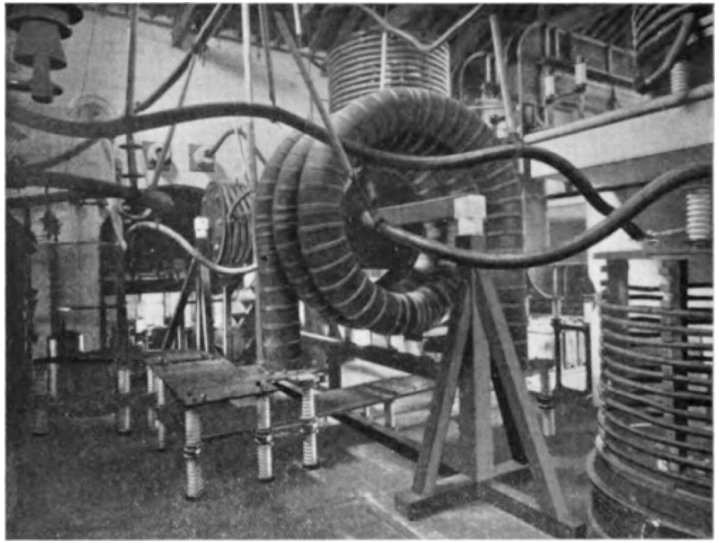
Dynamic Spectrum Management

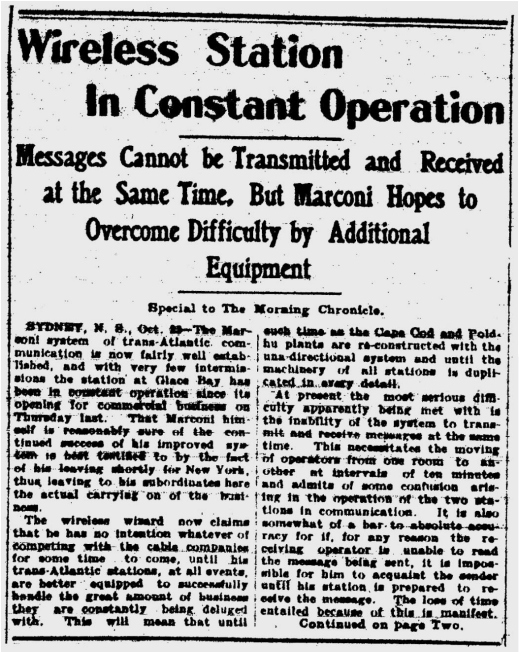
Amir Ghasemi
November 14, 2018

Source: Communications Research Centre Canada

100+ Years of Interference (Avoidance)



Marconi's trans-Atlantic transmitter



Wireless Station In Constant Operation

Messages Cannot be Transmitted and Received at the Same Time, But Marconi Hopes to Overcome Difficulty by Additional Equipment

Special to The Morning Chronicle.

SYDNEY, N. S., Oct. 29—The Marconi system of trans-Atlantic communication is now fairly well established, and with very few intermissions the station at Glace Bay has been in constant operation since its opening for commercial business on Thursday last. That Marconi himself is reasonably sure of the continued success of his improved system is best testified to by the fact of his leaving shortly for New York, thus leaving to his subordinates here the actual carrying on of the business.

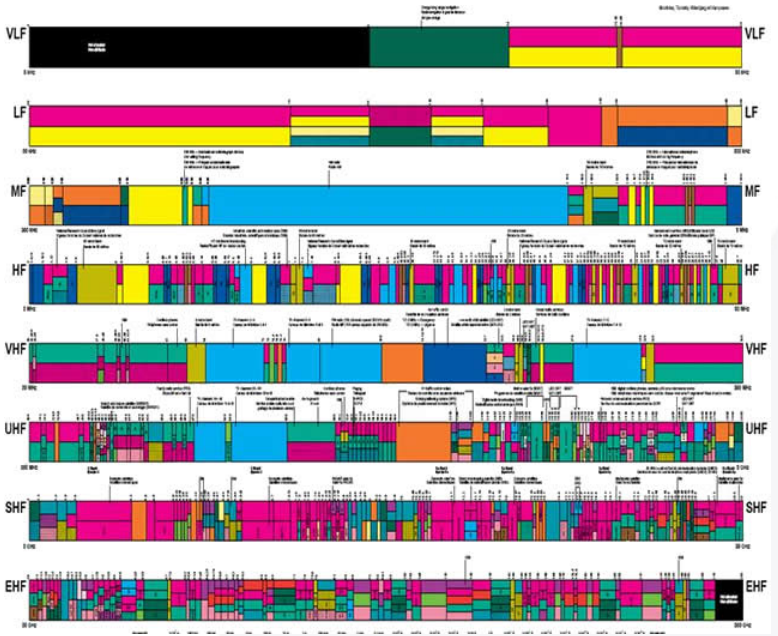
The wireless wizard now claims that he has no intention whatever of competing with the cable companies for some time to come, until his trans-Atlantic stations, at all events, are better equipped to successfully handle the great amount of business they are constantly being deluged with. This will mean that until such time as the Cape Cod and Poldhu plants are re-constructed with the una-directional system and until the machinery of all stations is duplicated in every detail.

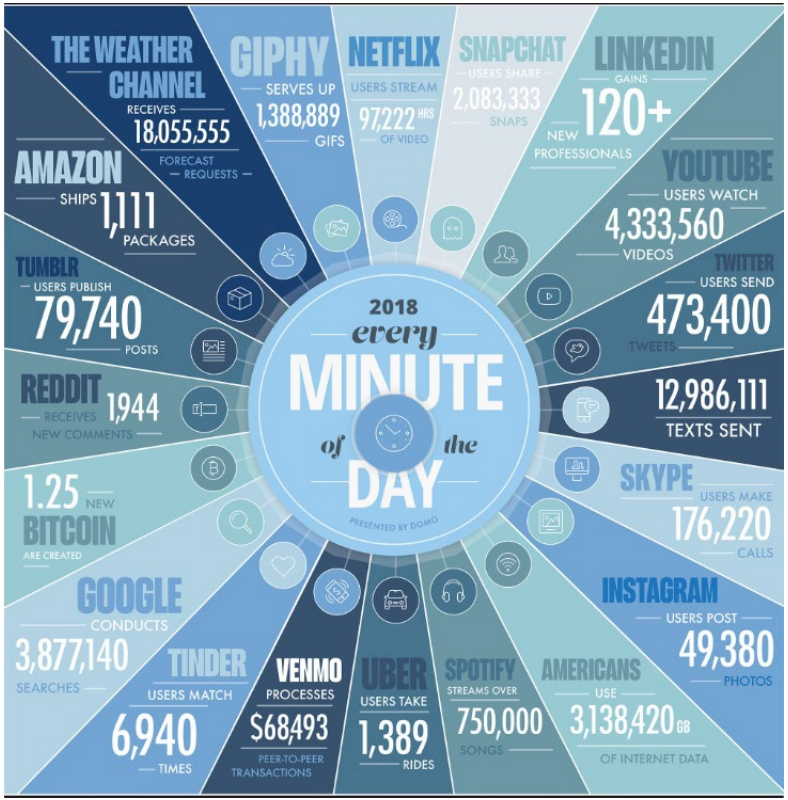
At present the most serious difficulty apparently being met with is the inability of the system to transmit and receive messages at the same time. This necessitates the moving of operators from one room to another at intervals of ten minutes and admits of some confusion arising in the operation of the two stations in communication. It is also somewhat of a bar to absolute accuracy for if, for any reason the receiving operator is unable to read the message being sent, it is impossible for him to acquaint the sender until his station is prepared to receive the message. The loss of time entailed because of this is manifest.

Continued on page Two.

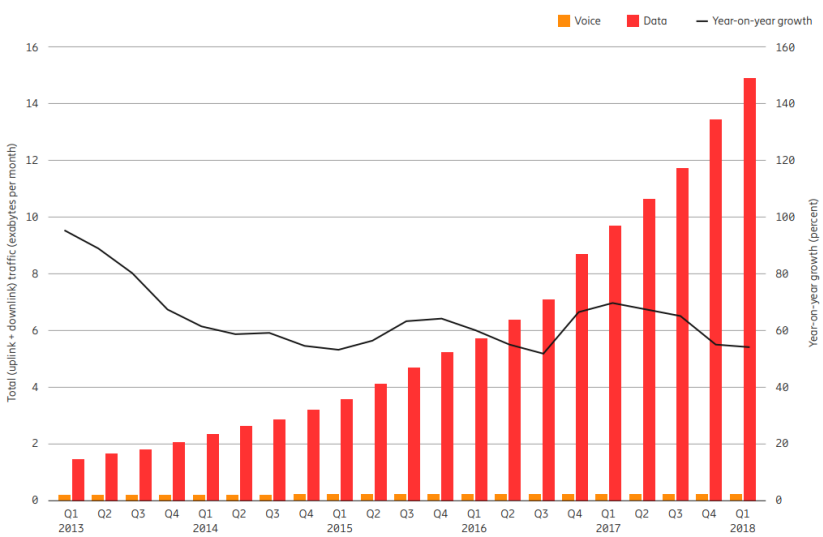
Overview

- Spectrum management today:
  - Hard guarantees via resource fragmentation and conservative assumptions
  - Manual, labour-intensive processes in some bands
  - Inefficient under time and location varying loads

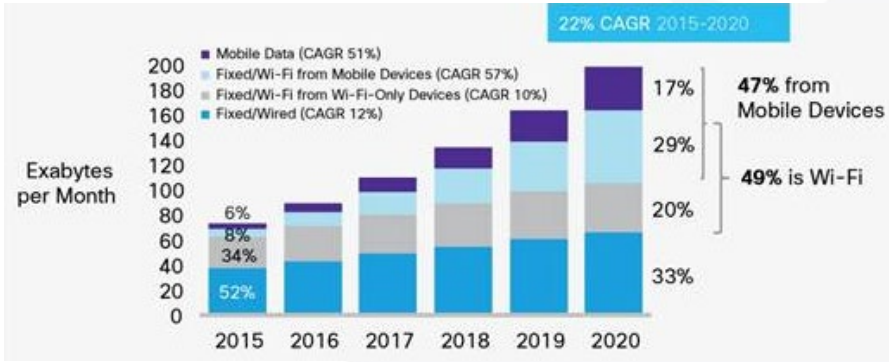




source: Domo Inc.



source: Ericsson (Q1 2018)



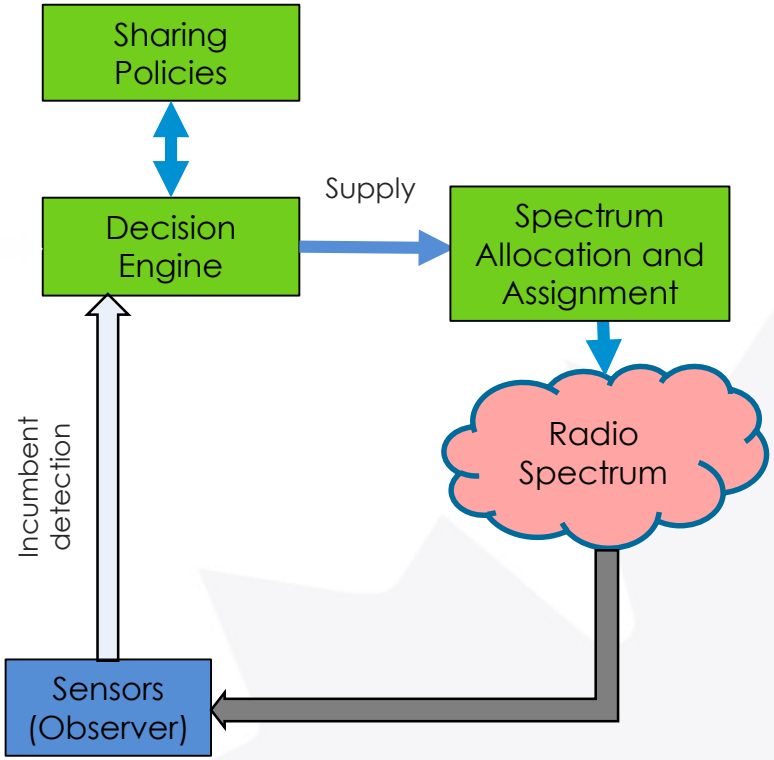
source: Cisco (2017)

Spectrum Outlook

- More mobile spectrum pressure
- mmWave shows some promise but bound by laws of physics
- Better use of spectrum below 6 GHz still needed
  - New technologies, repacking, auctions

Towards More Dynamic Management

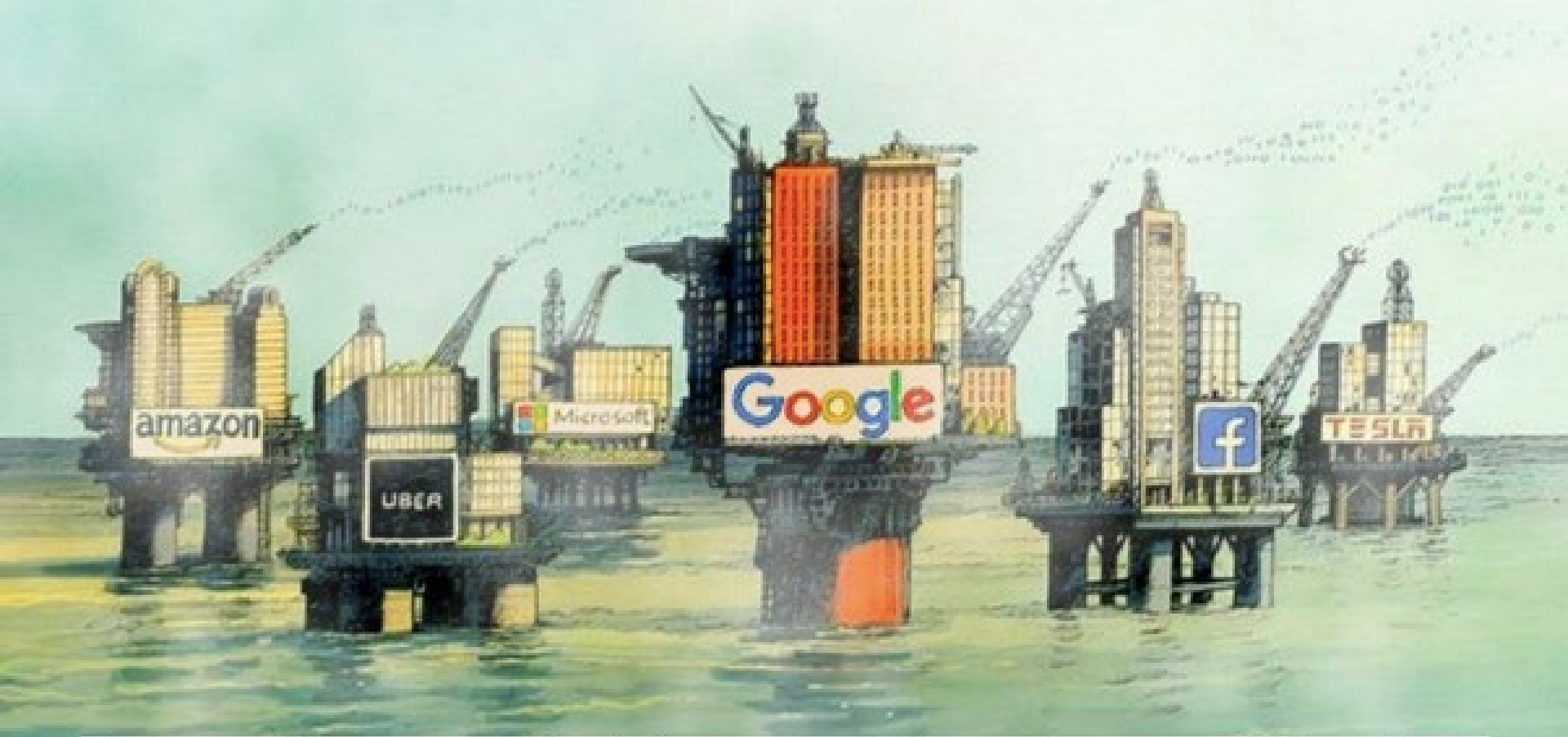
- Sharing with incumbent protection (TVWS, CBRS)
- Spectrum "supply" determined by incumbent activity



Dynamic Spectrum Management

- How can we manage increasing **demand** by sharing bands among different technologies?
- **How**, **when**, and **where** spectrum is being used?
- What policies would promote **efficiency** of systems sharing the spectrum?

Challenged by lack of data to model usage, predict demand, and measure success



The world's most valuable resource is no longer oil, but data.

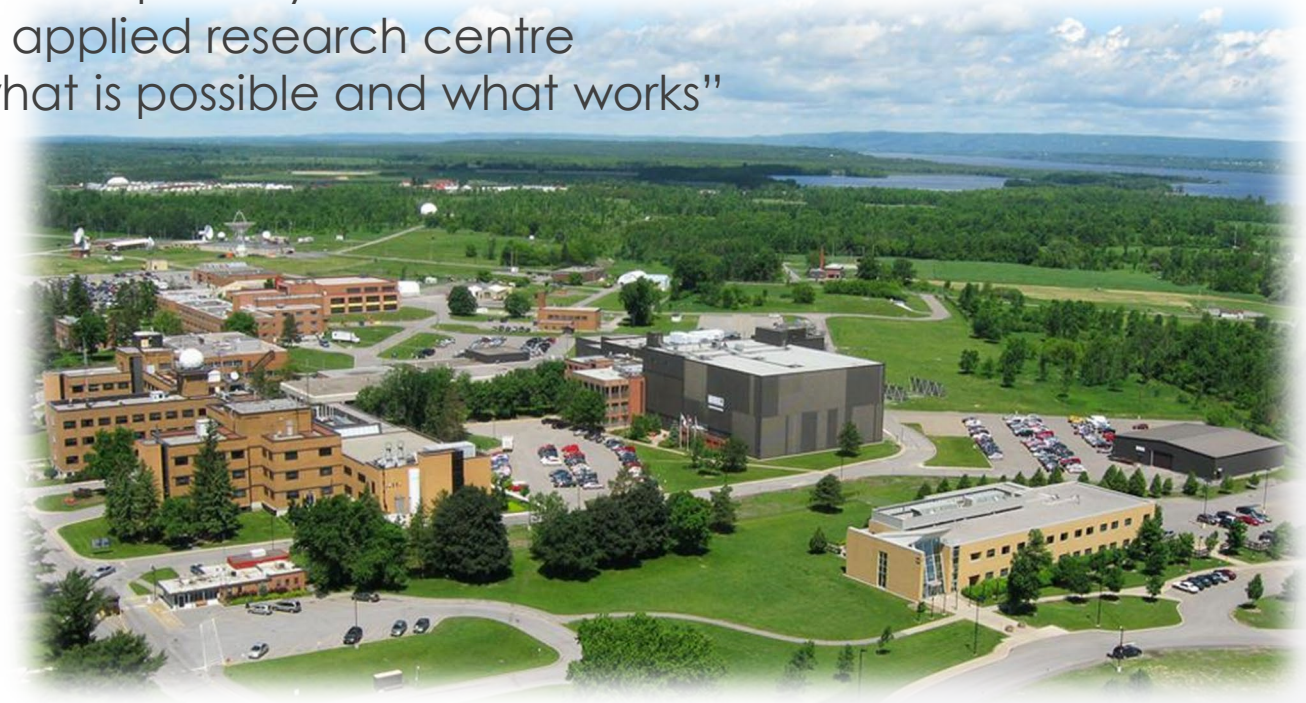
The Economist - May 2017

David Parkins

Communications Research Centre Canada (CRC)

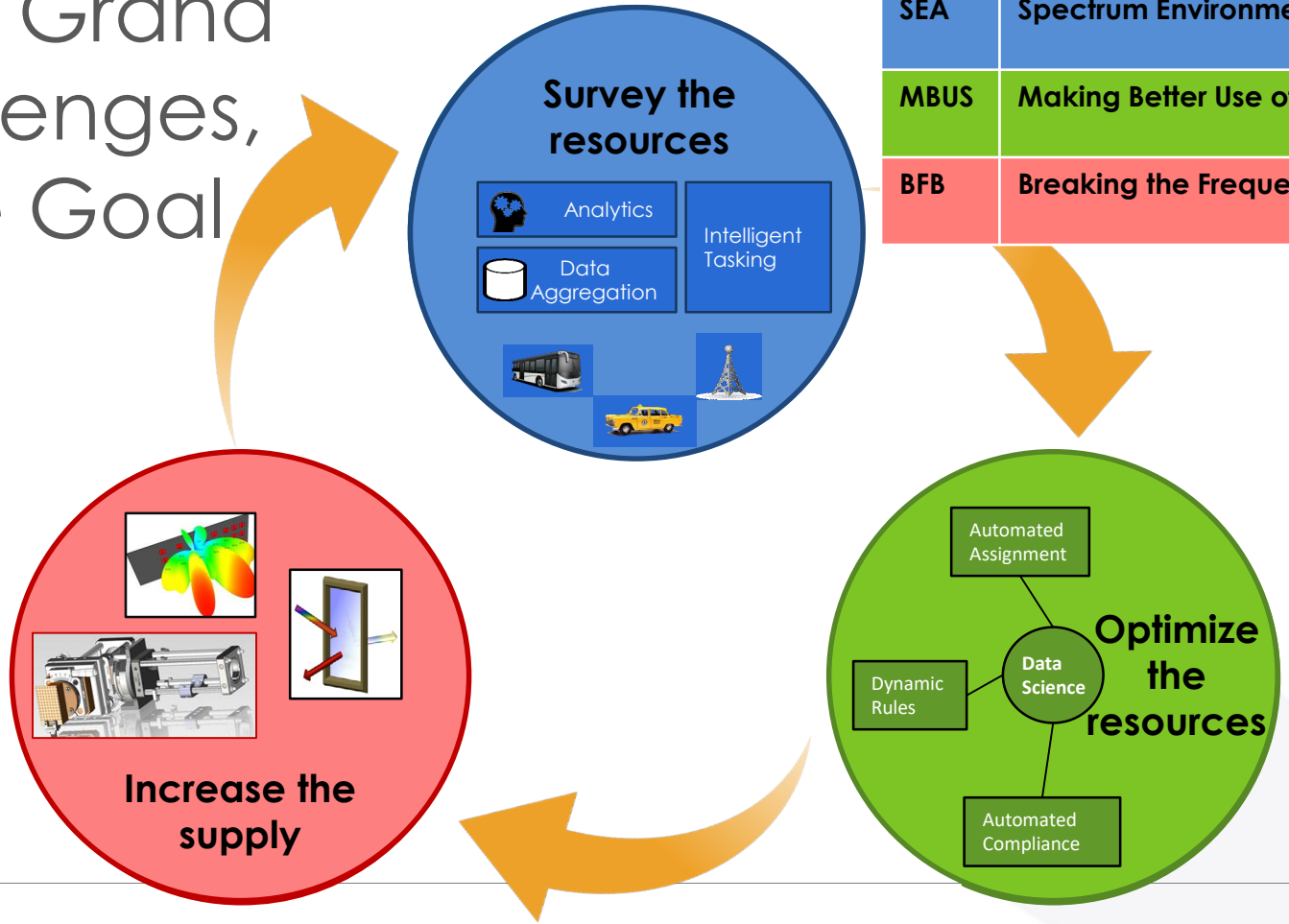
Federal government's primary R&D lab for advanced telecommunications

- A client-driven applied research centre
  focused on "what is possible and what works"

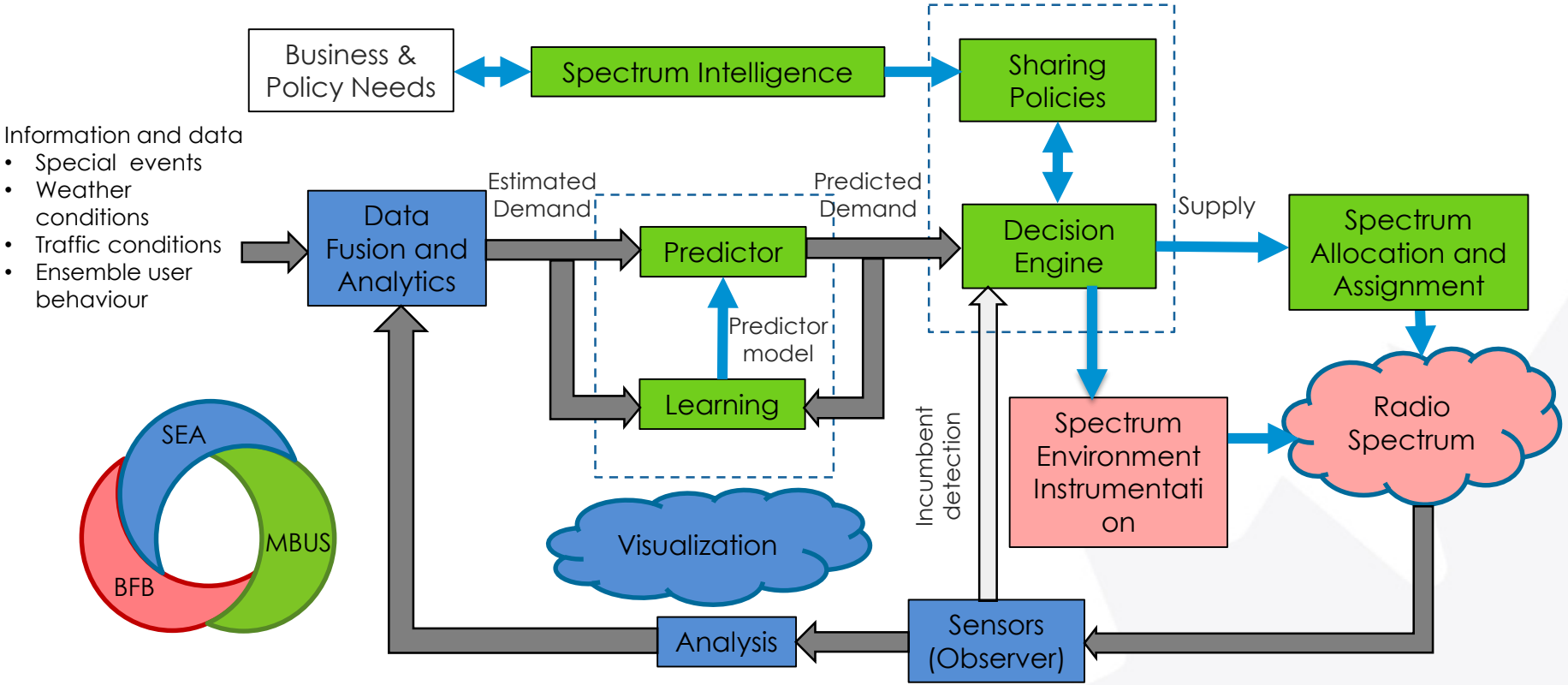


Three Grand Challenges, One Goal

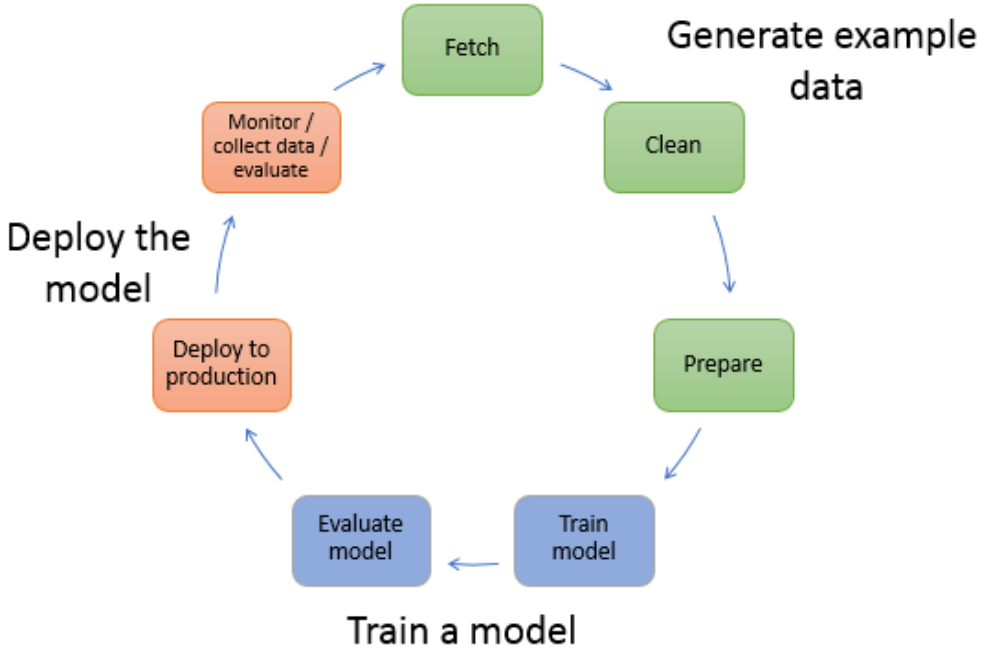
SEA	Spectrum Environment Awareness
MBUS	Making Better Use of Spectrum
BFB	Breaking the Frequency Barrier



Grand Challenge Framework



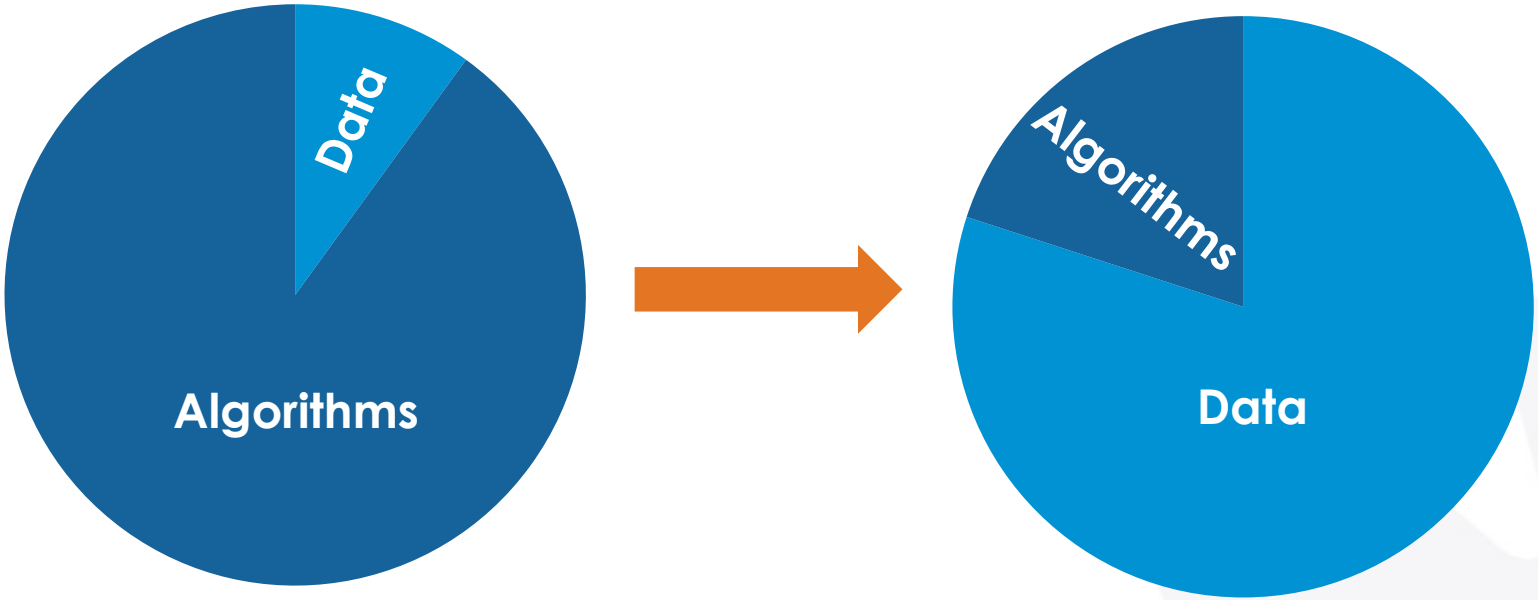
Generic Machine Learning (ML) Cycle



ML/AI in Wireless Communications

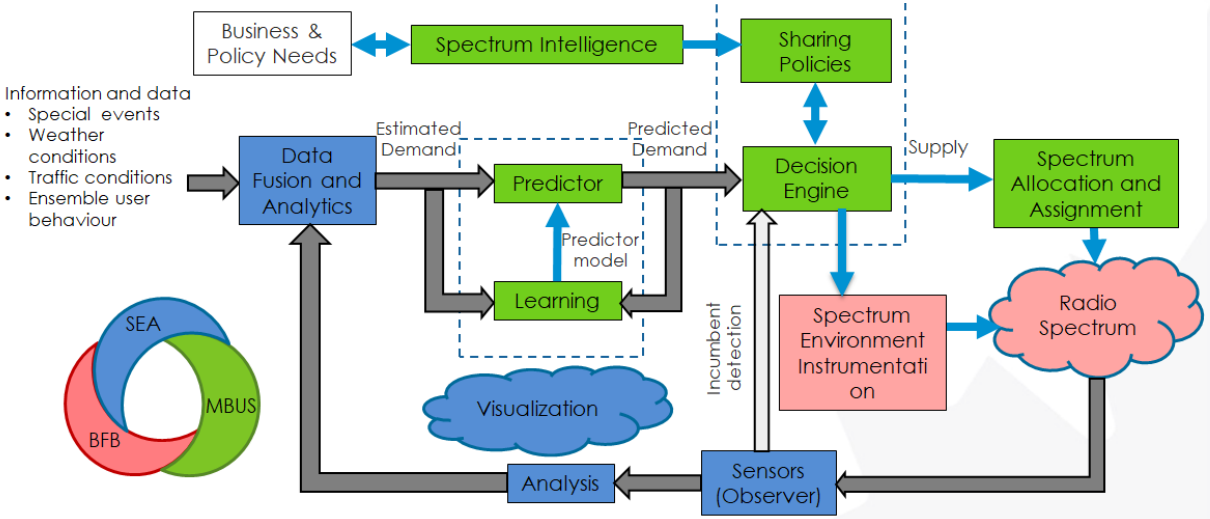
- Academia: signal processing, source/channel (de)coding, modulation recognition, etc.
- Manufacturers: network optimization, scheduling, rate control, anomaly detection
- Operators: mostly relying on manufacturers and 3rd parties so far
- Spectrum regulators: ?

Evolution toward Automating Evidence-Based Decisions



Spectrum Usage Data Acquisition

- Direct sensing
- Operator data
- Crowdsourcing



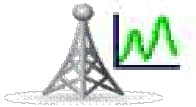
Cloud – Sensors and Data Collection

3rd Party Internet of Things (IoT) Sensors

Crowdsourcing

Mobile Opportunistic Sensing

Mobile Directed Sensing



Fixed Sensing

3rd Party Cloud Services

eWhere

OpenSignal

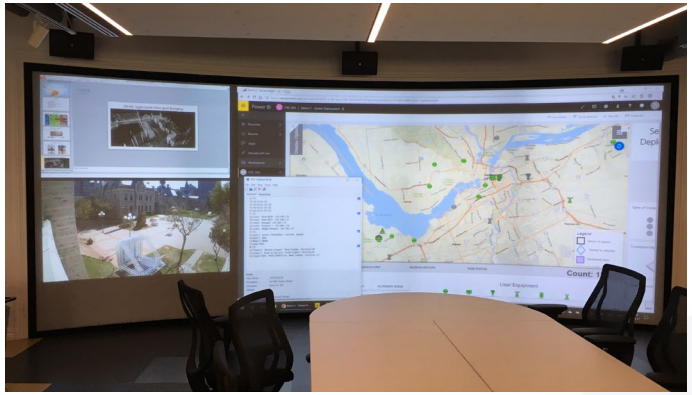
Sensor Management

Microsoft Azure

Big Data Analytics
Machine Learning
Storage

Microsoft Azure

Visualization



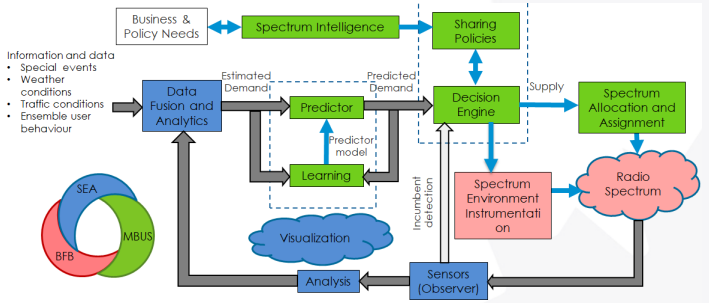
Support spectrum management

Cloud – Sensors and Data Collection

- 110 sensors located everywhere in Canada
- ~30 advanced sensors, each uploading 30GB of raw data to Azure cloud daily
- Automated nightly cluster computing processes format data for downstream analytics tasks

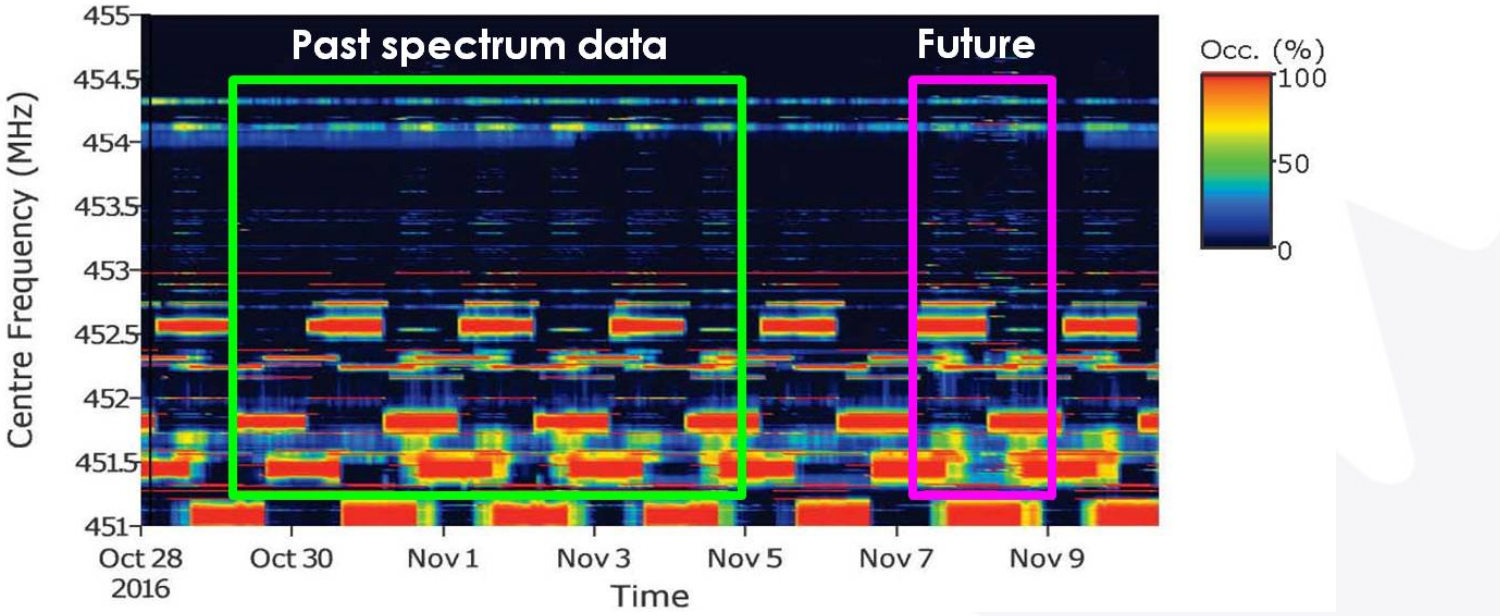
From Data to Knowledge

- Stages of data analytics
  - Descriptive (e.g., traffic modelling)
  - Predictive (spectrum occupancy prediction)
  - Prescriptive (dynamic spectrum assignment)
- Complex multi-dimensional problems
- AI/ML opportunities



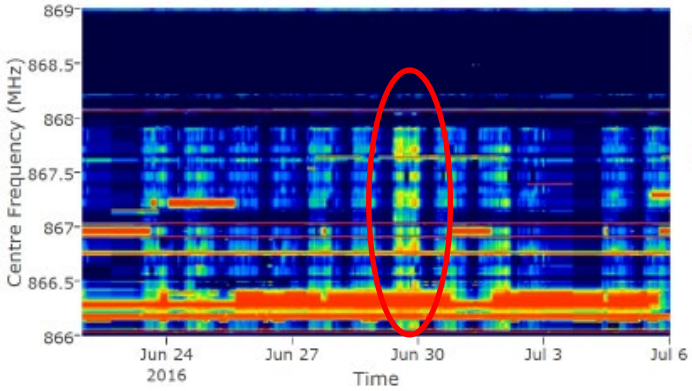
Using the Past to Forecast the Future

Leveraging historical data to make better use of land mobile radio (LMR) spectrum

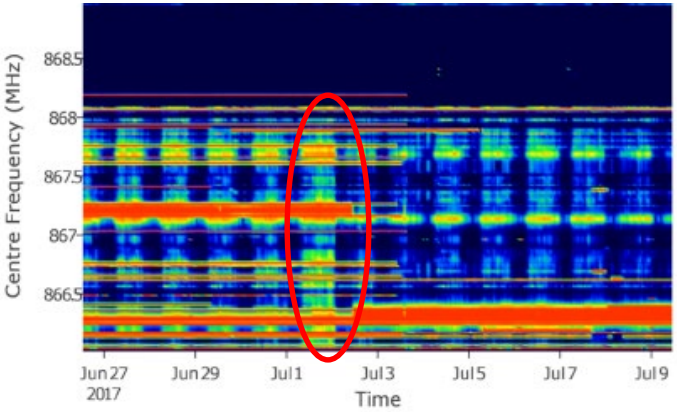


Spectrum Demand Prediction in LMR Bands

Spectrum Usage: External Factors

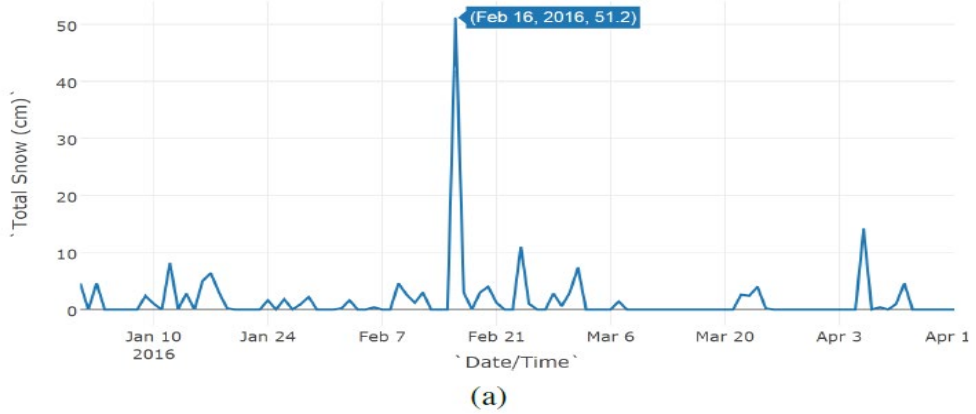


North American leaders' summit in Ottawa

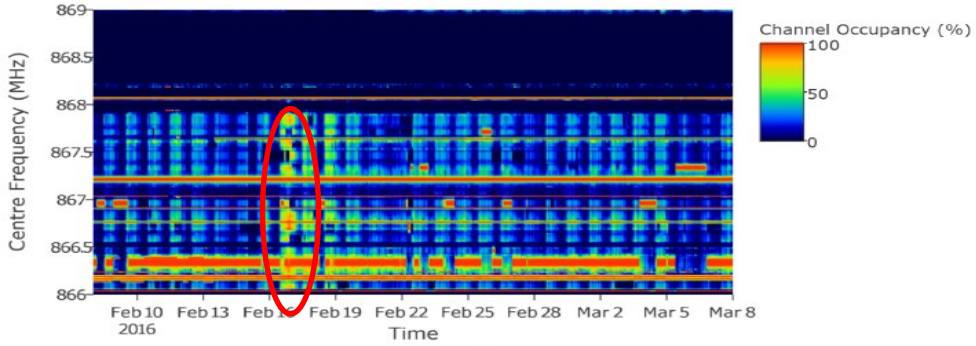


Canada Day 2017

Spectrum Usage: External Factors



(a)

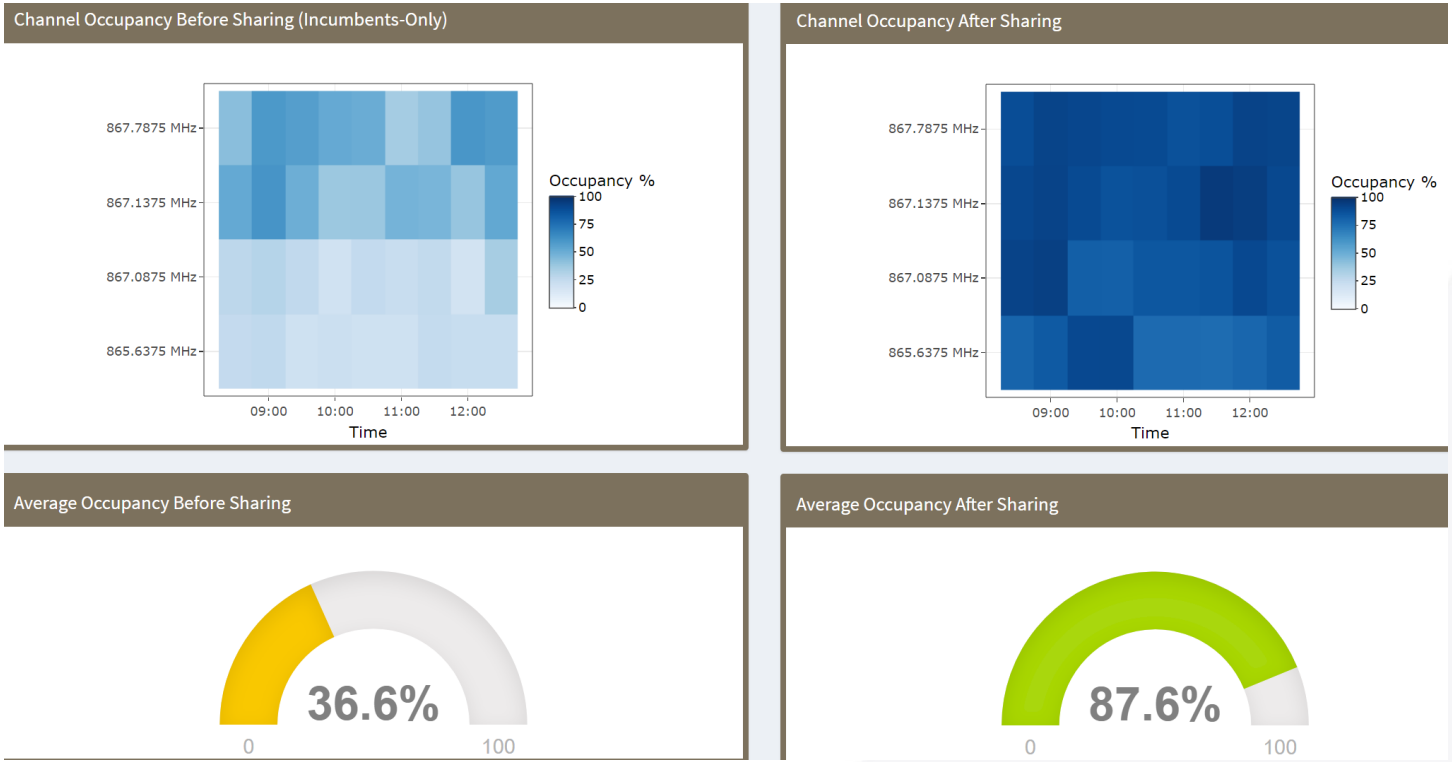


(b)

Ottawa's record snowstorm of 2016

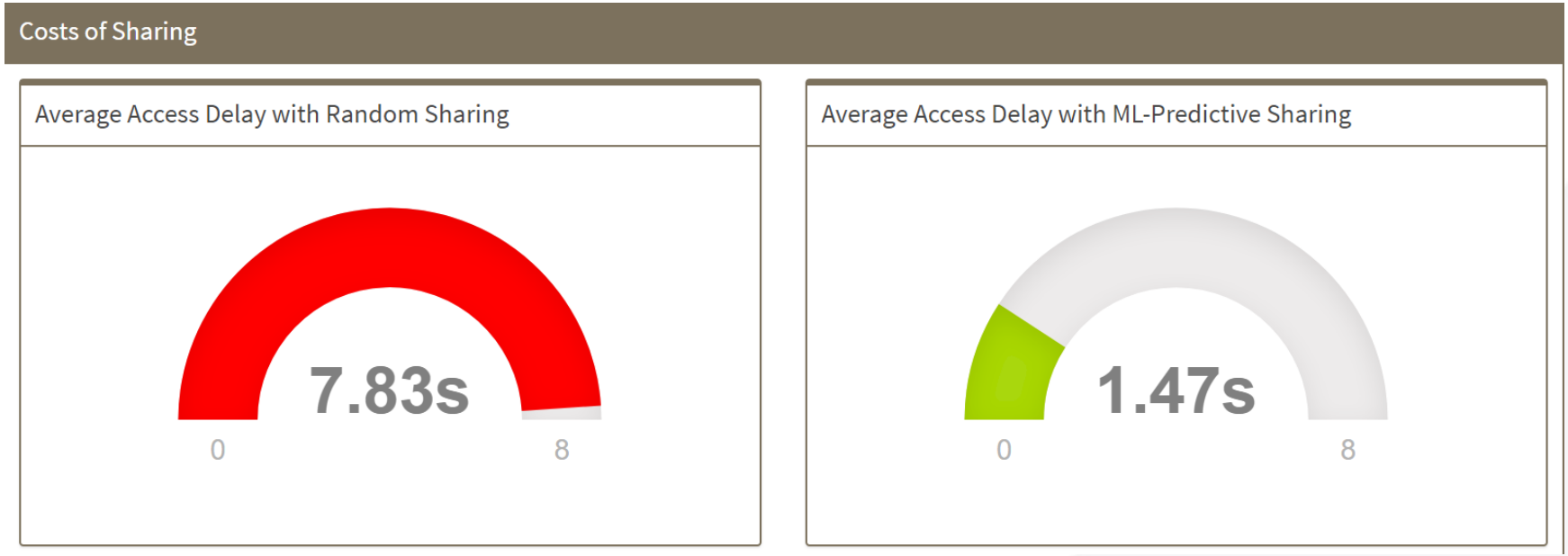
From Predictive to Prescriptive Analytics

Dynamic sharing of LMR channels with IoT traffic



From Predictive to Prescriptive Analytics

Leveraging ML-predicted LMR usage to reduce interference



Spectrum Data Beyond LMR

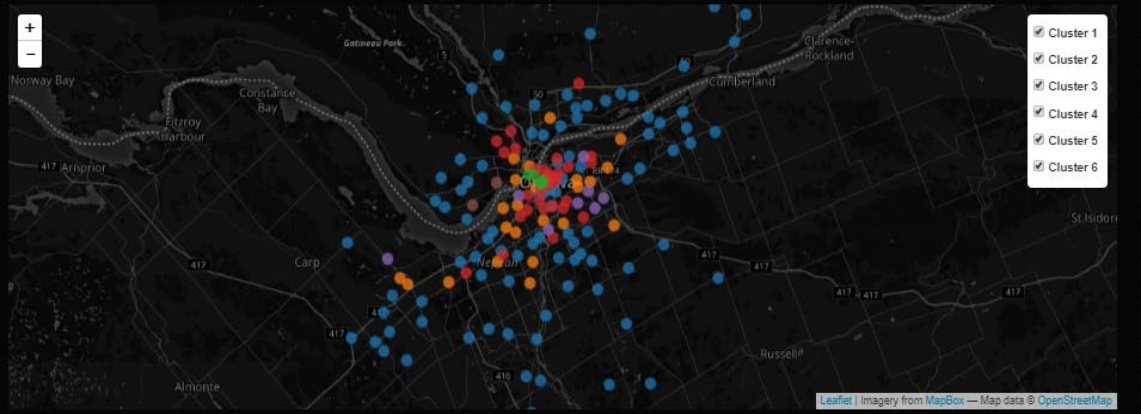
- Commercial mobile bands important to the industry and regulators
- How should we manage the spectrum for 5G and beyond?
- Is sharing viable? If so, under which model(s)?

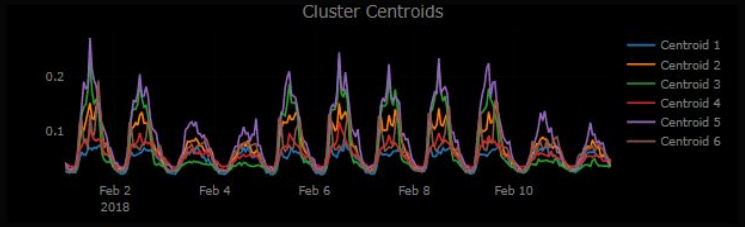
Need to understand the "demand behaviour"

Characterizing Commercial Mobile Spectrum

- Direct sensing not practical
- Operator data: aggregate demand patterns and ensemble user behaviour
- User data: crowdsourcing applications

Ottawa, Canada
Feb. 2018





Users as Sensors

- Crowdsourced mobile spectrum data to complement operator data
  - Models end-user performance
  - Identifies true cell shapes (coverage)
  - Helps detect anomalies

Ontario, Canada
2017-2018

Ontario, Canada
2017-2018

Ottawa, Canada
2018

Toronto, Canada 2018

Ottawa, Canada
2018

Summary

- Spectrum data analytics still in its infancy
- Lots of potential for network optimization, automation, and sharing via ML/AI
- Time and location varying spectrum usage can be leveraged to share spectrum dynamically
- Regulators can use demand and supply insights for dynamic spectrum management

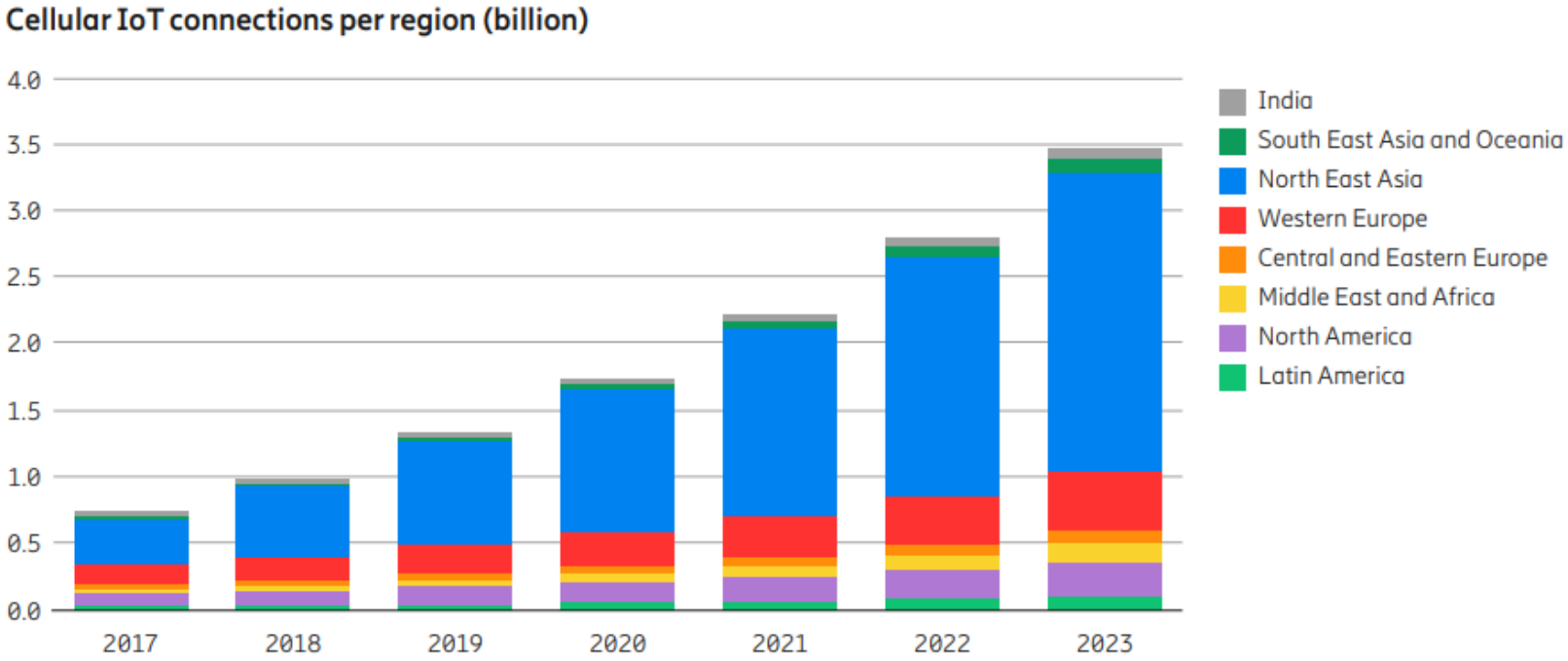
Summary

- Timely data needed to characterize usage, predict demand, and prescribe actions
- Heterogeneous technologies and services require a diverse data acquisition strategy
- More cooperation needed to define and procure relevant spectrum data


Canada

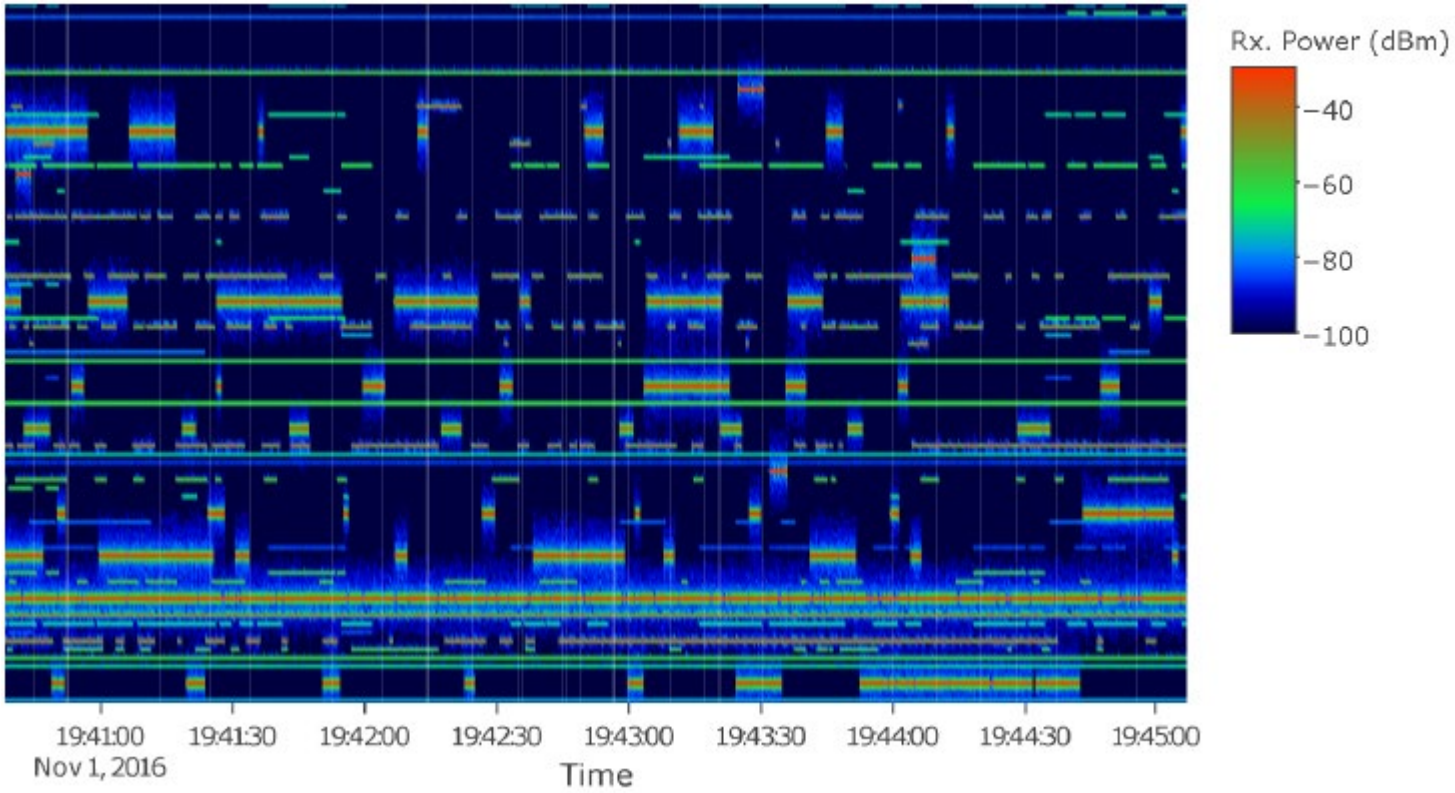
Backup Material

IoT Growth Forecast



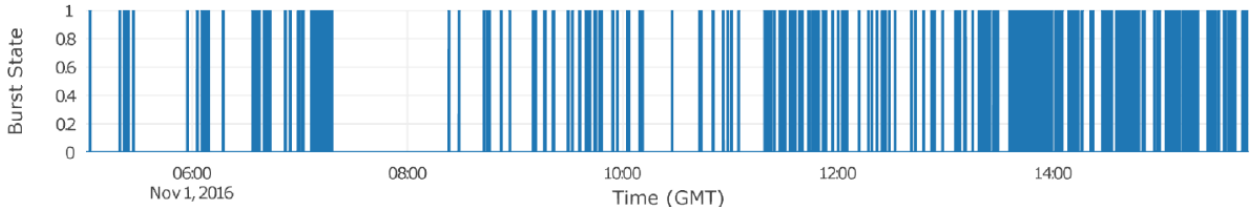
source: Ericsson (Q1 2018)

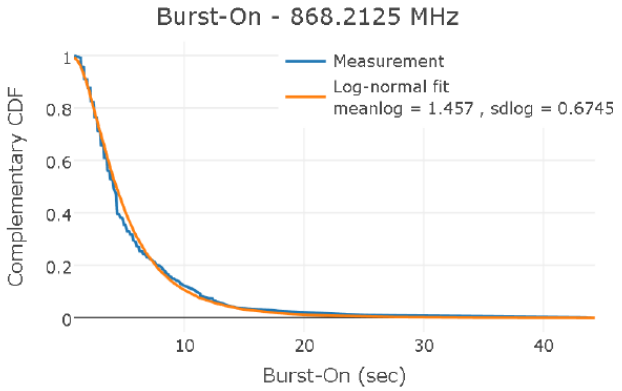
Measured Power in Public Safety Land Mobile Radio (866-869 MHz)

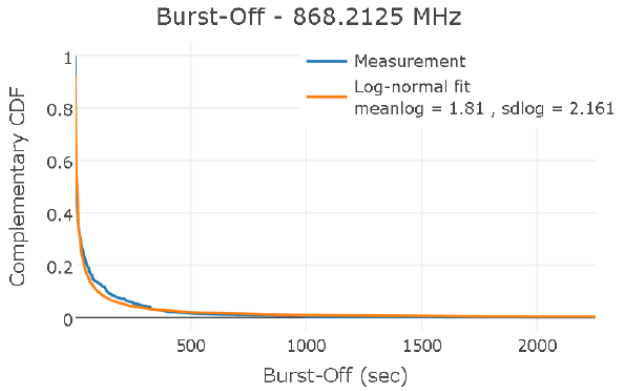


Land Mobile Radio (LMR) Channel Activity Patterns

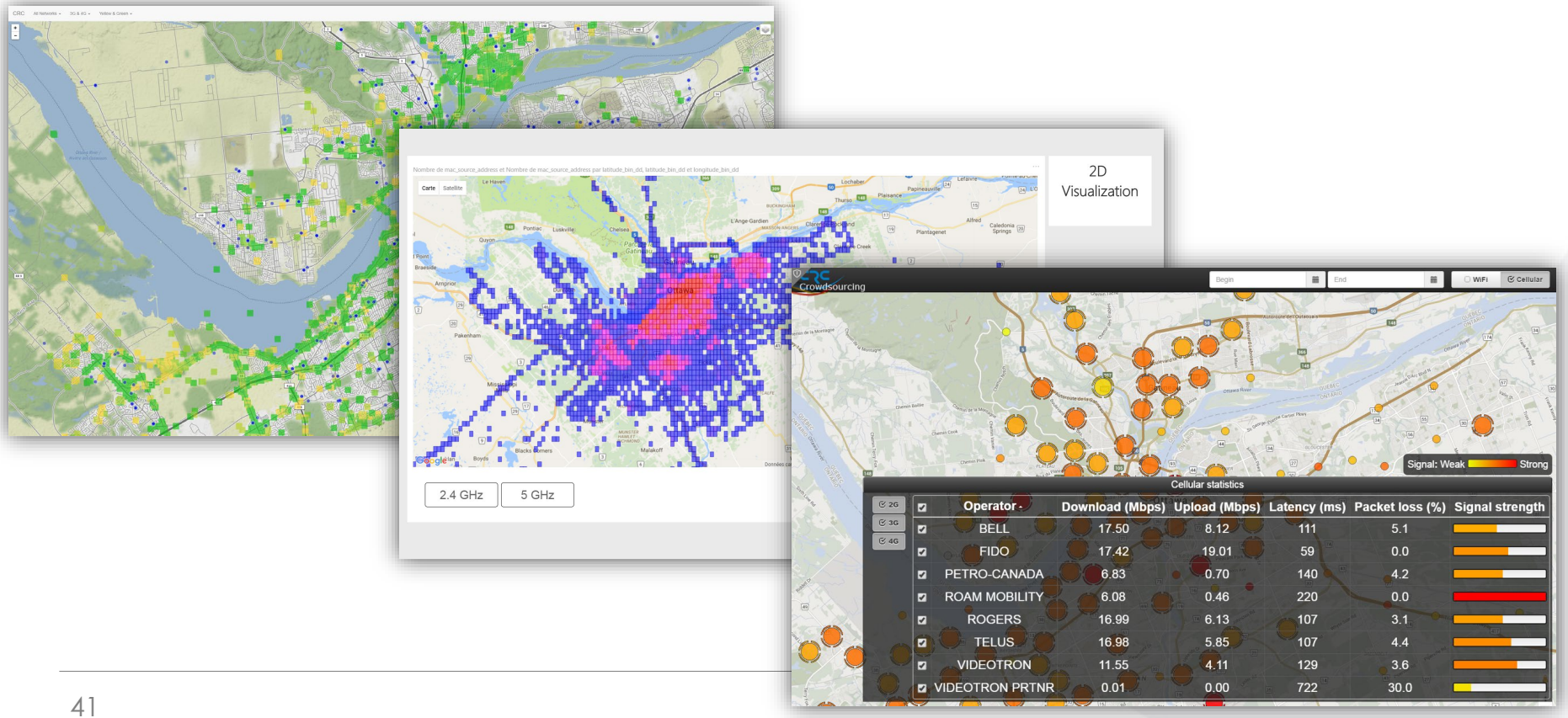
- Data-driven traffic modeling
- Quantifying spectrum sharing opportunities



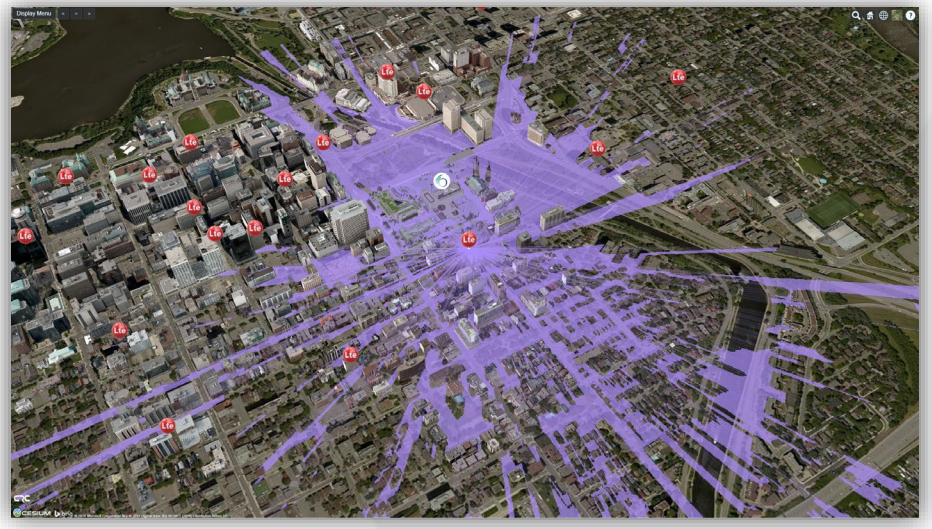




Crowdsourced Data



4G and 5G Coverage Models



Generic Machine Learning (ML) Pipeline