IxNetwork Industrial, Automotive, and Carrier Ethernet Test Solution

Validate Enhanced-Ethernet, Time-Sensitive Networks

Problem: Uncertainty About How Ethernet Can Replace Legacy Connectivity

The popularity of Ethernet in IT has propelled new adoption in other industries such as Ethernet virtual connections (EVCs) for metro Ethernet access, professional Audio-Video installations, automotive electronic control unit (ECU) connectivity, industrial automation and control, and time/clock distribution. But the successful replacement of these existing purpose-built Ethernet networks requires significant enhancements that include new signaling protocols and traffic control mechanisms. How can you ensure the enhanced Ethernet achieves the same level of performance and quality of the legacy connectivity for a converged IT/OT network?

Solution: Leading Ethernet Test System Extended for Industrial Ethernet

Keysight's IxNetwork is the leader in Ethernet test solutions for network equipment manufacturers (NEMs) and service providers. Leveraging our rich Ethernet expertise, the IxNetwork Industrial, Automotive, and Carrier Ethernet test solution provides unparalleled test coverage. Each IxNetwork test port can emulate hundreds of Ethernet endpoints with realistic behavior. Various test scenarios can be executed with our graphical user interface (GUI) or application programming interface (API) scripting to characterize performance bottlenecks and resiliency.

With this test solution, you can validate that your Ethernet implementation:

- Provides the carrier-grade scale and performance needed for metro EVC access
- Supplies the low latency/jitter and dedicated bandwidth needed for professional audio/video
- Provides the scheduling and reliability for mission-critical applications in industrial networks
- Achieves the scale and precision needed for timing and clock synchronization between networking devices

KEYSIGHT

Table of Contents

Highlights

- Validate industrial time-sensitive networking (TSN) scheduled traffic (IEEE 802.1Qbv) on multiple redundant time synchronization domains (IEEE 802.1AS-2020)
- Verify Frame Preemption (IEEE 802.1Qbu) with accurate emulation of fragments, preemptable and express frames
- Verify TSN standards for IEEE 802.1CB, IEEE 802.1Qci, and IEEE802.1Qcc
- Ensure professional quality AV that relies on stringent latency/jitter and resource reservation by emulating large volume of audio-video bridging (AVB) Talker-Listener instances and traffic
- Ensure high performing and scaling Carrier Ethernet services (E-Line, E-LAN, E-Tree) by emulating maintenance intermediate points (MIP) and maintenance end points (MEP)
- Verify functionality, quality, and scaling of PTP implementations to IEEE 1588v2 and G8265.1/G8275.1 telecom profiles and SMPTE ST-2059-2 Broadcast Media profiles by emulating Leader and Follower clocks
- Validate conformance with respect to Avnu Alliance Automotive Profile, TSN Conformance Test package
- Validate conformance with Avnu industrial test plan for IEEE 802.1Qbv
- Validate conformance with Avnu base TSN test plan for IEEE 802.1AS-2020 and IEEE 802.1Qbv

Key Features

- TSN emulation — Scheduled traffic (IEEE 802.1Qbv) based on gPTP time (IEEE 802.1AS-2020), Frame Preemption (IEEE 802.1Qbu / IEEE 802.13br), Frame Replication (IEEE 802.1CB), Filtering & Policing (IEEE 802.1Qci)
- Configuration of TSN devices through Netconf/Yang (IEEE 802.1Qcc, IEEE 802.1Qbv)
- AVB emulation — Stream reservation protocol IEEE 802.1Q Clause 35, forwarding and queueing of time-sensitive applications IEEE 802.1Qav, AV stream transport IEEE 1722
- Conformance test packages for new TSN standards, Avnu automotive profile, Avnu industrial test plan and Avnu component tests.
- Automatic generation of fragments through TSN wizard from the preemptable stream configuration in a frame preemption (IEEE 8021.Qbu) scenario
- Automatic generation of MACsec encrypted express streams and preempted fragments through TSN wizard in a frame preemption (IEEE 802.1Qbu) scenario
- IEEE 1588v2 precision time protocol (PTP) emulation
- Support for telecom PTP profiles ITU-T G.8265.1/G.8275.1/G.8275.2
- Support for SMPTE ST-2059-2 PTP profile for Professional Broadcast Application
- Ethernet service OAM emulation, IEEE 802.1ag and ITU-T Y.1731
- Synchronous Ethernet (ESMC) emulation
- Provider backbone bridges with traffic engineering (PBB-TE) emulation
- Ethernet link OAM emulation, defined in IEEE 802.3ah Clause 57
- Ethernet local management interface (ELMI), MEF 16

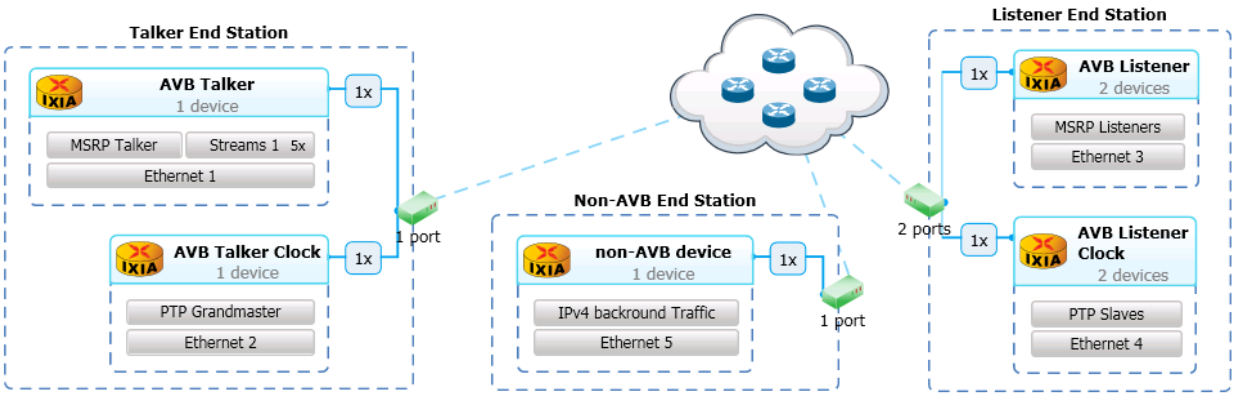


Figure 1. IxNetwork visual interfaces enable intuitive and comprehensive emulation of AVB/TSN Talkers and Listeners and gPTP Leaders and Followers

Conformance Coverage

Conformance Packages include the following:

- Scenario-based custom test case generation
- Graphical representation of test results
- Detailed logging
- Failure debugging at packet capture levels

Avnu Alliance Component test plan for IEEE 802.1AS-2020, IEEE 802.1Qbv, IEEE 802.1Qav and IEEE 802.1Qbu

As the adoption of TSN is increasing across different ecosystems, every device manufacturer must ensure a proper implementation of the IEEE 802.1 standards. Avnu has come up with TSN test specifications for IEEE 802.1AS-2020 — Timing & Synchronization for Time-Sensitive Applications, IEEE 802.1Qbv — Enhancements for Scheduled Traffic, IEEE 802.1Qbu – Frame Preemption and IEEE 802.1Qav – Forwarding and Queuing Enhancements for Time-sensitive Streams. Device manufacturers use the IxNetwork TSN test package to check compliance with the Avnu base TSN Test Plan.

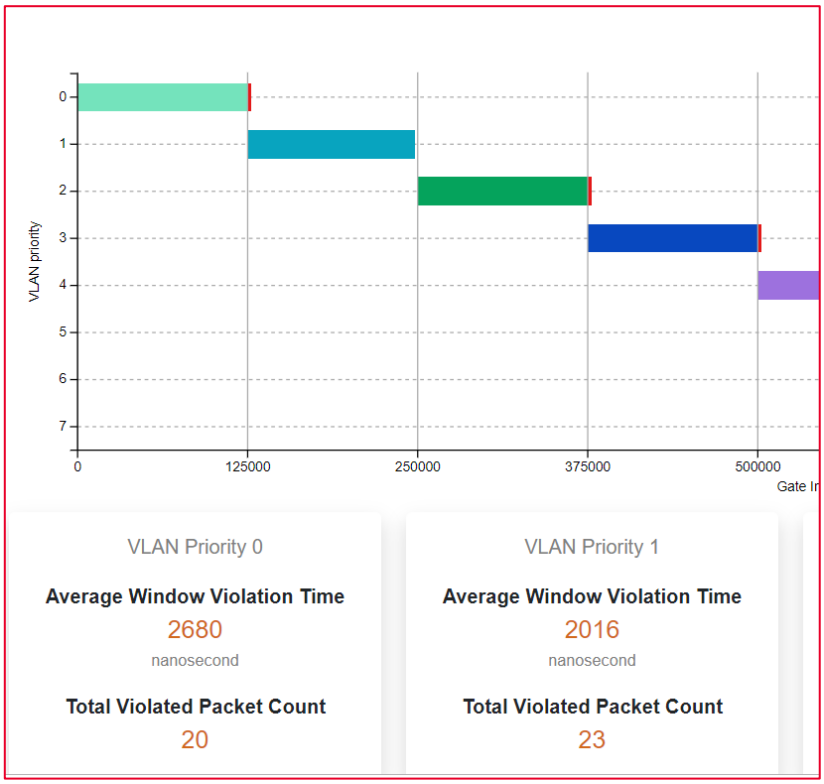
Avnu industrial test plan for IEEE 802.1Qbv

As the adoption of TSN is increasing in the industrial ecosystem, every device manufacturer must ensure a proper implementation of the IEEE 802.1 standards. Avnu has designed test cases to determine if a product conforms to specifications originally defined in IEEE 802.1Qbv-2015 Enhancements for Scheduled Traffic. Device manufacturers use the IxNetwork TSN test package to check compliance with the Avnu Industrial Test Plan.

Avnu automotive profile test plan

Avnu has released a specification and test plan to guide vendors in automotive AVB product development. The Avnu test plans can be used for the certification process by Avnu or certified test houses. The IxNetwork Avnu Automotive Test Package helps to validate implementations and prepare for the certification process. The test package contains the following:

- gPTP
- FQTSS
- Media Formats and SR Classes
- Exception Handling
- Diagnostics Counters
- Network and Device Startup



IxNetwork TSN conformance package

This package contains test cases for testing and benchmarking scenarios that span across these TSN standards:

- 802.1AS
- 802.1AS-2020
- 802.1Qbv
- 802.1Qbu
- 802.1CB
- 802.1Qci
- 802.1Qcc

Specifications

Ethernet Service OAM

Supported Standards	IEEE 802.1ag ITU-T Y.1731
Emulations	Emulation of Entities in a CFM Network, including: Maintenance End Point (MEP) Maintenance Intermediate Point (MIP)
Configuration	Full Configuration of Maintenance Point Parameters, including: Maintenance Association (MA) Name (all standard formats) Maintenance Domain (MD) Name (all standard formats) Maintenance Domain Level (0–7)
IEEE 802.1ag Protocols	Continuity Check Protocol Continuity Check Message (CCM) ◦ Full Range of Continuity Check Intervals (CCIs) supported 3.33 ms–10 minutes Loopback Protocol ◦ Loopback Message (LBM) and Loopback Reply (LBR) Linktrace Protocol ◦ Linktrace Message (LTM) and Linktrace Reply (LTR)
ITU-T Y.1731 Protocols	OAM Functions for Fault Management ◦ Ethernet Continuity Check (ETH-CC) ◦ Ethernet Loopback (ETH-LB) ◦ Ethernet Link Trace (ETH-LT) ◦ Ethernet Alarm Indication Signal (ETH-AIS) ◦ Ethernet Remote Defect Indication (ETH-RDI) ◦ Ethernet Locked Signal (ETH-LCK) ◦ Ethernet Test Signal (ETH-Test)

Ethernet Service OAM

	OAM Functions for Performance Monitoring ◦ Frame Loss Measurement (ETH-LM) ◦ Frame Delay Measurement (ETH-DM) ◦ Frame Delay Variation Measurement (ETH-DVM) ◦ Support for One-Way DM and DVM

Statistics

Bridge/MEP	Bridges Configured	Bridges Running
	MEPs Configured	MEPs Running
	MAs Configured	MAs Running
	Remote MEPs	MEP FNG Reset
	MEP FNG Defect	MEP FNG Defects Reported
	MEP FNG Defect	Clearing Session Flap Count
Continuity Check	CCM Tx/RX	RDI Tx/Rx
	CCM Received Equal	CCM Received Low
	Invalid CCM Received, Defective RMEPS	
	CCM Cross Connect Defects, CCM Unexpected Periods	
	CCM Unexpected Level, Out of Sequence CCM Received	
	RMEP Ok, RMEP Failed	
	RMEP Error NoDefect, RMEP Error Defect	
	RMEP XConn Defect, RMEP XConn NoDefect	
	AIS Tx/Rx	
	LCK Tx/Rx	
	TST Tx/Rx	
	TST Out of Sequence Tx/Rx	
	TST PRBS Bit Error Rx	
Performance Measurements	LMM Tx/Rx	
	LMR Tx/Rx	
	DMM Tx/Rx	
	DMR Tx/Rx	
	1DM Tx/Rx	
Linktrace	LTM Sent	LTM Received
	LTR Sent	LTR Received
	Invalid LTR Received	LTM Received State
	LTR Received State	
Loopback	LBM Tx/Rx	
	LBR Tx/Rx	
	Invalid LBM Received	Invalid LBR Received
	LBI Idle	LBI Transmitting
	LBI Waiting	LBR Respond
	LR Respond	

Ethernet Link OAM

Standards	IEEE 802.3ah-2004 Clause 57
Statistics	Local Discovery State Information PDU Tx/Rx Unique Information PDU Tx/Rx Event Notification PDU Tx/Rx Unique Event Notification PDU Tx/Rx Variable Request PDU Tx/Rx Variable Response PDU Tx/Rx Loopback Enable Control PDU Tx/Rx Loopback Disable Control PDU Tx/Rx Unsupported PDU Rx Errored Symbol Period Event Running Total Tx/Rx Errored Frame Event Running Total Tx/Rx Errored Frame Period Event Running Total Tx/Rx Errored Frame SS Event Running Total Tx/Rx Organization Specific PDU Tx/Rx Link Fault Tx/Rx Dying Gasp Tx/Rx Critical Event Tx/Rx Remote Revision Local Revision
Provider Backbone Bridges with Traffic Engineering (PBB-TE)	
Standards	IEEE 802.1Qay PBB-TE Nortel-led Carrier Ethernet Ecosystem Certified Interoperable PBT Implementation IEEE 802.1ah Provider Backbone Bridges
PBB-TE Specific Per Port Statistics	Trunks Configured Trunks Running
Standard and pre-standard B-VLAN TPID values	0x8100, 0x9100,0x9200 and 0x88A8
Configuration	Enable/Disable Individual Trunks Enable/Disable Optional TLV Validation Enable/Disable Out of Sequence CCM Detection
Per Trunk Configuration	MEP ID Source MAC Address / Destination MAC Address Short MA Name Format (supporting all standard formats) Short MA Name MD Level MD Name Format (supporting all standard formats) MD Name

Ethernet Link OAM	
	CCI Interval (supporting all standard intervals) B-VLAN ID B-VLAN Priority B-VLAN TPID

Ethernet Local Management Interface (ELMI)	
Protocol	Ethernet Local Management Interface (E-LMI)
Standard	MEF 16
Statistics	Learned Info: ◦ LMI Status ◦ LMI Status ◦ Protocol Version ◦ Send Sequence Num ◦ Receive Sequence Num ◦ Data Instance ◦ Invalid Protocol Version ◦ Invalid EVC Reference Id ◦ Invalid Message Type ◦ Out of Sequence IE ◦ Duplicated IE ◦ Mandatory IE Missing ◦ Invalid Mandatory IE ◦ Invalid Non-Mandatory IE ◦ Unrecognized IE ◦ Unexpected IE ◦ Short Message UNI Status ◦ EVC MAP type ◦ UNI Id Length ◦ UNI Id ◦ CM ◦ CF ◦ Per CoS ◦ CIR Magnitude ◦ CIR Multiplier ◦ CBS Magnitude ◦ CBS Multiplier ◦ EIR Magnitude

- EIR Multiplier
- EBS Magnitude
- EBS Multiplier
- UPB 000
- UPB 001
- UPB 010
- UPB 011
- UPB 100
- UPB 101
- UPB 110
- UPB 111

EVC Status

- Reference Id
- Status Type
- EVC Type
- Untagged/Priority Tag
- Default EVC
- EVC Id Length
- EVC Id
- Vlan Id
- CM
- CF
- Per CoS
- CIR Magnitude
- CIR Multiplier
- CBS Magnitude
- CBS Multiplier
- EIR Magnitude
- EIR Multiplier
- EBS Magnitude
- EBS Multiplier
- UPB 000
- UPB 001
- UPB 010
- UPB 011
- UPB 100
- UPB 101
- UPB 110
- UPB 111
- Global Statistics

E-LMI Aggregated Statistics

- UNI-C configured
- UNI-C Running

- UNI-N configured
- UNI-N Running
- Session Operational
- Session Flap
- Check Tx
- Check Rx
- Full Status Enquiry Tx
- Full Status Enquiry Rx
- Full Status Tx
- Full Status Rx
- Full Status Continued Enquiry Tx
- Full Status Continued Enquiry Rx
- Full Status Continued Tx
- Full Status Continued Rx
- Single EVC Asynchronous Status Tx
- Single EVC Asynchronous Status Rx
- UNI Status Tx
- UNI Status Rx
- EVC Status Tx
- EVC Status Rx
- CE-VLAN ID/EVC MAP Tx
- CE-VLAN ID/EVC MAP Rx
- Remote Protocol Version
- Invalid Protocol Version
- Invalid Message Type
- Out of Sequence IE Rx
- Duplicated IE Rx
- Mandatory IE Missing Rx
- Invalid Mandatory IE Rx
- Unrecognized IE Rx
- Unexpected IE Rx
- Short Message Rx
- Unsolicited Status Rx
- Invalid Status Rx

IEEE 1588 Precision Time Protocol (PTP)

Standards	IEEE 1588v2 (2008) G.8265.1 Telecom Profile G.8275.1 Telecom Profile G.8275.2 Telecom Profile IEEE 802.1AS gPTP Profile and parts of gPTP-rev for multiple domain support (requires separate 930-2113 AVB license) SMPTE ST-2059-2 PTP Power Profile IEEE C37.238-2017
Protocol Options	PTP over various encapsulations: IEEE 802.3/Ethernet (with optional VLANs), UDP/IPv4, UDP/IPv6 PTP Mode: Multicast, Unicast and Mixed Delay-Request Mechanisms: Delay Request/Response, Peer Delay, or One-Way mode (disabling the delay requests) Timestamping mode: One-step, Two-step Setting of IP ToS or DiffServ value VLAN 802.3 priority (with support for multiple nested VLANs) Lock emulated Follower time to emulated Grandmaster time to compute raw time error introduced by switches/bridges (Transparent or Boundary clocks) by disabling Update Time Frequency and time offset adjustment for each emulated session (Timestamp offset and Nanoseconds per Second)
Key Configuration Parameters	Clock parameters: Clock Identity, Port Number, Domain Messages rates: ◦ Announce Interval Log -9 (512/s) to Log 9 (1 per 512s) ◦ Sync Interval Log -9 (512/s) to Log 9 (1 per 512s) ◦ (P)Delay Request Interval Log -9 (512/s) to Log 9 (1 per 512s) ◦ Management interval Log -9 (512/s) to Log 9 (1 per 512s) Announce and Sync Receipt Timeout intervals Correction fields values for Sync, Follow-Up, (P)DelayReq, (P)DelayResp and PdelayResp Follow-up (when emulating Transparent Clock port) Grandmaster Identity, Steps Removed, and Path Trace TLV (when emulating a Boundary Clock port) BMCA related parameters: Priority 1, Clock Class, Clock Accuracy, Offset Scaled Log Variance, Priority 2 Strict Grant, Signal Interval and Grant Unicast Duration (configurable separately for Announce, Sync and DelayReq messages) Edit bits in Announce message including PTP Timescale, Time Source, Alternate Master Flag, Time Traceable, Frequency Traceable, Leap59, Leap61, Current UTC Offset Valid and Value Unicast parameters: Handle Announce TLV, Send Multicast Announce, Handle Cancel TLV, Renewal Invited, Learn Port ID, Signal Interval, Grant Unicast Duration, Grant Delay Response Duration G.8265.1 parameters: Request Interval, Request Interval Attempts, Request Hold-down Timer, Sync Receipt Timeout, Delay Response Receipt Timeout

	G.8275.1 parameters: Multicast Address (Non-forwardable or Forwardable), Not Follower and Drop Malformed (accept non-standard values in messages) gPTP parameters: Sync Receipt Timeout, FollowUp TLV fields (Cumulative Scaled Rate Offset, GM Time Base Indicator, Last GM Phase Change, Scaled Last GM Freq Change) Follower recovered clock quality measurement: enable Reverse Sync, Reverse Sync Interval SMPTE Data parameters: Default System Frame Rate Numerator, Default System Frame Rate Denominator, Master Locking Status, Time Address Flags, Current Local Offset, Jump Seconds, Time of Next Jump, Time of Next Jam, Time of Previous Jam, Previous Jam Local Offset, Daylight Saving, Leap Second Jump Debug parameters: Enable Offset Trigger, Offset Trigger (ns), Number of Records to Be Logged, Log Future Packet info, Log File Location, Log Clean Up, Log File Lifetime (days)
Impair Timing Messages (negative testing)	Announce Drop Rate (%) Sync Drop Rate (%) Follow Up delay with insertion rate (%) Follow-Up Drop Rate (%) Follow-Up Bad CRC Rate (%) (P)Delay Request Drop Rate (%) (P)Delay Request Timing Offset and Spread (P)Delay Response delay with insertion rate (%) (P)Delay Response Drop Rate (%) PDelay Response Follow-Up delay with insertion rate (%) PDelay Response Follow-Up Drop Rate (%) Drop Signal Request with Announce TLV Drop Signal Request with Sync TLV Drop Signal Request with Delay Response TLV
PDU Builder Support for PTP Messages for Negative Testing	
Statistics	PTP Total, Per Range or Device Group and Per Session Interface Identifier Range Identifier Session Status PTP Status (Listening/Uncalibrated/Leader/Follower) Offset (Time Error) Path Delay Time Slope Port Identity Master Port Identity Grandmaster Port Identity Min/Max/Avg Offset (Time Error) Min/Max/Avg Path Delay Announce Messages Tx/Rx

Sync Messages Tx/Rx
FollowUp Messages Tx/Rx
DelayReq Messages Tx/Rx
DelayResp Messages Tx/Rx
PdelayReq Messages Tx/Rx
PdelayResp Messages Tx/Rx
PdelayResp FollowUp Messages Tx/Rx
Signaling Messages Tx/Rx
Sync Messages Received Rate
FollowUp Messages Received Rate
DelayReq Messages Received Rate
DelayResp Messages Received Rate
PdelayReq Messages Received Rate
PDelayResp Messages Received Rate
PdelayRespFollowUp Messages Received Rate
Local Clock Class
Master Clock Class
Local Clock Accuracy
Master Clock Accuracy
Current UTC Offset
Steps Removed
Leap59
Leap61
Frequency Traceable
Time Traceable
Correction Field Sync Min/Max/Ave
Correction Field Follow-up Min/Max/Ave
Correction Field DelayReq Min/Max/Ave
Correction Field PDelayReq Min/Max/Ave
Correction Field DelayResp Min/Max/Ave
Correction Field PDelayResp Min/Max/Ave
Foreign Master 0–4
- Identity
- Port Number

Timestamp: T1, T2, T3, T4
Timestamps in UTC format
Inter-Arrival Time of Announce (real-time/min/max)
Inter-Arrival Time of Sync (real-time/min/max)
Inter-Arrival Time of FollowUp (real-time/min/max)
Inter-Arrival Time of DelayReq (real-time/min/max)
Inter-Arrival Time of DelayResp (real-time/min/max)
Inter-Arrival Time of PDelayReq (real-time/min/max)
Inter-Arrival Time of PDelayResp (real-time/min/max)
Inter-Arrival Time of PdelayResp Follow-up (real-time/min/max)

IEEE 1588 Precision Time Protocol (PTP)

Analyzer Support for Protocol Decode	
Test Composer PTP Events (Classic)	Change BMC Parameters ◦ Priority 1, Priority 2 ◦ Clock Class ◦ Clock Accuracy Change Log Message Intervals ◦ Announce Interval ◦ Sync Interval ◦ Delay Request Interval Change Misc. Parameters ◦ Domain ◦ Announce Receipt Timeout Change Negative Testing Parameters ◦ Delay Response with insertion rate ◦ Delay Response drop rate ◦ Follow Up delay with insertion rate ◦ Follow Up drop rate ◦ Follow Up Bad CRC rate PTP Clear Stats PTP Pause PTP Resume PTP Start PTP Stop
Test Composer PTP Events (NGPF)	Change all GUI configuration parameters Start and Stop sessions Clear Statistics Send IEEE 802.1AS Signaling Message

Ethernet Synchronization Messaging Channel Protocol (ESMC)

Standards	ITU-T G.8264
ESMC Protocol Features	SSM Quality Level and extended Quality Level Rate 1/s to 100/s (beyond legal limit of 10/s) Flag Mode (Auto, On or Off)
PDU Builder Support for ESMC Messages for Negative Testing	
Statistics	Last change (timestamp) Last quality (Quality Level) Total messages Tx/Rx

Ethernet Synchronization Messaging Channel Protocol (ESMC)	
	Even messages Tx/Rx
	STU/UNK Tx/Rx
	PRS Tx/Rx
	PRC Tx/Rx
	INV3 Tx/Rx
	SSU-A/TNC Tx/Rx
	INV5 Tx/Rx
	INV6 Tx/Rx
	ST2 Tx/Rx
	SSU-B Tx/Rx
	INV9 Tx/Rx
	EEC2/ST3 Tx/Rx
	EEC1/SEC Tx/Rx
	SMC Tx/Rx
	ST3E Tx/Rx
	PROV Tx/Rx
	DNU/DUS Tx/Rx
	Extended TLV Tx/Rx
	ePRTC Tx/Rx
	ePRC Tx/Rx
	eEEC Tx/Rx
	Minimum inter-arrival time
	Average inter-arrival time
	Maximum inter-arrival time
	Average message rate
	Maximum message rate
Analyzer (Optional) Support for Protocol Analysis and Decode	
Test Composer ESMC Events	Change ESMC ◦ Rate ◦ Quality Level ◦ Flag Mode
	ESMC Clear Stats
	ESMC Start
	ESMC Stop

Two-Way Active Measurement Protocol (TWAMP)

Standards	IETF RFC 5357
Statistics	TWAMP Control: Initiated Sessions, Successful Sessions, Failed Sessions, Active Sessions, Initiated Session Rate, Successful Session Rate, Failed Session Rate TWAMP Data: Datagram TX, Datagram RX, Datagram Lost, Datagram Unexpected, Data Streams Initiated, Data Streams Successful, Data Streams Failed TWAMP Test: Initiated Sessions, Successful Sessions, Failed Sessions, Active Sessions, Initiated Session Rate, Successful Session Rate, Failed Session Rate TWAMP Server Control: Initiated Sessions, Successful Sessions, Failed Sessions, Active Sessions, Initiated Session Rate, Successful Session Rate, Failed Session Rate TWAMP Server Data: Datagram TX, Datagram RX, Datagram Lost, Datagram Unexpected, Data Streams Initiated, Data Streams Successful, Data Streams Failed TWAMP Server Test: Initiated Sessions, Successful Sessions, Failed Sessions, Active Sessions, Initiated Session Rate, Successful Session Rate, Failed Session Rate

Audio Video Bridging (AVB) / Time Sensitive Networking (TSN) Protocols

Standard	IEEE 802.1Qat IEEE 802.1Qav IEEE 802.1Qbv IEEE 802.1AS IEEE 1722
MSRP Talker Configuration	Protocol Version Join Timer (ms) Leave Timer (ms) Leave All Timer (ms) Stream Count Domain Count Domains ◦ SR Class ID ◦ SR Class Priority ◦ SR Class VID
AVB Stream Configuration	Stream ID Destination MAC VLAN ID Max Frame Size Max Interval Frames Data Frame Priority

	Rank
	Port Tc Max Latency (ns)
MSRP Talker Statistics	Per packet statistics
	MSRP Packet Tx
	MSRP Packet Rx
	Per attribute type statistics
	MSRP Listener Advertise Rx
	MSRP Talker Advertise Tx
	MSRP Talker Advertise Rx
	MSRP Listener Ready Rx
	MSRP Listener Ready Failed Rx
	MSRP Listener Asking Failed Rx
	MSRP Domain Packet Rx
	MSRP Domain Advertise Tx
	MSRP Domain Advertise Rx
	MVRP Packet Tx
	MVRP Packet Rx
	MSRP Talker New Tx
	MSRP Listener New Rx
	MSRP Talker Mt Tx
	MSRP Listener Mt Rx
	MSRP Talker JoinMt Tx
	MSRP Listener JoinMt Rx
	MSRP Talker JoinIn Tx
	MSRP Listener JoinIn Rx
	MSRP Talker Lv Tx
	MSRP Listener Lv Rx
	MSRP Talker In Tx
	MSRP Listener In Rx
	Per Port statistics
	MSRP Packet Tx
	MSRP Packet Rx
	MSRP Listener Advertise Rx
	MSRP Talker Advertise Tx
	MSRP Talker Advertise Rx
	MSRP Listener Ready Rx
	MSRP Listener Ready Failed Rx
	MSRP Listener Asking Failed Rx
	MSRP Domain Packet Rx
	MSRP Domain Advertise Tx
	MSRP Domain Advertise Rx
	MVRP Packet Tx
	MVRP Packet Rx

	MSRP Talker New Tx
	MSRP Listener New Rx
	MSRP Talker Mt Tx
	MSRP Listener Mt Rx
	MSRP Talker JoinMt Tx
	MSRP Listener JoinMt Rx
	MSRP Talker JoinIn Tx
	MSRP Listener JoinIn Rx
	MSRP Talker Lv Tx
	MSRP Listener Lv Rx
	MSRP Talker In Tx
	MSRP Listener In Rx
MSRP Talker Actions	Stop
	Start
	Advertise New
SRP Talker Database	Talker Specific
	Attribute First Value
	Stream ID
	Data Frame Parameters
	TSpec
	PriorityAndRank
	Latency
	Applicant State
	Registrar State
	Source MAC Address
	Talker Advertise Tx
	Talker JoinMt Tx
	Talker JoinIn Tx
	Talker In Tx
	Talker New Tx
	Talker Mt Tx
	Talker Lv Tx
	Listener Advertise Rx
	Listener Ready Rx
	Listener Ready Failed Rx
	Listener Asking Failed Rx
	Listener New Rx
	Listener JoinMt Rx
	Listener JoinIn Rx
	Listener In Rx
	Listener Lv Rx
	Listener Mt Rx

	Domain Specific SR Class ID SR Class Priority SR Class VID Source MAC Address VLAN Specific VLAN ID Registrar State Source MAC Address
MSRP Listener Configuration	MSRP Listener Protocol Version Join Timer (ms) Leave Timer (ms) Leave All Timer(ms) Start VLAN ID VLAN Count Advertise As New Subscribed Stream Count Domain Count Subscribed Streams Stream ID Domains SR Class ID SR Class Priority SR Class VID
MSRP Listener Statistics	Per packet statistics MSRP Packet Tx MSRP Packet Rx Per Listener statistics MSRP Listener Advertise Tx MSRP Listener Tx MSRP Listener Rx MSRP Talker Advertise Rx MSRP Talker Failed Rx MSRP Listener Ready Tx MSRP Listener Ready Failed Tx MSRP Listener Asking Failed Tx MSRP Domain Advertise Tx MSRP Domain Advertise Rx

	MVRP Packet Tx MVRP Packet Rx MSRP Listener New Tx MSRP Talker New Rx MSRP Listener Mt Tx MSRP Talker Mt Rx MSRP Listener JoinMt Tx MSRP Talker JoinMt Rx MSRP Listener JoinIn Tx MSRP Talker JoinIn Rx MSRP Listener Lv Tx MSRP Talker Lv Rx MSRP Listener In Tx MSRP Talker In Rx Per Port Stats MSRP Packet Tx MSRP Packet Rx Per attribute type statistics MSRP Listener Advertise Tx MSRP Talker Advertise Rx MSRP Talker Fail Rx MSRP Ready Tx MSRP Ready Failed Tx MSRP Asking Failed Tx MSRP Domain Packet Rx MVRP Packet Tx
MSRP Listener Actions	Leave Stream Join Stream Stop Start
MSRP Listener Database	Listener Specific First Value ◦ SRP Stream ID ◦ Data Frame Parameters ◦ TSpec ◦ PriorityAndRank ◦ Accumulated Latency Attribute Type Attribute Sub Type Applicant State Registrar State Source MAC Address

	Error Code Bridge ID Talker Failed Rx Talker New Rx Talker JoinMt Rx Talker JoinIn Rx Talker In Rx Talker Lv Rx Talker Mt Rx Listener Advertise Tx Listener Ready Tx Listener Ready Failed Tx Listener Asking Failed Tx Listener JoinMt Tx Listener JoinIn Tx Listener In Tx Listener New Tx Listener Mt Tx Listener Lv Tx Accumulated Latency Received VLAN Max Frame Size Max Interval Frames Data Frame Priority Rank Domain Specific SR Class ID SR Class Priority SR Class VID Source MAC Address VLAN Specific VLAN ID Applicant State
gPTP Protocol Configuration	See the preceding 1588 PTP configuration parameters Automotive Ethernet AVB Functional and Interoperability Specification 1.4 — disable use of BMCA / Announce message
gPTP Actions	Send gPTP Specific Signaling Messages
gPTP Statistics	See the preceding 1588 PTP statistics

Platform Options

Visit www.keysight.com for more information on IxNetwork platform options.

Virtual Platform	IxNetwork Virtual Edition (VE)
Chassis	XGS12-HSL/SDL/SD Chassis XGS2-HSL/SDL/SD Chassis
Fixed Chassis	AresONE-M 800GE QSFP-DD800 AresONE-M 800GE OSPF800 AresONE-M 800GE Dual Interface Model AresONE-S 400G QSFP-DD AresONE 400G QSFP-DD AresONE 400G OSFP AresONE 400G High Performance QSFP-DD 400/200/100/50GE NOVUS ONE PLUS 3- and 5-Speed 10GE/5GE/2.5GE/1GE/100M
Appliances	NOVUS ONE 10GE/1GE/100M
Load Modules	K400 QSFP-DD 400/200/100/50GE K400 CFP8 400GE NOVUS High Density QSPF28 100/50/40/25/10GE NOVUS High Density SFP28/QSPF28 100/50/25/10GE NOVUS 3-Speed 10GE/1GE/100M NOVUS 5-Speed 10GE/5GE/2.5GE/1GE/100M Xcellon-Multis QSFP28 100/50/25GE Xcellon-Multis CFP4 100GE Xcellon-Multis CXP 100/40/10GE Xcellon-Multis QSFP 40/10GE Xcellon-Lava CFP 100/40GE Xcellon-Flex QSFP/SFP+ 40/10GE
	Note: AVB/TSN protocols are supported on: NOVUS 10GE/1GE/100M NOVUS 10GE/5GE/2.5GE/1GE/100M NOVUS ONE PLUS Only AVB is supported on: Xcellon-AVB 40/10GE (944-1132) 100BASE-T1 and 1000BASE-T1 interface speeds are supported through additional SFP transceiver modules (948-0062) TSN capability requires the following upgrade to the load modules: TSN OPTION ENABLEMENT (Factory Installed) — 905-1020 OR TSN FIELD UPGRADE OPTION 905-1021

IxNetwork Technology Solutions

Visit www.keysight.com for more Information on IxNetwork technology solutions.

IxNetwork Overview — L2/3 Network Infrastructure Performance Testing
IxNetwork Software Defined Networking (SDN) Test Solution
IxNetwork Routing and Switching Test Solution
IxNetwork MPLS Test Solution
IxNetwork Industrial, Automotive, and Carrier Ethernet Test Solution
IxNetwork Broadband and Authentication Test Solution
IxNetwork Data Center Ethernet Test Solution
IxNetwork MACsec Test Solution

Ordering Information

Ethernet Service OAM and PBB-TE

930-2032

IxNetwork, Optional Software, Ethernet CFM IEEE 802.1ag and ITU-T Y.1731 Protocol Emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

930-2033

IxNetwork, Optional Software, PBB-TE Emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

930-2034

IxNetwork, Software Bundle, Carrier Ethernet; includes 930-2032 and 930-2033; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

Ethernet Link OAM

930-2040

IxNetwork, Software Option, Ethernet Link OAM (IEEE 802.3ah Clause 57) Emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

IEEE 1588 Precision Time Protocol (PTP) & SYNC-E ESMC

930-2070

IxNetwork, Optional Software, IEEE 1588v2 (PTP) Emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

930-2073

IxNetwork, Optional Software, ITU-T SyncE (ESMC) Protocol Emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

930-2132

IXIA IxNetwork, Optional Software, Media Profiles for IEEE 1588v2 (PTP) Protocol Emulation; Enable IEEE 1588v2 (PTP) Protocol with SMPTE Profile and AES67 Profile for Professional Broadcast Application; REQUIRES: 930-2070 IEEE 1588v2 (PTP) Protocol Emulation; REQUIRES: pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

930-2137

IxNetwork, Optional Software, Power Profile for IEEE 1588v2 (PTP) Protocol Emulation; Enable IEEE 1588v2 (PTP) Protocol with IEEE C37.238-2017 Power Profile; REQUIRES: 930-2070 IEEE 1588v2 (PTP) Protocol Emulation; REQUIRES: pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

930-2501

IxNetwork, Optional Software Bundle, Timing Protocols Bundle; INCLUDES: 930-2070 IxNetwork, Optional Software, IEEE 1588v2 (PTP) Emulation; 930-2073 IxNetwork, Optional Software, ITU-T SyncE (ESMC) Emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

Ethernet Local Management Interface (ELMI)

930-2075

IxNetwork, Optional Software, ELMI (MEF 16) Emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

Two-Way Active Measurement Protocol (TWAMP)

930-2041

IxNetwork, Software Option, Two Way Active Measurement Protocol (TWAMP) RFC 5357 Emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

Audio Video Bridging (AVB)/Time Sensitive Networks (TSN)

905-1020

TSN Option Enablement for FACTORY INSTALLED CAPABILITY on NOVUS 10GE/1GE/100M Modules OR Novus One 10GE/1GE/100M Appliances (905-1020)

905-1021

TSN Option Enablement for FIELD UPGRADE CAPABILITY on NOVUS 10GE/1GE/100M Modules OR Novus One 10GE/1GE/100M Appliances (905-1021)

905-1065

TSN FACTORY INSTALLED OPTION for enabling TSN capability for the new purchase of the NOVUS-10GE/25GE8SFP28 (944-1164), 8-port, SFP28 10GE/25GE load modules

905-1066

IXIA TSN FIELD UPGRADE OPTION for enabling TSN capability on the NOVUS-10GE/25GE8SFP28 (944-1164), 8-port, SFP28 10GE/25GE load modules

930-2120

IXIA IxNetwork AVB/TSN for NOVUS 10GE/1GE/100M Modules OR NOVUS-S 10/25GE8SFP28 Modules includes 802.1AS-2011, 802.1AS 2020, Qbv Scheduled Traffic, Qbu Frame preemption ,1CB Redundancy, Qav CBS, MSRP, 1722 and 1733 protocol emulation , REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

930-2530

Ixia IxNetwork perpetual, Bundle - basic package (930-2221) and AVB/TSN for Novus ONE PLUS Fixed Chassis, includes IxNetwork Basic, 802.1AS-2011, 802.1AS 2020, Qbv Scheduled Traffic, Qbu Frame preemption ,1CB Redundancy, Qav CBS, MSRP, 1722 and 1733 protocol emulation

930-9530

Ixia IxNetwork, node-locked 12-month subscription Bundle - basic package (930-2221) and AVB/TSN for Novus ONE PLUS Fixed Chassis, includes IxNetwork Basic, 802.1AS-2011, 802.1AS 2020, Qbv Scheduled Traffic, Qbu Frame preemption ,1CB Redundancy, Qav CBS, MSRP, 1722 and 1733 protocol emulation

930-2531

IXIA IxNetwork Avnu bundle conformance and interoperability tests for TSN (930-2531). Includes: Avnu automotive, Avnu Component and Avnu Industrial test specifications.

930-2532

IXIA IxNetwork TSN/Avnu wireline bundle conformance and interoperability tests for TSN. INCLUDES: TSN conformance (930-2425) and Avnu conformance (930-2531)

948-0088

Technica SFP TRANSCEIVER with H-MTD connector, AUTOMOTIVE ETHERNET, 1000BASE-T1, 100BASE-T1, 1GBPS/100MBPS (Marvell 88Q2221M) - IEEE Compliant (948-0088)

948-0086

Technica SFP TRANSCEIVER with H-MTD connector, Automotive Ethernet, 2.5 Gb/s, 5 Gb/s, and 10 Gb/s (Marvell MV-Q3244) - IEEE Compliant (948-0086)

948-0098

Intrepid SFP TRANSCEIVER with H-MTD connector, AUTOMOTIVE ETHERNET, 1000BASE-T1, 100BASE-T1, 1GBPS/100MBPS (Marvell 88Q2221M) - IEEE Compliant (948-0098)

948-0096

Intrepid SFP TRANSCEIVER with H-MTD connector, Automotive Ethernet, 2.5 Gb/s, 5 Gb/s, and 10 Gb/s (Marvell MV-Q3244) - IEEE Compliant (948-0096)

948-0080

SFP Copper TRANSCEIVER, 10M/100M/1G support.

948-0099

Intrepid SFP Transceiver for Automotive Ethernet 10BASE-T1S, Microchip LAN8670.