Advanced Performance Measurement for IP and SDN Traffic with Cisco IOS IP Service Level Agreements

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BRKNMS-3043
Agenda

• Introduction
• IPSLA in the Connected Application
• IPSLA Accuracy
• Performance & Scalability
• Cool IPSLA Features & New Probes
• Design Recommendations – Applied IPSLA for Virtualization, SDN & NFV
• Conclusion
Rules of the Game!

- SPARK ROOM!! Ping mgeller@cisco.com
- Silence your phone, pda, pager, mp3 player…
- At CiscoLive! your evaluation is extremely important
- Please remember to wear your badge at all times
- Please visit the World of Solutions

- PLEASE! Ask questions any time
Meet the Engineer

• To make the most of your time at Networkers at Cisco Live 2016, schedule a Face-to-Face Meeting with top Cisco Engineers.

• Designed to provide a "big picture" perspective as well as "in-depth" technology discussions, these face-to-face meetings will provide fascinating dialogue and a wealth of valuable insights and ideas.

• Visit the Meeting Center reception desk located in the Meeting Centre in World of Solutions.
Prerequisites

• Before attending this session, familiarities with Cisco IOS® IP Service Level Agreements (IP SLAs) is essential

• Configuration and generic features will not be covered

• Only new or advanced topics, as well as design recommendations will be covered

• Some familiarity with Virtualization, SDN and NfV
Objectives

- This session targets network performance measurement only
- Understand the internals
- Cool IPSLA Features and New Probes (Cloud & SDN)
- Performance and scalability considerations
- How to get the most of IP SLAs
- Future and IP SLAs strategic vision
This Is Not

- An introduction to IP SLAs
- Recommendations on QoS configuration
- A talk on backend network management applications
- A speculation on upcoming features
- A marketing document
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- Cool IPSLA Features & New Probes
- Design Recommendations – Applied IPSLA for Virtualization, SDN & NFV
- Summary & Take Aways
Reminder

- IP SLAs in an active probing and monitoring feature in Cisco IOS
- Wide protocol and applications coverage: UDP, TCP, ICMP, HTTP, DNS, DHCP, FTP
- Microsecond granularity
- Use it through SNMP or CLI
- Already in Cisco IOS® (available on most platforms and interfaces type)
IP SLA Overview

Applications and Solutions
- ERP/CRM
- VoIP
- Video
- Web Portals
- Web Conf.
- Client-Server
- VPN
- CoS/QoS

Cisco IOS SLAs Functions
- IP SLA Monitoring
- Network Performance Monitoring
- Network Health Assessment
- Edge-to-Edge Network Availability
- Troubleshooting

Cisco IOS IP SLAs Metrics
- Delay
- Packet Loss
- Jitter
- Packet Sequence
- Connectivity
- Path
- Download Time

Cisco IOS IP SLAs Operations
- VoIP
- UDP Jitter
- UDP Echo
- ICMP PathJitter
- ICMP PathEcho
- HTTP
- DNS, DHCP
- TCP Connect
- FTP

Cisco IOS IP SLAs
Secure Cloud Services
Fully Flexible, Modular & Pluggable into Your Existing Infrastructure
NfV Security Services & Securing NfV

- Components:
  - Evolved IP+Optical network architecture
  - DC infra + virtualisation
  - Unified orchestration platform – Openstack focussed
  - Real-time OSS
  - Virtual service “onboarding”
### IP SLA Capability Overview

#### Domain

<table>
<thead>
<tr>
<th>TCP/IP</th>
<th>VoIP</th>
<th>Network Service</th>
<th>MPLS</th>
<th>Video</th>
<th>Cloud &amp; DC</th>
<th>Metro-Ethernet</th>
</tr>
</thead>
<tbody>
<tr>
<td>UDP Jitter</td>
<td>UDP Jitter (+VoIP g711, g729)</td>
<td>HTTP</td>
<td>LSP Ping</td>
<td>Cloud Service Level Monitor</td>
<td>Ethernet Echo (802.1ag)</td>
<td></td>
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<tr>
<td>UDP Echo</td>
<td>VoIP RTP (DSP required)</td>
<td>DNS</td>
<td>LSP Trace</td>
<td>Ethernet Jitter</td>
<td>Ethernet MEP VLAN</td>
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<tr>
<td>UDP Path Echo</td>
<td>VoIP H.323 and SIP Call Setup Delay</td>
<td>DHCP</td>
<td>LSP Auto-Discovery and Auto-Schedule</td>
<td>Auto-Discovery and Auto-Scheduling</td>
<td>Y.1731 on 7600</td>
<td></td>
</tr>
<tr>
<td>TCP Connect</td>
<td>VoIP H.323 and SIP Gatekeeper Delay</td>
<td>FTP</td>
<td>(ECMP Tree Trace)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>ICMP Echo</td>
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<td></td>
</tr>
<tr>
<td>ICMP Path Echo</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICMP Jitter</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

#### Core Value Features

<table>
<thead>
<tr>
<th>Flexible Operation Schedule</th>
<th>SNMP and CLI Set and Get Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT Threshold Alerts + Automatic Reaction Probes</td>
<td>Hourly Aggregate Statistics History (Up to 24hrs)</td>
</tr>
<tr>
<td>QoS Integration (with Engine 3)</td>
<td>Cisco IOS, IOS-XR, and Linux Operating System Support</td>
</tr>
<tr>
<td>Auto IP SLA with Endpoint Auto Discovery and Registration</td>
<td></td>
</tr>
</tbody>
</table>
UDP Jitter Operation

- Measures the delay, delay variation (jitter), corruption, misordering and packet loss by generating periodic UDP traffic.
- One-way results for jitter and packet-loss. If clocks are synchronized and IOS is at least 12.2(T), one-way delay is also measured.
- Detect and report out-of-sequence and corrupted packets.
- Since 12.3(4)T—also with MOS and ICPIF score for voice clarity estimation.
- This operation always requires IPSLA responder.
UDP Jitter—Measurement Example

Each packet contains STx, RTx, ATx, dx and the source can now calculate:

\[ Jitter_{SD} = (RT2-RT1)-(ST2-ST1) = i2-i1 \]
\[ Jitter_{DS} = (AT2-AT1)-((RT2+dt2)-(RT1+dt1)) = i4-i3 \]
Jitter Calculation—Beware!

If you count positive and negative jitter, you are penalized twice. Counting only positive jitter is enough.
UDP Jitter Operation (Example)

- Simulating G.711 VoIP call
- Use RTP/UDP ports 16384 and above, the packet size is 172 bytes (160 bytes of payload + 12 bytes for RTP)
- Packets are sent every 20 milliseconds
- Marked with DSCP value of 8 (TOS equivalent 0x20)

```plaintext
ip sla 1
  udp-jitter 10.52.130.68 16384 \n      num-packets 1000 interval 20
  tos 0x20
  frequency 60
  request-data-size 172
ip sla schedule 1 life forever start-time now
```

A = 20 ms
B = 20 s (1000 x 20 ms)
C = 40 s (60 s - 20 s)
UDP Jitter Example (New CLI)

Differences Between CLIs:

```plaintext
rtr 1
  type jitter dest-ipaddr 10.52.130.68 dest-port 16384 \
      num-packets 1000 interval 20
      request-data-size 172
      tos 20
      frequency 60
rtr schedule 1 life forever start-time now
ip sla monitor 1
  type jitter dest-ipaddr 10.52.130.68 dest-port 16384 \
      num-packets 1000 interval 20
      request-data-size 172
      tos 20
      frequency 60
ip sla monitor schedule 1 start-time now

ip sla 1
  udp-jitter 10.52.130.68 16384 \n      num-packets 1000 interval 20
      request-data-size 172
      tos 20
      frequency 60
ip sla schedule 1 life forever start-time now
```
UDP Jitter Output

Router-1#sh ip sla statistics 1
Round trip time (RTT)   Index 1
   Latest RTT: 1 ms
Latest operation start time: *10:33:11.335 PST Fri Oct 7 2005
Latest operation return code: OK
RTT Values
   Number Of RTT: 20
   RTT Min/Avg/Max: 1/1/4 ms
Latency one-way time milliseconds
   Number of Latency one-way Samples: 20
   Source to Destination Latency one way Min/Avg/Max: 1/1/2 ms
   Destination to Source Latency one way Min/Avg/Max: 1/1/3 ms
Jitter time milliseconds
   Number of Jitter Samples: 19
   Source to Destination Jitter Min/Avg/Max: 4/4/4 ms
   Destination to Source Jitter Min/Avg/Max: 3/3/3 ms
Packet Loss Values
   Loss Source to Destination: 0   Loss Destination to Source: 0
   Out Of Sequence: 0   Tail Drop: 0   Packet Late Arrival: 0
Voice Score Values
   Calculated Planning Impairment Factor (ICPIF): 0
   Mean Opinion Score (MOS): 0
Number of successes: 5
Number of failures: 3
Operation time to live: 3166 sec
UDP Jitter with VoIP MOS Score

- Introduced in Cisco IOS 12.3(4)T—“Advanced” feature set
- Modified jitter operation reports both Mean Opinion Score (MOS) and Calculated Planning Impairment Factor (ICPIF)
- Those results are estimates and should be used for comparison only and should not be interpreted as reflecting actual customer opinions
- Supported Codecs:
  - G.711 A Law (g711alaw: 64 kbps PCM compression method)
  - G.711 mu Law (g711ulaw: 64 kbps PCM compression method)
  - G.729A (g729a: 8 kbps CS-ACELP compression method)
- Note: this is not a real RTP voice stream, but it has the same characteristics. For real RTP stream generation, check IP SLAs’ “VoIP RTP” operation.
VoIP Operation: Sample Configuration

• Operation parameters autoconfigured to simulate a G729a codec
• 1000 packets, interval 20 ms (default values)
• Operation frequency will be randomized between 40 and 60 seconds

ip sla 30
  udp-jitter 192.1.3.2 16001 codec g729a
ip sla group schedule 30 30-31 schedule-period 1
frequency range 40-60 start-time now life forever
IP SLA Video Operation at a Glance

 VO Partners and NMS

• ActionPacked, LiveAction, ServOne
• Collaboration Manager: for CTS traffic (March 2011)
  Cisco Works LMS 4.1 (Apr 2011), 4.0 Patch (~Jan 2011)

Is my network ready for 100 HD Desktop Cameras, 30 IPVSC and a new Telepresence room?

Video Operation (VO)

• One of key IP SLAs operations
• Simulate real video application traffic based on application profiles
• Pre-packaged traffic profiles:
  • IPTV, Tele-Presence, Video Surveillance
• Use case:
  • Pre-deployment assessment
  • Post-deployment trouble shooting
• Platforms:
  • Today: 3K, 4K, 6K, ISR G2, ASR 1K
Summary

• IP SLAs is a Cisco IOS Feature
• Active monitoring with synthetic operations—sending additional traffic in the network.
• Detailed results like availability, delay, loss, and jitter per direction and MOS score.
• Easy to use, available on many platforms.
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IPSLA Accuracy—ICMP Echo Probe

- With unloaded receiver, IPSLA measures 15.0 ms
- With high CPU load on the receiver: 58.5 ms!!

Any System Will Report Wrong Results when Excessive CPU Time Is Spent on the Receiver Between the ICMP Echo Request and Echo Reply
Fortunately, We Have a Solution…
Processing Time Measurement

- When running the responder, we have a clear advantage, because
  - A mechanism to measure the processing time spent on the receiving router is in place, inserting a timestamp when the responder receives and sends the packet
  - Receive timestamp done at interrupt level, as soon as the packet is dequeued from the interface driver; with absolute priority over everything else

- With IPSLA, this mechanism is implemented for both UDP Echo and UDP Jitter operations
UDP Echo Operation (with IPSLA Responder)

Processing Delay on the Source: \( T_{ps} = T_5 - T_4 \)
Processing Delay on the Destination: \( T_{pd} = T_3 - T_2 \)
Round Trip Time Delay: \( T = [...] = T_2 - T_1 + T_4 - T_3 \)

- We have no control of queuing delay on the source and destination, but this is experienced by real traffic too, and must be accounted as such
IPSLA Accuracy: UDP Echo Probe

- With unloaded receiver: 15.0 ms
- With 90% CPU receiver: 15.3 ms

The IPSLA Responder Processing Delay Will Be Subtracted from the Final Results
Absolute Accuracy Tests

- To validate IPSLA’s accuracy, we wanted to compare its results with another measurement device.
- We’ve used the following topology:

![Network Diagram]

Remember Me?

Agilent RouterTester
Measurement Reference

Me too!!

Cisco 7200

RouterTester Measurement

IPSLA Measurement

PacketStorm Impairment Generator

Cisco 7200
Test Results

- Release used: 12.3(7)T Advanced Enterprise on a Cisco 7200 VXR with NPE400
- RouterTester and IPSLA sending packets at the same rate
- All results obtained for delay and jitter are in sync with Agilent’s result at ± 1 ms
- Accuracy is preserved under CPU load, but spikes may happen during high-frequency interrupt events, like writing to NVRAM (write memory)
- Better accuracy is sometimes possible, but is dependant upon implementation details (hardware + IOS image + configuration).
IPSLA Accuracy: ICMP vs. UDP

- As seen before—for RTT accuracy, **always use UDP Echo or jitter with IPSLA responder**
- Only in this case, processing time spent on the sender and responder routers will be subtracted
- Results more accurate regardless of the sender and receiver CPU process load
Summary

- IP SLAs uses a special time stamping mechanism at interrupt level and its accuracy preserved even under high CPU load.

- The absolute tested accuracy is ±1 ms. In other words, when it says 35 ms, it could be somewhere between 34 ms and 36 ms.
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### Cisco IOS IP SLAs Performance: CPU Load by Platform

*(Jitter Probe Running Eng 2+—2000 Active Jitter Oper —Cisco IOS 12.4(PI3)T)*

<table>
<thead>
<tr>
<th>Oper/Second</th>
<th>Pkts/Second</th>
<th>Oper/Minute</th>
<th>2800</th>
<th>2811</th>
<th>2851</th>
<th>2691</th>
<th>3745</th>
<th>3845</th>
<th>3825</th>
<th>1841</th>
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<td>4</td>
<td>200</td>
<td>240</td>
<td>3</td>
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<td>2</td>
<td>3</td>
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<tr>
<td>8</td>
<td>400</td>
<td>480</td>
<td>6</td>
<td>5</td>
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<td>1</td>
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<td>3</td>
<td>4</td>
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<td>5</td>
<td>6</td>
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<tr>
<td>16</td>
<td>800</td>
<td>960</td>
<td>10</td>
<td>9</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>7</td>
<td>8</td>
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<td>20</td>
<td>1000</td>
<td>1200</td>
<td>13</td>
<td>11</td>
<td>4</td>
<td>6</td>
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<td>8</td>
<td>10</td>
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<tr>
<td>24</td>
<td>1200</td>
<td>1440</td>
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<td>13</td>
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<td>4</td>
<td>4</td>
<td>10</td>
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<tr>
<td>28</td>
<td>1400</td>
<td>1680</td>
<td>18</td>
<td>14</td>
<td>6</td>
<td>9</td>
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<td>12</td>
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<td>1920</td>
<td>20</td>
<td>16</td>
<td>7</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>14</td>
<td>15</td>
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<td>2160</td>
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<td>23</td>
<td>14</td>
<td>18</td>
<td>9</td>
<td>9</td>
<td>27</td>
<td>26</td>
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</table>
### Cisco IP SLAs Performance: UDP-Jitter

UDP-Jitter Probe Running Engine 3—Cisco IOS 15.1(4)M

Default Parameters: Frequency (60secs), Request Size (32bytes), Packet Interval (20ms), Number of Packets (10)

<table>
<thead>
<tr>
<th></th>
<th>1921</th>
<th>2921</th>
<th>3925</th>
<th>3945</th>
<th>3945E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations (Total)</td>
<td>1000</td>
<td>2000</td>
<td>3000</td>
<td>4000</td>
<td>5000</td>
</tr>
<tr>
<td>Operations/Second</td>
<td>16.7</td>
<td>33.3</td>
<td>50</td>
<td>66.7</td>
<td>83.3</td>
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<tr>
<td>Packets Per Second</td>
<td>166.7</td>
<td>333.3</td>
<td>500.0</td>
<td>667.0</td>
<td>833.3</td>
</tr>
<tr>
<td>Operations/Min</td>
<td>1000</td>
<td>2000</td>
<td>3000</td>
<td>4000</td>
<td>5000</td>
</tr>
<tr>
<td>CPU Usage</td>
<td>~6%</td>
<td>~8%</td>
<td>~8%</td>
<td>~8%</td>
<td>~1%</td>
</tr>
</tbody>
</table>

Each configuration being different, use those numbers with care: they are only an indication. No SNMP polling were performed to gather the operation results.
IP SLA Performance: UDP-Jitter for VoIP

UDP-Jitter Probe for VoIP (G.729a) running Engine 3: Cisco IOS 15.1(4)M

Default Parameters: Frequency (60secs), Codec Packet Size (32bytes), Codec Interval (20ms), Codec Number of Packets (1000)

<table>
<thead>
<tr>
<th></th>
<th>1921</th>
<th>2921</th>
<th>3925</th>
<th>3945</th>
<th>3945E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations (Total)</td>
<td>150</td>
<td>225</td>
<td>275</td>
<td>400</td>
<td>900</td>
</tr>
<tr>
<td>Operations/Second</td>
<td>2.5</td>
<td>3.75</td>
<td>4.58</td>
<td>6.7</td>
<td>15.0</td>
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<tr>
<td>Packets Per Second</td>
<td>2500.0</td>
<td>3750.0</td>
<td>4583.3</td>
<td>6733.3</td>
<td>15000.0</td>
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<tr>
<td>Operations/Min</td>
<td>150</td>
<td>225</td>
<td>275</td>
<td>400</td>
<td>900</td>
</tr>
<tr>
<td>CPU Usage</td>
<td>~59%</td>
<td>~61%</td>
<td>~43%</td>
<td>~54%</td>
<td>~43%</td>
</tr>
</tbody>
</table>

Each configuration being different, use those numbers with care: they are only an indication.

No SNMP polling were performed to gather the operation results.
Summary

• Under normal conditions and with reasonable targets, a performance issue with IP SLAs is unlikely.

• Memory usage is reasonable, and should never be a problem on any platform.

• Compared to Engine 1, both performance and memory usage have been improved on IPSLA Engine 2 and 2+.
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Template-Based Configuration

- `ip sla auto-measure group wacho
destination ip-address `alist-1` port 16000
type jitter
schedule id `wa-sched`

- `ip sla list ip-address `alist-1`
ip-addresses 1.1.1.1, 2.2.2.2, 3.3.3.3
ip-addresses 10.1.1.1-100
ip-addresses exclude 10.1.1.5, 10.1.1.8

- `ip sla auto-measure schedule `wa-sched`
start-time now
QoS Integration (example)

**Observation:** Need to send the same operation in each class.

**Problem:** Provision the same operation multiple times is lengthy, error prone, and counter productive.

**Solution:** Discover the QoS classes on the outgoing interface and automatically instantiate probes.

```plaintext
class-map voice-traffic
    match dscp EF

class-map data-traffic
    match dscp AFnn

policy auto-measure
    class voice-traffic
        measure type ip-sla group voice-traffic-probes-grp
    class data-traffic
        measure type ip-sla group udp-jitter-probes-grp
```

QoS Class definition

How to measure in each class?
### End-Point Auto Registration

#### CLI Output

```bash
Hub# show ip sla auto discovery operational-state
IP SLAs auto-discovery result:
Discovered end points for group: test
<table>
<thead>
<tr>
<th>IP Address</th>
<th>Client ID</th>
<th>Status</th>
<th>Registered time</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.10.10.2</td>
<td>spoke-1</td>
<td>active</td>
<td>11:33:48 Nov 7 2006</td>
</tr>
<tr>
<td>20.20.20.2</td>
<td>spoke-2</td>
<td>active</td>
<td>11:33:52 Nov 7 2006</td>
</tr>
<tr>
<td>30.30.30.2</td>
<td>spoke-3</td>
<td>active</td>
<td>11:33:52 Nov 7 2006</td>
</tr>
</tbody>
</table>
```

#### CLI Commands

- **ip sla auto group** test
- **measure type** udp-jitter
- **destination** auto-discover  dest-port 5000
- **schedule** now

#### Diagram

```
Hub

ip sla responder auto-register 172.17.0.5

172.17.0.5

10.10.10.2

spoke-1

20.20.20.2

spoke-2

30.30.30.2

spoke-3

ip sla responder auto-register 172.17.0.5
```

- **Hub to Spoke-1**
  - ip sla 34567
  - udp-jitter 10.10.10.2 5000
- **Hub to Spoke-2**
  - ip sla 87422
  - udp-jitter 20.20.20.2 5000
- **Hub to Spoke-3**
  - ip sla 363435
  - udp-jitter 30.30.30.2 5000
IPSLA Application to App Visibility & Control

NBAR2 identifies applications using L3 to L7 information

Reporting Tool
ISRG2 & ASR collect application bandwidth and response time metrics, and export to management tool

App Visibility & User Experience Report
Advanced reporting tool aggregates and reports application performance

Use QoS or PfR to control application network usage to improve application performance

Application Recognition
Perf. Collection & Exporting
Reporting Tool
Control & OPT
New Operation in IP SLA: VO

Uses
- Service Level Agreement (SLA) Monitoring
- Network Assessment
- Multiprotocol Label Switching (MPLS) Monitoring
- Trouble Shooting

Measurement Metrics
- Latency
- Packet Loss
- Network Jitter
- Dist. of Stats
- Connectivity

Operations
- Jitter
- FTP
- DNS
- DHCP
- DLSW
- ICMP
- UDP
- TCP
- HTTP
- LDP
- H.323
- SIP
- RTP
- Video

Defined Packet Size, Spacing COS and Protocol

Cisco IOS Software

IP SLA

Source

MIB Data

Active Generated Traffic to Measure the Network

Destination

IP Server

Responder

Cisco IOS Software
# Video Monitoring Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Purpose</th>
<th>Mechanism</th>
<th>Monitor</th>
<th>User Interface</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive Mon.</td>
<td>Monitor a node</td>
<td>• Clone &amp; truncate pkt • Punt to cpu to process</td>
<td>Loss, delay, jitter</td>
<td>• Config via CLI, SNMP</td>
<td>• Real and synthetic traffic • Statically applied policy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Report via CLI, SNMP, Netflow</td>
<td></td>
</tr>
<tr>
<td>Media Trace</td>
<td>• Monitor end-to-end condition</td>
<td>RSVP. PM collects stat on each node</td>
<td>Loss, delay, jitter</td>
<td>CLI</td>
<td>• Real and synthetic traffic • dynamically applied policy on demand</td>
</tr>
<tr>
<td></td>
<td>• Control resources</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IPSLA</td>
<td>Generate synthetic video traffic for pre- deployment assessment</td>
<td>• Leverage existing IPSLA for media traffic • Need platform assistance</td>
<td>Loss, one way delay, jitter</td>
<td>CLI</td>
<td></td>
</tr>
</tbody>
</table>
TelePresence Jitter Requirements


- Cisco TelePresence has a peak-to-peak jitter target of 10 ms

<table>
<thead>
<tr>
<th>Metric</th>
<th>Target</th>
<th>Threshold 1 (Warning and Downgrade)</th>
<th>Threshold 2 (Call Drop)</th>
</tr>
</thead>
<tbody>
<tr>
<td>End-to-end</td>
<td>10 ms</td>
<td>20 ms</td>
<td>40 ms</td>
</tr>
<tr>
<td>Service Provider</td>
<td>5 ms</td>
<td>10 ms</td>
<td>20 ms</td>
</tr>
</tbody>
</table>
TelePresence Loss Requirements

- Cisco TelePresence is highly sensitive to packet loss, and as such has an end-to-end packet loss target of 0.05%.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Target</th>
<th>Threshold 1 (Warning and Downgrade)</th>
<th>Threshold 2 (Call Drop)</th>
</tr>
</thead>
<tbody>
<tr>
<td>End-to-end</td>
<td>0.05% (1 in 2000)</td>
<td>0.10% (1 in 1000)</td>
<td>0.20% (1 in 500)</td>
</tr>
<tr>
<td>Service Provider</td>
<td>.025%</td>
<td>.05%</td>
<td>.10%</td>
</tr>
</tbody>
</table>
# Cisco TelePresence Traffic Characteristics

<table>
<thead>
<tr>
<th>Resolution</th>
<th>1080p</th>
<th>1080p</th>
<th>1080p</th>
<th>720p</th>
<th>720p</th>
<th>720p</th>
<th>720p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Motion Handling</strong></td>
<td>Best</td>
<td>Better</td>
<td>Good</td>
<td>Best</td>
<td>Better</td>
<td>Good</td>
<td>Lite</td>
</tr>
<tr>
<td>Video per Screen (kbps)</td>
<td>4000</td>
<td>3500</td>
<td>3000</td>
<td>2250</td>
<td>1500</td>
<td>1000</td>
<td>936</td>
</tr>
<tr>
<td>Audio per Microphone (kbps)</td>
<td>64</td>
<td>64</td>
<td>64</td>
<td>64</td>
<td>64</td>
<td>64</td>
<td>64</td>
</tr>
<tr>
<td>Auto Collaborate Video channel</td>
<td>500</td>
<td>500</td>
<td>500</td>
<td>500</td>
<td>500</td>
<td>500</td>
<td>100</td>
</tr>
<tr>
<td>Auto Collaborate Audio channel (kbps)</td>
<td>64</td>
<td>64</td>
<td>64</td>
<td>64</td>
<td>64</td>
<td>64</td>
<td>64</td>
</tr>
<tr>
<td>CTS-1000 / CTS-500</td>
<td>Tx: 4,628</td>
<td>4,128</td>
<td>3,628</td>
<td>2,878</td>
<td>2,128</td>
<td>1,628</td>
<td>1,164</td>
</tr>
<tr>
<td></td>
<td>Rx: 4,756</td>
<td>4,256</td>
<td>3,756</td>
<td>3,006</td>
<td>2,256</td>
<td>1,756</td>
<td>1,292</td>
</tr>
<tr>
<td>CTS-3000 / CTS-3200</td>
<td>Tx: 12,756</td>
<td>11,256</td>
<td>9,756</td>
<td>7,506</td>
<td>5,256</td>
<td>3,756</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rx: 12,756</td>
<td>11,256</td>
<td>9,756</td>
<td>7,506</td>
<td>5,256</td>
<td>3,756</td>
<td></td>
</tr>
<tr>
<td>+ 20% for Layer 2-4 overhead</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTS-1000 / CTS-500 max bandwidth (kbps)</td>
<td>Tx: 5,554</td>
<td>4,954</td>
<td>4,354</td>
<td>3,454</td>
<td>2,654</td>
<td>1,954</td>
<td>1,397</td>
</tr>
<tr>
<td>includes Layer 2-4 overhead</td>
<td>Rx: 5,707</td>
<td>5,107</td>
<td>4,507</td>
<td>3,607</td>
<td>2,707</td>
<td>2,107</td>
<td>1,550</td>
</tr>
<tr>
<td>CTS-3000 / CTS-3200 max bandwidth (kbps)</td>
<td>Tx: 15,307</td>
<td>13,507</td>
<td>11,707</td>
<td>9,007</td>
<td>6,307</td>
<td>4,507</td>
<td></td>
</tr>
<tr>
<td>includes Layer 2-4 overhead</td>
<td>Rx: 15,307</td>
<td>13,507</td>
<td>11,707</td>
<td>9,007</td>
<td>6,307</td>
<td>4,507</td>
<td></td>
</tr>
</tbody>
</table>

## Optional Add-On Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>30fps Auto Collaborate (kbps)</th>
<th>+ 20% for Layer 2-4 overhead</th>
<th>SD Interoperability or WebEx Engage Video Channel</th>
<th>+ 20% for Layer 2-4 overhead</th>
<th>SD Interoperability Audio Channel</th>
<th>+ 20% for Layer 2-4 overhead</th>
</tr>
</thead>
<tbody>
<tr>
<td>30fps Auto Collaborate (kbps)</td>
<td>3,500</td>
<td>4,200</td>
<td>704</td>
<td>845</td>
<td>64</td>
<td>922</td>
</tr>
<tr>
<td>CTRS Recording in CIF (kbps)</td>
<td>704</td>
<td>+ 20% for Layer 2-4 overhead</td>
<td>704</td>
<td>+ 20% for Layer 2-4 overhead</td>
<td>64</td>
<td>+ 20% for Layer 2-4 overhead</td>
</tr>
<tr>
<td>SD Interoperability or WebEx Engage Video Channel</td>
<td>704</td>
<td>+ 20% for Layer 2-4 overhead</td>
<td>704</td>
<td>+ 20% for Layer 2-4 overhead</td>
<td>64</td>
<td>+ 20% for Layer 2-4 overhead</td>
</tr>
<tr>
<td>SD Interoperability Audio Channel</td>
<td>64</td>
<td>+ 20% for Layer 2-4 overhead</td>
<td>64</td>
<td>+ 20% for Layer 2-4 overhead</td>
<td>64</td>
<td>+ 20% for Layer 2-4 overhead</td>
</tr>
</tbody>
</table>
Is my network ready for 100 HD Desktop Cameras, 30 IPVSC and a new Telepresence room?

- Convenient for pre-deployment assessment, pre-event testing and post-event troubleshooting.
  - More bandwidth needed? Deploy PfR?
  - QoS needed?
- Fully integrated with IPSLA control and scheduling framework
- Extension to current IPSLA CLI and MIB interface to allow easy integration with NMS products
IPSLA Video Operation
Embedded Traffic Simulator

- IPSLA known in industry for jitter, ICMP, etc. probes
- Most probes measure experience without affecting user traffic (hopefully)
- Need traffic to stress test network
- IPSLA VO provides
  - Realistic representation of arbitrary video (RTP) traffic
  - Packet sizes, burstiness, traffic rate, etc.
  - pre-packaged profiles:
    - IPTV, Video Surv, CTS
    - Extensible via data file
  - Custom profile generation from packet capture
Pre-Deployment Planning

- **Objective**
  Enable clientless deployment and capacity planning
  - How many streams at bandwidth x at this time of day can we expect to support
  - What delay/loss impact does the addition of an extra stream at bandwidth X

- **Solution Value**
  Clientless pre-deployment and provisioning for network readiness assessment and traffic modeling

router(config) #

ipsladev3750e-3(config-ip-sla)#video ?
  Hostname or A.B.C.D  Destination IP address or hostname

ipsladev3750e-3(config-ip-sla)#video 192.168.1.4 ?
  <1-65535>  Port Number

ipsladev3750e-3(config-ip-sla)#video 192.168.1.4 4336 ?
  source-ip  Source address

ipsladev3750e-3(config-ip-sla)#video 192.168.1.4 4336 source-ip
  192.168.1.3 ?
  source-port  Source Port

```
router(config)#

ipsladev3750e-3(config-ip-sla)#$6 source-ip 192.168.1.3
source-port 3228 ?
  profile  traffic profile type to be configured

ipsladev3750e-3(config-ip-sla)#$p 192.168.1.3 source-port 3228 profile ?
  IPTV  IP Television traffic (2.6 Mbps)
  IPVSC IP video surveillance camera traffic (2.2 Mbps)
  TELEPRESENCE Cisco Telepresence 1080P traffic (6.6Mbps)

ipsladev3750e-3(config-ip-sla)#$p 192.168.1.3 source-port 3228 profile IPVSC
```

IP SLA Video Show Configuration

ipsladev3750e-3#show ip sla configuration 111
IP IP SLAs Infrastructure Engine-III
Entry number: 111
Owner:
Tag:
Operation timeout (milliseconds): 5000
Type of operation to perform: video
Video profile name: IPVSC
Video duration (seconds): 20
DSCP: cs5
Target address/Source address: 192.168.1.4/192.168.1.3
Target port/Source port: 4336/3228
Vrf Name:
Control Packets: enabled
Schedule:
  Operation frequency (seconds): 900  (not considered if randomly scheduled)
  Next Scheduled Start Time: Start Time already passed
  Group Scheduled: FALSE
  Randomly Scheduled: FALSE
  Life (seconds): 3600
  Entry Ageout (seconds): never
  Recurring (Starting Everyday): FALSE
  Status of entry (SNMP RowStatus): Active
Threshold (milliseconds): 5000
Distribution Statistics:
  Number of statistic hours kept: 2
  Number of statistic distribution buckets kept: 1
  Statistic distribution interval (milliseconds): 20
Enhanced History:
IP SLA Video Show Statistics

ipsladev3750e-1#show ip sla statistics 1
IPSLAs Latest Operation Statistics

IPSLA operation id: 1
Type of operation: video
Latest operation start time: 10:50:53 PST Fri Feb 25 2011
Latest operation return code: OK
Packets:
   Sender Transmitted: 2034
   Responder Received: 1994
Latency one-way time:
   Number of Latency one-way Samples: 1894
   Source to Destination Latency one way Min/Avg/Max: 0/29/31 milliseconds
   NTP sync state: SYNC
Inter Packet Delay Variation, RFC 5481 (IPDV):
   Number of SD IPDV Samples: 1847
   Source to Destination IPDV Min/Avg/Max: 0/1/3 milliseconds
Packet Loss Values:
   Loss Source to Destination: 60
   Out Of Sequence: 33
Number of successes: 1
Number of failures: 0
Operation time to live: 3578 sec
# IPSLA-VO Platforms, Image, License Details

<table>
<thead>
<tr>
<th>Platform</th>
<th>Sender Requirements</th>
<th>Responder Requirements</th>
<th>Starting from Image</th>
<th>License Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cisco Catalyst 3k</td>
<td>No platform-specific requirement</td>
<td>No platform-specific requirement</td>
<td>12.2(58)SE</td>
<td>IPBase</td>
</tr>
<tr>
<td>Cisco Catalyst 4k</td>
<td>SUP-7E</td>
<td>SUP-7E, SUP-6E</td>
<td>15.1(1)G</td>
<td>IPBase</td>
</tr>
<tr>
<td>Cisco ISR G2</td>
<td>PVDM-3 DSP, 3900, 2900</td>
<td>No DSP requirement, 3900, 2900, 1900,800</td>
<td>15.2(2)T</td>
<td>UCk9</td>
</tr>
</tbody>
</table>
voice-card 0
  voice-service dsp-reservation 0
!
license boot module c2900 technology-package uck9
!
interface GigabitEthernet0/0
  ip address 10.4.38.106 255.255.0.0
!
ip sla responder
ip sla 5
  video 1.3.38.130 2080 source-ip 10.4.38.106 source-port 3081 profile CTS-1080P-Best
  emulate source 10.4.86.177 9200 GigabitEthernet0/0
  duration 300
  dscp af41
  reserve dsp
  frequency 3600
ip sla schedule 5 life forever start-time now
ip sla 7
  video 1.3.38.130 2080 source-ip 10.4.38.106 source-port 3082 profile CTS-720P-Better
  duration 500
  frequency 1800
ip sla schedule 7 recurring start-time 21:30
!
ntp server 10.4.38.100
## WebEx Traffic Profiles for ISR

<table>
<thead>
<tr>
<th>Webex profile name</th>
<th>Resolution to configure in IPSLA VO</th>
<th>Typical frame rate (fps)</th>
<th>Averaging window size (ms)</th>
<th>Bit rate (kbps)</th>
<th>I-frame max size (kilobytes)</th>
<th>I-frame refresh interval (seconds)</th>
<th>RTP average size (total packet, bytes)</th>
<th>Encoder buffer control</th>
</tr>
</thead>
<tbody>
<tr>
<td>90p</td>
<td>QCIF</td>
<td>5</td>
<td>1333</td>
<td>72</td>
<td>5</td>
<td>27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>180p</td>
<td>CIF</td>
<td>10</td>
<td>667</td>
<td>215</td>
<td>13</td>
<td>27</td>
<td>1200</td>
<td>shaped</td>
</tr>
<tr>
<td>360p</td>
<td>4CIF</td>
<td>24</td>
<td>333</td>
<td>580</td>
<td>38</td>
<td>27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>720p</td>
<td>720p</td>
<td>30</td>
<td>267</td>
<td>2200</td>
<td>100</td>
<td>21</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ISR: IPSLA-VO Emulates Endpoint Traffic

ISR-G2#show ip sla config [x]
Input-interface: GigabitEthernet1/0
Emulate source address: x
Emulate source port: a

The ISR-G2 supports this interface emulation.
ISR: IPSLA-VO Configuration & Stat Differences
ISR uses some additional config & Stat fields than Cat3K and Cat4K

- **ISR-G2#show ip sla config [x]**
  - Input-interface: GigabitEthernet1/0
  - Emulate source address: 10.5.1.1
  - Emulate source port: 2223
  - Reserve Dsp: disabled

- **ISR-G2#show ip sla statistics [x]**
  - Number of Received Bytes: 31607647
  - Average Received Bit Rate: 4214352

- **ISR-G2 → Cat4K works OK!!**
- **ISR-G2 → Cat3K displays Zeros as Cat3K doesn’t measure this metric.**

 ISR#show ip sla statistics [x] Number of Received Bytes: 0 Average Received Bit Rate: 0
# Pre-Packaged and Custom Profiles

<table>
<thead>
<tr>
<th>Platform</th>
<th>Pre-Packaged Profile</th>
<th>Support for Custom Profiles</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cisco Catalyst 3k</strong></td>
<td>Telepresence&lt;br&gt;IPTV&lt;br&gt;IPVSC</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Cisco Catalyst 4k</strong></td>
<td>Telepresence&lt;br&gt;IPTV&lt;br&gt;IPVSC</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>CTS-1080P-Best&lt;br&gt;CTS-1080P-Better&lt;br&gt;CTS-1080P-Good&lt;br&gt;CTS-720P-Best&lt;br&gt;CTS-720P-Better&lt;br&gt;CTS-720P-Good&lt;br&gt;CTS-720P-Lite</td>
<td></td>
</tr>
</tbody>
</table>
Generating IPVSC Traffic Using ISR

(1) Custom IPVSC profile parameters;
   ip sla profile video IPVSC
   endpoint custom
   description Cisco 4000 HD Camera
   resolution 1080P
   frame rate 30
   bitrate maximum 4000
   bitrate window-size 167
   frame intra size maximum 100
   frame intra refresh interval 1
   rtp size average 1300
   rtp buffer output shaped
   content single-person

(2) Traffic characteristics
   BW ≈ 3.2Mbps
IPS LA VO System Flow

Generator

Responder

PI

PD

PD

PI

ctrl msg (start)

ack

start sink

success

update statistics

update statistics

TX statistics

stop sink

entire stat

ctrl msg (request stat)

test packet

test packet

start

stop

Generator

Responde r

0x0

0x0

0x0

0x0
Debugging Commands & Steps

Available DEBUG commands:

Sender debug

- ipsladev3750e-3#debug ip sla trace
- ipsladev3750e-3#debug ip sla error

- This will show both IP SLA debug and platform debug.
- Basic familiarity with IP SLA debug is expected

Responder Debug

- ipsladev3750e-3#debug ip sla trace 0
- ipsladev3750e-3#debug ip slaerror 0
IP SLAs—MPLS Health Monitor

- Automatically create and delete IP SLAs LSP ping or LSP traceroute operations based on network topology

- Works on the MPLS L3 layer, under the IP layer. Discovers MPLS issues even when IP routing is working ok.

- Dramatically reduces troubleshooting time, and cost associated to maintenance of MPLS networks.

- Other PEs are discovered using BGP next-hop, and operations configured accordingly.

- Requires 12.2(27)SBC and later.

- New capability for Metro Ethernet on 7600: Y.1731
Cisco IP SLAs
Performance Management Extensions (Y.1731 ...)

- Cisco IP SLAs Embedded Policy Management
  - Scheduling Automation / Policy Alerts / Data Collection
- In-band Performance Management Tool for Ethernet
  - Delay, Delay Variation and Packet Loss measurement
  - Built in CFM principles
- Automatic Discovery of Probe Endpoints
  - Using entries on CFM CCM database
Y.1731 Performance Monitoring

• Supported Features
  • Two-way delay measurement
  • One-way delay measurement
  • Single-ended loss measurement

• Unsupported Features
  • Dual-ended loss measurement
  • Meant only for point-to-point scenarios
  • Allows per CoS delay or loss measurements
Agenda

• Introduction
• IPSLA in the Connected Application
• IPSLA Accuracy
• Performance & Scalability
• Cool IPSLA Features & New Probes
• Design Recommendations – Applied IPSLA for Virtualization, SDN & NFV
• Summary & Take Aways
“Reasonableless Test”

• Don’t overdo it, your metrics must be:
  • Attainable
  • Measurable
  • Relevant
  • Controllable
  • Mutually Acceptable
  • Understandable
  • Cost Effective

• Use a limited but relevant number of indicators.

• Better is the enemy of good: good is good enough.
### Typical SLA Requirements

<table>
<thead>
<tr>
<th>Traffic Type</th>
<th>Maximum Packet Loss</th>
<th>Maximum One-Way Latency</th>
<th>Max. Jitter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VoIP</strong> (land line quality)</td>
<td>1 %</td>
<td>120 ms</td>
<td>30 ms</td>
</tr>
<tr>
<td><strong>Video-conferencing</strong></td>
<td>1 %</td>
<td>200 ms</td>
<td>50 ms</td>
</tr>
<tr>
<td><strong>Streaming video</strong> (one way video)</td>
<td>2 %</td>
<td>5 s</td>
<td>N/A (assuming the receive buffer is large enough)</td>
</tr>
</tbody>
</table>
# Real-time vs. Periodic Reporting

<table>
<thead>
<tr>
<th>Real-Time Reporting</th>
<th>Periodic Reporting</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Confirmation of status</td>
<td>▪ Historical reports</td>
</tr>
<tr>
<td>▪ Potential problems</td>
<td>▪ Objectives vs. Estimates</td>
</tr>
<tr>
<td>▪ Notification</td>
<td>▪ Anticipation: potential impact, things to avoid</td>
</tr>
<tr>
<td>▪ Nature of problem</td>
<td>▪ Change in service levels</td>
</tr>
</tbody>
</table>
# Cisco IOS IPSLA Uses and Metrics

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Data Traffic</th>
<th>VoIP</th>
<th>Service Level Agreement</th>
<th>Availability</th>
<th>Streaming Video</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimize packet loss</td>
<td>Minimize delay, packet loss, jitter</td>
<td>Measure delay, packet loss, jitter</td>
<td>Connectivity testing</td>
<td>Minimize delay, packet loss</td>
<td></td>
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<td>Maximize bandwidth</td>
<td>One-way</td>
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<td>Verify Quality of Service (QoS)</td>
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<th>Measurement</th>
<th>IP SLAs</th>
<th>MOS Voice Quality Score</th>
<th>Jitter</th>
<th>Packet loss</th>
<th>Latency</th>
<th>Enhanced accuracy</th>
<th>NTP</th>
<th>Connectivity tests to IP devices</th>
<th>Jitter</th>
<th>Packet loss</th>
<th>Latency</th>
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<tr>
<td>Latency</td>
<td>Packet loss</td>
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<td>per QoS</td>
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</table>
Secure Services Enablement

Policy  Orchestration  Analytics

Programmability  Network  Intelligence
Conventional Services Model

Remote Site

Enterprise A
Centralized Services Branch

Internet

Managed & Unmanaged Appliances

Firewall
VPN
Web Sec
WaaS
Email
VoIP

MPLS
VPN

User 1
User 50
User 51
User X

Enterprise A
NY Branch

Managed CE Routers

Enterprise A
LA Branch

Managed & Unmanaged Appliances

Conventional Services Model

Internet

Remote Site

Enterprise A
Centralized Services Branch

Firewall
VPN
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Email
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MPLS
VPN

User 1
User 50
User 51
User X

Enterprise A
NY Branch

Managed CE Routers

Enterprise A
LA Branch

Managed & Unmanaged Appliances
New SDN Service Opportunities

Virtual Branch

REST

Enterprise A “Virtual Branch”

3rd-Party VNFs/Apps
LISP/CSR
IPS
DDoS
ISE
vMS Orchestration
KVM / ESXi

Managed CE Routers

Internet

Remote Site

MPLS

VPN

CLI, OnePK API, Openflow

Managed CE Routers

Enterprise A NY Branch

User 51

User X

User 1

User 50

Enterprise A LA Branch

Cisco SmartLicense
VNF “PAYGO” server

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IPSLA Triggers vMS Events

Multi-vendor service orchestrator for existing and future networks

Single pane of glass for:
- L2-L7 networking
- Hardware Devices
- Virtual Appliances
- OpenFlow Switches

Tail-F Network Control System provides abstractions based on
- Data models
- Transactions

Sold to service providers
Perpetual license
SDN Controller Visibility Application
SDN Controller: QoS Management Application
“Per Tenant Elastic Services”

- 3rd-Party VNFS
- IPS
- LISP (CSR)
- WaaS
- DDoS
- DHCP/DNS
- "vMS" Orchestration
- "vMS" Orchestration
- Hypervisor (KVM/ESXi)
- Compute

**REST**

- Campus Controller (SDNaaS)
- ISE
- VPN (ASA)
- FW (ASA)
- ESA
- WSA

**VPN Connectivity and VM Lifecycle Management**

- MPLS VPN

**Opensource and/or Proprietary Hypervisors**

- Elastic Services & IPSLA

**Align with Existing Service Platforms (HCS, Private Cloud)**
Brings up Compute and Storage. Installer is used.

Used for provisioning of the chain service, Interface for automation & for OSS system.

Open Daylight receives attack information out of the network, reprograms the network and DefensePro App to Mitigate automatically.

Admin to book the service, triggers the Spin up of the chain.

Orchestration

REST/UI

Controller, Detectors

OpenDayLight

Portal

Orchestration Plugin

TeraVM

Attack Gen

radware

vDP Perimeter Protection

vDP+vFW+vIPS

DCI Router

BRKNMS-3043

OpenDayLight

Receives attack information out of the network, reprograms the network and DefensePro App to Mitigate automatically.

VRF Green

VRF Red

VRF Blue

www

SP Backbone

Data Center

“Hosting”

Customer Network 1

Customer Network 2

vDP Network & Application DDoS Protection

TeraVM

Used for provisioning of the chain service, Interface for automation & for OSS system.

www

SP Backbone
Applying IPSLA To The Virtual Enterprise

- Nexus 1000V
  - Distributed switch
  - NX-OS consistency
- ASA 1000V
  - Edge firewall, VPN
  - Protocol Inspection
- vWAAS
  - WAN optimization
  - Application traffic
- CSR 1000V
  - WAN L3 gateway
  - Routing and VPN
- Ecosystem
  - Citrix NetScaler VPX virtual ADC
  - Imperva Web App. Firewall

Multi-Hypervisor (VMware, Microsoft*, RedHat*, Citrix*)

vPath
VXLAN
Nexus 1000V

Virtualized/Cloud Data Center

WAN Router
Switches
Servers

Tenant A
Zone A

Cloud Services Router 1000V

Zone B

WAN Router

Citrix NetScaler VPX
Imperva SecureSphere WAF
vWAAS
ASAv Cloud Firewall
Cisco Virtual Security Gateway

Virtual Enterprise

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Typical N1Kv based Cloud Deployment

Cloud Service Level Monitoring probe runs here
Use case 1: Cloud Service Level Monitor

- IPSLA cloud service level monitor (CSLM) probe
  - Destination address is IP address on one of virtual m/c
  - Add IPSLA responder functionality in VEM

- Cloud Service Level Monitor probe monitors:
  - Latency, jitter, packet loss between R1 and VEM
  - VM location information (which VEM it is located)
  - Current resource levels (CPU, memory) on host which is hosting that VM

- What is use?
  - Gives tenant capability to monitor the SLA of cloud where their service is hosted.
Use case 2: Cloud Infra performance monitor

- Measure resource utilization on each VEM from VSM or R1
  - IPSLA queries VSM about VEMs it is managing
  - IPSLA creates CSLM probe for each VEM and measures rtt/jitter/packet loss data and resource utilization
  - Display comparative results for each VEM

- What is use?
  - Centralized view of resource allocation and performance
  - Useful for moving VMs for load balancing when probe is run from VSM
  - May be used to device application on VSM that move VMs dynamically based on resource levels
Use case 3: inter VEM performance monitor

• Measure inter VEM performance from VSM
  • Probes are configured and initiated on VSM but they actually measure performance between VEMs (latency, jitter, packet loss)
  • Two types of probes
    • Layer 3: use IP address of VMs on each VEM as source and destination
  • What is use?
    • Assist network operator in assigning VMs for particular application
# Video Per-Application Targets

## General Guidelines

<table>
<thead>
<tr>
<th>Application</th>
<th>Latency</th>
<th>Jitter</th>
<th>Loss (VoD)</th>
<th>Loss (Live)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Streaming Video</td>
<td>&lt; 1000ms</td>
<td>&lt; 100 ms</td>
<td>&lt; 0.1%</td>
<td>&lt; 0.05%</td>
</tr>
<tr>
<td>Video Conferencing</td>
<td>&lt; 150 ms</td>
<td>&lt;30 ms</td>
<td>NA</td>
<td>&lt; 0.10%</td>
</tr>
<tr>
<td>TelePresence</td>
<td>&lt; 150 ms</td>
<td>&lt;10 ms</td>
<td>NA</td>
<td>&lt; 0.05%</td>
</tr>
<tr>
<td>Digital Signage</td>
<td>&lt; 1000 ms</td>
<td>&lt; 100 ms</td>
<td>&lt; 0.1%</td>
<td>0%</td>
</tr>
<tr>
<td>IPTV</td>
<td>&lt; 1000 ms</td>
<td>&lt; 100 ms</td>
<td>&lt; 0.1%</td>
<td>0%</td>
</tr>
<tr>
<td>Video Surveillance</td>
<td>&lt; 1000 ms</td>
<td>&lt; 100 ms</td>
<td>&lt; 0.1%</td>
<td>&lt; 0.05%</td>
</tr>
</tbody>
</table>
Class of Service

• One operation instance to measure each class of service

• Same operation type for all classes

• Traffic coloring from within IP SLA with TOS/DSCP configuration

• Bear in mind the corner case with locally generated and colored traffic on some distributed platforms

• Workaround is to use a Shadow Router
IP SLA Operations with IPv6 & VRF Support

- dns
- ftp
- http
- icmp-echo
- path-echo
- path-jitter
- tcp-connect
- udp-echo
- udp-jitter
Why Use a Shadow Router?

• A **shadow router** is a dedicated box for IP SLAs. But why?

  • If your Provider Edge (PE) router is already overloaded (> 60% CPU at interrupt level)

  • If your PE lacks memory

  • If your PE is a distributed platform

  • If you want to separate measurement from forwarding

  • Upgrade freely for the latest and greatest IP SLA features without disturbing the traffic, then…

• Use a **shadow router** (router dedicated to IPSLA)
Shadow Router Configuration

- A shadow router is typically a dedicated router located near a ideal measurement point.
- A point-of-presence (POP) is an ideal location.
- It can be connected to the PE via various methods: direct IP connection, tunnels, dot1q
How to Probe?

- Full mesh
- Full mesh between same-customer CPEs
- Partial mesh
- Composite SLAs
Full Mesh

- Number of operations is proportional to the square of the number of nodes

<table>
<thead>
<tr>
<th>Nodes</th>
<th>Operation</th>
</tr>
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<tbody>
<tr>
<td>2</td>
<td>1</td>
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<tr>
<td>3</td>
<td>3</td>
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<tr>
<td>4</td>
<td>6</td>
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<td>5</td>
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<td>7</td>
<td>21</td>
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<td>8</td>
<td>28</td>
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<td>...</td>
<td>...</td>
</tr>
<tr>
<td>100</td>
<td>4950</td>
</tr>
</tbody>
</table>

Does not scale.
Full Mesh CE-to-CE [Example]

Accurate: direct measurement from end-to-end, best user-perspective view

Expensive: for n nodes, requires n(n-1)/2 operations

In certain cases, it might be difficult to poll the results with SNMP on the CE
Partial Mesh

- Full mesh is not always desirable, while partial mesh dramatically reduces the number of operations.
- Measurement points can be based on traffic matrix, traffic importance.
- For instance, try a coverage objective for 80% of the traffic.
- To build a traffic matrix, use NetFlow.

![Network diagram with nodes: Amsterdam, London, San Jose, Raleigh, Brussels, Paris]
Composite SLA for Delay [Example]

**Easy:** Total delay can be easily calculated by adding the measured delay along the path.

**Flexible:** You can split the measurement for Core Edge, and total.

Measurements are less accurate, as each measurement carry its own error tolerance (typically ± 1 ms per measurement).
Summary

- PE-PE, PE-CE or CE-CE, full-mesh or partial-mesh is all your decision!

- IPSLA can run on almost any existing Cisco router. When this is not possible/desirable then a shadow router is recommended

- Composite SLAs are a good idea while end-to-end jitter results are not required
Agenda

• Introduction
• IPSLA in the Connected Application
• IPSLA Accuracy
• Performance & Scalability
• Cool IPSLA Features & New Probes
• Design Recommendations – Applied IPSLA for Virtualization, SDN & NFV
• Summary & Take Aways
References

• Cisco IOS IPSLA home page
  • http://www.cisco.com/go/ipsla

• For questions related to Cisco IP SLAs that cannot be handled by the Technical Assistance Center (TAC), feel free to write an email to:
  • ask-ipsla@cisco.com
Summary and Conclusion

- IPSLA is a Cisco IOS feature available today to actively measure and report many network metrics.

- It is easy to use, and is supported by many existing network management applications.

- We also have MPLS OAM, Gatekeeper Registration, H323/SIP Call Setup operation, and many other new features.

- Stay tuned. We have an ambitious roadmap for new features like better voice measurements, multicast, Ethernet OAM and we’re always listening your suggestions!
Recommended Reading

**Network Management:** Accounting and Performance Strategies

Benoit Claise, CCIE® No. 2888
Ralf Walter

ciscopress.com


**Deploying IP QoS for Multiservice Networks**

Case Studies and Real-World Deployments

John Evans & Clarence Filsfils

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- Walk-in Self-Paced Labs
- Lunch & Learn
- Meet the Engineer 1:1 meetings
- Related sessions
# Internet of Things (IoT) Cisco Education Offerings

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Cisco Certification</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEW! IMINS2</td>
<td>An associate level instructor led training course designed to prepare you for the CCNA Industrial certification</td>
<td>CCNA® Industrial</td>
</tr>
</tbody>
</table>

- **Managing Industrial Networks with Cisco Networking Technologies (IMINS)**
  - This curriculum addresses foundational skills needed to manage and administer networked industrial control systems. It provides plant administrators, control system engineers and traditional network engineers with an understanding of the networking technologies needed in today's connected plants and enterprises.
  - Cisco Industrial Networking Specialist

- **Control Systems Fundamentals for Industrial Networking (ICINS)**
  - For IT and Network Engineers, covers basic concepts in Industrial Control systems including an introduction to automation industry verticals, automation environment and an overview of industrial control networks

- **Networking Fundamentals for Industrial Control Systems (INICS)**
  - For Industrial Engineers and Control System Technicians, covers basic IP and networking concepts, and introductory overview of Automation industry Protocols.

For more details, please visit: [http://learningnetwork.cisco.com](http://learningnetwork.cisco.com)

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## Business Transformation Cisco Education Offerings

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
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<tr>
<td><strong>For IT and Network Professionals:</strong></td>
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</table>
| Building Business Specialist Skills                                    | • Builds non-technical skills key to ensure business impact and influence. Topics include: business analysis, finance, technology adoption and effective communications.  
  • Bridges IT and business impacts of mature and emerging solutions including cloud plus Internet of Everything | Cisco Enterprise IT Business Specialist                   |
| **For Technology Sellers:**                                            |                                                                                                                                                                                                             |                                                          |
| Applying Cisco Specialized Business Value Analysis Skills              | Builds skills to discover and address technology needs using a business-focused, consultative sales approach                                                                                                 | Cisco Business Value Specialist                           |
| Executing Advanced Cisco Business Value Analysis and Design Techniques | Enables customer transformation through business architecture and solution selling expertise                                                                                                                      | Cisco Certified Business Value Practitioner               |
| Performing Cisco Business-Focused Transformative Architecture Engagements| Provides skills and an approach to build a strategic roadmap of IT initiatives, aligned to business priorities                                                                                              | Cisco Transformative Architecture Specialist              |

For more details, please visit: [http://learningnetwork.cisco.com](http://learningnetwork.cisco.com)
Questions? Visit the Learning@Cisco Booth or contact ask-edu-pm-dcv@cisco.com
Security Cisco Education Offerings

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<tr>
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<tbody>
<tr>
<td>CCIE Security</td>
<td>Expert Level certification in Security, for comprehensive understanding of security architectures, technologies, controls, systems, and risks.</td>
<td>CCIE® Security</td>
</tr>
<tr>
<td>Implementing Cisco Threat Control Solutions (SITCS)</td>
<td>Deploy Cisco’s Next Generation Firewall (NGFW) as well as Web Security, Email Security and Cloud Web Security</td>
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<tr>
<td>Implementing Cisco Secure Access Solutions (SISAS)</td>
<td>Deploy Cisco’s Identity Services Engine and 802.1X secure network access</td>
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<tr>
<td>Implementing Cisco Secure Mobility Solutions (SIMOS)</td>
<td>Protect data traversing a public or shared infrastructure such as the Internet by implementing and maintaining Cisco VPN solutions</td>
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<tr>
<td>Implementing Cisco Network Security (IINS 3.0)</td>
<td>Focuses on the design, implementation, and monitoring of a comprehensive security policy, using Cisco IOS security features</td>
<td>CCNA® Security</td>
</tr>
<tr>
<td>Securing Cisco Networks with Threat Detection and Analysis (SCYBER)</td>
<td>Designed for security analysts who work in a Security Operations Center, the course covers essential areas of security operations competency, including event monitoring, security event/alarm/traffic analysis (detection), and incident response</td>
<td>Cisco Cybersecurity Specialist</td>
</tr>
</tbody>
</table>

For more details, please visit: [www.cisco.com/go/securitytraining](http://www.cisco.com/go/securitytraining) or [http://learningnetwork.cisco.com](http://learningnetwork.cisco.com)
Questions? Visit the Learning@Cisco Booth or contact ask-edu-pm-dcv@cisco.com
# R&S Related Cisco Education Offerings

<table>
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<tr>
<th>Course</th>
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<tr>
<td>CCIE R&amp;S Advanced Workshops (CIERS-1 &amp; CIER-2) plus Self Assessments, Workbooks &amp; Labs</td>
<td>Expert level trainings including: instructor led workshops, self assessments, practice labs and CCIE Lab Builder to prepare candidates for the CCIE R&amp;S practical exam.</td>
<td>CCIE® Routing &amp; Switching</td>
</tr>
<tr>
<td>• Implementing Cisco IP Routing v2.0</td>
<td>Professional level instructor led trainings to prepare candidates for the CCNP R&amp;S exams (ROUTE, SWITCH and TSHOOT). Also available in self study eLearning formats with Cisco Learning Labs.</td>
<td>CCNP® Routing &amp; Switching</td>
</tr>
<tr>
<td>• Implementing Cisco IP Switched Networks V2.0</td>
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<tr>
<td>• Troubleshooting and Maintaining Cisco IP Networks v2.0</td>
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</tr>
<tr>
<td>Interconnecting Cisco Networking Devices: Part 2 (or combined)</td>
<td>Configure, implement and troubleshoot local and wide-area IPv4 and IPv6 networks. Also available in self study eLearning format with Cisco Learning Lab.</td>
<td>CCNA® Routing &amp; Switching</td>
</tr>
<tr>
<td>Interconnecting Cisco Networking Devices: Part 1</td>
<td>Installation, configuration, and basic support of a branch network. Also available in self study eLearning format with Cisco Learning Lab.</td>
<td>CCENT® Routing &amp; Switching</td>
</tr>
</tbody>
</table>

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# Wireless Cisco Education Offerings

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Designing Cisco Wireless Enterprise Networks</strong></td>
<td>Professional level instructor led trainings to prepare candidates to conduct site surveys, implement, configure and support APs and controllers in converged Enterprise networks. Focused on 802.11 and related technologies to design, deploy, troubleshoot as well as secure Wireless infrastructure. Course also provide details around Cisco mobility services Engine, Prime Infrastructure and wireless security.</td>
<td></td>
</tr>
<tr>
<td><strong>Deploying Cisco Wireless Enterprise Networks</strong></td>
<td></td>
<td>CCNP® Wireless Version 3.0 (Available March 22nd, 2016)</td>
</tr>
<tr>
<td><strong>Troubleshooting Cisco Wireless Enterprise Networks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Securing Cisco Wireless Enterprise Networks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Implementing Cisco Unified Wireless Network Essential</strong></td>
<td>Prepares candidates to design, install, configure, monitor and conduct basic troubleshooting tasks of a Cisco WLAN in Enterprise installations.</td>
<td>CCNA® Wireless (Available Now)</td>
</tr>
<tr>
<td><strong>Deploying Basic Cisco Wireless LANs (WDBWL)</strong></td>
<td>Understanding of the Cisco Unified Wireless Networking for enterprise deployment scenarios. In this course, you will learn the basics of how to install, configure, operate, and maintain a wireless network, both as an add-on to an existing wireless LAN (WLAN) and as a new Cisco Unified Wireless Networking solution.</td>
<td>1.2</td>
</tr>
<tr>
<td><strong>Deploying Advanced Cisco Wireless LANs (WDAWL)</strong></td>
<td>The WDAWL advanced course is designed with the goal of providing learners with the knowledge and skills to successfully plan, install, configure, troubleshoot, monitor, and maintain advanced Cisco wireless LAN solutions such as QoS, “salt and pepper” mobility, high density deployments, and outdoor mesh deployments in an enterprise customer environment.</td>
<td>1.2</td>
</tr>
<tr>
<td><strong>Deploying Cisco Connected Mobile Experiences (WCMX)</strong></td>
<td>WCMX will prepare professionals to use the Cisco Unified Wireless Network to configure, administer, manage, troubleshoot, and optimize utilization of mobile content while gaining meaningful client analytics.</td>
<td>2.0</td>
</tr>
</tbody>
</table>

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Design Cisco Education Offerings

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Cisco Certification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designing Cisco Network Service Architectures (ARCH) Version 3.0</td>
<td>Provides learner with the ability to perform conceptual, intermediate, and detailed design of a network infrastructure that supports desired capacity, performance, availability required for converged Enterprise network services and applications.</td>
<td>CCDP® (Design Professional) (Available Now)</td>
</tr>
<tr>
<td>Designing for Cisco Internetwork Solutions (DESGN) Version 3.0</td>
<td>Instructor led training focused on fundamental design methodologies used to determine requirements for network performance, security, voice, and wireless solutions. Prepares candidates for the CCDA certification exam.</td>
<td>CCDA® (Design Associate) (Available Now)</td>
</tr>
</tbody>
</table>

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Questions? Visit the Learning@Cisco Booth or contact ask-edu-pm-dcv@cisco.com
# Service Provider Cisco Education Offerings

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Cisco Certification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Deploying Cisco Service Provider Network Routing (SPROUTE) &amp; Advanced (SPADVROUTE)</strong>&lt;br&gt;Implementing Cisco Service Provider Next-Generation Core Network Services (SPCORE)&lt;br&gt;Edge Network Services (SPEDGE)</td>
<td>SPROUTE covers the implementation of routing protocols (OSPF, IS-IS, BGP), route manipulations, and HA routing features; SPADVROUTE covers advanced routing topics in BGP, multicast services including PIM-SM, and IPv6; SPCORE covers network services, including MPLS-LDP, MPLS traffic engineering, QoS mechanisms, and transport technologies; SPEDGE covers network services, including MPLS Layer 3 VPNs, Layer 2 VPNs, and Carrier Ethernet services; all within SP IP NGN environments.</td>
<td>CCNP Service Provider®</td>
</tr>
<tr>
<td><strong>Building Cisco Service Provider Next-Generation Networks, Part 1 &amp; 2 (SPNGN1), (SPNGN2)</strong></td>
<td>The two courses introduce networking technologies and solutions, including OSI and TCP/IP models, IPv4/IPv6, switching, routing, transport types, security, network management, and Cisco OS (IOS and IOS XR).</td>
<td>CCNA Service Provider®</td>
</tr>
<tr>
<td><strong>Implementing Cisco Service Provider Mobility UMTS Networks (SPUMTS); Implementing Cisco Service Provider Mobility CDMA Networks (SPCDMA); Implementing Cisco Service Provider Mobility LTE Networks (SPLTE)</strong></td>
<td>The three courses (SPUMTS, SPCDMA, SPLTE) cover knowledge and skills required to understand products, technologies, and architectures that are found in Universal Mobile Telecommunications Systems (UMTS) and Code Division Multiple Access (CDMA) packet core networks, plus their migration to Long-Term Evolution (LTE) Evolved Packet Systems (EPS), including Evolved Packet Core (EPC) and Radio Access Networks (RANs).</td>
<td>Cisco Service Provider Mobility CDMA to LTE Specialist; Cisco Service Provider Mobility UMTS to LTE Specialist</td>
</tr>
<tr>
<td><strong>Implementing and Maintaining Cisco Technologies Using IOS XR (IMTXR)</strong></td>
<td>Service Provider/Enterprise engineers to implement, verification-test, and optimize core/edge technologies in a Cisco IOS XR environment.</td>
<td>Cisco IOS XR Specialist</td>
</tr>
</tbody>
</table>

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# Collaboration Cisco Education Offerings

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Cisco Certification</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCIE Collaboration Advanced Workshop (CIEC)</td>
<td>Gain expert-level skills to integrate, configure, and troubleshoot complex collaboration networks</td>
<td>CCIE® Collaboration</td>
</tr>
<tr>
<td>Implementing Cisco Collaboration Applications (CAPPS)</td>
<td>Understand how to implement the full suite of Cisco collaboration applications including Jabber, Cisco Unified IM and Presence, and Cisco Unity Connection.</td>
<td>CCNP® Collaboration</td>
</tr>
<tr>
<td>Implementing Cisco IP Telephony and Video Part 1 (CIPTV1)</td>
<td>Learn how to implement Cisco Unified Communications Manager, CUBE, and audio and videoconferences in a single-site voice and video network.</td>
<td>CCNP® Collaboration</td>
</tr>
<tr>
<td>Implementing Cisco IP Telephony and Video Part 2 (CIPTV2)</td>
<td>Obtain the skills to implement Cisco Unified Communications Manager in a modern, multisite collaboration environment.</td>
<td>CCNP® Collaboration</td>
</tr>
<tr>
<td>Troubleshooting Cisco IP Telephony and Video (CTCOLLAB)</td>
<td>Troubleshoot complex integrated voice and video infrastructures</td>
<td></td>
</tr>
<tr>
<td>Implementing Cisco Collaboration Devices (CICD)</td>
<td>Acquire a basic understanding of collaboration technologies like Cisco Call Manager and Cisco Unified Communications Manager.</td>
<td>CCNA® Collaboration</td>
</tr>
<tr>
<td>Implementing Cisco Video Network Devices (CIVND)</td>
<td>Learn how to evaluate requirements for video deployments, and implement Cisco Collaboration endpoints in converged Cisco infrastructures.</td>
<td></td>
</tr>
</tbody>
</table>

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## Data Center / Virtualization Cisco Education Offerings

<table>
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<tr>
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<tbody>
<tr>
<td>Introducing Cisco Data Center Networking (DCICN);</td>
<td>Learn basic data center technologies and skills to build a data center infrastructure.</td>
<td>CCNA® Data Center</td>
</tr>
<tr>
<td>Introducing Cisco Data Center Technologies (DCICT)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implementing Cisco Data Center Unified Fabric (DCUFI);</td>
<td>Obtain professional level skills to design, configure, implement, troubleshoot data center network infrastructure.</td>
<td>CCNP® Data Center</td>
</tr>
<tr>
<td>Implementing Cisco Data Center Unified Computing (DCUCI)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Designing Cisco Data Center Unified Computing (DCUDC)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Designing Cisco Data Center Unified Fabric (DCUFD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Troubleshooting Cisco Data Center Unified Computing (DCUCT)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Troubleshooting Cisco Data Center Unified Fabric (DCUFT)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product Training Portfolio: DCNMM, DCAC9K, DCINX9K, DCMDS, DCUCS, DCNX1K, DCNX5K, DCNX7K</td>
<td>Gain hands-on skills using Cisco solutions to configure, deploy, manage and troubleshoot unified computing, policy-driven and virtualized data center network infrastructure.</td>
<td></td>
</tr>
<tr>
<td>Designing the FlexPod® Solution (FPDESIGN);</td>
<td>Learn how to design, implement and administer FlexPod solutions</td>
<td>Cisco and NetApp Certified FlexPod® Specialist</td>
</tr>
<tr>
<td>Implementing and Administering the FlexPod® Solution (FPIMPADM)</td>
<td></td>
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</tr>
</tbody>
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# Network Programmability Cisco Education Offerings

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<tbody>
<tr>
<td>Integrating Business Applications with Network Programmability (NIPBA);</td>
<td>Learn networking concepts, and how to deploy and troubleshoot programmable network architectures with these self-paced courses.</td>
<td>Cisco Business Application Engineer Specialist Certification</td>
</tr>
<tr>
<td>Integrating Business Applications with Network Programmability for Cisco ACI (NPISAACI)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Developing with Cisco Network Programmability (NPDEV); Developing with Cisco Network Programmability for Cisco ACI (NPISAACI)</td>
<td>Learn how to build applications for network environments and effectively bridge the gap between IT professionals and software developers.</td>
<td>Cisco Network Programmability Developer Specialist Certification</td>
</tr>
<tr>
<td>Designing with Cisco Network Programmability (NPDES); Designing with Cisco Network Programmability for Cisco ACI (NPISAACI)</td>
<td>Learn how to expand your skill set from traditional IT infrastructure to application integration through programmability.</td>
<td>Cisco Network Programmability Design Specialist Certification</td>
</tr>
<tr>
<td>Implementing Cisco Network Programmability (NPENG); Implementing Cisco Network Programmability for Cisco ACI (NPISAACI)</td>
<td>Learn how to implement and troubleshoot open IT infrastructure technologies.</td>
<td>Cisco Network Programmability Engineer Specialist Certification</td>
</tr>
</tbody>
</table>

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# Cloud Cisco Education Offerings

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<tbody>
<tr>
<td>Understanding Cloud Fundamentals (CLDFND)</td>
<td>Learn how to perform foundational tasks related to Cloud computing, and the essentials of Cloud infrastructure</td>
<td>CCNA Cloud</td>
</tr>
<tr>
<td>Introducing Cloud Administration (CLDADM)</td>
<td>Learn the essentials of Cloud administration and operations, including how to provision, manage, monitor, report and remediate.</td>
<td></td>
</tr>
<tr>
<td>Implementing and Troubleshooting the Cisco Cloud Infrastructure (CLDINF)</td>
<td>Learn how to implement and troubleshoot Cisco Cloud infrastructure: compute, network, storage.</td>
<td></td>
</tr>
<tr>
<td>Designing the Cisco Cloud (CLDDES)*</td>
<td>Learn how to design private and hybrid Clouds including infrastructure, automation, security and virtual network services</td>
<td>CCNP Cloud</td>
</tr>
<tr>
<td>Automating the Cisco Enterprise Cloud (CLDAUT)*</td>
<td>Learn how to automate Cloud deployments – provisioning IaaS (private, private with network automation and hybrid) and applications, life cycle management</td>
<td></td>
</tr>
<tr>
<td>Building the Cisco Cloud with Application Centric Infrastructure (CLDACI)*</td>
<td>Learn how to build Cloud infrastructures based on Cisco Application Centric Infrastructure, including design, implementation and automation</td>
<td></td>
</tr>
<tr>
<td>UCS Director Foundation (UCSDF)</td>
<td>Learn how to manage physical and virtual infrastructure using orchestration and automation functions of UCS Director.</td>
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</tbody>
</table>

* Available Q2CY2016

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