About the European Advanced Networking Test Center

- State of the art testing expertise focusing on innovative telecom technologies
- Emulating fully realistic scenarios representative for today’s production networks
- EANTC is 100% independent and vendor-neutral
- Adhering to highest quality standards and actively participating in test methods standardization

Network Design, Proof of Concept Testing and Audits for Service Providers

Acceptance Tests and Audits for Enterprises

Testing and Certification for Vendors

redefine the possible log in. berlin.
Goals

- Multi-vendor interoperability event open to all interested vendors
- Focusing on innovations in MPLS, EVPN, Segment Routing, SDN, Microwave and Clock Synchronization
- 6 Months of preparation with participating vendors
- Intense 2-week hot-staging at EANTC Berlin with 80+ attendees
- Helps to document state of the art and improve interoperability
Participating Vendors

ADVA
Arista
BISDN
Calnex
Cisco
Delta
ECI
Ericsson
Huawei
Intracom Telecom
IP Infusion
IXIA
Juniper Networks
Meinberg
Microsemi
Nokia
Seiko
Seiko Solutions Inc.
Ospirent
ZTE
## List of Participating Devices

<table>
<thead>
<tr>
<th>Participants</th>
<th>Devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADVA Optical Networking</td>
<td>GO102Pro, OSA 5430, XG480</td>
</tr>
<tr>
<td>Arista Networks</td>
<td>7050SX3, 7280SR</td>
</tr>
<tr>
<td>BISDN GmbH</td>
<td>Basebox</td>
</tr>
<tr>
<td>Calnex Solutions</td>
<td>Paragon-t, Paragon-X SNE</td>
</tr>
<tr>
<td>Cisco</td>
<td>ASR 9000, IOS XRv9000, NCS 540, NCS 5500; Network Services Orchestrator (NSO); Nexus 3100-V, 3600-R, 7700, 9300-FX</td>
</tr>
<tr>
<td>Delta Electronics</td>
<td>AG7648, AGC7648A</td>
</tr>
<tr>
<td>ECI Telecom</td>
<td>Neptune 1050, Neptune 1300</td>
</tr>
<tr>
<td>Ericsson</td>
<td>Ericsson 6274, 6471, 6672, 6675; Ericsson Eldaco; Ericsson MINI-LINK 63xx, 66xx</td>
</tr>
<tr>
<td>Huawei Technologies</td>
<td>ATN910C-F, ATN950C; Network Cloud Engine (NCE); NE40E; NE9000-8</td>
</tr>
<tr>
<td>Intracom Telecom</td>
<td>OmniBAS</td>
</tr>
<tr>
<td>IP Infusion</td>
<td>OcNOS</td>
</tr>
<tr>
<td>Ixia, a Keysight business</td>
<td>IxNetwork</td>
</tr>
<tr>
<td>Juniper Networks</td>
<td>NorthStar Controller MX104, MX204, MX480; QFX10002, QFX5110</td>
</tr>
<tr>
<td>Meinberg</td>
<td>LANTIME M1000S; microSync HR</td>
</tr>
<tr>
<td>Microsemi, a Microchip company</td>
<td>TimeProvider 4100, TimeProvider 5000</td>
</tr>
<tr>
<td>Nokia</td>
<td>7750 SR-7; Network Services Platform</td>
</tr>
<tr>
<td>Seiko Solutions</td>
<td>TS-2912-22</td>
</tr>
<tr>
<td>Spirent Communications</td>
<td>Spirent TestCenter</td>
</tr>
<tr>
<td>ZTE Corporation</td>
<td>ZENIC ONE; ZXCTN 6180H; ZXCTN 9000</td>
</tr>
</tbody>
</table>
Test Coverage

51 test cases in six main test areas; results from 174 multi-vendor combinations
Test Topology
<table>
<thead>
<tr>
<th>Date</th>
<th>Coffee Break Time</th>
<th>Demonstration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuesday</td>
<td>11:00</td>
<td>EVPN Multi-Homing with Integrated Routing and Switching (IRB)</td>
</tr>
<tr>
<td></td>
<td>16:00</td>
<td>Phase/Time Synchronization: Source Failover</td>
</tr>
<tr>
<td>Wednesday</td>
<td>11:10</td>
<td>Segment Routing IGP Flexible Algorithm (flex-algo)</td>
</tr>
<tr>
<td></td>
<td>16:10</td>
<td>Segment Routing IPv6 (SRv6)</td>
</tr>
<tr>
<td>Thursday</td>
<td>09:50</td>
<td>Multi-Vendor/Multi-Domain Controller Orchestrator</td>
</tr>
<tr>
<td></td>
<td>10:20</td>
<td>Layer 3 Microwave: MPLS-based Services</td>
</tr>
<tr>
<td></td>
<td>15:40</td>
<td>BGP-signaled Segment Routing Traffic Engineering</td>
</tr>
<tr>
<td>Friday</td>
<td>10:00</td>
<td>Topology Independent Loop-free Alternate (TI-FLA)</td>
</tr>
</tbody>
</table>
Test Area: SDN Controller/Switch Interoperability

Goals

- Verify Path Computation Element Protocol (PCEP) interoperability and Segment Routing traffic engineering in multi-domain network

Participants

- Controllers: Cisco, HUAWEI, Juniper, Keysight (Ixia), Nokia, Spirent, ZTE
- Network Nodes: Arista, BISDN, Cisco, Delta, ECI, Ericsson, HUAWEI, Juniper, Nokia

High-Level Results

- PCEP and Traffic Engineering in one AS was tested successfully between most vendors
- Exciting result in multi-domain SR traffic engineering, showing excellent interoperability in controllers and devices
Software Defined Networks (SDN)

Path Computation Element Protocol (PCEP)

- Centralized network management and service orchestration
- Flexibility in Traffic Engineering

→ 8 vendors tested as Orchestrator/Controller/PCE, with 17 network devices
→ 54 successful combinations tested
PCEP Coverage

PCE-/PCC-initiated path computation
- Successful path creation, deletion, recalculation and re-optimization upon network changes
- Tested between PCE: Cisco, HUAWEI, Juniper, Nokia, ZTE; PCC: Cisco, ECI, Ericsson, HUAWEI, Juniper, Nokia

FlowSpec to apply ACL policies to increase network security
- IPv4/IPv6, Rate limit/Redirect-to-VRF
- Tested between Keysight as controller and Arista, HUAWEI, Nokia as Network Nodes

→ Integrated security and traffic engineering in SDN-based network
BGP-Signaled Segment Routing Policies

BGP extension for SR Policy
- New SR Policy SAFI (codepoint 73)
- New NLRI with an AFI of 1 or 2 (IPv4 or IPv6) and with a SAFI of 73
- New SR Policy sub-TLVs

Features implemented and tested
- Add and delete SR Policies for IPv4 and IPv6
- Egress node adds BGP color extended community to the prefixes to match SR Policy
- Send IPv4/IPv6 traffic and labeled traffic using colored prefixes as destination

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Controller</th>
<th>Switch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arista</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Cisco</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Keysight</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Nokia</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Spirent</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Diagram showing network topology with controllers and routers (DUTs) labeled with AS 65001 and network links.
PCEP and Traffic Engineering across Multi-Domains

Cloud peering with Egress Peer Engineering
- MPLS label allocated for each engineered peer
- Elephant flow/mouse flows
- IPv4/IPv6

Results
- IPv4/IPv6 Service traffic with the same destination was steered to different engineered peers

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Controller</th>
<th>Switch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arista</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Cisco</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>HUAWEI</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Keysight</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Nokia</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Diagram:
- Controller
- Vendor Controller Switch
- Arista X
- Cisco X
- HUAWEI X
- Keysight X
- Nokia X

Legend:
- Physical Link
- VLAN
- BGP IPv4/IPv6
- BGP-LS
- Traffic Generator
- Transport Network
- Customer Domain
Multi-domain SR Traffic Engineering

Inter-domain LSP
- Computes inter-AS LSP when head-end LSR is not able to
- Key application of controller-based architecture

Features implemented and tested
- PCEP between controller and head-end LSR
- End-to-End L3VPN service
- Network Nodes: Cisco and HUAWEI
- Scenario 1 with two controllers: Cisco and HUAWEI
- Scenario 2 with single controller: Nokia

Results
- Inter-domain LSP was deployed by the controller
- End-to-End L3VPN traffic forwarded with no loss
Test Area: NETCONF/YANG

Goals
- Verify multi-vendor device configuration
- Controller based L2VPN/L3VPN service configuration
- Evaluate multi-domain controllers orchestration

Participants
- Network Controllers/Orchestrators: HUAWEI, Cisco, Keysight (Ixia)
- Network Nodes: BISDN & Delta, Cisco, ECI, Ericsson, HUAWEI

High-Level Results
- Successful business VPN deployment with NETCONF/YANG in a single domain and across multi-domains
- Multi-domain controllers orchestration for successful end-to-end service provisioning
Configuration using NETCONF/YANG

Multi-Vendor/Multi-Domain Controllers Orchestration

- Data Link
- Traffic Flows
- Management Link
- Management Network

RESTCONF/API
NETCONF/YANG
MPLS/SRv6

Ethernet Link
E2E L2/L3 MPLS Service
NETCONF/RESTCONF
RESTful HTTPs
BGP-LS/NETCONF
IP/MPLS Network
Test Area: Ethernet VPNs

Goals
- Verify EVPN support for large-scale data center/WAN architectures
- Additionally, new IETF drafts covered: Flexible Cross-Connect Service and EVPN Loop Protection (data plane protection)

Participants
- 12 vendors participated in at least one test case in this area
  - Arista, BISDN, Cisco, Delta, Ericsson, HUAWEI, IP Infusion, Juniper, Keysight, Nokia, Spirent, and ZTE

High-Level Results
- 24 combinations and scenarios successfully evaluated
  (only 1 interop issue found in the Proxy ARP test)
Scalable Ethernet Virtual Private Networks (EVPN)

Focused on IETF drafts by the BGP Enabled ServiceS (bess) working group

- Successfully tested business EVPN over VXLAN data plane
  - VLAN-based
  - VLAN-aware-bundle-based
- Verified EVPN over MPLS data plane to allow migration from IP/MPLS network
- Extension of VPN between different EVPN bridge domains
  - Symmetric and asymmetric Integrated Routing and Bridging (IRB)
  - Subnet routing
- Multiplexed Access Circuits over EVPN (Flex Cross-Connect) to lower VPWS count
- To minimize ARP/ND broadcasts we tested Proxy ARP and MAC Mobility
Proxy ARP Test

Built one broadcast domain with 16 devices
- PE learned neighbor address from remote PE via EVPN (RT-2)
- No flooding observed at receipt of ARP requests for learned neighbor address
- All EVPNs successfully tested except one
  - One vendor’s BGP update messages were rejected by a route reflector and another virtualized solution
EVPN – Carrier Ethernet Services

- E-Line (Multi-Homed) - IP/MPLS Network
- E-Line (Single-Homed) - IP/MPLS Network
- E-Tree - EVPN-MPLS Network

All-Active Multi-homed

Single-homed

Point-to-point (E-LINE)

Rooted-multipoint (E-TREE)
EVPN – Maintenance and Security

- Efficient integration of OAM based on mature standard Y.1731
- Secured operation by protecting the data plane from loops
EVPN – Interworking

→ Business EVPN cross data center with MPLS and VXLAN
→ Successful integration between IP-VPN and EVPN

EVPN-VXLAN/EVPN-MPLS Interworking

EVPN/IPVPN Interworking
Test Area: Segment Routing

Goals
• Verify Segment Routing traffic forwarding and protection in both SR-MPLS and SRv6 Data Plane
• Test Interoperability in SR LSP ping/traceroute, Seamless-BFD, TWAMP and network slicing in multi-plane network

Participants
• Vendors: Arista, Cisco, ECI, Ericsson, HUAWEI, Juniper, Keysight (Ixia), Nokia, Spirent, ZTE
• 4 vendors tested SRv6: Cisco, Huawei, Keysight (Ixia), Spirent

High-Level Results
• SR-MPLS proved to be a mature technology widely implemented by all participating vendors
• EVPN was supported and tested for the first time over SRv6 data plane
Segment Routing – Maintenance and Protection

- SR Ping/Traceroute successfully tested via Segment Routing LSP
- TWAMP: measured two-way forwarding delay
- Seamless BFD: detected link failure and triggered SR-TE switch to backup path in < 500ms using 3*100ms interval

→ MPLS Dataplane OAM and network protection successfully verified for SR
**SR Anycast** SID used to disjoint traffic paths in multi-plane networks

**BGP Segment Routing** tested BGP-LU NLRI to advertise BGP Prefix-SID between Leaf Nodes in multi-AS CLOS topology

→ SR Anycast and BGP SR provide scalability for large datacenter with multi-plane and multi-AS
→ TI-LFA and network slicing described in following slides
Segment Routing – SRv6

- Successfully established IPv4 L3VPN and IPv6 EVPNs over SRv6 between PE devices and emulated PEs.
- Segment routing Ping/Traceroute tested between PE devices via SRv6.
- Participants: Cisco, HUAWEI (routers); Keysight, Spirent (emulators).

→ EVPN over SRv6 was tested for the first time.
→ Two more vendors participated in VPN over SRv6 test compared to last year.
Segment Routing – TI-LFA for SRv6

Topology-independent loop-free alternate (TI-LFA)
- No signaling of backup paths
- Path calculation independent of network design
- No administrative overhead for backup paths

Features verified
- SRv6 L3VPN between Node 1 to Node 4
- Emulated link failure as shown
- Backup path via Node 2 and Node 3

Results
- TI-LFA backup path used Node 2 and Node 3
- Out-of-Service time less than 50ms
Segment Routing - Network Slicing

Flexible Algorithms
- based on ISIS FAD Sub-TLV extension
- ISIS computing constraint based path
- Traffic steering based on SR SIDs

Features implemented and tested
- Each PE configured with two Flex-Algos
- Each P node configured with only one of the Flex-Algos
- Bi-directional IPv4 traffic send from TG, each service was bound to one Flex-Algo

Results
- Service traffic disjoint in two network planes defined by two Flex-Algos
**Goals**
- Verify integration of microwave solutions with MPLS network control
- Focus on traffic engineering/bandwidth notifications

**Participants**
- Ericsson, Intracom (Microwave)
- Ericsson, Juniper (PE routers)

**High-Level Results**
- Microwave solutions under test showed increasingly smart integration with MPLS
- Bandwidth notification worked well in all scenarios
- No interoperability issues encountered
Microwave over MPLS: Test Details

Successfully tested features

- Ethernet bandwidth notification
- Integrated MPLS with PE and P role

No interop issues encountered
Test Area: Clock Synchronization

Goals

• Verify 5G-readiness, raising clocking precision
• Test specifics of clocking over 100 GbE and microwave

Participants

• ADVA, Ericsson, HUAWEI, Meinberg, Microsemi, Seiko (grandmaster clocks)
• ADVA, Ericsson, HUAWEI, Meinberg, Microsemi, ZTE (boundary or slave clocks)
• Calnex (test equipment)

High-Level Results

• Very solid results of sync quality under various conditions for all vendors
• First-time tests of 5G readiness promising
• First-time 100GbE boundary clock tests successful
Clock Synchronization

Current timing requirements

- Single frequency broadcasting on multiple sites (Terrestrial Digital Radio)
- 4G (LTE-A) and 5G mobile networks (carrier aggregation, frequency reuse)

Tested up to ITU G.8271/Y.1366 accuracy level 6

- Level 6A - 260 ns peak-to-peak time difference
Clock Synchronization: Test Cases

- 5G Synchronization readiness
  - In 11 combinations all 7 vendors achieved ITU-T G.8271 Level 6A accuracy
- Grandmaster clock degradation (diagram)
- Phase/Time Partial Timing Support
  - A total of 10 successful combinations with and without simulated link delay asymmetry
- PTP over microwave and 100GbE
  - 100GbE multi-channel mastered by 5 vendors
  - Microwave boundary clocks passed the test – issues with bursty traffic only in one case
White Paper

- Description of tested technologies and detailed results
- 40 pages explaining working demonstrations

www.eantc.de/showcases/mpls_sdn_2019

Free Copies at Interop Booth