Spectrum Data Mining: Measurement-Driven Insights for Sustainable Spectrum Management

Wireless Innovation Forum Conference

November 16, 2017

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Outline

- Introduction
- Spectrum Measurements
- Usage Patterns Modelling and Prediction
- Correlation with External Factors
- Conclusions and Future Work

Introduction

- Land Mobile Radio (LMR) systems are critical for many public safety and emergency response operations
- Typically, channels are assigned to LMR users based on predefined models/estimates of the traffic load and propagation loss
- Have to rely on conservative assumptions and wider protection margins to avoid interference
- Detailed information on how, when, and where spectrum is being used can help regulatory tasks such as planning, assignment, and interference resolution

Introduction

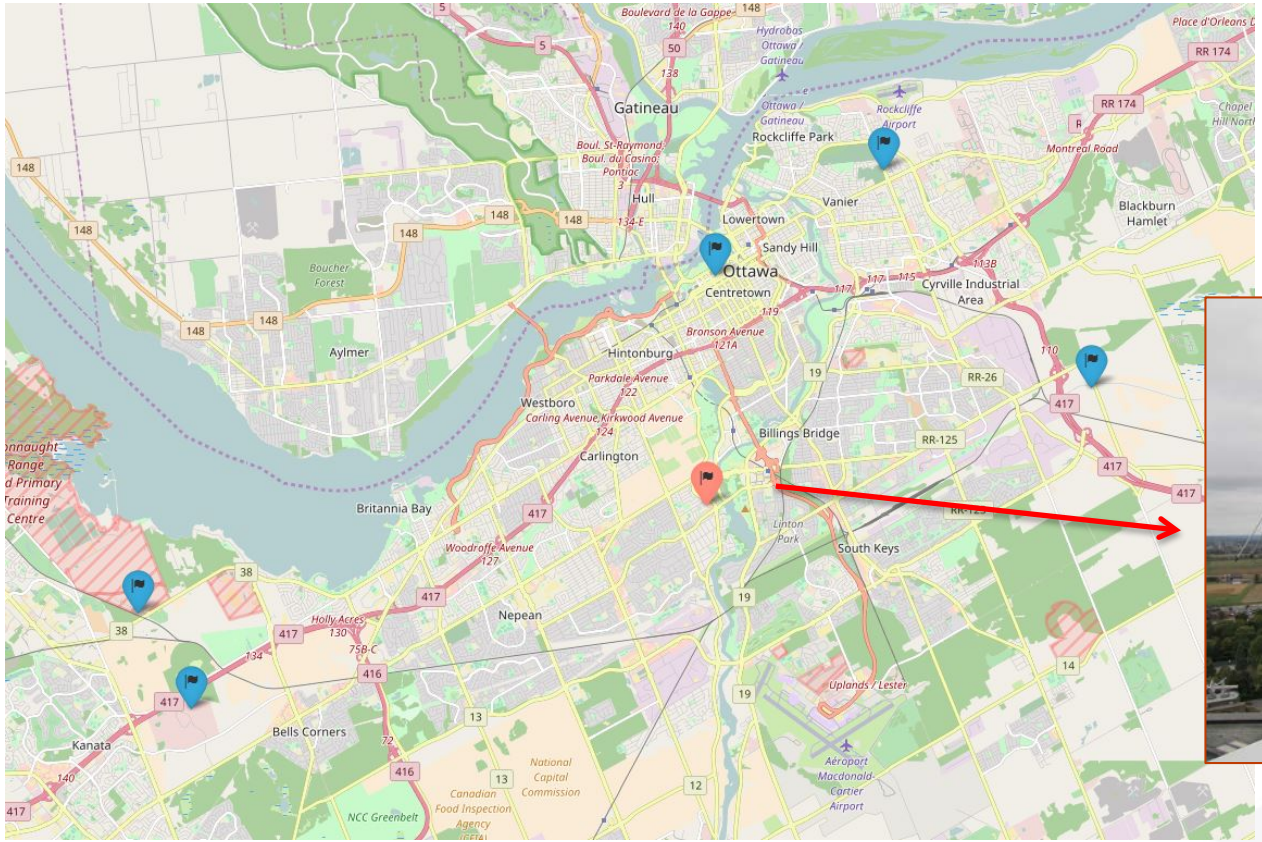
- The Communications Research Centre Canada (CRC) is the Canadian spectrum regulator's R&D organization

- One key research area focuses on spectrum analytics to enable more effective management

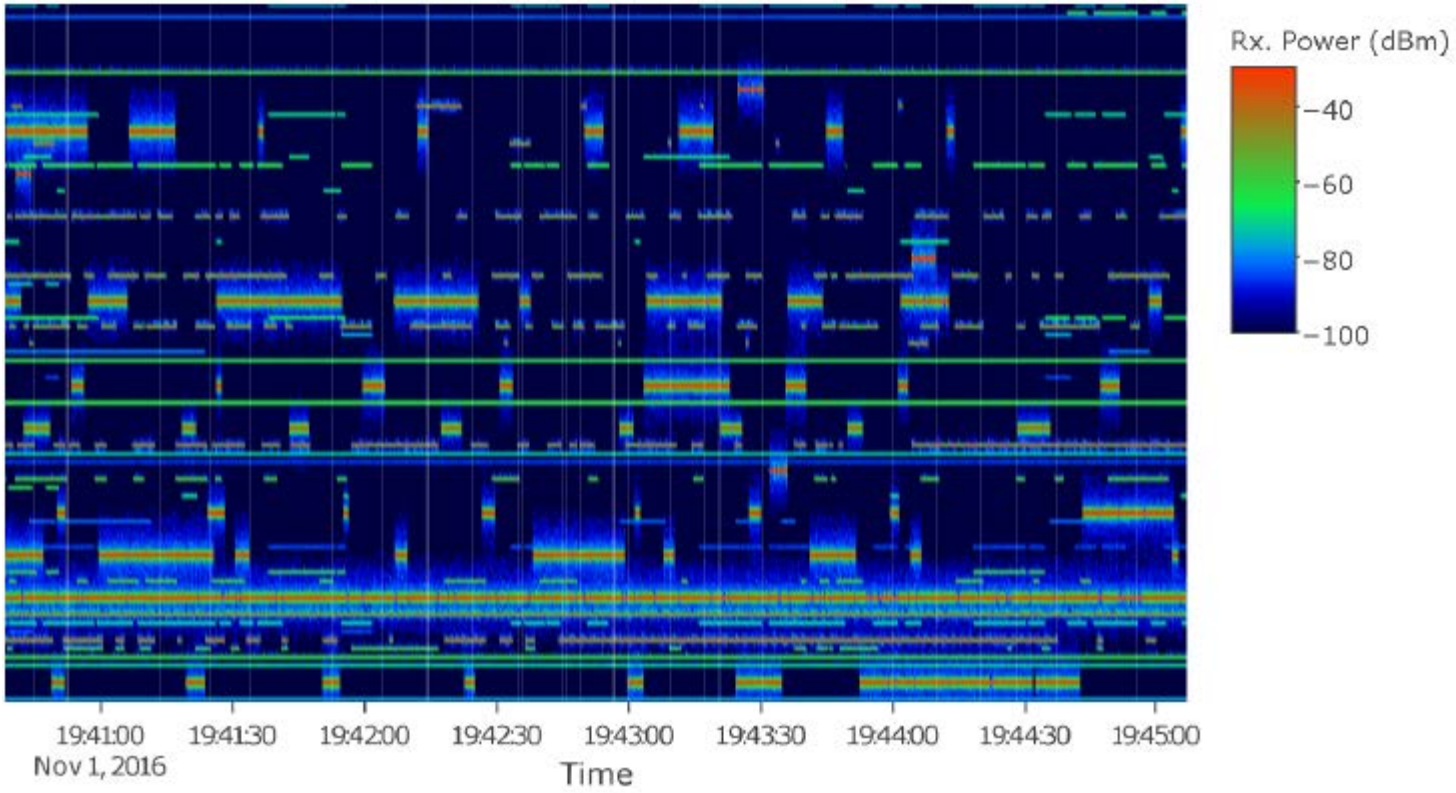
- Developed a proof-of-concept Spectrum Environment Awareness system (*) deployed in Ottawa since February 2016
  - continuous monitoring of spectrum usage below 6 GHz
  - measurements of LMR bands have average band sweep time = 0.3 s, resolution bandwidth = 1.98 kHz

(*) L. Li *et al.*, "A Cloud-based Spectrum Environment Awareness System", IEEE PIMRC 2017

LMR Sensor Deployment

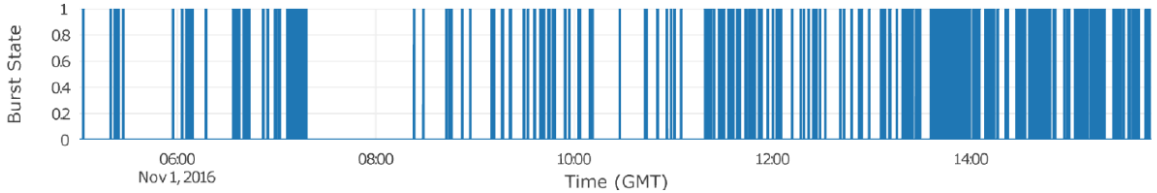


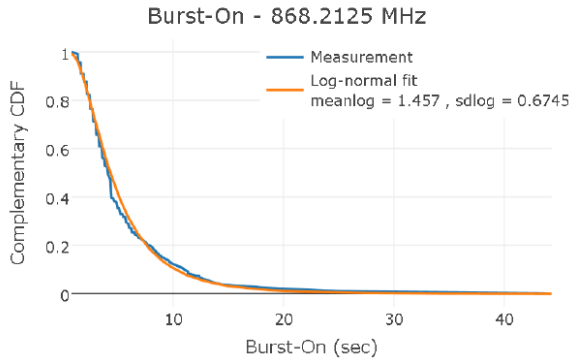
Spectrum Measurements: Measured Rx. Power (866-869 MHz)

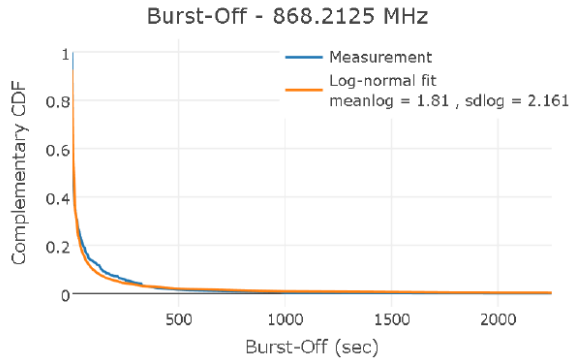


Spectrum Measurements: LMR Channel Activity Patterns

- Trunked public safety voice channels typically exhibit heavy-tailed distributions
- Data-driven traffic modeling can help quantify spectrum sharing opportunities (*)
- More complex patterns could be learned via machine learning techniques (e.g., deep generative neural networks)



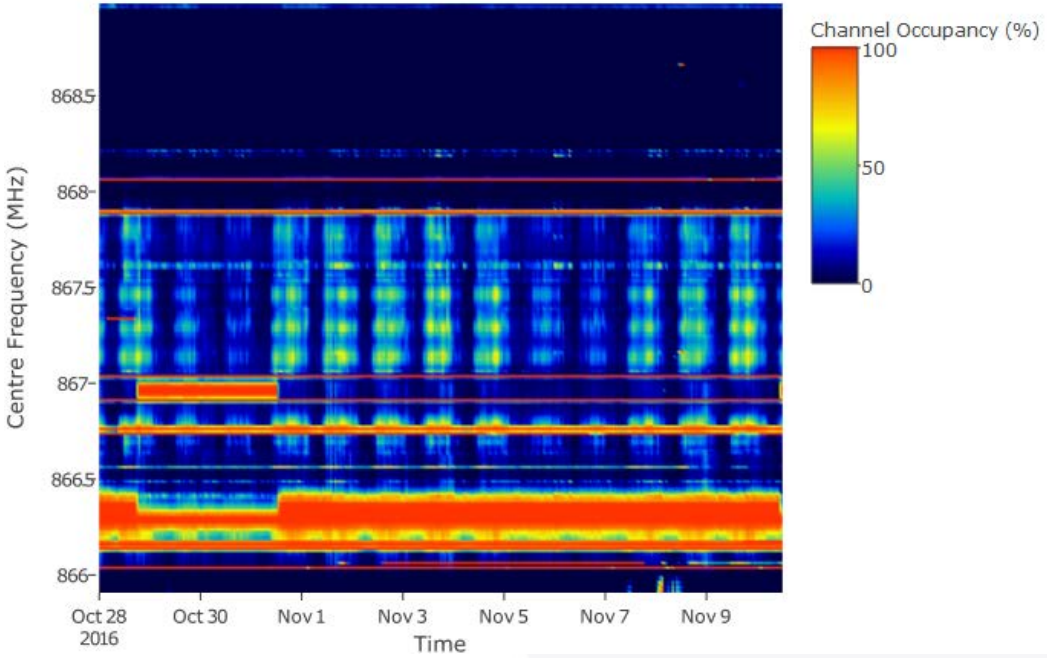




(*) H. Rutagemwa *et al.*, "Spectrum Sharing Opportunities in Land Mobile Radio Bands: A Data-Driven Approach", IEEE PIMRC 2017

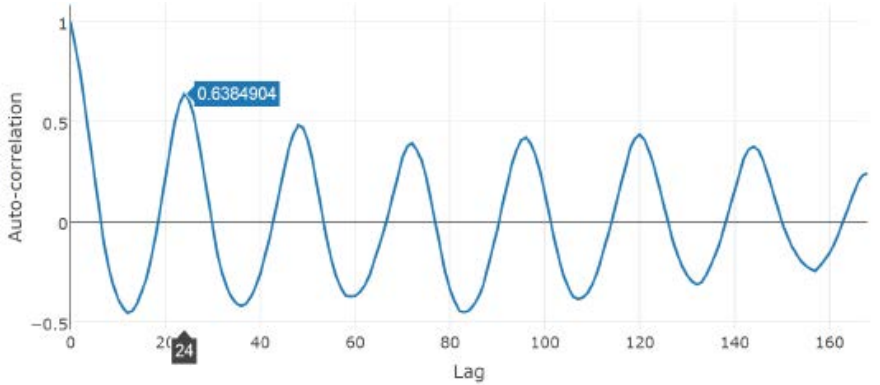
Spectrum Measurements: Measured LMR Occupancy (800 MHz band)

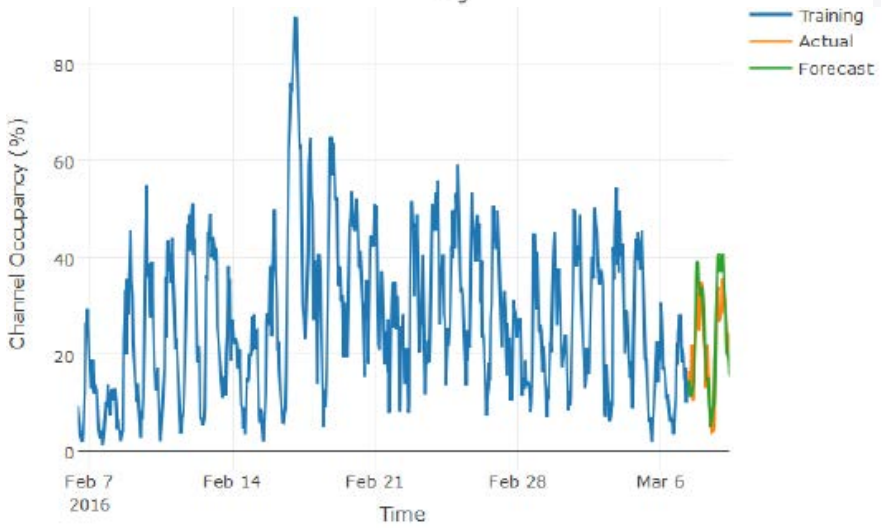
- Aggregate hourly usage statistics produced continuously via an Apache Spark cluster
- More convenient for longer-term analysis of usage patterns
- Reveals seasonality of spectrum usage across many channels



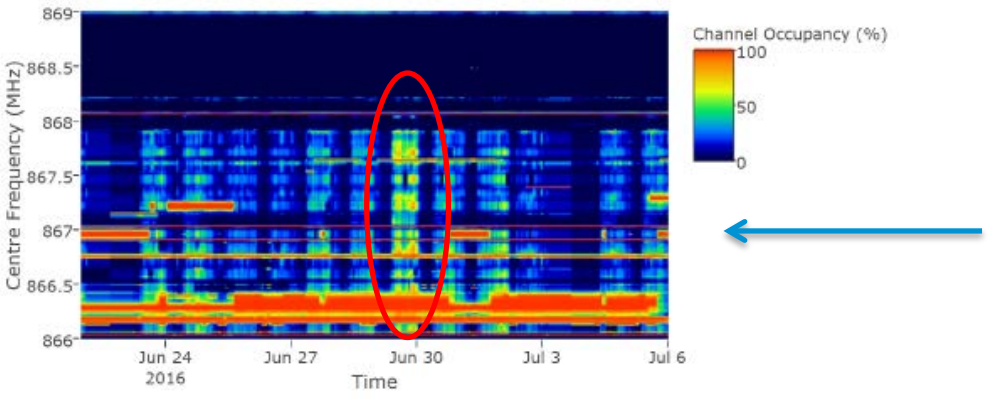
Usage Pattern Modelling and Prediction

- Daily and weekly periodicities observed in many LMR channels
- Temporal patterns can be learned and leveraged to predict a given channel's spectrum occupancy
- Predictive models enable a more proactive approach to spectrum assignment

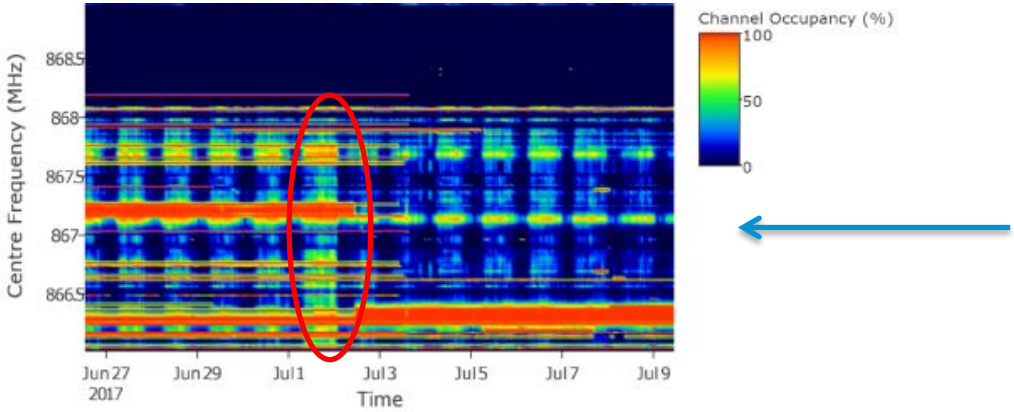




LMR Spectrum Usage: External Factors (Events)

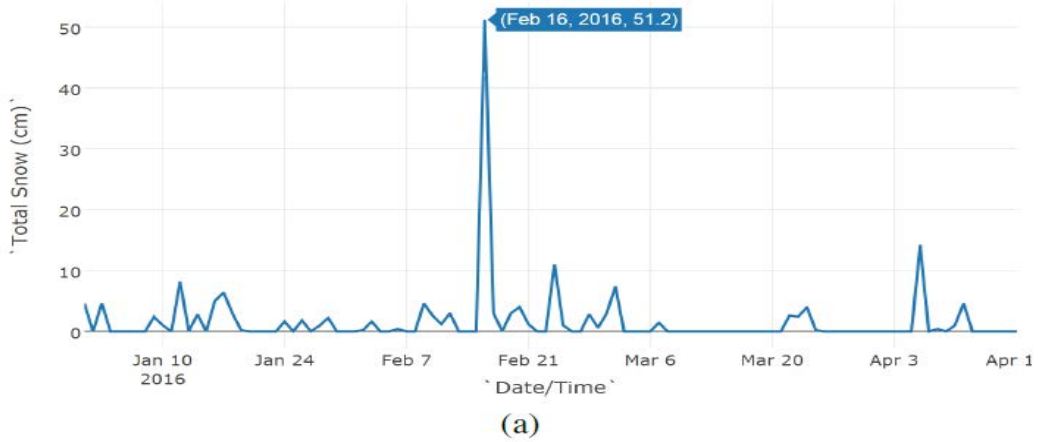


North American leaders' summit in Ottawa

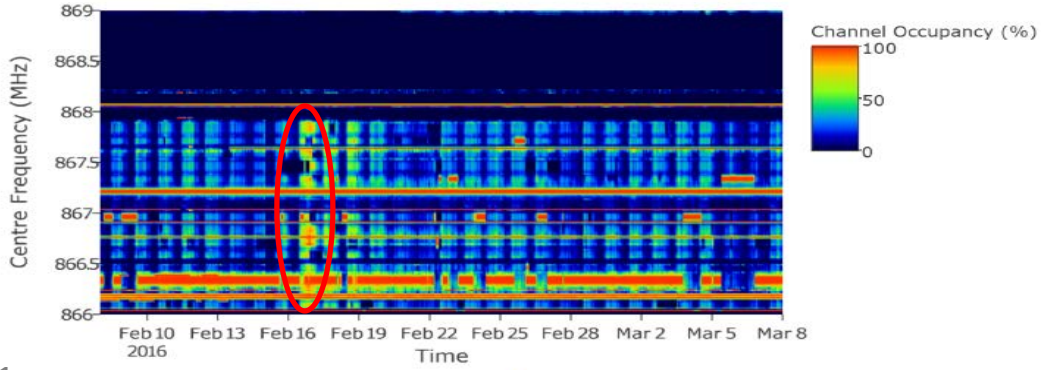


Canada Day 2017

LMR Spectrum Usage: External Factors (Weather)



(a)

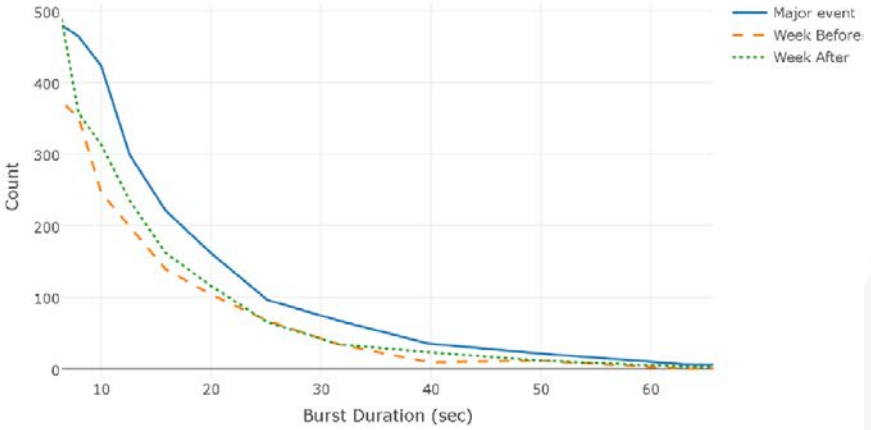


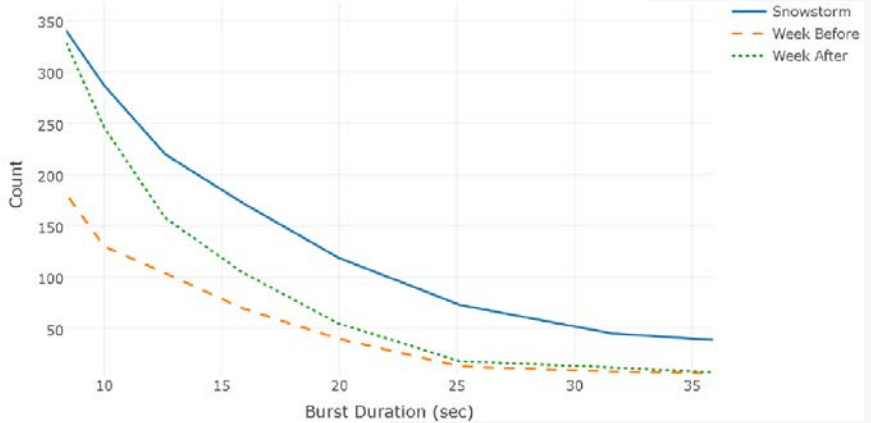
(b)

Ottawa's snowstorm of 2016

Correlation with External Factors

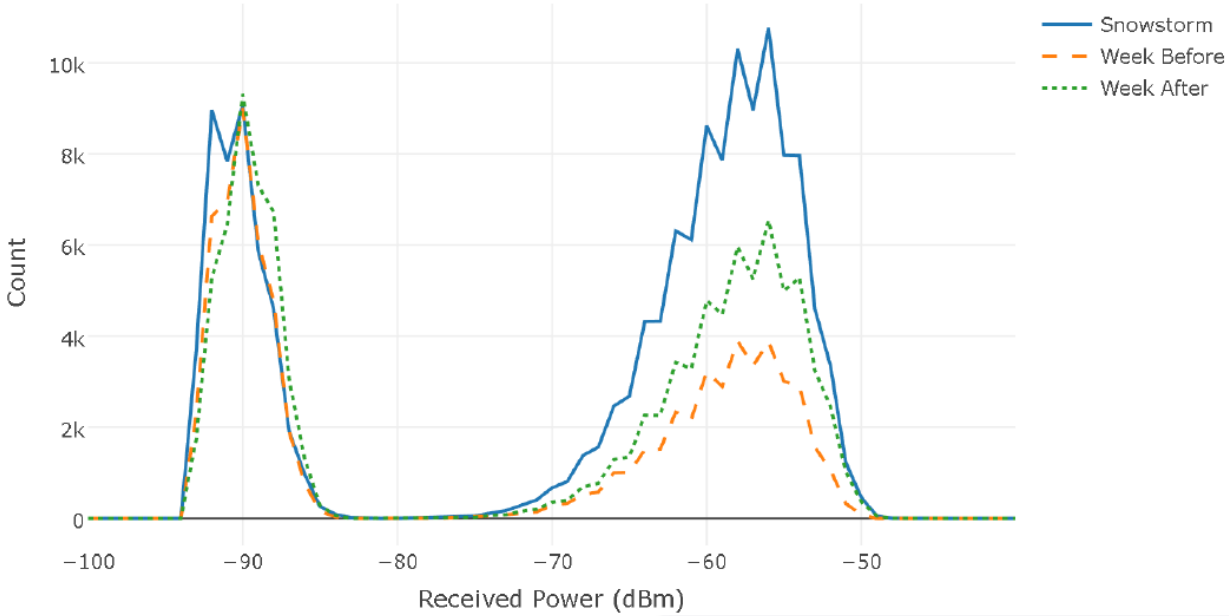
- Major events and severe weather correlate with the aggregate *hourly* usage statistics
- Distributions of high-resolution measurement data better reveal the impact of external factors
- Right tail of busy-state duration histogram indicates an increased number of longer bursts (conversations)





Correlation with External Factors

- Correlation between major events and LMR usage could result in changes to the modes of the received-power histogram (*)
- Alternatively, for many cases, a major event increases the intensity of one or more modes of the histogram instead
- Applying machine learning techniques would require domain knowledge and suitable feature selection



(*) A. Abdallah *et al.*, “Detecting the Impact of Human Mega-Events on Spectrum Usage”, IEEE CCNC 2016

Conclusions

- Continuous spectrum monitoring enables new data-driven approaches to facilitate spectrum management
- Temporal usage patterns can be learned and leveraged to predict future spectrum occupancy
- Fusion with external (non-spectrum) data, such as weather and events, can help identify fundamental factors driving the spectrum demand and improve predictive analytics

Further Work

- Spatial spectrum usage characterization
- Exploration of data-driven spectrum sharing opportunities in LMR and other bands
- Application of machine learning techniques to big spectrum data


Canada

Additional Material

- Machine learning applied to reveal spectrum usage-behaviour similarities across hundreds of LMR channels