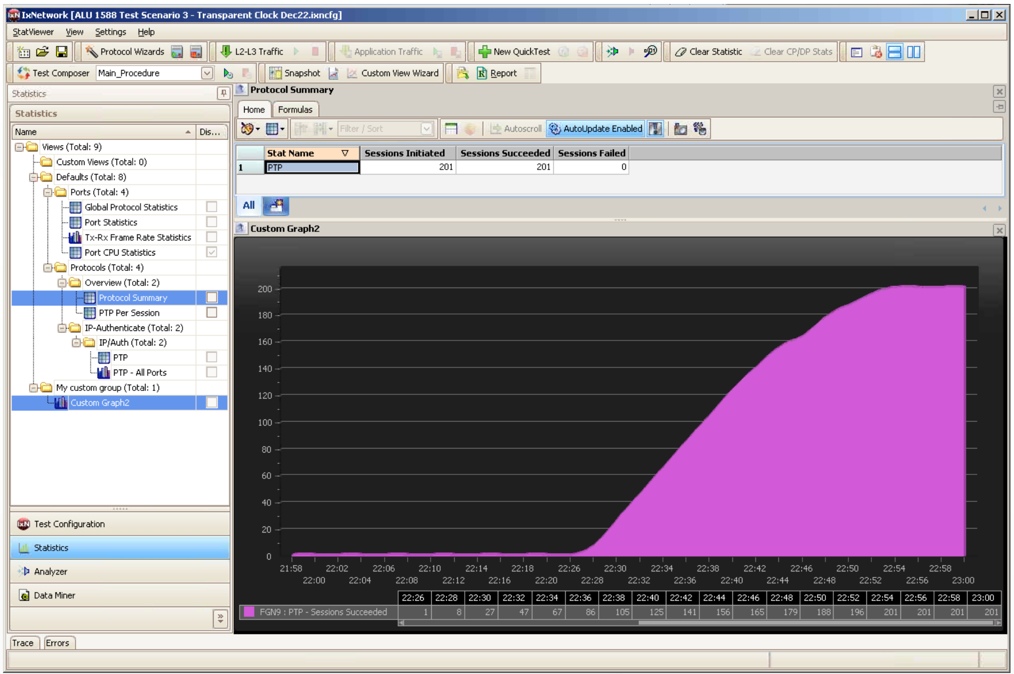

Figure 14. Monitor in real-time as 200 emulated slave clocks ramp up

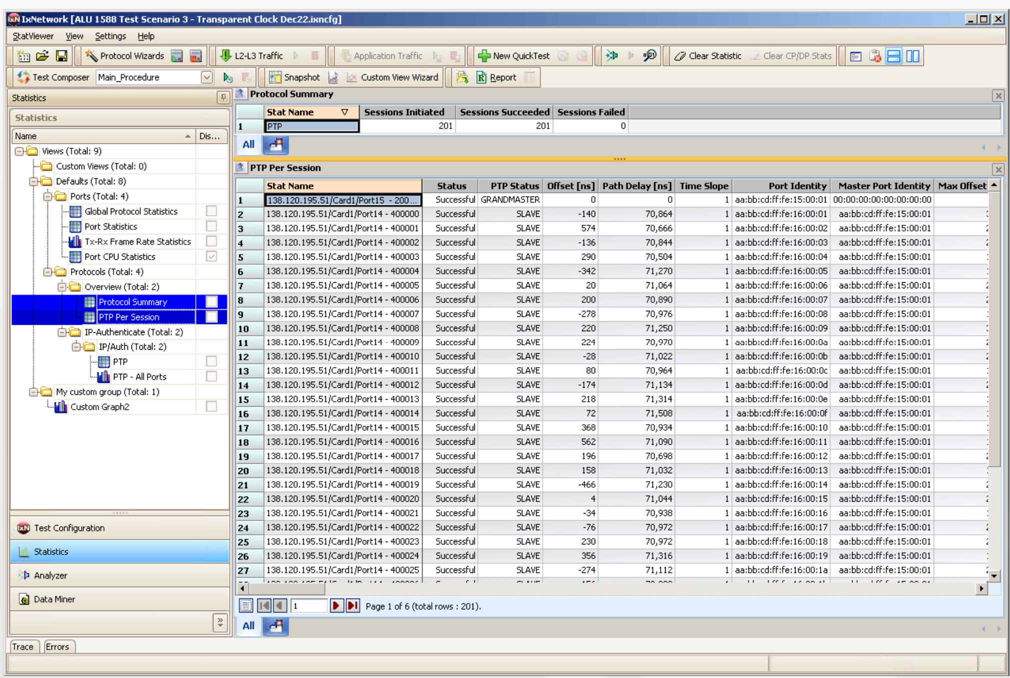

Figure 15. Real-time statistics for emulated grandmaster and 200 slave clocks

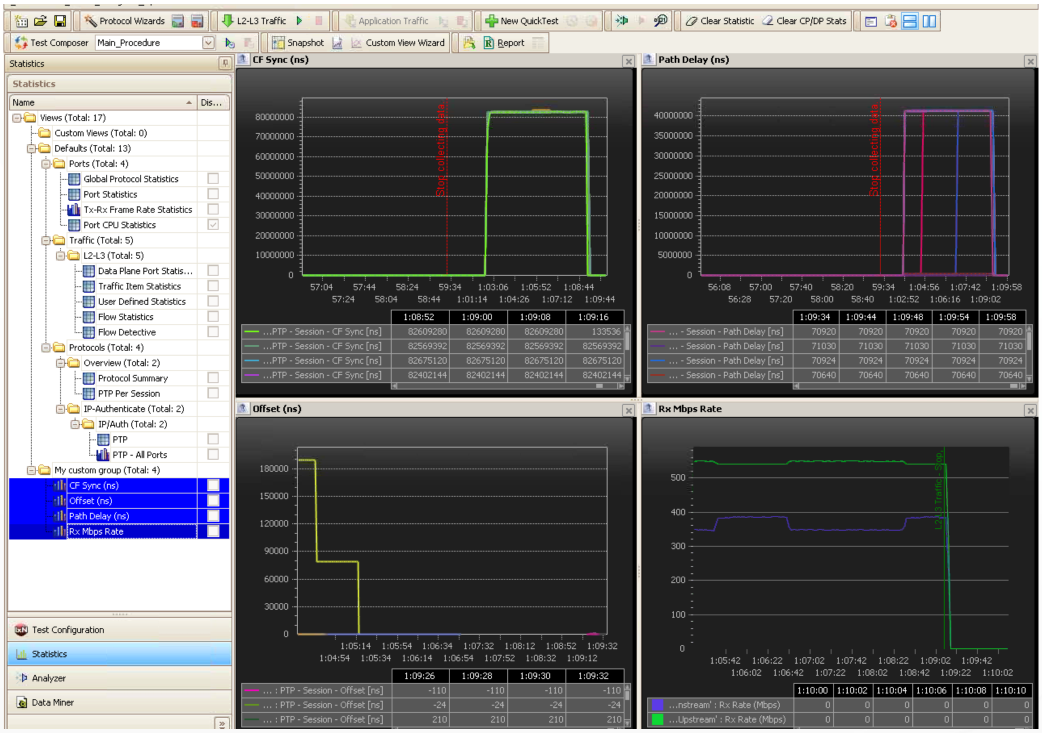

Figure16. View correction field of the sync message, path delay, offset, and Rx rate over time

Conclusions

The test results provide industry-first evidence that a packet-based backhaul network can satisfy both timing synchronization requirement, as well as traffic forwarding performance and QoS guarantees for wireless services.

This cutting-edge event demonstrated that packet networks with 1588 support can address the current and future needs of mobile backhaul, including LTE, and also enable other applications such as smart grid network infrastructure.

For further information consult the Ixia and Alcatel-Lucent websites.

About Ixia

Ixia is a leading provider of converged IP performance test systems and service verification platforms for wireless and wired infrastructures and services. Ixia's test systems are used by network and telephony equipment manufacturers, semiconductor manufacturers, service providers, governments, and enterprises to validate the performance and reliability of complex networks, devices, and applications. Ixia's multiplay test systems address the growing need to test voice, video, and data services and network capability under real-world conditions. For more information, visit Ixia on the Internet: www.ixiacom.com

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