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TSN domain boundary considerations

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Agenda

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1 Introduction and Recapitulation

2 Use Cases

3 TSN Domain Boundary in Detail

4 Identification of Standardized Mechanism

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1 **Introduction and Recapitulation**

2 Use Cases

3 TSN Domain Boundary in Detail

4 Identification of Standardized Mechanism

Continuation of our work…

Recapitulation

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- ***[1] Josef Dorr, Stephan Höme, Sven Kerschbaum, Günter Steindl***: **TSN inter domain communication concept** (January 2020)
  - Scope: TSN domains and inter TSN domain communication within a layer 2 broadcast domain
  - Consideration of TSN domains as black boxes

- ***[2] Josef Dorr, Stephan Höme, Sven Kerschbaum, Günter Steindl***: **Inter TSN domain communication concept** (June 2020)
  - Proposal for TSN domain definition, TSN domain characteristics and TSN domain ID
  - Approach for Inter TSN domain communication based on a Domain Management Function (DMF)
    - Abstraction of TSN domains as virtual bridges
    - Delegation of partial TSN stream reservation
    - Collaborative DMF

- **Focus of this presentation:**
  Consideration of TSN domain boundary ports within a layer 2 network

IEC/IEEE 60802 Requirements (excerpt, V1.2, 2018-12-03)

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Scope of this presentation

R2.1	The TSN-IA profile shall support **TSN domain interconnections via bridges (layer 2)**, or routers (layer 3), or application gateways (layer 7).
R2.2	To **support connectivity between multiple TSN domains** via bridges or routers a method for reserving time-sensitive streams over multiple TSN domains shall be specified, including: • Find the communication partner • Identify the involved TSN domains • Identify the involved management entities independent from the configuration model (centralized, hybrid, fully distributed) • Ensure the needed resources • Parameterize the TSN domain connection points to allow stream forwarding between domains if needed
R12	The TSN-IA Profile shall **support integration of** should allow to integrate **brownfield devices** (see UC12: New machine with brownfield devices).
R12.1	It shall be possible to decouple/**protect all TSN domain internal traffic** (stream traffic and non-stream traffic) from the brownfield cyclic real-time traffic.
R12.2	Brownfield cyclic real-time data traffic QoS requirements shall be met within the TSN domain
R19.1	All **machine internal communication, which is internal to a TSN domain** (stream traffic and non-stream traffic) **shall be protected from M2M inter-TSN-domain traffic** – and vice versa.
R19.4	All **machine internal communication** (stream traffic and non-stream traffic) **shall be protected from additional "pass-through" traffic**.

Inter TSN domain communication concept

Recapitulation [2]

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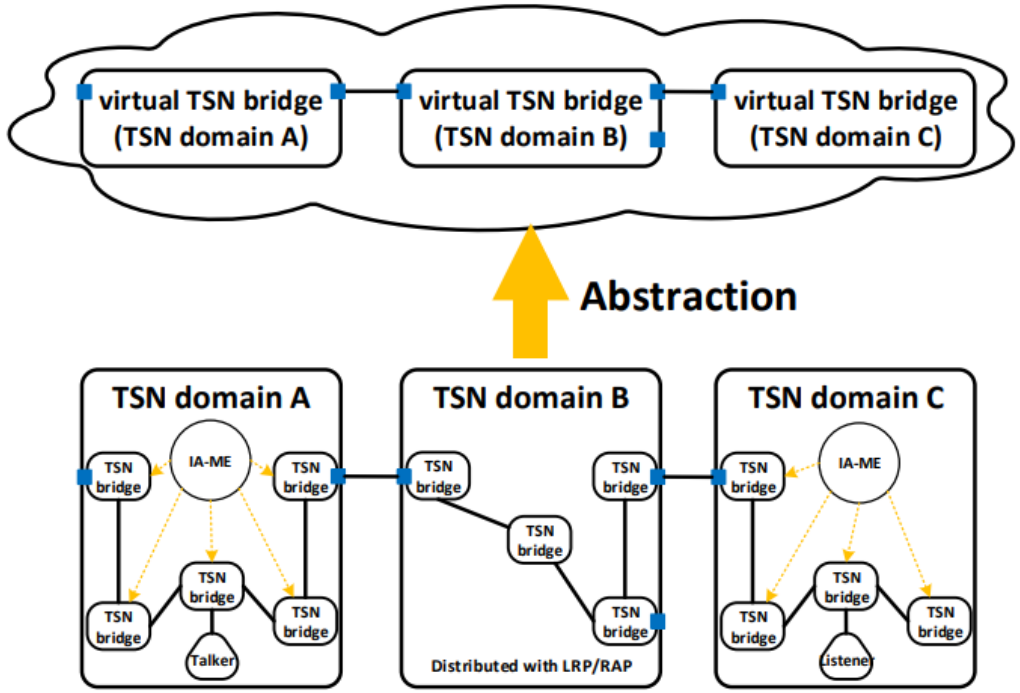
Abstraction of TSN domains as virtual bridges

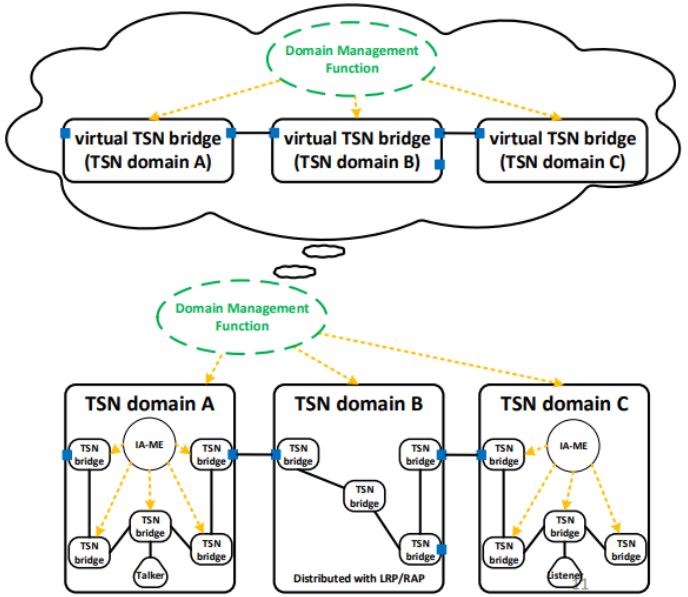


June 15, 2020

Proposal: Domain Management Function (DMF)

- **Today:**
  - IA-ME is responsible for all bridges (and end stations) in a TSN domain
- **Previous proposal [1]:**
  - Head IA-ME → Has knowledge of internals of all TSN domains → scaling issue, violation of black box approach
- **Black Box approach: → Stacked TSN domains**
  - IA-ME is only responsible for its domain
  - Abstraction of TSN domains into virtual TSN bridges

1) Marius Stanica: Coexistence & Convergence in TSN-based industrial automation networks



June 15, 2020

TSN domains are black boxes!

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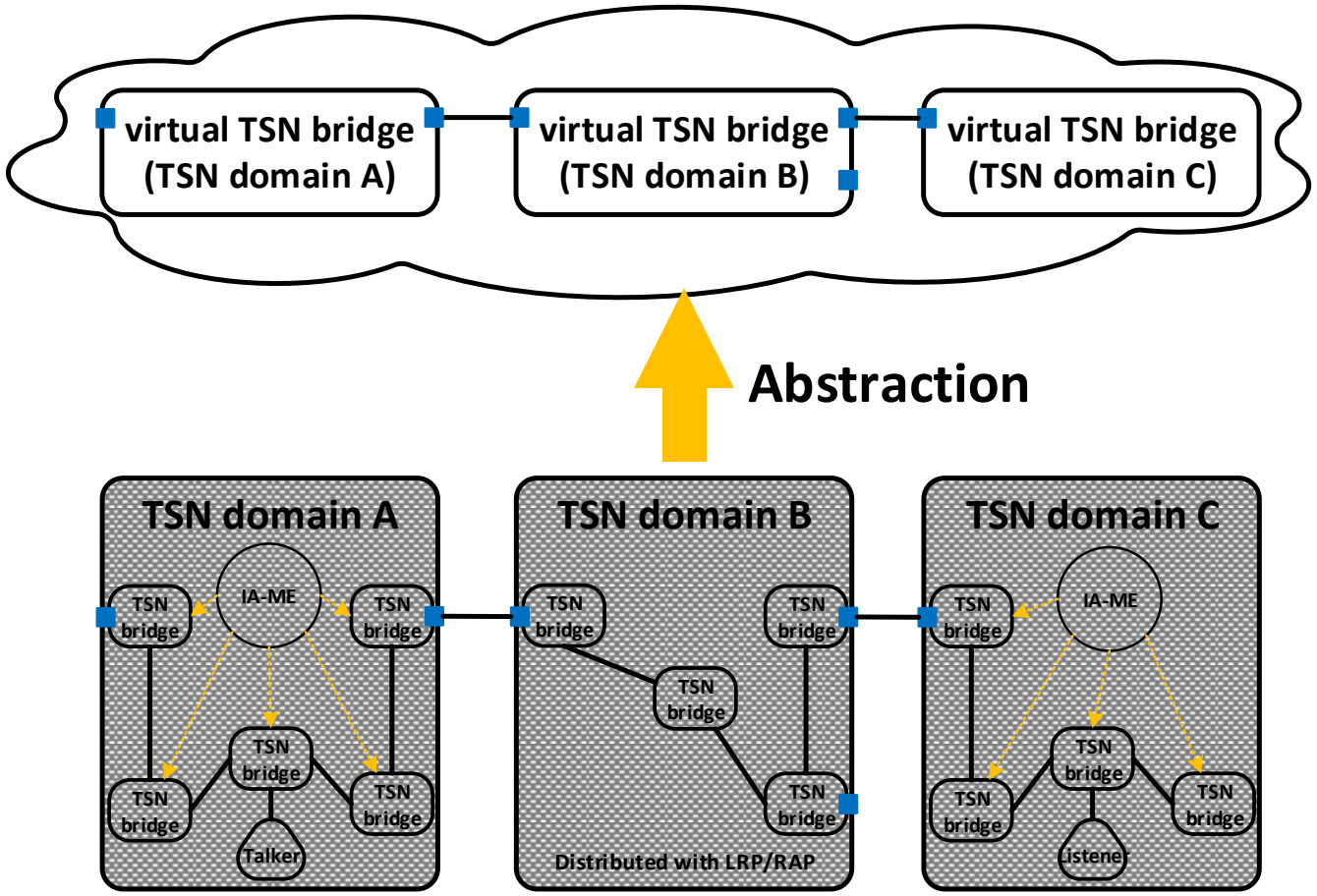

TSN domains are <u>black boxes</u>, i.e. their internals doesn't matter to the outside world

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Use Case 1: TSN stream traffic over TSN domain boundary

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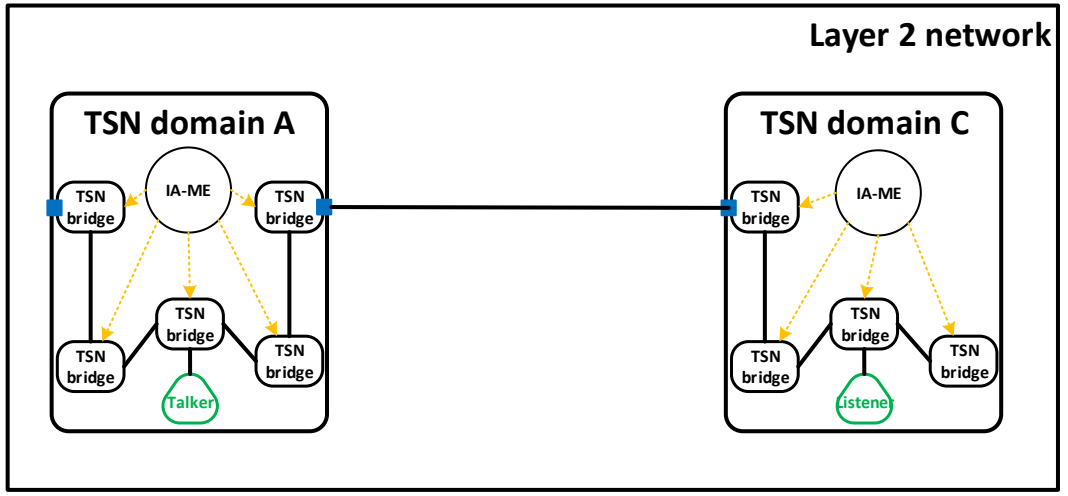
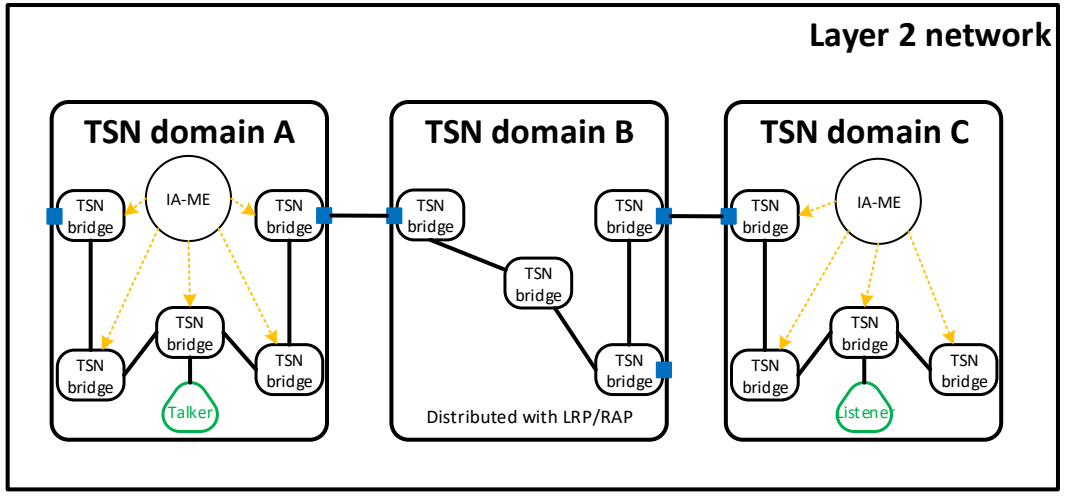
- Talker and listener belong to different TSN domains
- **TSN stream**[1)] between talker and listener

  a) Adjacent TSN domains
  b) Intermediary TSN domain(s)

Note: see Use Cases IEC/IEEE 60802 V1.3
Use case 17: Machine to Machine/Controller to Controller (M2M/C2C) Communication

1) In this presentation, the term TSN stream always refers to a IEEE 802.1Q time-sensitive stream!





Use Case 2: Non-TSN traffic over TSN domain boundary

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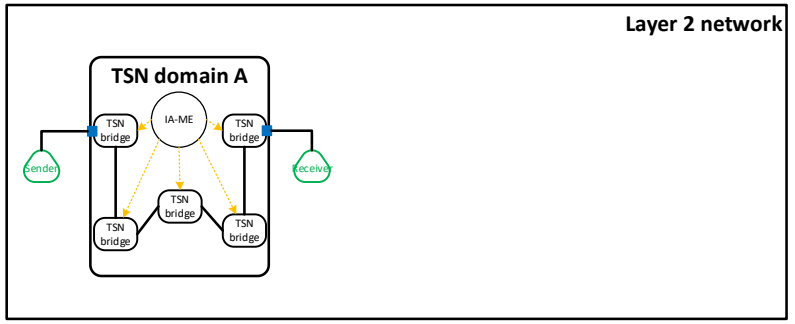
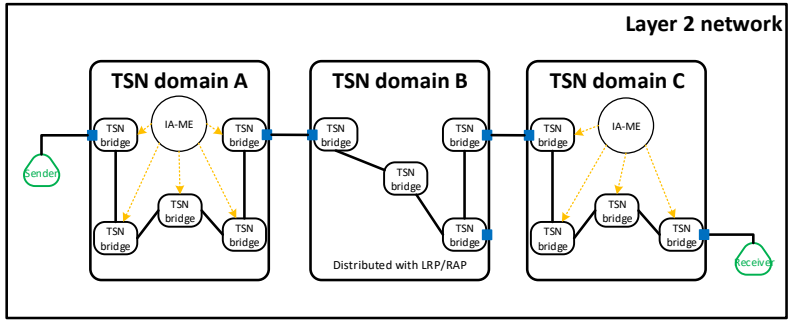
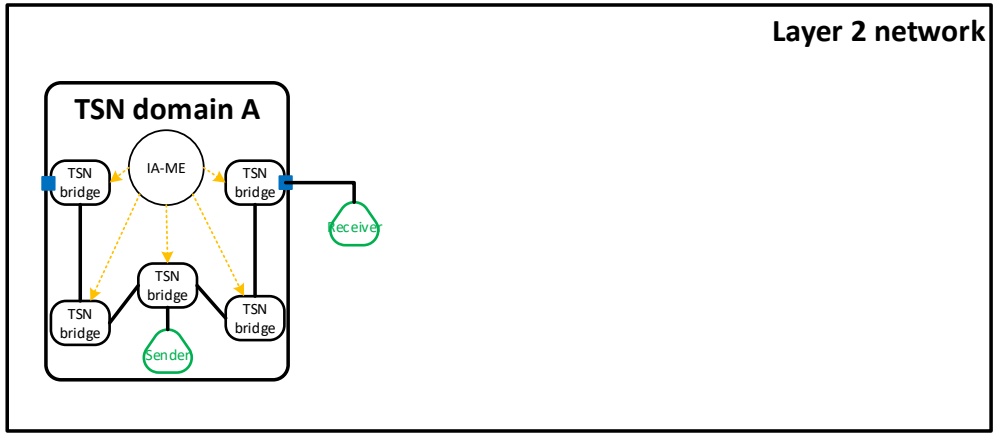
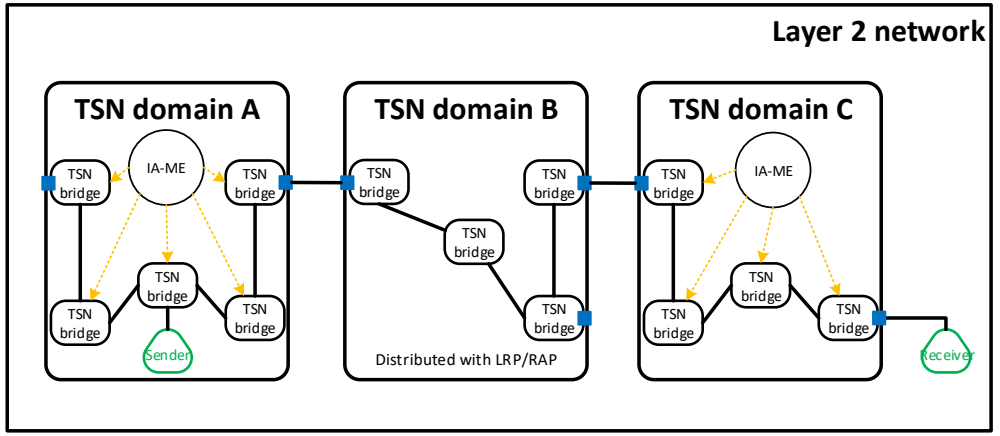
- **Non-TSN traffic** between sender and receiver
- **No QoS guarantees for pass-through traffic**

Note: see Use Cases IEC/IEEE 60802 V1.3
see case 18: Pass-through Traffic









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3 **TSN Domain Boundary in Detail**

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TSN domain boundary tasks

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1. **TSN domain boundary discovery**

2. **Protection of TSN domain internal resources**:
   - TSN streams and non-TSN traffic
   - Bridge resources, e.g. queuing memory, FDB entries

3. **Support of TSN streams between TSN domains** (i.e. TSN streams over TSN domain boundaries) while ensuring black box approach

4. **Optimization of non-TSN traffic over TSN domain boundary**

TSN domain boundary tasks and possible solutions

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1. **TSN domain boundary discovery**
   - ➔ **802.1AB: LLDP**

2. **Protection of TSN domain internal resources**:
   - TSN streams and non-TSN traffic
   - Bridge resources, e.g. queuing memory, FDB entries
   - ➔ **802.1Q: Priority regeneration**
   - ➔ **802.1Q: VLAN assignment, stripping and translation**
   - ➔ **802.1Q: Ingress policing**

3. **Support of TSN streams between TSN domains (i.e. TSN streams over TSN domain boundaries) while ensuring black box approach**
   - ➔ **802.1CB: Active Destination MAC and VLAN Stream identification**
     - Compare Stream DA and VLAN-ID
     - Replace Stream DA, VLAN-ID and priority

4. **Optimization of non-TSN traffic over TSN domain boundary**
   - ➔ **Priority “restauration” at egress port (PCP “tunneling” over TSN domain)**

Task 1: TSN domain boundary discovery

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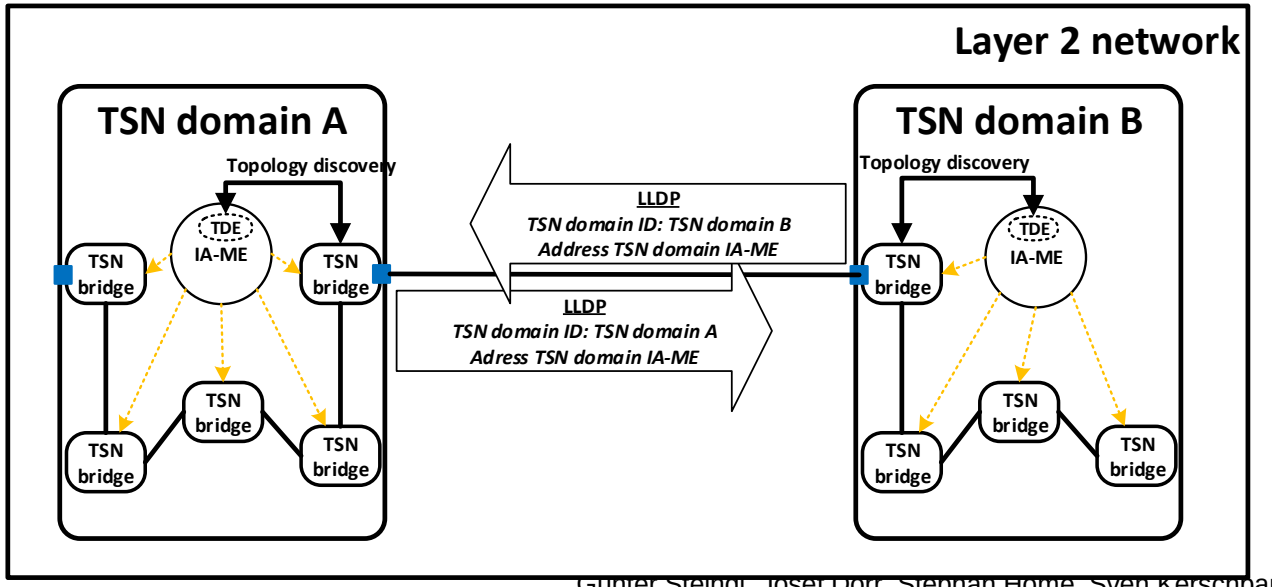
- **TSN domain advertisements based on LLDP:**
  - New 802.1Q TLV, e.g.
    - TSN domain ID encoded as UUID
    - Address of TSN domain management entity
      (IA-ME for centralized and LRP/RAP proxy for distributed configuration model)

➔ Each IA-ME (more precise: TDE) can build a table containing information about adjacent TSN domains based on the information derived by the topology discovery (reading LLDP exchanged information from the stations)



- *Notes:*
  - *LLDP: link layer discovery protocol*
  - *TLV: type-length-value*
  - *TDE: Topology Discovery Engine*

Task 2: Protection of TSN domain internal resources (1/4)

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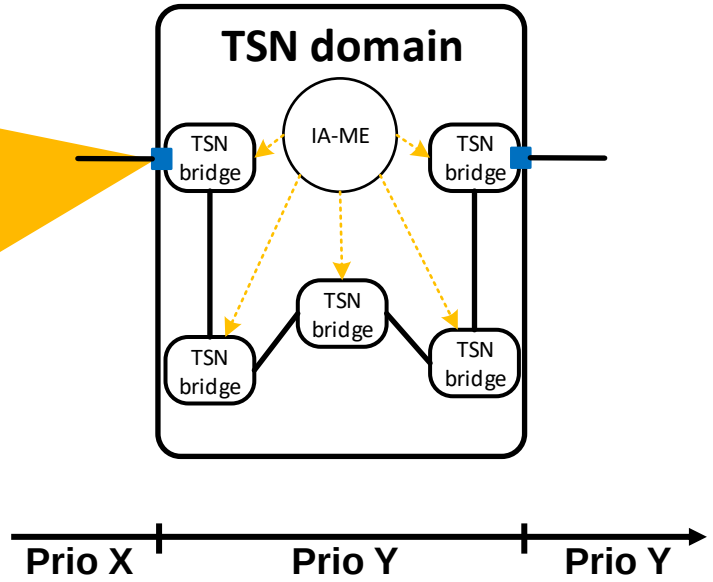
Priority regeneration at a TSN domain boundary ports

➔**Protection of bridge resources and calculated latencies**

- **Avoid interference of pass-through traffic with internal TSN domain traffic**
- Priority regeneration tables for ingress traffic

Exemplary table:

TCI.PCP Source	TCI.PCP Destination
7	1
6	4
5	3
4	1
3	0
2	0
1	0
0 or untagged	0



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Task 2: Protection of TSN domain internal resources (2/4)

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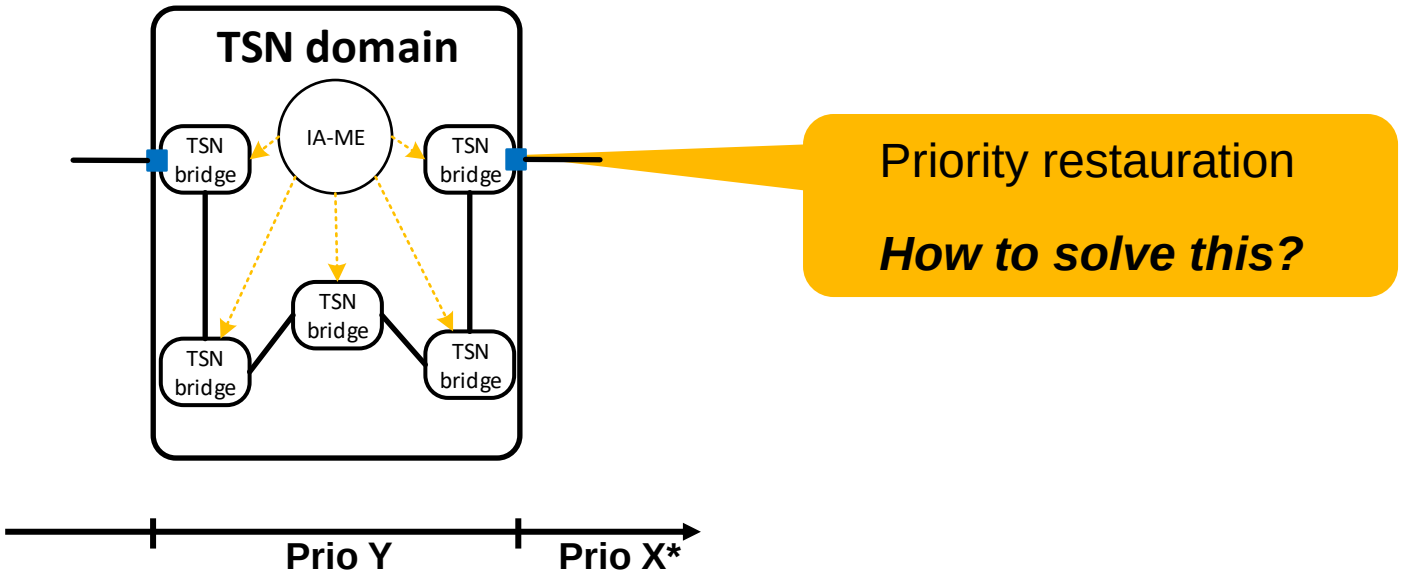
Priority "restauration" at egress TSN domain boundary ports

➔ **<u>Allows optimization for e.g. brownfield RT traffic</u>**

- Priority restauration for egress traffic



Priority "restauration" at egress port is currently not an IEEE standard!

Task 2: Protection of TSN domain internal resources (3/4)

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- **VLAN assignment/stripping/translation ➔ Protection of the TSN domain internal FDB configuration**
  - Separation of TSN streams and non-TSN traffic by using different VLANs and “Individual VLAN Learning”
  - Separation of internal TSN domain communication and (pass-through, M2M) communication

Task 2: Protection of TSN domain internal resources (4/4)

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- **Ingress traffic policing of Non-TSN traffic at TSN domain boundary ports**
  ➔ Protection of the TSN domain internal bandwidth

- Ingress policing according IEEE 802.1Q

- Separate policing for unicast and multicast/broadcast traffic (2x ingress policer)
- Ingress policing per traffic class: 8 traffic classes

➔ **8x2=16 ingress policer per port required**

Task 3: Support of TSN streams between TSN domain Active Destination MAC and VLAN Stream identification

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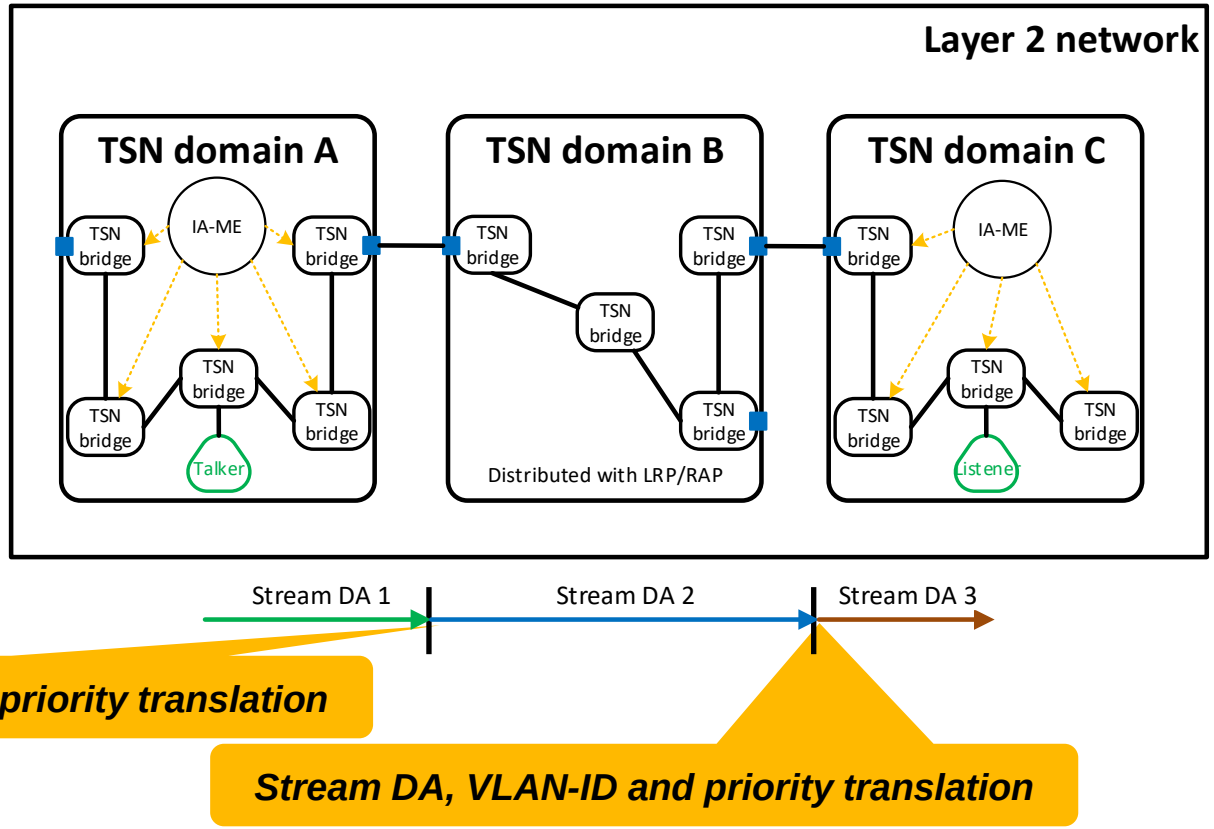
- **Assumptions:** (see 60802-Steindl-et-al-ExampleSelectionTables-0520-v24.xlsx)
  - **Maximal 128 inter TSN domain streams** (64 in, 64 out) per TSN domain
  - **Maximal 64 TSN domains** per layer 2 network (16 device x 64 TSN domains = 1024 devices)
  - **=> Maximal 4096 inter TSN domain streams** per layer 2 network (64 domains x 64 out streams)

- **Stream DA per TSN domain:**
  - Each IA-ME provides a Stream DA for the TSN stream in its TSN domain

- **Translation of Stream DA, VLAN-ID and priority at TSN domain ingress boundary ports**



Task 3: Support of TSN streams between TSN domain
In Detail: Why TSN stream DA translation is necessary!

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- **Intra TSN domain streams**:
  - Frames never leave TSN domain due to disabled default forwarding for the TSN stream-VLAN
  - Intra TSN domain streams in different TSN domains may use the same TSN stream DA

- **Inter TSN domain streams**: Two possibilities:
  - TSN stream DA is unique within all involved TSN domains
    ➔Requires Stream DA allocation service (may be P802.1CQ: Multicast and Local Address Assignment or consistent traffic engineering for multiple TSN domains)
  - TSN stream DA is only unique within its TSN domain
    ➔Stream DA translation necessary

- **TSN domains** should be treated as black boxes
- Internal TSN domain configuration shouldn't matter to the outside world

➔ TSN stream DAs are under the control of the TSN domain

➔ **TSN stream DAs are unique in the context of its TSN domain**
➔ **Translation at the ingress of TSN domain boundary necessary**

Note: Additionally, translation of PCP and VID needs to be defined

Task 3: Support of TSN streams between TSN domain
Forwarding of TSN stream frames over TSN domain boundaries

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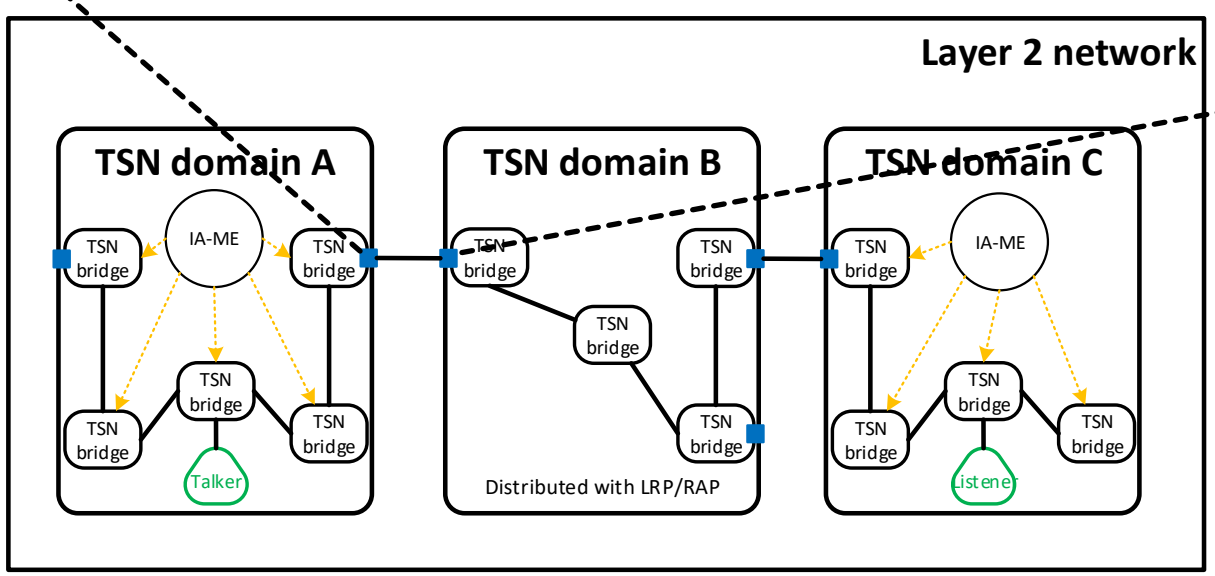
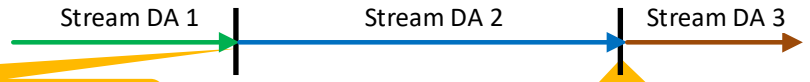
- Egress port is member of TSN stream VLAN of TSN domain A
- ➔ TSN stream can leave TSN domain A (i.e. bridge FDB entry)

1



2

- TSN stream identification based on DA+VLAN (802.1CB)
- ➔ Translation of {DA,VLAN, PCP}$^{\text{TSN domain A}}$ to {DA+VLAN, PCP}$^{\text{TSN domain B}}$
- Forwarding of TSN stream frames to internal LAN of the bridge
- Ingress port is member of TSN stream VLAN of TSN domain B
- ➔ TSN stream frames get forwarded according the TSN stream-VLAN FDB configuration of the bridges belonging to TSN domain B



Stream DA, VLAN-ID and priority translation

Stream DA, VLAN-ID and priority translation

Task 4: Support of non-TSN traffic over TSN domain boundary

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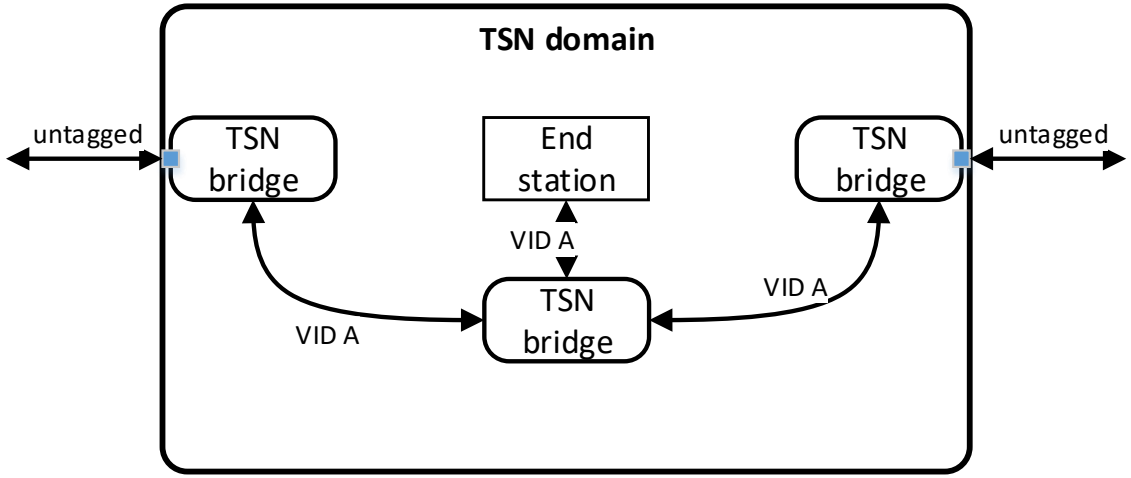
- **Only untagged Non-TSN traffic will be accepted by a TSN domain**
- **At the ingress of a TSN domain, Non-TSN traffic will be tagged by the non-TSN traffic VLAN of the TSN domain**
- **Non-TSN traffic will be untagged at the egress of the TSN domain**



NOTE: That's just one case – up to four non-TSN traffic VLANs are required according to the IEC/IEEE 60802 d1.2

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Conclusion
Standardized mechanism required at TSN domain boundary

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- LLDP (IEEE 802.1AB-2016)
  - **Missing feature:** New TLVs (TSN domain and management interface)

- Priority regeneration (IEEE 802.1Q-2018):
  - Only for ingress traffic standardized
    - Chapter 6.9.4 Regenerating priority
    - Chapter 12.20.3 The Priority Regeneration Override Table)
  - **Missing feature:** Priority restauration for non-TSN traffic at TSN domain boundary egress ports

- VLAN (IEEE 802.1Q-2018 Chapter 6.9 Support of the EISS)
  - Tagging and stripping
  - Translation

- Stream Identification IEEE 802.1CB-2017
  - Chapter 6.6 Active Destination MAC and VLAN Stream identification

- Ingress Policing IEEE 802.1Q-2018
  - Chapter 8.6.5 Flow classification and metering
  - Chapter 12.31 Managed objects for per-stream filtering and policing

Thank You!

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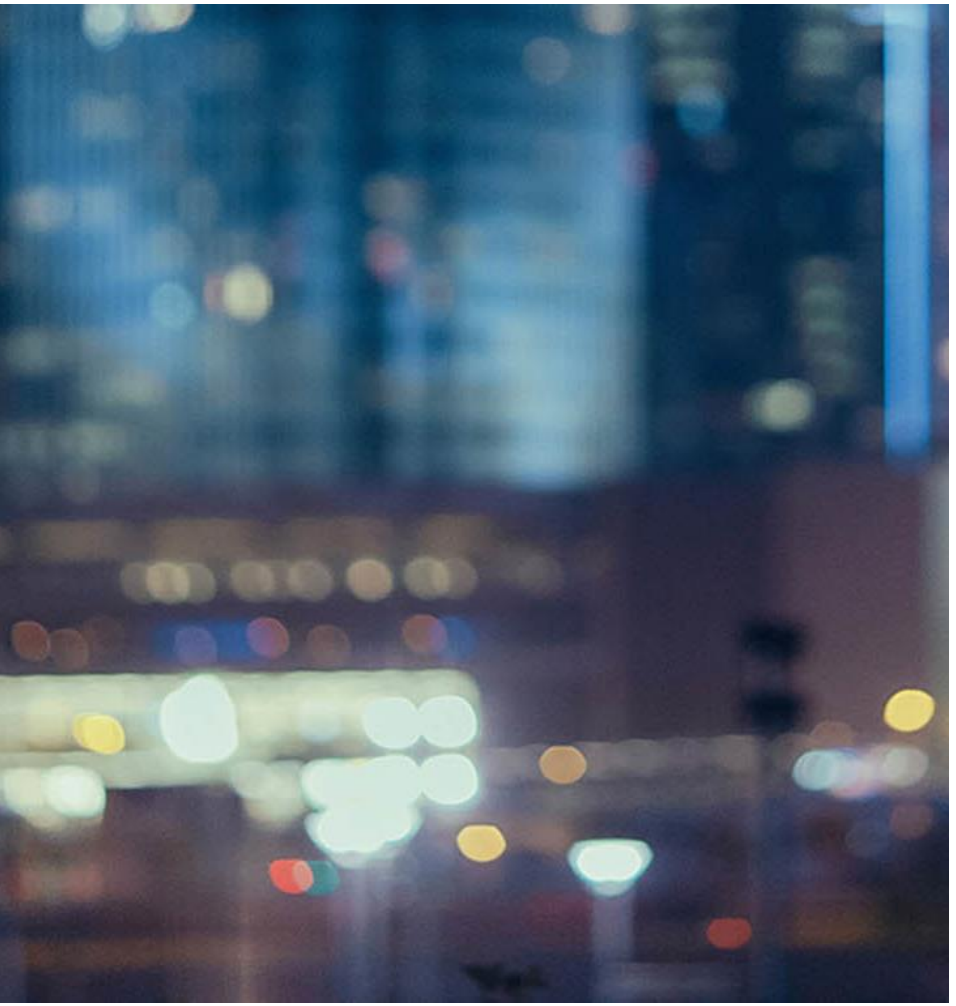

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