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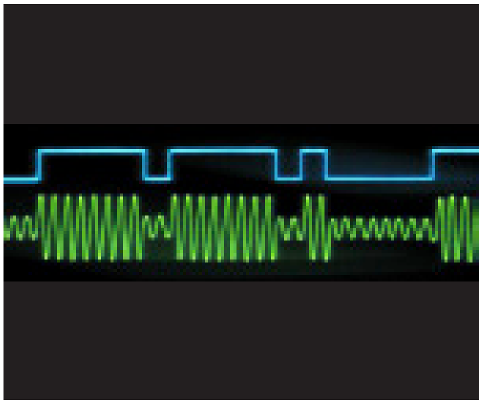
Packet Network Readiness: Testing and Verifying IEEE 1588-2008 Packet Synchronization



WHITE PAPER

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Abstract

A prerequisite in the transition away from traditional telecom networks is the ability to deliver carrier grade synchronization over packet networks. Developers, field engineers, network analysts, and others need to develop a new set of skills and resources to plan, test, and troubleshoot packet network environments. The Precision Time Protocol (IEEE 1588-2008, or PTP) provides the underlying technology for establishing precise and accurate time for wireless and wireline networks based on packet switched protocols, but additional capabilities are needed. A comprehensive tool to test and analyze PDV performance—and determine whether it will support a specific synchronization mask—is essential functionality to ensure network readiness and accelerate the transition to packet networks.

Introduction

Demand for greater bandwidth and performance is being driven by new applications in wireline and wireless markets. Multiple services are consuming greater capacity, driven by IPTV, VoIP, business services, and mobile applications. The market just for mobile data is expected to double[1] every year for the next four years. While legacy telecom networks are well understood, they cannot economically scale to address this explosive growth, because network costs increase linearly with the added bandwidth.

> Explosive growth in telecom network demand can be cost-effectively addressed by packet networks such as Ethernet.

Traditionally, telecom network technology was developed around voice services, using Time-Division Multiplexing (TDM) to ensure service as network traffic flows through switching and transmission equipment. Networks such as SONET/SDH are used to transmit circuit-based voice traffic, and have native capabilities to carry a timing reference at the physical layer. Inherent synchronization in TDM networks is a critical element in their ability to meet Service Level Agreements (SLAs) and maintain service quality. For example, precise and reliable synchronization distributed in TDM is crucial for wireless backhaul, providing transparent hand-off and good call quality.

Networks such as Ethernet can provide much greater capacity and performance at a lower cost. However, packet networks do not have an inherent capability to carry frequency. The Precision Time Protocol (IEEE 1588-2008, or PTP) is an enabling technology. PTP can distribute time and frequency synchronization over the packet switched network infrastructure. Deriving synchronization from the information contained within the PTP packets is essential to service quality. Just as with TDM-based networks, precise and accurate timing for a range of applications is essential for service quality and customer satisfaction.

Emerging Solutions

In TDM networks, measuring frequency and synchronization is well understood and relatively straightforward. But the tools for measuring packet synchronization are limited, and cannot ensure a predictable, measurable level of network quality. Network capture devices can collect packets, inject impairments, and replay network activity into a lab analyzer. Other tools can detect and measure only one or two network timing issues, such as jitter (also known as Packet Delay Variation, or PDV). PTP traffic clients can generate PTP packets to test network segments and devices under static conditions. Some manufacturers are even starting to combine these capabilities into a single device. But these are incomplete solutions. Only packet-level test, measurement, and analysis can ensure that the network achieves packet synchronization according to industry standard masks.

> Existing devices can test and/or measure network timing issues, but cannot analyze PTP performance to accurately measure packet synchronization.

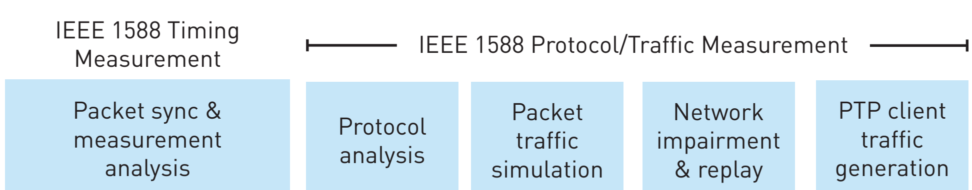

FIG 1: Existing devices cannot comprehensively test for network readiness, and represent partial solutions. Some only capture packets and no analysis, while others measure or test PTP packet activity. To determine IEEE 1588 (PTP) network readiness, comprehensive timing and measurement analysis is needed.

1 http://www.nytimes.com/2009/10/14/technology/companies/14cisco.html

The Need for Efficient and Accurate Readiness Testing

The ability to consistently and accurately test and troubleshoot network performance when delivering PTP—and derive synchronization—is required to assure cost-effective service quality. This can be difficult as service delivery traverses different operators and technologies.

> Service delivery typically traverses multiple networks and different operators, making it difficult to effectively verify network readiness.

Quickly measuring and analyzing PTP data to accurately determine packet synchronization is crucial to telecom service delivery and efficient rollouts. Several scenarios that demonstrate this are as follows:

Network Planning

Traditional equipment and techniques that have been successful in planning TDM networks are less useful in packet networks. Planning for application deployment over a packet network ultimately seeks to answer the question: Can the network meet the QoS and synchronization requirements for the deployed service or application? This can be a difficult question, as the network segments may pass through multiple operators, with different equipment. Network operators need to know how to tune the network to stay within the specified limits required for different types of service delivery. They need packet network planning tools to determine the optimum placement of PTP servers and ensure that other network elements (including PTP components) can ensure an acceptable level of service quality, and then verify service levels at various stages of deployment.

Field Troubleshooting

In a packet network, determining the root cause of QoS issues can be difficult. Field engineers will need the proper tools to capture PTP packets and calculate PDV (jitter) with respect to the appropriate synchronization requirement. Other field troubleshooting scenarios should be considered. For example, to determine root cause, the field engineer may need to capture network traffic and replay in the lab for further analysis. Delays associated with returning the captured data back to the lab, analyzing, and then returning to field locations to see if the problem has been resolved can increase costs and reduce customer satisfaction.

Bringing large pieces of equipment to the field is impractical, as is training field technicians to operate a range of devices that are required to capture packets, inject impairments, or generate PTP traffic for testing. A portable, unified tool is required. To maximize efficiency and minimize training, any such tool should guide the user to clear, quick results while providing drill-down capabilities for greater insight.

Engineering Design

To meet the demand for more network capacity, network equipment manufacturers are responding with new designs and capabilities. Comprehensive tools are required to assist engineers as they design new products. For example, a manufacturer of Ethernet switches will need tools that can quickly measure packet jitter profiles, helping them see the effects of changes in queuing algorithms on PTP and QoS levels. Microwave transmission equipment manufacturers have a similar need. The ability to record, create, store, and analyze custom profiles from lab and field data for use in development and test labs is crucial. A comprehensive instrument that can be used to identify specific traffic flows, record and replaying as an accurate simulation when testing product designs in the lab would be very productive.

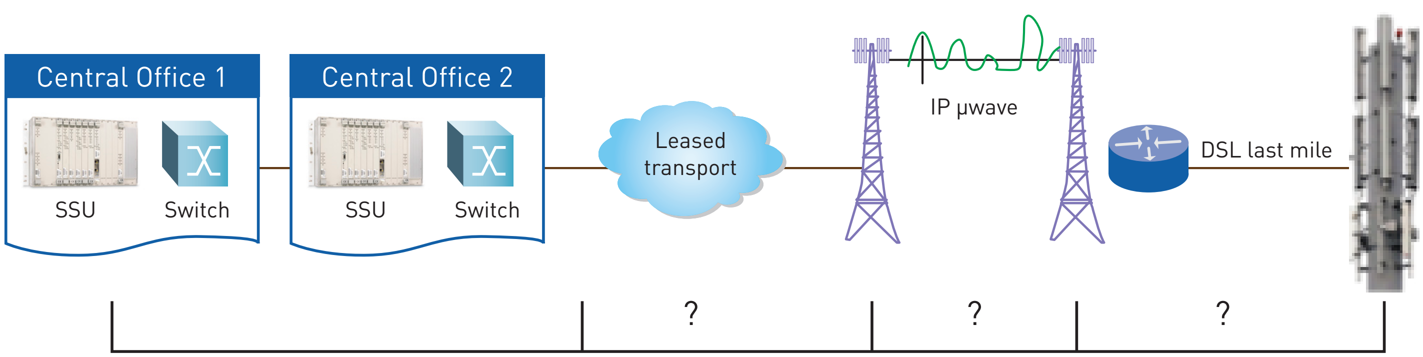

FIG 2: Packet synchronization can be difficult to determine when service delivery traverses different operators and protocols.

Factors Affecting Packet Synchronization

Designed for delivery over packet networks, PTP is sensitive to network behavior. There are several factors that can affect the quality of synchronization over packet networks, such as network load, queuing delays, dropped packets, emulation effects, hardware limits, number of hops, and so on. PDV represents the change in latency from packet to packet, which changes the PTP client's perception of time from the master. Applications are designed to tolerate a certain amount of PDV, but too much will affect service quality. As shown in the figure below, different degrees of accuracy are required, depending on the service.

There are several metrics associated with packet timing issues.

Correctly measuring PDV in a packet network is not enough to determine suitability for delivering synchronization packets. PTP packets *must be analyzed* in order to verify that the network has the right characteristics and profiles to produce the correct frequency and synchronization at the end point. The appropriate packets from the synchronization domain must be analyzed against a specific synchronization requirement, or a sync mask in the packet domain. A tool to analyze PDV performance and determine whether it will support a specific synchronization mask is essential functionality in a packet synchronization test tool.

Network timing behavior is not a stationary process—it is subject to dynamic conditions and changes over the short term and longer term. Packet delay must be characterized over time. In order to plan and analyze packet networks for application suitability, test equipment must be able to characterize packet delay over time. In addition, because many telecom applications must have time accuracy and precision on the order of microseconds, packet network timing measurement equipment must have an accuracy level that is significantly higher than that.

Accuracy requirements vary by service.

PDV on high-speed, low-latency, underutilized network links is easily measured and often not much of an issue. More problematic are those network links that include one or more leased transport lines, multiple hops, and heavily subscribed (or loaded) networks.

Recent developments in PDV analysis suggest that it is feasible to build accurate models of network behavior under varying conditions of load, number of switches, forwarding algorithms, and QoS implementation. It has also been shown that no single metric, such as TDEV or minTDEV, is sufficient to characterize PDV, and that a suite of metrics is necessary. However, selecting the appropriate packets, and analyzing these metrics has shown that packet synchronization can be correlated to QoS requirements for specific services.

Several metrics must be analyzed to accurately verify network readiness.

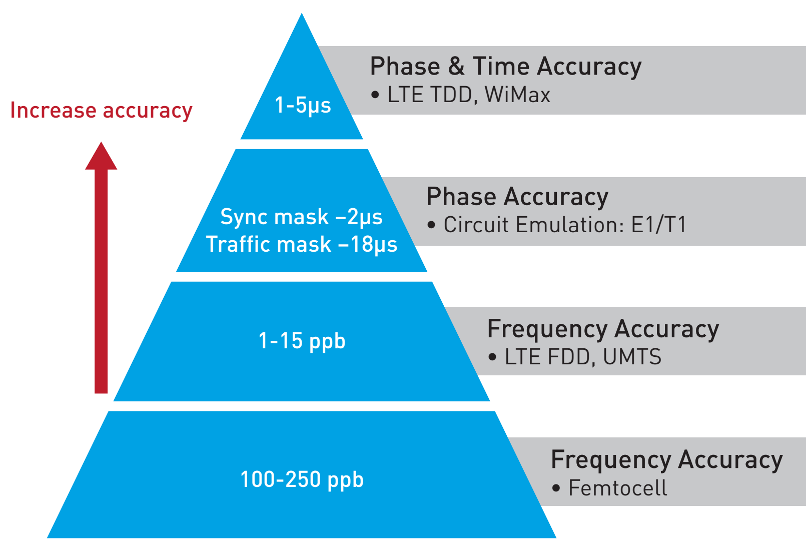

FIG 3: Different applications and services have different timing and synchronization requirements. With multiple services running on the same physical network, a device to test and analyze packet synchronization must be accurate across a range of applications.

More than Test and Measurement—Analysis

The migration to packet networks for telecom services has introduced a need to analyze the performance of a network that delivers synchronization and timing instances in a different way from the methodologies used in TDM networks. Part of the appeal of packet networks is their flexibility—they can be deployed over different media and with different protocol stacks. It follows that a proper test and measurement tool must also provide accuracy and flexibility for many types of networks and different situations.

> The industry needs comprehensive, portable solutions that can assure network readiness in a variety of situations.

Test, measurement and analysis capabilities for packet synchronization should include the following:

Nanosecond Accuracy

There should be extensive capabilities for precisely measuring and analyzing time stamps with nanosecond accuracy. PTP packets must be collected and identified in real time, and in multiple forms, to perform the measurements required to isolate problems and assure network suitability. This includes selecting the appropriate PTP packets and evaluating PDV against a selected synchronization mask, then analyzing the results to determine if the network meets defined ITU-T, ANSI, Telcordia, and other standards for a specific application or service. Packet synchronization measurements should be accurate to 1ppb for maximum frequency accuracy.

Simplify Complexity

The device should not only perform a wide range of tests and measurements for PTP and traditional synchronization, but should be able to quickly and easily indicate PASS or FAIL for individual sync and timing tests. For traditional synchronization, two types of performance metrics can help users to easily verify frequency performance. One is Time Deviation (TDEV) to measure clock stability and the other is Maximum Time Interval Error (MTIE) to measure the frequency offset from primary reference clocks. For a PTP network, similar types of performance metrics are needed to measure network stability for predicting IEEE 1588 client performance. To reduce the complexity of testing IEEE 1588 networks, the device should have the functionality to collect raw data, calculate into different types of performance metrics *and* easily qualify the result.

> Assuring network readiness can be difficult. Simple pass/fail results, with drill-down, can help speed network testing.

Network Flexibility

Measurement and analysis methods should be applicable across different types of deployed networks, such as Ethernet, xDSL, Gigabit Passive Optical Network (GPON), microwave, and others under a range of traffic conditions. Testing tools and methodologies must be robust enough to be used in a variety of situations.

Complete PTP Capabilities

To provide a full range of testing capabilities, a testing solution should test network links with portable PTP grandmaster clocks and slaves. A portable, all-in-one tool can be deployed to field locations to test packet synchronization capabilities (network suitability) before PTP elements are in place, and plan optimal placement of PTP elements with strong assurance they network will support the desired service.

All in One, Portable

An all-in-one test and measurement system can reduce the number of different tools required (minimize training requirements), and ensure that users have the capabilities they need to test in more situations, minimizing training across tools from multiple vendors and enabling technicians and engineers to address more problems. Portability can eliminate the time associated with returning captured traffic back to the lab for analysis.

Interoperability

Industry-standard interfaces and file formats mean that the test, measure, and analysis functionality can integrate with an operator's existing equipment and workflows.

Symmetricom Delivers

Symmetricom offers comprehensive IEEE 1588 end-to-end synchronization solutions, with multiple PTP server and client options, PTP monitoring and management, and now PTP test, measurement and analysis. TimeAnalyzer portable test tools provide comprehensive functions to measure and analyze packet-timing as well as traditional synchronization. They enable reliable measurement of IEEE 1588 packet flows under a variety of traffic conditions for a broad range of networks with nanosecond accuracy.

> TimeAnalyzer is a comprehensive, portable, all-in-one solution for accelerating the transition to packet networks.

The easy-to-use graphical user interface enables users to quickly configure a test system, collect PTP data for performance analysis, and determine if the end results meet requirements for telecom applications. Designed for use in the field and in the lab, TimeAnalyzer enables optimization and validation of the PTP solution prior to full-scale network deployment, and root cause troubleshooting. TimeAnalyzer is available as a standalone packet timing device, or an all-in-one packet timing and synchronization system.

More Information

IEEE 1588 (PTP) Resources: www.symmetricom.resources/downloads

- Designing and Testing IEEE 1588 Timing Networks
- Best Practices in IEEE 1588/PTP Network Deployment

Glossary

Below are some terms associated with PTP and accurate network timing.

Grandmaster Clock (GMC): The source for precise and accurate time on a network.

Jitter: Change in latency from packet to packet. Sometimes referred to as Packet Delay Variation (PDV). See also: PDV, Wander.

Maximum Time Interval Error (MTIE): A measure of the maximum time error of a clock over a specific time interval.

Minimum Time Deviation (MinTDEV): An estimate of network timing stability, based on an algorithm that indicates how well packet selection might work under various network scenarios. See ITU-T SG15.

Packet Delay: The phase drift between the master and the slave clocks over a network. The smaller this delay, the more accurate a network clock recovery algorithm will perform.

Packet Delay Variation (PDV): The short-term, random variation in end-to-end delay between packets. See also: Jitter, Wander.

Time Interval Error (TIE): A measure of the time error of a clock over a specific time interval.

Time Deviation (TDEV): The expected time variation derived from statistical calculations.

Wander: The long-term, random variation of end-to-end delay, comparing one selected group of packets to another.