Use Cases IEC/IEEE 60802 V0.5

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Abstract

This document describes use cases for industrial automation, which have to be covered by the joint IEC/IEEE TSN Profile for Industrial Automation.

Log

V01-V0.3		working drafts
V0.4	2018-03-02	Revised after circuit meeting
V0.5	2018-03-07	Revised and presented during Chicago meeting

Content

1 Terms and Definitions

1.1 Definitions

Reconfiguration	- Any intentional modification of the system structure or of the device-level content, including updates of any type - Ref: IEC 61158- Type 10, dynamic reconfiguration - Document to be provided by PI/PNO: Guidelines for high-availability
(Process) disturbance	- Any malfunction or stall of a process/machine, which is followed by production loss or by an unacceptable degradation of production quality - Ref: IEC 61158 – Failure - Ref. ODVA: Unplanned downtime - Document to be provided by PI/PNO: Guidelines for diagnosis
Operational _state of a plant (unit)/machine	- Normal state of function and production of a plant(unit)/machine
Maintenance _state of a plant (unit)/machine	- Planned suspension or partial suspension of the normal state of function of a plant(unit)/machine
Stopped _state of a plant (unit)/machine	- Full non-productive mode of a plant(unit)/machine
Convergent network concept	- All Ethernet-based devices are able to exchange data over a common infrastructure, within defined QoS parameters
Device	- End station, bridged end station, bridge
Brownfield	- Non TSN fieldbus devices
Greenfield	- TSN fieldbus devices
DCS	- Distributed Control System

1.2 IEEE802 terms

Priority regeneration	See IEEE 802.1Q-2014 clause 6.9.4 Regenerating priority
Ingress rate limiting	See IEEE 802.1Q-2014 clause 8.6.5 Flow classification and metering

2 TSN in Industrial Automation

Figure 1 gives an overview of the hierarchical structure of industrial manufacturing:

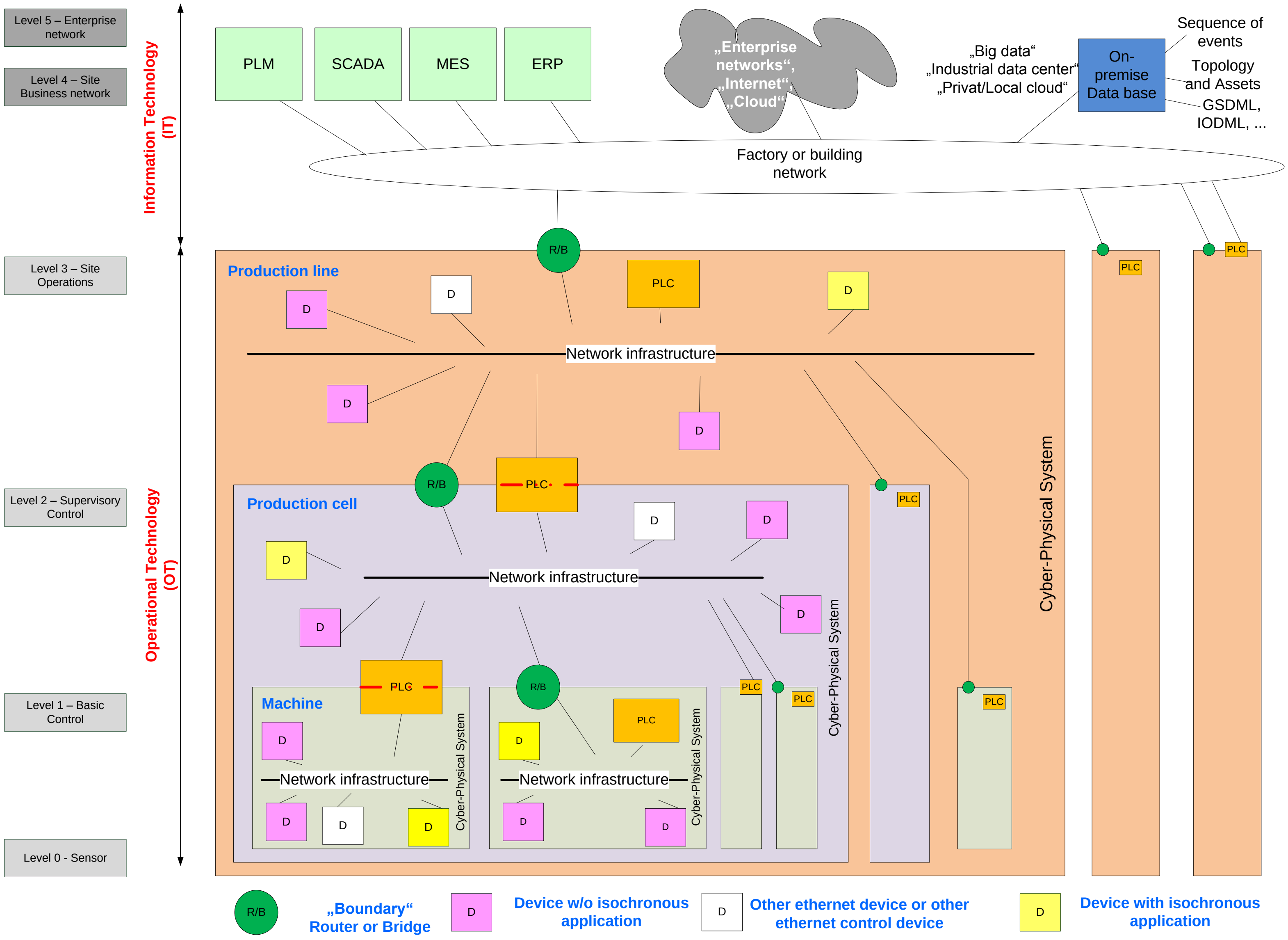


Figure 1 – Hierarchical structure of industrial automation

There is no generally accepted definition of the term “Cyber-Physical System (CPS)”. A report of Edward A. Lee [1] suitably introduces CPS as follows: „*Cyber-Physical Systems (CPS) are integrations of computation with physical processes. Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa.*”

Cyber-Physical Systems are the building blocks of “smart factories” and Industry 4.0 and TSN provides the mechanisms for connectivity to time critical industrial applications on converged networks in operational technology control levels.

TSN can be used in Industrial Automation for:

- Realtime (RT) Communication within Cyber-Physical Systems
- Realtime (RT) Communication between Cyber-Physical Systems

A CPS consists of:

- Controlling devices (typically 1 PLC),
- I/O Devices (sensors, actors),
- Drives,
- HMI (typically 1),
- Interface to the upper level with:
  - PLC (acting as gateway), and/or
  - Router, and/or
  - Bridge.
- Other Ethernet devices:
  - Servers or any other computers, be it physical or virtualized,
  - Diagnostic equipment,
  - Network connectivity equipment.

2.1 Use case: Synchronization in Industrial Automation

2.1.1 General

Time and working clock synchronization is needed for industrial automation systems.

Redundancy for Global Time may be solved with “cold standby”. Redundancy for Working Clock will be solved with “cold standby” or “hot standby” depending on the machine requirements.

Thus, three concurrent sync domains, one for Global time and two for Working Clock are required.

2.1.2 Time Synchronization

Time is used to plant wide align events and actions (e.g. for “sequence of events”). The assigned timescale is TAI, which can be converted into local date and time if necessary. Figure 2 shows the principle structure of time synchronization with the goal to establish a worldwide aligned timescale for time. Thus, often satellites are used as source of the time.

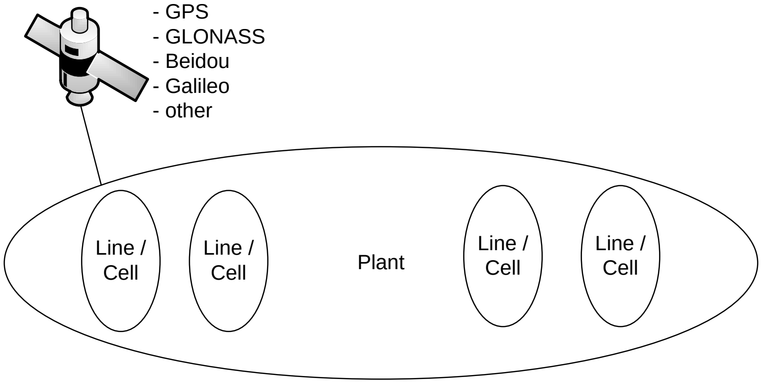


Figure 2 – plant wide time synchronization

2.1.3 Working Clock Synchronization

Working Clock is used to align actions line, cell or machine wide. The assigned timescale is arbitrary. Robots, motion control, numeric control and any kind of clocked / isochronous application rely on this timescale to make sure that actions are precisely interwoven as needed. Figure 3 shows the principle structure of Working Clock synchronization with the goal to establish a line / cell / machine wide aligned timescale. Thus, often PLCs, Motion Controller or Numeric Controller are used as Working Clock source.

If multiple PLCs, Motion Controller or Numeric Controller need to share one Working Clock timescale, an all-time active station must be used as Working Clock source.

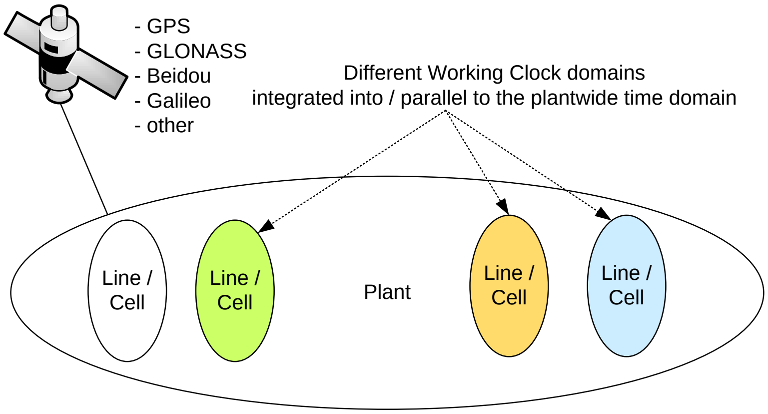


Figure 3 – line/cell/machine wide working clock synchronization

Working Clock domains may be doubled to support seamless redundancy.

2.2 Minimum required quantities

2.2.1 A representative example for requirements

Layer-2 domains in an industrial automation network for cyclic real-time traffic can span multiple Cyber-physical systems, which are connected by bridges. The following maximum quantities apply:

- 1 024 stations
- per PLC for Controller-to-Device (C2D) – one to one or one to many – communication:
  - 512 Talker and 512 Listener streams
  - 64kByte Output und 64kByte Input data
- per Device for Device-to-Device (D2D) – one to one or one to many – communication:
  - 2 Talker and 2 Listener streams
  - 1400Byte per stream
- per PLC for Controller-to-Controller (C2C) – one to one or one to many – communication:
  - 64 Talker and 64 Listener streams
  - 1400Byte per stream
- Example calculation for eight PLCs
  - → 8 x 512 x 2 = 8192 streams for C2D communication
  - → 8 x 64 x 2 = 1024 streams for C2C communication
  - → 8 x 64 x 2 = 1024kByte stream data for C2D communication
  - → 1024 x 1400 = 1400kByte stream data for C2C communication
- All above shown streams optionally redundant for seamless switchover due to the need for High Availability

Application cycle times for the 512 Talker and 512 Listener streams differ and follow the application process requirements.

E.g. 125 µs for those used for control loops and 500 µs to 512 ms for other application processes. All may be used concurrently and may have frames sizes between 1 and 1440 bytes.

2.2.2 A representative example of communication use cases

IO Station – Controller (input direction)

- Up to 2000 published + subscribed signals (typically 100 – 500)
- Scan interval time: 0.5 ..100ms (typical 10ms)

Controller – Controller (inter-application)

- Up to 1000 published + subscribed signals (typically 100 – 250)
- Application task interval time: 10..1000ms (typical 100ms)
- Resulting Scan interval time: 5 … 500 ms

Closing the loop within/across the controller

- Up to 2000 published + subscribed signals (typically 100 – 500)

- Application task interval time: 1..1000ms (typical 100ms)
- Resulting Scan interval time when spreading over controllers: 0,5 … 500 ms

Controller – IO Station (output direction)

- Up to 2000 published + subscribed signals (typically 100 – 500)
- Application task interval time: 10..1000ms (typical 100ms
- Resulting Scan interval time: 5 … 500 ms

2.2.3 “Fast” process applications

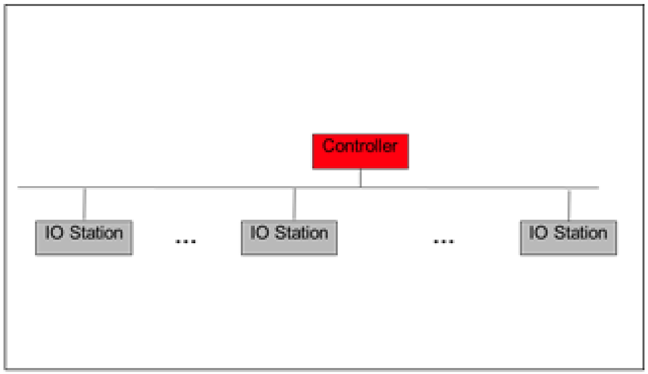


Figure 4 Logical communication concept for fast process applications

Specifics:

- Limited number of nodes communicating with one Controller (e.g. Turbine Control)
- Up to a dozen Nodes of which typically one is a controller
- Data subscriptions (horizontal):
  - 270 bytes published + subscribed per IO-station
  - Scan Interval time 0,5 to 2 ms
- Physical Topology: Redundant (as path and as device)

2.2.4 Server consolidation

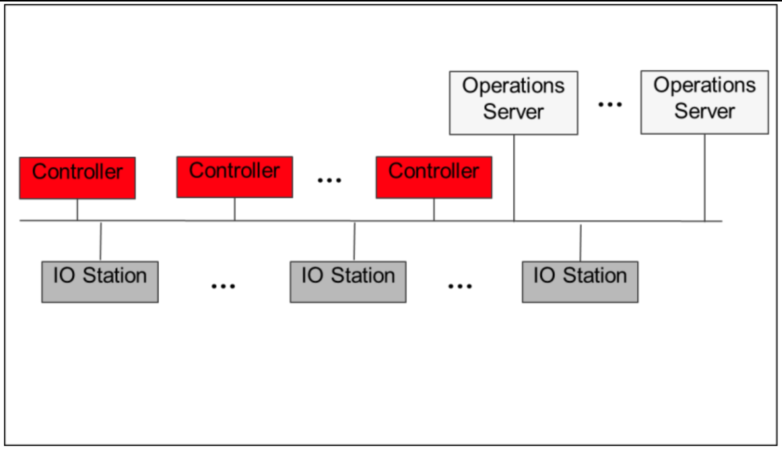


Figure 5 Server consolidated logical connectivity

Data access to Operations Functionalities consolidated through Servers

- Up to 100 Nodes in total
- Out which are up to 25 Servers

Data subscriptions (vertical):

- Each station connected to at least 1 Server
- max. 20000 subscribed items per Controller/IO-station
- 1s update rate
- 50% analog items -> 30% change every sec

Different physical topologies

- Rings, stars, redundancy

2.2.5 Direct client access

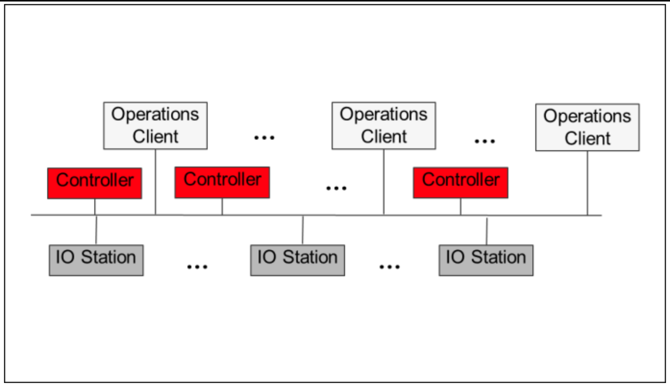


Figure 6 Clients logical connectivity view

Data access to Operations Functionalities directly by Clients

- Max 20 direct access clients

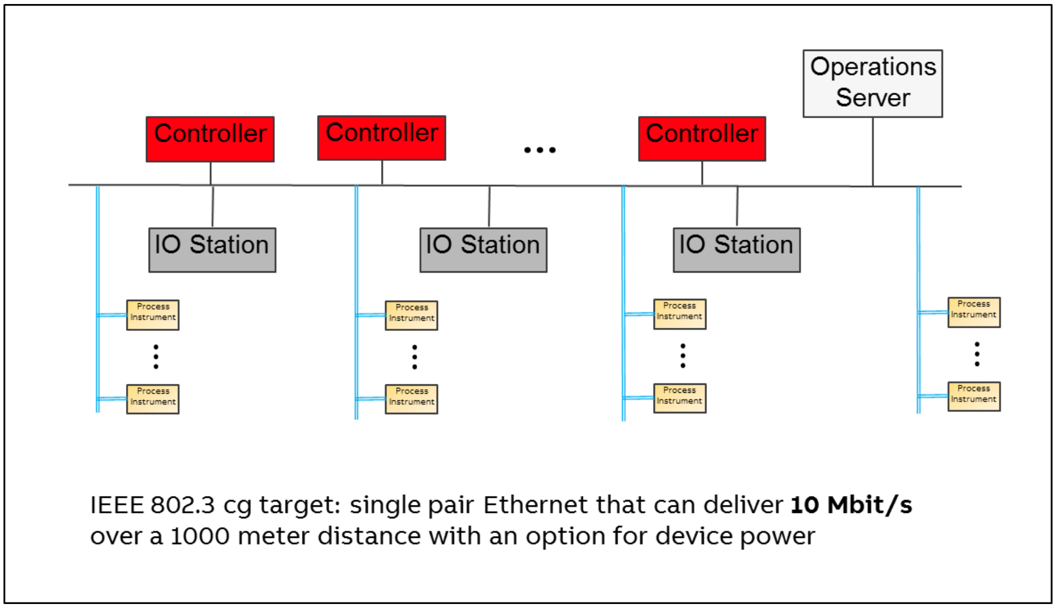
Data subscriptions (vertical):

- Up to 3000 subscribed items per client
- 1s update rate
- Worst case 60000 items/second per controller in classical Client/Server setup
- 50% analog items -> 30% change every sec

Different physical topologies

- Rings, stars, redundancy

2.2.6 Field devices



IEEE 802.3 cg target: single pair Ethernet that can deliver **10 Mbit/s** over a 1000 meter distance with an option for device power

Figure 7 Field devices with 10Mbit/s

Field Networks integrated with converged network

- Up to 50 devices per field segment
- Scan interval 50ms … 1s, typical 250ms
- Mix of different device types from different vendors
- Many changes during runtime

2.3 Cycle times

Network cycle times:

1 µs to 1 ms	at link speed 1 Gbit/s (or higher)
125 µs to 4 ms	at link speed 100 Mbit/s (or lower, e.g. 10 Mbit/s)

Application needs may limit this in principle flexible network cycle time to a granularity of e.g. 31,25µs * 2^n | n=0 to 5 (or 7).

Thus, Application cycle times are multiples of the network cycle times:

31,25µs – 512ms	with reduction ratios of 1 to 512

Application cycle times are the result of the used network cycle times together with reduction ratios.

Definition “Reduction ratio”:
The value of “reduction ratio” defines the number of network cycles between two consecutive transmits.

Definition “Phase”:

The value of “phase” in conjunction with “reduction ratio” defines the starting network cycles for the consecutive transmits.

2.4 Bridge Resources

The bridge shall provide and organize its resources in a way to ensure robustness for the traffic defined in this document as shown in Formula (1).

The queuing of frames needs resources to store them at the destination port. This resources may be organized either bridge globally, port globally or queue locally.

The chosen resource organization model influences the needed amount of frame resources.

For bridge memory calculation Formula (1) applies.

$$\text{MinimumFrameMemory} = (\text{NumberOfPorts} - 1) \times \text{MaxPortBlockingTime} \times \text{Linkspeed} \qquad (1)$$

Where

MinimumFrameMemory	is minimum amount of frame buffer needed to avoid frame loss from non stream traffic due to streams blocking egress ports.
NumberOfPorts	is number of ports of the bridge without the management port.
MaxPortBlockingTime	is intended maximum blocking time of ports due to streams per millisecond.
Linkspeed	is intended link speed of the ports.

Formula (1) assumes that all ports use the same link speed and a bridge global frame resource management. Table 1, Table 2, Table 3, and Table 4 shows the resulting values for different link speeds.

The traffic from the management port to the network needs a fair share of the bridge resources to ensure the required injection performance into the network. This memory is not covered by this calculation.

Table 1 – MinimumFrameMemory for 100 Mbit/s (50%@1 ms)

# of ports	MinimumFrameMemory [KBytes]	Comment
1	0	The memory at the management port is not covered by Formula (1)
2	6,25	All frames received during the 50%@1 ms := 500 µs at one port needed to be forwarded to the other port are stored during the allocation of this port due to stream transmission.
3	12,5	All frames received during the 50%@1 ms := 500 µs at two ports needed to be forwarded to the other port are stored during the allocation of this port due to stream transmission.
4	18,75	All frames received during the 50%@1 ms := 500 µs at three ports needed to be forwarded to the other port are stored during the allocation of this port due to stream transmission.
other	tbd	tbd

Table 2 – MinimumFrameMemory for 1 Gbit/s (20%@1 ms)

# of ports	MinimumFrameMemory [KBytes]	Comment
1	0	The memory at the management port is not covered by Formula (1)
2	25	All frames received during the 20%@1 ms := 200 µs at one port needed to be forwarded to the other port are stored during the allocation of this port due to stream transmission.

# of ports	MinimumFrameMemory [KBytes]	Comment
3	50	All frames received during the 20%@1 ms := 200 µs at two ports needed to be forwarded to the other port are stored during the allocation of this port due to stream transmission.
4	75	All frames received during the 20%@1 ms := 200 µs at three ports needed to be forwarded to the other port are stored during the allocation of this port due to stream transmission.
other	tbd	tbd

Table 3 – MinimumFrameMemory for 2,5 Gbit/s (10%@1 ms)

# of ports	MinimumFrameMemory [KBytes]	Comment
1	0	The memory at the management port is not covered by Formula (1)
2	31,25	All frames received during the 10%@1 ms := 100 µs at one port needed to be forwarded to the other port are stored during the allocation of this port due to stream transmission.
3	62,5	All frames received during the 10%@1 ms := 100 µs at two ports needed to be forwarded to the other port are stored during the allocation of this port due to stream transmission.
4	93,75	All frames received during the 10%@1 ms := 100 µs at three ports needed to be forwarded to the other port are stored during the allocation of this port due to stream transmission.
other	tbd	tbd

Table 4 – MinimumFrameMemory for 10 Gbit/s (5%@1 ms)

# of ports	MinimumFrameMemory [KBytes]	Comment
1	0	The memory at the management port is not covered by Formula (1)
2	62,5	All frames received during the 5%@1 ms := 50 µs at one port needed to be forwarded to the other port are stored during the allocation of this port due to stream transmission.
3	125	All frames received during the 5%@1 ms := 50 µs at two ports needed to be forwarded to the other port are stored during the allocation of this port due to stream transmission.
4	187,5	All frames received during the 5%@1 ms := 50 µs at three ports needed to be forwarded to the other port are stored during the allocation of this port due to stream transmission.
other	tbd	tbd

A per port frame resource management leads to the same values, but reduced the flexibility to use free frame resources for other ports.

A per queue per port frame resource management would increase (multiplied by the number of to be covered queues) the needed amount of frame resources dramatically almost without any benefit.

Example “per port frame resource”:

100 Mbit/s, 2 Ports, and 6 queue
Needed memory := 6,25 KOctets * 6 := 37,5 KOctets.

No one is able to define which queue is needed during the “stream port blocking” period.

3 Use case: Pass-through Traffic

Machines are supplied by machine builders to production cell/line builders in tested and approved quality. At specific boundary ports standard devices (e.g. barcode reader) can be attached to the machines. The machines support transport of non-stream traffic through the tested/approved machine ("pass-through traffic") without influencing the operational behavior of the machine, e.g. connection of a printer or barcode reader. Figure 8, Figure 9 and Figure 10 give some examples of pass-through traffic installations in industrial automation.

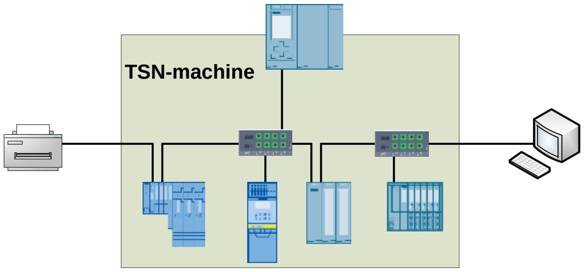


Figure 8 – pass-through one machine

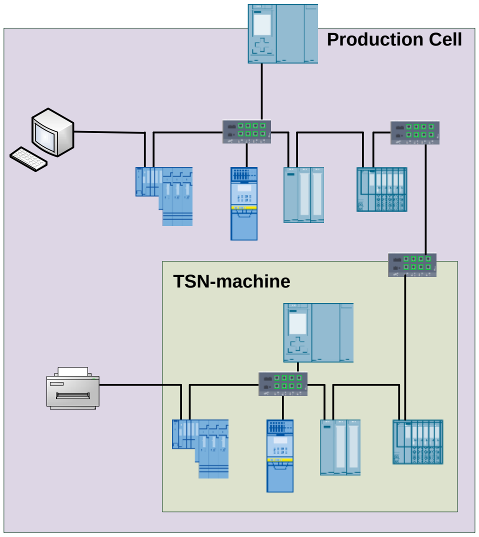


Figure 9 – pass-through one machine and production cell

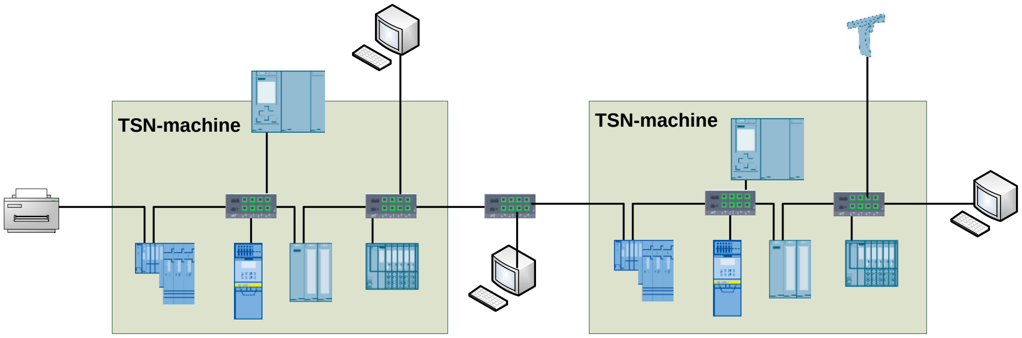


Figure 10 – pass-through two machines

<u>Requirement</u>:

<u>All</u> machine internal communication (stream traffic <u>and</u> non-stream traffic) is decoupled from and protected against the additional "pass-through" traffic.
"Pass-through" traffic is treated as separate traffic pattern.

<u>Useful 802.1Q mechanisms:</u>

- Priority Regeneration,
- separate "pass-through traffic queue",
- Queue-based resource allocation in all bridges,
- Ingress rate limiting.

4 Use case: Brownfield Integration

Brownfield devices with realtime communication are attached to a PLC, which supports both brownfield and greenfield, within a TSN-machine. This allows faster deployment of TSN devices into the field. Figure 11 gives an example of a TSN-machine with brownfield devices.

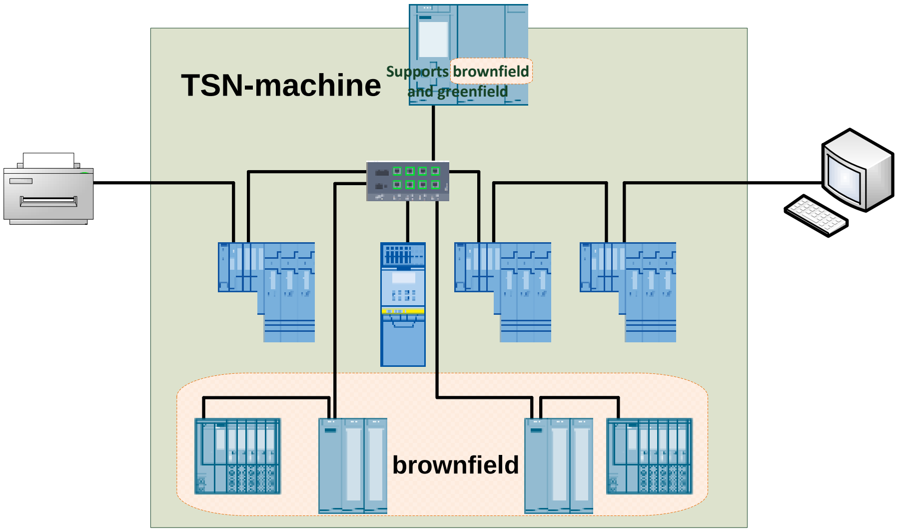


Figure 11 – machine with brownfield

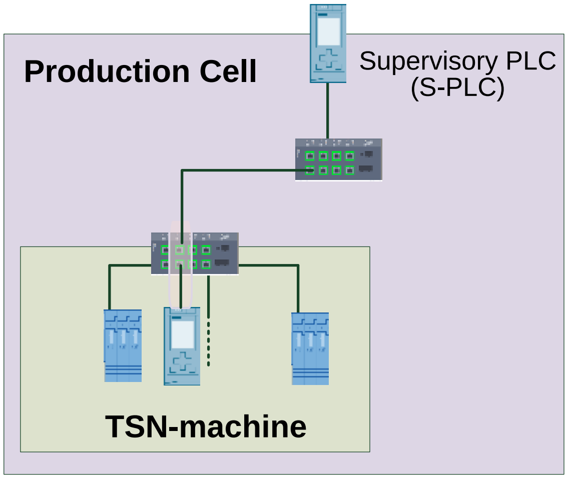
<u>Requirement</u>:
All machine internal stream traffic communication (stream traffic <u>and</u> non-stream traffic) is decoupled from and protected against the brownfield cyclic real-time traffic.
Brownfield cyclic real-time traffic QoS is preserved within the TSN-machine.

<u>Useful 802.1Q mechanisms</u>:

- Priority Regeneration,
- separate "brownfield traffic queue".
- Queue-based resource allocation.

5 Use case: Machine to Machine (M2M/C2C) Communication

Preconfigured TSN-machines, which include tested and approved internal communication, communicate with other preconfigured TSN-machines or with a supervisory PLC of the production cell.
Figure 12 gives an example of M2M communication to a supervisory PLC and Figure 13 shows an example of M2M communication relations between TSN-machines.



PLCs with one single interface involve overlapping communication paths of M2M and machine internal traffic. In this case two domains (TSN-machine / production cell) need to share TSN resources.

Figure 12 – M2M with supervisory PLC

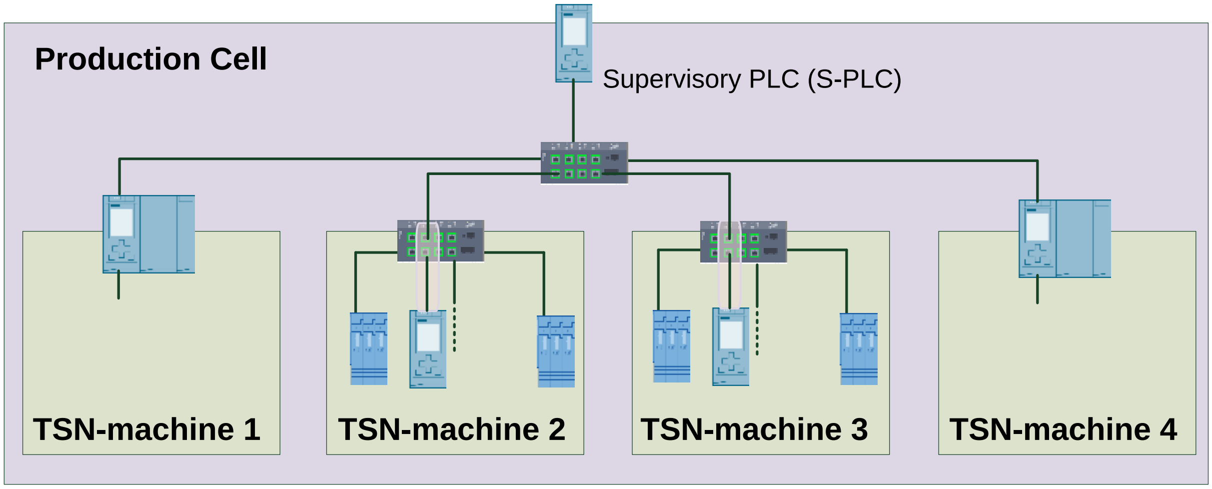


Figure 13 – M2M with four machines

From the communication point of view the two types of machine interface shown in Figure 13 are identical. The plc represents the machine interface and uses either a dedicated or a shared interface for communication with other machines and/or a supervisor PLC.

The communication relations between machines may or may not include or make use of a supervisory PLC.

Requirement:
All machine internal communication (stream traffic and non-stream traffic) is decoupled from and protected against the additional M2M traffic and vice versa.
1:1 and 1:many communication relations shall be possible.

Useful 802.1Q mechanisms:

- Priority Regeneration,
- Queue-based resource allocation,
- VLANs to separate address domains.

6 Use case: Modular Machine

6.1 Modular machine assembly

In this use case machines are variable assemblies of multiple different modules. Effective assembly of a machine is executed in the plant dependent on the current stage of production, e.g. bread-machine with the modules: base module, ‘Kaisersemmel’ module, ‘Rosensemmel’ module, sesame caster, poppy-seed caster, baking oven OR advertisement feeder for newspapars.
Figure 14 may have relaxed latency requirements, but Figure 15 need to work with very high speed and thus has very demanding latency requirements.

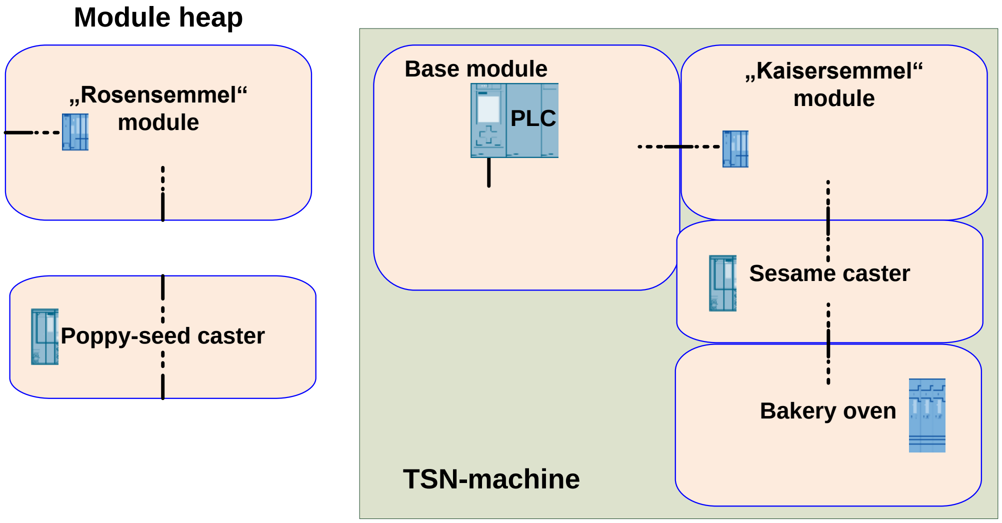


Figure 14 – modular bread-machine

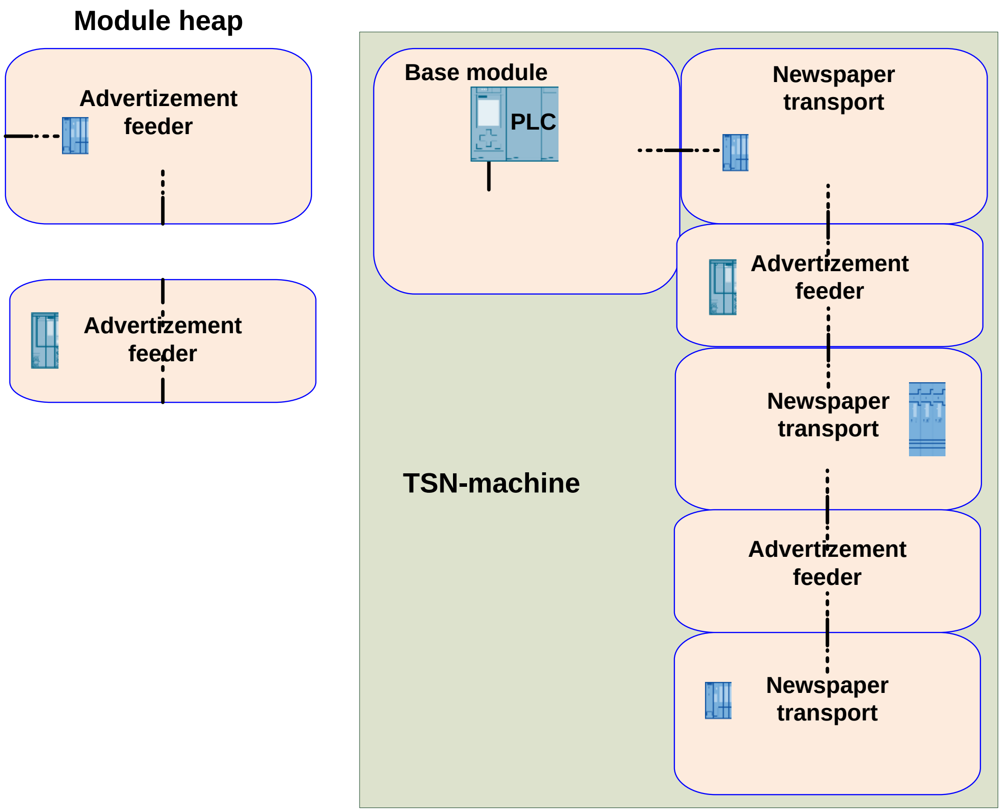


Figure 15 – modular advertisement feeder

<u>Requirement</u>:
Modules can be assembled to a working machine variably on-site (either in run, stop or power down mode) as necessary (several times throughout a day). The TSN-machine produces the selected variety of a product. TSN communication is established automatically after the modules are plugged without management/ configuration interaction.

6.2 Tool changer

Tools (e.g. different robot arms) are in power off mode. During production a robot changes its arms for different production steps.

They get mechanically connected to a robot arm and then powered on. The time till operate influences the efficiency of the robot and thus the production capacity of the plant. Robots may share a common tool pool. Thus the “tools” are connected to different robots during different production steps.

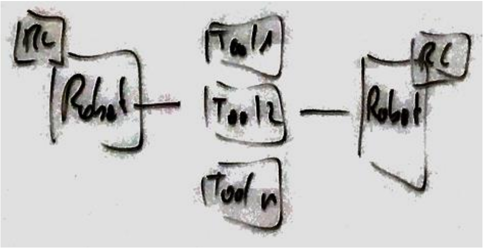


Figure 16 – tool changer

Requirement:

- Added portion of the network needs to be up and running (power on to operate) in less than 500ms.
- Extending and removing portions of the network (up to 16 devices) in operation
  - by one connection point (one robot using a tool)
  - by multiple connection points (multiple robots using a tool)

Useful 802.1Q mechanisms:

- preconfigured streams
- …

7 Use case: Dynamic plugging and unplugging of machines (subnets)

E.g. multiple AGVs (automatic guided vehicles) access various docking stations to get access to the supervisory PLC. Thus, an AGV is temporary not available. An AGV may act as CPS or as a bunch of devices.

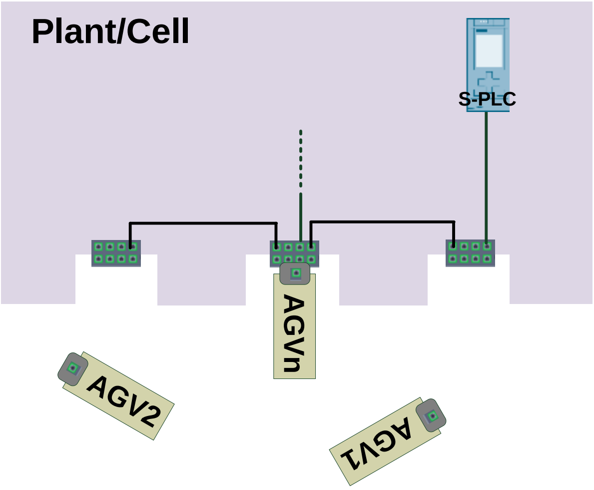


Figure 17 – AGV plug and unplug

Requirement:

The TSN traffic from/to AGVs is established/removed automatically after plug/unplug events.
Different AGVs may demand different traffic layouts.
The time till operate influences the efficiency of the plant.
Thousands of AGS may be used concurrently, but only a defined amount of AGVs is connected at a given time.

Useful 802.1Q mechanisms:

- preconfigured streams
- …

8 Use case: Energy Saving

Complete or partial plant components are switched off and on as necessary to save energy. Thus, portions of the plant are temporarily not available.

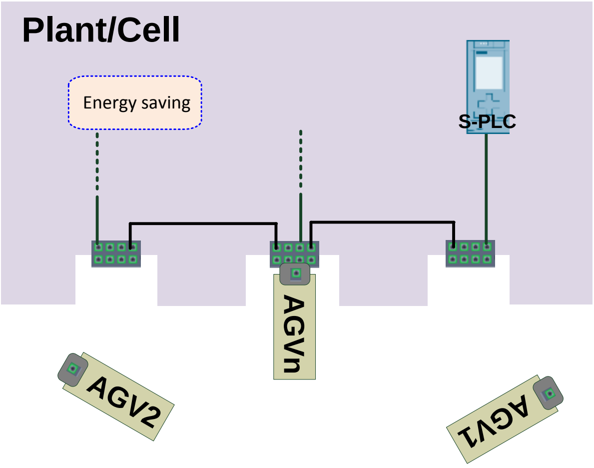


Figure 18 – energy saving

Requirement:
Energy saving region switch off/on shall not create process disturbance.

Useful 802.1Q mechanisms:

- Appropriate path computation by sorting streams to avoid streams passing through energy saving region.
- …

9 Use case: High Availability

9.1 Use case: Tunnel control

Tunnels need to be controlled by systems supporting high availability because airflow or fire protection may have an impact on people. In this case PLC, remote IO and network may be installed to support availability in case of failure.

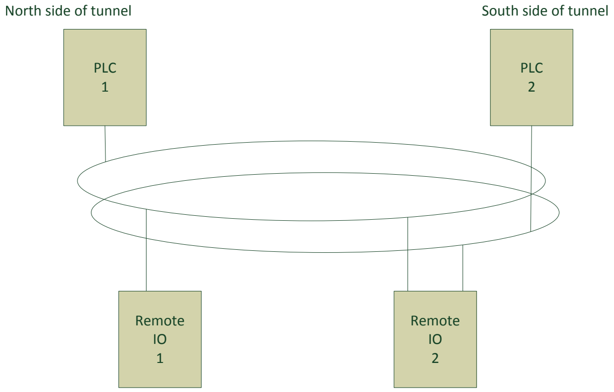


Figure 19 – Tunnel control

Requirement:
Failure shall not create process disturbance – e.g. keep air flow active / fire control active.

Useful 802.1Q mechanisms:

- Appropriate path computation by sorting streams to avoid streams passing through energy saving region.
- Redundancy for PLCs, Remote IOs and paths through the network
- …

9.2 Use case: Ship control

Ships need to be controlled by systems supporting high availability.

10 Use case: Different domain sizes for different Traffic Pattern

Figure 20 shows a machine which needs due to timing constraints (network cycle time together with required topology) two or more separated isochronous real-time domains but shares a common cyclic real-time domain.
Both isochronous domains may have their own Working Clock and network cycle. The PLCs need to share the remote IOs using cyclic real-time traffic.
Some kind of coupling (e.g. shared synchronization) between the isochronous domains / Working Clocks may be used (see Figure 21).

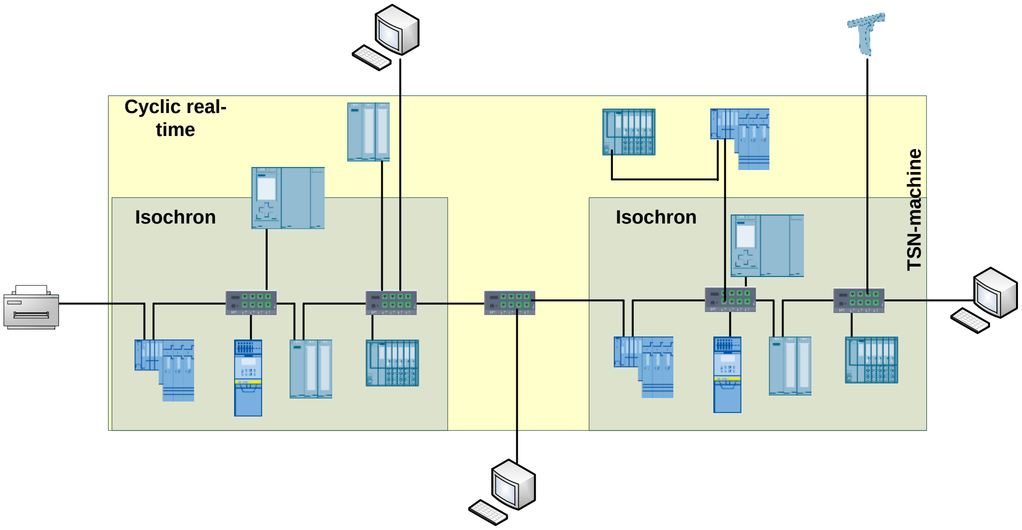


Figure 20 – Different domain size for different Traffic Pattern

Both isochron domains may have different network cycle times, but the cyclic real-time data exchange shall still be possible for PLCs from both isochron domains.

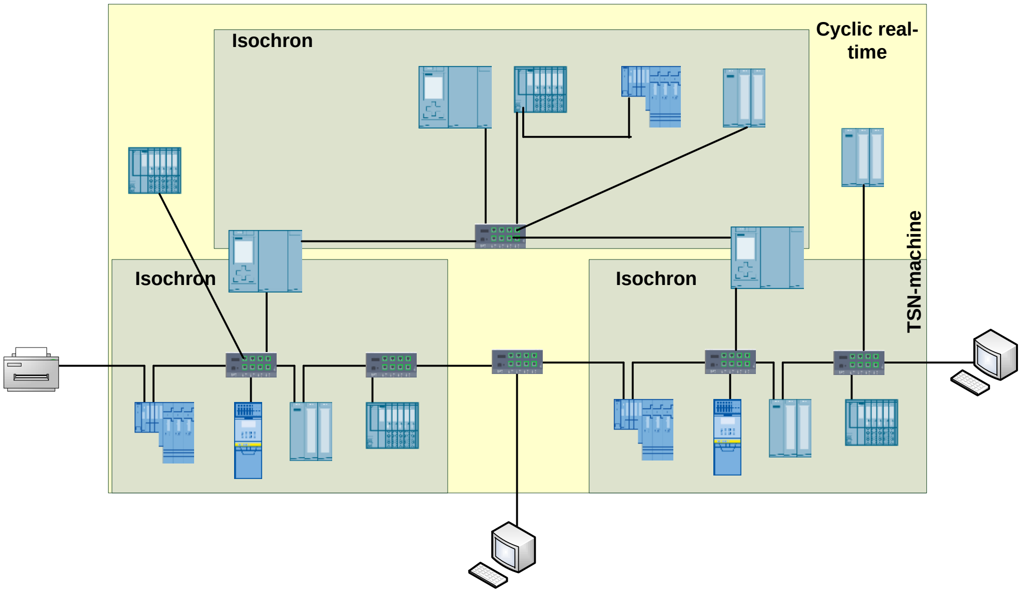


Figure 21 – Different domain size for different Traffic Pattern - coupled

Requirement:

All isochronous real-time domains may run independently, loosely coupled or tightly coupled. They shall be able to share a cyclic real-time domain.

Useful 802.1Q mechanisms:

- Priority Regeneration,
- separate “isochronous” and “cyclic” traffic queues,
- Queue-based resource allocation in all bridges,

- Ingress rate limiting.

11 Use Cases: Guaranteed low latency

To achieve the needed quality for Control loops the roundtrip delay (sometimes called makespan, too) of the exchanged data is essential.
Figure 22 shows the whole transmission path from application to application and back.
Figure 23 show a way how the network cycle and the application cycle interacts in this use case.

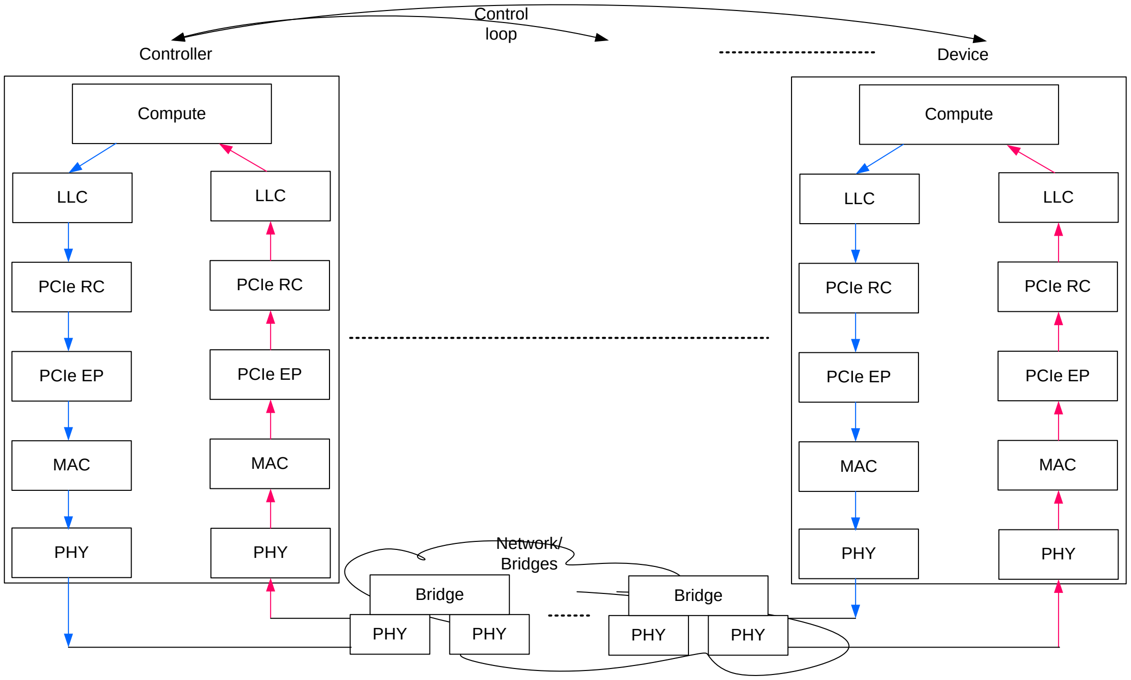


Figure 22 – Principle data path (Control loop)

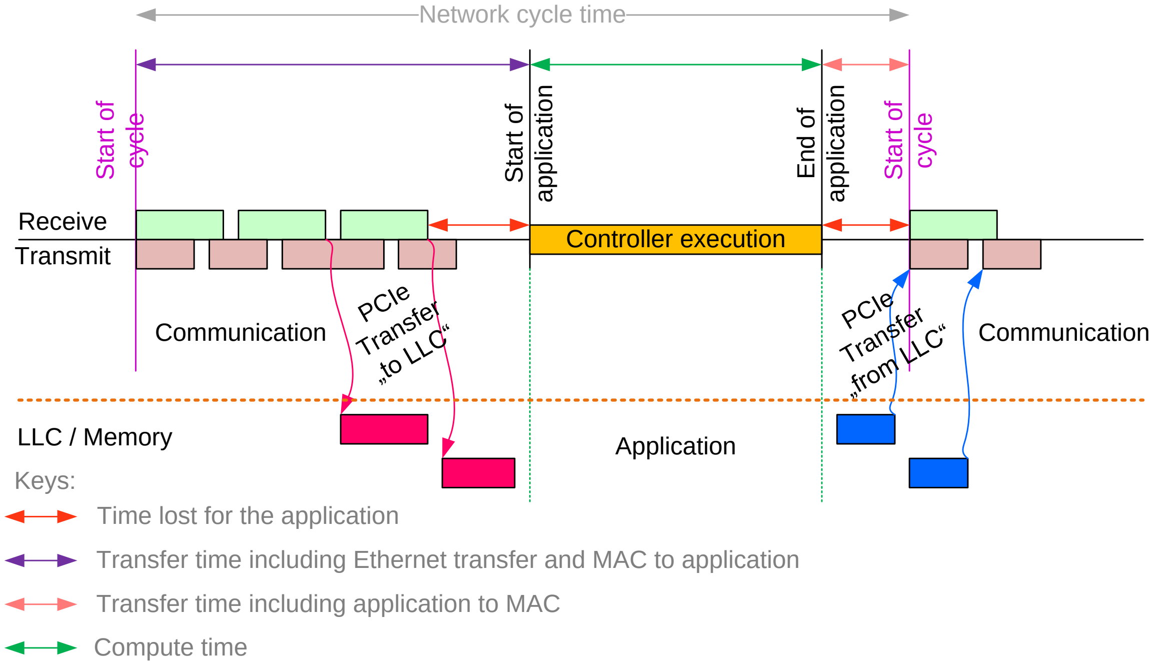


Figure 23 – Integration into the control loop

Requirement:

Required latency shall be achieved.

Useful 802.1Q mechanisms:

- Whatever helps
- …

12 Use Cases: Auto domain protection

Machines are built in a way that not always all devices are really installed either due to machine versioning or repair. In this case a TSN domain shall not expand automatically.

13 Use Cases: Wireless

Cyclic real-time communication over wireless and wired paths.
HMI panel connected wireless to the machine.

14 Use Cases: Network diagnosis

Where is the problem?

15 Use Cases: Ethernet sensor

10 Mbit/s, end station, to enable cheap and easy sensors to be connected directly to Ethernet.

16 Use Cases: Security

Protection against connection of not allowed devices e.g. 802.1X
Device identity management
Integrity (Device identity management, Device and Message Authentication)
Confidentiality
Availabilty (of the application)
Device access – (User Access Authentication) who is able to change something)
IEC62443
Qci as protection against malicious access

17 Use Cases: Gateway

Gateway to integrate non Ethernet fieldbuses into TSN domains.

18 Use Cases: Virtualization

Workload consolidation is done by virtualizing the hardware interfaces. Even in such kind of environment TSN shall be working.
vSwitch/vBridge

19 Use Cases: Firmware update

Firmware update is done during normal operation to make sure that the machine e.g. with 1000 devices is able be updated with almost no down time.

20 Use Cases: Sequence of events

Administrative demands for plant wide timestamped events need to be fulfilled.

21 Use Cases: Add machine

More production capacity is needed, such an additional machine is bought and added.

22 Use Cases: Add production cell

More production capacity is needed, such an additional production line is bought and added.

23 Use Cases: Add production line

A new production line is bought or build and added to the plant.

24 Use Cases: All existing traffic pattern

Today’s devices uses concurrently different traffic pattern, e.g.

- Isochron
- Cyclic real-time
- Alarms
- Read and Write Records
- Connection establishment
- Synchronization
- Neighborhood discovery
- Media redundancy
- …

25 Use case: Motion control network with different application cycles

Servo drives from different vendors (Vendor A and Vendor B) are working on the same network. For specific reasons the vendors are limited in the choice of the period for their control loop.

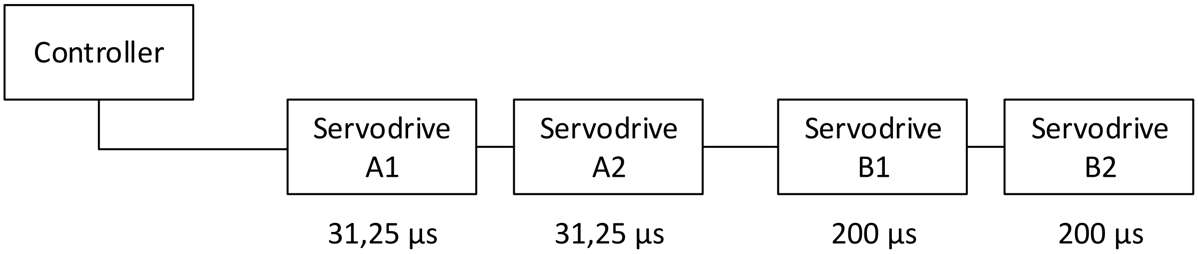


Figure 24 – network with different application cycles

The following Communication Relations are expected to be possible:

Servodrive A1 ←→ Servodrive A2: 31,25 µs
Servodrive B1 ←→ Servodrive B2: 50 µs

Controller ←→ Servodrive A1: 125 µs
Controller ←→ Servodrive B1: 200 µs

Servodrive A1 ←→Servodrive B1: 1 ms

<u>Requirement</u>:

- Isochronous data exchange

- Different cycles for data exchange, which are not multiples of each other
(cycles are not multiple of a common base, but fractions of a common base, here for instance 1 ms)

<u>Useful 802.1Q mechanisms:</u>

- Whatever helps
- …

26 Use case: More than one application using TSN

E.g. Technology A and B

27 Use case: Functional safety

Any impact for the network?
Example for IEC61784-3-3 will be added.

Maybe some additional use case for

- System safety

28 Use case: Mixed link speed

Having 10Mbit/s sensors connected to 100Mbit/s in Machine connected to 1Gbit/s cell backbone connected to 10Gbit/s production line backbone?

29 DCS Reconfiguration Use Cases

29.1 Challenges of DCS Reconfiguration Use Cases

The challenge these use cases bring is the influence of reconfiguration on the existing communication: <u>all has to happen without disturbances to the production!</u>

We consider important the use case that we can connect any number of new devices wherever in the system and they get connectivity over the existing (TSN) infrastructure without a change to the operational mode of the system.

29.2 Device level reconfiguration use cases

- SW modifications to a device
  - A change to the device’s SW/SW application shall happen, which does not require changes to the SW/SW application running on other devices (incl. firmware update): *add examples*

- Device Exchange/Replacement
  - The process device is replaced by another unit for maintenance reason, e.g. for off-process calibration or because of the device being defective (note: a “defective device may still be fully and properly engaged in the network and the communication, e.g. if just the sensor is not working properly anymore):
  - Use case: repair
- Add/remove additional device(s)
  - A new device is brought to an existing system or functionality, which shall be used in the application, is added to a running device, e.g. by enabling a SW function or plugging in a new HW-module. Even though the scope of change is not limited to a single device because also the other device engaged in the same application
  - For process devices, servers: BIOS, OS and applications updates, new VMs, workstations
  - Use cases: replacement with upgrade/downgrade of an existing device, simply adding new devices, removal of device, adding connections between devices
- Influencing factors relative to communication
  - Communication requirements of newly added devices (in case of adding)
  - Existing QoS parameters (i.e. protocol-specific parameters like TimeOuts or Retries)
  - Device Redundancy
  - Network/Media Redundancy
  - Virtualization
  - For servers: in-premise or cloud
  - Clock types in the involved process devices
  - Clock domains
  - Cycle time(s) needed by new devices
  - Available bandwidth
  - Existing security policies

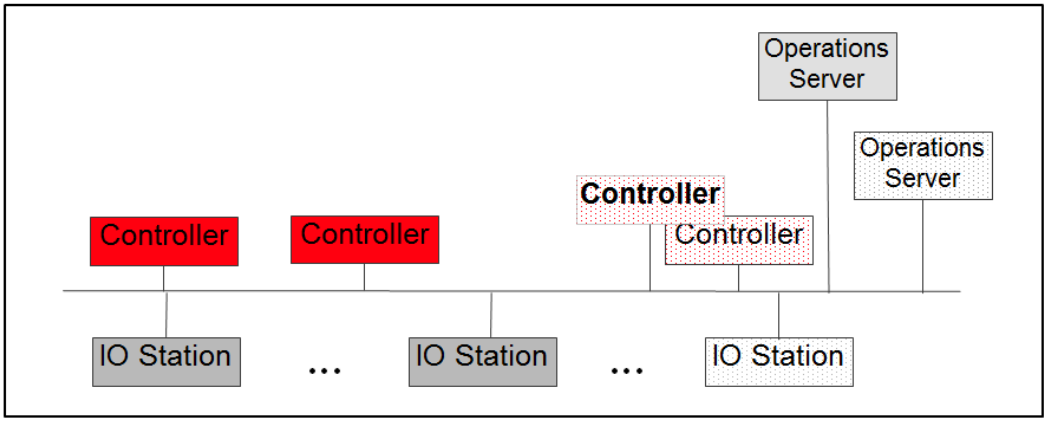


Figure 25 – Device level reconfiguration use cases

29.3 System level reconfiguration use cases

- Extend an existing plant
  - Add new network segment to existing network

  - Existing non-TSN / Newly added is TSN
  - Existing TSN / Newly added is TSN

- Update the system security policy
  - [New key lengths, new security zones, new security policy]
  - To be defined how and by whom to be handled

- Influencing factors
  - Same as for “device-level”

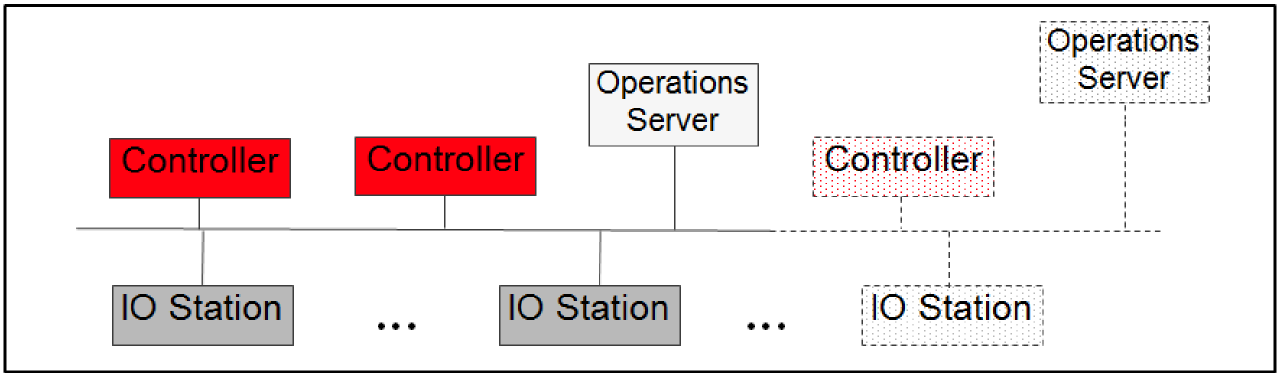


Figure 26 – System level reconfiguration use cases

30 Literature

[1] “Cyber Physical Systems: Design Challenges”, E. A. Lee, Technical Report No. UCB/EECS-2008-8; http://www.eecs.berkeley.edu/Pubs/TechRpts/2008/EECS-2008-8.html