# RAP in Industrial Automation

## Follow-up: Workflow and Benefits

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# Workflow Resource Allocation Model with RAP in Industrial Automation

(1) Application Planning: functions, devices, communication relations, …

(2) Network Planning: topologies, TSN domains, VLANs, …

(3) Application and Network Setup

(4) Network Provisioning

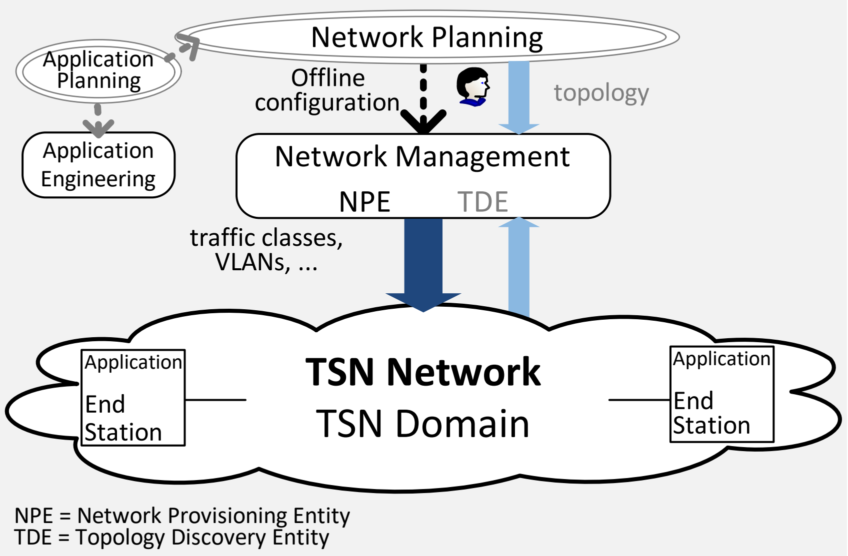
(5) Application Engineering/Provisioning

(6) Communication relation driven Talker and Listener Instantiation

(7) Stream Establishment and Reservation

# Workflow Resource Allocation Model with RAP in Industrial Automation
# Steps 1 - 4

- End station / application requirements determine Network Planning
- Network layout and setup can be configured offline
- Offline network layout and configuration can be input to simulation
- Network planning is input to network provisioning, including configuration of e.g.:
  - TSN domains
  - Synchronization
  - Traffic classes
  - VLANs, active topologies, and MSTIDs
  - Resource Allocation (RA) classes for streams



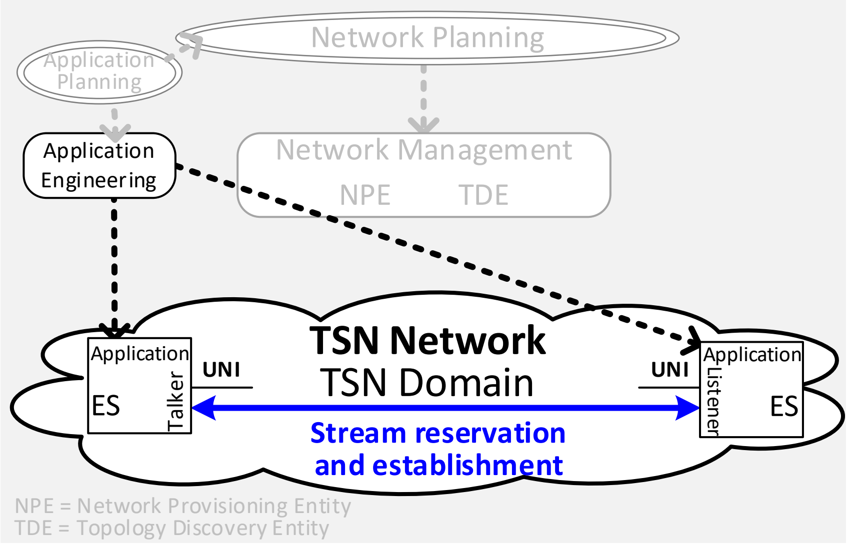

- Option: TDE can be applied for online – offline check of topology

# Workflow Resource Allocation Model with RAP in Industrial Automation
## Steps 5 – 7 in RAP Native mode

- Applications get QoS requirements from engineering
- Talkers and Listeners are instantiated with derived Stream characteristics, e.g. TSpec: MaxFrameSize, MaxIntervalFrames, ...
- Talkers and Listeners initiate stream establishment and reservation via:

  **(Talker-)UNI**:
  - Peer-to-peer propagation with accumulated maximum latency per hop (in accordance to the RA class definition) in a VLAN context.

  **(Listener-)UNI:**
  - Peer-to-peer propagation back to the talker defines the stream path with bandwidth and resource control and reservation per hop.



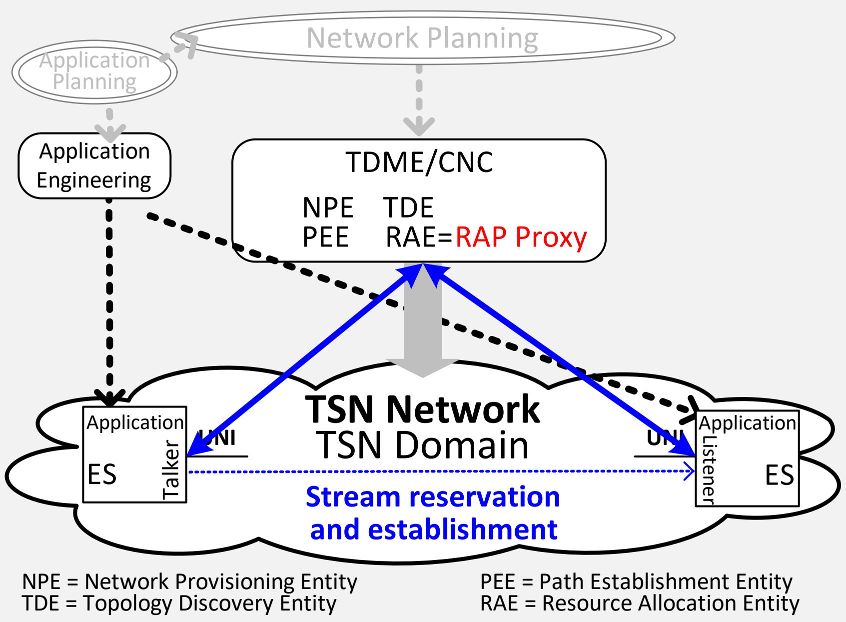

- Allows operation in any given active topology.
- Does not require path computation.

# Workflow Resource Allocation Model with RAP in Industrial Automation
## Steps 5 – 7 in RAP Proxy mode

- Applications get QoS requirements from engineering
- Talkers and Listeners are instantiated with derived Stream characteristics, e.g. TSpec: Min/MaxFrameSize, Min/MaxIntervalFrames, ...
- Talkers and Listeners initiate stream establishment and reservation via:

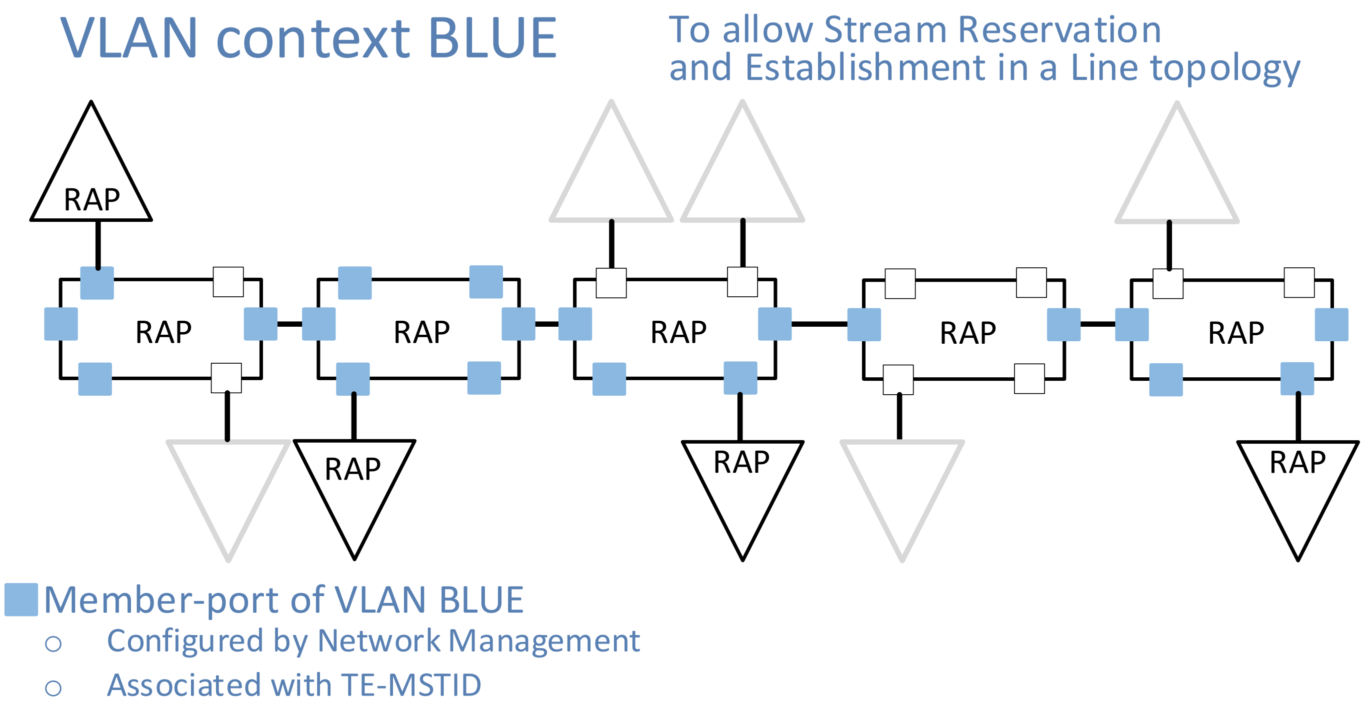
  **(Talker-)UNI**:
  - Propagation via RAP Proxy (with accumulated maximum latency) to Listener

  **(Listener-)UNI:**
  - Propagation back via RAP Proxy to the Talker
  - stream path establishment and reservation by RAP Proxy
- RAP information no longer follows the data path!

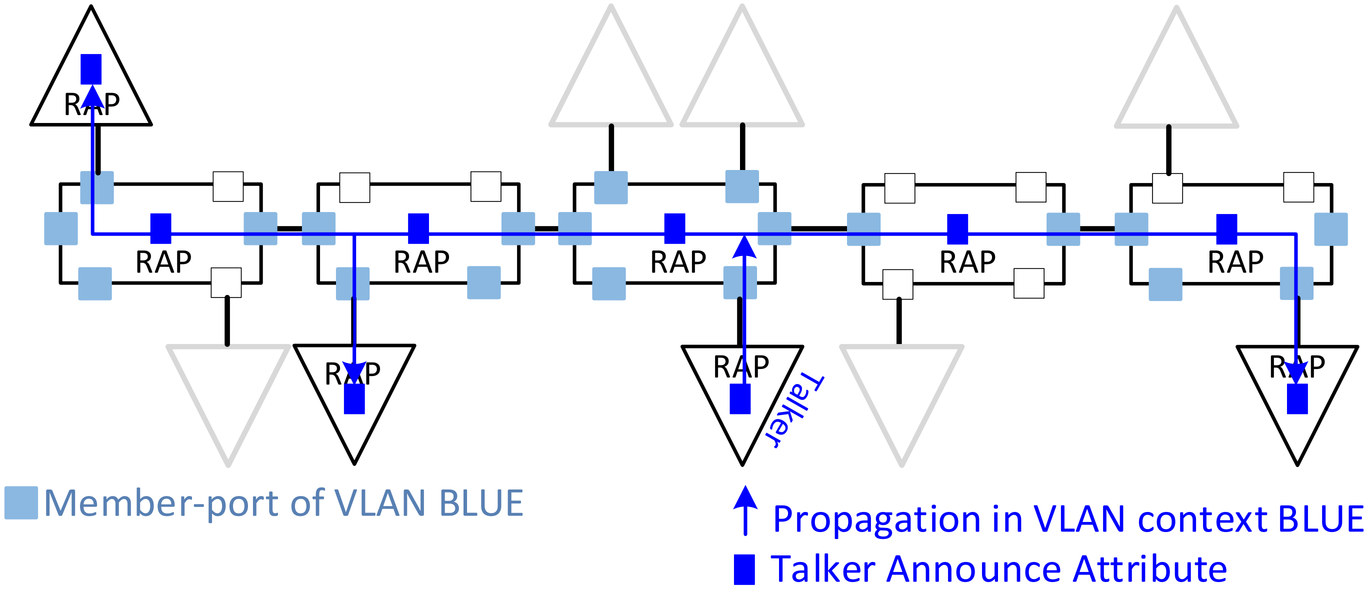



- Allows operation in any given active topology.

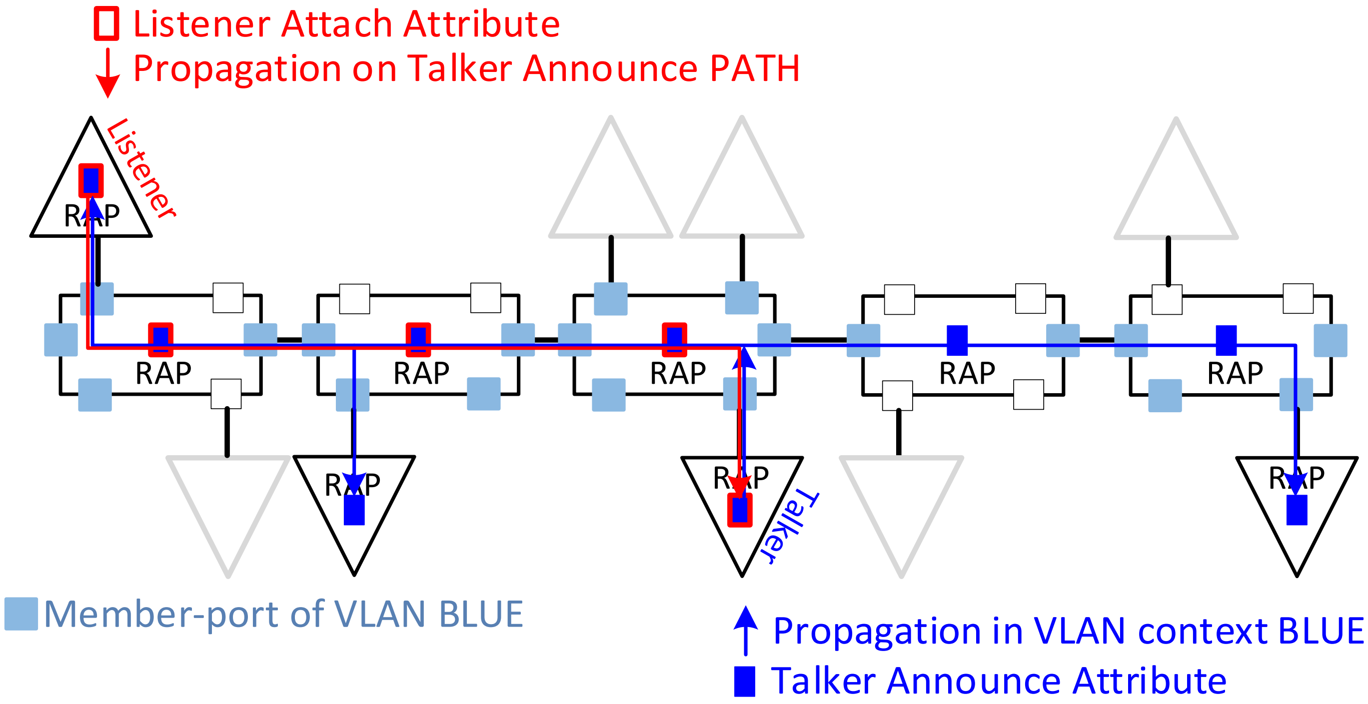
# Example: Stream establishment in RAP Native mode
# (1) VLAN context



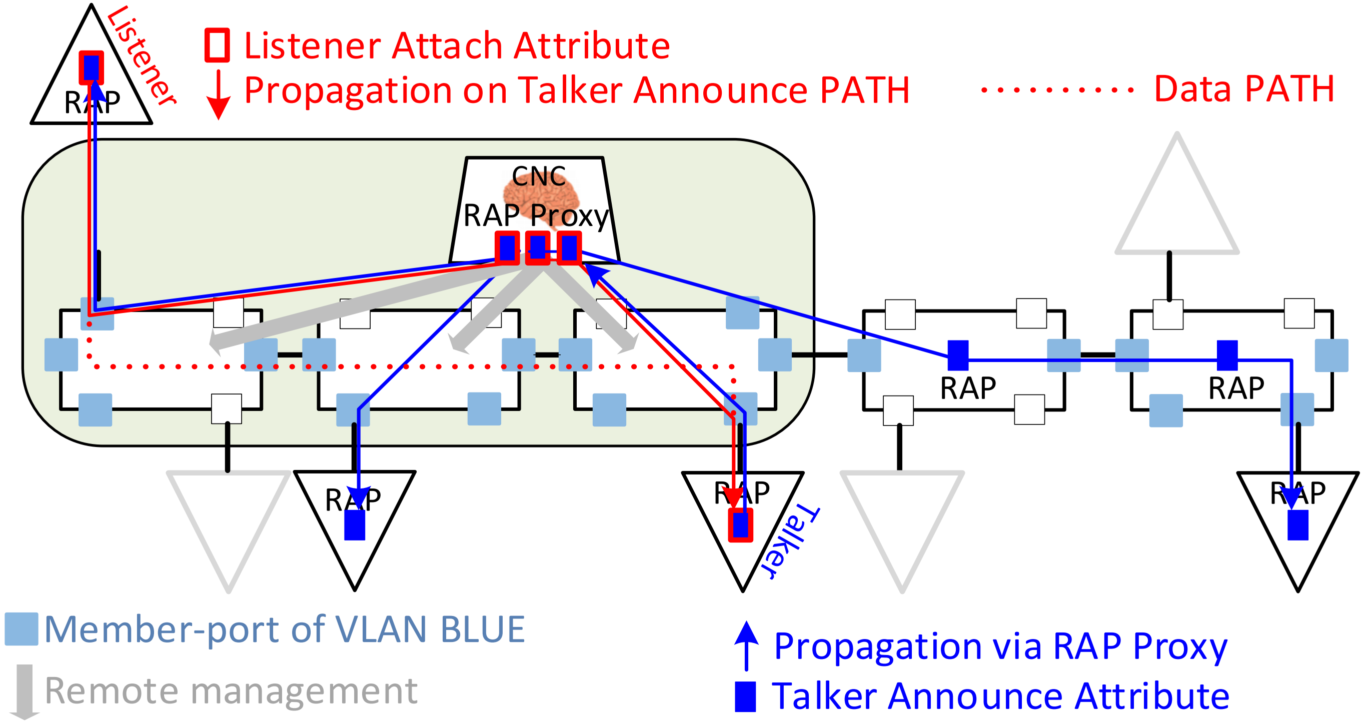
# Example: Stream establishment in RAP Native mode
# (2) Talker Announcement



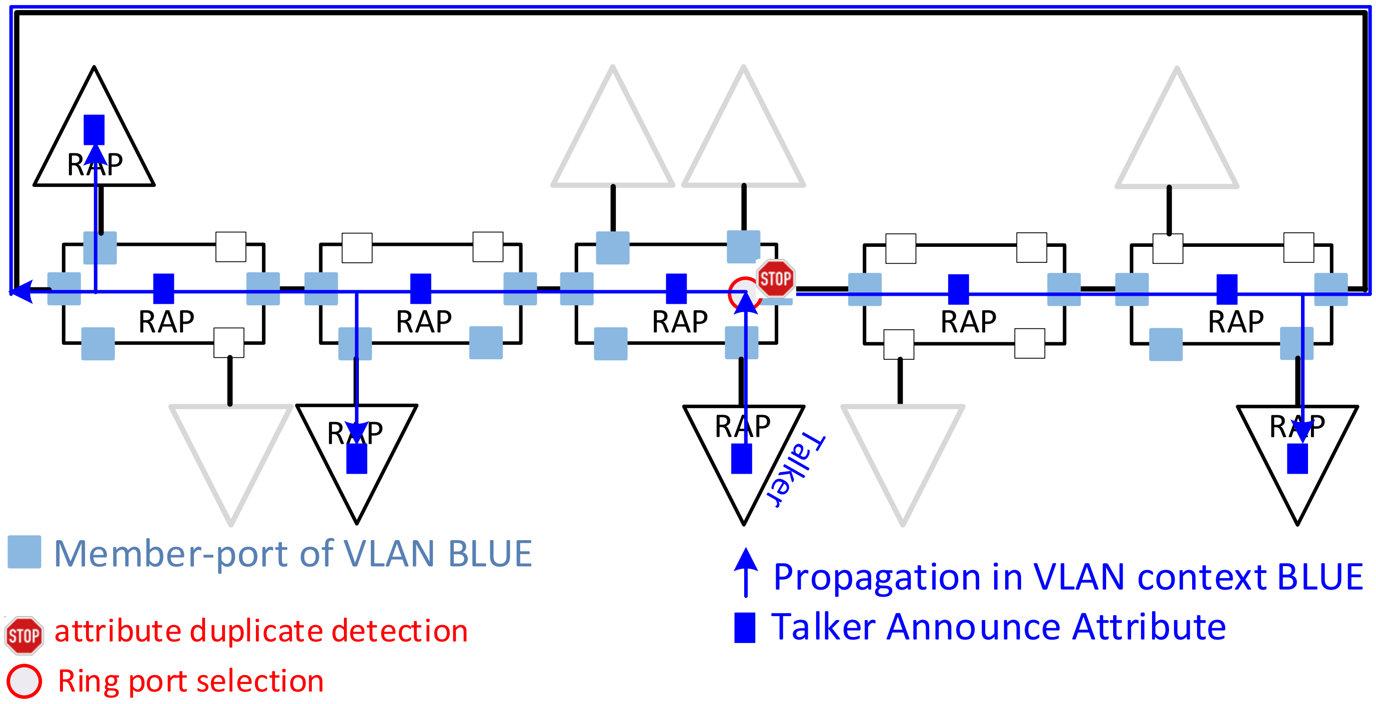
# Example: Stream establishment in RAP Native mode
# (3) Listener Attach



# Example: Stream establishment with RAP Proxy systems for Bridges



# Example: Stream establishment in ring topology in RAP Native mode




→ Enables Stream redundancy in a 2nd VLAN context

# Benefits of RAP in Industrial Automation (1)
## Multiple QoS mechanisms

- RAP supports multiple QoS mechanisms for a wide range of time sensitive applications.

From cyclic-asynchronous streams:

- Strict Priority model: shaping only on end stations based on local time, and reservation in Bridges (see: https://www.ieee802.org/1/files/public/docs2020/dd-grigorjew-strict-priority-latency-0320-v02.pdf)

- Shaping model: streams are shaped by CBS, ATS, … in end stations and Bridges

To isochronous streams:

- Qbv model: synchronized end stations and Bridges; constrained topologies; fixed gate control per RA class (see: https://www.ieee802.org/1/files/private/liaisons/liaison-LNI40-LRP_RAP-whitepaper-0420-v1.pdf)

# Benefits of RAP in Industrial Automation (2)
## Stream characteristics in every node

Each Bridge instance knows the Stream characteristics including Traffic Specification (TSpec). This applies to all Streams in their particular VLAN context.

- Allows optimizing queuing resources, latency, and bandwidth handling within Bridges (e.g. Logical 5G TSN Bridge).
- Allows detailed Stream diagnostics; failure status and ID of failed Bridge are provided.
- Allows lifetime control of reserved Bridge resources by periodic attribute refresh.
- Allows stream reservations across TSN domain boundaries (TSN inter-domain communication)

# Benefits of RAP in Industrial Automation (2)
## LRP/RAP proxies

LRP/ RAP proxy model can be used

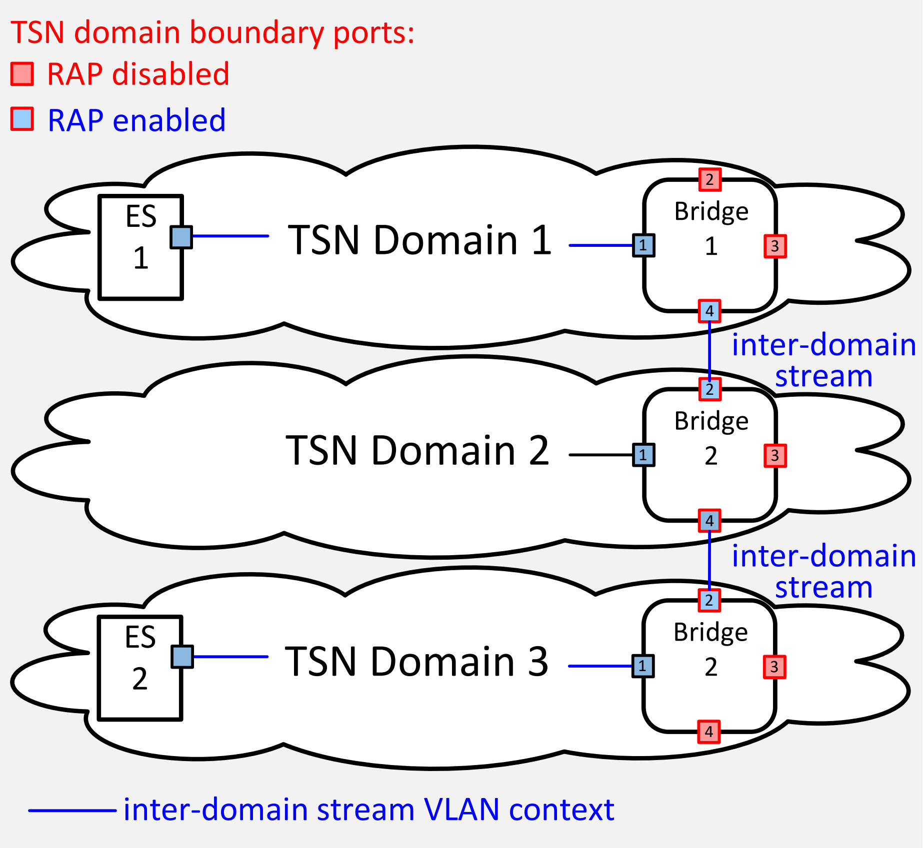
- to connect centralized TSN domains (TSN inter-domain communication)
- to support a mixture of distributed, centralized, and virtualized areas within a TSN domain (including the centralized network/distributed user model of IEEE 802.1Qcc 46.1.3.2)

  See:
  https://www.ieee802.org/1/files/public/docs2018/dd-finn-RAP-LRP-MSRP-Qcc-0918-v03.pdf
  https://www.ieee802.org/1/files/public/docs2018/cs-chen-RAP-LRP-interaction-0918-v01.pdf

# TSN domain boundary port configuration in RAP Native mode

- By default RAP is disabled by management at TSN domain boundary ports.
- At selected ports RAP is enabled by management to allow TSN inter-domain communication.
- When a TSN domain is attached with
  - compatible RA class (PCP), and
  - Inter-domain VLAN context (VIDx)

  → stream path is established by RAP

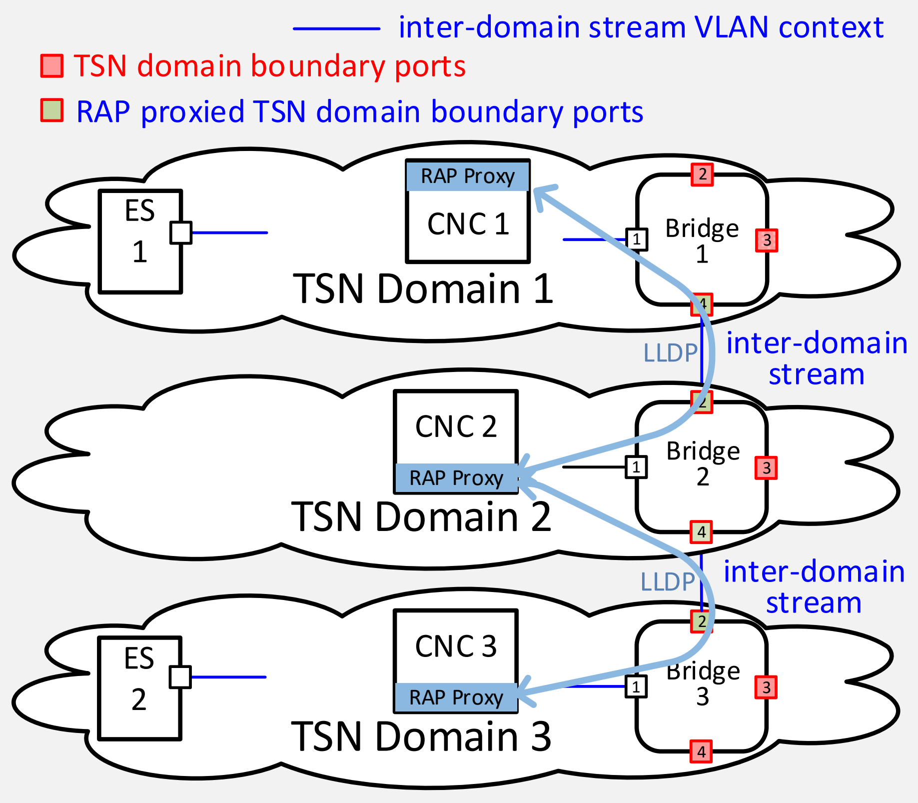


# TSN domain boundary port configuration with RAP Proxies as link between centralized TSN domains

- CNCs have an attached LRP/RAP Proxy
- Selected target ports are enabled by the CNCs to allow TSN inter-domain communication.
- When a TSN domain is attached with
  - compatible RA class (PCP), and
  - Inter-domain VLAN context (VIDx)

  → RAP traffic is exchanged between Proxies

  → Partial stream paths are established by CNCs

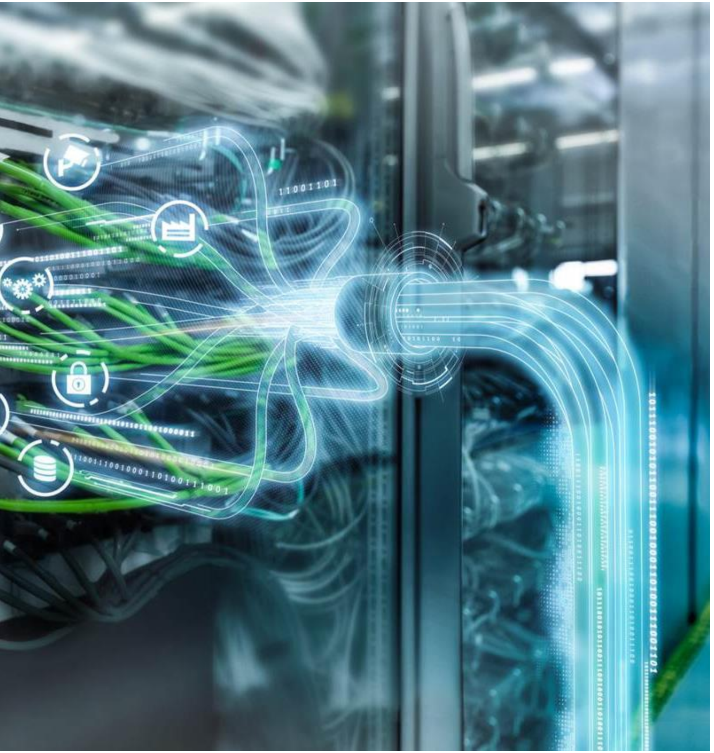


# Summary – Added values of RAP in Industrial Automation

- Low entry level:
  LRP/RAP in Native mode enable Stream based communication without CNCs

- Scalability:
  LRP/RAP enable Stream based communication across multiple TSN Domains

# Thank You



Questions?