DETERMINISTIC6G

Control Plane Extensions for Wireless-Aware Traffic Engineering

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Background

- Former contributions to P802.1Qdj on support for wireless
  - "Configuration Enhancements for 5G as TSN Bridge" https://www.ieee802.org/1/files/public/docs2020/dj-farkas-configuration-enhancements-for-5G-0920-v01.pdf
  - "Configuration Enhancements for Wireless TSN" https://www.ieee802.org/1/files/public/docs2021/dj-seewald-wireless-tsn-0721-v01.pdf
  - *These contributions were not considered in P802.1Qdj for wireless being out of scope*

- Recent contribution on adding support for wireless
  - "Control Plane Extensions for Wireless-Aware Traffic Engineering with Corresponding YANG Data Models" https://www.ieee802.org/1/files/public/docs2024/new-duerr-control-plane-extensions-and-YANG-for-wireless-aware-TE-0924-v01.pdf
  - "Control Plane Extensions for Wireless-Aware Traffic Engineering" https://www.ieee802.org/1/files/public/docs2025/new-farkas-control-plane-extensions-for-wireless-aware-TE-0225-v01.pdf

Recap: Nodal Representation

- From outside, a Domain / Region often appears as a network node, e.g., MST Region, see IEEE Std 802.1Q

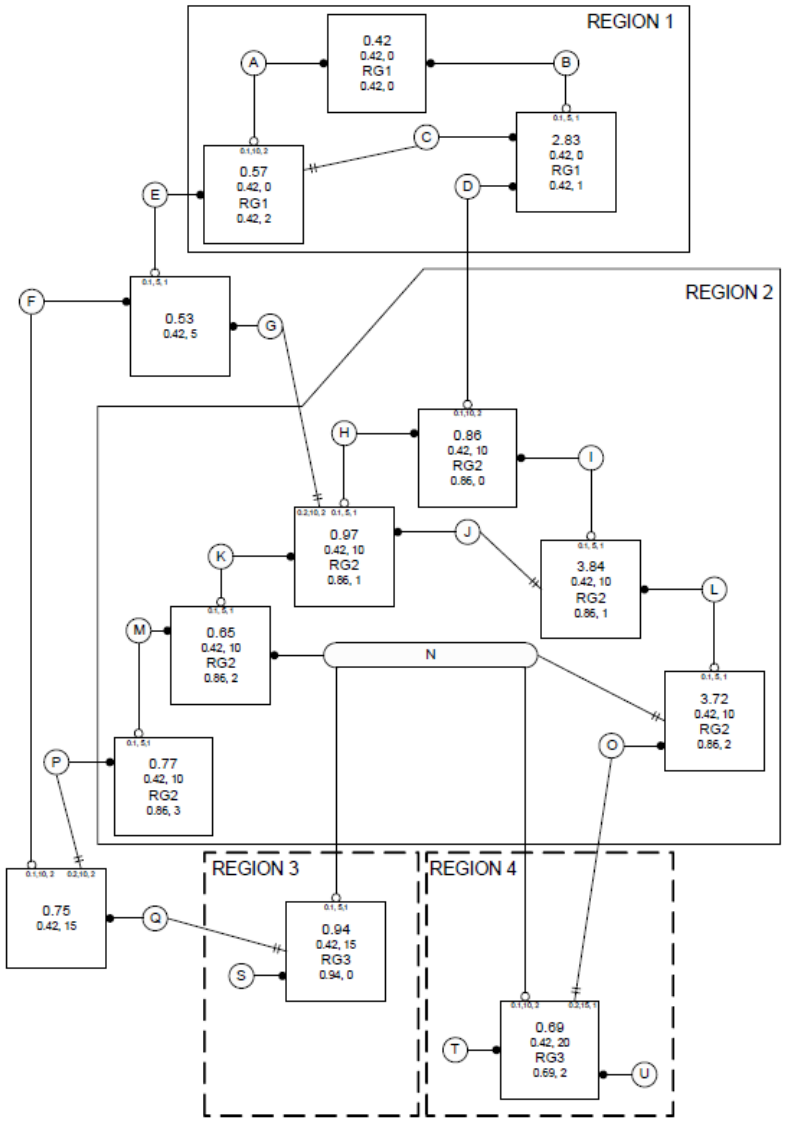
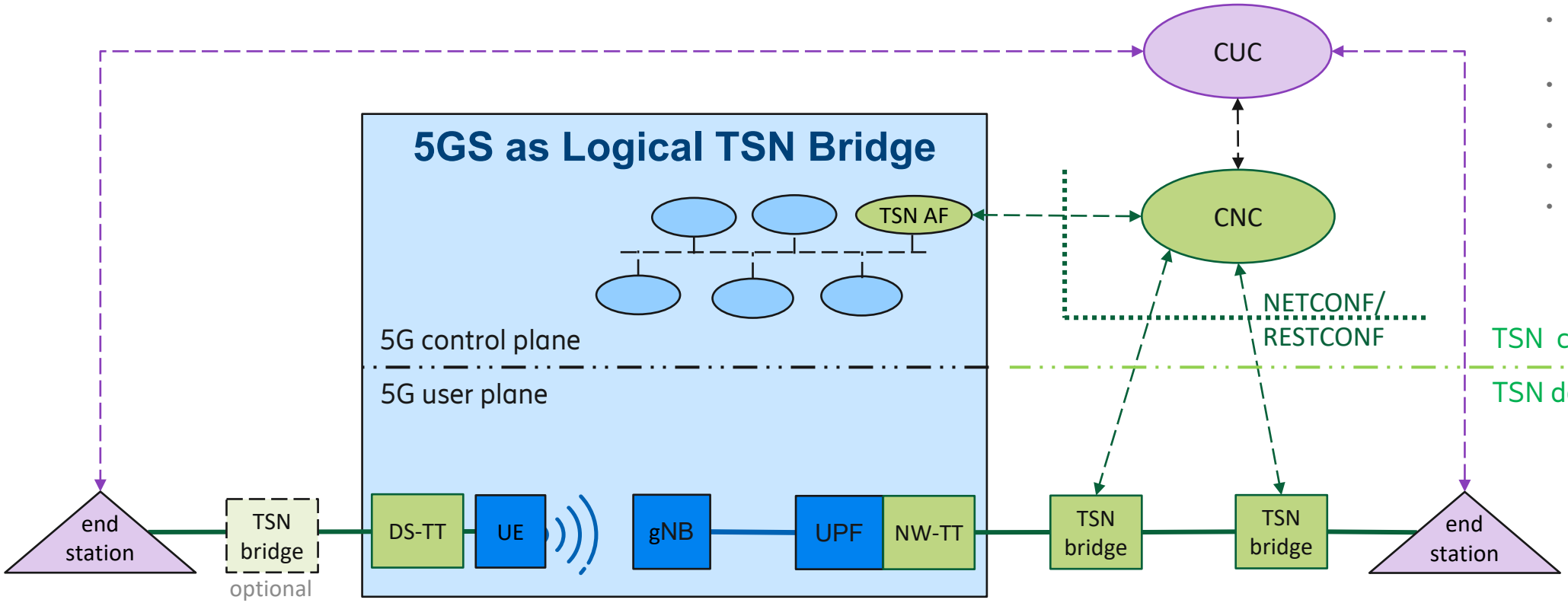


Figure 13-7—CIST Priority Vectors, Port Roles, and MST Regions

Recap: 5G as Logical TSN Bridge

- As per 3GPP standards, the 5G System (5GS) acts as a logical (virtual) TSN bridge



- AF: Application Function
- DS-TT: Device-Side TT
- gNB: GNodeB (5G base station)
- NW-TT: Network-side TT
- TT: TSN Translator
- UE: User Equipment
- UPF: User Plane Function

Recap: Bridge Delay

- "Each set of Bridge Delay attributes is accessed using three indices: **ingress Port**, **egress Port**, and **traffic class**."
- "The delays represent the **worst-case range per the design of the Bridge**, and are **not measured**."

Table 12-38—Bridge Delay attributes

Name	Data type	Operations supported[a]	Conformance[b]	References
independentDelayMin	unsigned integer	R	B	12.32.1.1
independentDelayMax	unsigned integer	R	B	12.32.1.1
dependentDelayMin	unsigned integer	R	B	12.32.1.2
dependentDelayMax	unsigned integer	R	B	12.32.1.2

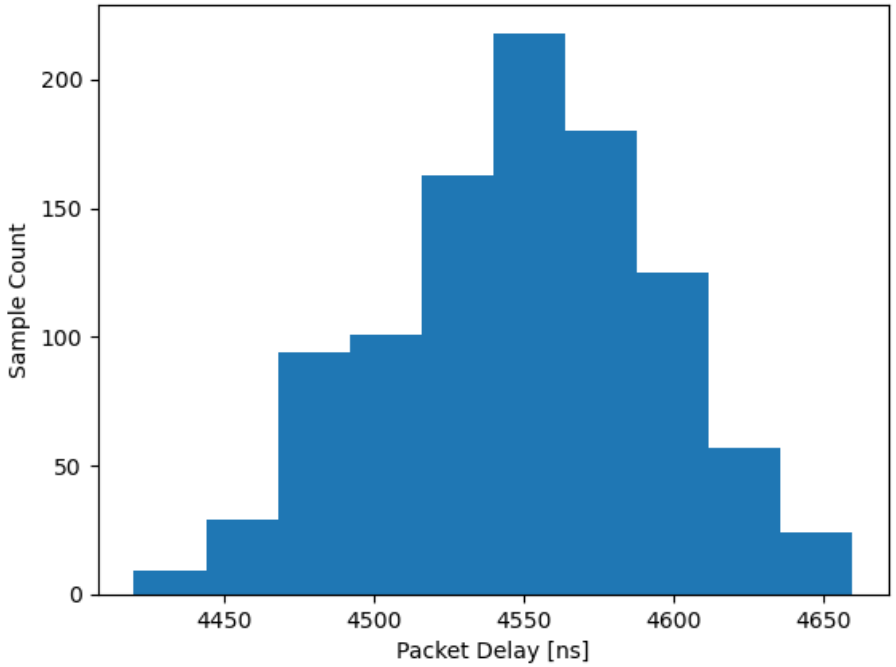
[a] R = Read only access; RW = Read/Write access.
[b] B = Required for Bridge or Bridge component support of Stream reservation remote management; b = Optional for Bridge or Bridge component support of Stream reservation remote management.

[IEEE Std 802.1Q 2022]

The Challenge: Wireline vs Wireless

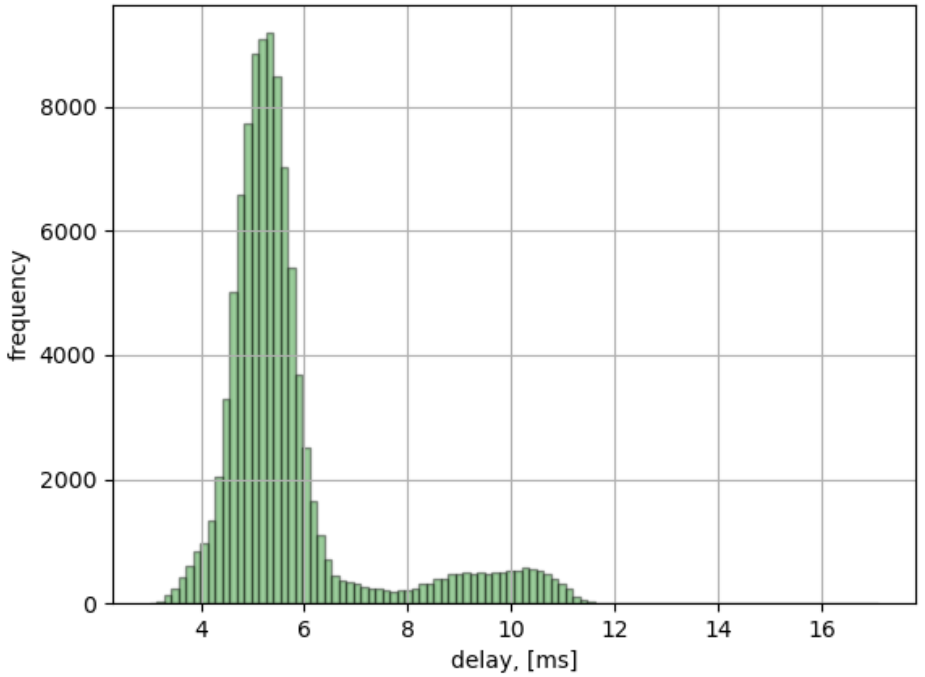
- Ignoring the differences between wireline and wireless characteristics makes Traffic Engineering (e.g., scheduling) very difficult and inefficient in heterogeneous deployments

Wireline Bridge



vs

5GS Virtual Bridge

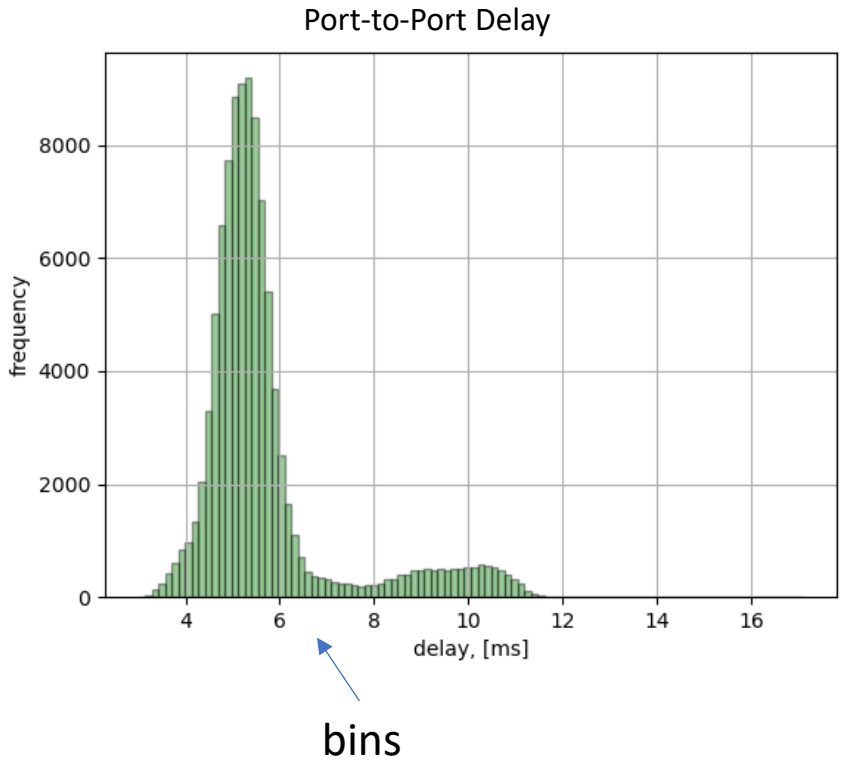


Delay data from measurements: https://github.com/DETERMINISTIC6G/deterministic6g_data

A Solution: Extend Bridge Delay to Histogram

- Extending Bridge Delay to a histogram (instead of the current min and max values) enables capturing wireless characteristics in a chosen granularity in support of Traffic Engineering

```
grouping delay-histogram {
    description "Delay histogram";
    leaf start {
        type uint64;
        description
            "The start value of the first bin in nano-seconds.
            If not specified, the first bin starts at 0.";
    }
    leaf bin-count {
        type uint32;
        mandatory true;
        description "Number of bins.";
    }
    list bin {
        description "Bins of histogram.";
        key index;
        leaf index {
            type uint32;
            mandatory true;
            description "The index of this bin.";
        }
        leaf width {
            type uint64;
            mandatory true;
            description "The width of this bin in nano-seconds.";
        }
        leaf count {
            type uint32;
            mandatory true;
            description "Count of values in this bin.";
        }
    }
```



Proposal

- Start a new project to amend the Bridge Delay attributes in IEEE 802.1Q
- The amendment could introduce histogram for Bridge Delay attributes
- This would enable exposing wireless characteristics, e.g., to CNC
- This would enable more efficient Traffic Engineering, i.e., save resources and energy
- This might be beneficial for some non-wireless use cases as well

Proposal – cont'd

- Proposed motion:
  - 802.1 authorizes the TSN TG to generate PAR and CSD at the May 2025 interim session for pre-circulation to the EC for an amendment to IEEE 802.1Q to specify extensions to the Bridge Delay attributes.
- Initial draft text for some parts of the PAR:
  - 5.2.b Scope of the project:
    - This amendment specifies procedures and managed objects to extend Bridge Delay attributes (12.32.1). Additionally, this amendment addresses errors and clarifications.
  - 5.5 Need for the Project:
    - IEEE 802.1Q currently does not provide support for traffic engineering to take into account the characteristics of wireless systems included in bridged networks. Wireless systems often appear as a logical bridge in a bridged network. The Bridge Delay attributes are important for traffic engineering. Extensions to the Bridge Delay attributes would enable fine grained traffic engineering, e.g., when wireless systems are included in bridged networks.

Further References

- Delay measurements of virtual TSN bridge (documentation and data):
  - D4.2: Latency measurement framework https://deterministic6g.eu/images/deliverables/DETERMINISTIC6G-D4.2_v1.0.pdf
  - Github: https://github.com/DETERMINISTIC6G/deterministic6g_data
- Wireless-friendly scheduling
  - D3.4: Report on Optimized Deterministic End-to-End Schedules for Dynamic Systems, https://deterministic6g.eu/images/deliverables/DETERMINISTIC6G-D3.4-v1.0.pdf
  - Contact authors for more information: simon.egger@ipvs.uni-stuttgart.de
- YANG models, NETCONF integration (files and documentation)
  - D3.4: Report on Optimized Deterministic End-to-End Schedules for Dynamic Systems, https://deterministic6g.eu/images/deliverables/DETERMINISTIC6G-D3.4-v1.0.pdf
  - Github: https://github.com/DETERMINISTIC6G/deterministic6g_yang_models

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