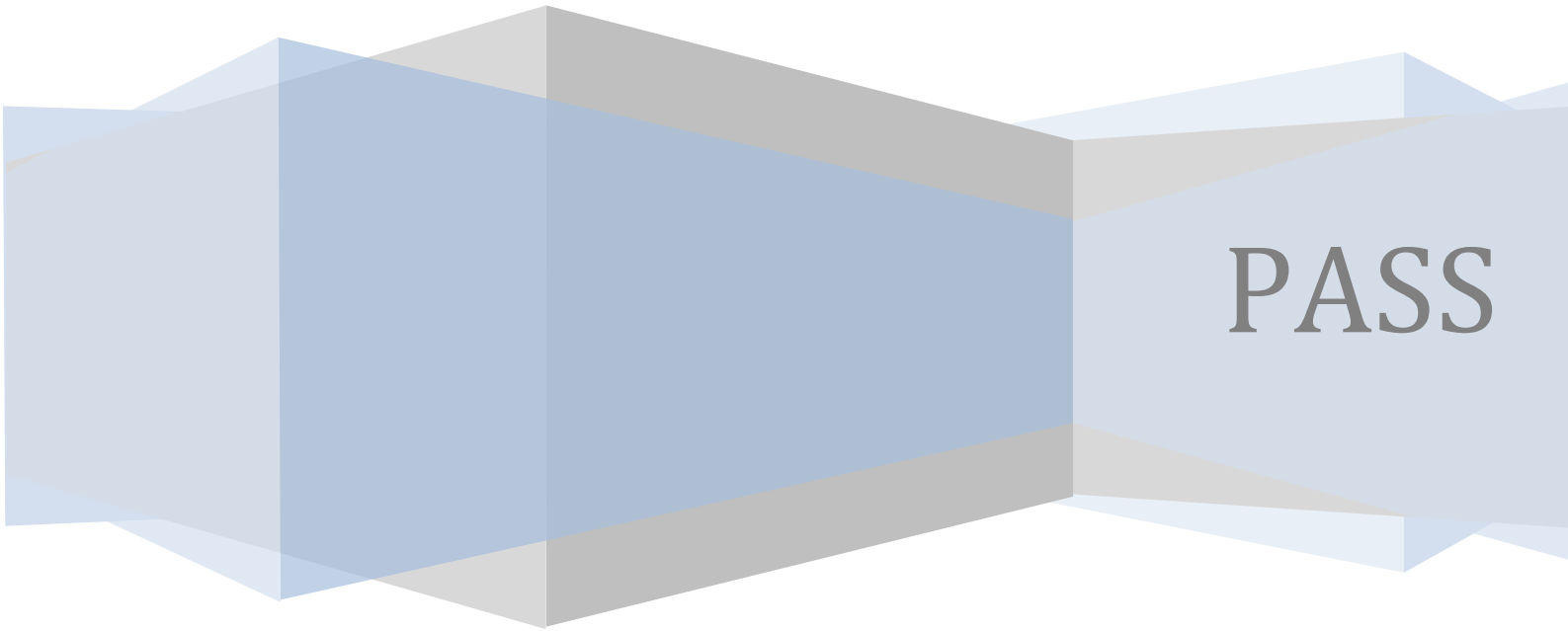
Spirent Journal of IEEE 802.3ba 100 GB Ethernet PASS Test Methodologies



Introduction

Today's Devices Under Test (DUT) represent complex, multi-protocol network elements with an emphasis on Quality of Service (QoS) and Quality of Experience (QoE) that scale to terabits of bandwidth across the switch fabric. The Spirent Catalogue of Test Methodologies represents an element of the Spirent test ecosystem that helps answer the most critical Performance, Availability, Security and Scale Tests (PASS) test cases. The Spirent Test ecosystem and Spirent Catalogue of Test Methodologies are intended to help development engineers and product verification engineers to rapidly develop and test complex test scenarios.

How to use this Journal

This provides test engineers with a battery of test cases for the Spirent Test Ecosystem. The journal is divided into sections by technology. Each test case has a unique Test Case ID (Ex. TC_MBH_001) that is universally unique across the ecosystem.

Tester Requirements

To determine the true capabilities and limitations of a DUT, the tests in this journal require a test tool that can measure router performance under realistic Internet conditions. It must be able to simultaneously generate wire-speed traffic, emulate the requisite protocols, and make real-time comparative performance measurements. High port density for cost-effective performance and stress testing is important to fully load switching fabrics and determine device and network scalability limits.

In addition to these features, some tests require more advanced capabilities, such as

- Integrated traffic, routing, and MPLS protocols (e.g., BGP, OSPF, IS-IS, RSVP-TE, LDP/CR-LDP) to advertise route topologies for large simulated networks with LSP tunnels while simultaneously sending traffic over those tunnels. Further, the tester should emulate the interrelationships between protocol s through a topology.
- Emulation of service protocols (e.g., IGMPv3, PIM-SM, MP-iBGP) with diminution.
- Correct single-pass testing with measurement of 41+ metrics per pass of a packet.
- Tunneling protocol emulation (L2TP) and protocol stacking.
- True stateful layer 2-7 traffic.
- Ability to over-subscribe traffic dynamically and observe the effects.

Finally, the tester should provide conformance test suites for ensuring protocol conformance and interoperability, and automated applications for rapidly executing the test cases in this journal.

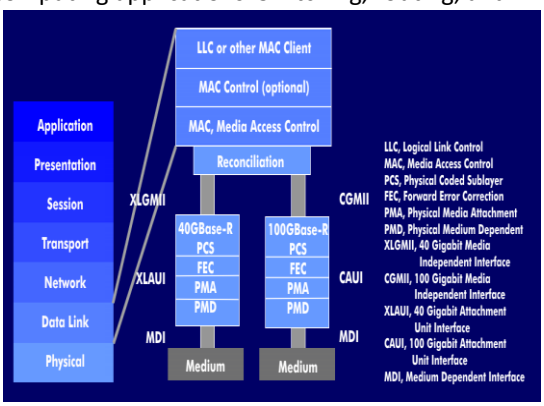
Further Resources

Additional resources are available on our website at http://www.spirent.com

Table of Contents

Testing IEEE 802.3ba 100 GB Ethernet

Core networking applications have demonstrated the need for bandwidth beyond existing capabilities and beyond the projected bandwidth requirements for computing applications. Switching, routing, and aggregation in data centers, in terabit exchanges and service provider peering points, and high bandwidth applications such as video on demand and high performance computing, need a 100 Gigabit Ethernet interface. The need for 100 GB Ethernet at the core of the network initially, extending to the edge eventually, is driven by many factors, including elimination of aggregation protocols, bandwidth growth at the edge of the network, and the rise of for-pay services like HD IPTV, VoIP, cloud computing, and cloud storage. The 100 GB delivery test requirements are different than previous 1 GB and 10 GB because of the strong emphasis placed on QoS/CoS, realism, stacked protocols, and multiplay services over 100 GB.



Imprecise clocking between systems at 40 GB/100 GB can increase latency and packet loss. Testing with backwards compatible system is critical.

Latency issue is an important issue. At 10 GB, especially at high densities, the specification allows for a little variance for clocks. As you aggregate traffic into 10 GB ports, small differences between clocks can cause high latency and packet loss. At 40 GB, the tolerances are even smaller. This is a critical requirement in data centers today. The innovations in data-center networking and Ethernet address lower latencies and enhanced queuing and buffering. Key test metrics for IEEE 802.3ba 100 GB Ethernet are:

LAYER 1 SKEW PERFORMANCE. Lane skew was a contributor in older Ethernet roll out issues, being able to add skew and to measure effects are a critical part of the physical layer setup.

LAYER 1 LANE SWAPPING. Measuring the ability of the DUT to manage the virtual to physical translation is critical because lane swapping errors can lead to interface link-down problems that are difficult to debug in deployed systems.

LAYER 1 PER-LANE UNIQUE BERT (PRBS). The ability to test the physical pathways using unique PRBS BERT patterns reveal physical lane stability and crosstalk issues

LATENCY AND JITTER. Testing 100 GB to 100 GB, 100 GB to 40 GB, and 100 GB to multiple 10 GB ports is a critical test of backwards compatibility. The ability to measure jitter to 2.5 ns in the core is essential.

RFC2544 100 GB THROUGHPUT. Measuring the forwarding rate at 100 GB is critical to prove forwarding performance.

CORRECT SEQUENCING DETECTION. Validates the buffering storage-and-reassembly algorithm while under load and across different Ethernet technologies. Reported metrics include lost, duplicate, late, and reordered packets.

HSE_001 Determine whether the DUT works error free in loopback

Abstract

This test determines whether the DUT works error free against itself. This test places the DUT in loopback mode and verifies that traffic is received correctly without errors. This test provides long duration verification and determines basic pathway and switching robustness. References: IEEE 802.3ba. For product verification, engineering and manufacturing.

Description

This test case determines whether the DUT works error free in loopback. In this mode, each lane maps traffic to its respective virtual lane. Then, virtual lanes are mapped to the physical layer. On the receive side, the procedure is reversed.

Relevance

- To create a baseline of expected results before involving the 100 GB module
- Provides long duration verification of the DUT
- Determines that the basic pathway and switching functions work correctly on the DUT

Version

1.0

Test Category

High Speed Ethernet.

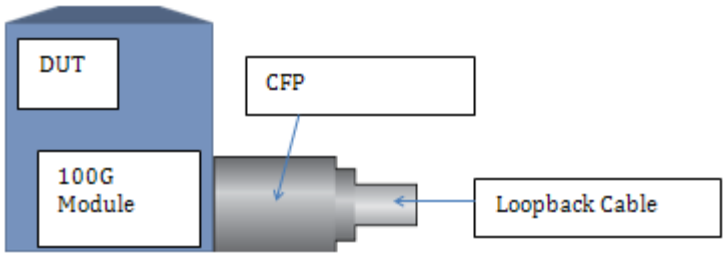
PASS

[ ] Performance [x] Availability [ ] Security [ ] Scale

Required Tester Capabilities

- Spirent TestCenter 2U-HS Chassis (Alternately, Spirent TestCenter SPT-9000A chassis) with Controller 2
- Spirent TestCenter NG-100G-F2 module
- Spirent TestCenter CPU-5004A module
- L1 Testing Capabilities at 100 GB
- PRBS Generating Capabilities for Layer 1 testing at 100 GB

Topology



Test Procedure

1. Insert the transceiver (CFP preferred) into the 100 GB module in the DUT.
2. Connect an optical loopback cable to the transceiver (CFP preferred).
   a. Set the DUT to transmit PRBS traffic – preferably PRBS 31.
      i. If the DUT can't generate PRBS traffic, a ping test can be substituted.
   b. Run the test for at least a 24 hour period.
   c. Verify that no errors are received.

Variables & Relevance

Variable	Relevance
Optics	The optics need to run error free in another 100 GB-capable device to rule out any issues with them.
Loopback Cable	The loopback cable must be clean and able to pass error-free traffic on any other known good transceiver.

Desired Result

The DUT should not report errors. Errors indicate an issue with how the DUT handles traffic, especially if the same optics didn't log errors with a different 100 GB-capable device.

Key Measured Metrics

Statistic	Relevance
PRBS Error Counter	Any error count increment indicates a problem with how the DUT handles traffic.

Analysis

The user should not see errors on any lanes. Errors indicate an issue with how the DUT handles traffic. To rule out transceiver issues, perform the same test with the same transceiver using a 100BG port on the tester and observe the results. If no error is reported, the issue is with the DUT. If errors are reported, use a different transceiver and rerun the test.

HSE_002 Determine whether the 802.3ba optics run error free

Abstract

This test determines whether the 100 GB optics (CFP recommended) function correctly. Insert the optics into the tester board and insert an optical cable in loopback mode. Run the PRBS mixture and verify if PRBS is recognized and there are no lane swapping, errors or inversion. Also, verify that all lanes are recognized and aligned. Repeat this test for all optics. By measuring potential errors over a long duration, this test determines whether the optics function correctly. References: IEEE 802.3ba. For product verification, engineering and manufacturing.

Description

This test case measures the ability of the HSE Ethernet port optics to run error free. Numerous traffic patterns are generated across the optics. The optics are then measured for traffic rate and error conditions.

Relevance

- Characterizes the optics
- Determines whether the optics can pass traffic successfully
- Determines whether the optics can run error free
- Provides long duration verification of the optics
- Determines the skew introduced while running traffic

Version

1.0

Test Category

High Speed Ethernet.

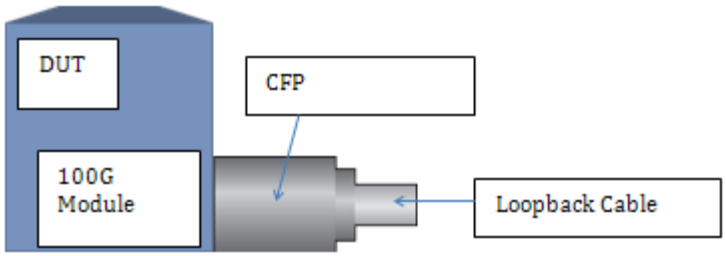
PASS

[ ] Performance [x] Availability [ ] Security [ ] Scale

Required Tester Capabilities

- Spirent TestCenter 2U-HS Chassis (Alternately, Spirent TestCenter SPT-9000A chassis) with Controller 2
- Spirent TestCenter NG-100G-F2 module
- Spirent TestCenter CPU-5004A module
- L1 Testing Capabilities at 100 GB
- PRBS Generating Capabilities for Layer 1 testing at 100 GB
- Skew reporting capabilities per lane

Topology



Test Procedure

1. Insert the optics into the tester 100 GB module.
2. Insert a loopback cable into the optics.
3. Open the tester GUI and connect to the chassis.
4. In the Layer 1 PMA test screen:
   a. Run the PRBS mixture on all lanes.
   b. Let it run for at least 24 hours.
      i. Verify that the PRBS frames are recognized properly.
      ii. Verify that there are no RX PRBS frames.
      iii. Verify that there is no lane swapping.
      iv. Verify that there are no PRBS inversions.
      v. Observe the skew value between lanes.
5. Repeat the above steps for all the optics/transceivers that is used in testing.

Variables & Relevance

Variable	Relevance
Optics	The optics should be compatible with the tester 100 GB module
Loopback Cable	The loopback cable must be clean and able to pass error-free traffic on any other known good transceiver.
PRBS Mixture	The more complex the PRBS mixture, more robust the test.

Desired Result

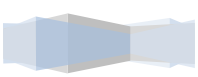
There should be no PRBS errors or inversions at the PMA layer. Also, there should be no lane swapping at the PCS layer. These symptoms indicate an issue with the optics.

Key Measured Metrics

Statistic	Relevance
PRBS Error Counter	Any error count increment or inversions indicate a possible issue with the optics.
Lane Alignment	Lane swapping at the PCS layer indicates an issue with the optics.
Skew	Look at the skew statistics at the PCS Layer.

Analysis

The user should not see PRBS errors, inversions, or lane alignment errors reported. These items indicate an issue with the optic/transceiver. Absence of these items indicates that the optic/transceiver is functioning properly and is qualified to be used in further testing. The skew value must be in an acceptable range for the manufacturer. Repeat the test for all optics/transceivers to be used in testing and use only those that pass.



HSE_003 Determine whether PMA layer is error free

Abstract

This test determines whether the PMA layer on the DUT functions without bit errors. Put the DUT in a PMA loopback (PCS loopback does not work) and generate traffic with a mix of PRBS patterns to verify the patterns are recognized and there are no swapped lanes, errors or inversions. References: IEEE 802.3ba. For product verification, engineering and manufacturing.

Description

This test case determines whether the DUT can generate traffic without errors at the PMA layer. The primary function of the PMA is to multiplex M input lanes to N output lanes where needed.

- Bit level multiplexing only
- The PMA also performs clock recovery, clock conversion, test pattern generation and detection and loopbacks where applicable. This test case validates multiplexing validity and clocking, recovery mechanisms, etc.

Relevance

Determines the Interoperability between the DUT and the tester at the PMA layer.

Version

1.0

Test Category

High Speed Ethernet.

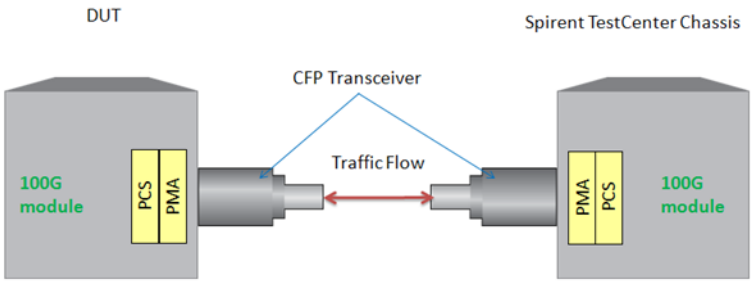
PASS

[ ] Performance [x] Availability [ ] Security [ ] Scale

Required Tester Capabilities

- Spirent TestCenter 2U-HS Chassis (Alternately, Spirent TestCenter SPT-9000A chassis) with Controller 2
- Spirent TestCenter NG-100G-F2 module
- Spirent TestCenter CPU-5004A module
- L1 Testing Capabilities at 100 GB
- PRBS Generating Capabilities for Layer 1 testing at 100 GB

Topology



Test Procedure

1. Connect the tester to the DUT using optical cables.
2. Configure the DUT to PMA loopback mode.
3. Open the tester PMA configuration window.
    a. Run the PRBS mixture.
    b. Run the test for 5 minutes.
        i. Verify that the PRBS frames are recognized.
        ii. Verify that no RX PRBS frames are received.
        iii. Verify that no lane swapping occurs.
        iv. Verify that there are no PRBS inversions.

Variables & Relevance

Variable	Relevance
Optics	The optics must run error free in another 100 GB-capable device to verify functionality.
DUT Capabilities	The DUT should be able loopback traffic at the PMA layer.

Desired Result

No PRBS errors, inversions or lane swapping should be reported. These items indicate an issue with the DUT PMA Layer.

Key Measured Metrics

Statistic	Relevance
PRBS Error Counter	An error count increment indicates a problem with how the DUT handles traffic at the PMA layer.
Lane Swapping	Lane swapping at the PCS layer indicates a possible issue with the DUT PMA Layer.

Analysis

No RX PRBS errors, inversions or lane swapping should be reported. These items indicate an issue with the DUT PMA layer. Additional testing should use only known good optics/transceivers in both the DUT and the tester.

HSE_004 Determine whether PMA layer is error free over a long term

Abstract

This test determines whether the PMA layer on the DUT functions without bit errors for a long duration. Put the DUT in PMA loopback (PCS loopback does not work) and generate traffic with the PRBS 31 pattern on all lanes for approximately 1 hour to verify that there are no swapped lanes, errors or inversions. References: IEEE 802.3ba. For product verification, engineering and manufacturing.

Description

This test case determines whether the DUT can generate error free traffic over a duration at the PMA layer. This is achieved by generating long-duration traffic and measuring error conditions.

Relevance

Determines the Interoperability between the DUT and the Spirent TestCenter module at the PMA layer.

Version

1.0

Test Category

High Speed Ethernet.

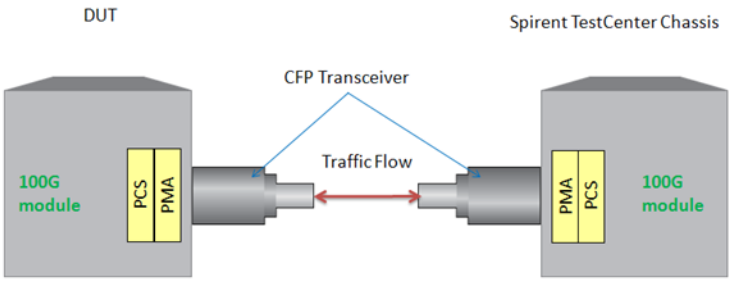
PASS

[ ] Performance [x] Availability [ ] Security [ ] Scale

Required Tester Capabilities

- Spirent TestCenter 2U-HS Chassis (Alternately, Spirent TestCenter SPT-9000A chassis) with Controller 2
- Spirent TestCenter NG-100G-F2 module
- Spirent TestCenter CPU-5004A module
- L1 Testing Capabilities at 100 GB
- PRBS Generating Capabilities for Layer 1 testing at 100 GB

Topology



Test Procedure

1. Connect the tester to the DUT using optical cables.
2. Configure the DUT to PMA loopback mode.
3. Open the tester PMA configuration window.
   a. Select the PRBS 31 mixture.
   b. Run the test for 1 hour.
      i. Verify that the PRBS frames are recognized.
      ii. Verify that no RX PRBS frames are received.
      iii. Verify that no lane swapping occurs.
      iv. Verify that there are no RX PRBS inversions.

Variables & Relevance

Variable	Relevance
Optics	The optics must run error free in another 100 GB-capable device to verify functionality.
DUT Capabilities	The DUT should be able loopback traffic at the PMA layer.

Desired Result

No PRBS errors, inversions or lane swapping should be reported. These items indicate an issue with the DUT PMA Layer.

Key Measured Metrics

Statistic	Relevance
PRBS Error Counter	An error count increment indicates a problem with how the DUT handles traffic at the PMA layer.
Lane Swapping	Lane swapping at the PCS layer indicates a possible issue with the DUT PMA Layer.

Analysis

No RX PRBS errors, inversions or lane swapping should be reported. These items indicate an issue with the DUT PMA layer. Additional testing should use only known good optics/transceivers in both the DUT and the tester.

HSE_005 PCS Marker alignment functionality

Abstract

This test determines whether PCS functions work properly. While traffic is running, note PCS marker alignment and lane mapping to verify that all lanes are recognized and are aligned. Swap lanes randomly and note lane mapping to verify PCS marker alignment. Validating PCS lane markers enhances interoperability and reduces the possibility of random errors in the field. References: IEEE 802.3ba. For product verification, engineering and manufacturing.

Description

This test case verifies that the virtual lane markers are properly implemented in the 100G DUT design, by generating large amounts of traffic and determining whether physical-to-virtual translation occurs correctly.

Relevance

Determines Interoperability between the DUT and the tester at the PCS layer.

Version

1.0

Test Category

High Speed Ethernet.

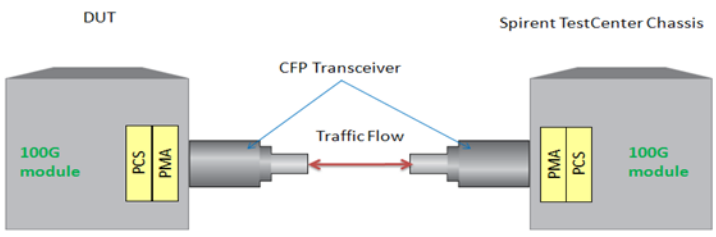
PASS

[ ] Performance [x] Availability [ ] Security [ ] Scale

Required Tester Capabilities

- Spirent TestCenter 2U-HS Chassis (Alternately, Spirent TestCenter SPT-9000A chassis) with Controller 2
- Spirent TestCenter NG-100G-F2 module
- Spirent TestCenter CPU-5004A module
- L1 Testing Capabilities at 100 GB
- PRBS Generating Capabilities for Layer 1 testing at 100 GB

Topology



Test Procedure

1. Connect the tester to the DUT using optical cables.
2. Configure traffic generated from the tester to be sent through the DUT to the same tester port.
3. Open the tester PCS configuration window.
4. Start Layer 1 or PRBS traffic.
   a. Keep the normal operational mode.
      i. Verify RX PCS alignment markers.
      ii. Verify that no bit errors are reported.
      iii. Verify RX PCS lane mapping.
   b. Swap lanes randomly.
      i. Verify RX PCS lane mapping.
   c. Swap lanes in a reverse pair order
      i. Verify RX PCS lane mapping.

Variables & Relevance

Variable	Relevance
Optics	The optics must run error free in another 100 GB-capable device to verify functionality.
DUT Capabilities	The DUT should be able loopback traffic at the PCS Layer.

Desired Result

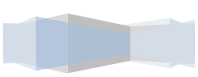
No PCS marker alignment, lane swapping or bit errors should be reported. These items indicate an issue with the DUT PCS layer.

Key Measured Metrics

Statistic	Relevance
PCS Marker Alignment	The tester detects and reports RX PCS market alignment issues. Alignment marker issues usually indicate that the DUT PCS layer is not inserting the markers properly.
Lane Swapping	RX lane swapping detection indicates an issue with how the DUT transmits frames.
Skew	Verify that the per-lane skew value is in an acceptable range.

Analysis

The user shouldn't see PCS marker alignment, lane swapping or bit errors during the test. These items indicate an issue with the DUT PCS layer. Additional testing should use only known good optics/transceivers in both the DUT and the tester. If using more than 2 ports on the DUT so that traffic is sent from one test port and received on another), test the DUT ports individually first.



HSE_006 Measure the maximum lane skew capability of the DUT

Abstract

This test determines the maximum skew on the DUT. While traffic is running, insert a skew of 180 ns on multiple lanes and verify that the PCS markers remain aligned. Increase the skew until lane alignment is lost to find the maximum skew for the DUT. Maximum skew compensation is an important metric in interoperability. References: IEEE 802.3ba. For product verification, engineering and manufacturing.

Description

This test case measures the range and correctness of individual lane skew inside the DUT HSE implementation. Lane skew is a difference in timing delay across lanes. Skew must be compensated for on the receive time before the data stream may be reconstituted by the RX port.

Relevance

Determines the max skew value on the DUT without losing PCS lane alignment.

Version

1.0

Test Category

High Speed Ethernet.

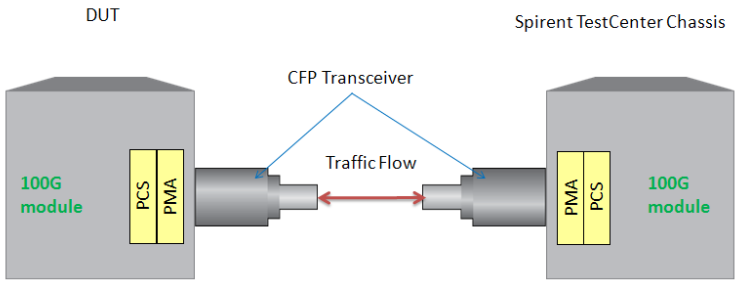
PASS

[ ] Performance [x] Availability [ ] Security [ ] Scale

Required Tester Capabilities

- Spirent TestCenter 2U-HS Chassis (Alternately, Spirent TestCenter SPT-9000A chassis) with Controller 2
- Spirent TestCenter NG-100G-F2 module
- Spirent TestCenter CPU-5004A module
- Skew inserting and detecting Capabilities at 100 GB
- PRBS Generating Capabilities for Layer 1 testing at 100 GB

Topology



Test Procedure

1. Connect the tester to the DUT using optical cables.
2. Configure traffic generated from the tester to be sent through the DUT to the same tester port.
3. Open the tester PCS configuration window.
4. Start L1 traffic.
   a. Insert skew of 10 ns on the first PCS lane.
   b. Verify PCS Lane Alignment is not lost.
   c. Increase the skew until the PCS lane alignment is lost.
   d. Repeat the above steps for all the PCS lanes.

Variables & Relevance

Variable	Relevance
Optics	The optics must run error free in another 100 GB-capable device to ensure verify functionality.
DUT Capabilities	The DUT should be able to loopback traffic at the PCS Layer.

Desired Result

The maximum skew value determined should be within the IEEE 802.3ba standards for 100 GB and also within the range for which the DUT was designed.

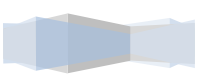
Key Measured Metrics

Statistic	Relevance
PCS Lane Alignment	The tester detects and reports RX PCS market alignment issues.
Skew	Verify if the per lane skew value is within the IEEE 802.3ba standards range.

Analysis

The IEEE 802.3ba specification suggests a max PCS skew value of 180 ns. The DUT is compliant to the IEEE 802.3ba 100 GB standards if the max skew value is within the specified range. Also, the manufacturer may have an expectation of the max skew value based on their hardware design. This value should be less than the max stated in the standards. This test case determines whether that requirement is met as well.

If using more than 2 ports on the DUT so that traffic is sent from one test port and received on another, test the DUT ports individually first.



Appendix A – Telecommunications Definitions

APPLICATION LOGIC. The computational aspects of an application, including a list of instructions that tells a software application how to operate.

APPLICATION SERVICE PROVIDER (ASP). An ASP deploys hosts and manages access to a packaged application by multiple parties from a centrally managed facility. The applications are delivered over networks on a subscription basis. This delivery model speeds implementation, minimizes the expenses and risks incurred across the application life cycle, and overcomes the chronic shortage of qualified technical personnel available in-house.

APPLICATION MAINTENANCE OUTSOURCING PROVIDER. Manages a proprietary or packaged application from either the customer's or the provider's site.

ASP INFRASTRUCTURE PROVIDER (AIP). A hosting provider that offers a full set of infrastructure services for hosting online applications.

ATM. Asynchronous Transport Mode. An information transfer standard for routing high-speed, high-bandwidth traffic such as real-time voice and video, as well as general data bits.

AVAILABILITY. The portion of time that a system can be used for productive work, expressed as a percentage.

BACKBONE. A centralized high-speed network that interconnects smaller, independent networks.

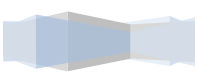
BANDWIDTH. The number of bits of information that can move through a communications medium in a given amount of time; the capacity of a telecommunications circuit/network to carry voice, data, and video information. Typically measured in Kbps and Mbps. Bandwidth from public networks is typically available to business and residential end-users in increments from 56 Kbps to 45 Mbps.

BIT ERROR RATE. The number of transmitted bits expected to be corrupted per second when two computers have been communicating for a given length of time.

BURST INFORMATION RATE (BIR). The rate of information in bits per second that the customer may need over and above the CIR. A burst is typically a short duration transmission that can relieve momentary congestion in the LAN or provide additional throughput for interactive data applications.

BUSINESS ASP. Provides prepackaged application services in volume to the general business market, typically targeting small to medium size enterprises.

BUSINESS-CRITICAL APPLICATION. The vital software needed to run a business, whether custom-written or commercially packaged, such as accounting/finance, ERP, manufacturing, human resources and sales databases.



BUSINESS SERVICE PROVIDER. Provides online services aided by brick-and-mortar resources, such as payroll processing and employee benefits administration, printing, distribution or maintenance services. The category includes business process outsourcing (BPO) companies.

COMMERCE NETWORK PROVIDER. Commerce networks were traditionally proprietary value-added networks (VANs) used for electronic data interchange (EDI) between companies. Today the category includes the new generation of electronic purchasing and trading networks.

COMPETITIVE ACCESS PROVIDER (CAP). A telecommunications company that provides an alternative to a LEC for local transport and special access telecommunications services.

CAPACITY. The ability for a network to provide sufficient transmitting capabilities among its available transmission media, and respond to customer demand for communications transport, especially at peak usage times.

CLIENT/DEVICE. Hardware that retrieves information from a server.

CLUSTERING. A group of independent systems working together as a single system. Clustering technology allows groups of servers to access a single disk array containing applications and data.

COMPUTING UTILITY PROVIDER (CUP). A provider that delivers computing resources, such as storage, database or systems management, on a pay-as-you-go basis.

CSU/DSU. Channel Server Unit/Digital Server Unit. A device used to terminate a telephone company connection and prepare data for a router interface.

DATA MART. A subset of a data warehouse, intended for use by a single department or function.

DATA WAREHOUSE. A database containing copious amounts of information, organized to aid decision-making in an organization. Data warehouses receive batch updates and are configured for fast online queries to produce succinct summaries of data.

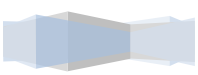
DEDICATED LINE. A point-to-point, hardwired connection between two service locations.

DEMARCATION LINE. The point at which the local operating company's responsibility for the local loop ends. Beyond the demarcation point (also known as the network interface), the customer is responsible for installing and maintaining all equipment and wiring.

DISCARD ELIGIBILITY (DE) BIT. Relevant in situations of high congestion, it indicates that the frame should be discarded in preference to frames without the DE bit set. The DE bit may be set by the network or by the user; and once set cannot be reset by the network.

DS-1 OR T-1. A data communication circuit capable of transmitting data at 1.5 Mbps. Currently in widespread use by medium and large businesses for video, voice, and data applications.

DS-3 OR T-3. A data communications circuit capable of transmitting data at 45 Mbps. The equivalent data capacity of 28 T-1s. Currently used only by businesses/institutions and carriers for high-end applications.



ELECTRONIC DATA INTERCHANGE (EDI). The electronic communication of business transactions (orders, confirmations, invoices etc.) of organizations with differing platforms. Third parties provide EDI services that enable the connection of organizations with incompatible equipment.

ENTERPRISE ASP. An ASP that delivers a select range of high-end business applications, supported by a significant degree of custom configuration and service.

ENTERPRISE RELATIONSHIP MANAGEMENT (ERM). Solutions that enable the enterprise to share comprehensive, up-to-date customer, product, competitor and market information to achieve long-term customer satisfaction, increased revenues, and higher profitability.

ENTERPRISE RESOURCE PLANNING (ERP). An information system or process integrating all manufacturing and related applications for an entire enterprise. ERP systems permit organizations to manage resources across the enterprise and completely integrate manufacturing systems.

ETHERNET. A local area network used to connect computers, printers, workstations, and other devices within the same building. Ethernet operates over twisted wire and coaxial cable.

EXTENDED SUPERFRAME FORMAT. A T1 format that provides a method for easily retrieving diagnostics information.

FAT CLIENT. A computer that includes an operating system, RAM, ROM, a powerful processor and a wide range of installed applications that can execute either on the desktop or on the server to which it is connected. Fat clients can operate in a server-based computing environment or in a stand-alone fashion.

FAULT TOLERANCE. A design method that incorporates redundant system elements to ensure continued systems operation in the event of the failure of any individual element.

FDDI. Fiber Distributed Data Interface. A standard for transmitting data on optical-fiber cables at a rate of about 100 Mbps.

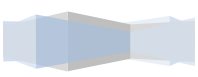
FRAME. The basic logical unit in which bit-oriented data is transmitted. The frame consists of the data bits surrounded by a flag at each end that indicates the beginning and end of the frame. A primary rate can be thought of as an endless sequence of frames.

FRAME RELAY. A high-speed packet switching protocol popular in networks, including WANs, LANs, and LAN-to-LAN connections across long distances.

GBPS. Gigabits per second, a measurement of data transmission speed expressed in billions of bits per second.

HOSTED OUTSOURCING. Complete outsourcing of a company's information technology applications and associated hardware systems to an ASP.

HOSTING PROVIDER. Provider who operates data center facilities for general-purpose server hosting and collocation.



INFRASTRUCTURE ISV. And independent software vendor that develops infrastructure software to support the hosting and online delivery of applications.

INTEGRATED SERVICES DIGITAL NETWORK (ISDN). An information transfer standard for transmitting digital voice and data over telephone lines at speeds up to 128 Kbps.

INTEGRATION. Equipment, systems, or subsystem integration, assembling equipment or networks with a specific function or task. Integration is combining equipment/systems with a common objective, easy monitoring and/or executing commands. It takes three disciplines to execute integration: 1) hardware, 2) software, and 3) connectivity – transmission media (data link layer), interfacing components. All three aspects of integration have to be understood to make two or more pieces of equipment or subsystems support the common objective.

INTER-EXCHANGE CARRIER (IXC). A telecommunications company that provides telecommunication services between local exchanges on an interstate or intrastate basis.

INTERNET SERVICE PROVIDER (ISP). A company that provides access to the Internet for users and businesses.

INDEPENDENT SOFTWARE VENDOR (ISV). A company that is not a part of a computer systems manufacturer that develops software applications.

INTERNETWORKING. Sharing data and resources from one network to another.

IT SERVICE PROVIDER. Traditional IT services businesses, including IT outsourcers, systems integrators, IT consultancies and value added resellers.

KILOBITS PER SECOND (KBPS). A data transmission rate of 1,000 bits per second.

LEASED LINE. A telecommunications line dedicated to a particular customer along predetermined routers.

LOCAL ACCESS TRANSPORT AREA (LATA). One of approximately 164 geographical areas within which local operating companies connect all local calls and route all long-distance calls to the customer's inter-exchange carrier.

LOCAL EXCHANGE CARRIER (LEC). A telecommunications company that provides telecommunication services in a defined geographic area.

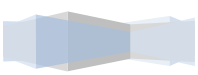
LOCAL LOOP. The wires that connect an individual subscriber's telephone or data connection to the telephone company central office or other local terminating point.

LOCAL/REGIONAL ASP. A company that delivers a range of application services, and often the complete computing needs, of smaller businesses in their local geographic area.

MEGABITS PER SECOND (MBPS). 1,024 kilobits per second.

METAFRAME. The world's first server-based computing software for Microsoft Windows NT 4.0 Server, Terminal Server Edition multi-user software (co-developed by Citrix).

MODEM. A device for converting digital signals to analog and vice versa, for data transmission over an analog telephone line.



MULTIPLEXING. The combining of multiple data channels onto a single transmission medium. Sharing a circuit - normally dedicated to a single user - between multiple users.

MULTI-USER. The ability for multiple concurrent users to log on and run applications on a single server.

NET-BASED ISV. An ISV whose main business is developing software for Internet-based application services. This includes vendors who deliver their own applications online, either directly to users or via other service providers.

NETWORK ACCESS POINT (NAP). A location where ISPs exchange traffic.

NETWORK COMPUTER (NC). A thin-client hardware device that executes applications locally by downloading them from the network. NCs adhere to a specification jointly developed by Sun, IBM, Oracle, Apple and Netscape. They typically run Java applets within a Java browser, or Java applications within the Java Virtual Machine.

NETWORK COMPUTING ARCHITECTURE. A computing architecture in which components are dynamically downloaded from the network onto the client device for execution by the client. The Java programming language is at the core of network computing.

ONLINE ANALYTICAL PROCESSING (OLAP). Software that enables decision support via rapid queries to large databases that store corporate data in multidimensional hierarchies and views.

OPERATIONAL RESOURCE PROVIDER. Operational resources are external business services that an ASP might use as part of its own infrastructure, such as helpdesk, technical support, financing, or billing and payment collection.

OUTSOURCING. The transfer of components or large segments of an organization's internal IT infrastructure, staff, processes or applications to an external resource such as an ASP.

PACKAGED SOFTWARE APPLICATION. A computer program developed for sale to consumers or businesses, generally designed to appeal to more than a single customer. While some tailoring of the program may be possible, it is not intended to be custom-designed for each user or organization.

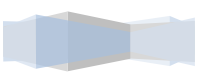
PACKET. A bundle of data organized for transmission, containing control information (destination, length, origin, etc.), the data itself, and error detection and correction bits.

PACKET SWITCHING. A network in which messages are transmitted as packets over any available route rather than as sequential messages over circuit-switched or dedicated facilities.

PEERING. The commercial practice under which nationwide ISPs exchange traffic without the payment of settlement charges.

PERFORMANCE. A major factor in determining the overall productivity of a system, performance is primarily tied to availability, throughput and response time.

PERMANENT VIRTUAL CIRCUIT (PVC). A PVC connects the customer's port connections, nodes, locations, and branches. All customer ports can be connected, resembling a mesh, but PVCs usually run between the host and branch locations.



POINT OF PRESENCE (POP). A telecommunications facility through which the company provides local connectivity to its customers.

PORTAL. A company whose primary business is operating a Web destination site, hosting content and applications for access via the Web.

REMOTE ACCESS. Connection of a remote computing device via communications lines such as ordinary phone lines or wide area networks to access distant network applications and information.

REMOTE PRESENTATION SERVICES PROTOCOL. A set of rules and procedures for exchanging data between computers on a network, enabling the user interface, keystrokes, and mouse movements to be transferred between a server and client.

RESELLER/VAR. An intermediary between software and hardware producers and end users. Resellers frequently add value (thus Value-Added Reseller) by performing consulting, system integration and product enhancement.

ROUTER. A communications device between networks that determines the best path for optimal performance. Routers are used in complex networks of networks such as enterprise-wide networks and the Internet.

SCALABILITY. The ability to expand the number of users or increase the capabilities of a computing solution without making major changes to the systems or application software.

SERVER. The computer on a local area network that often acts as a data and application repository and that controls an application's access to workstations, printers and other parts of the network.

SERVER-BASED COMPUTING. A server-based approach to delivering business-critical applications to end-user devices, whereby an application's logic executes on the server and only the user interface is transmitted across a network to the client. Benefits include single-point management, universal application access, bandwidth-independent performance, and improved security for business applications.

SINGLE-POINT CONTROL. One of the benefits of the ASP model, single-point control helps reduce the total cost of application ownership by enabling widely used applications and data to be deployed, managed and supported at one location. Single-point control enables application installations, updates and additions to be made once, on the server, which are then instantly available to users anywhere.

SPECIALIST ASP. Provide applications which serve a specific professional or business activity, such as customer relationship management, human resources or Web site services.

SYSTEMS MANUFACTURER. Manufacturer of servers, networking and client devices.

TELECOMS PROVIDER. Traditional and new-age telecommunications network providers (telcos).

THIN CLIENT. A low-cost computing device that accesses applications and and/or data from a central server over a network. Categories of thin clients include Windows-Based Terminals (WBT, which comprise the largest segment), X-Terminals, and Network Computers (NC).

TOTAL COST OF OWNERSHIP (TCO). Model that helps IT professionals understand and manage the budgeted (direct) and unbudgeted (indirect) costs incurred for acquiring, maintaining and using an application or a computing system. TCO normally includes training, upgrades, and administration as well as the purchase price. Lowering TCO through single-point control is a key benefit of server-based computing.

TOTAL SECURITY ARCHITECTURE (TSA). A comprehensive, end-to-end architecture that protects the network.

TRANSMISSION CONTROL PROTOCOL/INTERNET PROTOCOL (TCP/IP). A suite of network protocols that allow computers with different architectures and operating system software to communicate over the Internet.

USER INTERFACE. The part of an application that the end user sees on the screen and works with to operate the application, such as menus, forms and buttons.

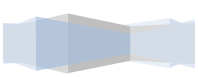
VERTICAL MARKET ASP. Provides solutions tailored to the needs of a specific industry, such as the healthcare industry.

VIRTUAL PRIVATE NETWORK (VPN). A secure, encrypted private connection across a cloud network, such as the Internet.

WEB HOSTING. Placing a consumer's or organization's web page or web site on a server that can be accessed via the Internet.

WIDE AREA NETWORK. Local area networks linked together across a large geographic area.

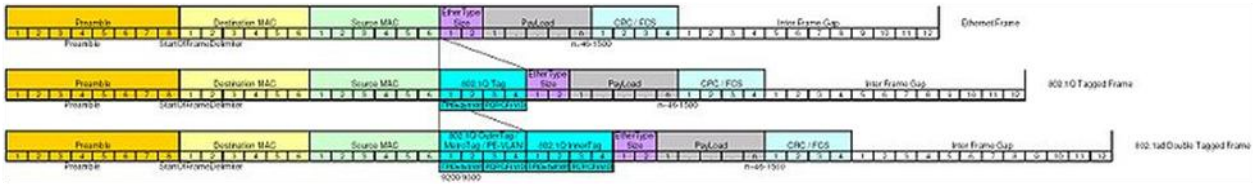
WINDOWS-BASED TERMINAL (WBT). Thin clients with the lowest cost of ownership, as there are no local applications running on the device. Standards are based on Microsoft's WBT specification developed in conjunction with Wyse Technology, NCD, and other thin client companies.



Appendix B – Layer 2 802.1q CoS

The following tables represent best practices for Layer 2 VLAN / Q-in-Q CoS. Each row relates the appropriate metric to measured minimum acceptable for its respective traffic class.

VLAN 802.1p CoS / Q-in-Q Priority

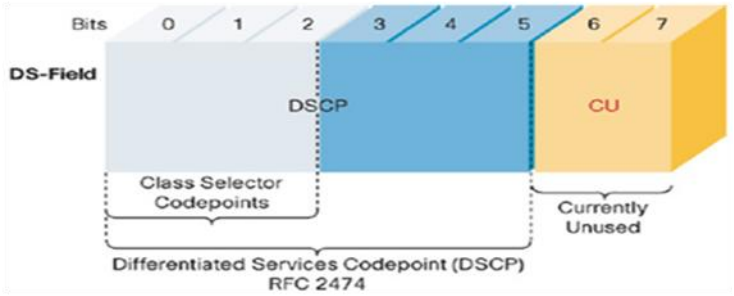


802.1 PRI CoS	Min. RX / TX Bandwidth Ratio	Max Jitter (uSec)	Max Latency (uSec)	Max Loss (Frames)	Max Duplicate (Frames)	Max Reordered (Frames)	Max Late (Frames)
7	1	0	>=1	0	0	0	0
6	1	0	2	0	0	0	0
5	.99	1	2	0	0	0	0
4	.98	1	3	0	0	0	0
3	.95	2	5	0	1	1	1
2	.90	3	5	1	1	1	1
1	.85	5	10	1	2	2	2
0	ANY	ANY	ANY	ANY	ANY	ANY	ANY

Appendix C – RFC 2474 Layer 3 QoS

The following tables represent best practices for Layer 2 VLAN / Q-in-Q CoS. Each row relates the appropriate metric to measured minimum acceptable for its respective traffic class.

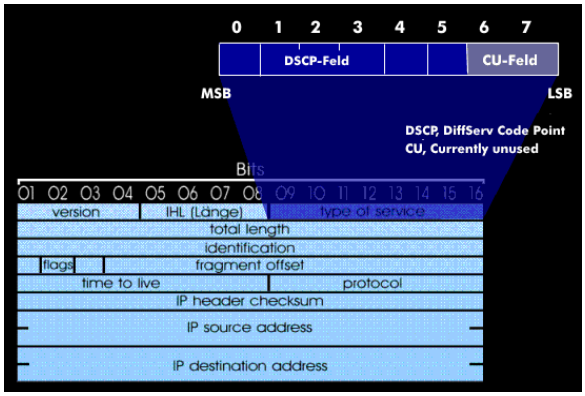
IPv4 / IPv6 DiffServ



Codepoint	Max Jitter (uSec)	Max Latency (uSec)	Max Loss (Frames)	Max Duplicate (Frames)	Max Reordered (Frames)	Max Late (Frames)
EF	0	>=1	0	0	0	0
AF31	0	2	0	0	0	0
AF21	2	5	0	1	1	1
AF11	3	5	1	1	1	1
BE	ANY	ANY	ANY	ANY	ANY	ANY

Appendix D – RFC 2474 Layer 3 QoS Definitions

The following table represents the definitions of each DiffServ Codepoint possibility.



DSCP Value	DF Code Point	Equivalent IP Precedent	Description
000 000 00	BE	000 - Routine	Best Effort, Unclassified Quality
001 010 10	AF11	001 - Priority	High-Throughput Transactions with high loss sensitivity
001 100 12	AF12	001 - Priority	High-Throughput Transactions with some loss sensitivity
001 110 14	AF13	001 - Priority	High-Throughput Transactions with loss resiliency
001 010 18	AF21	001 - Immediate	Low-Latency Transactions with high loss sensitivity
010 100 20	AF22	001 - Immediate	Low-Latency Transactions with some loss sensitivity
010 119 22	AF23	001 - Immediate	Low-Latency Transaction with loss resiliency
011 010 26	AF31	011 - Flash	Broadcast Media with high loss sensitivity
011 110 28	AF32	011 - Flash	Broadcast Media with some loss sensitivity
011 110 30	AF33	001 - Flash	Broadcast Media with loss resiliency
100 010 34	AF41	100 – Flash Override	Live Media with high loss sensitivity
100 110 36	AF42	100 – Flash Override	Live Media with some loss sensitivity
100 110 38	AF43	100 – Flash Override	Live Media with loss resiliency
101 110 46	EF	101 – Critical	Mission Critical Transactions or VoIP