The Many Approaches to Resilient Time Distribution

# Network Timing and Network Redundancy

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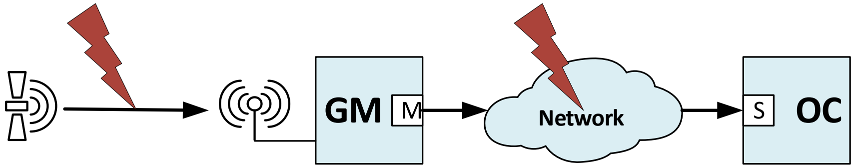
# Reliable/Resilient Time

## What Network Redundancy can do

- Having GNSS resilience and redundant Time-Servers or Grandmasters is important, but bringing the time information through the network to the End-Node is equally important and this requires a network redundancy scheme




- Network redundancy increases the reliability and resiliency within the network; however it will not improve any security aspects!

- We will only look at OSI Layer 2 (L2) network redundancy protocols to give an idea of the concepts

# L2 Network Redundancy Protocols

Commonly used in Automation and Utility Networks

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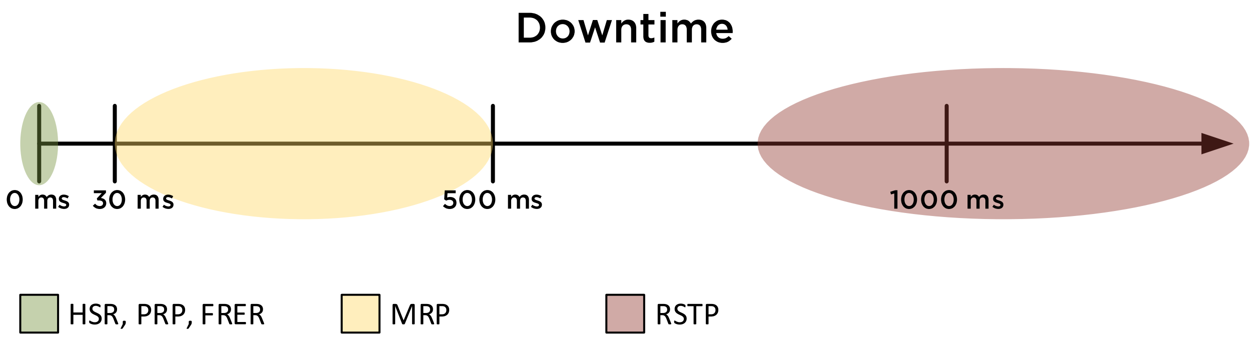
- **Rapid Spanning Tree Protocol: RSTP (IEEE802.1D)**
  - Token based mesh topology which is self reconfigured to a tree topology
- **Media Redundancy Protocol: MRP (IEC62439-2)**
  - Managed token-based ring topology with opening and closing the ring
- **Parallel Redundancy Protocol: PRP (IEC62439-3)**
  - Duplicated network with duplicating frames and duplicate rejection
- **High Availability Seamless Redundancy: HSR (IEC62439-3)**
  - Ring topology with duplicated frames and duplicate rejection
- **Frame Replication and Elimination for Reliability: FRER (IEEE802.1CB)**
  - Any network topology duplicated frames and duplicate rejection

# L2 Network Redundancy Protocols
## Downtime on Data Traffic

- RSTP: ~1s but not guaranteed and deterministic
- MRP: <1s (500ms, 200ms, 30ms, 10ms), deterministic
- PRP & HSR & FRER: 0s, seamless redundancy




Which redundancy protocol shall be used heavily depends on the desired network topology, costs for deployment, acceptable downtime and often industry restrictions/standards!

# L2 Redundancy and Synchronization
## The fundamental problem

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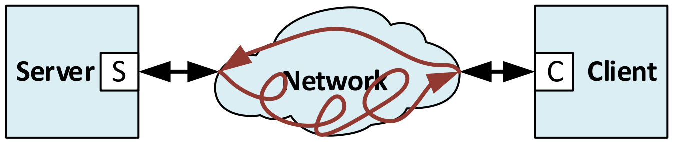
- **L2 Network Redundancy hides the redundancy from applications and higher level protocols**
  - It is not seen that multiple paths exists
  - Paths might change dynamically (maybe also during normal condition, and of course at an error)
- **Network Time Synchronization Protocols (e.g. NTP/PTP) need a fixed path for high accuracy synchronization, they need to know which path a frame took!**
  - Same path for Uplink (NTP Client => Server, PTP Slave => Master) and Downlink (NTP Server => Client, PTP Master => Slave)

# L2 Redundancy and Synchronization

## How to combine it with NTP

- **NTP and RSTP/MRP/HSR/PRP/FRER**
  - Since NTP has no timing support by the network, jitter due to congestion in switches is expected even with local servers which limits the accuracy of NTP (~ms accuracy) and due to often used software timestamping and low refresh rates
  - During a switchover of paths or especially in the case of seamless redundancy the Uplink and Downlink might not be the same
    - In the case of seamless redundancy if both path delays are almost equal, path switches might happen randomly even in non-faulty conditions




Sudden changes in delays or offsets which are larger than the "normal" jitter can be filtered out which basically solves the problem for NTP

# L2 Redundancy and Synchronization

## How to combine it with PTP



- **PTP and Network Redundancy**
  - For PTP also the network infrastructure must be PTP aware
  - PTP is path aware, and when it comes to Hardware Timestamping also requires to know from which port a frame was sent and received (frame ⇔ timestamp correlation)
  - In general, if multiple paths are possible only Peer-To-Peer (P2P) delay measurement shall be used which guarantees that whatever path Sync messages will take the summed delay in the correction field is correct
    - This is also why TSN, Utility and Automation network Profiles only allow the P2P delay mechanism

PTP needs to know about the multiple paths and treat them individually.
Avoid E2E delay mechanisms and 2-Step if you use network redundancy!

# L2 Redundancy and Synchronization

## How to combine it with PTP

- **PTP and Network Redundancy cont.**
  - The BMCA allows dynamic reconfiguration and builds a synchronization tree independent of the network topology used
    - It has timeouts on messages (mainly on Announce messages)
    - The higher the message rate and the lower the timeouts the faster it reconfigures
  - The BCMA shall be used to handle redundant paths
    - With PTP Transparent Clocks (TC) topology changes propagate faster
  - The synchronization might happen over different paths than the normal data

Resynchronization and reconfiguration for PTP happens based on PTP frame timeouts and the BMCA. PTP TCs propagate changes faster than PTP BCs

# L2 Redundancy and Synchronization

## How to combine PTP with RSTP

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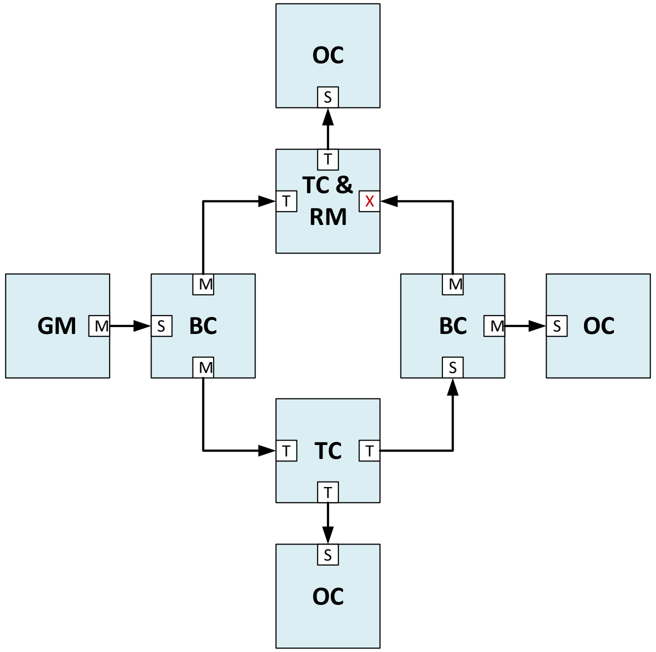
- **PTP and RSTP**
  - In general PTP BCs and TCs send and receive only over RSTP-open ports (except P2P delay)
    - Avoid loops since TCs don’t take part in the BMCA
    - Switchover limited by RSTP plus BMCA in Slaves (TC) and in Switches (BC)
  - PTP BCs may send and receive PTP frames over RSTP-closed ports
    - BMCA handles the synchronization topology which might be better for synchronization purposes than the one chosen by RTSP (PTP is in this case point-to-point), but this requires an All-BC network which might be difficult to control

RSTP can take quite long in larger networks to converge and might cause multiple resync cycles.

# L2 Redundancy and Synchronization
## How to combine PTP with MRP

- **PTP and MRP**
  - The scheme for combining MRP with PTP is the similar to the one for RSTP
    - But only the MRP Ring Manager opens and closes the ring so only this node needs to take special care for handling PTP frames (loop prevention)
  - The switchover time is normally only determined by the BMCA since the MRP recovery time is normally shorter than the Announce message rate and timeout and reconfiguration time of the BMCA

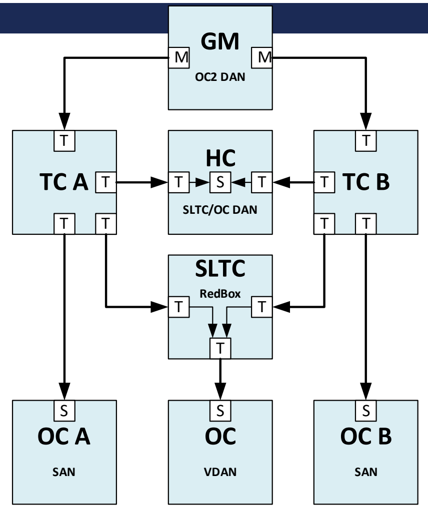


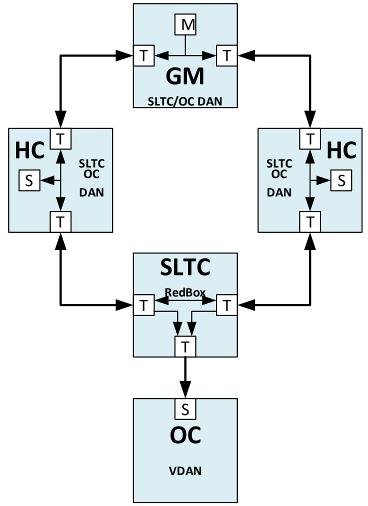

PTP frames only come from one direction, since the ring is always open (either opened by the MRP Ring Manager or because of an error).

# L2 Redundancy and Synchronization

How to combine PTP with PRP/HSR/FRER

- **PTP and HSR/PRP/FRER**
  - Active redundant path, PTP frames are received over multiple paths
  - IEC62439-3 defines how to combine PTP with HSR/PRP (Annex A)
  - Concept of Doubly Attached Ordinary Clock (OC2):
    - 2 x BMCA individually, additional selection of OC
  - Concept of Stateless Transparent Clock (SLTC) :
    - PTP Clock ID - Port ID modification in SLTC as a tiebreaker for the BMCA
    - End-Nodes as Hybrid Clocks (HC = OC + SLTC)

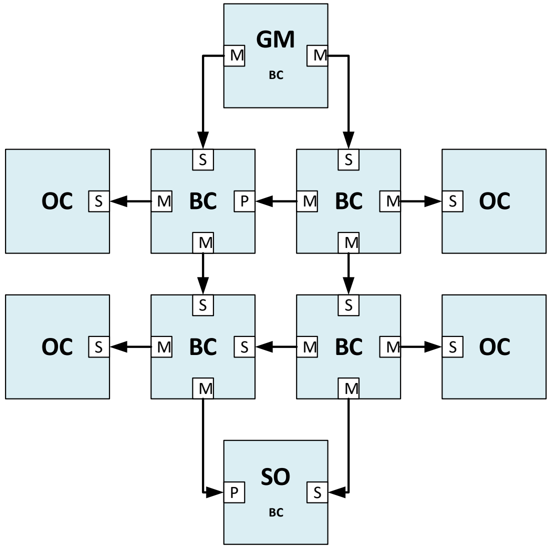


# L2 Redundancy and Synchronization

## How to combine PTP with PRP/HSR/FRER

- **PTP and HSR/PRP/FRER cont.**
  - Application specific criteria might be introduced for selecting a path
    - Extension of BMCA, e.g. delay or correction field (TCs don’t increment hops)
  - Main difference to RSTP/MRP: there is an active standby path during non-error situation
    - Switchover only limited by BMCA
    - BMCA can not only be used for the switchover at an error but also for selecting the best path for synchronization




Normal traffic is handled seamlessly, PTP traffic switches between paths since they need to be treated individually.

# L2 Redundancy and Synchronization

## Effects of PTP switchover

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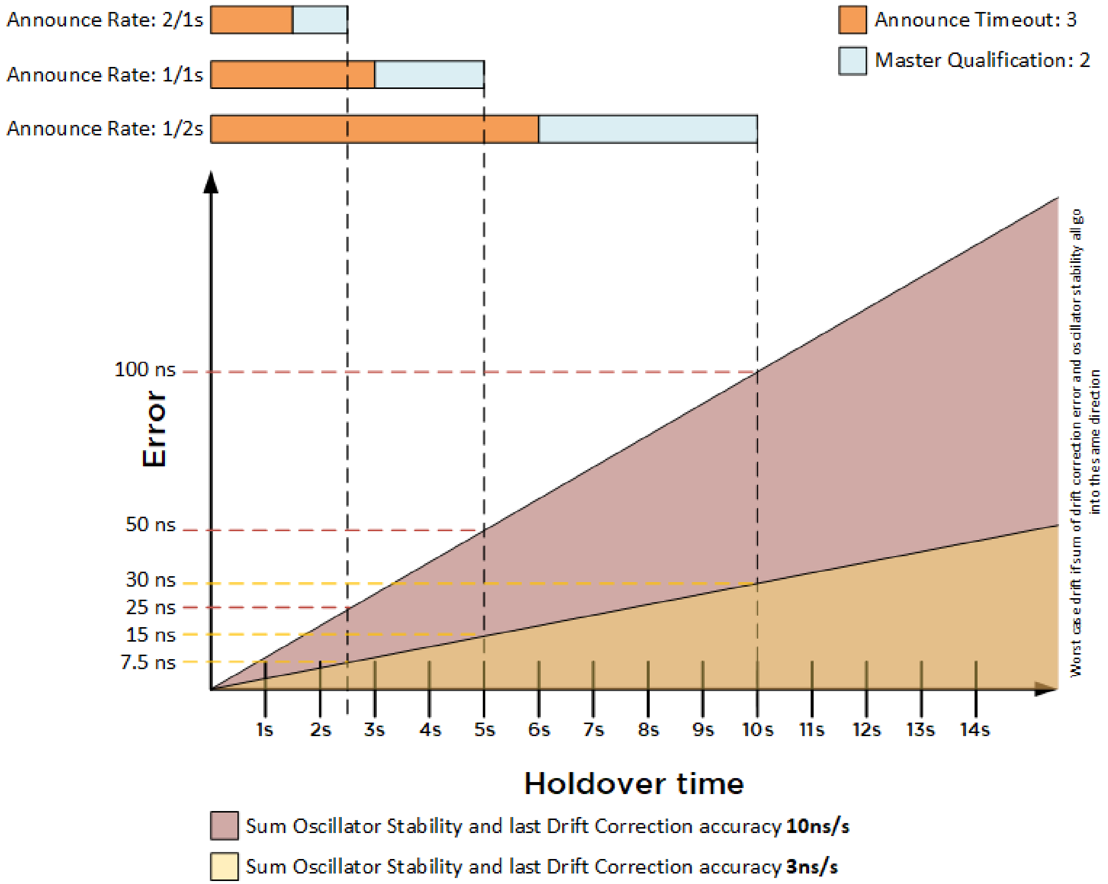
- **As we have seen the BMCA is defining the switchover time**
  - The Announce message rate and Announce timeout define the reaction time for change detections by the BMCA => higher rate and/or shorter timeout => faster switchover
- **Until the BMCA selects the alternative path the Slave is in free-running mode**
  - Depending on last measured frequency correction and oscillator stability

The required message rates and timeouts depend on the acceptable max error and the stability of the Slave/Boundary clock. Since message rates and the acceptable max error are often fixed (or a narrow range) by PTP Profiles, the only parameter to change is the stability of the oscillator.

# L2 Redundancy and Synchronization

## Expected Error Ranges

- **Error in relationship of Announce rates and Oscillator stability**




- With “cheap” oscillators the error introduced by the switchover is 25ns – 100ns
- With a bit more expensive oscillators the error can already be decreased by a factor of 3 (or even more)

# Summary

- **Combining Network Redundancy with NTP/PTP is straight forward**
  - Knowing that Synchronization Protocols require to handle paths individually and L2 Network Redundancy Protocols hide this from higher layers
- **Error introduced by switchover is in a decent range (<=100ns)**
  - Error range can be tuned by message rates and or oscillator stability
- **Downtime introduced by L2 Network Redundancy Protocols has no significant effect on the Synchronization recovery time!**
  - Message rates for NTP/PTP are in many cases lower than the range of the downtime of the Network Redundancy Protocols. Only at high Announce rates e.g. 128/s the L2 switchover times kick in

# Summary

- For PTP use PTP Transparent Clocks (TC) and the Peer-To-Peer (P2P) delay mechanism to allow for fast and deterministic switchover and persistent propagation delay compensation
- For NTP filter out measurements of sudden changes of the measured roundtrip delay (to makes sure no transient measurements are used for correction)
- NTP and PTP combined with HSR and PRP is field proven: IEC61850 choose these mechanisms for time synchronization and redundancy

**Not only concentrate on GNSS and Time Server resilience but also on your network resilience!**

# Thank you!

See Network Timing and Network Redundancy live at our booth!!!

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# NetTimeLogic GmbH

## Who we are

- Founded in 2015
- Based in Zürich, Switzerland

swiss
made

- Modular FPGA only implementations of synchronization, network redundancy and TSN IP cores and everything FPGA related
  - FPGA vendor independent
- Modular Hardware Platform
- Services, Consulting, Training