

# Evaluating carrier-class Ethernet services and infrastructure

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**Broadband Technology Event**

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# Agenda

1. Introduction
2. Carrier Ethernet Market Drivers
3. Development & Deployment Challenges
4. Technologies, New Challenges, and Real Test Results
5. Conclusion
6. Questions

# Introduction

Developing and deploying **Carrier Ethernet** devices and services offers **new revenue generation opportunities** while **reducing infrastructure and operational costs**. However, the implementation path is fraught with **scalability, robustness** and **interoperability risks**:

- Will network **infrastructure scale** to meet customer growth and new services?
- How well can evolving **fault-management technologies** such as CFM, BFD, LACP, RSVP FRR and MSTP cooperate to **reduce network outage**?
- Can switched technologies, such as **PBB/PBT**, and **VPLS** technologies from different vendors transparently coexist, providing end-to-end service?

# Introduction (Cont'd)

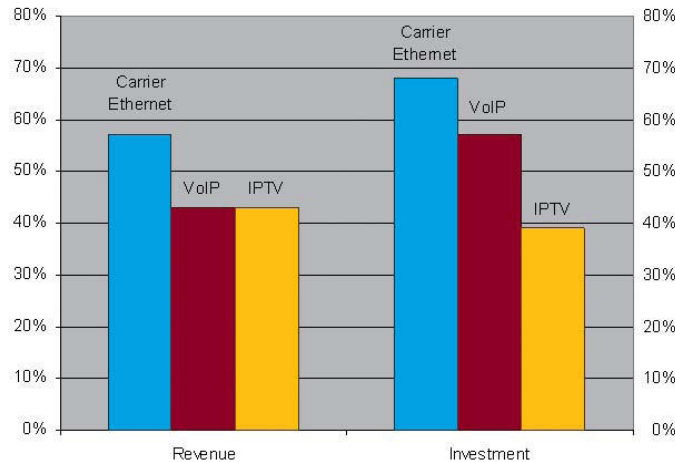
During this presentation, we will:

- Briefly examines the **market and technology drivers**
- Assesses the key **development and deployment risks** on several Carrier Ethernet technologies
- Answers the questions above by revealing **tangible test scenarios** and showing **real test results** from testing commercially available devices using the **N2X Multiservices Test System**.

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# Carrier Ethernet Market Drivers



**Ethernet is driving carrier investment and revenue expectations even more than VoIP or IPTV**

**Carrier Ethernet service revenue is expected to grow at a faster rate than IPTV, VoIP and VPNs.**

**Carriers are deploying Ethernet for two major reasons:**

**To improve their “top line” by **creating new revenue** from end-to-end Ethernet services.**

**To improve their “bottom line” by **reducing capital and operational network expenditure**.**

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# Development & Deployment Challenges

Revenue and cost drivers are encouraging equipment developers and standards people to **invent new protocols and technologies** to make **Ethernet** – traditionally a best effort Enterprise LAN technology – **truly carrier-class**.

These technologies **improve** network **robustness, scalability and manageability**, enabling end-to-end **Ethernet services** across different network infrastructure technologies such as IP/ MPLS and SONET/SDH.

# Development & Deployment Challenges (Cont'd)

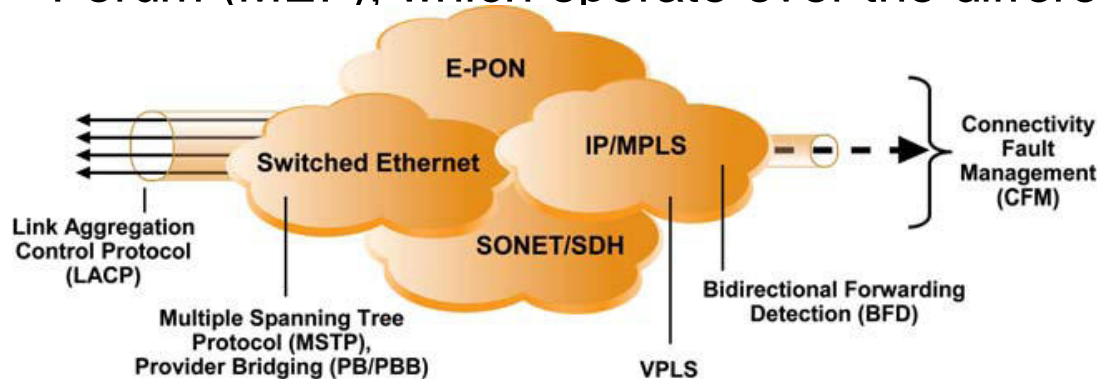


Application Services, such as IPTV, VoIP and Video on Demand may operate over Carrier Ethernet services or directly over the infrastructure

## Carrier Ethernet Services



Carrier Ethernet Services (E-LAN and E-Line), defined by the Metro Ethernet Forum (MEF), which operate over the different infrastructure technologies.



Network infrastructure includes switched Ethernet, as well as other technologies such as IP/MPLS and LACP.

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# Technologies, New Challenges, and Real Test Results

Section walk through:

- Emerging Carrier Ethernet technologies: OAM, CFM, MSTP, BFD, and LACP.
- Carrier Ethernet services QoS
- Application service example: IPTV a service to be delivered to the end user with a high Quality-of-Experience (QoE).

For each, technology and test challenges will be reviewed, typical test scenario exposed; and real test results presented.

# Ethernet OAM and CFM Technology

Ethernet Operations, Administration and Maintenance (E-OAM):

Group of network management functions that provide network **fault indication**, **performance information**, and data and **diagnosis functions** in the context of Ethernet.

Two standards co-developed for E-OAM:

- IEEE 802.1ag “Connectivity Fault Management” (CFM)
- ITU-T Y.1731 “OAM functions and mechanisms for Ethernet based networks.”

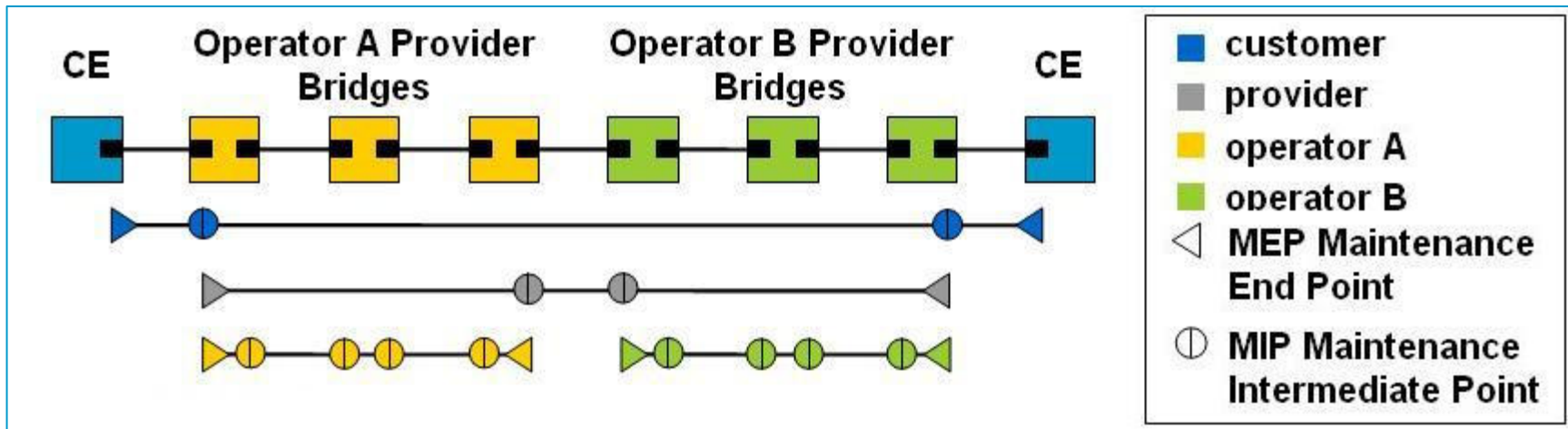
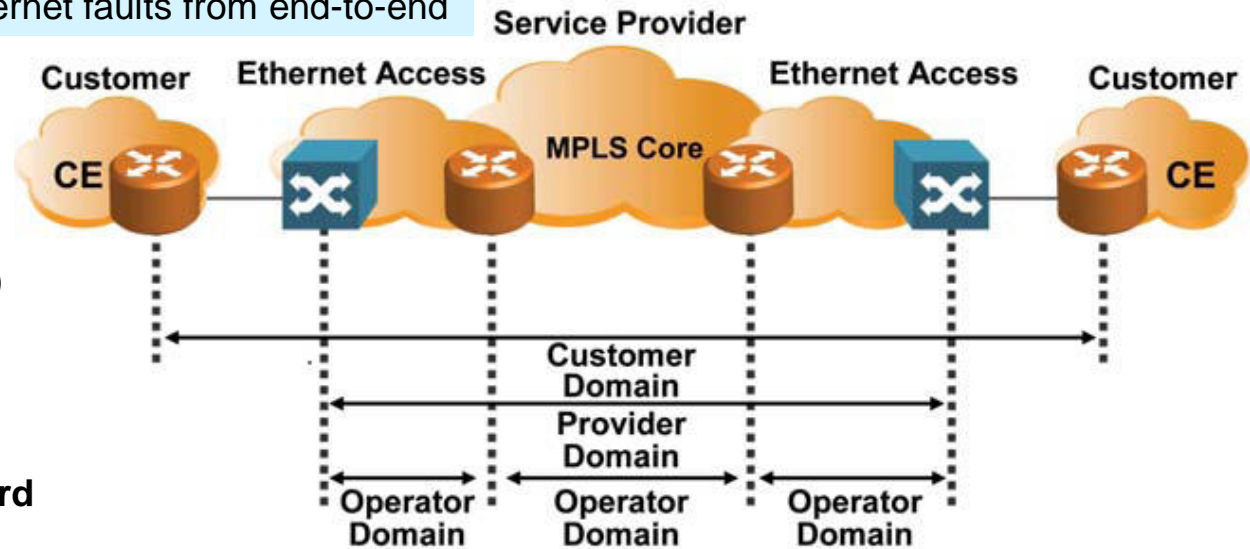
# Ethernet OAM and CFM Technology (Cont'd)

## Connectivity Fault Management (CFM)

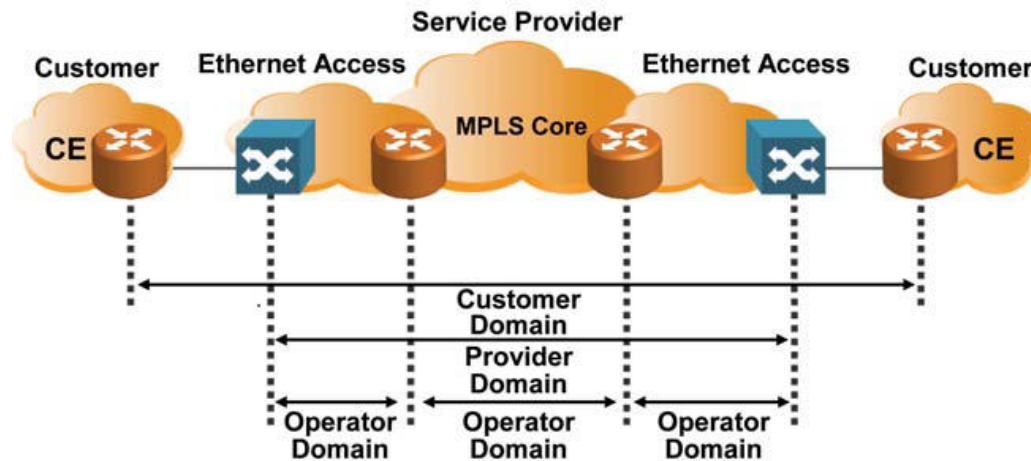
Detects, verifies and isolates Ethernet faults from end-to-end

### 4 CFM Message Types

- Layer 2 Loopback (ping)
- Layer 2 Link Trace (traceroute)
- Layer 2 Continuity Check (a periodic heartbeat)
- Alarm Indication Signal (AIS)
  - Only in ITU-T Y.1731 standard
  - **Not in IEEE CFM standard**



# Ethernet OAM and CFM Test Challenges



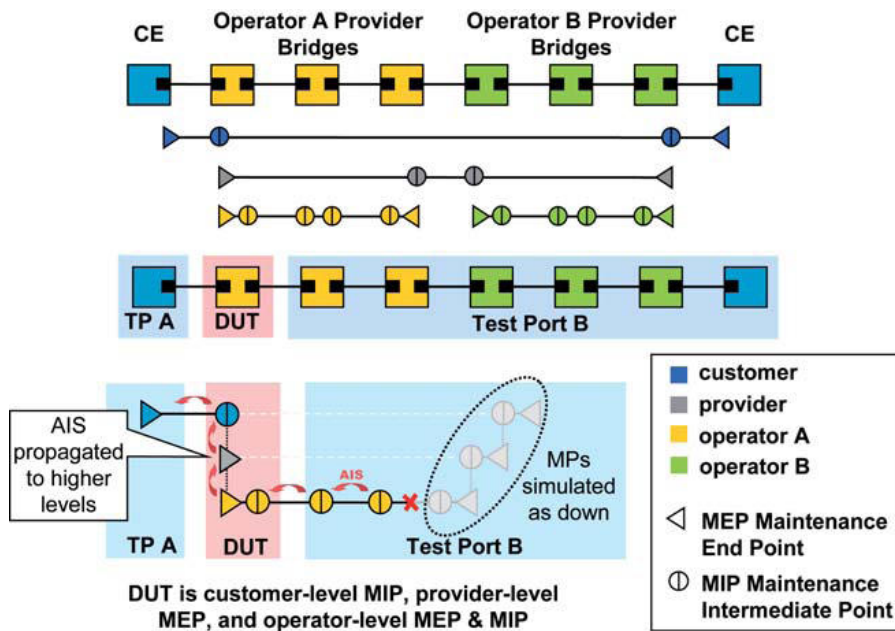
Incompatible CFM frames from another vendor – will they cause interoperability issues?

What is the optimal Continuity Check message timer value, in the presence of other line-card processing?

Scalability – How many Maintenance Entities (end points and intermediate points) can be supported?

Are AIS notifications propagated to higher levels?

# Ethernet OAM and CFM Test Scenario



**Test objective: verify that an AIS notification generated at Test Port B propagates up through the 3 DUT levels and is detected at Test Port A. The test steps are listed below.**

- Simulate network fault by suppressing Continuity Check and generating AIS
- Check AIS propagation to upper levels
- Verify that upper layers suppress alarms – e.g. Loss of Continuity (LOC)

# Ethernet OAM and CFM Test Results

**1. CCDB before LOC**

**2. No RDI received**

**3. Disable Link on MD Level 3**

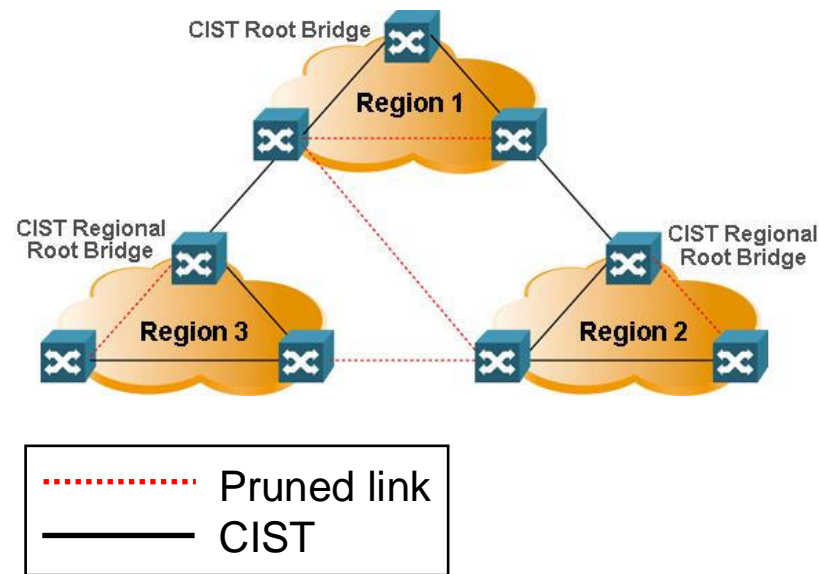
**4. CCDB after LOC**

**5. RDI received from remote MEP on MD Level 3**

#	Level	MAC	MEP ID	Character String	Maintenance Domain Name	State	CCM Interval	RDI	Expected Cor
1	1	00:00:66:01:01:05	100	operator		OK	1 s	No	Yes
2	3	00:00:66:01:01:09	300	provider		OK	1 s	No	Yes
3	7	00:00:66:01:01:0D	700	customer		OK	1 s	No	Yes
4	7	00:00:66:01:01:0E	701	customer		OK	1 s	No	Yes
5	7	00:00:66:01:01:0F	702	customer		OK	1 s	No	Yes
6	7	00:00:66:01:01:10	703	customer		OK	1 s	No	Yes
7	7	00:00:66:01:01:11				OK	1 s	No	Yes
8	7	00:00:66:01:01:12				OK	1 s	No	Yes
9	7	00:00:66:01:01:13				OK	1 s	No	Yes
10	7	00:00:66:01:01:14				OK	1 s	No	Yes
11	7	00:00:66:01:01:15	708	customer		OK	1 s	No	Yes
12	7	00:00:66:01:01:16	709	customer		OK	1 s	No	Yes

#	Level	MEP ID	State	CCM Interval	RDI	Expected Cor
1	1	100	OK	1 s	No	Yes
2	3	300	OK	1 s	Yes	Yes
3	7	700	OK	1 s	No	Yes
4	7	701	OK	1 s	No	Yes
5	7	702	OK	1 s	No	Yes
6	7	703	OK	1 s	No	Yes

# MSTP Technology



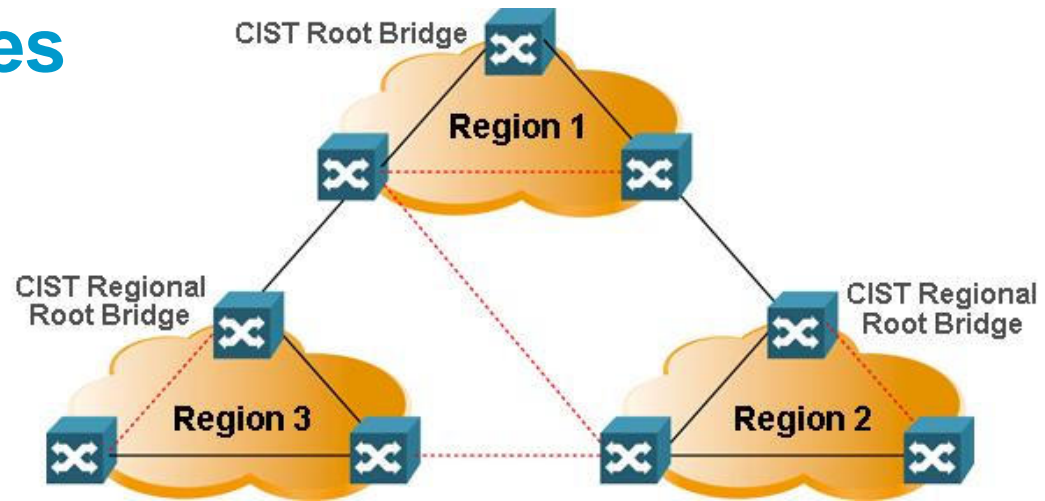
MSTI	VLANs
10	100-104, 110-150, 155-199
20	200-204, 210-250, 255-299

The **Multiple Spanning Tree Protocol (MSTP)** calculates a **loop-free LAN topology** on **multiple VLAN sets** in a scalable manner, enabling **load balancing** and **manageability**.

Figure shows three MSTP regions interconnected by the black lines, delineating the **Common and Internal Spanning Tree (CIST)**.

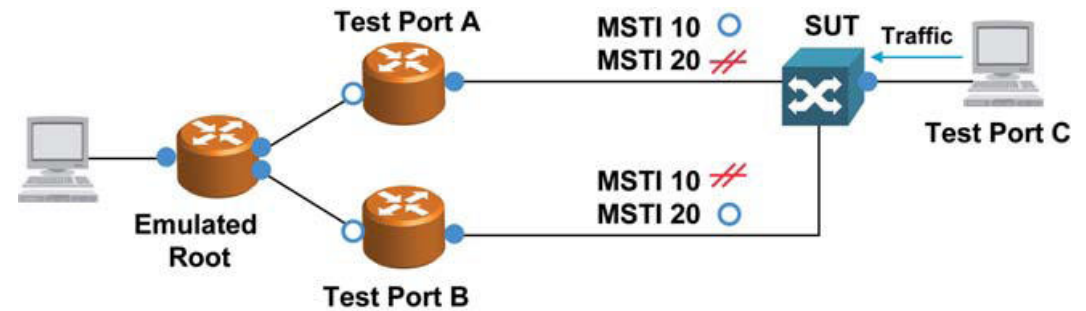
Within each region, **multiple spanning tree instances (MSTIs)** can operate, with each instance carrying an independent set of VLANs. The red lines are **links pruned** by the protocol to **remove loops** for a particular MSTI.

# MSTP Test Challenges



- Scalability:  
Can the full range of 4,094 VLAN IDs map to the 64 MSTIs?
- MSTP interaction with CFM – do/should blocked ports pass CFM messages?
- Slow MSTP reconvergence – how much packet loss and what impact on service QoE; or reconvergence to lower-bandwidth links – is high-priority traffic given precedence?  
We will discuss this latter test challenge in the next section.

# MSTP Test Scenario



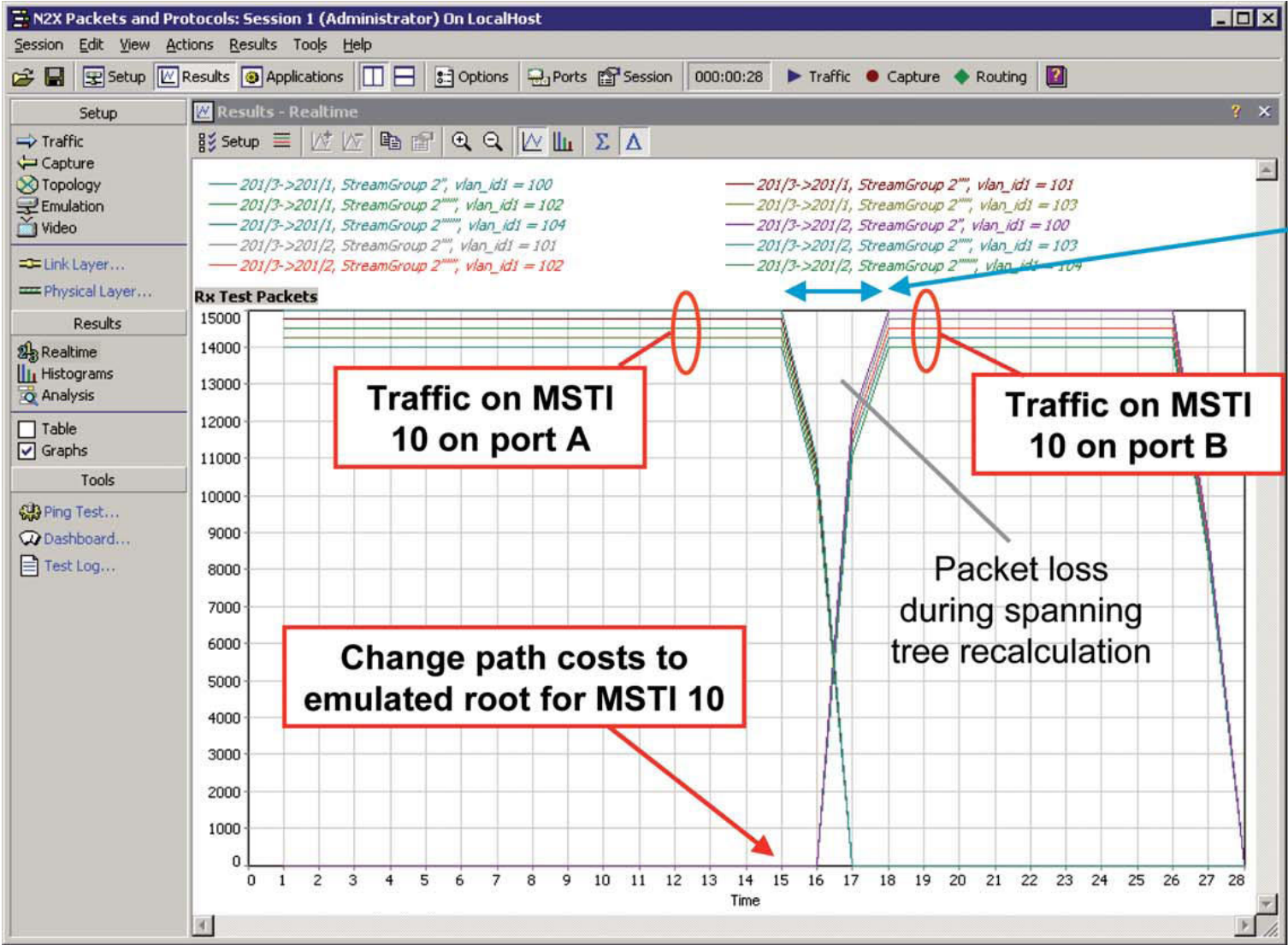
●	Designated, forwarding
○	Root, forwarding
⊘	Discarding

MSTI	VLANs
10	100-104, 110-150, 155-199
20	200-204, 210-250, 255-299

**Test objective: Verify MST load-balancing and measure the impact of a path cost change.**

- Configure two MSTIs for two sets of VLANs to balance traffic between Test Ports A and B
- Send traffic from Test Port C to the emulated hosts behind the root
- Trigger MST recalculation by modifying the path cost on MSTI 10 from Port A to root, while the test is running
- Verify that MSTI 10 traffic on Test Port A switches to Test Port B
- Measure the packet loss and time to recalculate the spanning tree and restore the services.

# MSTP Tests Results



**N2X  
precisely  
measures  
switchover  
time**

**Traffic on MSTI  
10 on port A**

**Traffic on MSTI  
10 on port B**

**Change path costs to  
emulated root for MSTI 10**

Packet loss  
during spanning  
tree recalculation

# BFD Technology



BFD can trigger IGP reconvergence

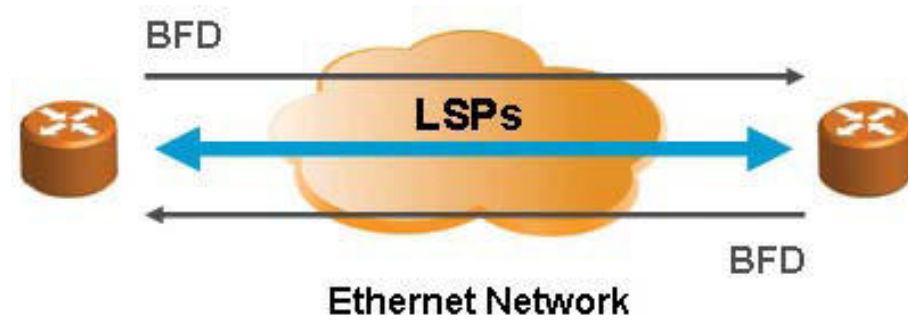


BFD can trigger MPLS Fast ReRoute

The Bidirectional Forwarding Detection (BFD) protocol detects forwarding plane connectivity via a keep-alive mechanism, which speeds up fault detection and accelerates service restoration. BFD is important for Ethernet, which has no native fault notification mechanism.

Figure shows BFD used in an IP-routed network to trigger fast routing reconvergence, rather than relying on slower timeout approaches inherent in OSPF, IS-IS and IGP.

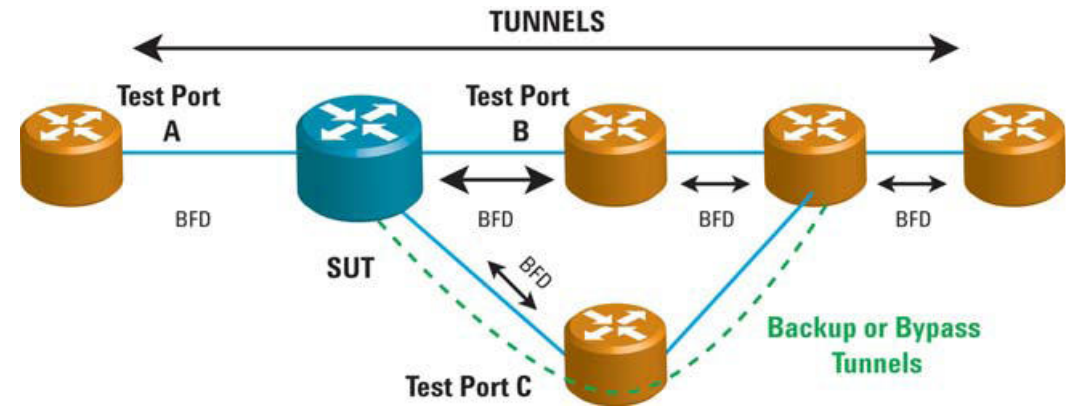
# BFD Test Challenges



BFD can trigger MPLS Fast ReRoute

- Scalability – What is the smallest BFD timer value possible for the number of sessions required?
- Incompatible BFD packets from another vendor – will they cause interoperability issues?
- Will different interpretations of evolving draft specifications lead to interoperability issues?
- Can adequate recovery time be achieved to minimize service disruption?
- What are optimal timer values in the presence of other line card processing?

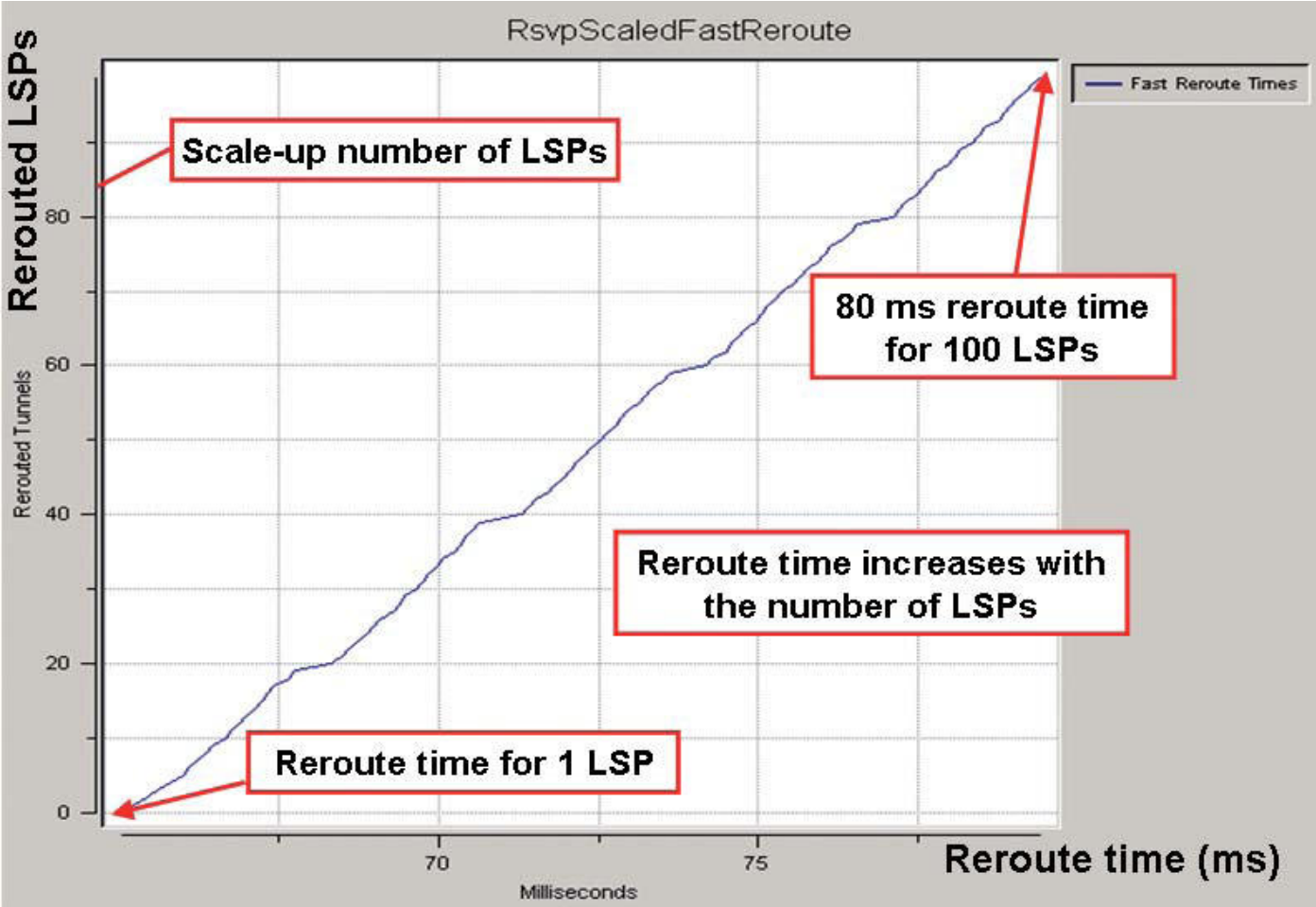
# BFD Test Scenario



**Test objective: measure LSP reroute time after BFD goes down.**

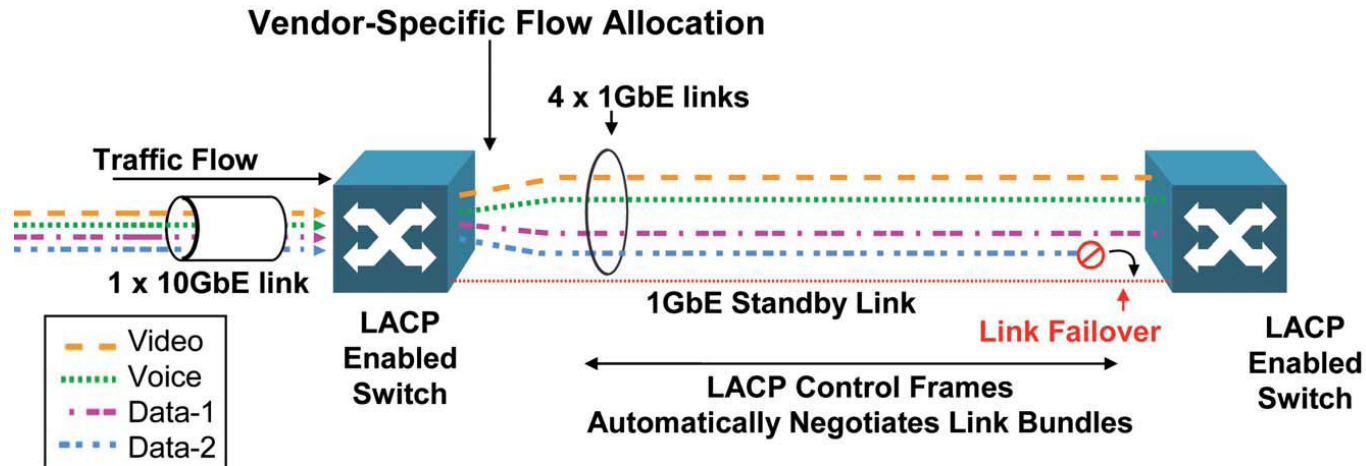
- A primary Label Switched Path (LSP) is emulated from test port A to test port B, through the DUT, and on to the emulated Label Switched Routers (LSRs) further down the chain.
- A backup or bypass LSP is emulated from test port A to test port C, through the DUT, and on to the same emulated LSRs.
- BFD is used to protect all the LSPs.
- A BFD down event is initiated at test port B and a timestamp T1 is recorded.
- The first MPLS packets received at Port C are timestamped as T2.
- Finally, the MPLS Fast Reroute time is calculated as the difference between T2 and T1.

# BFD Test Results



The test exposed before can be scaled to multiple LSPs to find the scaling and performance limits of the SUT.

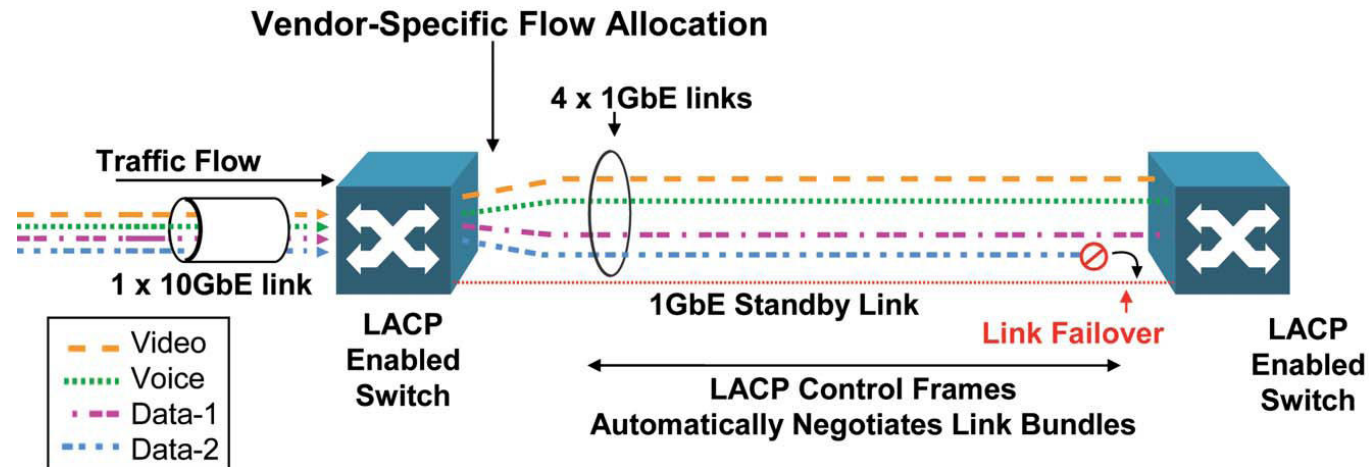
# LACP Technology



Link Aggregation is a technology that bundles several physical Ethernet links into a single, logical link. This allows a service provider to provision links at speeds other than 10/100, GbE and 10 GbE, and it makes better use of the available bandwidth. Link Aggregation Control Protocol (LACP) is the IEEE-defined control protocol used to negotiate and setup a link bundle, also known as a Link Aggregation Group (LAG).

The other benefit of LACP is High Availability. If a link goes down, the flows on that link are reallocated onto the other active links. Alternatively, the flows can be reallocated onto a hot standby link.

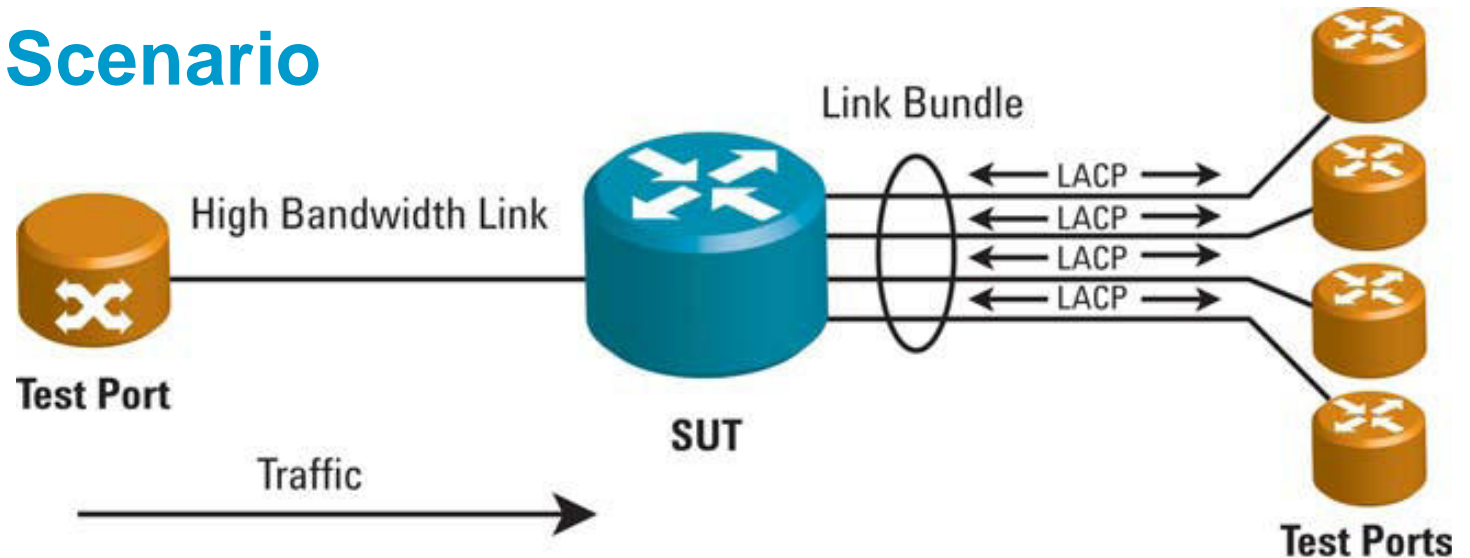
# LACP Test Challenges



## Tests challenges with regards to honoring SLAs:

- How quickly are the flows reallocated onto the other links?
- How many packets are lost?
- Is there a spike in latency?
- How much slower is reallocation if the traffic is scaled?

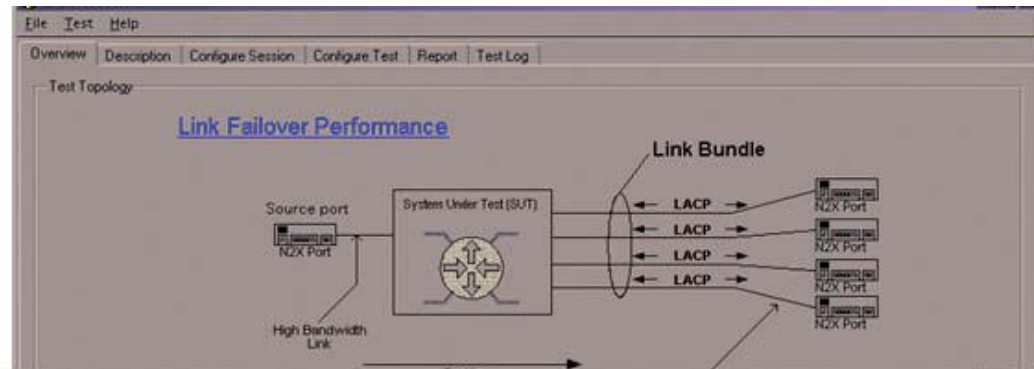
# LACP Test Scenario



**Test objective: measure the time taken to reallocate traffic flows when a link fails.**

- A link bundle is created and traffic is sent through the DUT with multiple flows, evenly distributed by the SUT
- The laser is turned off to simulate link failure, and the 'down' event is time-stamped
- The time taken to reallocate traffic onto alternative active or standby links is then measured
- Packet loss incurred during reallocation is also measured

# LACP Test Results



After Link Failure

Stream Group	Stream Index	Pass/Fail	Tx Packets	Rx Packets	Packets Lost	Min Latency	Avg Latency	Max Latency	Switchover time (ms)
39	0	FAIL	73530	73476	54	19.410	145.340	220.170	4.2441
39	1	FAIL	73530	73527	3	9.310	36.855	198.350	
39	2	FAIL	73530	73476	54	19.490	145.342	215.560	4.2442
39	3	FAIL	73529	73527	2	9.310	36.855	198.350	
39	4	FAIL	73529	73475	54	19.530	145.344	216.610	4.3250
39	5	FAIL	73529	73527	2	9.310	36.856	198.350	
39	6	FAIL	73529	73475	54	19.570	145.346	215.930	4.3249
39	7	FAIL	73529	73526	3	9.310	36.854	198.350	
39	8	FAIL	73529	73475	54	19.330	145.337	213.970	4.2430
39	9	FAIL	73529	73526	3	9.310	36.854	198.350	

Total number of packets transmitted from source port after link failure : 735293  
 Total number of packets received on link bundle ports after link failure : 735010

Run Ended: Wed May 30 08:59:41 2007 (duration = 00:00:56)

Test stopped

Version 0.14 Tcl/Tk 8.3.4

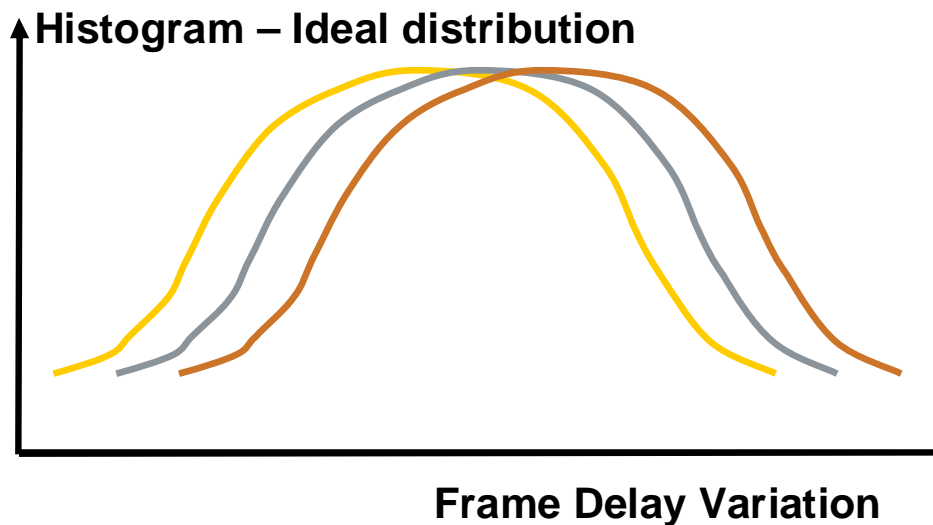
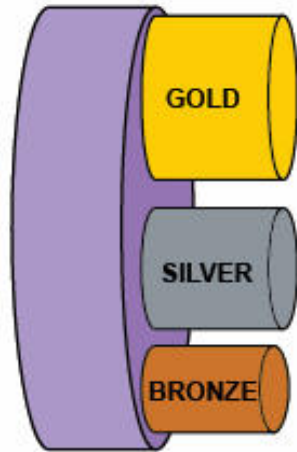
54 packets lost on streams that were reallocated

2-3 packets lost on streams that were not reallocated!

Increased latency

Failover time: 4.2 ms

# Carrier Ethernet Services QoS



## Service Level Agreements:

Performance Objectives (frame delay, jitter, loss) for Ethernet traffic within agreed Bandwidth Profiles

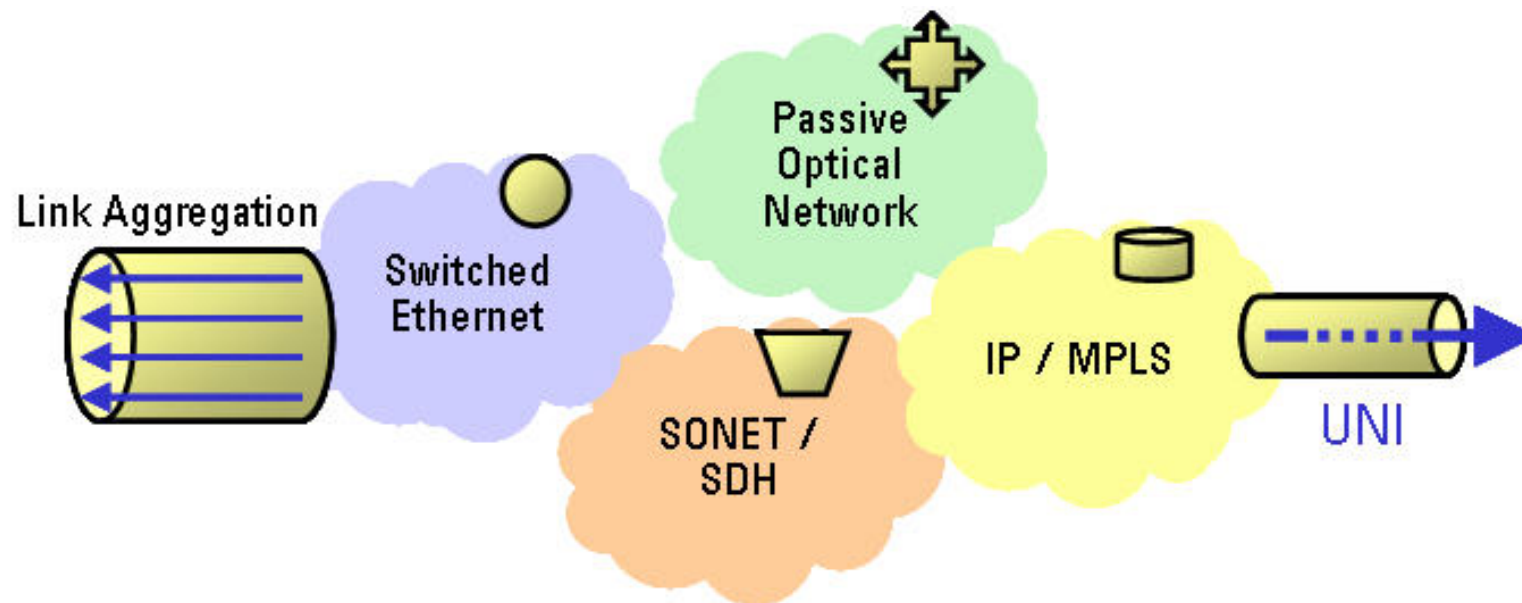
To facilitate **SLAs**, carriers always **prioritize** their customers' traffic, as **gold**, **silver** and **bronze** class of services. Consequently, it is important to ensure that **network devices** can meet SLA requirements, especially for the gold (premium) traffic class.

Ideally, the gold traffic will have the lowest frame delay variation – in other words, jitter – as shown in the small histogram representation.

# Carrier Ethernet Services QoS Test Challenges

## Can SLAs for E-LAN and E-Line Services be met?

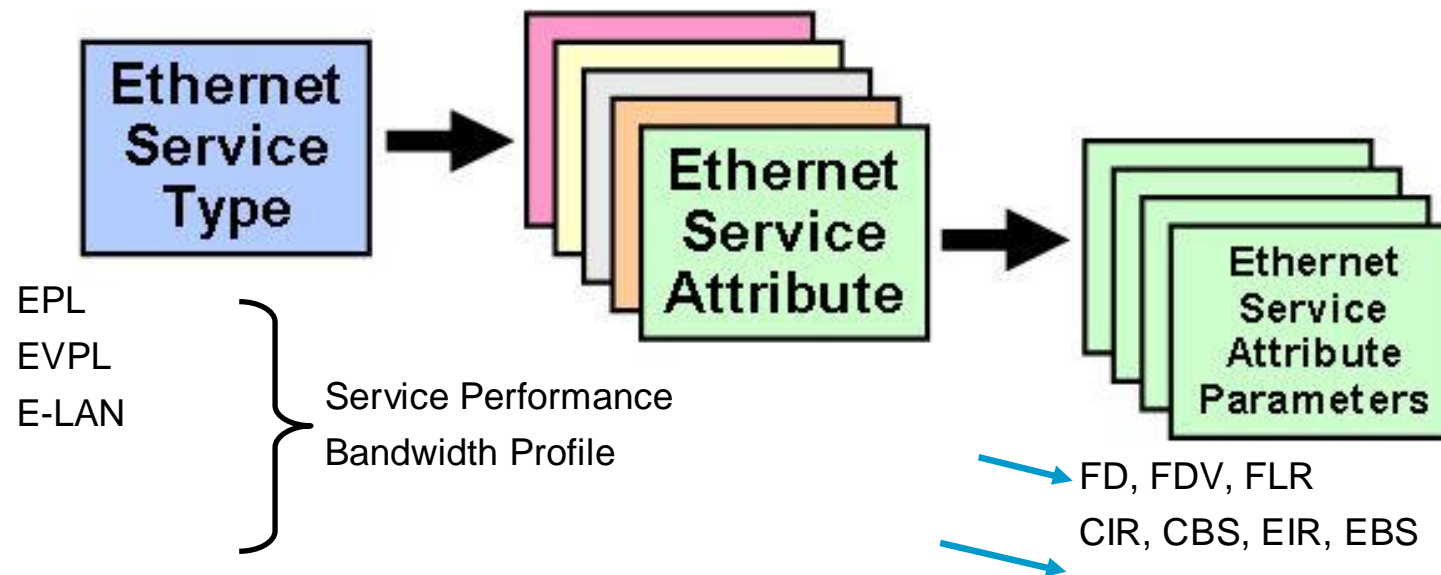
- For frame loss
- For frame delay
- For jitter



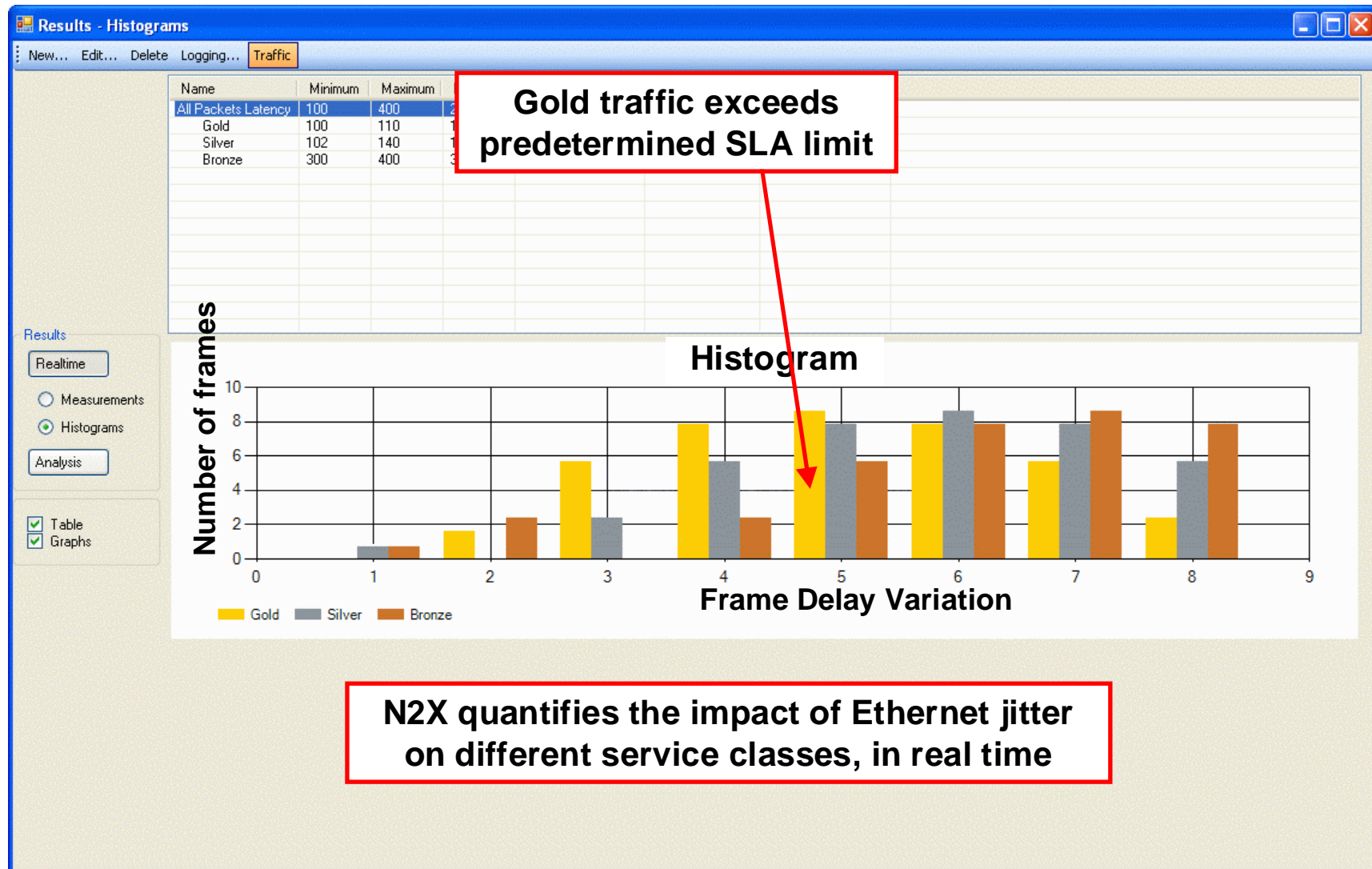
# Carrier Ethernet Services QoS Test Scenario

**Test objective: Regression test to ensure SLAs can be met**

- Run MEF 9 & 14 **conformance test suites**
- Capture **filters** and **triggers** help to find and diagnose problems fast
- Repeat tests after each equipment **software upgrade** or **configuration change**



# Carrier Ethernet Services QoS Test Results



# Application Service Example: IPTV Services over Ethernet Technology



It is essential to **test the impact of frame impairments** occurring at the infrastructure layer on the **user's experience at the application layer**. This is called **Quality of Experience** or **QoE**.

The **IETF RFC 4445** defines a method for quantifying **QoE** and an associated metric called **Media Delivery Index** (MDI) that has two components:

- Media Loss Rate (MLR), which is related to frame loss.
- Delay Factor (DF), which is related to jitter and the maximum required buffer needed to smooth that jitter (and avoid buffer overflow and underflow)

# Application Service Example: IPTV Services over Ethernet Test Challenges

MDI has two components:

- Delay Factor (DF)
- Media Loss Rate (MLR)

Service	Maximum acceptable Delay Factor (DF)
All	9 – 50 ms

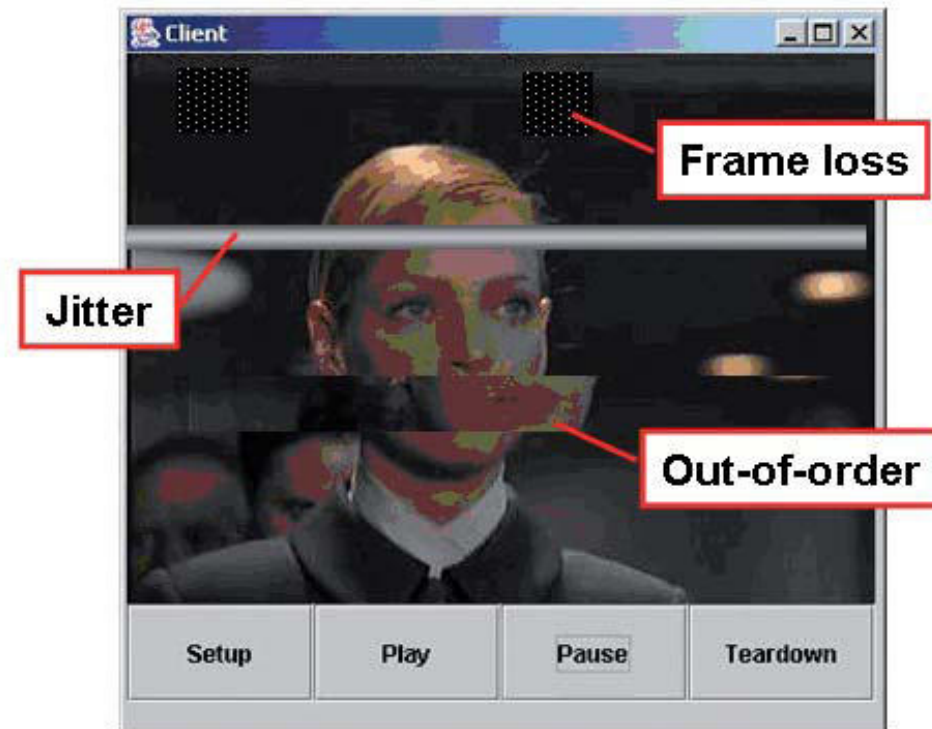
Service	Maximum acceptable Media Loss Rate (MLR)
SDTV	0.004 packets/sec
VOD	0.004 packets/sec
HDTV	0.0005 packets/sec

**Typical MLR target:** 1 packet dropped per 30 minutes for SDTV programming

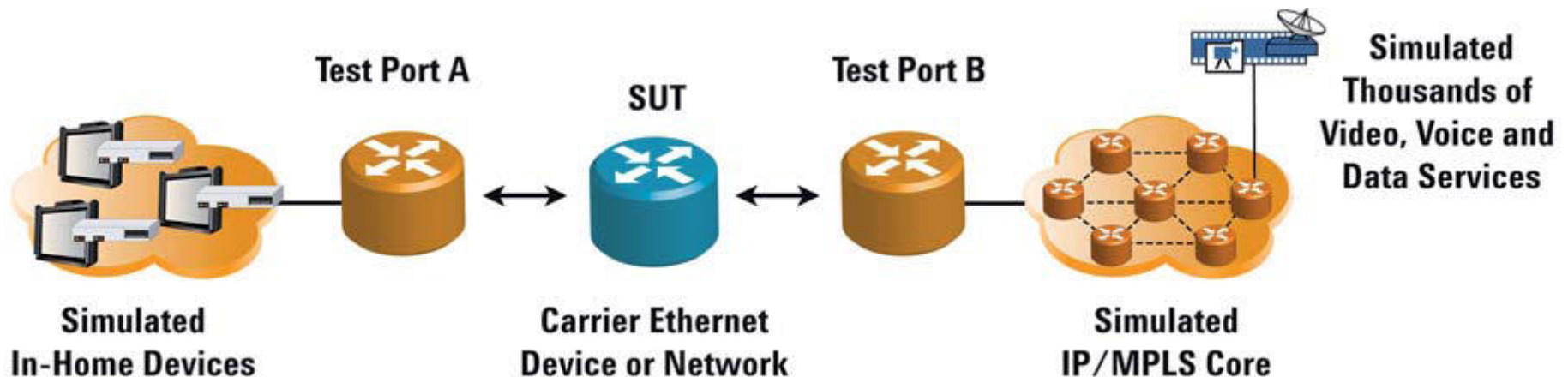
**Ideal:** Zero packet loss.

## Possible Dis-eases

Ethernet frame loss, latency and jitter will contribute to MDI



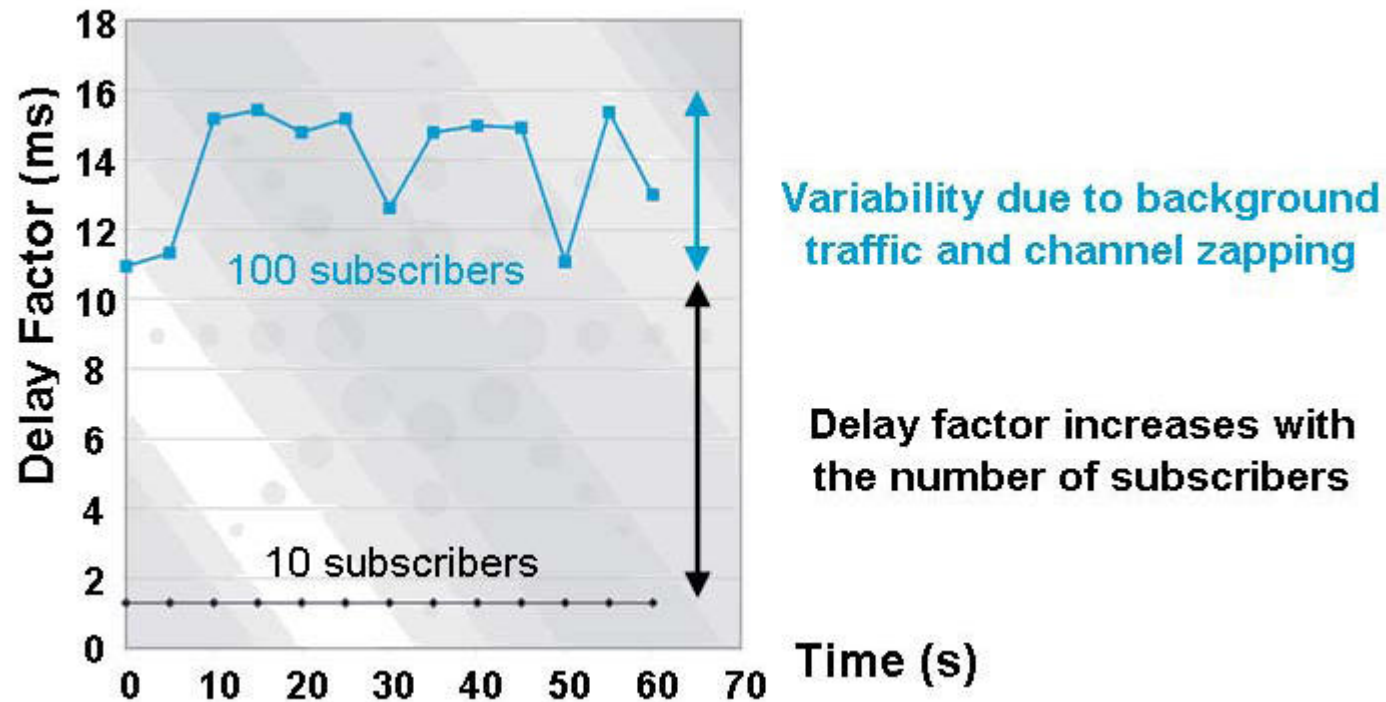
# Application Service Example: IPTV Services over Ethernet Test Scenario



## Test objective: measure the Delay Factor performance of a real device

- Behind Test Port B, thousands of voice, video and data services are simulated
- Behind Test Port A, multiple subscribers (with in-home devices) who are receiving multiple IPTV services and rapidly changing (also known as zapping) channels are simulated.
- MDI Delay factor measured for each emulated subscriber.

# Application Service Example: IPTV Services over Ethernet Test Results



# Conclusion

Solve your Carrier Ethernet implementation challenges **before they bite!**

Pre-deployment testing enables your customers to **feast on services**

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# QUESTIONS ?



# THANK YOU !