IEEE 802.1 FOR HOMENET

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Authors
IEEE 802.1 Task Groups

- **Interworking (IWK, Stephen Haddock)**
  - Internetworking among 802 LANs, MANs and other wide area networks

- **Time Sensitive Networks (TSN, Michael David Johas Teener)**
  - Formerly called Audio Video Bridging (AVB) Task Group
  - Time-synchronized low latency streaming services through IEEE 802 networks

- **Data Center Bridging (DCB, Pat Thaler)**
  - Enhancements to existing 802.1 bridge specifications to satisfy the requirements of protocols and applications in the data center, e.g.

- **Security (Mick Seaman)**

- **Maintenance (Glenn Parsons)**
Basic Principles

- MAC addresses are “identifier” addresses, not “location” addresses
  - *This is a major Layer 2 value, not a defect!*
- Bridge forwarding is based on
  - Destination MAC
  - VLAN ID (VID)
- Frame filtering for only forwarding to proper outbound ports(s)
  - Frame is forwarded to every port (except for reception port) within the frame's VLAN if it is not known where to send it
  - Filter (unnecessary) ports if it is known where to send the frame (e.g. frame is only forwarded towards the destination)
- Quality of Service (QoS) is implemented after the forwarding decision based on
  - Priority
  - Drop Eligibility
  - Time
Data Plane Today

- **802.1Q today is 802.Q-2011** *(Revision 2013 is ongoing)*
  - Note that if the year is not given in the name of the standard, then it refers to the latest revision, e.g. today 802.1Q = 802.1Q-2011 and 802.1D = 802.1D-2004

- **802.1Q already involves**
  - Q-in-Q = Provider Bridges (PB) [IEEE 802.1ad-2005]
  - MAC-in-MAC = Provider Backbone Bridges (PBB) [IEEE 802.1ah-2008]

- **802.1Qbg-2012 Edge Virtual Bridging (EVB) is also part of today’s 802.1Q data plane** *(802.1Qbg not yet amended to 802.1Q)*

- **802.1Q is not only about 12-bit C-VLANs any more**
The Distributed Protocols for Control of the Active Topology

- RSTP: a single spanning tree shared by all traffic
- MSTP: different VLANs may share different spanning trees
- SPB: each node has its own Shortest Path Tree (SPT)

We are not limited to shared spanning trees any more

Note: the Spanning Tree Protocol (STP) is historical, it has been replaced by RSTP
Control Compatibility in Two Ways

• A bridge always prefers the company of bridges running the latest algorithm it knows: SPB over MSTP over RSTP over old STP.
  • A network of bridges running one algorithm appears as a single bridge to bridges running an older algorithm.
  • Basic spanning tree interconnects the clouds of like algorithms.
  • Thus, plug-and-play extends over bridges running different 802.1 algorithms.

• Bridges can be configured to confine any given algorithm to certain VLANs.
  • The same bridge or network can be configured to run any combination of MSTP, SPB, controller-supervised forwarding, or a variety of non-802 protocols simultaneously, each on different VLANs.
Multiple Registration Protocol (MRP)

- Flooding protocol (not unlike IS-IS or OSPF) that registers, on every bridge port, one’s neighbors’ ability to transmit and/or need to receive various kinds of data:
  - Multiple VLAN Registration Protocol (MVRP): Frames flooded to particular VLANs, e.g. broadcasts or unknown unicasts.
  - Multiple MAC Registration Protocol (MMRP): Multicast MAC addresses or {VLAN, MAC} pairs. *Not necessarily IP multicast.*
  - Multiple Stream Reservation Protocol (MSRP or SRP): Talkers wanting to send or Listeners wanting to receive data flows with bandwidth, latency, and congestion loss requirements.
- In some cases MRP is being supplanted by IS-IS.
Software Defined Networking Aspects

• Software Defined Networking (SDN) principles are supported by 802.1Q
• Separation of the control plane from the data plane
  • The bridge architecture separates the control plane from the data plane
  • The External Agent is geographically separated
• Separate topologies per VLAN
  • Any given VLAN can be assigned to MSTP, SPB, External Agent, or any other standard- or user-defined control methodology
• Centralized controller having a view of the network
  • The External Agent can be a centralized SDN Controller
  • The bridges may run the Link Layer Discovery Protocol (LLDP) [802.1AB] for retrieval by controller
  • The bridges can run IS-IS to distribute topology, whether any VLANs are assigned to control by SPB or not
• Programmability of the network
  • Well defined objects and functionality for programming the bridges
Shortest Path Bridging (SPB)

- SPB applies a link state control protocol to MAC Bridging
  - Based on the ISO Intermediate System to Intermediate System (IS-IS) intra-domain routing information exchange protocol \(\rightarrow\) ISIS-SPB
  - Leverages the automation features of link state, e.g. auto-discovery
  - Preserves the MAC Service model, e.g. delivery in-order

- ISIS-SPB operation
  - Link state data base \(\rightarrow\) Identical replica at each bridge
    - Topology information
    - Properties of the bridges
    - Service information
  - Computation instead of signaling or registration protocols
    - Leverage Moore’s law and technology trends

- ISIS-SPB specifications
  - IEEE 802.1aq specifies operation and backwards compatibility provisions
  - ISIS extensions for SPB (new TLVs) also documented in IETF RFC 6329
SPB Operation Modes

- A bridge only uses its own SPT for frame forwarding
  - Destination MAC + VID based forwarding allows two options to realize the SPTs

SPB has two operation modes

The implementation of the same principles to forwarding is different

**SPBM**: SPB MAC
- Backbone MAC identified SPTs
- Designed to leverage the scalability provided by PBB /“MAC-in-MAC”/
- No B-MAC flooding/learning
- Managed environments

**SPBV**: SPB VID
- VID identified SPTs
- Applicable to all types of VLANs
- Flooding and learning
- Plug&play
Load Spreading

• Using the shortest path automatically spreads traffic load to some extent

• Further load-spreading by exploiting equal cost paths to create multiple SPT Sets
  • Up to 16 standard tie-breaking variations to produce diverse SPTs

• Provisioned load spreading
  • A VLAN is assigned to an SPT Set
IS-IS in the home? Seriously?

- Consider a stack of devices near the TV set.
- They could be connected via wires and RJ-45 connectors, as well as Ether-over-Power and Wi-Fi.
IS-IS in the home? Seriously?

- Assume that the root of the spanning tree is at or to the left (in this diagram) from the Access Point.
- The cost from each box to the root is the same.
- Therefore, the 1 Gb/s wired links get blocked to prevent loops.
- This is why 802.1 is eschewing spanning tree for the home.
SPBV: Plug-and-play

- If adjacent bridges discover they are both running SPBV, they use that protocol in preference to any form of spanning tree.
- At the edges of the SPBV cloud, SPBV bridges connect to older implementations using spanning tree. There is complete forward and backward compatibility.
- SPBV bridges use IS-IS to assign each bridge a small integer bridge ID.
- As end stations (or configuration in bridges) request membership in VLANs, the bridge IDs are combined with the VLANs to build a 12-bit VLAN ID space that encodes both the source bridge ID and VLAN into.
Ongoing SPB Related Activities

• Deployments
  • Multiple vendors shipping product
  • Three interops so far: Alcatel-Lucent, Avaya, Huawei, Solana, Spirent
  • Next interop: May 6, 2013, http://www.interop.com

• Equal Cost Multiple Paths (ECMP) [802.1Qbp]
  • Per hop load balancing for unicast
  • Shared trees for multicast
  • Standardized Flow Hash → OAM enabler
  • New tag to carry Flow Hash and TTL

• Path Control and Reservation (PCR) [802.1Qca]
  • Beyond shortest path → Explicit path control
  • Leveraging link state for
    • Bandwidth and stream reservation
    • Redundancy (protection or restoration) for data flows
    • Distribution of control parameters for time synchronization and scheduling
Quality of Service in 802.1Q

• 8 priority code points in MAC hardware and/or VLAN tag.
• 1-8 queues per port, with default assignments to priorities.
• Default QoS is straight priority: 7, 6, 5, 4, 3, 2, 0 1.
• Bridges can be configured for “Enhanced Transmission Selection” that applies weights to queues, to ensure a minimum service level for lower priorities.
• A queue can be configured with a Credit Based Shaper, in which case it is drained ahead of any priority queue. A CPS queue is used only for data streams reserved by MSRP.
• (New work) Time-scheduled gates can be applied to queues to ensure certain priorities have < 1μS jitter.
• (New work) Low-priority packets can be preempted and resumed.
Priority-based Flow Control (PFC) [802.1Qbb]

- Prevents congestion drop for protocols designed for flow controlled networks (e.g. Fiber Channel over Ethernet)
  - Priorities are individually configured with PFC
  - Traffic in other priorities not affected
- Operates across a single hop
- PFC Pause Frame is sent to pause transmission for a time duration when receive buffer reaches high water mark. Sending with zero time value releases the pause.
- Just like the old 802.3X Pause, but operates on individual priority levels.
Stream Reservation

• The Stream Reservation Protocol (SRP):
  • Advertises streams in the whole network
  • Registers the path of streams
  • Calculates the “worst case latency”
  • Specifies the forwarding rules for AVB streams
  • Establishes an AVB domain
  • Reserves the bandwidth for AVB streams
  • An MRP Application

• Especially the bandwidth reservation is important in order to:
  • Protect the best effort traffic, as only 75% of the bandwidth can be reserved for SR class traffic
  • Protect the SR class traffic as it is not possible to use more bandwidth for SR class traffic than 75% (this is an important factor in order to guarantee a certain latency)
Stream Reservation Example

Talker Advertise

Listener

Bridge

AVB Stream
Traffic Shaping

- As audio/video streams require a high bandwidth utilization, it was necessary to set the maximum available bandwidth for this new traffic class quite high (75%)
- The Credit Based Shaper (CBS) spaces out the frames as much as possible in order to reduce bursting and bunching, thus
  - Protects the best effort traffic as the maximum interference (AVB stream burst) for the highest non-AVB priority is limited and known
  - Protects the AVB streams, as it limits the back to back AVB stream bursts which can interfere in a bridge
- The Credit Based Shaper in combination with the Stream Reservation Protocol is intended to provide delays under 250 us per bridge.
Credit Based Shaper Example

- Credit:
  - idleSlope
  - sendSlope

- Queue Depth:
  - three AVB packets are queued

- Transmitted Data:
  - interfering traffic
  - credit positive, AVB packet launched as soon as interfering traffic is finished
  - credit positive, 2nd AVB packet launched
  - credit positive, 3rd AVB packet launched
  - credit positive, 4th AVB packet launched

- Time:
  - credit negative, 2nd AVB packet held
Preemption and Time Scheduled Queuing

• The credit based shaper works well for audio/video applications, but is not suitable for control applications where worst case delays must be reduced to a minimum.

• Time-aware (scheduled) queuing combined with preemption reduces delays to near the best theoretical levels, with the minimum impact on non-scheduled traffic.

  • SRP or a management agent is required to provide an admission control scheme to limit low-latency traffic to the amount that can be supported by the links in the path between a talker and corresponding listener(s).
Link Aggregation [802.1AX-REV]

- Revision in progress
- Includes Distributed Resilient Network Interconnect (DRNI)
- No longer tied to 802.3 – works over any real or virtual medium
- Supports one, two or three systems at each end of the aggregation
- Connects two networks so that neither network is aware of the details of the interconnect
- Failures do not propagate from network to network
- Systems can be bridges, routers, end stations, or anything else
- Backwards compatible with existing Link Aggregation
- Allows systems to negotiate which data streams take which path, so that bi-directionally congruent flows are possible, and so that extensive state synchronization (e.g., of forwarding tables) is not necessary among systems
- Supports any means of identifying streams: VLANs, 5-tuples, etc.
Security

- Port-based Network Access Control [802.1X]
  - Defines encapsulation of Extensible Authentication Protocol (EAP) over IEEE 802 (EAP over LAN, or EAPOL).
  - Widely deployed on both wired and Wi-Fi networks
- MAC Security (MACsec) [802.1AE]
  - MACsec secures a link not a conversation
  - MACsec counters 802.1X man-in-the-middle attacks
- Secure Device Identity [802.1AR]
  - Supports trail of trust from manufacturer to user
  - Defines how a Secure Device Identifier may be cryptographically bound to a device to support device identity authentication.
Summary
REFERENCES
IEEE 802.1 Standards – Interworking


IEEE 802.1 Standards –
Time Sensitive Networks


• Note that 802.1Q-2011 incorporates TSN amendments
  - 802.1Qat-2010, “IEEE standard for local and metropolitan area networks: Virtual bridged local area networks – Amendment 14: Stream reservation protocol (SRP)"
IEEE 802.1 Standards – Data Center Bridging


- Note that 802.1Q-2011 incorporates 802.1Qau-2010, “IEEE standard for local and metropolitan area networks: Virtual bridged local area networks – Amendment 13: Congestion notification,”
IEEE 802.1 Standards – Security


Ongoing IEEE 802.1 Projects

- **Interworking**
  - **P802.1Qbp**, “Draft standard for local and metropolitan area networks: Media access control (MAC) bridges and virtual bridged local area networks – Amendment: *Equal cost multiple paths (ECMP)*,” [http://www.ieee802.org/1/pages/802.1bp.html](http://www.ieee802.org/1/pages/802.1bp.html)
  - **P802.1Qbz**, “Draft standard for local and metropolitan area networks: Media access control (MAC) bridges and virtual bridged local area networks – Amendment: *Enhancements to Bridging of 802.11*,” [http://www.ieee802.org/1/pages/802.1bz.html](http://www.ieee802.org/1/pages/802.1bz.html)
  - **P802.1Qca**, “Draft standard for local and metropolitan area networks: Media access control (MAC) bridges and virtual bridged local area networks – Amendment: *Path control and reservation*,” [http://www.ieee802.org/1/pages/802.1ca.html](http://www.ieee802.org/1/pages/802.1ca.html)

- **Time Sensitive Networks**

- **Security**

- Note that access to “802.1 private area” is free. Access control is for ongoing work and prepublication standards. Ask 802.1 people!
Further Reading

• **Book**

• **Papers**

• **Tutorial**

• **Wikipedia**
  - Time Sensitive Networks: [http://en.wikipedia.org/wiki/Audio_Video_Bridging](http://en.wikipedia.org/wiki/Audio_Video_Bridging)
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<td>DA</td>
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