CN's shared PSBN LTE Proof Of Concept

CN's LTE PoC Project Overview - Objectives

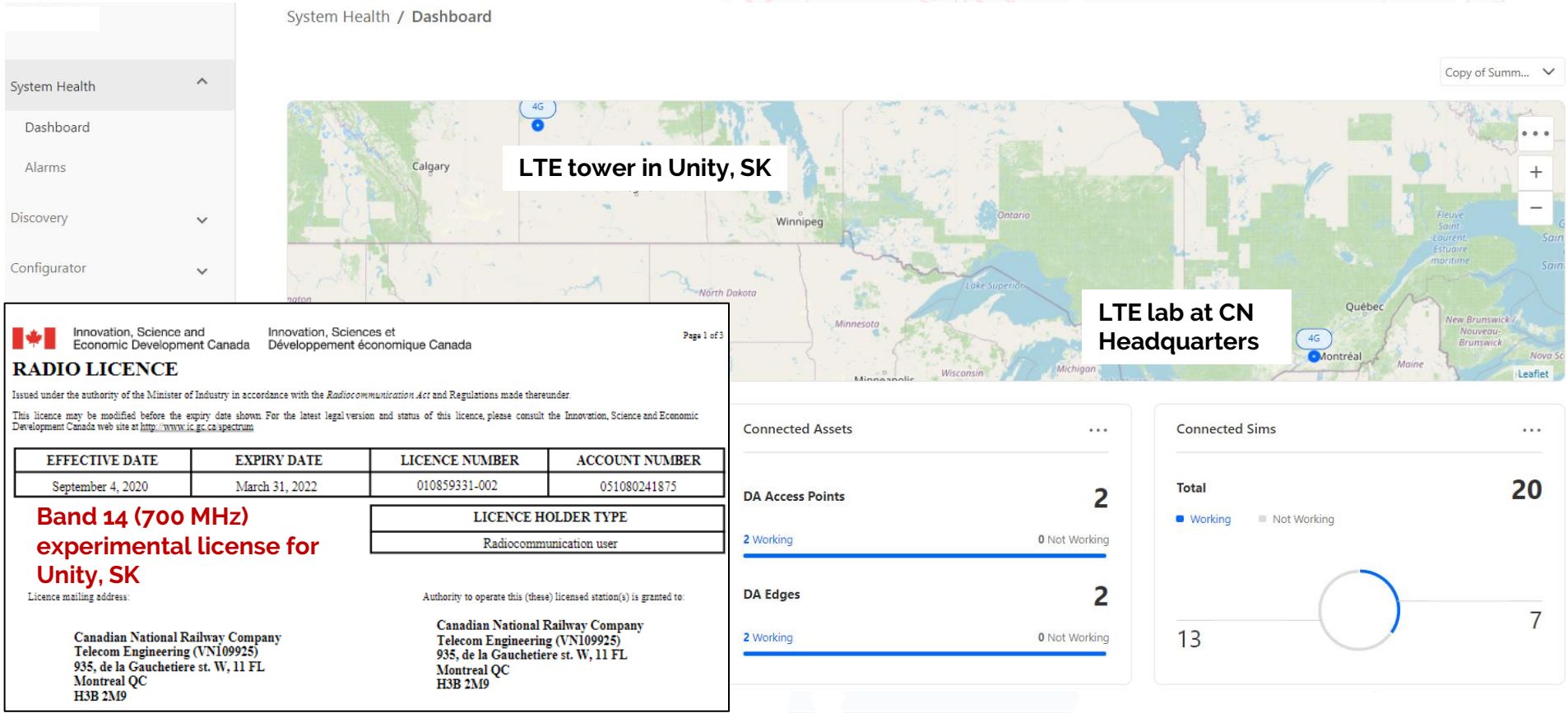
- Assess the benefit of **dedicated broadband wireless capability** when planned, integrated, operated, and maintained by rail

- Evaluate the feasibility of a **shared radio access network** amongst rail, public safety, and/or commercial cellular providers by leveraging Quality of Service (QoS) prioritization, a native LTE functionality

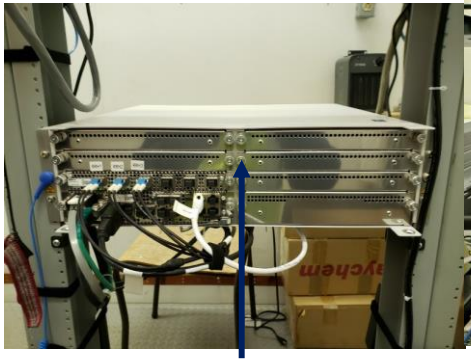
- **Foster CN's and RAC's objective to obtain regulatory clearance to operate LTE radio sharing on Public Safety Band 14 (FDD 10 + 10 MHz paired spectrum)**, while demonstrating mutually beneficial outcomes both, for the rail industry and remote communities

LTE PoC Project – Technical Aspects

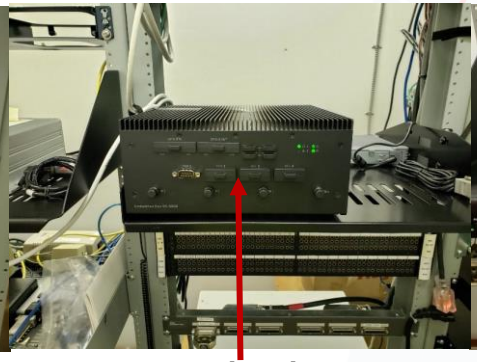
- **Tier-1 provider was selected to provide LTE equipment for both CN's Lab and Unity, SK sites.**



Unity Installation – Overview & Installation

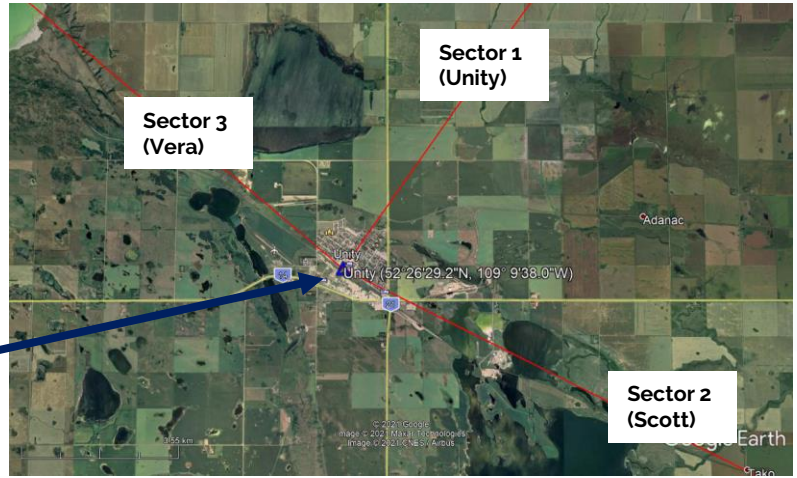


BBU
Base Band Unit, processes baseband. Connected to the RRU via fiber cables. Connected to the Juniper Router



EPC in a box
LTE Core

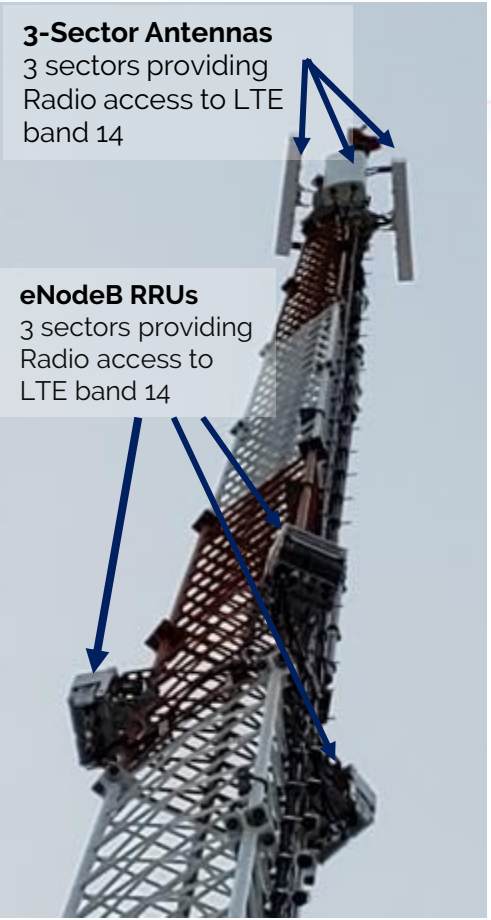
Linux Application server
Houses the Qpid back office instance



Unity Tower/Site

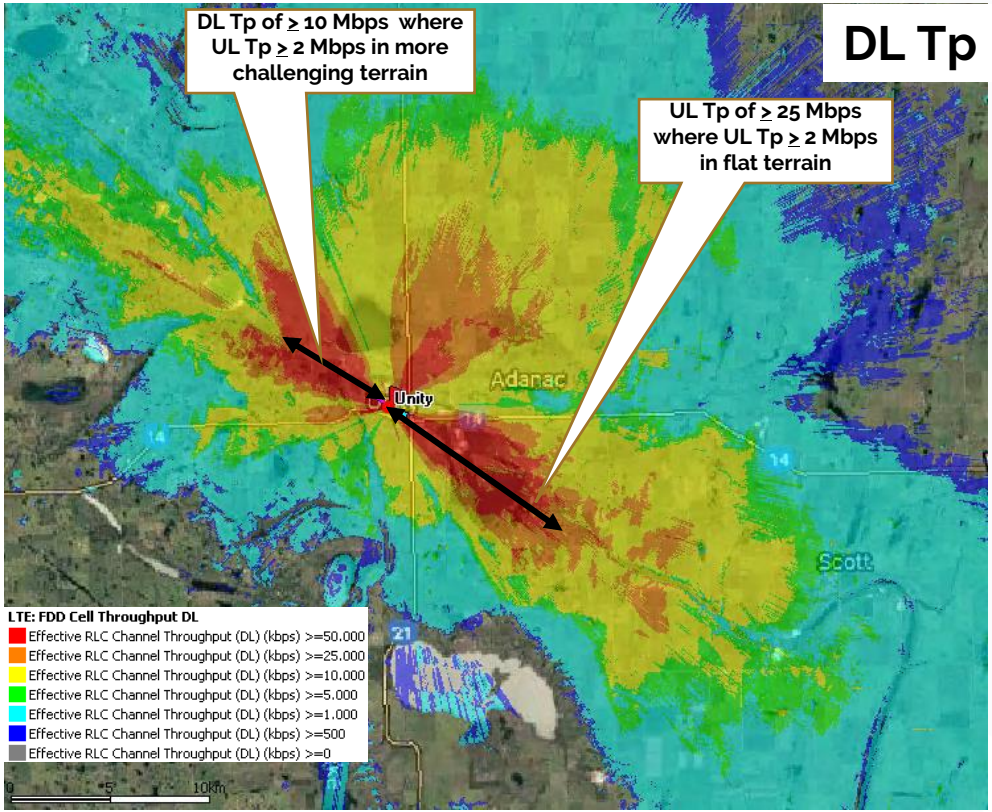
3-Sector Antennas
3 sectors providing Radio access to LTE band 14

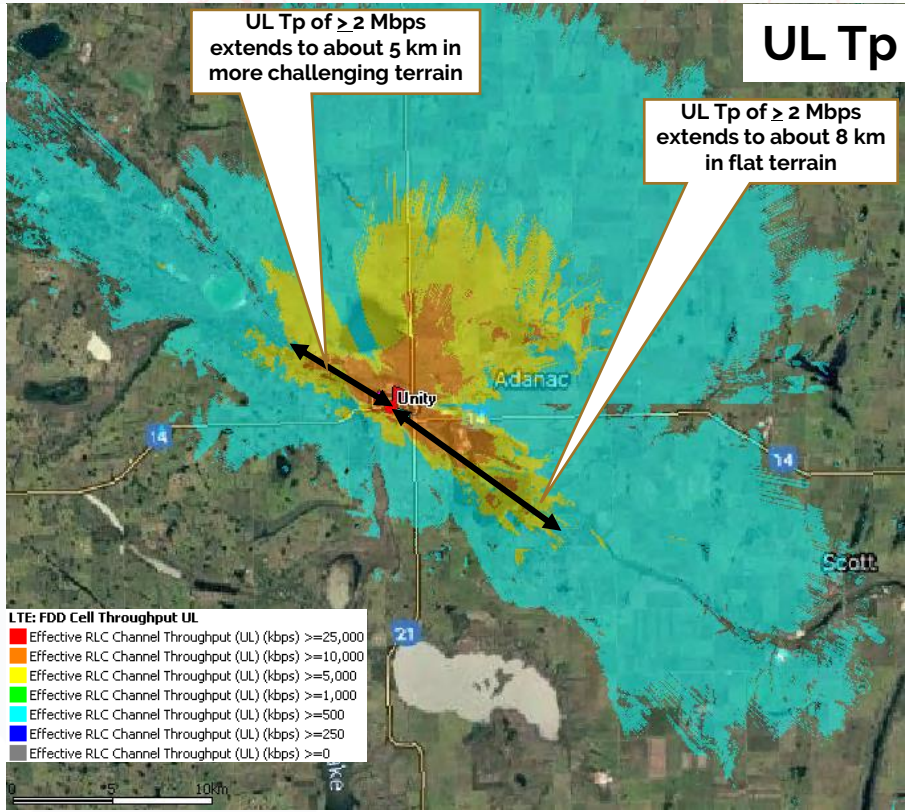
eNodeB RRUs
3 sectors providing Radio access to LTE band 14



Unity Drive tests - Objectives

- **Cell edge definition: UL Thput ≥ 2 Mbps performance objective**



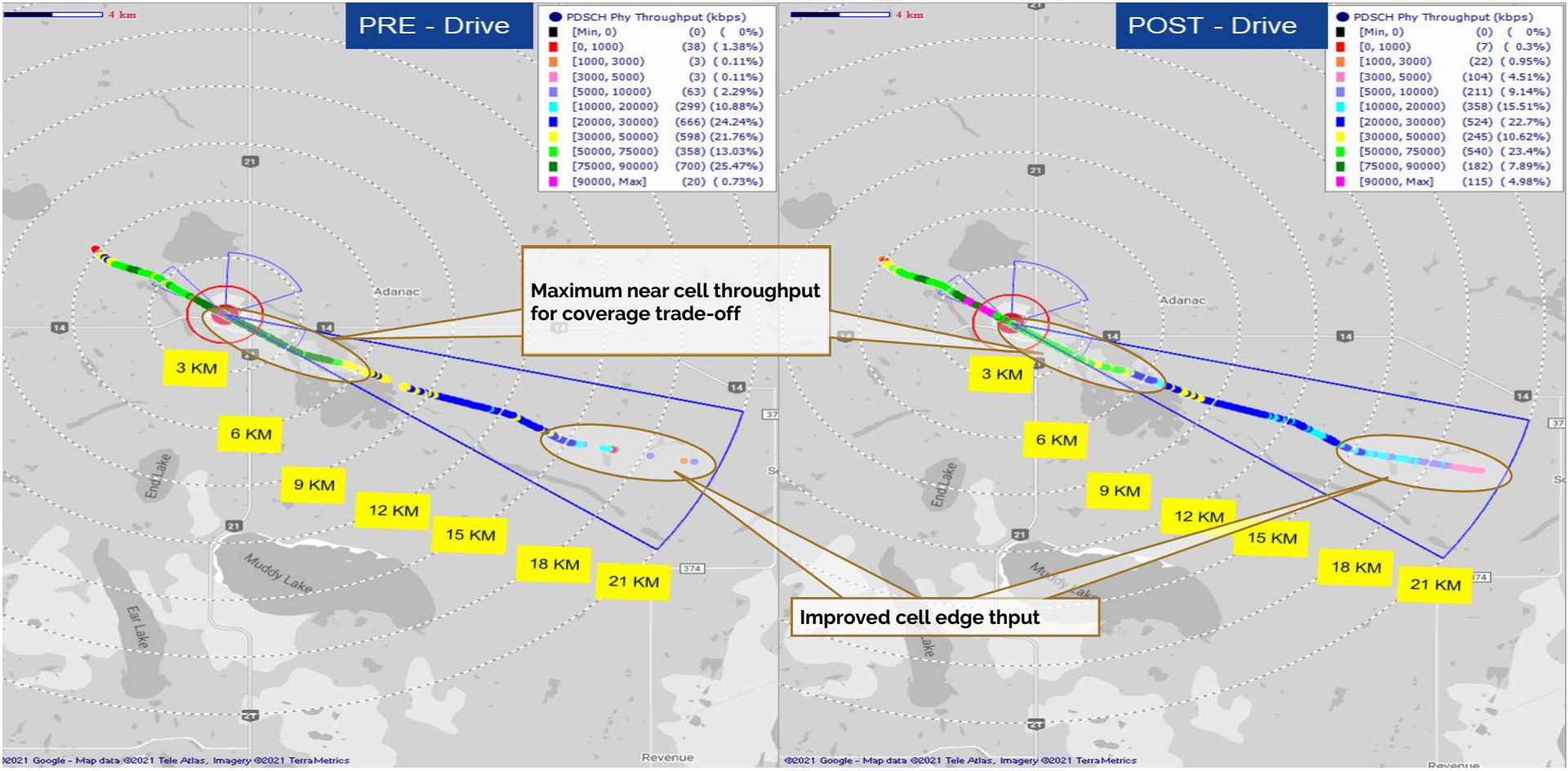


Unity Acceptance Tests – Sanity Check

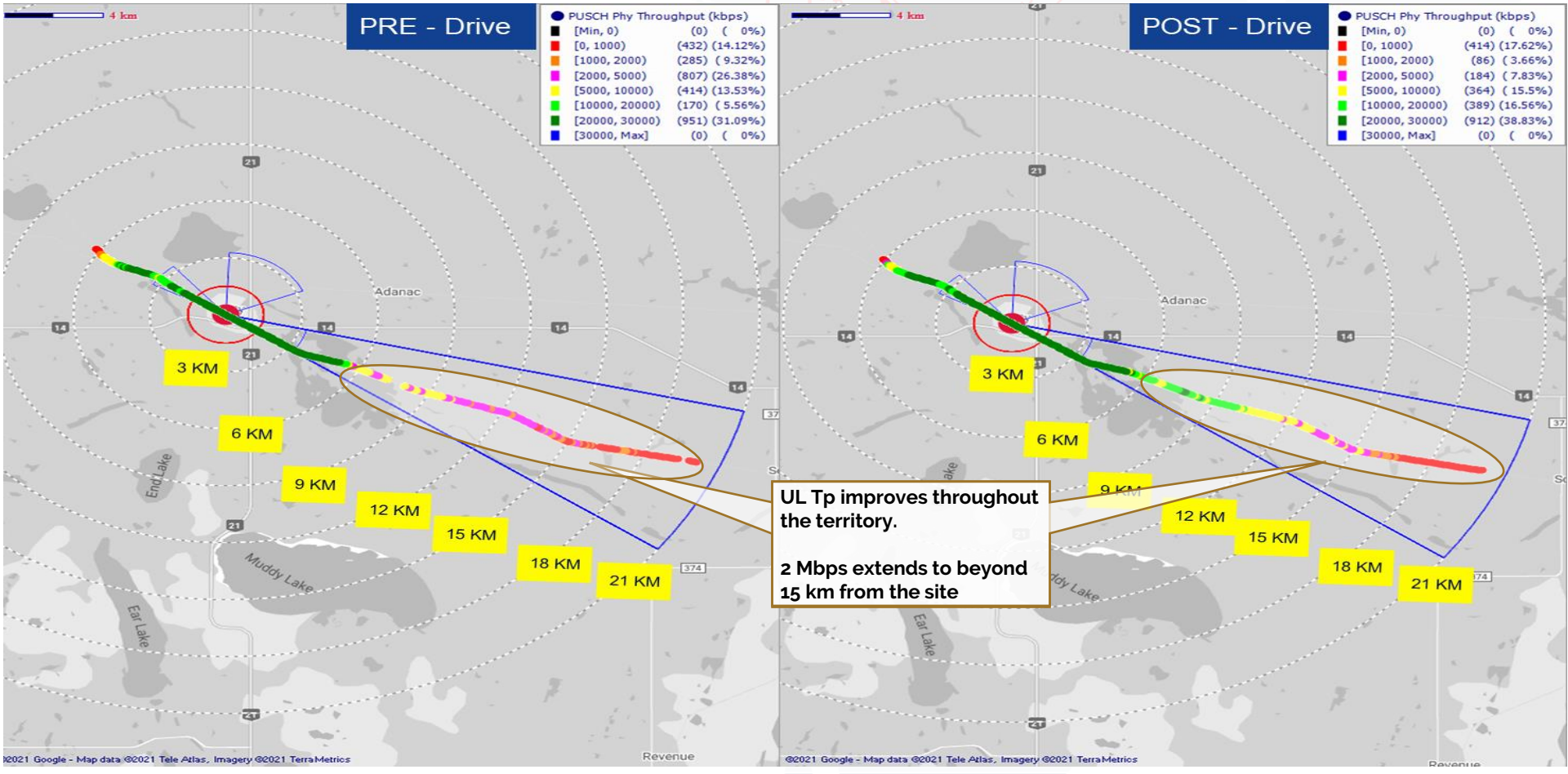
STATIONARY TEST	Peak Throughput	Sector ID	Peak PDSCH DL Throughput Mbps	Status	Peak PUSCH UL Throughput Mbps	Status
		Sector 1	95.6	PASS	29.0	Pass
		Sector 2	95.4	PASS	29.0	Pass
		Sector 3	95.5	PASS	29.0	Pass
	Latency	Test	Sector ID	Expected	Actual	Status
		Connection Setup	Sector 1	sec	3.00	Pass
			Sector 2		2.00	Pass
			Sector 3		2.16	Pass
		RTT	Sector 1	msec	20.2	Pass
			Sector 2		22.2	Pass
			Sector 3		19.6	Pass
Intra-Site HO	Direction	Test	PCI to PCI / Sec to Sec		Actual	Status
NON STATIONARY TEST	CW	HOSR	Sec1 to Sec2	msec	6	Pass
			Sec2 to Sec3		35	Pass
			Sec3 to Sec1		16	Pass
	CCW	HOSR	Sec3 to Sec2	msec	30	Pass
			Sec2 to Sec1		14	Pass
			Sec1 to Sec3		15	Pass

On par with optimal expected technology performance

Unity Hi-rail tests – DL Optimization drives



Unity Hi-rail tests – UL Optimization drives



Quality of Service lab testing– Objective & parameters

Objective

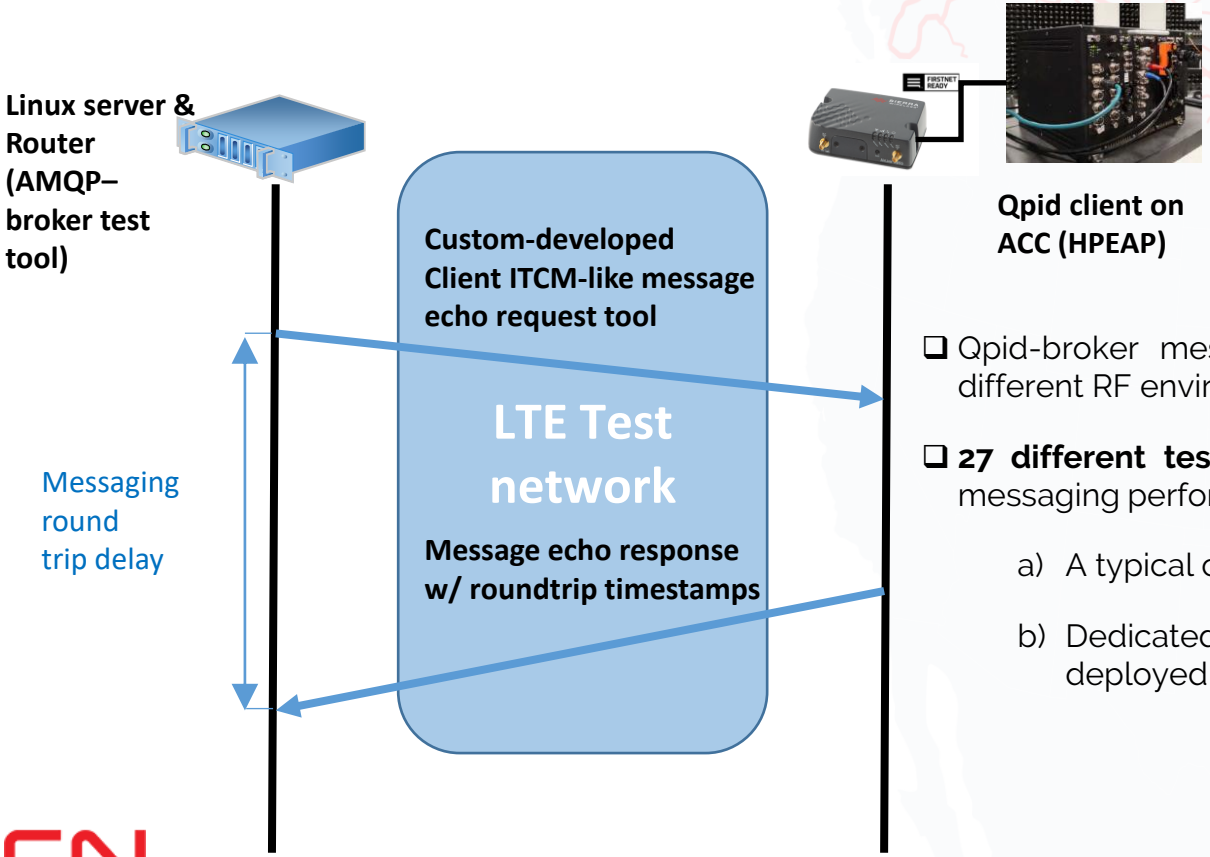
- Validate the impact of QoS functionality on messaging (ITCM-like) delay under various network and radio conditions

Observation Thresholds

- **Warning threshold**: Messaging service is deemed to be in a marginal state if single end-to-end latency exceeds 5 seconds

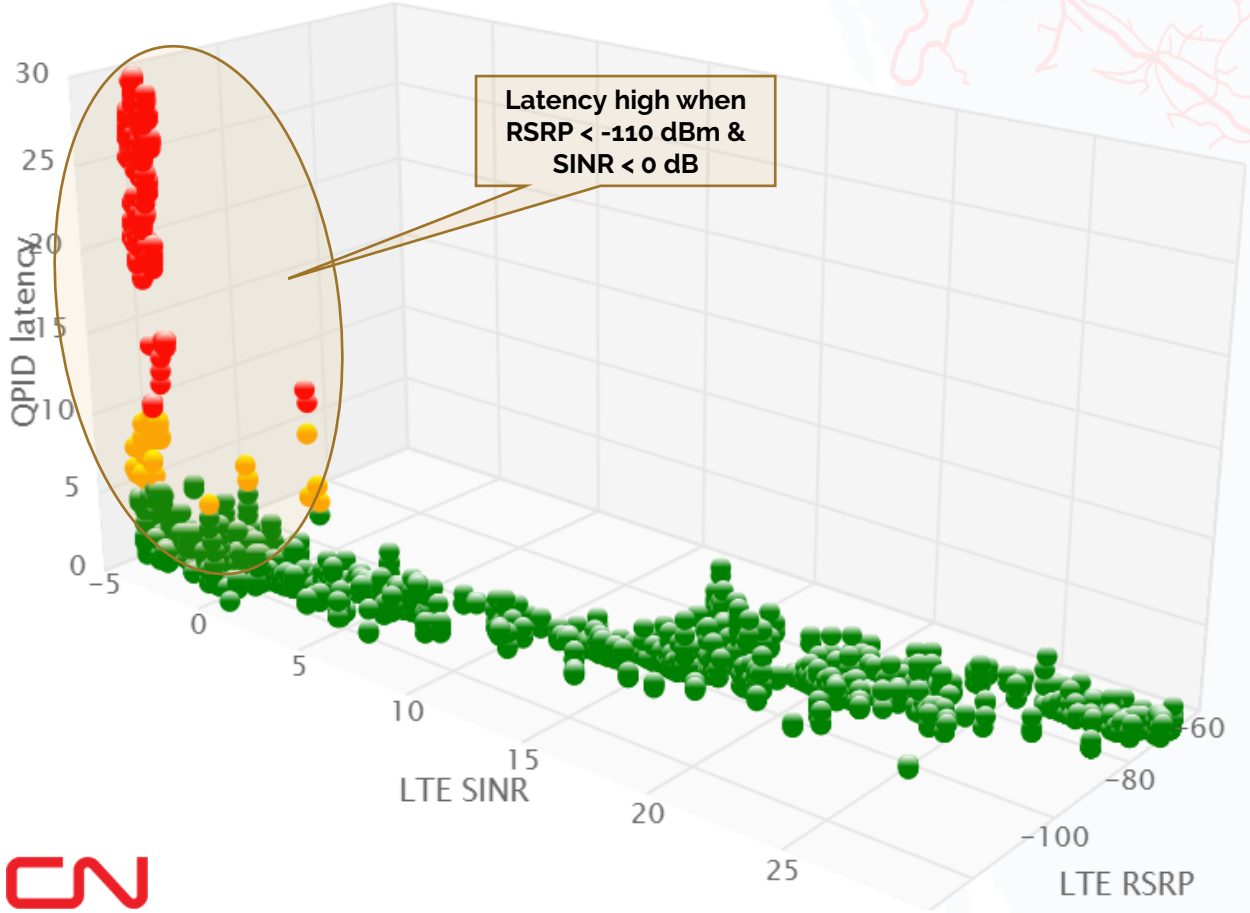
- **Fault threshold:** 10 seconds is considered an imminent train enforcement condition due to excessive queuing

ITCM like performance testing



- Qpid-broker messaging success, failure, and latency in different RF environments and QoS profiles were measured
- **27 different test cases** executed to compare ITCM-like messaging performance between:
  a) A typical commercial cellular network configuration
  b) Dedicated LTE Network planned, designed and deployed by CN rail

VARIABLE RF CONDITIONS – Baseline results: No QoS vs 4 x BE contenders



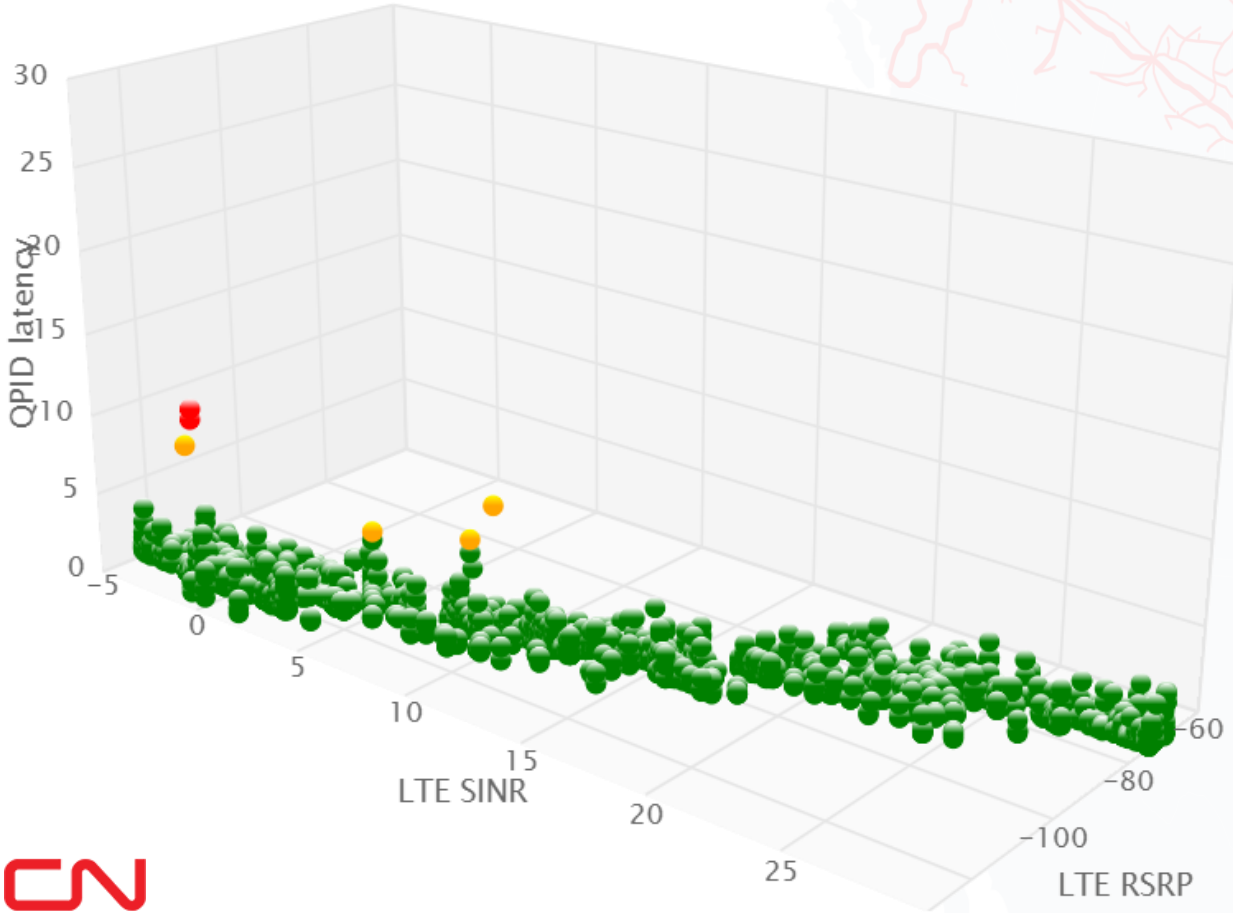
Qpid Latency (s)	
Average	3.23
Max	39.87
Min	0.09
Standard Deviation	7.49

Test Case Descriptions: Varying RF in Commercial network configuration of a BE Qpid in contention from 4 BE UEs

Results & Observations:

- In a commercial cellular network with no QoS or control over coverage, Qpid latency could quickly rise above acceptable limits
- Latency high when RSRP < -110 dBm & SINR < 0 dB

VARIABLE RF CONDITIONS – MC QoS profile vs 4 x BE contending users



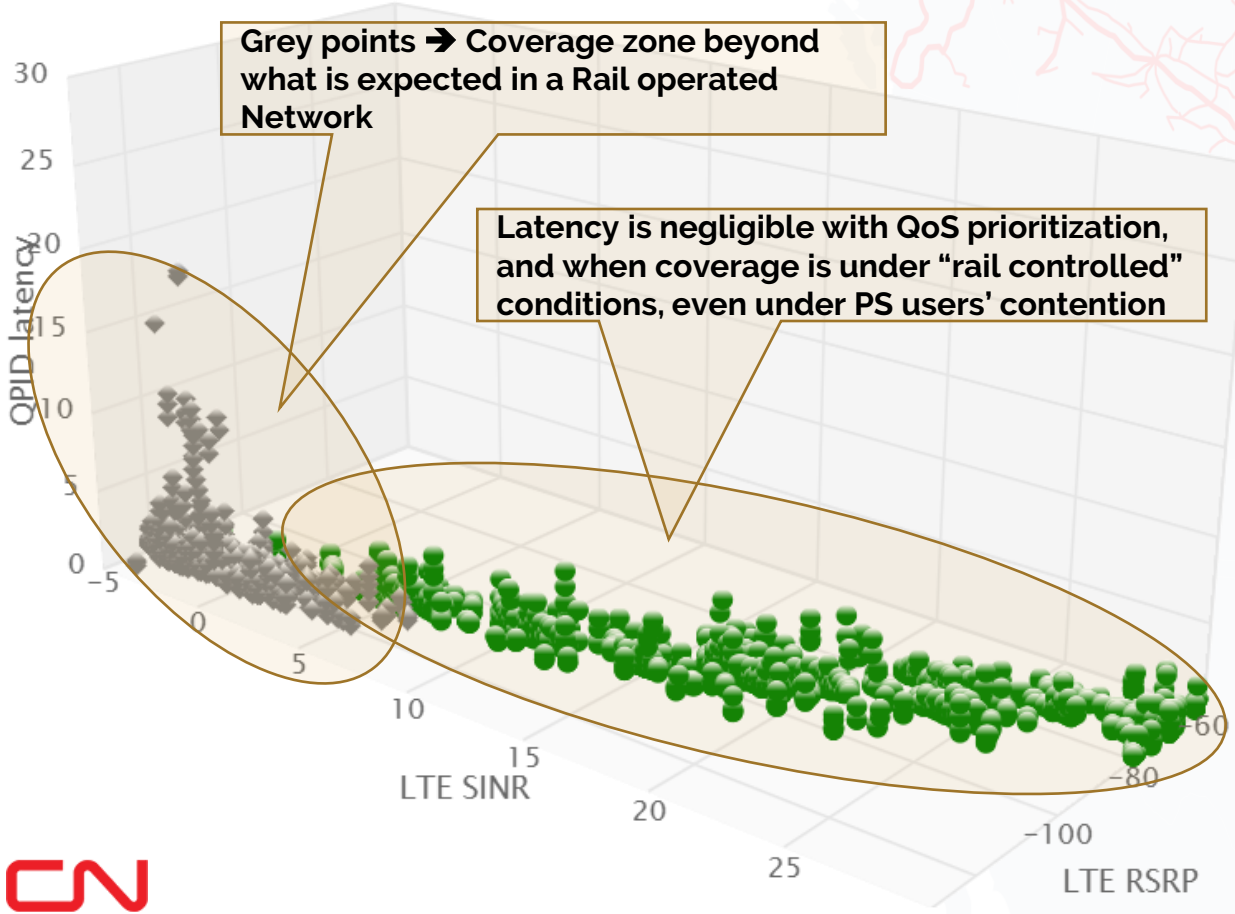
Qpid Latency (s)	
Average	0.54
Max	10.89
Min	0.08
Standard Deviation	0.54

Test Case Descriptions: Varying RF in Commercial network configuration of a CIO Qpid in contention from 4 BE UEs

Results & Observations:

- ➔ ***Step 1: Introducing Quality of Service***
- Even in a commercial cellular network with best effort coverage, QoS can help curtail poor latency performance
- Some unacceptable excessive latency is still visible in fringe radio conditions

VARIABLE RF CONDITIONS –2xBE & 2xPS (Higher priority) and MC QoS profile



Qpid Latency (s)	
Average	0.49
Max	4.78
Min	0.08
Standard Deviation	0.42

Test Case Descriptions: Varying RF in Rail network configuration of a CIO Qpid in contention from 2 BE & 2 PS UEs

Results & Observations:

- ➔ ***Step 2: QoS + Rail controls minimum cell edge radio conditions***
- Latency is negligible with QoS prioritization, and when RF is in typical rail conditions, even in the presence of contention from PS users
- Contention from PS users is negligible

Conclusion: controlled coverage and QoS deliver “hand in hand”

- **Messaging over Best Effort wireless cellular communications is susceptible to inadequate messaging latency**, such as over commercial networks’ marginal coverage areas, and in the presence of traffic contention from other users

- Quality of Service coordination among multiple user profiles ensures suitable messaging delay performance
  - **Combined with minimum coverage observance**, **QoS can deliver excellent messaging performance**, even under contention from concurrent data intensive users
  - Successful **co-existence with Public Safety and Best Effort users is possible** while maintaining adequate rail mission critical application performance

- **The main benefit of a rail operated LTE network is the ability to control both coverage and QPP (Quality of Service, Priority and Pre-emption) enabling mission-critical grade reliable, and highly capable performance**

Backup slides

Abbreviations and Acronyms

BBU	Base Band Unit
BE	Best Effort
CIO	Critical Infrastructure Operator
CQI	Channel Quality Indicator (1 to 15)
DL	Downlink – from the Back Office to the UE
DUT	Device Under Test
eNB	eNodeB LTE radio providing over the air access to LTE
EPC	Evolved Packet Core
ISED	Innovation, Science, and Economic Development
ITCM	Interoperable Train Control Messaging
LTE	Long Term Evolution
PS	Public Safety
PSBN	Public Safety Broadband Network
QCI	QoS Class Identifier
QoS	Quality of Service

Qpid	Open-source messaging system which implements the Advanced Message Queuing Protocol (AMQP)
QPP	Quality of Service, Priority, and Pre-emption
RAC	Railway Association of Canada
RRU	Remote Radio Unit
RSRP	Reference Signal Receive Power
RSRQ	Reference Signal Receive Quality
RV55	Sierra Wireless Airlink RV55 Gateway
SINR	Signal-to-Interference Noise Ratio
S10	Samsung Galaxy S10
TEMS	Infovista software used to evaluate and characterize/collect LTE KPIs
UL	Uplink – from the UE to the Back Office
UE	User Equipment
VLAN	Virtual Local Area Network
WCC	Wireless Communications Committee

Shared PSBN LTE … what is it?

- Shared LTE (Long Term Evolution) PSBN (Public Safety Broadband Network) is a proposed public private partnership between:
  - Canadian Critical Infrastructure Operators (CIOs, e.g. the RAC and the CEA)
  - Public Safety Canada, and
  - potentially mobile service providers

  …. with **multi-faceted benefits** to all involved parties

Railway Association of Canada | RIGHT TRACK

Canadian Electricity Association | Association canadienne de l'électricité

- Public Safety Canada has a mandate to facilitate the deployment of a nation-wide Public Safety Broadband Network (PSBN) for the First Responders' community (equivalent to FirstNet[1] in the US)

- PSBN is expected to be primarily operated by established Mobile Wireless providers as an augmentation to their networks, reusing mostly legacy infrastructure **in exchange for spectrum**

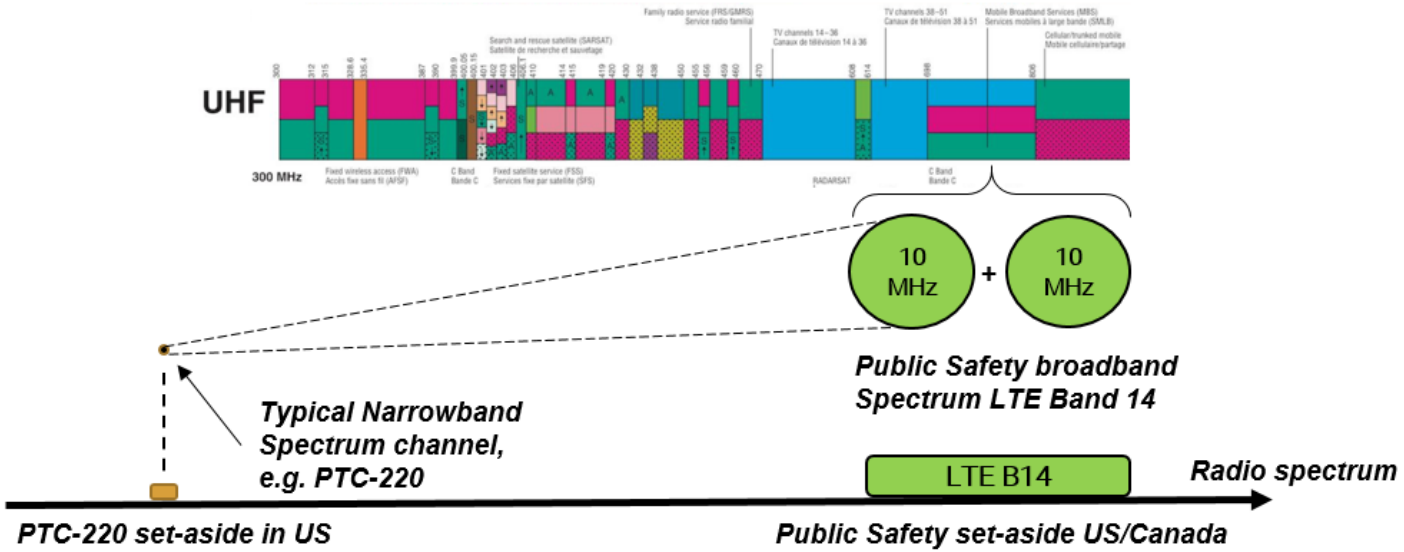
- Telecom operators have limited financial incentive to deploy in rural and remote regions where legacy telecommunications infrastructure is scarce

[1] ***FirstNet***: *US Homeland Security's First Responder network (inc. 2021)*

Shared PSBN LTE … what's in it for Rail?

- Rail obtains access to dependable broadband wireless connectivity, fulfilling a significant part of our operational needs by leveraging our infrastructure in rural and remote Canada

- The proposal hinges on deploying LTE base stations on shared broadband spectrum allocated to PSBN, a precious asset (estimated economic value of Canada-wide license: **CAD 600 million**)
  - ***Note***: *Broadband spectrum, a scarce asset, has otherwise remained elusive to Industry as government-led spectrum auctions are reserved to public mobile wireless service providers only*



Narrowband (PTC-220) versus PSBN spectrum order-of-magnitude comparison

Context - Reliable broadband wireless communications

- Rail dedicated wireless technologies, e.g., PTC 220 MHz, ATCS 900 MHz, VCCS 160 MHz work on **narrowband dedicated** spectrum, **licensed** to the rail industry
  - ✓ Despite their **limited capacity** they **deliver on reliability, resiliency and availability**

- As Operational Rail technology evolves it is expected to gradually impose **higher capacity and performance requirements** on the underlying communication networks

- Wireless broadband networks **(LTE/5G)** bring multiple orders-of-magnitude increase in capacity and performance
  - ✓ **Commercial broadband** services**,** however**,** cater primarily for consumer electronics, and **do not ensure high availability, nor service reliability performance (no SLAs)**

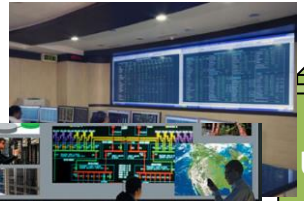
  - ✓ **It's simply not part of the TELCOs' business model !**
  - ✓ **… hence, the quest for dedicated Broadband wireless capability**

Government's awareness –
Transport Canada's Rail Safety Act review 2018 – Call for action

- A panel of experts mandated by Minister Garneau's office concluded:
  - ✓ "***Dedicated radio spectrum is vital*** *for putting an effective train control strategy in place across the national rail network. Spectrum, however, is in high demand, and individual railway companies cannot ensure sufficient bandwidth is available to meet their identified communication needs for* ***high-speed mobile data*** *and radio spectrum."* [1]
  - ✓ "*A* ***shared broadband network*** *to support multi-modal transportation safety solutions requires a national approach, and* ***engagement with multiple federal departments*** *(e.g., Innovation, Science and Economic Development Canada or ISED, and Public Safety Canada)."* [1]
- The review made the point loud and clear. CN and its partners set out to work together on a decisive Industry/Government **collaboration proposal to enable broadband wireless dedicated capability** for rail in Canada

1 - Complete Review name: "Enhancing Rail Safety in Canada: Working Together For Safer Communities The 2018 Rail Safety Act Review"

1 - Shared RAN PPP: Public Safety (PSBN), CIOs, MNOs for rural access



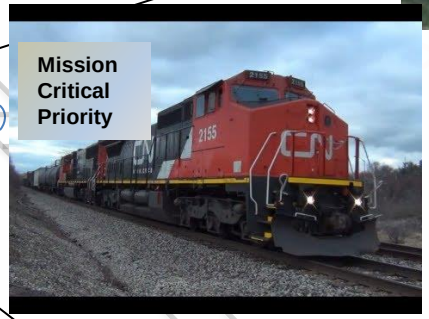
PSC Core NW

CIOs (Rail, Utilities, etc) Core NW

Telco operator

Telco operator

700 MHz Public Safety LTE B14



- ✓ *Extended PSBN reach into remote communities*
- ✓ *CIOs leverage their Operational footprint while enabling their partners*
- ✓ *Rural communities may benefit of Broad-band Internet Access leveraging excess capacity-leasing to MNOs*