Shortest Path Bridging
IEEE 802.1aq

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Abstract

802.1aq Shortest Path Bridging is being standardized by the IEEE as an evolution of the various spanning tree protocols. 802.1aq allows for true shortest path routing, multiple equal cost paths, much larger layer 2 topologies, faster convergence, vastly improved use of the mesh topology, single point provisioning for logical membership (E-LINE/E-LAN/E-TREE etc), abstraction of attached device MAC addresses from the transit devices, head end and/or transit multicast replication, all while supporting the full suit of 802.1 OA&M.
Outline

• Challenges
• What is 802.1aq/SPB
• Applications
• How does it work
• Example (won’t cover but included here)
Challenges

- L2 networks that scale to ~1000 bridges.
- Use of arbitrary mesh topologies.
- Use of (multiple) shortest paths.
- Efficient broadcast/multicast routing and replication points.
- Avoid address learning by tandem devices.
- Get recovery times into 100’s of millisecond range for larger topologies.
- Good scaling without loops.
- Allow creation of very many logical L2 topologies (subnets) of arbitrary span.
- Maintain all L2 properties within the logical L2 topologies (transparency, ordering, symmetry, congruence, shortest path etc).
- Reuse all existing Ethernet OA&M 802.1ag/Y.1731
Example STP 36 nodes

1 - Can’t use these links

2 - LEARN A1..A100

ROOT

SOURCE

A1.. A100

DEST

2 - LEARN A1..A100
Outline

• Challenges
• **What is 802.1aq/SPB**
• Applications
• How does it work
What is 802.1aq/SPB

- IEEE protocol builds on 802.1 standards
- A new **control** plane for Q-in-Q and M-in-M
  - Leverage existing inexpensive ASICs
  - Q-in-Q mode called SPBV
  - M-in-M mode called SPBM
- **Backward compatible to 802.1**
  - 802.1ag, Y.1731, Data Center Bridging suite
- **Multiple loop free shortest paths routing**
  - Excellent use of mesh connectivity
  - Currently 16, path to 1000’s including hashed per hop.
- **Optimum multicast**
  - head end or tandem replication
What is 802.1aq/SPB (cont’d)

• **Light weight form of traffic engineering**
  – Head end assignment of traffic to 16 shortest paths.
  – Deterministic routing - offline tools predict exact routes.

• **Scales to ~1000 or so devices**
  – Uses IS-IS already proven well beyond 1000.
  – Huge improvement over the STP scales.

• **Good convergence with minimal fuss**
  – sub second (modern processor, well designed)
  – below 100ms (use of hardware multicast for updates)
  – Includes multicast flow when replication point dies.
    Pre-standard seeing 300ms recovery @ ~50 nodes.

• **IS-IS**
  – Operate as independent IS-IS instance, or within IS-IS/ IP, supports Multi Topology to allow multiple instances efficiently.
What is 802.1aq/SPB (cont’d)

• Membership advertised in same protocol as topology.
  – Minimizes complexity, near plug-and-play
  – Support E-LINE/E-LAN/E-TREE
  – All just variations on membership attributes.

• Address learning restricted to edge (M-in-M)
  – FDB is computed and populated just like a router.
  – Unicast and Multicast handled at same time.
  – Nodal or Card/Port addressing for dual homing.

• Computations guarantee ucast/mcast…
  – Symmetry (same in both directions)
  – Congruence (unicast/multicast follow same route)
  – Tune-ability (currently 16 equal costs paths – opaque allows more)
End result - Visually

Multiple Shortest Path routing + Ethernet OA&M

All links usable
Outline

• Challenges
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• How does it work
Application (M|R)STP replacement

- Many more nodes without regions
- Low effort to get good routing
- Fast convergence – link state v.s. distance vec
- Address isolation m-in-m.

![Diagram showing small number of trees vs. large number of source specific trees (computed).](image)

- All links usable
- No regions needed
- Scoped exactly to C-VLAN or S-VLAN members

Regions for scale

Unused links
Application Data Center

• Multiple shortest path routing (inter server traffic)
• Deterministic traffic flows.
• Flexible subnet – expand/shrink anywhere.
  • Virtualization operates in subnet.
• Fully compatible with all 802.1 Data Center Bridging protocols & OA&M.
• Address isolation through m-in-m
• Fast recovery
• No loops
Application Data Center (cont’d)

• Totally compatible with VMware server functions:
  • OA&M, motion, backup etc.
  • Apps that sit on VMware ‘just work’.
• Totally compatible with Microsoft load balancing (multicast over the L2)
• VRRP transparent.
• It just makes the L2 part of the DC larger and better utilized.
• Compatible with emerging Inter DC overlay work.
Application Metro/L2VPN

- Very light weight L2VPNs ($2^{24}$ data path) of: E-LAN, E-LINE, E-TREE flavors (a very cheap VPLS)
- Can do VPLS style head end replication
- Can do p2mp style transit replication (just one tx flag).
- Can support receive only membership (E-TREE)

- E-LINE
  = 2 tx/rx members

- E-LAN
  > 2 tx/rx members

- E-TREE n rx members
  1 tx member.
Outline

• Challenges
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• Applications
• How does it work
How does it work?

• From Operators Perspective
  - Plug NNI’s together
  - Group ports/c-vlan/s-vlan at UNIs that you want to bridge (2^{24} groups=‘services’ m-in-m mode.)
  - Assign an I-SID to each group..

• Internally
  - IS-IS reads box MAC, forms NNI adjacencies
  - IS-IS advertises box MACs (so no config).
  - IS-IS reads UNI port services and advertises.
  - Computations produce FIBs that bridge service members.
Data Path (M-in-M mode)

- C-vlan/S-vlan or untagged traffic arrives at UNI
- Its encapsulated with B-SA of bridge
- Its encapsulated with I-SID configured for group
- Its encapsulated with B-VID chosen for route
- C-DA is looked up, if found B-DA is set
- C-DA not found, B-DA is multicast that says:
  - Multicast to all other members of this I-SID group from ‘me’. Or can head-end replicate over unicast.
  - C addresses to B address association learned at UNI only.
FDB (unicast M-in-M mode)

• A unique shortest path from node to all others is computed.

• BMAC of other nodes installed in FIB pointing to appropriate out interface.

• Above is repeated for 16+ shortest paths each causes a different B-VID to be used.

• Symmetry is assured through special tie-breaking logic. 16+ different tie-breaking algorithms permit 16+ different shortest paths.
FDB visually: ucast m-in-m mode

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<tr>
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<td>9</td>
</tr>
<tr>
<td>:4</td>
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<table>
<thead>
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<th>IF</th>
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<tbody>
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<td>1</td>
<td>3</td>
</tr>
<tr>
<td>:1</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>:1</td>
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<td>3</td>
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<tr>
<td>:1</td>
<td>4</td>
<td>6</td>
</tr>
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</table>
FDB (mcast M-in-M mode)

*If* no services require tandem replication there is no tandem FDB:

Very VPLS like .. Pretty boring….head replication over unicast paths .. Yawn..

*Else* (mp2mp like but without signaling)

*If* my node is on a unique shortest path between node A, which transmits for a group I, and node B which receives on group I, then:

merge into the FDB an entry for traffic from { A/Group I } to the interface towards B.
How does it work – transit multicast format (n/a for head replication)

Example: { SOURCE: 0A-BC-DE / ISID: fe-dc-ba }

MMAC-DA: A3-BC-DE-FE-DC-BA
FDB visually: mcast m-in-m mode

<table>
<thead>
<tr>
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<table>
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<th>MMAC</th>
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<th>IF</th>
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<tbody>
<tr>
<td>{1/255}</td>
<td>4</td>
<td>5,6</td>
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</table>
Highlighted is the routing from each member to all others.

Note the symmetry.

Unicast and multicast Follows exactly these Routes.

Multicast can be replicated at fork points or head end replicated to the uni-cast paths by configuration at edge.
The Control Plane (m-in-m mode)

- Industry standard IS-IS Link State Protocol is basis for 802.1aq.
- Does not require any IP to operate.
- Does not preclude IPV4 or IPV6 being present in same IS-IS instance.
- SYSID carries B-MAC address
- Introduces no new PDU’s to IS-IS.
- Hello TLVs augmented to pass Equal Cost Algorithm / Vid information and new NLPID.
- Update TLV’s augmented to advertise SPB specific link costs.
- Update TLVs augmented to advertise ISID information.
- Update TLVs augmented to advertise nodal ‘short form’ name SPSOURCEID (transit mcast only).
802.1aq ISIS LSP extensions at a glance

<table>
<thead>
<tr>
<th>LSPID</th>
<th>Seq Num</th>
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<td>ECT-VID 100</td>
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<tr>
<td>SPB ISID</td>
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</tr>
</tbody>
</table>

LSP fragment for node :1 with 2 peers :4 and :3 and two services 255, 256
Loop Suppression & Avoidance

Suppression
• done on the data path using an SA check.
• prevents 99.99% loops if FDB’s create one.
• no impact on convergence rates.
• exploits symmetric/congruence properties of routing.
• uses reverse learning options of most h/w to discard.

Avoidance
• done by the control path
• ensures no loops are ever configured in FDBs.
• hellos augmented with topology ‘digests’
• mismatched digests => some forwarding entries unsafe.
• blocks only ‘unsafe’ entries.
• works for ALL forwarding modes current and planned.
802.1aq OA&M (inherited *by design*)

**Service/Network Layer – 802.1ag Connectivity Fault mgmt**
- Hierarchy (honors maintenance levels/abstraction)
  - Continuity Check
  - L2 traceroute
  - L2 ping

**Link Layer – 802.3ah**
- Link Monitoring (logical/physical)
- Remote Failure Indication
- Remote Loopback

**Service Layer - Y.1731**
- Multicast Loopback – depends on congruency/symmetry
- Performance Measurements (Loss/Delay etc.)
- One way/two way delays – symmetry important
Recovery

• ISIS augmented with multicast LSP flood to all 802.1aq nodes.
• Every 802.1aq node joins default service ISID 0xffffffff.
• This E-LAN is just for control plane.
• LSPs can be advertised over this E-LAN.
• Very fast distribution protocol (h/w multicast).
• On failure each end of link advertises over this ‘default’ E-LAN (in addition to normal updates).
• Reaches all 802.1aq participants at h/w multicast speed with no CPU involvement transit.
• Conceptually like having a shared LAN joining all nodes with a physical port but no DR election etc. is done, only used as unreliable very fast distribution mechanism backed up by normal IS-IS hop by hop LSPs.
Outline

- Challenges
- What is 802.1aq/SPB
- Applications
- How does it work
- **Example (included in this deck - enjoy)**
- Q&A
Outline

- Challenges
- What is 802.1aq/SPB
- Applications
- How does it work
- Example (backup slides)
- **Q&A** (avail anytime)
References

“IEEE 802.1aq” : www.wikipedia.org:
http://en.wikipedia.org/wiki/IEEE_802.1aq

“IEEE 802.1aq” www.ieee802.org/1/802-1aq-d2-6.pdf

“Shortest Path Bridging” – Efficient Control of Larger Ethernet Networks” :
upcoming IEEE Communications Magazine – Oct 2010

“Provider Link State Bridging” :
IEEE Communications Magazine V46/N9– Sept 2008
ieeecommunicationsmagazinevol46no9sep2008-carrierscaleethernet.pdf

See also the worked example – in backup slides in this deck

Thank-You
EXAMPLE
EXAMPLE NETWORK:

36 node network
8 member E-LAN ISID=255

Full Transit Replication
EXAMPLE – ISIS PEERS AT NODE :3

Logging on to node :3
We can see the basic SPB info and the ISIS peers....
### EXAMPLE – LSDB at node :3

**Database information for ISIS(1)**

<table>
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<tr>
<th>LSPID</th>
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*(In TLV) – Leaking Route, *(By LSPID) – Self LSP, + – Self LSP(Extended), ATT – Attached, P – Partition, OL – Overload
EXAMPLE LSP VERBOSE
OF NODE :1 at NODE :3

<ottawa-9300-3>d isis lsdb 4455.6677.0001.00-00 verbose

Database information for ISIS(1)
--------------------------------

Level-1 Link State Database

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NLPIID SPB(0xC1)
AREA ADDR 22.3344
+NBR ID 4455.6677.0003.00 COST: 10
+NBR ID 4455.6677.0004.00 COST: 10
SPB ECT-ALGORITHM 0 ECT-VID 100
SPB ECT-ALGORITHM 1 ECT-VID 101
SPB ECT-ALGORITHM 2 ECT-VID 0
.......
SPB ECT-ALGORITHM 15 ECT-VID 0
SPSID 07-00-01
SPB BMAC 44-55-66-77-00-01
ECT-VID 100
SPB ISID 255T&R

<ottawa-9300-3>
EXAMPLE – NODE :3 ROUTE TO :10
(first equal cost path)

Total unicast fib entries is 68
EXAMPLE – NODE :3 ROUTE TO :10
(second equal cost path)

<ottawa-9300-3>d spb umac

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Total unicast fib entries is 68

<ottawa-9300-3>
Here are the multicast routes from node 1 for service 255 and also from node 26 for service 255. Note the symmetry in the route between the two multicast trees. The unicast route between :1 and :26 is also along that same path for the chosen B-VID. Since we’ve asked for transit replication for all members of the E-LAN we install MCAST ...
MULTICAST ADDRESS IS: [ SOURCE = 07-00-01 | ISID=00-00-ff ]

We only get this state if we configure transmit membership in the E-LAN. Transmit still possible without multicast state but uses serial replication at head end. Operator chooses trade-off between state/bandwidth usage.
Here are all mFIBs on nodes :3 and :13 related to this E-LAN.