IEEE CYBER-C CONFERENCE

5G INNOVATION & CHALLENGE

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5G OVERVIEW & TECHNOLOGY LANDSCAPE

5G INDUSTRY OUTLOOK AND STATS

Consumer expectations driving largest 5G Market Share

- High-Speed Infrastructure Growth
- Strong data network
- 5G-enabled Smartphones
- With minimal delay

North America expected to hold the largest share of the 5G infrastructure market in 2020

Global 5G Infrastructure Market worth 33.72 Billion USD by 2026

5G Connections is expected to exceed 2.7B by 2025

*From MARKETSandMARKETS and CCS

DATA GROWTH

DATA GROWTH

No signs of slowing

360,000%

Data traffic growth on AT&T's mobile network since 2007

HEALTHCARE

MANUFACTURING

FINANCIAL SERVICES

PUBLIC SAFETY

TRANSPORTATION

INDUSTRY EVOLUTION

3G → 4G/LTE

Real throughput for customer in production/field 10-15 Mbps

Higher throughput up to 150 Mbps with LTE-A

Latency: *80 ms*

5G

Higher throughput up to *10 – 20 Gbps*

Latency: *20 ms*

HEALTHCARE

MANUFACTURING

FINANCIAL SERVICES

PUBLIC SAFETY

TRANSPORTATION

5G INCLUDES KEY CAPABILITIES ESSENTIAL FOR NEXT GENERATION MOBILE EXPERIENCES

Speed & Efficiency

Will support 1 Gbps+ speeds

Fiber-enabled backhaul

Increases spectral efficiency with use of multiple antennas

Massive IoT

Will support low-cost IoT modules

Enables billions of connected devices world-wide

Low latency
High reliability

Real-time network

Expanded coverage

Supports immersive multimedia experiences

AT&T

5G promise unlocks use cases that are dependent on speed, coverage & low latency

	 *Autonomous vehicles*	 *Robotics*	 *AR/VR*	 *eSports*	 *Drones*	 *Far-field communication*
Speed	✓	✓	✓	✓	✓	✓
Coverage	✓	-	-	-	✓	✓
Latency	✓ <5 ms	✓ <5 ms	✓ 10-15 ms	✓ 10-15 ms	✓ <15 ms	✓ <20 ms
Examples	In-car video	Manufacturing	Training	Augmented sports	Package delivery	Connected responder

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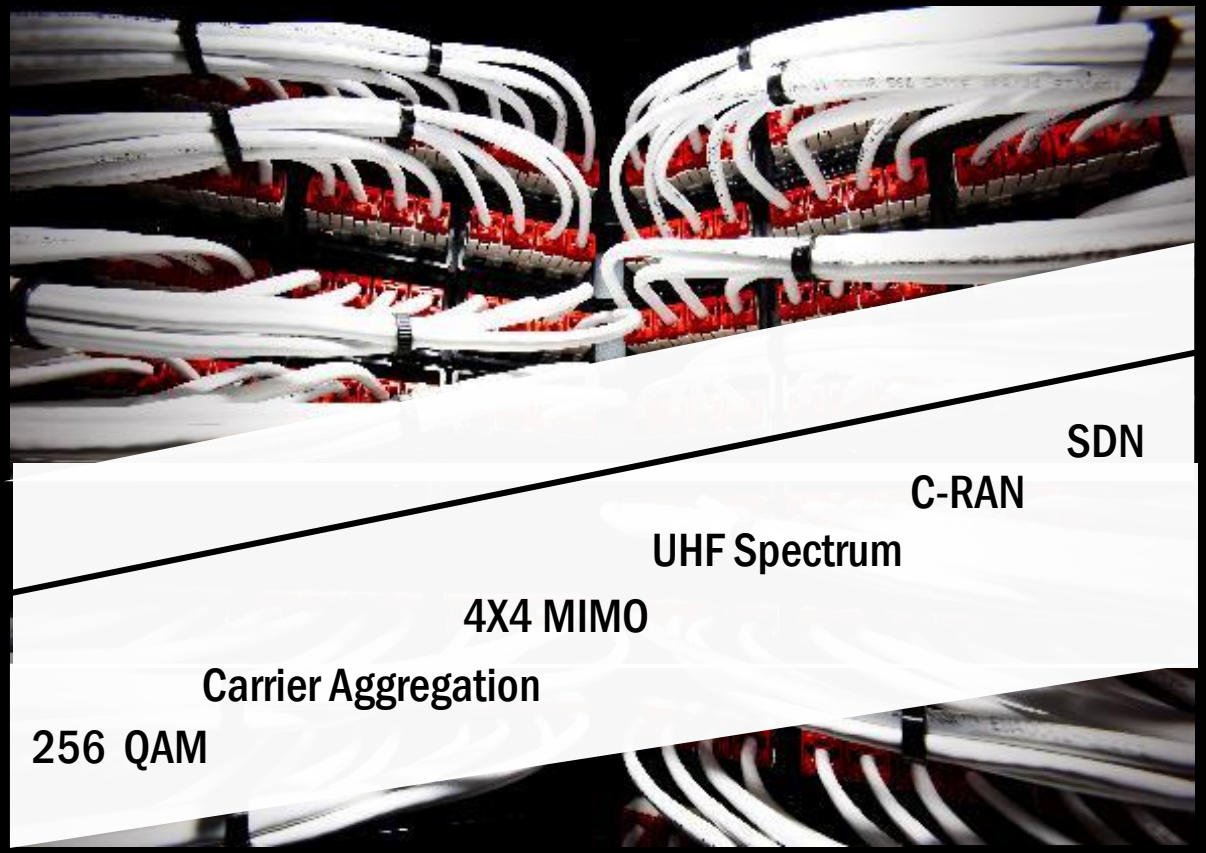
5G & SDN

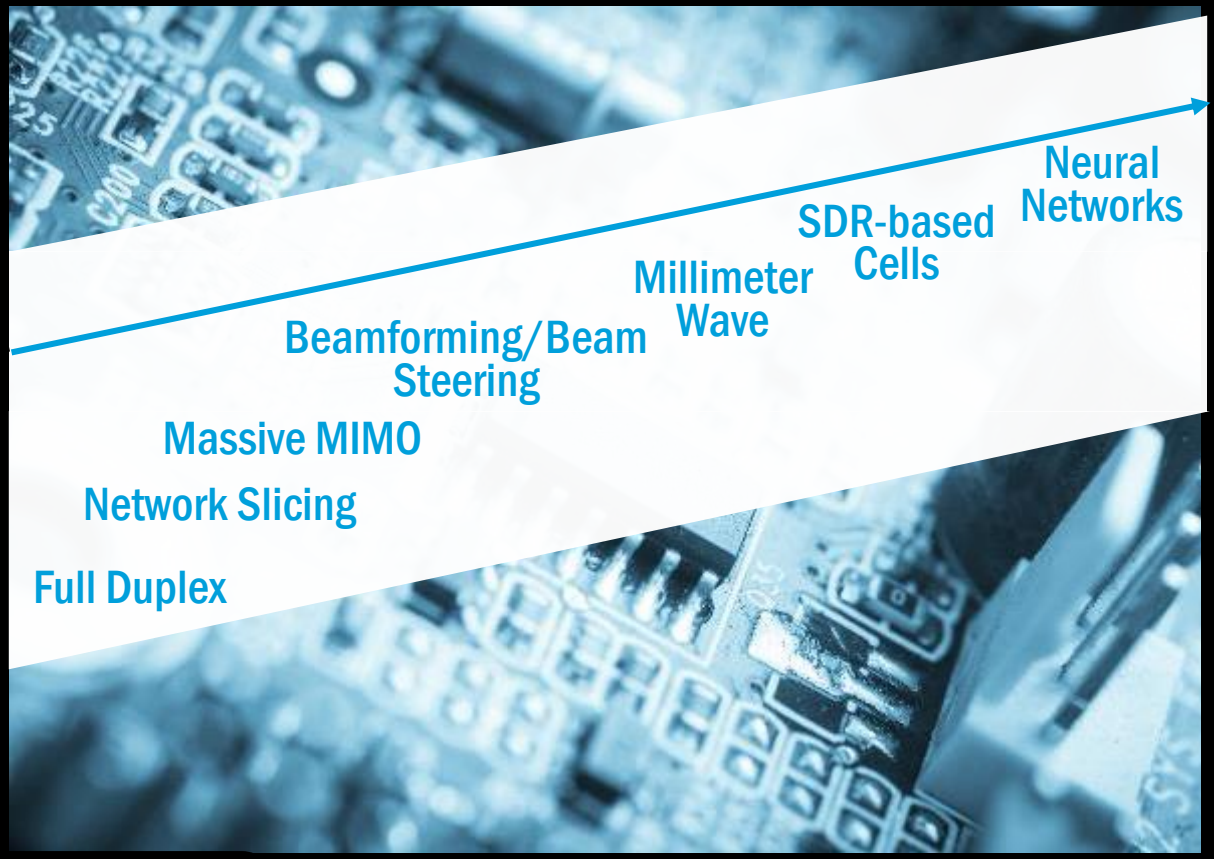
WORLDS COLLIDING

SOFTWARE-DRIVEN WIRELESS TECHNOLOGY EVOLUTION

TODAY



FUTURE



THE FUTURE IS SOFTWARE-DRIVEN RADIO

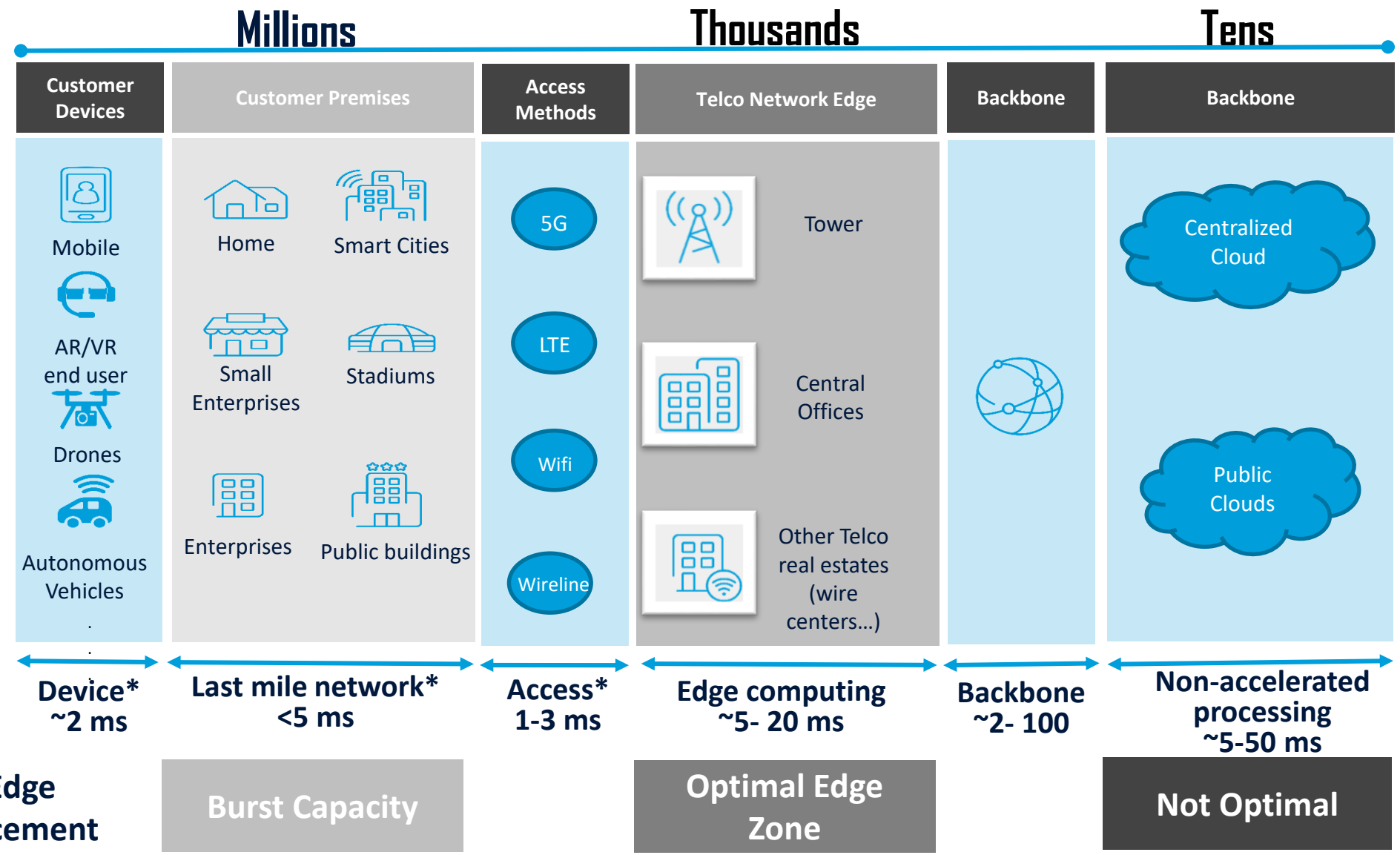
Emerging Technologies are demanding lower latency and accelerated processing at the edge

NFV Edge Infrastructure	Wireless (vRAN, vEPC..)	Wireline (PON, ..)	uCPE (SD-WAN..)	IP Enterprise services
Autonomous Devices	Drones	Autonomous vehicles	Industry Robots	Medical
Immersive Experiences	Virtual Reality	Augmented Reality	360 Video	Wearable Cognitive Assistance
IOT & Analytics	Industrial Sensors	Home Devices	Retail	Healthcare

Emerging Technology Enablers

On-demand NFV | Hardware Acceleration | A.I. | Microservices | 5G

Operator's owned Network Edge are optimal zone for edge placement



Telco Operated

* Estimates

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AT&T'S 5G ENABLEMENT

The Evolution to 5G

Five-Way Match Key Enablers

RAN Hardware

RAN Software

Fiber Transport

SDN Core (transitioning to Edge)

Devices

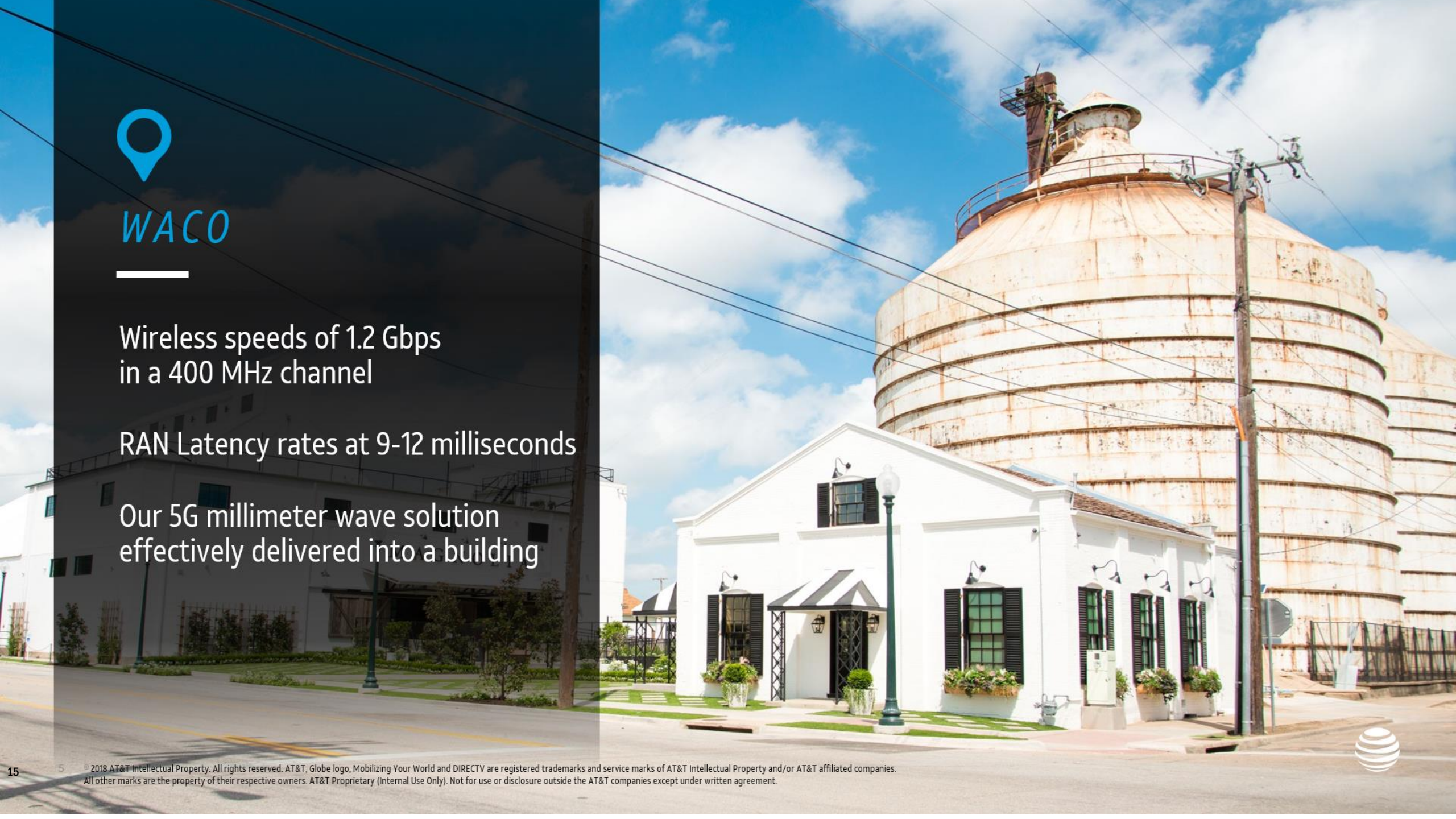
5G AT&T JOURNEY

First 5G Business Customer Trial
OCTOBER 2016

Expanded Multi-City 5G Trials
SUMMER 2017

New 5G testbed
AUSTIN, TEXAS

Commercial Launch
Atlanta, Dallas, Waco 2018



WACO

Wireless speeds of 1.2 Gbps
in a 400 MHz channel

RAN Latency rates at 9-12 milliseconds

Our 5G millimeter wave solution
effectively delivered into a building

KALAMAZOO & SOUTH BEND

No impacts on 5G mmWave signal performance due weather

mmWave signals can penetrate materials better than anticipated

1 Gbps speeds under line of sight conditions up to 900 feet

Full end-to-end 5G network architecture

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CHALLENGES & OPPORTUNITIES

Emerging Real-time Applications

Virtual Reality

Field Force Automation

Drones

IoT

Self-Driving & Connected Cars

Tele-Medicine

EDGE COMPUTE ENABLES EFFICIENT OFFLOADING FOR AUTONOMOUS CARS

Challenging Ultra-Dense RF Environment

Satellite and terrestrial-based broadcast, V2X/V2V, 2.4/5 GHz Wi-Fi, BlueTooth®, CBRS, Cellular, LMR, Amateur Radio, CB

- LIDAR
- Short range sensors
- Cameras

- Machine learning software
- Visual recognition
- Image Mapping

- Edge analytics
- Real-time traffic updates

- Software updates
- Entertainment
- Advanced data analytics

- Local compute (parking assist, stop/start, etc.)
- Natural language processing

- 360 sensor scans
- V2V / V2X

AT&T Cell Site

Edge Computing (EC)

AT&T Core Network

Centralized Cloud Service Provider (CSP) Data Centers

Key Interference Characteristics

1. Spectral Adjacency
2. Harmonics
3. Intermodulation

Source: Intel, Google, McKinsey, AT&T Corporate Strategy

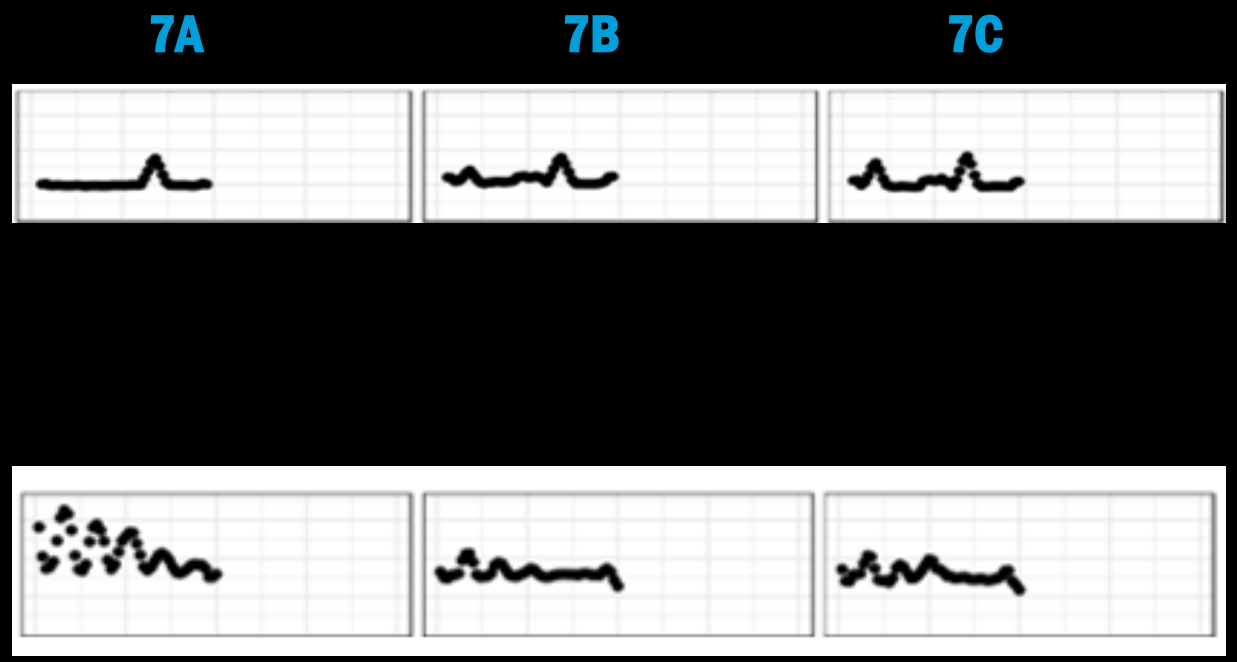
AT&T

BROADCASTER INTERFERENCE: DATA PATTERNS

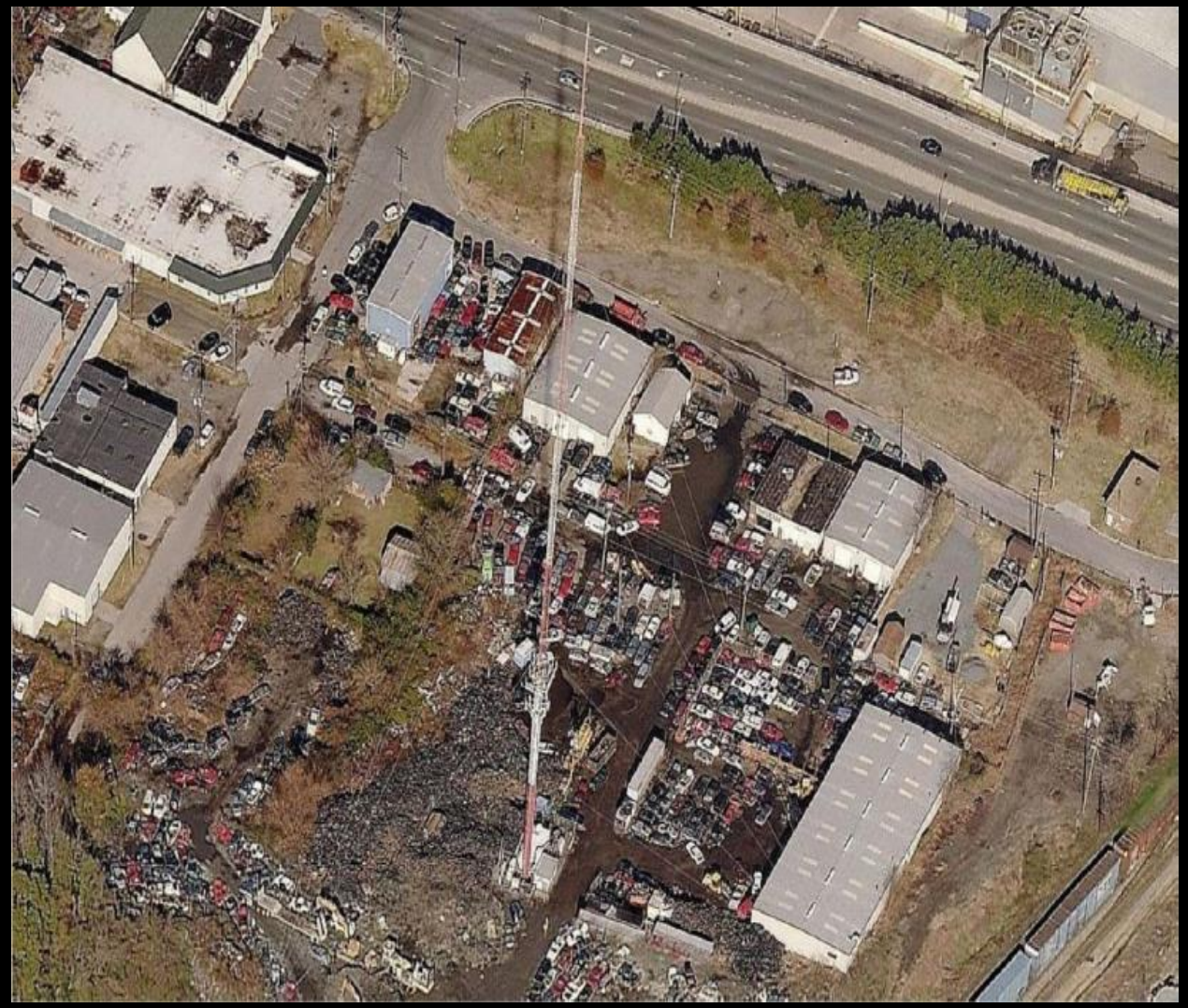
Harmonics drive Interference

Site has *already* had filter installed to remediate Broadcaster Interference issue. The shape of its current data indicates that this did not solve the problem -> this could be an auto-check

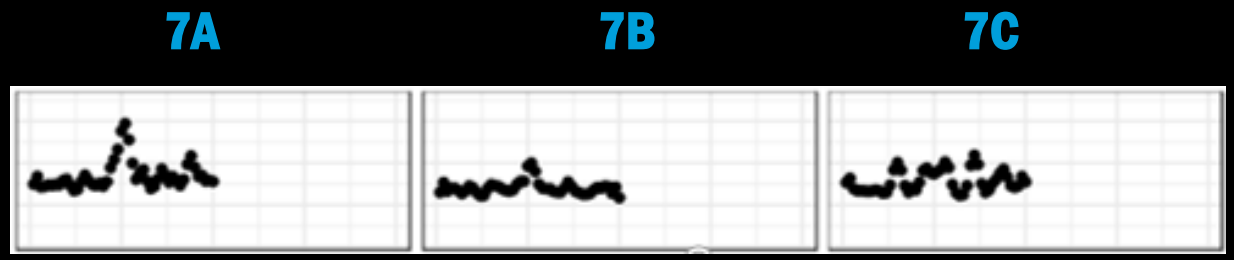
Site is confirmed to have Harmonic Interference.



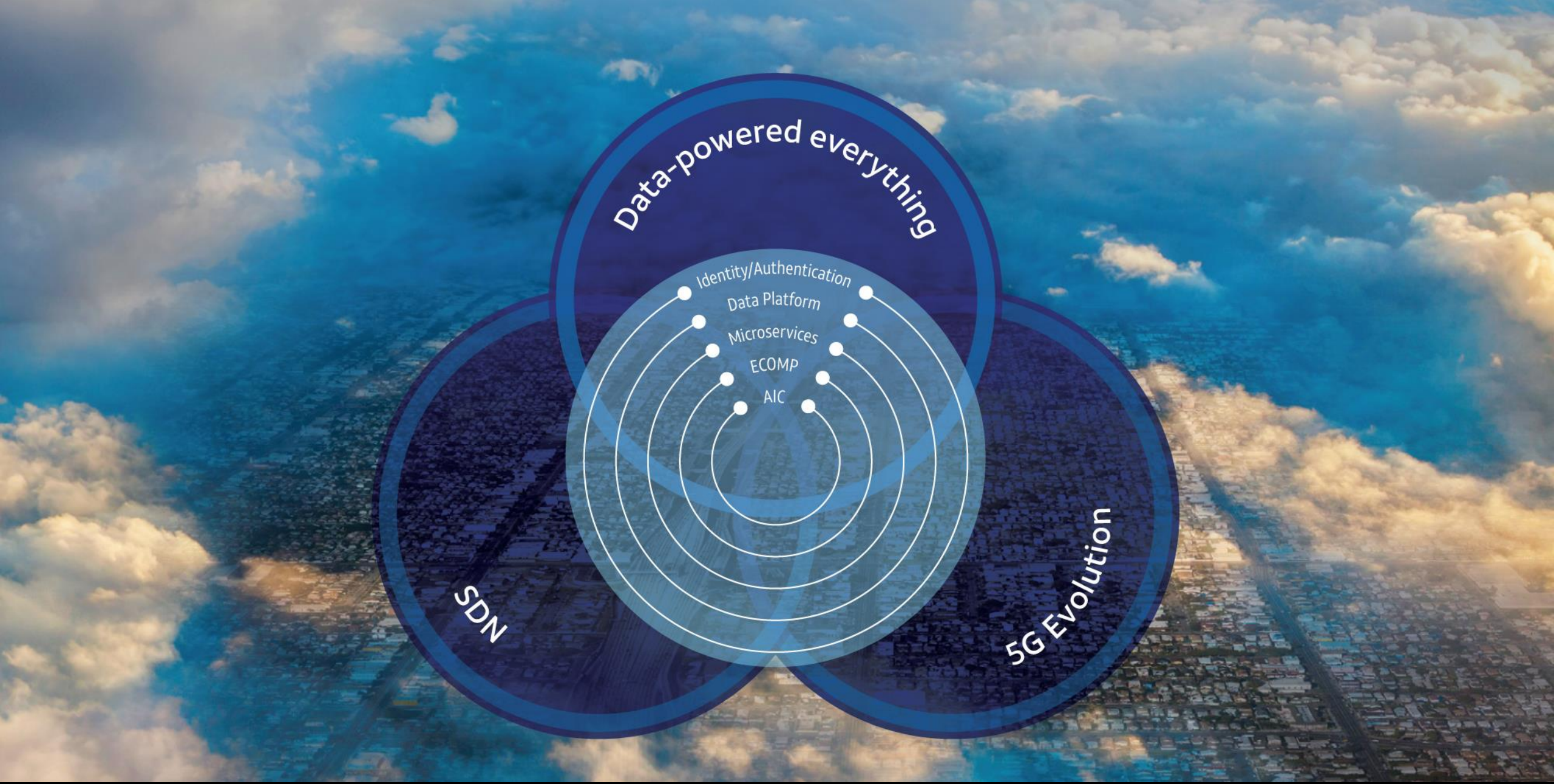
PASSIVE INTERMODULATION (PIM)



Reflections Drive Self-Interference



- Signals reflected by excited defrosters from the car rear windows in surrounding lots.
- This issue forced relocation of the site.
- Interpreting a signature from cases like these might enable us to “trial” locations (with MOOs) before we do permanent installs.
- Saving money when these interesting, hard to diagnose cases do pop up



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WORLD™