Innovation, Science and Economic Development Canada
Communications Research Centre Canada

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Centre de recherches sur les communications Canada

Radio Platforms for Sustainable Spectrum Management and mmWave Communications

Wireless Innovation Forum Conference

November 15, 2017

Chris Squires

Research Engineer, Radio Technologies

Outline

- CRC – Who we are and what we do
- Sustainable Spectrum Management
- Radio Research Platforms at CRC
  - Spectrum Sensors
  - mmWave Systems
- Next Steps
- Summary

CRC – Who we are, what we do

Communications Research Centre

Innovation, Science and Economic Development

"To maximize the economic and social benefits that Canadians derive from the use of the radio frequency spectrum resource."

Spectrum and Telecommunications Sector

Planning, Standards, Regulations, Licencing, Compliance, Policy, R&D

Communications Research Centre Canada

R&D to advance the efficient exploitation of the radio spectrum

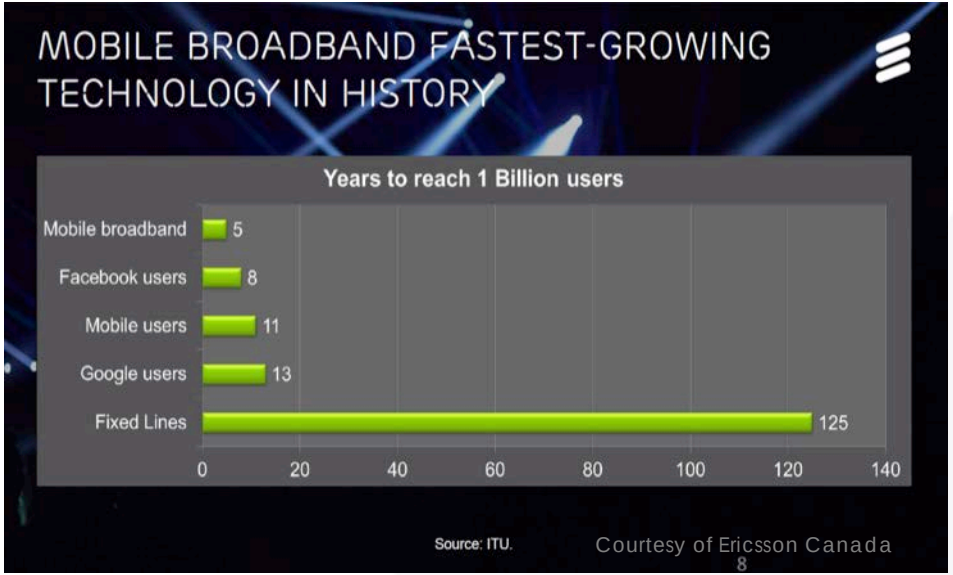
"Show what is possible and what works"

Sustainable Spectrum Management

The CRC's Grand Challenges

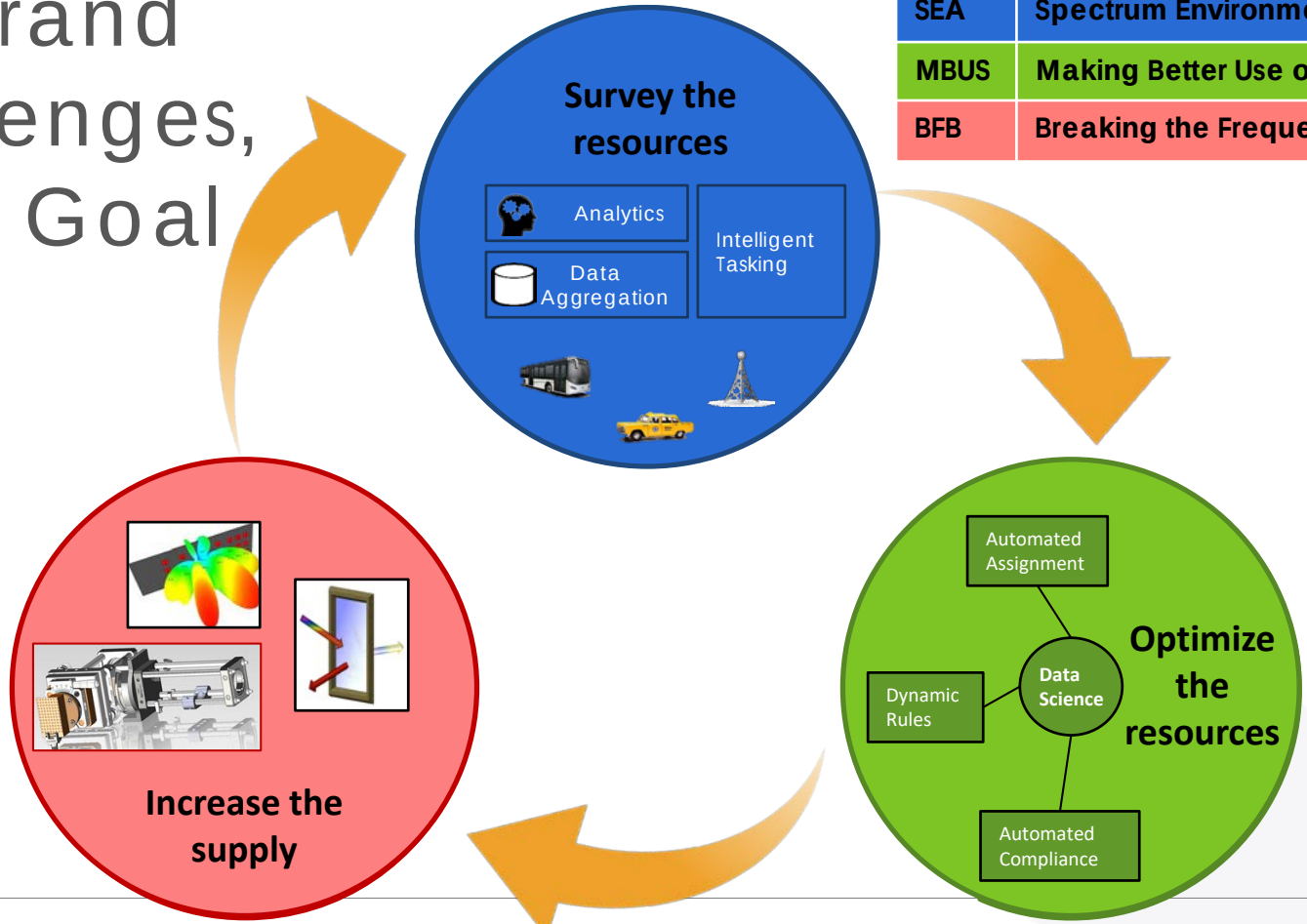
Context

- Spectrum demand continues to grow exponentially
- The pace of innovation in wireless technology is accelerating
- Research for sustainable spectrum management is needed



3 Grand Challenges, One Goal

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

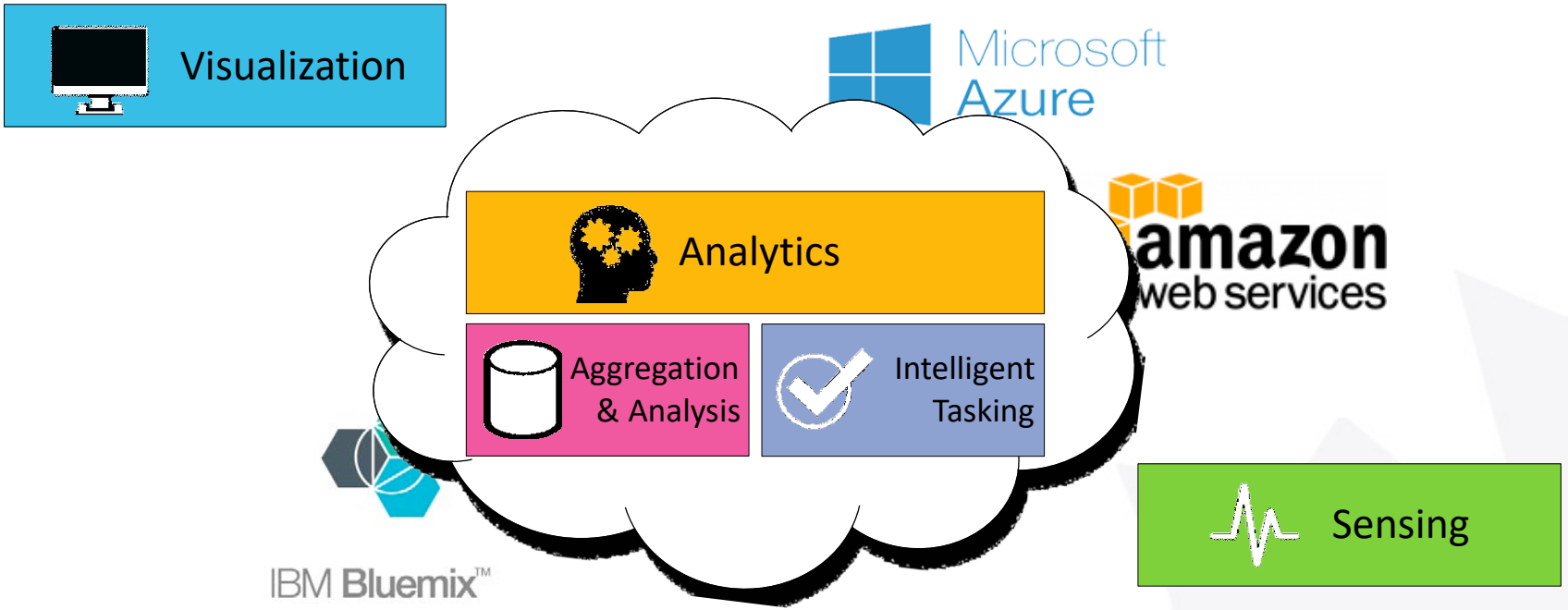


Spectrum Sensors & mmWave Radios

- Context
- Radio Platforms
- Results

Spectrum Sensors – Context

Grand Challenge: Spectrum Environment Awareness – Architecture



Spectrum Sensors – Radio Platforms

SEA Sensor Ecosystem

CRC Custom Sensors

CRC Spectrum Explorer

Integrated Spectrum Observation Centre

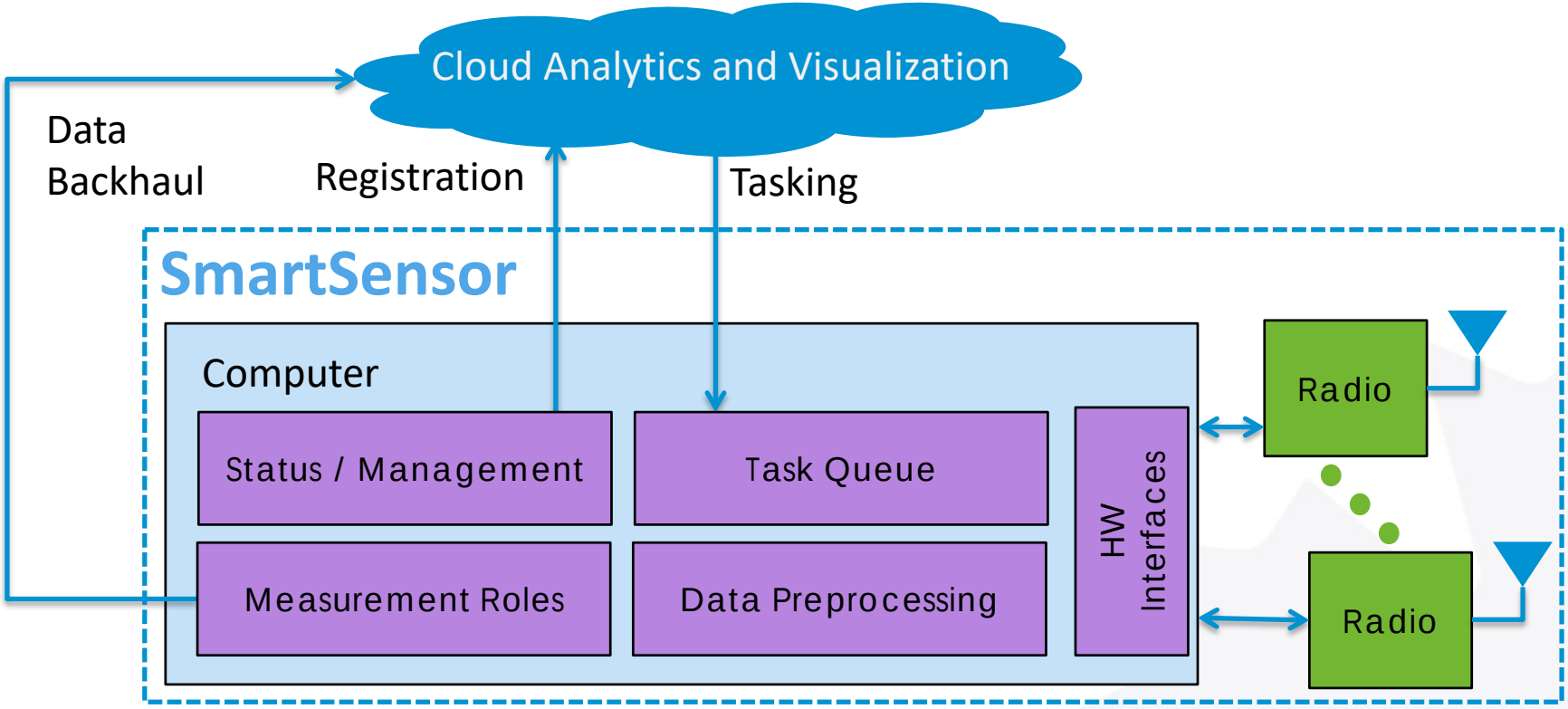
CRC Crowdsourcing App

Cognitive Systems Amera / Ada

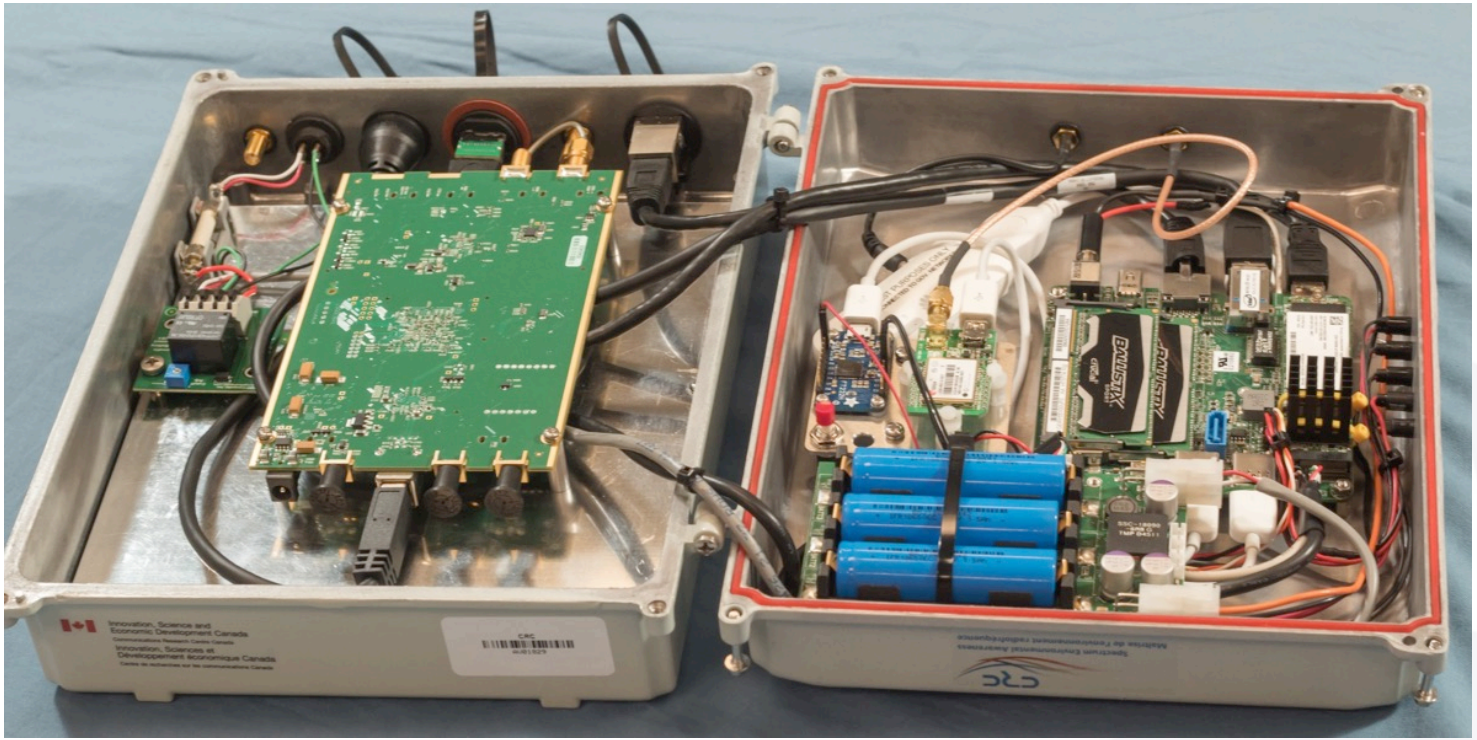
Cloud-to-Cloud Communication

Rohde & Schwarz LTE Sensor

CRC SmartSensor Framework



CRC Wideband Scanner



CRC Wideband Scanner

Channel

Raw measurements

- Channel ID
- Power, SNR
- Carrier offset, bandwidth
- Time and location (latitude, longitude, altitude)
- Hardware parameters
- Processing parameters

Consolidated as histogram for geographical area and period of time

- Channel ID
- Power, SNR
- Carrier offset, bandwidth
- Burst / idle durations
- Correlation matrix
- Analysis parameters

Band

Consolidated as time series

- Channel occupancy
- Occupied bandwidth
- Power, noise level
- Location
- Band definition
- Analysis parameters

CRC Wi-Fi Sensor

Wi-Fi sensor:

- Compex WLE200NX radio card used in other projects
  - 2.4 and 5 GHz with standard antenna
  - 802.11a/b/g fully supported
  - 802.11n supported by hardware but not software, level of effort required is out of scope for demo

Measurement capabilities:

- RSSI
- Data rate
- Air time
- Packet length
- Packet count
- Packet type and subtype
- Channel ID
- Source MAC
- Destination MAC
- SSID
- Time and location

CRC LTE Scanner

LTE scanner

- Rohde & Schwarz TSME/TSMA mobile network scanner with ROMES4 software
  - Data uploaded to the cloud manually or using scripts

Measurement Capabilities:

- Physical cell identifier
- System bandwidth
- Duplex mode
- Mobile country code, mobile network code
- Power, SINR
- RSSI, RSRP, RSRQ
- Average number of UEs
- Resource block usage
- Average cell throughput
- Minimum / maximum cell throughput

CRC Crowdsourcing App

Device, network and service parameters, including speed test results, limited by what is available from selected phone models

- Device model, manufacturer, OS type and version, radio version
- Mobile network type / technology, SIM operator code
- LTE: global cell identifier, mobile country code, mobile network code, RSSI, physical cell identifier, tracking area code, timing advance, RSRP, RSRQ, RSSNR, channel quality indicator
- Wi-Fi: SSID, BSSID, RSSI, channel frequency
- Download speed, upload speed, latency, packet loss
- Latitude, longitude, timestamp, accuracy

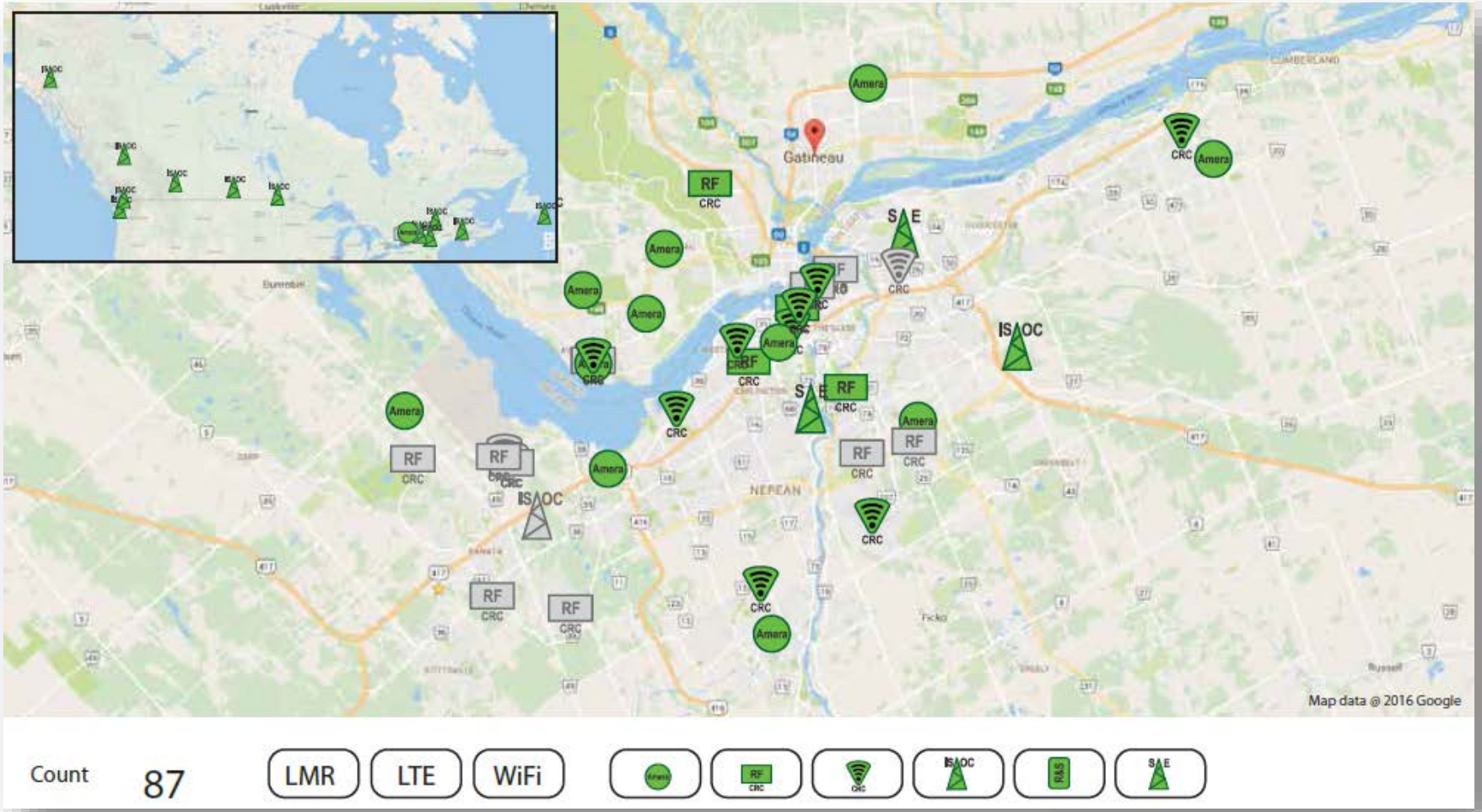
Underlined parameters are new in Enhanced App

Spectrum Sensors – Results

CRC Big Data Analytics Centre

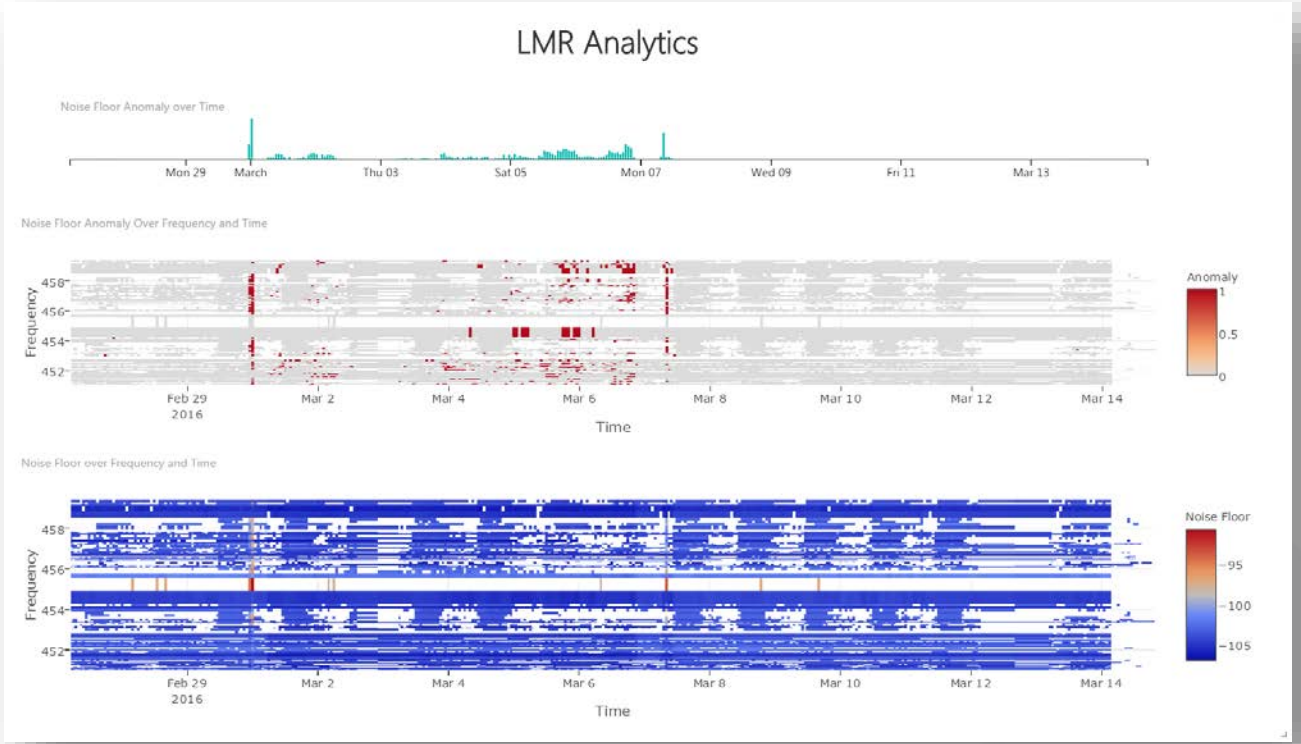
CHRISTIE®

coolux®
MEDIA SYSTEMS

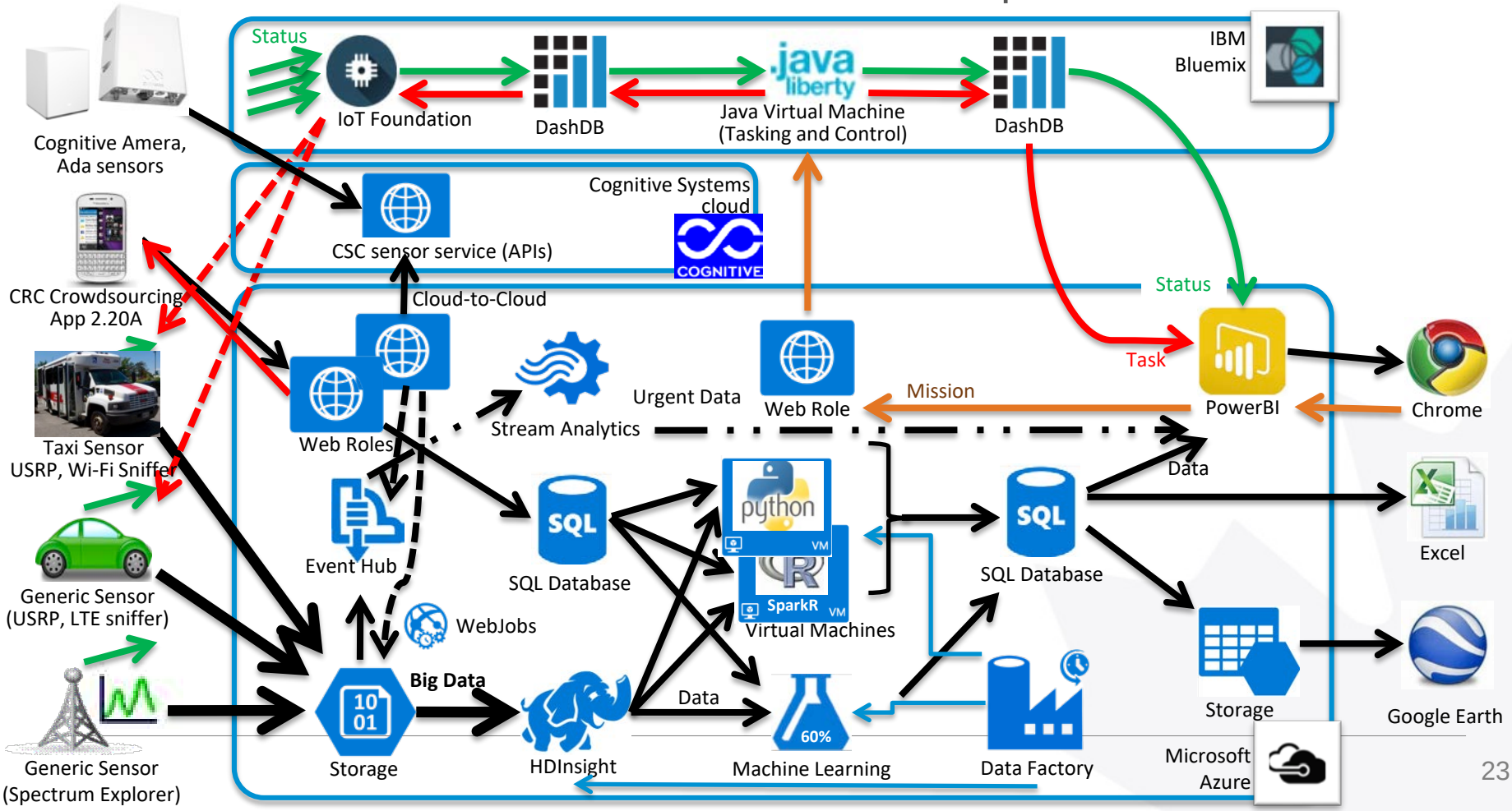

Gatineau
Amera
RF
CRC
S E
ISAOC
NEPEAN
Map data @ 2016 Google
Count
87
LMR
LTE
WiFi

CRC SEA System Prototype *Analysis Reports*

– *Land Mobile Radio Analytics*



CRC R&D Test Bed Cloud Infrastructure Components



mmWave - Context

Grand Challenge: Breaking the Frequency Barrier

- Understand the fundamentals of mmWave communications through propagation measurement, modelling and radio experimentation
- Shaping the wireless environment with engineered surfaces
- System prototype for urban environment for 28 GHz 5G coverage (demonstration)
- Provide spectrum regulator with technical information that may impact policies and regulation

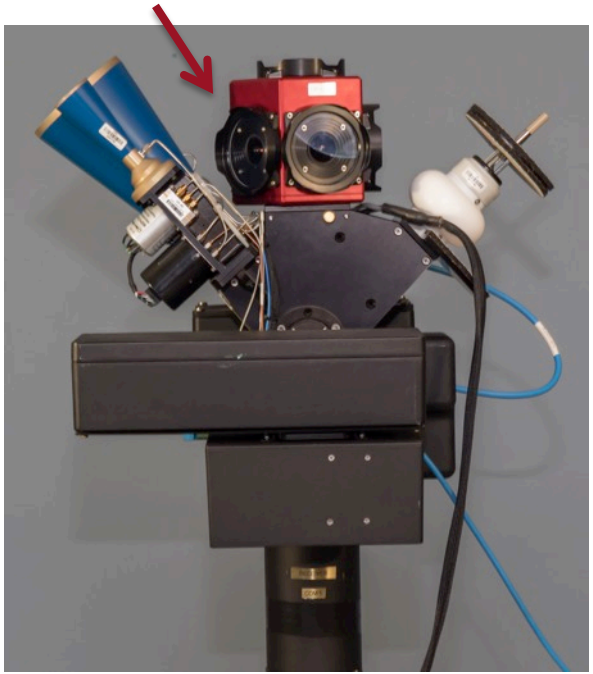
CRC Channel Sounder

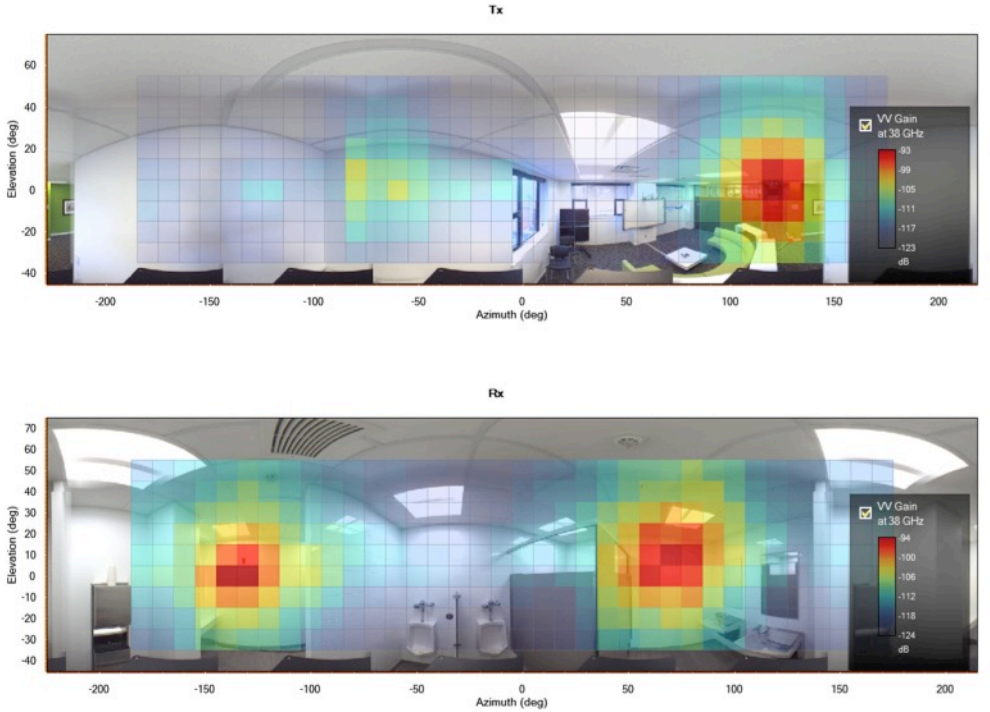
- Vector network analyzer (VNA) based system for double-directional channel characterization
- Wideband measurements in 7 frequency bands in the 2–60 GHz range
- Vertical and horizontal polarization
- Directional scanning via mechanical antenna steering
- 50 m cable between Tx and Rx limits range

Tx and Rx equipment – mounted with antennas, pan/tilt units

CRC Channel Sounder: Visualization

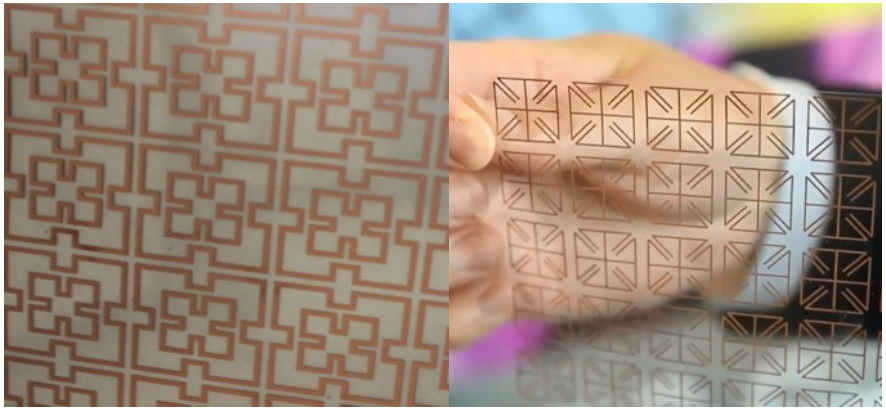
Calibrated panoramic images





Engineered Surfaces

- Shaping the wireless environment

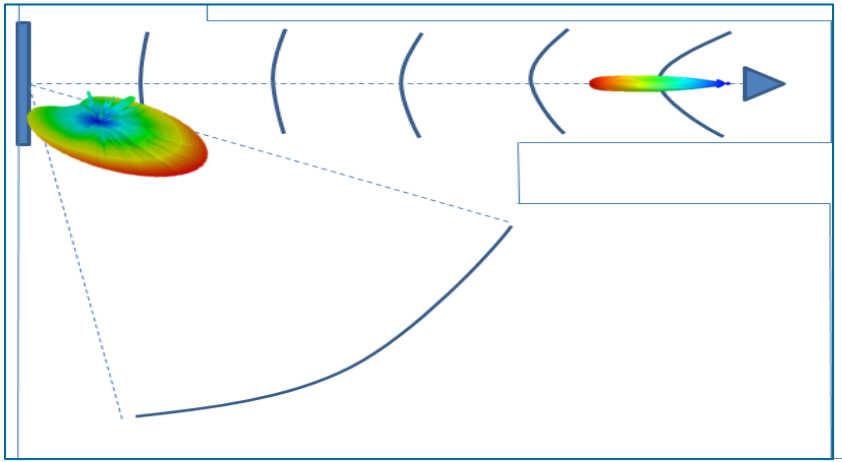


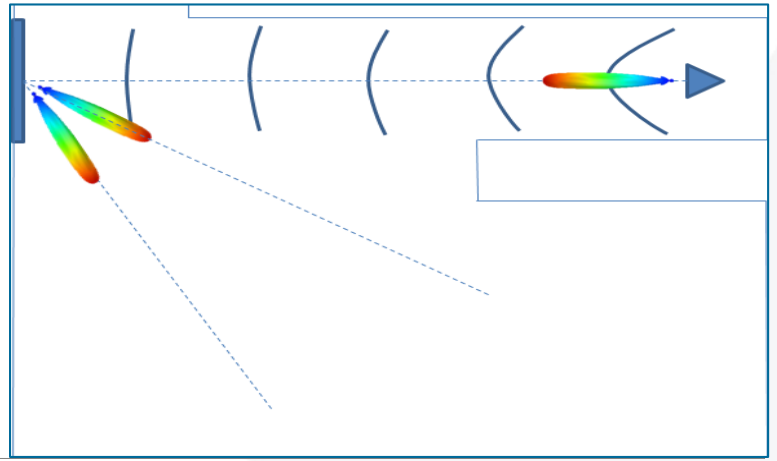
NRC · CNRC

GGI SOLUTIONS

Designing Reflection Coverage Enhancement

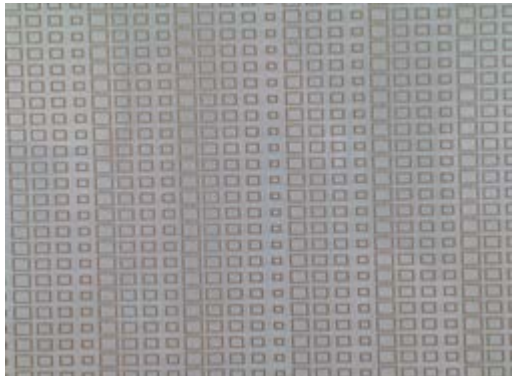
- Reflecting surface should be flush with the wall, such as wallpaper or a work of art
- The surface should result in coverage for a range of angles or facilitate multi-paths





Engineer 28 GHz Coverage Using Passive Engineered Surfaces

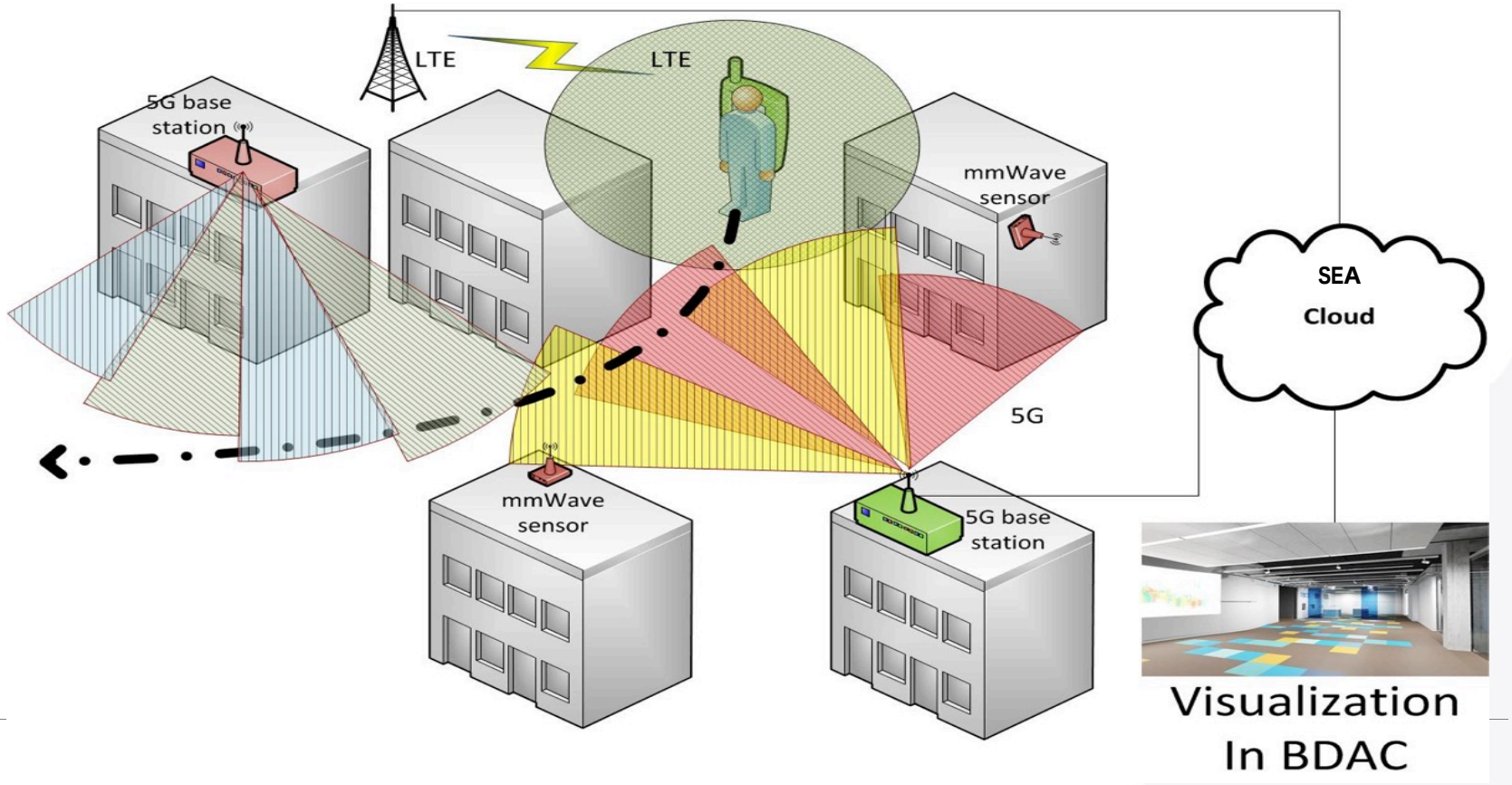
- Expansion of coverage without new BTS equipment reduces need for infrastructure with power and backhaul
- Guidance on where to place them requires accurate modelling and simulation in mmWave bands



Grating to divert energy at specified angle

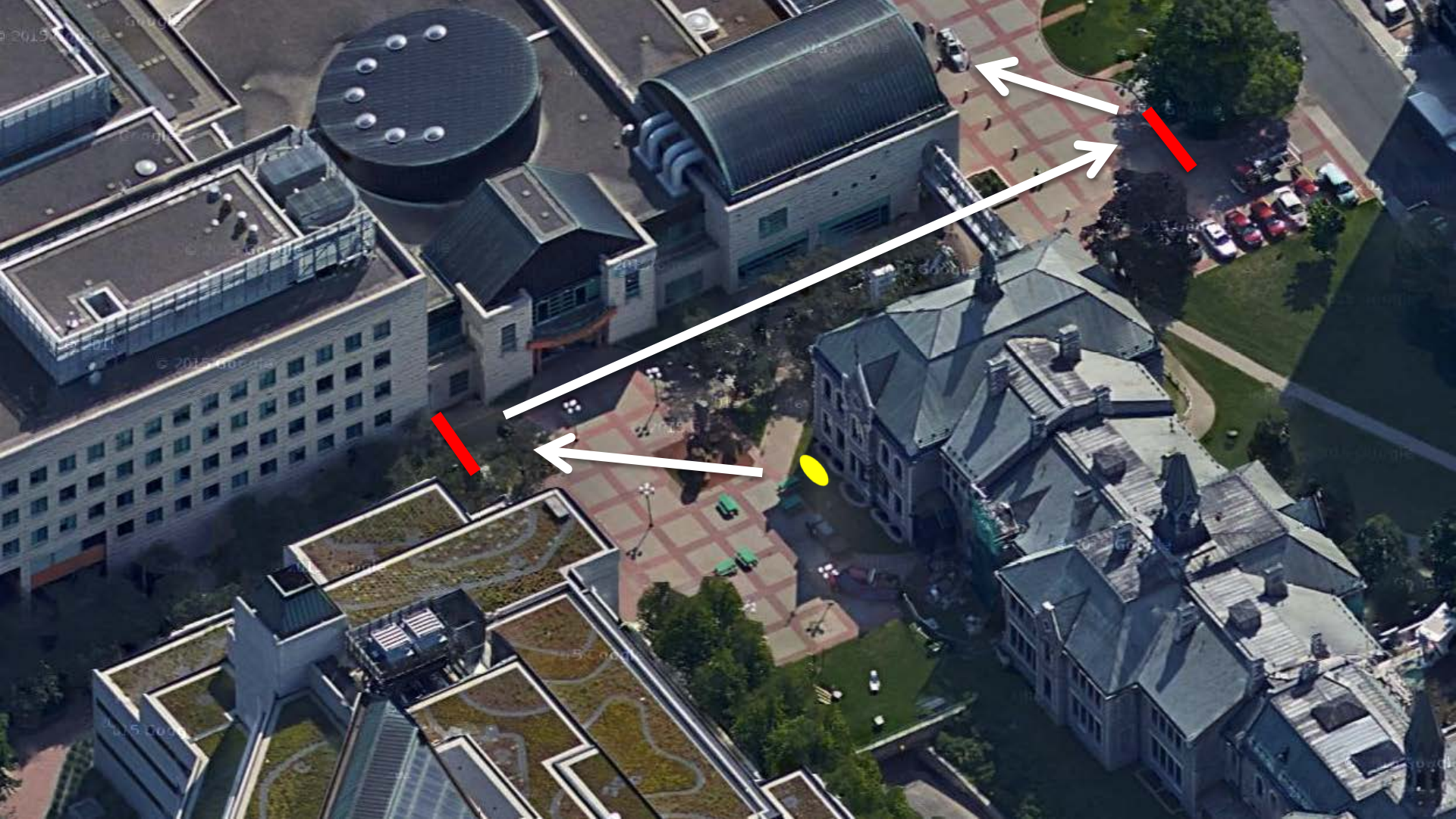
Frequency selective surface obeys Snell's law

mmWave Demo Concept



5G mmWave Test Bed – Ottawa City Hall

- Experiment with 28 GHz UE and base station
- Outdoor test bed with primarily pedestrian traffic
- Partnership with City of Ottawa supports logistical and technical needs
- Spectrum sensors installed for real-time monitoring



mmWave – Radio Platforms

Requirements for Demo at 26/28 GHz

System

- Signal type?
- Connectivity to CRC Cloud / BDAC
- Data payload: iperf / video

Base station

- Multi-sector / antennas
- LTE backhaul

UE

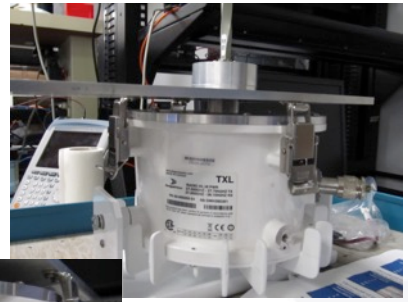
- Mobile / portable / battery
- Antenna
- Position tracking

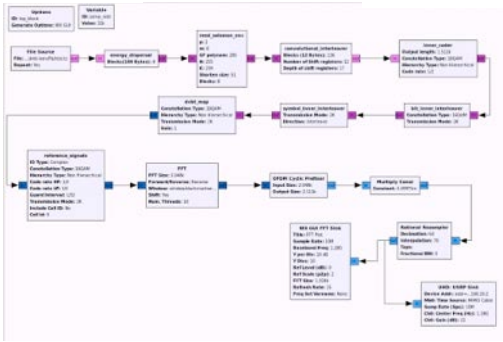
Engineered surfaces

mmWave Radio – Experiment #1

GNURadio
THE FREE & OPEN SOFTWARE RADIO ECOSYSTEM

DVB T





DragonWave

mmWave Radio – Experiment #1

- Experiment with SDRs in combination with 28 GHz up/down converters
- GNU/Radio DVB-T unidirectional link
- B210 USRP transmitter and receiver

- Issues with up/down conversion: carrier frequency offset

mmWave Radio – Experiment #2

- LTE experiment with SDR in combination with 28 GHz up/down converters
- Open source software: srsLTE
- Unidirectional link
- B210 USRP transmitter and receiver
- Offset issues fixed within srsLTE
- Video transmission 10-15 Mbps

Frequency Offset Issue

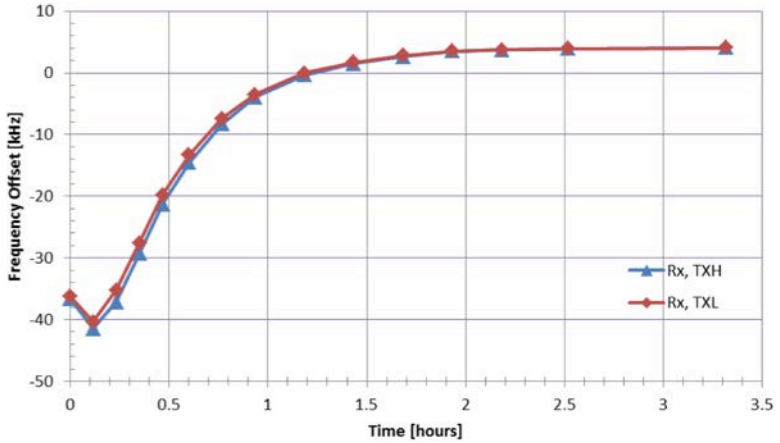


Figure 1. Frequency offset of bidirectional tone signals during warm up.

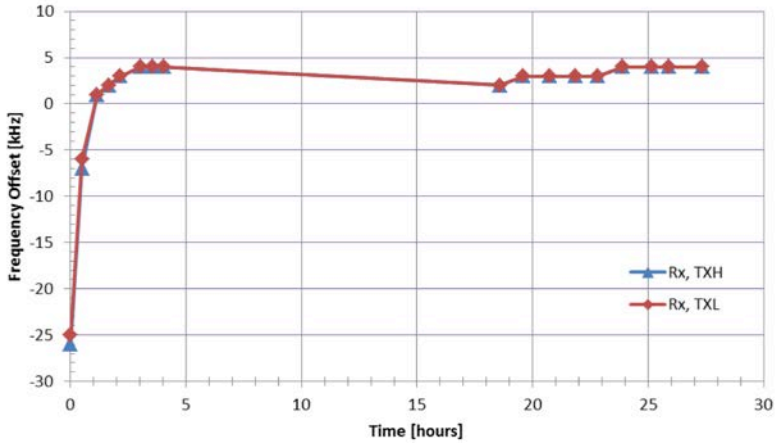
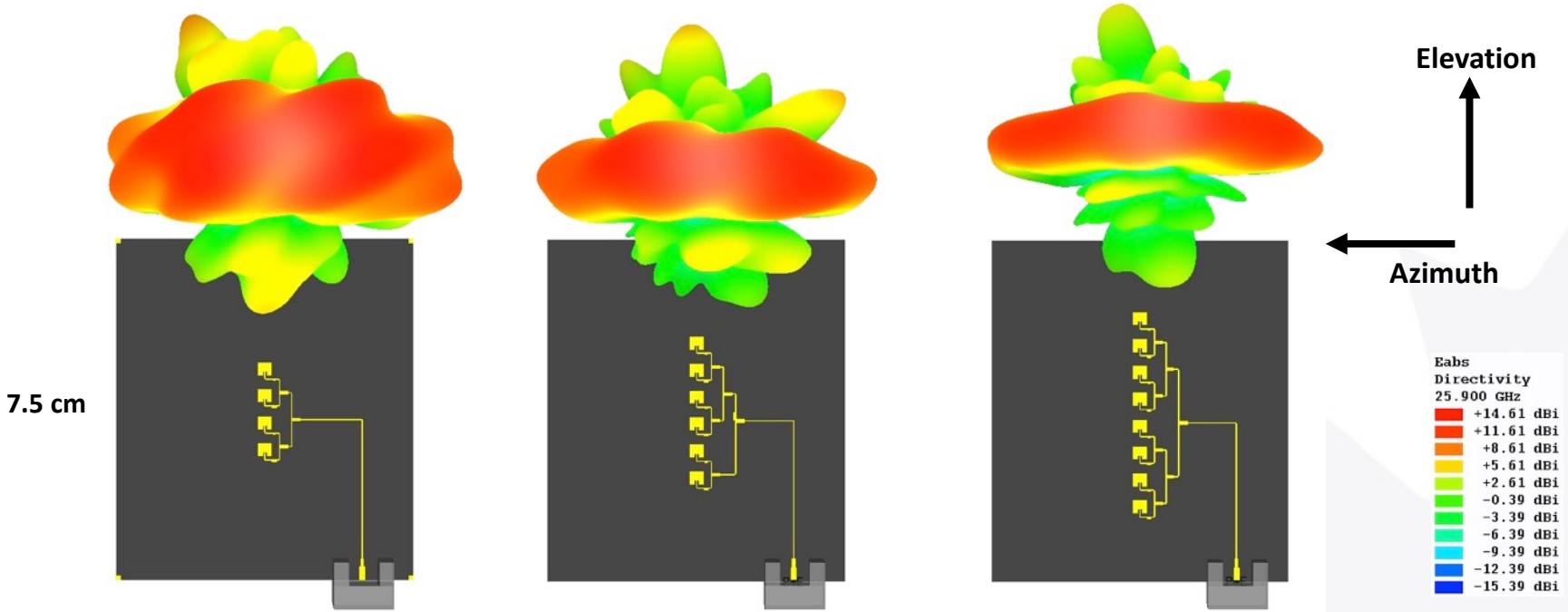


Figure 1. Frequency offset of bidirectional tone signals over a 28 hour period.

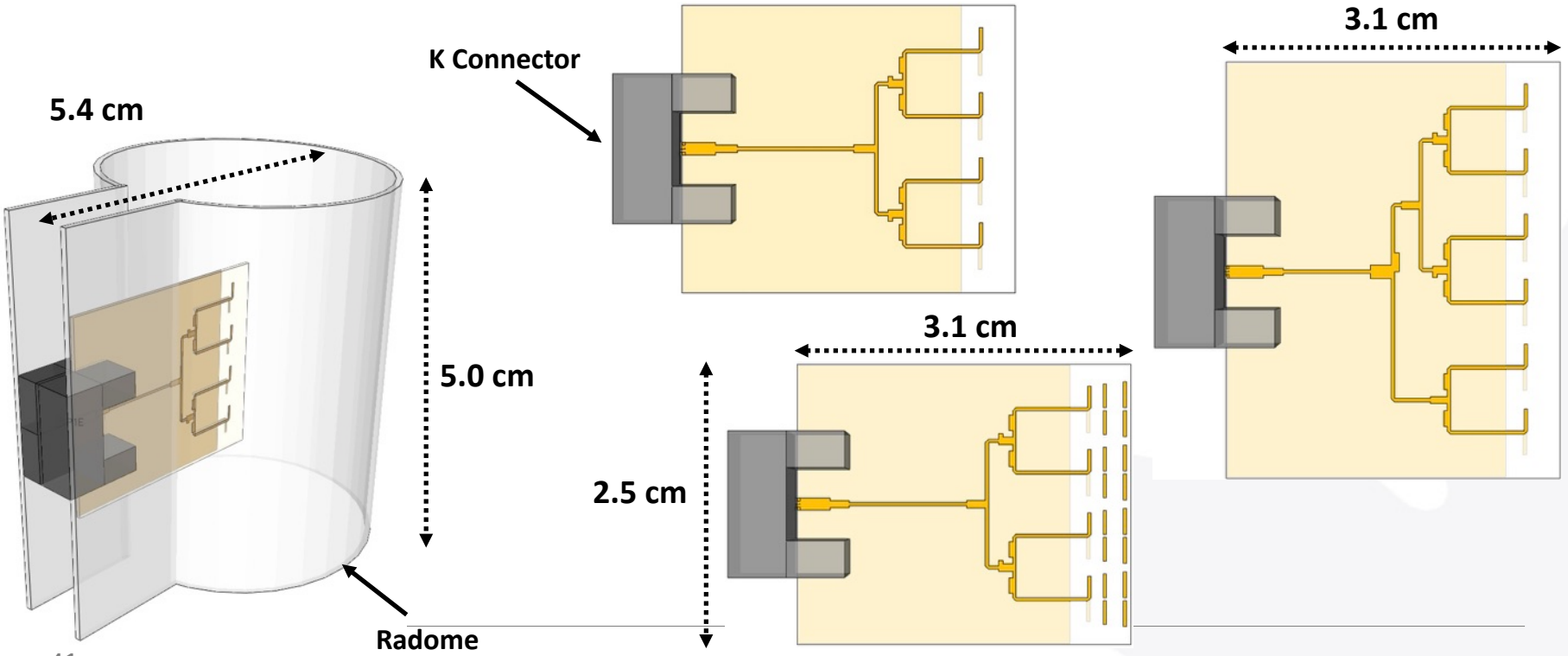
Tracking and compensation integrated into srsLTE based software

mmWave Antenna Using VP Array

Simulated Radiation Patterns



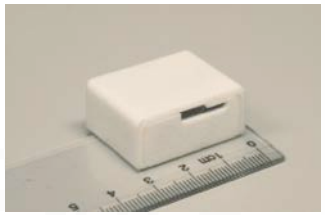
mmWave Antenna Mechanical Design

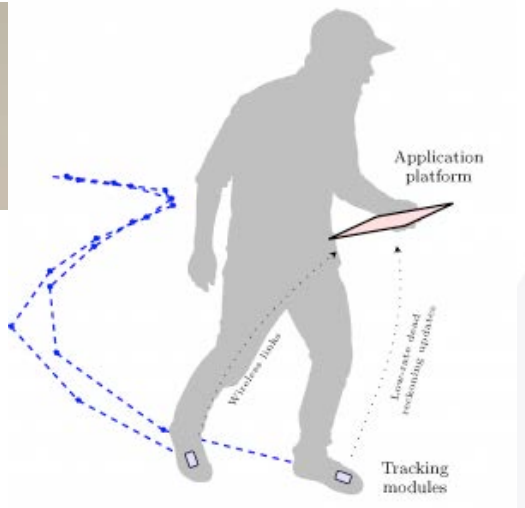


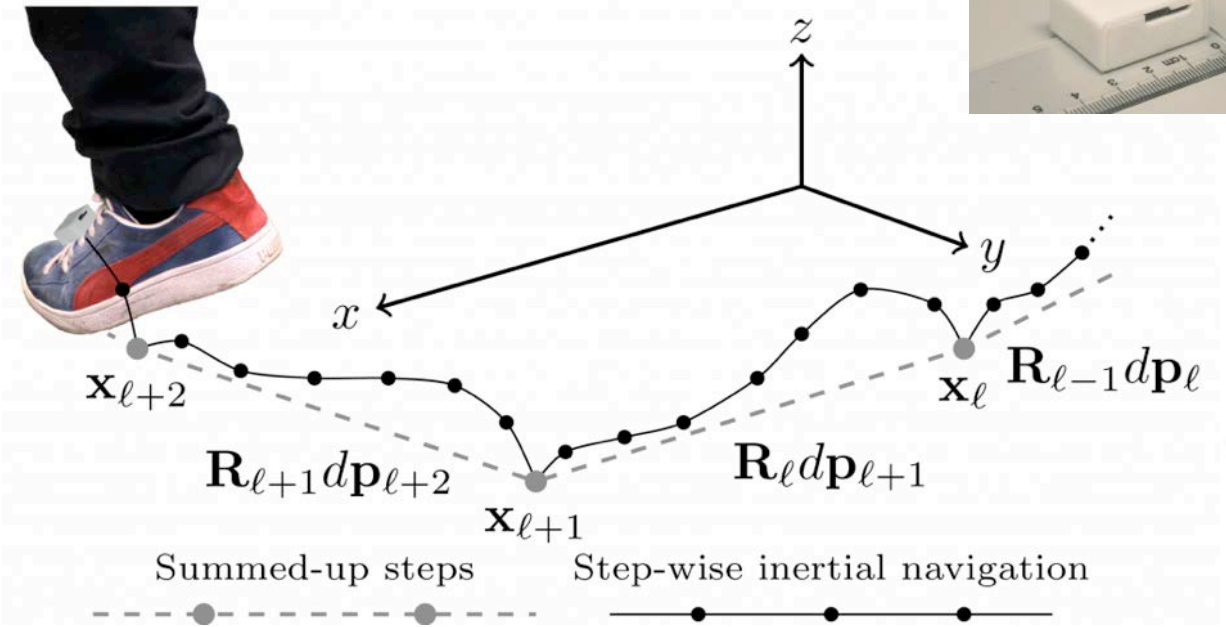
mmWave Antenna

Precise Positioning

Inertial Navigation System – OpenShoe







INERTIAL ELEMENTS

mmWave – Results

CRC mmWave Base Station

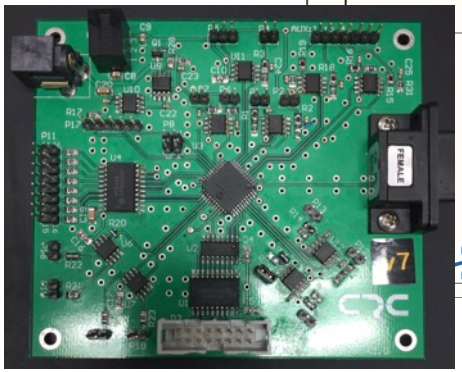
CRC Backpack “Mobile” UE

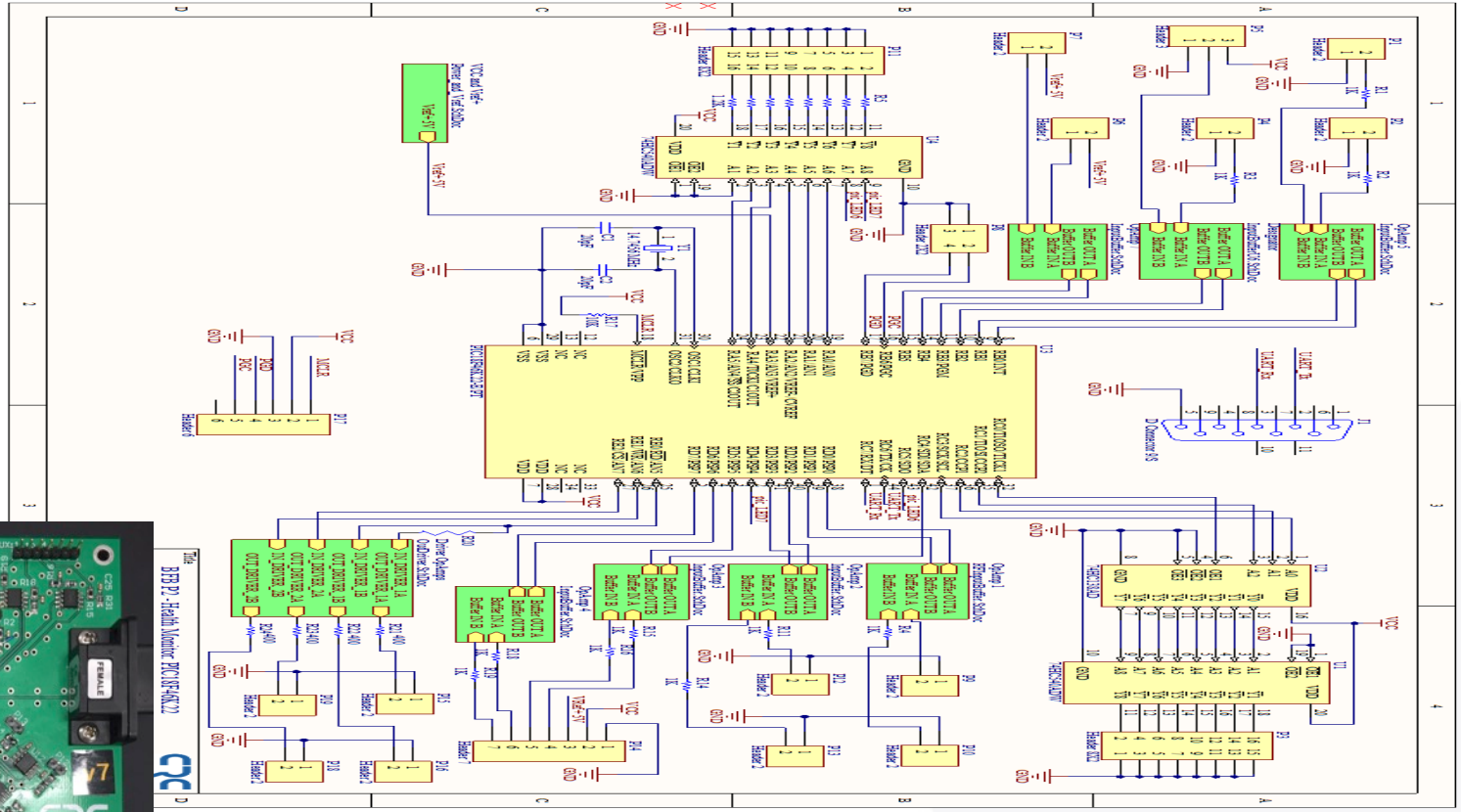
28 GHz UE

Engineered Surface: Diffuser

Interior of 28 GHz Backpack UE

UE Health Monitor

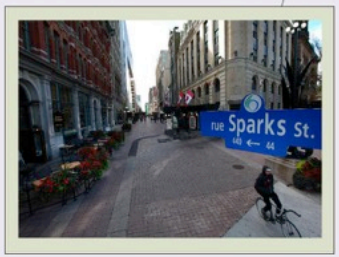


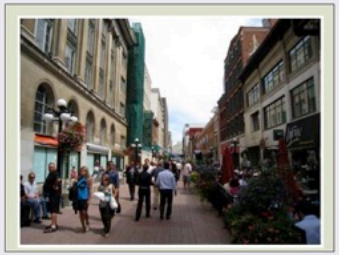


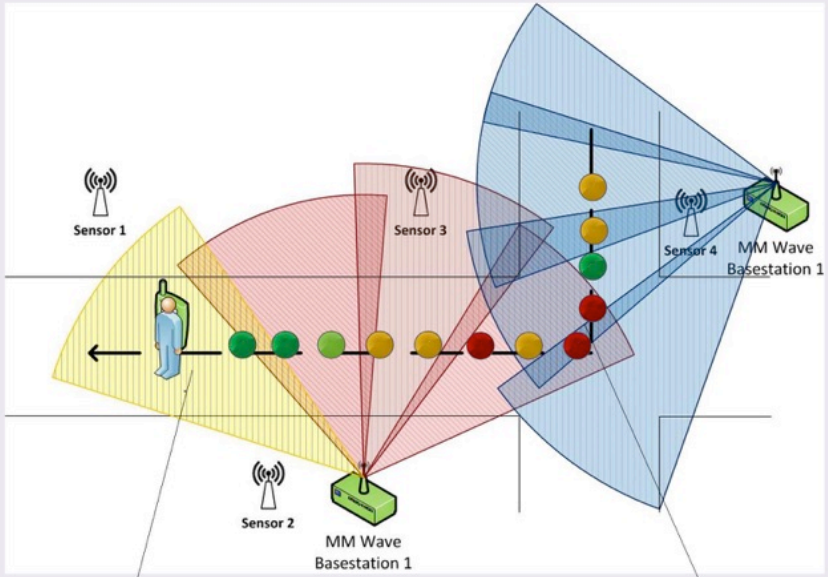
Visualization

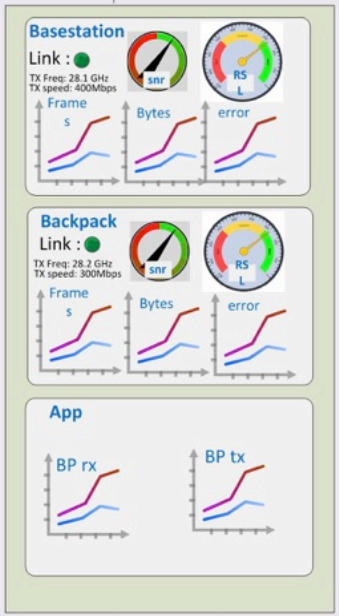
Live video feed from BP5

Dashboard showing mmWave & application stats (details on next page)







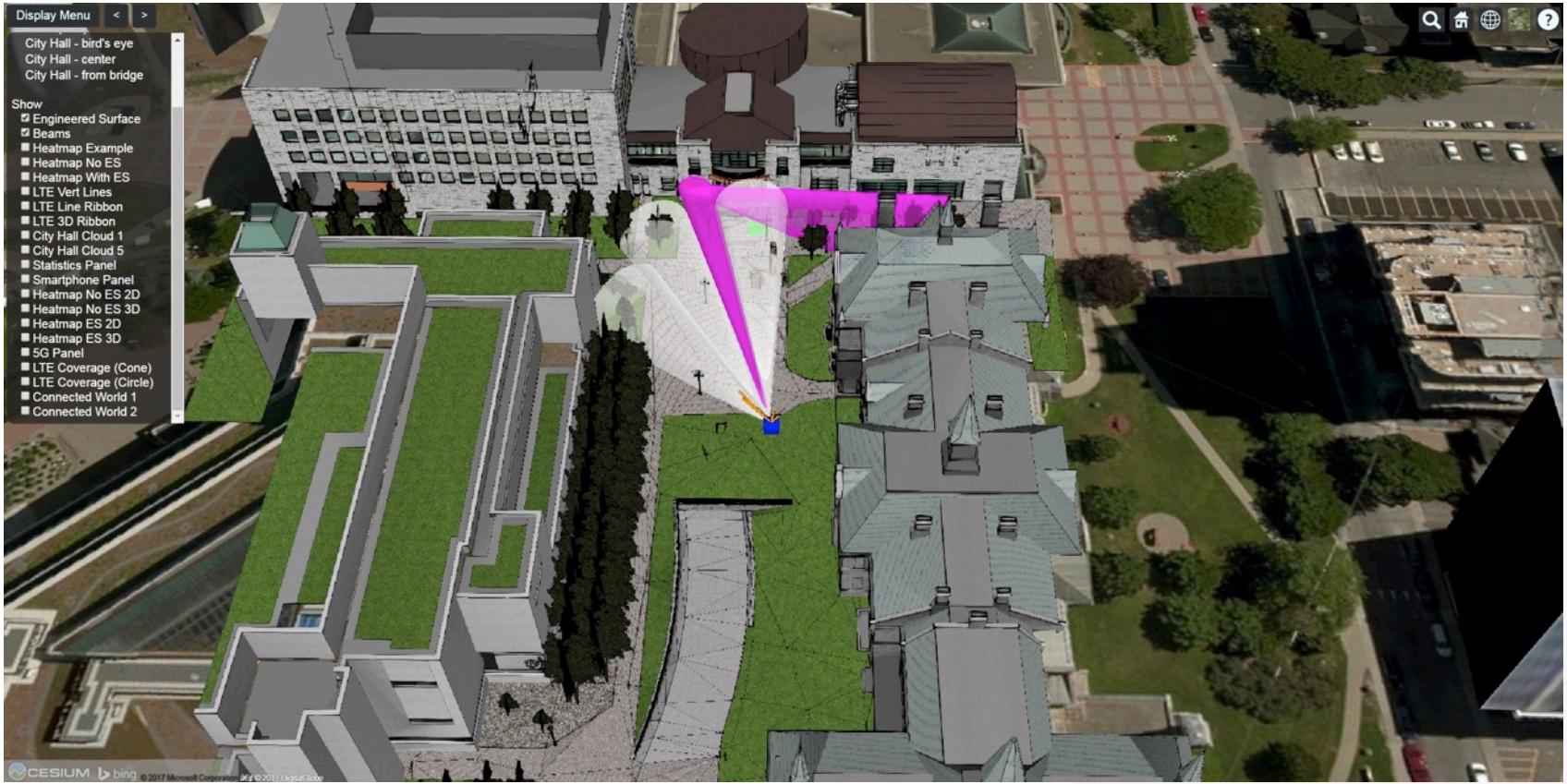


Visualization in BDAC

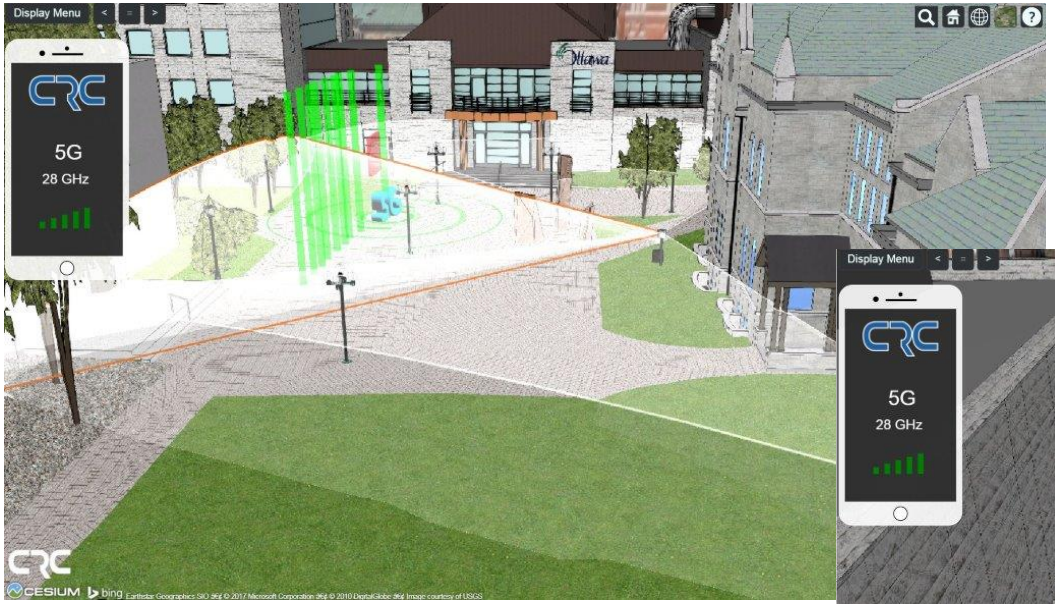
Active Antenna Highlighted

"Breadcrumbs" indicate path taken
Color indicate RX Signal Level
(Need a way to clear the "crumbs")

Spectrum Visualization



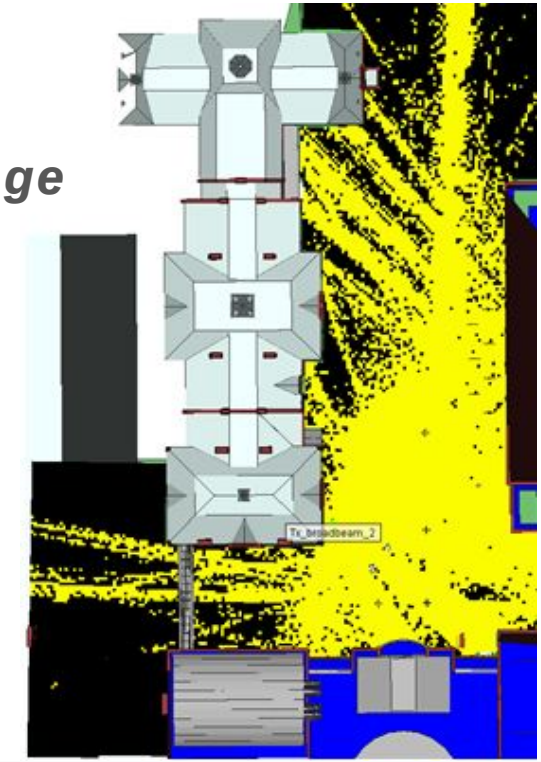
Live Demo with Real-time Visualization Capability



Visualization also serves as R&D tool: shows technical status of BTS and UE equipment, and archives results

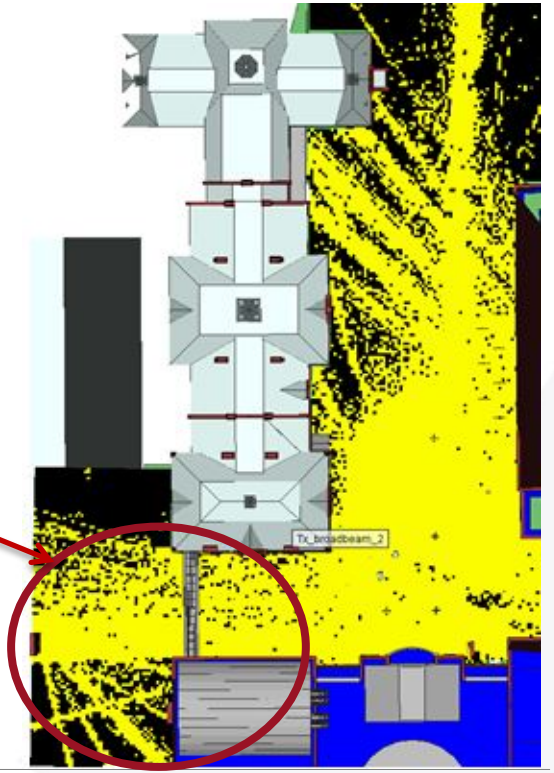
Impact of Engineered Surface Reflectors on Coverage with LTE at 28 GHz

Basic Coverage



Enhancement from Reflectors

Improvement by careful placement of reflectors



Next Steps

Spectrum Sensors: Next Steps

- LMR bands
- Local processing / acceleration
- srsLTE-based LTE sensor
- Sensor calibration and validation procedures

mmWave Radios: Next Steps

- Bi-directional communications
- eNodeB
- Multi-sectors
- Reduced form factor
- Increased bandwidth

Making Better Use of Spectrum

How can dynamic spectrum knowledge be used to enable more effective use of spectrum?

- Develop fairness and efficiency metrics to assess and improve coexistence between dissimilar systems
- Demonstrate how SEA information, including identified complex events and trends, can be used to facilitate dynamic spectrum sharing
- Explore techniques for dynamic spectrum allocation / assignment based on predicted demand

Future Spectrum Management

- Dynamic assignment matched to demand
- Widely improved utilization with dynamic sharing
- Greater contiguity for broadband services
- Flexible licensing and pricing via dynamic markets

Efficient and responsive dynamic spectrum management

Summary

CRC has developed advanced research, development & demonstration systems for

- Spectrum monitoring
- Big data collection, cloud based analytics & visualization
- Wireless mmWave propagation characterization
- Mobile mmWave wireless communications
- Engineered mmWave wireless environments

- Platform development will continue as CRC focuses R&D efforts on systems to show the dynamic use of radio spectrum


Canada

Additional Material

mmWave Backpack UE Architecture