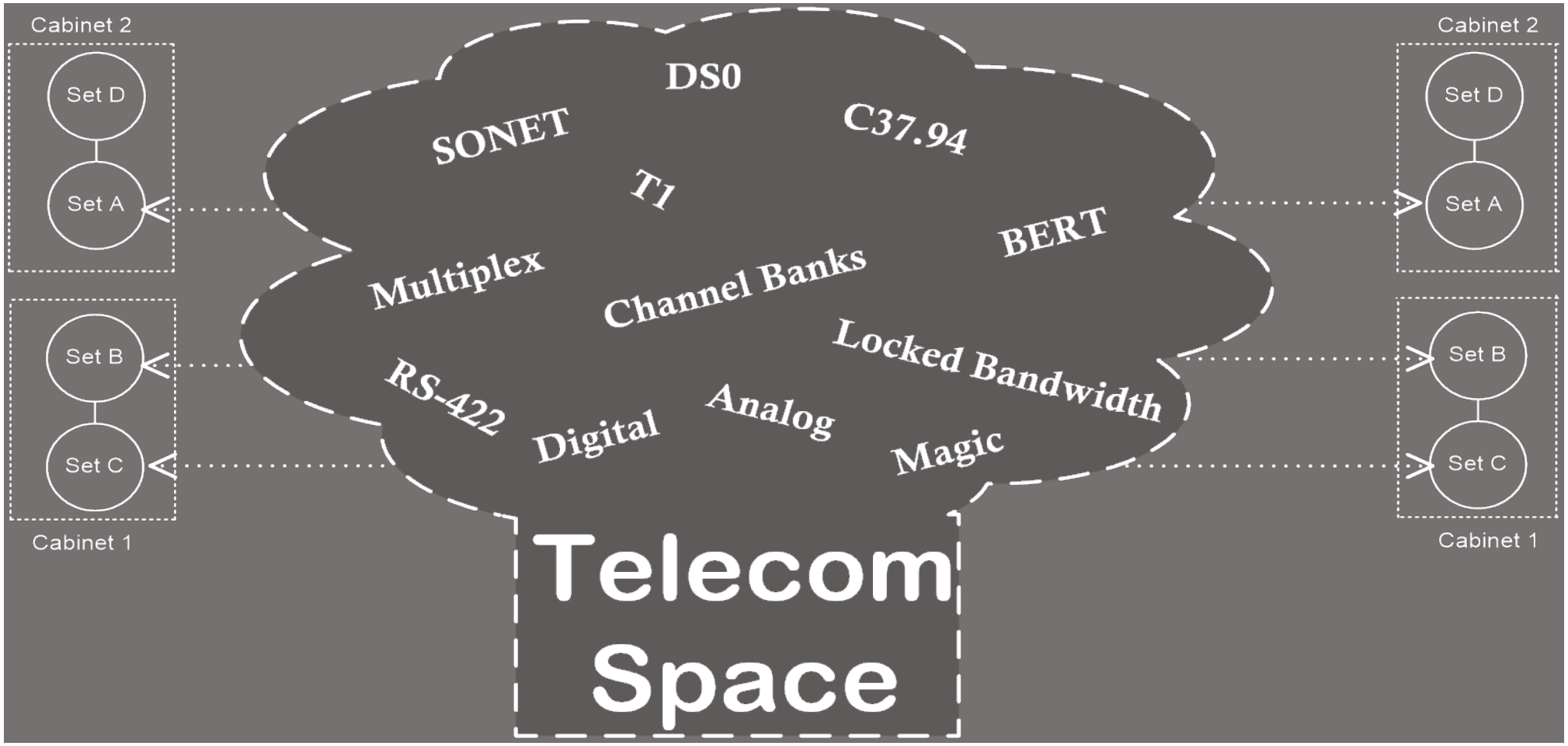

Review of Digital Substation Communication Technologies

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Introduction

- Digital substations instead of copper wiring rely on the exchange of electrical signals represented as values in data communication streams

- Sufficient understanding and proper selection of communication technology and architecture are critical in achieving required availability and reliability levels dictated by the protection and control applications

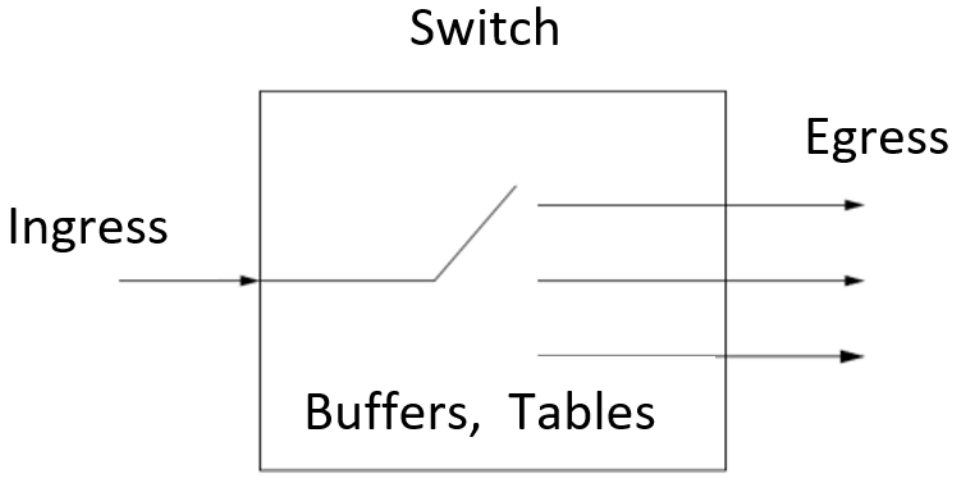
- Review and guidance on communication technologies used for digital substations is very timely, as the number of projects grows

Paper Content

- Communication Technologies used for Digital Substations
  - Communication fundamentals
  - Layer 2 Ethernet – the Standard digital substation communication technology
  - Software Defined Networking (SDN)
- Communication Redundancy Technologies
  - With data losses (RSTP, SONET)
  - Without data losses (PRP, HSR)
- Communication Architecture Considerations
  - Point to point vs switched
  - Consolidation of networks and functions
- Considerations from the deployed Digital Substation projects

Ethernet: a Switched Communication Channel

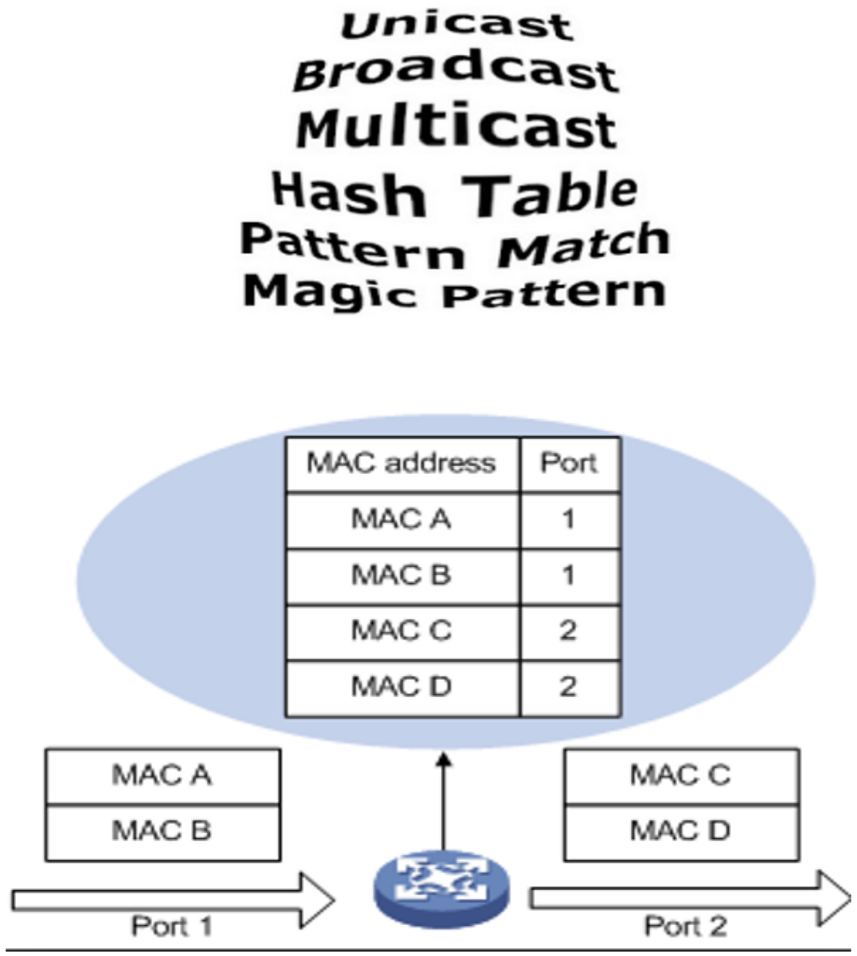
- Dedicated and multiplexed communication channels have dedicated resources assigned to data exchange between transmitter and receiver
- Ethernet operates as a Switched Channel and its performance depends on resources availability.



Ethernet applied to Digital Substations

- Binary and analog values in digital substations are encapsulated into Ethernet frames transmitted over fiber optic cable
- Values are multicasted (sent from one source to many recipients)
- Binary data on status change is repeatedly re-transmitted at randomized intervals
- Priority feature allocates internal resources to critical data
  - Default Priority level for both analog and binary data is 4 (out of 8 levels)
- Data forwarding (without broadcasting) at wire speed is achievable

Ethernet Data Forwarding



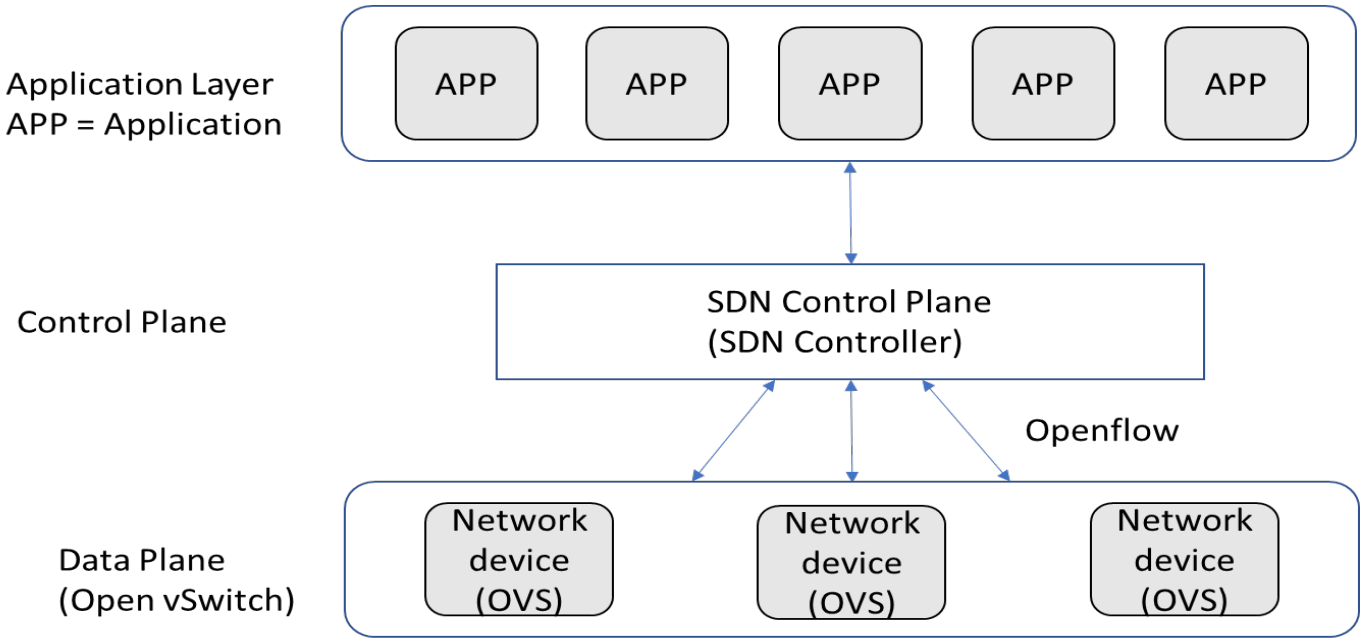
- Buffer space is needed to store full frame (for store-and-forward method)
- For correct data forwarding, quick and accurate search mechanism is needed.
- Inaccurate forwarding leads to unnecessary broadcasts that reduce bandwidth and can cause denial-of-service.
- Hash Tables have collisions causing broadcasts, while Content Addressable Memory (CAM) is precise and preferred.

Ethernet Switch Design Considerations

- A well-structured and sufficient internal data buffering
- Large well-designed MAC Address Table, CAM chip is preferred
- Robust queue management for 4 or 8 IEEE 802.1Q priority levels
- Proper forwarding of Priority only frames with IEEE 802.1Q tags' VLAN ID = 0 (maybe disabled by default and needs to be enabled)

Standard mindfully designed Ethernet switches, with minimal settings meet the requirements of digital substation applications

Software Defined Networking

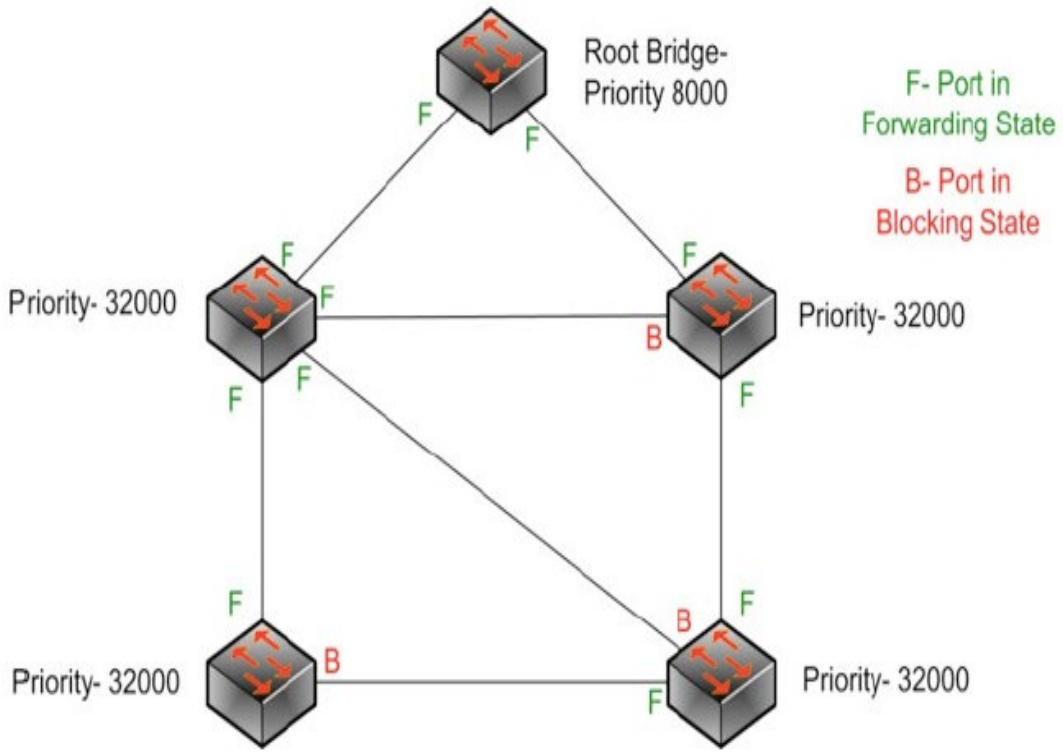


- Adds a Control Plane and per stream configuration
- Utilizes the same standard Ethernet features
- Not standardized for communication in digital substations

Communication Redundancy: WITH data losses

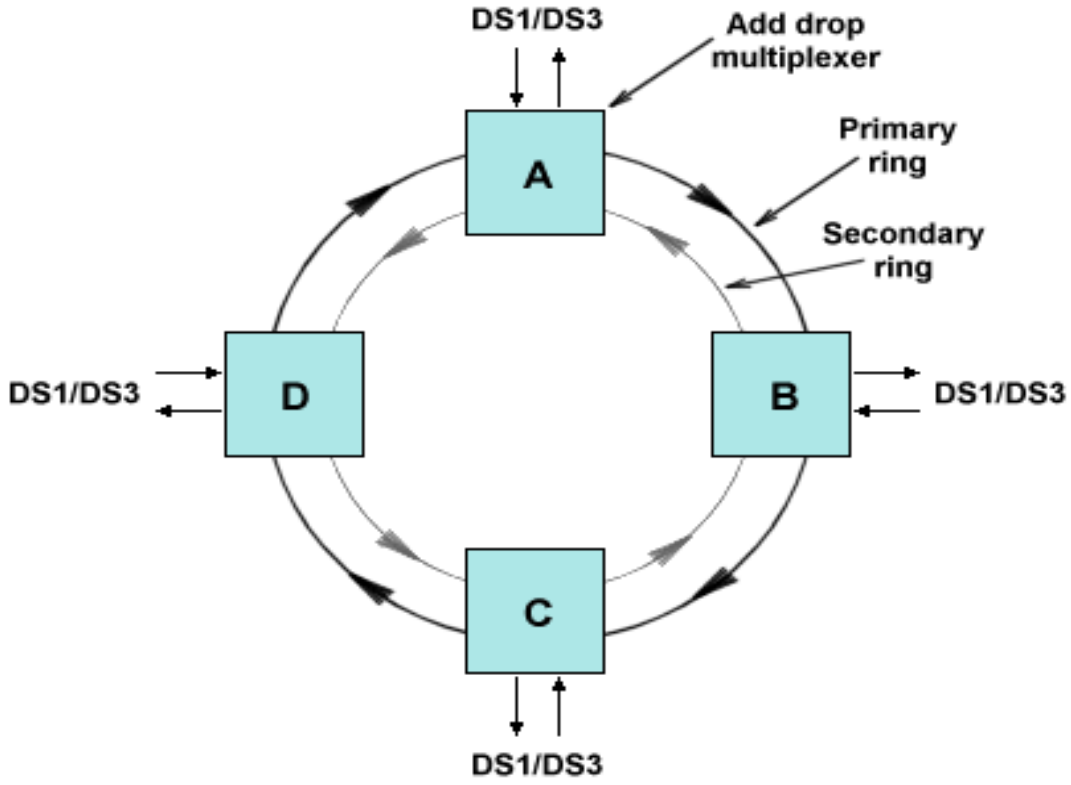
Spanning Trees:

Min loss is 5ms per network hop



SONET:

Typically 50ms per system

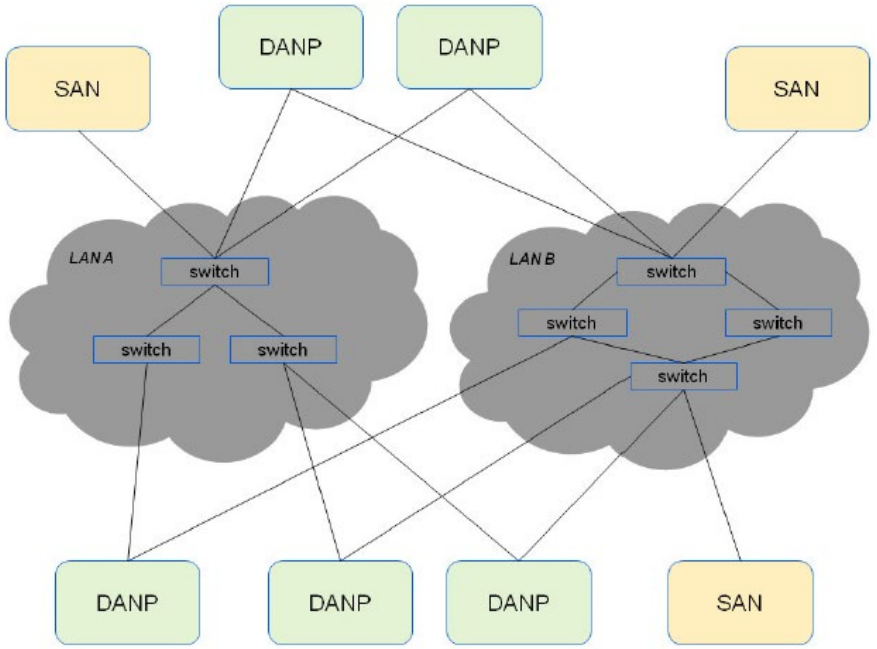


Can change path for both data direction after single fiber cut

Communication Redundancy: with NO losses

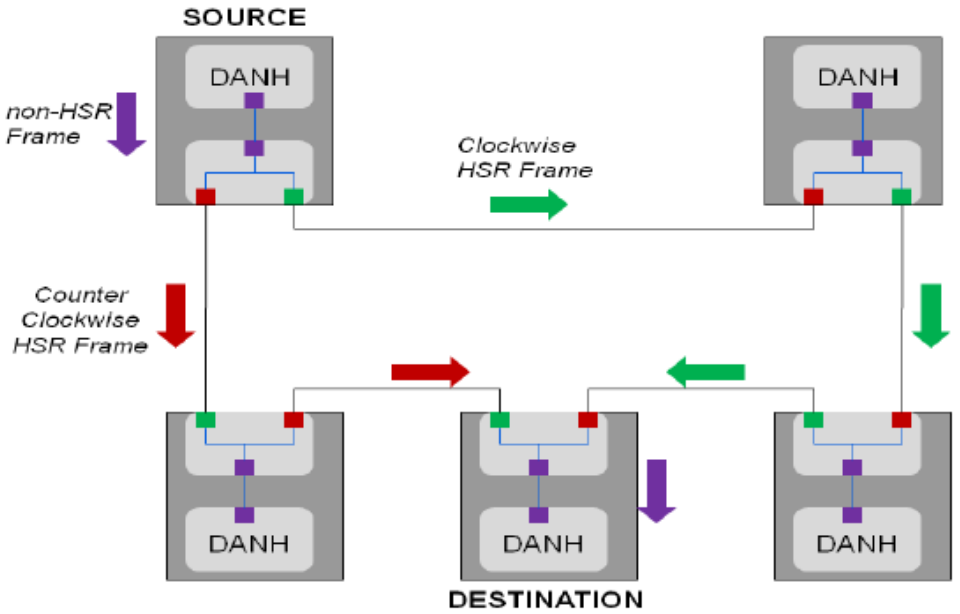
PRP:

LAN A and LAN B



HSR:

Ring Configurations



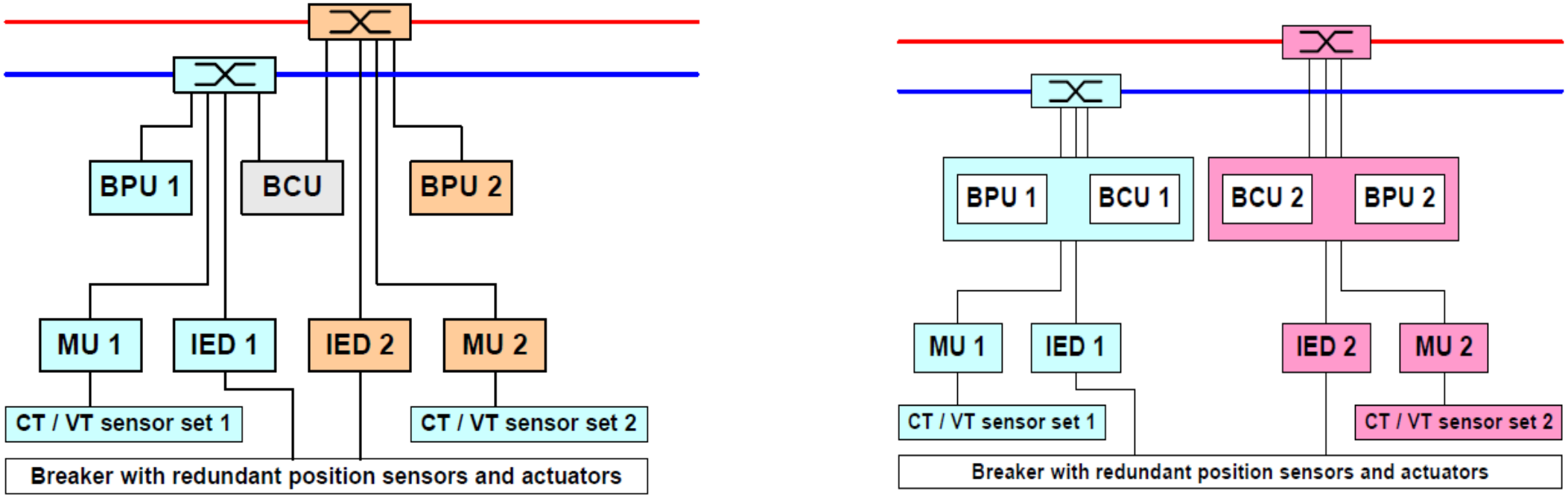
Why use methods with data losses when no loss redundancy is standardized and available ?

Communication Architecture Considerations

- Both point-to-point and switched communication architectures are used
- While point-to-point connections have highest availability, they do not use communication resources efficiently.
- Switched architectures provide more efficient use of resources. They also support data streaming to multiple locations which, per PRC-005-2, can assist with reducing or even eliminating periodic maintenance testing.
- Use of switches (as any other additional devices) decrease overall system's MTBF, so optimization of architectures is desirable.

Communication Architecture Considerations

- Studies and MTBF calculations showed that simplified architectures with reduced number of switches provide higher reliability and support redundancy. Functions and future network consolidation are suggested



Source: L. Andersson, K-P Brand, Ch. Brunner, W. Wimmer "Reliability investigations for SA communication architectures based on IEC 61850", PowerTech, June 2005, St-Petersburg, Russia

Conclusions

- Layer 2 Ethernet is standardized as communication technology for digital substation applications, including frame format, data transmission rates, etc.
- Both point-to-point and switched communication architectures are possible and used, each has its pros and cons
- For best performance, mindfully designed Ethernet switches are needed: well-organized data buffering, accurate forwarding tables, priorities support
- Networks with well-designed Ethernet switches with few settings meet requirements of protection and control applications in digital substations.

Thank you !