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IEEE 802.1ASbt for Industrial Networks

Requirements of Industrial Automation for Time Synchronization

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Outline

- Additional Parameter Sets for Industrial Automation in gPTP
  - for Universal Time
  - for Working Clock
- Redundancy for Working Clock Synchronization
  - Assumptions on architecture and approaches
  - Industrial requirements
  - Two Use-cases
    - Media redundancy
    - Media + GM redundancy

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Additional Parameter Sets for Industrial Automation

Parameters	For Universal Time	For Working Clock
Hop count	up to 128	up to 64
Sync accuracy at the last hop	< ± 100 µs	< ± 1 µs
Sync interval	125 ms	31.25 ms
Forwarding delay of Sync msgs in bridges	< 10 ms	< 1 ms
Frequency tolerance (quartz or oscillator quality in term of frequency stability)	< ± 50 ppm	< ± 50 ppm
Max. frequency drift rate *	3 ppm/sec	3 ppm/sec

* due to temperature changes, shock, vibration or aging, @SyncMaster, modelled as sine curve)

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Redundancy for Working Clock Synchronization

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Assumptions on Architecture and Approaches

- use different domain numbers for redundant GMs and redundant sync trees, thus each of redundant sync msg is transported within its own gPTP instance

- execute the following operations outside gPTP
  - computation of redundant sync trees with an interface to directly set domain-specific port roles in gPTP, e.g. using ISIS (similar as specified for PCR)
  - determination of redundant GMs, e.g. primary and hot standby GMs
  - allocation of domain numbers for redundant GMs/sync trees
  - protocol of collecting information from gPTP and feeding configurations back to gPTP
  - use of redundant sync information to adjust local clocks at time-aware end-stations

Industrial Requirements for Redundancy in Working Clock Synchronization

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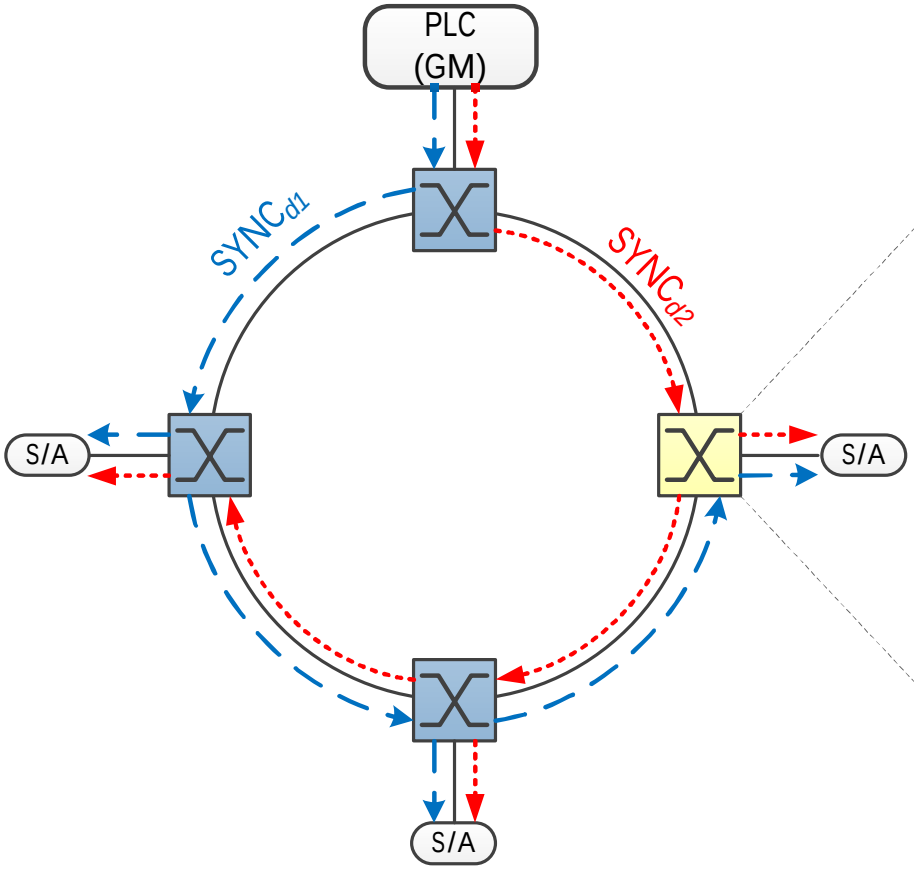
- Static configurations for synchronization - **Working Clock is engineered!**
  - GMs (incl. hot-standby GM if using GM redundancy) are pre-chosen
  - Redundant sync trees are pre-calculated
    - gPTP Announce messages are NOT used to select GM and to establish sync tree
    - gPTP Announce messages can be still used to distribute GM information!

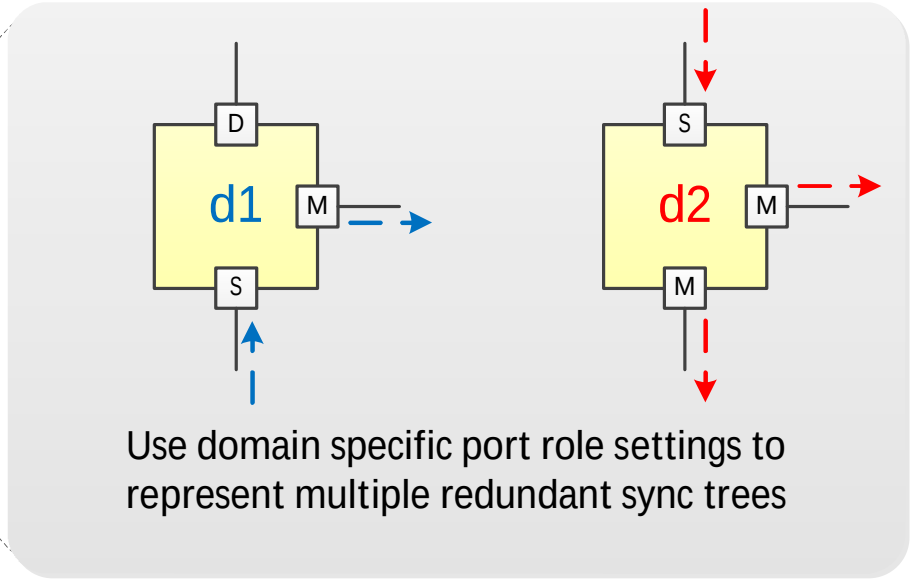
- Redundancy is primarily used in Working Clock synchronization to handle single failure
  - In normal operations, end-stations always receive multiple sync msgs via redundant paths from either the same or redundant GMs
    - Algorithms of using redundant information are application-specific

  - In case of single failure, sync msgs received on other unaffected paths are still available, thus reconfiguration by re-choosing GM or re-computing sync tree is NOT needed
    - Automatic reconfiguration through gPTP is NOT desired because reconfiguration time over 64 hops in AS violates max. hold-over time (e.g. 100 ms)
    - MTTR (Mean Time to Repair) **<<** MTBF (Mean Time between Failures)

  - Signaling of detected failures (e.g. via announce or sync timeouts) is still needed for diagnostics

Use-cases of Redundant WC Synchronization
1. Media Redundancy - Normal

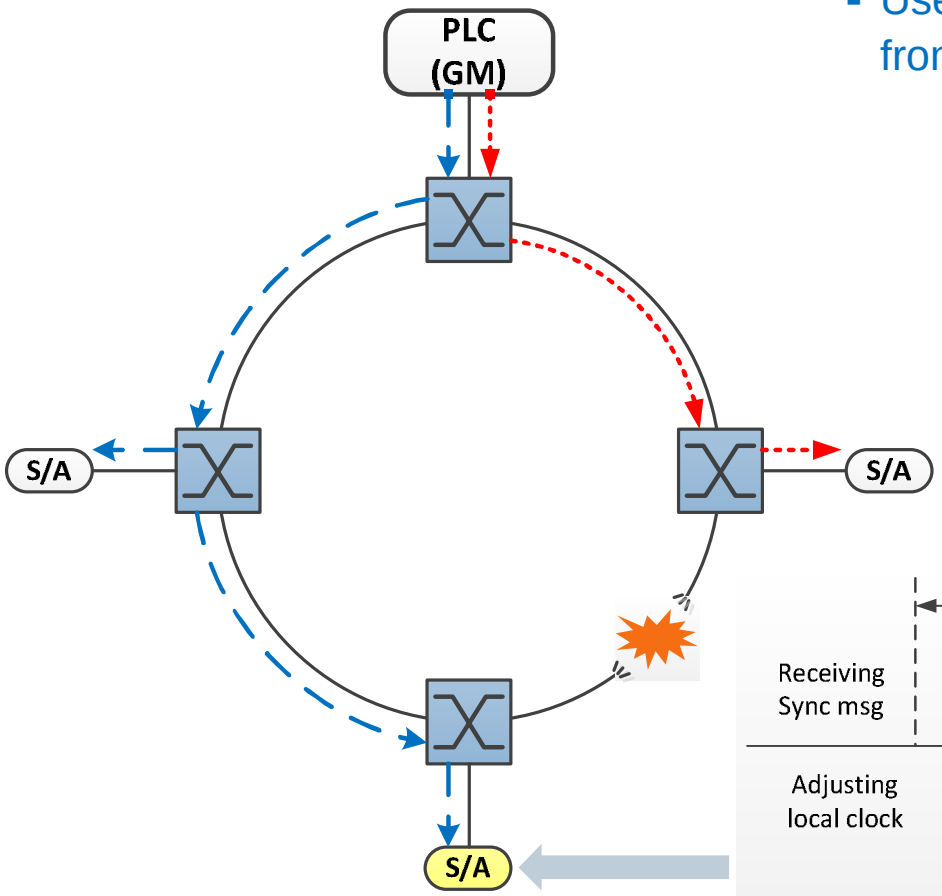




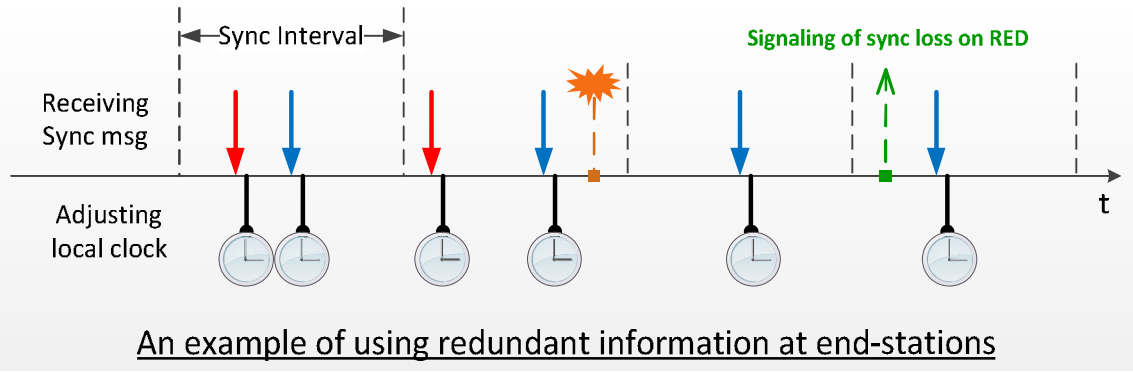
S/A Sensor/Actuator

One GM with two Sync trees in two gPTP domains (d1 and d2)

Use-cases of Redundant WC Synchronization
1. Media Redundancy - Single Failure



- Use media-redundancy to protect synchronization from single link failure
  - Each end-station can still receive Sync msgs from the other path without the need of reconfiguration
  - Detection of sync loss on one path using timeout triggers signaling of failure, but no automatic reconfiguration of sync trees



An example of using redundant information at end-stations

Single Sync-Path Failure

Use-cases of Redundant WC Synchronization
2. Media + GM Redundancy - Topology

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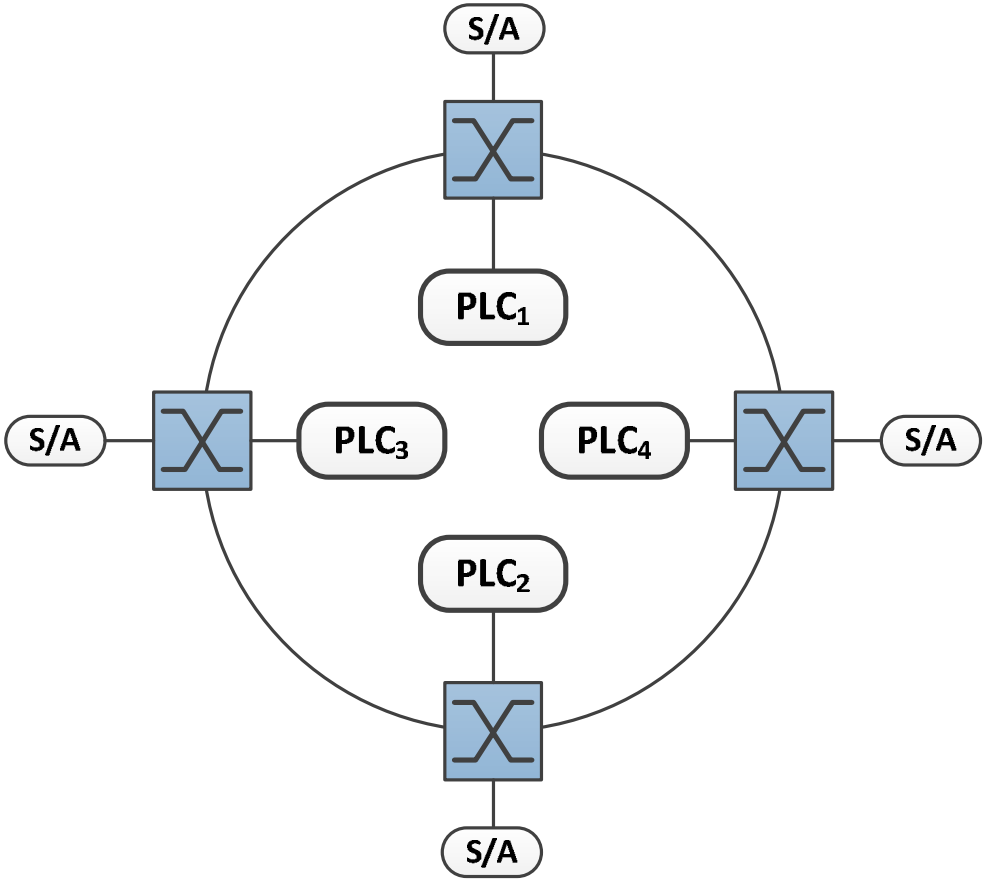

Use-cases of Redundant WC Synchronization
2. Media + GM Redundancy - Normal

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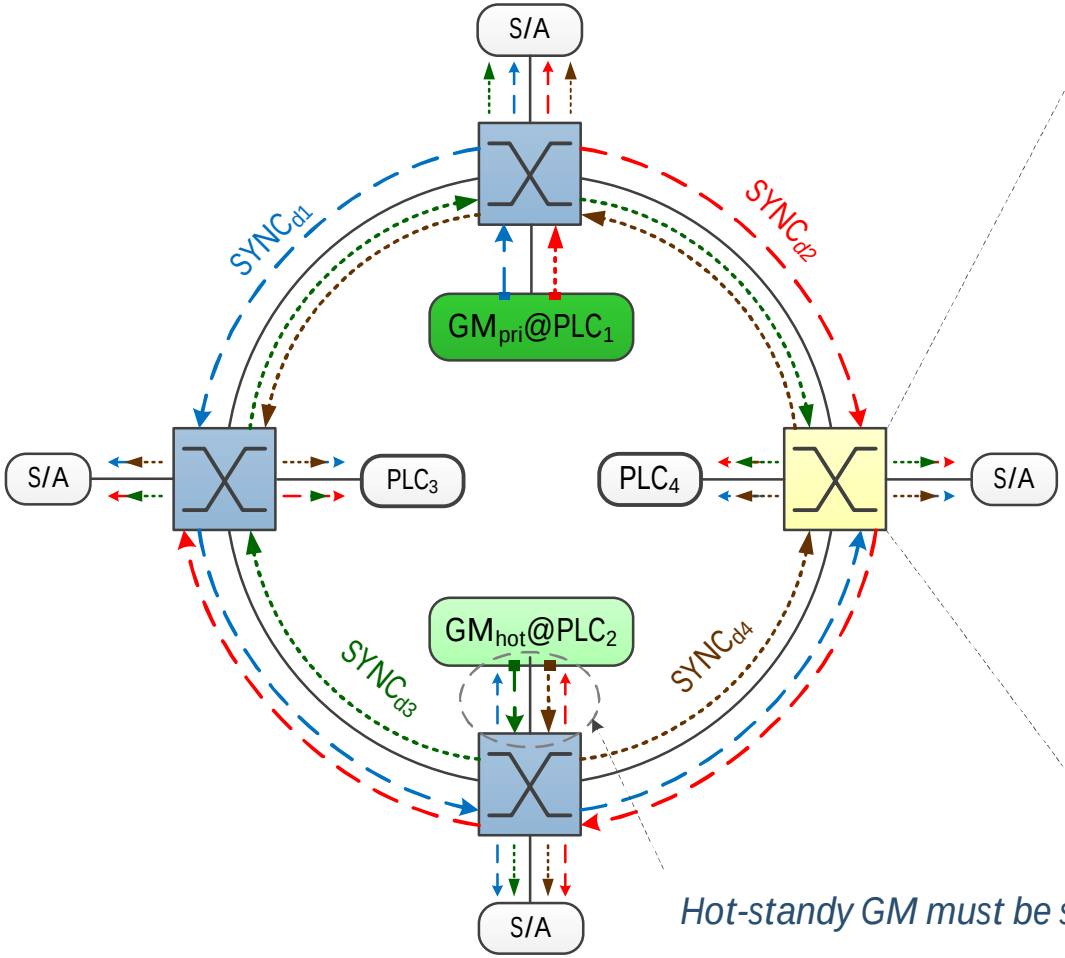

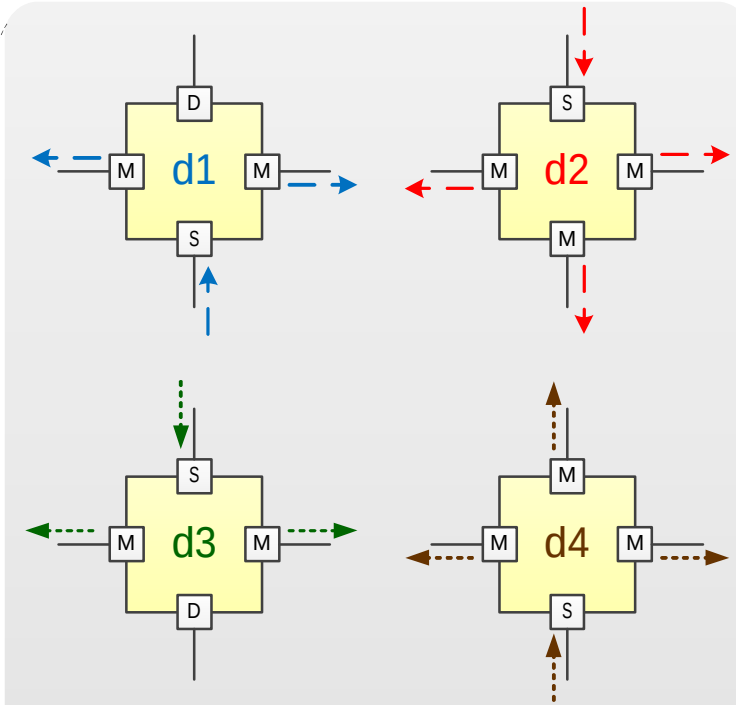

Use domain specific port role settings to represent multiple redundant sync trees

Hot-standy GM must be synchronized with primary GM

One primary GM and one hot-standby GM with four Sync trees in four gPTP domains (d1, d2, d3 and d4)

Use-cases of Redundant WC Synchronization
2. Media + GM Redundancy – Single Failure

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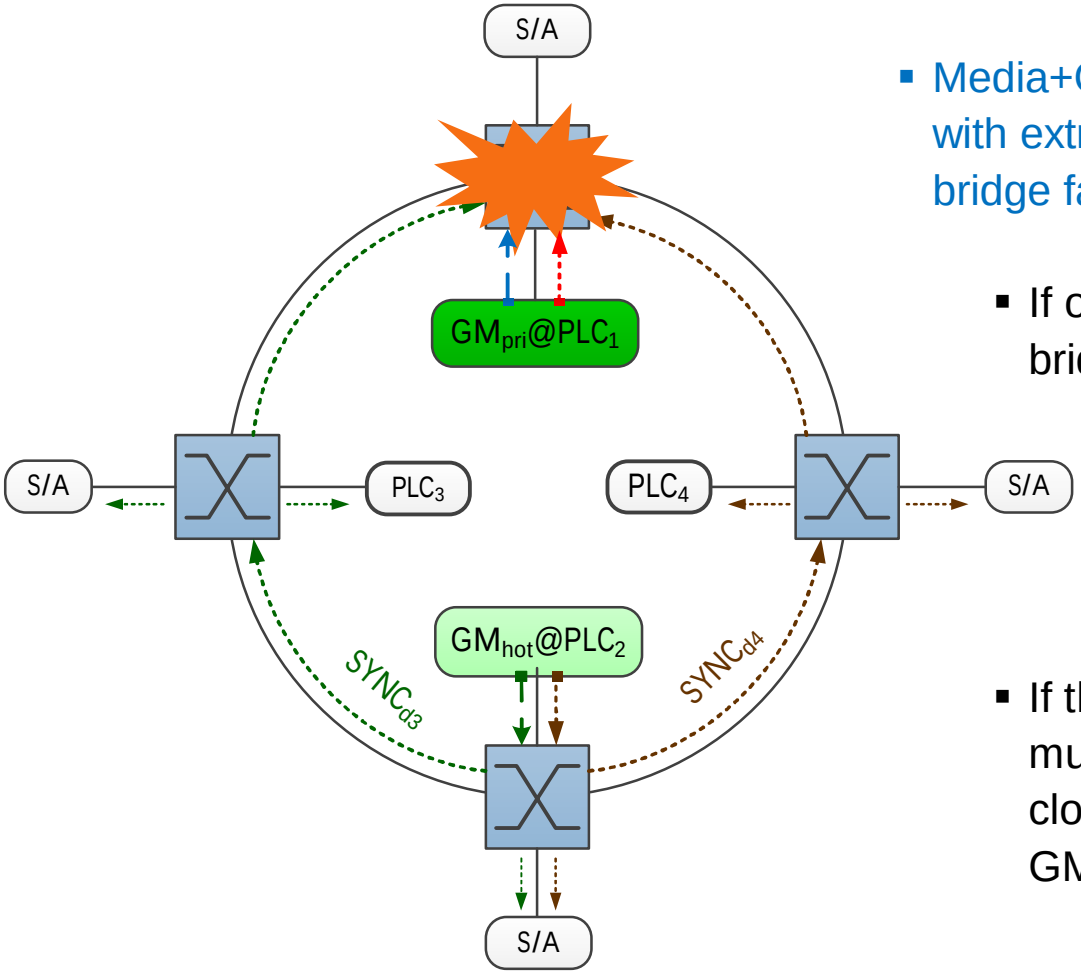

- Media+GM redundancy provides high-availability with extra robustness against single GM or bridge failure
  - If one GM fails (or is disconnected due to bridge failure), the other one is still active
  - If the primary GM fails, the hot-standby GM must keep transmitting timing even when its clock lose synchronization with the primary GM

Single Bridge Failure with Connection to one GM

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Summary

Version 2 gPTP Extensions

- interface to set gPTP port role (master, slave, passive, …) per domain
- interface to set GM role (grandmaster, hot-stand-by, …)
- domain specific forwarding of sync messages on time-aware bridges
- guaranteed short forwarding & residence time for sync messages in time aware systems
  - < 1ms for working clock
  - < 10ms for universal time