Line Current Differential: Communication Channel Considerations

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Introduction

Motivation

- Line current differential protection is becoming a de-facto standard line protection for many power systems
- Evolution of communication technologies presents new communication choices for line current differential protection
- Tighter interactions between protection and communications groups call for mutually acceptable choices

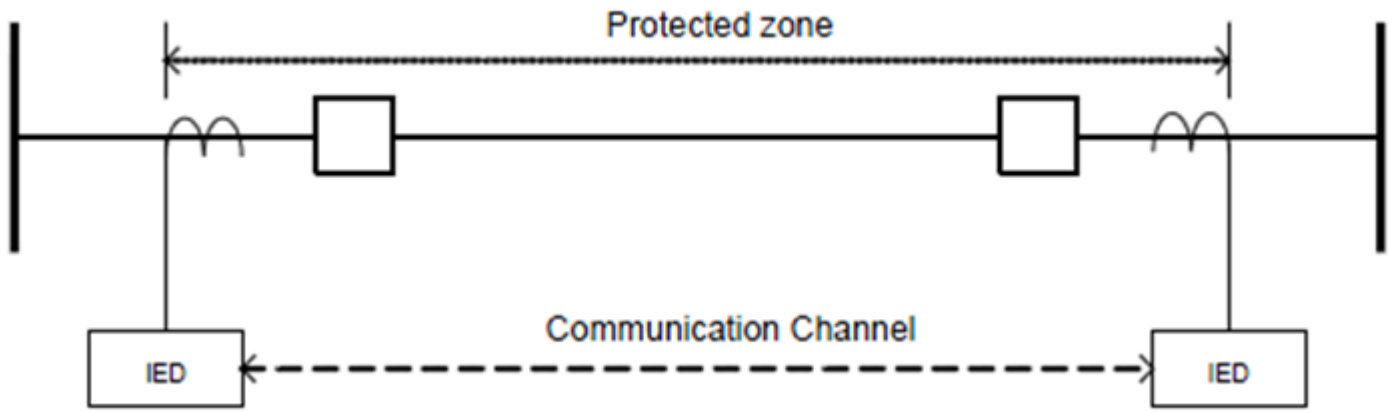
Are newer communication technologies

acceptable for line current differential protection ?

Outline

- A brief introduction to line current differential protection, and its dependency on communication channel
- An overview of newer communication technologies
  - Dedicated channel
  - Multiplexed channel
  - Switched channel
- Utility use cases for line current differential over
  - IEEE C37.94 over SONET channel
  - Multi-Protocol Label Switching (MPLS) channel
- Conclusions

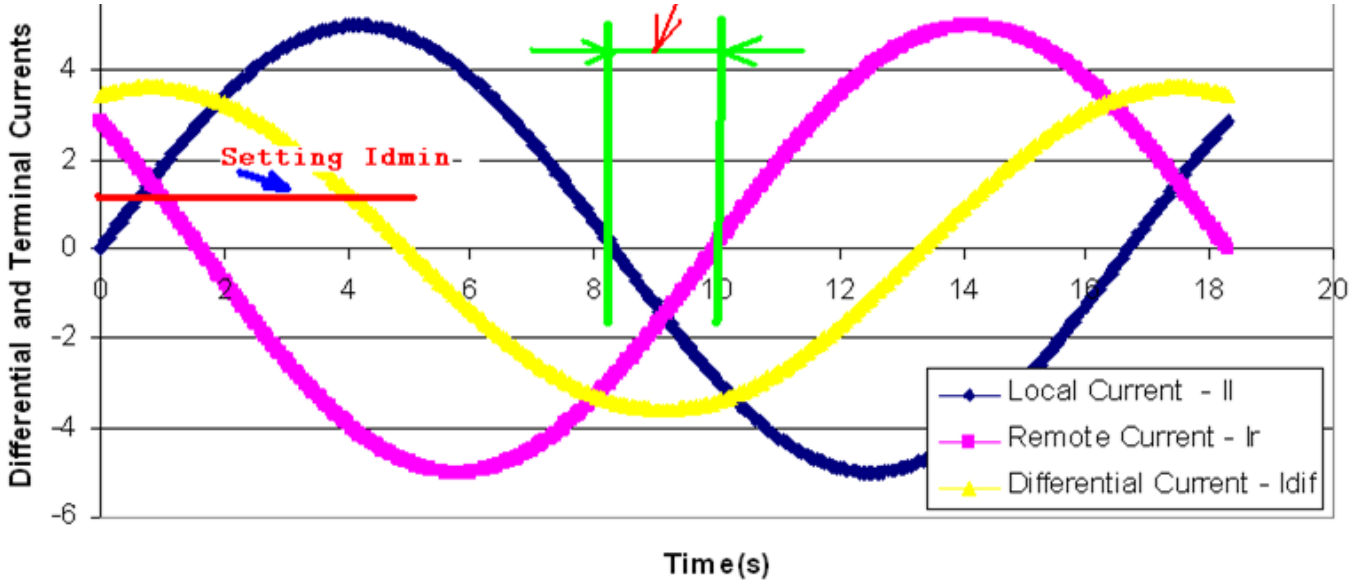
Line current differential protection
Basic idea



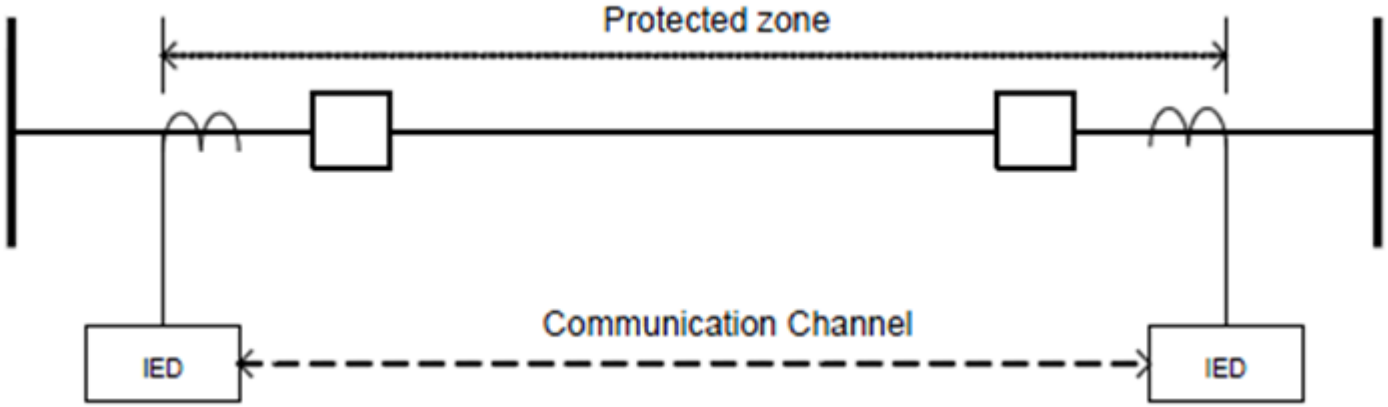
- Based on Kirchhoff's law for currents
- Uses synchronized current samples from 2 ends of the line
- Dedicated , multiplexed or ***switched*** communication channel can be used

Line current differential protection
Dependencies on communication channel

- Availability
- Bit Error Rate
- One-way Latency
- Samples synchronization
  - Synchronization error
  - Delay symmetry

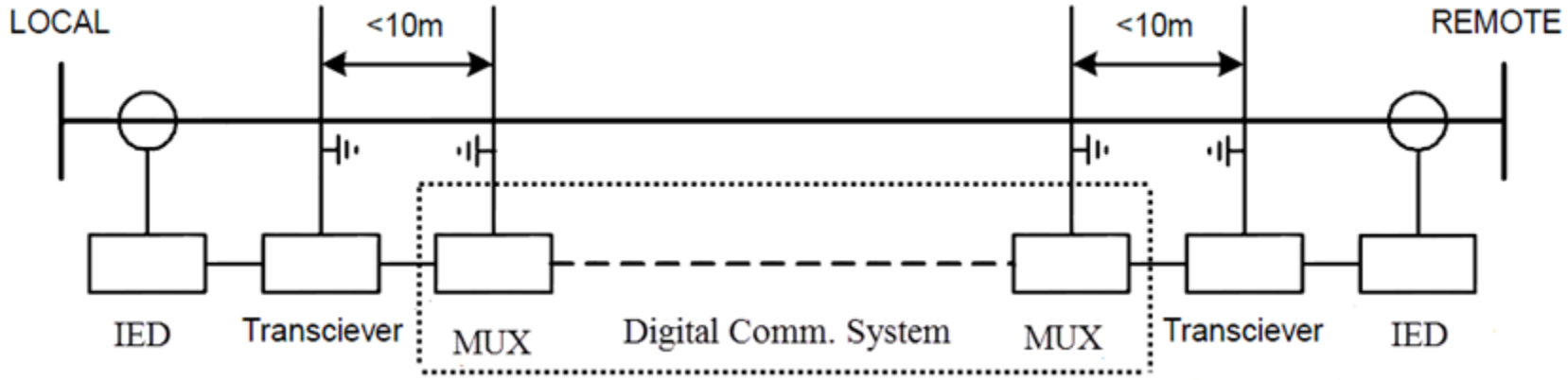


Communication channels
Dedicated



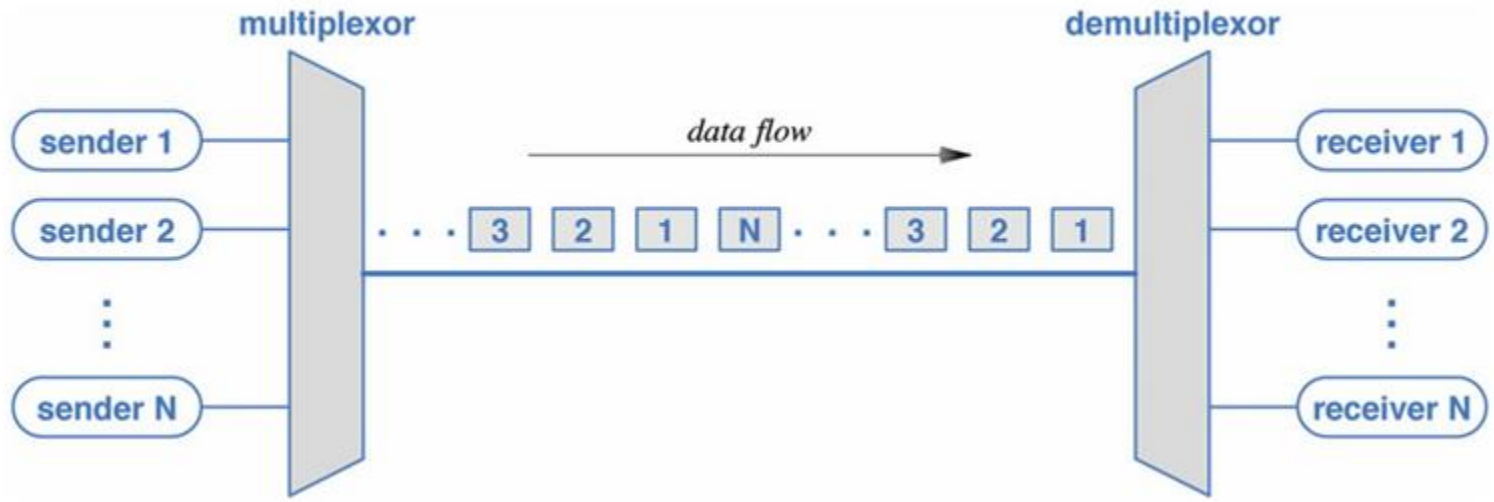
- Provides direct point-to-point connection between two IEDs
- High availability, deterministic and symmetrical communication delay
- Proprietary communication protocols (can use IEEE C37.94 frame format)

Communication channels
Multiplexed



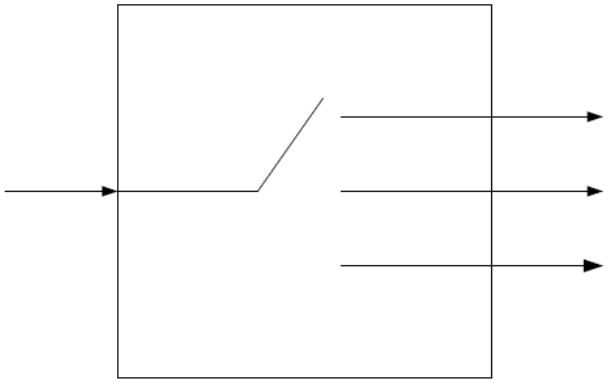
- Provides multiple point-to-point connections between multiple IEDs
- Dedicates resources for each connection, thus can be considered as ***a set of dedicated channels***
- High availability, deterministic and symmetrical communication delays.
- Proprietary protocols for data exchange. IEEE C37.94, SONET/SDH are common protocols

Multiplexed channels
Basic principle



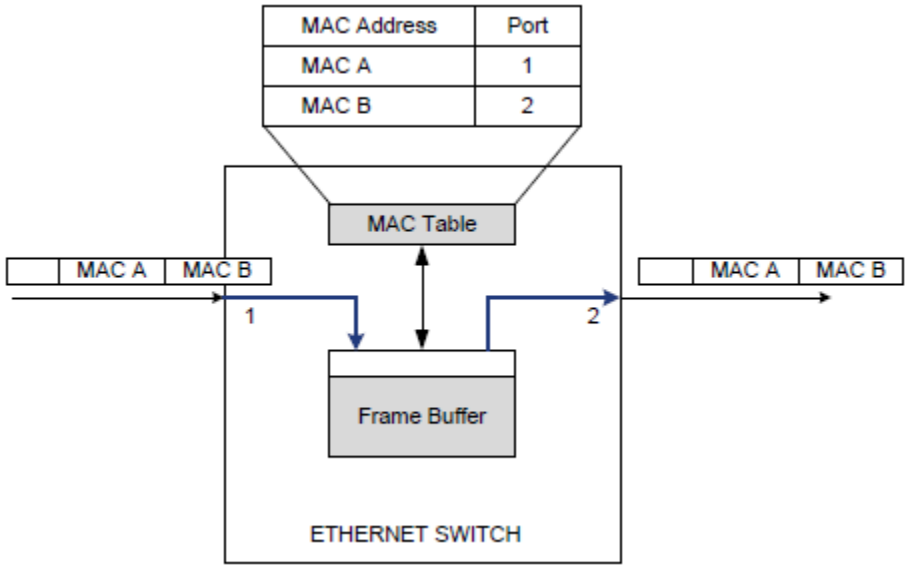
- Provides shared (multiplexed) media for multiple connections
- Channels use different
  - Frequency, in analog carrier (Frequency Division Multiplexing, FDM)
  - Time in digital carrier (Time Division Multiplexing, TDM)
  - Wavelength in optical carrier (Wave Division Multiplexing, WDM)

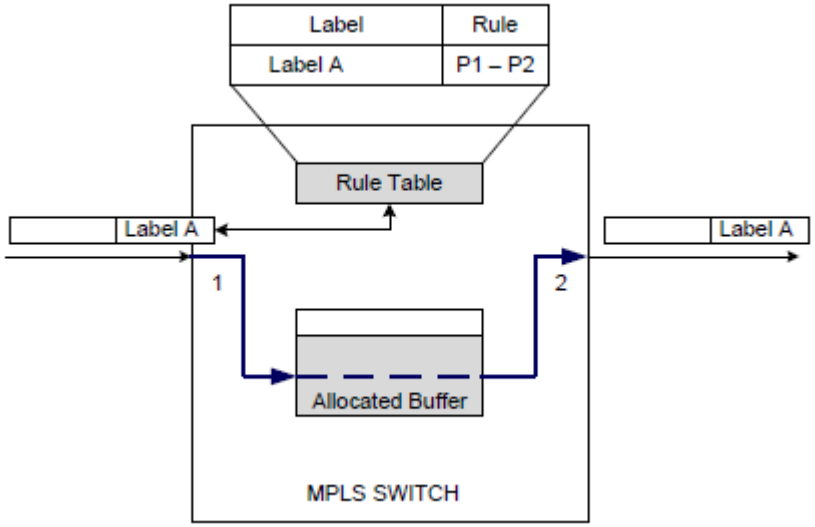
Communication channels
Switched



- Switches or connects an input channel to an output channel
  - In analog world electromechanical ***relays*** were used
  - In digital world a switch forwards or ***relays*** data
- Requires
  - Knowledge of **where** to connect an input to
  - **Resource availability** (output channels, internal buffers)

Switched channels
Ethernet vs. Multi-Protocol Label Switching





- Learns and stores **48-bit MAC addresses** to make switching decisions
- Buffer management is based on **priorities**
- **Managed** resource availability
- **Multicast** **(one to many)** capabilities

- Uses **20-bit MPLS labels** to make fast switching decisions
- **Dedicated** buffers allocated for services
- **Engineered** **Circuit Emulation** functions similarly to a ***dedicated channel***

Utility Case Study 1
SONET multiplexed communication channel

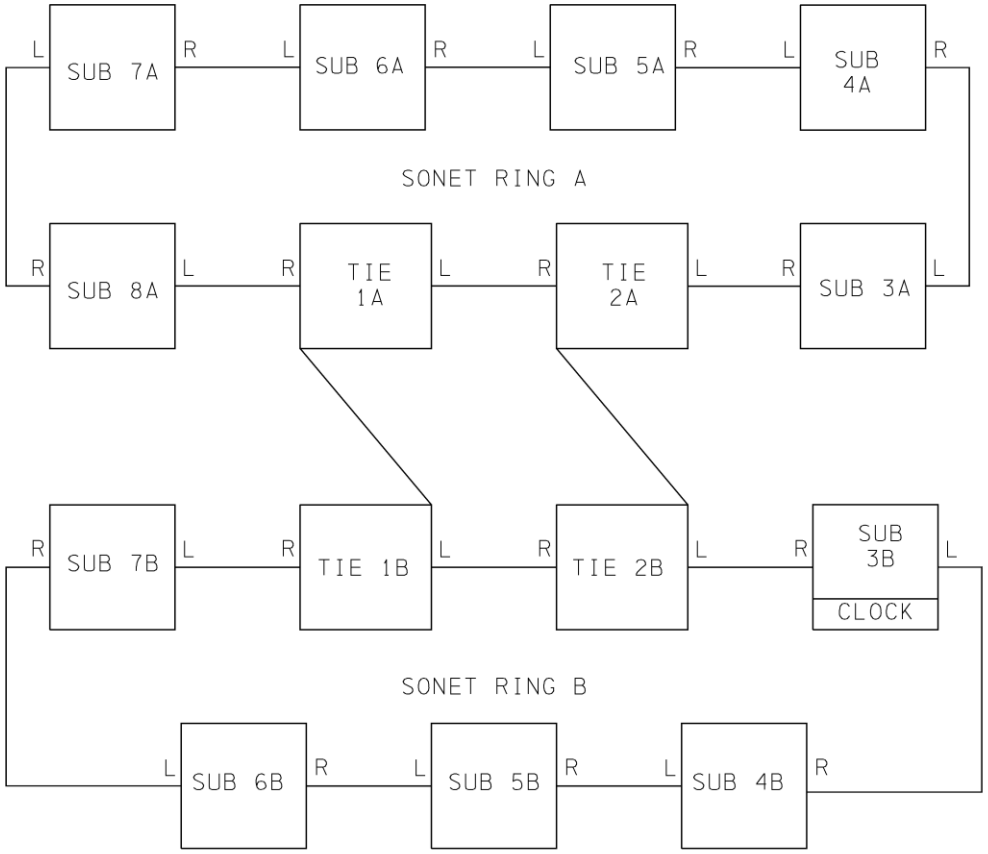
Utilizes SONET system built on Fibre Optic backbone installed on Lines.

- Primarily Urban deployment within and around a major city of 1 million plus.
  - 316,000 residential and 35,000 commercial customers
  - 30 transmission substations and 203 kilometres of aerial and underground transmission lines
  - 6 distribution substations and approximately 5,100 circuit kilometres of primary distribution feeder

Utility Case Study 1
SONET Multiplexed communication channel

SONET multiplexed channel

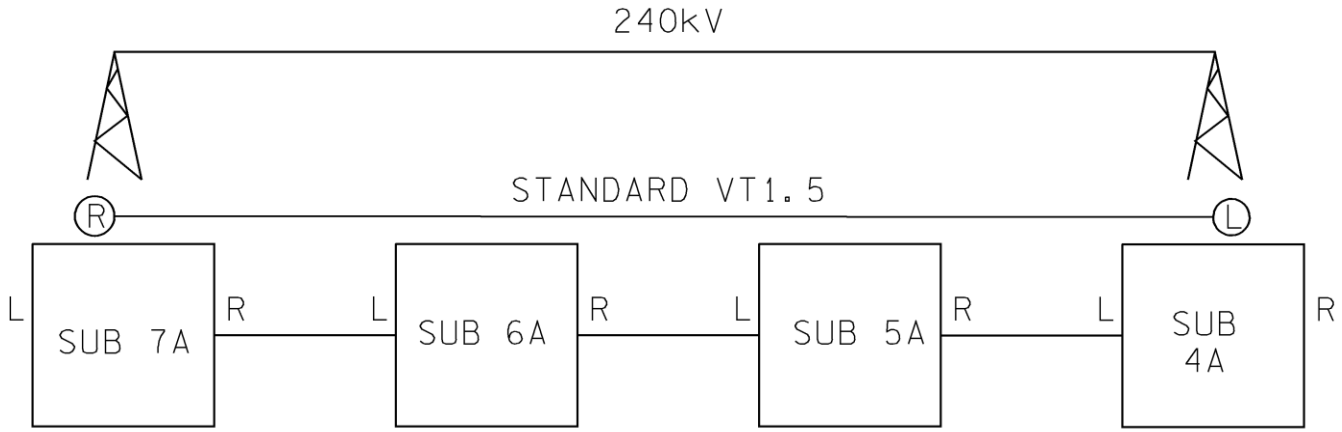
- Redundancy on many levels:
  - Multiple SMF cable connecting each substation
  - Double ring
  - Double tie site
  - Optical cards are redundant
- Limited geographical deployment



Utility Case Study 1
Multiplexed communication channel

SONET multiplexed channel

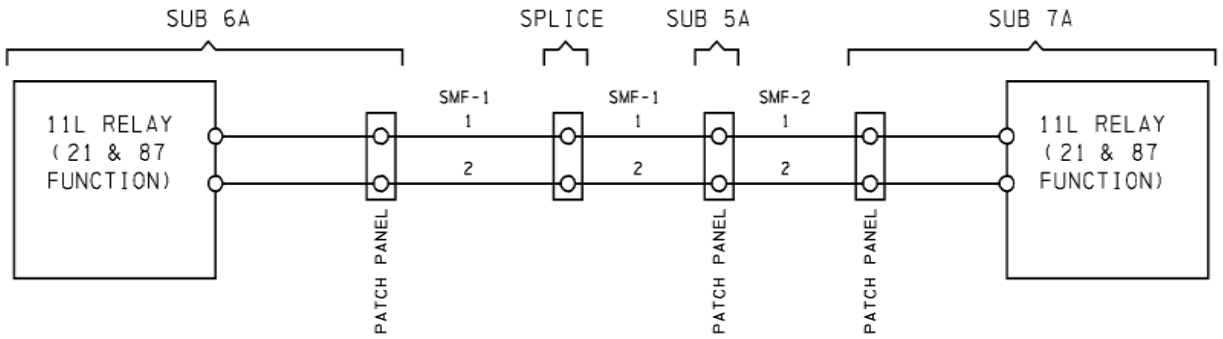
- Low latency:
  - “Standard” VT between sites minimizes add/drop delays
  - Specifying preferred direction for shortest physical path
- IEEE C37.94 implementation:
  - Communication port connector on relay and SONET card must match
  - SONET internal circuit addressing to ensure proper TX/RX pair



Utility Case Study 1
Dedicated communication channel

Dedicated FO channel

- Reliable, however introduces single point of failure if cable is severed
- Single mode fibre (SMF) a requirement for longer distances
- Connection can be over several patched cables
  - Resemble a single cable from relay point-of-view
- Very low latency
- IEEE C37.94 implementation:
  - Very simple, no additional interface beyond the companion relay

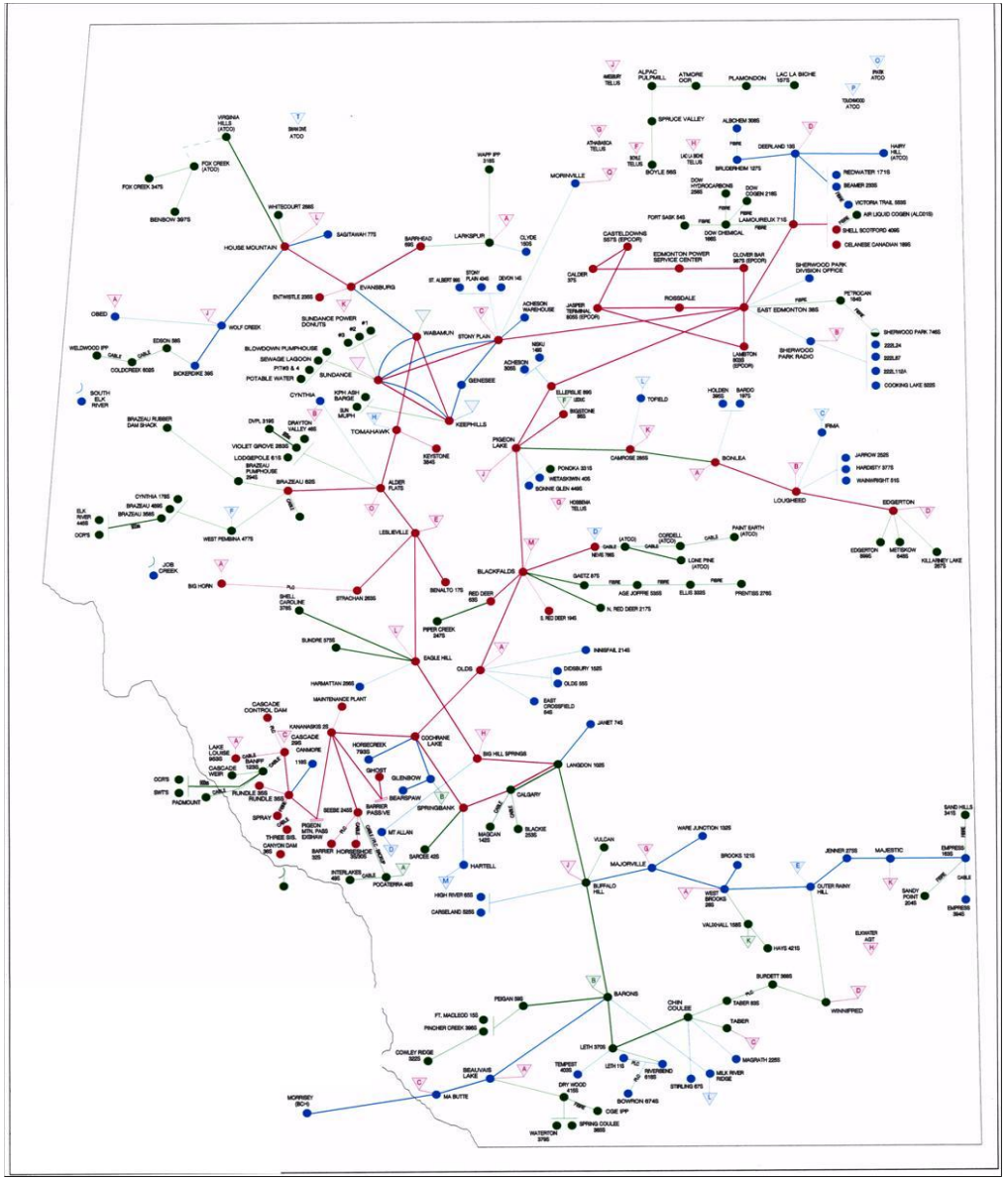


Utility Case Study 2

MPLS

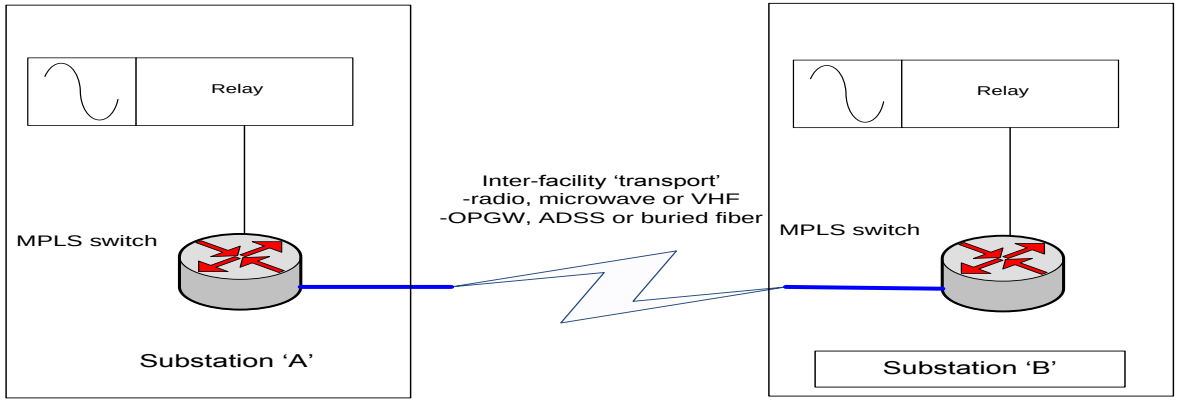
Transitioning to an MPLS system built primarily on Microwave radio, previously utilized TDM over an ATM core backbone.

- Rural deployment stretching between several major cities, legacy centralized generation and increasing distributed generation.
  - Half the geographic area of the province
  - Over 280 substations and 12,000 kilometres of aerial transmission

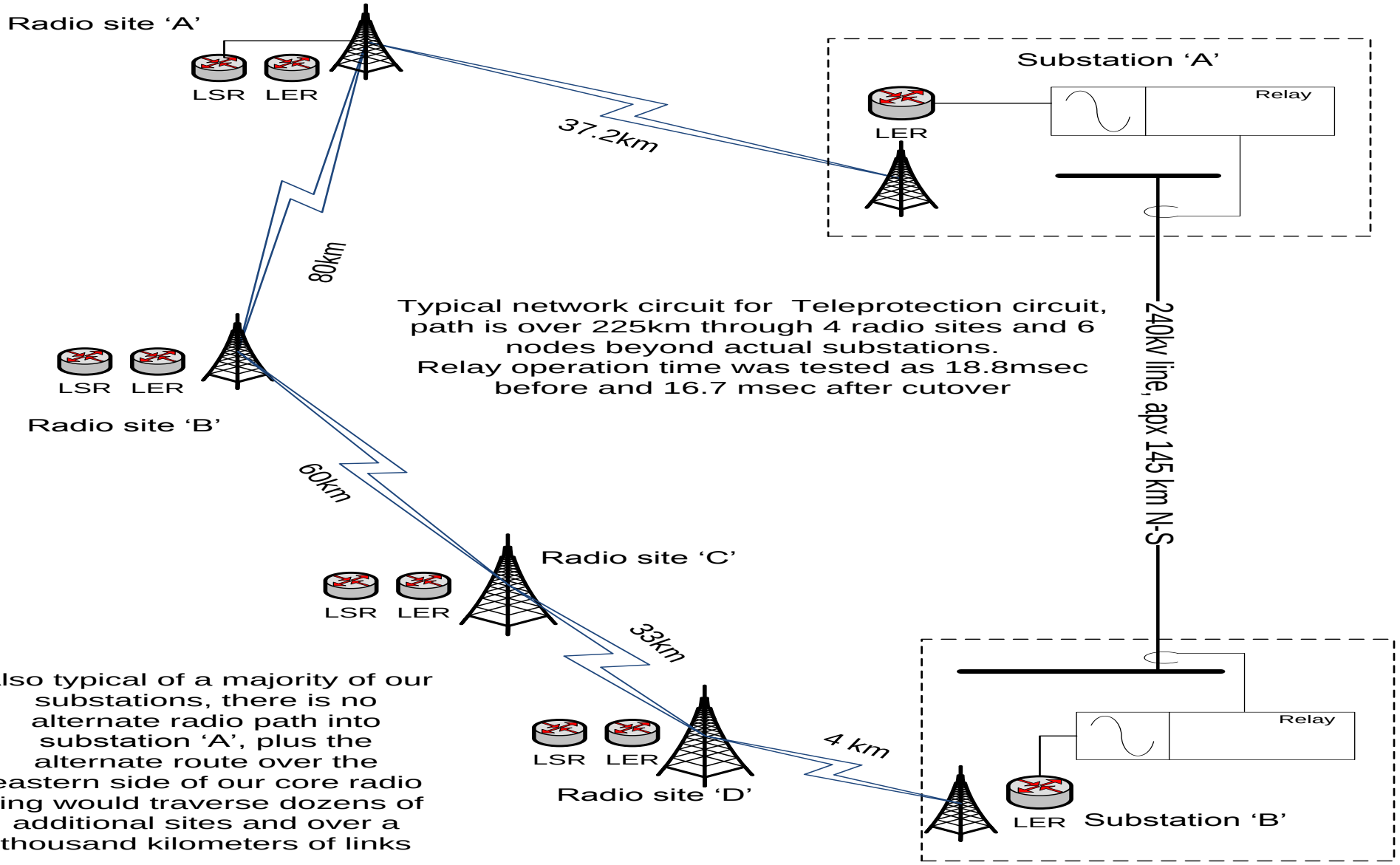


Utility Case Study 2
MPLS

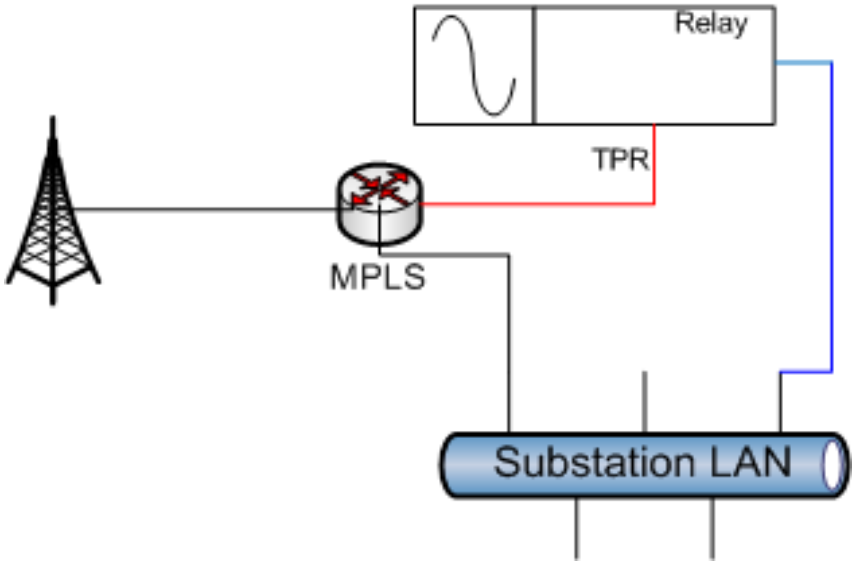
- Existing backhaul microwave radio network of 250+ hops still being utilized, some fibre build on new lines & rebuilds coming on-stream but still covers less than 5% of line lengths.
- In-service Teleprotection circuits primarily utilize lower speed G.703 and RS-232 interfaces between relays, due to limitations of legacy TDM technology and radio capacity.
- MPLS network deployment does not change existing Teleprotection scheme concept, in that inter IED communications is still on direct a dedicated point-point circuit utilizing the concept of a specific provisioning called a ‘C-pipe’, (Circuit Emulation), which creates a dedicated pathway based on substation end nodes and the circuit constraints of delay and throughput, plus any alternate routing of the circuit if possible and/or required.



Utility Case Study 2 MPLS



Utility Case Study 2
MPLS



- Key factor to Teleprotection is the critical traffic is handled at the top transport level, not impacted by any other
- Benefit in a ‘bandwidth challenged’ environment is the remaining capacity can be more effectively utilized dynamically, for occasional upstream data transmission such as SER records, on-site network access, etc.

Conclusions

- Line current differential protection schemes are not possible without communications. Availability, latency, bit error rate and synchronization are the key parameters of communication channel to be considered
- Various communication technologies could be used for line current differential schemes, these could provide dedicated, multiplexed and switched channel
- While multiplexed channel can be considered to be a set of dedicated channels, switched channel is fundamentally different
- Utility cases with dedicated and multiplexed communication channel showed that required performance of communication channel is easily achievable with minimal configuration efforts
- Utility cases with switched channel showed that required performance of communication channel is achievable if diligent network engineering is performed
- MPLS networks can be engineered to support dedicated connection across the network, thus can operate similar to dedicated communication channels