Addressing Analog Leased Line Obsolescence by Preserving Protection Channel Performance Over Ethernet

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Consumers Energy Company Overview

- Is combined electric and natural gas utility
- Includes generation, transmission, and distribution
- Began in 1886 as Jackson, Michigan streetlight venture
- Serves Michigan residents today
  - 6.7 million of state's 10 million residents
  - All 68 counties in lower peninsula

What Applications Run Over Analog Lines?

Cogeneration anti-islanding with direct transfer trip (DTT)

- Takes generator offline, no risk of islanding with load
- Needs generator to trip within 1 second of channel loss
- Requires service performance objective (SPO) Class A circuit or communications channel of comparable class

What Applications Run Over Analog Lines?

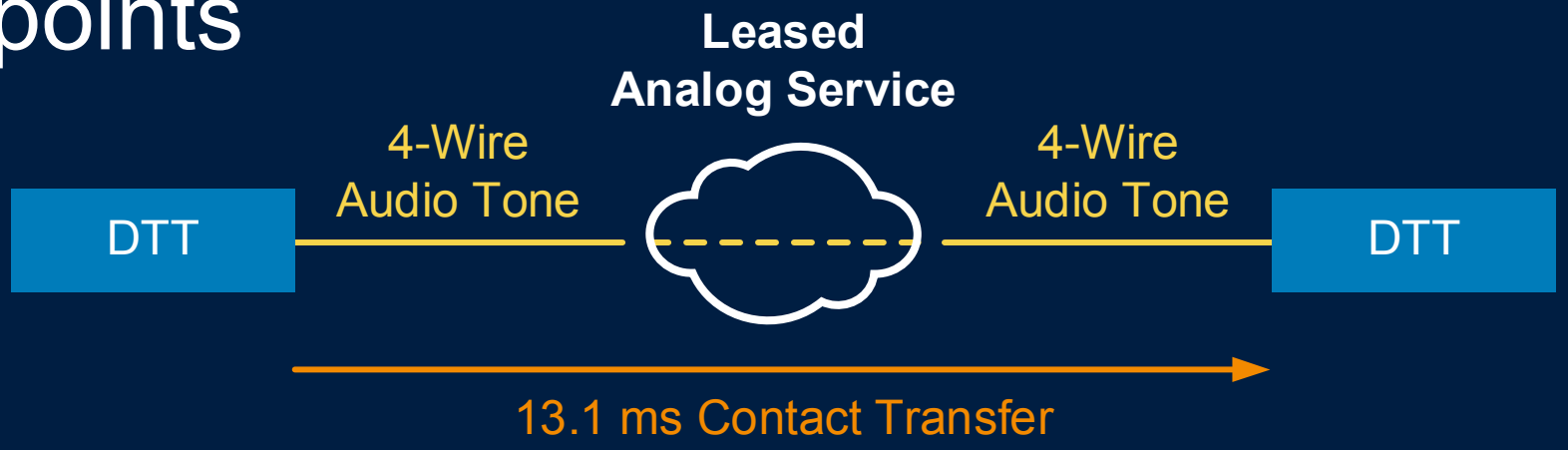
System coordination using permissive overreaching transfer trip (POTT) or line current differential

- Where long lines connect to short lines
- Where large sources interconnect with small sources
- Where traditional coordination cannot be achieved and still meet clearing criteria

Consumers Energy does **NOT** rely exclusively on pilot schemes for protection

Consumers Energy Leased Lines and Sites

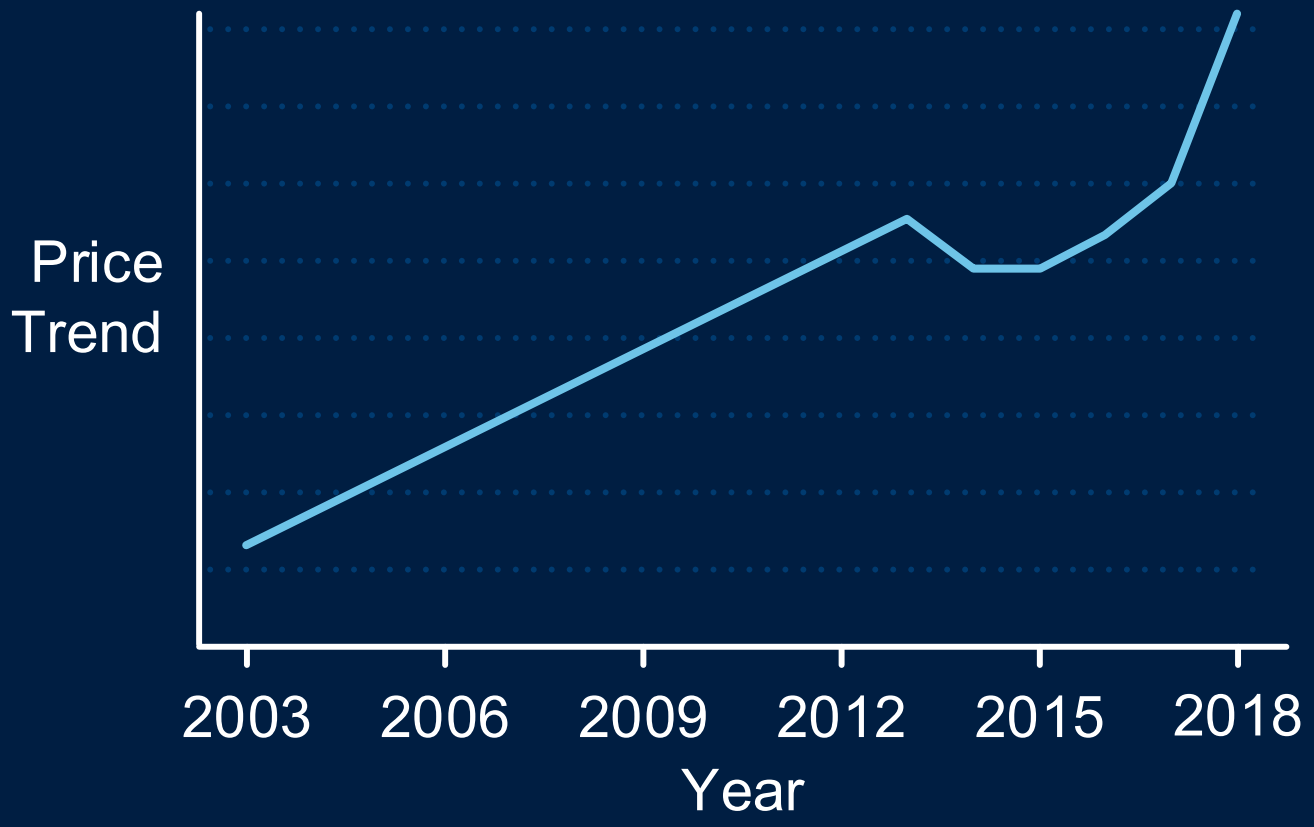
- Roughly 70 endpoints (35 circuits)
- Old standard equipment



- Line current differential protective relays – integrated direct copper analog connection
- DTT and POTT tone devices – connected to copper circuit; I/O interface to breakers and protective relays

Industry Push to Retire Copper Services

- Local carrier no longer allows new analog installations
- Maintenance costs are increasing and reliability is decreasing



"FCC Votes to Hasten Copper Retirement and Notification Process, Hopeful for IP/Fiber Upgrades"
—*Telecompetitor.com*, November 2017

Leased Circuit Performance and Service Requirements

- Point-to-point connectivity
- IEEE 487 SPO Class A circuit uninterruptible service performance
  - Available before, during, and after fault
  - Highest priority for availability and restoration

Leased Circuit Performance and Service Requirements

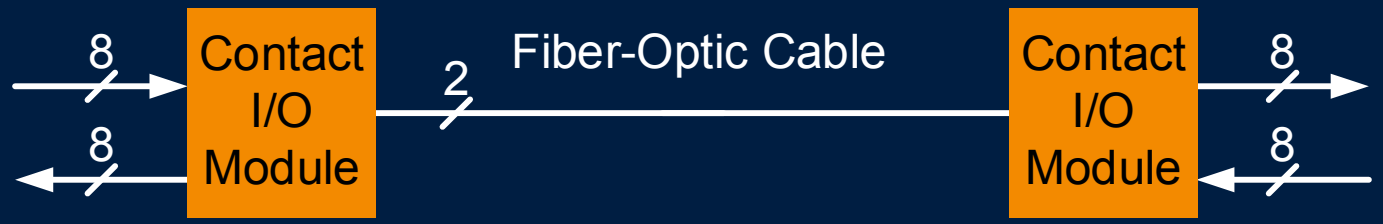
- Supports existing substation equipment
- Matches existing DTT latency performance of 13.1 ms
- Has high reliability, with negligible impact on differential scheme and no misoperations from channel latency or interference

Ethernet Service Class Offerings From Local Carrier Service Level Agreements (SLAs)

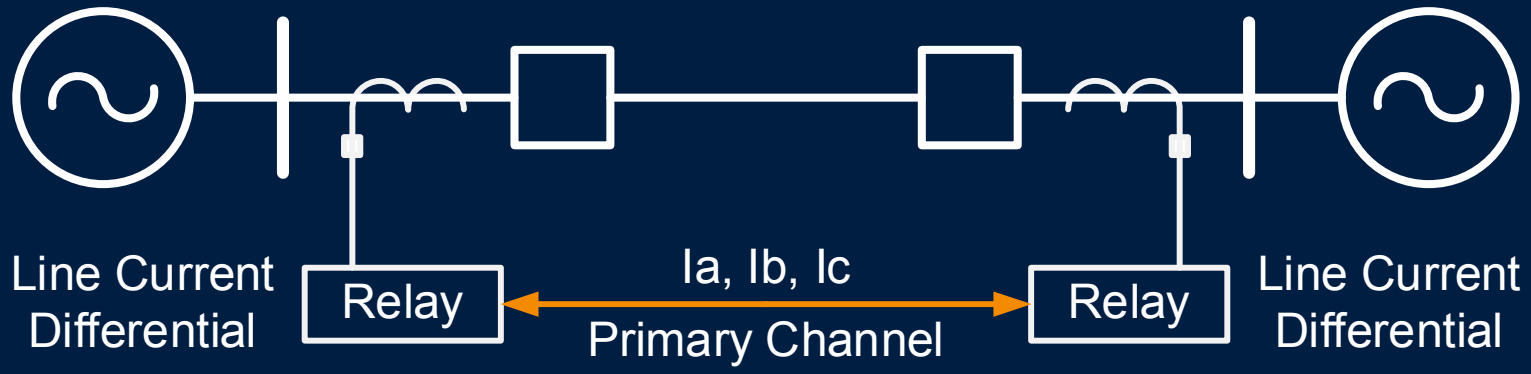
Specifications	Real Time	Guaranteed Data	Business
Latency (ms)	5	13	30
Jitter (ms)	3	10	NA
Packet delivery rate (%)	99.995	99.95	99.9
Availability (%)	99.99	99.99	99.99
Mean time to repair (hours)	4	4	4

Newest Consumers Energy Standards

DTT

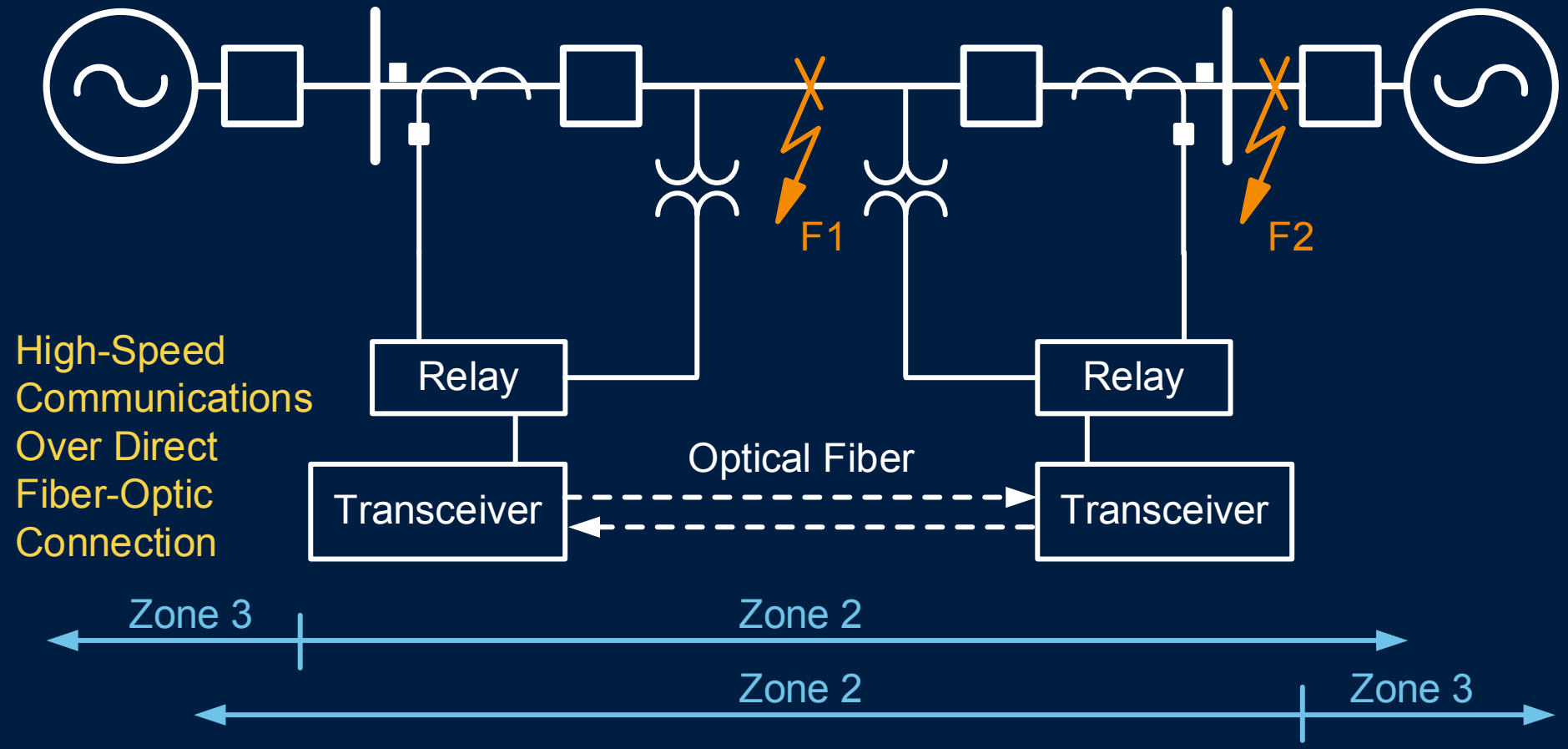


Line Current Differential



Newest Consumers Energy Standards

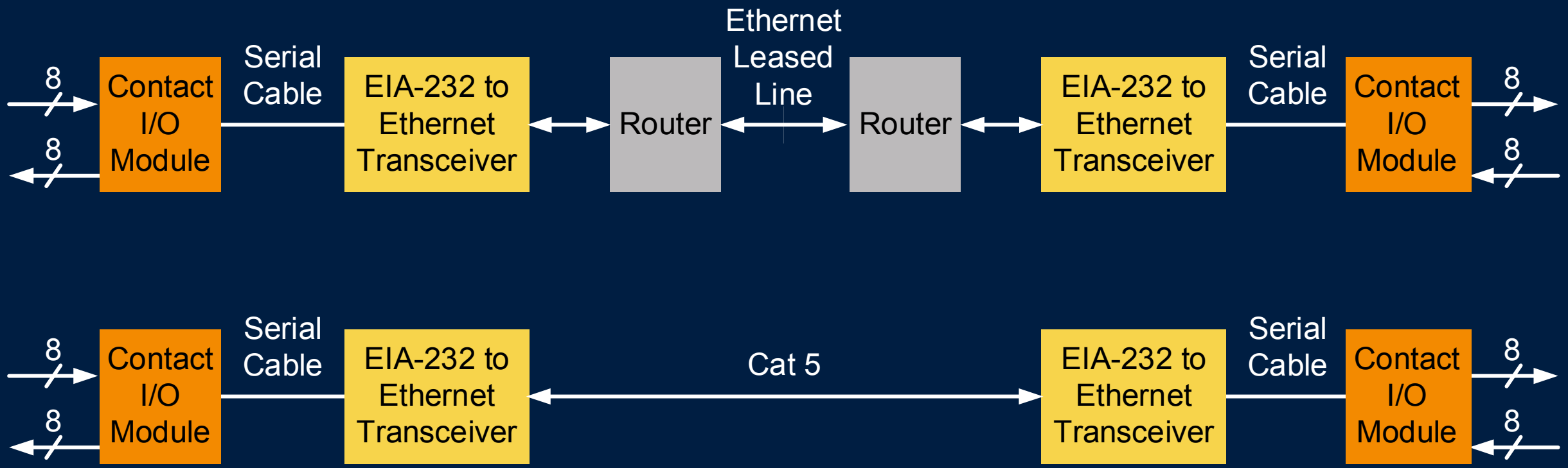
POTT



Seeking Ethernet Solution

- Started with simple DTT contact transfer
- Evaluated direct Ethernet I/O solution
- Found industrial solutions inadequate
  - Insufficient contact and power voltage ratings (125 Vdc rare)
  - Additional auxiliary relays, power supplies, and wiring needed
  - Questionable tolerance to heat, cold, and power surges
  - Best-effort latency and packet delivery

Direct Serial-to-Ethernet DTT Solutions Failed to Work



Transceivers Came From Multiple Manufacturers

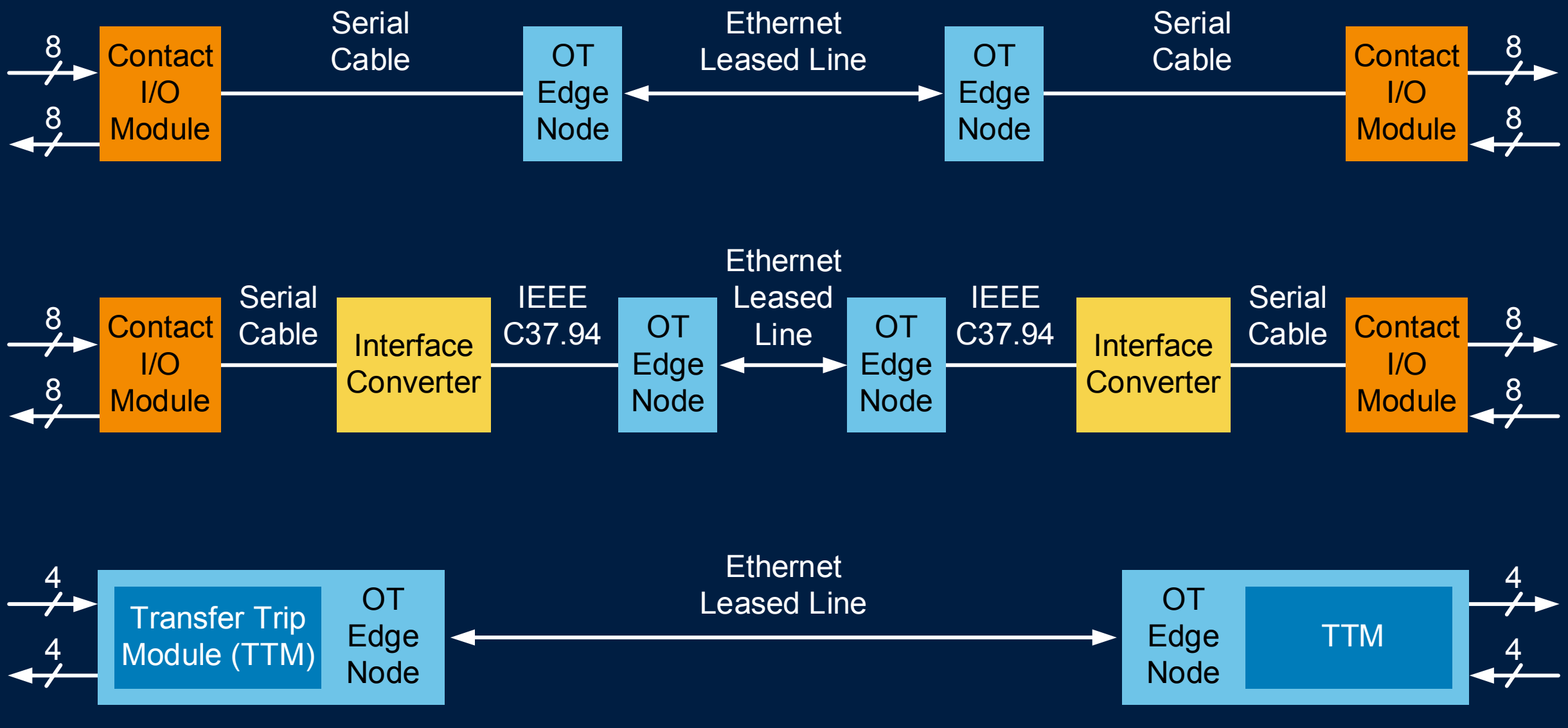
Why Does Direct Serial-to-Ethernet Conversion Not Work?

- Ethernet alone is not deterministic enough
- Jitter causes packet-queuing delays
- Delays compound until synchronization is lost

Maintaining Synchronization in DTT Solutions

- Solutions must actively keep jitter in check and use known latency to synchronize data coming in with data going out
- Existing time-division multiplexing (TDM) devices are well-suited to task and, with some modification, can be adapted to run over packet networks

Discovering Workable DTT Solutions

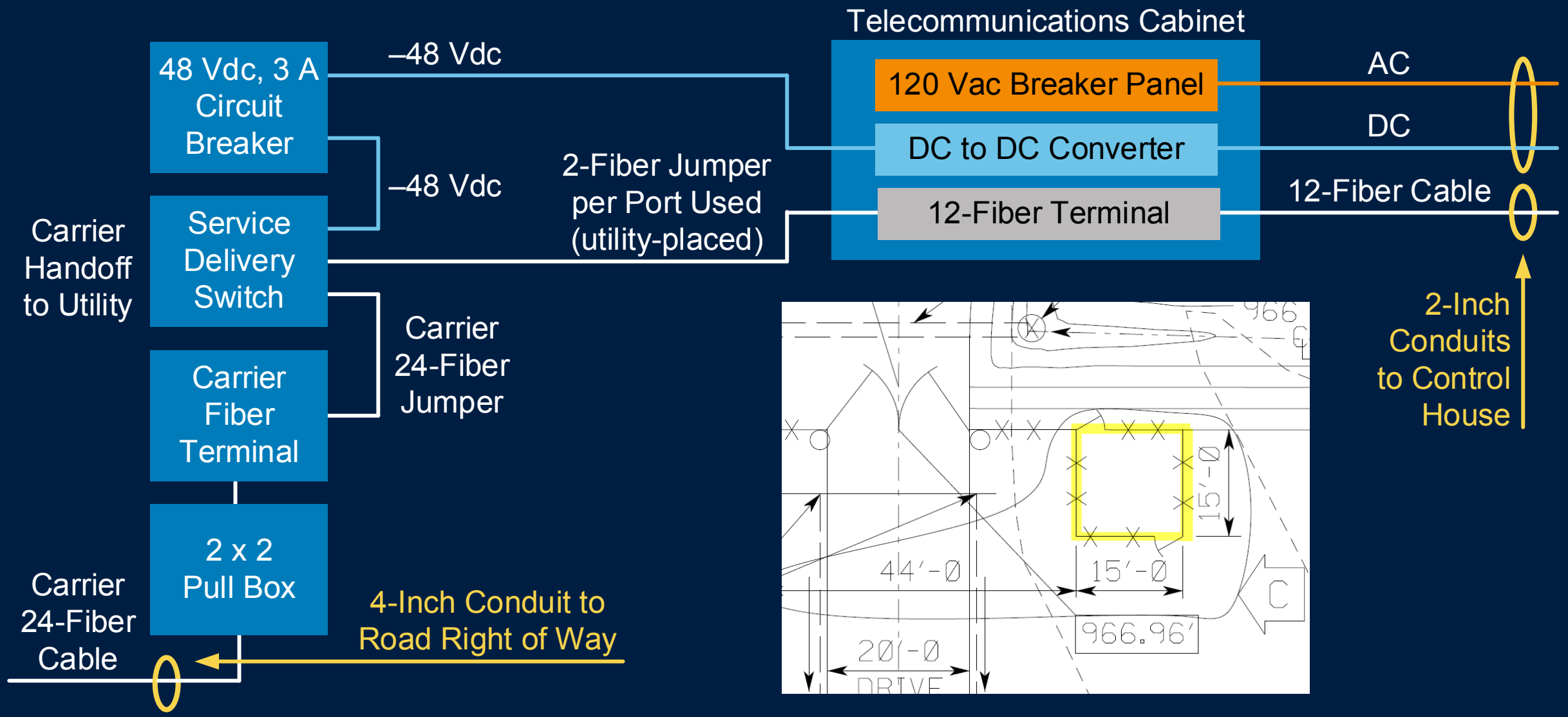


Initial Lab Trial and Evaluation Results

Solution	Direct Fiber Optics (ms)	Leased Ethernet (ms)
Contact I/O module to edge node via EIA-232	~24	~25
Contact I/O module to transceiver to edge node via EIA-232 and IEEE C37.94	~18	~19
DTT contacts on edge node	~9	~10

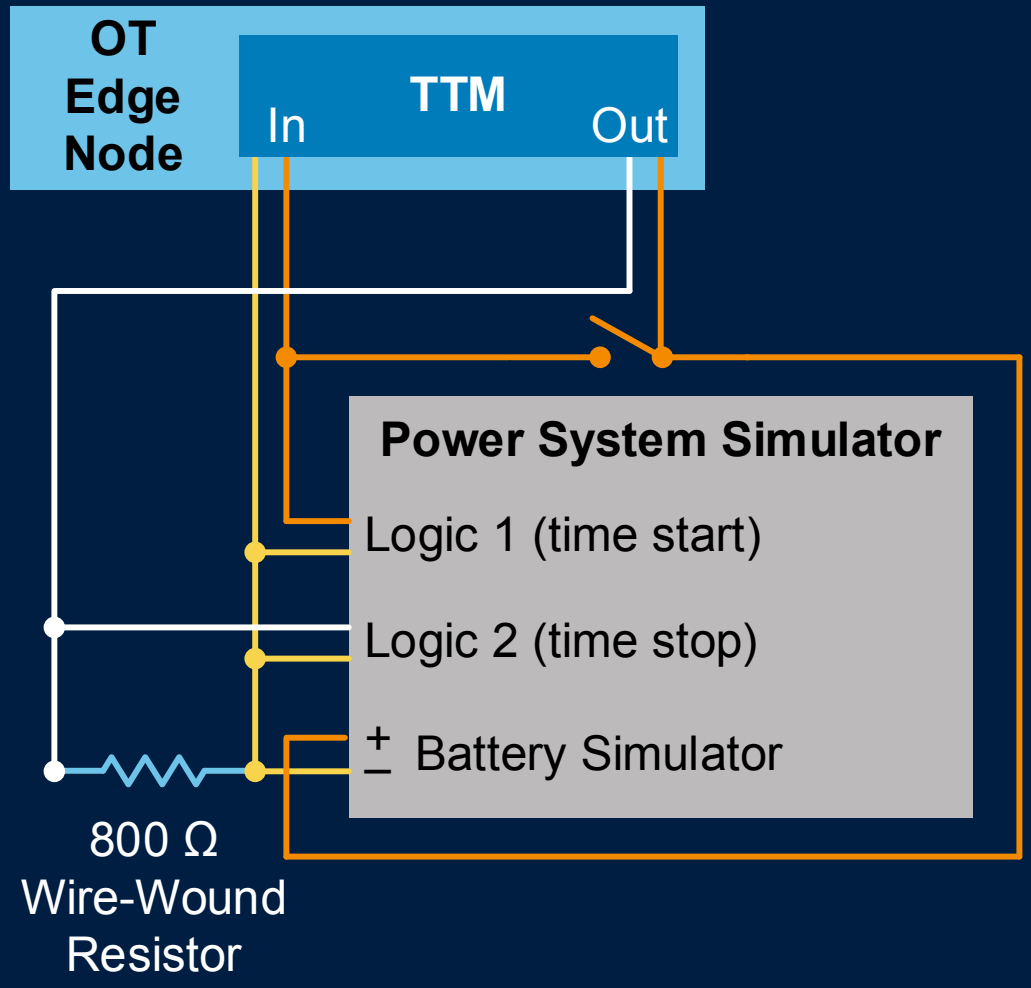
Analog circuit latency is 13.1 ms; upper limit requirement is 32 ms

Field Trials and New Consumers Energy Telecommunications Demarcation

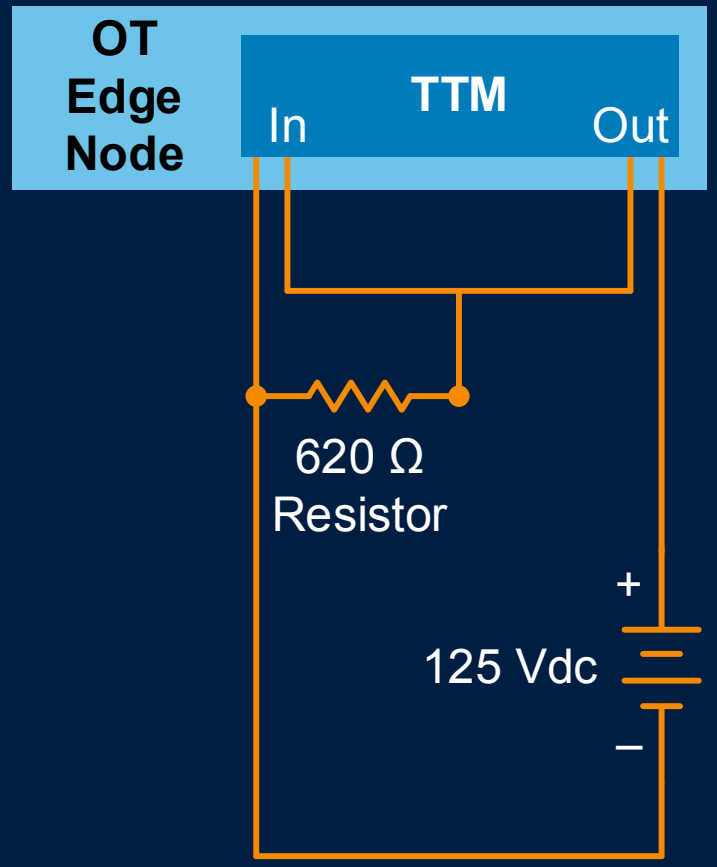


Parnell to Churchill Substation Live Circuit Trial

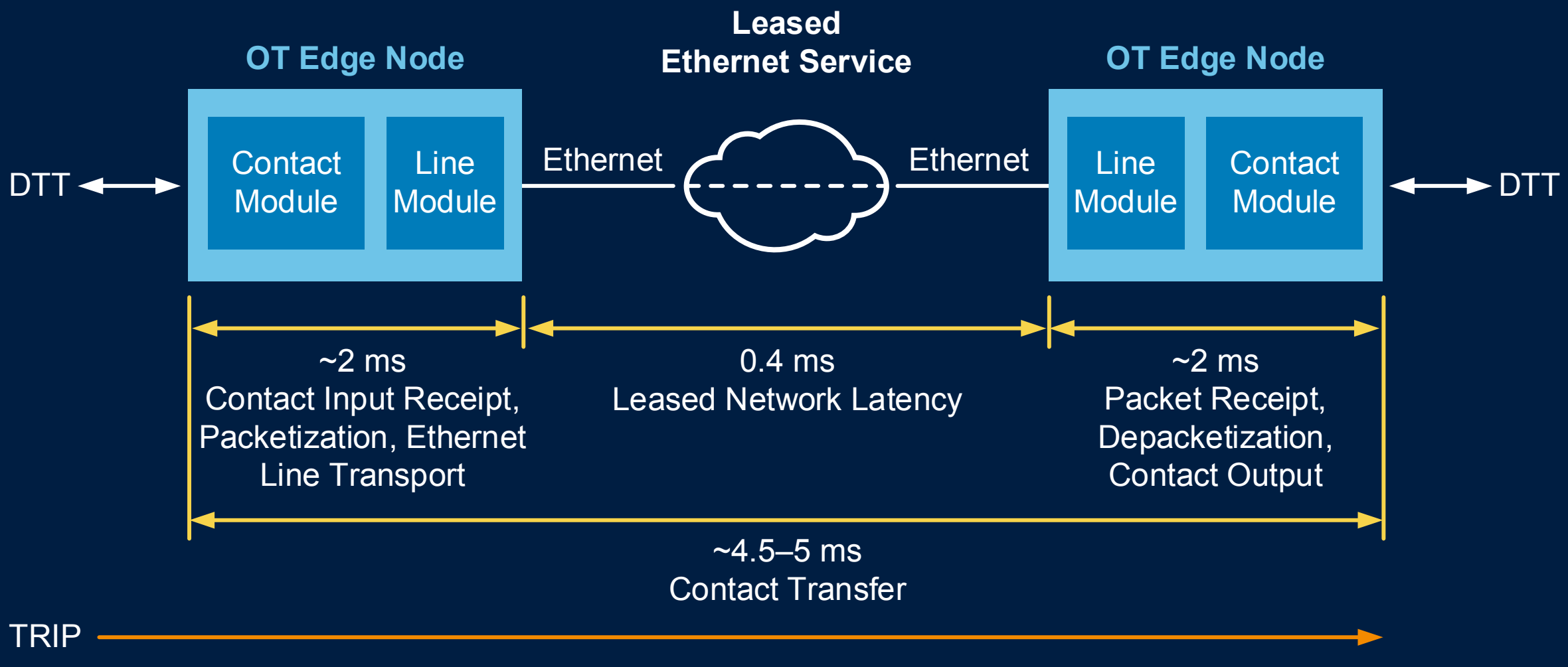
Parnell Laboratory



Churchill Substation



Substation Site Live Trial Results for DTT



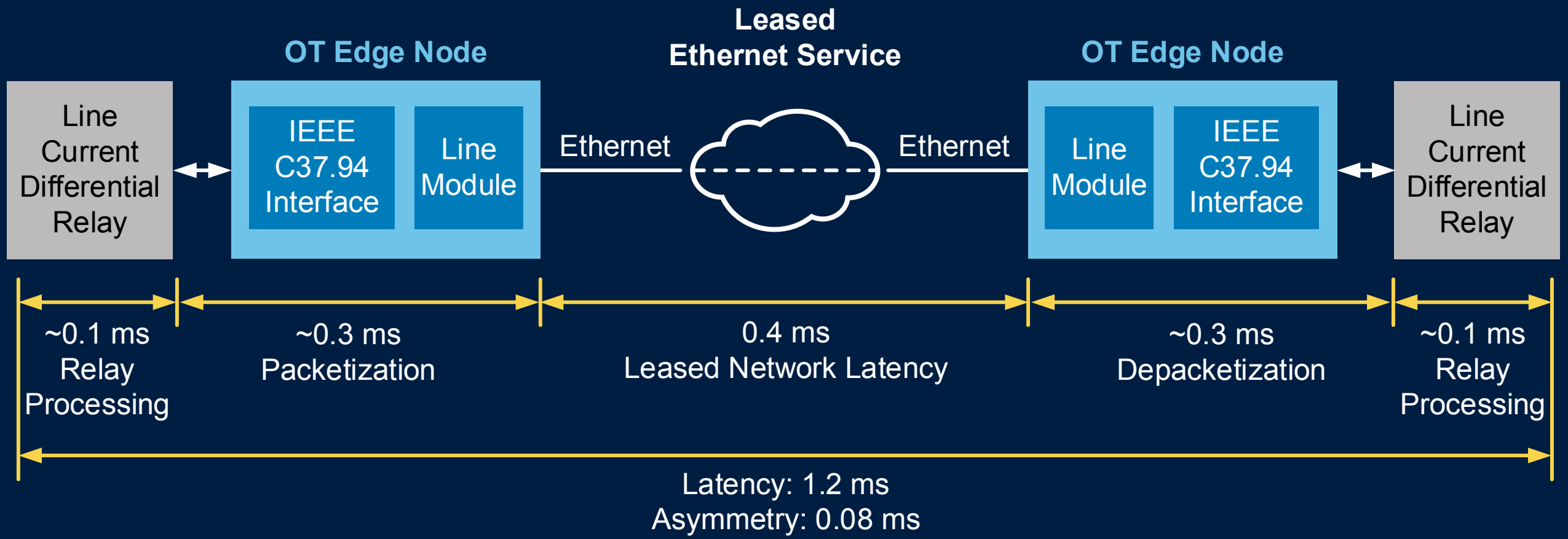
Evaluating Live Trial Results for DTT

Analog 13.1 ms **Ethernet 4.5 to 5 ms**

- Channel monitored for about five months
- Only one interval identified with a brief interruption
- OT edge node flexibility and reliability instilled confidence to install active DTT or POTT scheme

New teleprotection standard if operation remains problem-free

Substation Site Trial Results for Line Current Differential



Live Trial Results for Line Current Differential

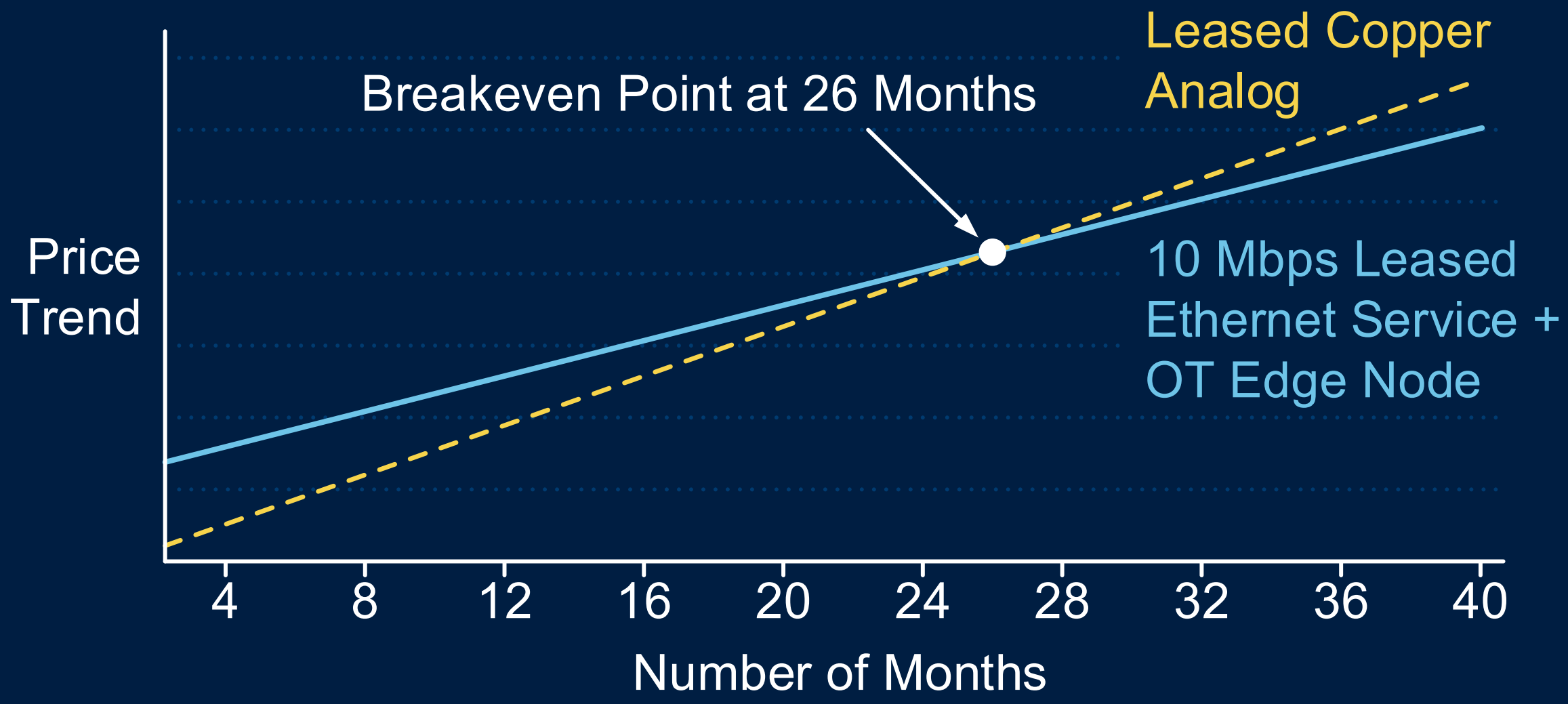
Channel Monitored for About Three Months

Parameter	Channel Performance (ms)
Round trip delay	2.3
Transmit delay	1.2
Receive delay	1.1
Asymmetry	0.08

No Dropped Packets (except for one network outage)

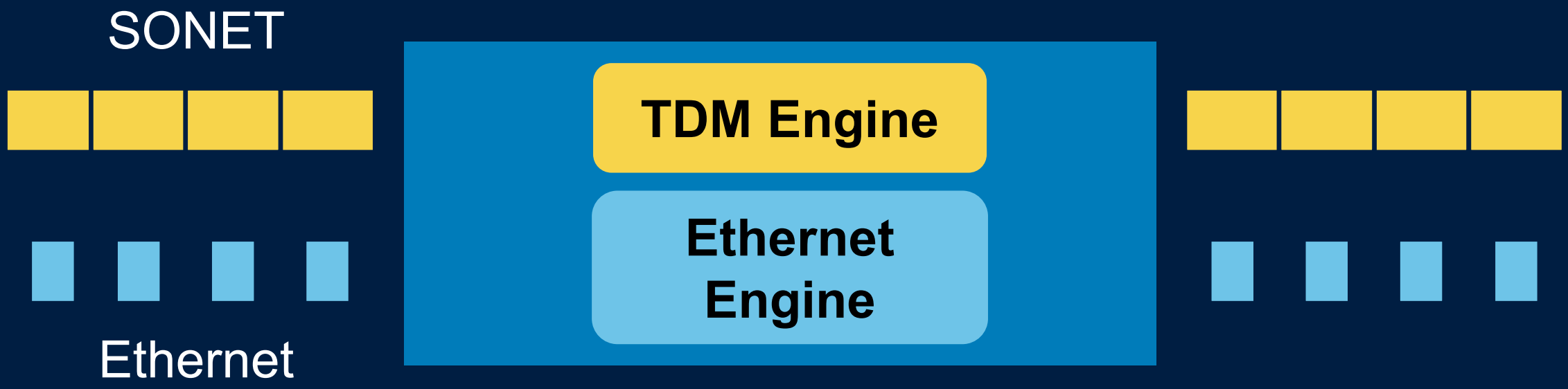
Discovering Breakeven Point

Migrating Circuit and Two Endpoints

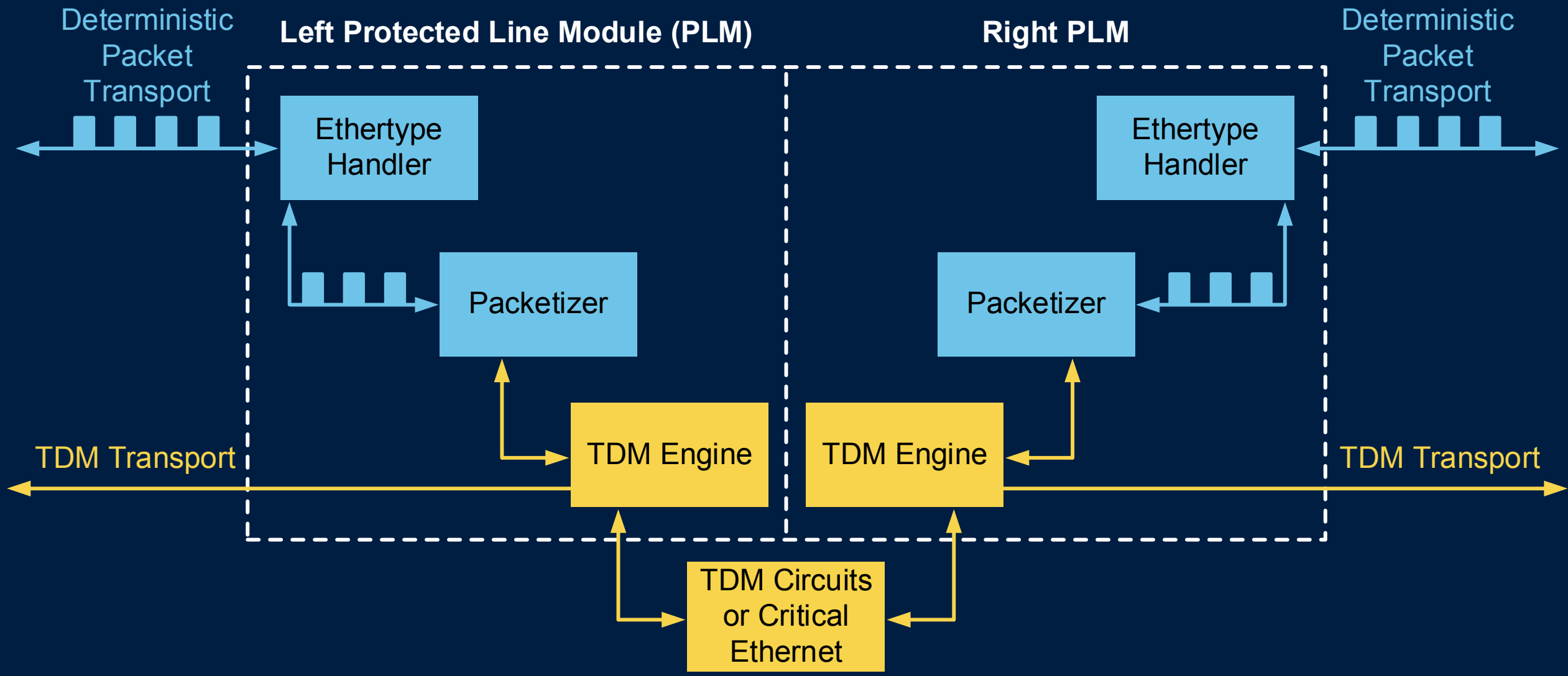


Preserving Deterministic TDM Performance Over Packet Transport

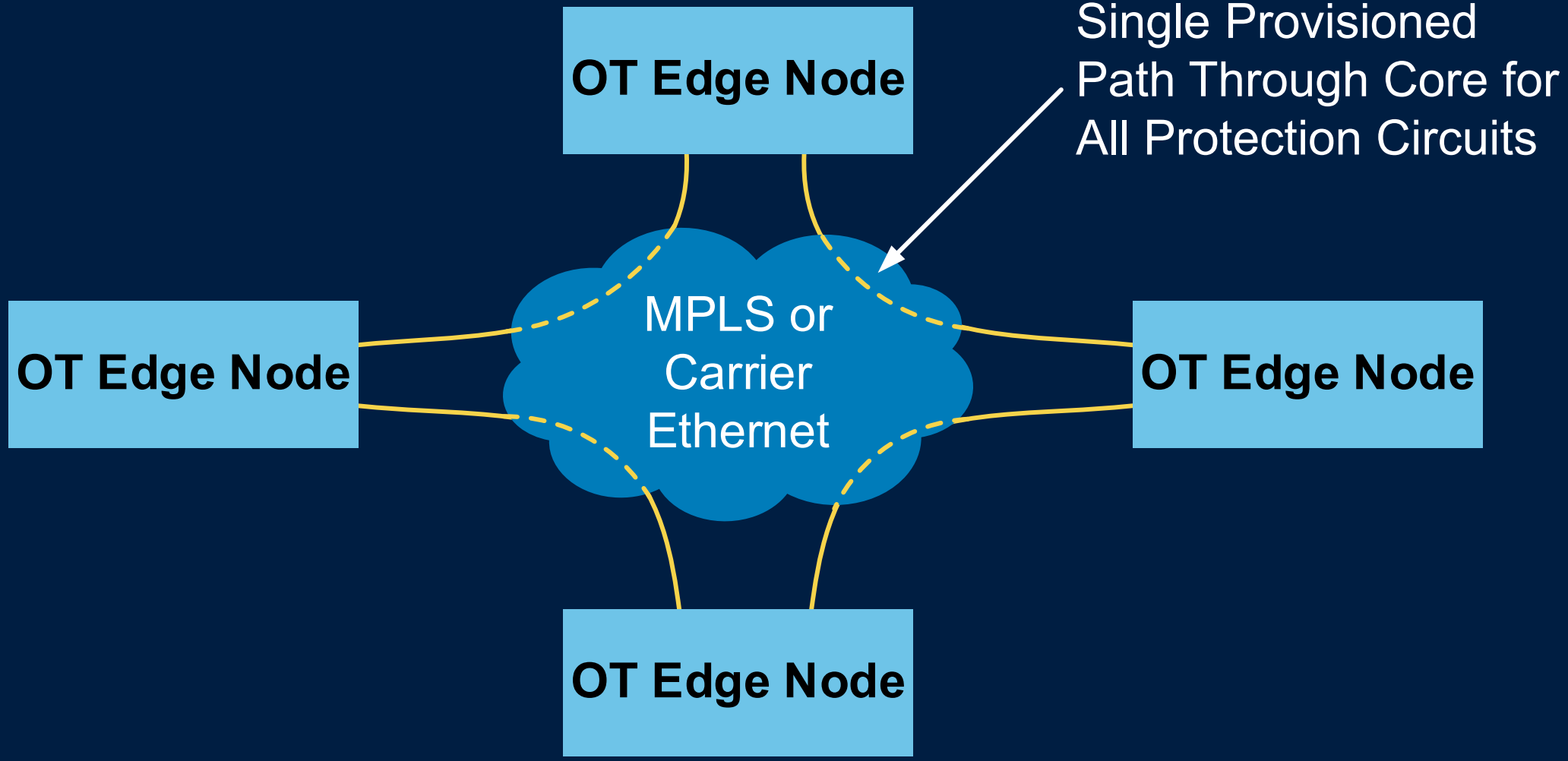
Virtual Synchronous Network (VSN)



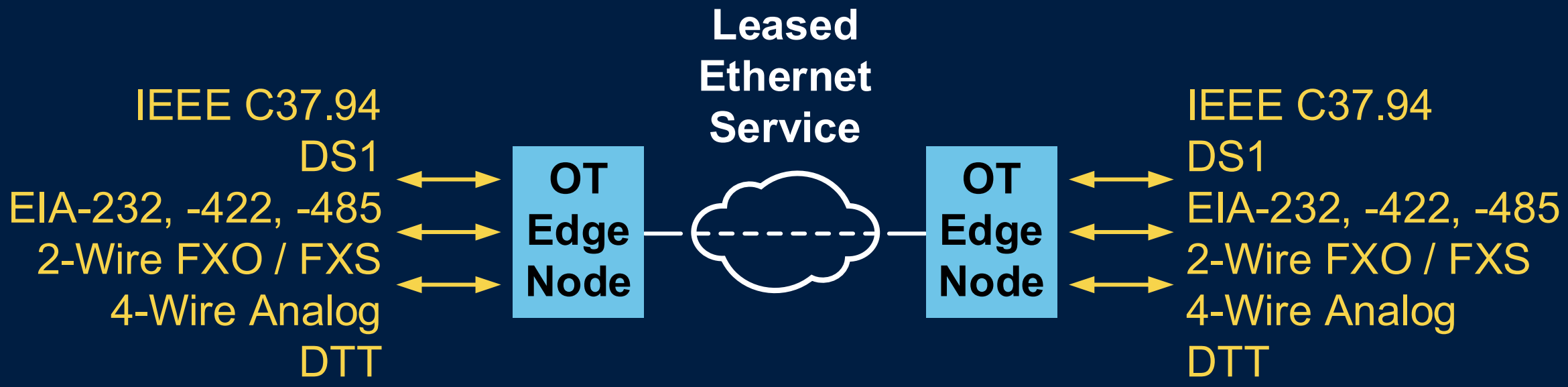
Achieving Deterministic Packet Transport



VSN Tunnel Across Core Transport



VSN Provides Solution for Leased Analog Replacement



- Improved performance
- Enhanced reliability
- Cost savings

Overall Conclusions

- Establishing relationship with telecommunications service provider is key
- Leased Ethernet meets DTT cost, reliability, and performance requirements
- Trials show that leased Ethernet performance is sufficient for line current differential protection

Questions?