Homeland Security

Envisioning a Smart Public Safety Ecosystem:

5G and IoT Potential Public Safety Impacts

Workshop on 5G Technologies for Tactical and First Responder Networks
The Johns Hopkins University Applied Physics Laboratory
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Agenda/Topics

- High Level Overview
- Portland Example Design
- Potential Impacts for Public Safety Communications
- Public Safety Role Moving Forward

5G Overview

- **Demand attentive network**
  - Continuously optimize network resources and latency
  - Higher performance and user experience at low cost of investment
  - Pushing more processing/computing to edge
- **Advanced, dynamic spectrum sharing**
  - Multiple parties using the same band
  - Contiguous coverage of densely packed small cells
  - Seamless data rates of up to 1 Gbps
- **Converged wireless network**
  - Millimeter wave (mmWave) wireless links (> 24 GHz) for mobile access and fixed access
  - Nomadic "spot" area coverage access for speeds > 1 Gbps

5G Use Cases

Mission critical (MC) applications

Smart cities/infrastructure/grid and homes

Human-machine (H2M) interaction

Vehicle-to-X (V2X) communications for safer vehicles, autonomous driving

Fixed broadband HD TV distribution

Immersive gaming, virtual reality, augmented reality, 3D and UHD video telepresence, remote surgery

Faster data rates and lower latency for current mobile applications such as streaming data, video, and voice

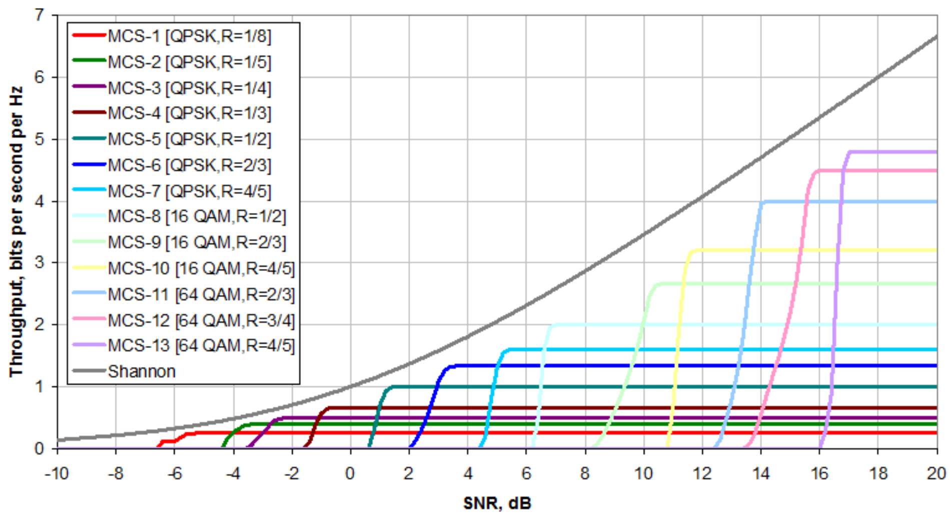
5G New Radio (NR) and Core Network

- Greater amount of spectrum mmWave frequency bands
- Massive Multiple Input Multiple Output (MIMO) for dense spatial re-use and highly directional beamforming antennas
- Smart Beamforming and tracking, interference reduction (mmWave bands)
- Smaller cells, rapid deployment and mesh-like connectivity
- Lower outage probability
- Much higher throughput in targeted areas of coverage
- Greater leveraging of Software Defined Networks (SDN) and Network Function Virtualization (NFV) to allow for integrated, distributed, “programmable”, context-aware network

Network Capacity – How to Deliver 5G?

- Network capacity is a function of the number of frequency bands, the amount of spectrum in each frequency band, the number of cells and the cell spectral efficiency (CSE) of each cell based on user clustering

Source: 3GPP TR 36.942

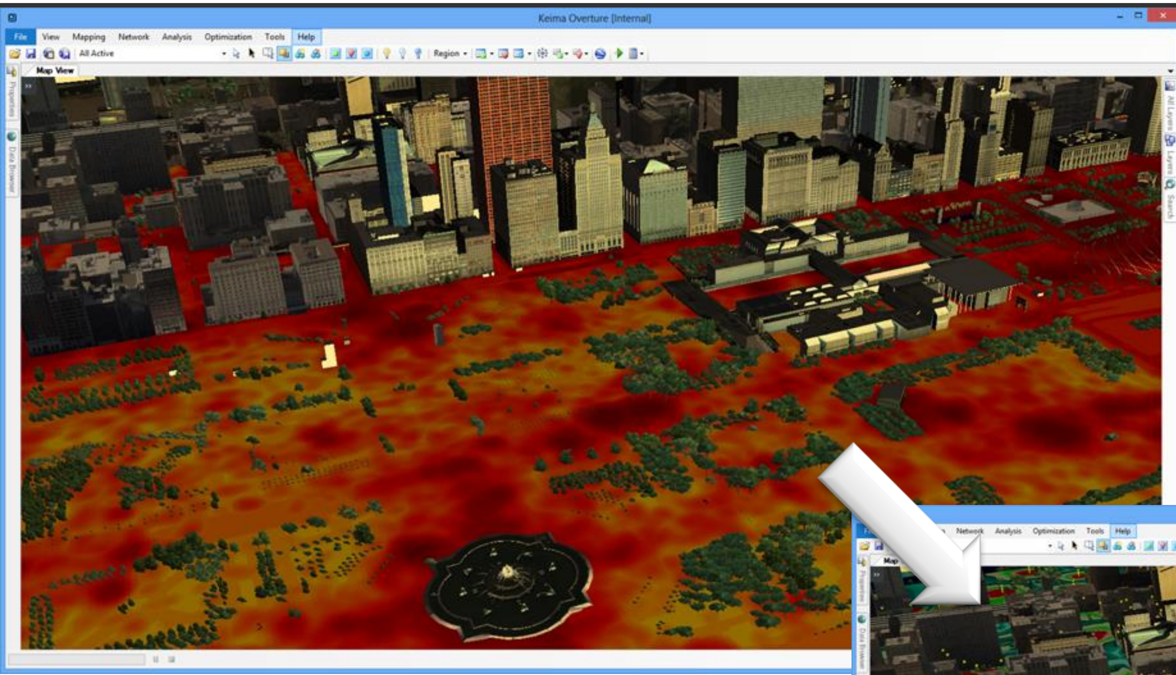


- 5G will require site densification across multiple frequency bands and a large amount of spectrum to increase capacity and resiliency in a given coverage area while mitigating interference

$$\text{Network Capacity (bps)} = \sum_{\text{bands}} \sum_{\text{cells}} \text{Quantity of Spectrum (Hz)} \times \text{Cell Spectral Efficiency (bps Hz}^{-1}\text{)}$$

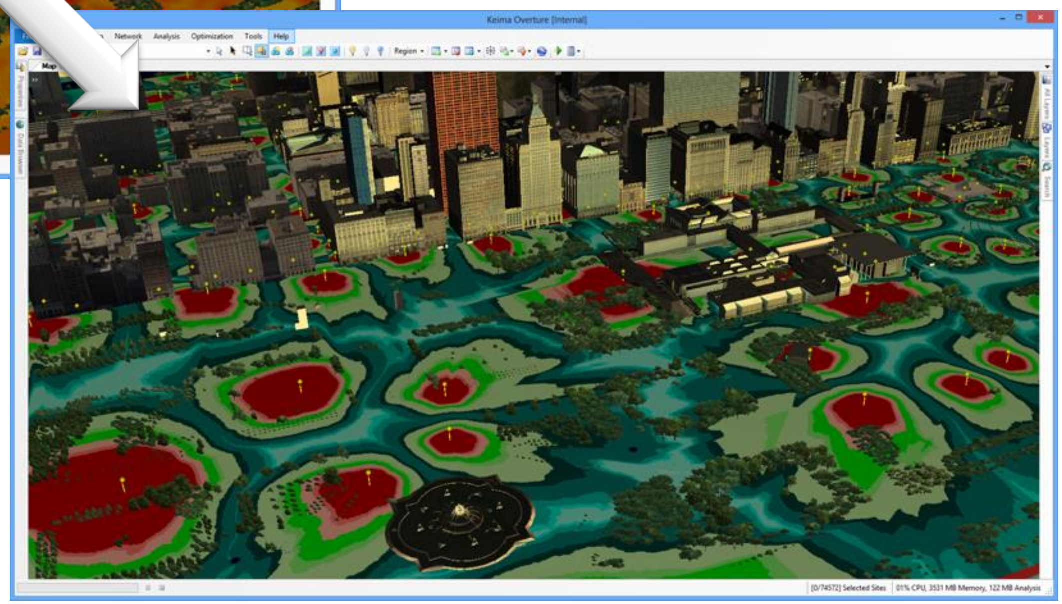
Need for more (and higher) frequency bands, massive MIMO, and smart beamforming

Deployment of Small Cells



"Leveraging geo-tagged social data (where the public moves during the day or clusters) to accurately predict where loss of life is most likely to occur at a certain location or area at any time during a 24-hour period"

Source: Keima – Overture Tool

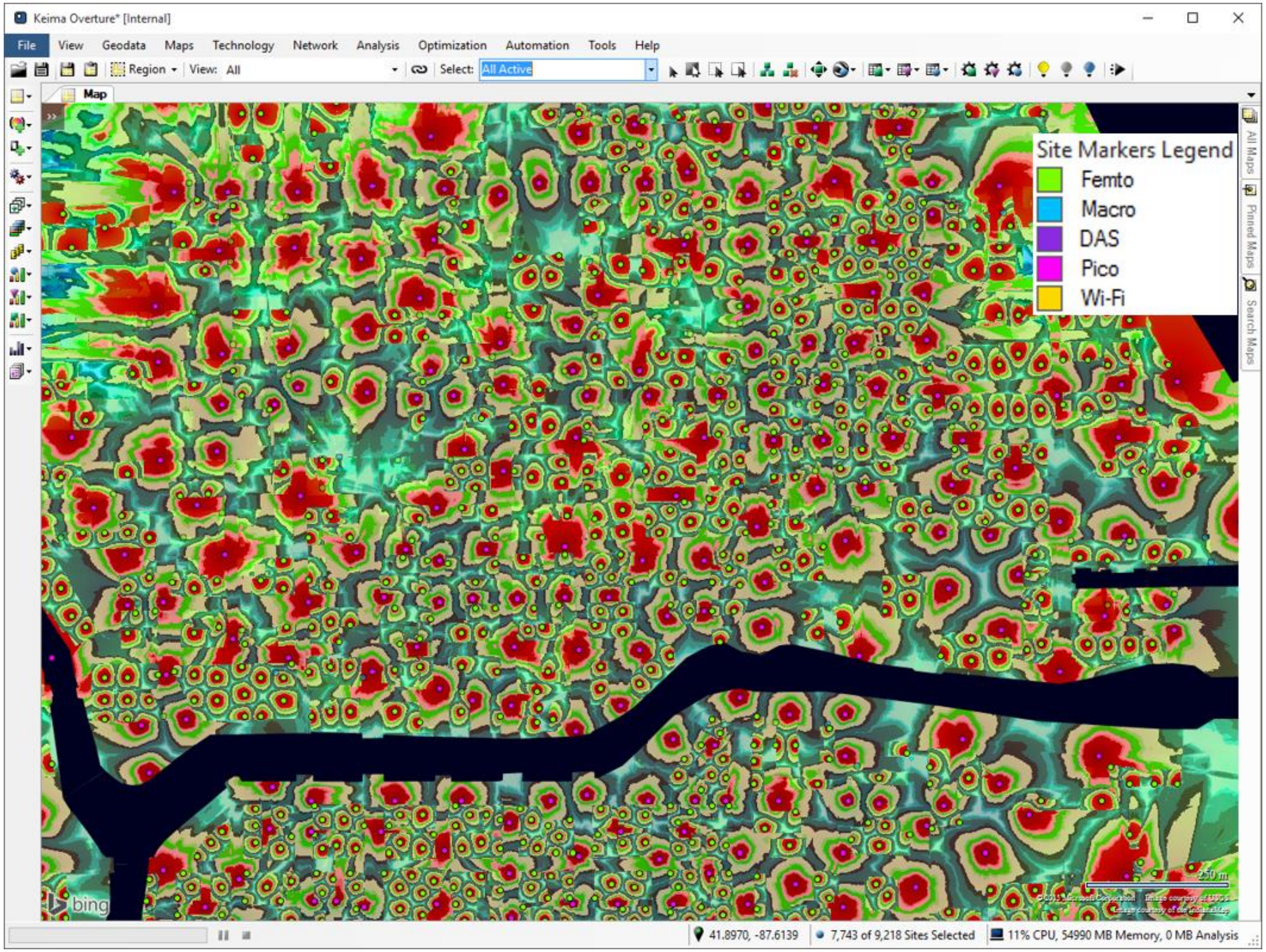


Tactically placing small cells exactly where the public clusters during the day to optimize network coverage and maximize capacity

4G Moving towards 5G Node Densification

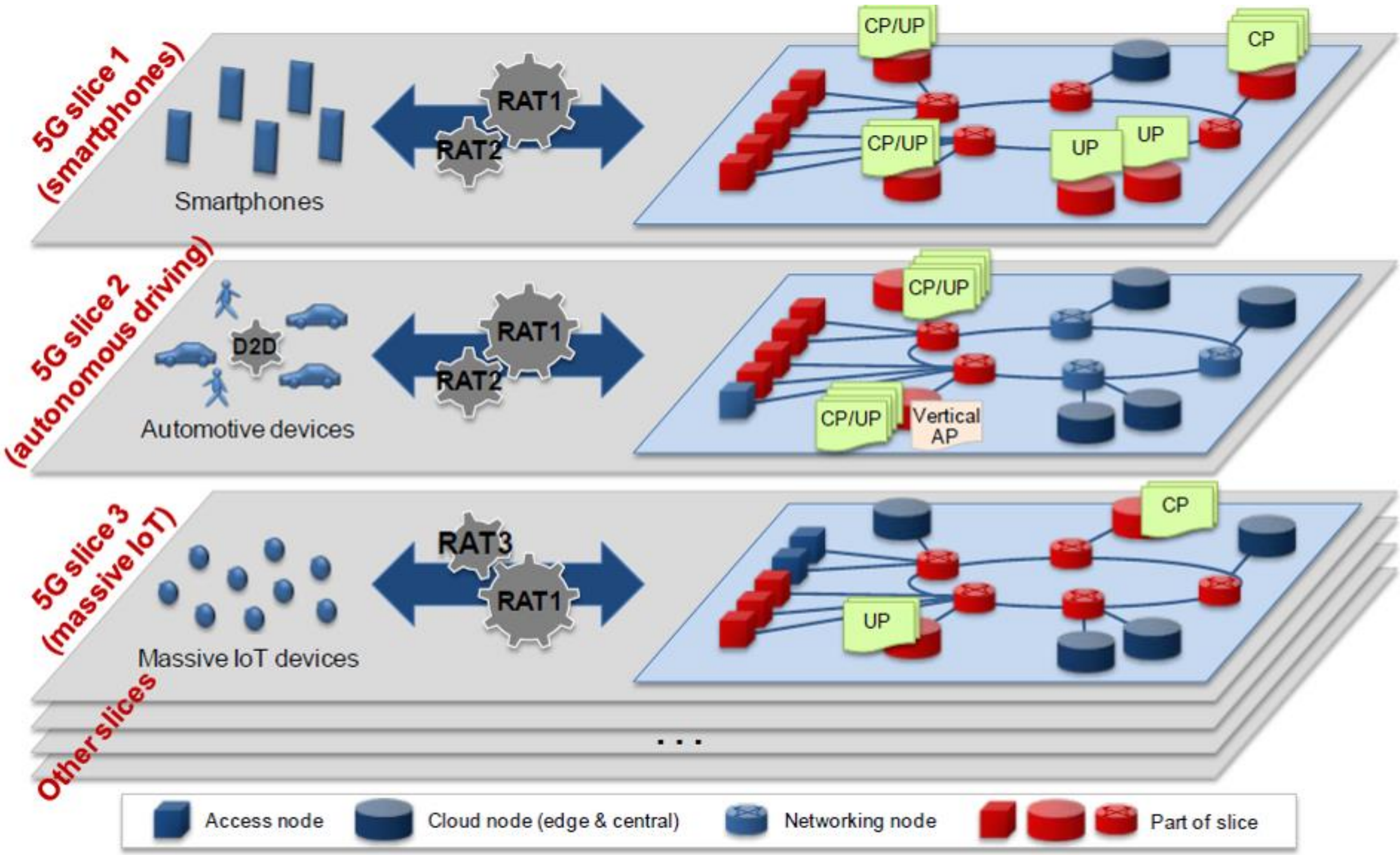
- Seamless integration of multiple site types, frequency bands, and access technologies

- Reducing the distance between users and cell sites with automatic reconfiguration



Source: Keima – Overture Tool

5G Network Slicing



CP: Control Plane (signaling)
UP: User Plane (traffic)
AP: Application Provider

Source: NGMN 5G White Paper

Internet of Things (IoT)

IoT Benefits for Public Safety

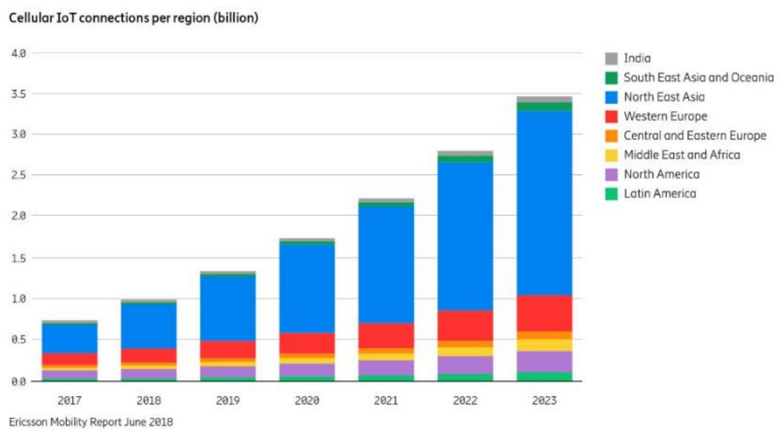
Ubiquitous network connectivity

Enhanced situational awareness

Process optimization

Real-time response and control of autonomous systems

- **IoT goes beyond simply connecting objects** to the Internet; it allows physical objects to intelligently self-identify and communicate with other devices, creating a new model of information-sharing



Connected devices (billion)

IoT	2017	2023	CAGR
Wide-area IoT	0.8	4.1	30%
Cellular IoT[1]	0.7	3.5	30%
Short-range IoT	6.2	15.7	17%
Other devices			
PC/laptop/tablet	1.6	1.7	0%
Mobile phones	7.5	8.6	2%
Fixed phones	1.4	1.3	0%
Total connected devices	**17.5**	**31.4**	**11%**

Source: Ericsson Mobility Report, June 2018

5G Key Issues

- **Coexistence**
  - Coexistence with other priority services (e.g., Emergency, Critical IoT)
  - Flexible mechanisms to establish and enforce relative priority policies
  - Coexistence with commercial services that are bandwidth intensive and requires key performance indicators such as low latency and high reliability (e.g., Drone Control, Transportation Control, Medical)
- **Network Slicing**
  - Public Safety communications and IoT could be implemented with 5G network (or networks) service providers as a Network Slice as a service (NS-as-a-service) with its own prioritized signaling and traffic handling and directed over certain Radio Access Technologies (RATs) based on their resiliency and availability
- **Access Control**
  - New requirements given lessons learned for 4G LTE such as need for more specific access category types and potential need for prioritized RACH
- **Ability to Leverage Emerging 5G Capabilities for PS Service Portfolio Extensions**
  - New UE capabilities, multiple identities, multiple devices under one PS subscription
  - Vertical application (e.g., IoT, Tactile Internet)
  - Network Capabilities (e.g., Slicing, NFV), devices connecting to multiple slices at a time
  - Multiple Network Access and Connectivity (e.g., NR, 4G, Wi-Fi, Bluetooth, Fixed Wireless and Satellite)

5G Timeline

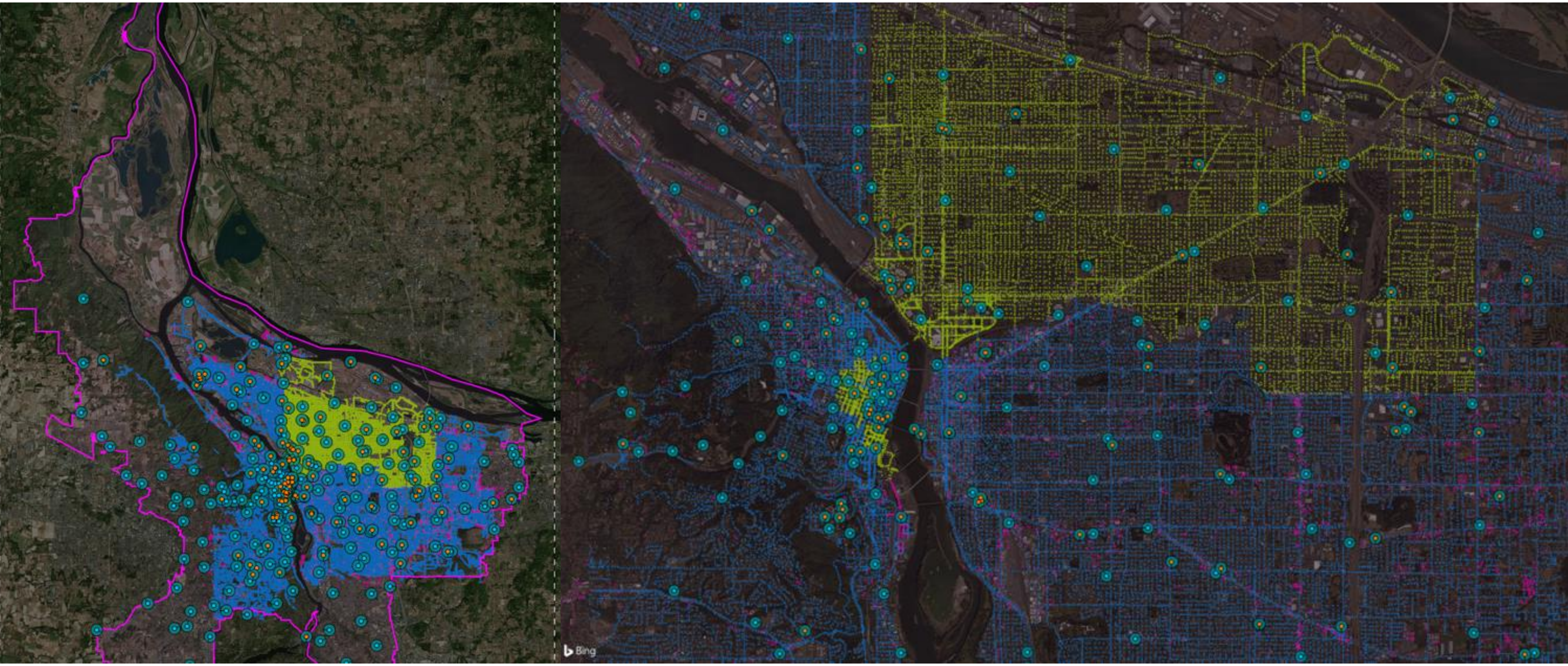
- 3GPP 5G Phase 1 architecture work during 2017- June 2018 focused on Service Based Architecture, Common Core Network, Network Slicing, and Application Support
- Fixed wireless commercial launches 2018
- Distributed network slicing/services begin 2019
  - Begin with “large slices” but becoming more focused/granular over time
- 5G mobility trials late 2018 into 2019
- 5G initial mobility network deployments/commercial launches begin ~ 2019, 2020?
- 5G mobility and full network slicing capability widespread deployment 2022+

PORTLAND EXAMPLE 5G DESIGN

Sensors, Smart Cities, IoT, Fixed and Mobile 5G mmWave Multi-Band, Multi-Cell Heterogeneous Network (Het-Net) with Adaptive Network Slicing and Data Analytics

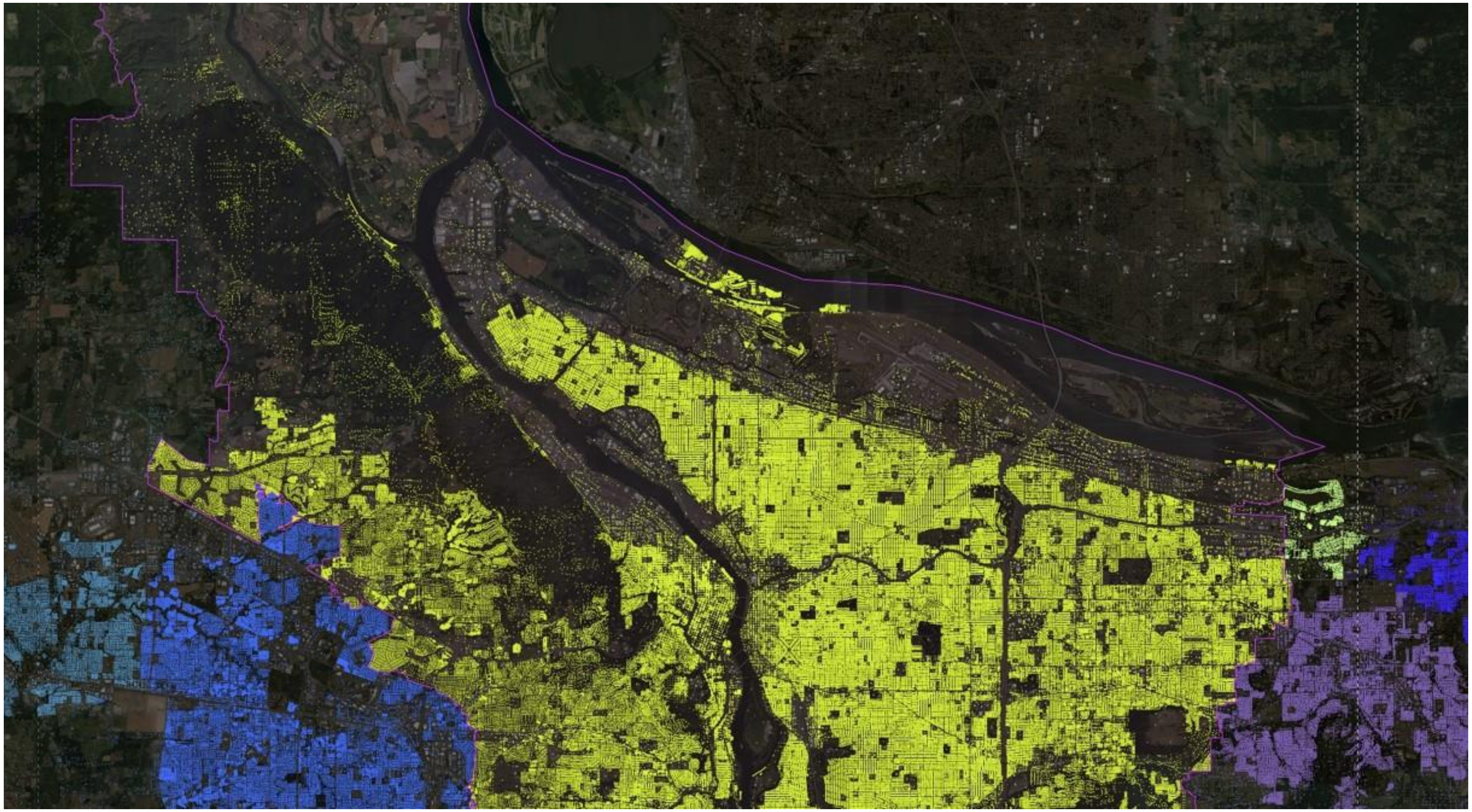
Ubiquitous network connectivity
Enhanced situational awareness
Process optimization
Real-time response and control

Portland Macro Sites and Light Poles



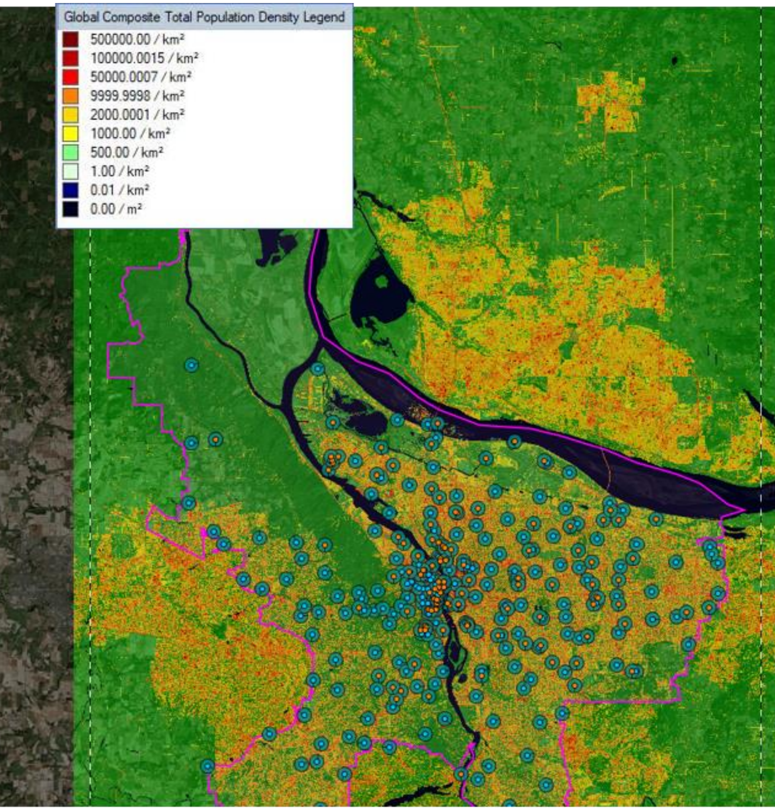
- Macro sites are commercial fiber-connected LTE sites (blue) and Public Safety critical facilities (orange)
- Macros sites at 700 MHz mobile coverage across Portland with sensors on light poles and buildings, subset of buildings light poles have IP cameras for streaming video

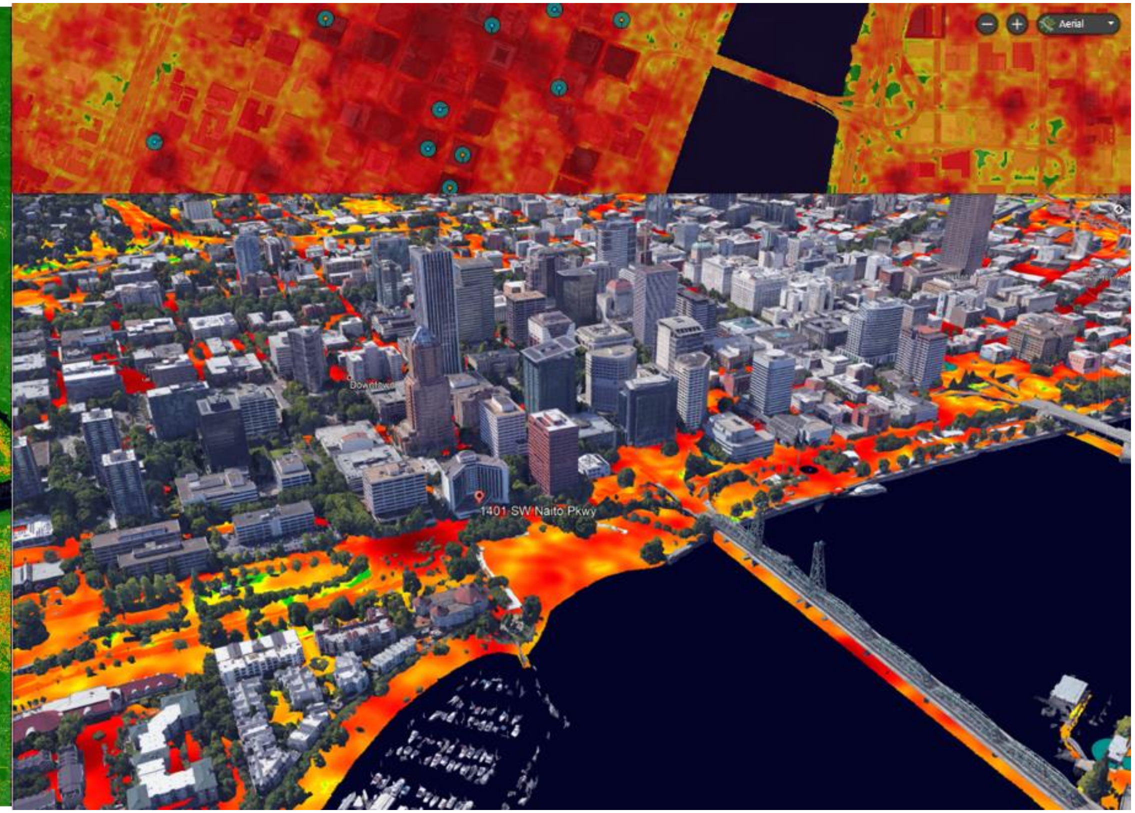
Portland Building Addresses



- Leverage buildings where light pole height insufficient to reach maco sites via line-of-sight (LoS), sensors on light poles and buildings, subset of buildings light poles have IP cameras for streaming video

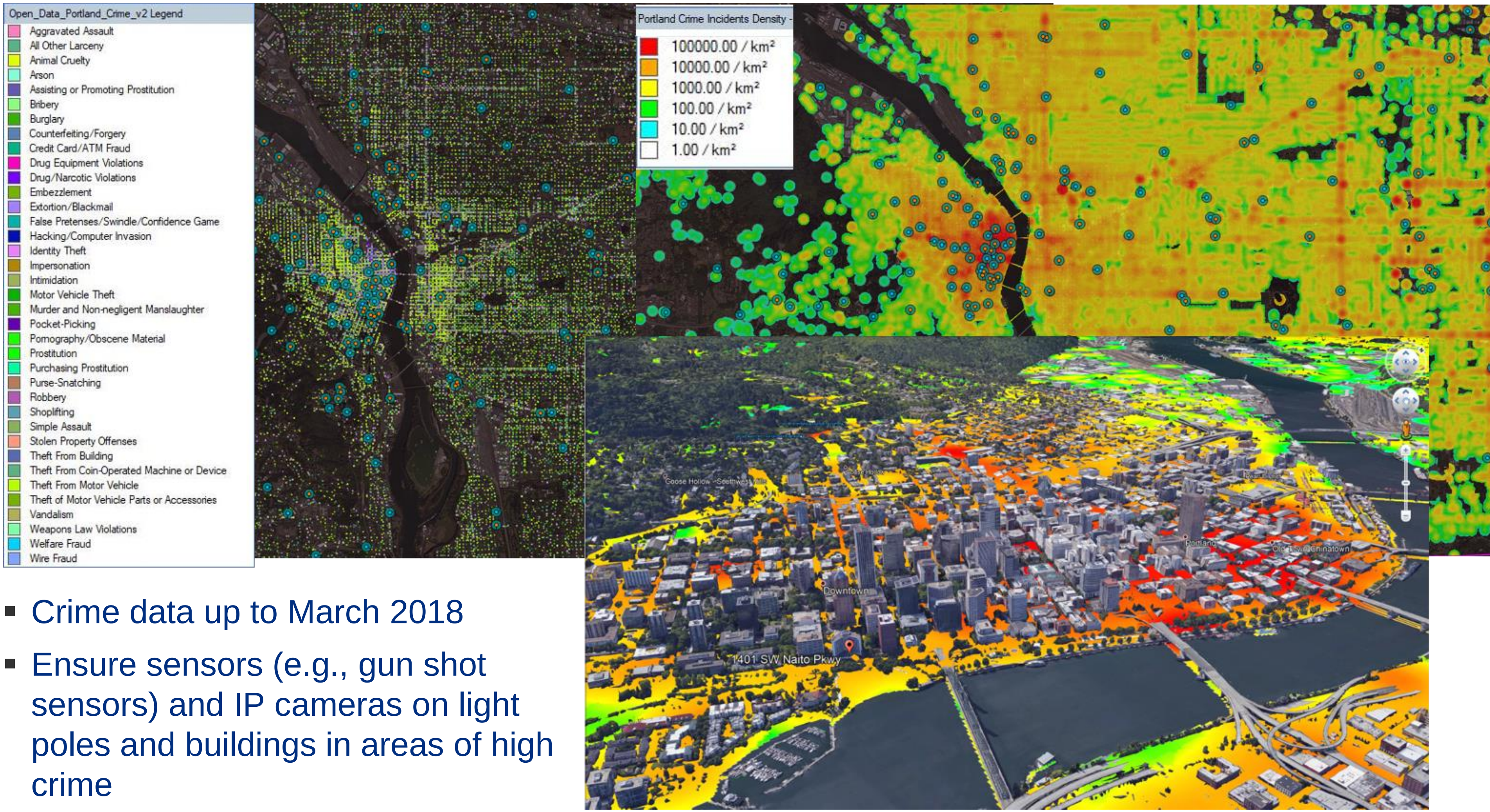
Portland Social Intensity Heat Map





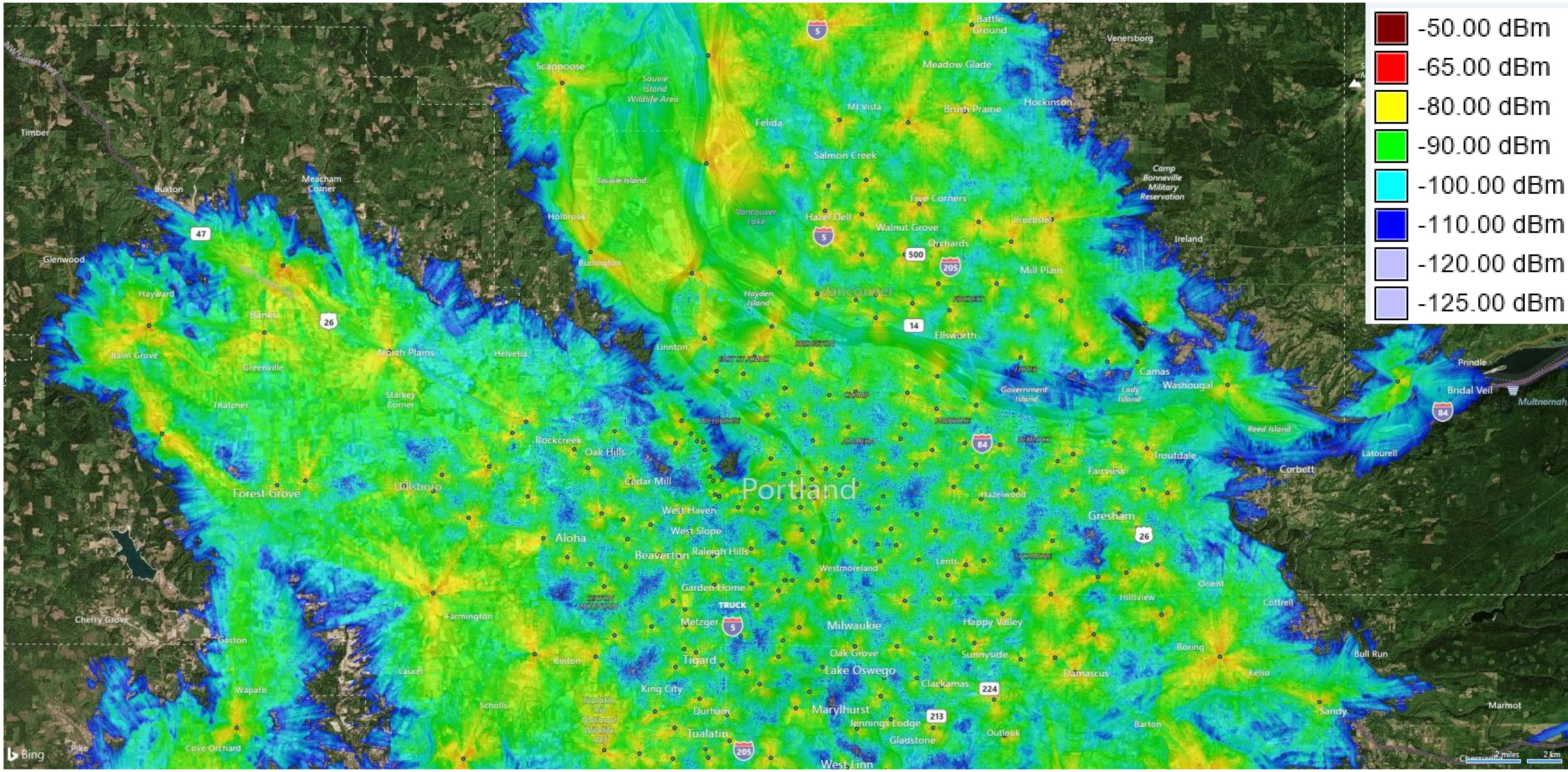
- Where the public in Portland moves (high mobility and low mobility) during the day or clusters to accurately predict where loss of life is most likely to occur at a certain location or area at any time during a 24-hour period
- 1m accuracy

Portland Crime Intensity Heat Map



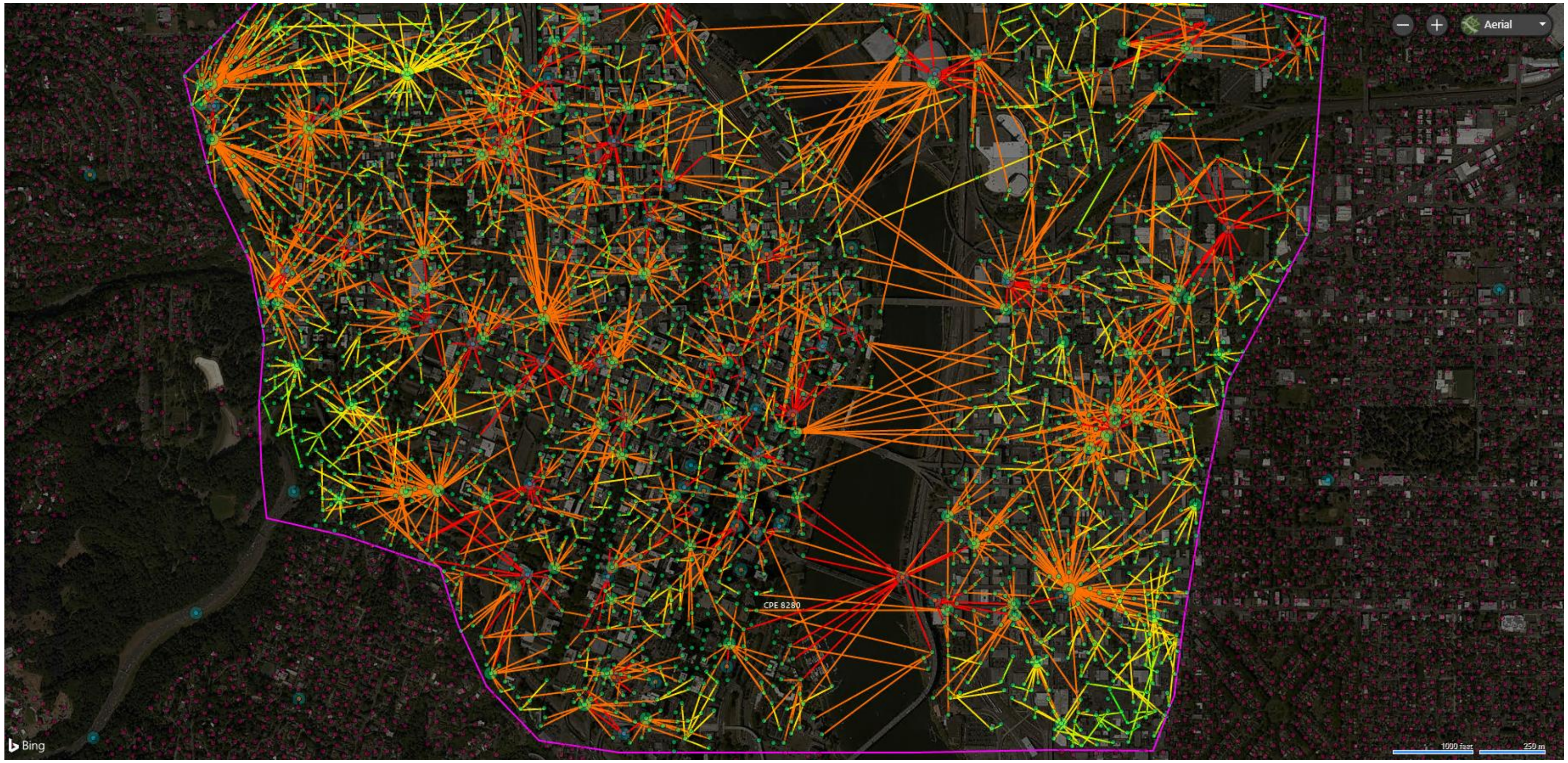
- Crime data up to March 2018
- Ensure sensors (e.g., gun shot sensors) and IP cameras on light poles and buildings in areas of high crime

Portland/Vancouver, WA Area 700 MHz Design – Macros to Sensors



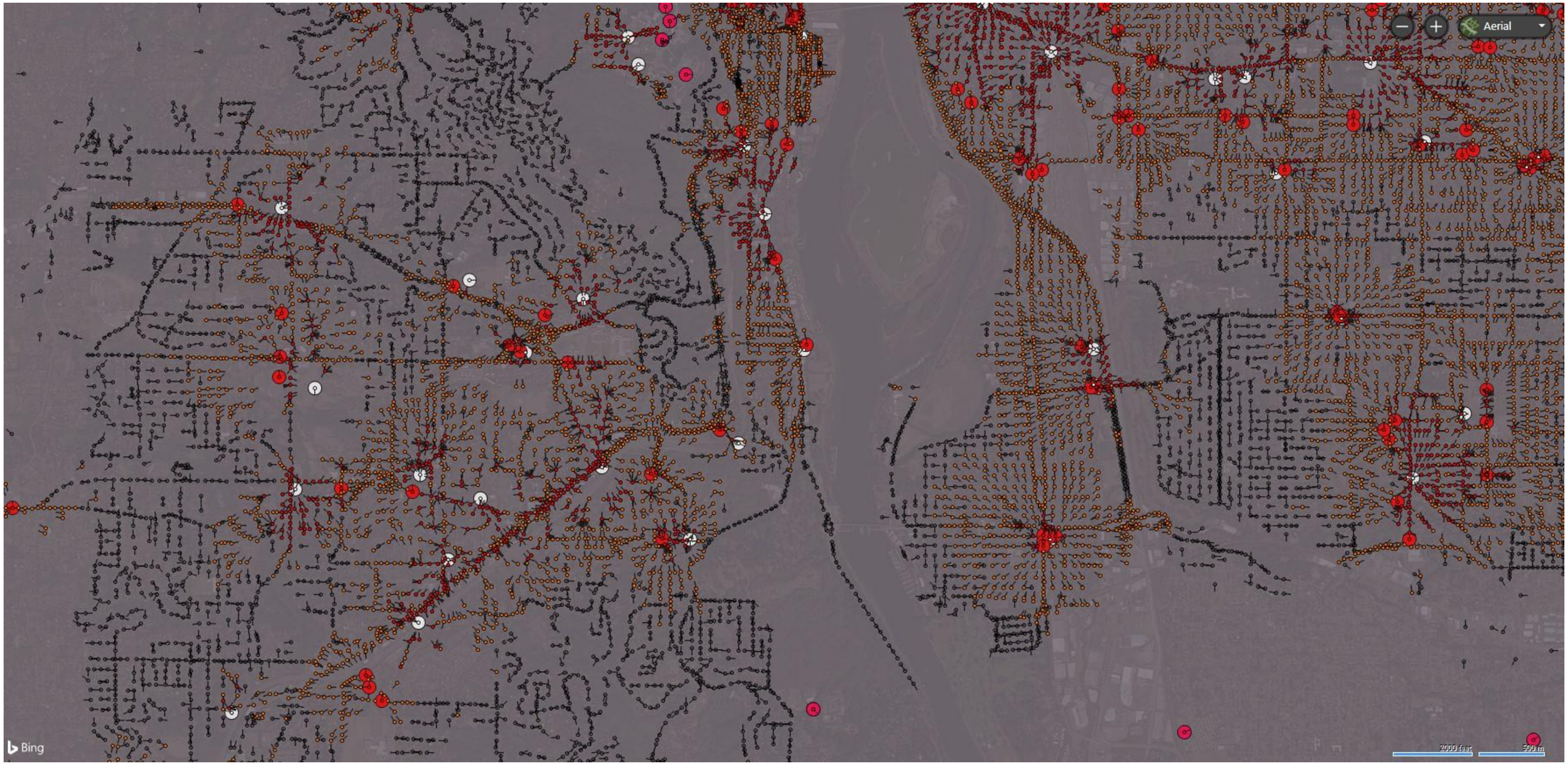
- 700 MHz wireless access to light poles and buildings, coverage per RSRP
- Network slicing in core network picks up sensor alert (e.g., gun shot) and begins to actively monitor IP cameras in vicinity of incident

Portland 5G Fixed Wireless Design



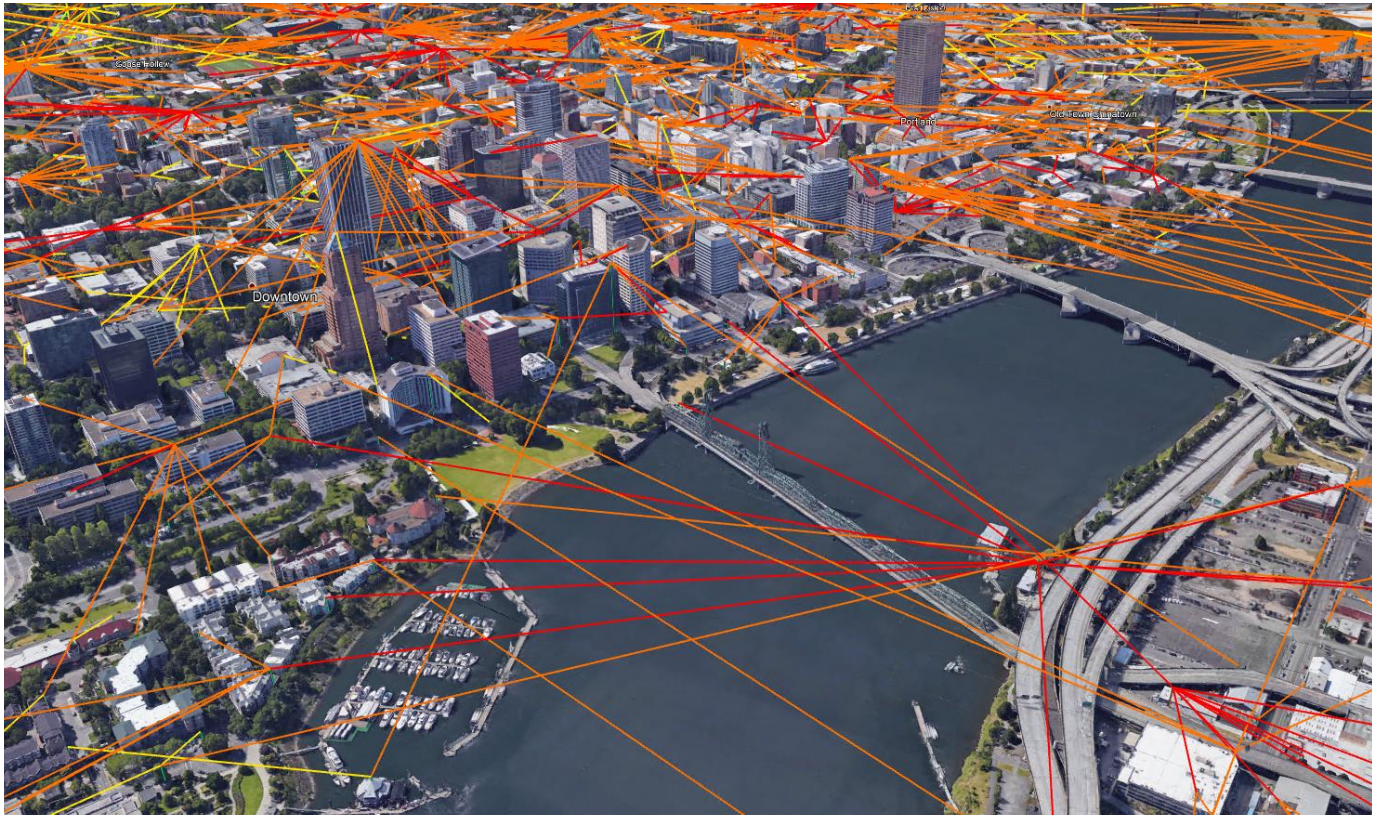
- mmWave 28 GHz, > 500 MHz aggregated channels capacity with prioritized backhaul from IP cameras on light poles/buildings back to macro sites (via mini-hubs on buildings) to distribute on-site video of public safety incident (e.g., active shooter) to command and law enforcement arriving on scene
- Public safety "network slice" to prioritize video from light poles and buildings

Portland 5G Fixed Wireless Design



- Analyzing each light pole for connectivity to hub sites
- Tier 1: Red, Tier 2: Yellow, Tier 3: Transparent (not good candidates for IP camera placement)

Portland 5G Fixed Wireless Design



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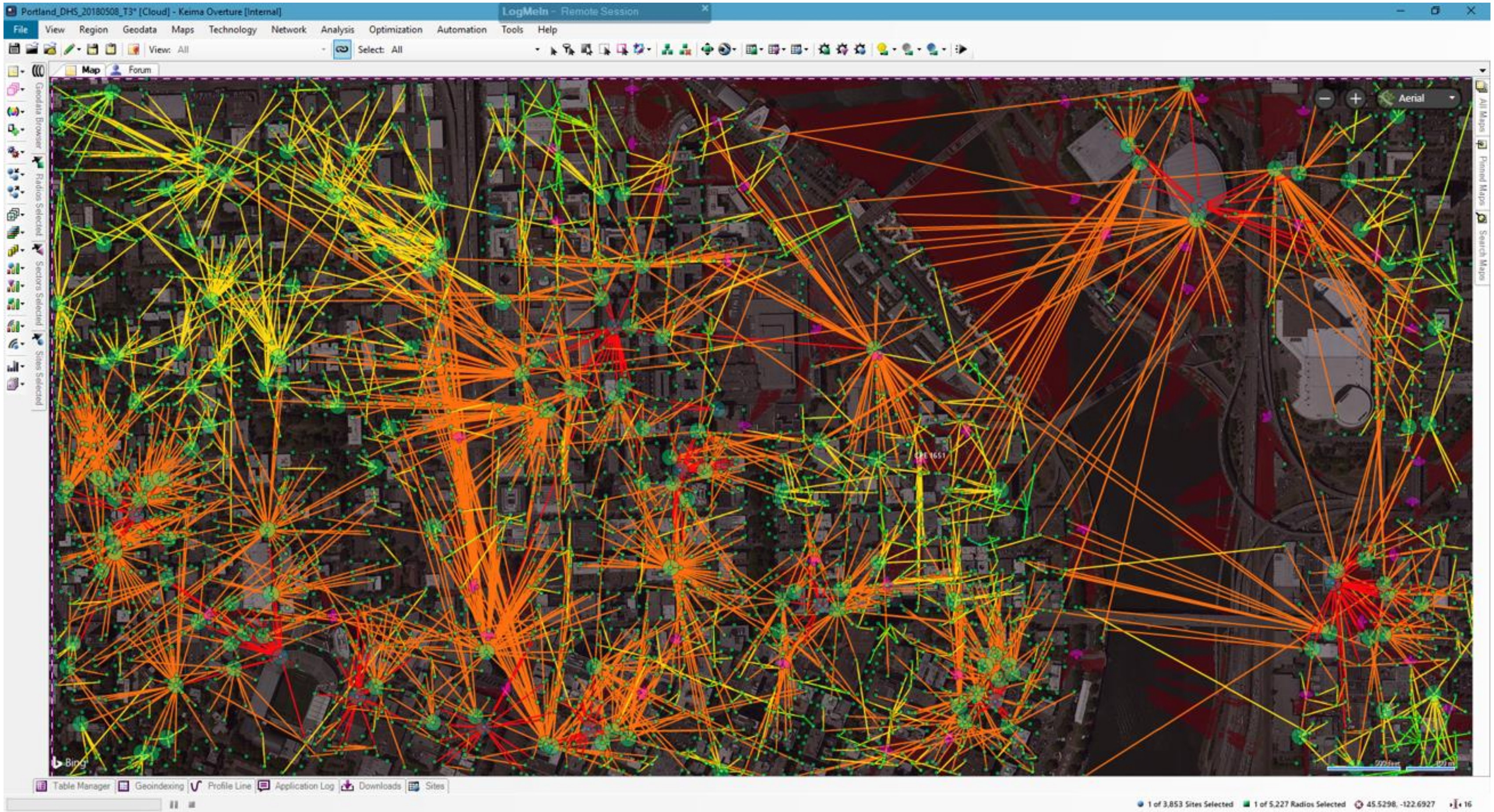
Portland 5G Fixed and Mobile Wireless Design



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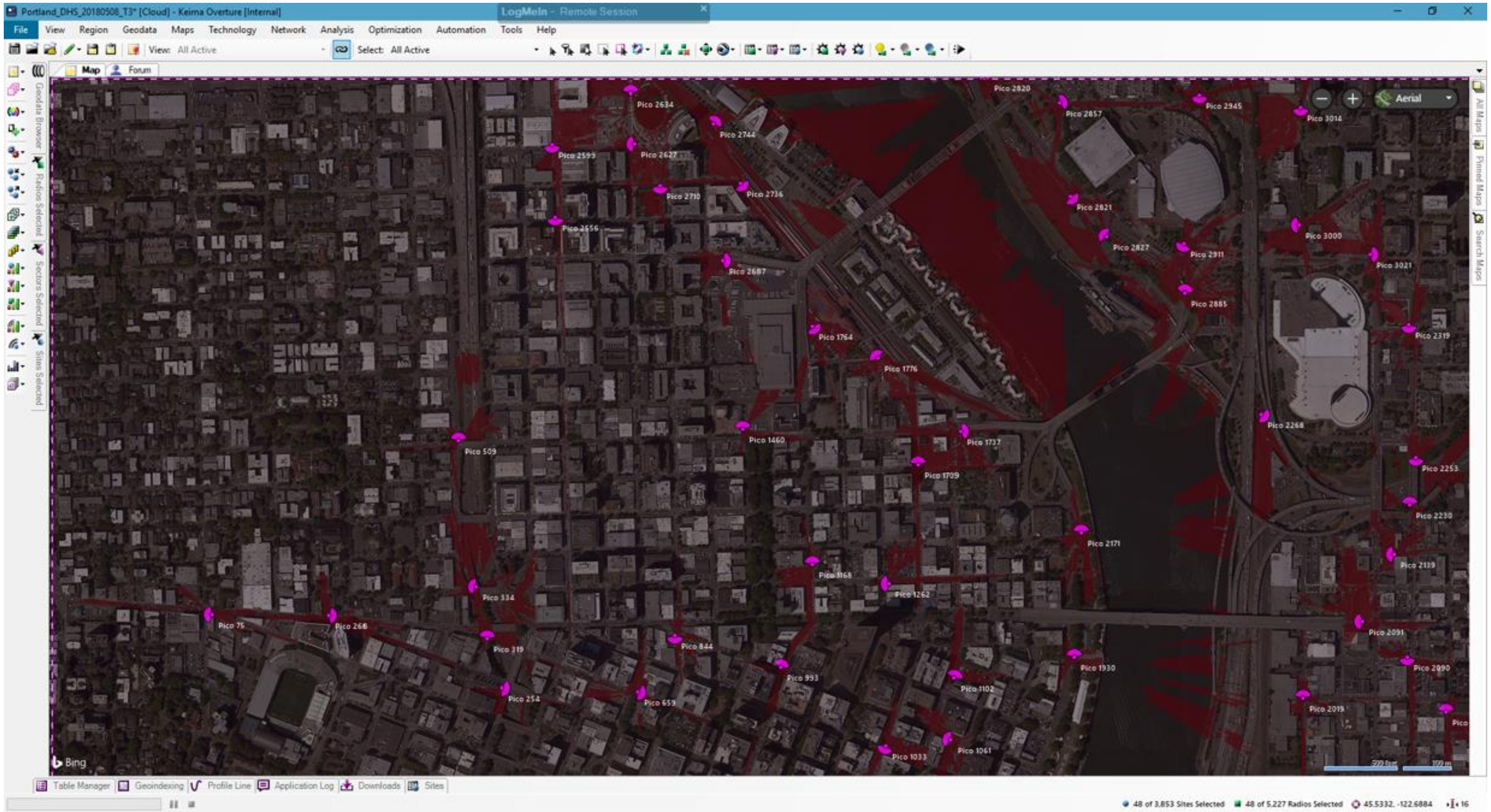
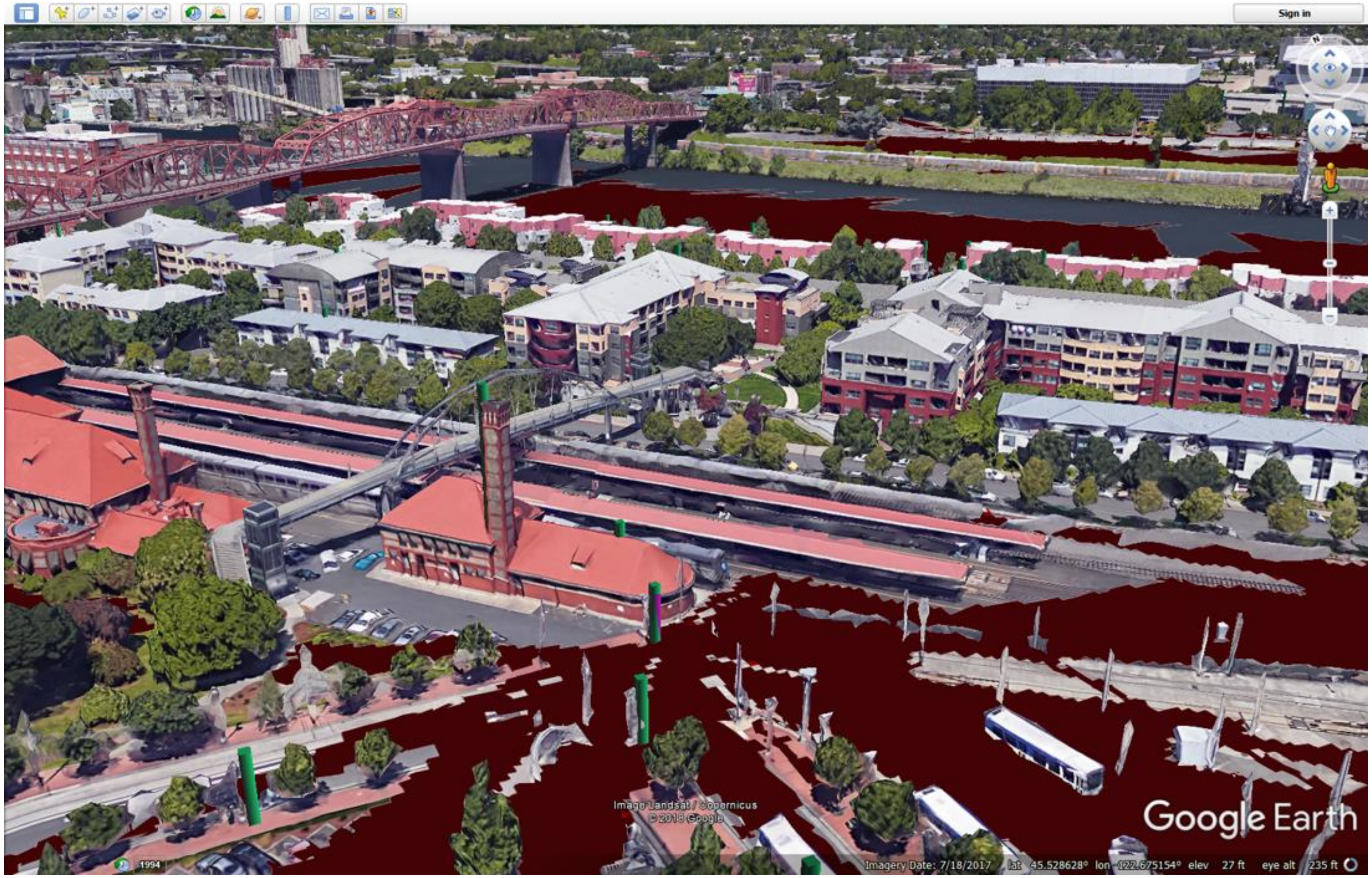
Portland 5G Mobile Wireless Design



- mmWave 28 GHz, > 500 MHz mobility from IP camera on street pole connected to vehicle via “Smart Cities” network slice to transmit video to on-scene law enforcement (with elevated priority via dynamic network slicing moving closer to scene) as well as public safety command

Portland 5G Mobile Wireless Design



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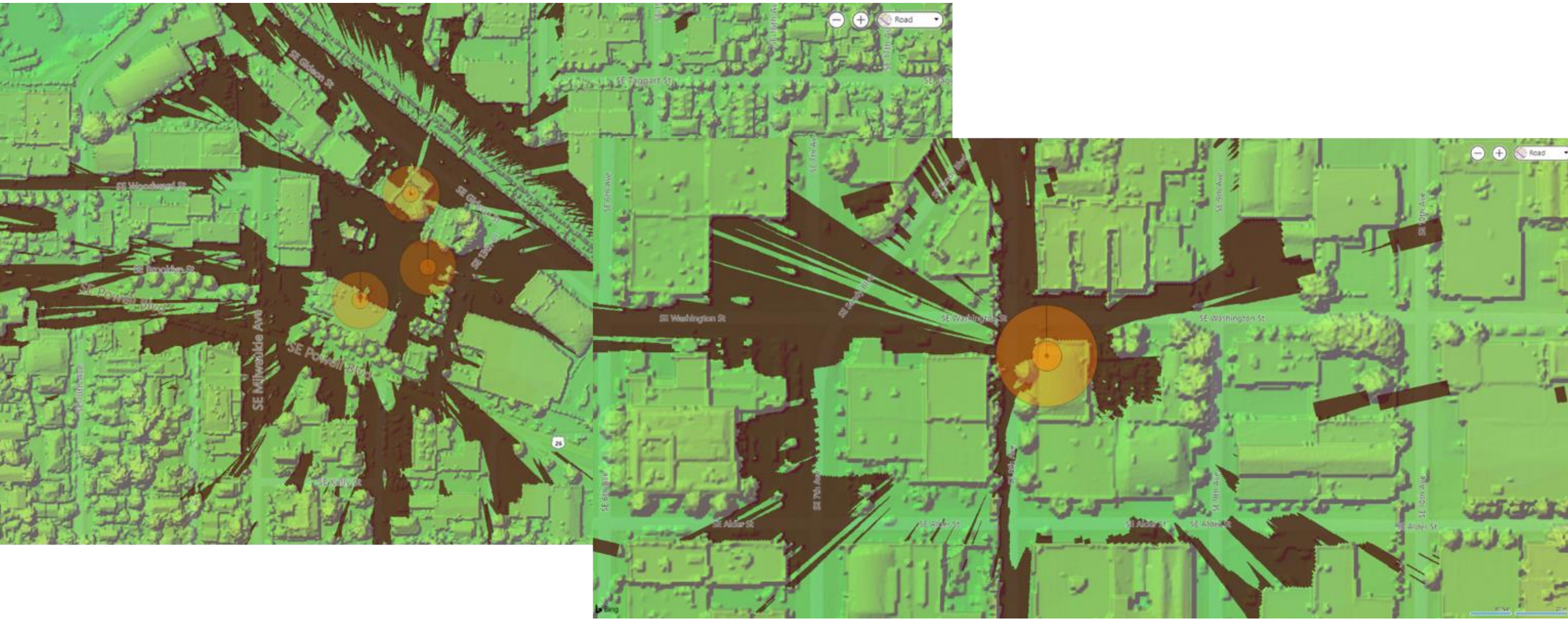
Portland 5G Mobile Wireless Design



- mmWave 28 GHz, > 500 MHz mobility from IP camera on buildings and street pole connected to vehicle via “Smart Cities” network slice to transmit video to on-scene law enforcement (with elevated priority via dynamic network slicing moving closer to scene) as well as public safety command
- Eventually video surveillance distributes to and compliments video from drones and other aerial assets

PUBLIC SAFETY IMPACTS

Potential Impacts for Public Safety

- Priority Service, Spectrum Use and Sharing
- Security
- Provisioning/Administration/Network Operations
- Devices and IoT

High Level Potential Impacts

- Advantages
  - Increased coverage, availability, and throughput in populated areas
  - Support for new technologies, applications, and services
  - Optimized, specialized treatment of users, applications, devices across differing slices of core network and virtualization
  - Lower latency
  - Network analytics for predictive and proactive reassignment of resources
- Areas of Concern
  - Increase in order of magnitude of connectivity density (D2D, M2M, V2X)
  - Increase in order of magnitude of devices/IoT
  - Increase in small cell density
  - Network of networks
  - Integration with critical infrastructure
  - Increased complexity in modeling and testing
  - OAM&P with virtualization/NFV/SDN

Public Safety Opportunities

- Encourage available, resilient, prioritized, and secure 5G public safety communications
- Participate in the evolving trends in standards, testing, trials, and vendor development
- Develop Public Safety user community use cases and operational requirements for 5G
- Develop guidance on issues and concerns to be addressed through governance, technology advancements, service agreements, standard operating procedures, and/or training and exercises
- Exciting technology but how does it align with operational requirements?

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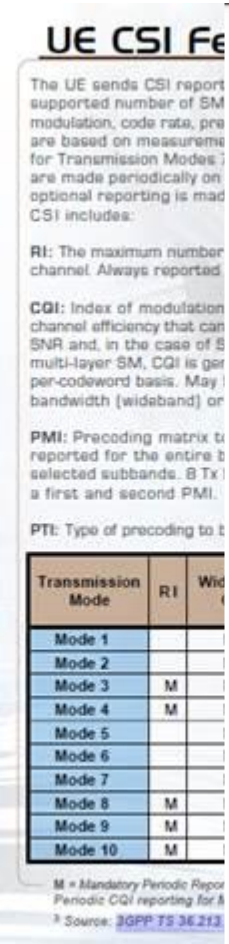
Modulation Efficiency and Spectral Efficiency

All these tables are showing you bits/ symbol or spectral efficiency anchored in symbol bandwidth (i..e in LTE subcarrier BW = 15kHz).
Also, if it's bit's per symbol it's gorss TP so you have to remove overhead, before you provide CSE.

The units on the efficiency column are labled as bps/Hz, but this should be bits/symbol (or bits/RE). The original 3GPP reference is misleading because it does not show any units and does not say if this is spectral efficiency or modulation efficiency (poor editing on the 3GPP side since 2007, because the same table is used in the most recent TS 36.213 doc.)

Note that if you take the Code Rate (first divide by the 1024 IFFT window size), and then divide by the Modulation Order, this will yield the "efficiency" column. Thus units are "bits"/"symbol". Ex. CQI index 1: (78/1024)/2=0.1523

Let me know your thoughts, but I think this needs to be corrected. Some websites ignore units altogether and publish bogus conclusions… but this is 3GPP fault for being sloppy with units.



3GPP TS 36.213 version 10.2.0 Release 10 63 ETSI TS 136 213 V10.2.0 (2011-06)

Table 7.2.3-0: PDSCH transmission scheme assumed for CSI reference resource

Transmission mode	Transmission scheme of PDSCH
1	Single-antenna port, port 0
2	Transmit diversity
3	Transmit diversity if the associated rank indicator is 1, otherwise large delay CDD
4	Closed-loop spatial multiplexing
5	Multi-user MIMO
6	Closed-loop spatial multiplexing with a single transmission layer
7	If the number of PBCH antenna ports is one, Single-antenna port, port 0; otherwise Transmit diversity
8	If the UE is configured without PMI/RI reporting: if the number of PBCH antenna ports is one, single-antenna port, port 0; otherwise transmit diversity If the UE is configured with PMI/RI reporting: closed-loop spatial multiplexing
9	If the UE is configured without PMI/RI reporting: if the number of PBCH antenna ports is one, single-antenna port, port 0; otherwise transmit diversity Closed-loop spatial multiplexing with up to 8 layer transmission, ports 7-14 (see subclause 7.1.5B)

Table 7.2.3-1: 4-bit CQI Table

CQI index	modulation	code rate x 1024	efficiency
0	out of range		
1	QPSK	78	0.1523
2	QPSK	120	0.2344
3	QPSK	193	0.3770
4	QPSK	308	0.6016
5	QPSK	449	0.8770
6	QPSK	602	1.1758
7	16QAM	378	1.4766
8	16QAM	490	1.9141
9	16QAM	616	2.4063
10	64QAM	466	2.7305
11	64QAM	567	3.3223
12	64QAM	666	3.9023
13	64QAM	772	4.5234
14	64QAM	873	5.1152
15	64QAM	948	5.5547