IEEE 802.1 FOR HOMENET

March 14, 2013

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)**

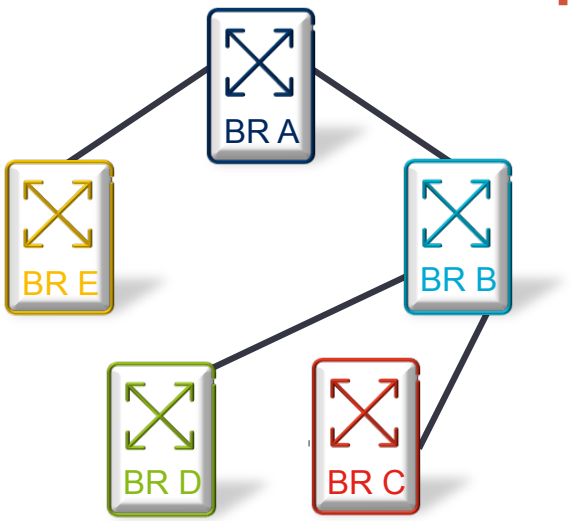
Basic Principles

- 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

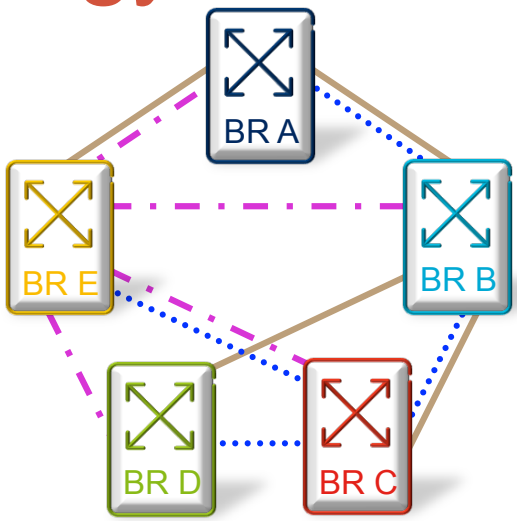
- 802.1Q today is 802.Q-2011 (Revision 2013 is ongoing)
  - Note that if the year is not given in the name of the standard, then it refers to the latest revision, e.g.
    today 802.1Q = 802.1Q-2011 and 802.1D = 802.1D-2004
- 802.1Q already involves
  - Q-in-Q = Provider Bridges (PB)
    [IEEE 802.1ad-2005]
  - 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



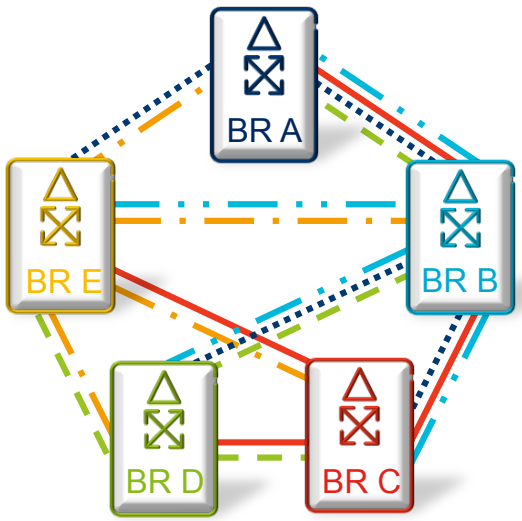
RSTP

Rapid Spanning Tree Protocol



MSTP

Multiple Spanning Tree Protocol



SPB

Shortest Path Bridging

- 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

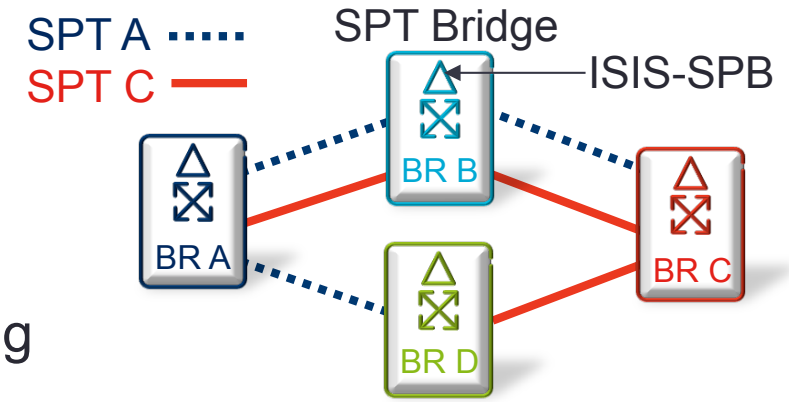
- Software Defined Networking (SDN) principles are supported by 802.1Q
- Separation of the control plane from the data plane
  - The bridge architecture separates the control plane from the data plane
  - The External Agent is geographically separated
- Separate topologies per VLAN
  - Any given VLAN 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 → **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 → 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

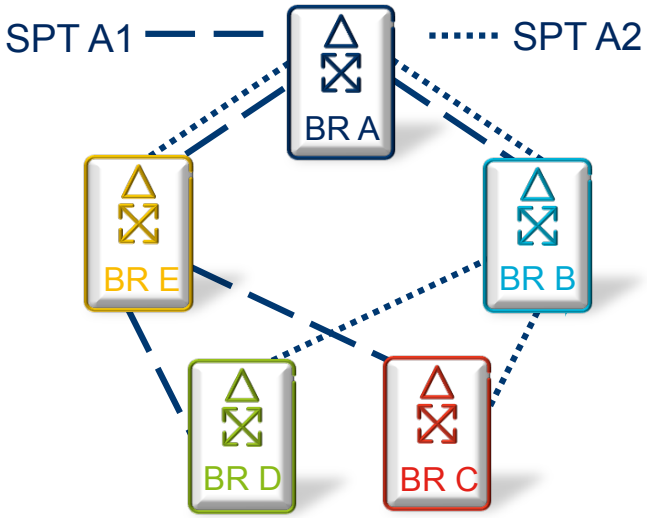
- **SPBM**: SPB MAC
  - Backbone MAC identified SPTs
  - Designed to leverage the scalability provided by PBB /“MAC-in-MAC”/
  - No B-MAC flooding/learning
  - **Managed environments**
- **SPBV**: SPB VID
  - VID identified SPTs
  - Applicable to all types of VLANs
  - Flooding and learning
  - **Plug&play**

Load Spreading

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

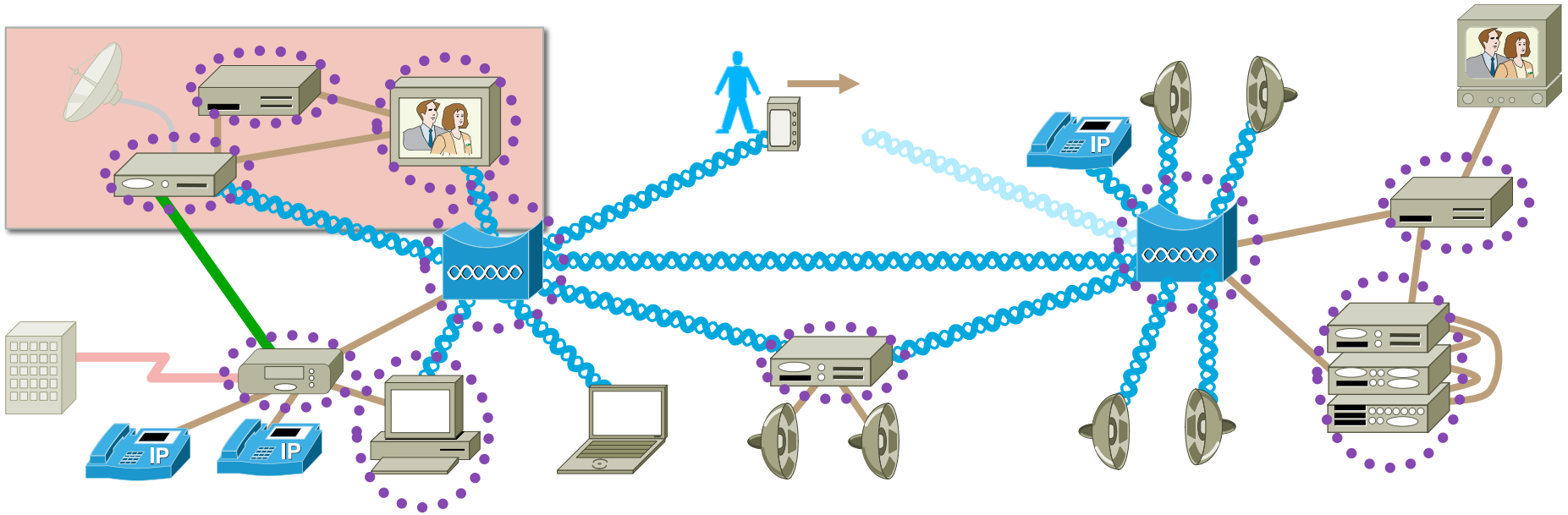
- Further load-spreading by exploiting equal cost paths to create multiple SPT Sets
  - Up to 16 standard tie-breaking variations to produce diverse SPTs

- Provisioned load spreading
  - A VLAN is assigned to an SPT Set



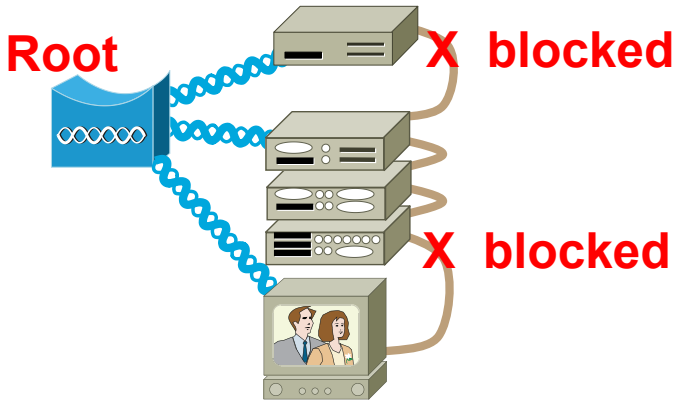
SPT options for Bridge A

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

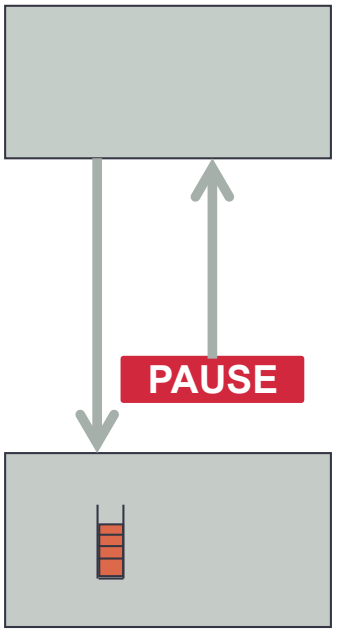
- Deployments
  - Multiple vendors shipping product
  - Three interops so far: Alcatel-Lucent, Avaya, Huawei, Solana, Spirent
  - Next interop: May 6, 2013, http://www.interop.com
- Equal Cost Multiple Paths (ECMP) [802.1Qbp]
  - Per hop load balancing for unicast
  - Shared trees for multicast
  - Standardized 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.



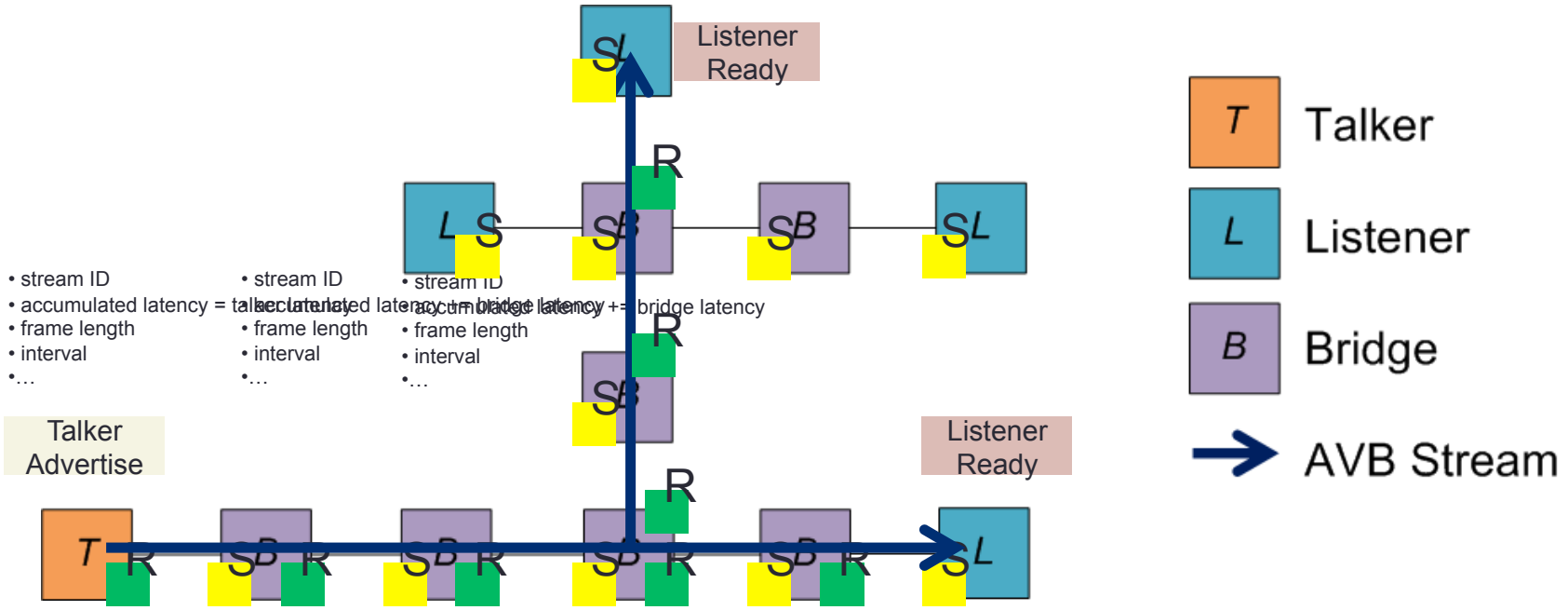
Buffer reaches high water mark

Pause is sent

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)

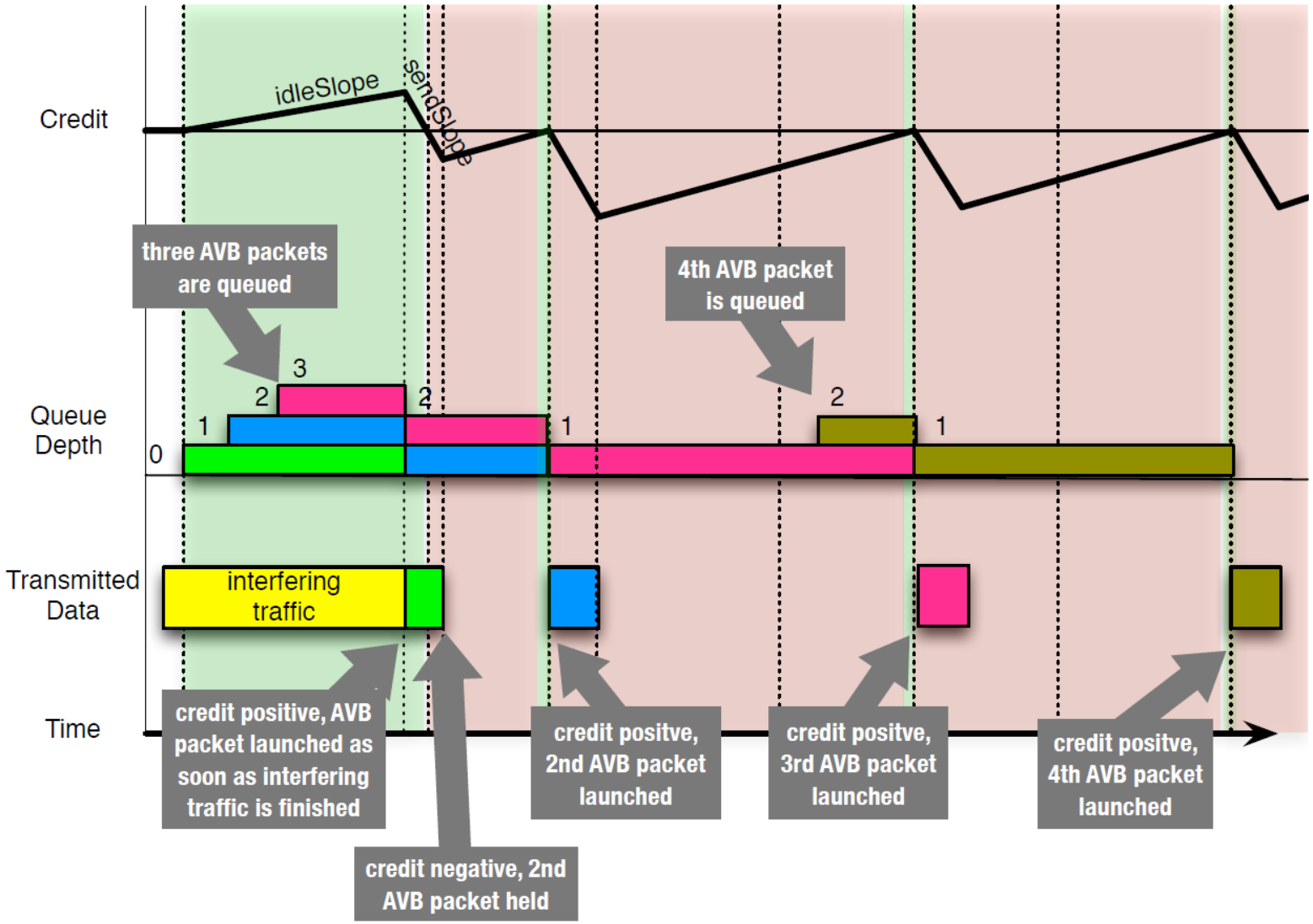
Stream Reservation Example



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



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

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Summary

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IEEE 802.1 Standards – Interworking

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  - 802.1Qav-2009, "IEEE standard for local and metropolitan area networks: Virtual bridged local area networks – Amendment 12: Forwarding and queuing enhancements for time-sensitive streams"

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Ongoing IEEE 802.1 Projects

- Interworking
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  - **P802.1AX-REV**, “Draft standard for local and metropolitan area networks: **Link aggregation**,” Revision incorporating **Distributed Resilient Network Interconnect (DRNI)**, http://www.ieee802.org/1/pages/802.1AX-rev.html
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- 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
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  - Shortest Path Bridging: http://en.wikipedia.org/wiki/IEEE_802.1aq

ABBREVIATIONS

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ACM	Association for Computing Machinery
AVB	Audio Video Bridging
AP	Access Point
BCB	Backbone Core Bridge
BEB	Backbone Edge Bridge
B-MAC	Backbone MAC
BMCA	Best Master Clock Algorithm
B-VID	Backbone VLAN ID
B-VLAN	Backbone VLAN
CCM	Continuity Check Message
CBS	Credit Based Shaper
CM	Clock Master
CS	Clock Slave
C-MAC	Customer MAC
C-TAG	Customer TAG
C-VID	Customer VLAN ID
C-VLAN	Customer VLAN
CFM	Connectivity Fault Management
DA	Destination Address
DCB	Data Center Bridging
DCBX	Data Center Bridging eXchange
DCN	Data Center Network
DRNI	Distributed Resilient Network Interconnect
EB	Edge Bridge
ECMP	Equal Cost Multiple Paths
E-LINE	Ethernet Line (point-to-point) service
E-LAN	Ethernet LAN (multipoint) service
E-TREE	Ethernet Tree (rooted multipoint) service
EVB	Edge Virtual Bridging
FDDI	Fiber Distributed Data Interface
GM	Grand Master
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
IETF	Internet Engineering Task Force
IPS	Infrastructure Protection Switching
IP	Internet Protocol
I-SID	Backbone Service Instance Identifier
IS-IS	Intermediate System to Intermediate System
ISIS-SPB	IS-IS for SPBV and SPBM
ISO	International Organization for Standardization
I-tag	Backbone Service Instance TAG
ITU	International Telecommunication Union
ITU-T	ITU Telecommunication Standardization Sector
IWK	Interworking
LAN	Local Area Network
MAC	Media Access Control
LBM	Loopback Message
LBR	Loopback Reply
LLDP	Link Layer Discovery Protocol
LTM	Linktrace Message
LTR	Linktrace Reply
MAC-in-MAC	used for PBB
MAN	Metro Area Network
MEF	Metro Ethernet Forum

MEP	Maintenance association End Point
MIB	Management Information Base
MIP	Maintenance domain Intermediate Point
MoCA	Multimedia over Coax Alliance
MKA	MAC Security Key Agreement Protocol
MMRP	Multiple MAC registration Protocol
MRP	Multiple Registration Protocol
MSRP	Multiple Stream registration Protocol
MSTP	Multiple Spanning Tree Protocol
MVRP	Multiple VLAN Registration Protocol
OAM	Operations, Administration and Maintenance
PAR	Project Authorization Request
PB	Provider Bridge
PBB	Provider Backbone Bridge
PBB-TE	Provider Backbone Bridging - Traffic Engineering
PCR	Path Control and Reservation
PE	Provider Edge
PFC	Priority Flow Control
PTP	Precision Time Protocol
Q-in-Q	used for PB
QCN	Quantized Congestion Notification
QoS	Quality of Service
SDH	Synchronous Digital Hierarchy
S-VID	Service VLAN ID
S-VLAN	Service VLAN
SPB	Shortest Path Bridging
SPBM	Shortest Path Bridging MAC
RDI	Remote Defect Indication
RFC	Request For Comments
RSTP	Rapid Spanning Tree Protocol
SDN	Software Defined Network
SONET	Synchronous Optical Networking
SPBV	Shortest Path Bridging VID
SPT	Shortest Path Tree
SR	Stream Reservation
SRP	Stream Reservation Protocol
S-tag	Service TAG
S-VLAN	Service VLAN
STP	Spanning Tree Protocol
TESI	Traffic Engineering Service Instance
TSN	Time Sensitive Networks
TTL	Time to Live
TLV	Type, Length, Value
VDP	VSI Discovery and Configuration Protocol
VID	VLAN Identifier
VLAN	Virtual LAN
VM	Virtual Machine
VN	Virtual Network
VoIP	Voice over IP
VSI	Virtual Service Instance