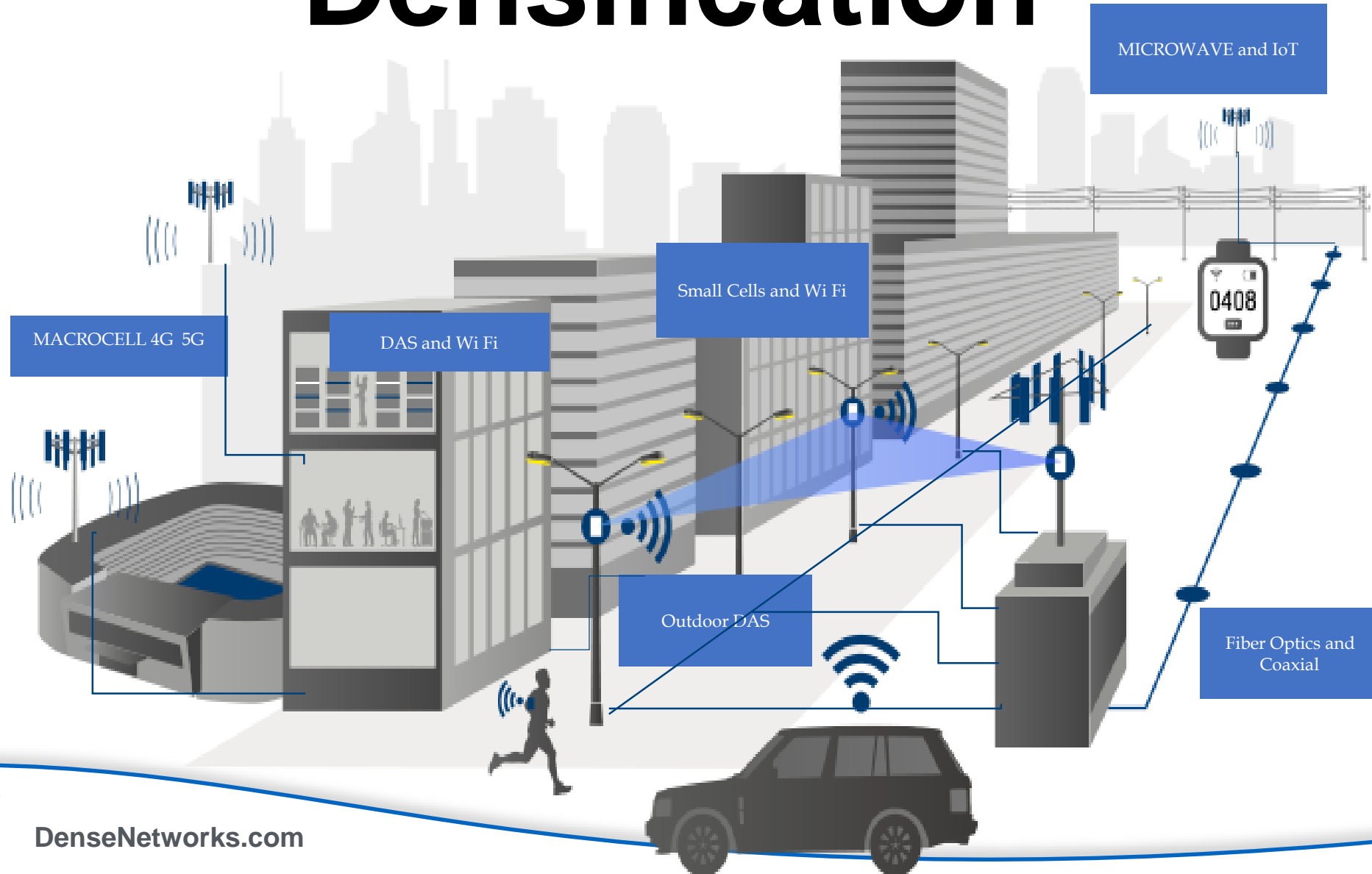
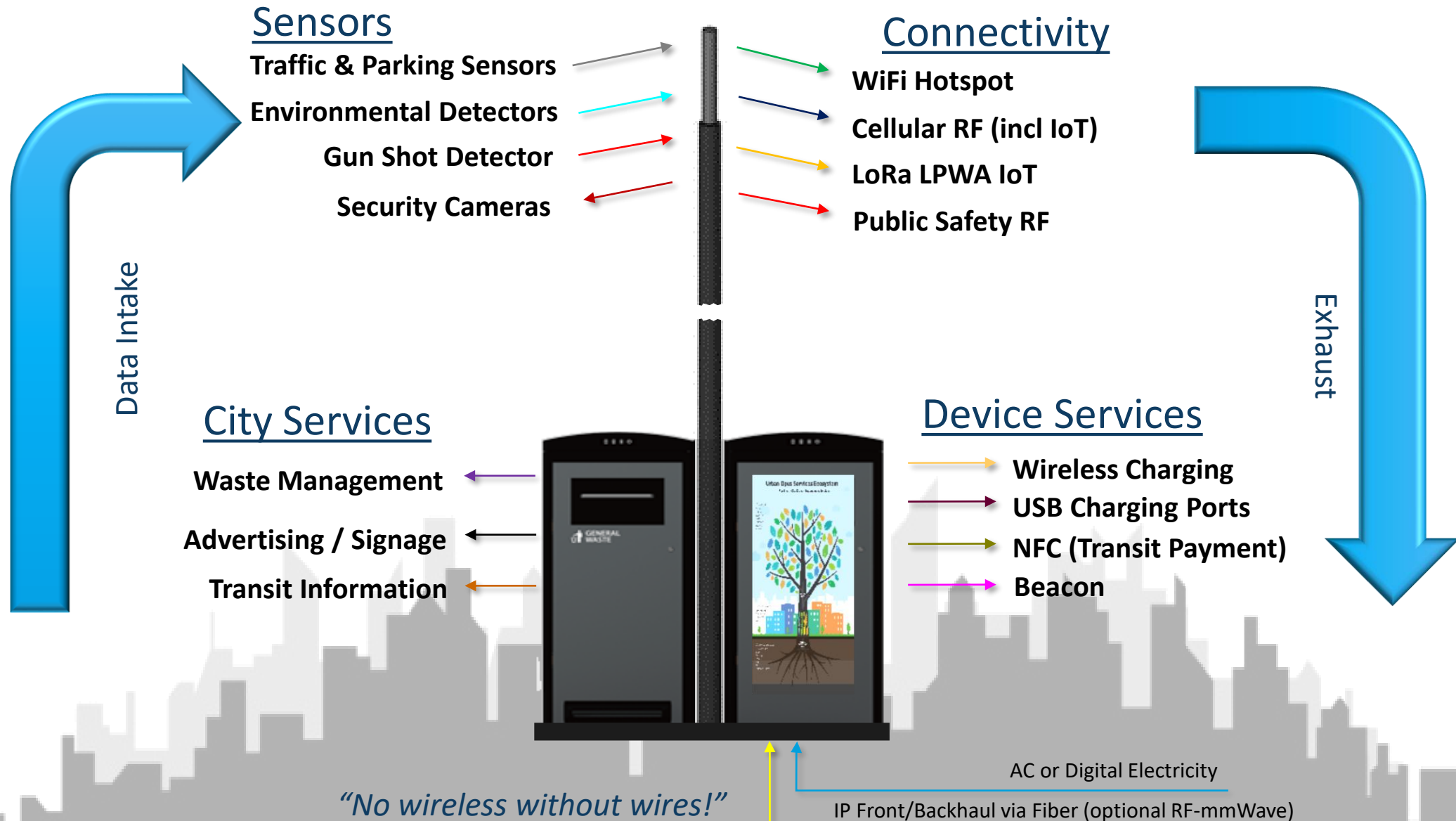


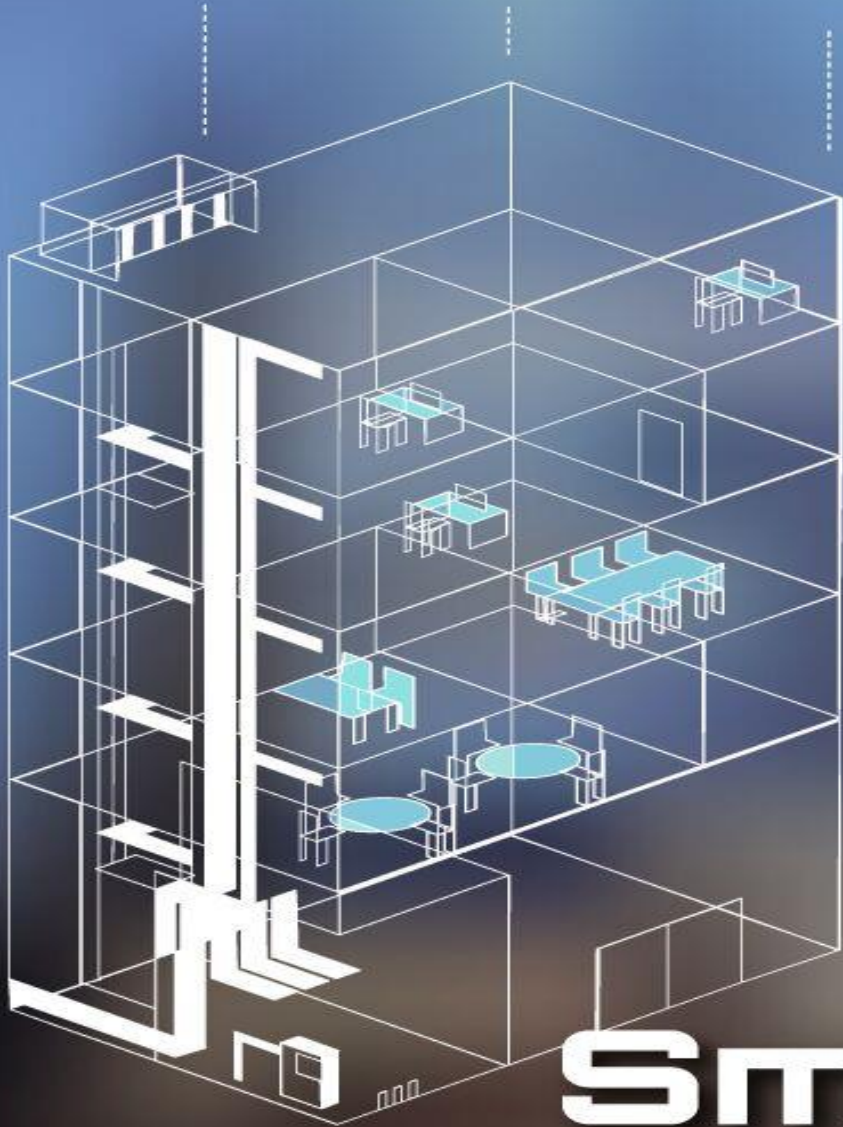
# Densification



# Network Edge of the Smart City



# BUILDING MANAGEMENT SYSTEM



# Smart Buildings

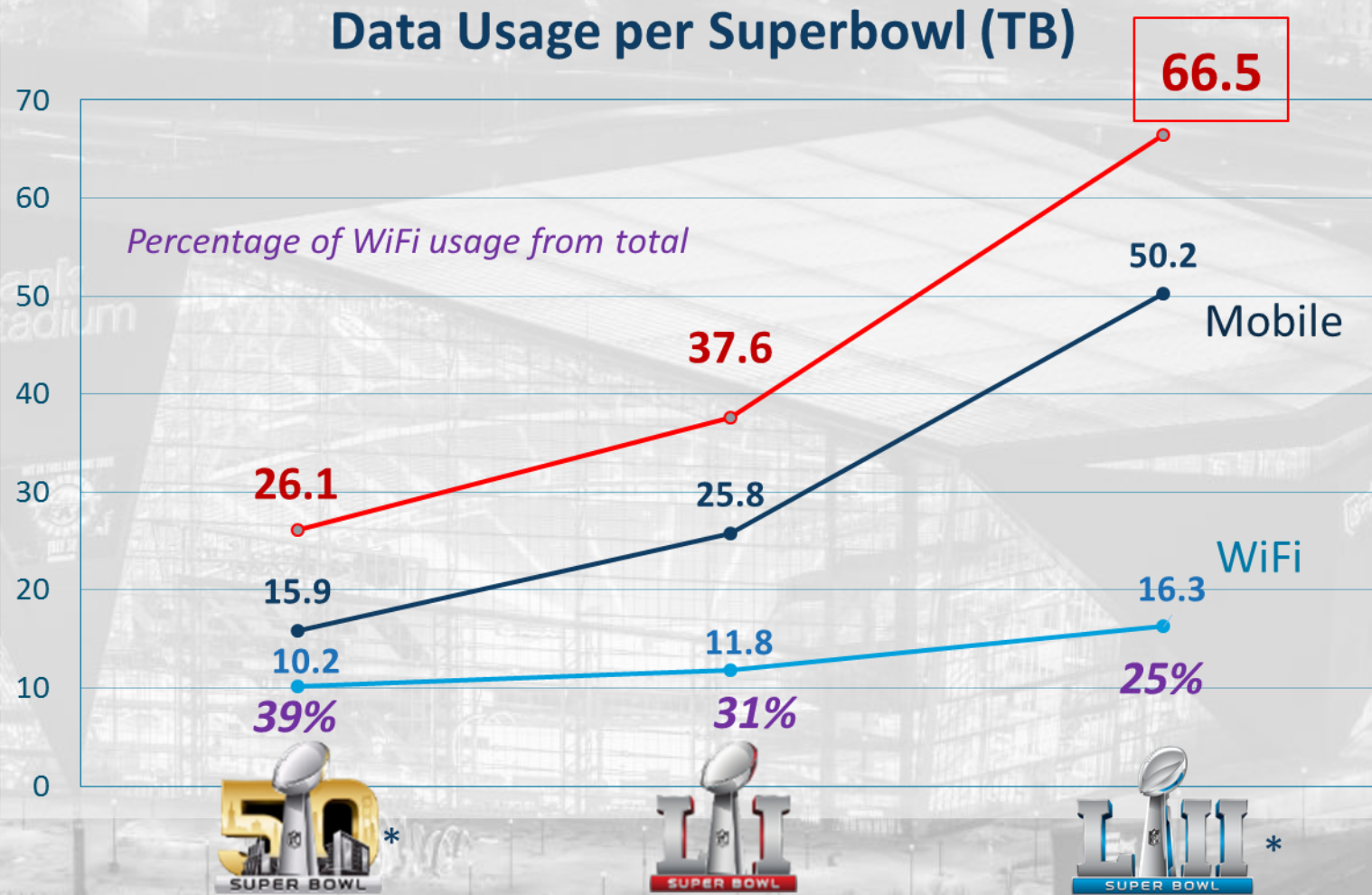
Indoor wireless networks create outstanding coverage and capacity in your building or venue – even when it’s at its most crowded – and this is crucial as mobile connectivity is revolutionized with 5G technologies.



# Mobile/Wireless Bandwidth Demand



US Bank Stadium  
Minneapolis, MN



\* JMA Wireless in-building solutions used for mobile traffic

SOURCES:

- Data usage at Super Bowl 52 grows 48% as social media use skyrockets <https://www.techrepublic.com/article/data-usage-at-super-bowl-52-grew-48-as-social-media-use-skyrockets/>
- Super Bowl 51 makes digital history with record-breaking data usage <https://www.techrepublic.com/article/super-bowl-51-makes-digital-history-with-record-breaking-data-usage/>
- AT&T, Verizon and Sprint see a combined 50.2 TB of cellular traffic for Super Bowl 52 <https://www.mobilesportsreport.com/2018/02/verizon-sees-18-8-tb-of-cellular-data-used-at-super-bowl-52/>
- Super Bowl fans use a record 10TB of data on Levi's Stadium WiFi network, up 63% from 2015 <https://www.geekwire.com/2016/super-bowl-data-usage/>

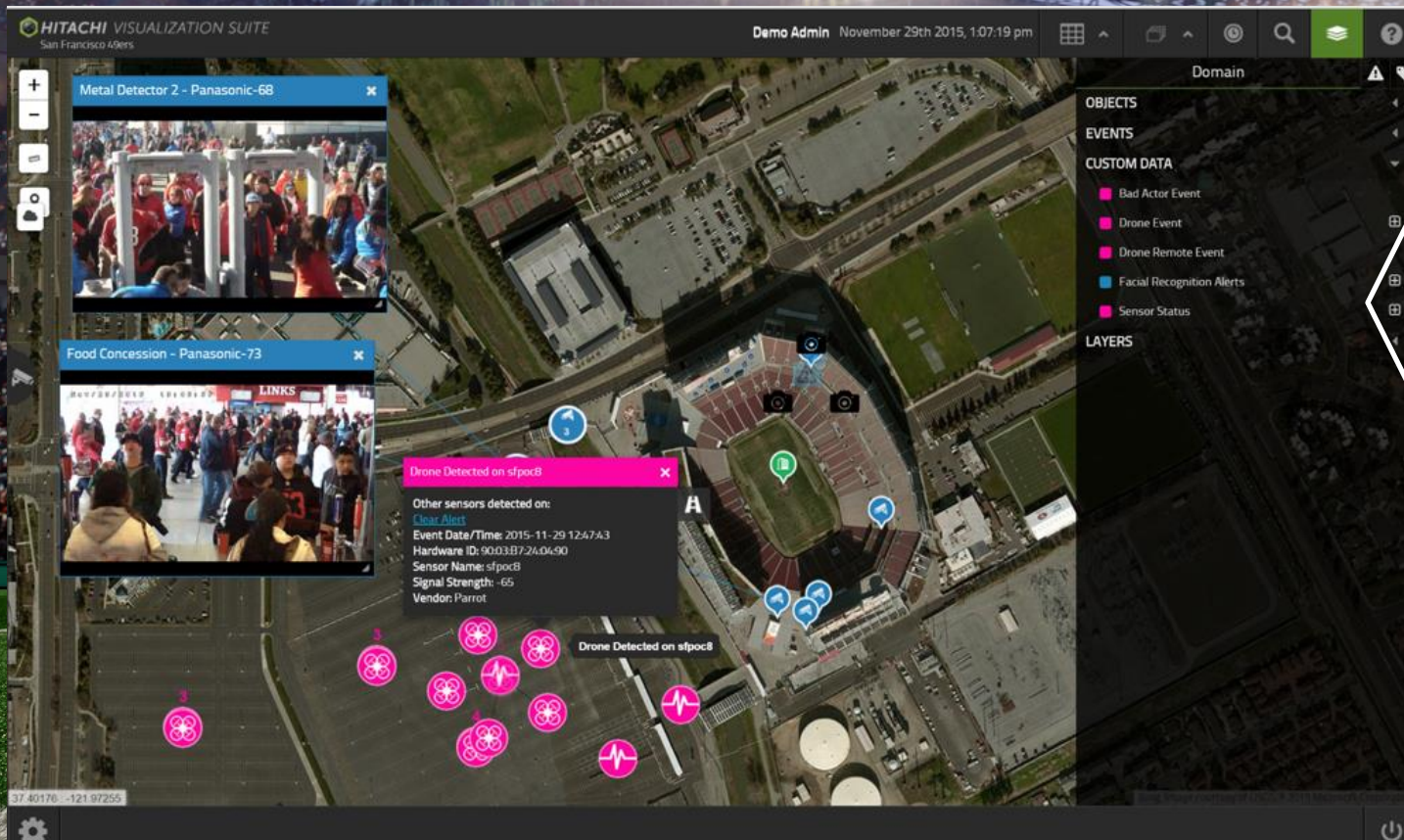




# Smart and Safe Stadiums

NEXT  
2018

**Challenge:** Emerging threats to stadiums and venues, need to improve operations and customer experience while ensuring safety.

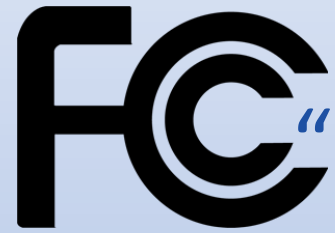
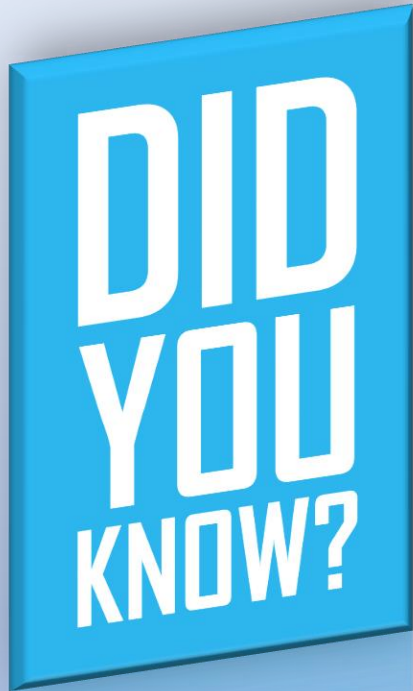


## TRANSFORMATION

- Drone detection, facial recognition and fan experience
- Millions of fans, visitors and city residents kept safe



# Driver: NG911 Location Accuracy



“The FCC estimates that a one minute improvement in 9-1-1 dispatch time could save 10,000 lives each year”





Office Buildings

Industrial

Suburbs

Public Areas

Major Venues

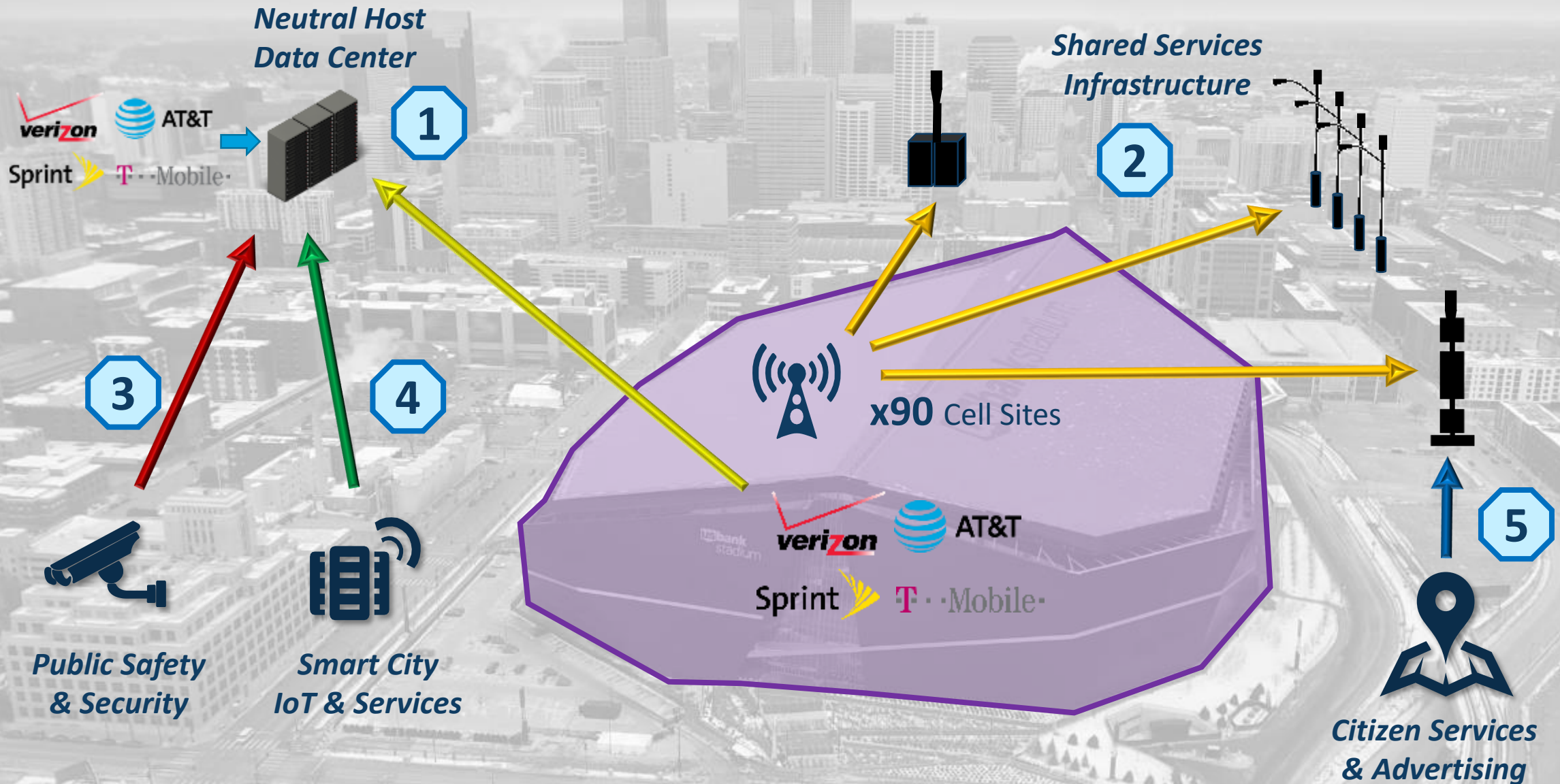
Private Campus

Transportation Systems

Metro Area Neutral Host

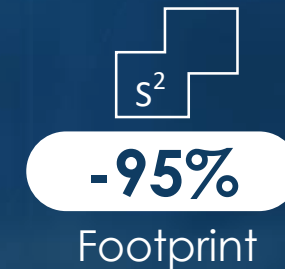
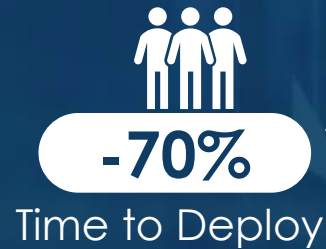
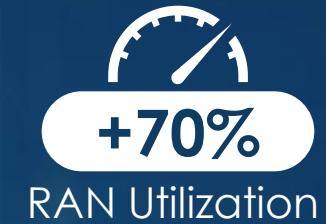


# Metro Area Neutral Host

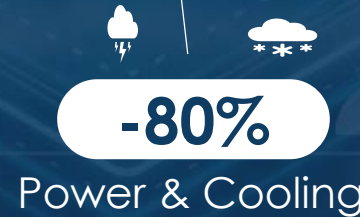


# City network edge efficiencies

- data center mobile infrastructure



intel  
**XRAN**  
SOFTWARE





# Driver: FirstNet Internet of Life-Saving Things (IoLST)\*

\*Slide Source: FirstNet Presentation to IACP – Philadelphia, October 2017

**Personal Devices**  
Fitbit, health monitors, insulin pumps, heart monitors, health apps, PulsePoint



**Buildings**  
burglar/fire alarms, video surveillance, intrusion detection etc.



**Vehicles**  
telematics, cars, trucks, UAS/UAV, watercraft



**EMS Devices, Apps**  
AED, portable EKG, EPCR, ER tech



**Responders**  
body-worn video, dashcam video, SCBA, bomb robots, biomonitors, wearables



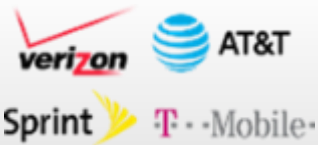
**Control & Analysis systems, software**



# Spectrum Diversity on the Path to 5G

## Mobile Cellular

- Multiple Carriers -



## Shared & Unlicensed

- CBRS, 5G, LAA, WiFi -



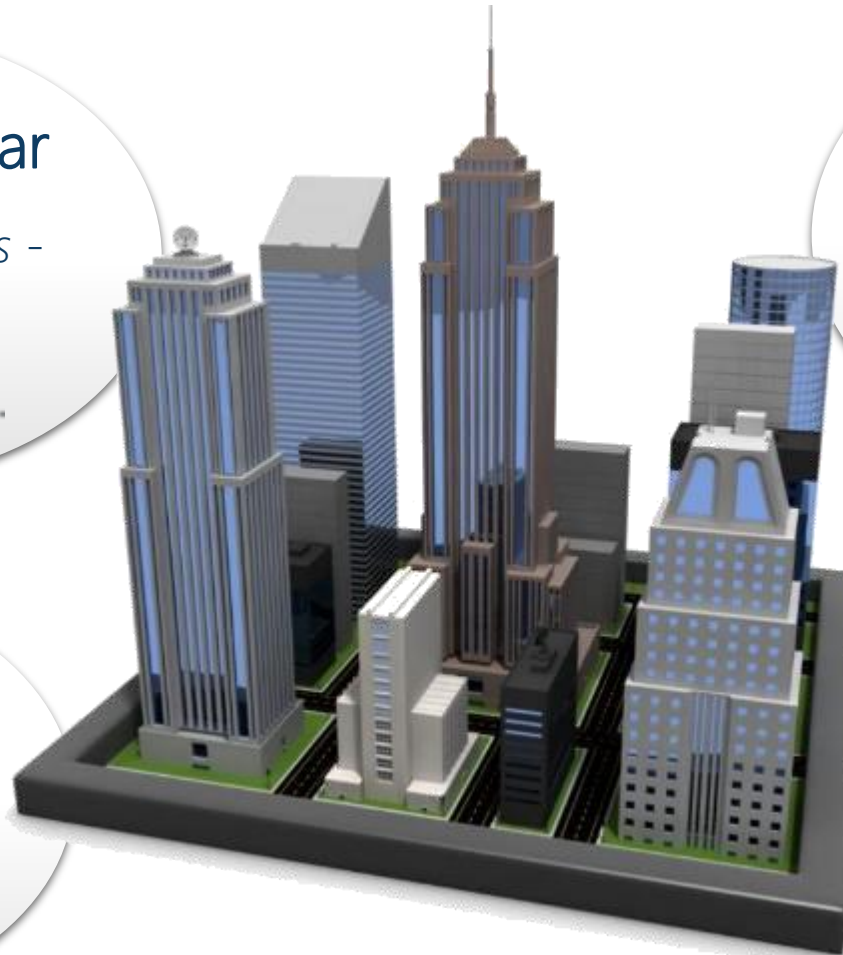
## Public Safety

- FirstNet, LMR -



## Internet of Things

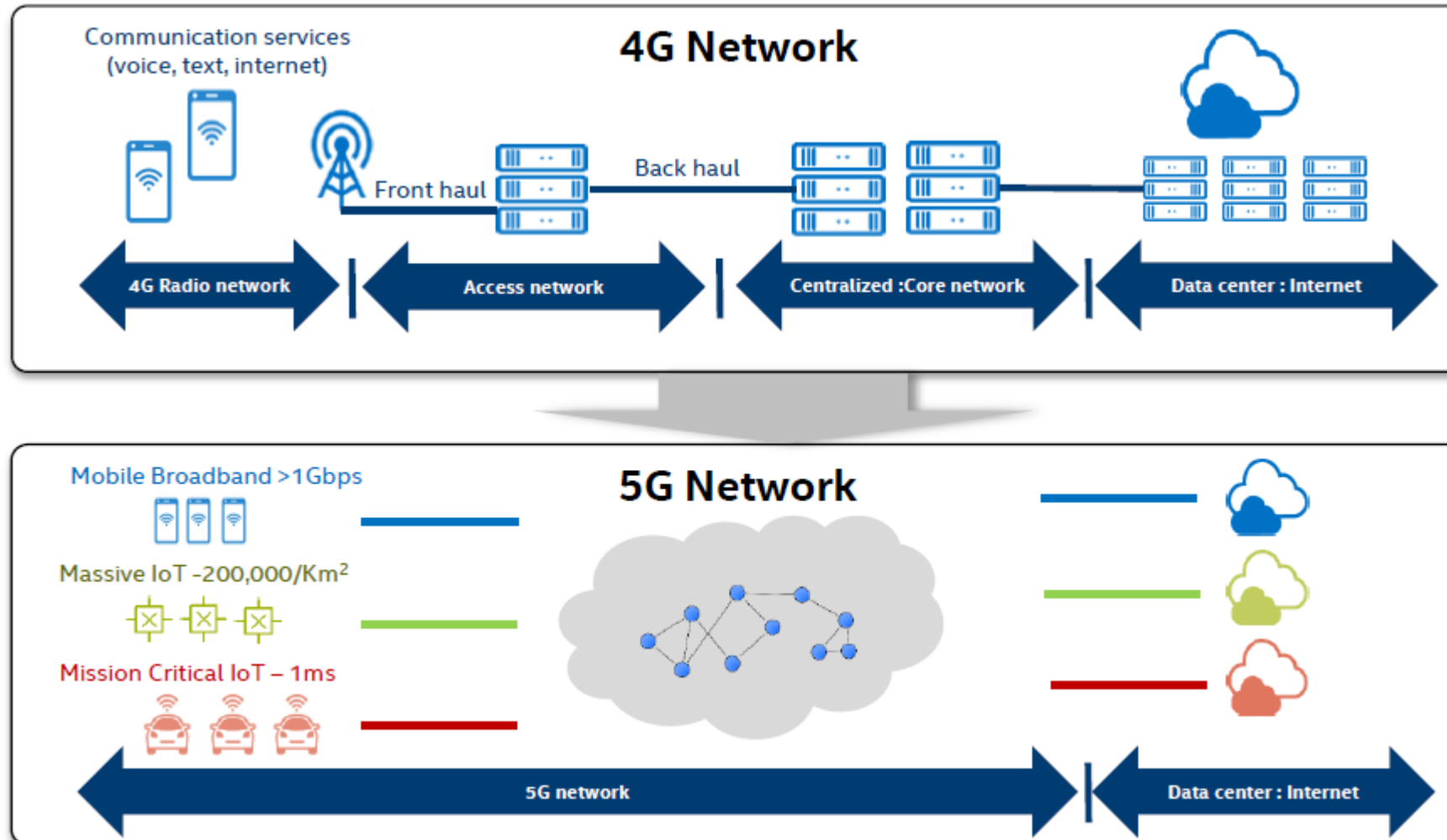
- NB-IoT, CAT-M, LoRa







# Multiple Dimensions of 5G



Source: Intel



# Low-e Glass

6 mm Glass Pane = **-0.8 dB** @ 900 MHz

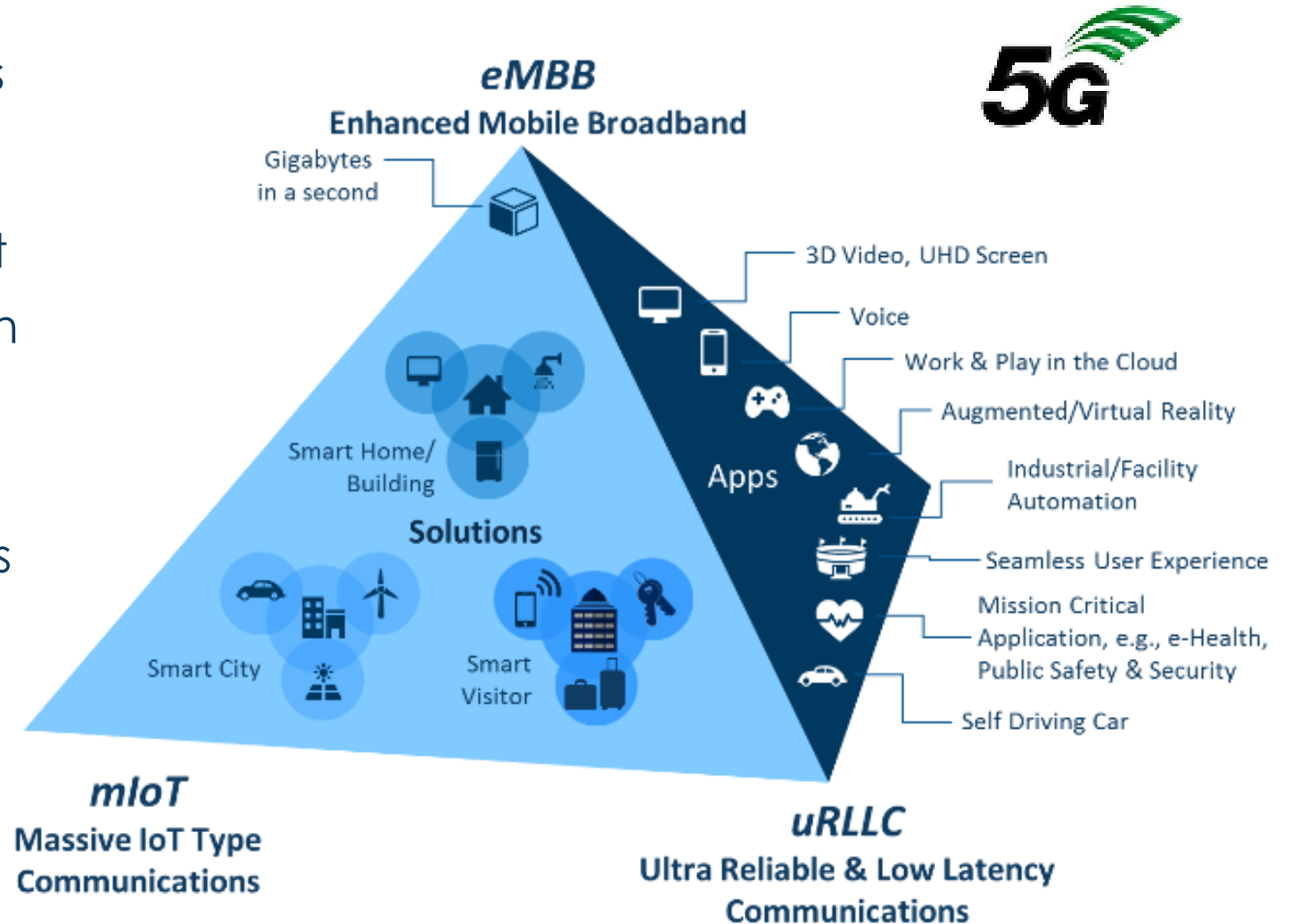
Double Glazing w/ 2 coated Glass Pane = **-23 dB** @ 900 MHz

	Material	Source	Shielding effect / dB		
			900 MHz	1800 MHz	3 GHz
Glazing	Glass pane 6 mm	[8]	-0.8	-1.3	-1.9
	Double glazing 4 mm/air 12 mm/5mm	[5]	-0.8	-1.1	-1.2
	Double glazing with commercial low-e 4 mm coated/air 12 mm/5mm	[5]	-30.6	-26.8	-27
	Double glazing with 2 coated glass	[2]	-23	-30	-36
	Double glazing with square pattern (4 %) low-e coating 4 mm coated/air 12 mm/5mm (measured)	[5]	-1.3	-1.3	-1.9
Glazing with patterned low-e	Double glazing with triangle pattern (2 %) low-e coating 4 mm coated/air 12 mm/5mm (measured/ <i>simulated</i> )	This work	-2.0/-2.0	-2.3/-2.2	-4.0/-3.9
	Double glazing with triangle pattern (2 %) low-e coating 4 mm coated/air 8 mm/5mm ( <i>simulated</i> )	This work	-2.1	-3.2	-1.5
	Double glazing with triangle pattern (2 %) low-e coating 4 mm coated/air 16 mm/5mm ( <i>simulated</i> )	This work	-1.8	-1.4	-7.1

**Source:** Bouvard, Olivia & Lanini, Matteo & Burnier, Luc & Witte, Reiner & Cuttat, Bernard & Salvadè, Andrea & Schöler, Andreas. (2017). Mobile communication through insulating windows: a new type of low emissivity coating. Energy Procedia. 122. 781-786. 10.1016/j.egypro.2017.07.396.

# 5G Goals and Opportunity

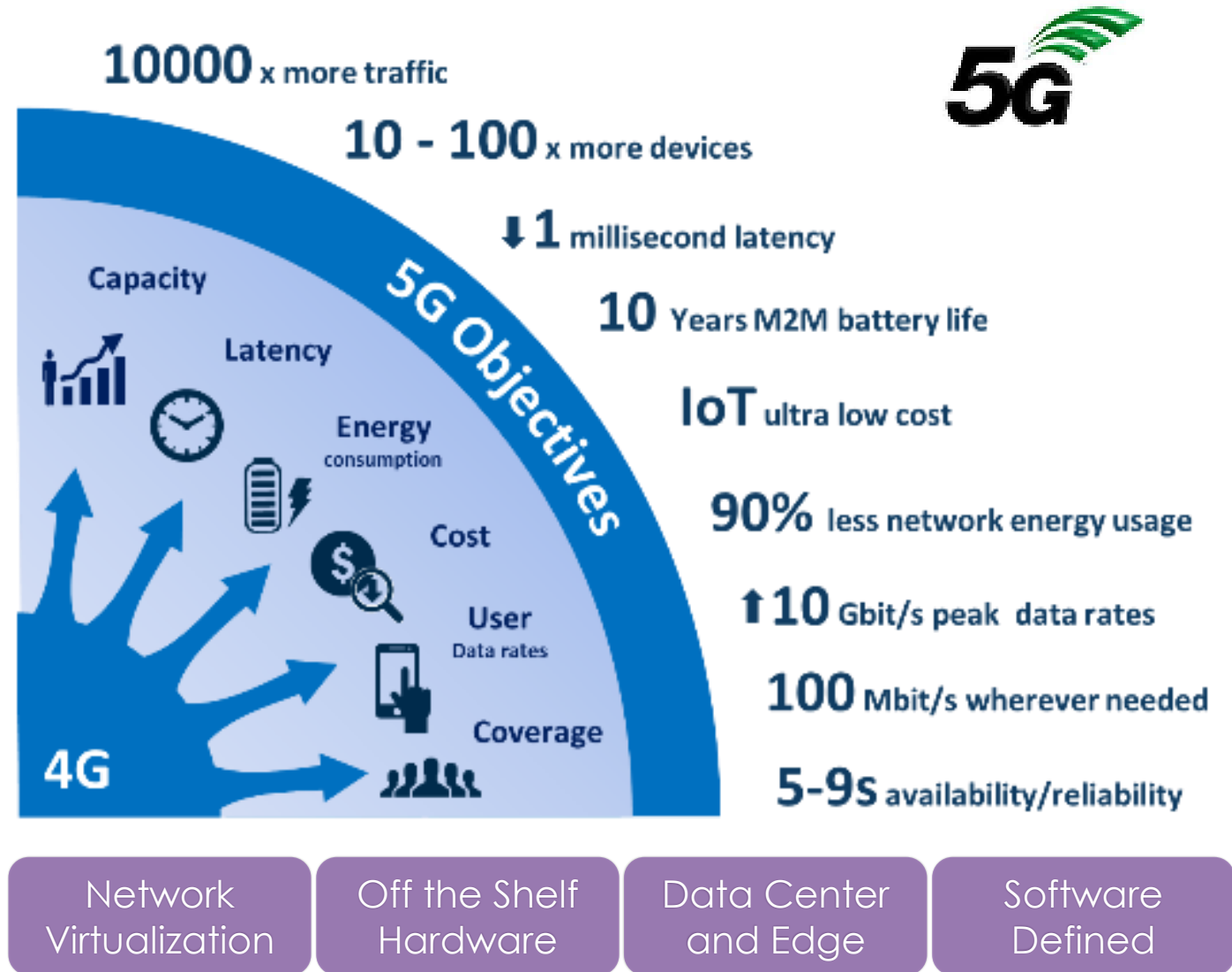
- 5G Goals breakdown boundaries and constraints of 4G
- Most goals are backward compatible to 4G to some extent
- 5G is by design interoperable with 4G and other connectivity
- Goals can enable solutions, applications and opportunity but are “trapped” until both networks available and users deploy.



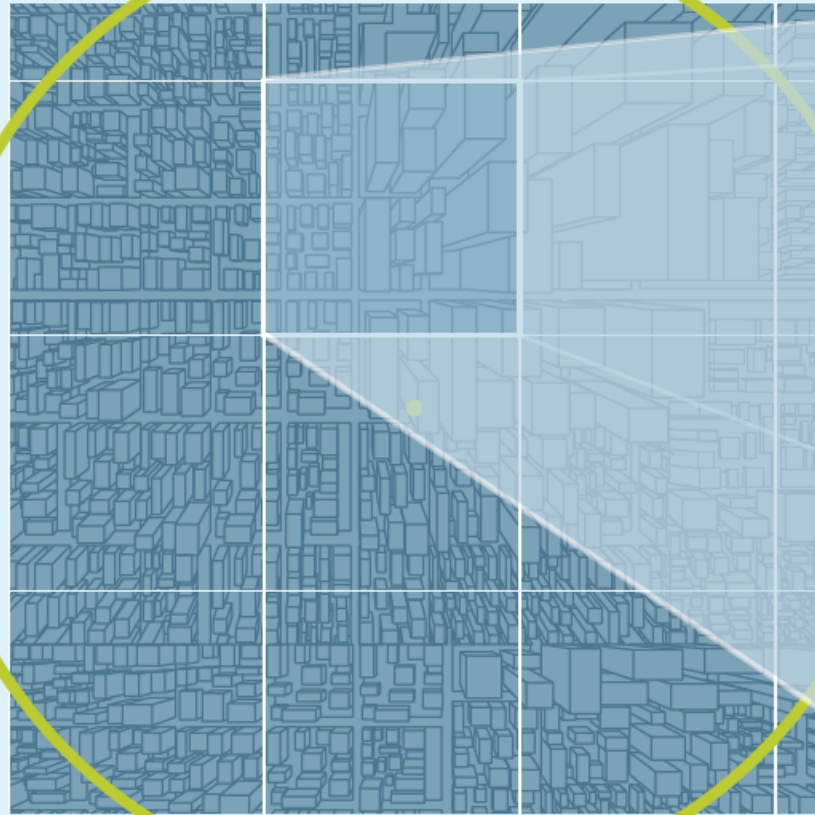


# 5G Objectives

- User vs. Edge vs. Core
- Not just about speed and scale
  - Energy/Power
  - Availability/Reliability
  - Cost
  - Ease of Deployment
- Different users will value different objectives
- Builds on 4G infrastructure
  
- Other technology and business shifts are concurrently happening

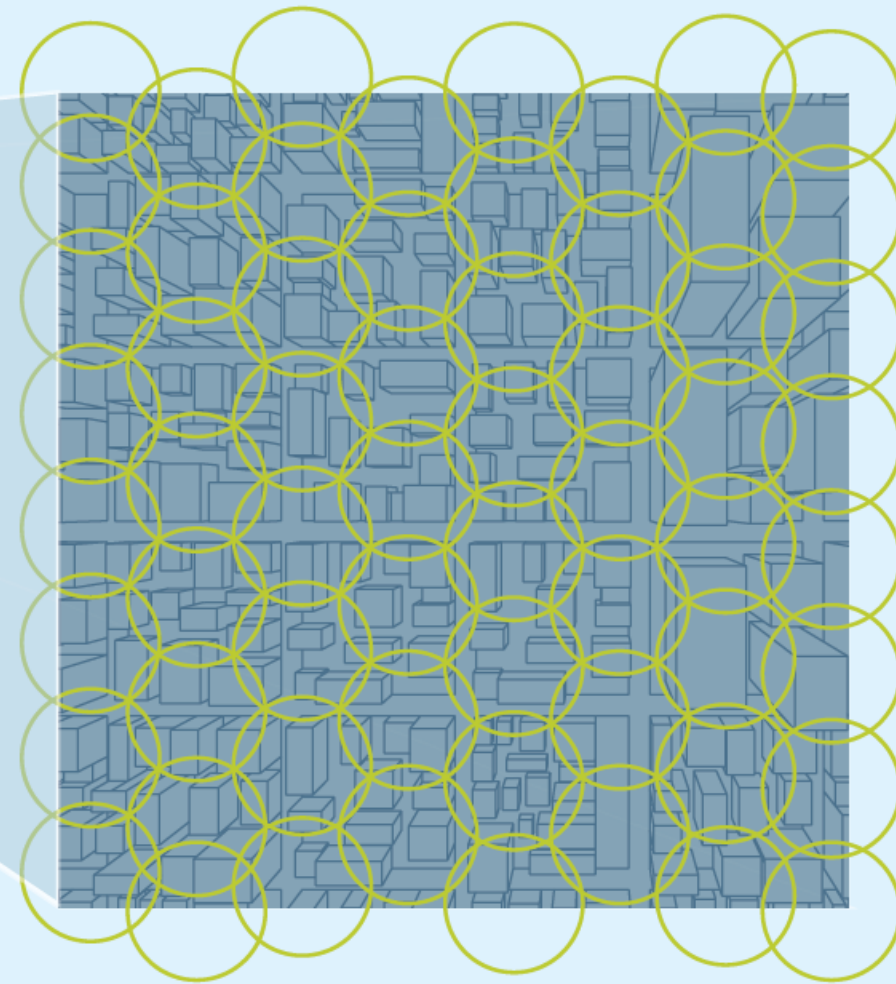


# Why 5G Differs From Existing Cellular Networks



## TODAY'S 4G NETWORK

This sketch (which does not depict an actual city) shows the range of a single 4G macro cell at the center of the circle. Such a small cell, served by fiber, can potentially serve 10 square miles. The white square shows one square mile.



## FUTURE 5G NETWORK

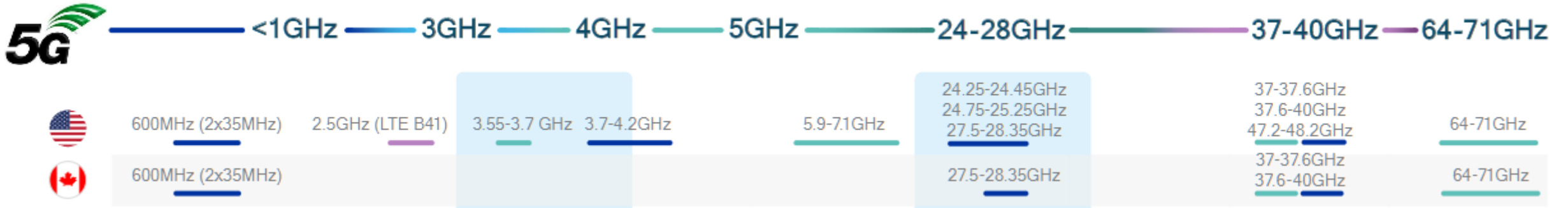
This sketch, showing one square mile, provides one estimate of how many 5G cells would be needed: 60, each covering a 750-foot diameter area. These small cells could require about eight miles of fiber.

*The sketch is conceptual. Actual deployments would be customized for local conditions and demand, and might need additional or fewer 5G cells.<sup>5</sup>*



# Spectrum Utilization for 5G

Source: Qualcomm



*Less Penetration  
Less Coverage  
Less Latency*



**New 5G band**

- Licensed
- Unlicensed/shared
- Existing band

*More Capacity  
More Antennas  
More Radios  
Smaller Antennas*

# 5G Gift Basket of Technology



**5G**

**Topology:** Distributed, User & Control Separation

**Spectrum:** New, Expanded, Shared, Dynamic

**Antennas:** Massive MIMO, Beam Forming

**Edge Computing:** Applications, APIs

**Security:** Authentication, Privacy

**IoT:** Low Power, Low Latency, NB-IoT, CAT-M

**Radio:** New Radio (NR), Software, Micro Cells

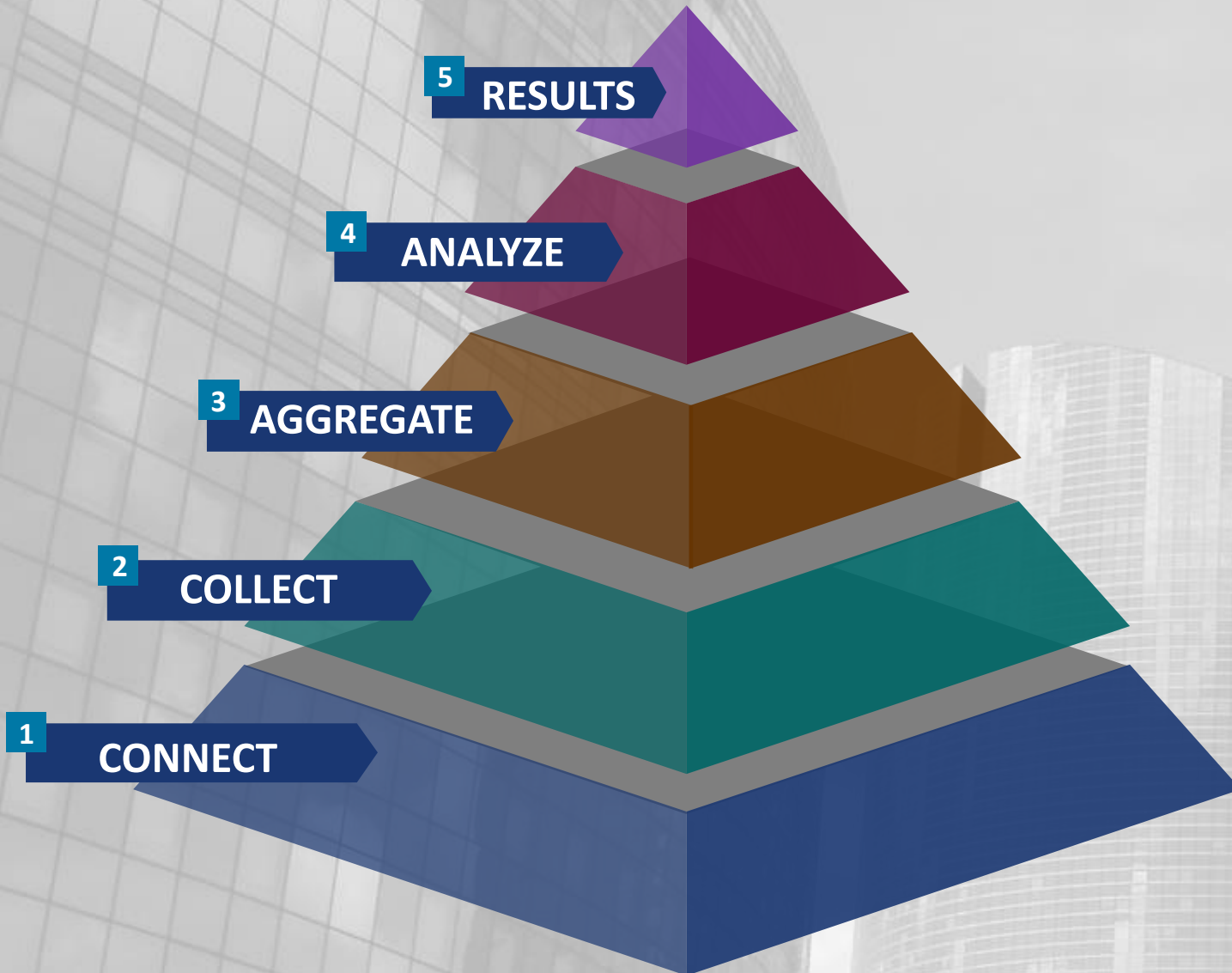
**Network:** Slicing, Virtualization, SDN, SON, COTS

**Interoperability:** Path from 4G (NSA), Coexist with 4G (SA)

*“Its all good but you don’t have to eat everything!”*



# Building Smart City Infrastructure



## USERS & CONSUMERS



Transform user and customer experience with engaging, enhanced and autonomous services

## ANALYTICS & INTELLIGENCE



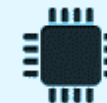
Transform data into insight, action and knowledge. Integrate into business and operational processes.

## DATA FLOW & DEVICE CONTROL



Collect data and manage devices on the network. Use edge computing and gateways prior to sending to the cloud.

## DEVICES & SENSORS



Deploy devices and sensors to measure existing and new data sets. Inventory assets that are not measured today.

## CONNECTIVITY & ACCESS



Build a network foundation for connectivity and access for more bandwidth, device types & mobility.