

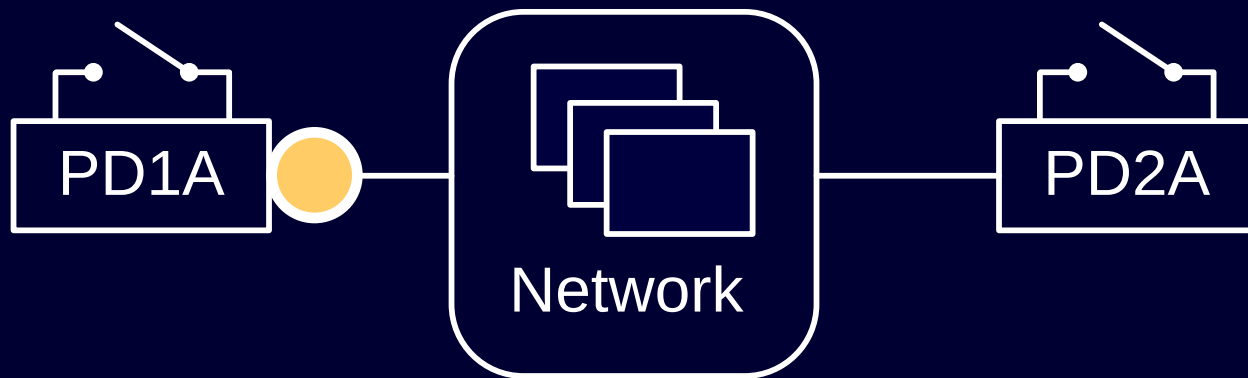
Modern Ethernet Failure Recovery Methods for Teleprotection and High-Speed Automation

D. DOLEZILEK C. GORDON, D. ANDERSON,
and T. TIBBALS

Schweitzer Engineering Laboratories, Inc.

Primary Protection Application

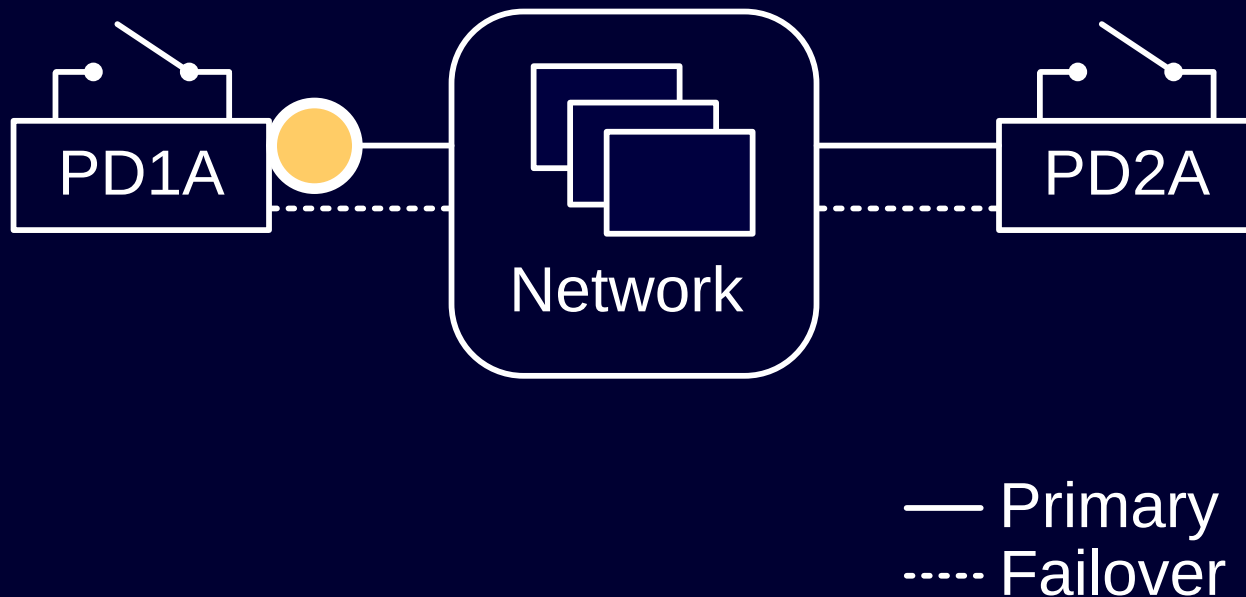
Singular Application, Information, Message, and Packet



Primary protection and LAN

Primary Protection Application

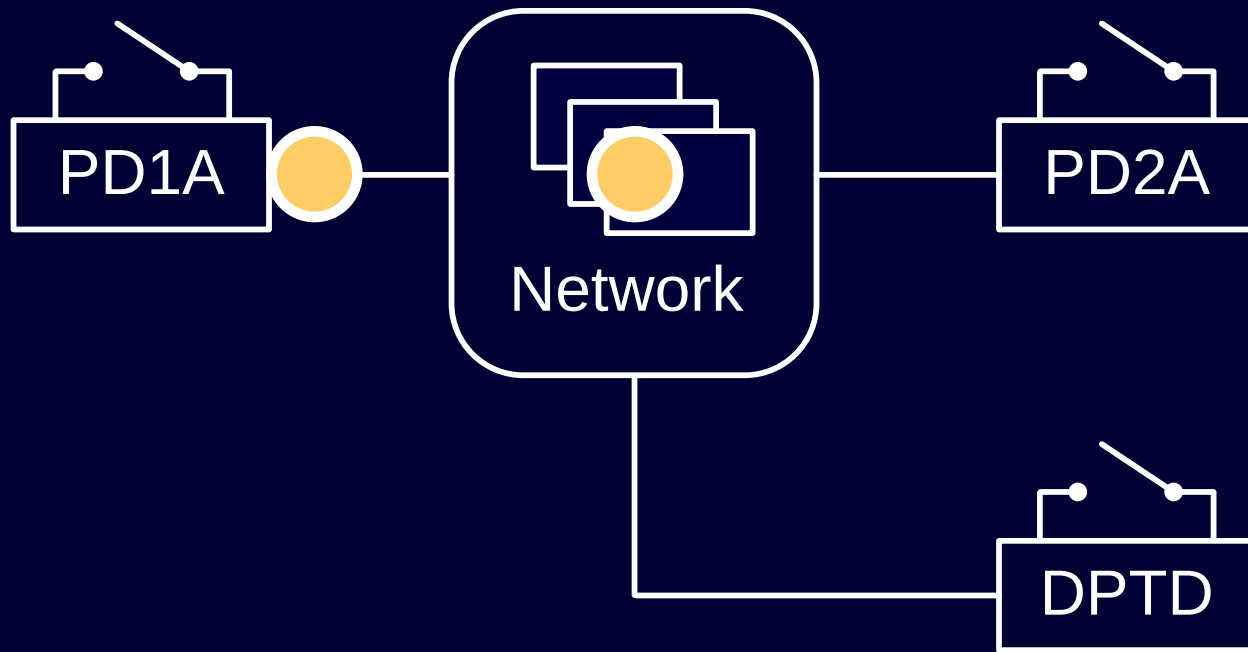
Singular Application, Information, Message, and Packet



Hot-standby second IED link

Dual Primary Tripping Applications

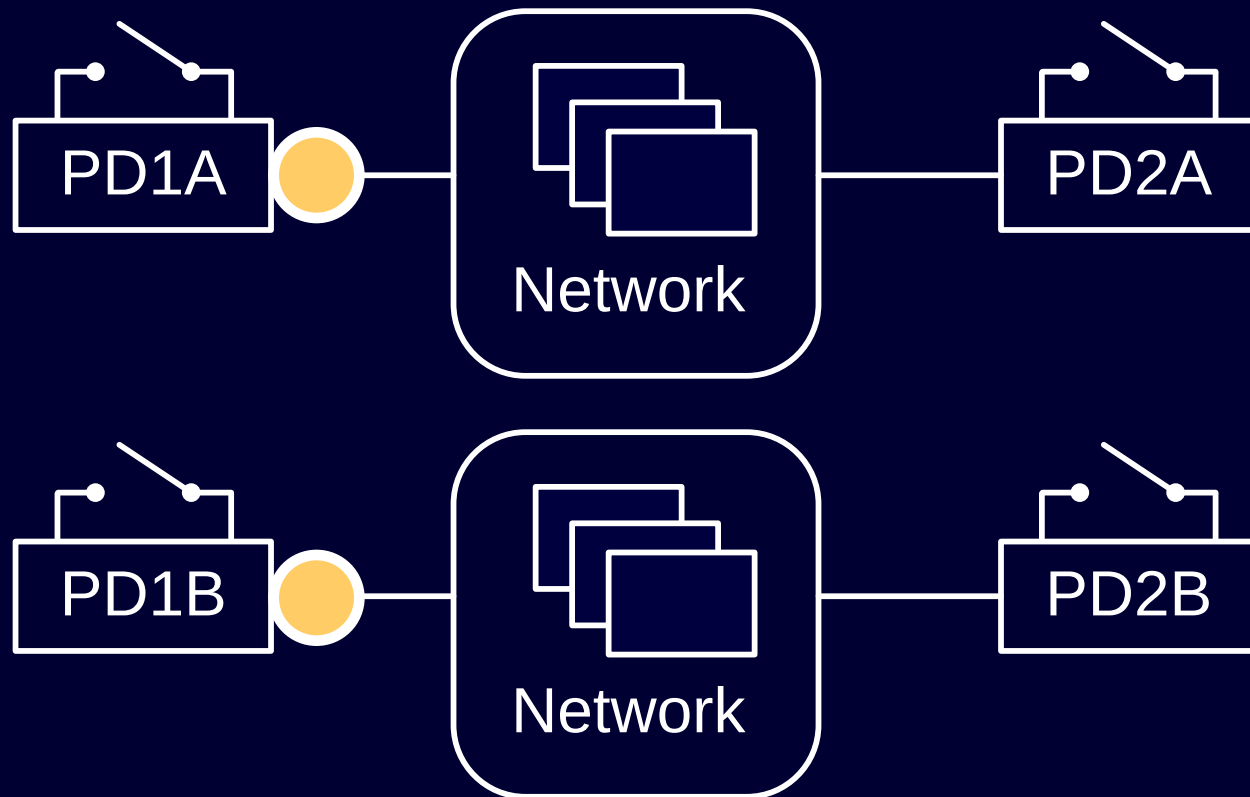
Redundant Application With Multicast Packet



Dual primary trip device (DPTD)

Dual Primary Protection Applications

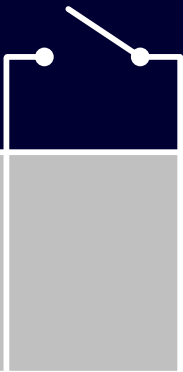
Redundant Application, Information, Message, and Packet



Dual primary LAN

Duplicate Information, Same Source

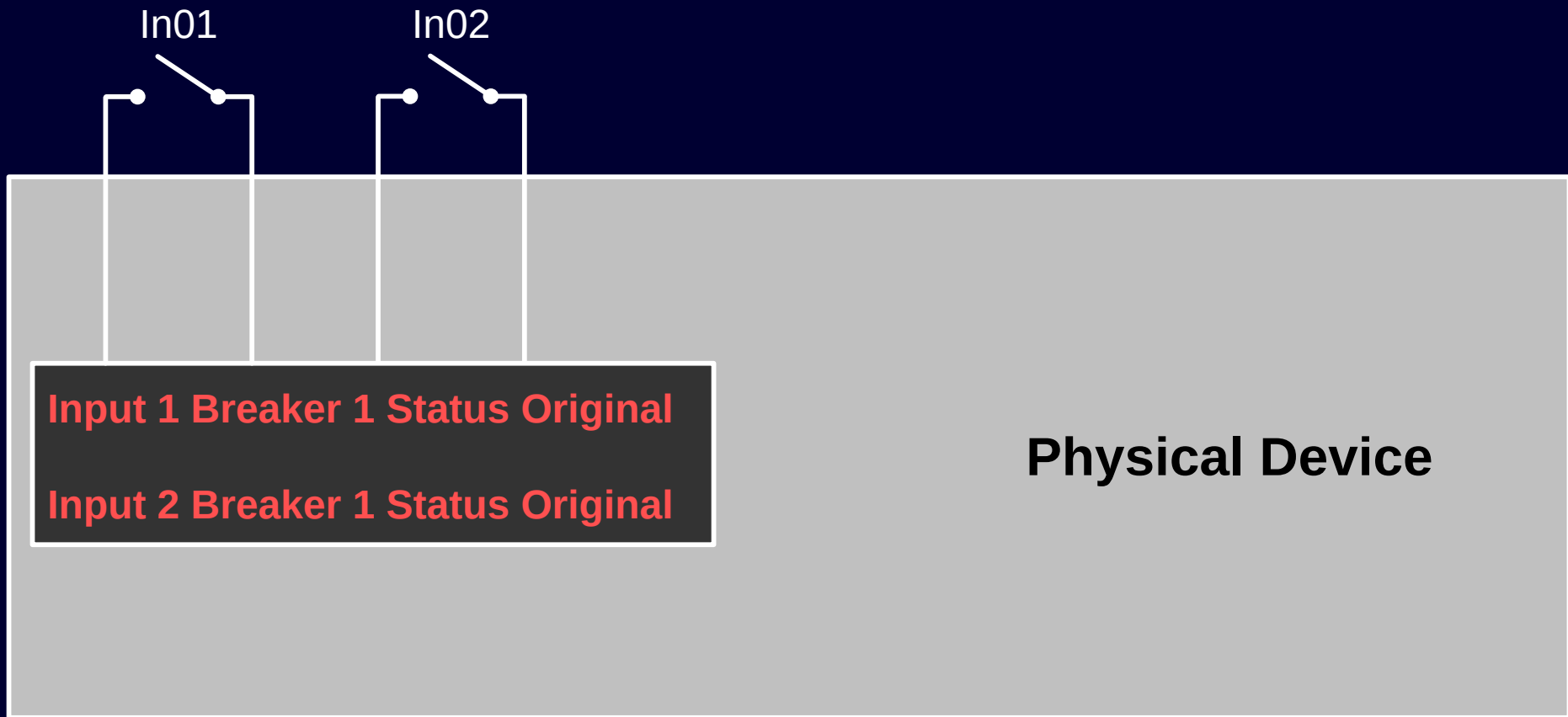
In01



Input 1 Breaker 1 Status Original
Input 1 Breaker 1 Status Duplicate

Physical Device

Redundant Information, Unique Sources, Single IED



IEEE 802.1Q VLAN Tags Are Used to Manage Messages Among Networks

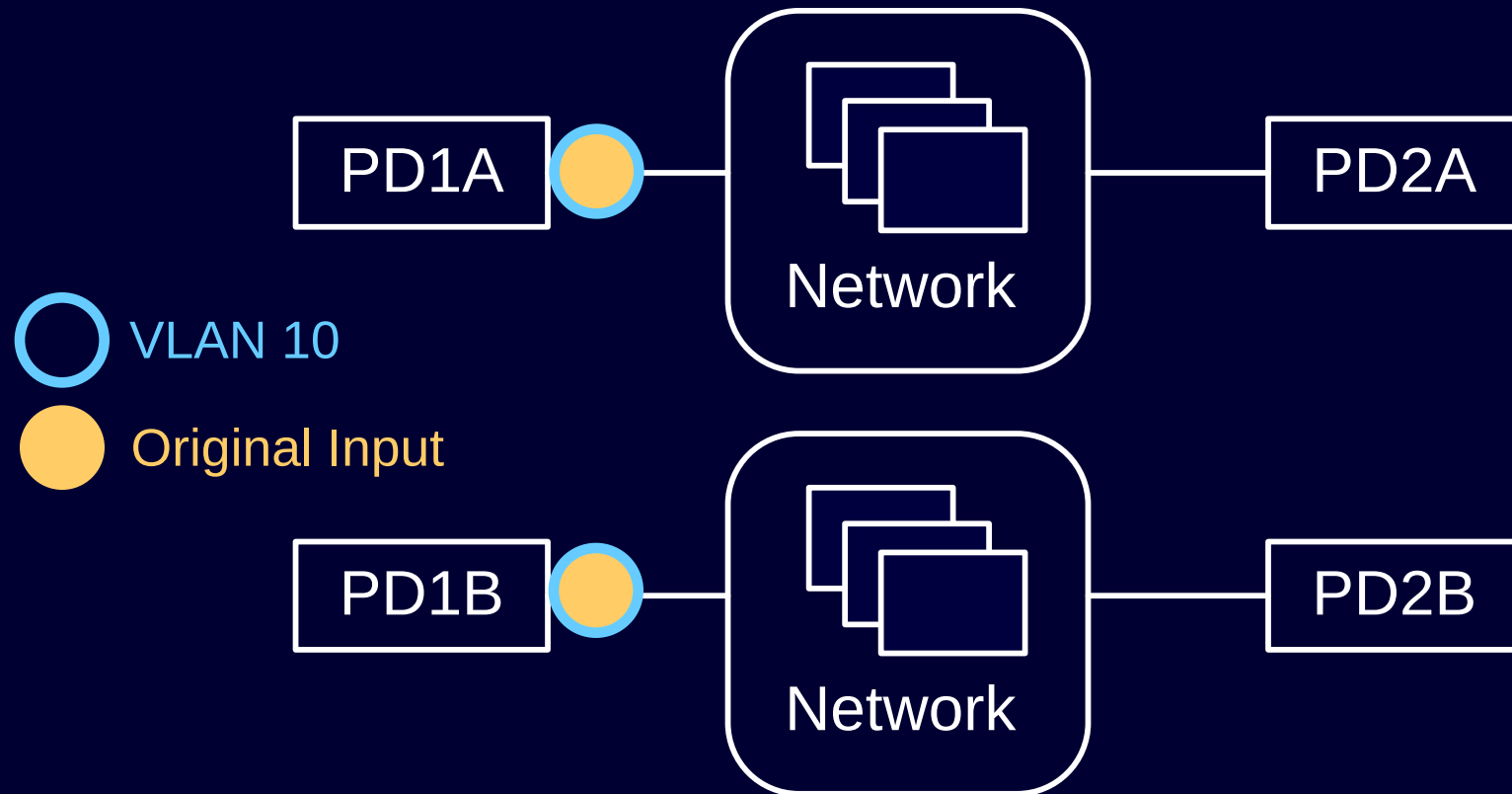


Input 1 Breaker 1 Status #1
Input 1 Breaker 1 Status #2
Input 2 Breaker 1 Status #1

[illegible]

Dual Primary Protection Applications

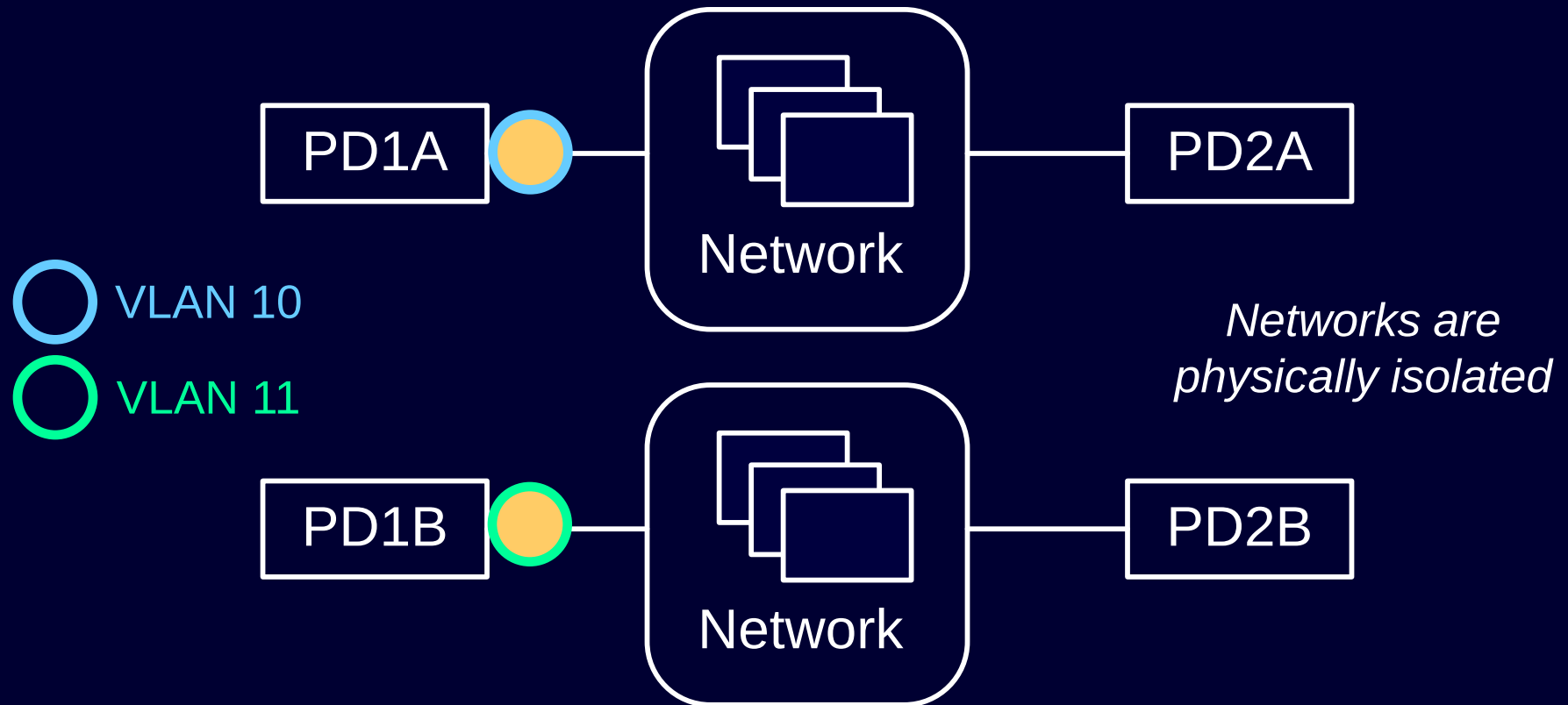
Redundant Application, Information, Message, Packet



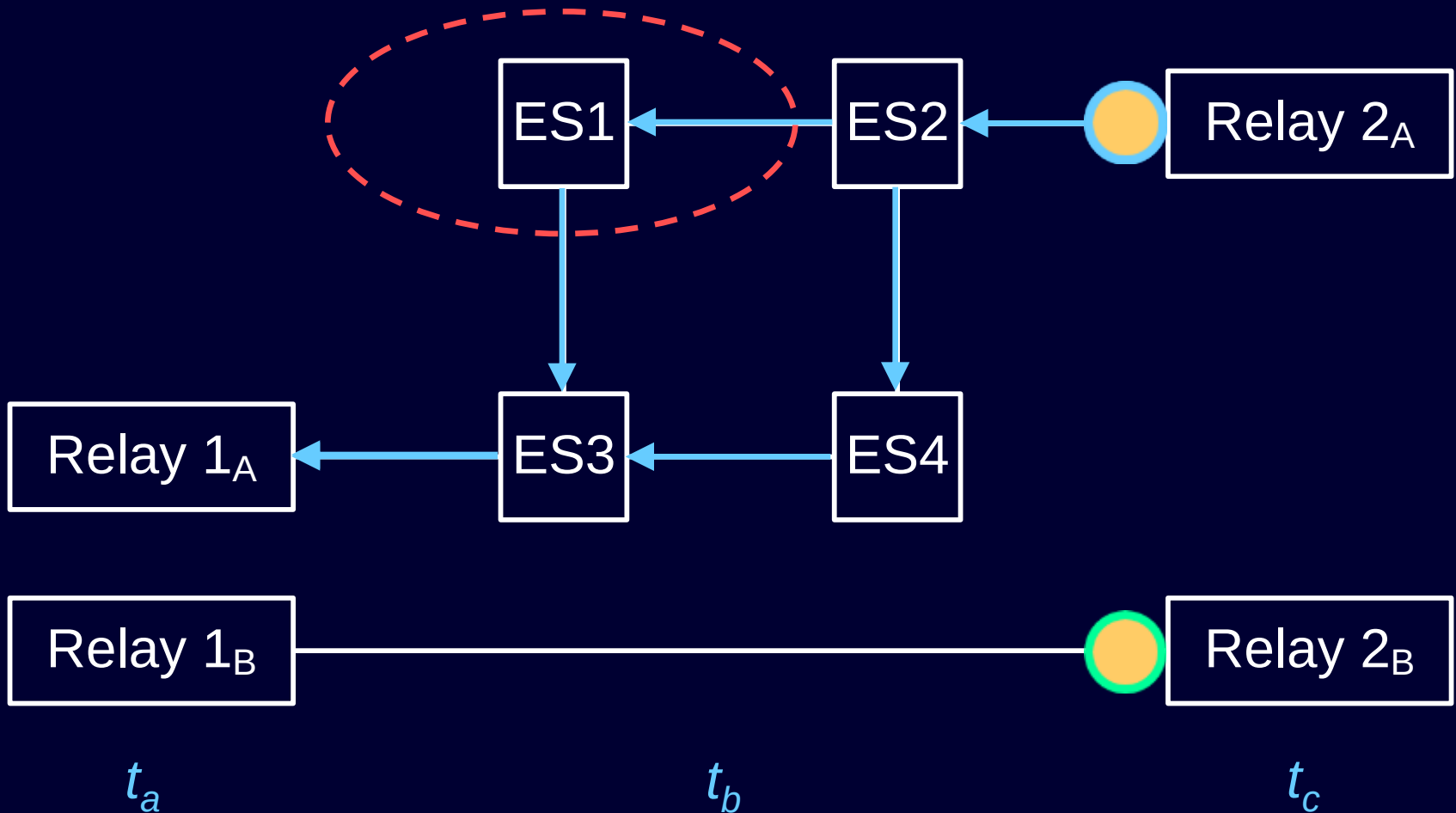
Dual primary LAN

Dual Primary Protection Applications

Redundant Application, Information, Message, Packet



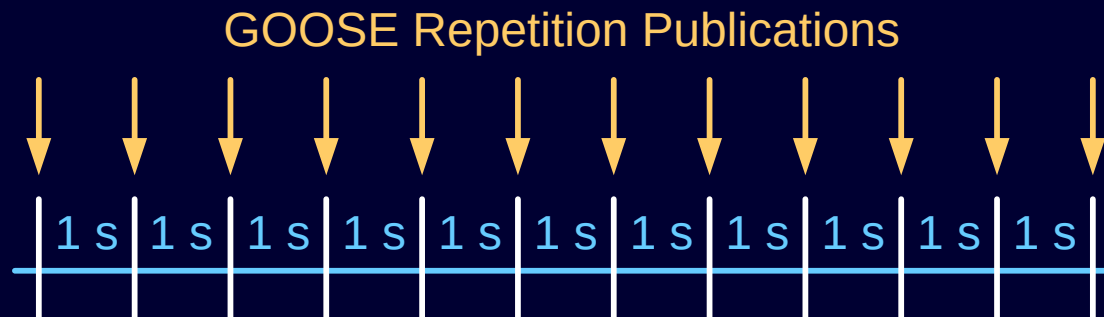
Reconfiguration Finds New Hot-Standby Path After Failure



ESn = Ethernet Switch

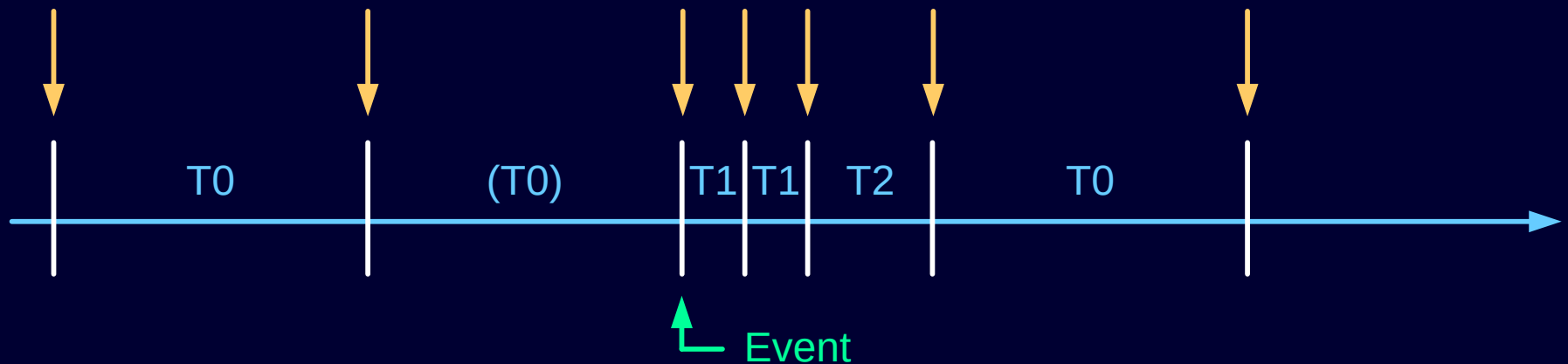
While Contents Remain Unchanged, Messages Are Published Periodically

- Repetition mode allows subscribers to supervise connection
- Fast repetition reduces time to detect failure but uses more bandwidth
- 1-second repetition is typical in Ethernet networks



GOOSE Retransmitted in a Burst After Change of State

- Retransmissions attempt to overcome network darkness
- Time between retransmissions grows to reduce network load

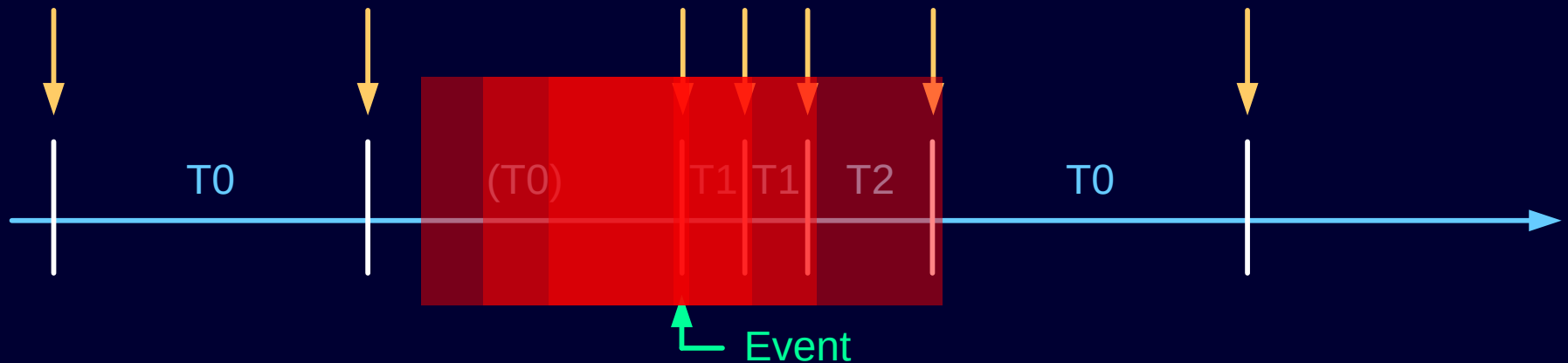


Immediate Signal Via GOOSE Among SEL Devices Measured at < 14 ms

Signaling Messages	Recovery Time	Transfer Time	Trip Time DI to DO
1st (t_0)	No failure	< 3 ms	< 14 ms

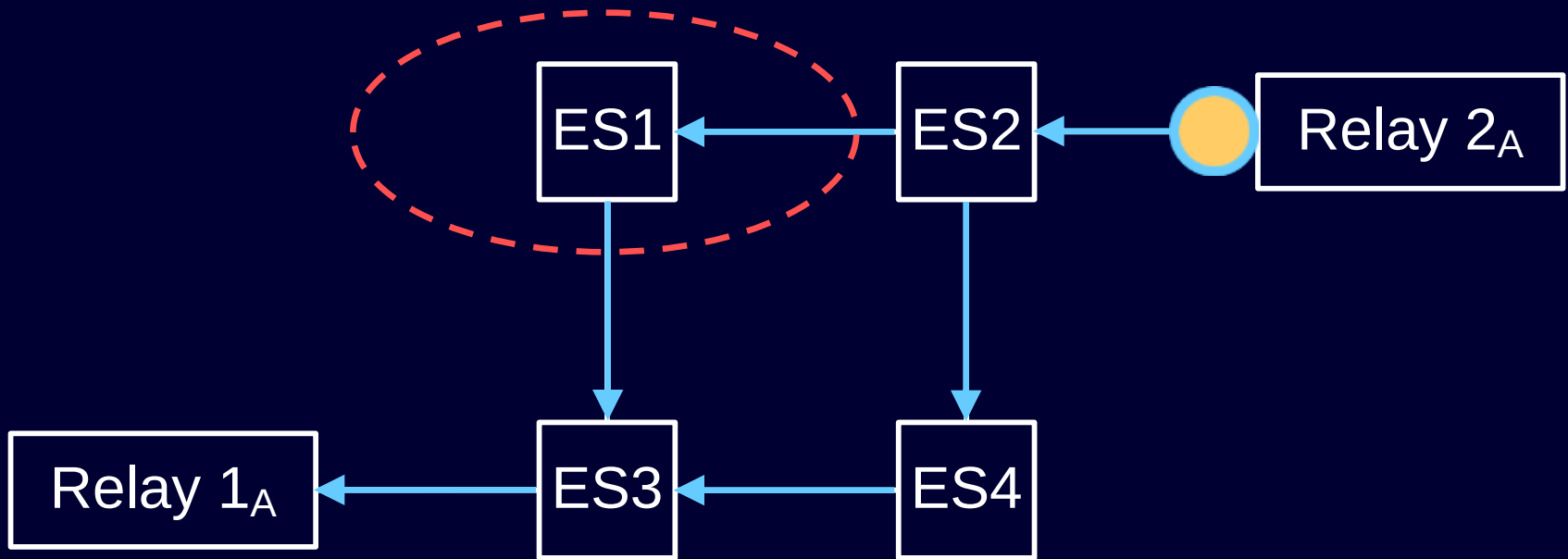
Periods of Darkness Can Overlap Numerous Retransmissions

When all retransmissions are dropped, signal does not work



Example: 4, 4, and 8 ms retransmission times and 17 ms period of darkness

Fast Reconfiguration Reduces Likelihood of Packet Loss

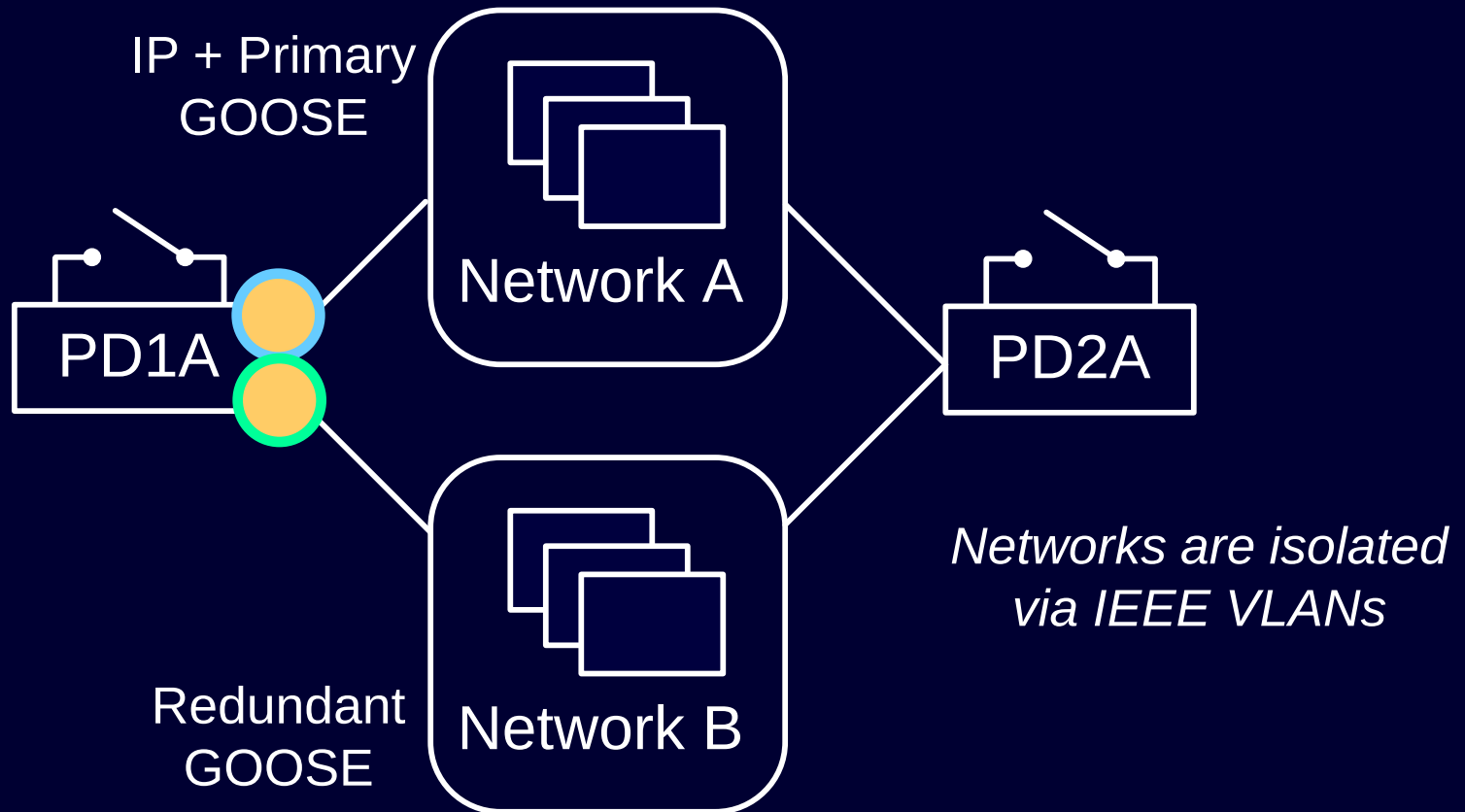


Zero Information Loss as Long as Network Recovers in < 15 ms

Signaling Messages	Recovery Time	Transfer Time	Trip Time DI to DO
1st (t_0)	No failure	< 3 ms	< 14 ms
2nd ($t_0 + 4$ ms)	< 3 ms	< 8 ms	< 18 ms
3rd ($t_0 + 8$ ms)	< 7 ms	< 12 ms	< 22 ms
4th ($t_0 + 16$ ms)	< 15 ms	< 20 ms	< 30 ms

Duplicate Information in Datasets

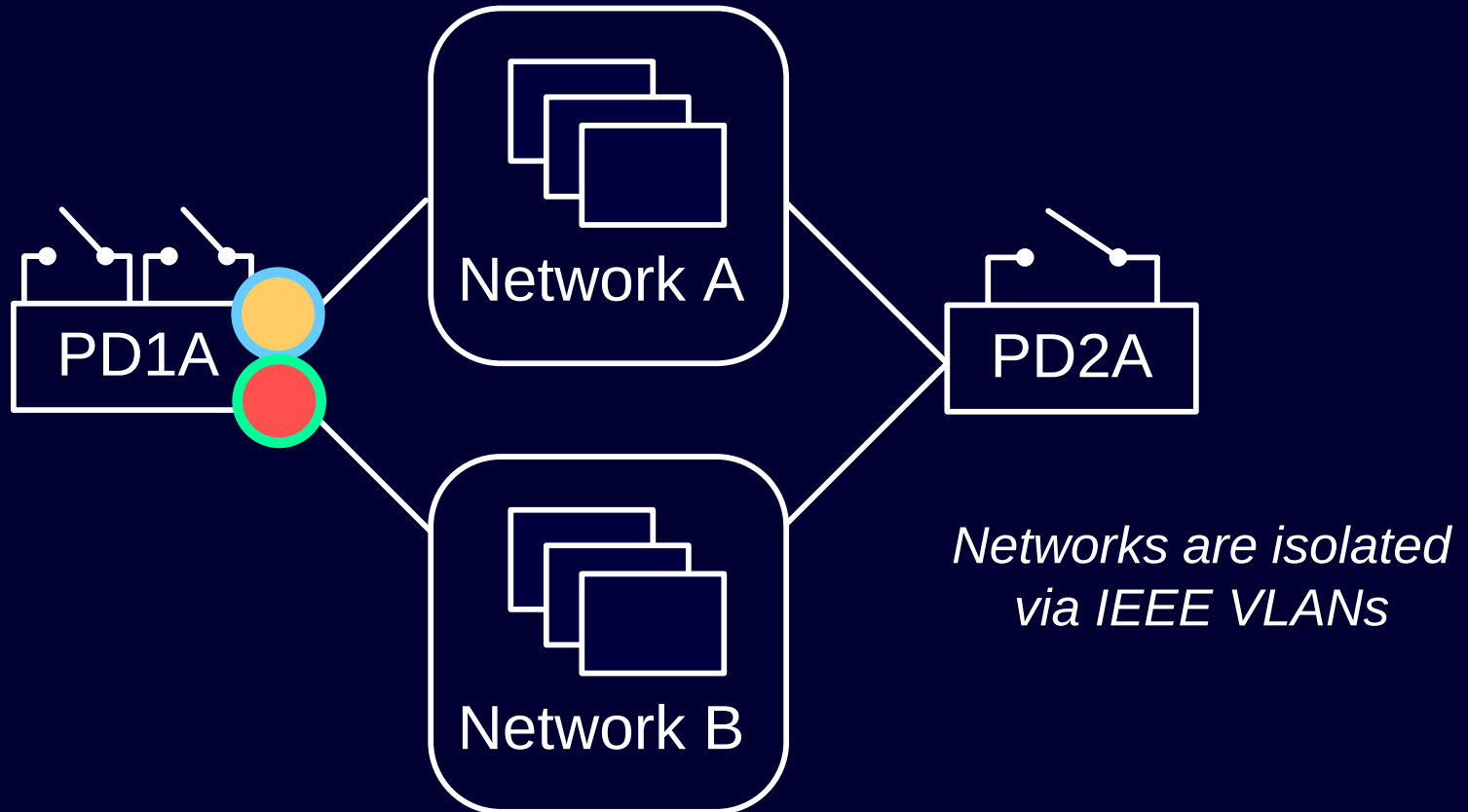
Redundant Message and Packet



Single application, single input, dual primary GOOSE

Dual Primary Dataset

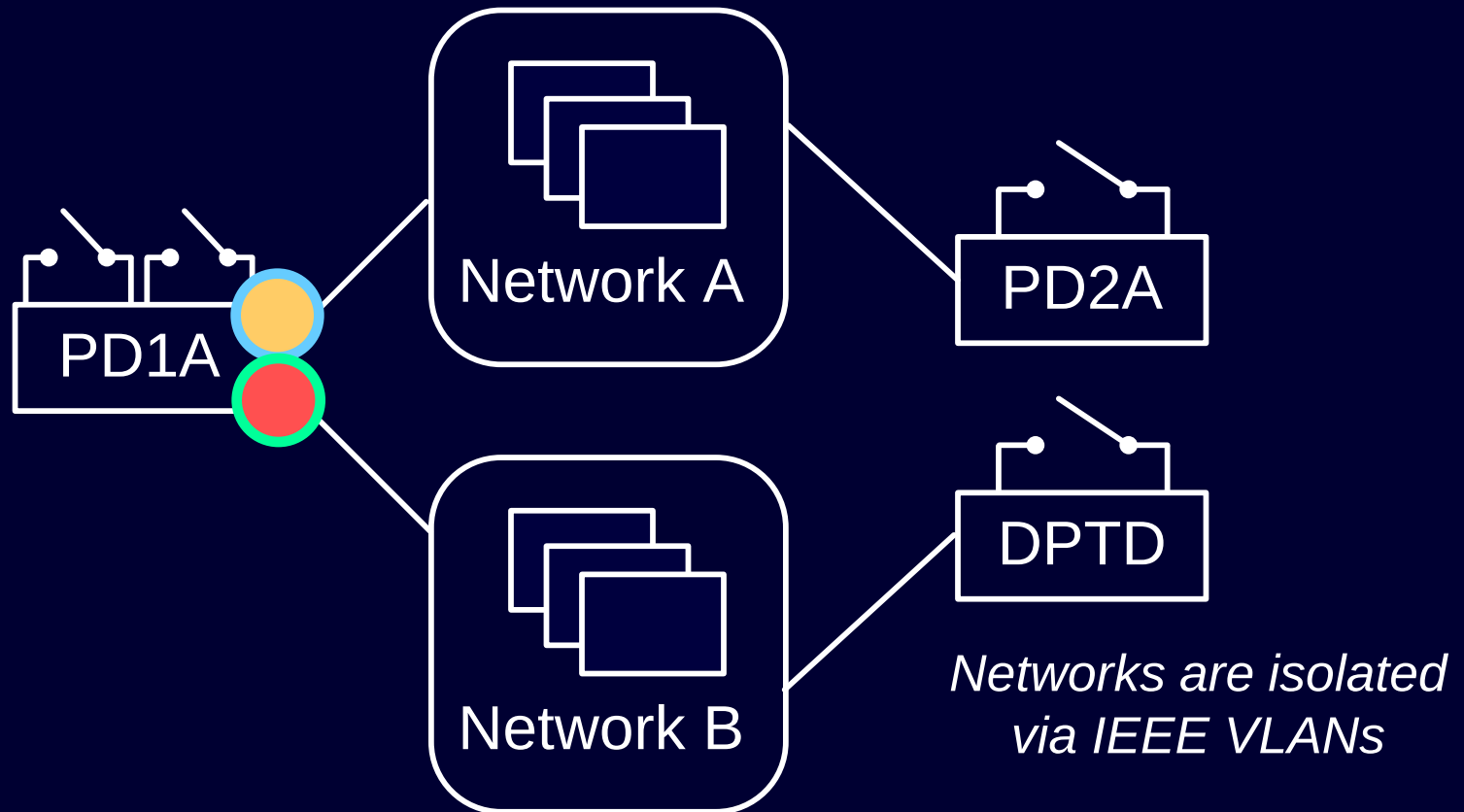
Redundant Information, Message, and Packet



Single application, redundant input, dual primary GOOSE

Dual Primary Dataset

Redundant Information, Message, and Packet

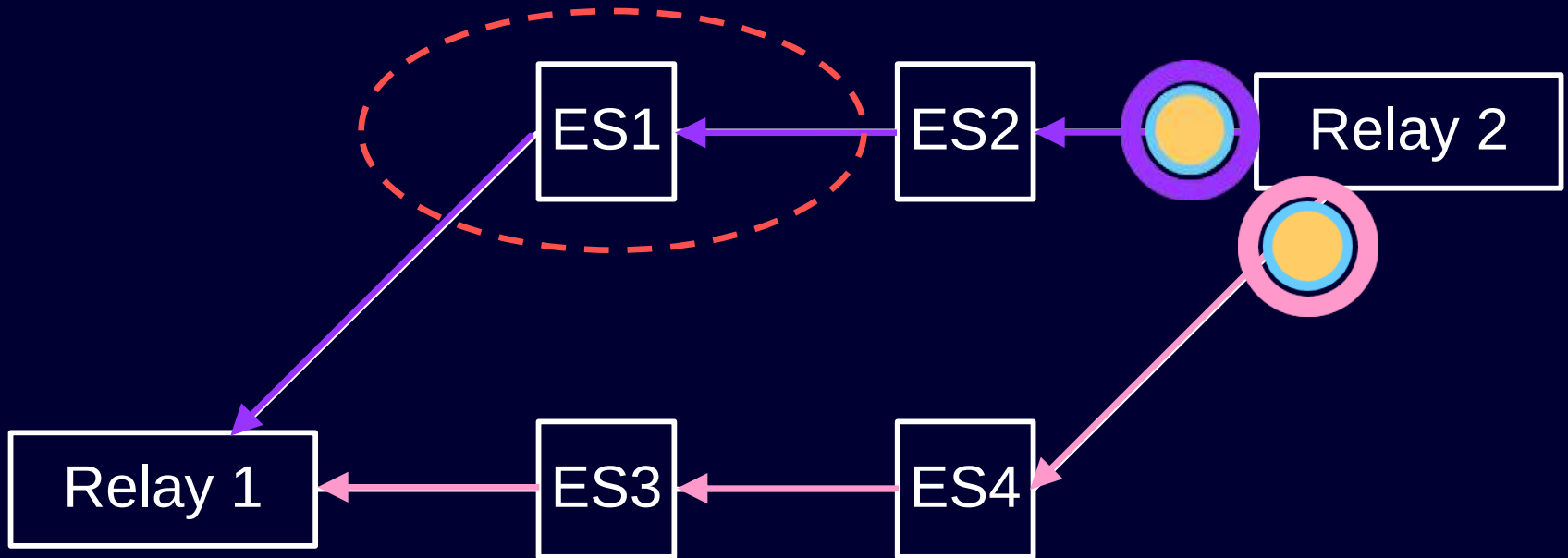


Partial redundant applications

Managing LAN Separation With VLANs Is Simplest and Most Effective

- All Ethernet switches and IEC 61850 devices already support VLANs
- Adding second network for redundant GOOSE is simple (provides redundant information, message, and packet)
- Same VLAN methods work in both LANs
- HSR and PRP only duplicate packets
- Only VLANs will work in SDN LANs

IEC 62439-3 PRP Overcomes Single Network Failure



PRP adds additional tag to packet

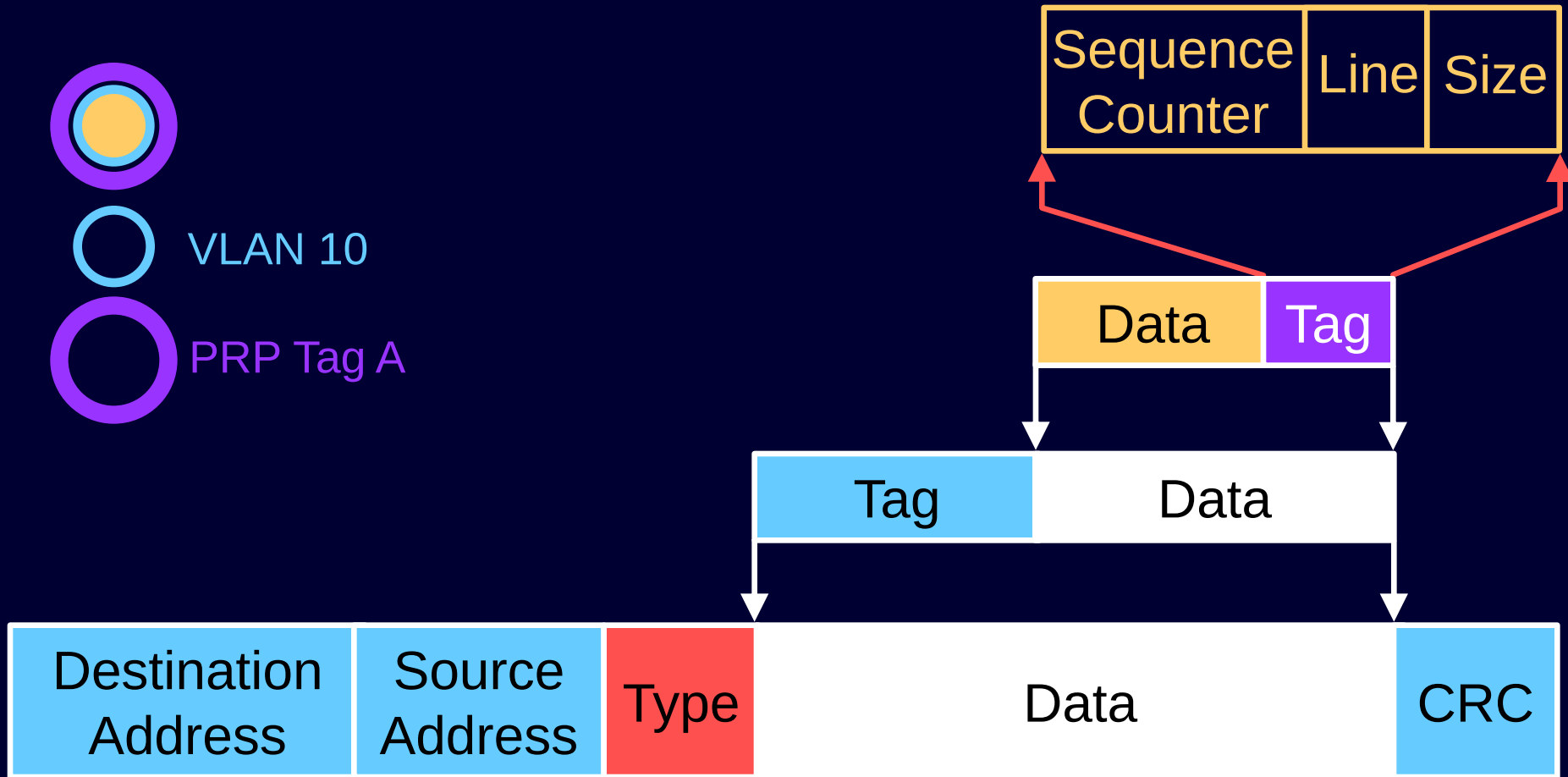
PRP Adds Another Tag at End of Packet and Maintains Integrity of Ethernet



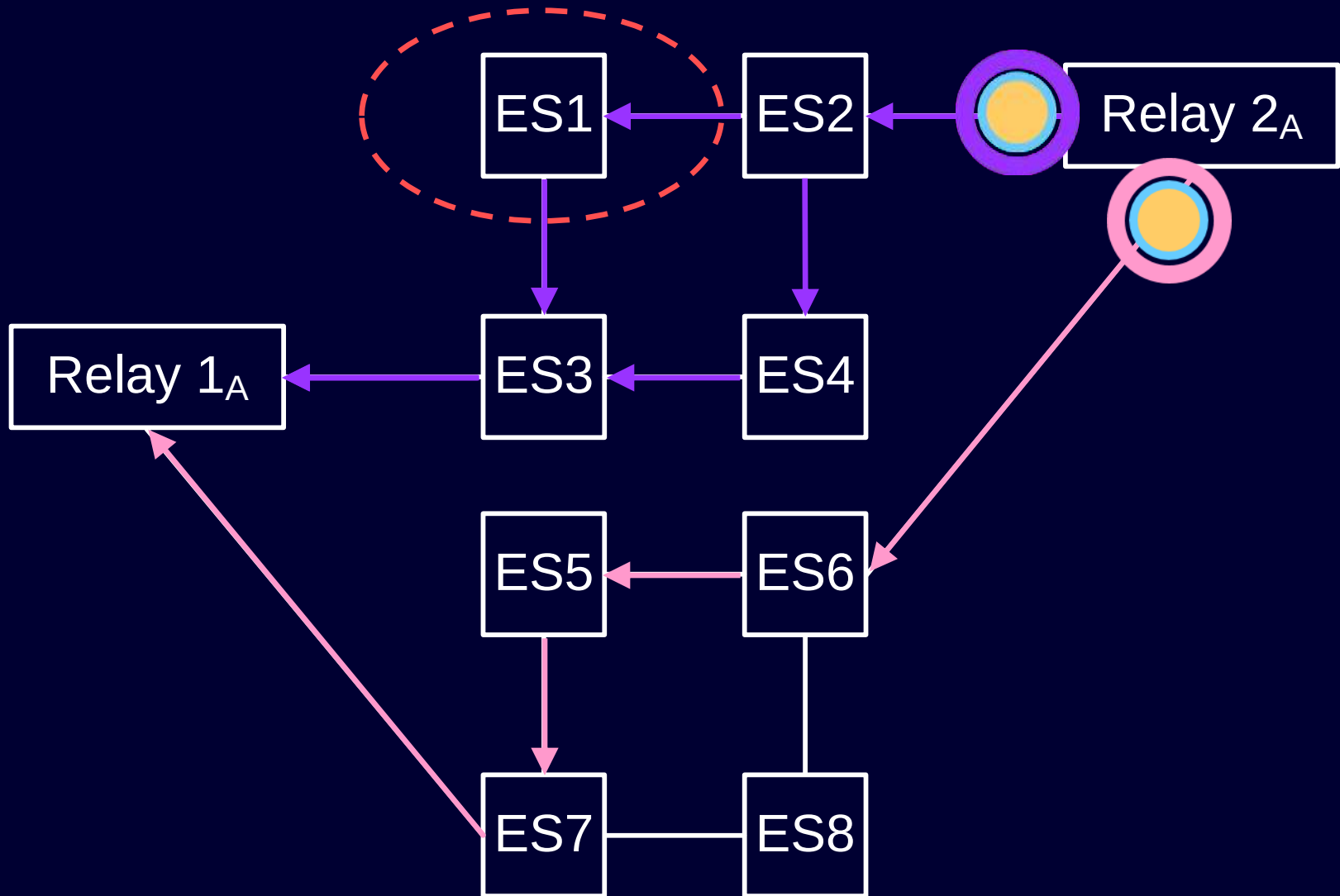
VLAN 10



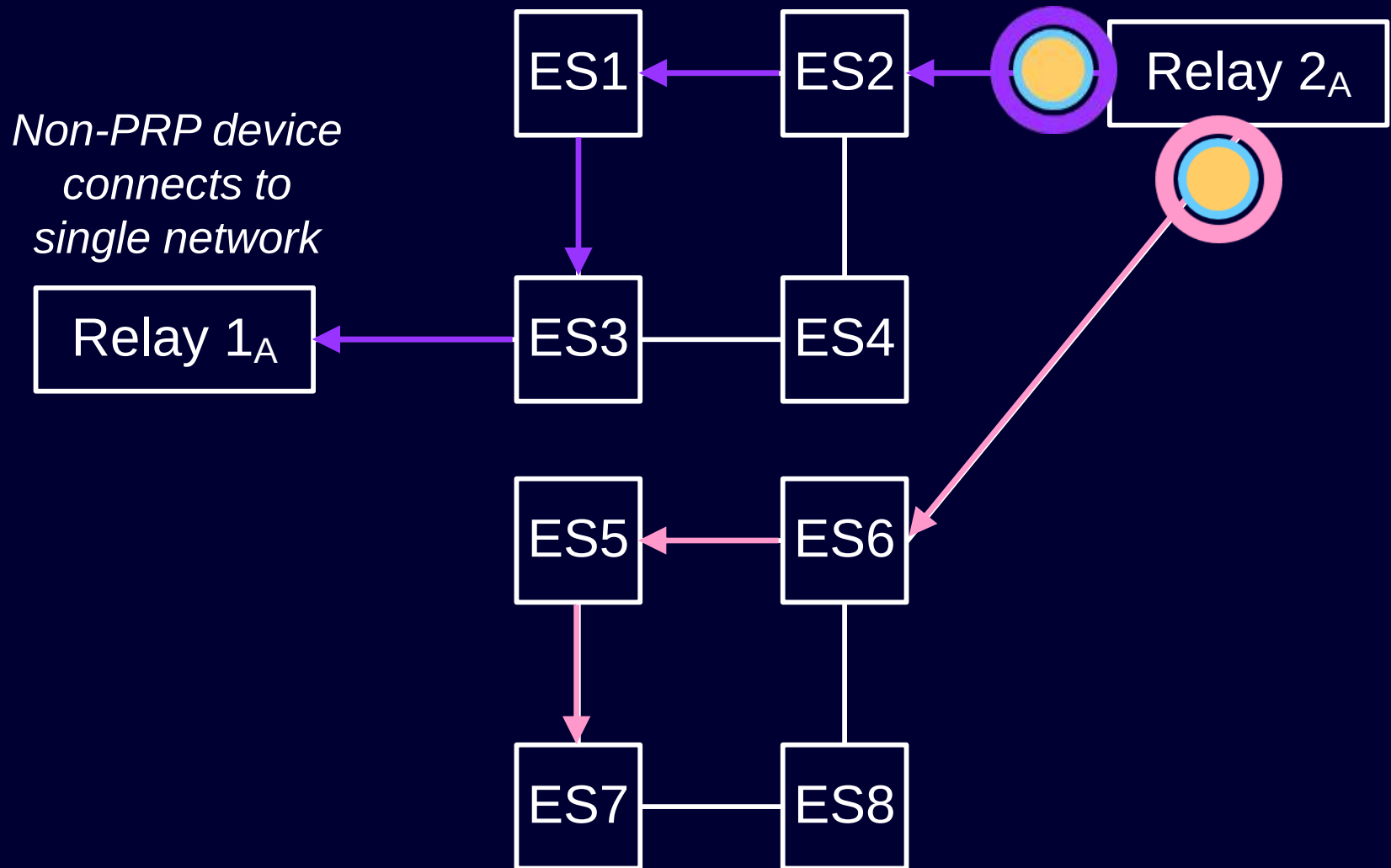
PRP Tag A



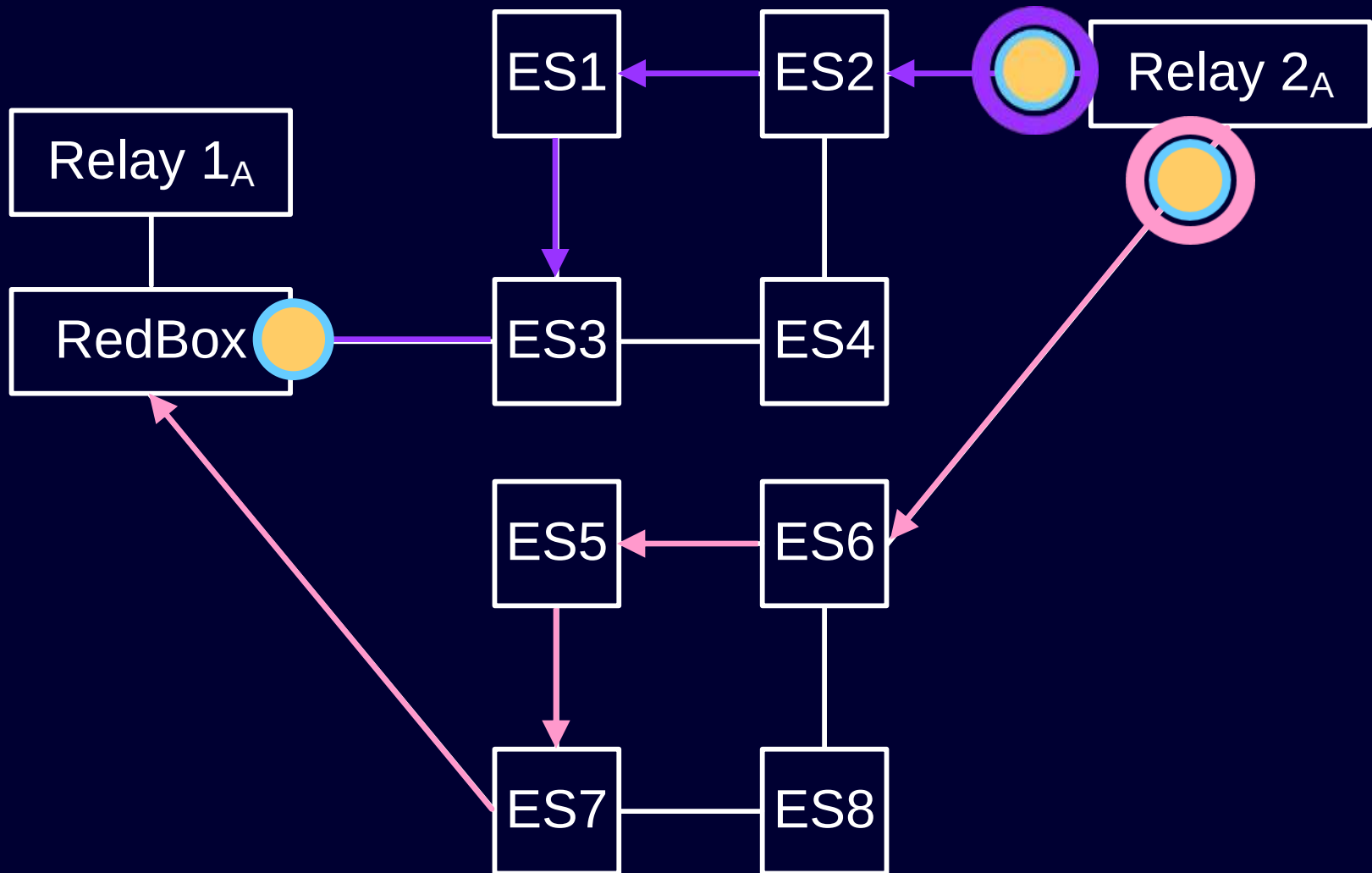
PRP Plus RSTP Further Reduces Likelihood of Dropped Packets



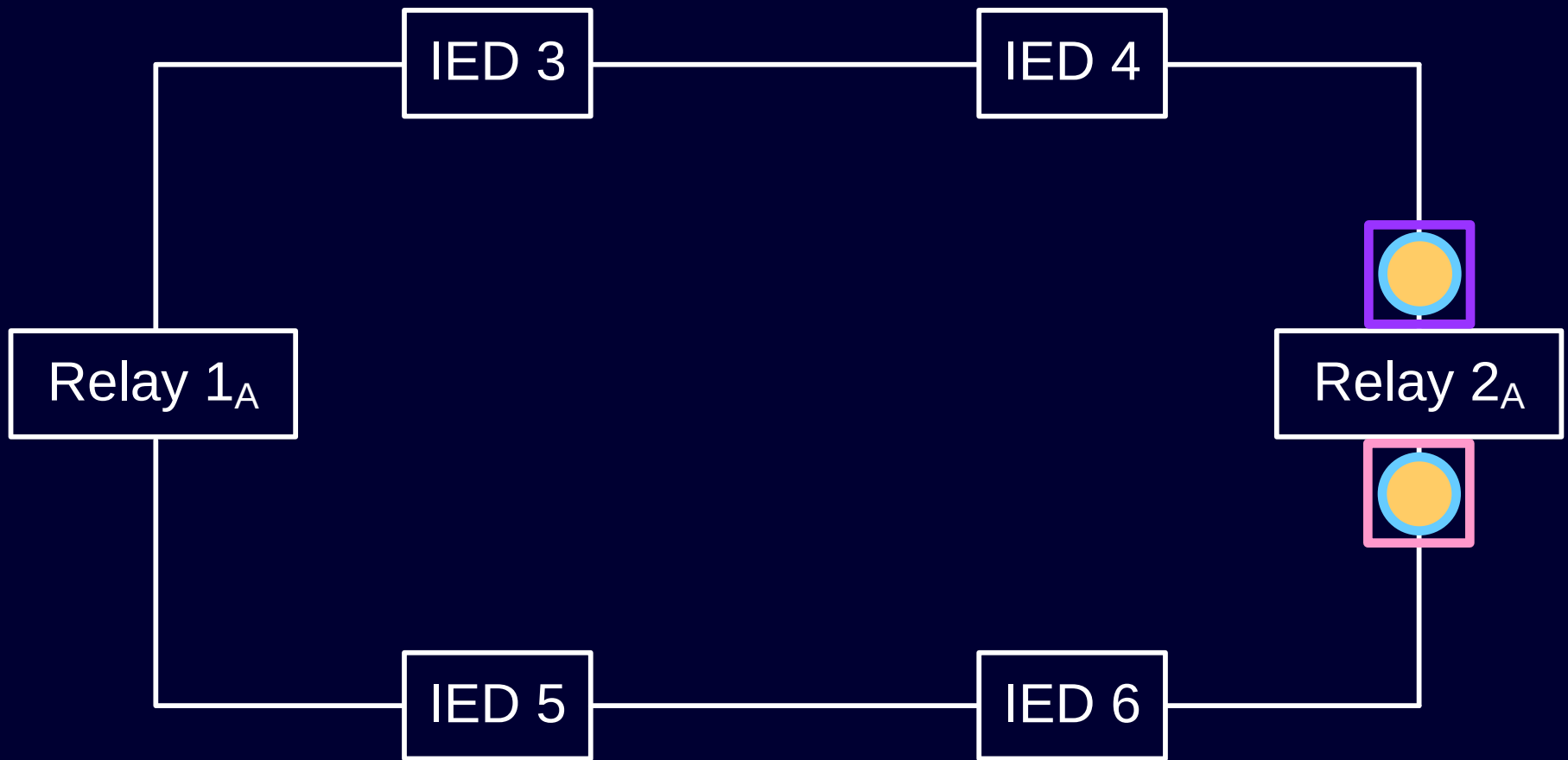
Traditional Non-PRP Devices Can Accept Single PRP Ethernet Message



PRP Redundancy Box (RedBox) Dual Connects Traditional Devices

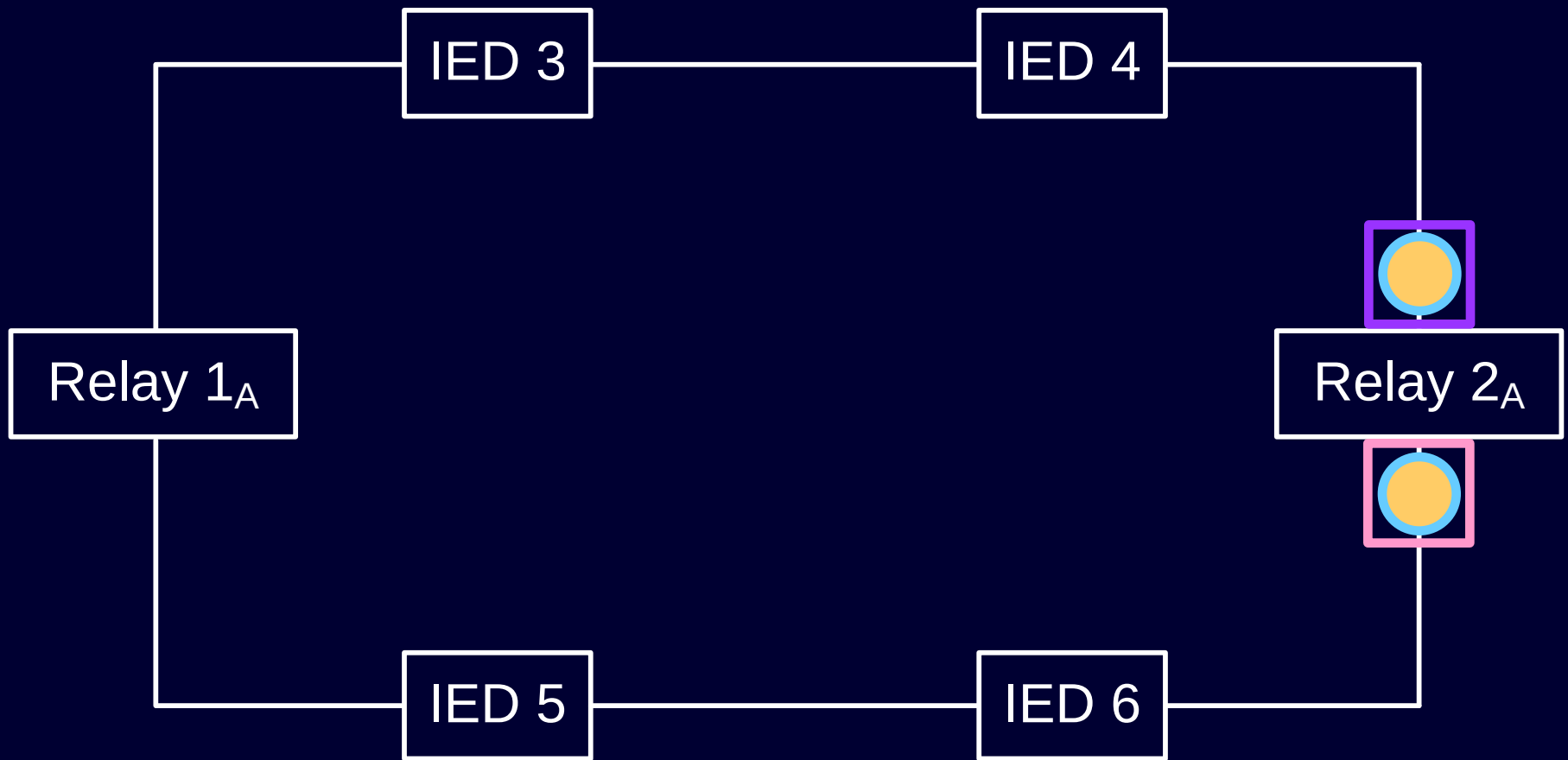


IEC 62439-3 HSR Adds Tag to Outside of Packet, No Longer Ethernet

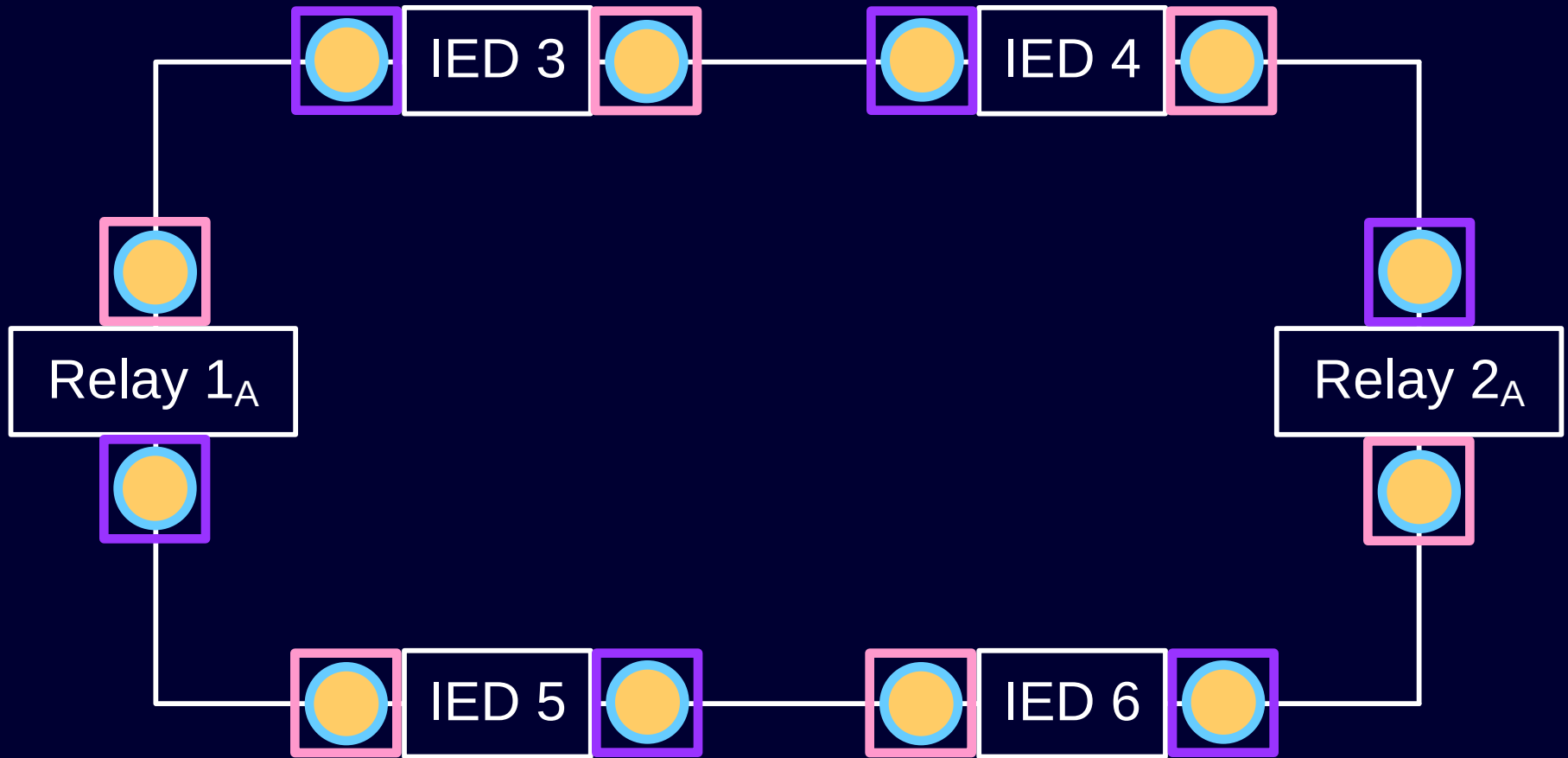


HSR mimics ICON[®] dual rotating messages

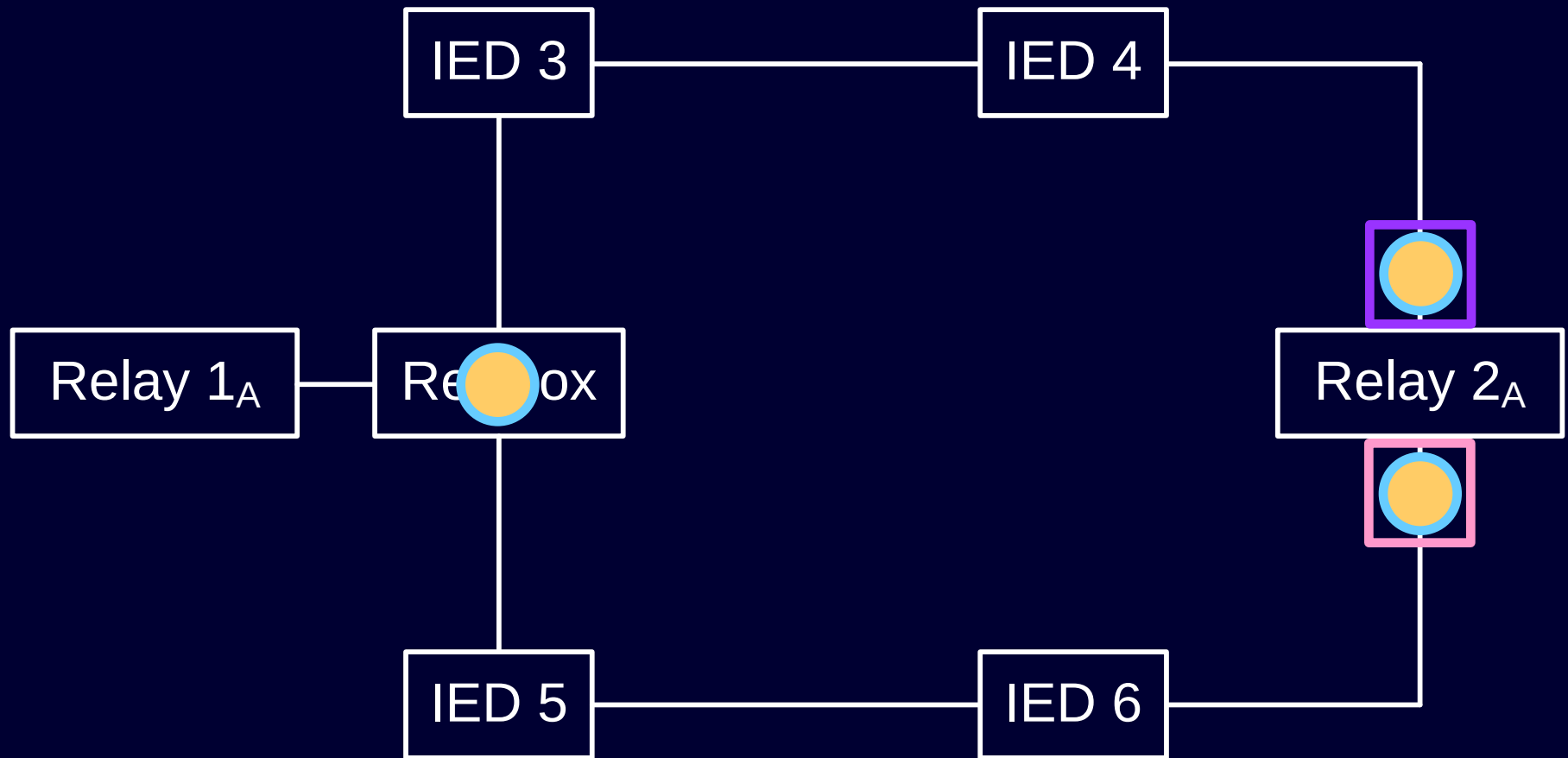
GOOSE Signal Passes Through Each Device, Each Device Causes Latency



Each Device Must Process Each Message Which Increases Burden



IEC 62439-3 HSR RedBox Connects Traditional Devices



HSR copies TDM dual rotating messages

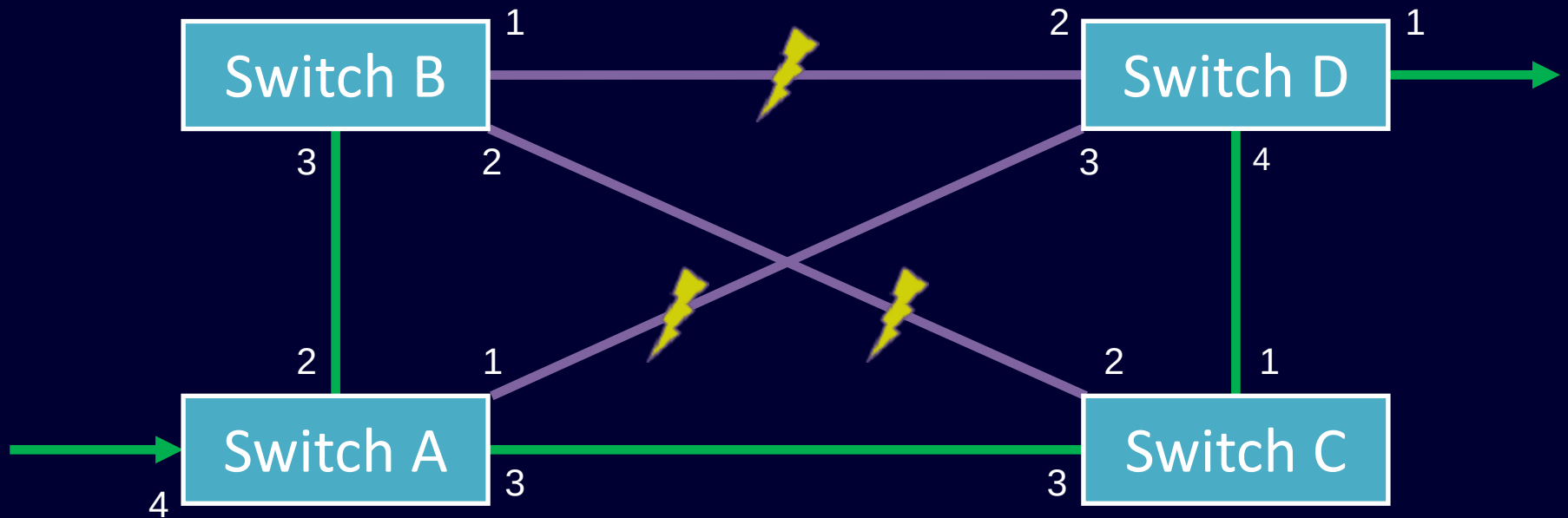
SDN Allows Dual Primary Connections to One Network

Redundant Information, Message, and Packet



Both IED links Active

SDN Network Performs Reconfiguration in Microseconds



Numerous reconfiguration choices

Good, Bad, and Ugly Redundancy

- VLANs – simple Ethernet network plus redundant GOOSE network, any device
- VLANs – same methods work in SDN
- HSR – no network, duplicate messages, only HSR devices*
- PRP – duplicate Ethernet networks, duplicate GOOSE, only PRP devices*

*RedBox can connect traditional devices