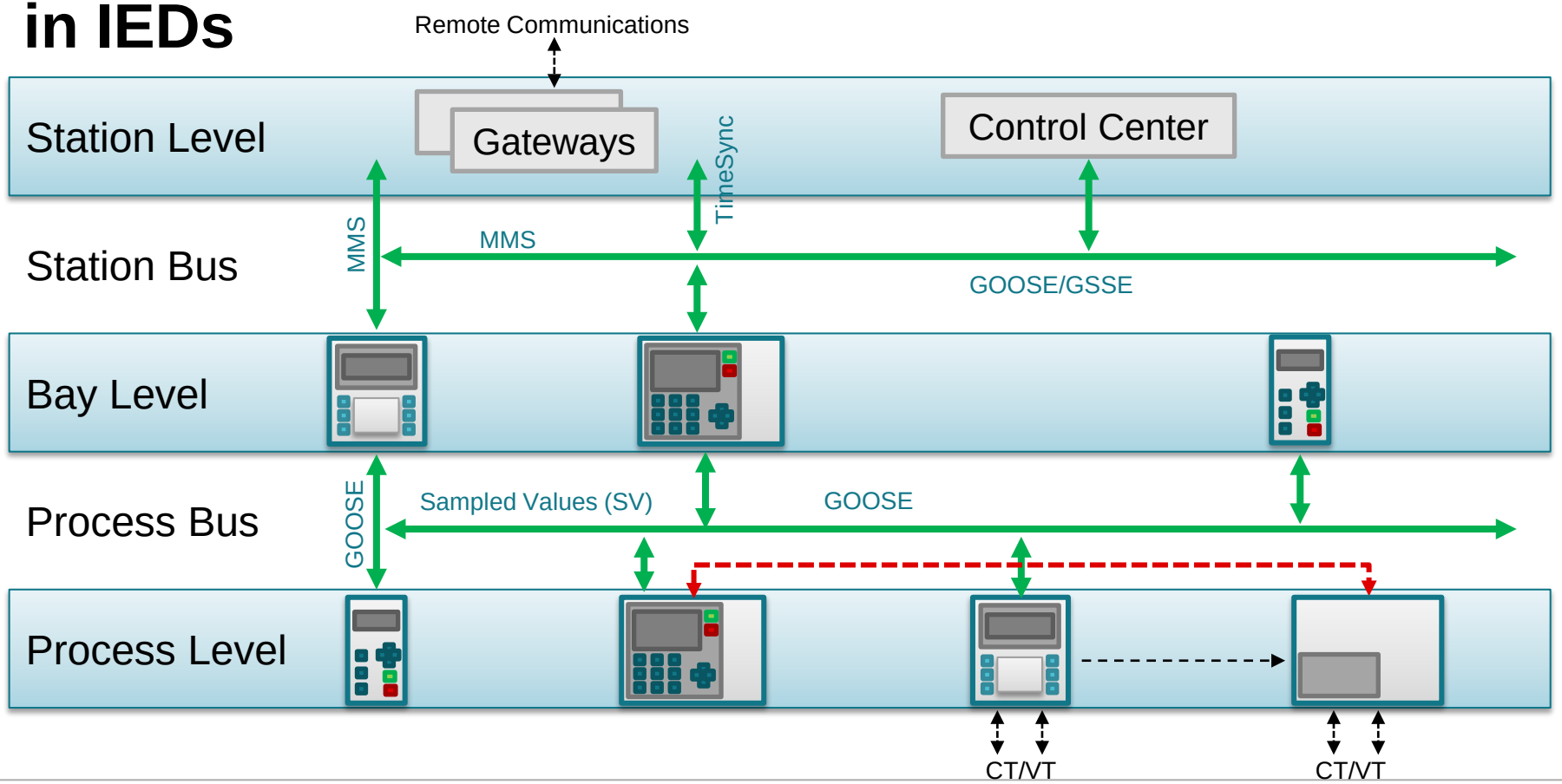
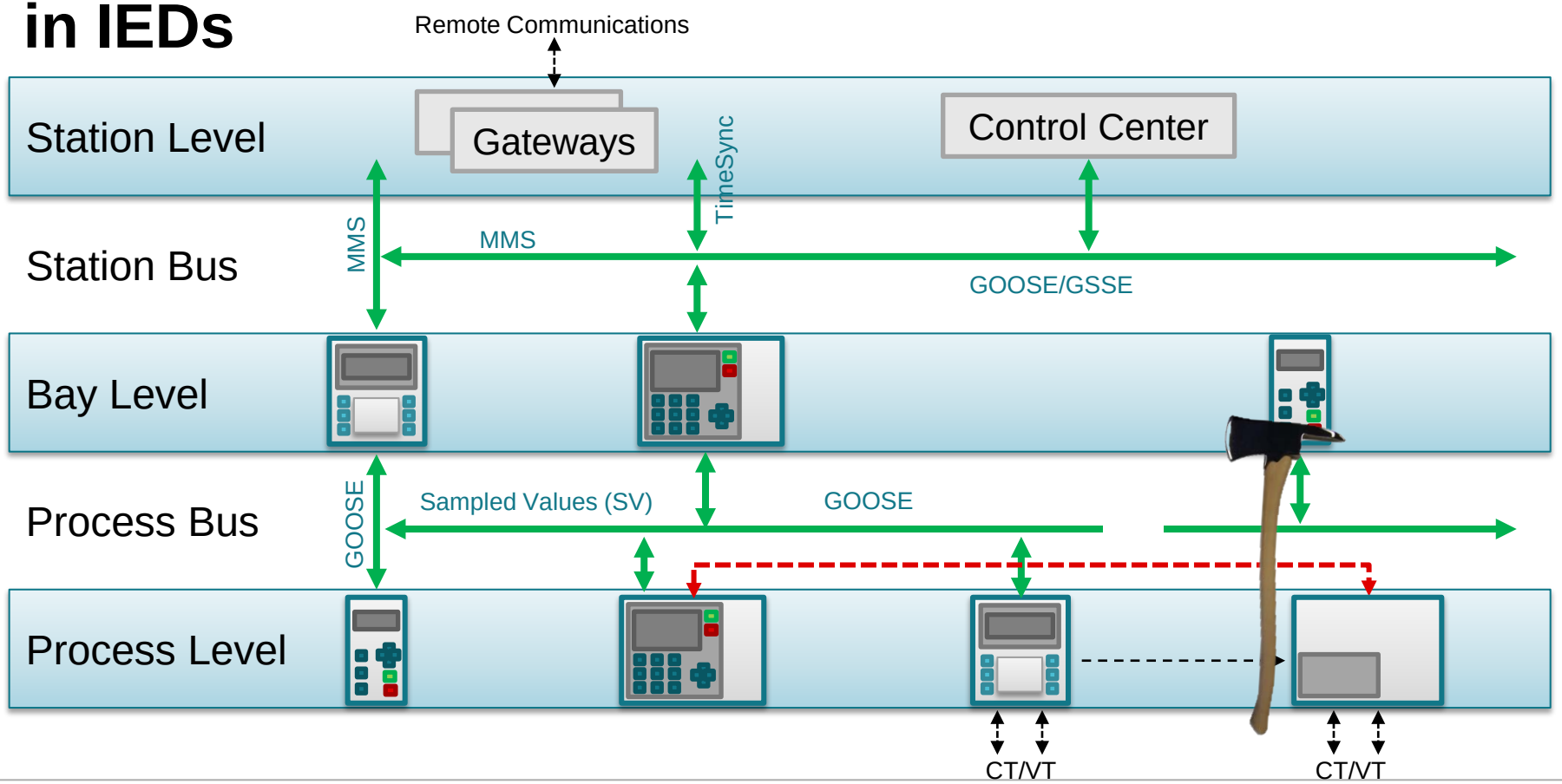
HSR and PRP Redundancy on RT Linux

Part 2: Redundancy Overview

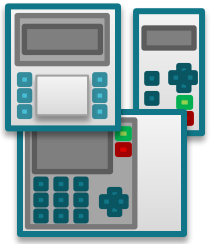
Substation Automation System IEC61850 enabled in IEDs

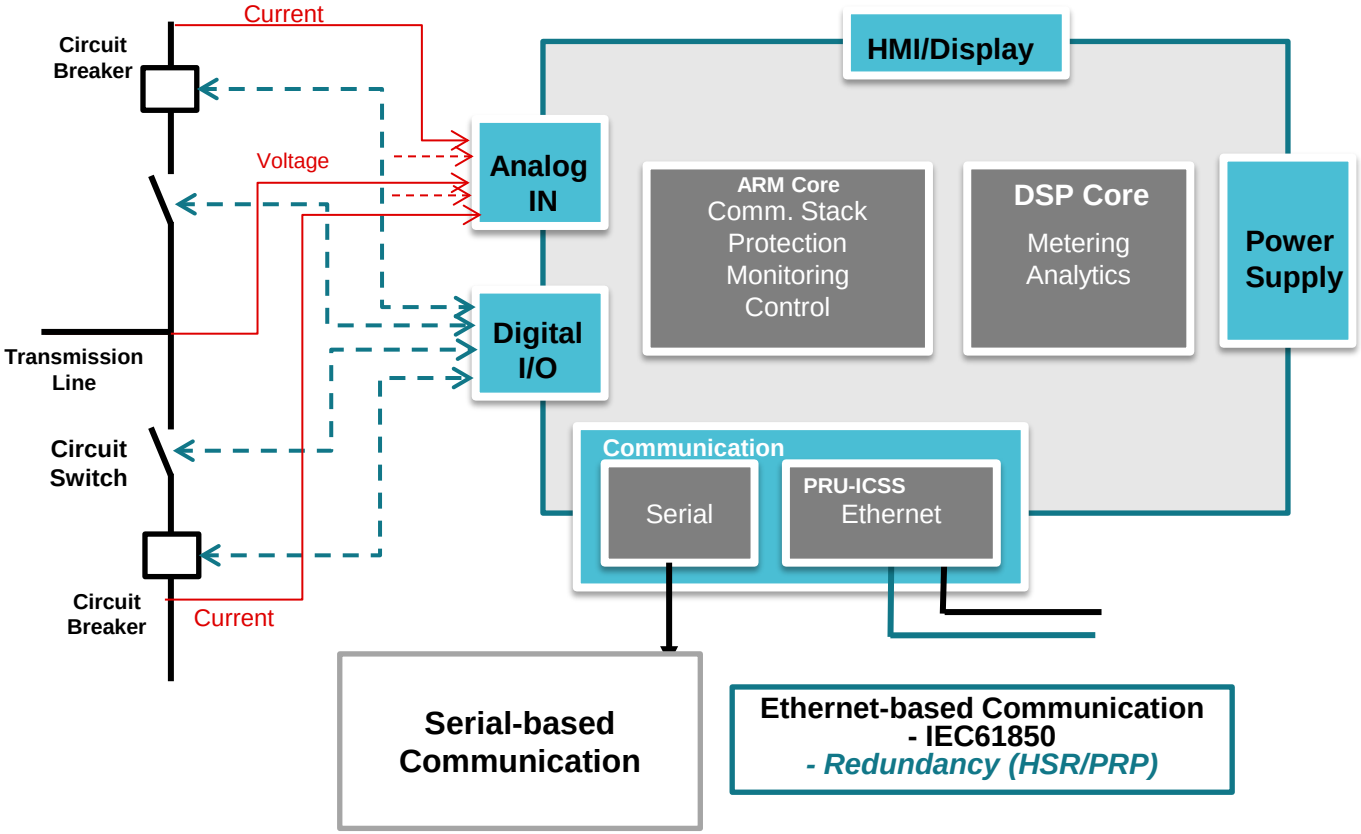


Substation Automation System IEC61850 enabled in IEDs

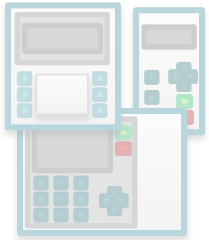


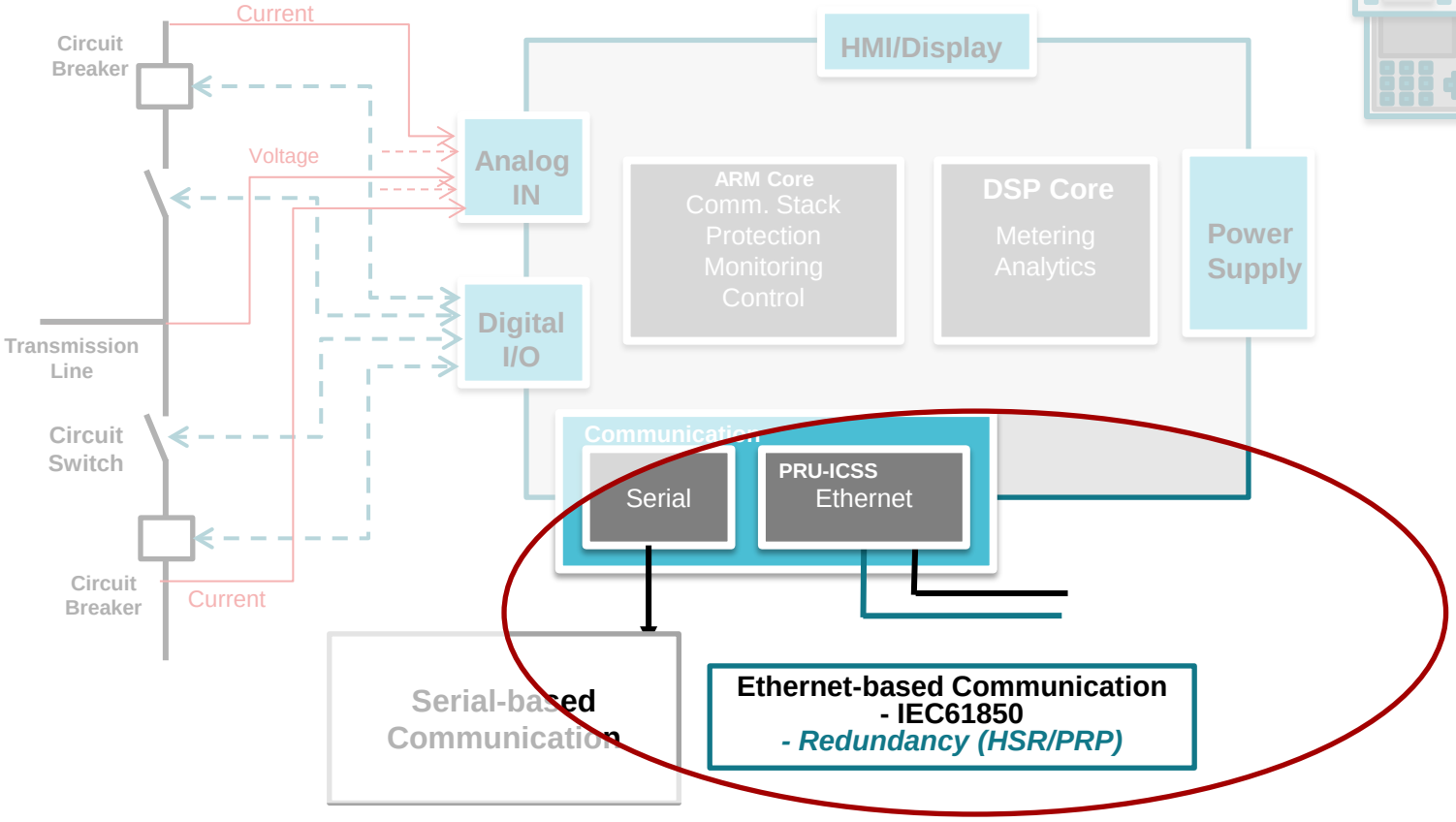
IED block diagram with redundancy



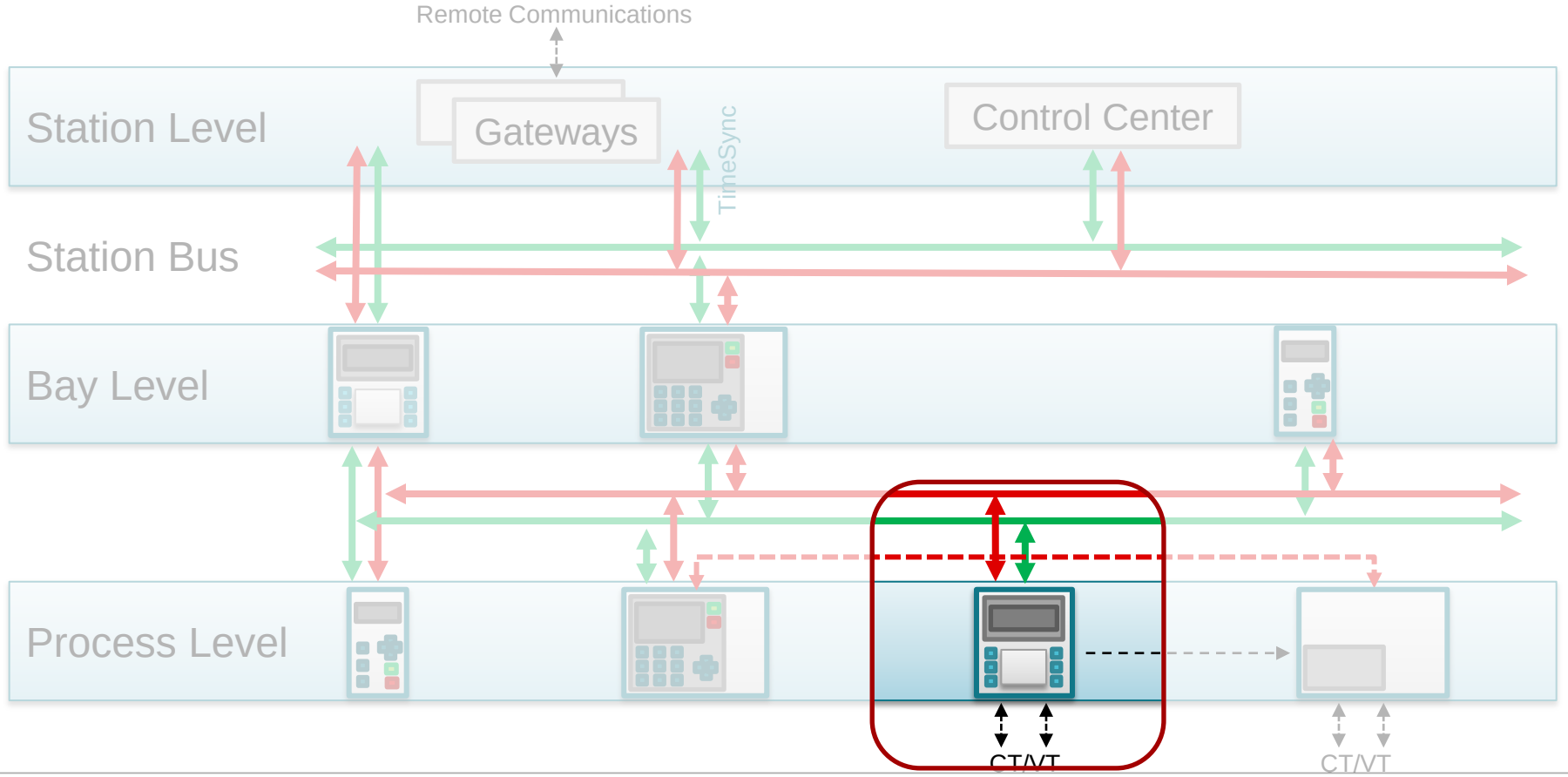


IED block diagram with redundancy

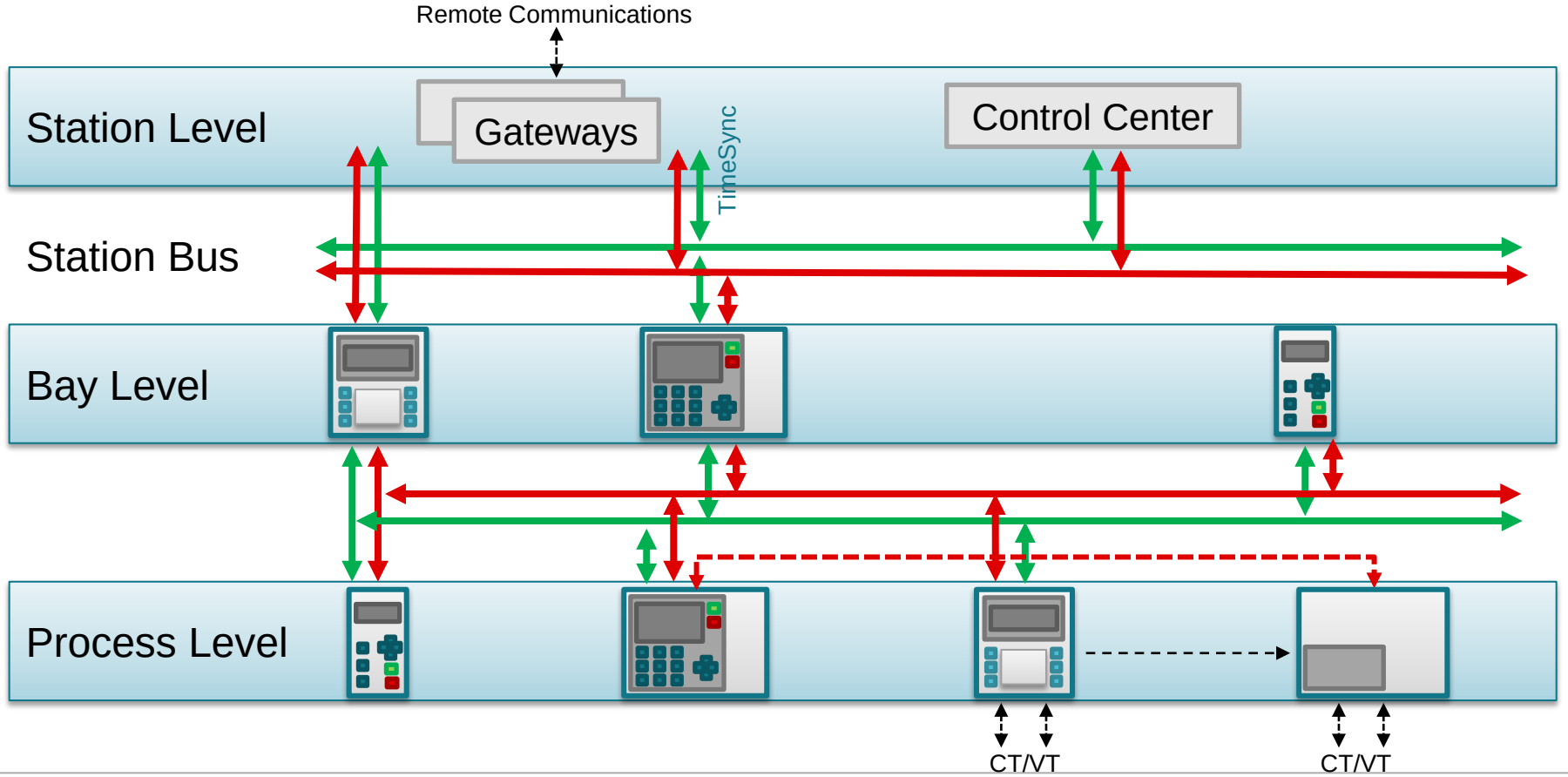




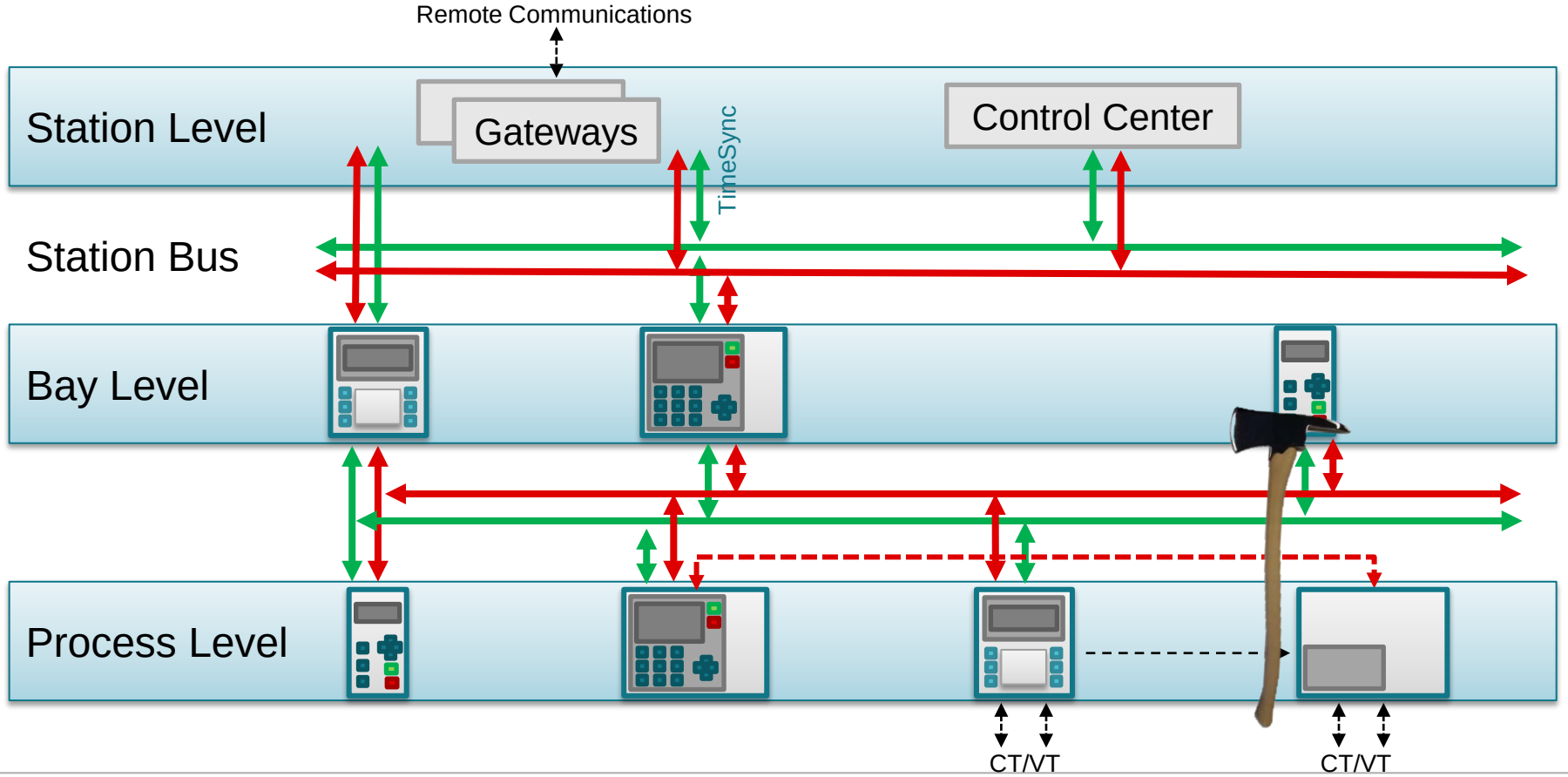
Substation Automation System with redundancy



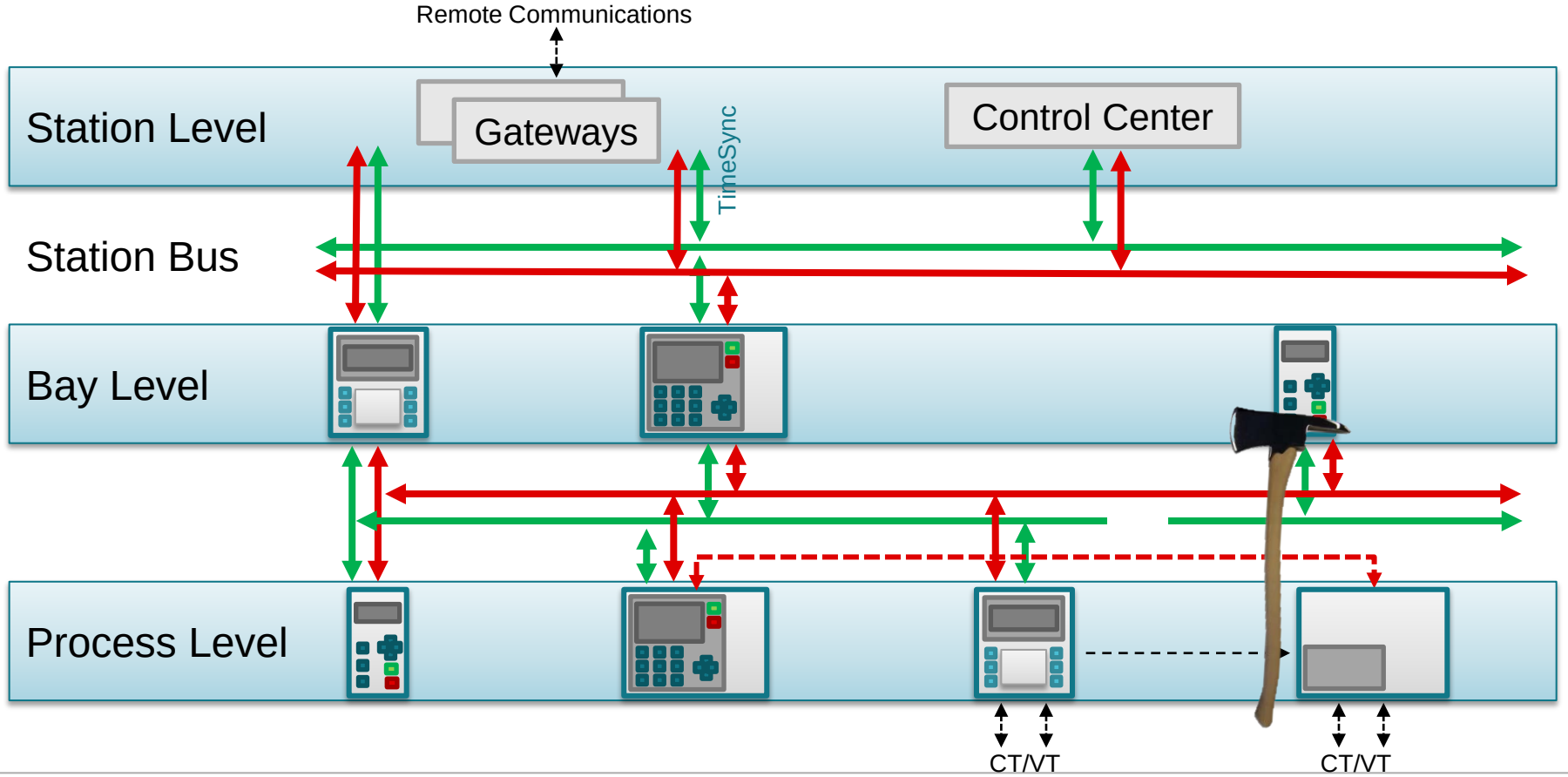
Substation Automation System with redundancy



Substation Automation System with redundancy



Substation Automation System with redundancy



Markets with common roots including redundancy

Energy



- Generation
- Transmission
- Distribution

Factory



- Automation
- Production
- Monitoring

Transportation



- Avionics
- Railway
- Automotive

RELIABILITY

ETHERNET PROTOCOLS

REDUNDANCY

HSR & PRP redundancy goals

Redundancy goals for HSR (High-availability Seamless Redundancy) and PRP (Parallel Redundancy Protocol):

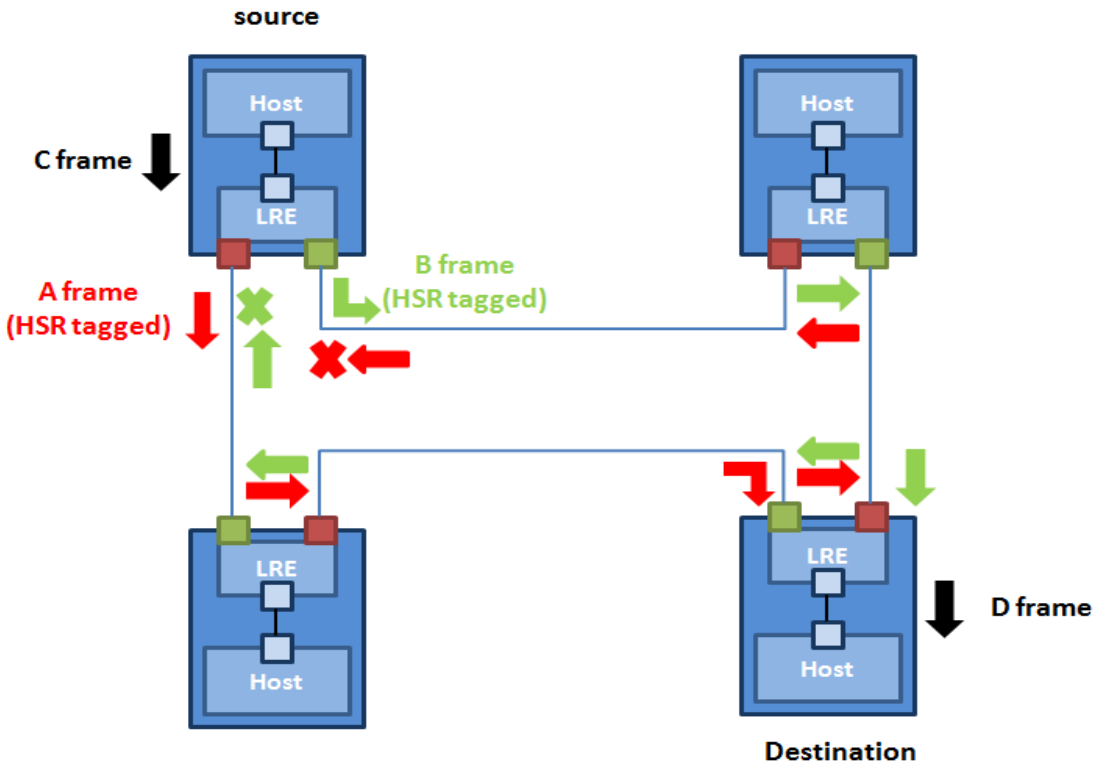
- Provide zero switchover time in case of failure
- Create a network with no single point of failure
- Fulfill dependability and real-time requirements of demanding applications such as:
  - Substation automation
  - Motion control
  - Avionics communication
- Allow for chaining of devices for cost-effective networking
- Allow for complex topologies such as rings and rings of rings
- Support protocol independence, which is the ability to be layered with any industrial Ethernet or other protocols

Ethernet redundancy: IEC 62439 standard

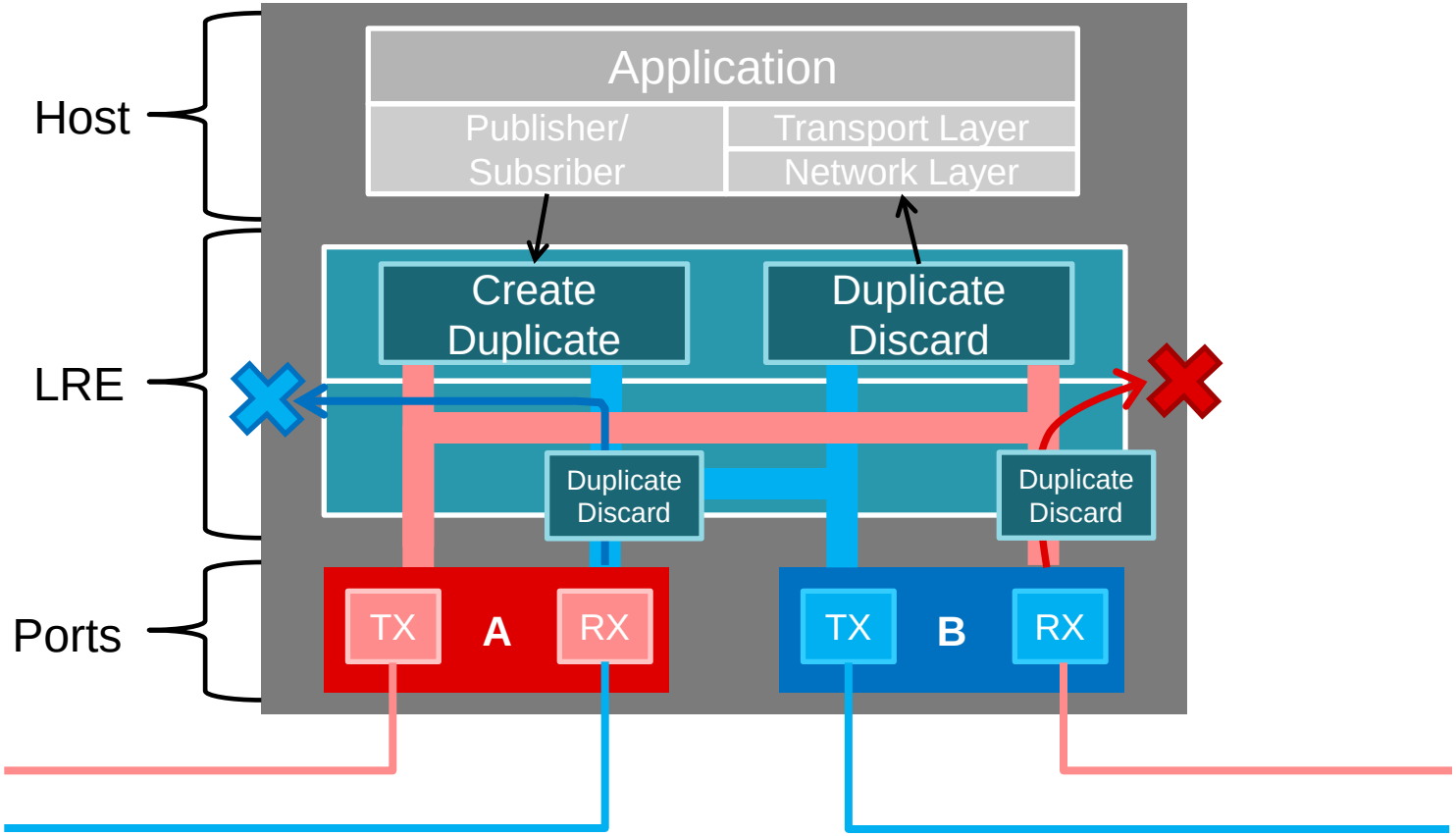
- IEC 62439 standard describes methods to implement Ethernet based network redundancy without packet loss
- IEC 62439 standards covers different system requirements
- General automation systems
  - The standard recommends to use **RSTP** (Base: IEEE standards, RSTP); No need for a new standard.
  - Grace time **< 500 ms**
- Benign real-time systems that are cost-sensitive:
  - Grace time **< 200 ms**
  - The standard shall define an adequate bridge redundancy scheme and redundant devices attachment.
  - Base: RSTP and further developments; Solution: **MRP, DRP, RRP**
- Critical real-time systems that require higher coverage:
  - Grace time **= 0 ms**
  - The standard shall define a parallel network solution and redundant device attachment.
  - Base: ARINC AFDX and similar; Solution: **PRP, HSR**

HSR principle: ring network

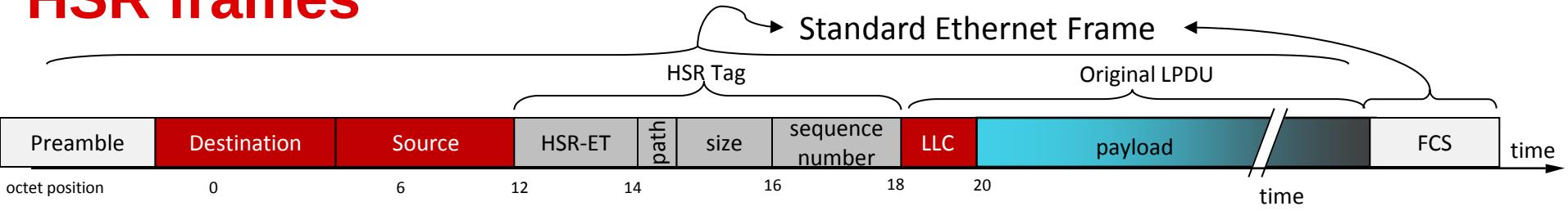
- Nodes (DAN-H) are arranged as a ring with two identical ports (A and B).
- For each frame, two copies are sent (A frame and B frame).
- The source node removes the frames it injected into the ring.
- Destination nodes consume the first frame of a pair and discard the duplicate.
- If the ring is broken, frames still arrive over the intact path. Loss of path is detected by duplicate not arriving.
- LRE: Link Redundancy Entity – manages incoming and outgoing duplicates at each node



Overview with HSR logic scheme



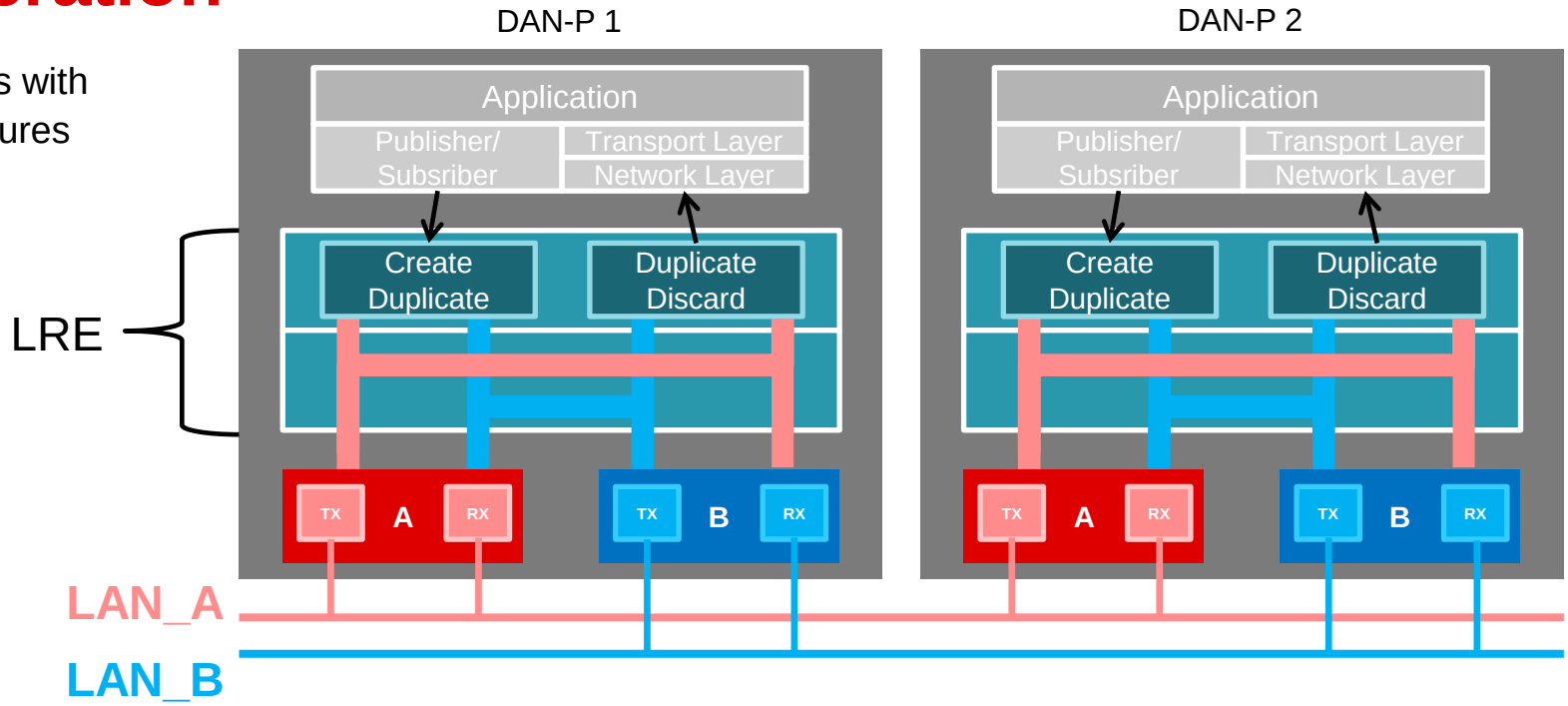
HSR frames



- HSR does not use standard Ethernet frames
- Each frame has an HSR Ethertype, a path indicator, a size field and a sequence number
- The sender inserts the same sequence number in both frames of a pair, and increments the sequence counter by one for each sending from this node
- The receiver keeps track of the sequence counter for each source MAC address it receives frames from. Frames with the same source and sequence number value coming from different lines are discarded.
- To supervise the network, a node may keep a table of all other nodes in the network from which it receives frames. This allows to detect nodes absence and bus errors at the same time.
- A node recognizes the frame it sent through its source address and sequence number

PRP operation

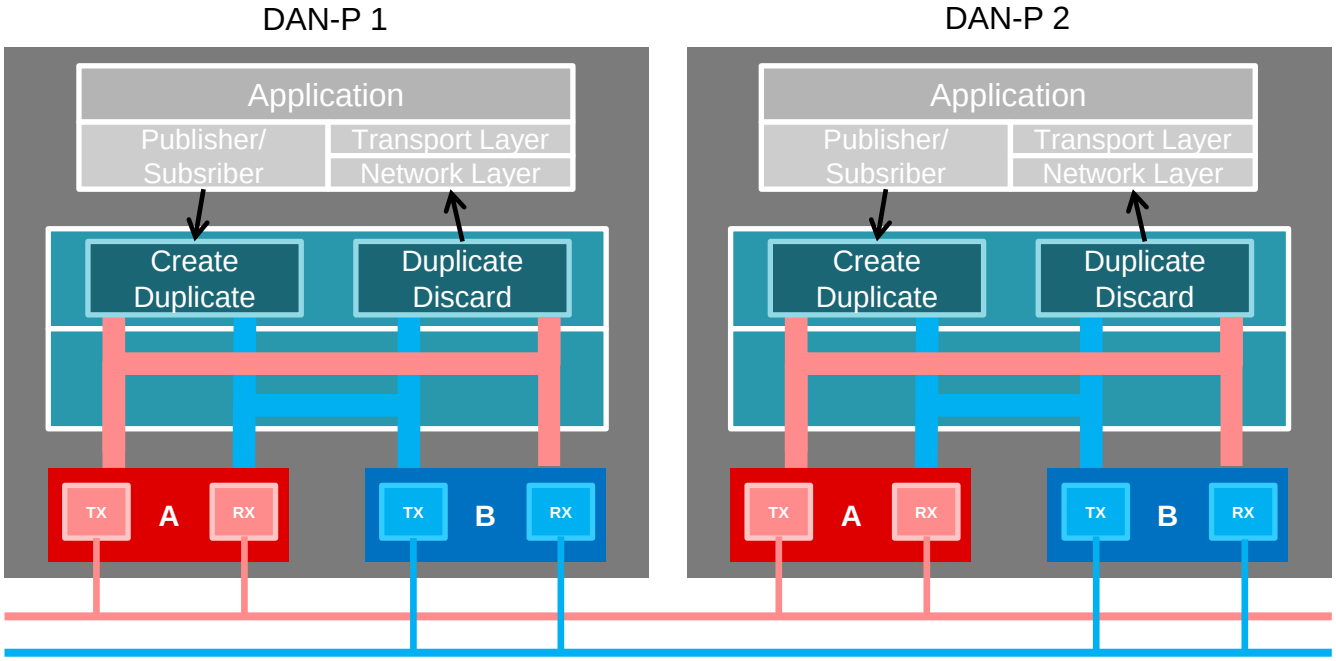
- 2 separate LANs with independent failures



LRE: Link Redundancy Entity – manages incoming and outgoing duplicates at each node

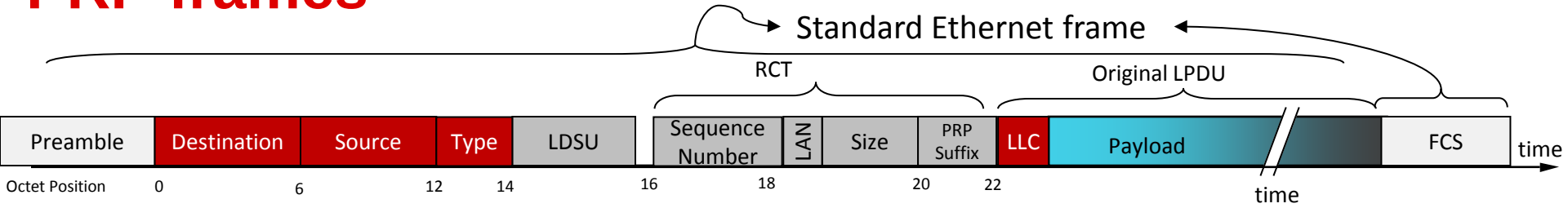
PRP operation

- 2 separate LANs with independent failures
- Each PRP node (DAN-P) has two Ethernet interfaces:
  - Same MAC address and IP address(es)
  - PRP is a layer 2 redundancy and is transparent to higher network protocols
- Packets are duplicated on transmit and duplicates are discarded when received



PRP main difference compared to HSR: No dependence on network topology (HSR uses a ring)

PRP frames



- PRP does use standard Ethernet frames
- Each frame has an Redundancy Control Trailer (RCT):
  - 16-bit sequence number
  - 4-bit LAN identifier, 1010 (0xA) for LAN_A and 1011 (0xB) for LAN_B
  - 12-bit frame size
- The sender inserts the same sequence number in both frames of a pair, and increments the sequence counter by one for each frame sent from this node.
- To allow the receiver to distinguish frames coming from PRP nodes vs non-PRP node, the sender appends the frame with the length of the Link Service Data Unit (LSDU) in octets in the 12-bit frame size field.
- The receiver tracks the sequence counter for each source MAC address it receives. Duplicate frames are discarded.

Section summary

- As systems become more reliant on communication, redundancy helps avoid inevitable failures
- HSR uses a ring structure that can be expanded to rings of rings
- HSR packets are not compliant with standard Ethernet
- PRP allows for more flexible network topologies
- PRP does use standard Ethernet packets
- Both can achieve low-latency redundancy to meet the needs or modern applications

For more information

- HSR and PRP on RT Linux Training Series: http://training.ti.com/hsr-prp-rt-linux-training-series
- Sitara Processors Product Overview: http://www.ti.com/sitara
- AM571x Industrial Development Kit (IDK): http://www.ti.com/tool/tmdxidk5718
- AM572x Industrial Development Kit (IDK): http://www.ti.com/tool/tmdxidk5728
- Processor SDK Software Developer Guides:
  - Linux: http://processors.wiki.ti.com/index.php/Processor_SDK_Linux_Software_Developer's_Guide
  - RTOS: http://processors.wiki.ti.com/index.php/Processor_SDK_RTOS_Software_Developer_Guide
- PRP TI Design using TI-RTOS: http://www.ti.com/tool/tidep0054
- HSR TI Design using TI-RTOS: http://www.ti.com/tool/tidep0053
- For questions regarding topics covered in this training, visit the Sitara Processors support forum at the TI E2E Community website: https://e2e.ti.com/support/arm/sitara_arm/f/791