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The Road to 5G:

Providing The Connectivity Fabric for Everything

QUALCOMM®



Yesterday

Today

Tomorrow



Human communication ▶ Scaling to connect virtually anything, anywhere

Devices as end-points ▶ New and intelligent ways to connect & interact

Best effort data services ▶ Also, new kinds of control & discovery services

Disparate networks ► Convergence of access, spectrum types, services

Mobile has made a leap every ~10 years

Qualcomm has played an increasing role in fueling these leaps

1990s



2G

Digital
voice

2000s



3G

Mobile
broadband

2010s



4G

Faster and
better

5G

Connecting

new industries
and devices

Enabling

new services

Empowering

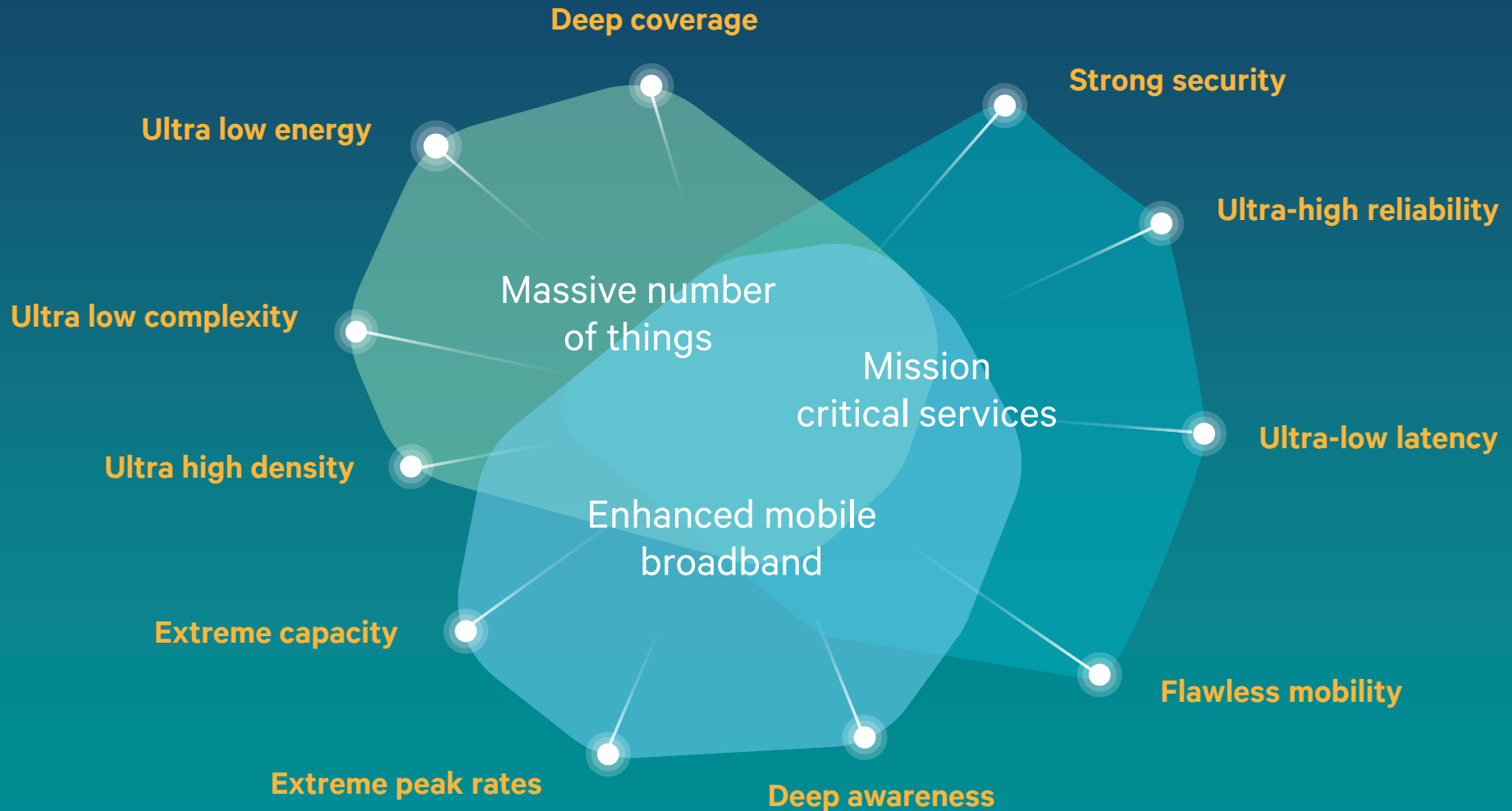
new user
experiences

Scalable

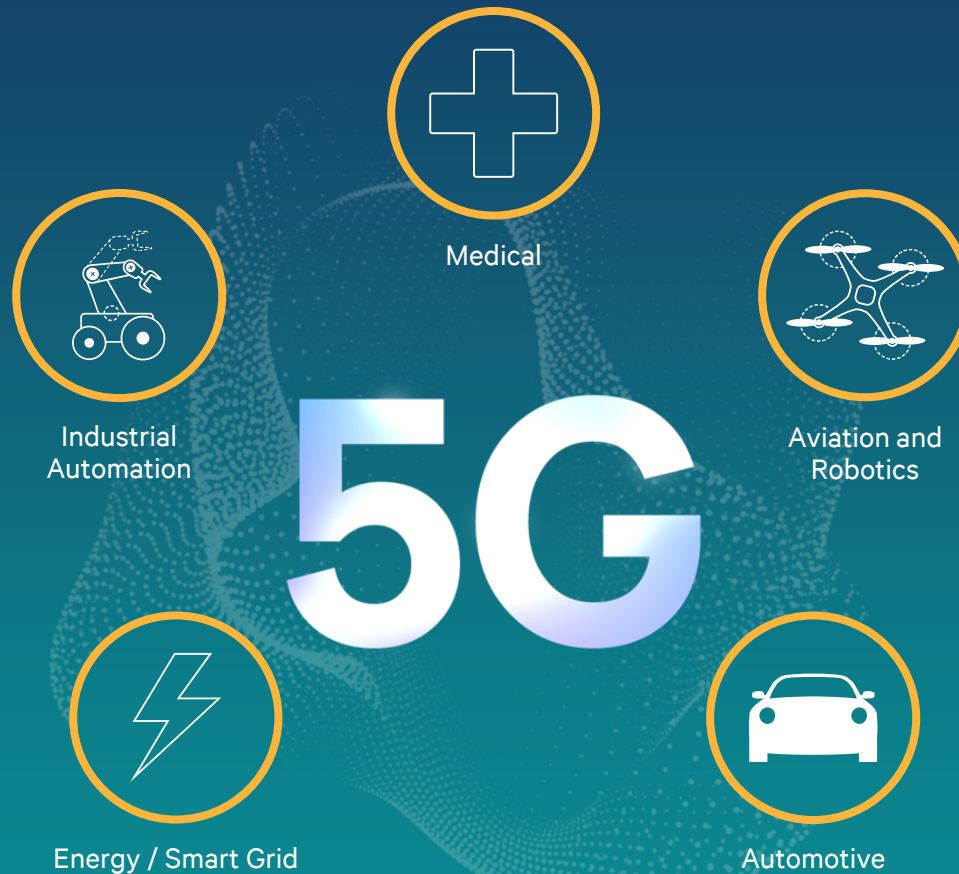
Edgeless

Unified

5G will be scalable across an extreme variation



New ultra-reliable, low-latency, mission critical services



High Reliability

Extremely low loss rate

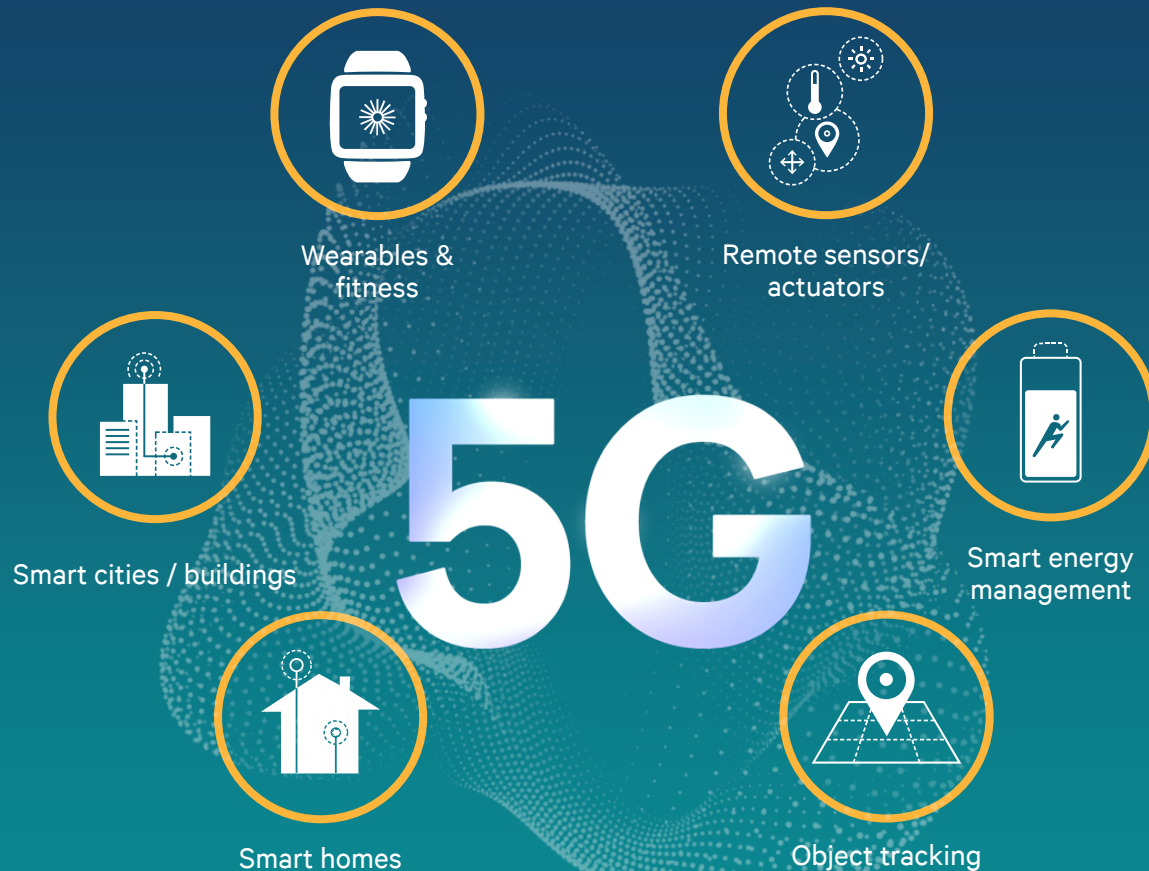
Low Latency

Down to 1ms e2e latency

High Resilience

Multiple links for failure tolerance and mobility

Scaling down to connect low cost 'things'



Power Efficient

Multi-year battery life

Low Complexity

Low device and network cost

Long Range

Deep coverage

Scaling up to extreme mobile broadband



Extreme Throughput

Multi-Gbps

Low Latency

Down to 1ms e2e latency

Uniform Capacity

Regardless of proximity to tower

Multiple enablers toward edgeless connectivity

Uniform experiences—coverage, mobility, capacity—with no perception of ‘cell edges’

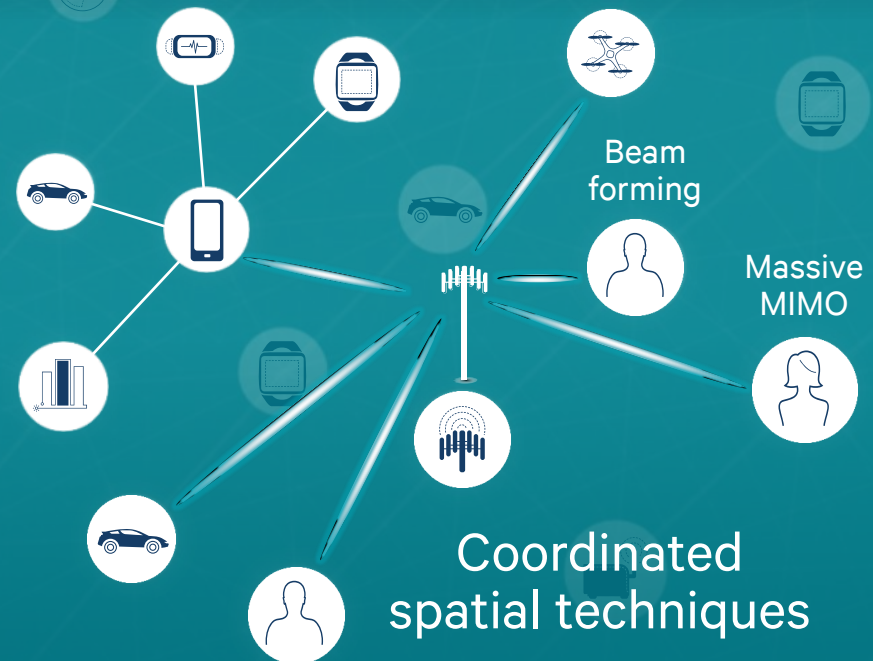
Multi-hop to
extend coverage



Integrated access and
backhaul, relays



Device-to-device discovery
and communications



A unified, more capable 5G platform for the next decade

Configurable for specific services, verticals, deployment scenarios or phased rollout

Unified Air Interface—a common framework

Wide area IoT

Mobile Broadband

Ultra-reliable Control

Multi-connectivity—including 4G and Wi-Fi

Scalable, multi-access core network

Flexible deployment, services, security and subscription models

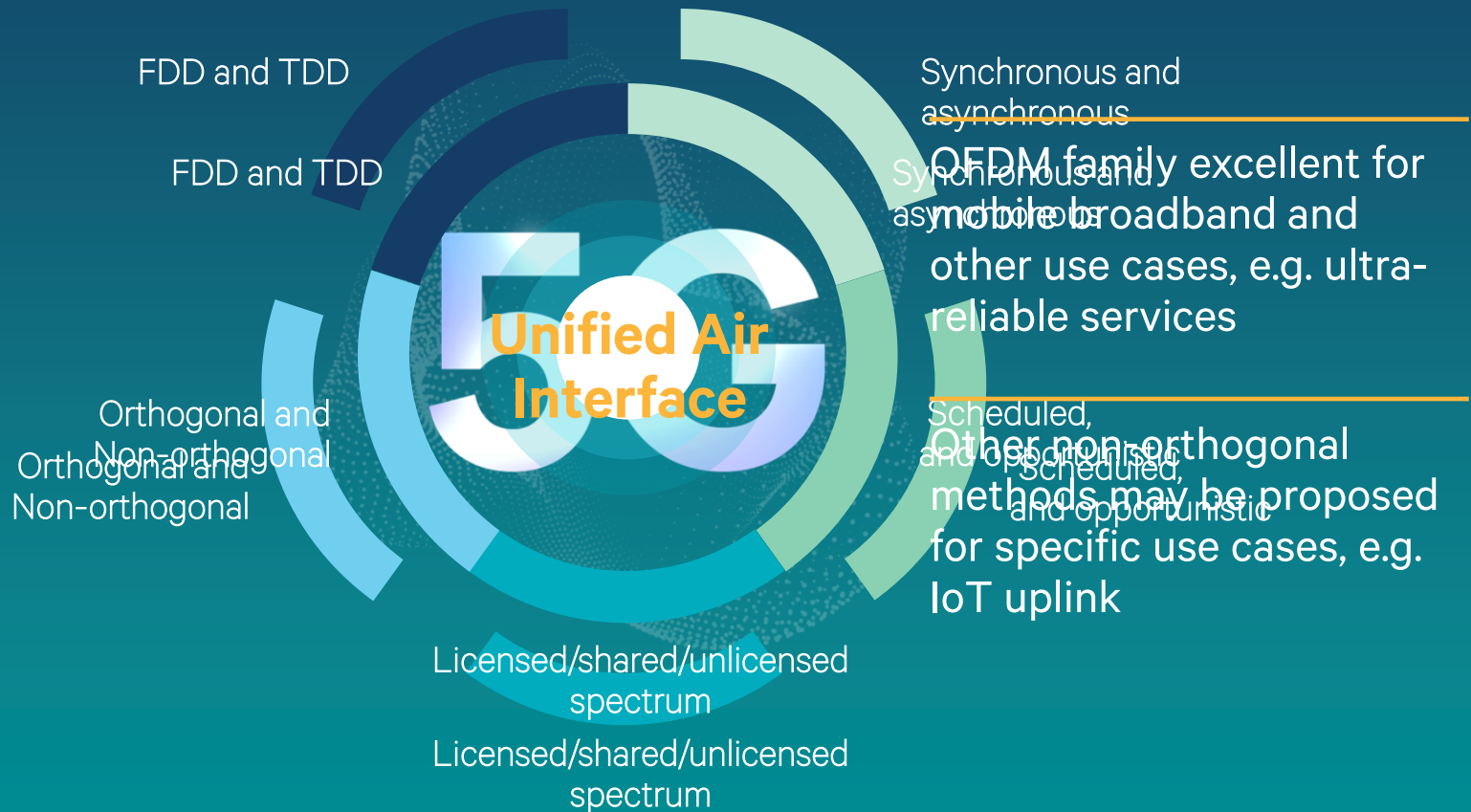
Residential

Venue /
neutral hosts

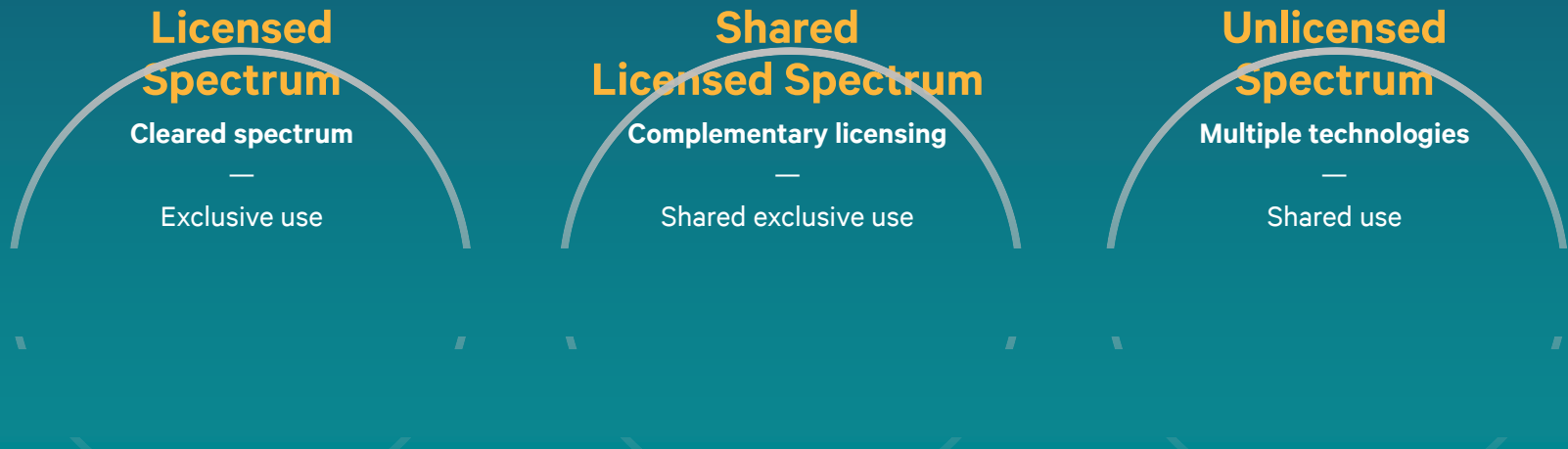
IoT
Vertical

Traditional operator; mobile broadband,
multiple IoT verticals, mission critical services

5G will build on the OFDM family foundation



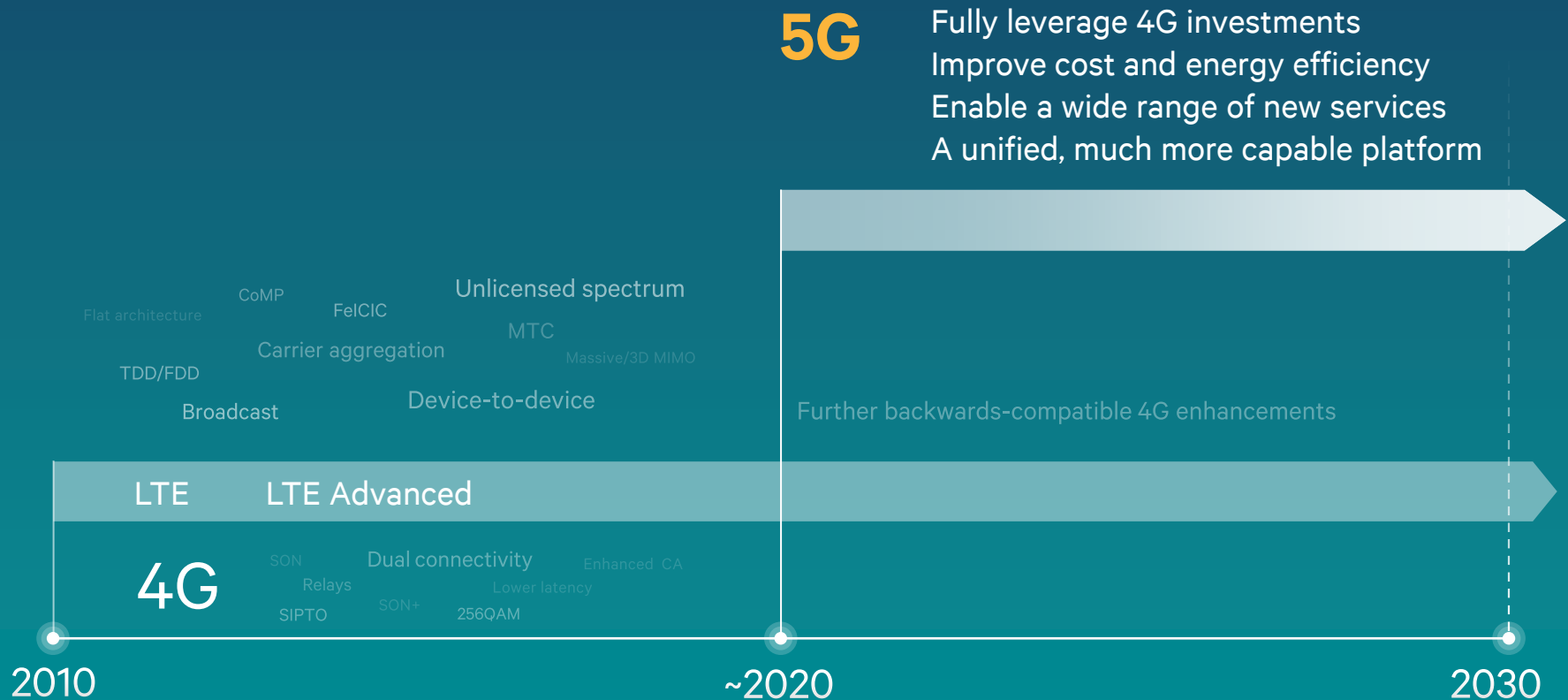
Unified 5G design across spectrum types and bands



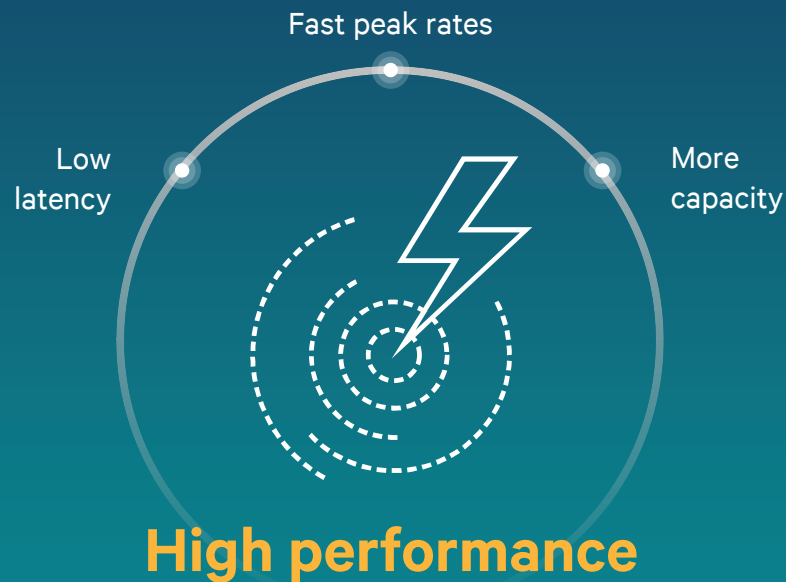
Multi-dimensional multi-connectivity



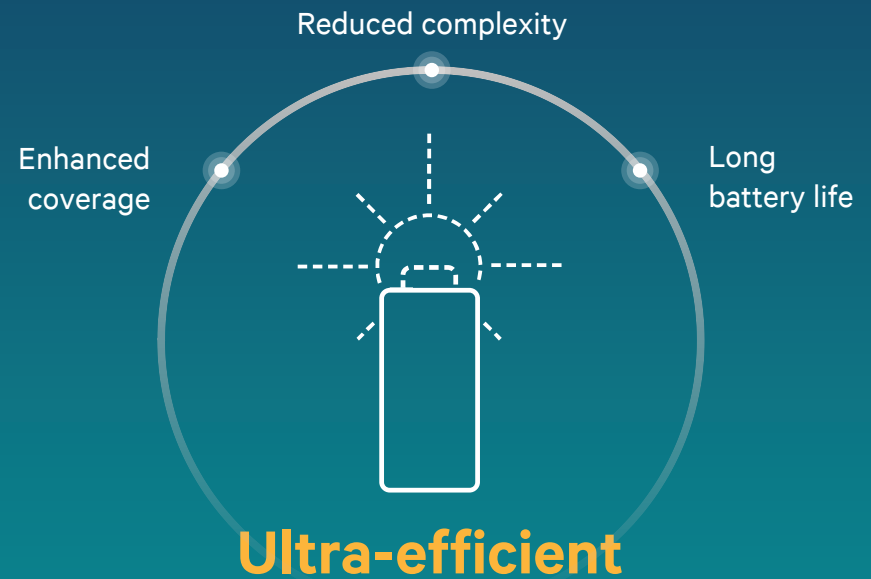
In parallel: driving 4G and 5G to their fullest potential



Scaling LTE for the Internet of Things



LTE Advanced CA¹



LTE Cat-0, LTE-M, C-IOT

LTE Broadcast

Virtually unlimited number of users can receive same content



LTE Broadcast

Virtually unlimited number of users can receive same content

Simulation results

1.7x*

3x

7x

*Throughput gain vs. unicast

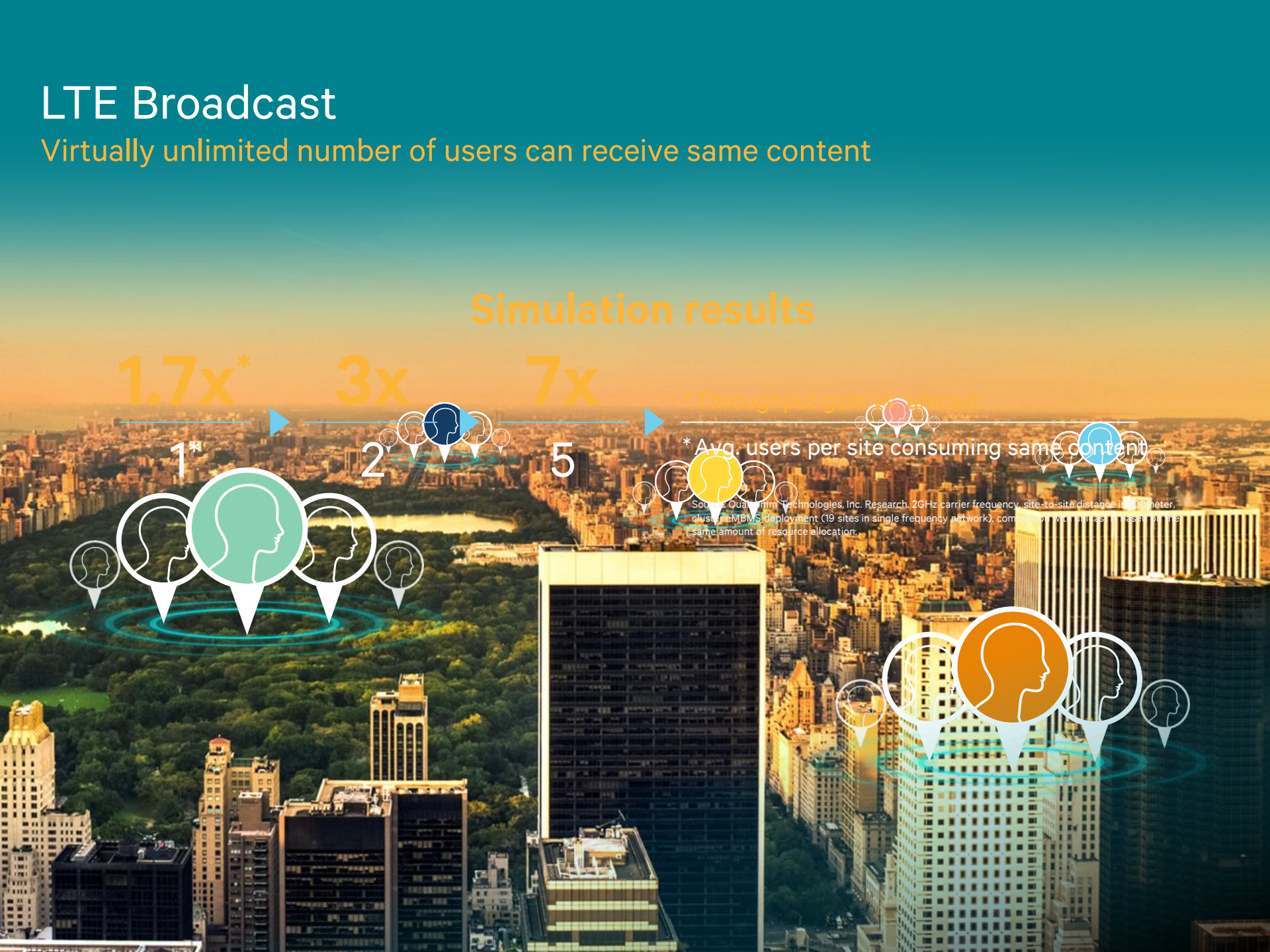
1*

2

5

*Avg. users per site consuming same content

Source: Qualcomm Technologies, Inc. Research. 2GHz carrier frequency, site-to-site distance is 100 meter, cluster eMBMS deployment (19 sites in single frequency network), comparison with unicast is based on the same amount of resource allocation.



LTE Direct

- Scalable
- Universal
- Always-on
- Global



Yoga classes

Social event

Book signing

Used bike for sale

Room for rent

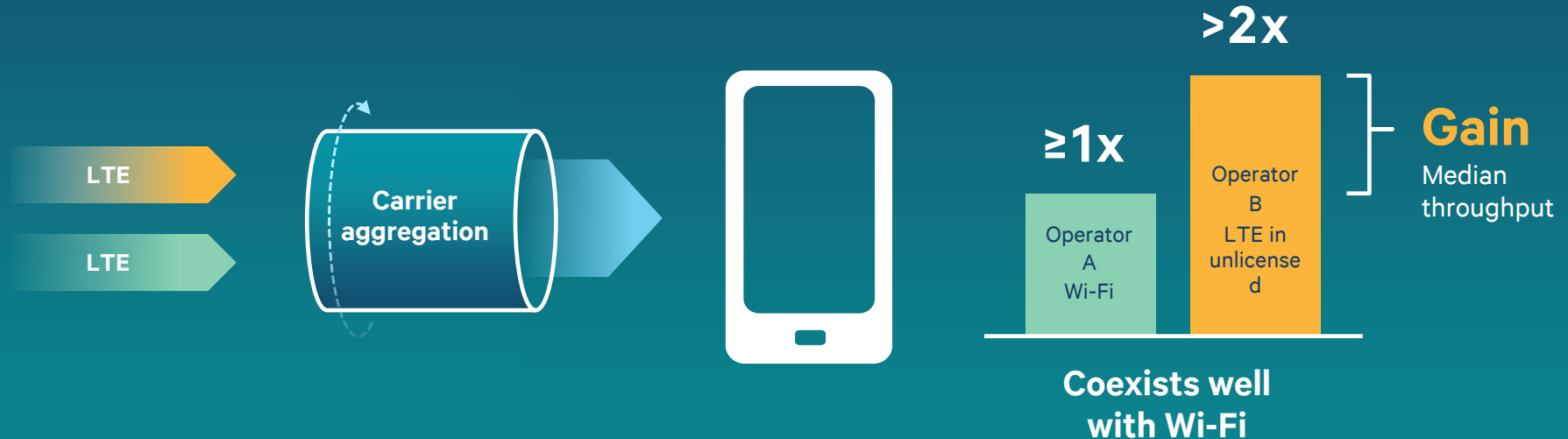
V2V

Free live show

Aggregating licensed and unlicensed spectrum to deliver greater performance in 4G

LTE in unlicensed spectrum

(for new small cells using 5GHz)



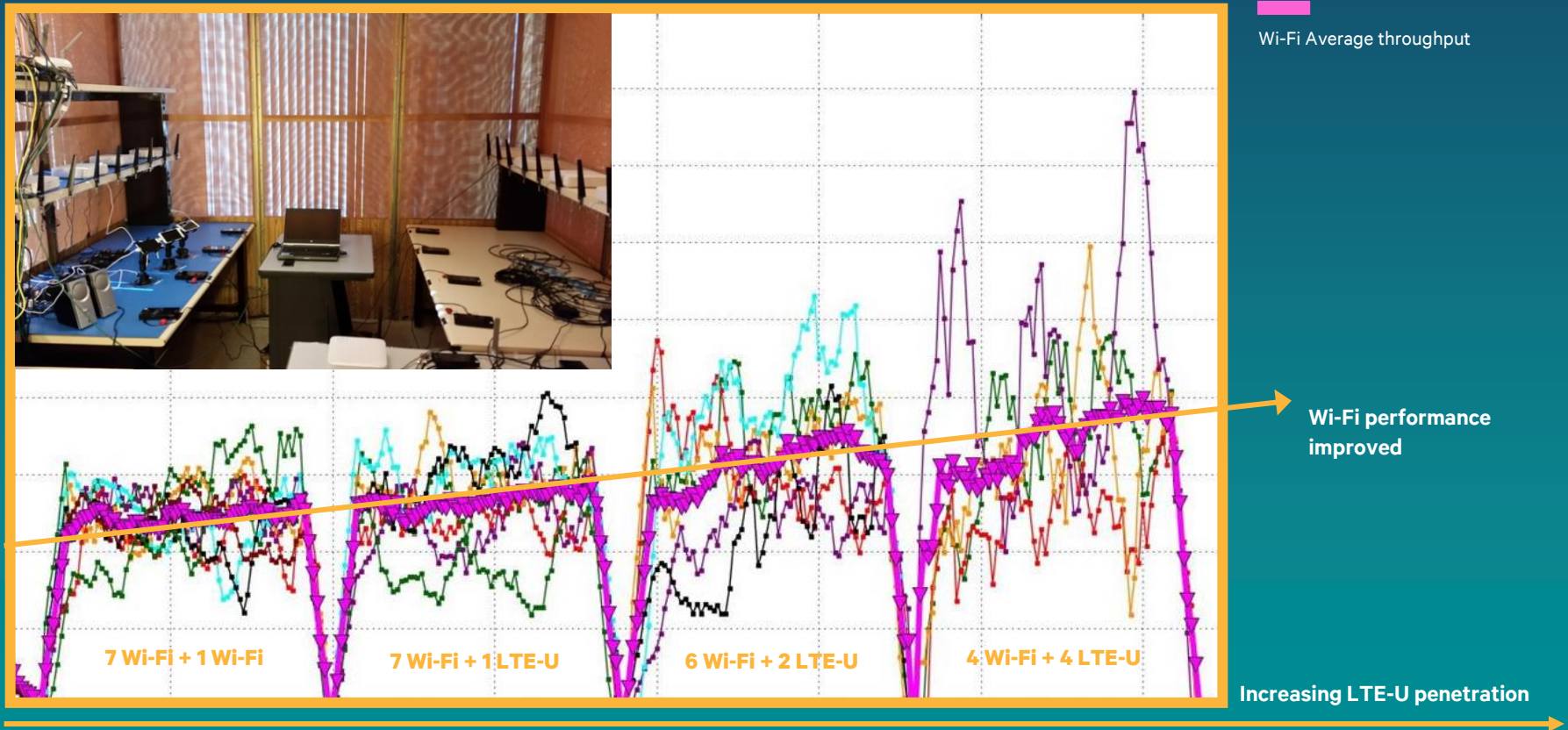
■ Unlicensed spectrum

■ Licensed spectrum

Assumptions: Two operators. 48 Pico+108 Femto cells per operator. 300 users per operator with 70% indoor. 3GPP Bursty model. 12x40MHz @ 5GHz for unlicensed spectrum.
LTE 10 MHz channel at 2 GHz; 2x2 MIMO, Rank 1 transmission, eICIC enabled; LTE-U - Phase II, 2x2 MIMO (no MU-MIMO); Wi-Fi - 802.11ac 2x2 MIMO (no MU-MIMO), LDPC codes and 256QAM).

LTE-U is a good neighbor – not adversely affecting Wi-Fi

Using adaptive duty cycle (CSAT) for fair coexistence



MuLTEfire™

LTE-based technology solely for unlicensed spectrum



4G LTE-like performance

Enhanced capacity and range
Improved mobility, quality of experience



Wi-Fi-like deployment simplicity

Operates in unlicensed spectrum
Leaner, self-contained¹ network architecture

MuLTEfire is an initiative of Qualcomm Technologies, Inc.

¹ Does not require a traditional core network

Making the best use of licensed and unlicensed spectrum

Licensed spectrum

With opportunistic use of unlicensed



LTE/LTE Advanced

(Including LTE-U/LAA,
LTE/Wi-Fi agg.)

Unlicensed spectrum

LTE-based technology



MuLTEfire™

Unlicensed spectrum

802.11 technology



Wi-Fi 802.11ac/ad/ax

The expanding role of LTE Advanced—a new paradigm

Scale to connect the Internet of Things



Carrier Aggregation
High performance



Ultra efficient
Cat-0, LTE-M



Bring new ways to connect & interact

**Evolving the
LTE Direct Platform
Device-to-Device**



Multi-hop



Vehicle-to-Vehicle /
Infrastructure



Empower new classes of services

Mission-
critical
control
LTE ULL



Broadcast
**LTE
Broadcast**

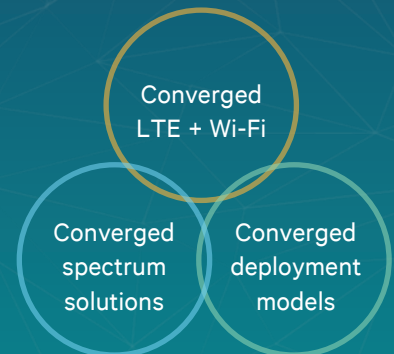
Discovery
**LTE Direct
Proximity**



Public Safety
**LTE Direct
MCPTT**

Create a converged connectivity platform

Link aggregation



**LTE-U
and LSA**

MuLTEfire™

Qualcomm fuels major technology shifts in the industry

Anticipating the big challenges and investing early on to solve them

>\$36B Cumulative R&D*

Scorpion CPU
development initiated

1st Android
smartphone

Redefined computing
From desktop to smartphones

CDMA 3G Standard

**Digitized mobile
communications**
From analog to digital

1ST WCDMA HSDPA
multimode chipset

1ST LTE Advanced carrier
aggregation smartphone

1ST 64-BIT 3G/
LTE integrated chip

**Transforming
the edge of
the Internet**

LTE/Wi-Fi
convergence

LTE-U

Machine learning

5G

Computer vision

Security and privacy

Thank you

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