TSN domain boundary considerations
Josef Dorr, Stephan Höme, Sven Kerschbaum, Günter Steindl
Siemens AG
Agenda

1. Introduction and Recapitulation
2. Use Cases
3. TSN Domain Boundary in Detail
4. Identification of Standardized Mechanism
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Continuation of our work...

• [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
### 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/protection 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

Abstraction of TSN domains as virtual bridges

Proposal: Domain Management Function (DMF)

- Today:
  - IA-ME is responsible for all bridges (and end stations) in a TSN domain

- Previous proposal 3):
  - Head IA-ME \(\rightarrow\) Has knowledge of internals of all TSN domains \(\rightarrow\) scaling issue, violation of black box approach

- Black Box approach: \(\Rightarrow\) Stacked TSN domains
  - IA-ME is only responsible for its domain
  - Abstraction of TSN domains into virtual TSN bridges

3) Marius Stanic: Consistence & Convergence in TSN-based industrial automation networks
June 15, 2020
TSN domains are black boxes!

TSN domains are black boxes, 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

- 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

- **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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TSN domain boundary tasks

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

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

➔ 802.1AB: LLDP

➔ 802.1Q: Priority regeneration
➔ 802.1Q: VLAN assignment, stripping and translation
➔ 802.1Q: Ingress policing

➔ 802.1CB: Active Destination MAC and VLAN Stream identification
   • Compare Stream DA and VLAN-ID
   • Replace Stream DA, VLAN-ID and priority

➔ Priority “restauration” at egress port (PCP “tunneling” over TSN domain)
Task 1: TSN domain boundary discovery

- 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)

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:

<table>
<thead>
<tr>
<th>TCI.PCP Source</th>
<th>TCI.PCP Destination</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>0 or untagged</td>
<td>0</td>
</tr>
</tbody>
</table>
Task 2: Protection of TSN domain internal resources (2/4)

Priority “restauration” at egress TSN domain boundary ports

⇒ Allows optimization for e.g. brownfield RT traffic
  • Priority restauration for egress traffic

How to solve this?

Priority “restauration” at egress port is currently not an IEEE standard!
Task 2: Protection of TSN domain internal resources (3/4)

• 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)

• 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

- **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

![Diagram of TSN domain A, B, and C with Stream DA, VLAN-ID and priority translation](diagram.png)
Task 3: Support of TSN streams between TSN domain
In Detail: Why TSN stream DA translation is necessary!

• **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

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

  [Diagram showing network setup]

- TSN stream identification based on DA+VLAN (802.1CB)
  Translation of \{DA,VLAN, PCP\}_{TSN domain A} to \{DA+VLAN, PCP\}_{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 to the TSN stream-VLAN FDB configuration of the bridges belonging to TSN domain B

Stream DA, VLAN-ID and priority translation

Layer 2 network
Task 4: Support of non-TSN traffic over TSN domain boundary

- 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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Standardized mechanism required at TSN domain boundary

- 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 restoration 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!

Josef Dorr  
Mobile: +49 172 4612256  
E-mail: josef.dorr@siemens.com

Stephan Höme  
Mobile: +49 172 2702173  
E-mail: stephan.hoeme@siemens.com

Sven Kerschbaum  
Mobile: +49 172 7653184  
E-mail: sven.kerschbaum@siemens.com

Günter Steindl  
Mobile: +49 173 9137406  
E-mail: guenter.steindl@siemens.com

siemens.com