User Network Interface & Protocols
Requirements for TSN in Industrial Networks

- **Multiple applications share the same network**
  - Guaranteed bandwidth for multiple applications (OPC_UA, Video, Condition Monitoring, etc.)
  - Guaranteed latency for streams
  - High availability
  - …

- **Different network organization models shall be supported** (e.g. fully centralized, centralized, distributed)
  - A traffic class organization shall be transparent to end stations

- **UNI shall be based on standardized functionality for stream classification and identification** (e.g. IEEE 802.1Q DA, VLAN, Priority)
Advantages of UNI

• One Stream-Service interface for session protocol (e.g. OPC_UA, ....)

• MAC Streams and IP Streams are supported (mostly transparent for session protocol)

• One stream configuration model for End Station

• All organization models (decentralized, centralized and fully centralized) are supported

• Within one network multiple organization models can coexists
  
  • **Example:**
    • Fully Centralized organization model for a closed system (“hard” real time, highly optimized)
    • Decentralized or centralized organization model for “soft” real time applications
L2 UNI makes use of multiple protocols:

**MUST:**
- LLDP (network capabilities exchange between edge-port and end-station)
- Stream registration and reservation (MSRP/MSRP++)

**OPTIONAL:**
- Precision time sync (e.g. IEEE 802.1AS, IEEE 1588) to maintain a synchronized time
- Registration protocols (MMRP, MVRP) to register MAC addresses and VLANs
- Port security (IEEE 802.1X) to provide network access control
- ...

Additional optional network services:
- Allocation of unique Stream ID
- Allocation of unique Stream DA (e.g. IEEE 1722 MAAP)
- Local Medium Access Control (MAC) Address Usage (802c)
- ...
User Network Interface for MAC Streams based on OSI Reference Model

End Station

Application
Presentation
Session
Transport
Network
Data Link
Physical

— Stream / Flow Service Interface

LLDP, gPTP, MVRP, MMRP, MSRP/MSRP++

L2 UNI

Bridge

Data Link
Physical

LLDP, gPTP, MVRP, MMRP, MSRP/MSRP++

L2 UNI

End Station

Application
Presentation
Session
Transport
Network
Data Link
Physical

Stream / Flow Service Interface

—
User Network Interface for IP Flows based on OSI Reference Model

End Station

- Application
- Presentation
- Session
- Transport
- Network
- Data Link
- Physical

Stream / Flow Service Interface

PORT

L2 / L3 UNI

Data Link
Physical

Bridge

Data Link
Physical

IP Router

Network
Data Link
Physical

e.g. ARP, RSVP

LLDP, gPTP, MVRP, MMRP, MSRP/MSRP++

e.g. IS-IS, gPTP, MVRP, MMRP, MSRP / MSRP++
User Network Interface for MAC Streams in a distributed organized Traffic Class / Tree ("open systems")

Application Engineering (optional)

End Station

Presentation

Session

Transport

Network

Data Link

Physical

L2 UNI

Application

Presentation

Session

Transport

Network

Data Link

Physical

Edge-Bridge

Bridge

Edge-Bridge

Data Link

Physical

Bridge

Data Link

Physical

Bridge

Data Link

Physical

End Station

Application

Presentation

Session

Transport

Network

Data Link

Physical

L2 UNI

Application Protocol

Stream Service Interface

"Out of Band" Model

Example Services: I.55, 156.5, 61.2, 1.0; gPON, MNP, MSRP, MMRP, MSRP/MSRP++
User Network Interface for MAC Streams in a centralized organized Traffic Class / TE-Tree (“open systems”)

Centralized Network Control Services (opt. per Traffic Class)
- Path Computing Element (PCE)
- Reservation (opt. protocol)
- Incremental scheduling (mandatory for TAS Traffic Class)

“Out of Band” Model
User Network Interface for MAC Streams in a fully centralized organized Traffic Class / TE-Tree ("within a closed system")
Stream / Flow Service Interface in Session Layer

Stream / Flow service interface in session layer for

**Source** (for Streams called Talker)
- Stream ID
- Service Class
- TSpec (SDU size, period, ..)
- Availability
- L2 / L3 Service
- ...

**Sink** (for Stream called Listener)
- Stream ID
- Req. Latency
- ...

A specified Stream / Flow service interface is important for Session layer protocols like OPC_UA, ...!
**Example for Mapping Service Class to Traffic Class**

*Mapping example: Service Classes* (RFC 4594)

<table>
<thead>
<tr>
<th>Service Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telephony</td>
</tr>
<tr>
<td>Multimedia Conferencing</td>
</tr>
<tr>
<td>Real-Time Interactive</td>
</tr>
<tr>
<td>Multimedia Streaming</td>
</tr>
<tr>
<td>Broadcast Video</td>
</tr>
<tr>
<td>Network Control</td>
</tr>
<tr>
<td>Precision Time Sync</td>
</tr>
<tr>
<td>Telephony Signaling</td>
</tr>
<tr>
<td>Low-Latency Data</td>
</tr>
<tr>
<td>OAM</td>
</tr>
<tr>
<td>High-Throughput Data</td>
</tr>
<tr>
<td>Standard</td>
</tr>
<tr>
<td>Low-Priority Data</td>
</tr>
</tbody>
</table>

**Ethernet Priority / Class of Service**

<table>
<thead>
<tr>
<th>Ethernet Priority</th>
<th>Class of Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>SR Class A</td>
</tr>
<tr>
<td>2</td>
<td>SR Class B</td>
</tr>
<tr>
<td>7</td>
<td>Network Control</td>
</tr>
<tr>
<td>6</td>
<td>BE High Priority</td>
</tr>
<tr>
<td>0</td>
<td>BE Standard</td>
</tr>
<tr>
<td>1</td>
<td>BE Low Priority</td>
</tr>
</tbody>
</table>
Thank you for your attention!

Franz-Josef Götz
PD TI AT 4
Gleiwitzer Str. 555
90475 Nürnberg
Phone: +49 (911) 895-3455
E-Mail: franz-josef.goetz@siemens.com