Test and Turn Up of Ethernet Based Business Services

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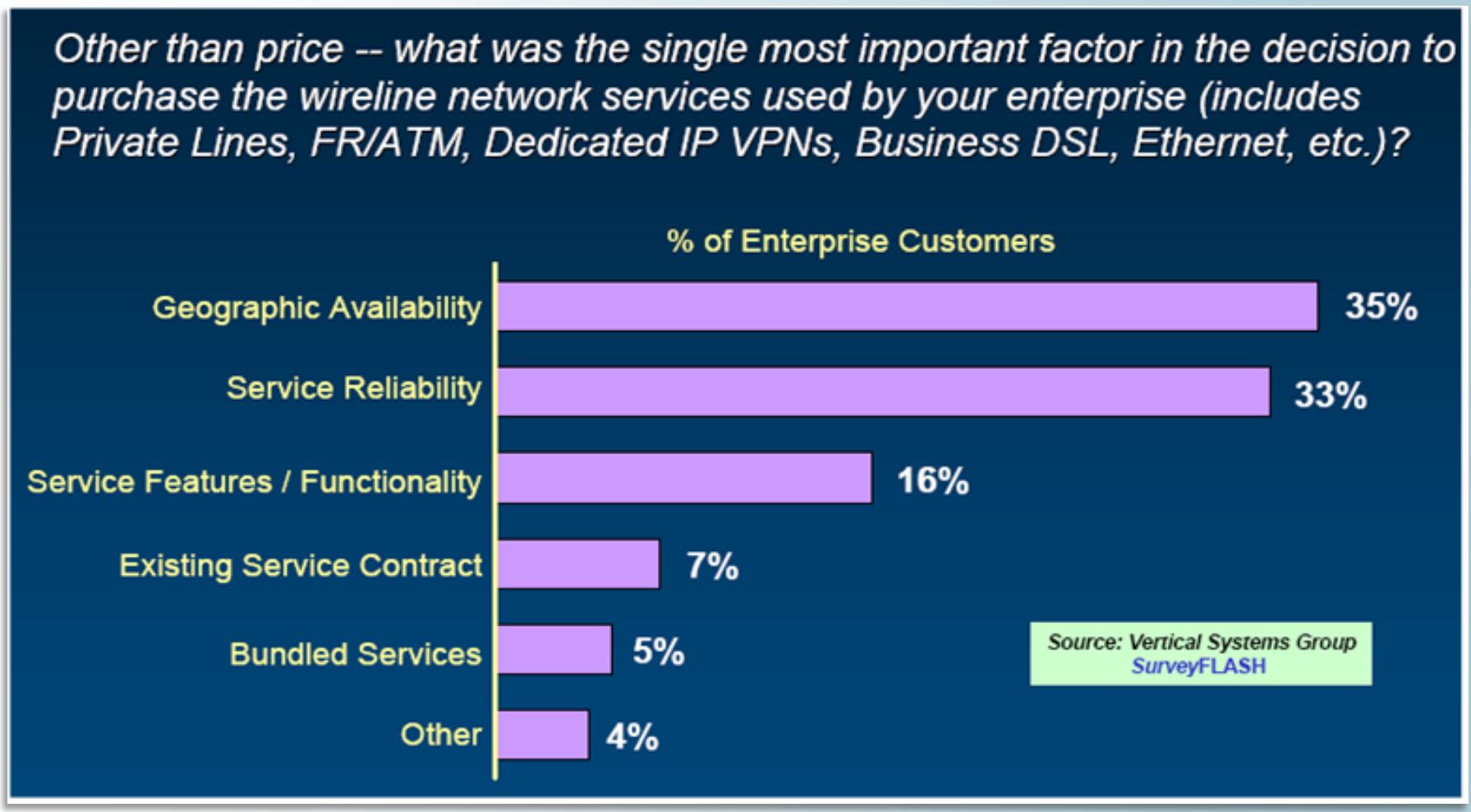
Business Services in the MSOs

- The Old Way (RBOCs were the only option)
  - Leased Lines (DS1, DS3) for pt to pt
  - Frame Relay or ATM for Switched Data Services
  - SONET Based Networks
- The MSOs join the game
  - MetroE
  - Dedicated Internet Access (DIA)- Layer 3 Ethernet
  - Cell Backhaul
  - Ethernet Gateway (aka Type 2 or NNI)
  - Business Voice Services
    - PRI-ISDN
    - VOIP (SIP) Trunking
- All of these Business Services are delivered by utilizing the MSOs Ethernet Network

Access Methods

- Service may be delivered over
  - Copper Plant
  - HFC Plant
  - Dedicated Fiber
  - WDM
- Each Technology has its Strengths

Availability and Reliability are Key Challenge



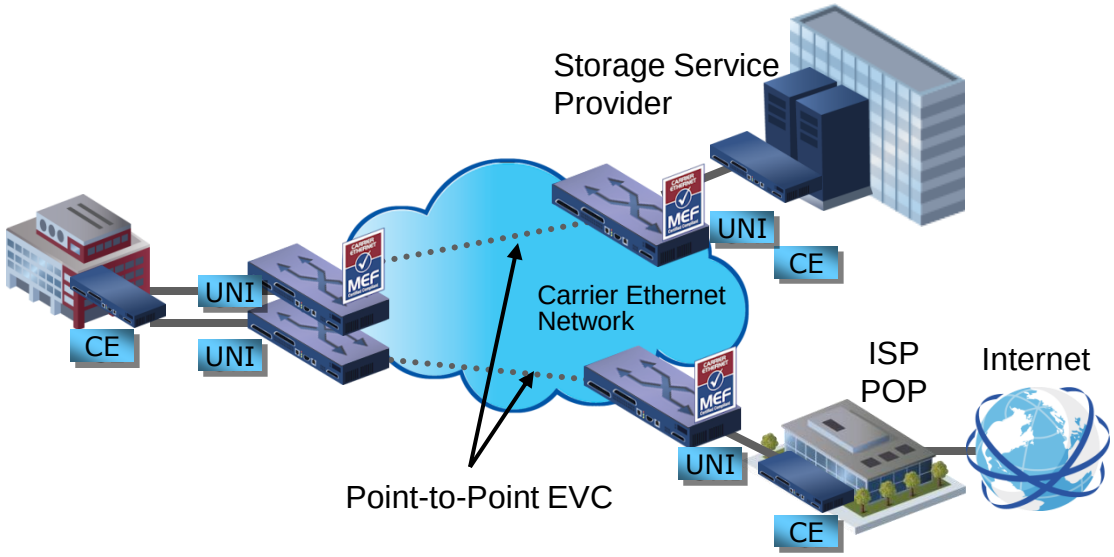
Based on customer survey in the USA

MEF Ethernet Services Definitions

Service Type	Port-Based	VLAN-Based
Point-to-Point	Ethernet Private Line **(EPL)**	Ethernet Virtual Private Line **(EVPL)**
Multipoint-to-multipoint	Ethernet Private LAN **(EP-LAN)**	Ethernet Virtual Private LAN **(EVP-LAN)**
Rooted multipoint	Ethernet Private Tree **(EP-Tree)**	Ethernet Virtual Private Tree **(EVP-Tree)**

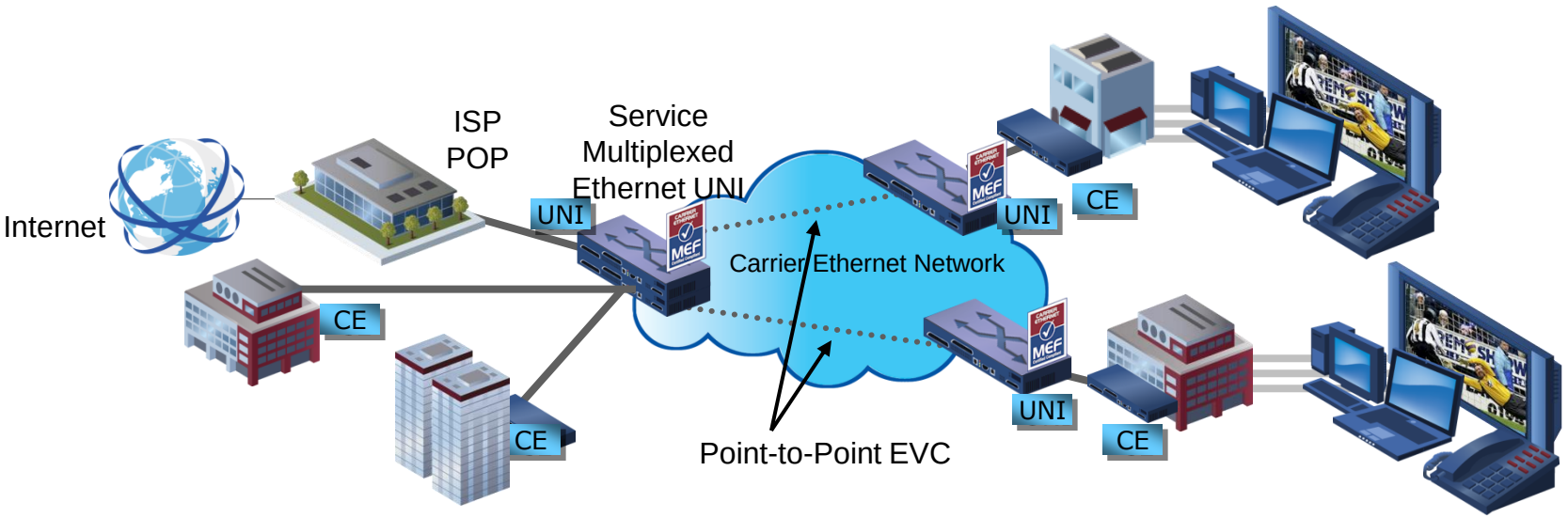
Ethernet Private Line (EPL)

- The most popular Ethernet service
- Replaces a TDM Private line
- Dedicated UNIs for Point-to-Point connections
- Single Ethernet Virtual Connection (EVC) per UNI



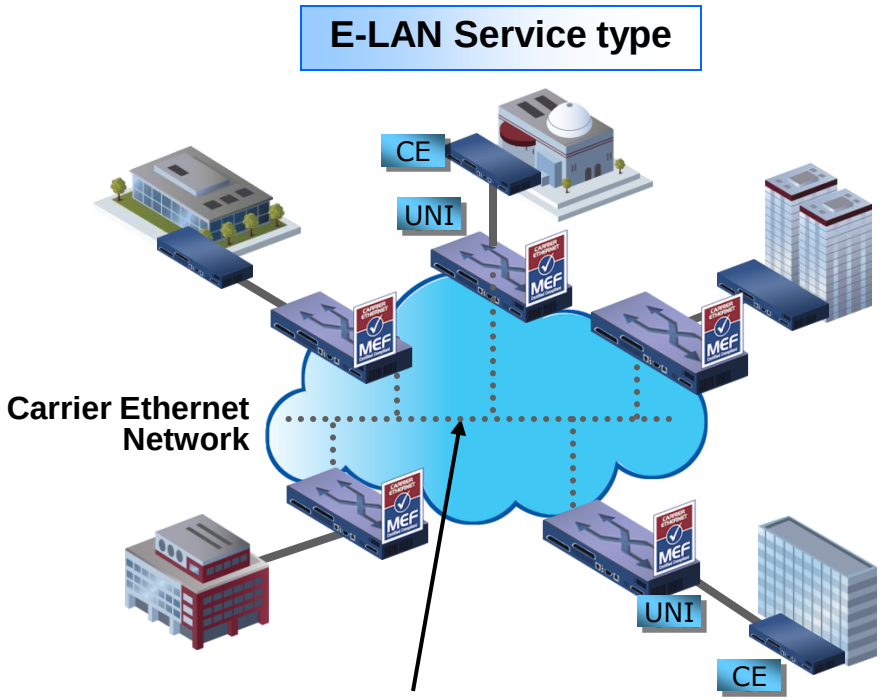
Ethernet Virtual Private Line (EVPL)

- Replaces Frame Relay or ATM services
- Allows single physical connection (UNI) to customer premise equipment for multiple virtual connections
- VLANs are used to identify multiple connections



Ethernet LAN Services (EP-LAN/EVP-LAN)

- E-LAN Service used to create
  - Multipoint L2 VPNs
  - Transparent LAN Service
  - Foundation for Multicast networks

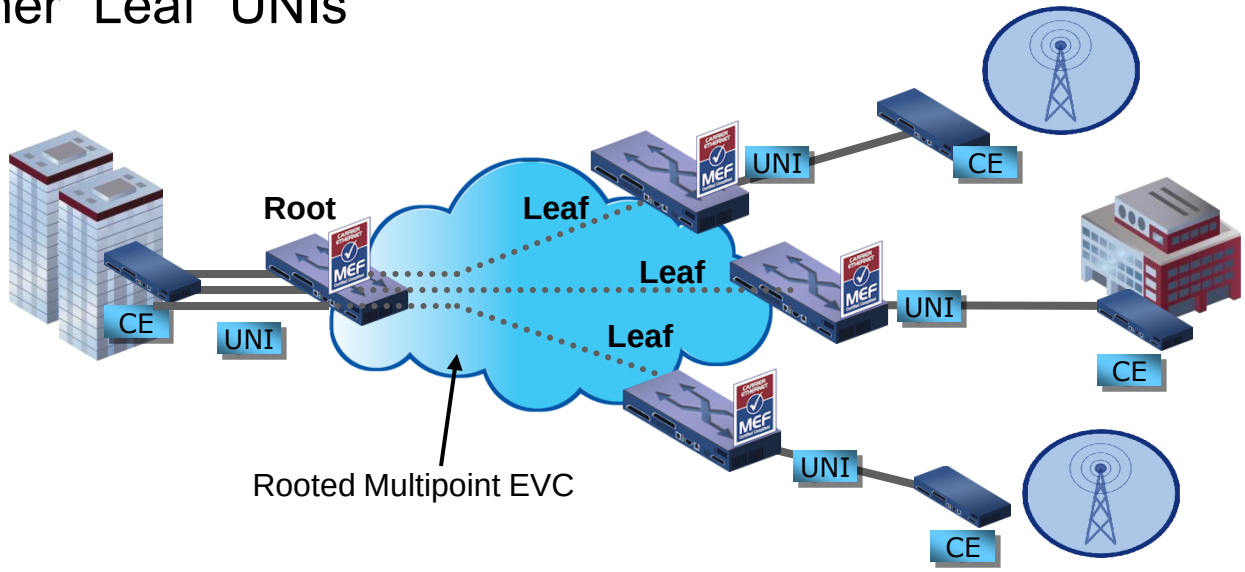


Multipoint-to-Multipoint EVC

MEF certified Carrier Ethernet products **UNI:** User Network Interface, **CE:** Customer Equipment

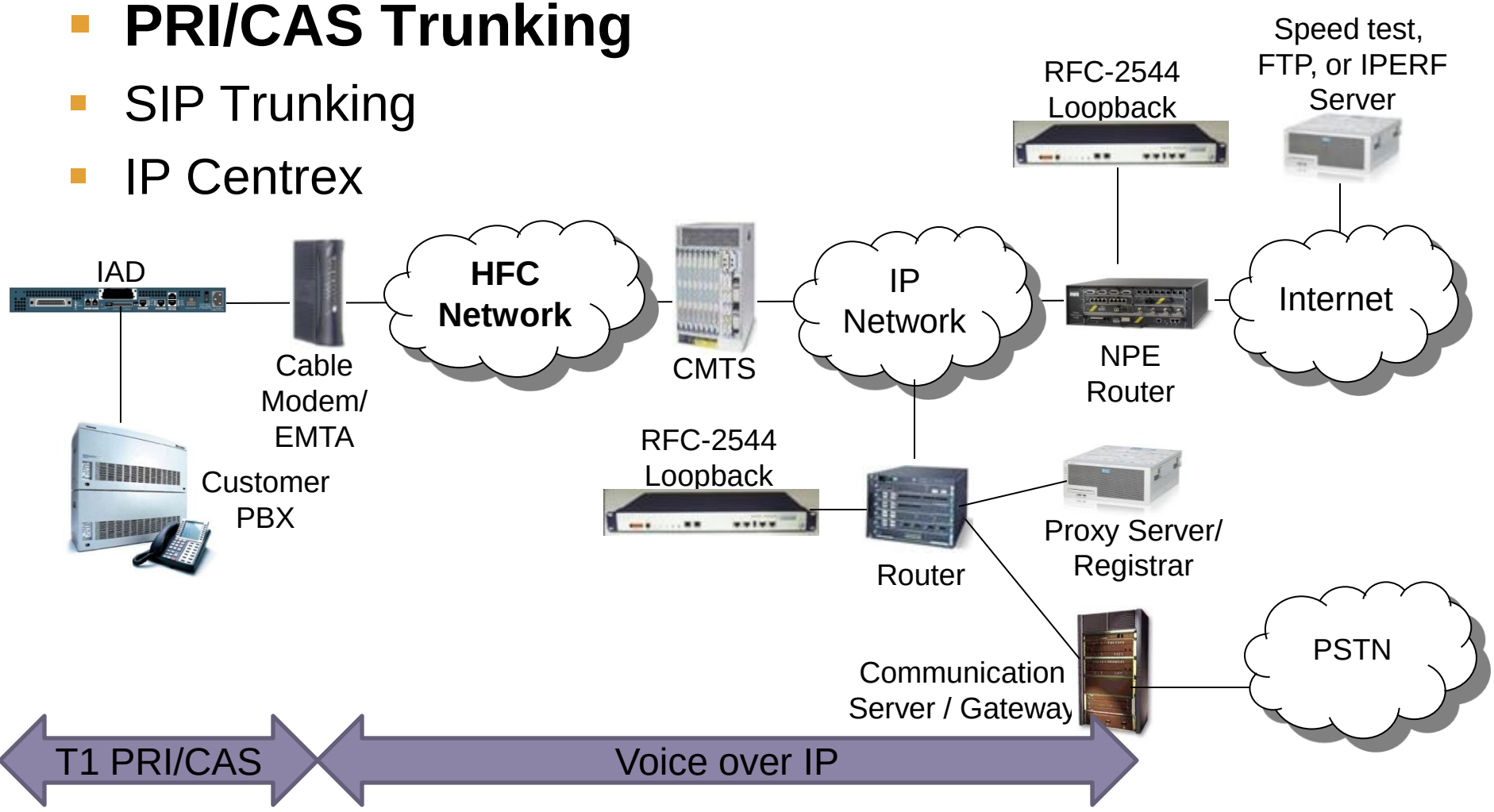
Ethernet Tree Services (EP-Tree/EVP-Tree)

- E-Tree Service Used for Applications requiring Point-to-Multipoint topology
  - Mobile cell site backhaul, Video on demand, internet access, triple play backhaul, franchising applications
- Provides traffic separation between ‘Leaf’ UNIs
  - Traffic from any “leaf” UNI can be sent/received to/from “Root” UNI(s) but never being forwarded to other “Leaf” UNIs



Business Phone Services

- Digital Phone
- **PRI/CAS Trunking**
- SIP Trunking
- IP Centrex



Business Phone Services

- Digital Phone
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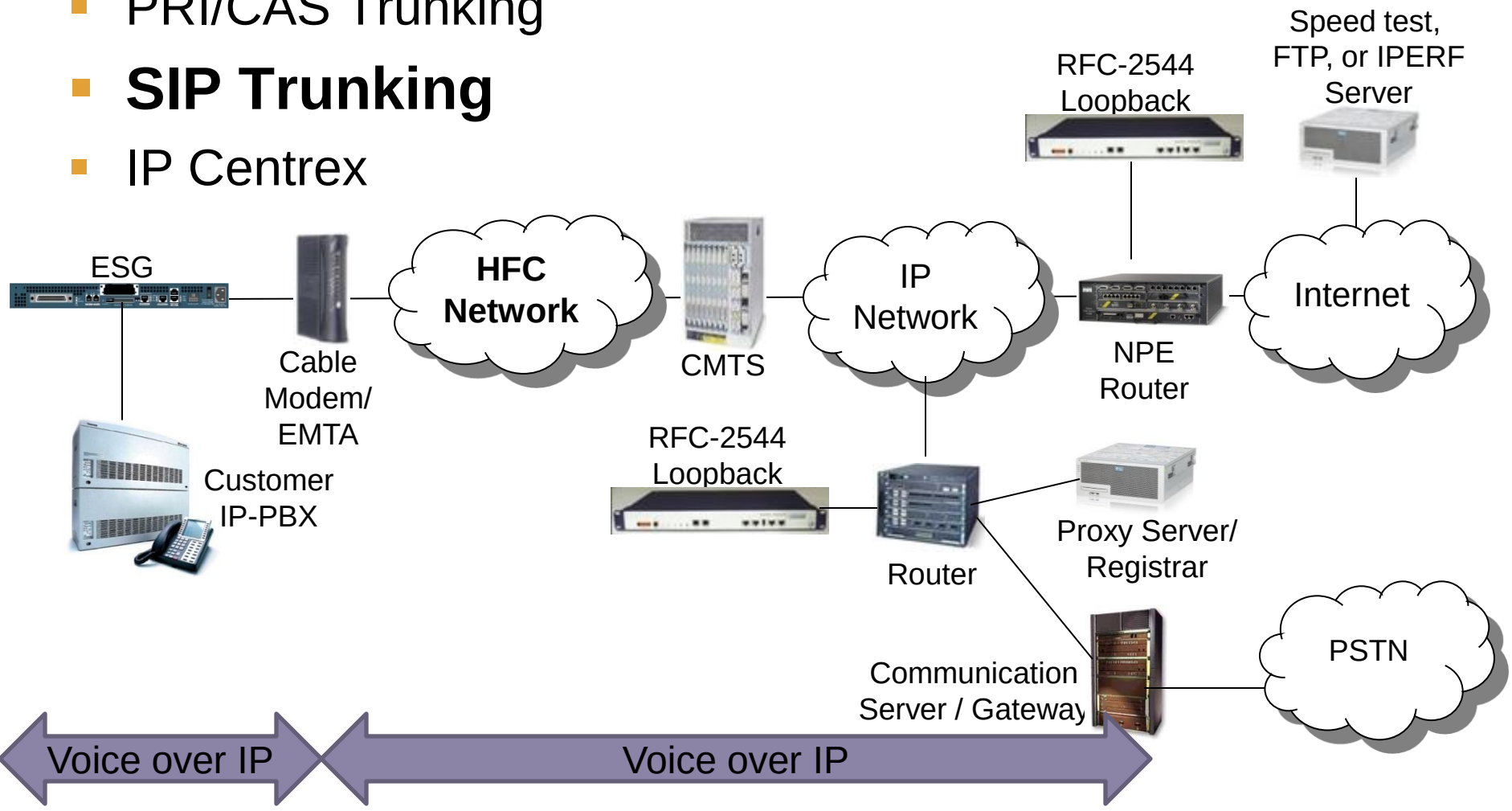


Ethernet Basics

SONET – Ethernet OSI Layer Comparison

SONET

- Layer 1

Ethernet

- Layers 1 and 2

	SONET	Ethernet	
	Application	Application	HTTP, Email, FTP
	Presentation	Presentation	
	Session	Session	
	Transport	Transport	TCP/UDP
IP	Network	Network	IP Routing
ATM	Datalink	Datalink	Ethernet (MAC)
SONET	Physical	Physical	Ethernet

OSI Layer Model

The Physical Layer

- The Physical Layer
  - Copper – CAT-5e/6
  - Optical
    - SingleMode, Multi-Mode Fiber
    - 850nm, 1310nm, 1550nm

CAT-5e

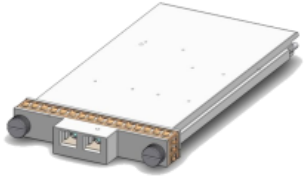
Multimode Fiber

SingleMode Fiber

- Rates
  - 10/100BaseT – Primarily Electrical
  - 1GigE – Optical and Electrical
  - 10GigE – High Speed Optical Interconnects
  - 40/100GigE – Latest Standard

SFP

XFP



CFP

Application
Presentation
Session
Transport
Network
Datalink
Physical

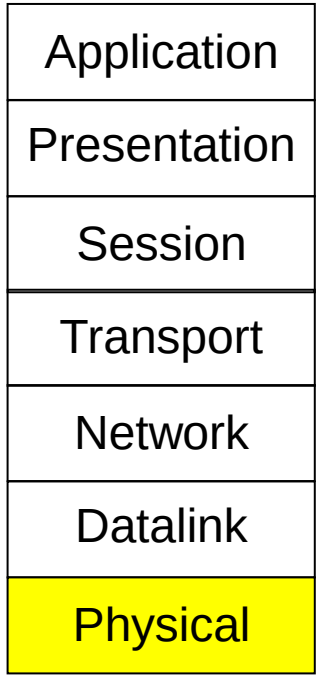
Ethernet Physical Layer

- Most common Ethernet Physical Layers
- Key concept is to use the correct wavelength

	10 Mbps	100 Mbps	1 Gbps	10 Gbps
Electrical (copper)	100 meters	100 meters	100 meters	
Optical Multimode (850nm)		2000 meters	550 meters	100 meters
Optical Singlemode (1310nm)		15000 meters	10000 meters	10000 meters
Optical Singlemode (1550nm)			40000 meters	40000 meters

Ethernet Link establishment

- Physical Layer link establishment
  - **Step 1 (optical only)**
    - Light is seen on both sides
  - **Step 2**
    - Byte synchronization takes place
  - **Step 3**
    - Each node is set for
      - **10, 100, or 1000 Mbps**
      - **Half Duplex/Full Duplex**
      - **Flow control** on/off
    - Done by internal setup or **Auto-Negotiation**



Duplex Mismatch

- Auto-Negotiation – establishing duplex
  - advertises flow control and FDX/HDX capabilities to the other side
  - Must be the same on both ends of a connection
- Full Duplex/Half Duplex
  - Full Duplex – transmit and receive at the same time (phone)
  - Half Duplex – sides take turns transmitting and receiving (walkie talkie)
- Auto-Negotiation Mismatch
  - One side on and one side off leads to duplex mismatch
    - Link appears to be active (green LEDs)
    - Once traffic ramps collisions and errors bring link to a standstill

HDX 

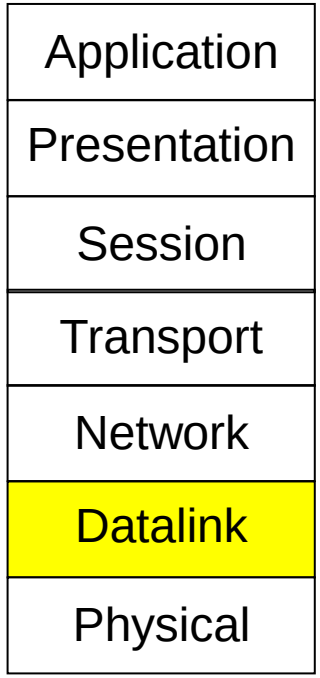
FDX 

Application
Presentation
Session
Transport
Network
Datalink
Physical

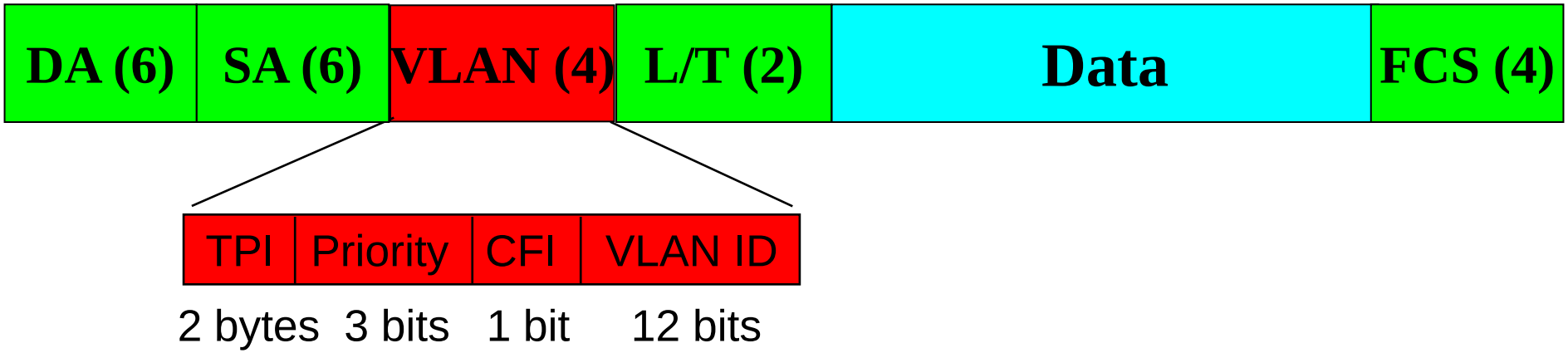
Ethernet Frame Format

Pre (7)	SFD (1)	DA (6)	SA (6)	L/T (2)	Data (46-10,000)	FCS (4)

- The Datalink layer relies on layer 2 overhead for physical addressing and error detection.
- Same frame format regardless of rate (10/100/Gigabit/10 Gigabit)
- Frames are separated by a Preamble and Start of Frame Delimeter (SFD) (Note: these fields are included in Layer 1 results but not Layer 2 results)
- Frames are sent from a Source MAC Address (SA) to Destination MAC Address (DA)
- Length or Type (L/T) Field is dependent upon Frame Type (802.3 or DIX)
- Data or Payload field is Variable length. Test frames include a sequence #, time stamp, and BERT pattern.
- MTU determines maximum frame length. 64 - 1518 bytes, or up to 10,000 bytes for Jumbo frames
- At the end of each frame is an FCS (frame check sequence) to detect errors



VLAN (Virtual Local Area Network)

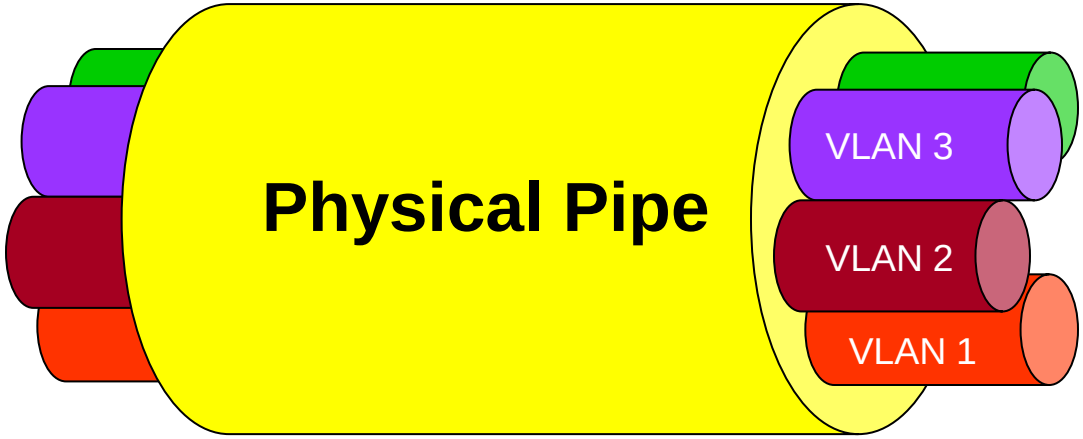


- "VLAN tags" are optional fields for Ethernet links
- Two Important Fields in Ethernet VLAN's:
  - VLAN ID
    - Specifies the VLAN group
    - Allows seperation of traffic by customer or service
  - VLAN Priority
    - Prioritze Traffic (for ex Gold, Silver, Bronze)
    - Prioritize signaling and real time traffic (Voice and video) over data traffic
    - Prioritize interactive applications over batch applications

Application
Presentation
Session
Transport
Network
Datalink
Physical

Virtual LAN (VLAN)

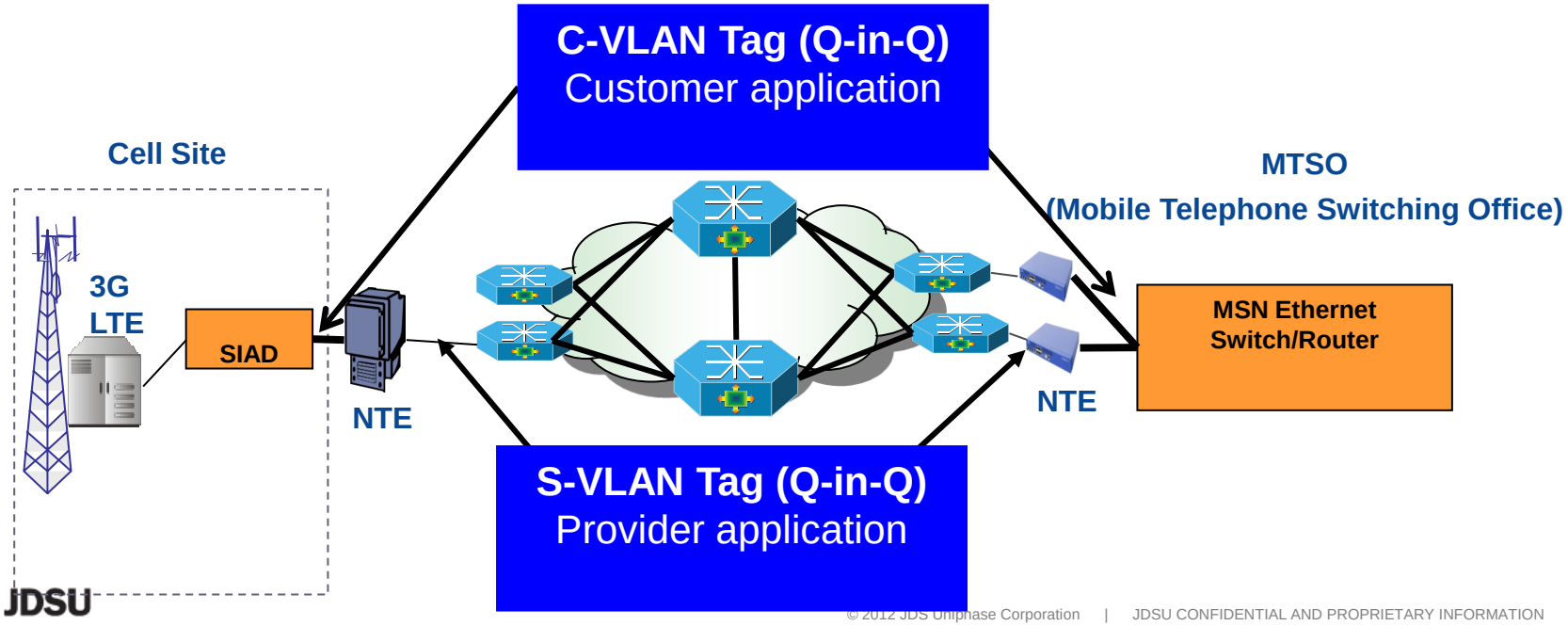
- **Benefits**
  - Enables logical segmentation of traffic/networks
    - Many virtual pipes in one physical pipe
  - Separates Broadcast Domains
  - Provides Security
  - Operates at Layer 2



Q-in-Q Tagged VLAN

Preamble (7)	SFD (1)	DA (6)	SA (6)	SVLAN (4)	CVLAN (4)	L/T (2)	Data (46-1500)	FCS (4)

- Allows for customer and service provider VLANs
  - S-VLAN Tag – 4 bytes
    - Specifies which provider VLAN group (customer)
    - Traffic switched & prioritized in core network by S-VLAN tag
  - C-LAN Tag – 4 bytes
    - VLAN with customer significance



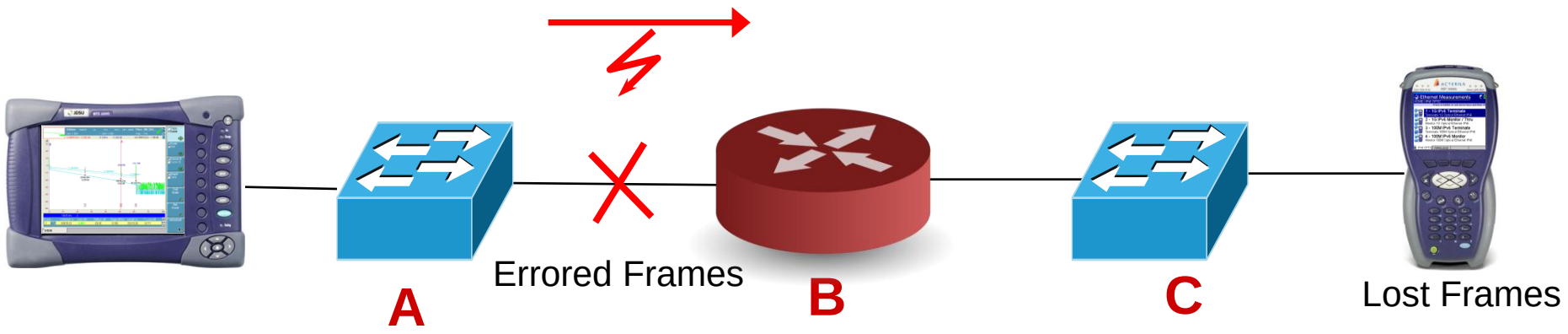
IP Addresses

- IP Header is 20 bytes long with numerous fields
  - Destination & Source Address
  - TOS/DSCP bits (3)
- IP addresses
  - Are 32 bits long and expressed in octets (xxx.xxx.xxx.xxx with xxx = 0-255)
    - Note: For IPv6 increases to 128 bits
  - Can be statically configured or dynamically assigned via DHCP
- IP uses the TOS/DSCP field to prioritize IP traffic
  - TOS/DSCP is **in addition** to VLAN priority
  - TOS/DSCP is used by routers or IP switches to properly queue IP traffic
- Gateway IP Address is IP address of router that knows other networks
- Net Mask is also a 4 octet value (xxx.xxx.xxx.xxx) that separates network and host part of address
- ARP messages are used to map MAC addresses to IP addresses

Application
Presentation
Session
Transport
Network
Datalink
Physical

Ethernet Switching Rules

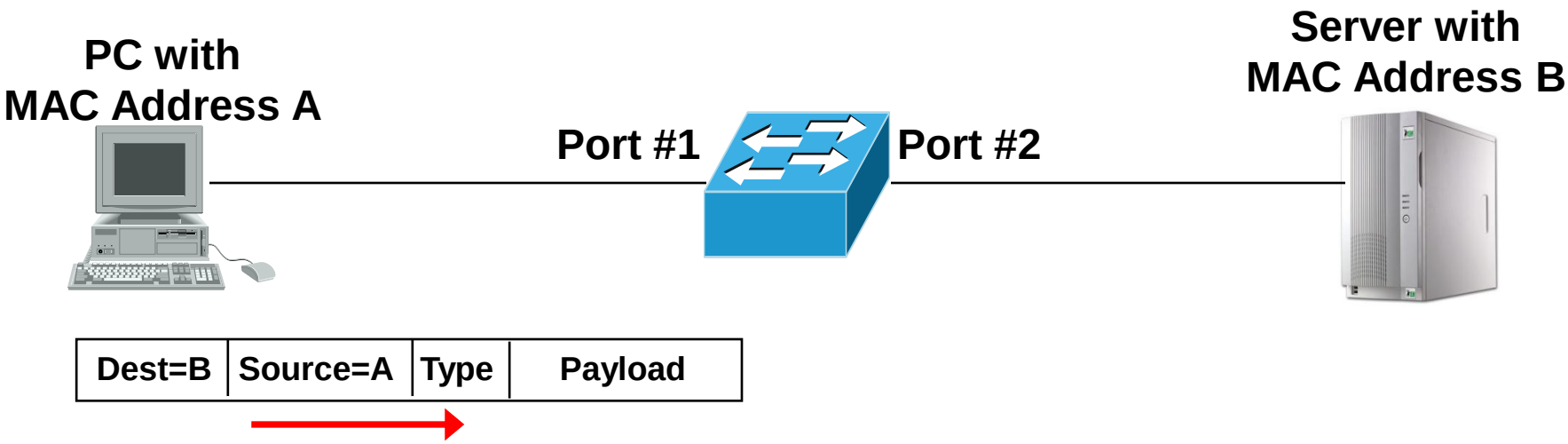
- Errored Frames are discarded by Ethernet devices
  - If LOST FRAME errors are occurring that means that the frame was dropped in transit.
  - For example, errors occurring between A and B will be seen by the switch receiving them.
  - However, errors occurring from A to B won't be seen by C.
  - Only way to view this is to have a sequence number in each packet and detect if packets were lost in transit.



Ethernet Switch Operation

- Switch operation
  - Any traffic for A, forward to port #1
  - Any traffic for B, forward to port #2

Port	MAC Addresses
1	A
2	B
3	
4	



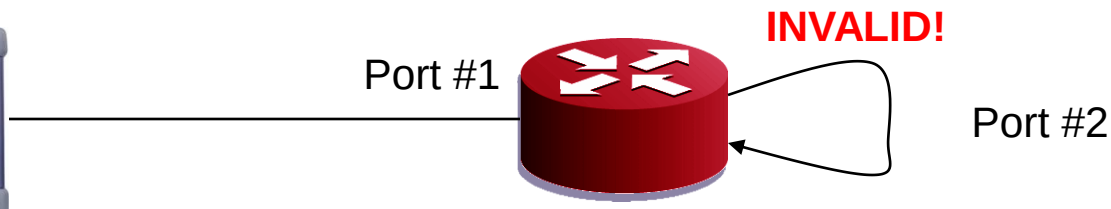
- Can also switch based on VLAN

Ethernet Rule #2 - Loops

- Can't hard loop a switch
  - Switch will see frame destined for B coming into Port #2 and will not forward it back to port #1. Frame will be dropped.

MAC Address	Port
A	1
B	2

T-BERD with MAC Address A

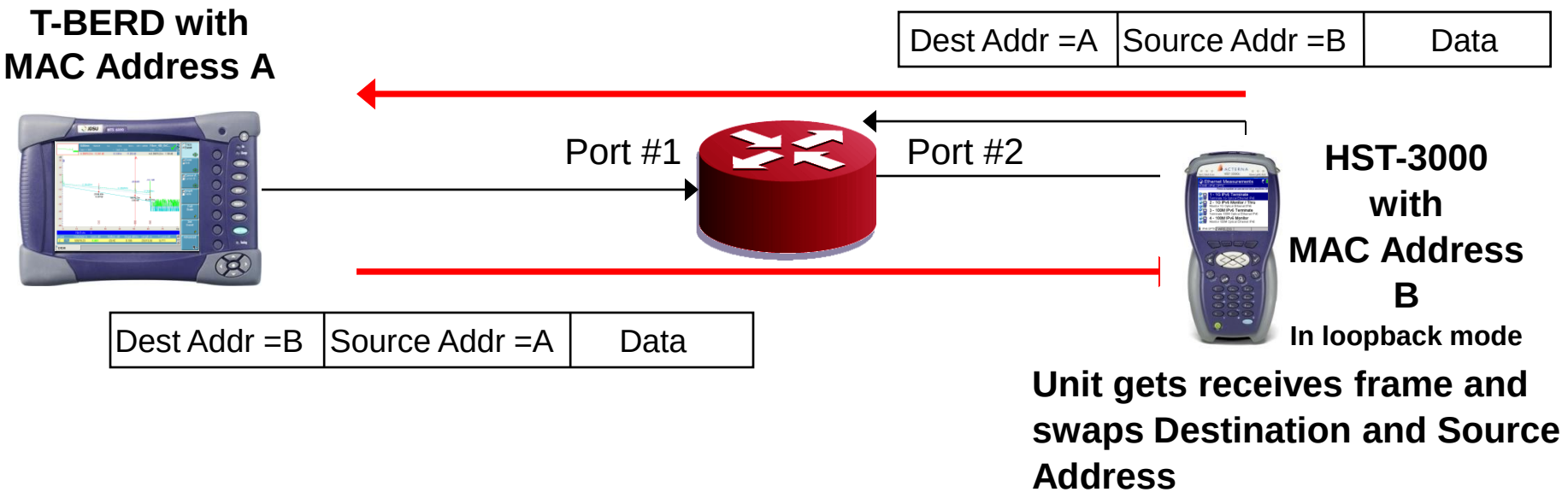


Dest Addr =B	Source Addr =A	Data

Ethernet Rule #2 - Loops

- For a loop to work on the switch, the Source and Destination addresses within the frame must be swapped
- This is what happens when test equipment is “looped up”

MAC Address	Port
A	1
B	2



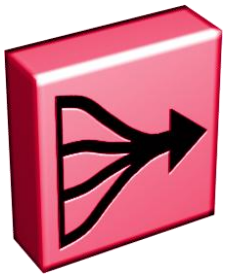
Unit gets receives frame and swaps Destination and Source Address

Policing and Shaping

- Traffic policing and Shaping are methods of enforcing Committed Information Rates

Policing

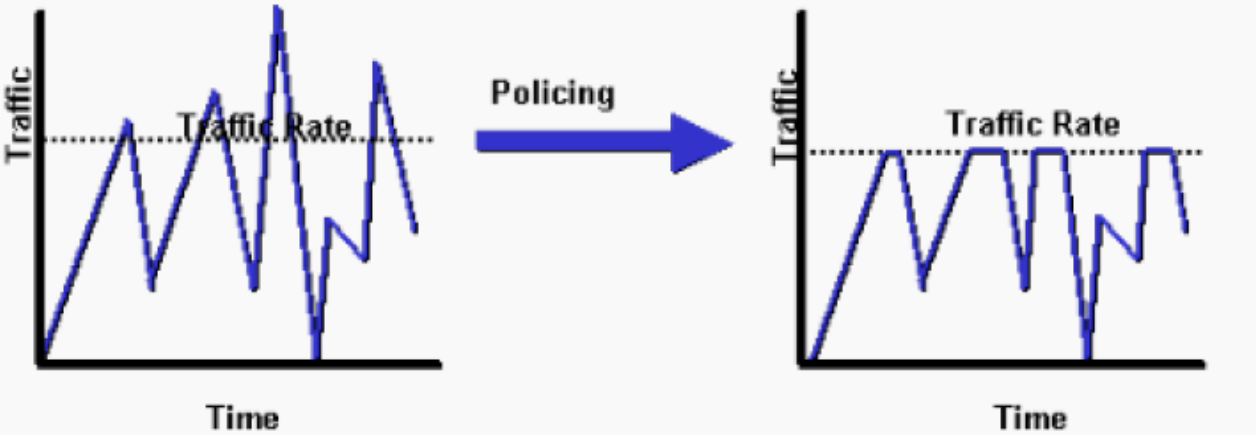
Traffic policing will **drop** the excess packets that are above a predefined traffic rate

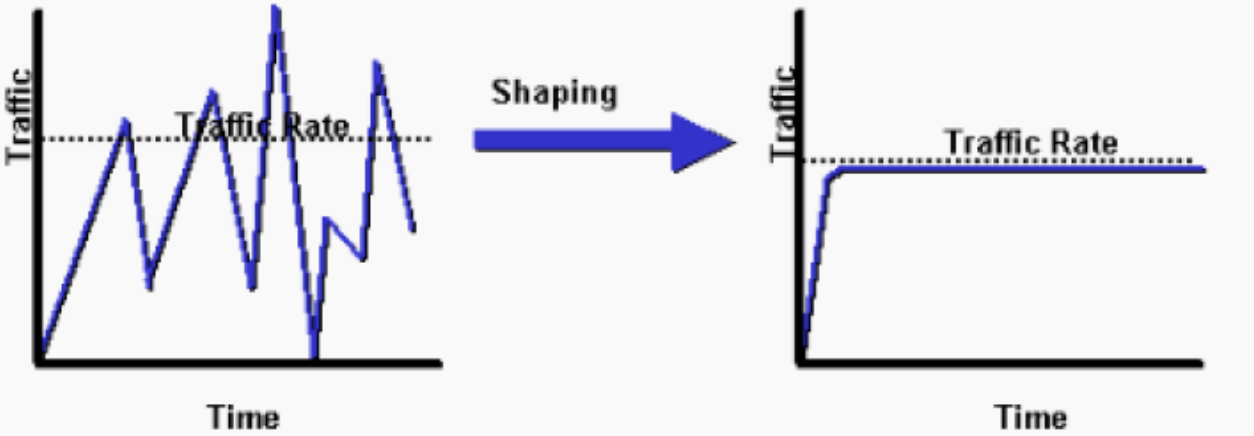


Shaping

Traffic shaping will **buffer and queue** the excess packets that are above a predefined traffic rate

Effects of Policing versus Shaping





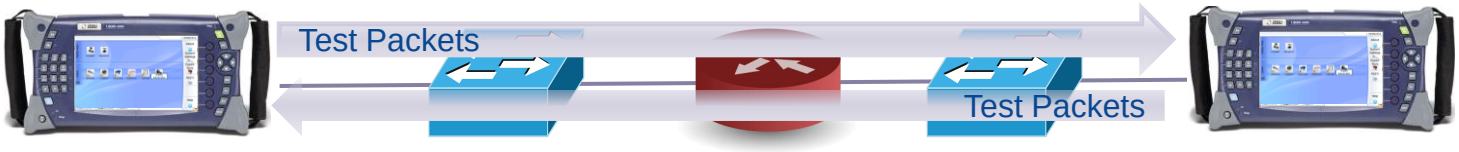
Key points:

- Most routers and multi-layer switches can perform shaping
- Network providers can provide better QoS by shaping customer traffic

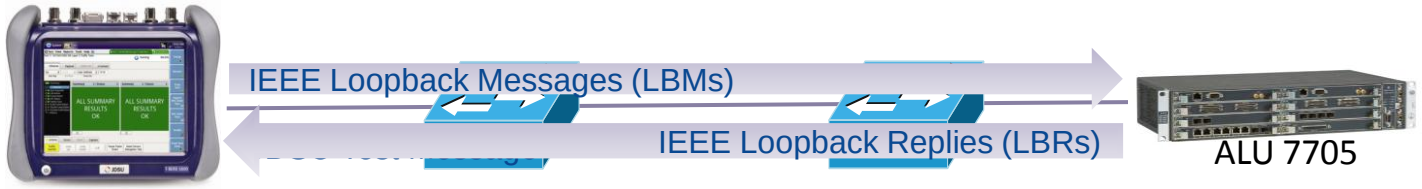
Turning up and Troubleshooting Metro Ethernet

Loopback devices

- Traffic can either be generated **Head to Head** between two test sets or to a **Loopback Device**. Test Sets and some layer 2 switches support special software loopback that swap Source and Destination MAC addresses and IP addresses. **Vendor Proprietary loopback messages** are used to place a device in local loopback mode.

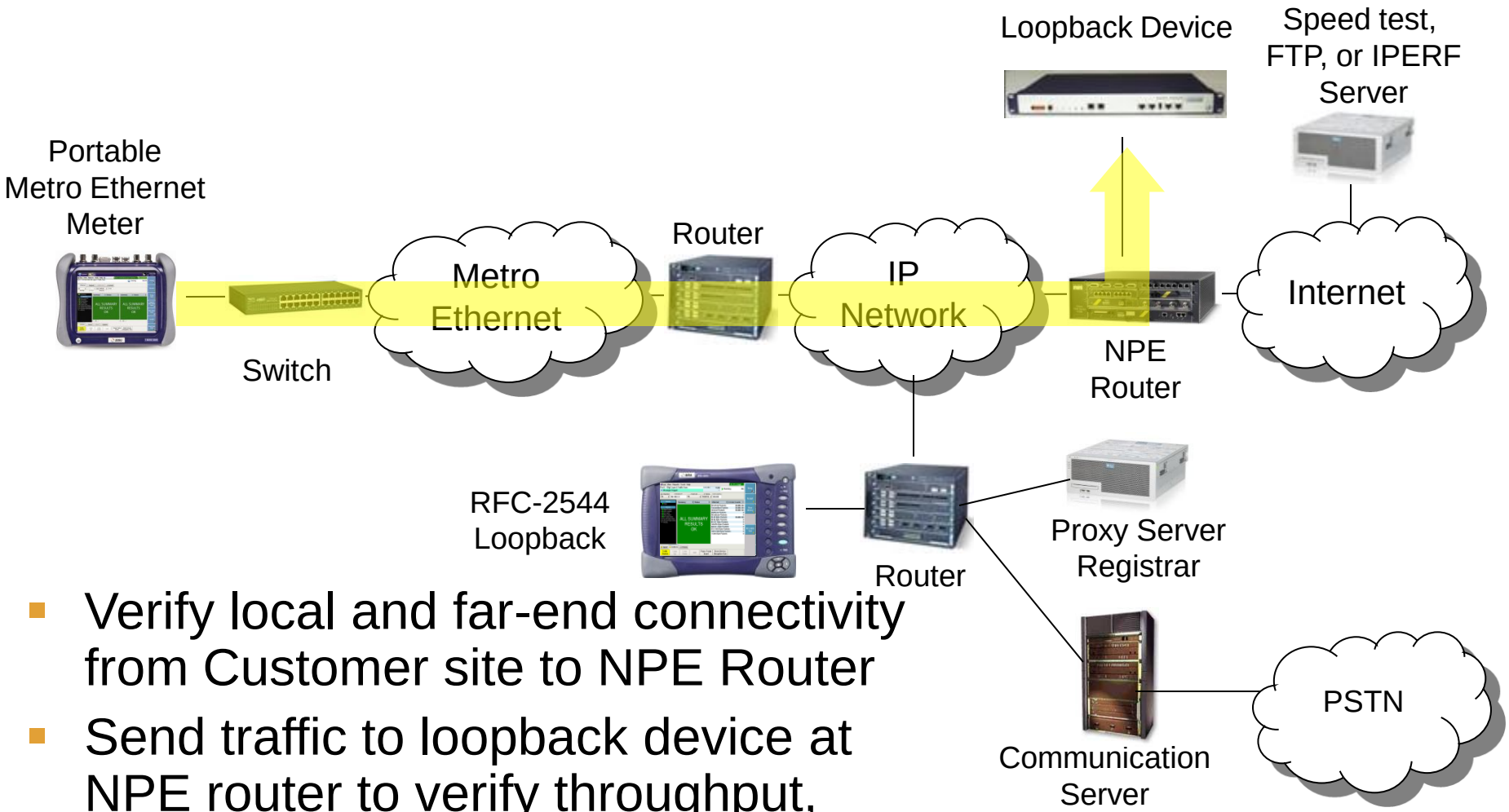


- Some Test equipment, switches and NIDs also support **IEEE 802.11ag Loopback Messages**.



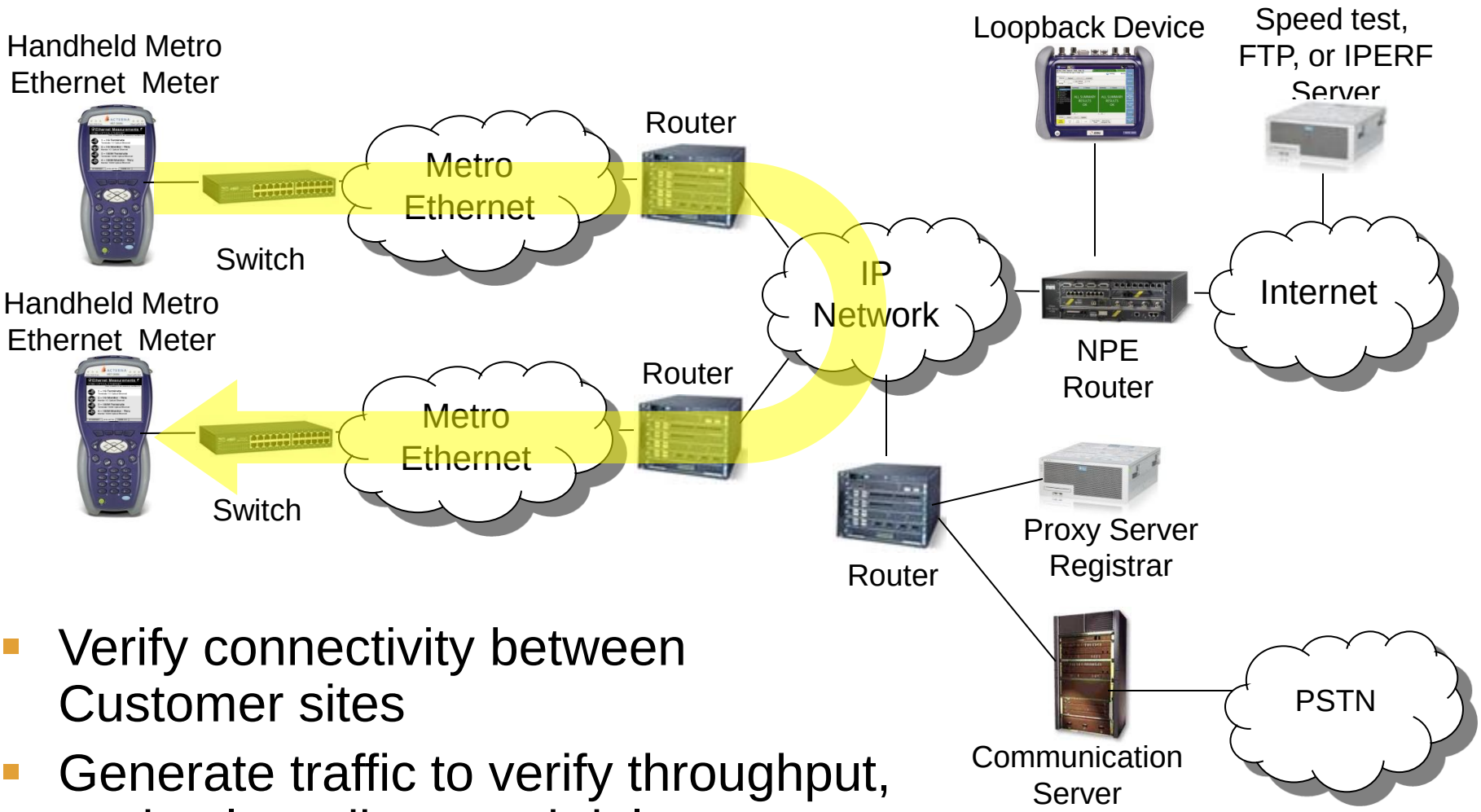
- **Due to the behavior of Layer 2 switches and routers, hard loops cannot be used for loopback.**

Testing Metro Ethernet for Internet Access



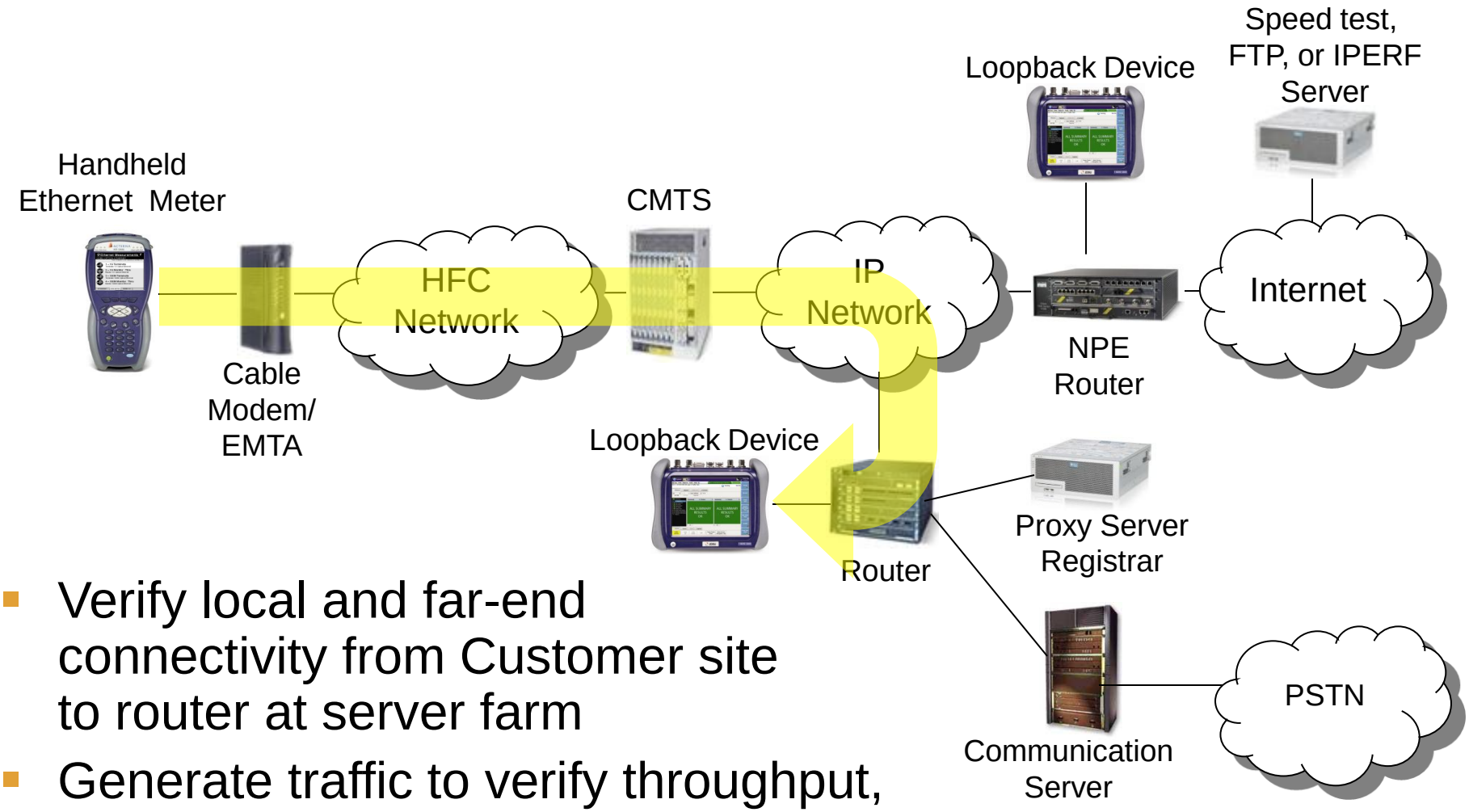
- Verify local and far-end connectivity from Customer site to NPE Router
- Send traffic to loopback device at NPE router to verify throughput, packet loss, jitter, an delay meet SLA or MOP requirements

Testing Metro Ethernet for EPL/EVPL



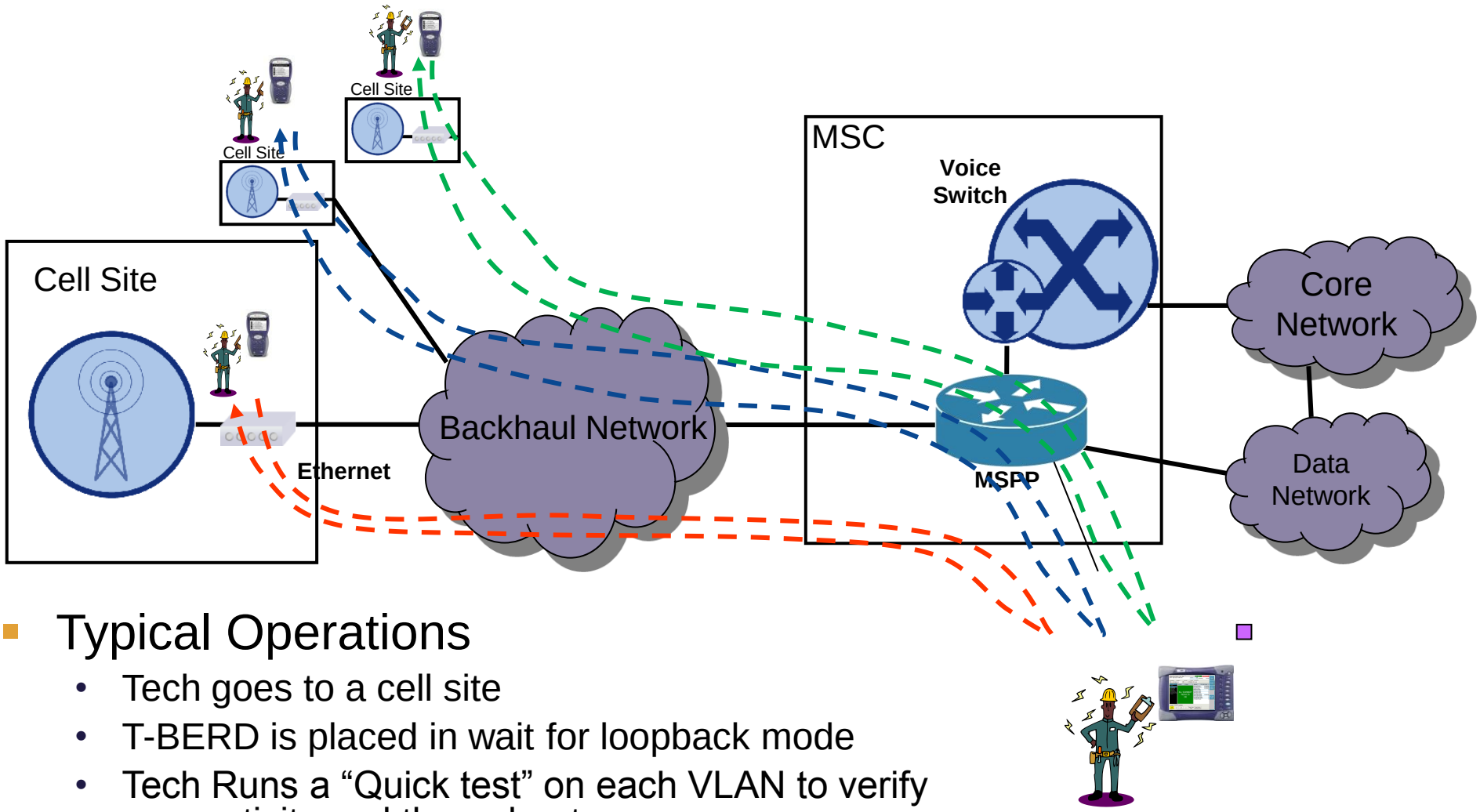
- Verify connectivity between Customer sites
- Generate traffic to verify throughput, packet loss, jitter, and delay meet SLA or MOP requirements

Testing Metro Ethernet for Voice Trunking



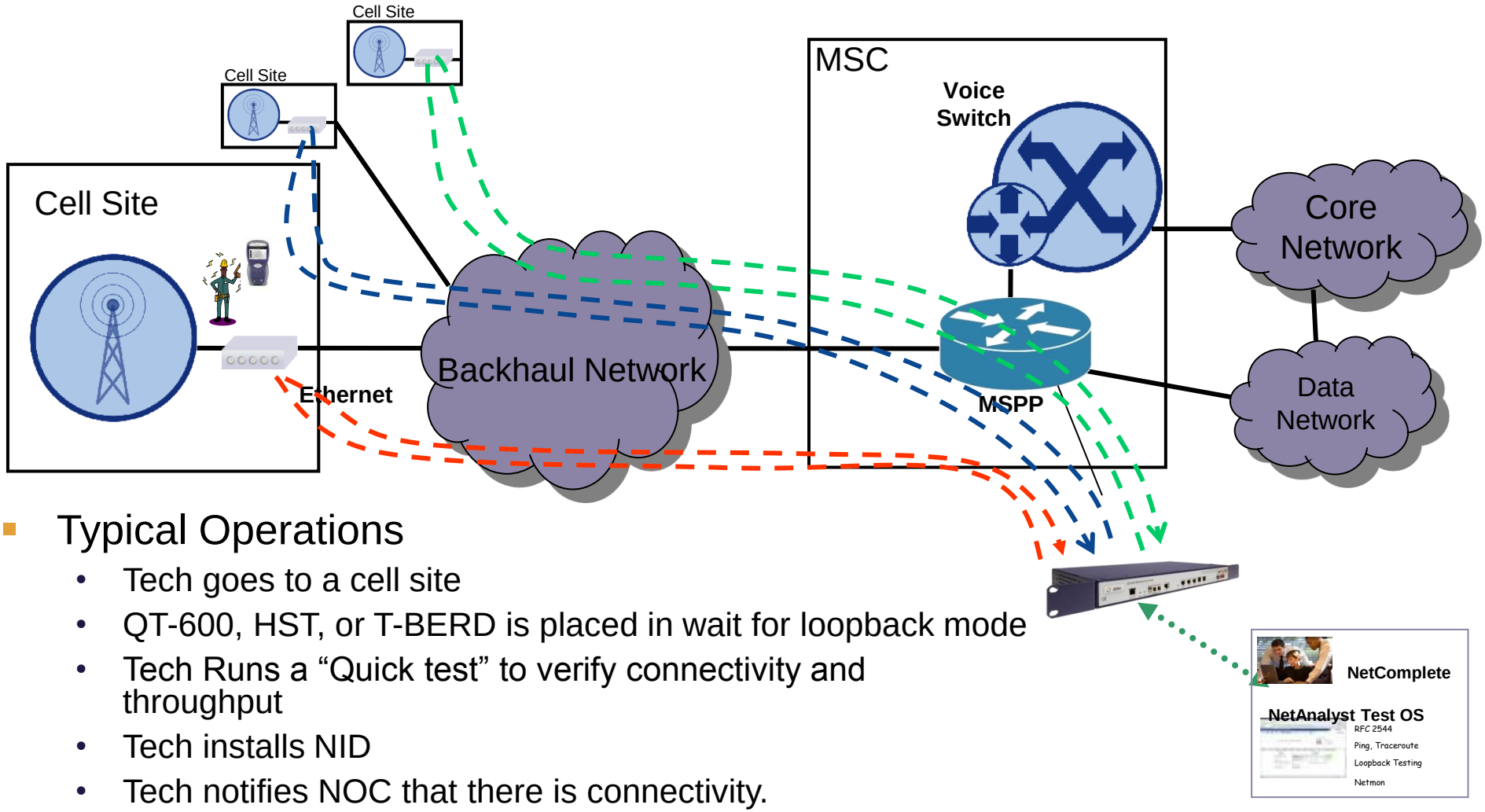
- Verify local and far-end connectivity from Customer site to router at server farm
- Generate traffic to verify throughput, packet loss, jitter, an delay meet SLA or MOP requirements

Portable to Portable Testing for Cell Backhaul



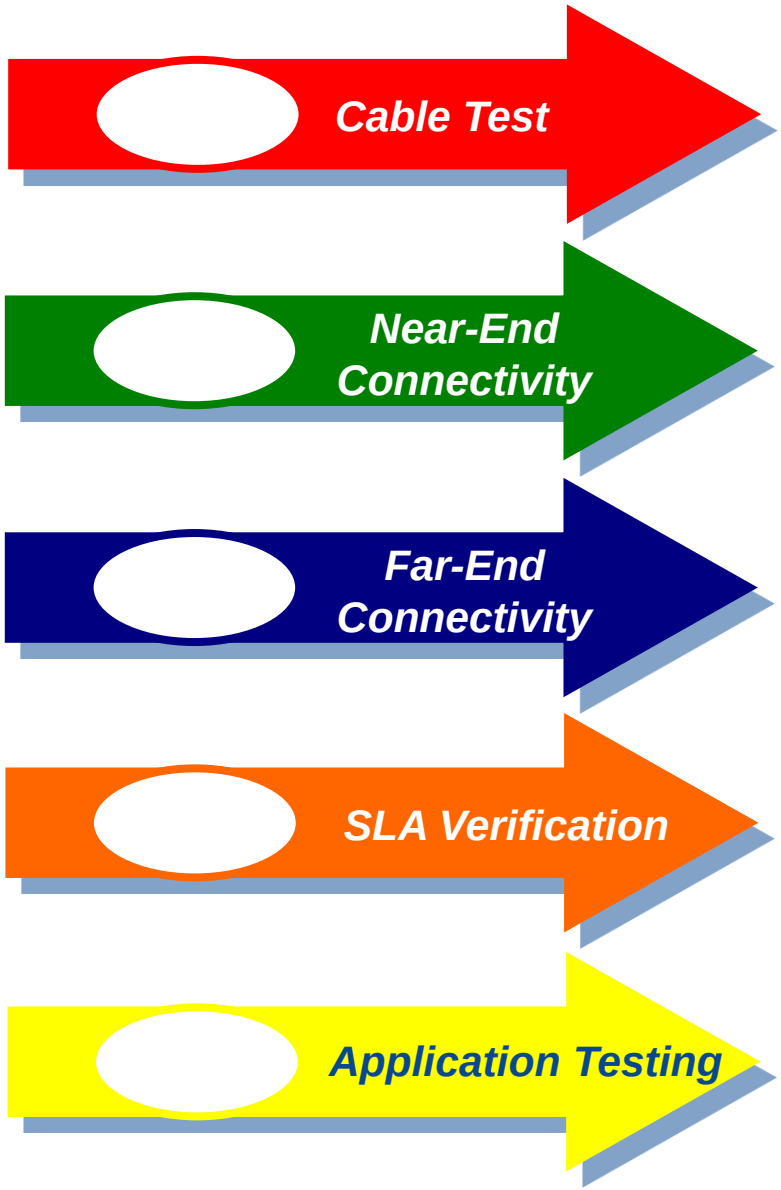
- Typical Operations
  - Tech goes to a cell site
  - T-BERD is placed in wait for loopback mode
  - Tech Runs a “Quick test” on each VLAN to verify connectivity and throughput
  - Full RFC-2544 test is run on each VLAN to T-BERD at MSC

Portables and Systems Solution for Cell Backhaul



- Typical Operations
  - Tech goes to a cell site
  - QT-600, HST, or T-BERD is placed in wait for loopback mode
  - Tech Runs a “Quick test” to verify connectivity and throughput
  - Tech installs NID
  - Tech notifies NOC that there is connectivity.
  - Full RFC-2544 test is run to NID
- Value
  - Keeps Techs moving and working – Sites turned up faster

Metro Ethernet Installation Test Process



Copper Certification;
Clean & Inspect all fibers;
Fiber Qualification/Characterization

Sync and Link Active LED light up,
Summary page turns green,
Autonegotiation succeeds

Loop-Up far-end device

Manual Traffic test, RFC 2544, or Y.1564 test to verify service level (Throughput, CBS Frame Loss, Delay, Jitter)

RFC-6349 TCP test to verify data throughput;
Voice Testing to verify PRI/SIP Trunking;
IP Video Testing to verify video QOS

Jumper Cables

Multimode Duplex Fiber Optic Cable
Orange

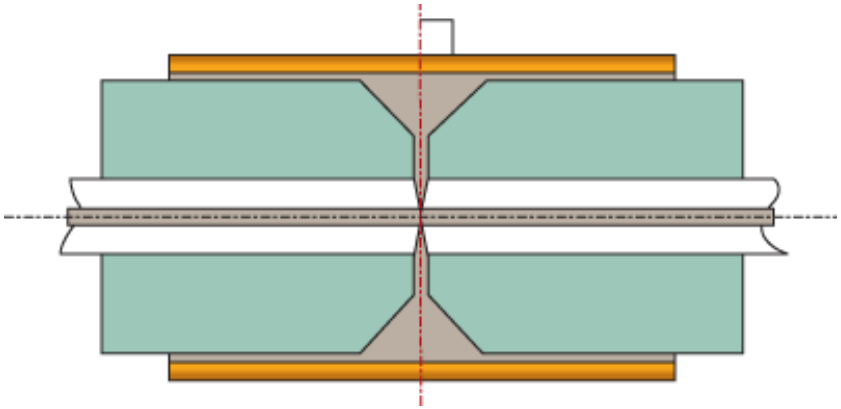
Singlemode Duplex Fiber Optic Cable
Yellow

- You CANNOT connect Multimode to Singlemode

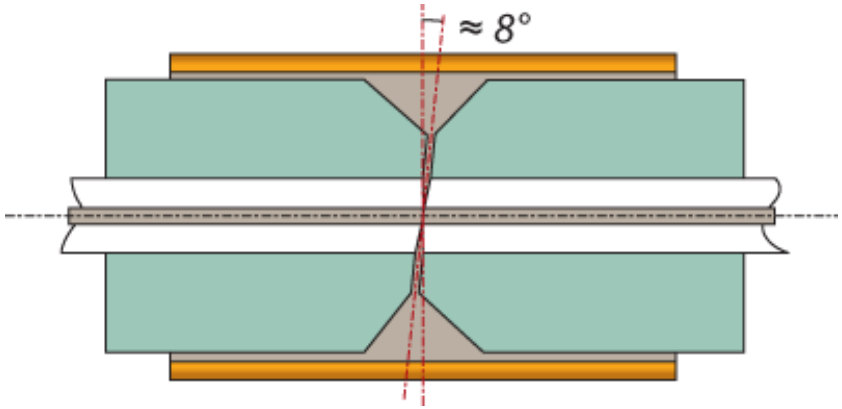
- You CAN connect different core sized cables (Multimode to Multimode, Singlemode to Singlemode) however, you will experience loss -
For example, connecting 50/125 to 62.5/125 you will experience 2 dB of loss

Types of Endfaces

- PC – Physical Contact



- APC – Angled Physical Contact



- The angle reduces the amount of light reflected at the connector interface.

SC - PC

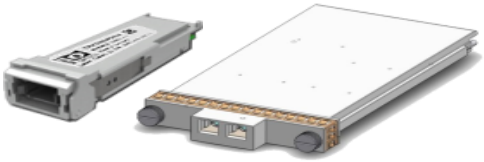
SC - APC

Pluggable Optics

SFP = Small **F**orm-factor **P**luggable is a compact, hot-swappable optical transceiver used for 1 Gbps Ethernet and other applications.

XFP:**10** Gigabit **P**luggable for 10 Gbps Ethernet and other applications.

QSFP+/CFP:
40/100 Gigabit **P**luggable for 40 to 100 Gbps Ethernet

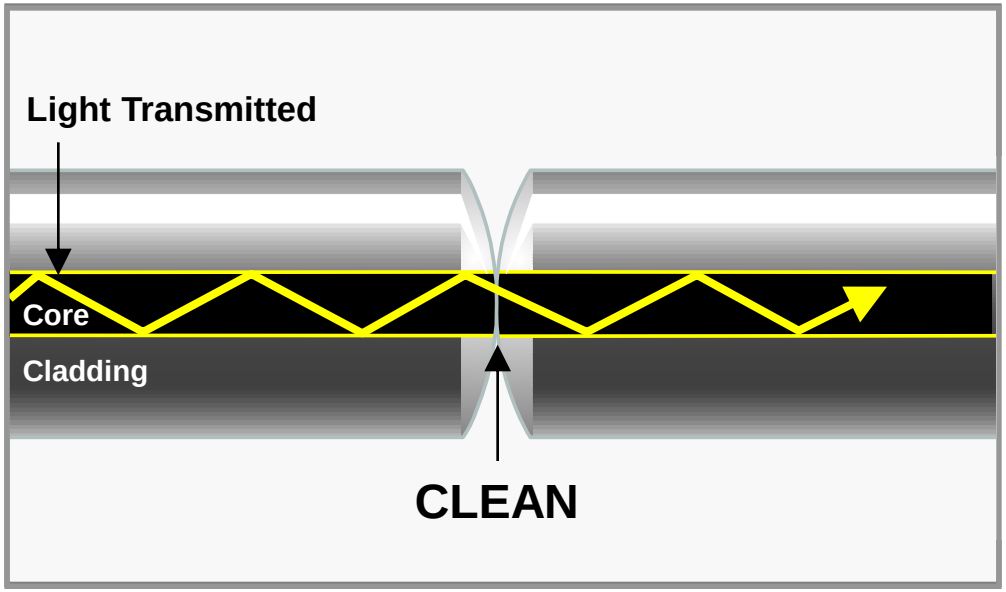


Test Application	Description	Manufacturer	Manufacturer Part Number	Optical Power dBm		Rx Sensitivity dBm
				Min	Max	
1 GigE Optical Ethernet	SFP GigE, 850nm, 300m, SX	JDSU	JSH-42S4DR3	-9	-1.5	-17
		JDSU	JSH-21S3AR3			
		Finisar	FTRJ8519P1BNL			
		Finisar	FTLF8519P2BNL			
	SFP GigE, 1310nm, 20km, LX	JDSU	JSH-21L3AR3	-9.5	-3	-21
		Finisar	FTRJ1319P1BTL			
		Finisar	FTLF1319P1BTL			
	SFP GigE, 1550nm, 80km, ZX	JDSU	JSH-12Z0CE1-80	0	5	-21
		JDSU	CT2-GI2LKTD53C5			
		Finisar	FTLF1519P1BCL			
		Finisar	FTLF1519P1BCL			
1GEth BiDirectional Optical	SFP BiDi 1GEth, TX1310nm, RX1490, 10Km, SM	OE Solutions	RBT12SLX-ST3	-9	-3	-19
		Source Photonics	FTM-9612C-SL10G			
	SFP BiDi 1GEth, TX1490nm, RX1310, 10Km, SM	OE Solutions	RBT12SLX-ST4	-9	-3	-19
		Source Photonics	FTM-9912C-SL10G			
1 GigE CWDM Optical 1471 nm - 1531 nm	SFP CWDM 1G, 1471 nm, CWDM	JDSU	CT2-GI2LBCW13C5	4	0	-23
		JDSU	SFP-ML2LCC47DCA			
	SFP CWDM 1G, 1491 nm, CWDM	JDSU	CT2-GI2LBCW23C5	4	0	-23
		JDSU	SFP-ML2LCC49DCA			
	SFP CWDM 1G, 1511 nm, CWDM	JDSU	CT2-GI2LBCW33C5	4	0	-23
		JDSU	SFP-ML2LCC51DCA			
	SFP CWDM 1G, 1531 nm, CWDM	JDSU	CT2-GI2LBCW43C5	4	0	-23
		JDSU	SFP-ML2LCC53DCA			
1 GigE CWDM Optical 1551 nm - 1611 nm	SFP CWDM 1G, 1551 nm, CWDM	JDSU	CT2-GI2LBCW53C5	4	0	-23
		JDSU	SFP-ML2LCC55DCA			
	SFP CWDM 1G, 1571 nm, CWDM	JDSU	CT2-GI2LBCW63C5	4	0	-23
		JDSU	SFP-ML2LCC57DCA			
	SFP CWDM 1G, 1591 nm, CWDM	JDSU	CT2-GI2LBCW73C5	4	0	-23
		JDSU	SFP-ML2LCC59DCA			
	SFP CWDM 1G, 1611 nm, CWDM	JDSU	CT2-GI2LBCW83C5	4	0	-23
		JDSU	SFP-ML2LCC61DCA			

What Makes a GOOD Fiber Connection?

The 3 basic principles that are critical to achieving an efficient fiber optic connection are "The 3 P's":

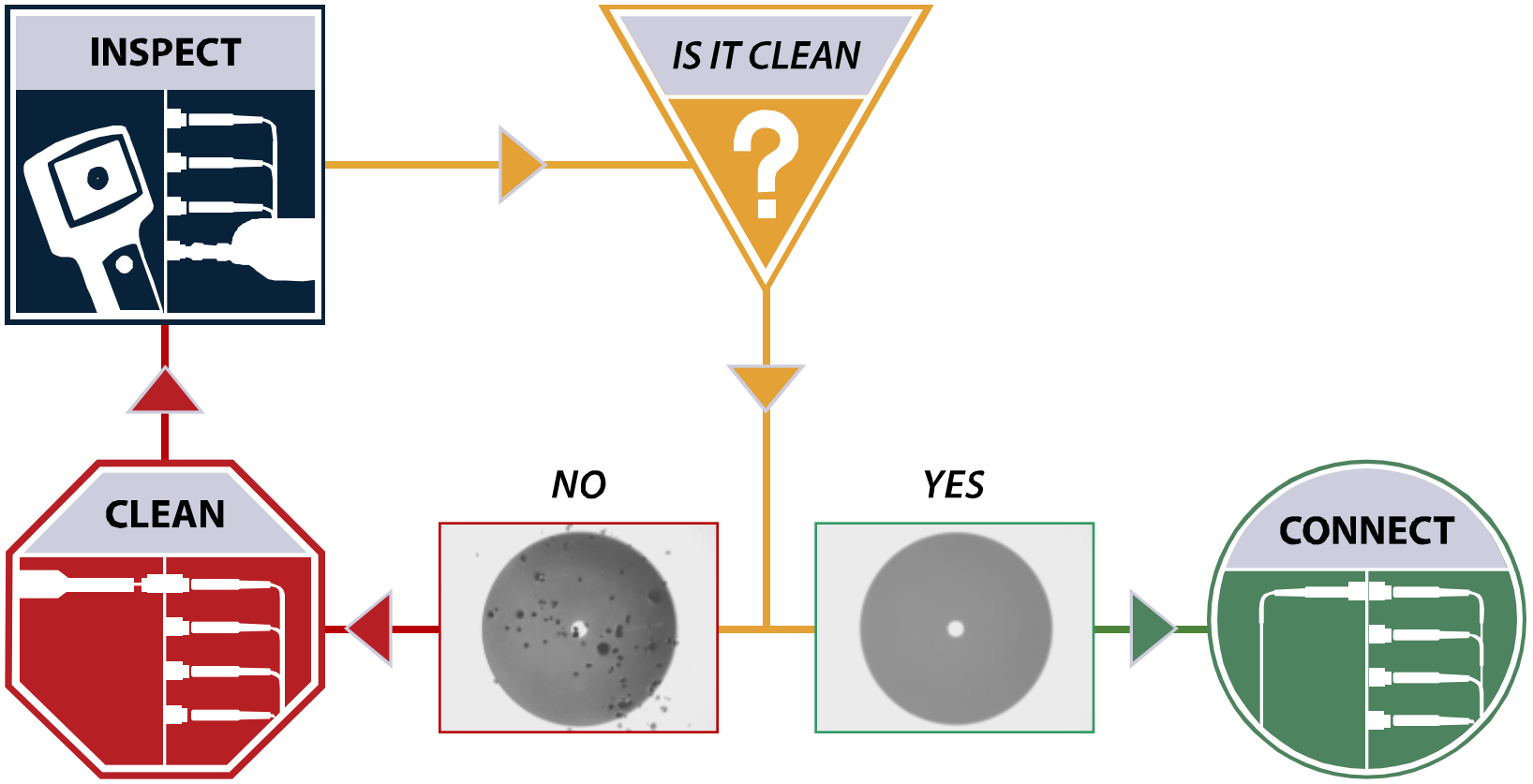
- **Perfect Core Alignment**
- **Physical Contact**
- **Pristine Connector Interface**



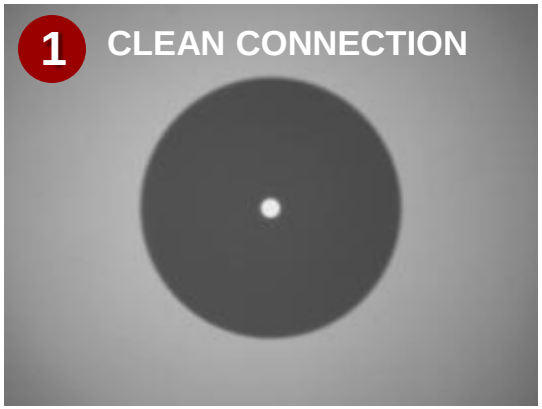
Today's connector design and production techniques have eliminated most of the challenges to achieving Core Alignment and Physical Contact.

Inspect Before You Connect℠

Follow this simple **“INSPECT BEFORE YOU CONNECT”** process to ensure fiber end faces are clean prior to mating connectors.



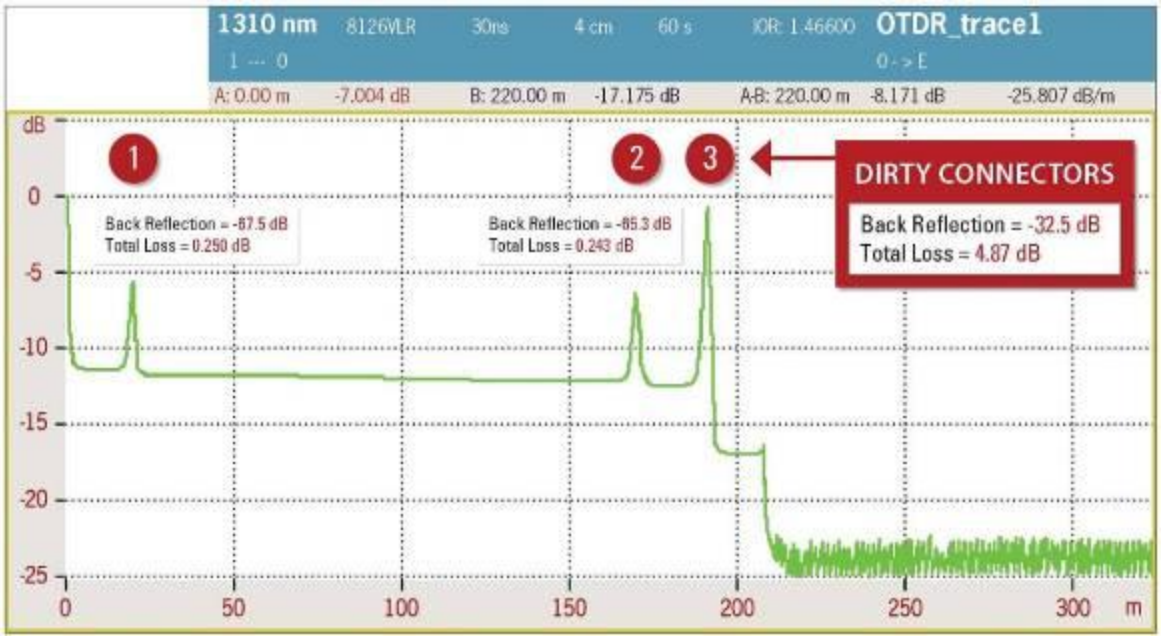
Contamination and Signal Performance



Back Reflection = **-67.5 dB**
Total Loss = **0.250 dB**

Back Reflection = **-32.5 dB**
Total Loss = **4.87 dB**

Fiber Contamination and Its Effect on Signal Performance



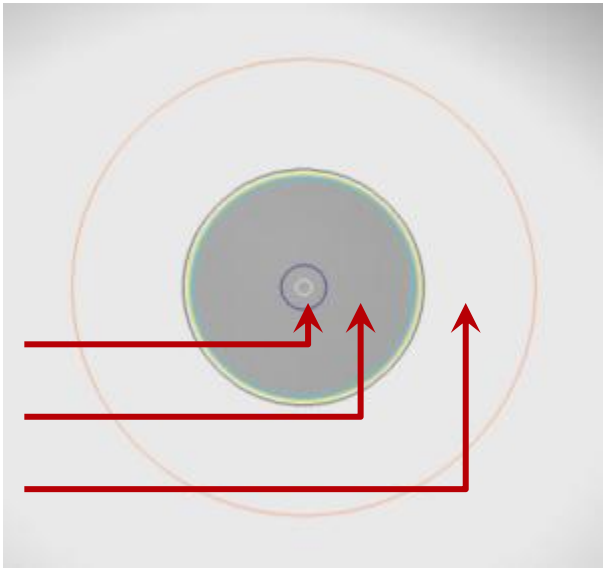
Clean Connection vs. Dirty Connection

This OTDR trace illustrates a significant decrease in signal performance when dirty connectors are mated.

IEC 61300-3-35 Acceptance Criteria

- These criteria are designed to guarantee a common level of performance
- Separate criteria for different connector types
  - SM-UPC (RL>45db)
  - SM-APC
  - SM-PC (RL>26dB)
  - MM
  - Multi-fiber

Example of Pass/Fail Criteria (SM-UPC)



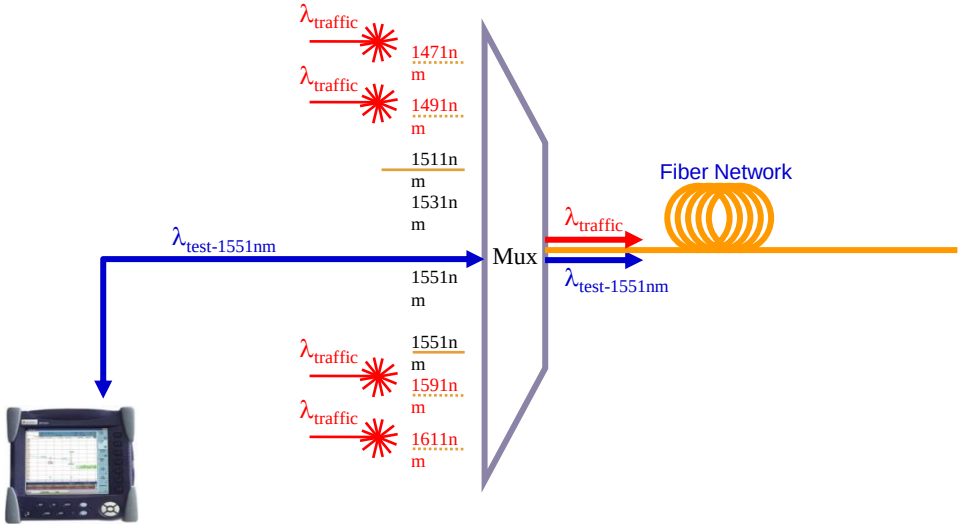
ZONE NAME	SCRATCHES	DEFECTS
A. CORE (0–25µm)	None	None
B. CLADDING (25–120µm)	No limit <= 3µm None > 3µm	No limit < 2µm 5 from 2–5 µm None > 5µm
C. ADHESIVE (120–130µm)	No limit	No limit
D. CONTACT (130–250µm)	No limit	None => 10µm

Power Meters – measure optical power

Standalone, USB, or integrated meters verify optical power levels meet requirements of receivers.

CWDM OTDRs
for Channel/Wavelength Provisioning & Troubleshooting

- Test new wavelength route not yet in use
- Make sure wavelength goes through
- In-service test when other wavelengths already active
  - OTDR test without disturbing current traffic
  - Reliable OTDR test taking other wavelength powers into account

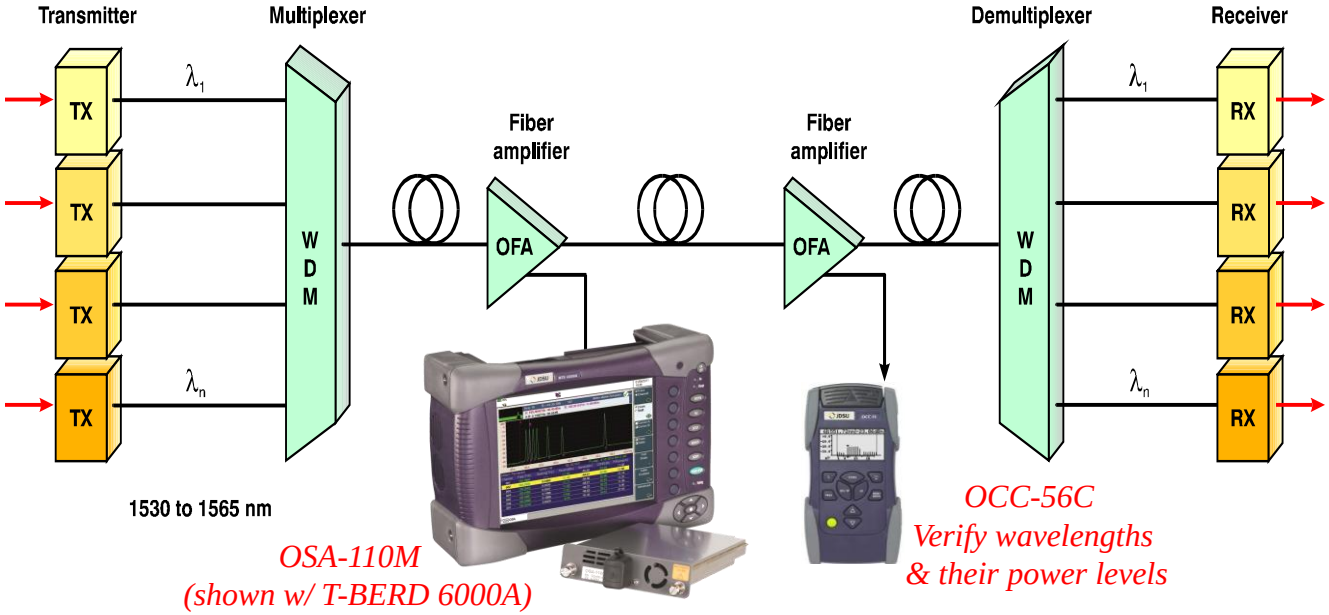


CWDM OTDR 1551nm testing

1311nm shot through Mux and Demux in presence of other wavelengths

DWDM Deployments

DWDM Tunable Light Source



OSA-110M (shown w/ T-BERD 6000A)

OCC-56C Verify wavelengths & their power levels

OCC-56C Verify wavelengths & their power levels

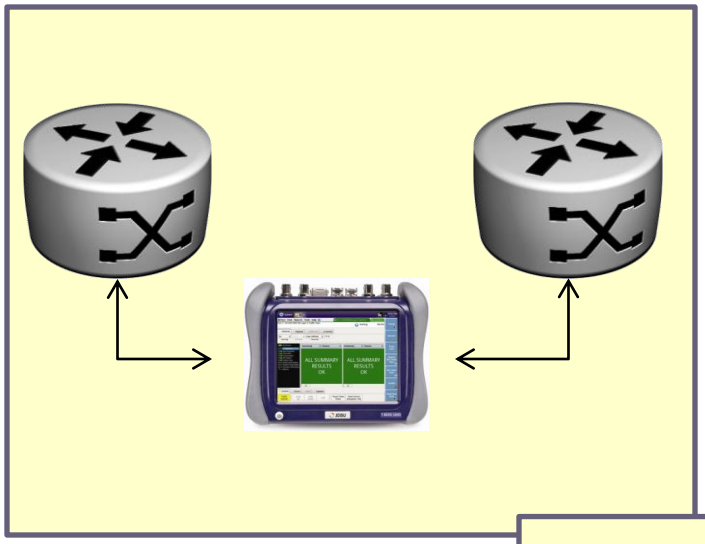
- **No Such Thing as a DWDM OTDR**
- **Use DWDM Tunable Laser Source to send thru DWDM filters**
- **Verify presence of DWDM wavelengths & that Power Levels are within manufacturers specifications**
  - **Power Meter-**
    - Wavelength settable – use on drop side only (can only have 1 wavelength on the fiber)
  - **Optical Channel Checkers**
    - AUTODETECTs which C-band DWDM wavelengths are on the fiber & their power levels (use on drop or common fiber sides)
  - **Optical Spectrum Analyzer (OSA)**
    - Full Spectrum Analysis (CWDM & DWDM)
    - Auto id wavelengths, power levels, OSNR, drift…

OTDR Testing on DWDM:

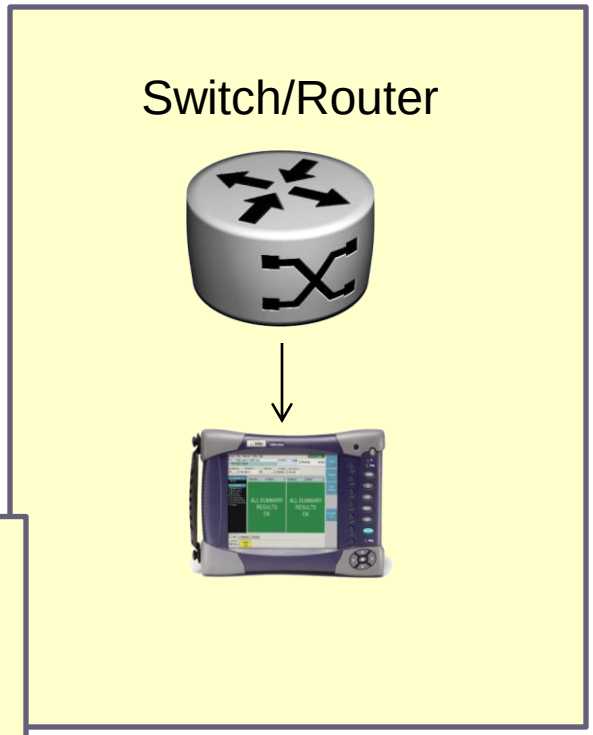
- *Use standard OTDR (1310/1550 nm)*
- *Disconnect fiber from DWDM mux/demux and test drop side locally from each side*

Test Access

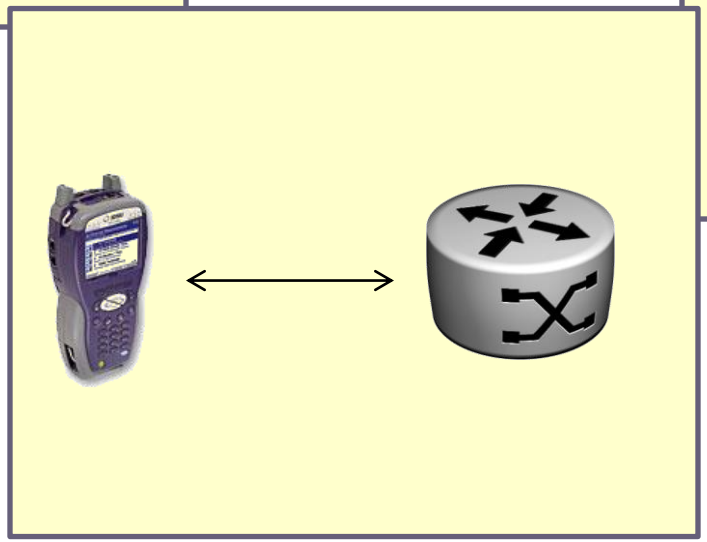
Bi Directional Thru Mode – 'Non Intrusive'



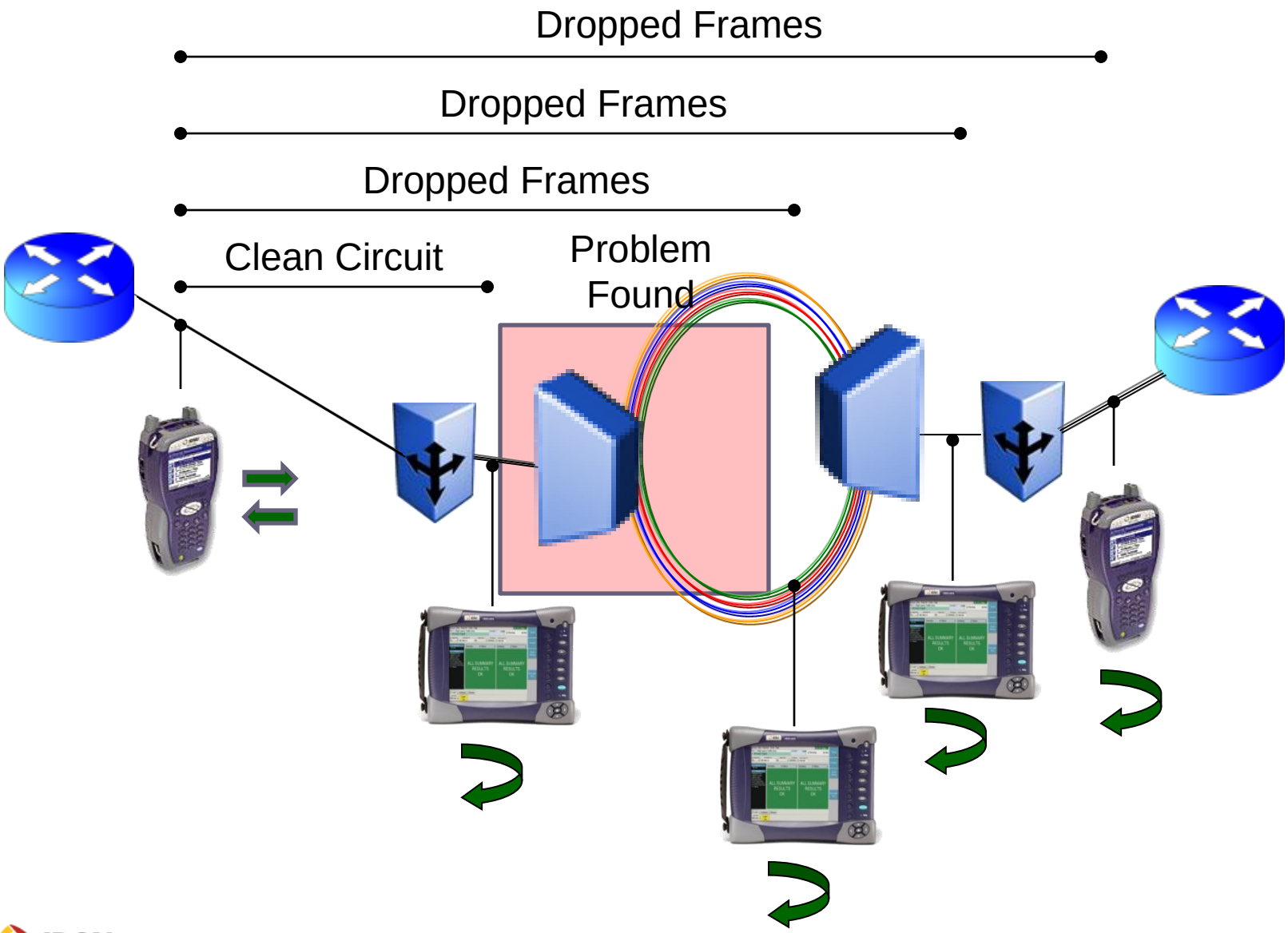
Mirrored Port – Non Intrusive



Terminate - Intrusive



Sectionalization

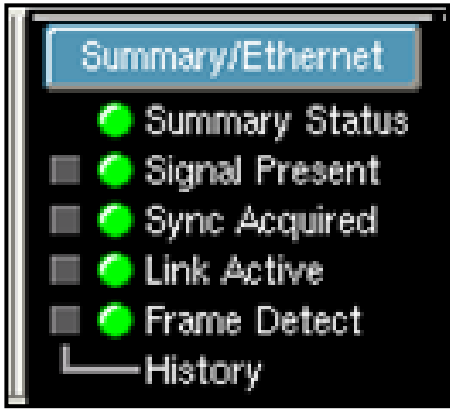


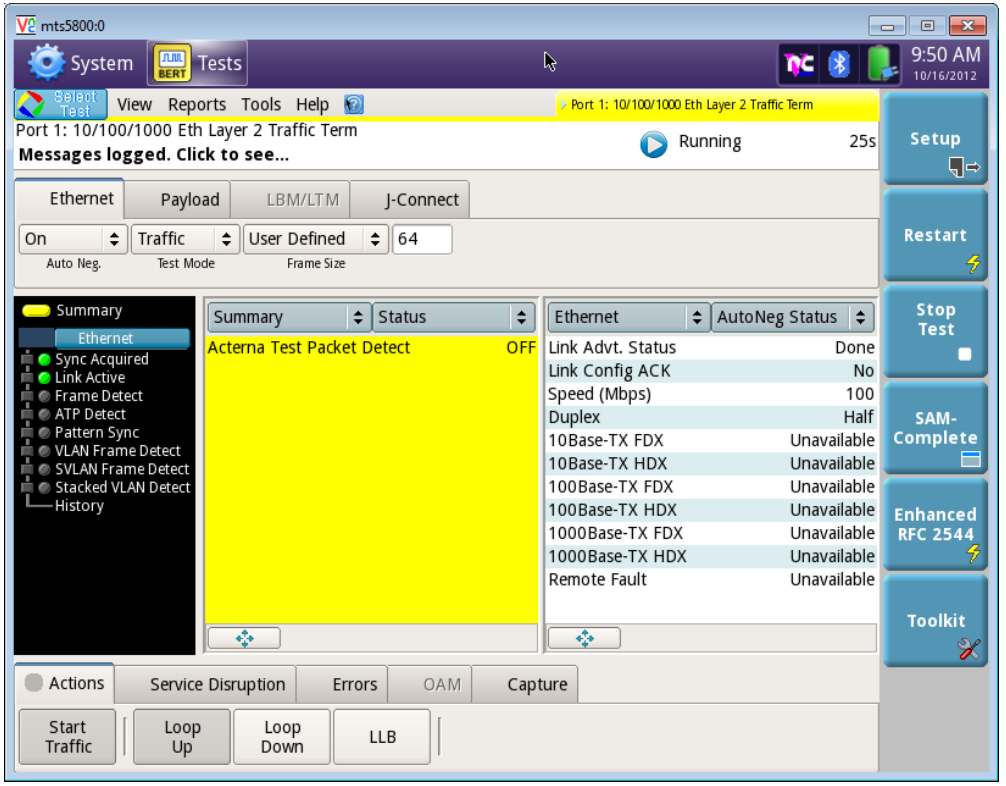
Near End Connectivity

- Connecting to the near end equipment:
  - Step 1 (optical only) – Lasers are activated, "Signal Present" is displayed at the test set
  - Step 2 - Byte synchronization takes place. "Sync Acquired" is displayed.
  - Step 3 – Link becomes Active.

Test Set and near end equipment are set for:

- Same speed
- Full Duplex
- Done by internal setup or Auto-Negotiation
- **Check for mismatches!**

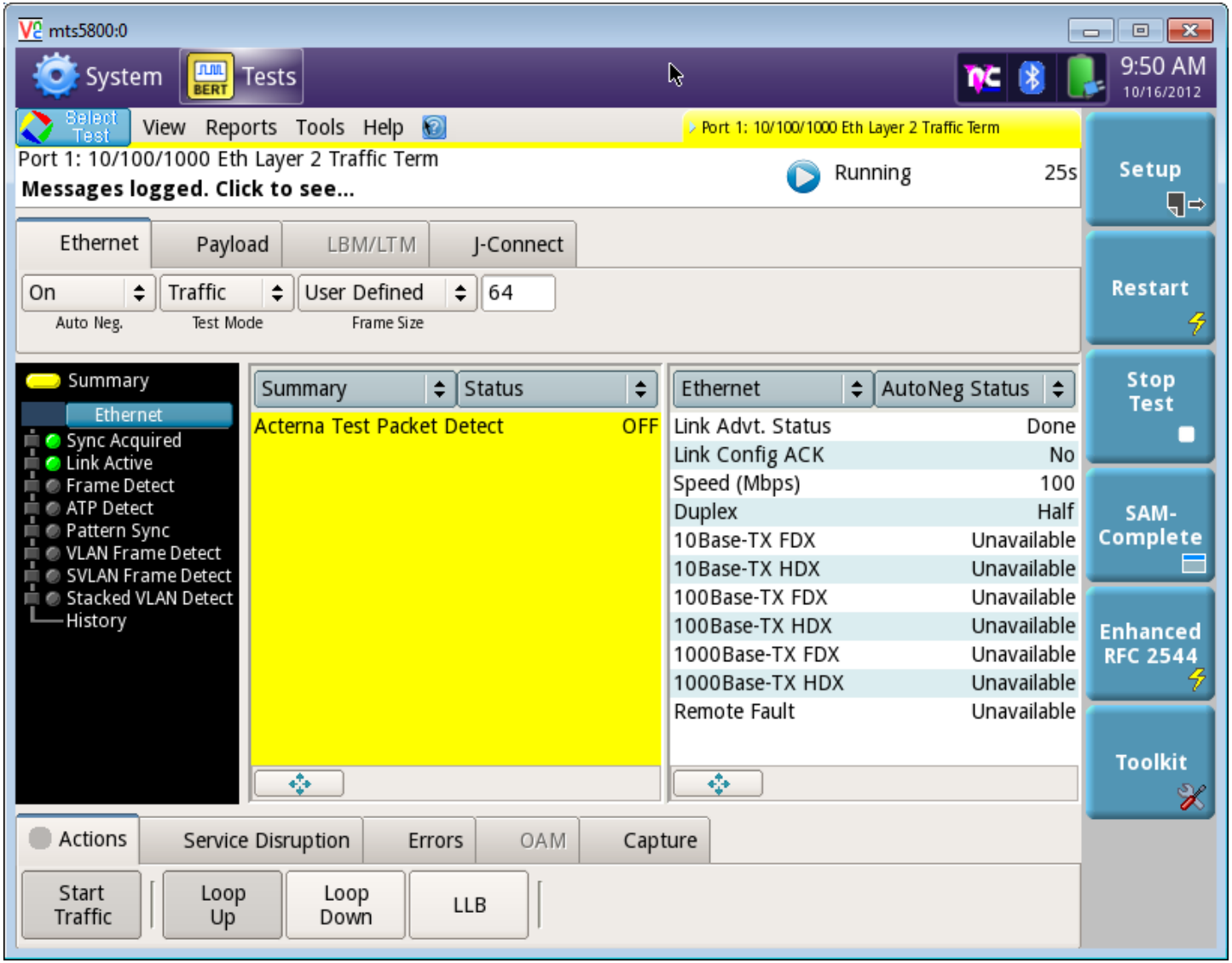




Near End Problems

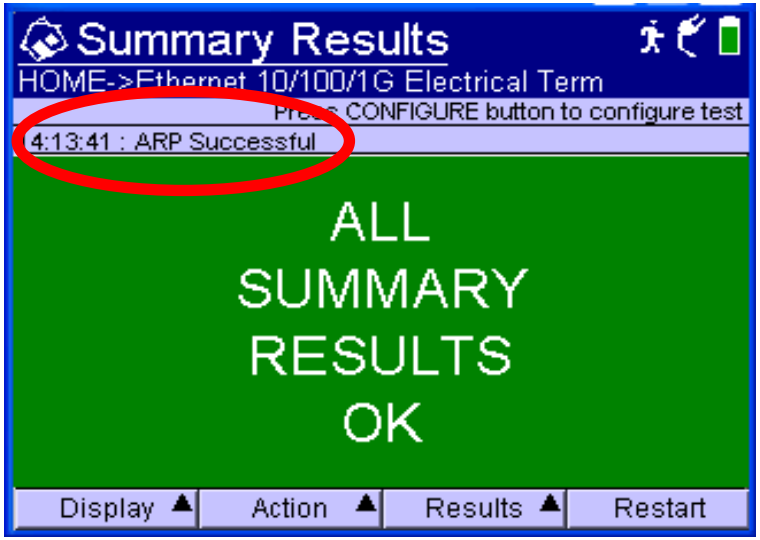
- Most common problem is incorrect setting for auto negotiation
  - Autonegotiation should be set for the same on both sides
  - If it fails one side becomes set for Half-Duplex and errors and collisions appear on the link
- Other common problems include:
  - Disabled switch/router ports
  - Wrong SFP selected
  - Incorrect SFP or fiber type
  - Bad cables
- You cannot loop or start traffic until you have near end connectivity.

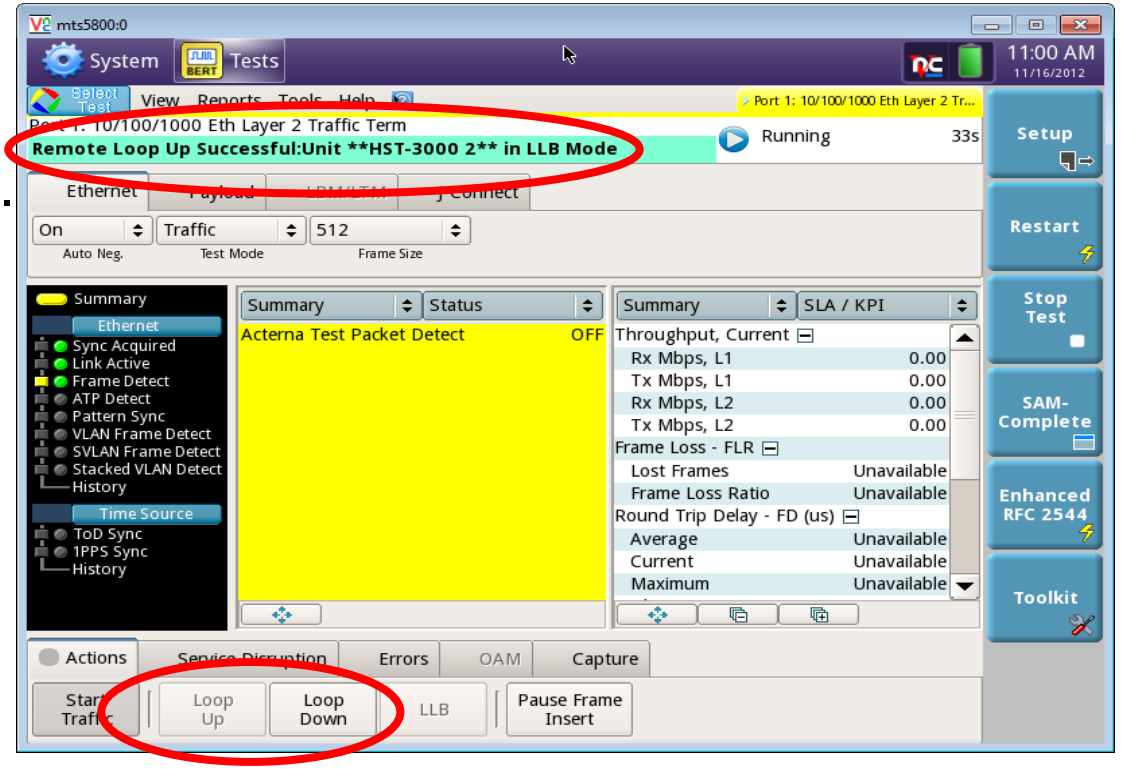
Autonegotiation Mismatch – Is this good or bad?



Far End Connectivity

- On a Layer 3 network, loop up, Address Resolution Protocol (ARP) , or Ping can verify far end connectivity. You cannot loop or start traffic until you get a successful reply.
- On a Layer 2 network, the loop up command and reply verify far end connectivity and place the far end test set in Local Loopback (LLB) mode.
- When in LLB, the test set will swap MAC and IP Addresses so that packets can be routed back to the originating test set.





Address Resolution Protocol (ARP)

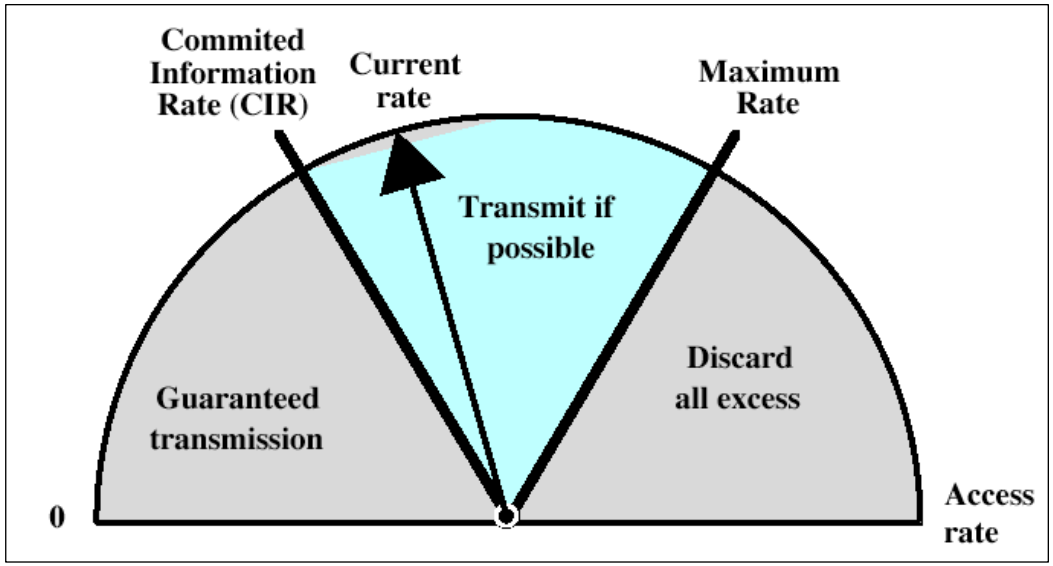
- Protocol used to associate a MAC address with an IP Address
- IP host sends out an Ethernet broadcast packet containing the desired IP destination address.
- The desired host (or a router acting on its behalf) replies to the packet by sending a packet which contains an IP address and Ethernet address pair.

Far End Problems

- Common Layer 2 problems are:
  - Incorrect encapsulation (None, VLAN, Q in Q)
  - Incorrect VLAN ID
  - Incorrect VLAN mapping in the Network
- Common Layer 3 problems are:
  - Incorrect IP Addresses (source or destination address, DHCP)
  - Incorrect Default Gateway address or Subnet Mask
  - IP routing issues in the network
- Ping and Traceroute can troubleshoot Layer 3 problems

Service Level Agreements (SLAs)

- What is “acceptable” service?
  - Defined through Service Level Agreement between provider and the end customer
  - SLAs usually specify **throughput, delay, frame loss**, **jitter,** availability, and mean-time to repair
- Committed Information Rate
  - The maximum guaranteed “Layer 1” data rate
  - Although Metro Ethernet access rates are typically 100Mbps or 1Gbps, the CIR can be specified in 1 Mbps increments
  - Delay, Frame Loss, and jitter should be measured at the CIR



- Excess Information Rate
  - The maximum “Layer 1” data before frames are discarded
  - Frames are transmitted only if bandwidth is available

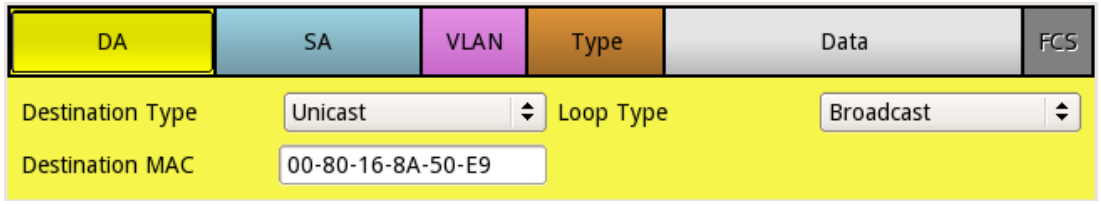
Why can't I just test with Ping or Ethernet OAM?

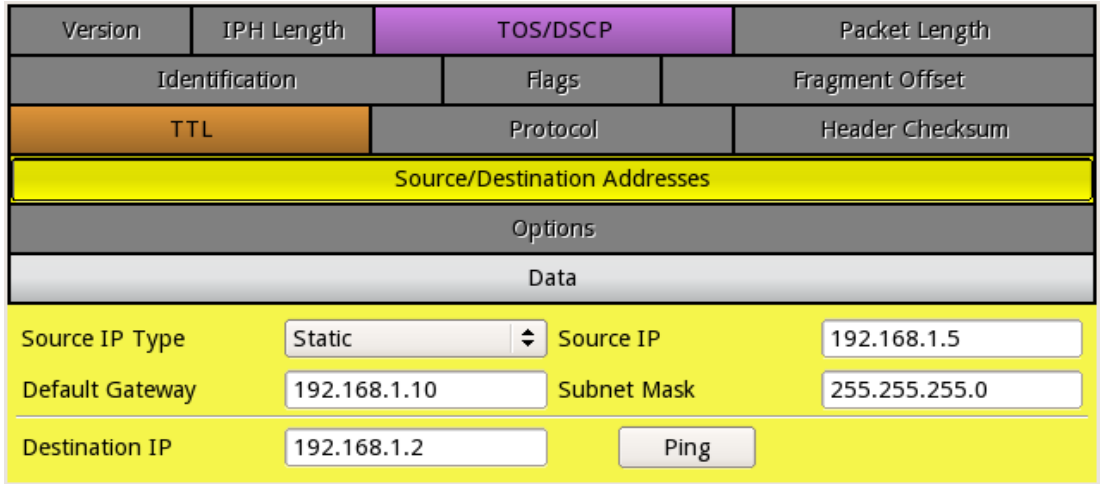
- Same reasons you didn't test with just a ping in the T1 world
- PING and OAM do not check CIR of the link
  - Unknown if you are delivering 5Mb, 100Mb or 500Mb on a 100Mb service
  - Testing at the CIR shows other problems as it fills the buffers and network elements with test traffic stressing the network fully
- PING and OAM frames are not treated the same as customer traffic
  - Ping and Ethernet OAM are handled in software by the network elements (with the processor), customer and test traffic is handled in hardware
  - Just because a network element can handle OAM traffic doesn't mean it can handle customer traffic and vice versa
- It is important to not just test to the NTE but through the NTE as problems may exist on the drop sides of the customer itself

Ethernet OAM/Ping is like shining a light through a tunnel to see if you can run a train through it. It isn't a bad first step, but you better do more testing before starting live traffic.

Layer 1, 2, and 3 Throughput

- **Traffic generation** is performed to assess the throughput and performance of the Network. Traffic must be formatted properly for the equipment in the test path:
  - Layer 2 equipment such as switches and NIDs require an **Ethernet Header** with valid **MAC addresses**.
  - Layer 3 equipment such as Routers require an **IP header** with valid **IP addresses**.

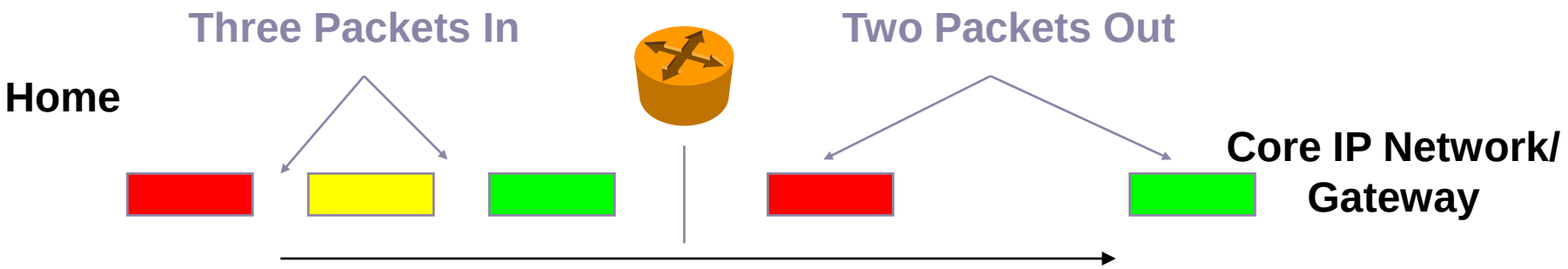




- **Test Results** can also be displayed at multiple layers:
  - **Layer 1 Throughput** includes all overhead
  - **Layer 2 Throughput** excludes interframe gaps and Preambles that mark the start of frames
  - **Layer 3 Throughput** excludes layer 2 overhead (DA, DA, VLAN, Type, FCS)
  - **Layer 4 Throughput** excludes IP overhead (Version, IPH Length, TOS, …)

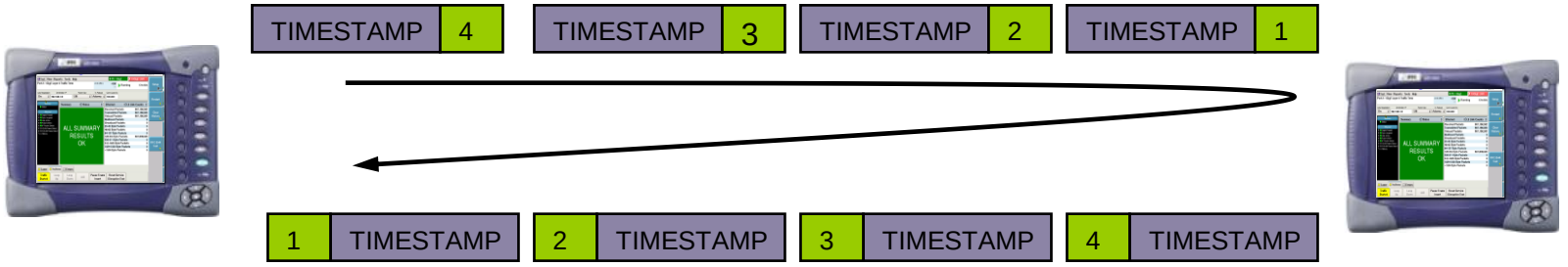
Frame Loss – Count of lost or dropped frames

- **Affected by**
  - Buffer overruns in network components
  - Network Congestion
  - Bad network elements
- **Customer Complaints**
  - Voice: clicks and fuzziness or even dropped calls in extreme situations
  - Video: pixelization or blue screens
  - Data: extremely long time to load web pages
- **Detailed Comments**
  - Test is run with a sequence number in every packet
  - Run at max throughput as most packet loss problems can't be seen unless the network and buffers are being stressed



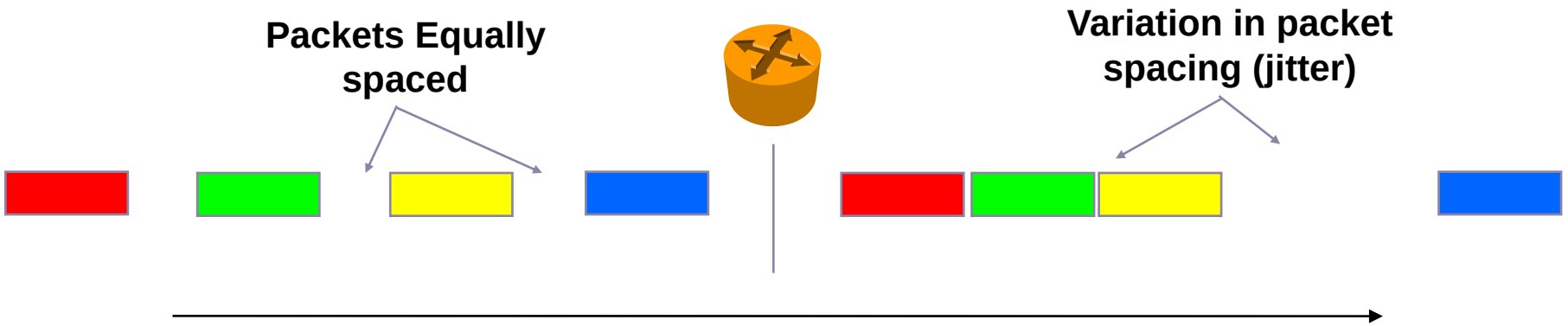
Round Trip Time (Latency) – Network Delay

- **Affected by**
  - Priority queuing and traffic shaping methodologies
  - Network Congestion and overall network layout (buffering)
  - Length and type of Link (satellite or terrestrial)
- **Customer Complaints**
  - Voice: overtalk or echo
  - Wireless backhaul: dropped calls
  - Gamers: overall choppiness and delay
- **Detailed Comments**
  - The key time to test round trip time is when throughput is being maxed on the link, to ensure that buffering and live traffic is not going to delay the traffic
  - Since PINGs are handled differently in network elements, are considered lowest priority traffic, and are sent at a very low bandwidth, they do not get accurate latency measurements



Packet Jitter – variation in arrival time between packets

- **Affected by**
  - Priority queuing and traffic shaping methodologies
  - Network Congestion and overall network layout
  - Length and type of Link (satellite or terrestrial)
- **Customer Complaints**
  - Voice: clicking and popping noises
  - Video: pixelization or blue screens
- **Detailed Comments**
  - The key time to test packet jitter is when throughput is being maxed on the link, to ensure that queuing, buffering, and congestion are not increasing jitter



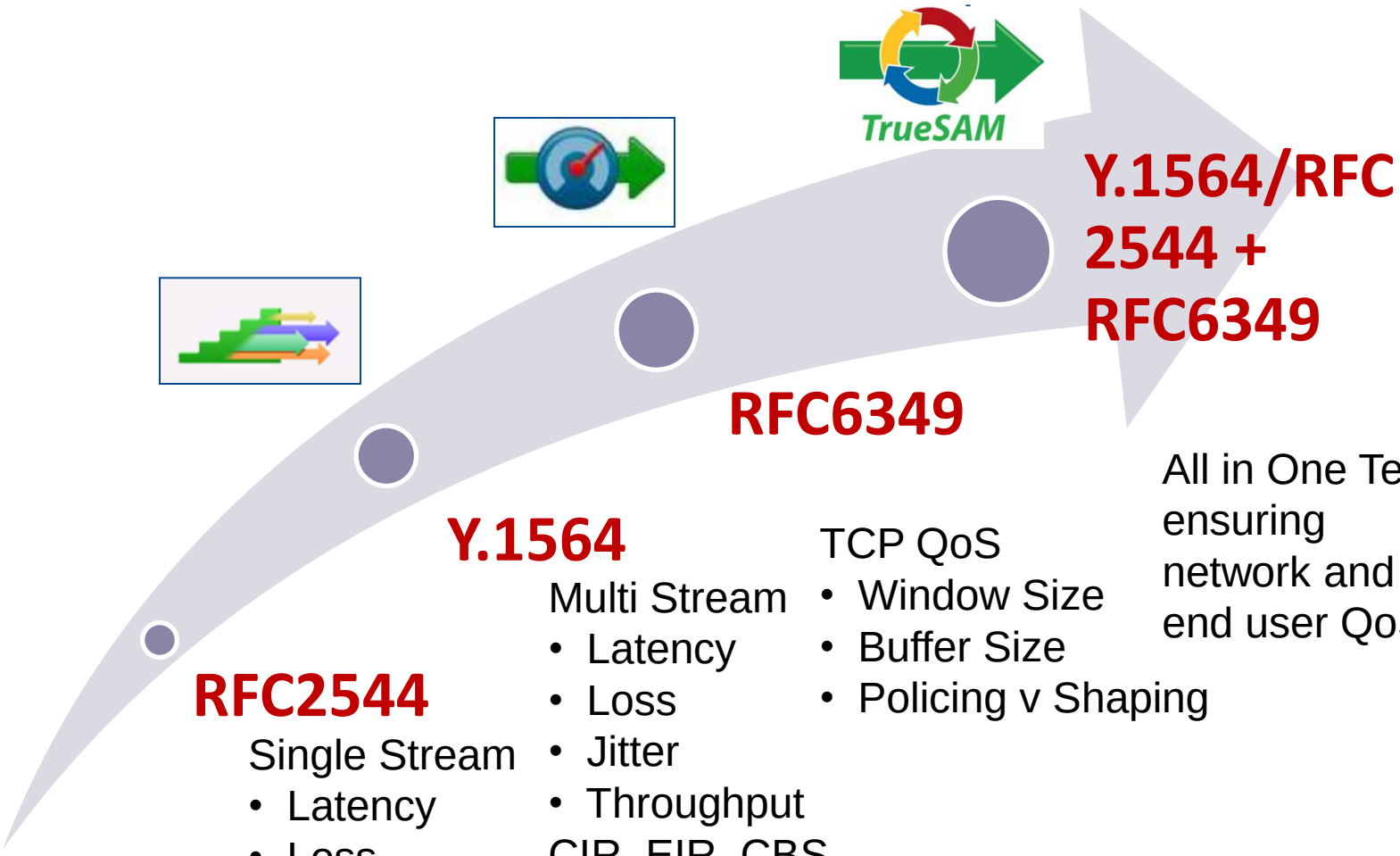
SLA Verification

- SLA verification involves testing the link for throughput, delay, frame loss, and jitter using various frame sizes
- Tests can be performed either manually (pressing the start traffic button) or automatically (RFC 2544 or Y.1564)
- Manual testing can provide:
  - One Way Delay measurement
  - Long-term (i.e. 72 hour) soak tests
- End result is a pass/fail assessment on the overall quality of the link

Sample SLA/MOP Values for Ethernet

Characteristics (one way)	Mobile Backhaul services	EPL/EVP	Voice Trunking Services
Bandwidth (CIR)	1 Mbps to 10 Gbps	1 Mbps to 10 Gbps	80 Kbps per call (2 Mbps per PRI)
Committed Burst Size	64 KBytes	64 KBytes	n/a
Frame Delay (Latency)	< 8 ms	< 25 ms	< 100 ms
Frame Delay Variation (Jitter)	< 2 ms	< 25 ms	< 20 ms
Frame Loss	< .001 %	< .01%	< 1 %
Throughput	99.995 %	99.99 %	n/a
Availability	99.999 %	99.99 %	99.99 %
Mean-time to repair	2 hours	4 hours	4 hours

Ethernet Standards Evolution



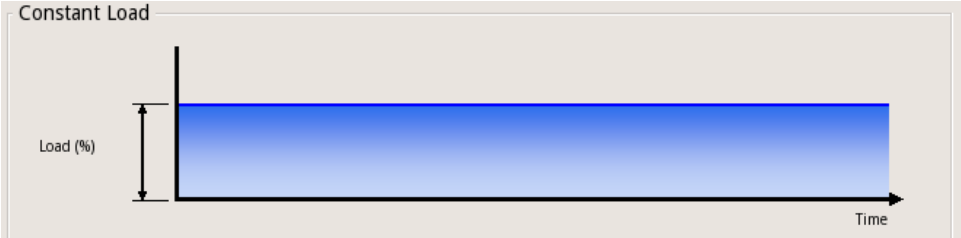
Testing Methodologies

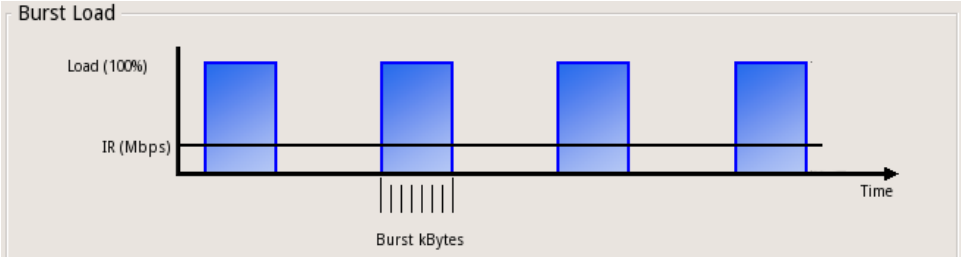
	Manual Testing	Enhanced RFC-2544	Y.1564 SAMComplete	RFC-6349 TrueSpeed	JDSU TrueSAM ™
Layer 2 Transparency	Yes	No	No	No	Yes
Layer 1-3 Throughput (CIR)	Yes	Yes	Yes	No	Yes
Layer 1-3 Throughput (EIR)	Yes	No	Yes	No	Yes
Policing	Yes	No	Yes	No	Yes
Round Trip Delay	Yes	Yes	Yes	Yes	Yes
Jitter	Yes	Yes	Yes	No	Yes
Frame Loss	Yes	Yes	Yes	No	Yes
Back to Back/CBS	Yes	Yes	Yes	Yes	Yes
Multiple Frame Sizes	Yes	Yes	No	No	Yes
System Recovery	Yes	Yes	No	No	Yes
Multiple Streams/COS	Yes	No	Yes	No	Future
TCP Throughput	Yes	No	No	Yes	Yes
Realtime Results	Yes	No	No	No	No
Realtime traffic manipulation	Yes	No	No	No	No
User Level	Expert	Novice	Novice to Intermediate	Novice to Intermediate	Novice to Intermediate

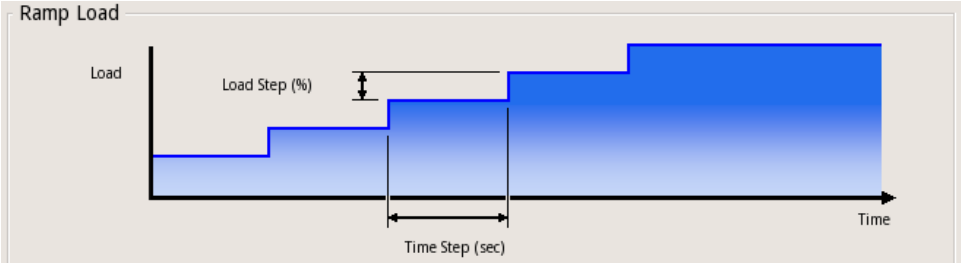
Manual Traffic Generation

Traffic Generation testing is performed to verify a network's ability to support a specified load of traffic. It can be performed on networks prior to activation, or on active networks to assess the ability to handle extra users or applications. **Throughput**, **Frame Loss**, **Jitter**, **Delay,** and **Maximum Burst Size (MBS)** are measured while generating load.

- **Constant Load** – Fixed frame intervals allows **Jitter** to be measured.
- **Bursts** – Representative of actual network traffic. Allows **CBS** to be verified.
- **Ramp** – Determine threshold at which network impairments such as frame loss and congestion occur.

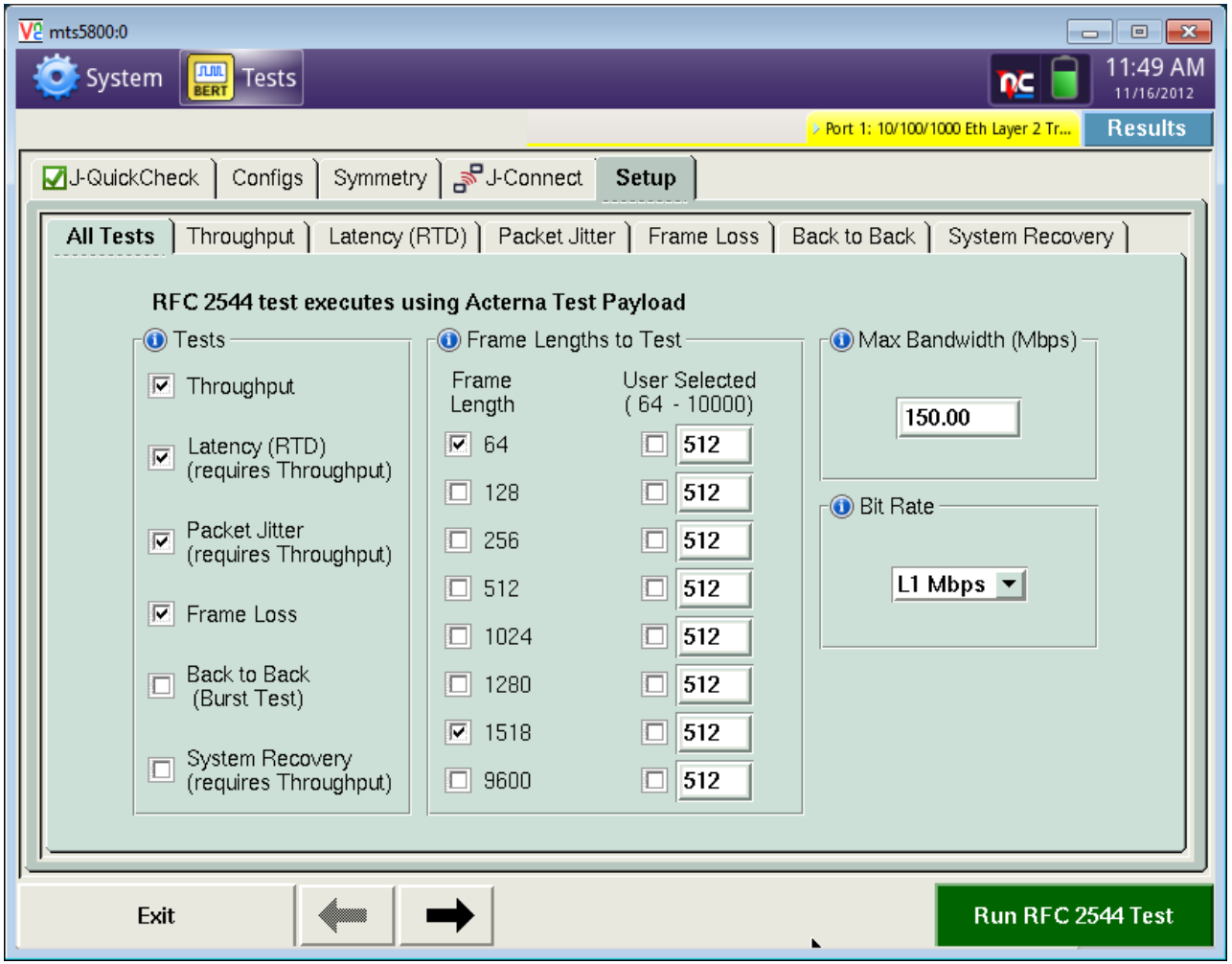






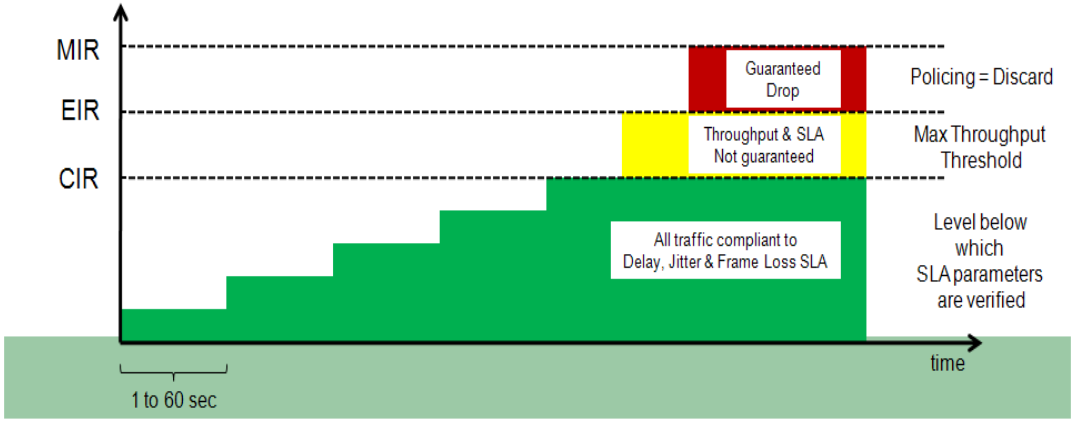
SLA Testing with RFC 2544

- RFC 2544 testing validates the key parameters of a service level agreement.
  - **Throughput**
  - **Frame Loss**
  - **Delay**
  - **Jitter**
- Tests various frame lengths to simulate different traffic types
- Generates a pass/fail report indicating whether the link meets the SLA requirements

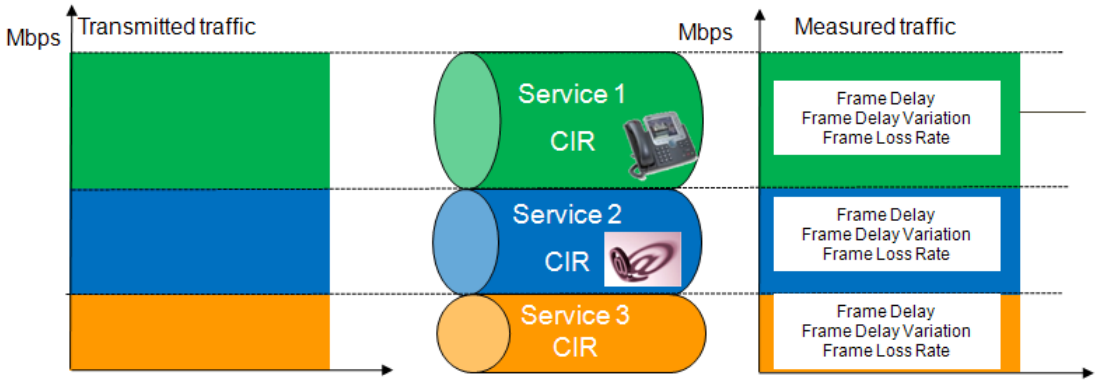


SLA Testing with Y.1564

- Y.1564 validate the typical SLA of Carrier Ethernet-based services against a Bandwidth Profile (CIR, EIR, CBS, EBS) and KPIs (Delay, Jitter, Frame Loss)
- Offers a quick repeatable **Multi-Stream** test with pass/fail results
- Two Phase Test Methodology:



1. Service Configuration Test (**Ramp Test**)
   - Each stream/service is validated



2. Service Performance Test (**Multi Stream**)
   - All services are tested concurrently at the CIR

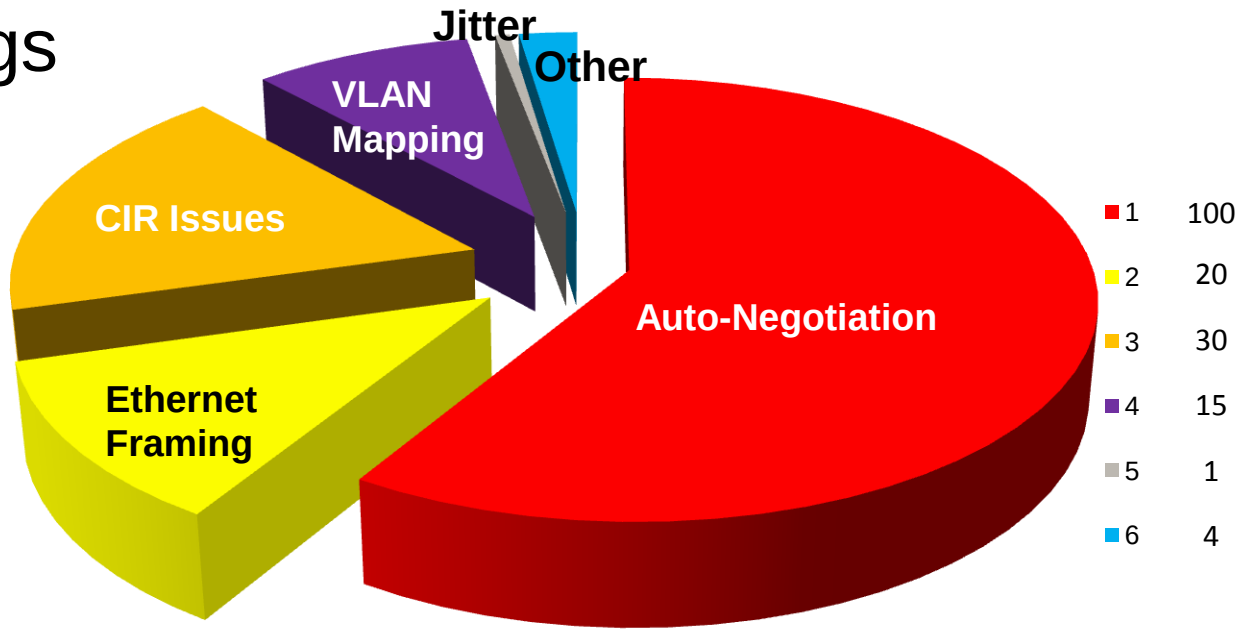
SLA Problems

- Failed tests may be due to incorrectly configured test settings:
  - Incorrect CIR
  - Invalid MTU
  - Invalid thresholds
  - Speed/Duplex Mismatch
  - Wrong Frame Type Selected (DIX vs 802.3)
- Throughput issues may be due to autonegotiation mismatches, network elements being set up incorrectly, or congestion/bottleneck in the network.
  - VLAN tagging by network elements may oversubscribe links.
- Frame Loss issues may be a faulty network element or bad fiber between locations
- Round Trip and Jitter issues are almost always due to excessive buffering in the network elements
- Failed tests can be characterized by reducing the throughput and testing individual frame sizes

Testing Ethernet Circuits – Lessons Learned

Top problems seen while testing MetroEthernet:

- Auto-Negotiation set incorrectly
- DIX versus 802.3 framing
- Misconfigured CIR
- VLAN Mappings
- Jitter



Resolving the "Slow Throughput" Complaints

- RFC 2544 and Y.1564sam only verify network performance at Layer 2 and 3 (Ethernet and IP), **but** end-customers complain that the "network is slow" (i.e. Facebook, YouTube, are slow)
- RFC 6349 IETF standard recognizes this and designates TCP throughput testing to **test the network "AS THE CUSTOMER EXPERIENCES IT"**

Turn-up Related Problem	RFC2544	Y.1564	RFC 6349
Single Service, Layer 2/3 SLA Issues (loss, jitter, etc.).	✓	✓	N/A
Multi-service, Layer 2/3 SLA Issues (service prioritization, loss, jitter, etc.).	✗	✓	N/A
Demonstrate the effect of End customer TCP Window size on throughput (CPE issue).	✗	✗	✓
Inadequate device buffers to handle bursty applications.	✗	✗	✓
Policing effects to TCP performance.	✗	✗	✓

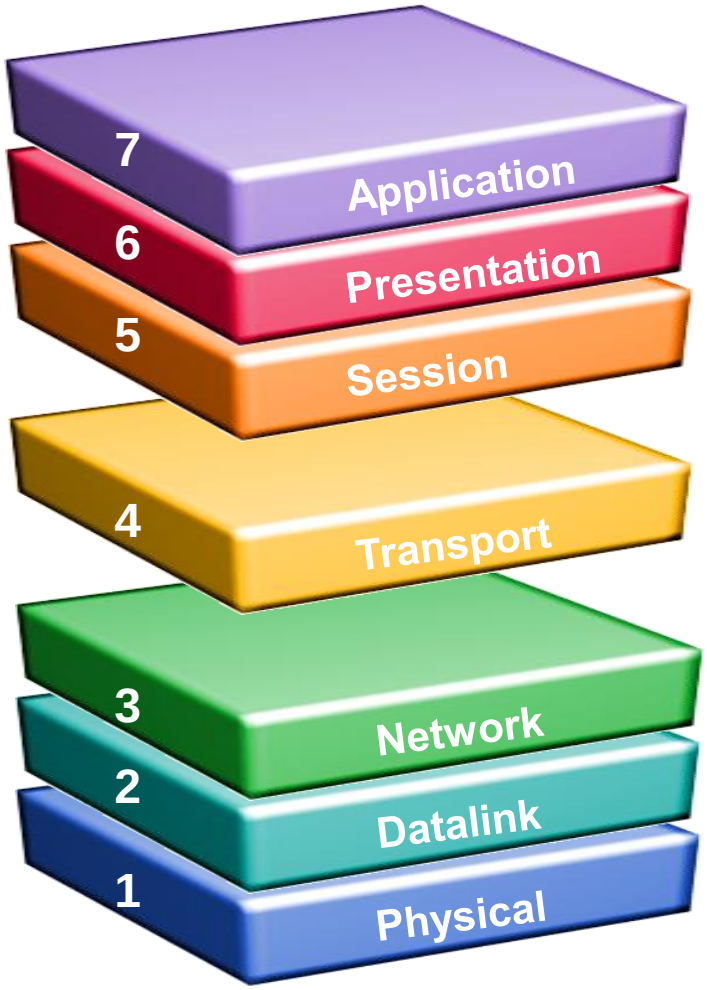
IETF

TCP

RFC 6349 = TrueSpeed!!!

JDSU

What Applications use TCP?



HTTP, FTP, E-mail, Sharepoint, Communicator, etc.

TCP → RFC-6349 TrueSpeed™

IP

Ethernet

RFC-2544 & Y.1564sam

Constant Bit Rate (CBR) Traffic Testing

GigE LAN

100 Mbps WAN

Voice: 20 Mbps

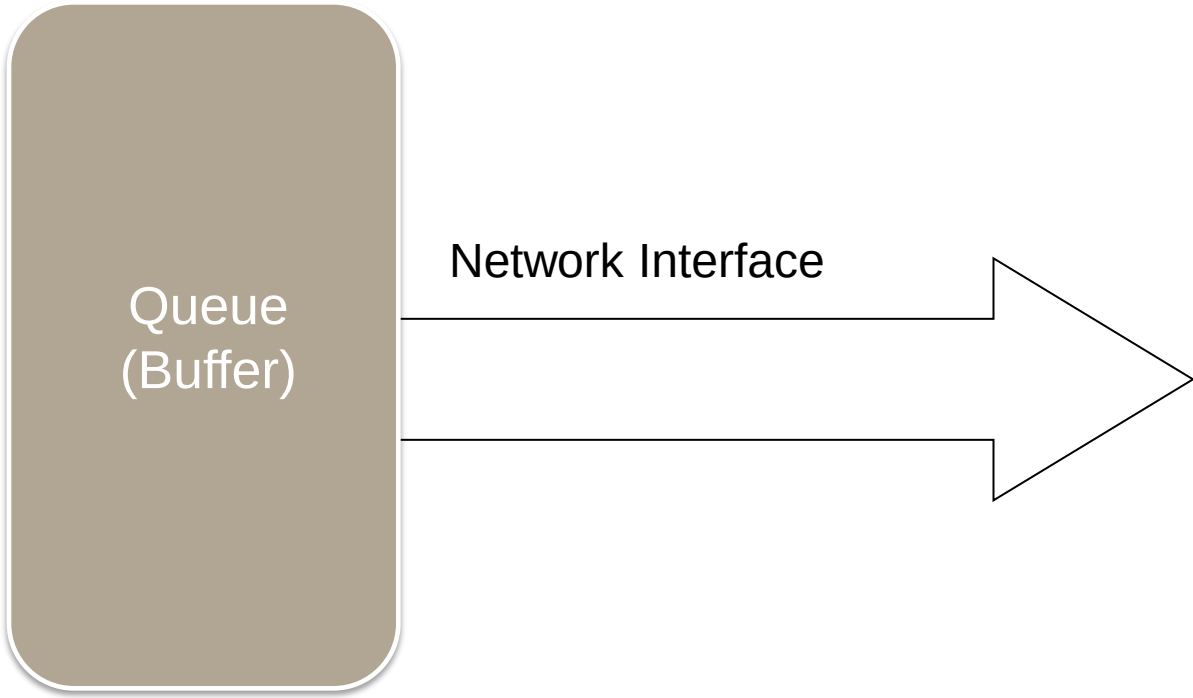
Constant

Video: 30 Mbps

Constant

Data Application: 25 Mbps

Constant



Testing a Data Application as non-bursty traffic **is not realistic** and everything works fine

CBR + Bursty Traffic Testing

GigE LAN

100 Mbps WAN

Voice: 20 Mbps

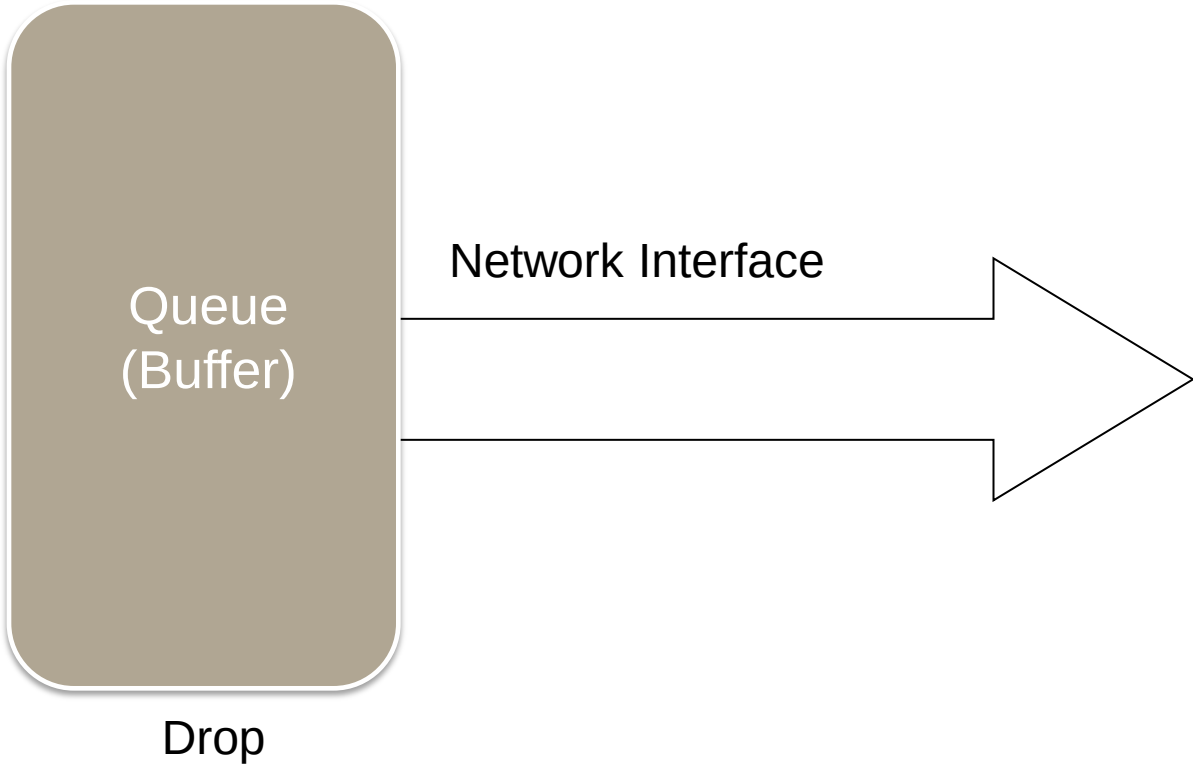
Constant

Video: 30 Mbps

Constant

Data Application: 25 Mbps

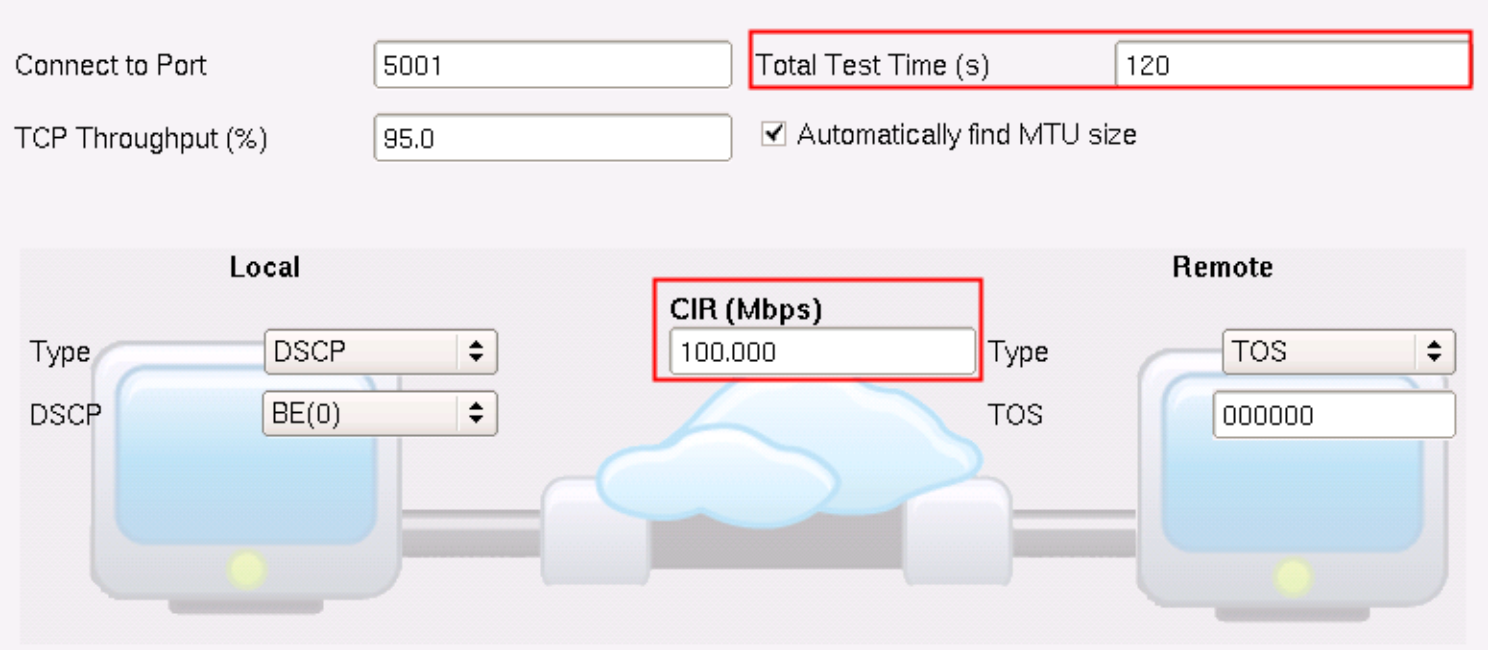
Bursty



Testing a Data Application as bursty traffic can reveal buffering issues which degrade performance

TrueSpeed Turn-up

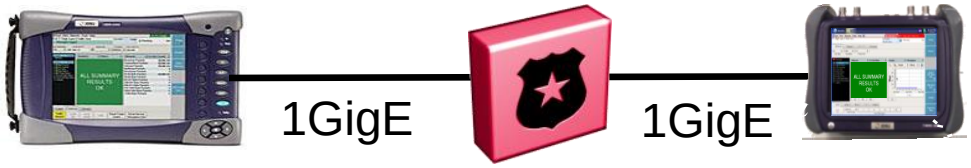
- What TCP window size do I use?, how many TCP sessions do I run to “fill the pipe”?, how can I tell if there’s a problem and what it is?
- You just need to know the speed the customer ordered, TrueSpeed figures out the rest:
  - Simple set-up – throughput and test time (entered by user)
  - Auto populate TCP window size and # of connections
  - Run upload then download (speed test) all from the local unit
  - Report simple “Pass / Fail” to local user



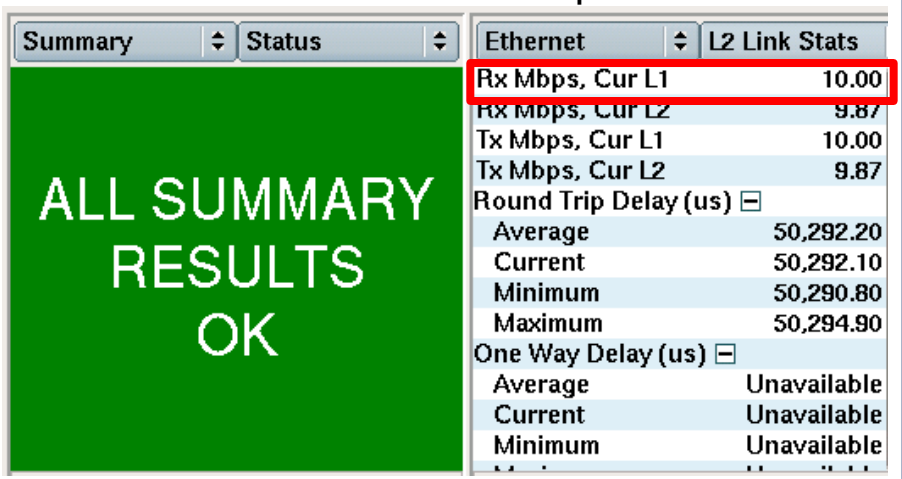
Truespeed- "Test as the customer experiences the network"

- Running RFC2544 or other Layer 2/3 installation tests (Y.1564) is always the first step
- But even when these Layer 2/3 tests "pass", end-customers can still complain that the "network is slow" and the cause of poor application performance (i.e. FTP, web browsing, etc.)
- Need to test "as the customer experiences the network" (TCP sessions)
- JDSU's **RFC 6349** compliant **TrueSpeed™** test allows the same technician who conducts traditional RFC2544 or Y.1564 tests to run an automated TCP throughput test in **3-5 minutes!**
- Save up to 30% OPEX costs by eliminating or quickly resolving finger pointing scenarios

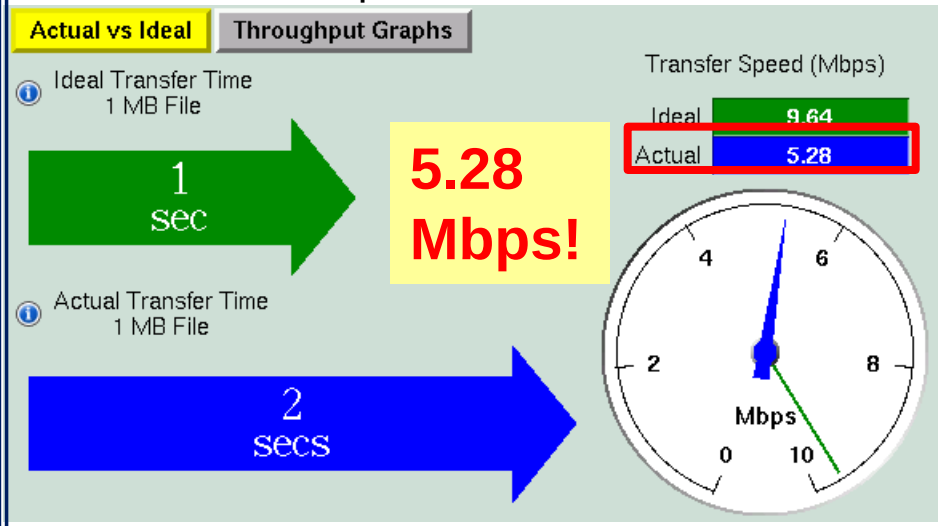
Example: 10Mbps SLA enforced using a Policer → traffic exceeding SLA is dropped



Traditional Layer 2 test showed "green" results when tested at 10 Mbps



The TCP throughput (Truespeed) result was quite different!

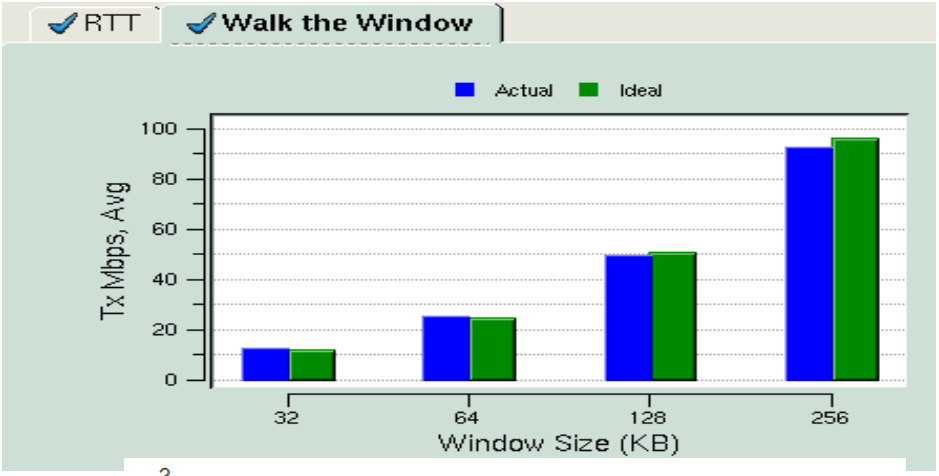


Truespeed Results Allow Identification of the Problem

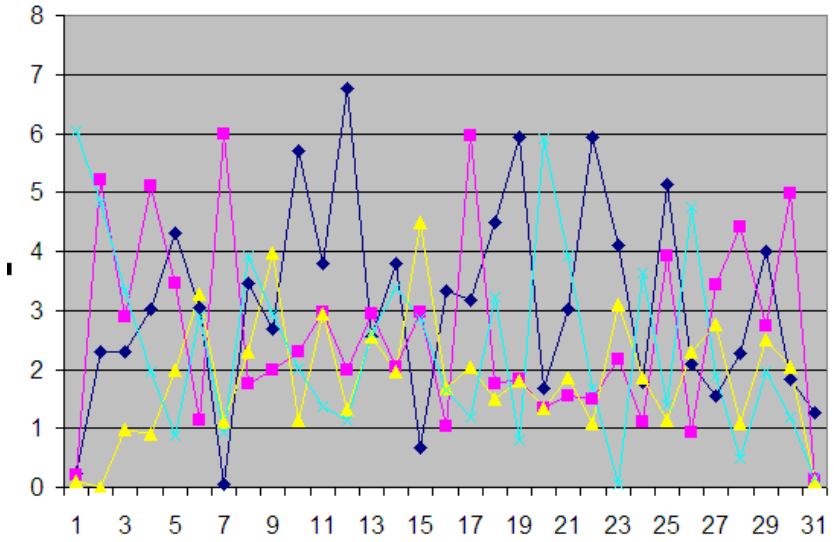
Problem: I ordered 100Mb but I'm only getting 10Mb on web downloads, file transfers- FIX IT!!!

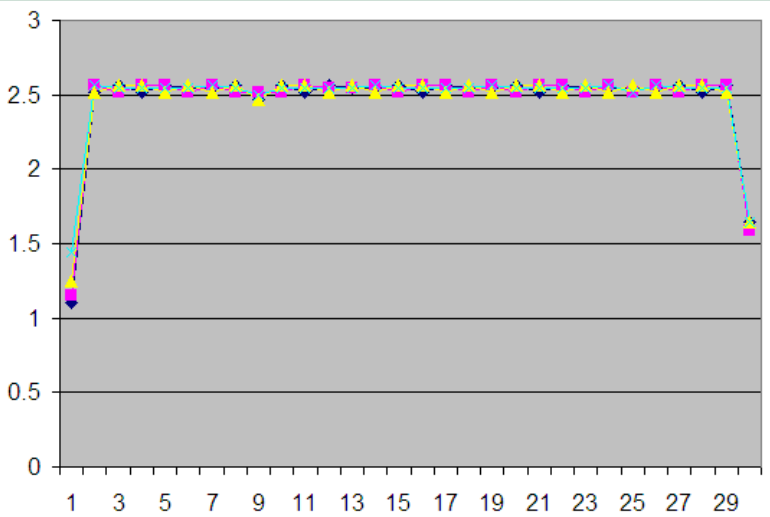
"Walk the Window" Results Graph:

- Customer shown that with a Window size of 32 Kb max througput achievable will only be 10 Mb
- If Window sizing is adjusted on CPE side max throughput will go to 100Mb



Throughput Graphs:

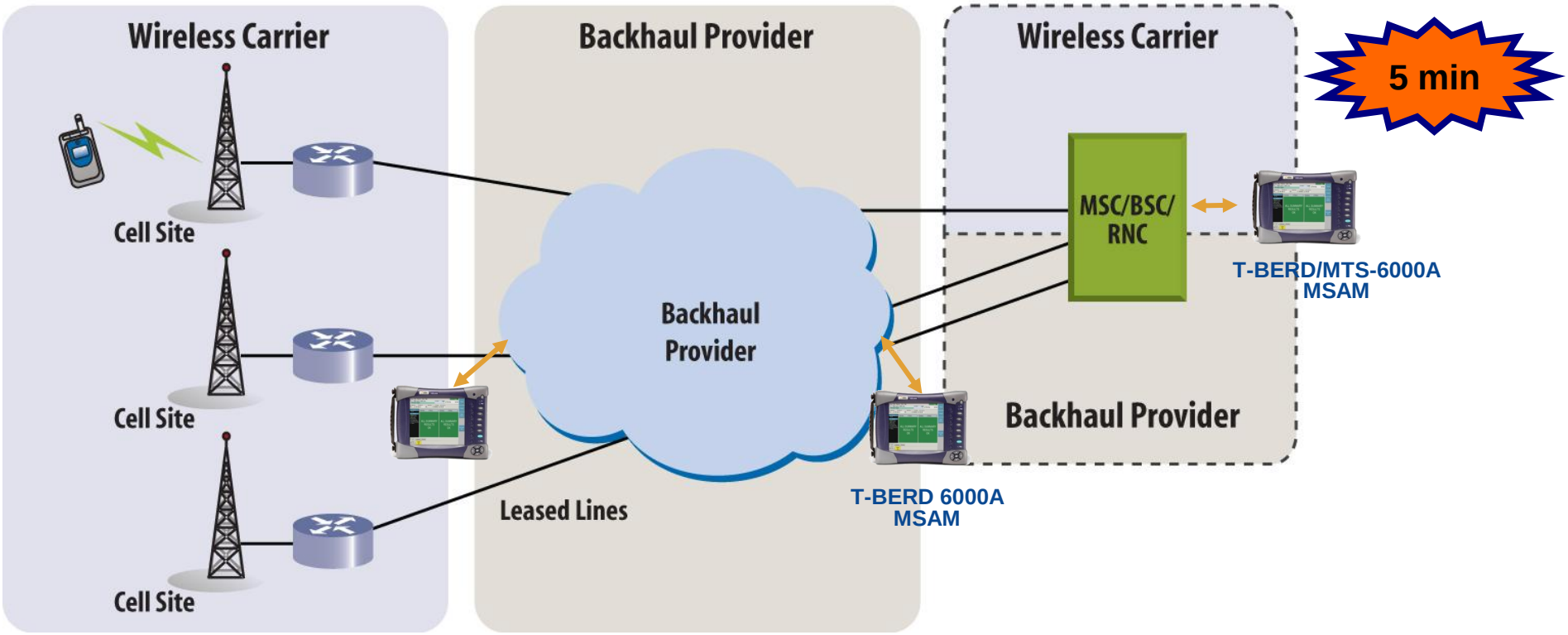




- TCP connections are NOT evenly sharing the link and **policing** occuring but no traffic smoothing

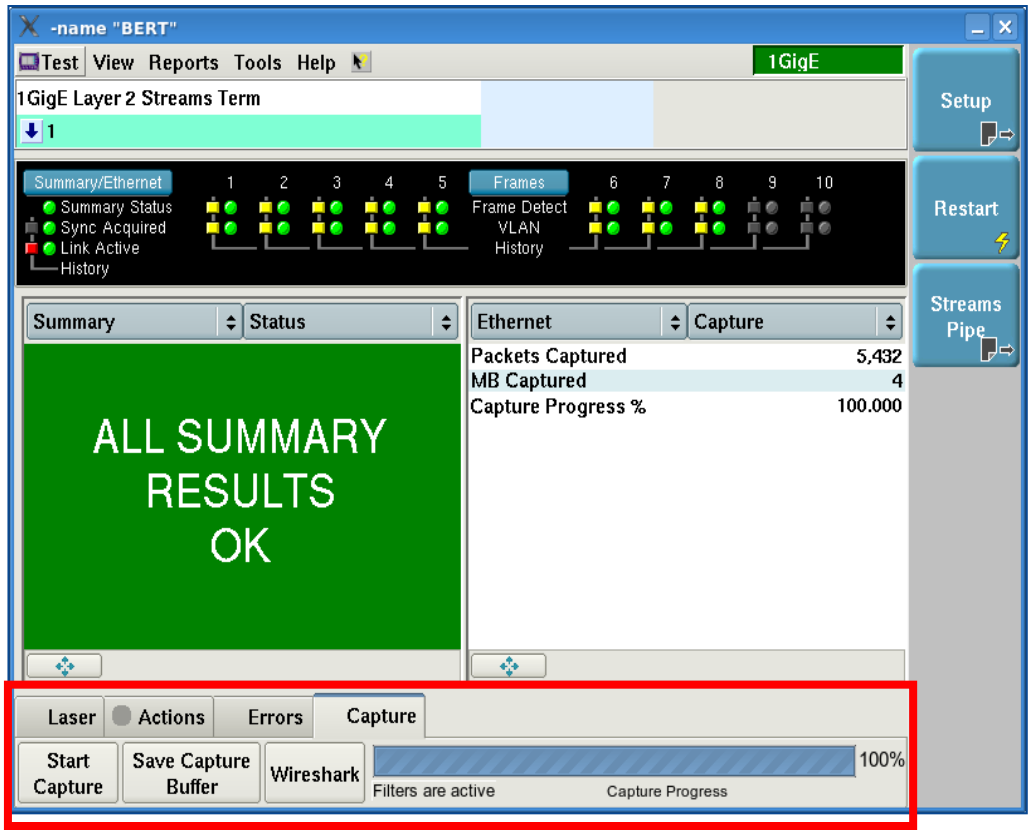
Traffic was **shaped** and TCP was "smoothed" by the shaping function on the switch

Packet Capture at Full Line Rate



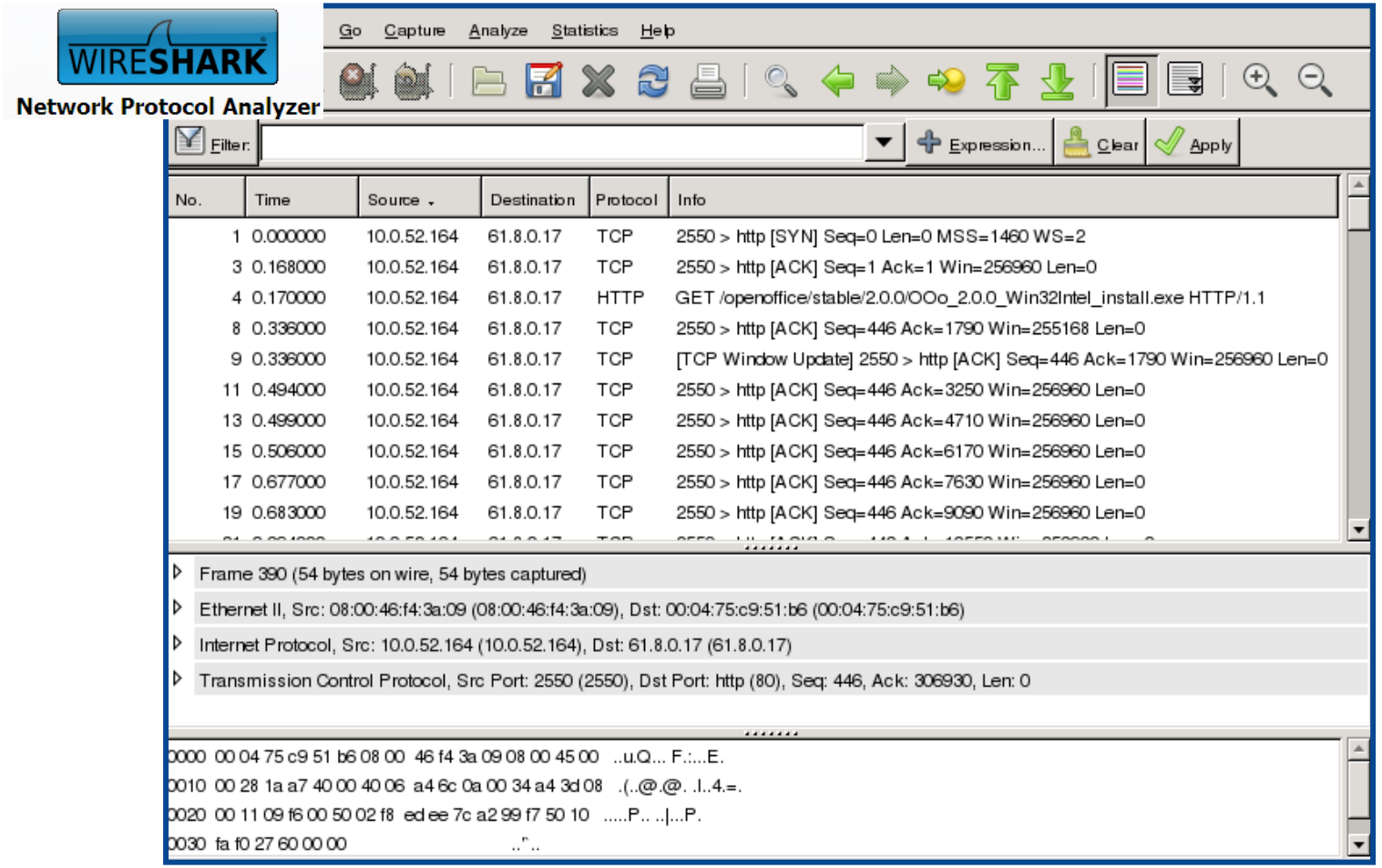
- Example- Run Packet Capture for Network Seperation Testing ensuring that customer traffic is not permeating onto provider network (or vice versa)
- Place T-BERD in Monitor Mode
- Test Method
  a. Perform full line rate packet capture at 1G or 10G to detect invading non-provider traffic
  b. Check packet decodes in WireShark on unit for customer control plane packets, incorrect VLANs, etc

Capture



- Capture packets from existing Ethernet & IP Applications
  - Apply filters to maximize efficiency
  - Ability to export capture files that can be given to higher level techs
  - Capture in both directions simultaneously using Thru mode

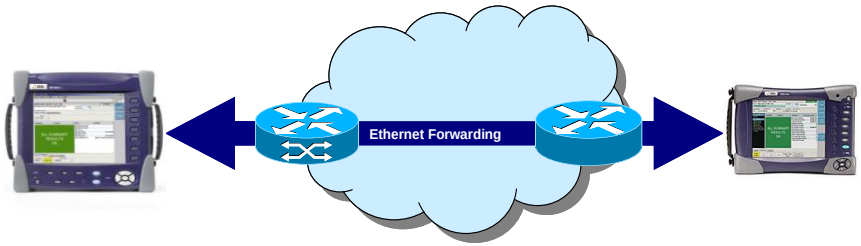
Decode using Wireshark



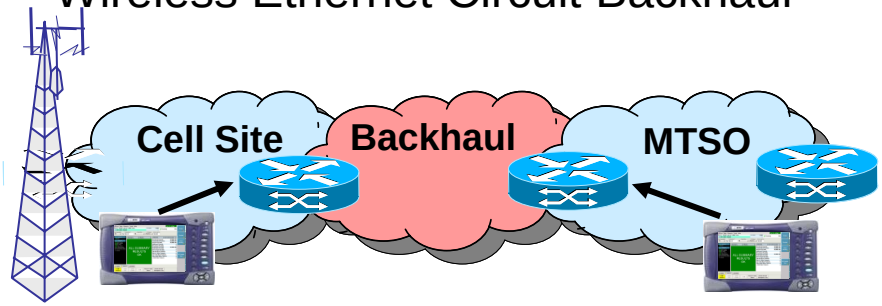
- Utilize Wireshark on unit for post capture decode

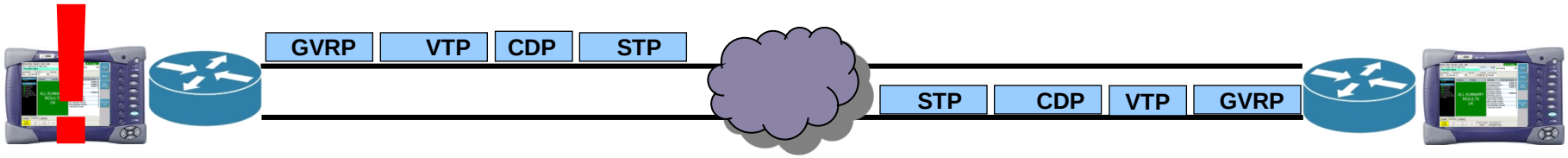
J-Proof (L2 Transparency) Case Study

Ethernet Circuit Turn-Up



Wireless Ethernet Circuit Backhaul

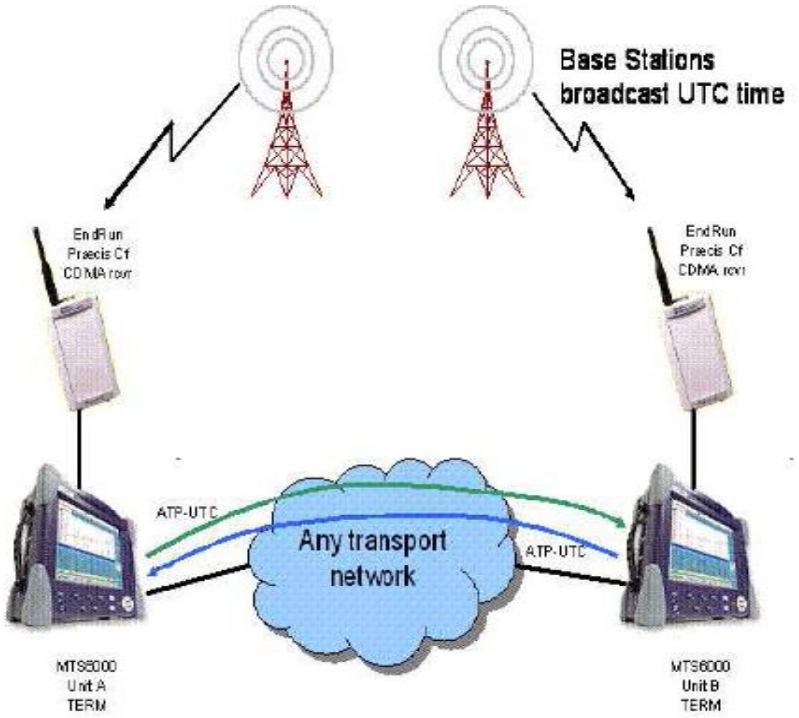


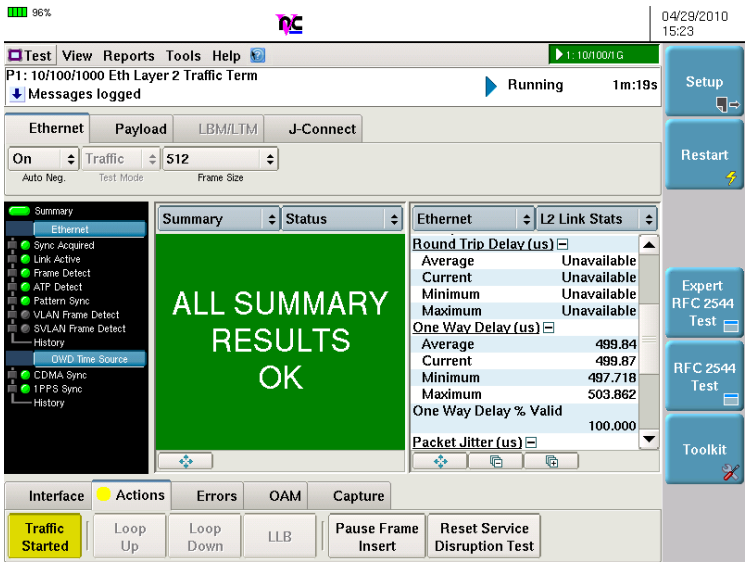


Location A **A CDP frame is dropped by switch!** **Location B**

- A provider is selling an end-to-end transparent Layer 2 service and part of the link is leased from another network operator
- After completing the RFC 2544 test in which everything passed, they conduct a J-Proof test to emulate Layer 2 protocol frames.
- This will ensure that the entire link is properly forwarding ALL types of traffic
- The test discovers that CDP frames are being dropped. The 3rd party provider switches are not configured properly and are attempting to process the CDP frames (and then discarding them) instead of transparently forwarding them

One Way Delay





- *The delay of information transmitted may not be the same as the delay of information received.*
- *The One Way Delay test option enables Cell Site Ethernet backhaul providers to measure the delay of Ethernet, IPv4 and IPv6 traffic that is received from a sender using a highly accurate CDMA receiver.*

Testing & Trouble Shooting Summary

- **What's your Test Access (Terminate, Thru, Mirror port,….)**
- **Physical Layer**
  - **Fiber Inspection to verify clean fiber connection**
  - **Power Levels good ?Negotiation mismatch**
  - **OTDR trace is good (**no breaks, bad splices, macrobends,….)
  - **Correct SFP or XFS installed** (correct wavelength, rated for the service (GigE, 10GigE,…
- **Layer 2/3 (Basics)**
  - **Negotiation Mismatches-** BOTH sides have correct negotiation (If see HALFDUPLEX in results it's a Red Flag)
  - **DIX vs 802.3 Frame type-** use DIX as your default
  - **Sending L2/L3 Test Packet (vs BERT)-** has time stamp and Frame sequence counters to ensure you can get required test measurements (Latency/delay, Lost frames, Out of Sequence Frames, …..)
  - **Test gear can "talk" with each other to run required tests**
    - **Loop up/down commands**
    - **Recognizes the Test Packet to ensure proper results (Throughput, Latency, Jitter, Frame Loss,,….)**
- **Troubleshooting & Advanced/In-depth Testing**
  - **Sectionalization**
  - **Committed Burst Size (CBS)- may be required as part of turnup test as well**
  - **RFC-6349 "Truespeed"**
    - **Resolving the "slow throughput" complaints (and an RFC-2544 or Y.1564 runs clean)**
    - **Run during turnup or for troubleshooting**
  - **Packet Captures (at line rate)**
    - **Capture at line rate and get detailed analysis to figure out root cause problem**
  - **Layer 2 Transparency Tests**
    - **Verify control plane protocols are not being manipulated as they travel through the network**

Questions