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Synchronization in the power grid with IEEE1588

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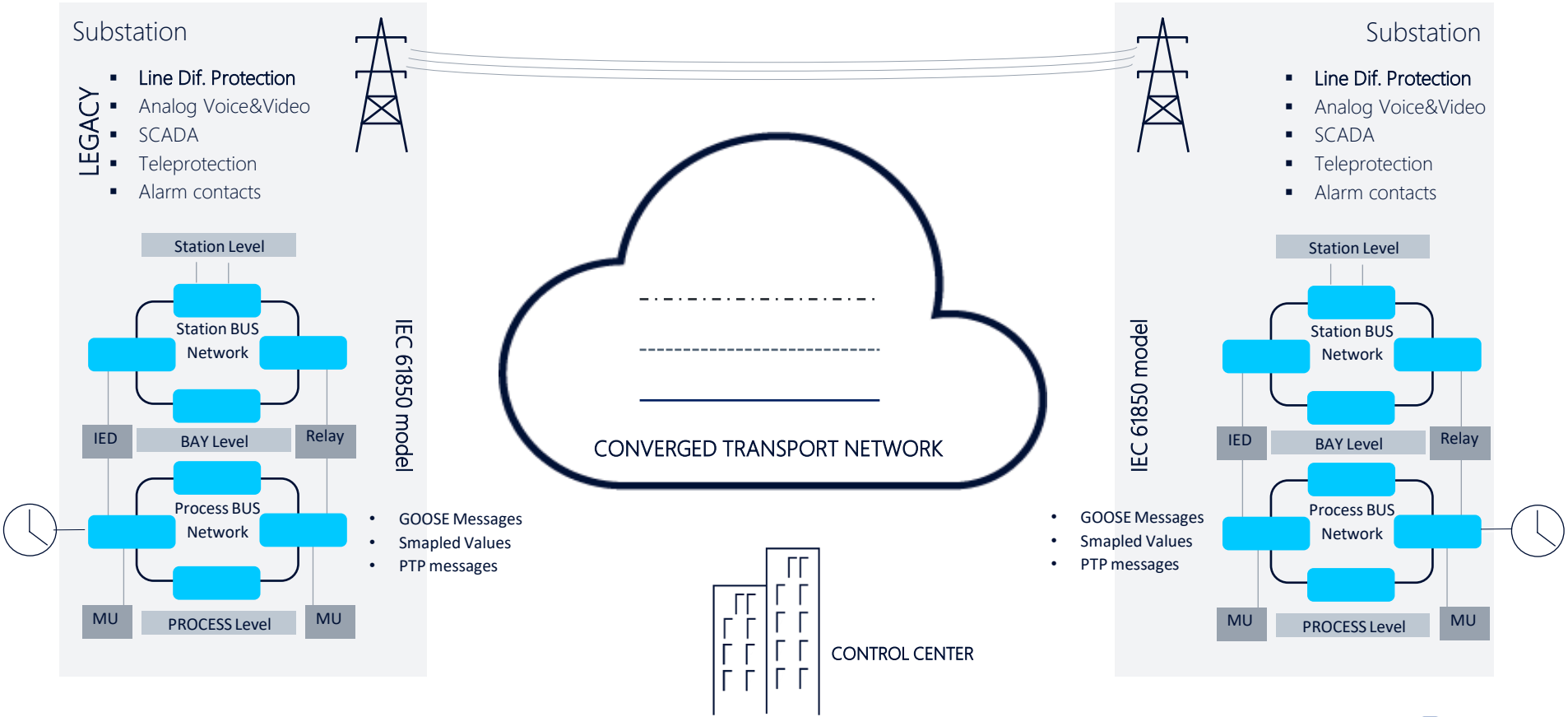
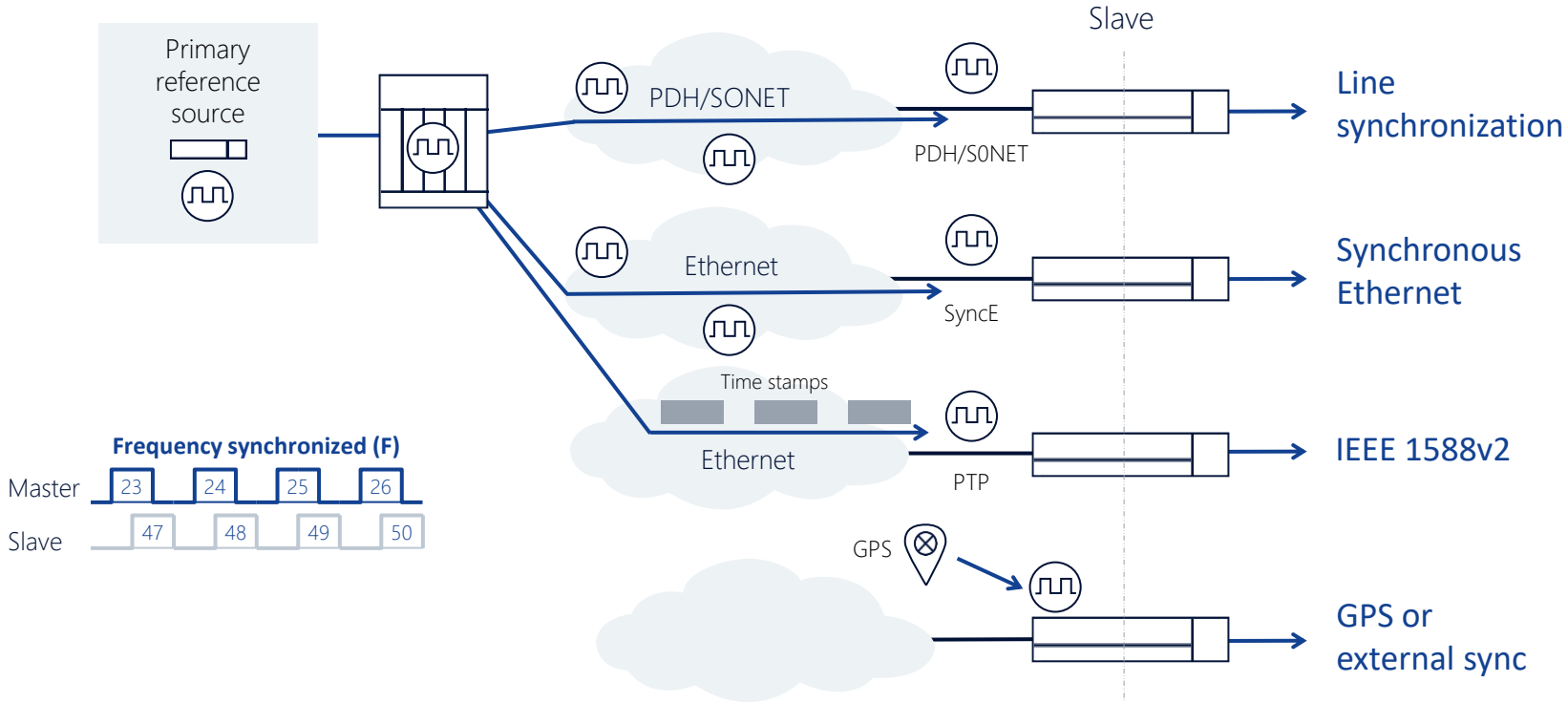
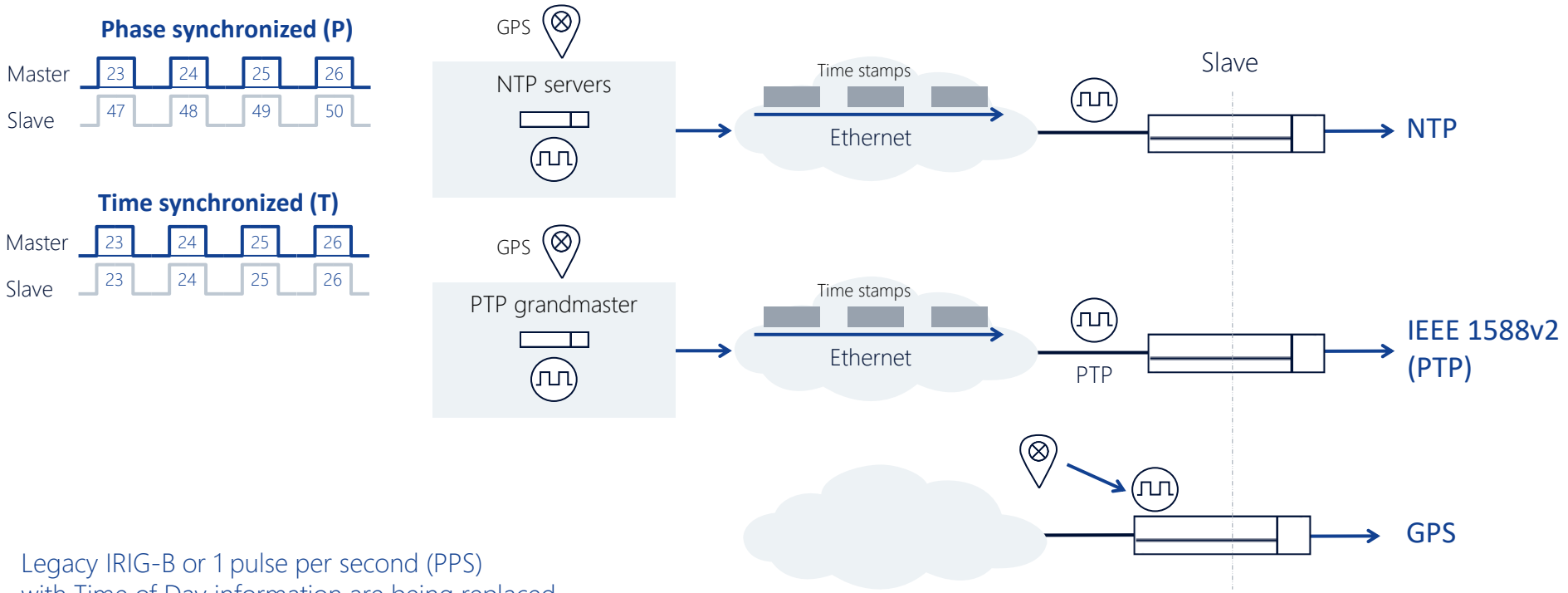
Synchronization requirement for mission critical applications



Sync options for **frequency** clock signal across the packet network



Sync options for **time** clock signal across the packet network



Legacy IRIG-B or 1 pulse per second (PPS)
with Time of Day information are being replaced

Digital substations need time sync

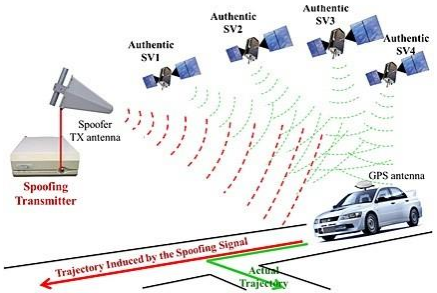
Application	Time accuracy requirements	SNTP	GNSS/GPS & PTP
Event stamping	10 ms	√	√
Zero-crossing & synchrocheck	1 ms	√	√
Digital fault recording	Better than 1 ms		√
Line Differential Relays	10 µs to 20 µs		√
Faul Location	1 µs to 3 µs		√
Wide Are Protection	1 µs		√
Synchrometrology (Synchrophasor)	Better than 1 µs		√
Anti-islanding	Better than 1 µs		√
Wide Area Power Oscillation Dumping	Better than 1 µs		√
Communication Events			
IEC61850 GOOSE	100 µs to 1 ms		√
MU/IEC61850 sampled values	1 µs		√

NIST report: Timing Challenges in the Smart Grid
NASPI report: Time Synchronization in the Electric Power System

GNSS vulnerabilities

Mechanical, Electronic

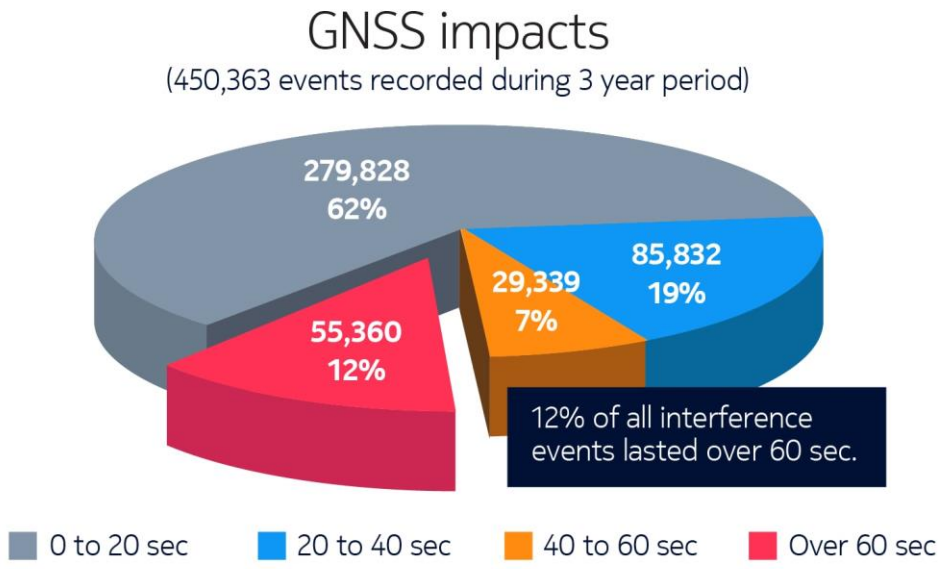
Spoofing



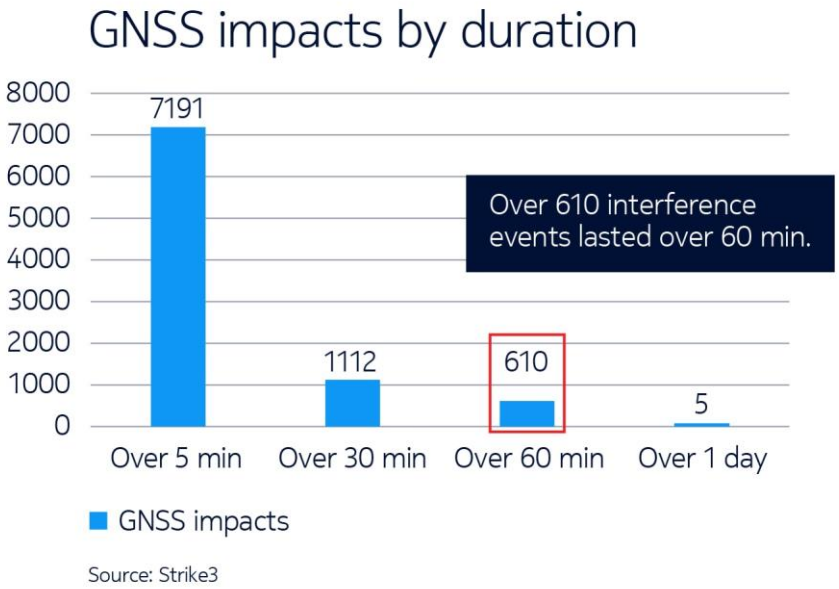
Environmental

Jamming

GNSS reliability



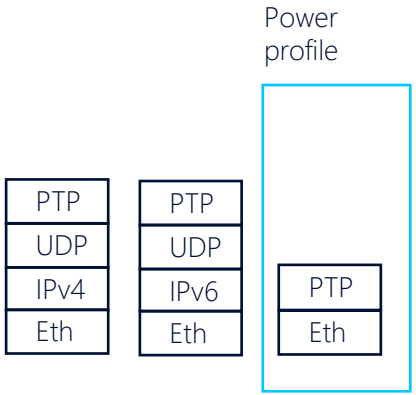
Source: Strike3



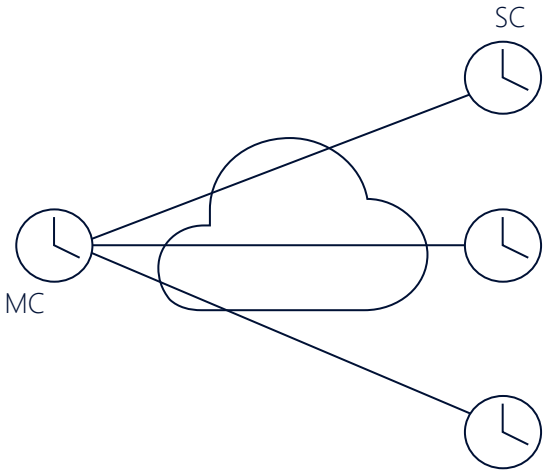
Source: Strike3

IEEE 1588v2

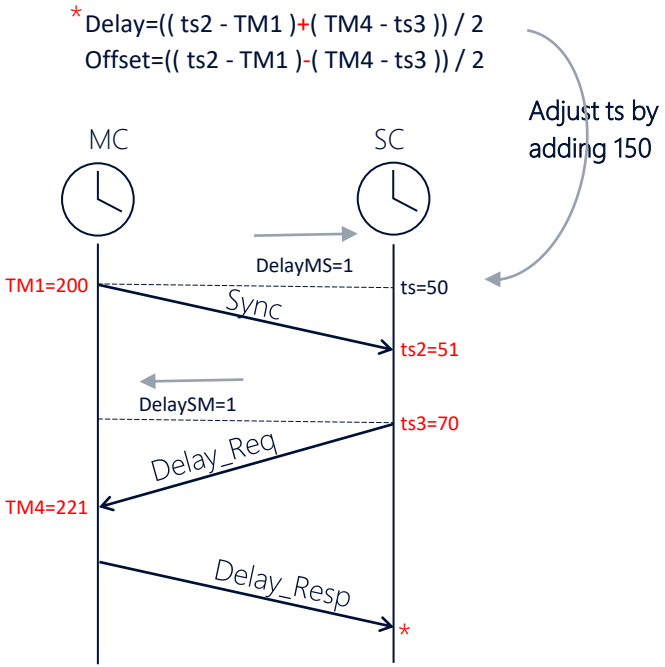
Basic aspects of Packet Timing Protocol (PTP)



1588 can be IP- or Ethernet-based



Peering relationship between grand master clock (MC) to slave clock (SC)



The peers exchange timestamp info and measure delay

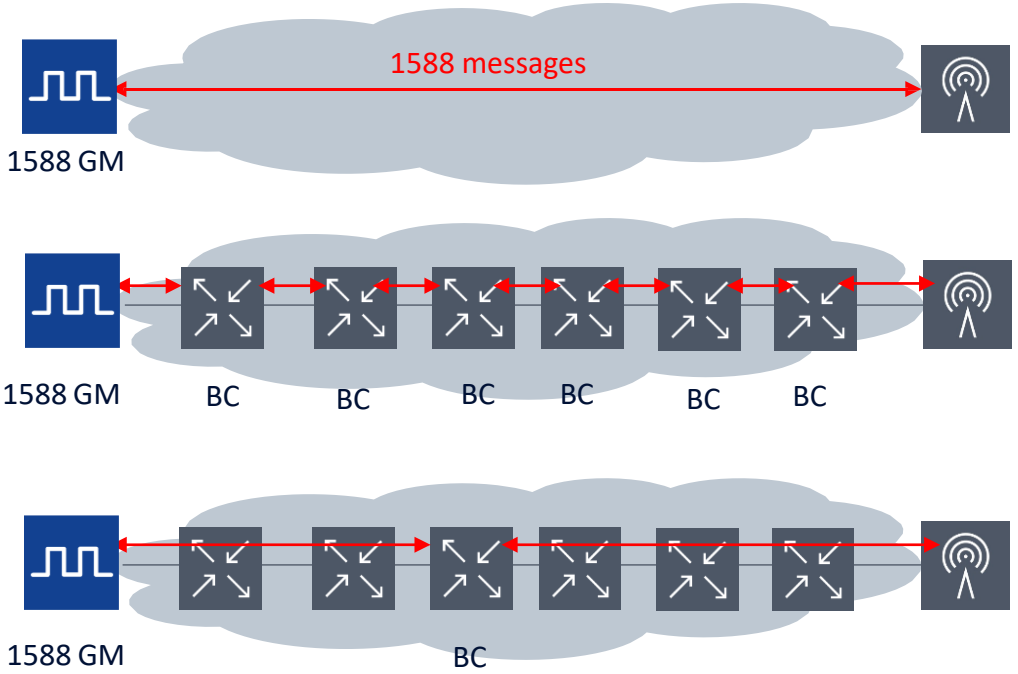
Telecom profiles

Frequency Sync with 1588 (G.8265.1)

Time Sync

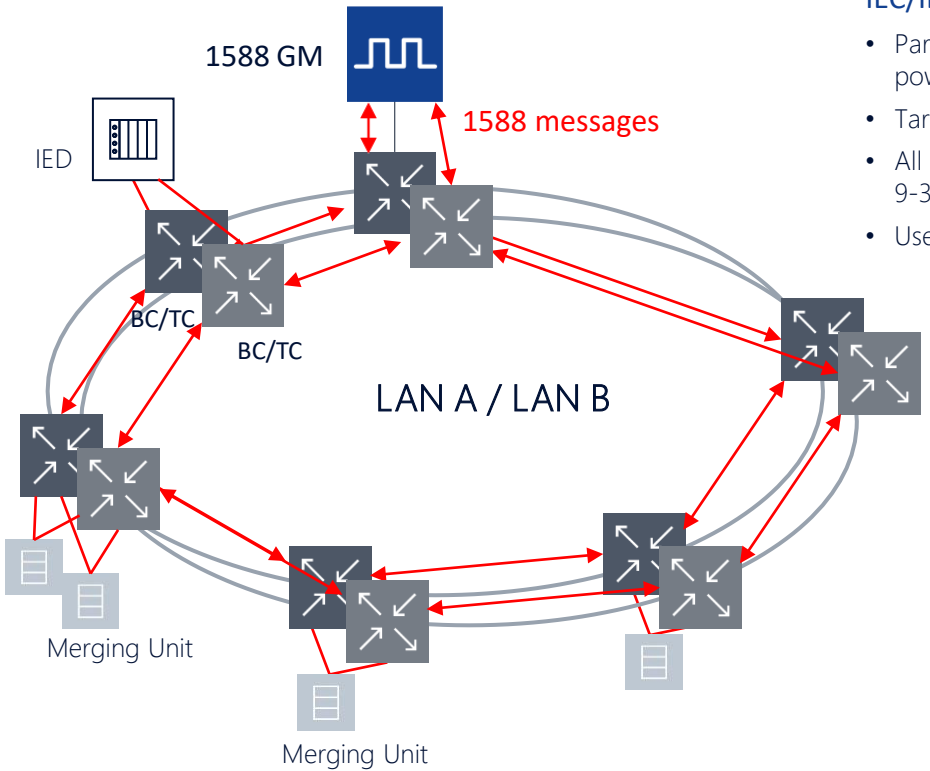
Full on-path support model (FTS – G.8275.1)

Partial on-path support model (PTS – G.8275.2)



Profile	Standards encap type	Freq recovery	Time recovery
1588 default (2008)	IP or Ethernet	Yes	Yes
G.8265.1 (2010)	IP	Yes	No
G.8275.1 (2014)	Eth	No	Yes
G.8275.2 (2016)	IP	Yes	Yes

Power profiles



IEC/IEEE 61850-9-3 (2016)

- Part 9-3: Precision time protocol profile for power utility automation (2016-05)
- Target is 1 µs accuracy for network time
- All network elements must comply to 61850-9-3
- Uses peer delay mechanism

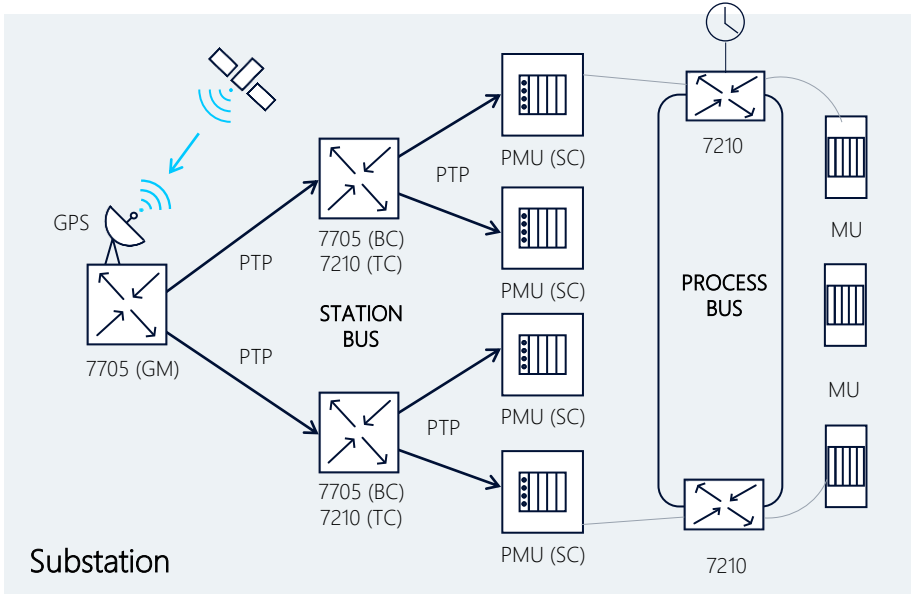
IEEE C37.238-2017

- Extension of IEC/IEEE 61850-9-3, to provide additional functionality
- Includes a mandatory TLV (total time inaccuracy) and an optional TLV (alternate time offset)

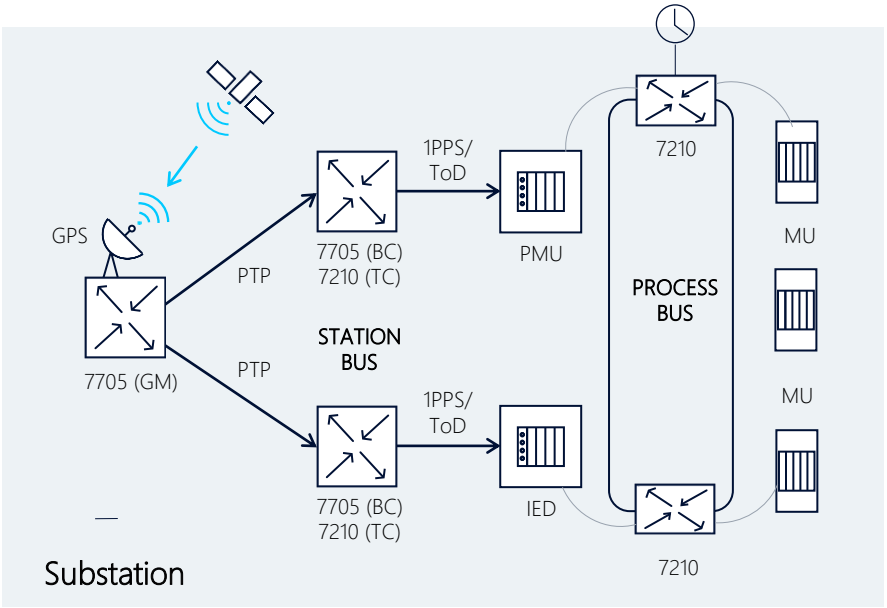
Profile	Standard encap type	Frequncy Recovery	Time recovery	SyncE assist option
IEC/IEEE 61850-9-3 (2016)	Ethernet	Yes	Yes	Yes
C37.238 (2017)	Ethernet	Yes	Yes	Yes

7705 as GM and BC for power profile network

Support for both IEC/IEEE 61850-9-3 and C37.238-2017



Optional SyncE

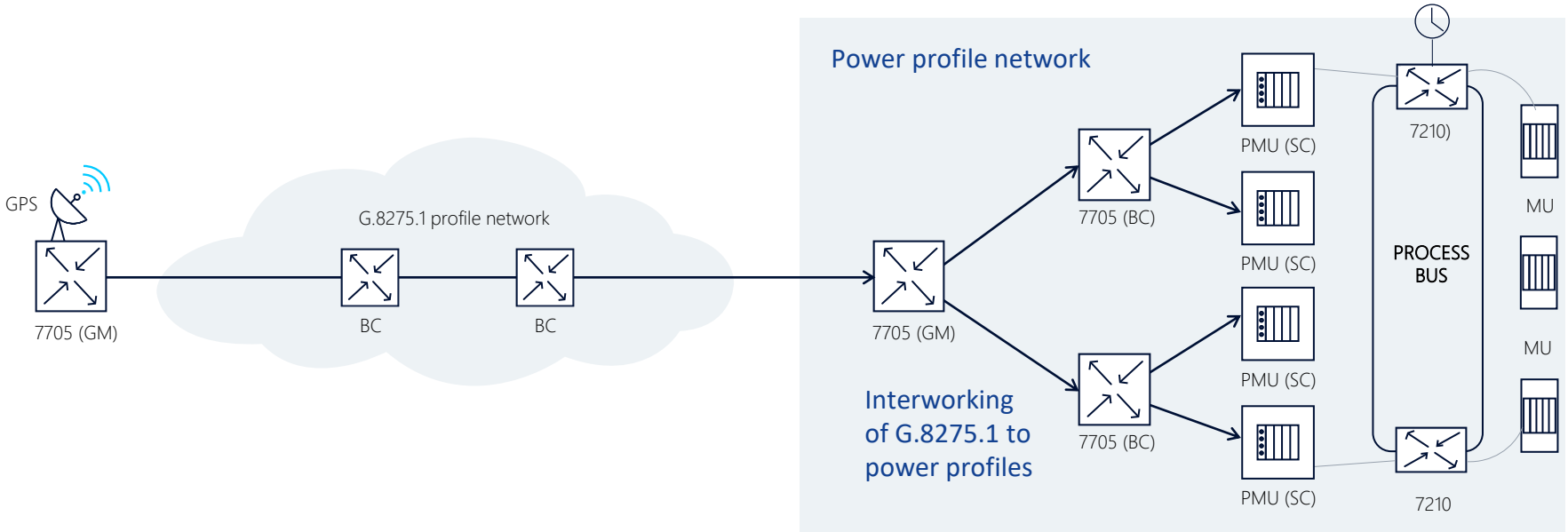


Optional SyncE

Inter-site sync distribution with profile interworking

Extend existing G.8275.1 PTP network to interwork with power profile

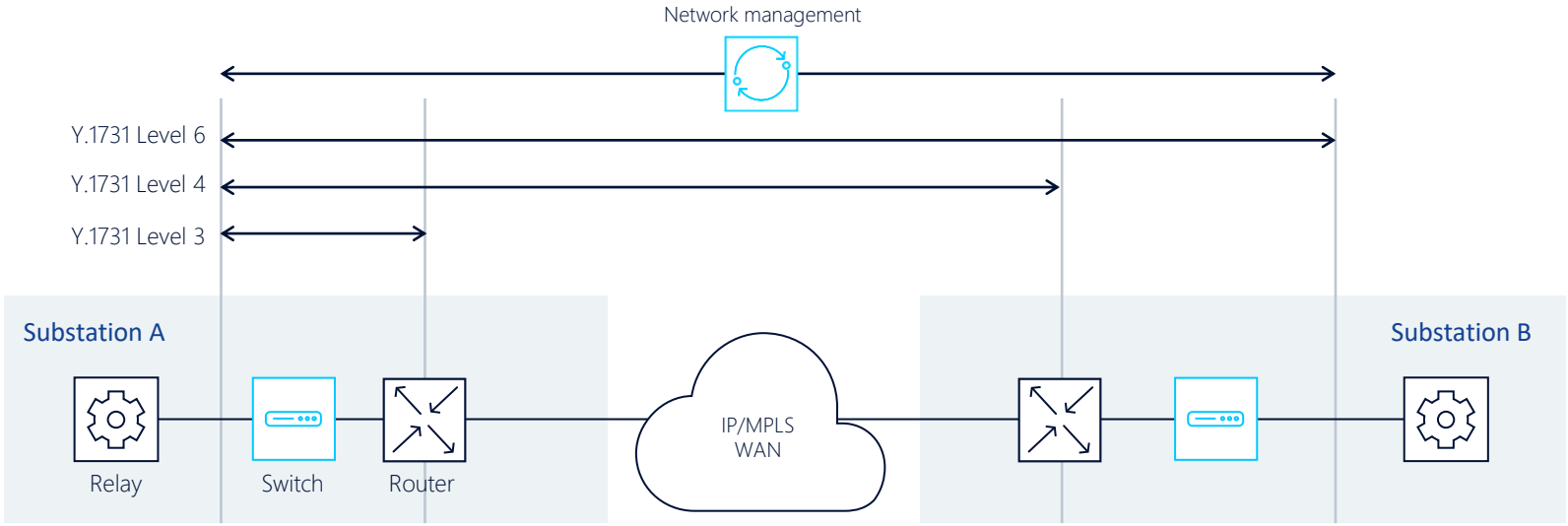
7705 supports interworking of PTP from G.8275.1 to IEC/IEEE 61850-9-3 and C37.238-2017



*New in 2021

Attaining service assurance in a multi-domain network

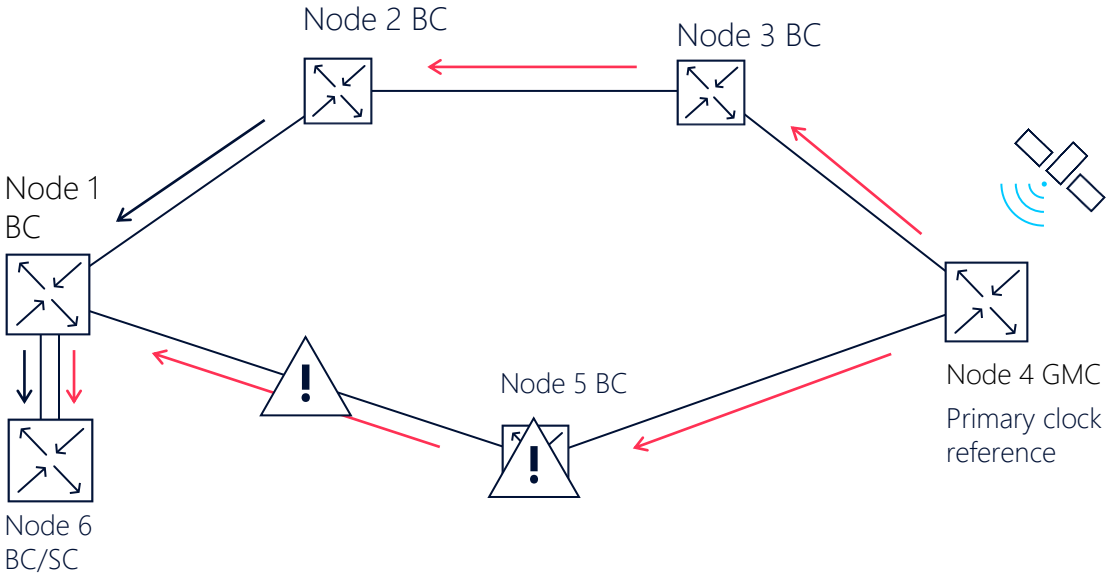
Taking advantage of the capability of multi-level Ethernet OAM



ITU-T Y.1731 – Ethernet OAM standard (ex, 1-way delay)
OAM – operations, administration & maintenance

Attaining high sync resiliency

Network redundancy & BMCA are key

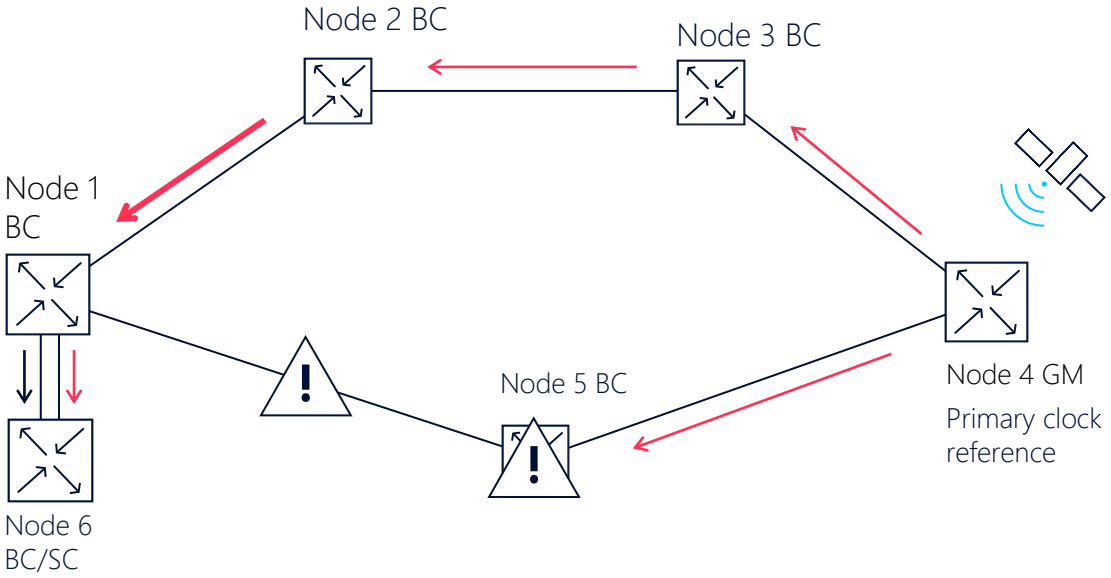


Network redundancy protection

- Dual-homing/ ring architecture

Attaining high sync resiliency

Network redundancy & BMCA are key



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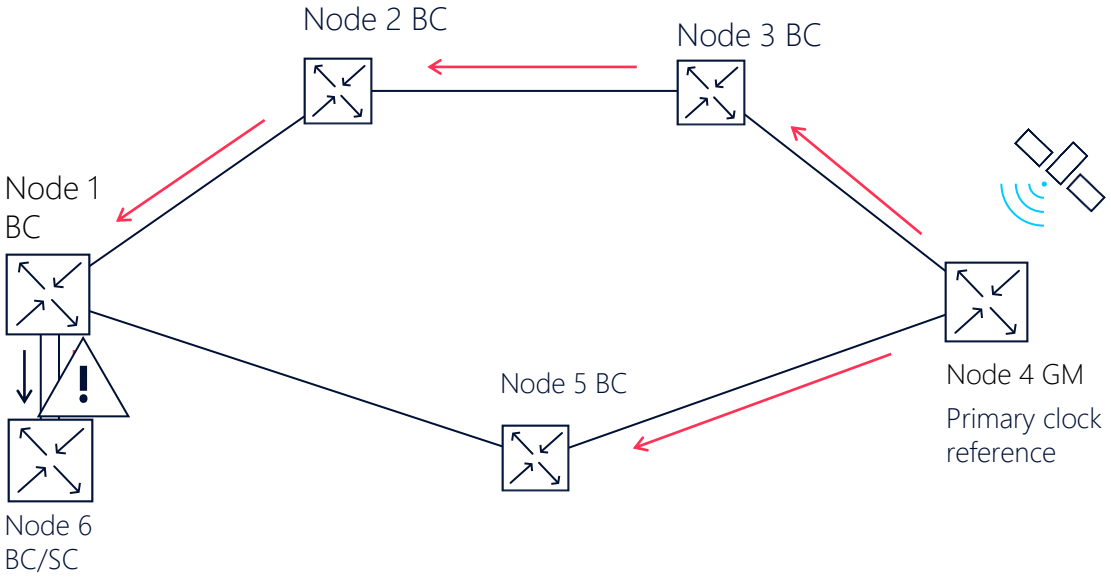

Network redundancy protection

- Dual-homing/ ring architecture
- Redundant link

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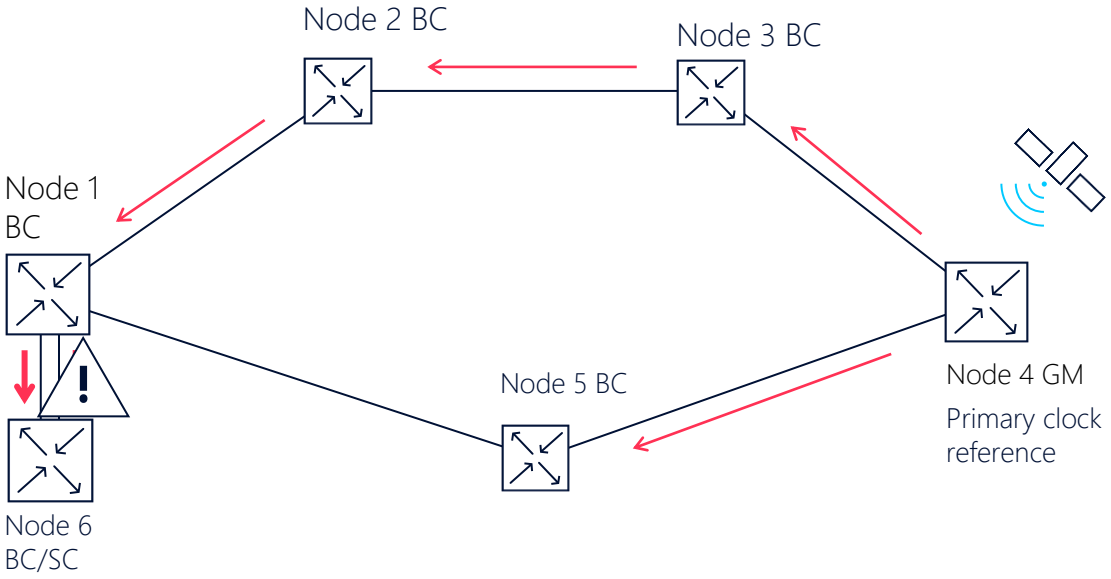

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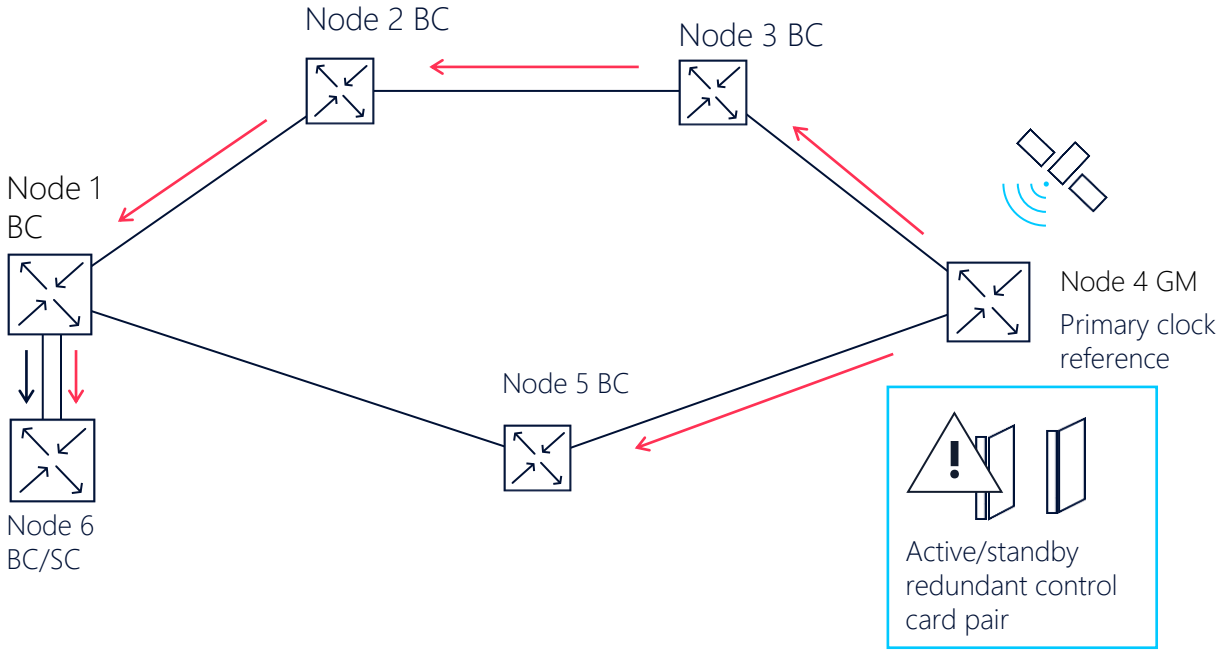

No impact
on sync flows

Network redundancy protection

- Dual-homing/ ring architecture
- Redundant link

Nodal redundancy protection

- Control card protection

Attaining high sync resiliency

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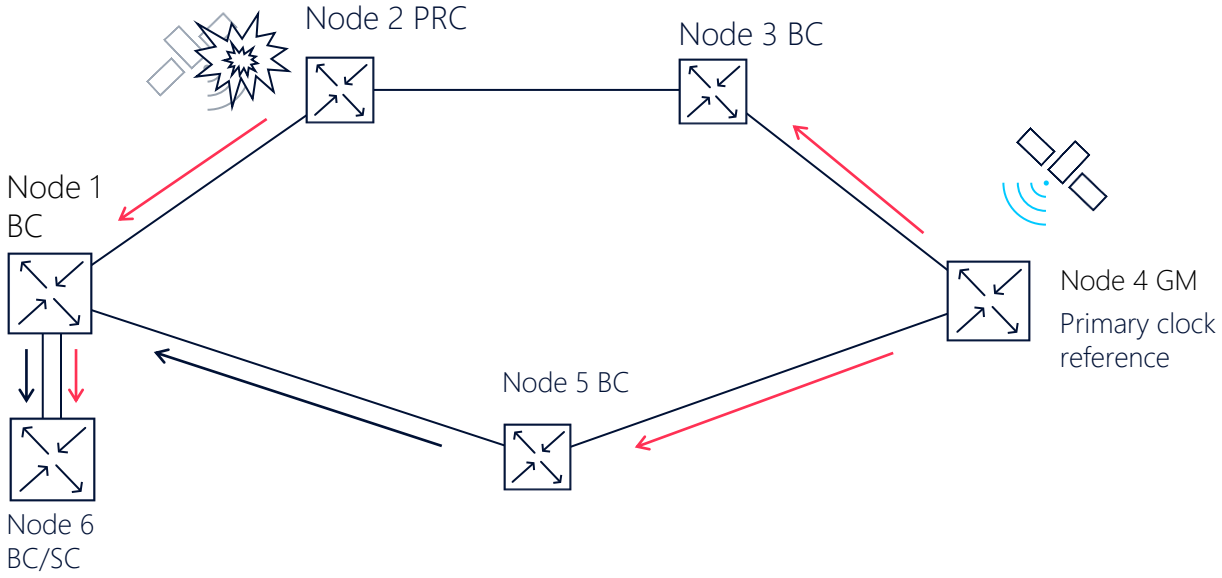

Network redundancy protection

- Dual-homing/ ring architecture
- Redundant link

Nodal redundancy protection

- Control card protection

Primacy clock reference redundancy protection

- GPS signal integrity
- GM clock

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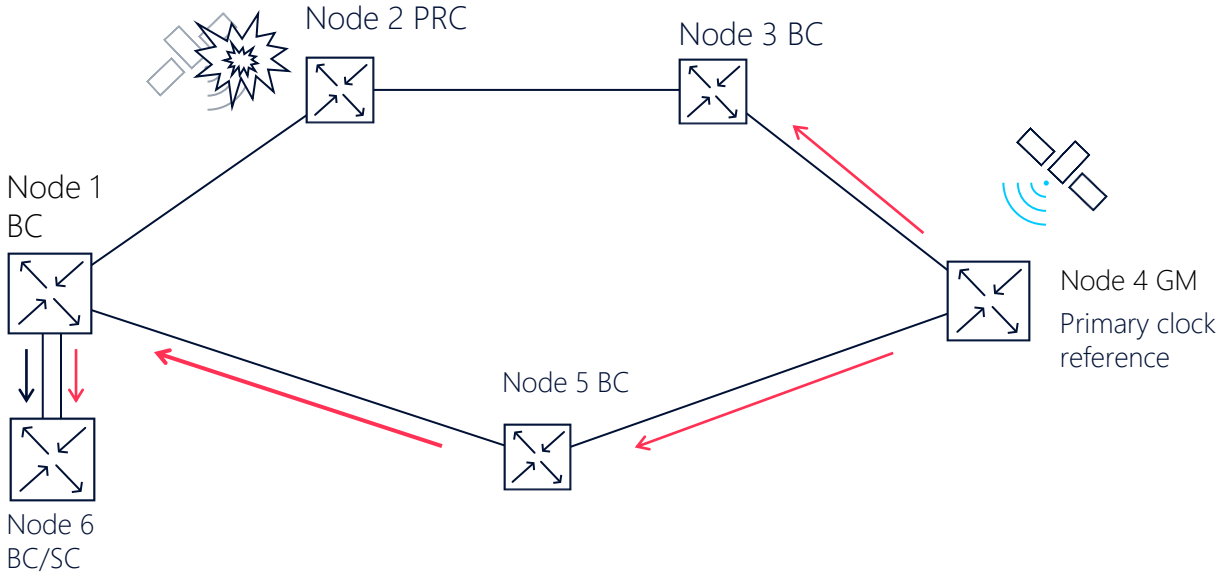
Attaining high sync resiliency

Network redundancy & BMCA are key



Network redundancy protection

- Dual-homing/ ring architecture
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Primacy clock reference redundancy protection

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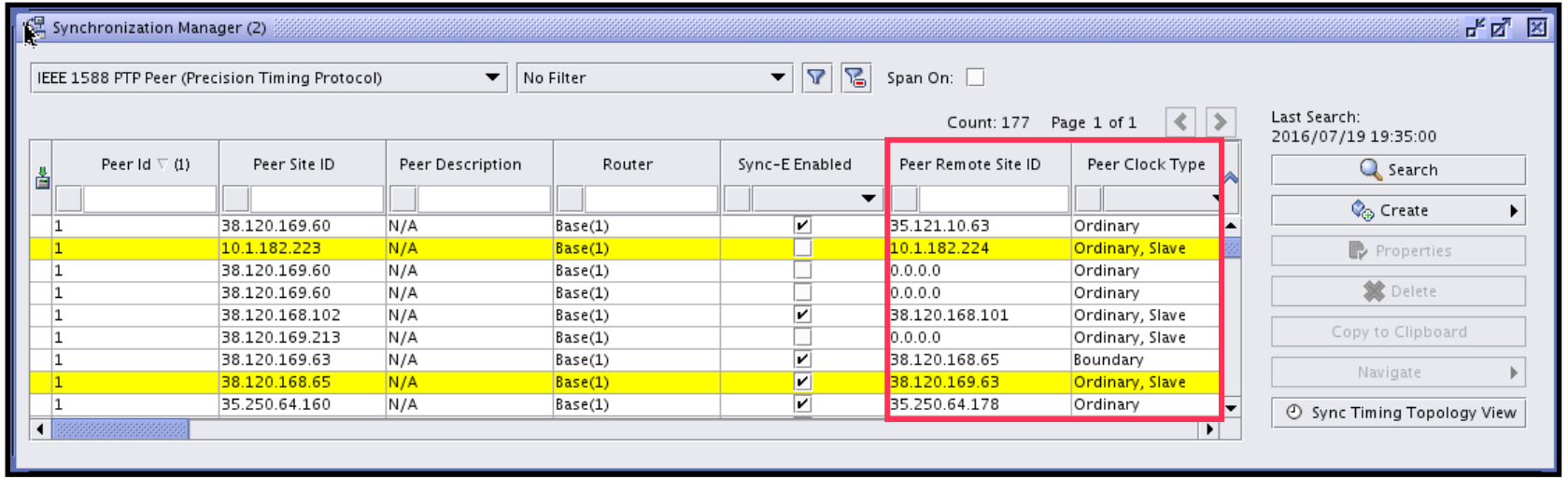
A novel approach is needed

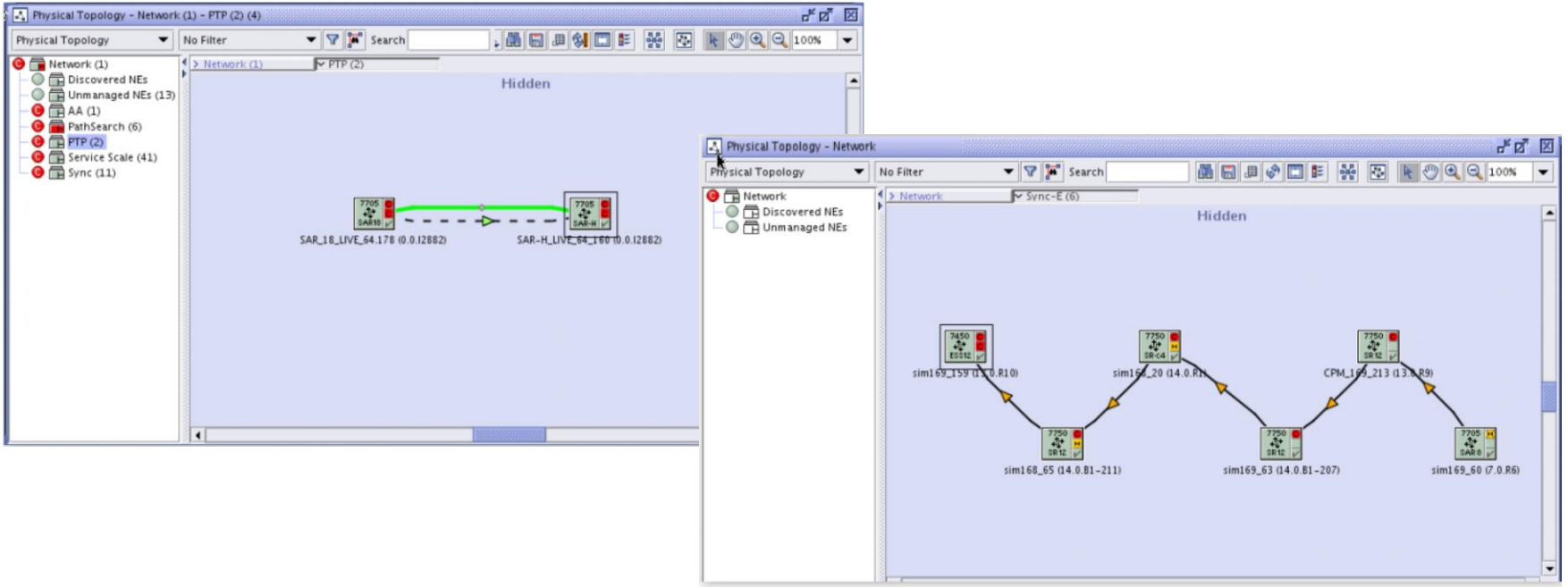
NSP managing the sync network as a network



Peer Id (1)	Peer Site ID	Peer Description	Router	Sync-E Enabled	Peer Remote Site ID	Peer Clock Type
1	38.120.169.60	N/A	Base(1)	✔	35.121.10.63	Ordinary
1	10.1.182.223	N/A	Base(1)		10.1.182.224	Ordinary, Slave
1	38.120.169.60	N/A	Base(1)		0.0.0.0	Ordinary
1	38.120.169.60	N/A	Base(1)		0.0.0.0	Ordinary
1	38.120.168.102	N/A	Base(1)	✔	38.120.168.101	Ordinary, Slave
1	38.120.169.213	N/A	Base(1)		0.0.0.0	Ordinary, Slave
1	38.120.169.63	N/A	Base(1)	✔	38.120.168.65	Boundary
1	38.120.168.65	N/A	Base(1)	✔	38.120.169.63	Ordinary, Slave
1	35.250.64.160	N/A	Base(1)	✔	35.250.64.178	Ordinary

Sync management with NSP

1588 topology and flow in display



Session Recap

1. Clock Synchronization Requirements for DSS is essential for the successful operation of a DSS
   - Both Frequency and Time
   - Performance needed by end devices
   - Network topology
   - Existing equipment limitations
2. There is a wide range of Clock synchronization techniques; SyncE,1 PPS, IRIG, and PTP,….
   - To meet the high accuracy requirements for an IEC 61850-based DSS, PTP is the best method for time synchronization.
   - Use IEEE1588v2 for time and/or frequency with the appropriate profile
   - Must match with profile supported by end devices
   - Make sure performance budget across the network can be met based on each clock's specifications
3. A robust and engineered network is critical for reliable Clock Synchronization in DSS.

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