Upgrading From a Successful Emergency Control System to a Complete WAMPAC System for Georgian State Energy System

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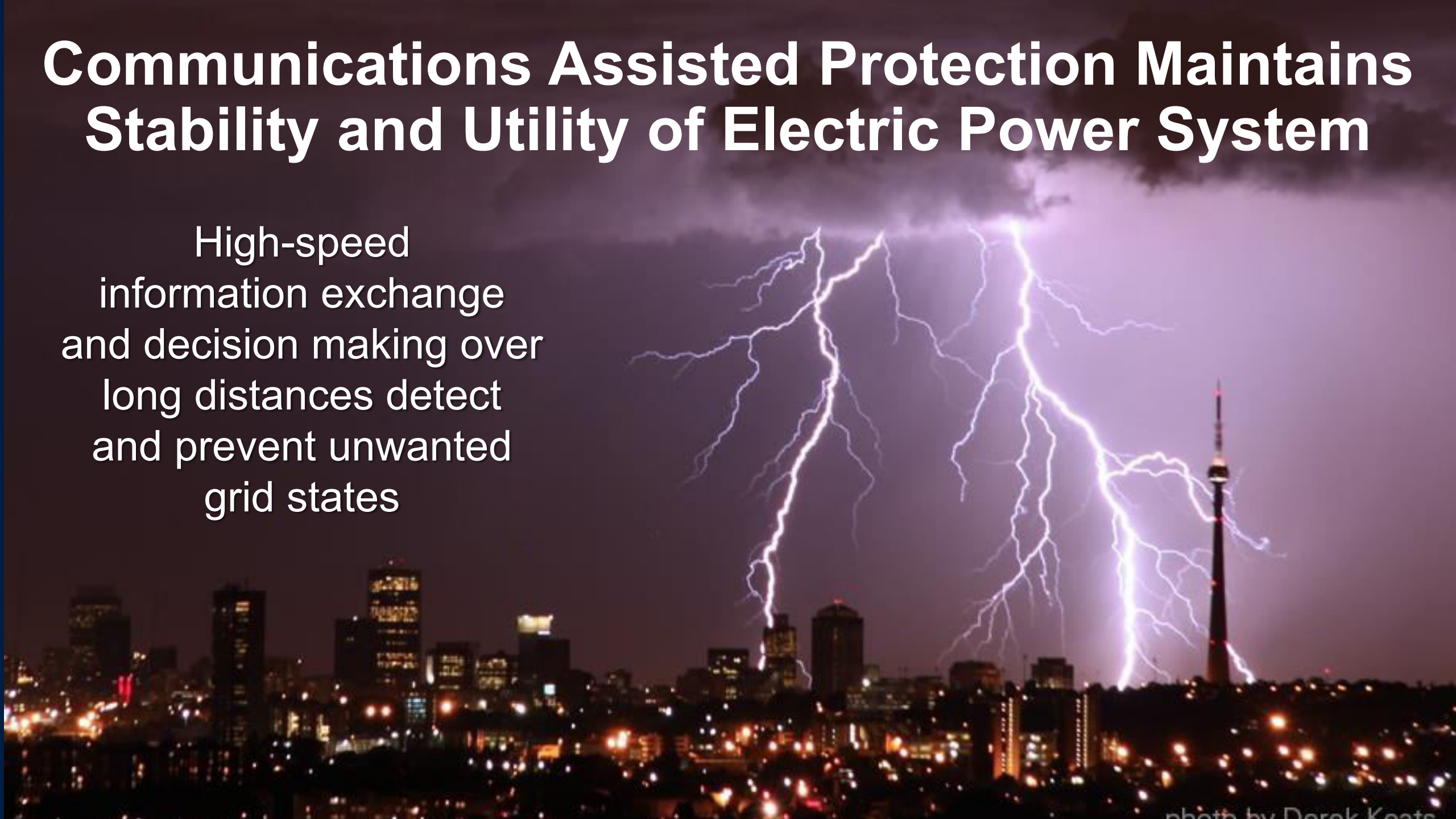
Communications Assisted Protection Maintains Stability and Utility of Electric Power System

High-speed information exchange and decision making over long distances detect and prevent unwanted grid states



Managing Energy Flowing at the Speed of Light Requires Mission Critical Precision

- Detect, isolate energy system fault
- Respond, reconfigure alternate path or source
- Recover, restore energy flow


Protect


Detect


Isolate


Calculate


Analyze


Communicate


Control


Restore

Message Delivery Performance Criteria Defined by International Standards

IED performance requirements

IEC 61850, IEC 60834, IEC 15802, IEEE 802.1

Latency specifications

IEC 61850, IEC 60834, IEC 15802, IEEE 802.1

Speed

IEC 61850

Message Delivery Quality Criteria Defined by International Standards

Dependability and security requirements
IEC 61850, IEC 60834

Availability requirements
IEC 61850, IEC 60834, IEEE 802.1

Reliability metrics
IEC 61850, IEEE 1613, IEC 60870

IEC 61850 References Hardware Quality Measures Described in IEC 60870-4

Reliability class severity (R1, R2, or R3) measured as MTBF

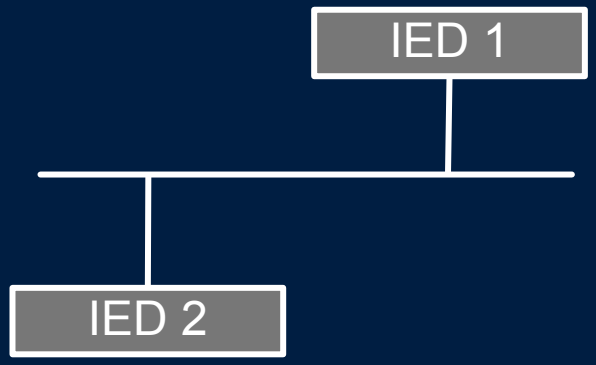
Availability class severity (A1, A2, or A3) measured as % availability

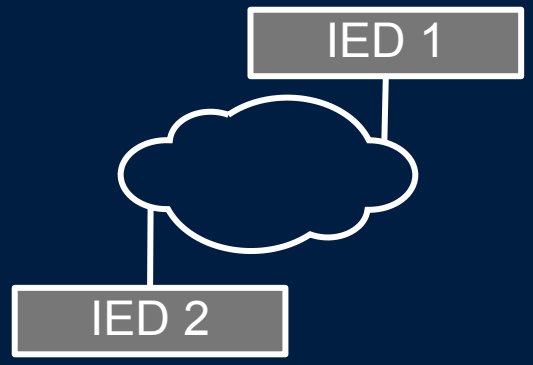
Maintainability class severity (M1, M2, M3, or M4) measured as MTTR and (RT1, RT2, RT3, or RT4) as MRT

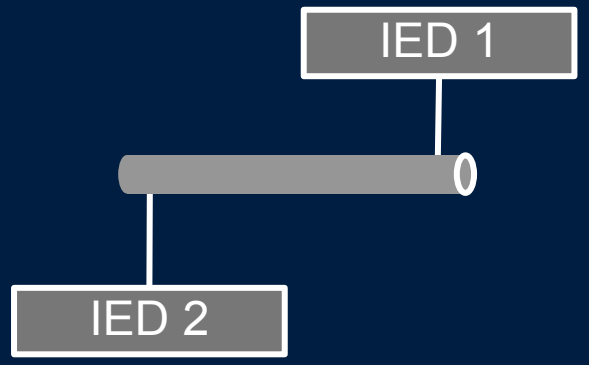
International Standards Dictate Speed, Dependability, Reliability, and Performance

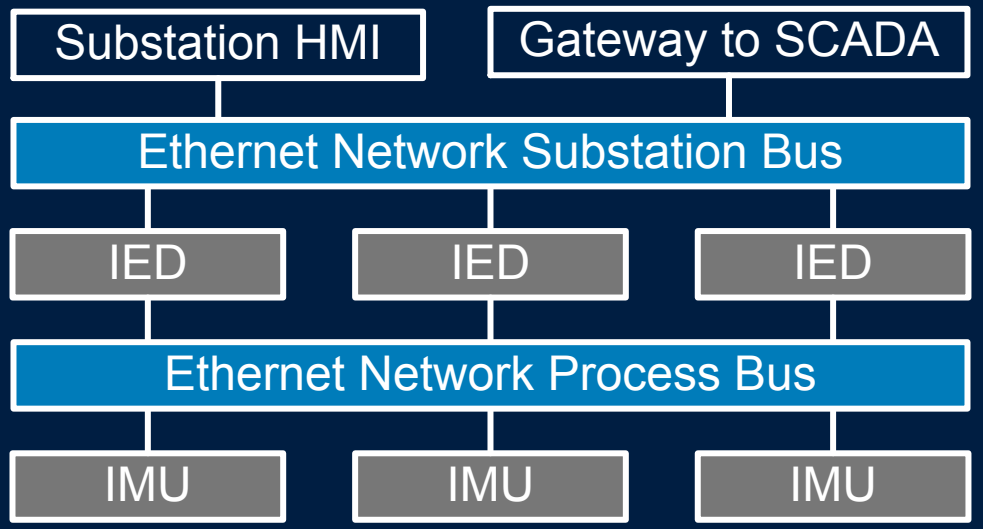
- Protection signals via digital messages
  - Speed < 3 msec
  - Latency < 1 msec
  - Network failover < 15 msec
  - Zero dropped GOOSE per year
  - < 9 unwanted GOOSE per day
  - 99.99% of the time

IT, IEEE, and Industry Publications Mask Importance of Network Design



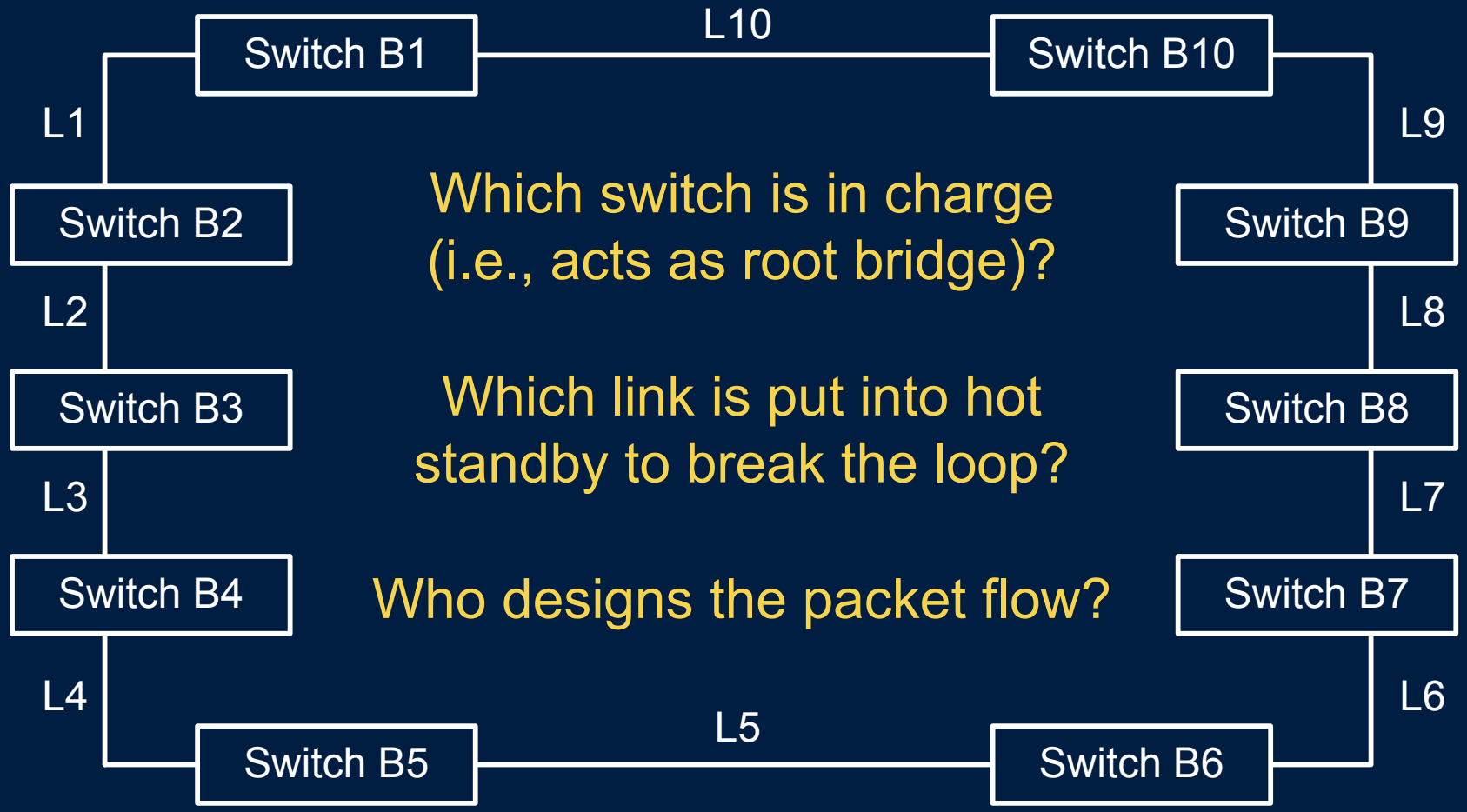




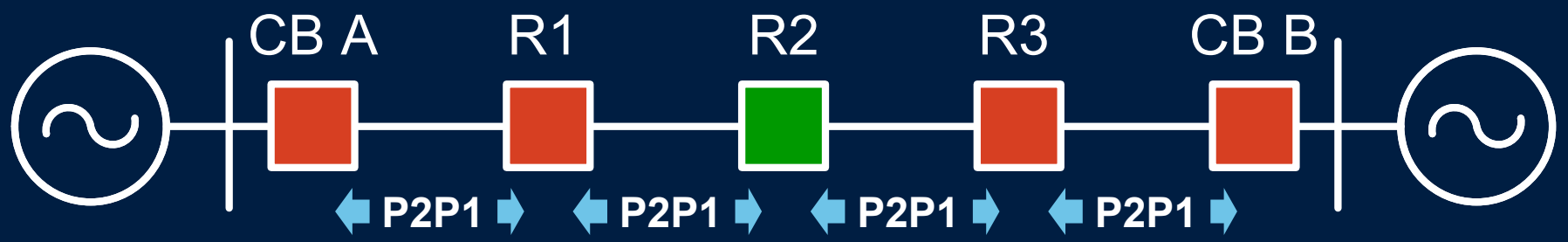


Drawing LANs as clouds, boxes, tubes, or “magic” buses hides true design and engineering required

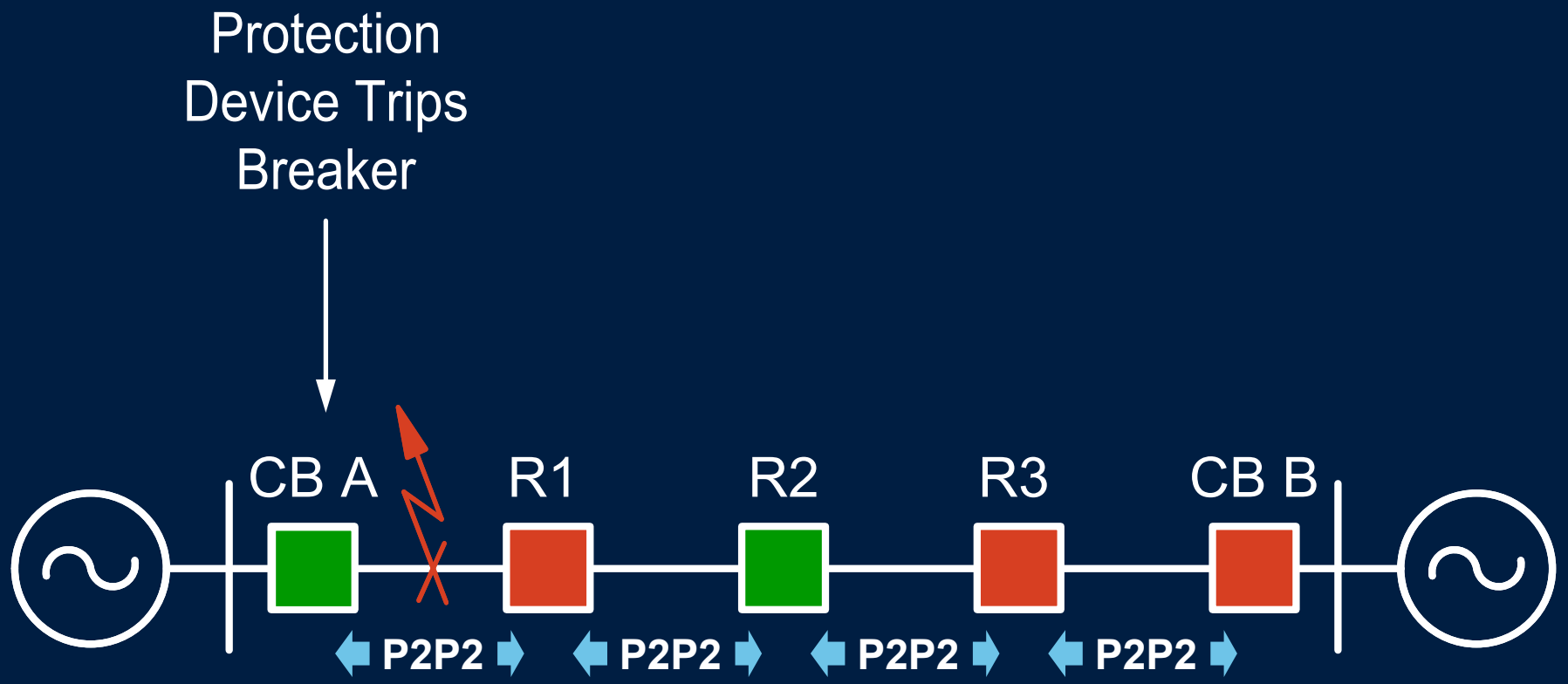
Traditional Rings Rely on Spanning Tree Algorithm (STA) and RSTP



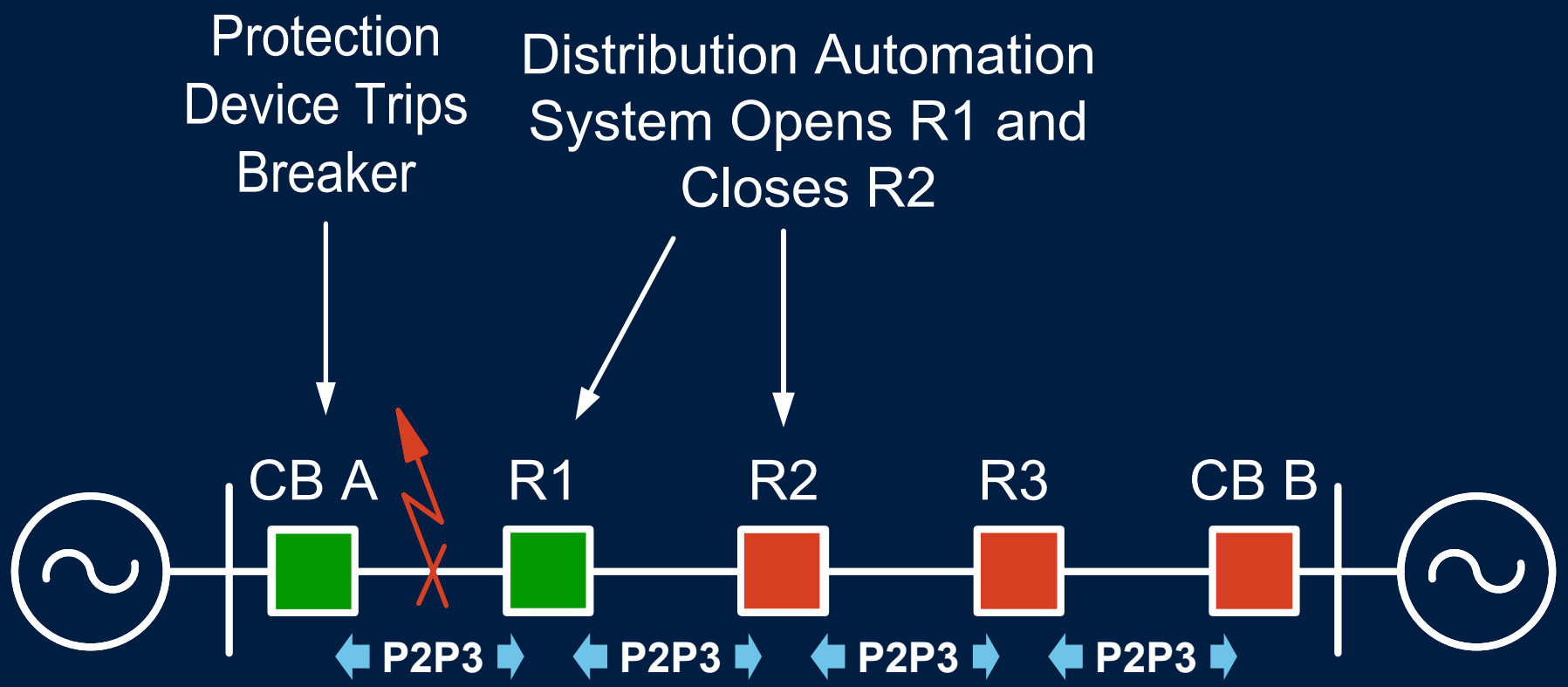
IEDs Exchange Peer-to-Peer Communications



Peer-to-Peer Communications Share Topology Change Information



Fault Isolated, Hot Standby Enabled, and Network Reconfigured



Managing Ethernet Packet Flow Requires Mission Critical Precision

- Detect, isolate Ethernet system fault
- Respond, reconfigure alternate path
- Recover, restore packet flow


Protect


Detect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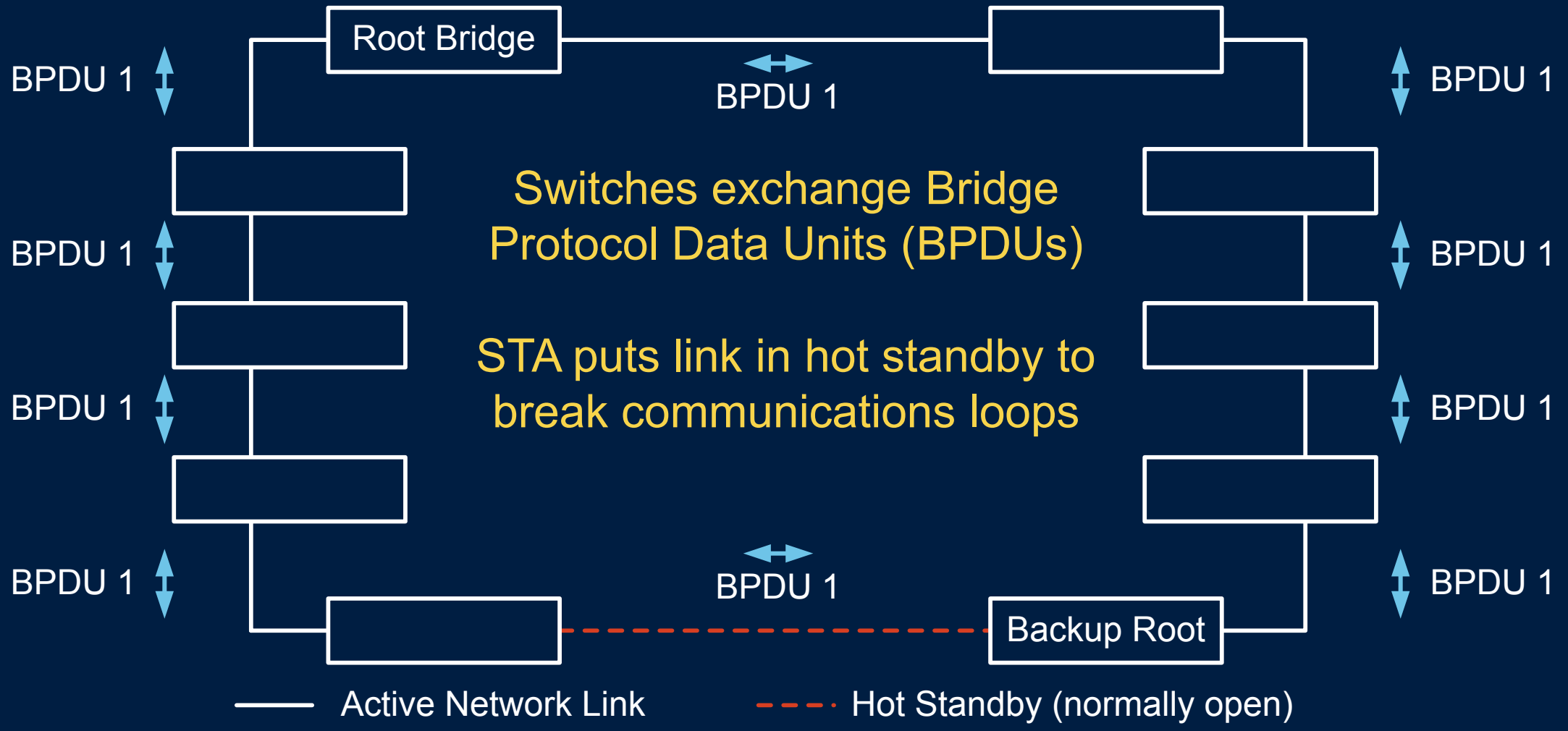
Restore

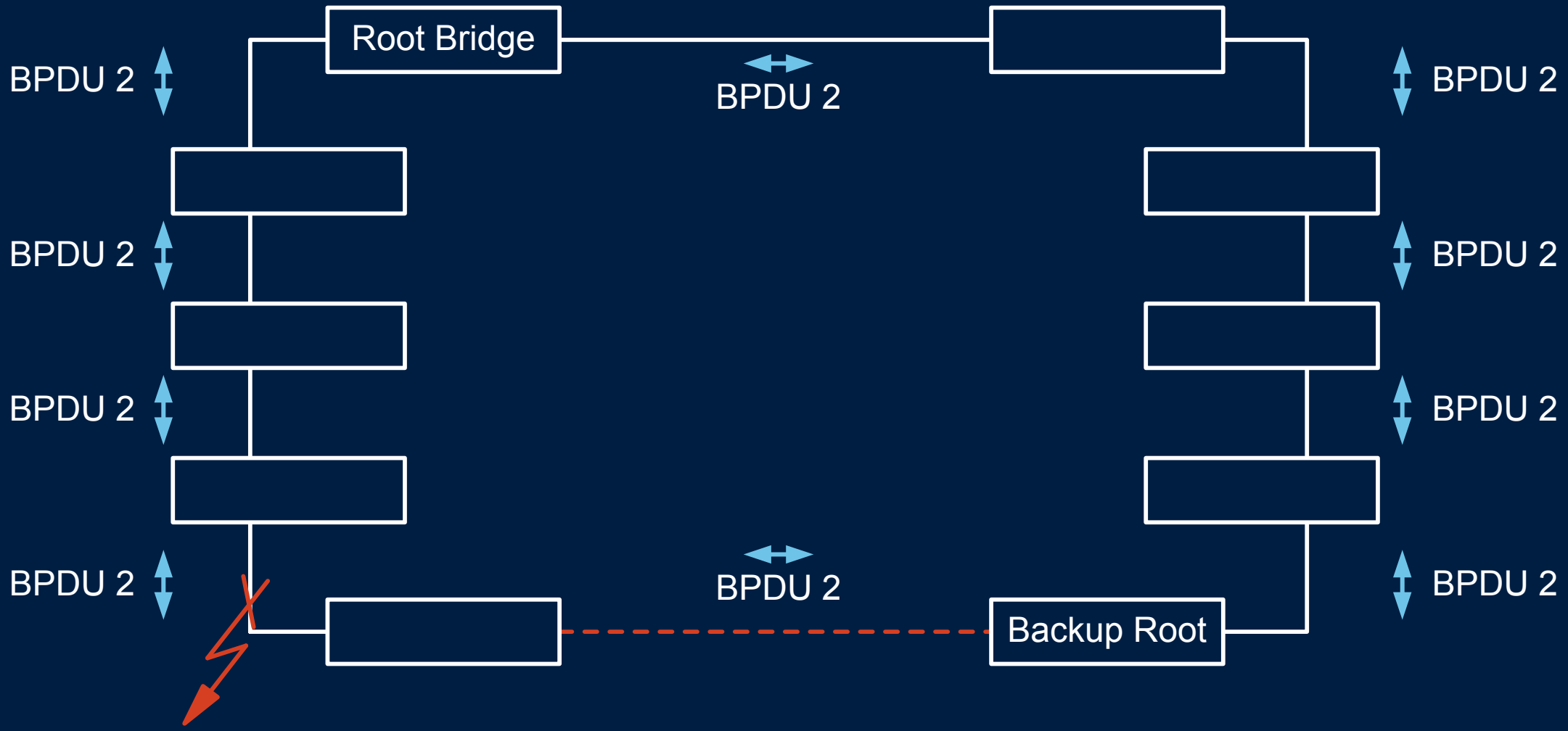
Repairable vs. Reconfigurable Ethernet

- Repairable
  - Duplicate messages via IEC 62439-3 PRP or HSR
  - No intelligence; human intervention required to repair fault
- Reconfigurable
  - Redundant paths via IEC 62439-1 RSTA
  - Faults detected and isolated; network traffic rerouted without human interaction

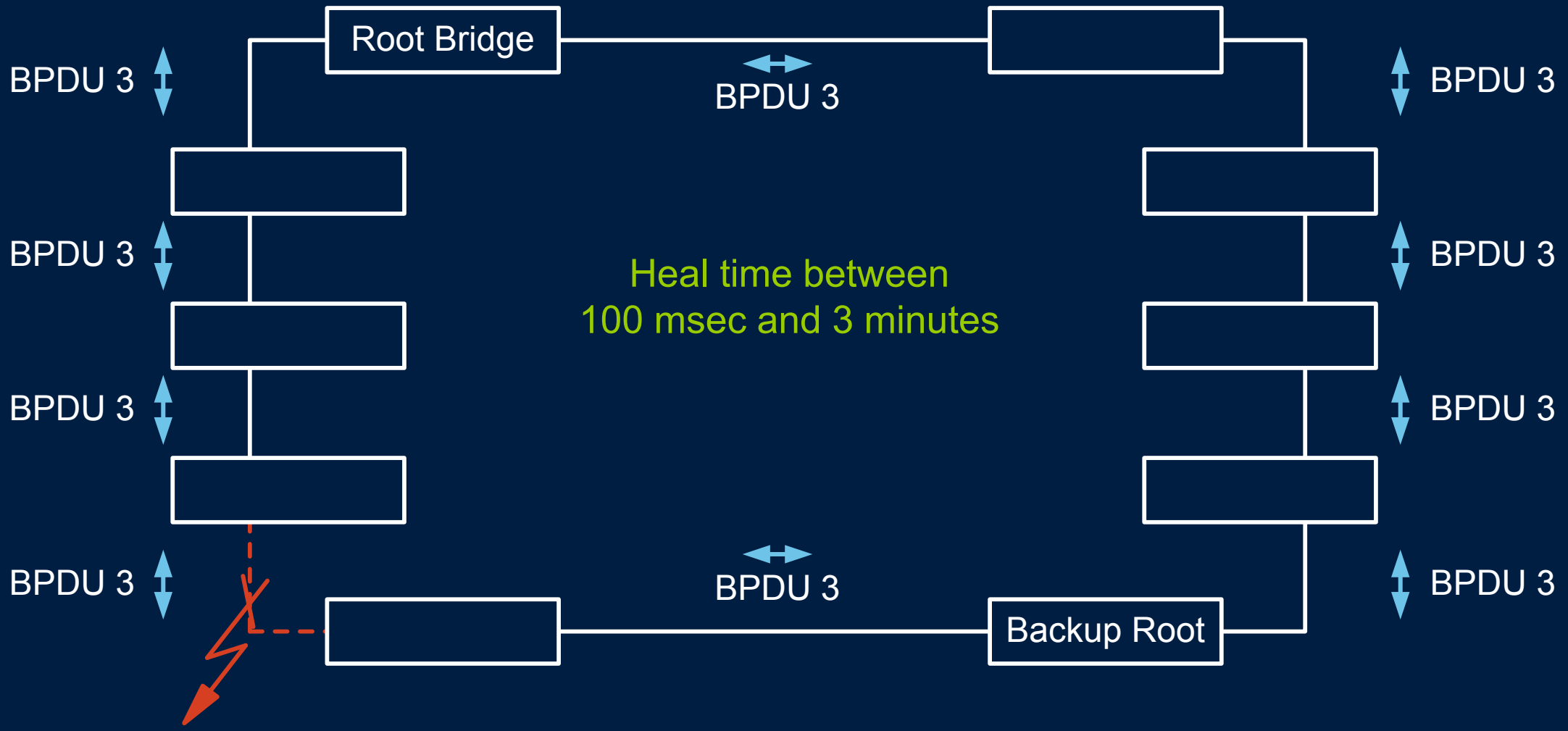
Ethernet LAN BPDU Point-to-Point Communications Work Similarly



Point-to-Point BPDUs Share Topology Change Information



Fault Isolated, Hot Standby Enabled, and Network Reconfigured



Behavior of Each Switch Port Must Be Designed and Configured

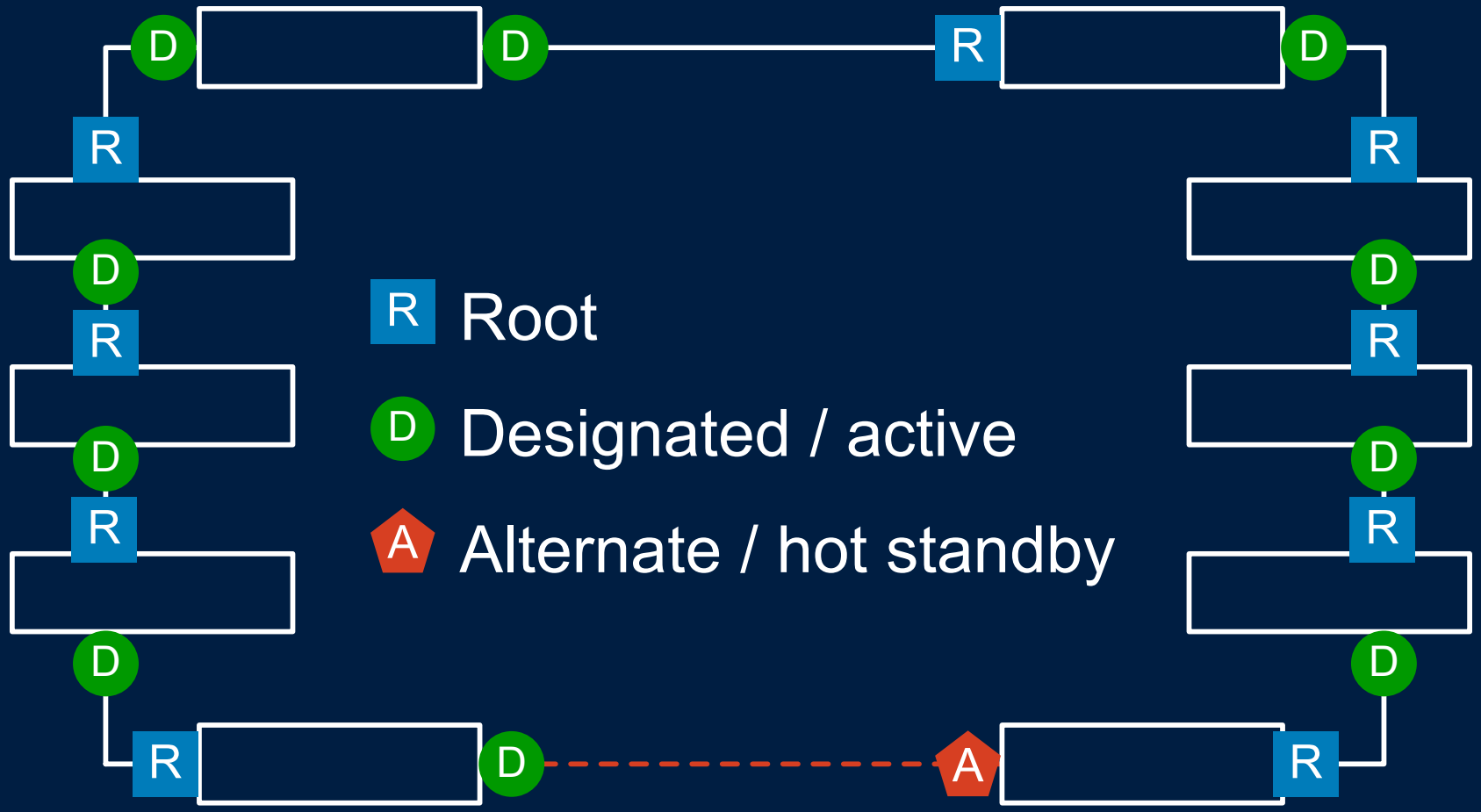
Port Roles

- R Root
- D Designated / active
- A Alternate / hot standby

Port State

- Blocking
- Forwarding
- Learning

RSTP Ring Port Designations



Role of Each Switch in LAN Must Be Designed and Configured

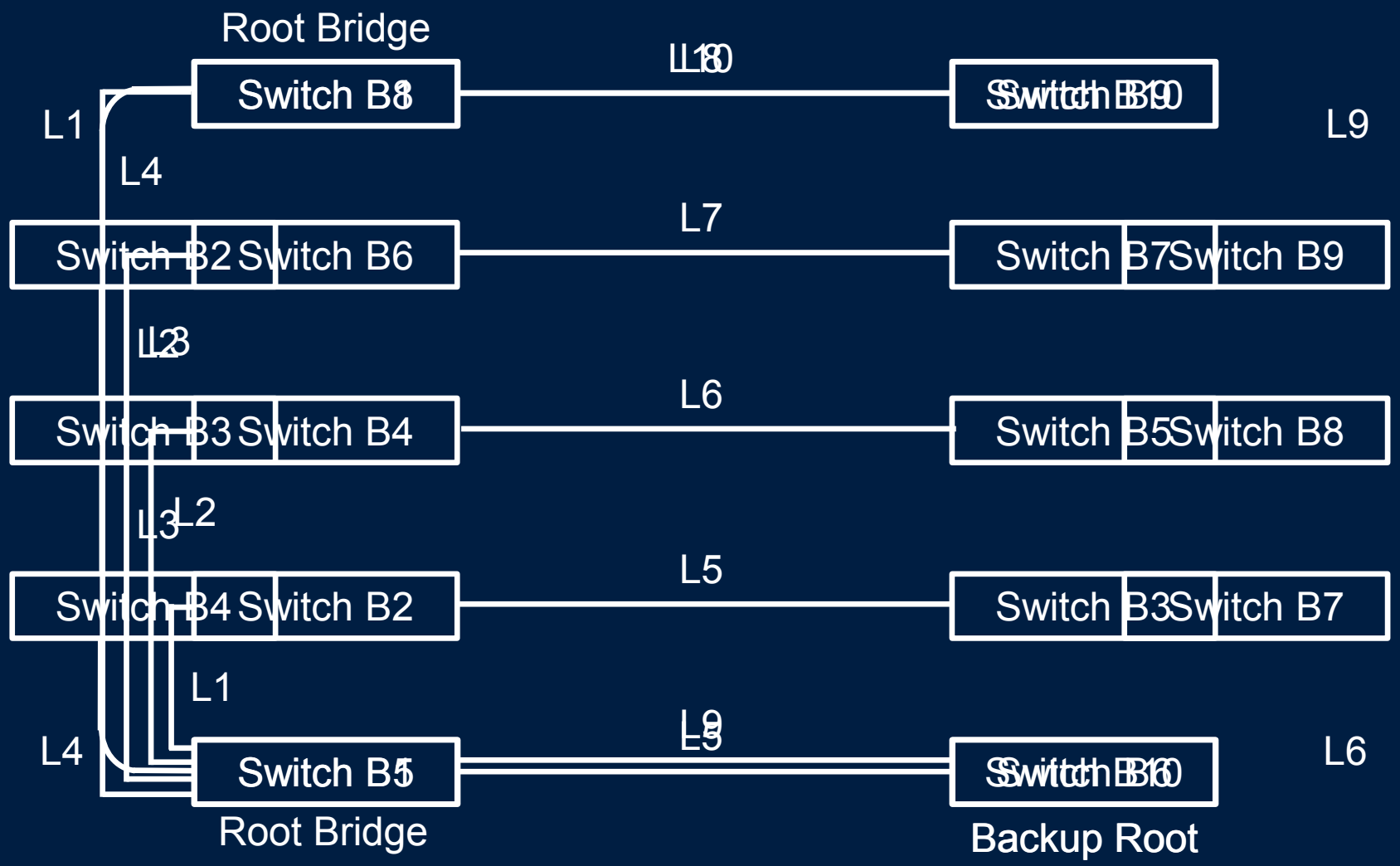
Switch Settings

- Bridge priority
- Maximum number of hops to root bridge

Port Settings

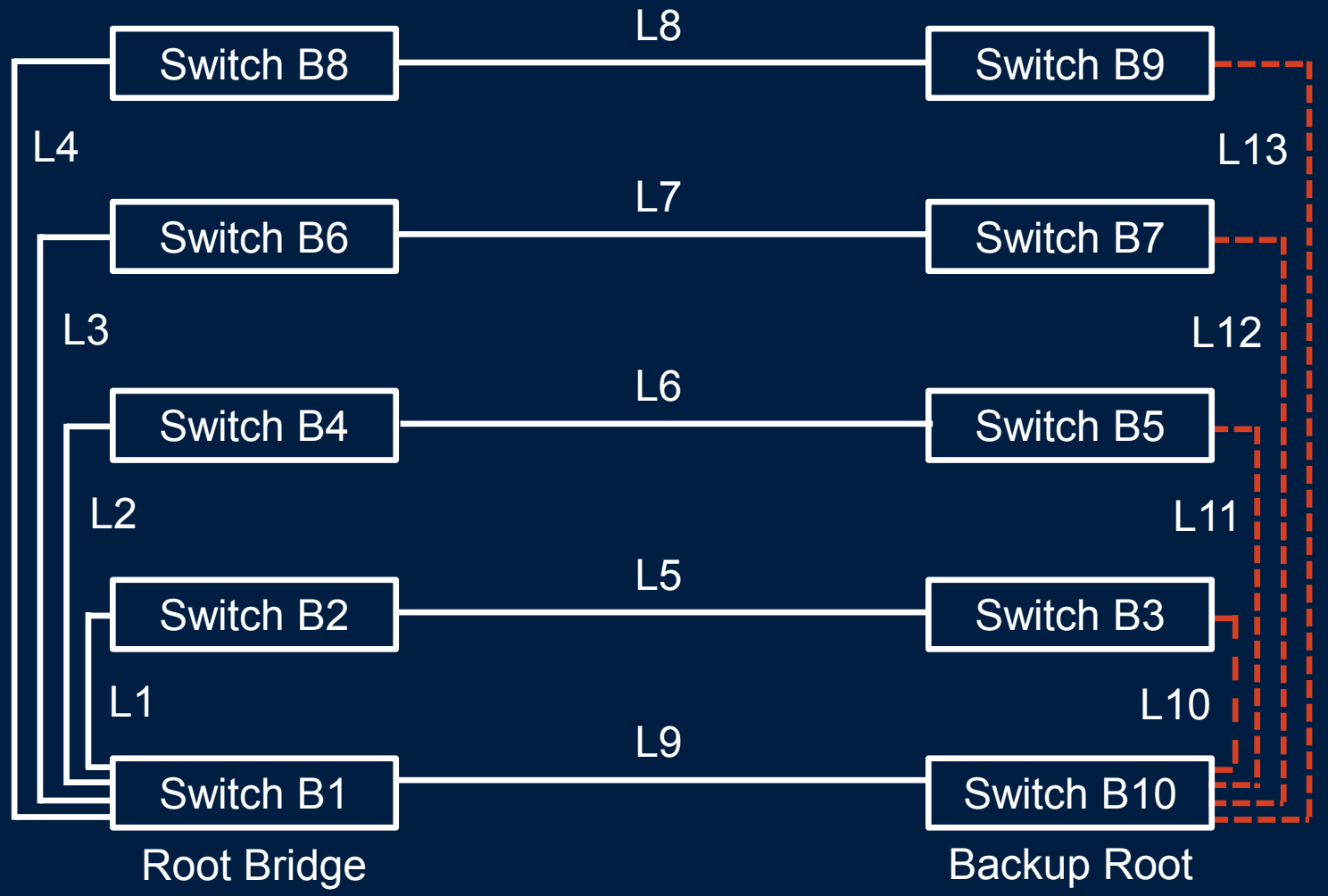
- Port priority
- Path cost

Engineered Ethernet Is Resilient, Dependable, and Secure



Three New Cables, Dramatic Resiliency, and Increased Reconfiguration Options

Three New Cables, Dramatic Resiliency, Increased Reconfiguration, Four Hot Standby



Survive loss of 5 switches and 10 cables

Each Failure Mitigated in 7 to 15 msec

GSE LAN and WAN Communications Design Goals

- Deterministic
- Precise time
- Low latency
- Fast healing
- Secure
- Utility-rated

Placeholder for GSE Video

Opened 500 kV Backbone, RAS Response <10 ms