

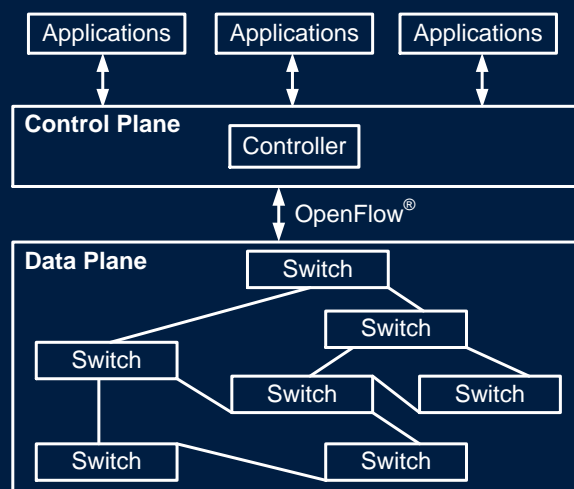
# Improve Protection Communications Network Reliability Through Software-Defined Process Bus

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## Understand SDN Architecture

- Fast-growing network demands agility and intelligence
- SDN decouples network management and switch hardware
- Control and data plane manage SDN switches



## **SDN – Control Plane**

- Is a centralized controller
- Configures packet filter and forward rules
- Manages fleet of switches
- Requires less patch management
- Provides network statistics

## **SDN – Data Plane**

- Receives rules from control plane
- Executes packet filtering and forwarding rules
- Requires less processing burden
- Improves hardware reliability and performance

## Industrial Control System Demands

- Reliability
- Security
- Determinism
- Real-time performance

## SDN for OT Network

- Cybersecurity – deny by default
- Real-time performance
  - Monitor network health (e.g., congestions)
  - Improve hardware reliability and performance
- Purpose-engineered network path – multilayer packet inspection, filtering, and flexible path programming

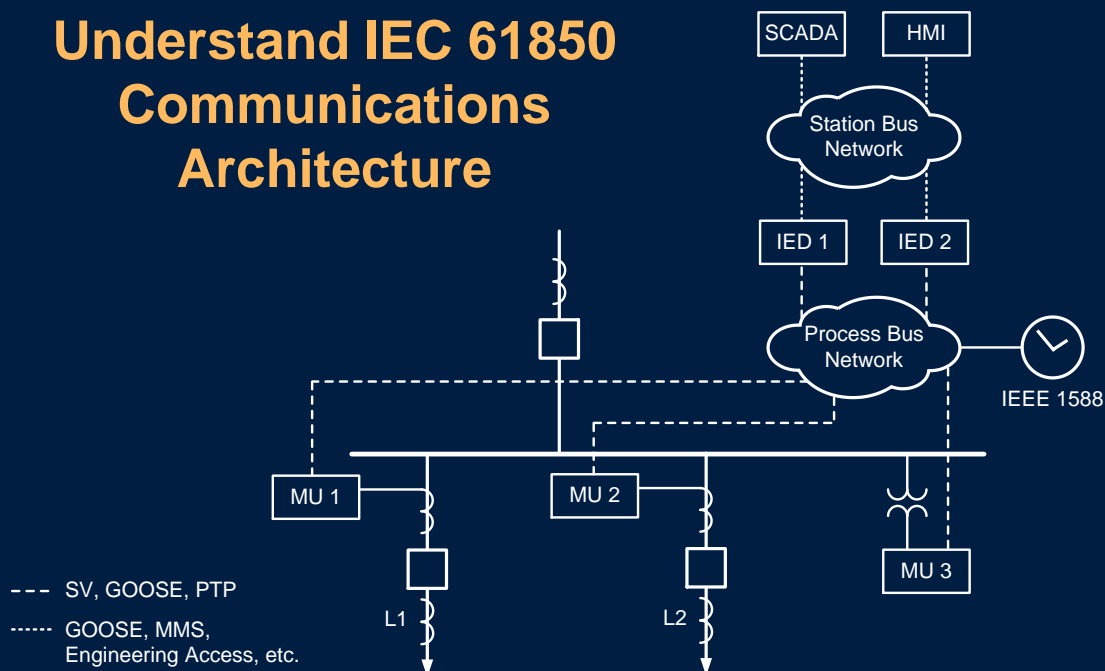
## OT SDN vs. IT SDN

Key Attribute	OT SDN	IT SDN
Network state	Persistent	Dynamic
Network control	Purpose-engineered	Traffic-reactive
Controller purpose following switch deployment	Monitor	Control
Security	Deny-by-default	Forward-by-default
Fault-healing speed	Link detect	Flow setup time
Network management	Proactively planned	Fault-reactive

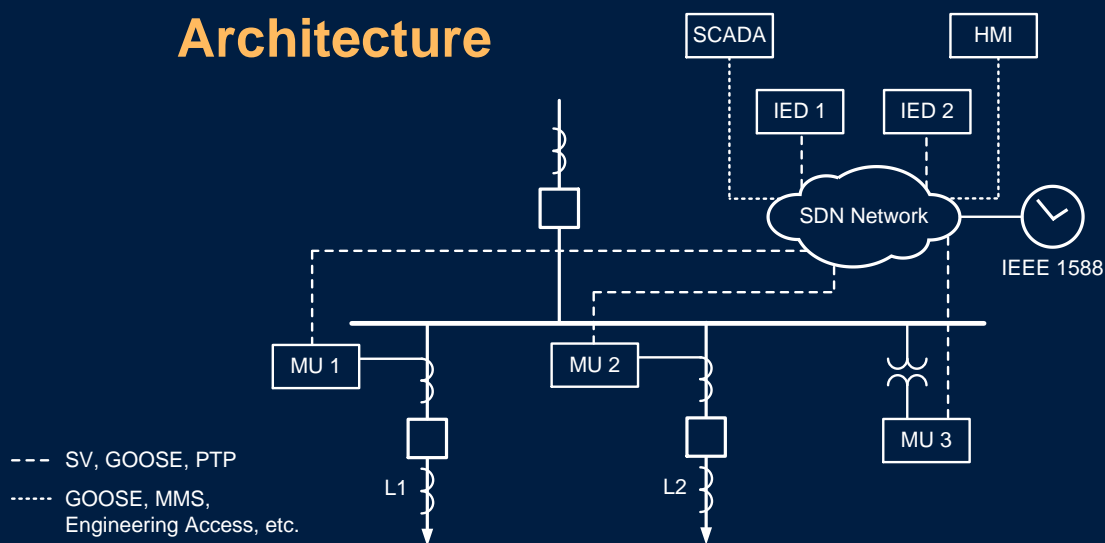
## Understand IEC 61850 Communications Architecture

- Time-critical messages
  - Sampled Values (SV) – transfer time <3ms
  - GOOSE
- Non-time-critical messages – Manufacturing Message Specification (MMS) and GOOSE
- Others – Simple Network Time Protocol (SNTP) and Precision Time Protocol (PTP)

# Understand IEC 61850 Communications Architecture



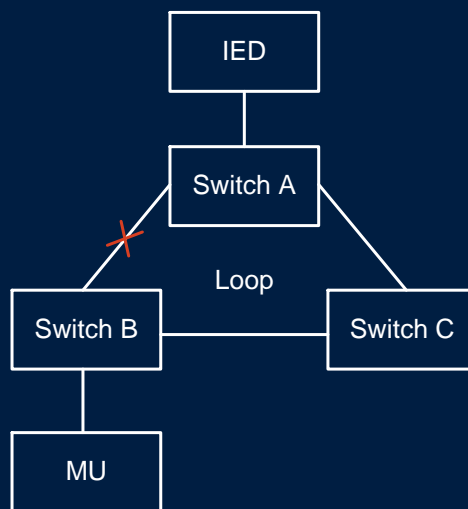
# Understand IEC 61850 Communications Architecture



## Understand IEC 61850 Communications Architecture

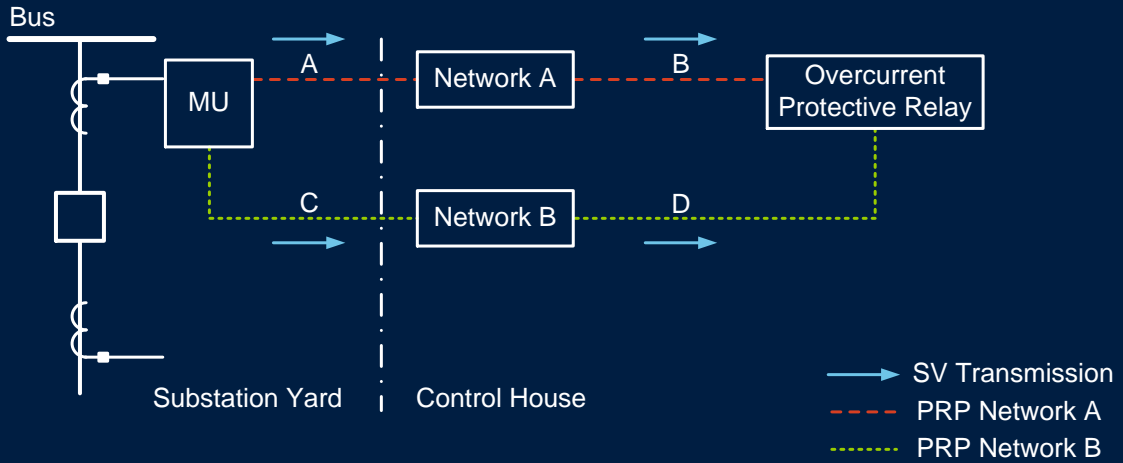
- Station bus and process bus
- Physically separated station bus and process bus
- Logically separated station bus and process bus

## Existing Methods for Network Healing Rapid Spanning Tree Protocol (RSTP)



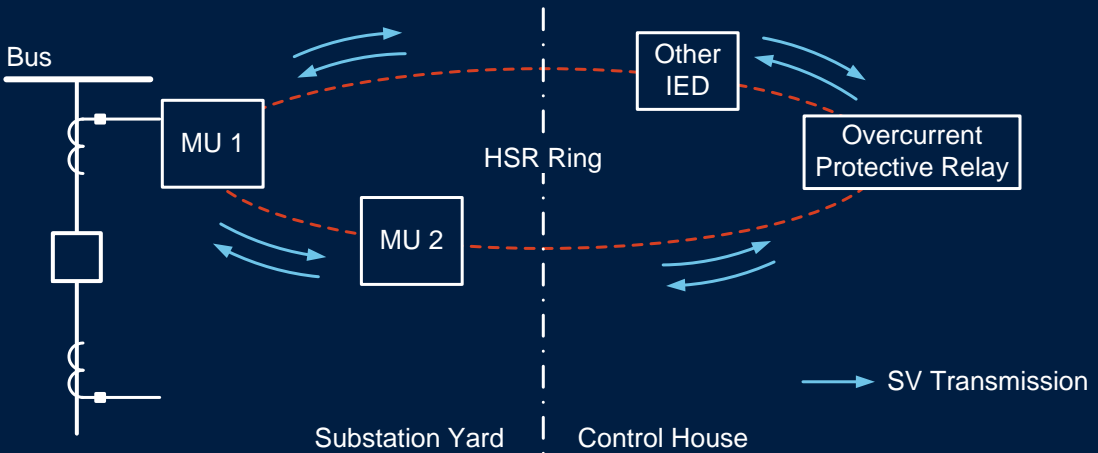
# Existing Methods for Network Redundancy

## Parallel Redundancy Protocol (PRP)



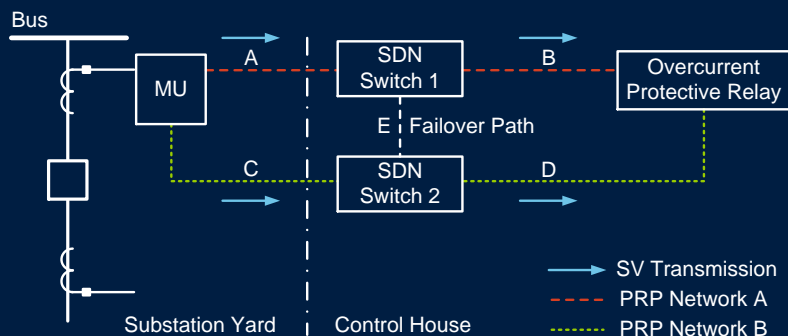
# Existing Methods for Network Redundancy

## High-Availability Seamless Redundancy (HSR)

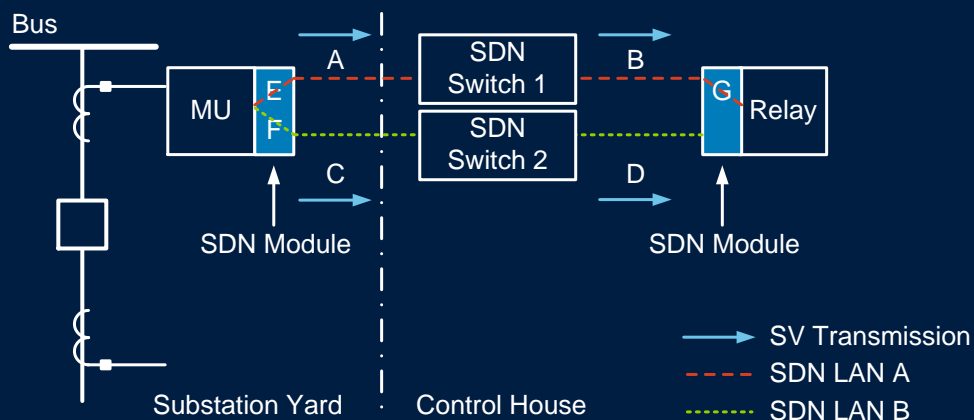


# Use SDN to Improve PRP Network Reliability

- Enhance PRP network availability
- Consider example
  - Path A and D or Path B and C are not available
  - Failover path delivers packet



# One Controller Manages SDN Modules and Switches

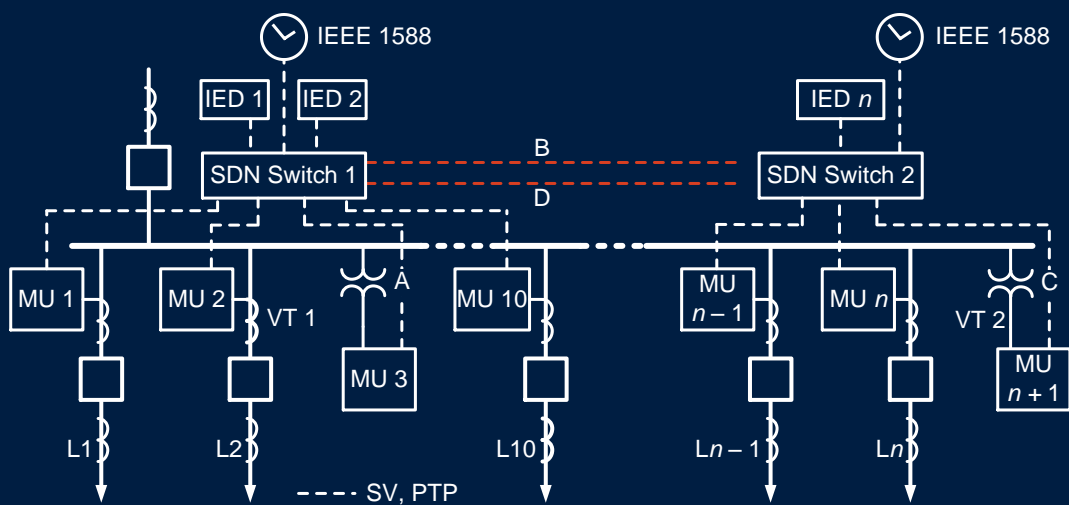




## Apply SDN to Improve Instrument Transformer Signal Availability Via Data Sharing

- SV delivers instrument transformer measurements
- SDN shares SV between applications (e.g., provide VT signal redundancy over SDN path planning)

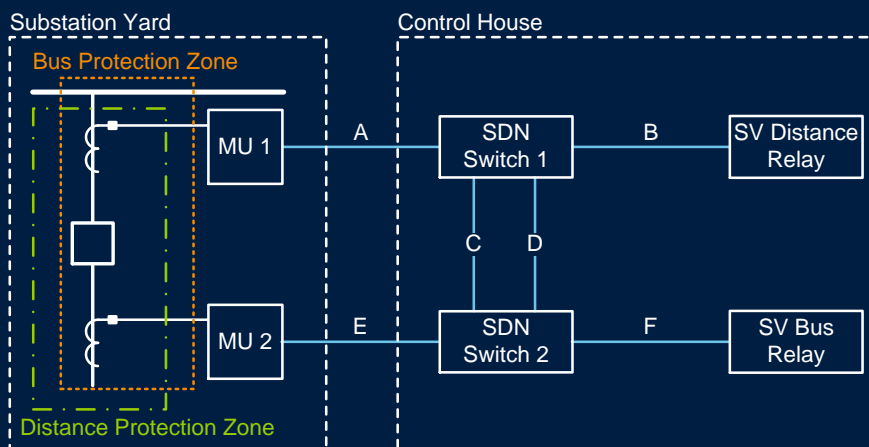
## Supplying Redundant CT and VT Signals Via SV Subscription Switching at IEDs



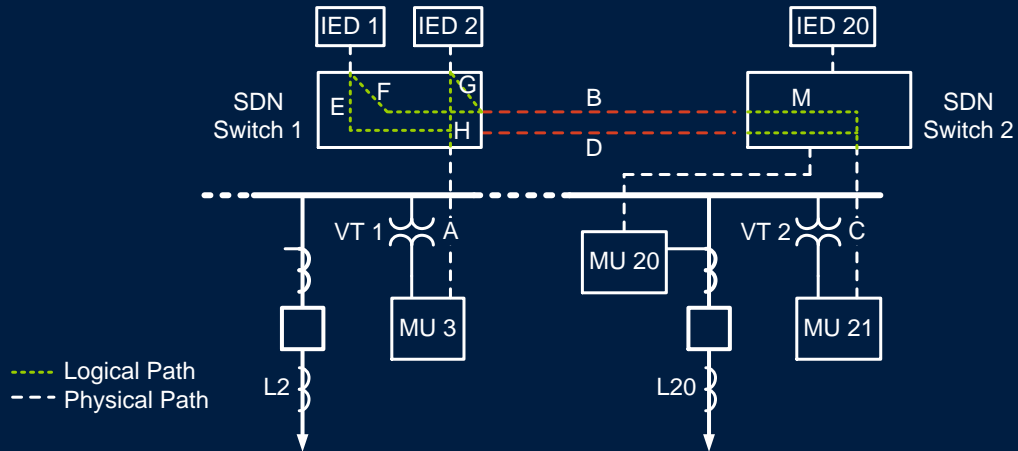
## Supplying Redundant CT and VT Signals Via Network-Level Switching

- Purpose-engineer network path
- Create fast failover schemes – failover speed  $<100 \mu\text{s}$
- Failover to pre-engineered network path – deterministic path planning
- May use instrument transformer signals from other protection zones

## May Use Instrument Transformer Signals From Other Protection Zones

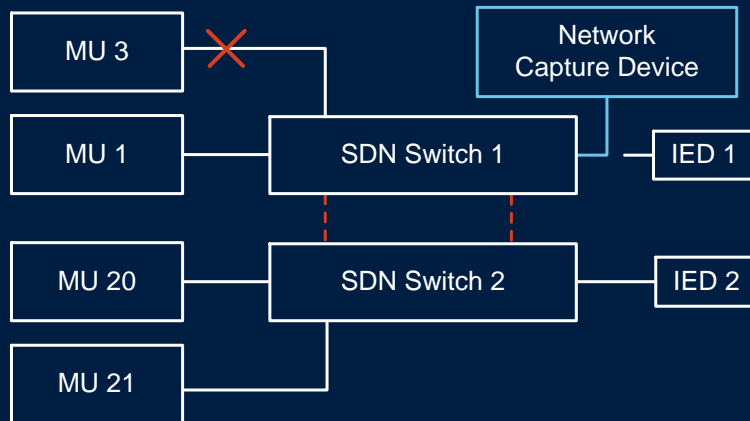


# Redundant Voltage Measurement Substitution



# Fast Failover Provides SV Redundancy

## Process Bus Traffic Capture Diagram



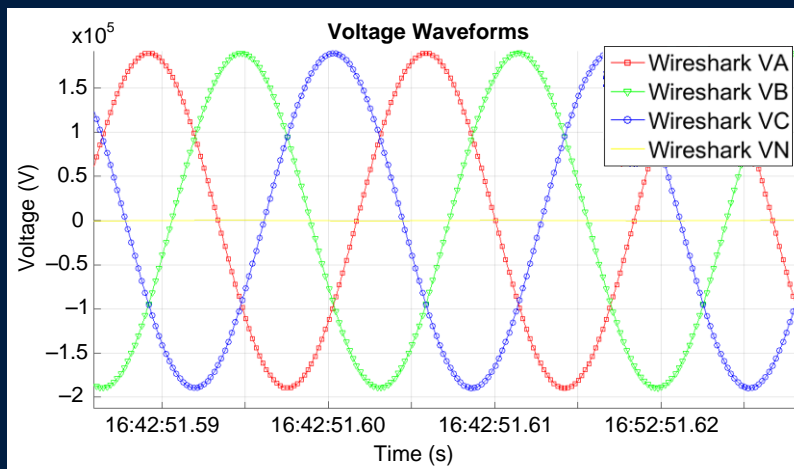
# Inspect Sinusoidal Signal Upon Sample Loss

## Wireshark® Capture of SV Messages Upon Failover

No.	Source	Destination	Time	Protocol	Length	Time delta from previous captured frame	smpCnt
25958	11:db:56	Iec-Tc57_04:00:01	2017-03-13 16:42:51.606702178	IEC61850 Sampled Values	101	0.000208400	2908
25959	11:db:56	Iec-Tc57_04:00:01	2017-03-13 16:42:51.606910730	IEC61850 Sampled Values	101	0.000208552	2909
25960	11:db:56	Iec-Tc57_04:00:01	2017-03-13 16:42:51.607118730	IEC61850 Sampled Values	101	0.000208000	2910
25961	11:db:56	Iec-Tc57_04:00:01	2017-03-13 16:42:51.607327290	IEC61850 Sampled Values	101	0.000208560	2911
25962	11:db:56	Iec-Tc57_04:00:01	2017-03-13 16:42:51.607535642	IEC61850 Sampled Values	101	0.000208352	2912
25963	11:d7:d5	Iec-Tc57_04:00:01	2017-03-13 16:42:51.607744202	IEC61850 Sampled Values	106	0.000208560	2913
25964	11:d7:d5	Iec-Tc57_04:00:01	2017-03-13 16:42:51.607952522	IEC61850 Sampled Values	106	0.000208320	2914
25965	11:d7:d5	Iec-Tc57_04:00:01	2017-03-13 16:42:51.608160514	IEC61850 Sampled Values	106	0.000207992	2915
25966	11:d7:d5	Iec-Tc57_04:00:01	2017-03-13 16:42:51.608368994	IEC61850 Sampled Values	106	0.000208480	2916

# Inspect Sinusoidal Signal Upon Sample Loss

## Sinusoidal Signals Continuing as SDN Creates New Logical Path



## Conclusion

- Provide logical segregation for IEC 61850 traffic
- Enhance PRP reliability using SDN fast failover
- Achieve intelligent SV stream sharing between IEDs
  - Redundant stream switching at IEDs
  - Redundant stream switching at SDN switch
- Increase cybersecurity
- Gain greater network situational awareness

Questions?