Channel Performance Considerations for Ethernet Circuits Applied to Teleprotection

Technical report PES-TR76

Produced by the H32 working group

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Introduction

- The Communications channel is part of the protection system
- Communications technology evolves faster than protective relay technology
- Shift towards packet based (Ethernet) presents new challenges

Purpose

The assignment of this working group was to create a document for use by protection engineers with their IT / Telecom counterparts to agree on the expected performance of protective relay circuits applied over Ethernet circuits

The Heart of the Report

4. General communications channel performance considerations for teleprotection
    - 4.1 Availability
    - 4.2 Channel Latency (end-to-end delay)
    - 4.3 Delay Asymmetry
    - 4.4 Channel Quality
    - 4.5 Performance Monitoring
    - 4.6 Performance Recommendations
5. Ethernet communications channel performance considerations for teleprotection
    - 5.1 Ethernet Network Architecture
    - 5.2 Ethernet Switch Queues
    - 5.3 Queue Priorities
    - 5.4 Jitter or Delay Variation
    - 5.5 Network Engineering
    - 5.6 Path Planning Considerations
    - 5.7 Network Failover

Section 4
General communications channel performance considerations for teleprotection

Availability

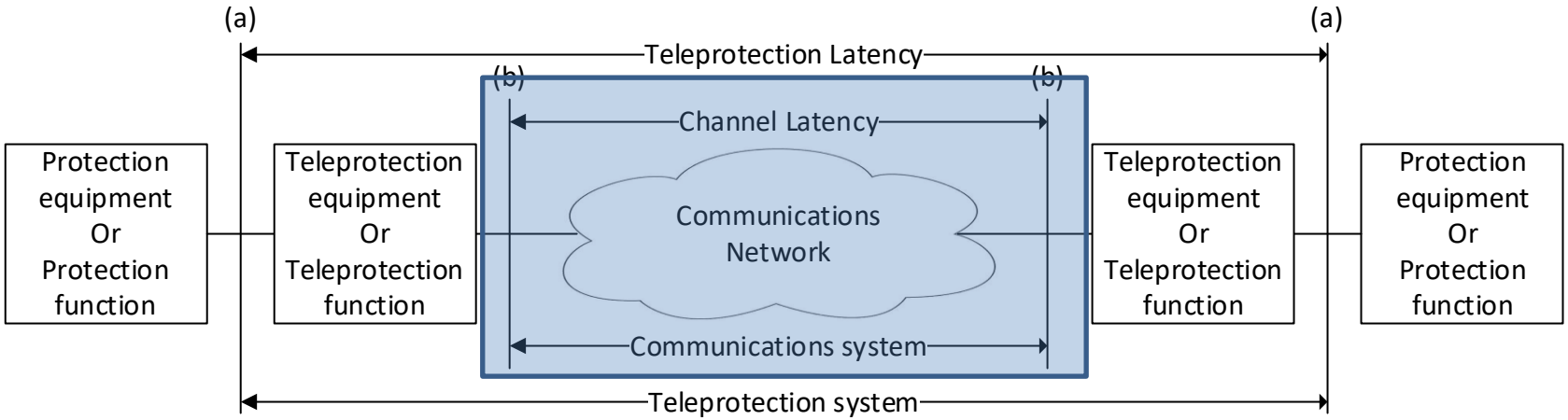
Availability is a measure of the frequency of equipment failures as a function of time, typically expressed in yearly intervals

IEC 60834-1 specifies 99.99%

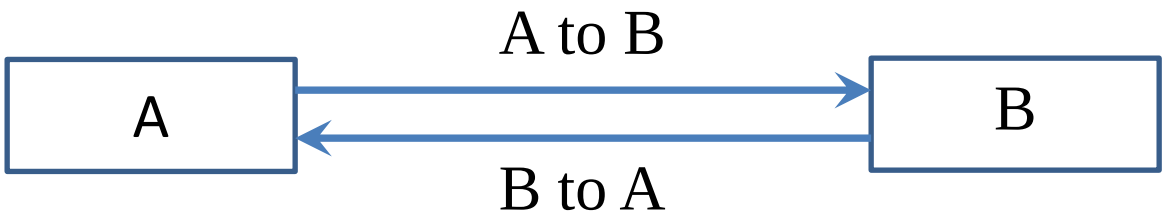
Availability	Time Lost (hours)	Time Lost (minutes)	Time Lost (seconds)
99.90%	8.76	525.6	31,596
99.98%	1.75	105.12	6,307.20
99.99%	0.876	52.56	3,153.60
99.999%	0.0876	5.26	315.36
99.9999%	0.00876	0.53	31.54
99.99999%	0.000876	0.05	3.15
1 year=365 days/yr*24 hrs/day = 8760 hrs/year			

The criteria for protection system availability is typically specified as 99.999% . This availability can be achieved by eliminating single points of failure in equipment such as having redundant processors, power supplies as well as using redundant systems.

Channel Latency (end-to-end delay)



Delay Asymmetry



Latency from A-B = 3 ms
Latency from B-A = 4 ms

Asymmetry = |Latency A>B – Latency B>A|

Asymmetry = |3 ms – 4 ms| = 1 ms

Channel Quality

- Digital channel quality is defined in terms of bit error rate (BER) performance. IEC 60834-1 specifies bit error rates per voltage level for normal operation
- Expected BER levels are provided in IEEE PSRC Report on Digital Communications for Relay protection

Performance Monitoring

- It is not enough to verify that the communications circuit meets requirements at commissioning, and then trust that all will remain well. Some relays can monitor and alarm for several parameters: loss of communication, excess bit error rate, channel asymmetry, or other circuit parameters.

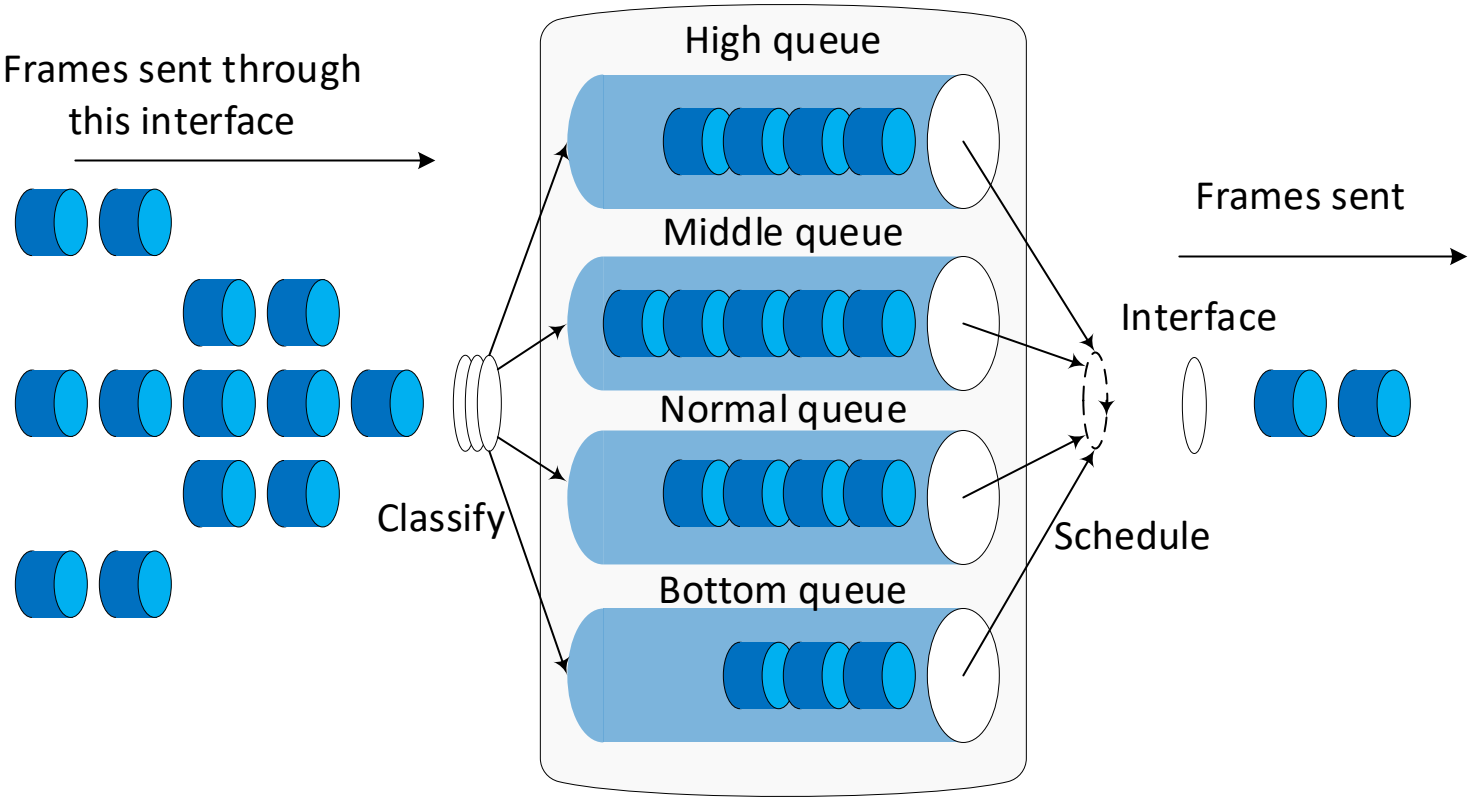
- Relay system and communication network performance monitoring varies greatly between manufacturers and equipment vintage.

Performance Recomondations

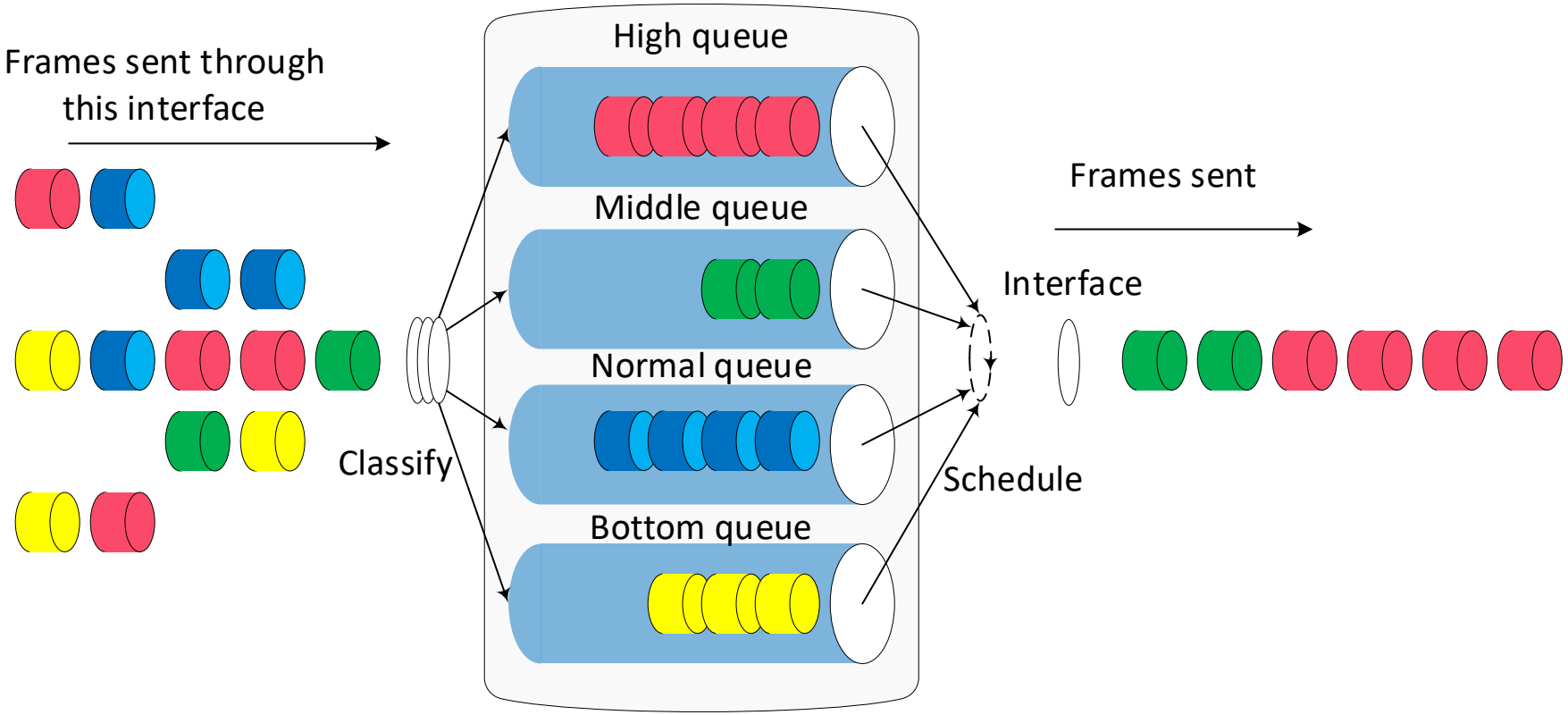
	Current differential protection*			Pilot protection		
	Latency (ms)**	Asymmetry (ms)**	Failover (ms)***	Latency (ms)**	Asymmetry (ms)**	Failover (ms)***
Critical	5	0.5	5	5	5	5
High voltage	10	1	10	10	10	10
Sub-transmission	15	1	50	15	10	50

Section 5
Ethernet communications channel performance considerations for teleprotection

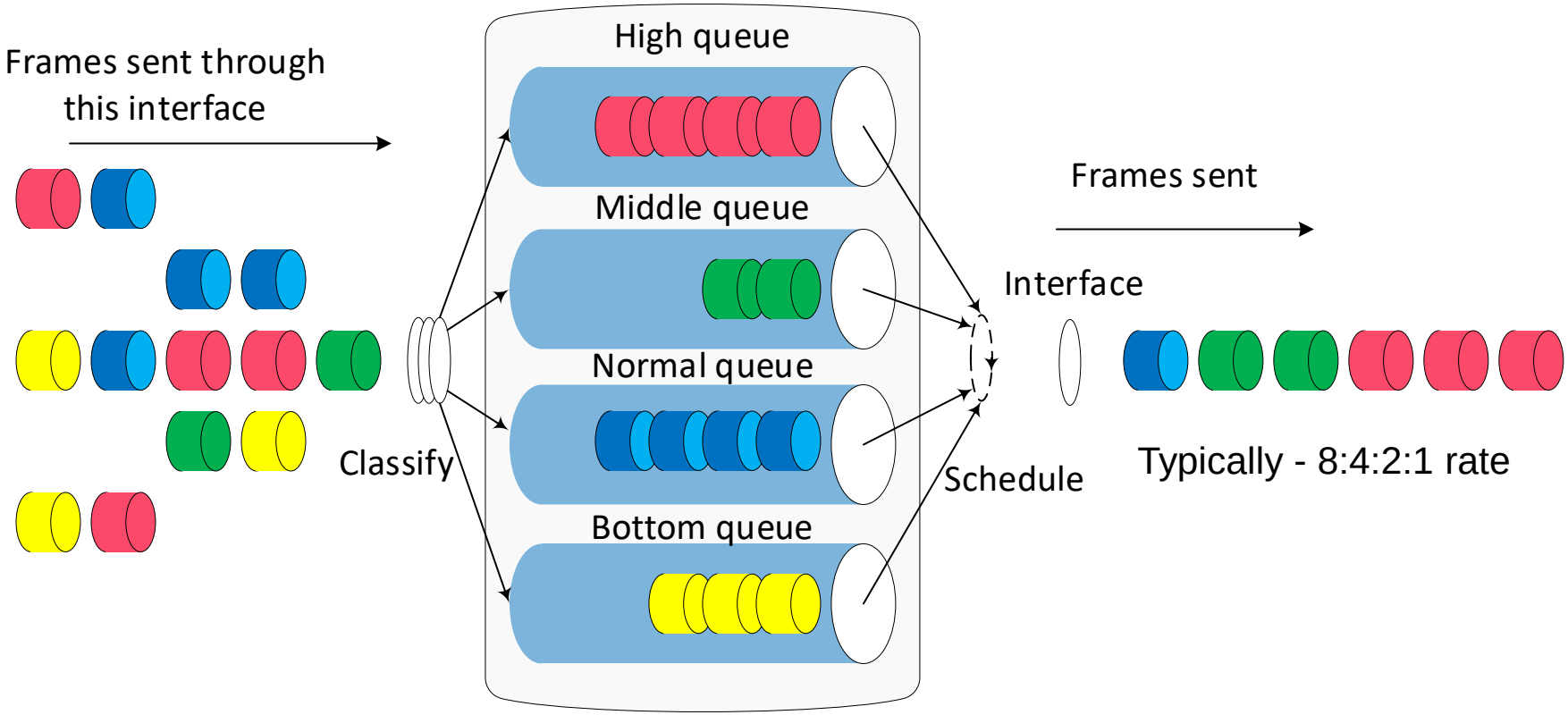
Ethernet Switch Queues



Queue Priorities - Strict

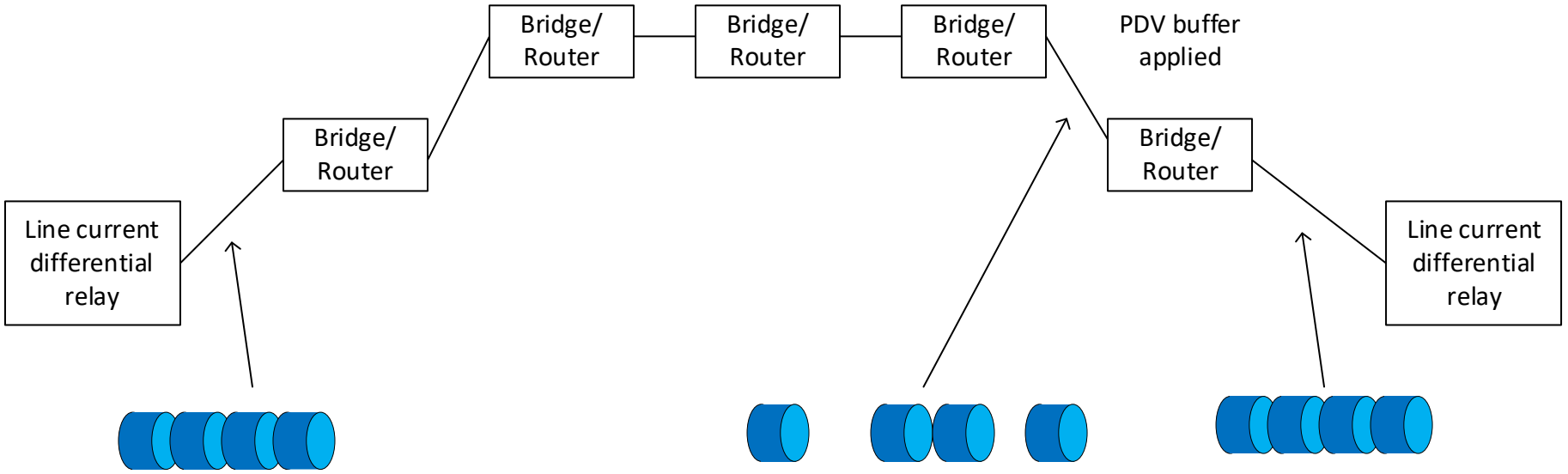


Queue Priorities – Round Robin



Jitter / Delay Variation

- Standard communication-based term is packet delay variation (PDV)



PDV buffer delays the release of data to the relay and removes the effects of network queuing delays

Network Engineering

- Network engineering is responsible for checking that an Ethernet network is suitable for teleprotection applications for all paths (both primary and backup). For example, paths' switch priority-queue assignments can be set to provide:
  - The worst-case latency of each teleprotection path is specified.
  - Worst-case latencies are within the acceptable ranges of the teleprotection applications for all primary and alternate paths.

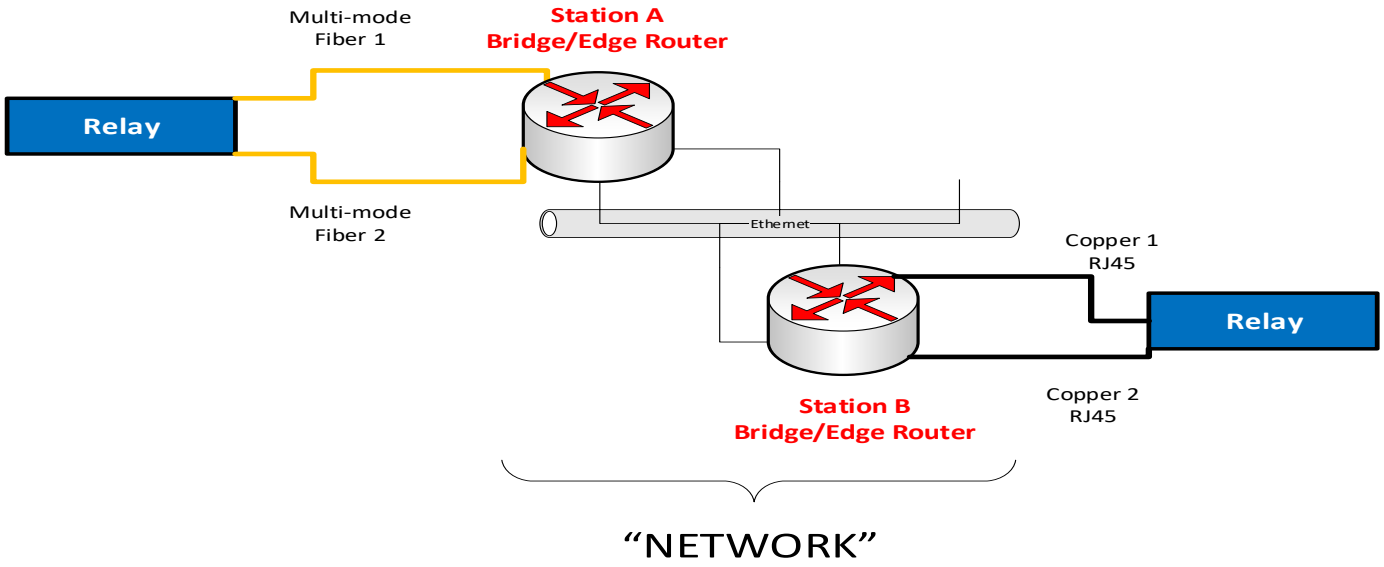
Path Planning

- A viable plan incorporates consideration of the monitoring and response capabilities of the protective relay utilizing the communications circuit in question. These capabilities may include but are not limited to:
  - Relays recognizing a complete loss of communication with each other.
  - Relays recognizing end-to-end latency has exceeded acceptable limits.
  - Relays recognizing unacceptable quality of data.

Network Failover

The complex connection design has several recoverable cable-failure scenarios:

- Within the substation directly associated with the relays.
- Within the substation indirectly associated with the relays.
- Outside of the substation.



Appendix A - Sample Protection Communication Requirements Agreement Form

Circuit ID	Interface (type and bandwidth)	Committed Information rate (mbps)	Worst-Case Channel Latency (milliseconds)		Worst-Case Jitter (aka PDV) (milliseconds)		Worst-Case Channel Asymmetry (milliseconds)		Worst-Case Failover (e.g. upon fiber failure) (milliseconds)	
			Required	*Offered*	*Required*	*Offered*	*Required*	*Offered*	*Required*	*Offered*
<circuit 1>										
<circuit 2>										
<circuit 3>										

Table 3 Teleprotection Circuits Performance Specifications

Conclusion

This report assists protection engineers and communications engineers who are working on implementing protection channels over Ethernet networks by outlining specific performance requirements the protection engineer needs to communicate to the network engineer.

The report provides a sample protection communications requirements agreement form that is intended as a method to document the agreed performance.