DOE UltraScienceNet - Update

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Brief Review of USN

Next Phase Activities

VLANS over L2 and L3 Networks

- Baseline measurements
- SONET vs MPLS VLANs
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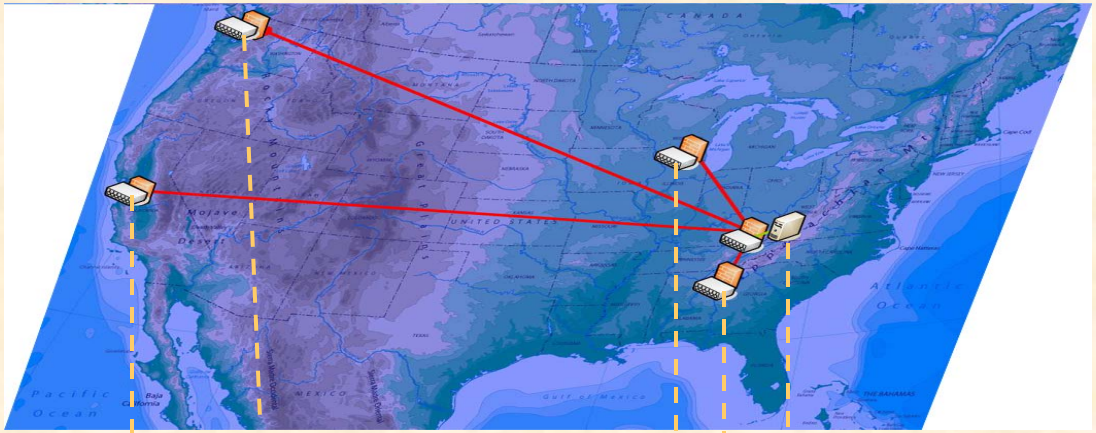
- Summary

USN Architecture:
Separate Data-Plane and Control-Planes

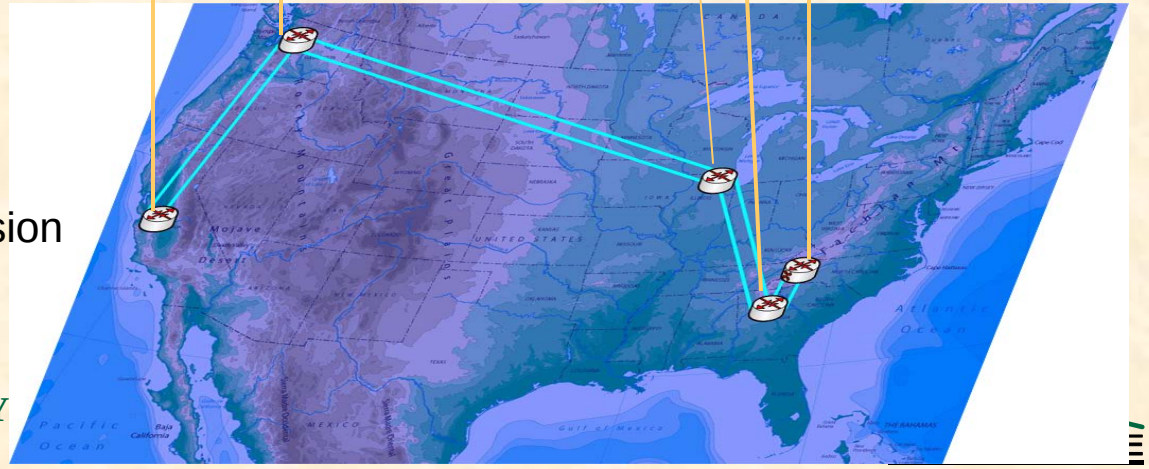
Secure control-plane with:

- Encryption, authentication and authorization
- On-demand and advanced provisioning



Dual OC192 backbone:

- SONET-switched in the backbone
- Ethernet-SONET conversion



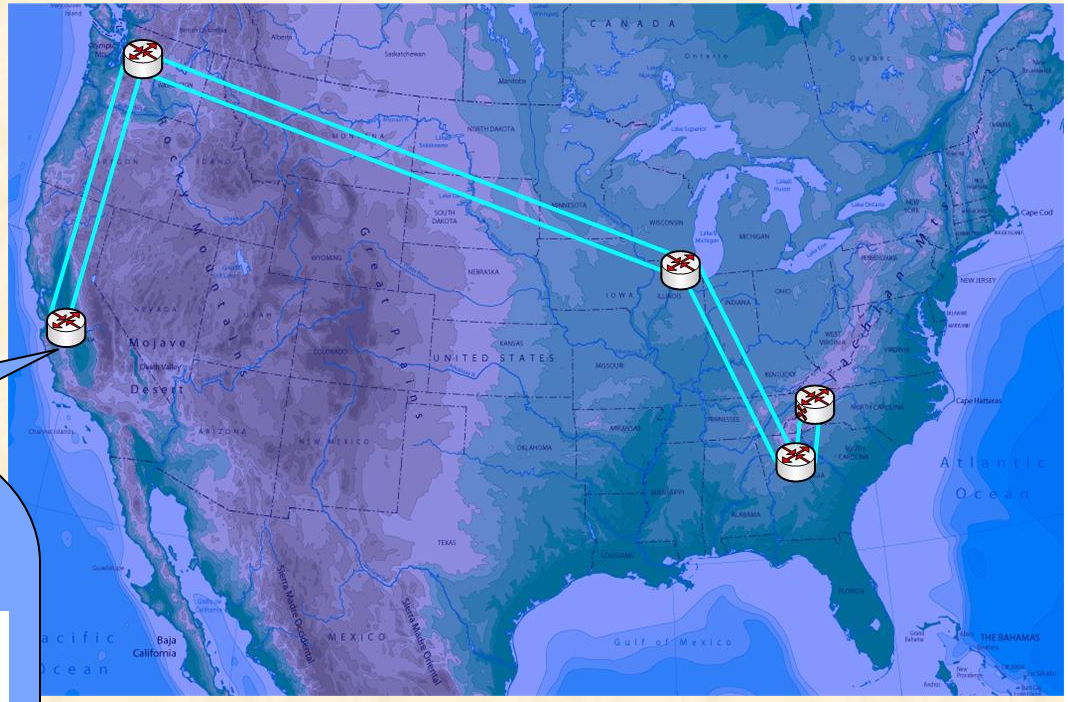
USN Data-Plane: Node Configuration

In the Core:

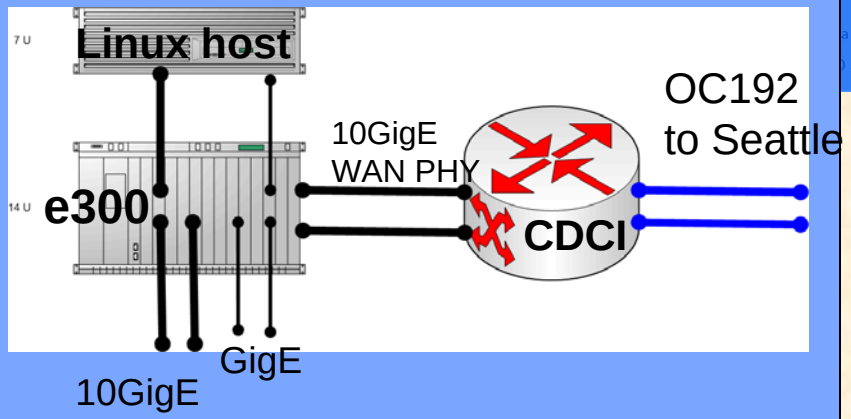
- **Two OC192 switched by Ciena CDCIs**

At the Edge

- **10/1 GigE provisioning using Force10 E300s**



Node Configuration



Connections to CalTech and ESnet

Data Plane User Connections:

Direct connections to:

core switches –SONET &1GigE

MSPP – Ethernet channels

Utilize UltraScience Net hosts

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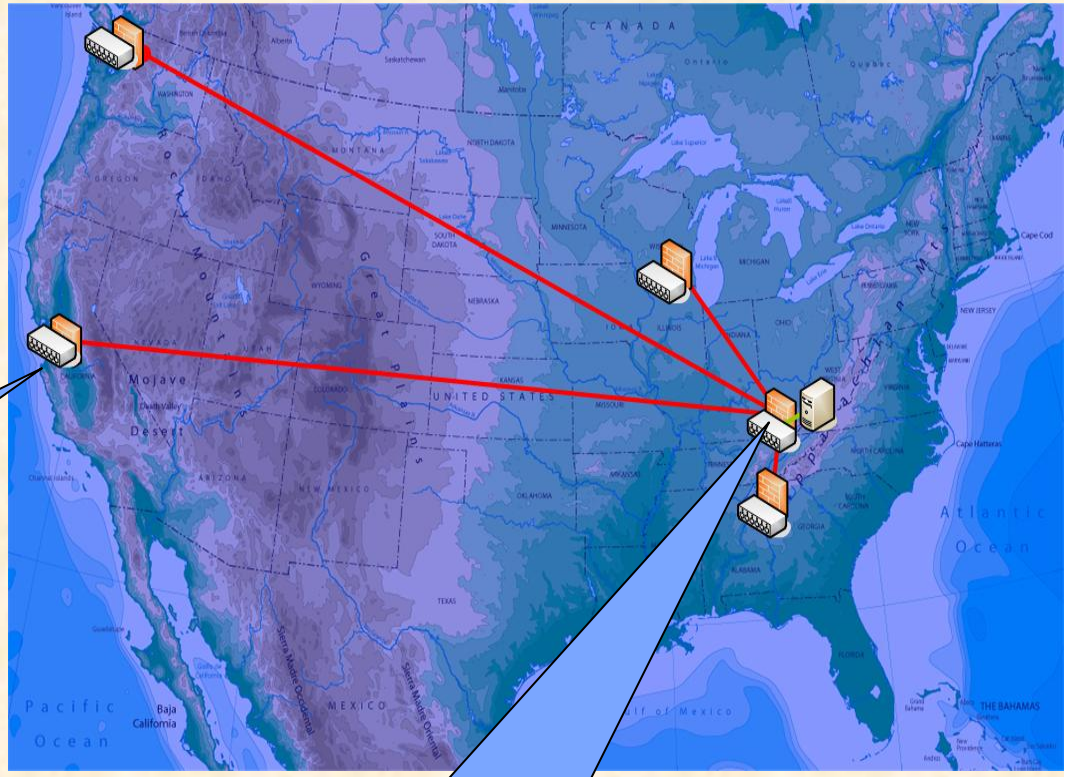
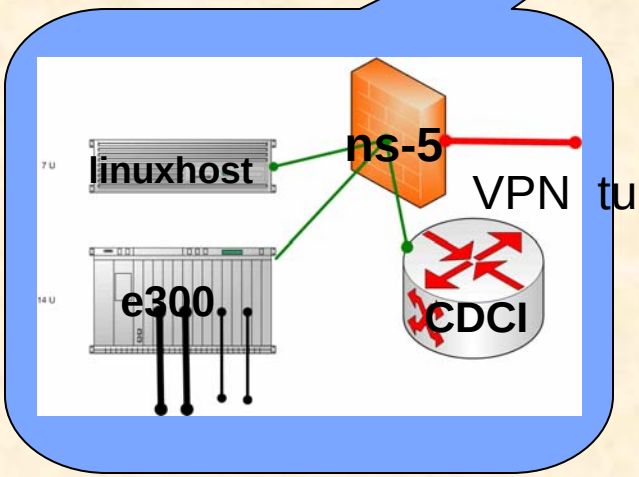
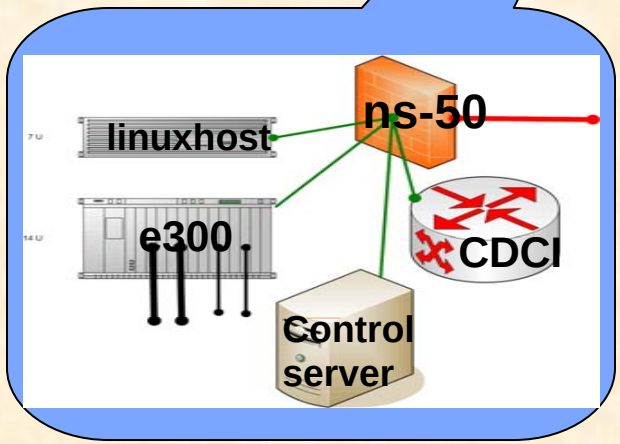
Secure Control-Plane

VPN-based authentication, encryption and firewall

- Netscreen ns-50 at ORNL
  NS-5 at each node
- Centralized server at ORNL
  - bandwidth scheduling
  - singnalling







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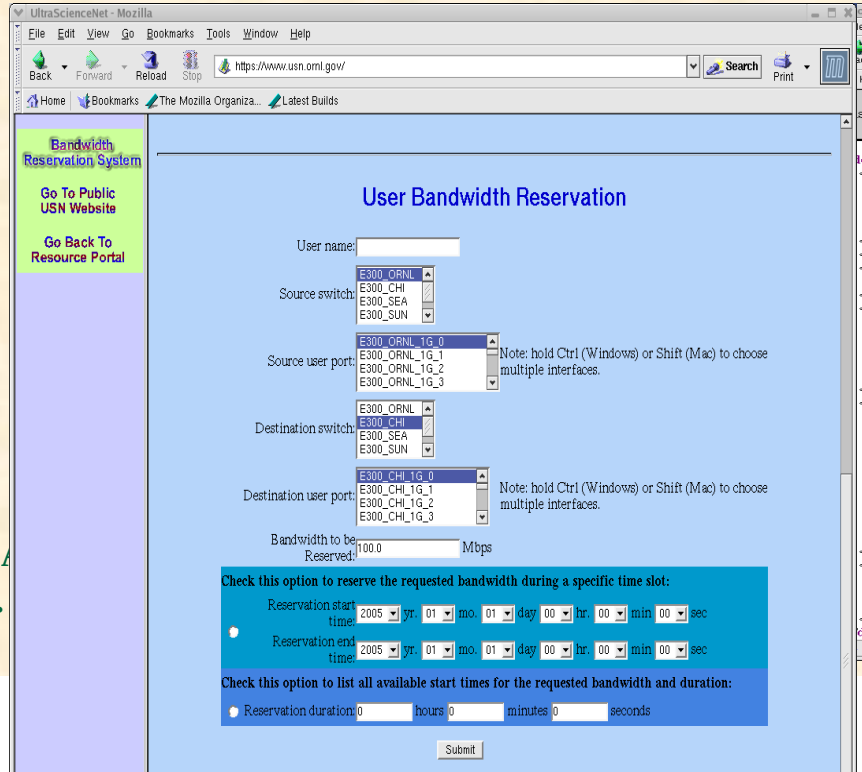
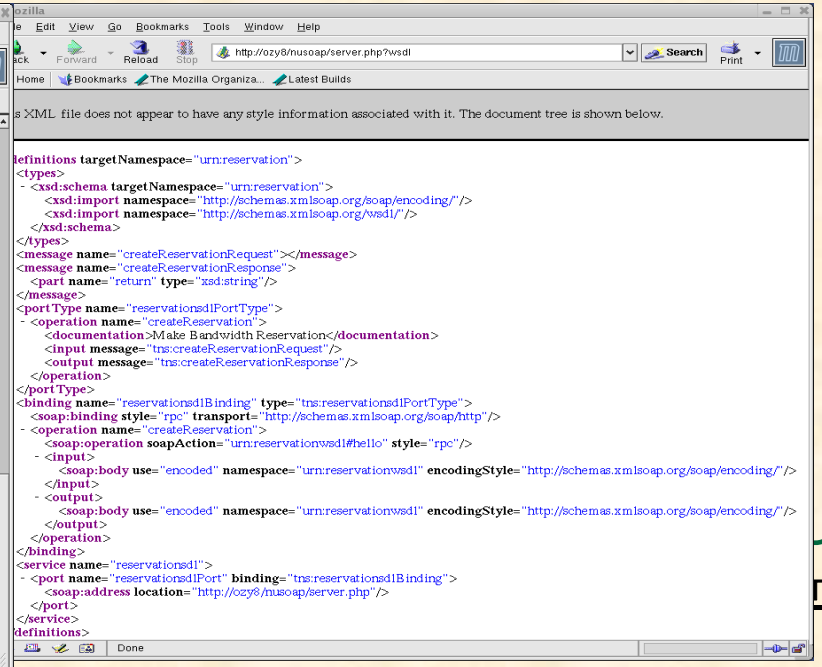
USN Control Plane

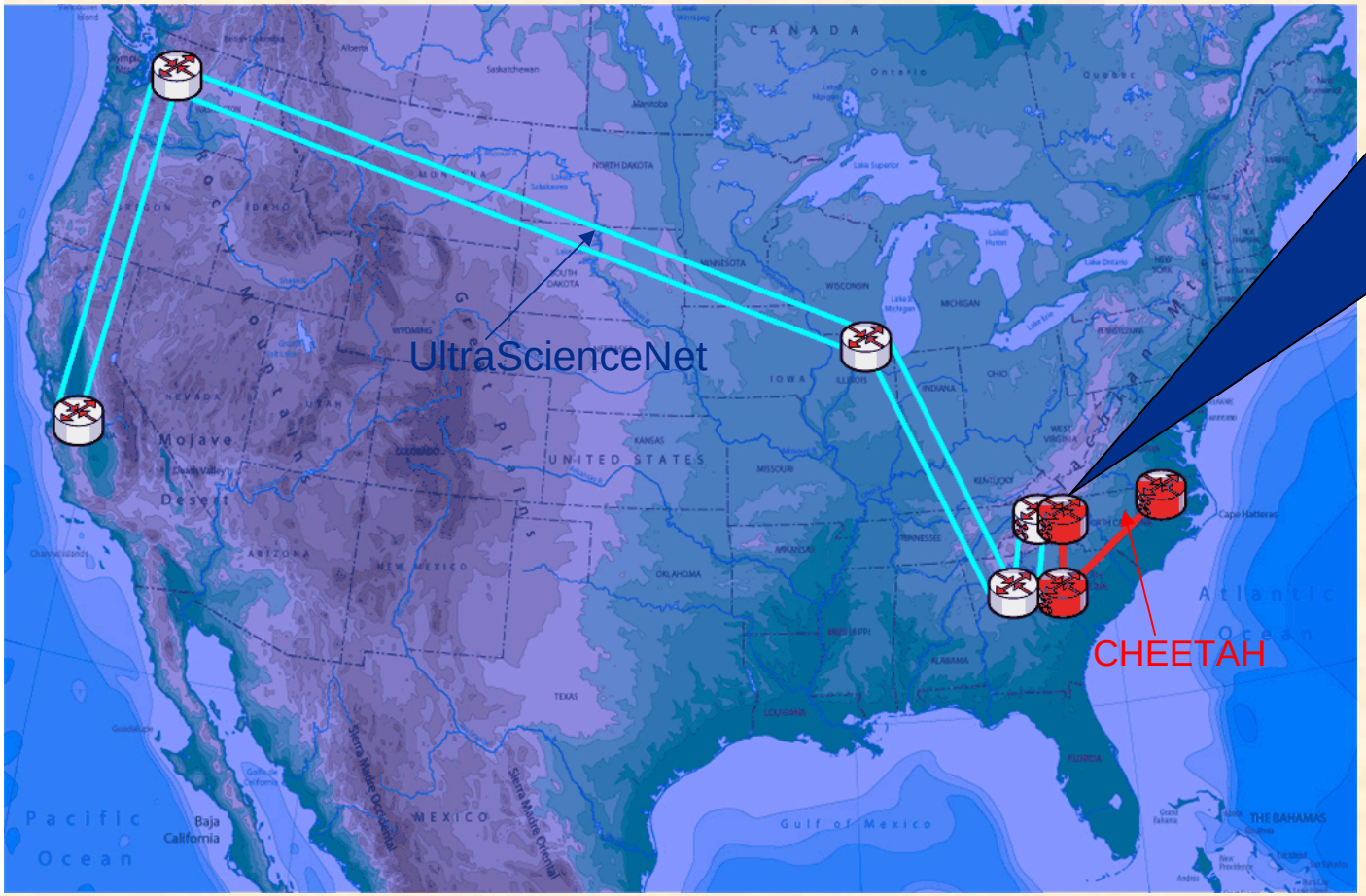
- **Phase I**
  - **Centralized path computation for bandwidth optimization**
  - **TL1/CLI-based communication with CoreDirectors and E300s**
  - **User access via centralized web-based scheduler**
- **Phase II (current)**
  - **GMPLS wrappers for TL1/CLI**
  - **Inter-domain "secured" GMPLS-based interface**
  - **Webservices interface**
  - **X509 authentication for web server and service**

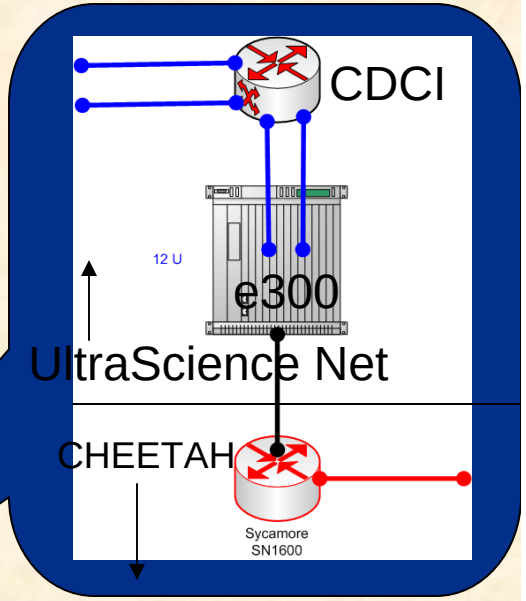




Peering: UltraScience Net – NSF CHEETAH

- **Peering: data and control planes**
  - **Coast-to-coast dedicated channels**
  - **Access to ORNL supercomputers**





Peering at ORNL:
Data plane:
10GigE between SN16000 and e300
Control-Plane:
VPN tunnel

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Current Status: Data-Plane

- **Data-Plane Connections:**
  - **Chicago-Sunnyvale**
    - **May 2005: 10GigE WAN-PHY between E300**
    - **August 2005: 2 x OC192 links between CDCIs**
  - **ORNL-Chicago**
    - **August 2005: 2 x OX192 links between CDCIs**
- **User-connections**
  - **August 2005**
    - **PNNL, FNL, CalTech, ESnet**
  - **November 2005**
    - **SLAC**
  - **May 2006**
    - **Atlanta node installation**

Current Status: Control-Plane

- **ORNL, Chicago, Seattle, Sunnyvale, Atlanta nodes are setup**
  - **VPN, console servers are setup**
  - **Signaling modules – GMPLS extensions are being implemented**
  - **Bandwidth/channel reservation system – being tested with X.509 authentication**
  - **Webservice is being tested**
- **SC2005 node moved to Atlanta**

USN Next Steps

- Infrastructure development is close to completion
- USN will continue to play research role in advanced networking capabilities:
  - Networking Technologies for Leadership Class Facilities
    - covered last ESCC meeting results on Cray X1(E)
  - Integrated Multi-Domain Interoperation System for USN-ESnet-CHEETAH-HOPI
    - on-going efforts with OSCARS and HOPI: plans presented at JointTechs 2006 summer workshop
  - Hybrid Optical Packet and Switching Technologies
    - VLAN testing and analysis over L1-2 and MPLS connections: this presentation
    - Configuration and testing of hybrid connections

USN Next Step: Leadership Class Facilities

- Interconnects with dedicated wide-area paths.
- Alignment and impedance matching techniques for both data and execution paths.
- Testing high-performance wide-area storage and file systems over layer-2 and layer-1 standard and non-standard (infiniband) wide area transport.

USN Next Step: Multi-Domain Networking

Integrated control-plane technologies for dedicated channels spanning across USN into other networks:

1. Meta-schedulers to provide on-demand and in-advance paths over multiple domains.
2. Development, alignment and integration of provisioning and signaling technologies including MPLS of OSCARS and GMPLS of HOPI and CHEETAH.

USN Next Steps: Hybrid Optical Packet and Switching Technologies

- VLAN testing and analysis over L1-2 and MPLS connections
- Technologies for networks where shared IP connections co-exist with dedicated channels provisioned at layers 1-3.
- Technologies for provisioning dedicated channels over hybrid networks for
  - (i) point-to-point connections; and
  - (ii) forming dynamic back-plane networks of a pool of such connections between distributed NLCF systems.

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Background

Relative performance of VLANs provisioned over:

- SONET layer-1 paths
- MPLS layer-3 paths

Broader Networking Question:
Layer-1 or layer-2 or layer-3 channels for dedicated bandwidth connections?

Feasibility and Performance of Composed SONET-MPLS VLANS:

Data-plane unification of dedicated paths over layer-1, layer-2 and layer-3 paths

Broader Question: Peering data-paths across networks that provide VLANs over Layer-1 or layer-2 or layer-3

Systematic analysis of application and IP level measurements:
Using USN and CHEETAH, we

- collected ping and TCP measurements
- performed comparative performance analysis
- composed and tested VLANS over SONET and IP connections

Connections and Measurements

Two types of measurements:

- Ping (standard version)
- TCP client/server: roundtrip time of 1K packets

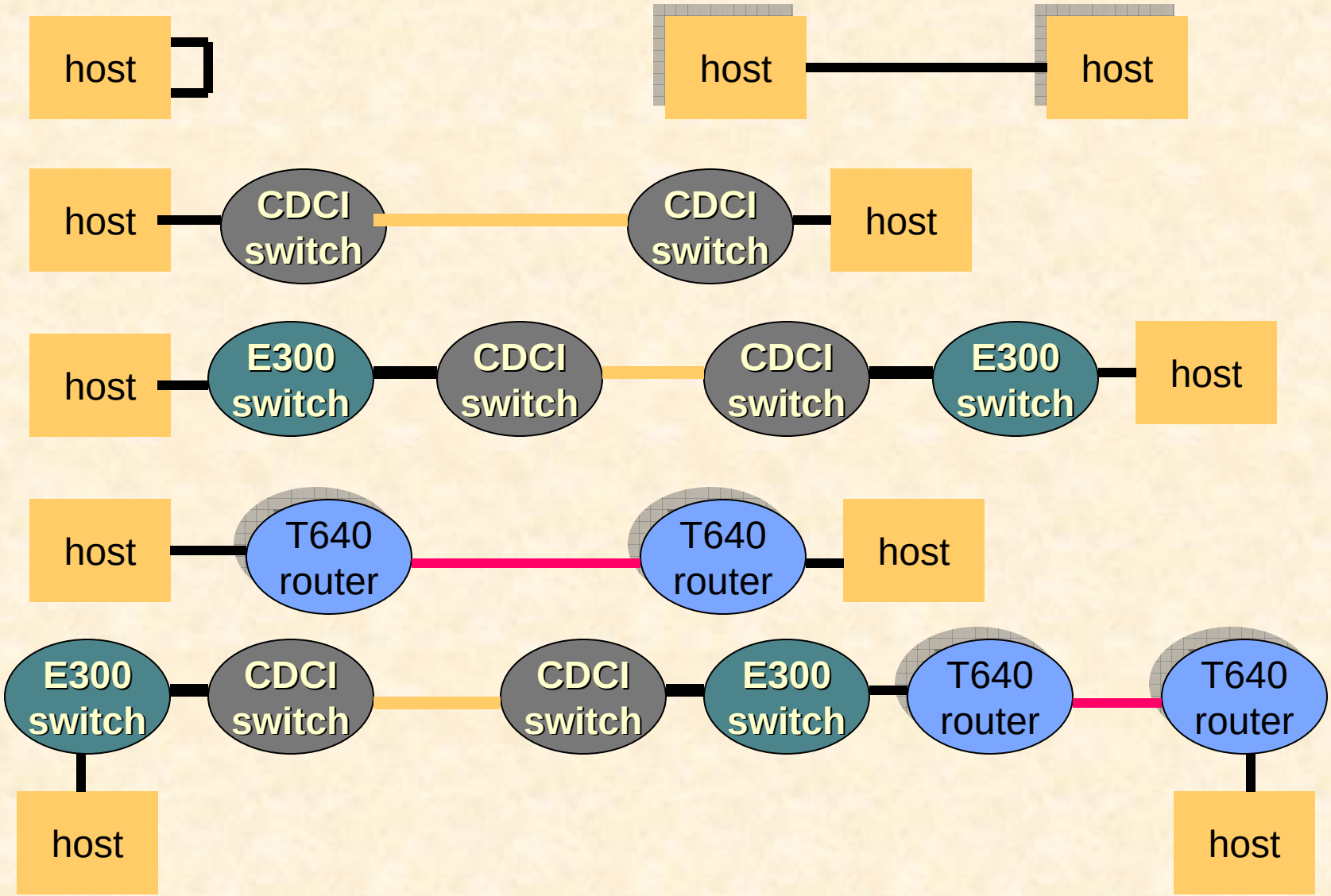
Types channels:

- host-local NIC
- host-host
- host-switch/router-host – LAN connection
- host-SONET-host – 1000 miles; OC-21
- host-MPLS-host – 300 miles; 1Gig VLAN
- host-SONET-MPLS-host; 1300 miles 1Gig VLAN

Comparison Method:

- normalization of wide-area measurements based on mean delay

Test-Configurations



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  - Host measurements
  - LAN first-hop measurements
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Baseline Measurements – linux hosts

Linux host

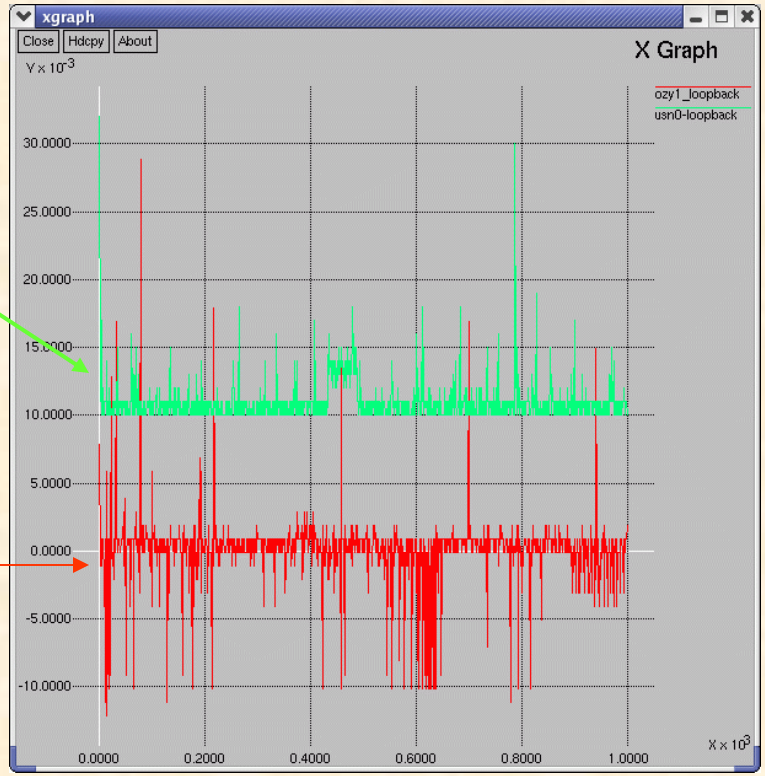
ozy1-NIC: 1GHz Pentium III

Number of ping measurements=1000
mean time=0.043117ms
percent range: [71.897528,166.987803]
:95.090275
std_deviation (percent)= 6.341750

Linux host

usn0-NIC: Xeon 3.2 GHz

Number of measurements=1000
mean=0.010960
percent range: [91.240939,291.971025]
: 200.730086
std_deviation (percent)= 14.330526

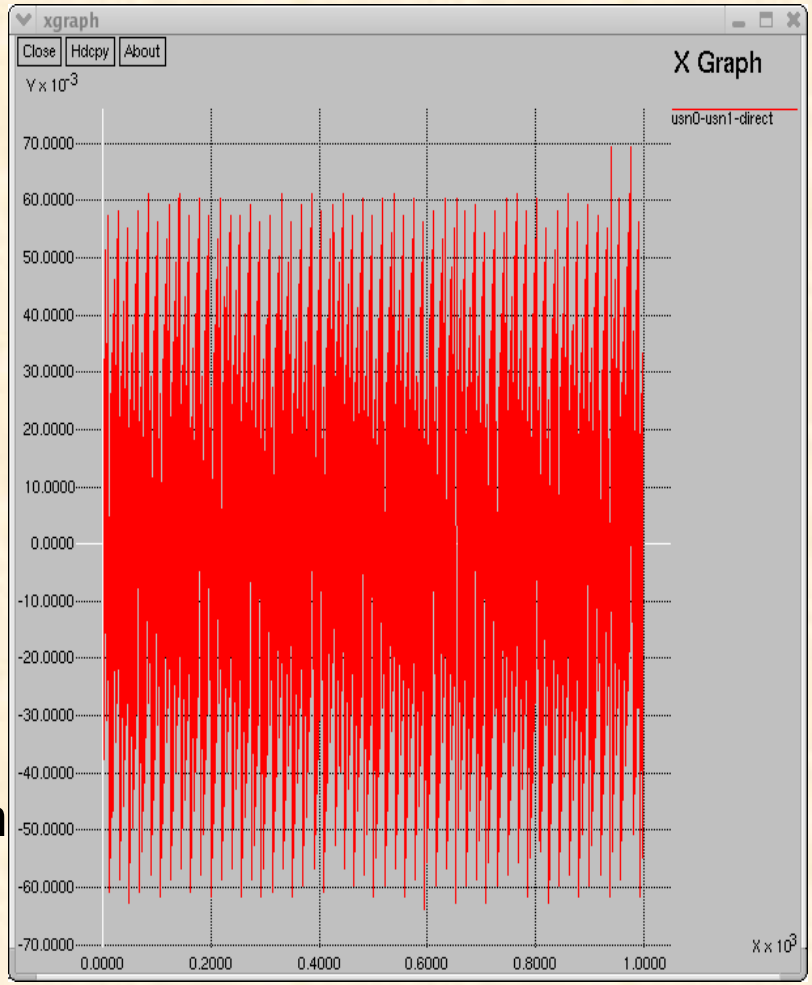


Hosts Connected Back to back

usn0-usn1 hosts: Xeon 3.2GHz

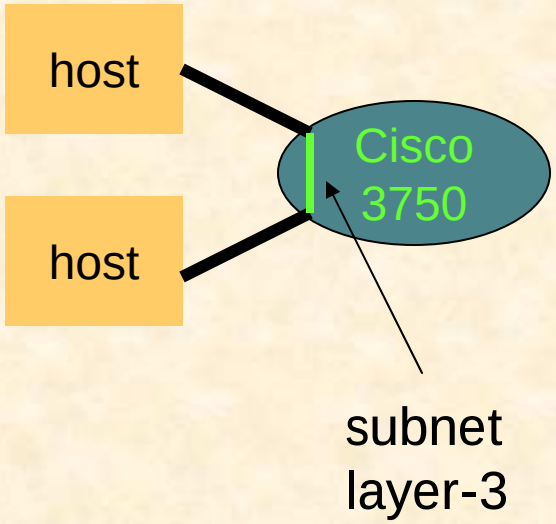
Back to back NIC connection

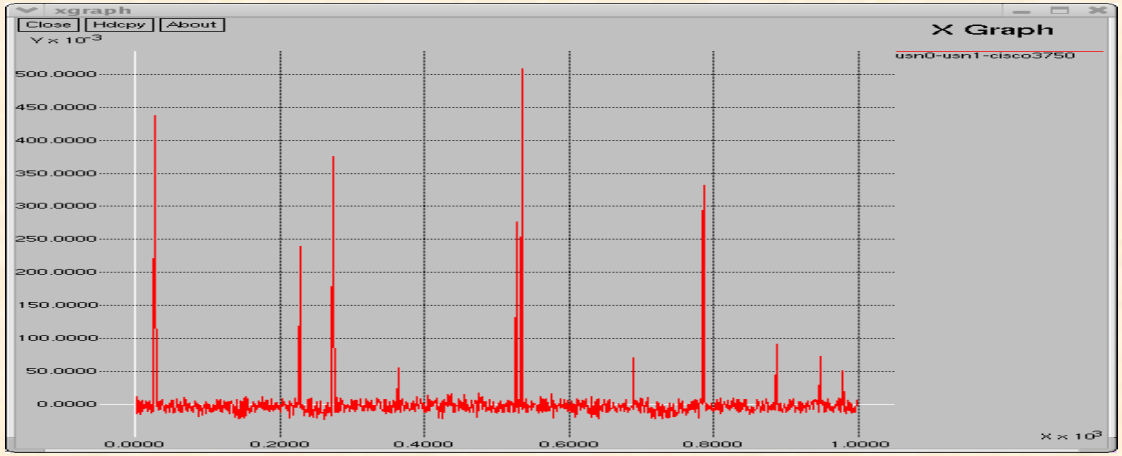
Number of ping measurements=1000
mean time =0.122728ms
percent range: [48.073878,156.443807]
: 108.369929
std_deviation (percent)= 29.437985



These dynamics need a closer inspection for possible chaotic behavior

Hosts with first hop router: Subnet Layer-3 connection





usn0-usn1-cisco3750

Number of measurements=1000

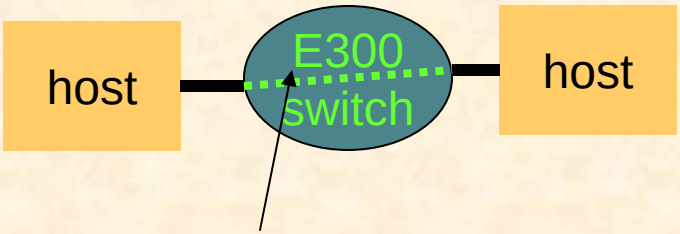
mean time=0.491746

percent range: [95.374373,203.356866]

: 107.982494

std_deviation(percent)= 6.949724

Hosts with first hop switch: Layer-2 cross-connect on Force10



Layer-2 cross-connect Via VLAN

usn0-usn1-e300:

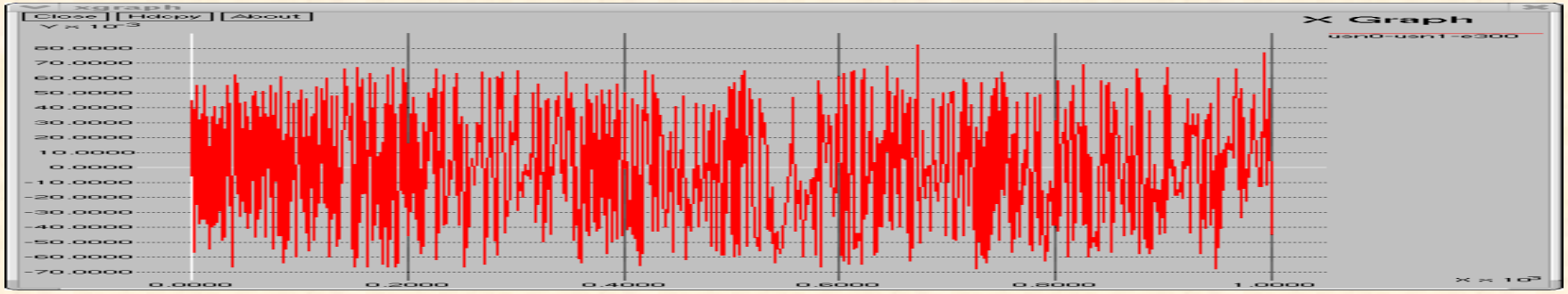
Number of **PING** measurements=1000

mean=0.211787ms

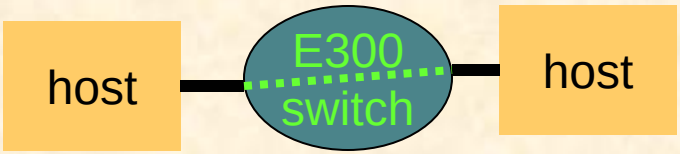
percent range: [67.992896,138.818836]

: 70.825939

std_deviation (percent)= 17.278263



Hosts with first hop switch: TCP measurements: 1K packets roundtrip times



usn1-usn0-e300

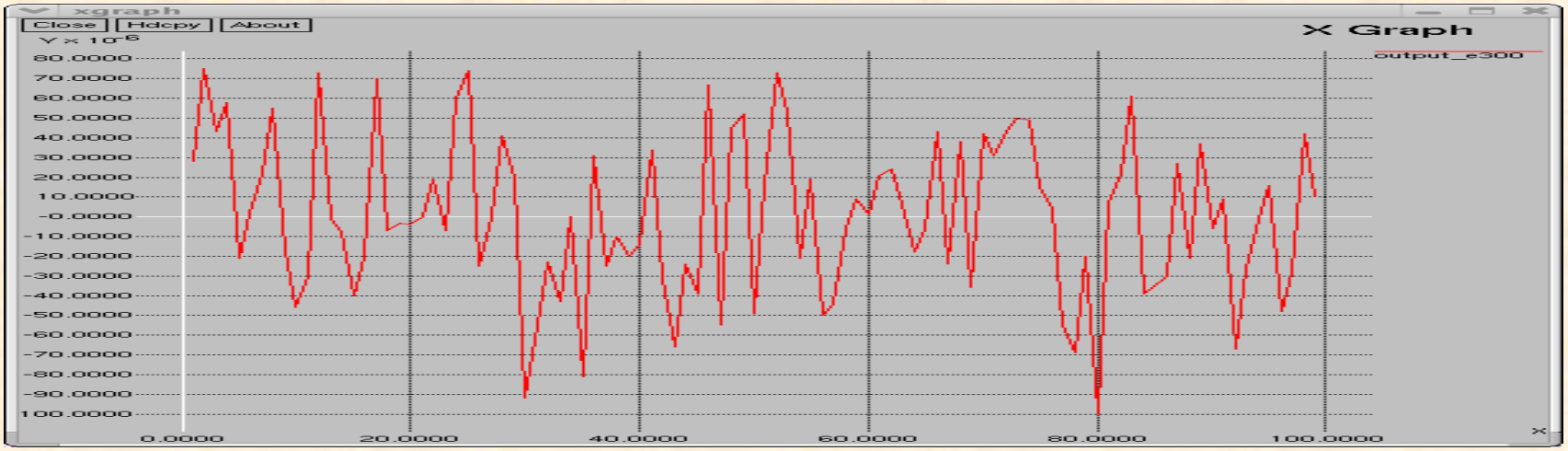
Number of measurements=100

mean roundtrip time=0.001282sec

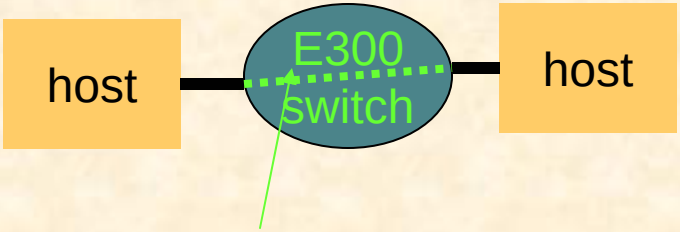
percent range: [92.177176,105.824383

actual range: [0.001182,0.001357

std_dev (%)= 3.120498



Comparison of LAN connections: Layer-2 cross-connect on Force10 subnet Layer-3 on Cisco 3750

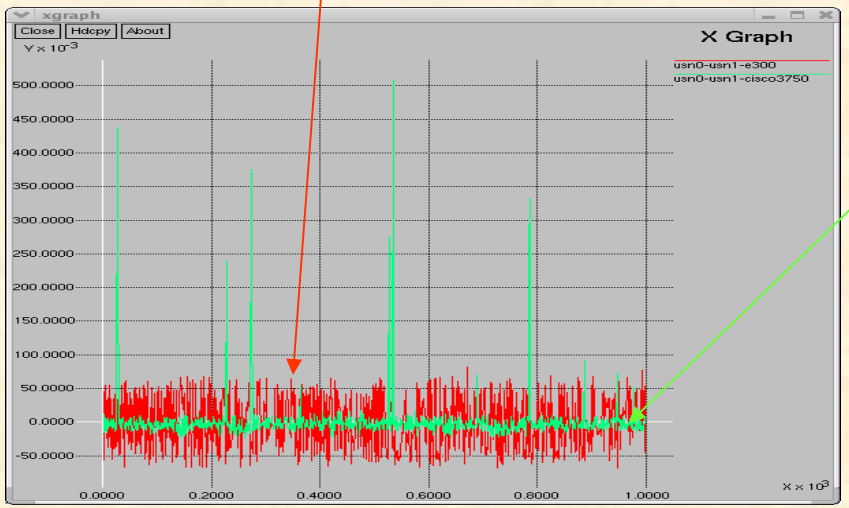


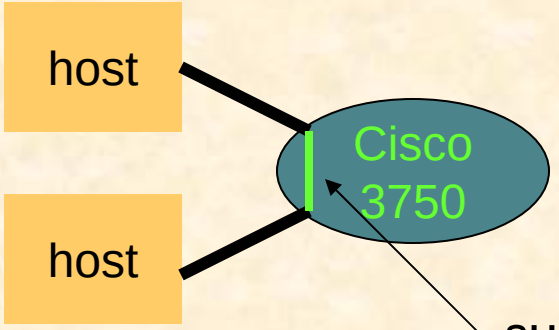
usn0-usn1-e300:

Mean time =0.211787ms

percent range: [67.992896,138.818836]

Layer-2 cross-connect via VLAN





subnet layer-3

usn0-usn1-cisco3750

mean time=0.491746ms

percent range: [95.374373,203.356866]

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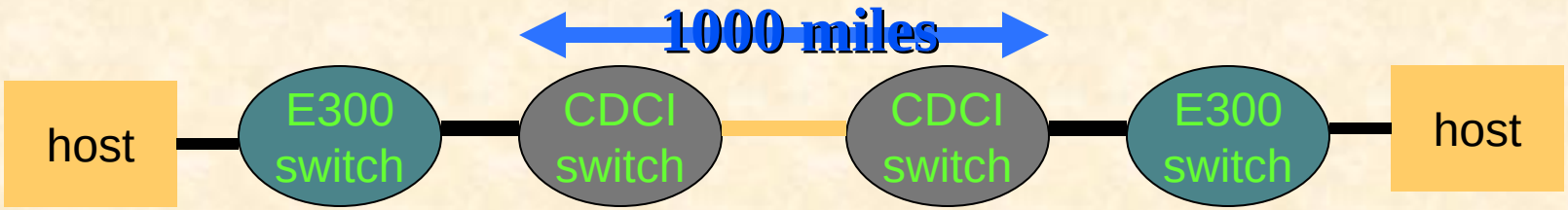
SONET Channel OC21c
1000 miles 1GigE VLAN



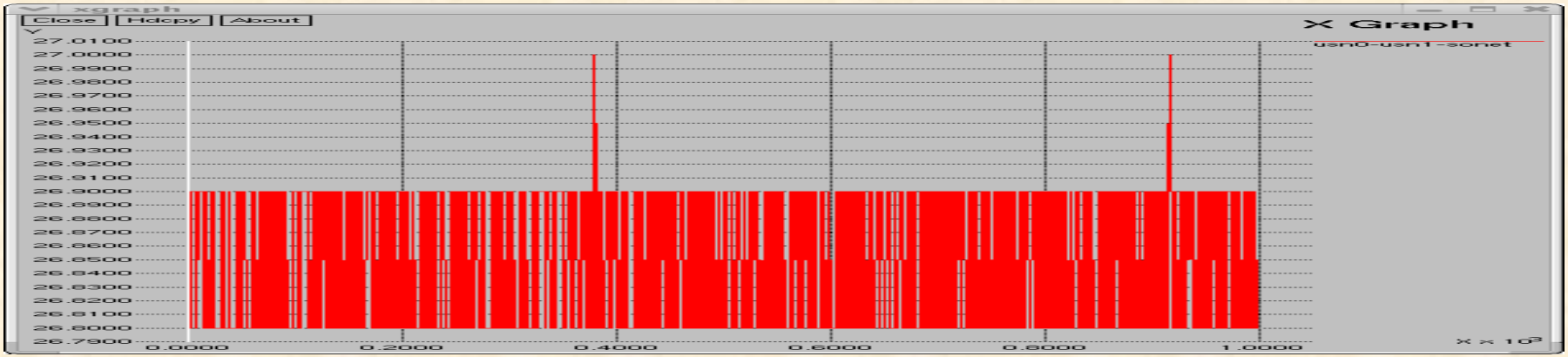
Number of PING measurements=1000

mean time=26.845877ms

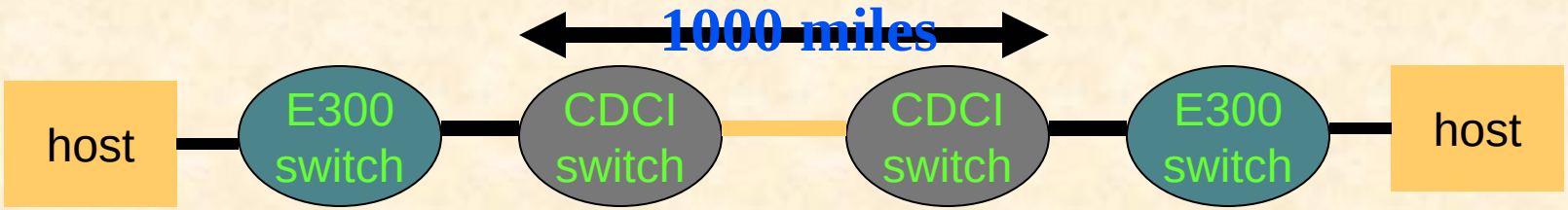
percent range: [99.829108,100.574104]: 0.744996

range: [26.799999,27.000000]: 0.200001

std_deviation (percent)= 0.187035



SONET Channel OC21c: TCP measurements 1000 miles 1GigE VLAN



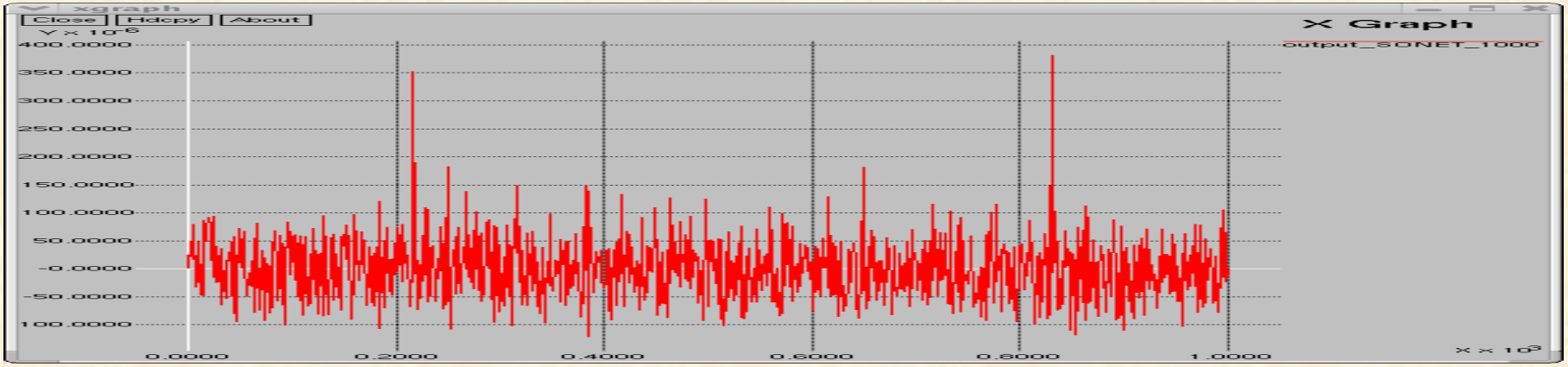
Number of TCP measurements=1000

mean=0.028064sec

percent range: [99.569830,101.358615]: 1.788785

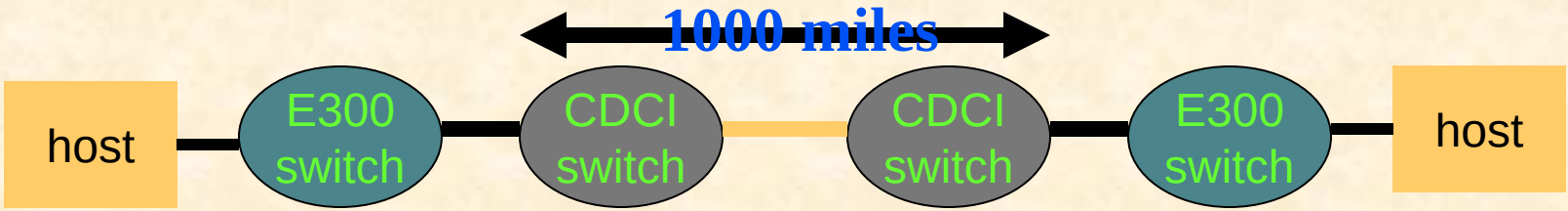
actual range: [0.027943,0.028445]: 0.000502

std_deviation_percent= 0.184920



SONET Channel OC21c: TCP measurements

1000 miles 1GigE VLAN normalized with LAN



usn1-usn0-SONET

mean=0.028037

percent range:

[99.598089,101.417140]

std_dev (%)= 0.214886

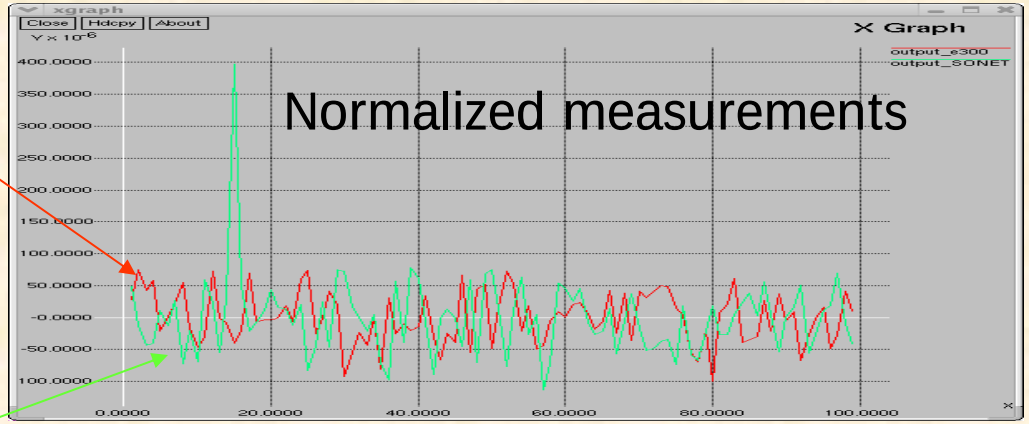
usn1-usn0-e300

mean=0.001282

percent range:

[92.177176,105.824383]

STD_dev (%)= 3.120498



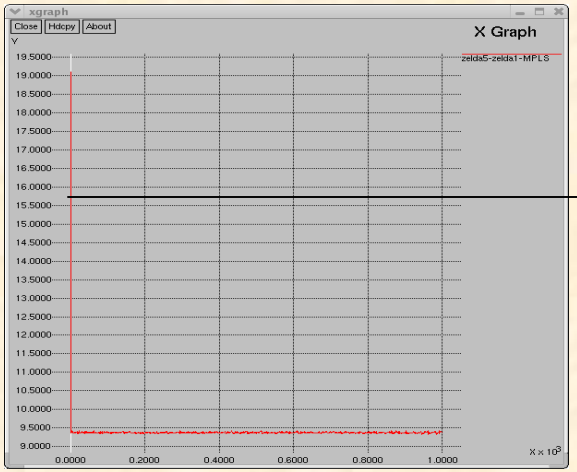
<u>Conclusion:</u>

Jitter levels of 1000 miles of SONET connection is of same order as LAN

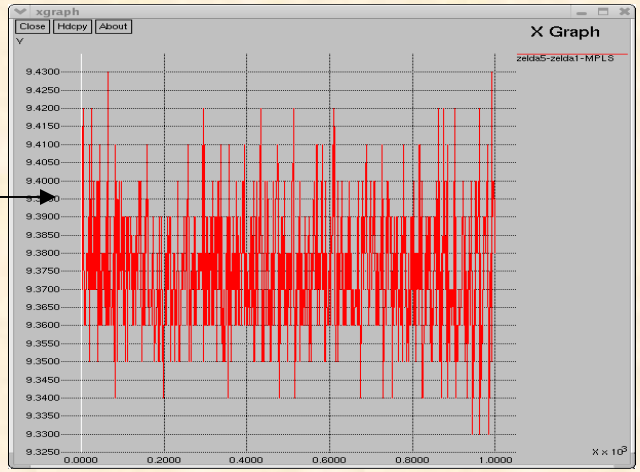
MPLS Tunnel with VLAN Tagging
1Gig Tunnel ~300 miles

1Gig MPLS tunnel

Number of ping measurements=999
mean time=9.384557ms
percent range: [99.418653,203.525865]: 104.107212
variance= 0.094847
std_deviation (%)= 3.281692

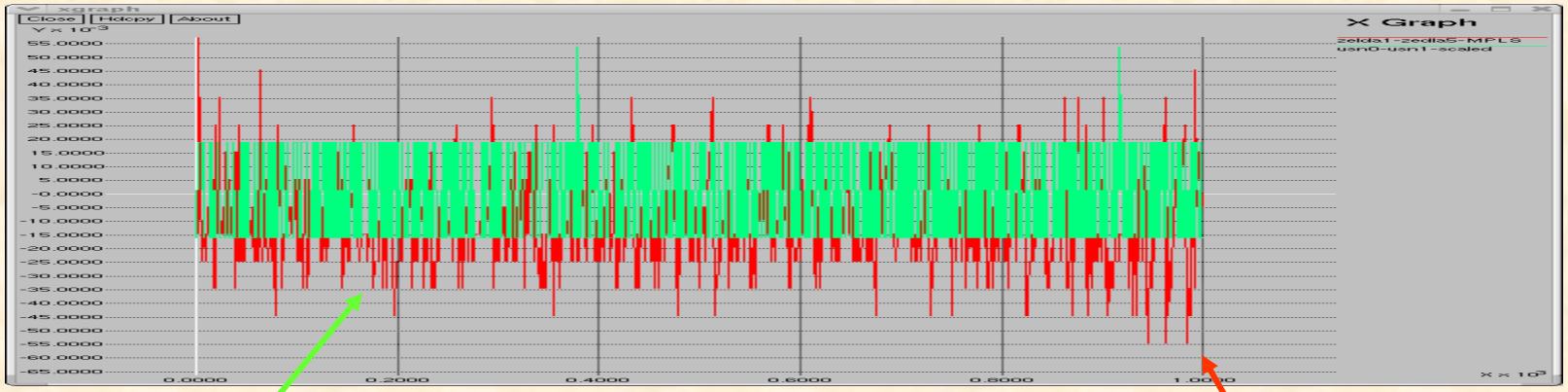


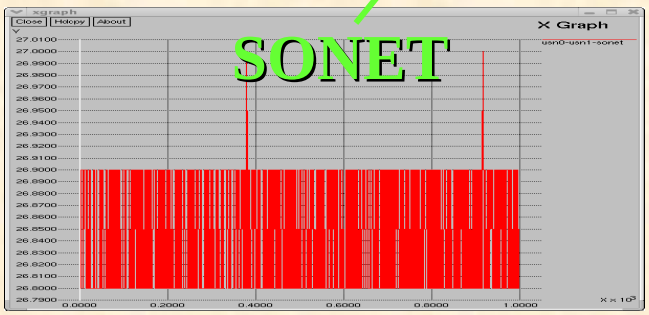
outlier removed

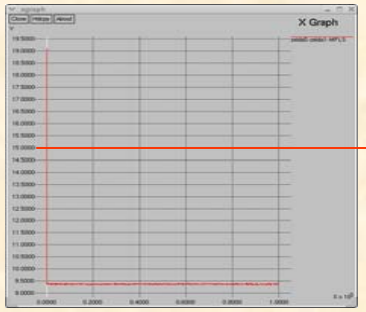


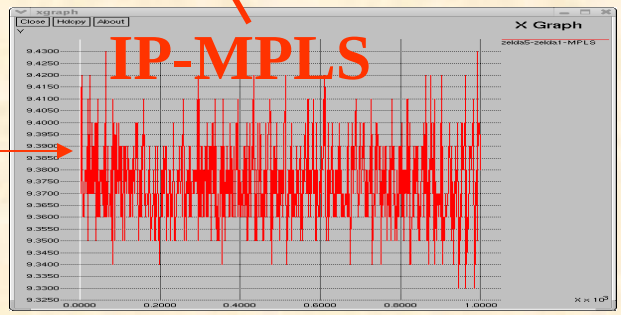
Comparison of VLANs: SONET vs. MPLS tunnels

Measurements are normalized for comparison:









mean time=26.845877ms
percent range: [99.8,100.6]
std_dev (%)= 0.187035

mean time=9.384557ms
percent range:[99.4,203.5]
std_dev (%)= 3.281692

<u>Conclusion</u>
VLANs over SONET have smaller jitter levels

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Composition of VLANs Over Fundamentally different networks

Feasibility and Performance of Composed SONET-MPLS VLANS:

Data-plane unification of dedicated paths over paths provisioned over layers 1 through 3-1

VLANs are typically native to layer-2: other layers need to be moved up/down to implement VLANs:

SONET connections (layer1): VLANs are provisioned using edge switches (E300 in our case)

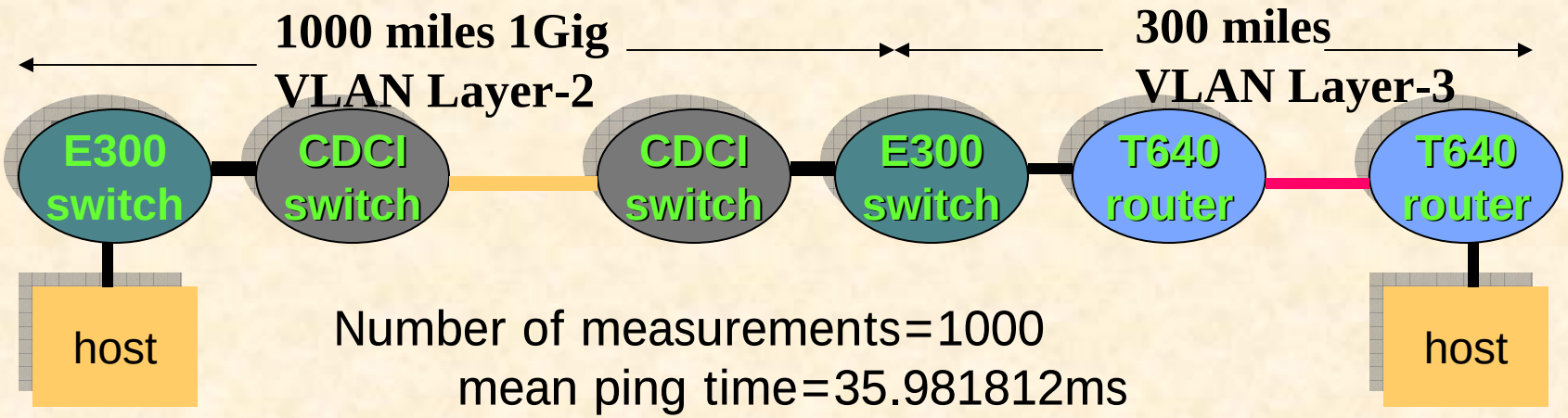
Layer-2 connections – GigE WAN/LAN PHY: VLANs are provisioned natively

IP networks (layer 3) – VLANs are provisioned over MPLS tunnels using IEEE 802.1q – routers may differ as to how they implement this feature

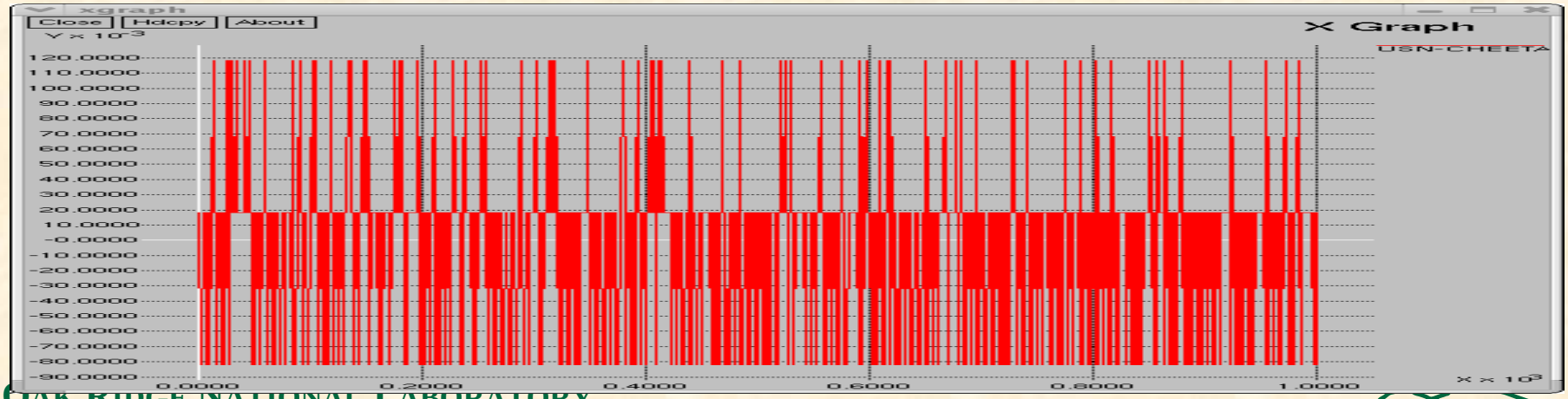
Broader Question: Peering data-paths across networks that provide VLANs over Layer-1 or layer-2 or layer-3

Composed VLAN:

SONET and Layer-3 Channels - Gig 1300 miles

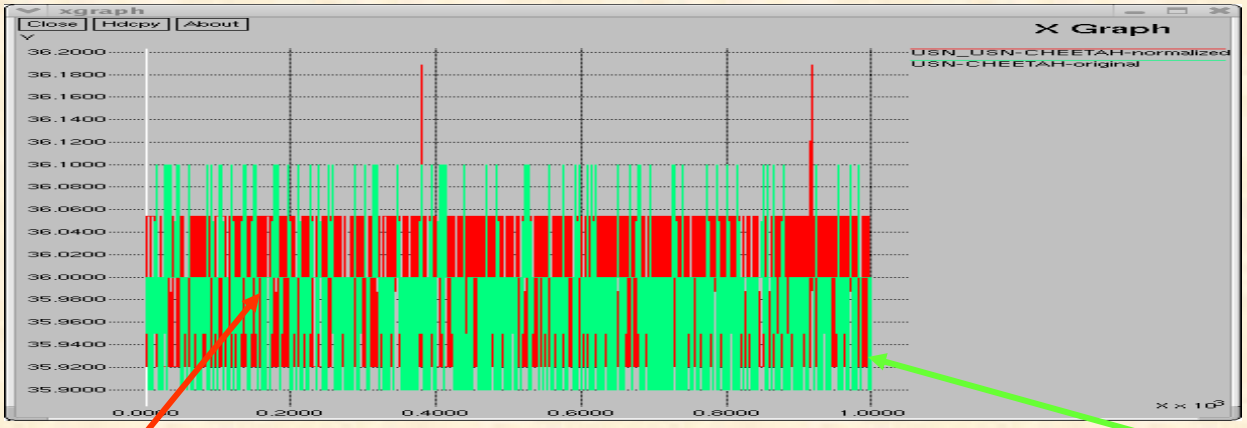


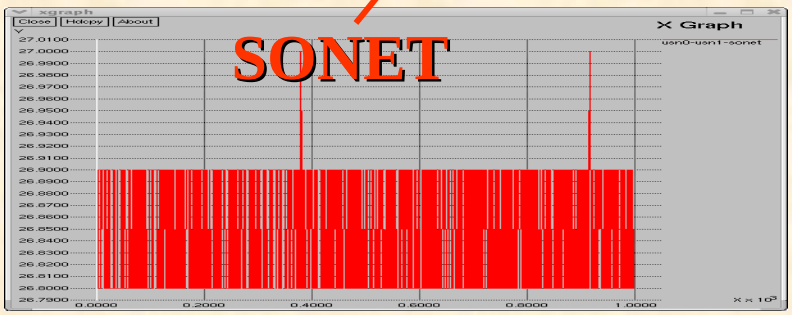
Number of measurements=1000
mean ping time=35.981812ms
percent range: [99.772635,100.328463]
range: [35.900002,36.099998]: 0.199997
std_deviation (percent)= 0.151493

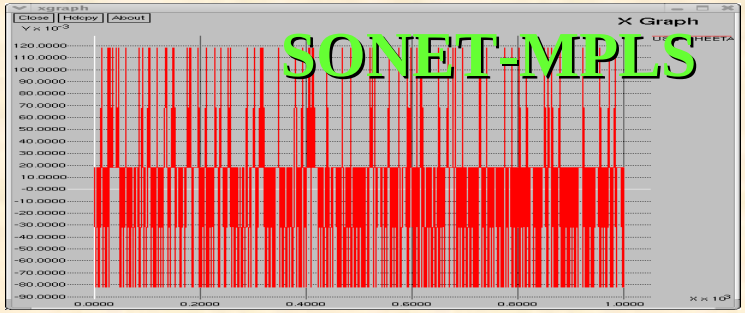


Comparison of VLANs: SONET vs. SONET-MPLS composed tunnels

Measurements are normalized for comparison:







mean time=26.845877ms
percent range: [99.8,100.6]
std_dev (%)= 0.187035

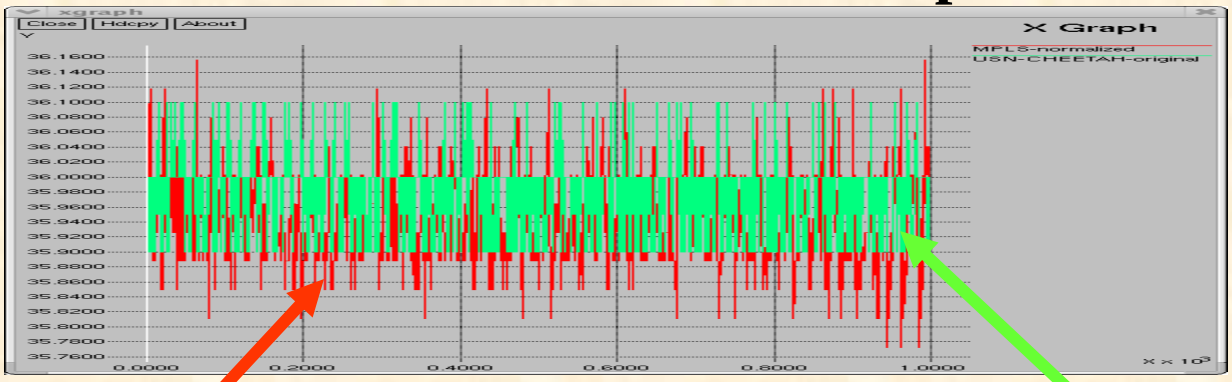
mean ping time=35.981812ms
percent range: [99.8,100.3]
std_dev (%)= 0.151493

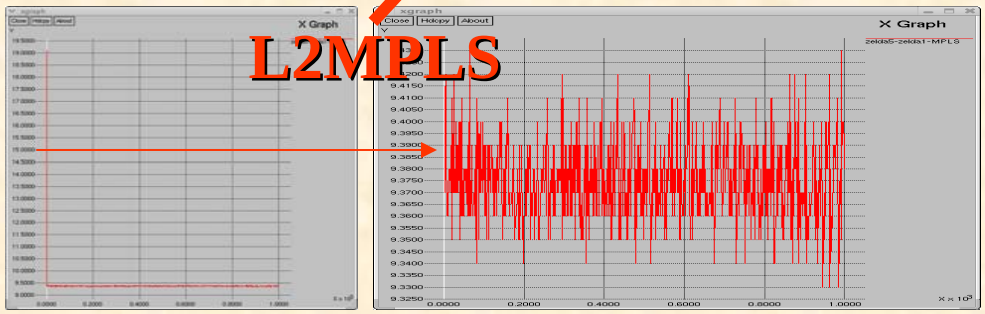
<u>Conclusion</u>
VLANs over SONET have smaller jitter levels

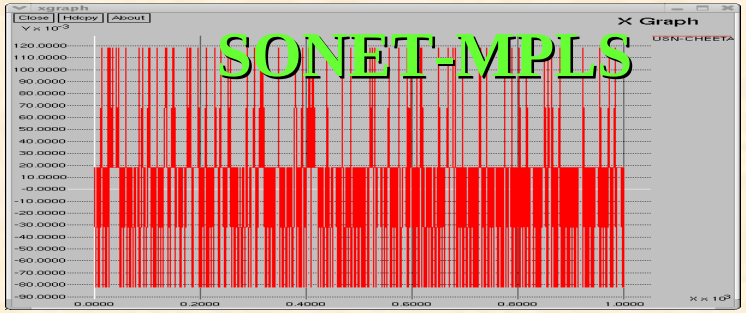
UT-BATTELLE

Comparison of VLANs: L2MPLS vs. SONET-MPLS composed tunnels

Measurements are normalized for comparison:







mean time=9.384557ms
percent range:[99.4,203.5]
std_dev (%)= 3.281692

mean ping time=35.981812ms
percent range: [99.8,100.3]
std_dev (%)= 0.151493

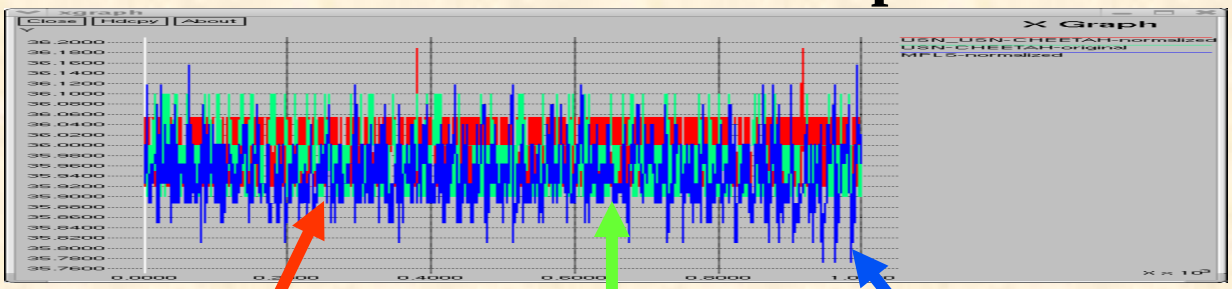
Conclusion

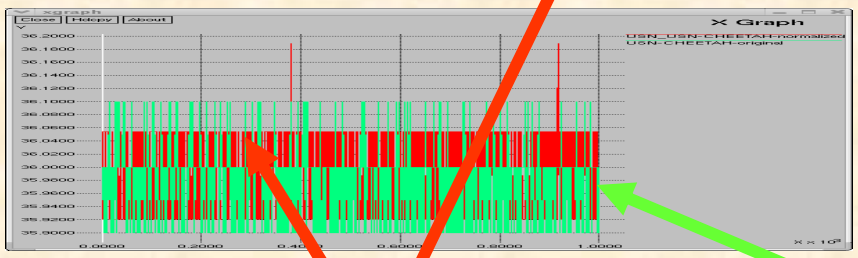
SONET-MPLS composed have smaller jitter levels

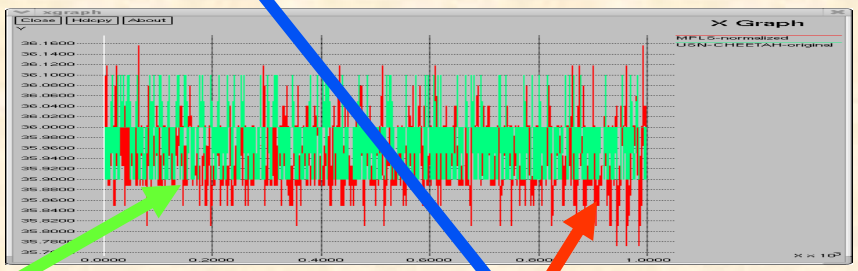
UT-BATTELLE

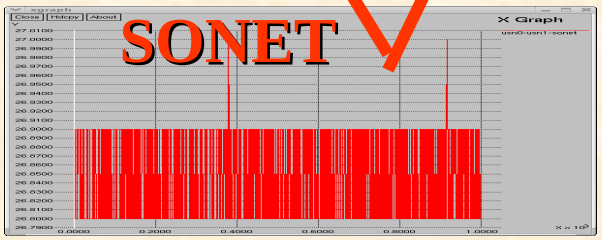
Normalized Comparison of VLANs:
SONET - SONET-MPLS composed – L2MPLS

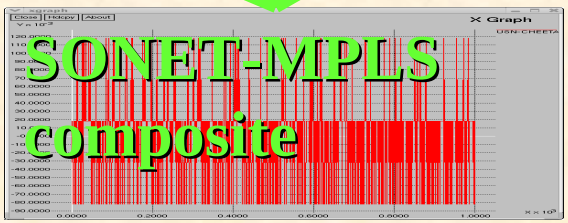
Measurements are normalized for comparison:

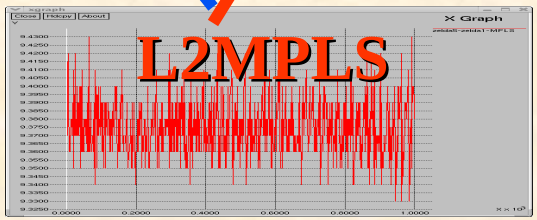












mean time=26.845877ms
std_dev (%)= 0.187035

mean time=35.981812ms
std_dev (%)= 0.151493

mean time=9.384557ms
std_dev (%)= 3.281692

SONET channels have smaller jitter levels

Normalization Framework

Basic Question: We collected measurements on two connections of different lengths and types, how do we objectively compare parameters?

Example: Ping measurements on 1000 mile SONET-VLAN and 300 mile MPLS-VLANS, can we objectively conclude about jitte on such VLANs?

$M_T(d)$ Measurements on path of type *T* of distance *d*

$\hat{M}_T(d)$ Estimates of measurements on path of type T of distance d

$P \odot \hat{M}_T(d)$ Parameters computed using measurements

$$\begin{tikzcd}
M_{T_1}(d_1) \arrow[dr, "\Theta_{T_1}"] & & M_{T_2}(d_2) \arrow[dl, "\Theta_{T_2}"'] \\
& \hat{M}_{T_1}(d) \arrow[d] & \hat{M}_{T_2}(d) \arrow[d] \\
& P \odot \hat{M}_{T_1}(d) & P \odot \hat{M}_{T_2}(d) \arrow[l, "\aleph_P"']
\end{tikzcd}$$

Jitter Comparison on SONET-MPLS VLANs

Basic Question: We collected measurements on two connections of different lengths and types, how do we objectively compare parameters?

$$M_{SONET}(1000) \xrightarrow[\text{scale}]{\Theta_{T_1}} \hat{M}_{SONET}(300) \rightarrow P \odot \hat{M}_{SONET}(300)$$

$$M_{MPLS}(300) \xrightarrow[\text{identity}]{\Theta_{T_2}} \hat{M}_{MPLS}(d) \rightarrow P \odot \hat{M}_{MPLS}(d)$$

$$P \odot \hat{M}_{MPLS}(d) \xrightarrow{\aleph_P} P \odot \hat{M}_{SONET}(300)$$

scale with respect to mean

Another Method

P **- FFT**

$\aleph_P$ **- Identity**

Conclusions:

Status Update of USN and Future Plans

Our Experiments and Analysis of VLANs show:

SONET-VLANs provide:

- Lower levels of jitter both at ping and TCP level

VLANs unify data plane connections over layers 1-3

- data paths of layers 1-3 can be aligned at VLAN level
- composed paths inherit low jitter characteristics of layer 1 components

Future Work:

- Detailed application-level and protocol-level performance evaluation
- Automated methods for VLAN alignment at disparate networks
- Security aspects of VLAN peering