IEEE SA STANDARDS ASSOCIATION

FOUNDATIONAL TECHNOLOGIES

TSN Time Sensitive Networking Powered by IEEE 802

DRIVING DIGITAL TRANSFORMATION THROUGH IEEE 802.1 TSN TECHNOLOGY

IEEE TIME-SENSITIVE NETWORKING WEBINAR SERIES: AN INTRODUCTION TO IEEE 802.1

SPEAKER: GLENN PARSONS, PRINCIPAL STANDARDIZATION ADVISOR, 5G TRANSPORT, ERICSSON

MODERATED BY: SRI CHANDRASEKARAN, SR DIRECTOR & PRACTICE LEAD, FOUNDATIONAL TECHNOLOGIES, IEEE SA

16 Sept 2021

IEEE

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To ask QUESTIONS throughout the webinar, use the Q&A feature.

SPEAKER – GLENN PARSONS

Principal Standardization Advisor, 5G Transport, Ericsson

Glenn Parsons leads standards strategy and policy for Ericsson, including network architecture for 5G radio transport networks.
Glenn is an internationally known expert in networking, including mobile transport and Ethernet. Over the past number of years, he has held several technical management and editor positions in various standards activities including MEF, IETF, IEEE SA, and ITU-T. He has also held elected and appointed leadership roles in standardization governance in IEEE SA and ITU-T. He is currently involved with 5G transport standardization in IEEE SA and ITU-T and is the chair of IEEE 802.1 working group. In addition to being the founding Editor-in-chief for IEEE Communications Standards Magazine, he was previously a Senior Technical Editor for IEEE Communications Magazine.

He graduated in 1992 with a B.Eng. degree in electrical engineering from Memorial University of Newfoundland, Canada.

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THE IMPACT OF TIME-SENSITIVE NETWORKS

AN INTRODUCTION TO IEEE 802.1

September 2021

IEEE

BEFORE WE START – DISCLAIMER

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OUTLINE

IEEE 802.1 working group

802.1 Architecture

802.1 Interworking

802.1 YANG

802.1 Time-Sensitive Networking (TSN)

802.1 Security

Summary

IEEE 802.1 WORKING GROUP

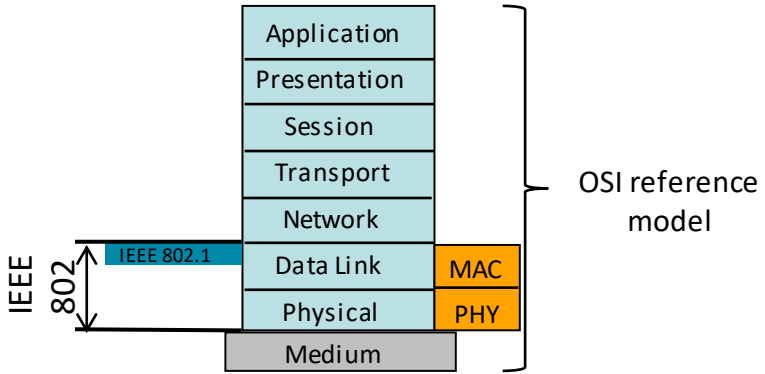
IEEE 802.1

Architecture and Bridging

- Traditionally, the Higher Layer Interface

Part of the LAN / MAN Standards Committee

- Along with 802.3, 802.11, 802.15, …
- Wired and wireless standards for data link and physical layers
- In operation since March 1980

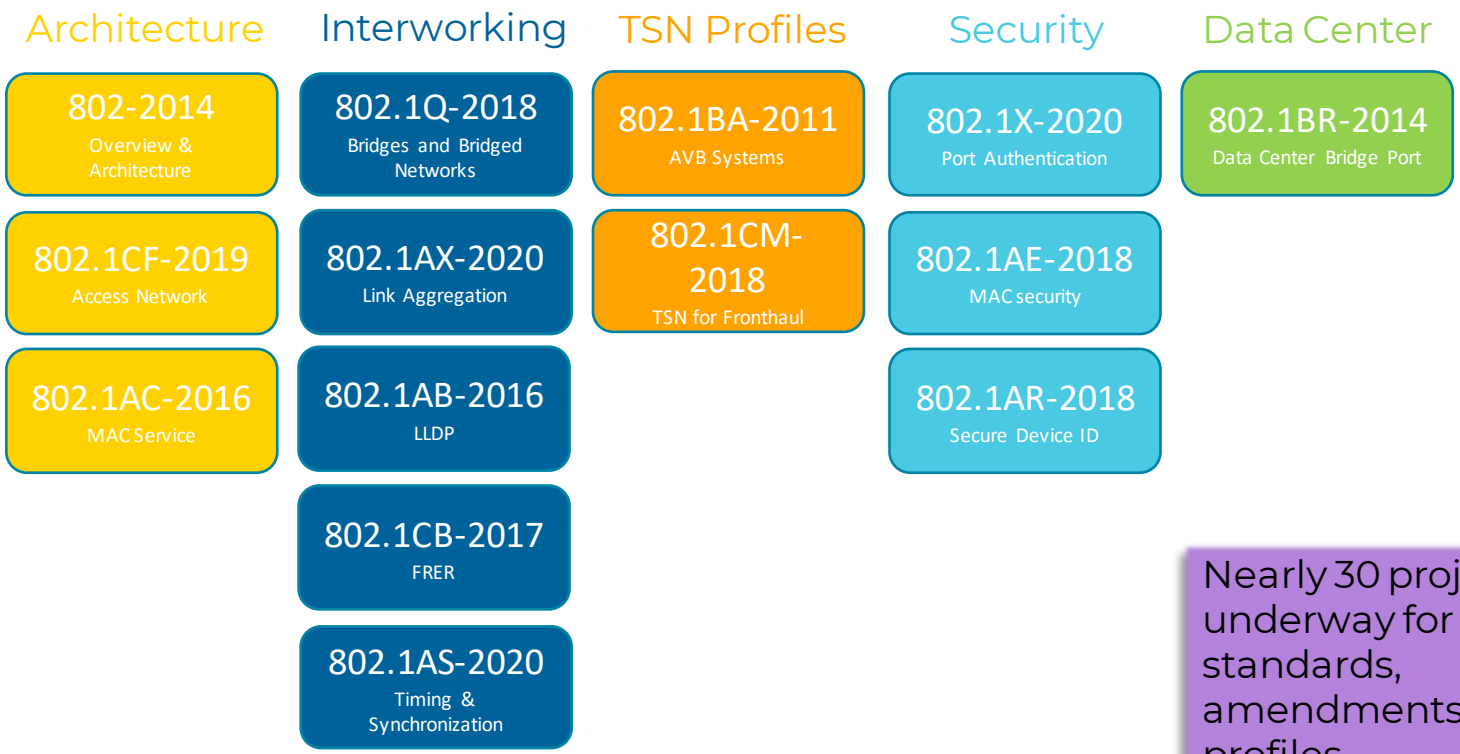


IEEE 802.1 Working Group

Chair: Glenn Parsons
Vice-chair: Jessy Rouyer

- **TSN Task Group** — *Chair: János Farkas*
- **Security Task Group** — *Chair: Mick Seaman*
- **Maintenance Task Group** — *Chair: Paul Congdon*
- **YANGsters** — *Chair: Scott Mansfield*
- **NENDica** — *Chair: Roger Marks*

APPROVED IEEE 802.1 BASE STANDARDS



Nearly 30 projects are underway for new standards, amendments and profiles

802.1 ARCHITECTURE

802 REFERENCE MODEL

MSAP MAC service access point
LSAP link service access point

PSAP PHY service access point

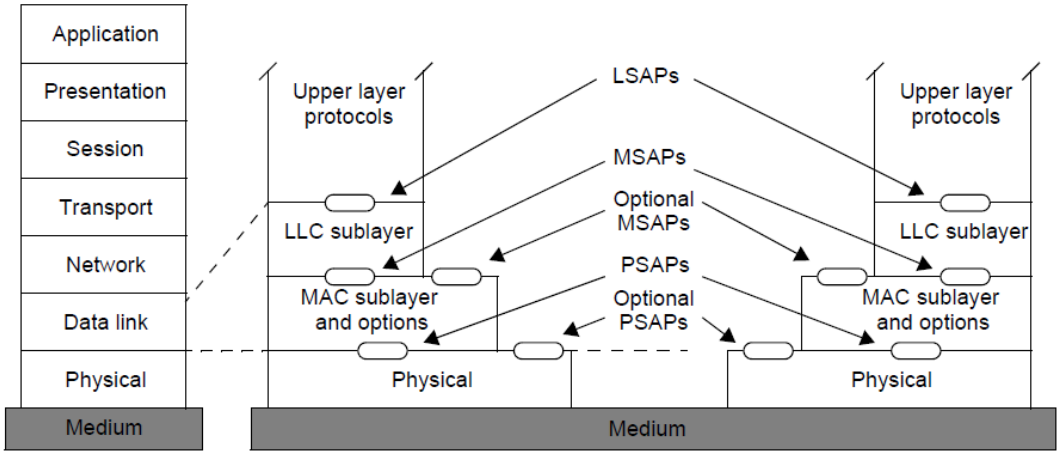


Figure 3 - IEEE Std 802

Current IEEE 802 family of working groups

- **802.1** Bridging and Architecture
- **802.3** Ethernet
- **802.11** Wireless LAN (WLAN)
- **802.15** Wireless Personal Area Network (WPAN)
- **802.16** Broadband Wireless Access (BWA)
- **802.21** Media Independent Handover
- **802.22** Wireless Regional Area Networks (WRAN)

BRIDGING TIES IT TOGETHER

IEEE Std 802.1AC specifies the MAC Service provided by all IEEE 802 LANs

IEEE Std 802.1Q specifies interworking among IEEE 802 LANs by bridging at the MAC sublayer

- Interworking can be heterogeneous (across different 802 technologies).
- MAC frames are forwarded (or filtered) based on address and Virtual LAN information in the MAC frame.
- Relaying and filtering belong entirely within the MAC sublayer.

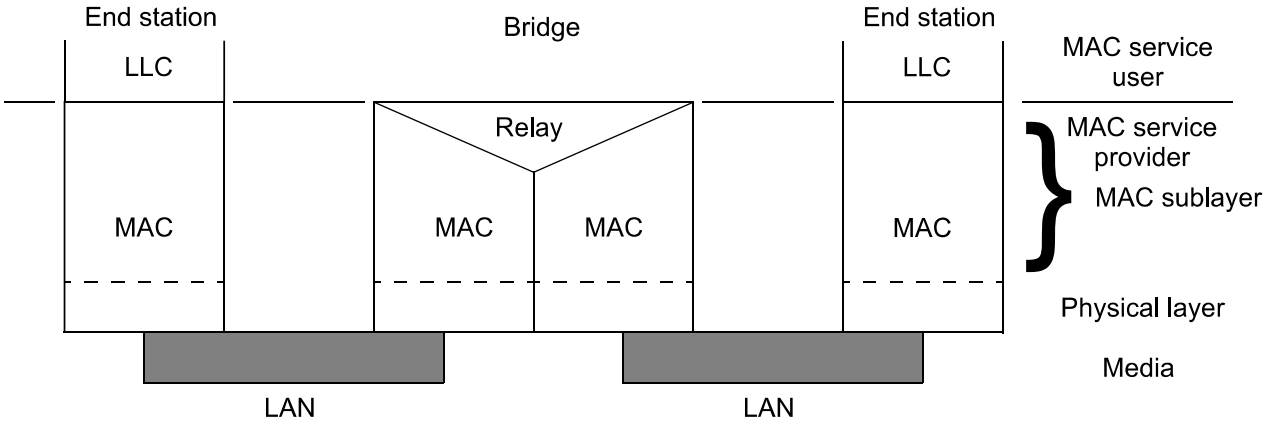


Figure 7 - IEEE Std 802

802.1 INTERWORKING

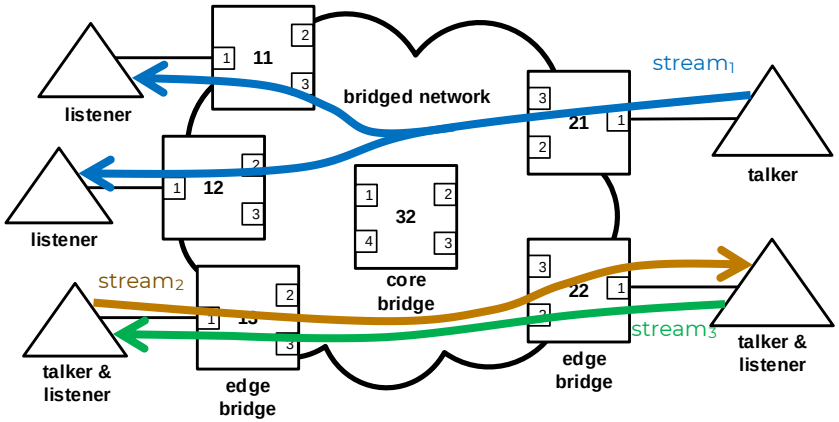
FUNDAMENTAL COMPONENTS

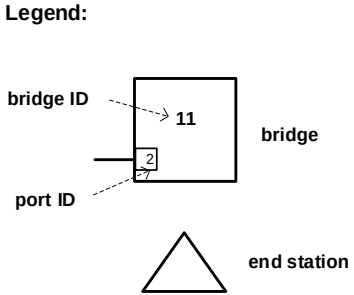
From the IEEE Std 802.1Q perspective, the world is divided into two types of devices: bridges and end stations

Talker: The end station that is the source or producer of a stream

Listener: The end station that is the destination, receiver, or consumer of a stream

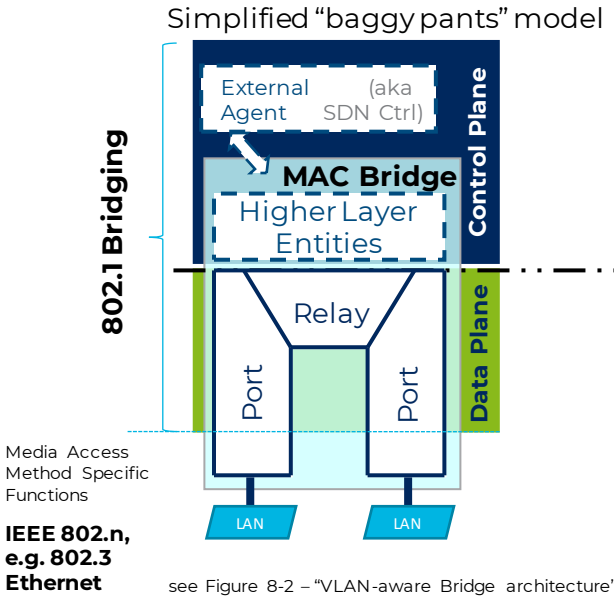
Stream: A unidirectional flow of data from a Talker to one or more Listeners





BRIDGE ARCHITECTURE

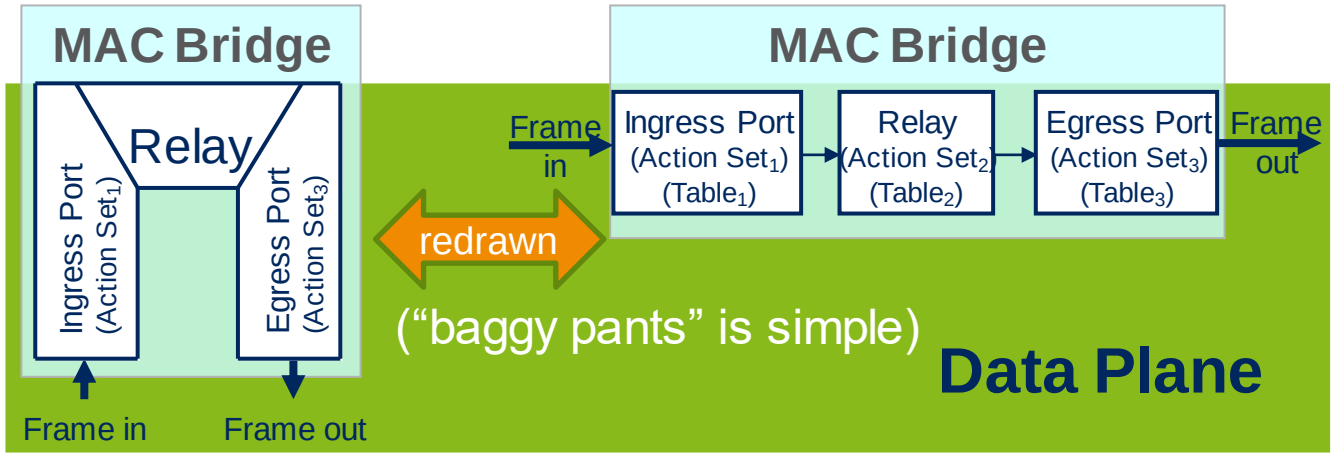
Control Plane Separated from Data Plane



- Control protocols are implemented as Higher Layer Entities
- External Agent (SDN Controller) may provide control instead of the distributed protocols
- The data plane is comprised of
  - A MAC Relay and
  - At least two ports

see Figure 8-2 – "VLAN-aware Bridge architecture" of IEEE Std 802.1Q for more details

BRIDGE DATA PLANE ACTIONS



Ingress Port (Action Set$_1$)

Filtering (drop), (un)tagging, VID translation, de/en-capsulation

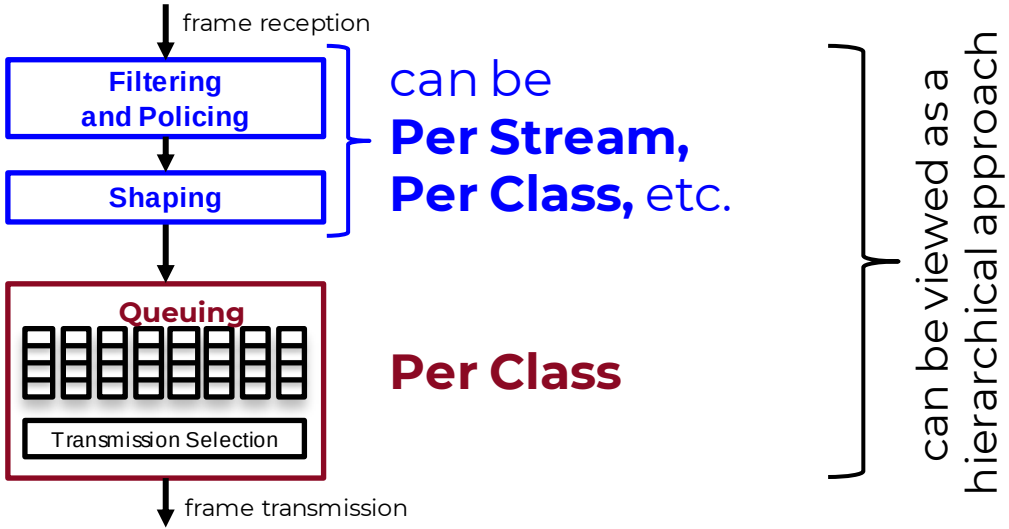
Relay (Action Set$_2$)

Forwarding, filtering

Egress Port (Action Set$_3$)

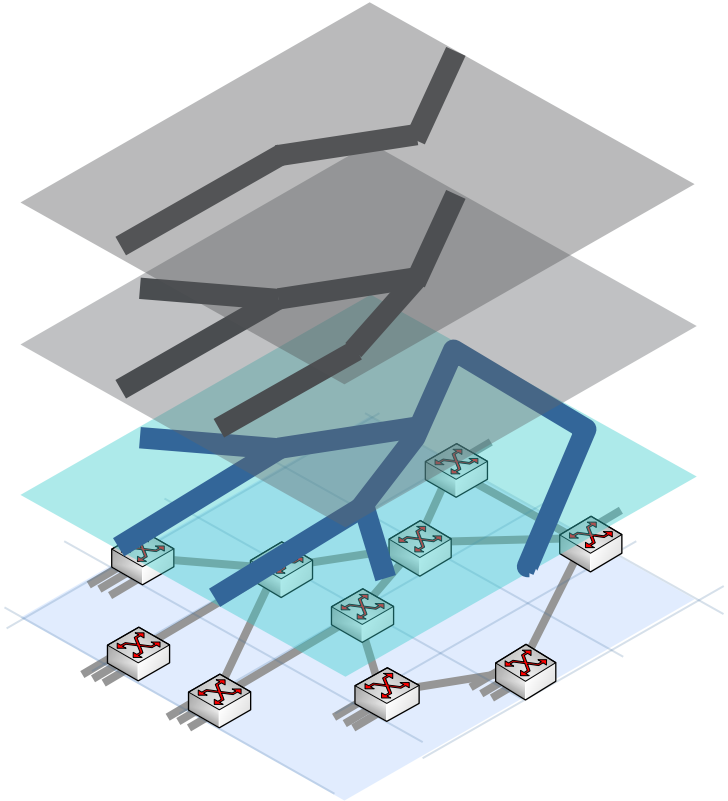
Filtering, (un)tagging, VID translation, de/en-capsulation, metering, queuing, transmission selection

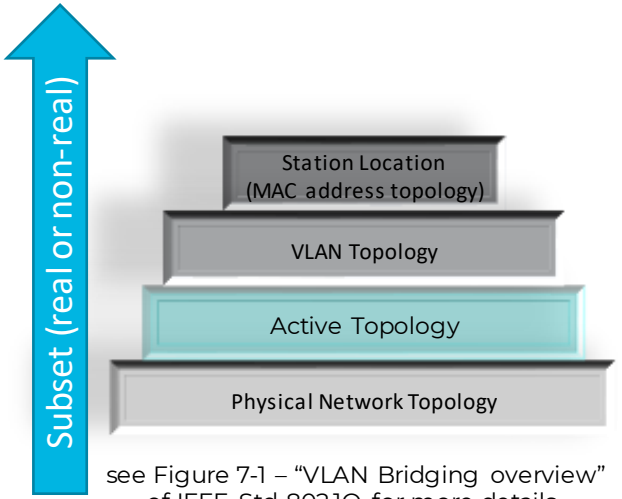
ILLUSTRATION OF QOS FUNCTIONS



note: other functions are not shown in this figure, e.g., relay, reliability

TOPOLOGY LAYERS (CONTEXTS)

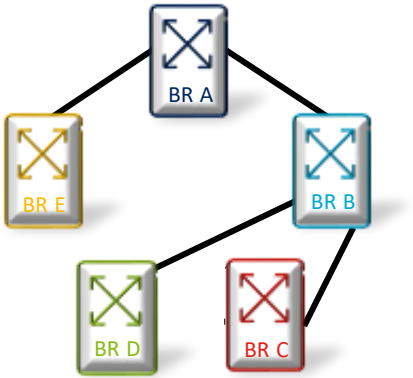




see Figure 7-1 – "VLAN Bridging overview" of IEEE Std 802.1Q for more details

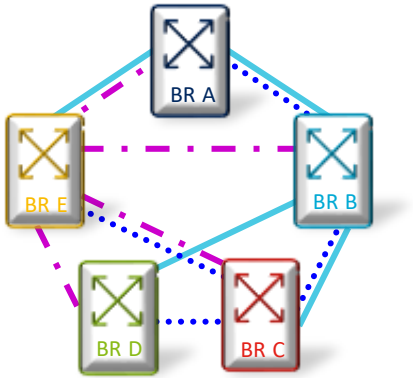
THE ACTIVE TOPOLOGY

Distributed Protocols for the Control Plane



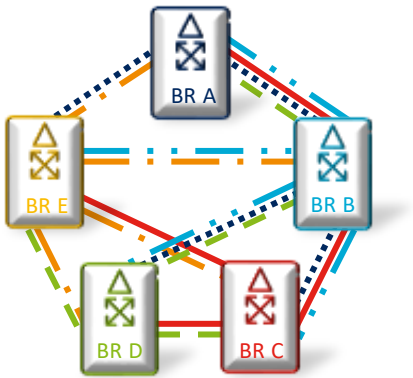
RSTP

Rapid Spanning Tree Protocol



MSTP

Multiple Spanning Tree Protocol



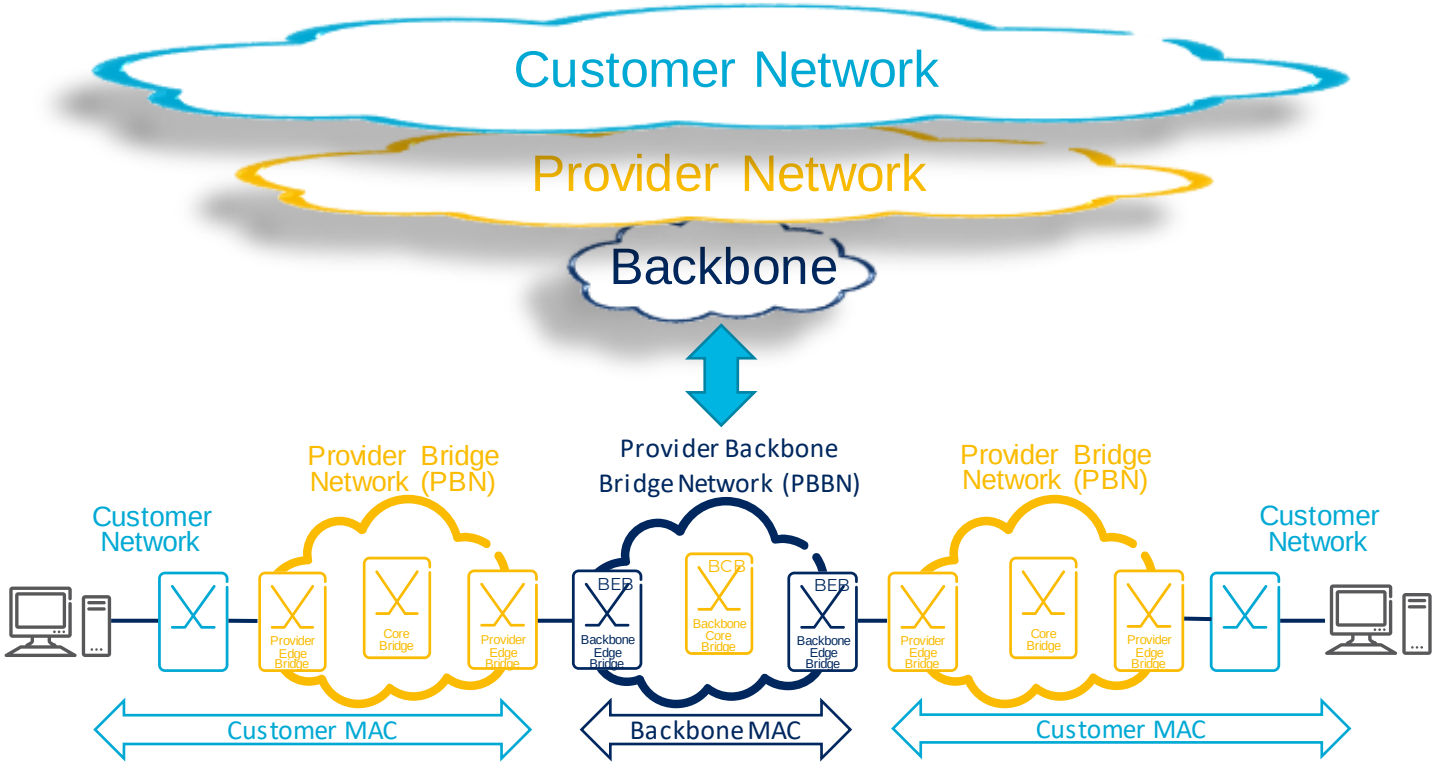
SPB

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)**

Note: the Spanning Tree Protocol (STP) is historical, it has been replaced by RSTP

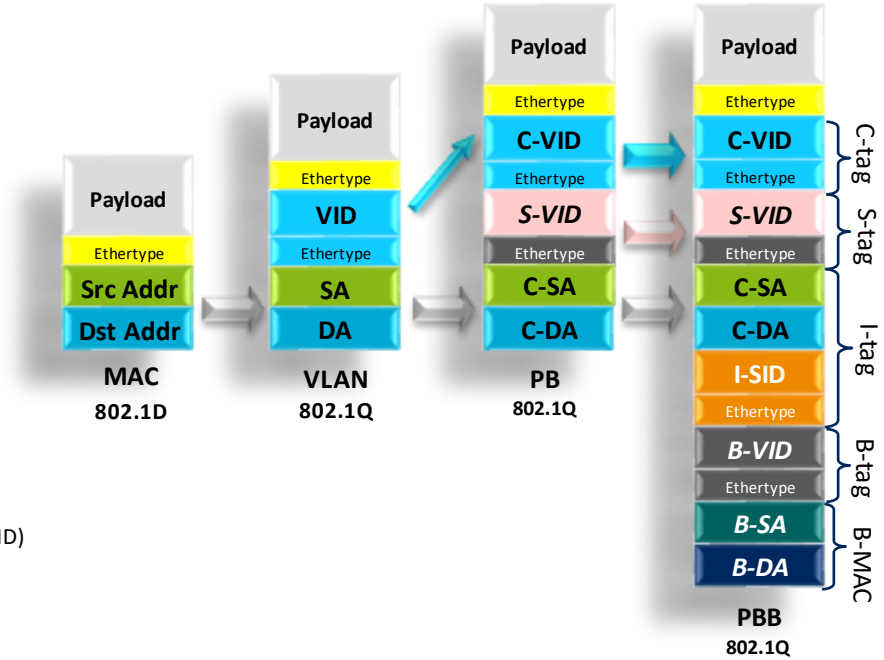
NETWORK OVERLAYS EXAMPLE



NETWORK VIRTUALIZATION IS BASED ON THE DATA PLANE

- **Data plane evolution**
- MAC bridging to VLAN bridging -- it is not complicated

- **Provider Bridges (PB, *aka Q-in-Q*)**
- Scalability
  - Overlaying virtual networks
  - 4K VLAN problem solved
- **Provider Backbone Bridges (PBB, *aka MAC-in-MAC*)**
- Scalability
  - 24-bit I-SID as a single virtual network ID
  - Forget about the 4K VLAN problem
- Separation
  - MAC address space separation (C-MAC vs. B-MAC)
  - Service layer is separated from transport layer (I-SID vs. B-VID)
- **Overall**
- Uniform forwarding kept: based on Destination MAC (DA) and VID
- L2 data plane provides powerful virtualization
- There may be several levels of tagging or encapsulation



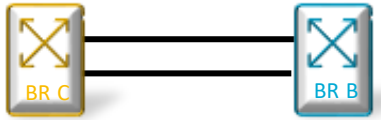
LINK AGGREGATION

LAG [802.1AX] was originally defined in 802.3 to combine multiple Ethernet connections

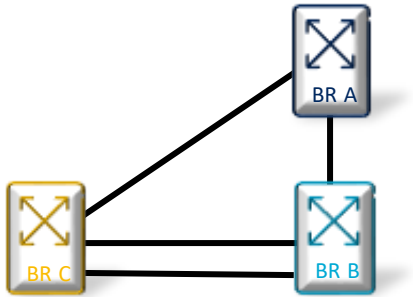
- Connects two networks so that neither network is aware of the details of the interconnect
- Failures do not propagate from network to network
- Systems can be bridges, routers, end stations, or anything else

Distributed Resilient Network Interconnect (DRNI)

- No longer tied to IEEE Std 802.3 Ethernet – works over any real or virtual medium
- Supports one, two or three systems at each end of the 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.



LAG



DRNI

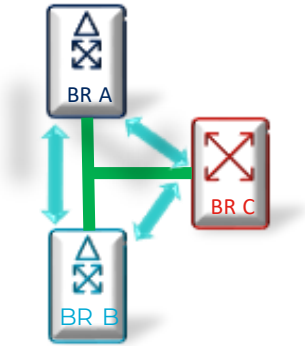
LINK LAYER DISCOVERY PROTOCOL (LLDP)

LLDP [802.1AB] is a link layer protocol used by network devices for advertising their identity, capabilities, and neighbors on an IEEE 802 local area network

Information Exchanged is in the form of TLVs and includes mandatory and *optional* information such as:

- System name and description
- Port name and description
- IP management address
- *VLAN name*
- *System capabilities (switching, routing, etc.)*
- *MAC/PHY information*
- *MDI power*
- *Link aggregation*

LLDP is extensible and can been extended by other groups



802.1 YANG

NETWORK MANAGEMENT PROTOCOL SOUP

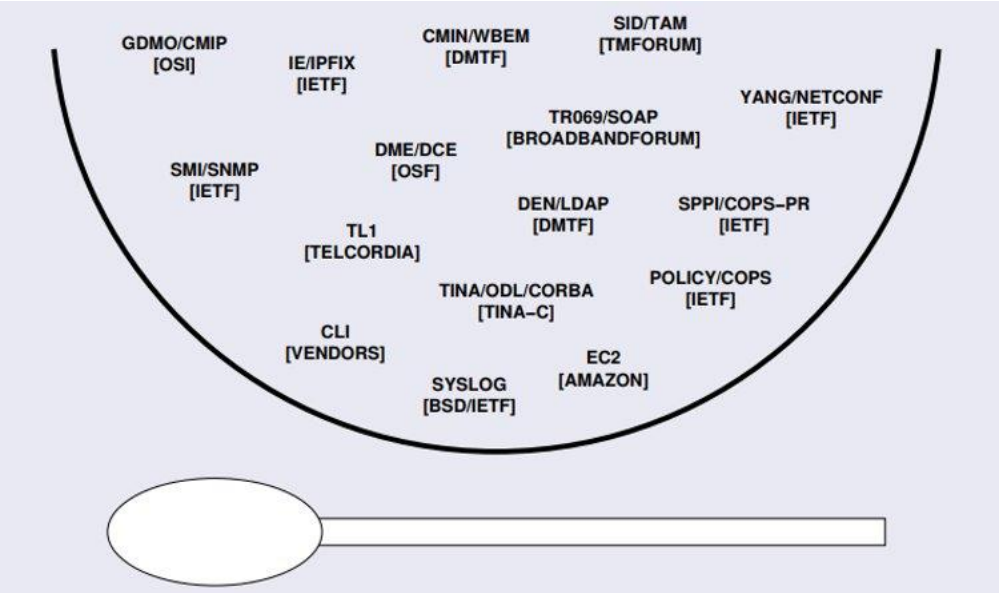
Network Management is the process of administering and managing the networks of one or many organizations.

- fault analysis
- performance management
- provisioning of networks
- maintaining the quality of service

Several SDOs have defined an architecture:

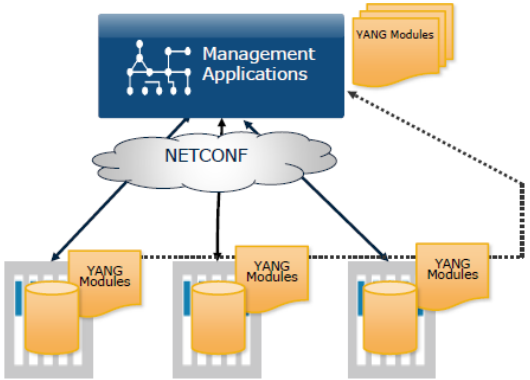
- ISO – FCAPS
- TMF – FAB

…and there are many protocols:

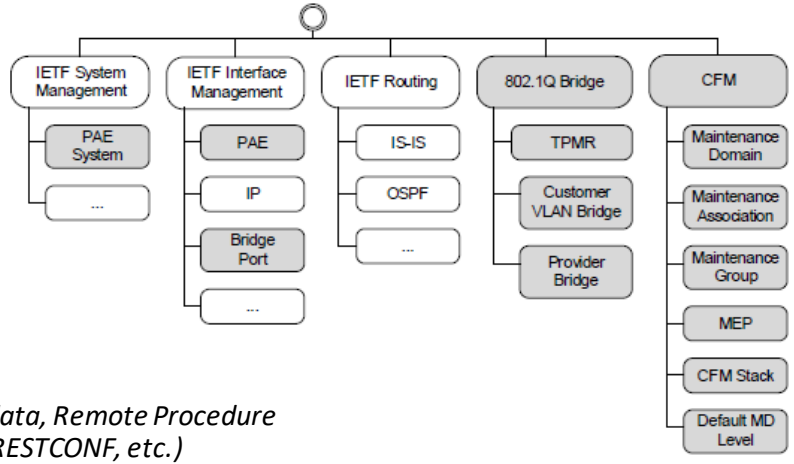


WHAT IS NETWORK MANAGEMENT FOR?

Simplified automation of configuration and monitoring



IEEE 802.1Q YANG hierarchy – Figure 48-2



YANG

YANG is a data modeling language used to model configuration data, state data, Remote Procedure Calls, and notifications for network management protocols (e.g., NETCONF, RESTCONF, etc.)

NETCONF

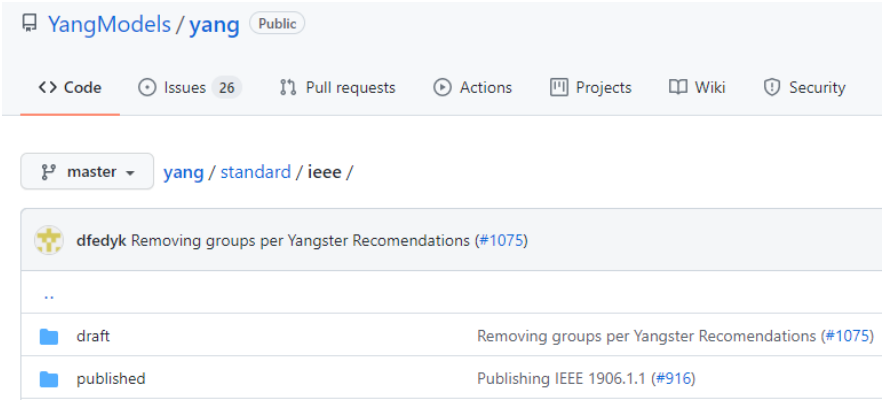
The Network Configuration Protocol (NETCONF) provides mechanisms to install, manipulate, and delete the configuration of network devices.

YANG IN IEEE STANDARDS

Open Source tooling from has provided a significant improvement in YANG module development

802.1 Working Group YANG process:

- Module drafts in development posted on YANG Catalog GitHub with IEEE license indication – all module contributions are considered contributions to the standard
- Publication of module in IEEE standard – copied inline and attached to PDF as text files
- Publication of module on 802.1 WG website
- Publication of module on YANG Catalog GitHub
- Copyright release to freely reproduce the YANG modules so that they can be used for their intended purpose.



https://github.com/YangModels/yang/tree/master/standard/ieee

802.1 TIME-SENSITIVE NETWORKING

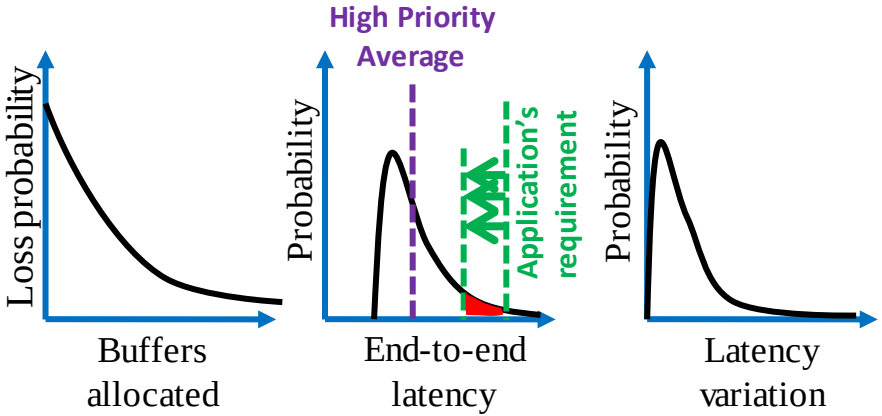
WE ARE INTERESTED IN DETERMINISTIC SERVICE

Traditional Service

Curves have long tail

Average latency is good

Lowering the latency means
losing packets (or overprovisioning)

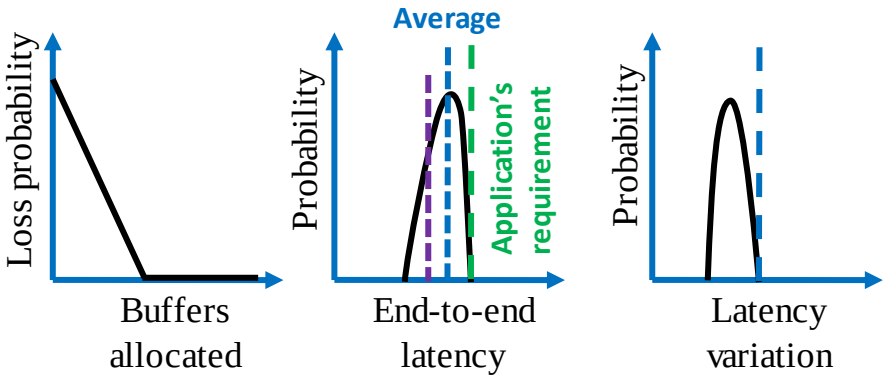


Deterministic Service

Packet loss is at most due to equipment failure (zero congestion loss)

Bounded latency, no tails

The right packet at the right time



TSN PROFILES

Wide breadth of choices in IEEE 802 standards

TSN Time-Sensitive Networking Powered by IEEE 802

A TSN Profile

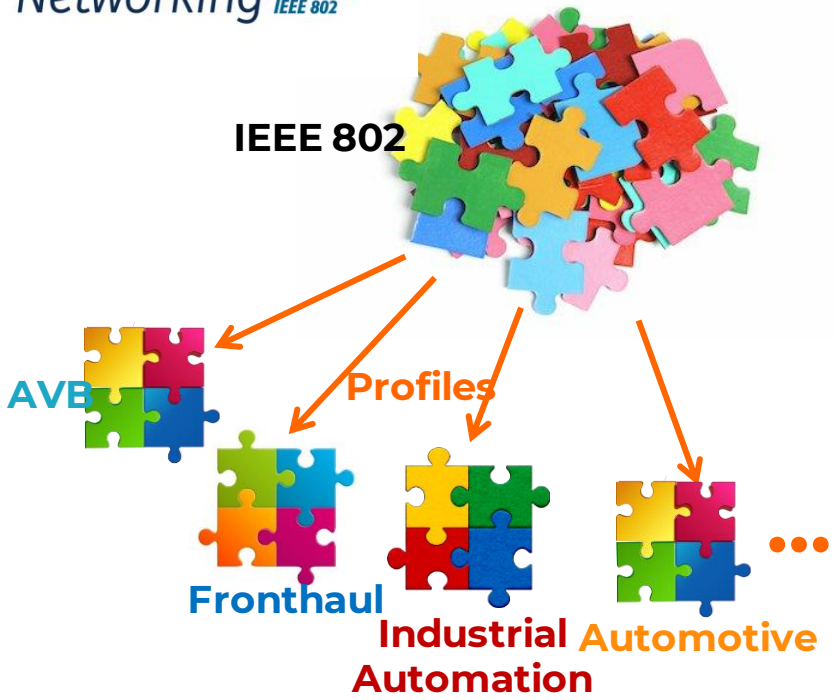
- Narrows the focus ➔ ease interoperability and deployment
- Selects features, options, defaults, protocols, and procedures
- Describes how to build a network for a particular use
- Provides configuration guideline if needed

TSN profile standards:

- IEEE Std 802.1BA Audio-Video Bridging (AVB) networks
- IEEE Std 802.1CM TSN for Fronthaul
- IEEE Std 802.1CMde Amendment on Sync enhancements

Ongoing TSN profile projects:

- IEC/IEEE P60802 TSN Profile for Industrial Automation
- IEEE P802.1DG TSN Profile for Automotive In-Vehicle Ethernet
- IEEE P802.1DF TSN Profile for Service Provider Networks
- IEEE P802.1DP TSN Profile for Aerospace



Time-Sensitive Networking (TSN) Profiles (Selection and Use of TSN tools)

Audio Video Bridging [802.1BA/Revision]	Fronthaul [802.1CM/de]	Industrial Automation [IEC/IEEE 60802]	Automotive In-Vehicle [P802.1DG]	Service Provider [P802.1DF]	Aerospace Onboard [IEEE P802.1DP / SAE AS6675]

TSN Components

(Tools of the TSN toolset)

Time synchronization:
Timing and Synchronization [802.1AS-2020]
(a profile of IEEE 1588)
Hot Standby [P802.1ASdm]
YANG [P802.1ASdn]
Inclusive Terminology [P802.1ASdr]

Synchronization

Reliability

High availability / Ultra reliability:
Frame Replication and Elimination [802.1CB]
Path Control and Reservation [802.1Qca]
Per-Stream Filtering and Policing [802.1Qci]
Reliability for Time Sync [802.1AS-2020]

Latency

Bounded low latency:
Credit Based Shaper [802.1Qav]
Frame Preemption [802.1Qbu & 802.3br]
Scheduled Traffic [802.1Qbv]
Cyclic Queuing and Forwarding [802.1Qch]
Asynchronous Traffic Shaping [802.1Qcr]
Shaper Parameter Settings [P802.1Qdq]
QoS Provisions [P802.1DC]

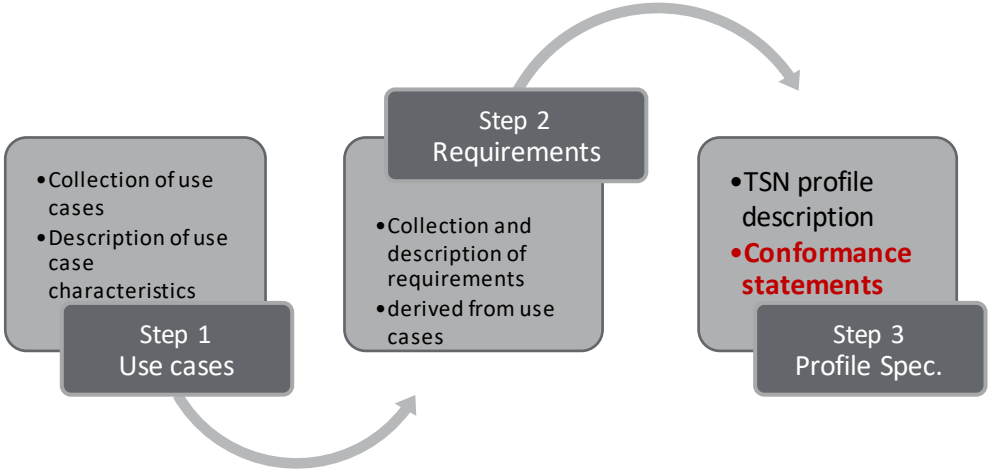
Resource Management

Zero congestion loss = Bounded latency

Dedicated resources & API:
Stream Reservation Protocol [802.1Qat]
Link-local Registration Protocol [802.1CS]
TSN Configuration [802.1Qcc]
Foundational Bridge YANG [802.1Qcp]
YANG for CFM [P802.1Qcx]
YANG for LLDP [P802.1ABcu]
YANG for 802.1Qbv/Qbu/Qci [P802.1Qcw]
YANG & MIB for FRER [P802.1CBcv]
Extended Stream Identification [P802.1CBdb]
Resource Allocation Protocol [P802.1Qdd]
TSN Configuration Enhancements [P802.1Qdj]
LLDPv2 for Multiframe Data Units [P802.1ABdh]
Multicast and Local Address Assignment [P802.1CQ]

Note: A 'P' in front of '802.1' indicates an ongoing Project.

TYPICAL PROFILE WORKFLOW



IEEE Std 802.1BA for Audio-Video Bridging (AVB) networks

Plug & Play → defaults are essential

IEEE Std 802.1CM TSN for Fronthaul

Fully engineered → configuration guidelines are given (in addition to device conformance)

IEC/IEEE 60802 TSN Profile for Industrial Automation

Plug & Produce

Engineering

IEEE P802.1DG TSN Profile for Automotive In-Vehicle Ethernet Communications

Fully engineered, closed network

802.1 SECURITY

SECURITY

Port-based Network Access Control [802.1X]

Defines encapsulation of Extensible Authentication Protocol (EAP) over IEEE 802 (EAP over LAN, or EAPOL) to support network access control and the creation of secure infrastructures.

Widely deployed on both Ethernet and Wi-Fi networks

Also specifies the MACsec Key Agreement (MKA) protocol used by IEEE Std 802.1AE.

MAC Security (MACsec) [802.1AE]

MACsec secures a link or a VLAN with encryption

MACsec counters 802.1X man-in-the-middle attacks

Secure Device Identity [802.1AR]

Supports trail of trust from manufacturer to user

Defines how authentication credentials (DevIDs) may be cryptographically bound to a device to support device identity authentication.

PRIVACY

Privacy Considerations [802E]

Specifies a privacy threat model for IEEE 802 technologies

Provides recommendations on how to protect against privacy threats

Promotes a consistent approach to threat mitigation by IEEE 802 protocol developers

MAC Privacy Protection [802.1AEdk]

Specifies privacy enhancements that reduces the ability of external observers to correlate user data frames, their sizes, transmission timing and transmission frequency with users' identities and activities.

The encapsulation format allows one or more user data frames and padding to be carried within the confidentiality protected data of a consolidating frame, hiding the users' MAC addresses and original frame sizes.

802.1 WORKING GROUP

SUMMARY

IEEE 802.1 is an individual-based working group open to all

- **Tieing together 802 LANs for over 40 years with a rich set of standards**
- Bridging, aggregation, discovery, security, management, …

- **The evolution of bridging is time-sensitive networking**
- Profiles of common functionality for a series of applications spaces:
  - AV, fronthaul, industrial automation, automotive, aerospace, …

- **The volunteer experts continue to excel and innovate**
- Recognized with 2020 IEEE Emerging Technology Award

ADDITIONAL INFORMATION

802.1 Working Group website - http://ieee802.org/1

IEEE-SA process

https://standards.ieee.org/about/policies/index.html

http://www.ieee802.org/1/files/public/docs2020/admin-parsons-SA+802-process-overview-0720.pdf

802 process

http://www.ieee802.org/devdocs.shtml

802 orientation

http://www.ieee802.org/orientation.shtml

WG process

https://1.ieee802.org/rules/

https://www.ieee802.org/1/files/public/docs2021/admin-parsons-WG-logistics-orientation-0721.pdf

WG technical orientations

http://www.ieee802.org/1/files/public/docs2018/tsn-farkas-intro-0318-v01.pdf

http://www.ieee802.org/1/files/public/docs2018/detnet-tsn-farkas-tsn-overview-1118-v01.pdf

http://www.ieee802.org/1/files/public/docs2018/detnet-tsn-farkas-tsn-basic-concepts-1118-v01.pdf

IEEE 802.1

DRIVING DIGITAL TRANSFORMATION THROUGH IEEE 802.1 TSN TECHNOLOGY

IEEE TSN WEBINAR SERIES NEXT EVENT: AN OVERVIEW OF TIME-SENSITIVE NETWORKING

THURSDAY, 02 DECEMBER 2021 | 09:00 - 10:00 AM ET

SPEAKER – JÁNOS FARKAS

IEEE 802.1 Time-Sensitive Networking Task Group Chair, Ericsson Research

Dr. János Farkas is a principal researcher in the area of deterministic networking. He is active in the standardization of deterministic networking technologies in packet networks, for which he received the IEEE Standards Association Medallion. He serves as the Chair of the IEEE 802.1 Time-Sensitive Networking Task Group, and as a Co-Chair of the IETF Deterministic Networking Working Group.

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