RAP in Industrial Automation
## Workflow and Benefits

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Workflow Approach 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

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Workflow of distributed stream reservation with RAP
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

NPE = Network Provisioning Entity
TDE = Topology Discovery Entity
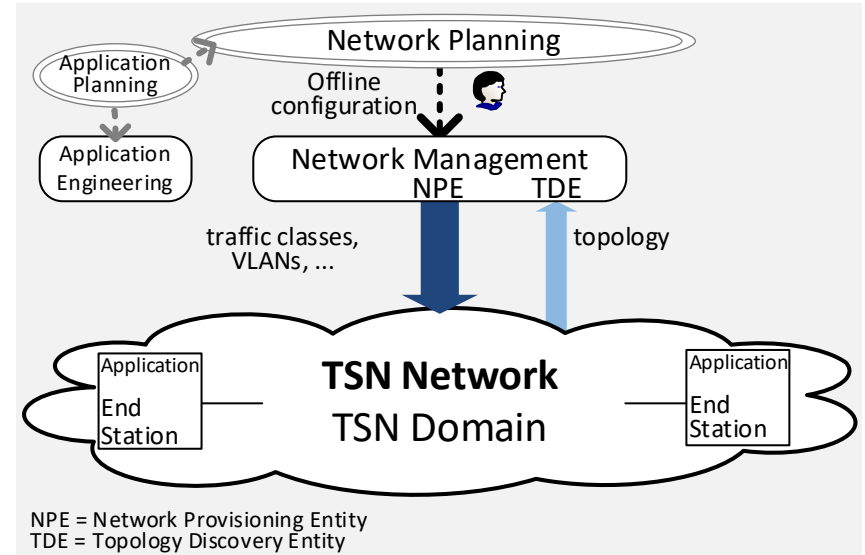
- Option: TDE can be applied for online – offline check of topology

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# Workflow of distributed stream reservation with RAP
Steps 5 - 7

- 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.
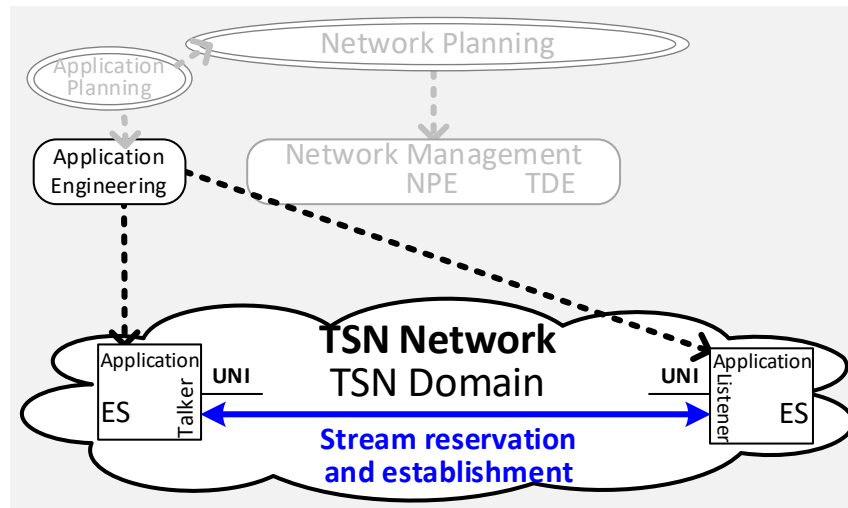
- Allows operation in any given active topology.

- Does not require path computation.

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)

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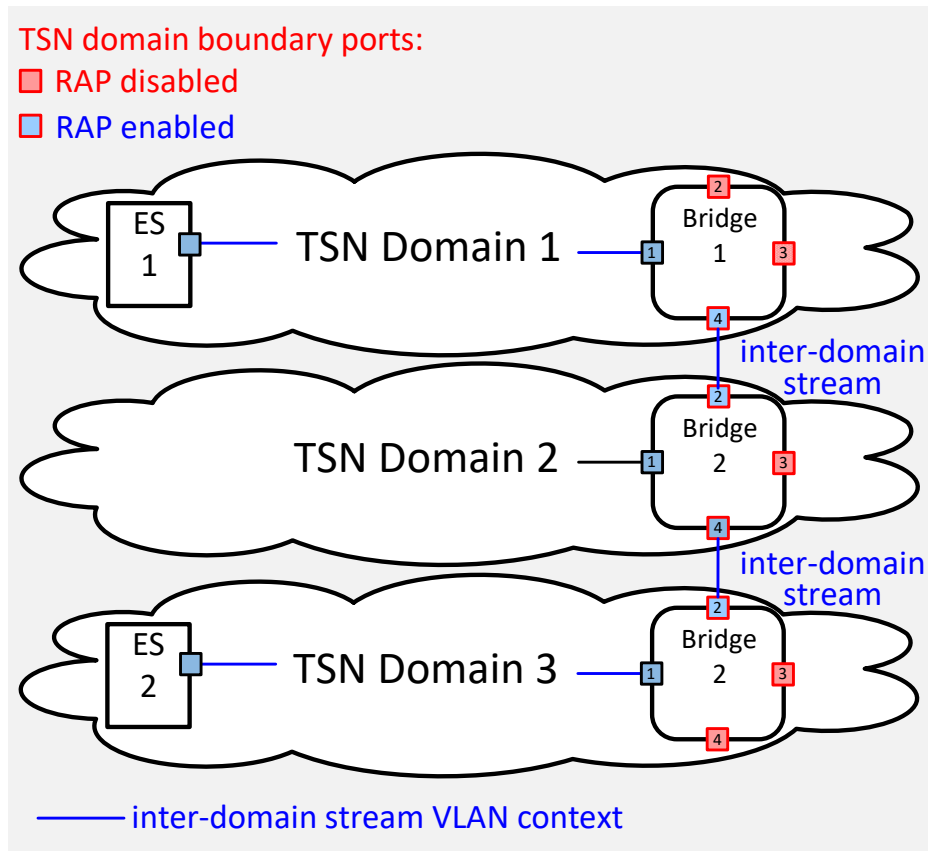# Benefits of RAP in Industrial Automation (2)
Stream characteristics in every node

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)

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TSN domain boundary port configuration with RAP

- 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 ports:
☐ RAP disabled
☐ RAP enabled

ES 1 — TSN Domain 1 — Bridge 1
2, 1, 3, 4

inter-domain stream

TSN Domain 2 — Bridge 2
2, 3, 4

inter-domain stream

ES 2 — TSN Domain 3 — Bridge 2
2, 1, 3, 4

—— inter-domain stream VLAN context

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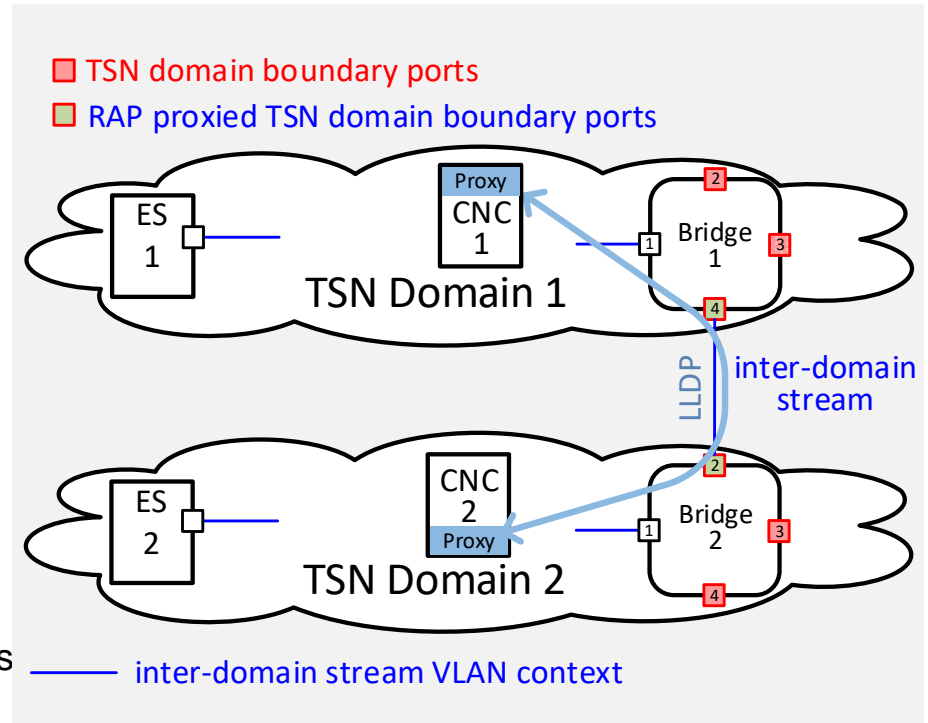
  See:
  https://www.ieee802.org/1/files/public/docs2018/dd-finn-RAP-LRP-MSRP-Qcc-0918-v03.pdf
  https://www.ieee802.org/1/files/public/docs2018/cs-chen-RAP-LRP-interaction-0918-v01.pdf

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LRP/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

☐ TSN domain boundary ports
☐ RAP proxied TSN domain boundary ports

TSN Domain 1

ES 1
Proxy CNC 1
Bridge 1

inter-domain stream

LLDP

TSN Domain 2

ES 2
CNC 2 Proxy
Bridge 2

—— inter-domain stream VLAN context

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Summary – Added values of RAP in Industrial Automation

- Low entry level and robustness:
  LRP/RAP enable Stream based communication without CNCs (*single point of failure*)

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

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Thank You

Questions?