

A scenic view of Central Park in New York City. In the foreground, a man is sitting on the grass, looking towards the right. In the background, many people are sitting on the grass, and a dense line of trees separates the park from a city skyline with several tall skyscrapers. The sky is bright and clear.

The 1000x Data Challenge, The latest on Wireless, Voice, Services and Chipset Evolutions.

4G World, Wednesday October 31st



Agenda

4G World Wednesday October 31st 1:30pm to 4:30pm

▶ 1:30 pm **The 1000x mobile data challenge**

- 1:30 How do we enable 1000x?
- 1:45 How do we get access to new spectrum to reach 1000x?
- 2:00 Taking HetNets to the next level for 1000x
- 2:15 The small cell products to power 1000x
(3G/4G small cells, Wi-Fi)

Rasmus Hellberg, Sr Director, Tech Marketing,
Prakash Sangam Director, Tech Marketing
Rasmus Hellberg Sr Director, Tech Marketing
Prakash Sangam, Director, Tech Marketing

▶ 2:45pm **The Chipset evolution and multimode challenges**

- 2:45 Smartphone signaling and power enhancements
- 3:05 Solving the global multimode and carrier aggregation challenges
- 3:25 Circuit switched fallback, performance and interworking
(LTE FDD/TDD GSM, UMTS, TD-SCDMA, 1X)

Sunil Patil, Director, Product Management
Peter Carson ,Sr Director Marketing
Sunil Patil, Director, Product Management

▶ 3:45pm **The Voice and data Service evolution—together with Ericsson**

- 3:45 The latest on VoLTE
(RCS, SRVCC VoLTE, VoIP over other accesses),
- 4:00 How do we achieve the Smart Pipe? (QoS and more)
- 4:10 LTE Broadcast services and opportunities

Eric Parsons, Strategic Product Manager,
LTE, Ericsson
Peter Carson, Sr Director Marketing
Mazen Chmaytelli, Sr Dir, Business Dev.

1000X

The 1000x Mobile Data Challenge

More Spectrum, More Small Cells, More
Indoor Cells and Higher Efficiency

October 31st 2012

QUALCOMM[®]

Driving Network Evolution

To learn more, Go to www.qualcomm.com/1000x

► More details provided at:

- 1) 1000x: More Spectrum: www.qualcomm.com/spectrum
- 2) 1000x: More Small Cells www.qualcomm.com/hetnets
- 3) 1000x: Higher efficiency www.qualcomm.com/efficiency

September 18th 2012

October 17th 2012

November 21st 2012

The logo features the text "1000x" in a bold, orange, sans-serif font. The "x" is stylized with a long horizontal stroke that extends to the left and an upward-pointing arrow integrated into its right side, symbolizing growth or a 1000-fold increase.

Mobile Data Traffic Growth—Industry Preparing for 1000x

PREPARING FOR
1000x
DATA TRAFFIC GROWTH

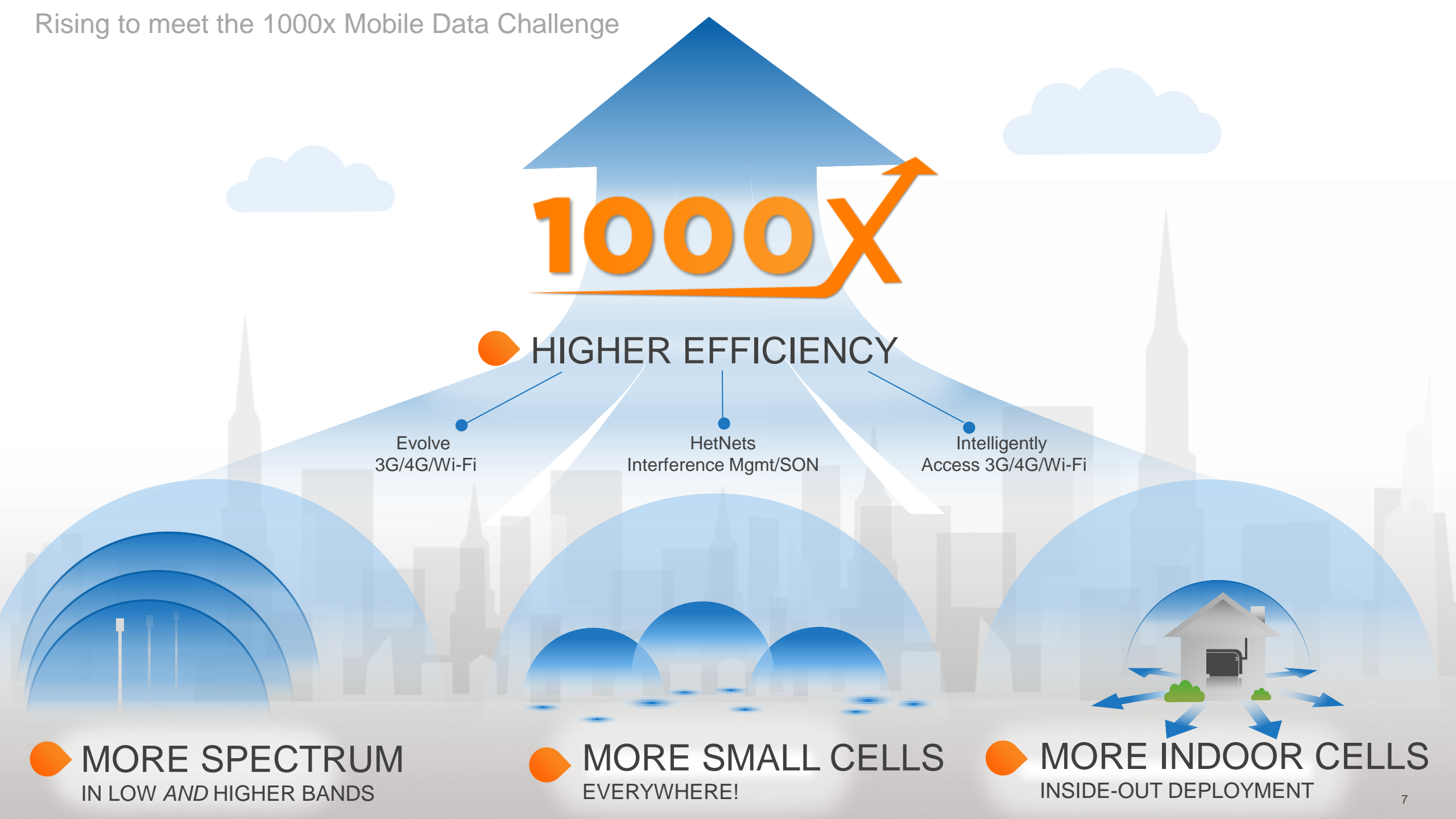
GLOBAL DATA
TRAFFIC GROWTH

~2x

FROM 2010- 2011*

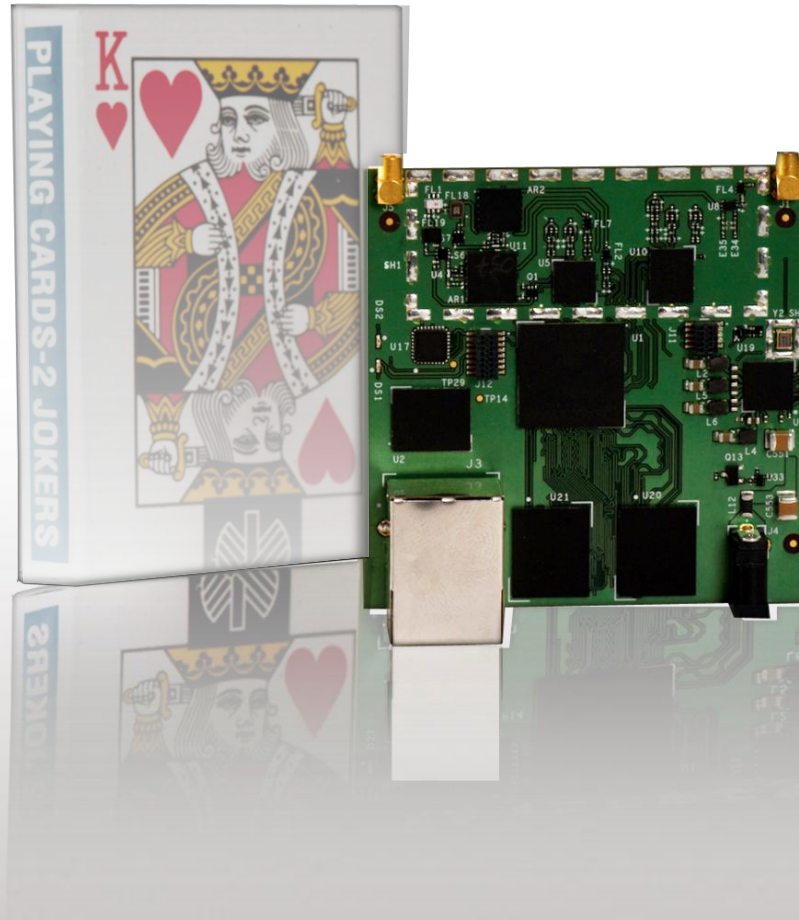


*Global growth, some regions grew more/less

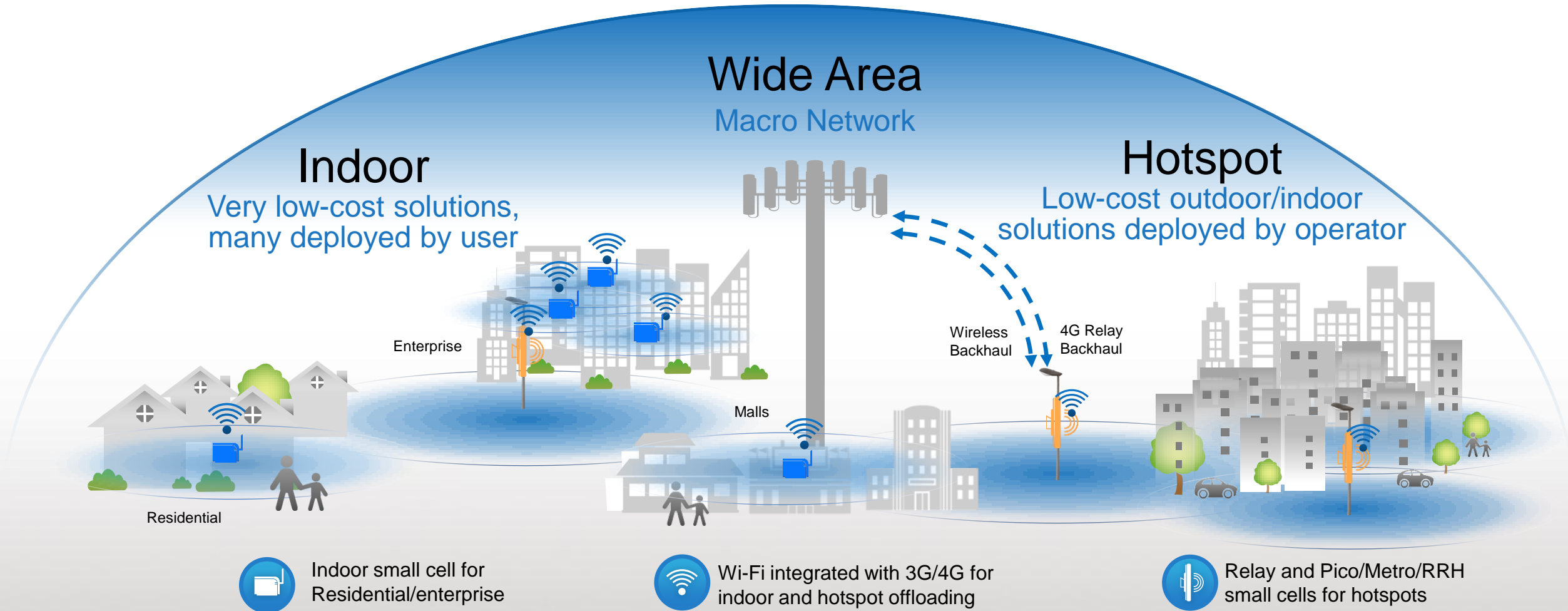


Extreme Densification—3G/4G+Wi-Fi Small Cells Everywhere

Low cost, small size and ease of deployment



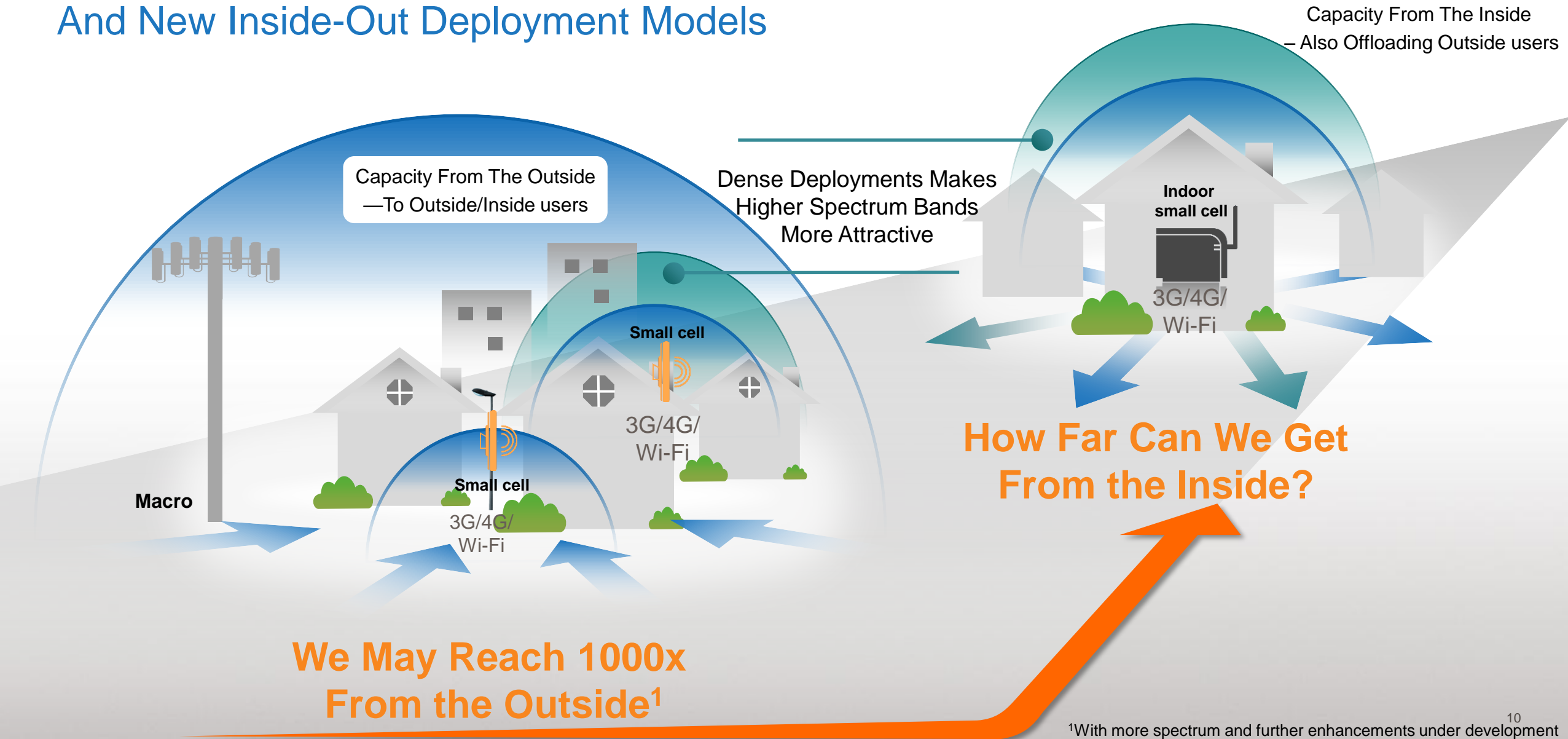
More Small Cells—Bring Network Closer to User



Leveraging Heterogeneous Networks – HetNets

Evolution From Outside To Inside

And New Inside-Out Deployment Models





**Imagine Small Base Stations
Deployed by The User,
Basically Everywhere!**

Neighborhood Small Cells Is One Enabler Towards 1000x

Add 10x Spectrum

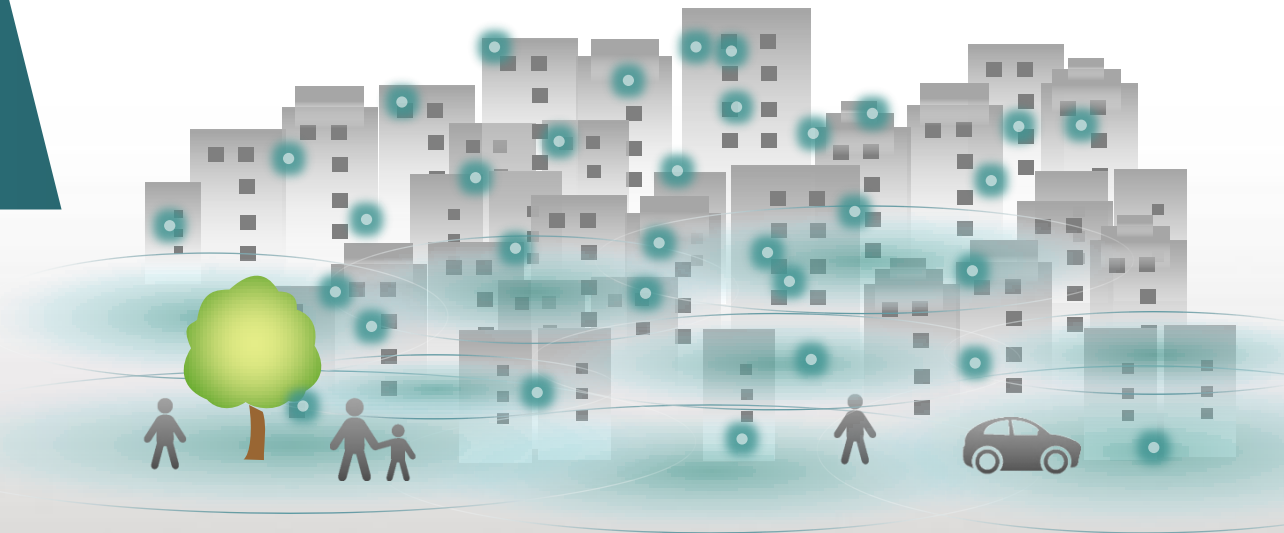
10Mhz
for
macros
@ 2GHz

Example With Higher Band:

100MHz *dedicated* to
small cells @ 3.6GHz¹

Negligible loss in coverage and
capacity at high small cell density

Dense Indoor Deployment



Median throughput gain
versus Macro only baseline

1000x

~ 20 %
Household
Penetration

500x

~ 9%
Household
Penetration

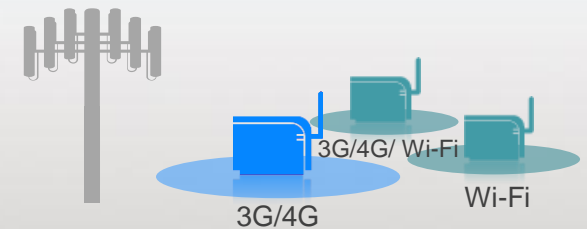
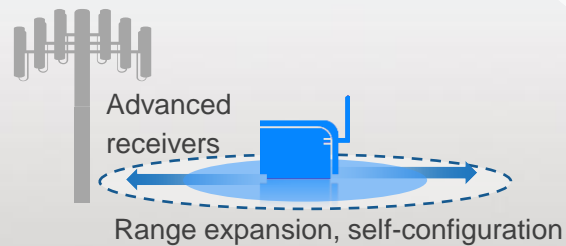
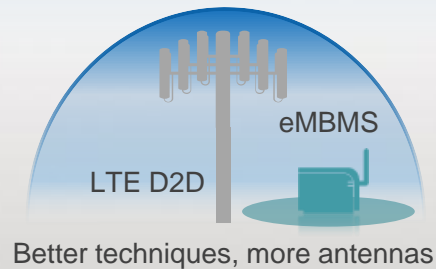
Squeezing More Out Of Spectrum

HIGHER EFFICIENCY

Evolve
3G/4G/Wi-Fi

HetNets
Interference Mgmt/SON

Intelligently Access
3G/4G/Wi-Fi



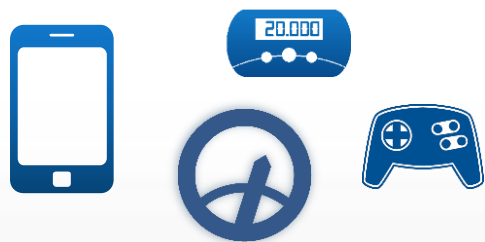
More Efficient Services and Applications

Optimizations, caching, traffic management, etc.

Significant Gains Still Possible For Certain Classes of Traffic

>10x

(HSPA+ Advanced example, compared to HSPA+ R7/R8)



Small Data Bursts

>10x

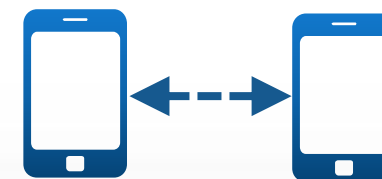
(More per 6 multicast users in a network vs. 6 unicast users in dense urban area, but up to ~3x gain for just two users)



LTE Broadcast

>10x

(Less resources to discover proximal devices within 20s in a cell with 800 users, vs. regular LTE. Can also discover 16x more devices than Wi-Fi Direct)



Device to Device Discovery and Communication—LTE Direct

LTE Broadcast

5

Users Per Site
Sharing Content

7x

Throughput Gain



LTE Broadcast

2

Users Per Site
Sharing Content

3x

Throughput Gain



LTE Broadcast

1

User Per Site
Sharing Content

1.7x

Throughput Gain



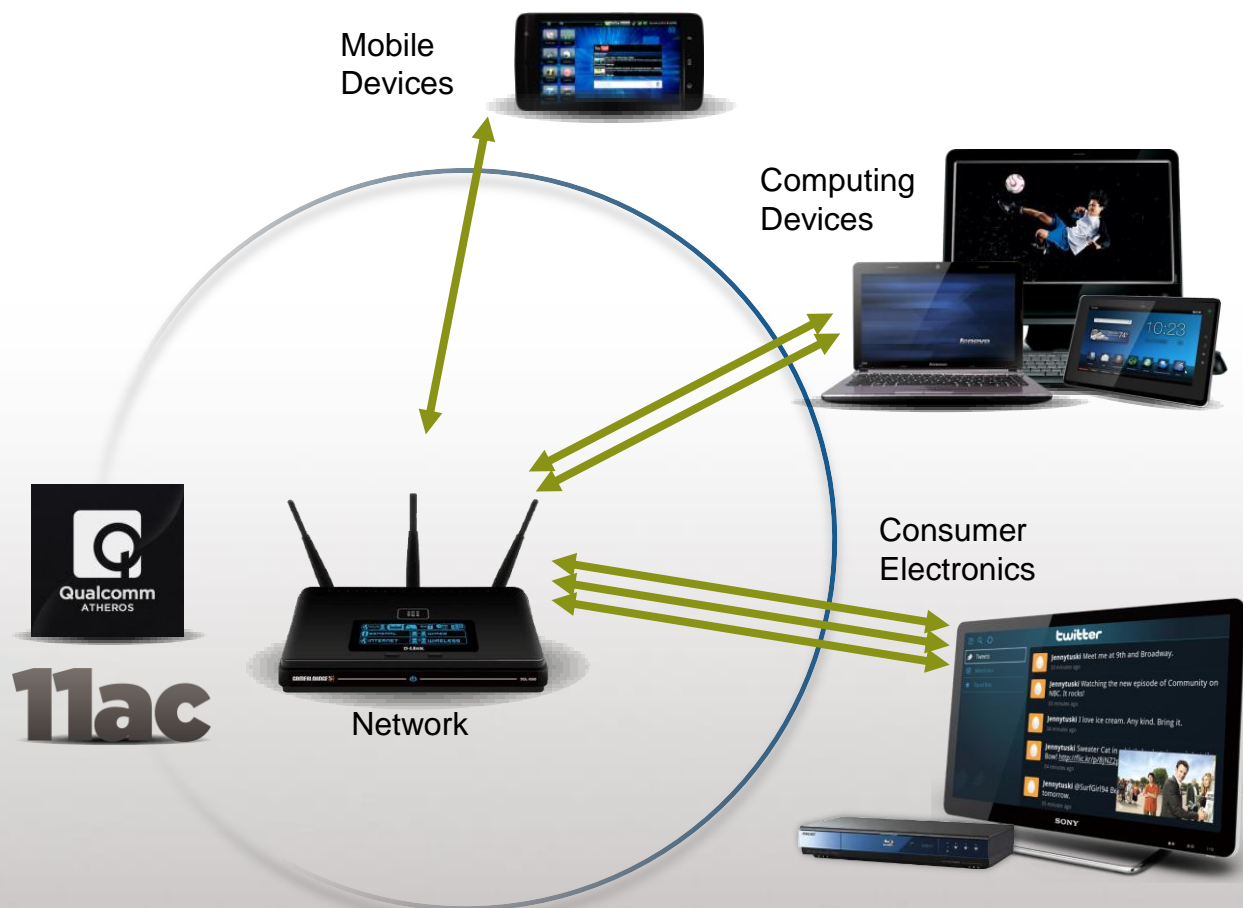
Driving More Efficient Wi-Fi End-To-End

Driving the Wi-Fi Evolution

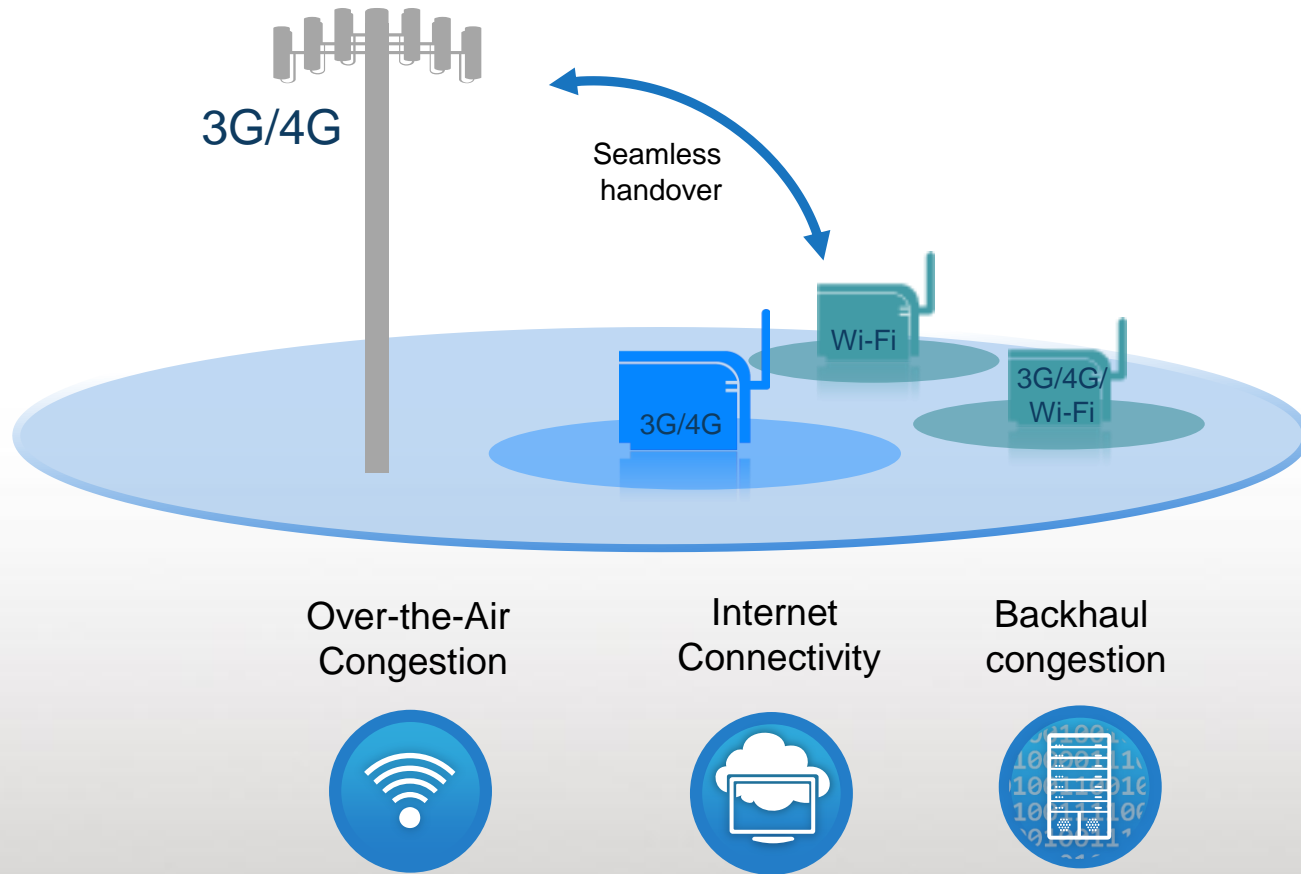
802.11ac

- ▶ Leveraging relatively interference free 5 GHz
 - > 1Gbps peak rate
 - ~3x higher capacity per stream over 11n
- ▶ Multi User MIMO and up to 8 antennas—serving multiple users simultaneously
- ▶ HD video in whole home

Driving the 802.11ac End-To-End Ecosystem



Intelligently Utilize Best and Multiple Accesses—3G/4G Small Cell/Macro, Wi-Fi



There Are Multiple Ways To Reach 1000x

1000X

HIGHER
EFFICIENCY

The Low Hanging Fruit!

Different mixes of Spectrum, Small Cell Types, Indoor, Outdoor to Reach 1000x



MORE SPECTRUM
IN LOW AND HIGHER BANDS



MORE SMALL CELLS
EVERYWHERE!



MORE INDOOR CELLS
INSIDE-OUT DEPLOYMENT

Qualcomm At The Forefront To Enable 1000x

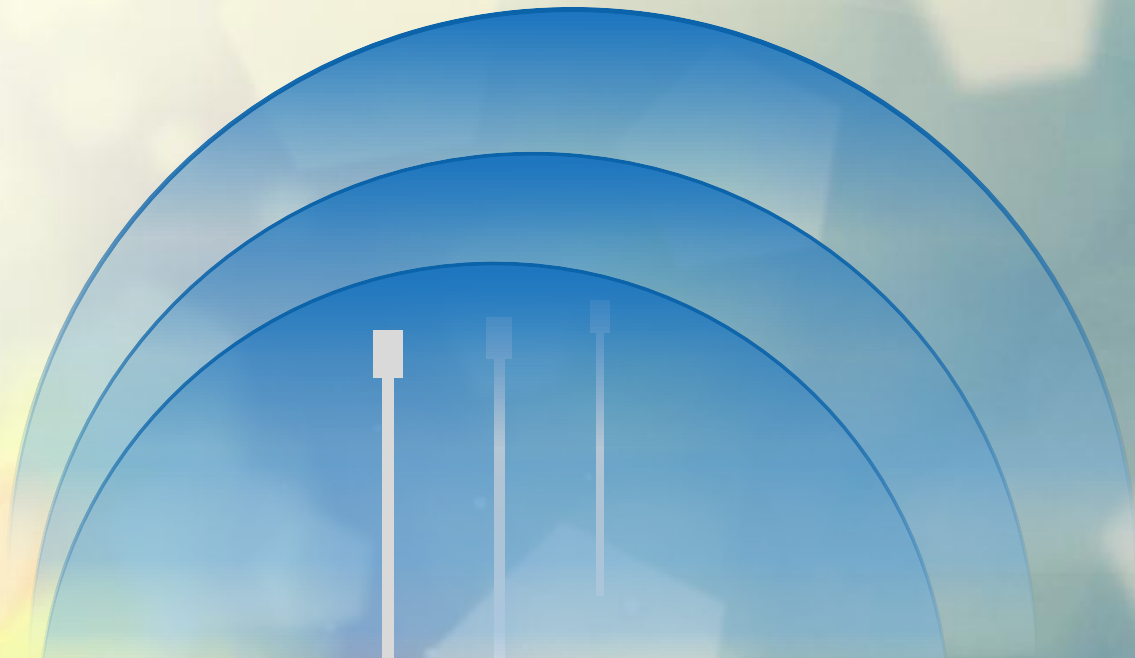


**Will There Be 1000x Demand?
It's Just a Matter of Time...**

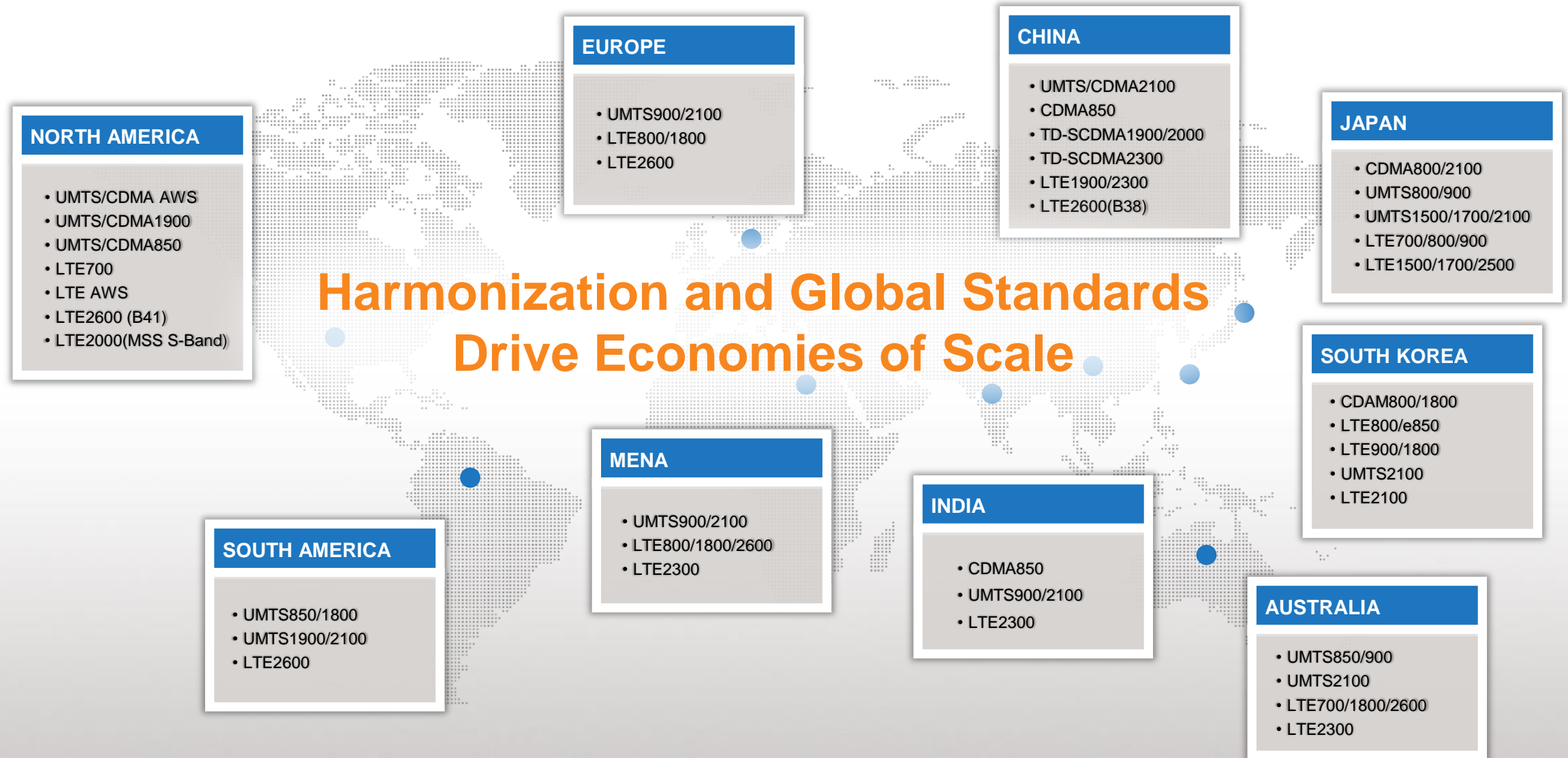
1000x 

1:45pm More Spectrum

A New Way To Access Underutilized Spectrum:
Authorized Shared Access (ASA)—Suited for Small Cells

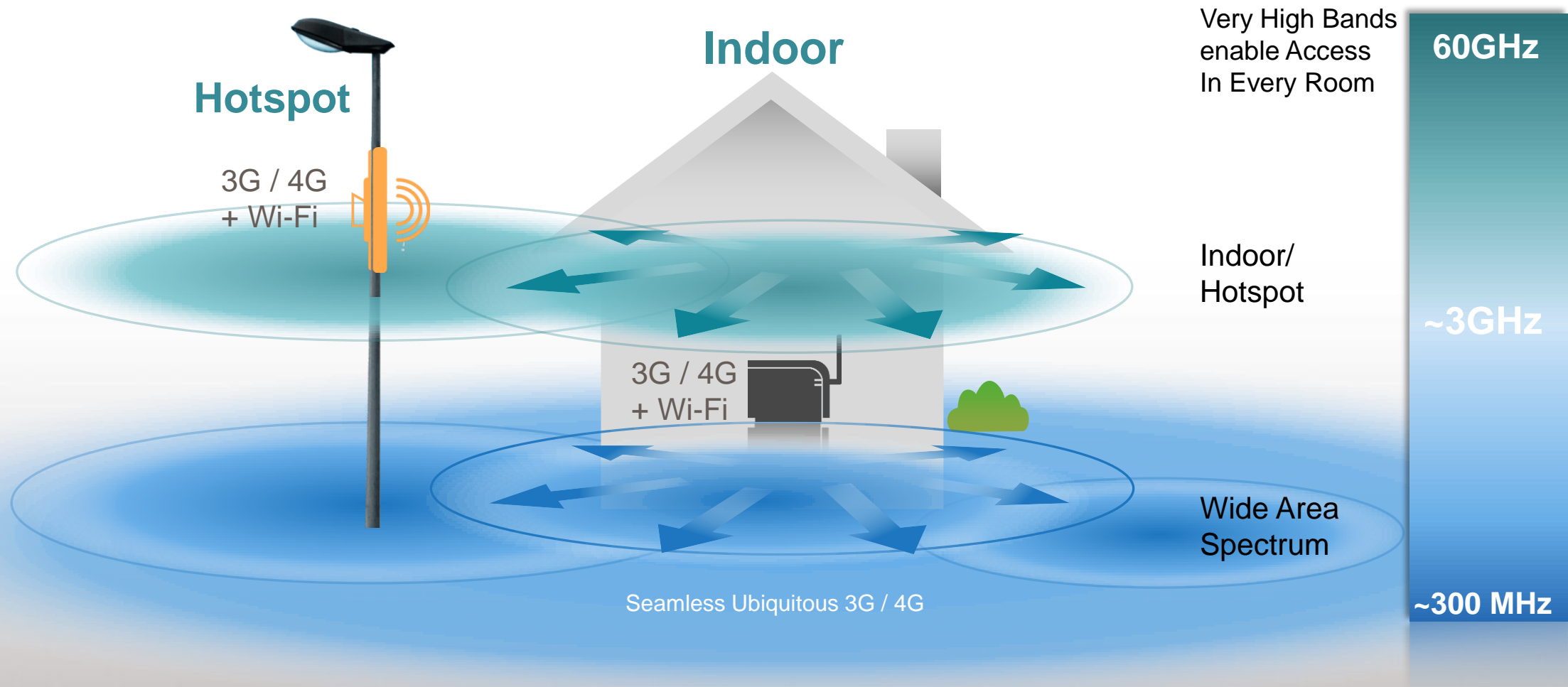


Current Spectrum Provides the Foundation of 1000x – With More Small Cells and Higher Efficiency

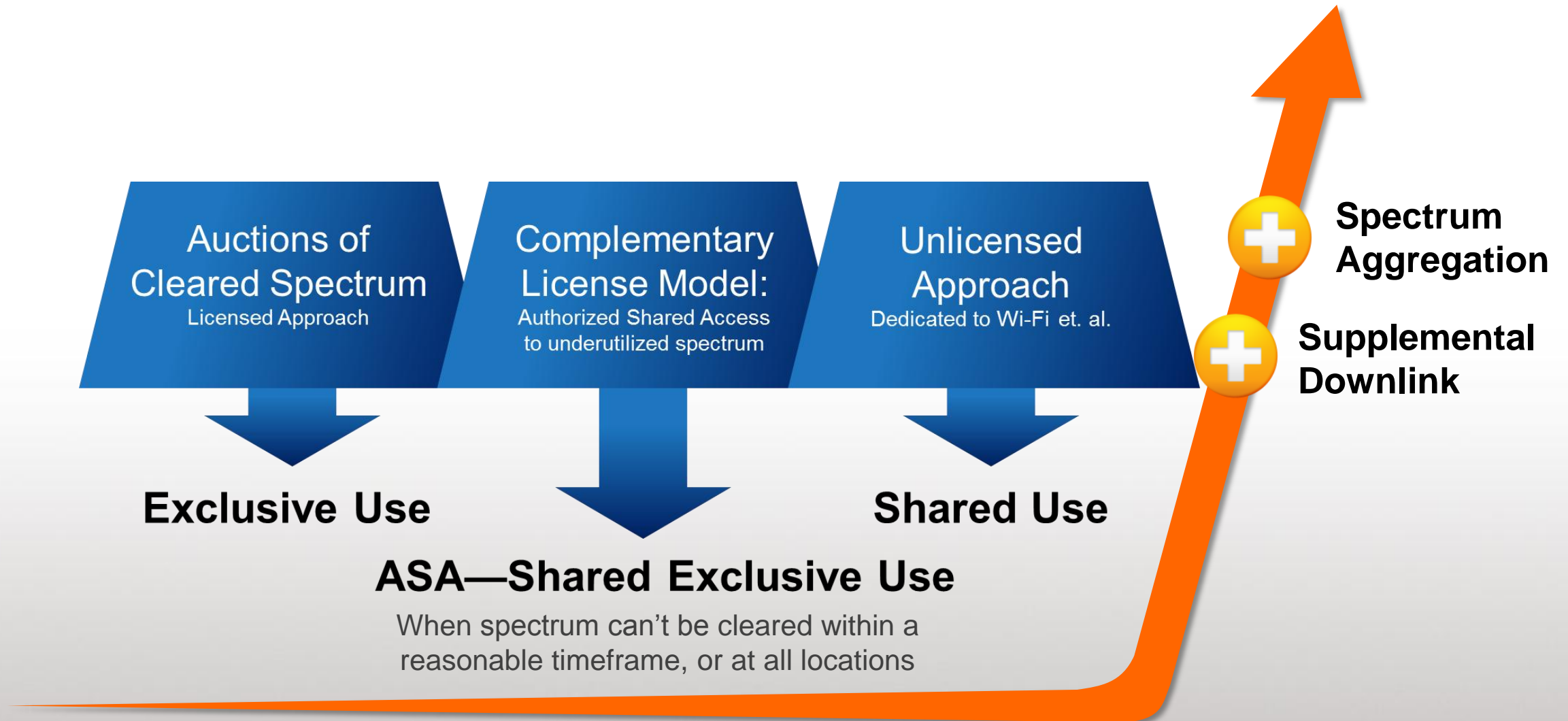


More Indoor, Higher Spectrum Bands

Dense Small Cell Deployment Makes Higher Bands Attractive¹



Multiple Efforts Are Required to Access More Spectrum



Allocated Spectrum May Be Underutilized

Incumbents (e.g. government) may not use spectrum at all times and locations

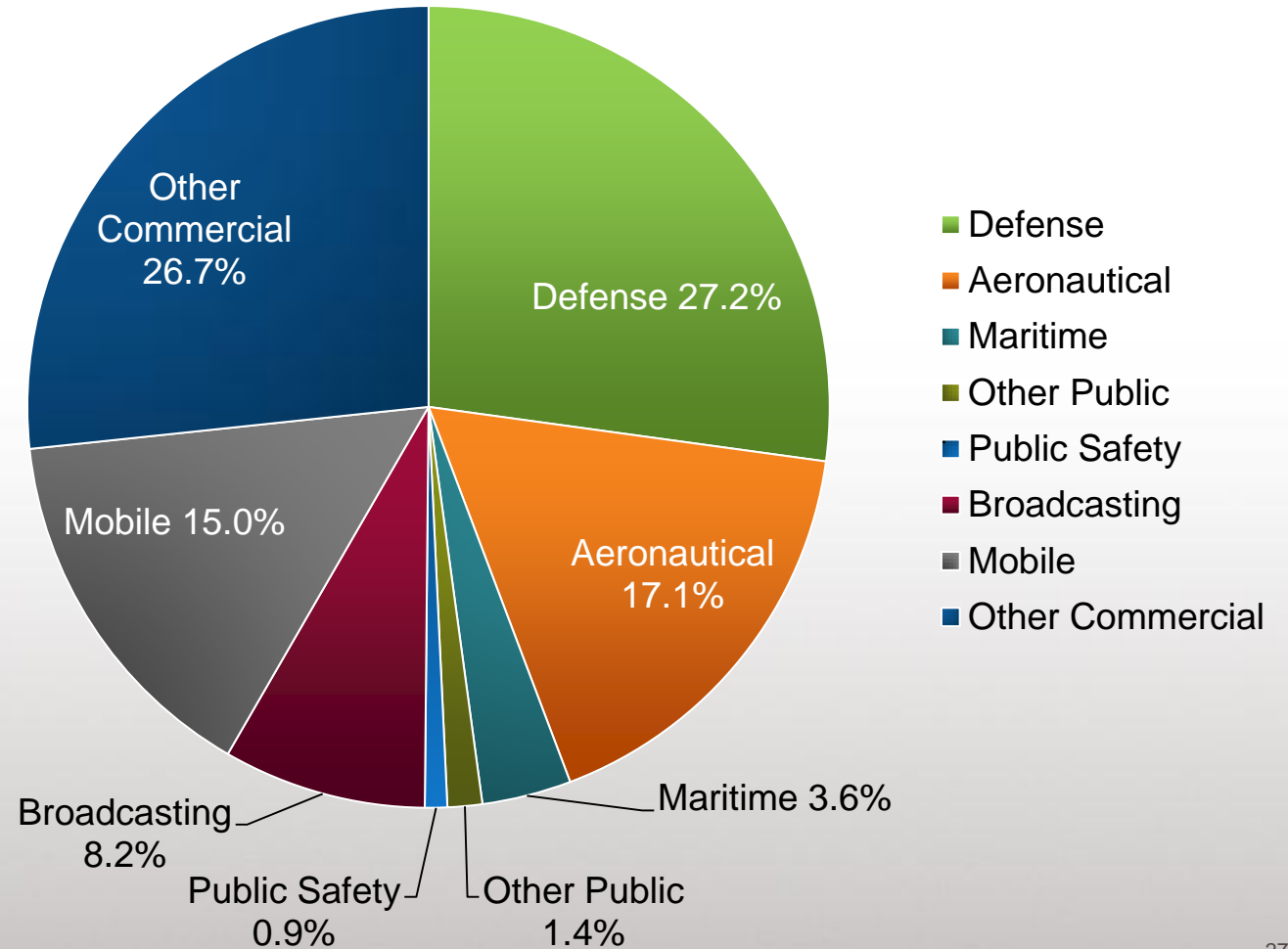
Challenge Today



Repurposing and vacating spectrum takes longer and longer time.

ASA Opportunity

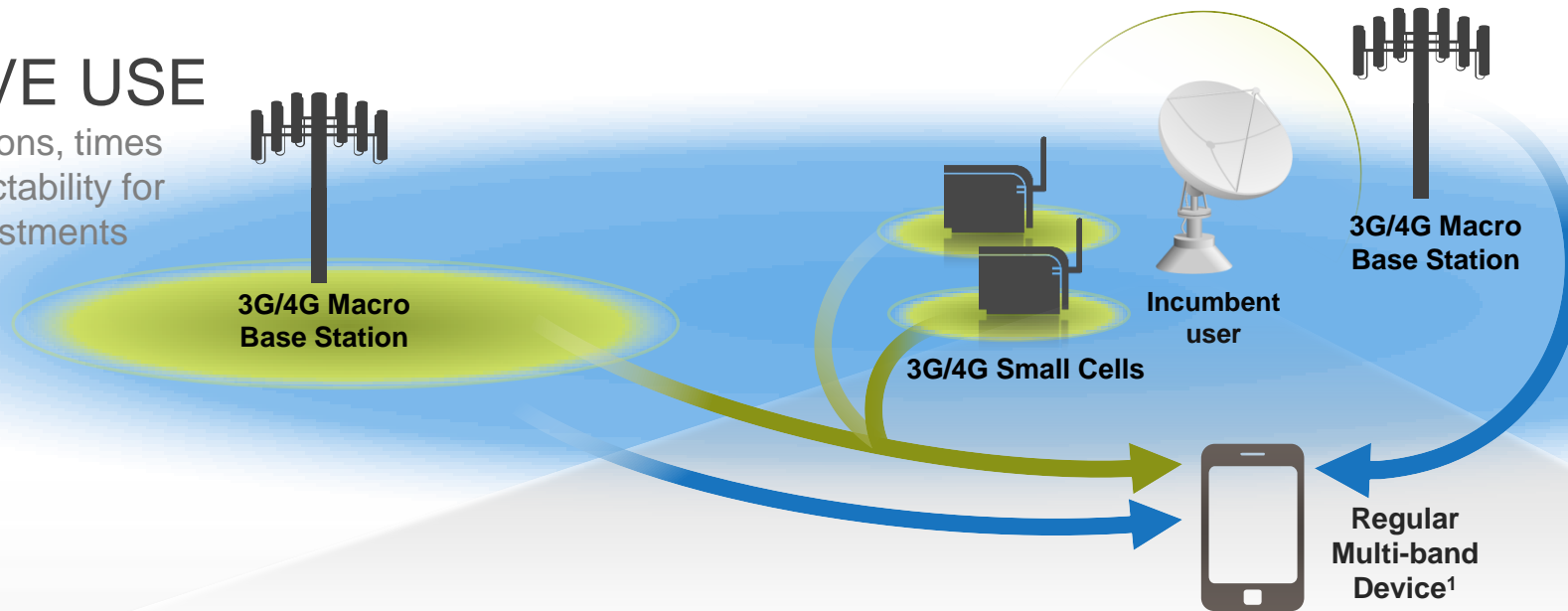
- ▶ Accelerate harmonization and potential re-farming.
- ▶ Access underutilized spectrum, which may always have incumbent spectrum holders.



Authorized Shared Access(ASA) is Optimal For Small Cells

EXCLUSIVE USE

- At given locations, times ensures predictability for long-term investments



OPTIMAL FOR SMALL CELLS

- Small cells can be closer to incumbent than macros

Incentive-Based Cooperation Model

PROTECTS INCUMBENTS

- Binary use—either incumbent or rights holder
- Protection zones



Satellite



Military Radar



Public Safety

¹No device impact due to ASA, just a regular 3G/4G device supporting global harmonized bands targeted for ASA. Carrier aggregation would be beneficial to aggregate new ASA spectrum with existing spectrum, but is not required.

ASA Targets Harmonized Spectrum—Suitable For Small Cells

Leveraging global, available 4G technologies to ensure economies of scale

ASA CANDIDATE EXAMPLES	2.3 GHz (100 MHz)	2.6 GHz (100+ MHz)	~3.5 GHz (100-200 MHz)
Applicable Regions	EUROPE (Traditionally licensed in e.g. India)	MENA (Traditionally licensed in e.g. Europe)	USA, EU, LATAM, SEAP
Incumbent Users	Telemetry, public safety, cameras	Various	Naval Radar (US) Satellite (EU, LATAM. SEAP)
Suitable Technology	LTE TDD	LTE FDD/TDD	LTE TDD
Possible Launch	~2015		

3.4 to 3.8 GHz

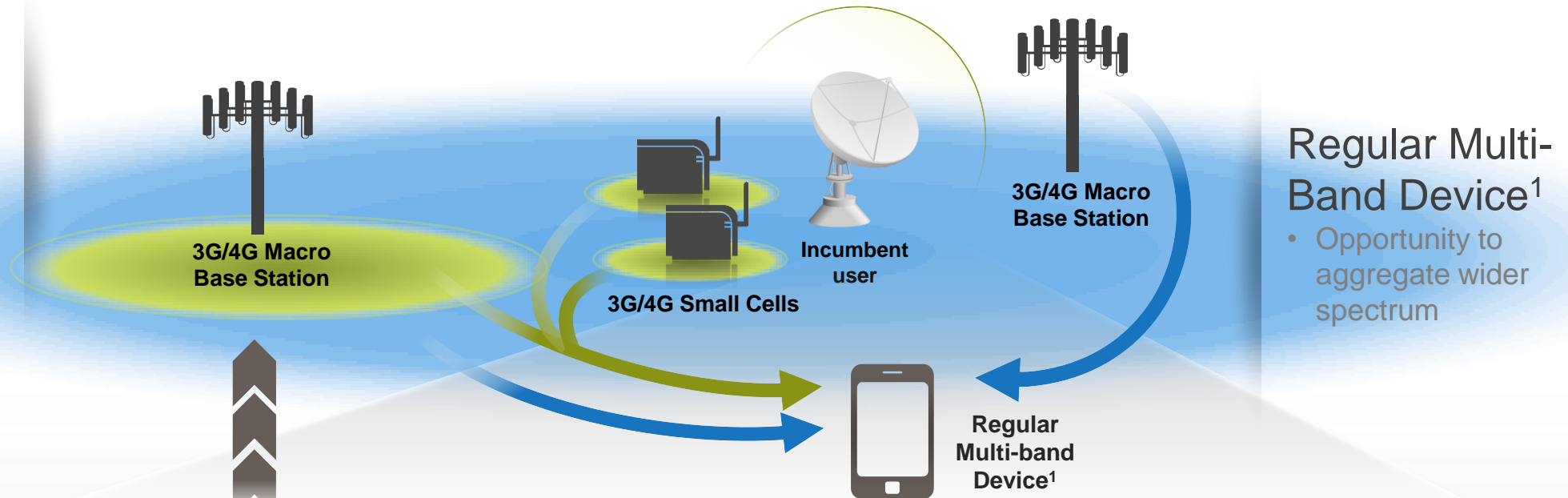
Emerging as a key band for 3G/4G small cells, some parts can be traditionally licensed, but some parts need to be **ASA licensed**, such as ~3.5GHz in the US/EU¹

¹3GPP has already defined bands 42/43 for 3.4 GHz to 3.8 GHz, 3.5GHz in the US defined as 3550 – 3650 MHz, but up to 200MHz could be targeted for ASA in e.g. SEAP/LATAM. Note that ASA targets IMT spectrum bands, but the concept can be applied generally to all spectrum bands and other technologies

ASA Takes Advantage of Existing Products and Standards

COST-EFFECTIVE

- Use available 3G/4G infrastructure—no ASA impact on standards
- Complements installed 3G/4G

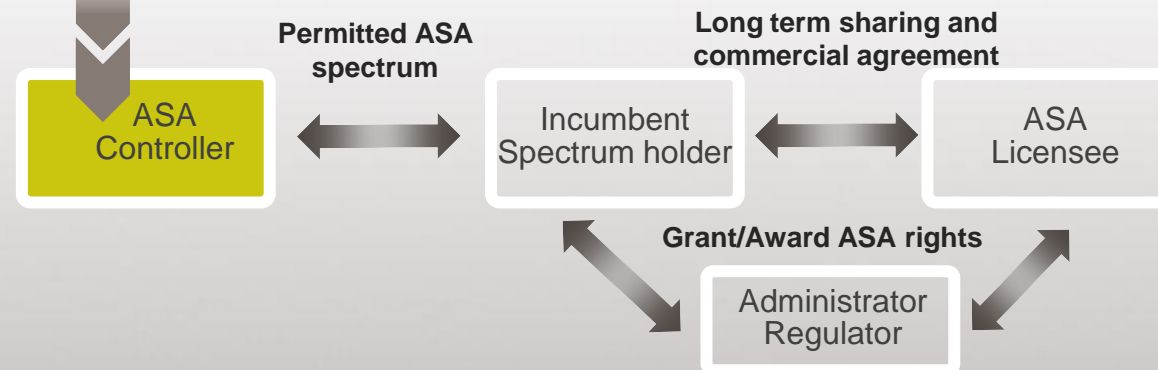


Regular Multi-Band Device¹

- Opportunity to aggregate wider spectrum

SIMPLE

- Simple technology with defined interfaces
- Regulatory framework



¹No device impact due to ASA, just a regular 3G/4G device supporting global harmonized bands targeted for ASA. Carrier aggregation would be beneficial to aggregate new ASA spectrum with existing spectrum, but is not required.

²The O&M system of the ASA rights holder enforces the permitted bands

ASA has Broad Industry Support



- ▶ Backed by the wireless industry

- Digital Europe, Ericsson ,Huawei, Intel, Nokia, NSN, Qualcomm
-

- ▶ Broad support in Europe; Policy Makers, European Commission, Regulators (CEPT), Standards (ETSI)

- Endorsed by EU 27 Member States, naming it LSA (Licensed Shared Access)¹
 - Endorsed by ECC CEPT which released a report on ASA's benefits (April 2012) and is working on harmonizing the 2.3GHz band
 - Study started in ETSI on ASA requirements and network architecture
-

- ▶ Global ASA Momentum

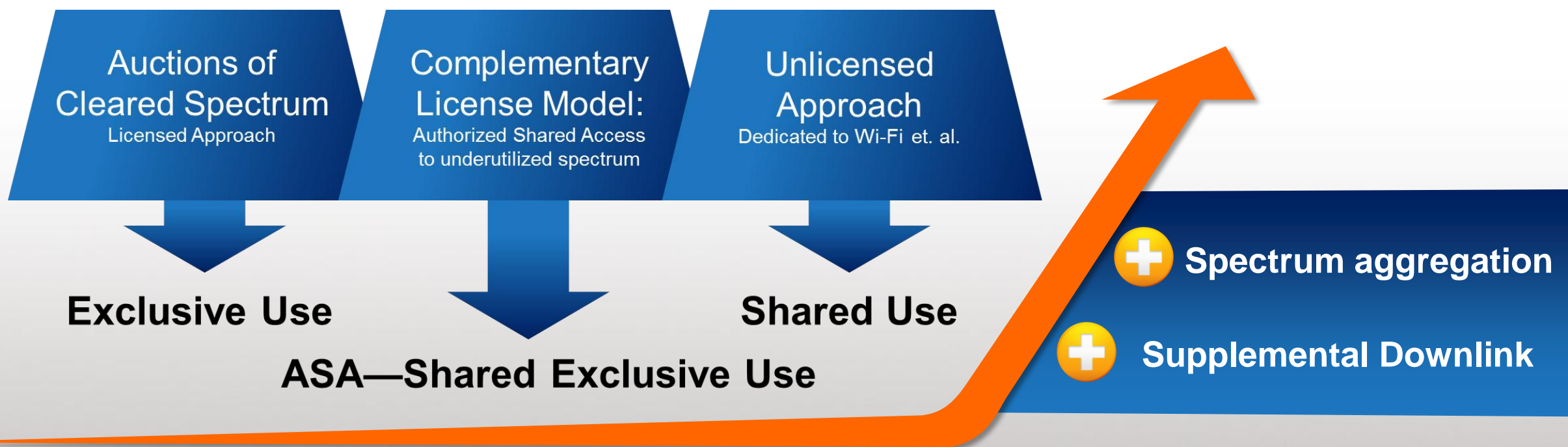
- Interest in the US, China, South East Asia and Brazil

¹ASA has been named LSA (Licensed Shared Access) in the EU by the Radio Spectrum Policy Group'

Summary

1000X

Multiple Efforts Are Required to Access More Spectrum



2:00pm More Small Cells

Taking HetNets To The Next Level



We Can Reach The Air Link Limit—Shannon's Law

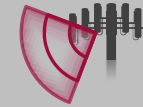
Still ways to improve system capacity



Number of
Antennas



More
Spectrum



E.g. Mitigate
interference

$$\text{Capacity} \approx n \cdot W \cdot \log_2\left(1 + \frac{\text{Signal}}{\text{Noise}}\right)$$

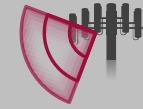
The Biggest Gain—Re-Use Shannon's Law Everywhere!



Number of
Antennas



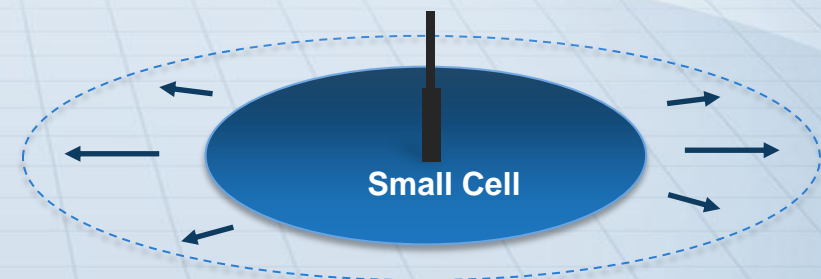
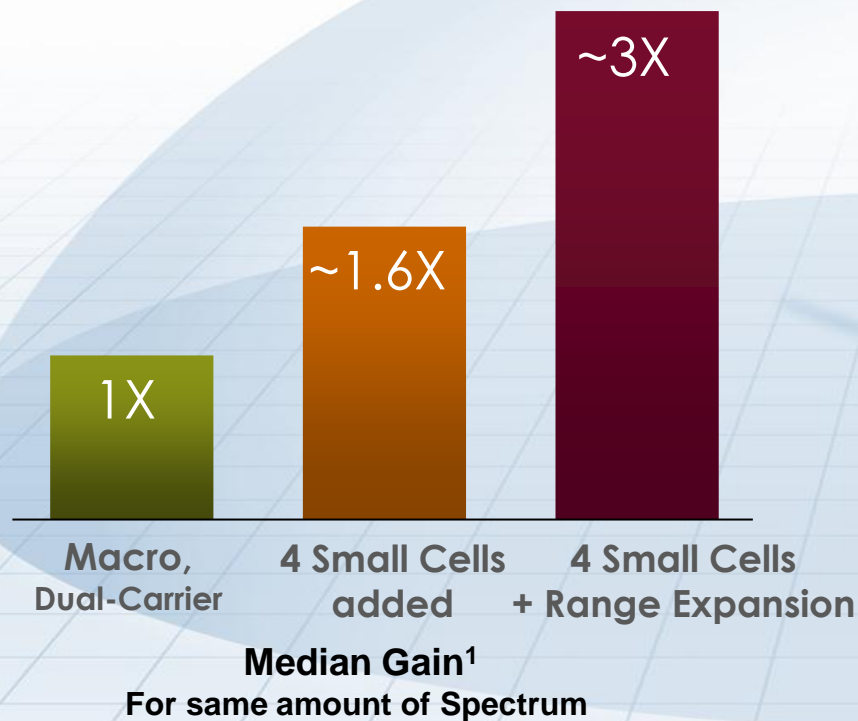
More
Spectrum



E.g. Mitigate
interference

$$\text{Capacity} \approx n \cdot W \cdot \log_2\left(1 + \frac{\text{Signal}}{\text{Noise}}\right)$$



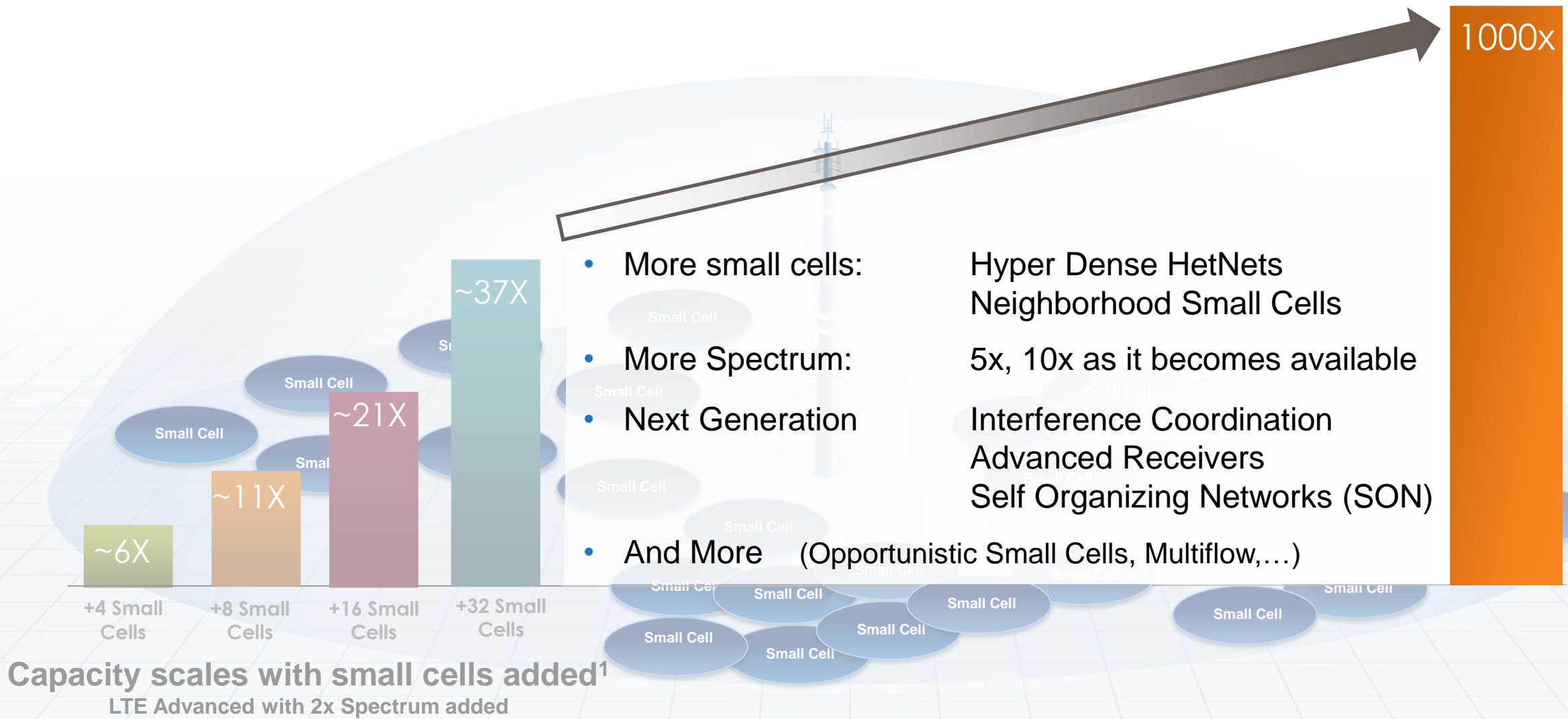


**Possible With HSPA+ Today
And LTE Advanced (eICIC/IC)**

HSPA+ example, Similar Gain for LTE Advanced

1000x Begins With Optimizations Available Today —Range Expansion Further Increases Capacity

¹Gain in median downlink data rate, 4 small cells of pico type added per macro and 50 % of users dropped in clusters closer to picos (within 40m), Model PA3 full buffer ISD 500m. Enabling range expansion features: reduced power on second macro carrier, dual carrier devices and mitigating uplink and downlink imbalance (3dB Cell-individual offset (CIO) and pico noise-figure pad)



The Roadmap To 1000x: More Small Cells, More Spectrum and Improved Techniques

¹Assumptions: Pico type of small cell, 10MHz@2GHz + 10MHz@3.6GHz, D1 scenario macro 500m ISD, uniform user distribution scenario. Gain is median throughput improvement, from baseline with macro only on 10MHz@2GH, part of gain is addition of 10MHz spectrum. Users uniformly distributed—a hotspot scenario could provide higher gains. Macro and outdoor small cells sharing spectrum (co-channel)

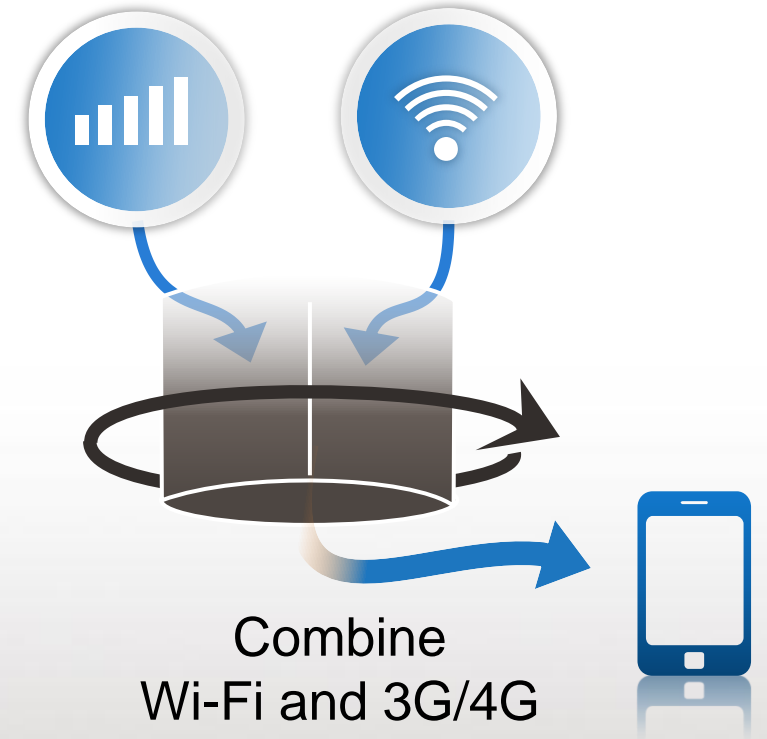
Tighter Wi-Fi—3G/4G Interworking



Convergence of Cellular and Wi-Fi Infrastructure



- 1) Seamless Access—Passpoint/Hotspot 2.0¹
- 2) Operator Deployed Wi-Fi access managed via 3G/4G²

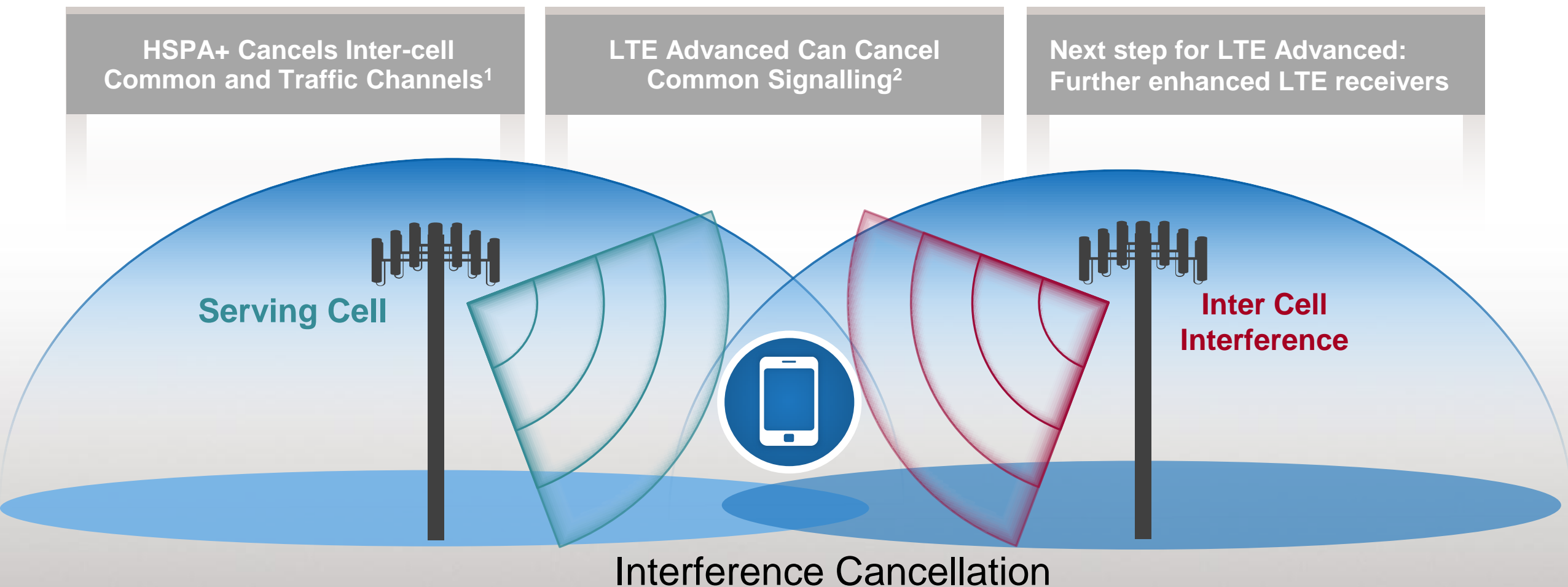


Combine Wi-Fi and 3G/4G

¹Passpoint is the WFA certified implementation of hotspot 2.0, supported by Qualcomm, which enables a simpler, secure and seamless access to Wi-Fi networks. ²Such as more dynamic control of which traffic to offload to Wi-Fi through device centric and/or network centric solutions. Standards enhancements for RAN network centric interworking approaches considered for R12 and beyond.

Next Generation Advanced Receivers

To mitigate interference—even more beneficial in dense HetNets



¹Qualcomm's commercial Q-ICE supports equalization and inter-cell interference cancellation. ²Performance requirement added to 3GPP for cancellation of common signaling (PSS/SSS/PBCH/CRS) in Rel 10/11.

Opportunistic Small Cells for Dense HetNets



**Device triggered Small Cells
(On/Dormant)**

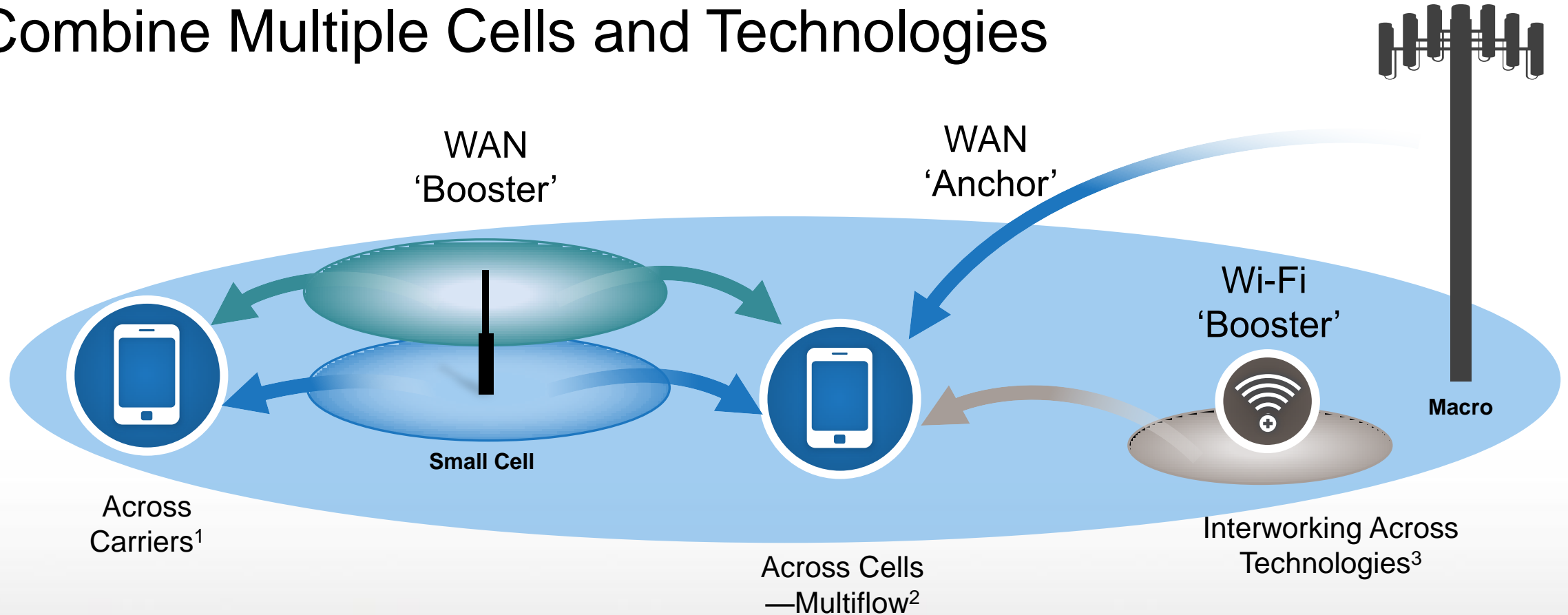
▶ Reduces energy consumption

▶ Reduces interference to further improve capacity

▶ Possible today¹

¹Dormant small cells triggered by the presence of active devices in the vicinity (for 3G/4G).

Combine Multiple Cells and Technologies



► Improved Offload
to Small Cells

► Efficient Network
Load Balancing

► Improved
Mobility

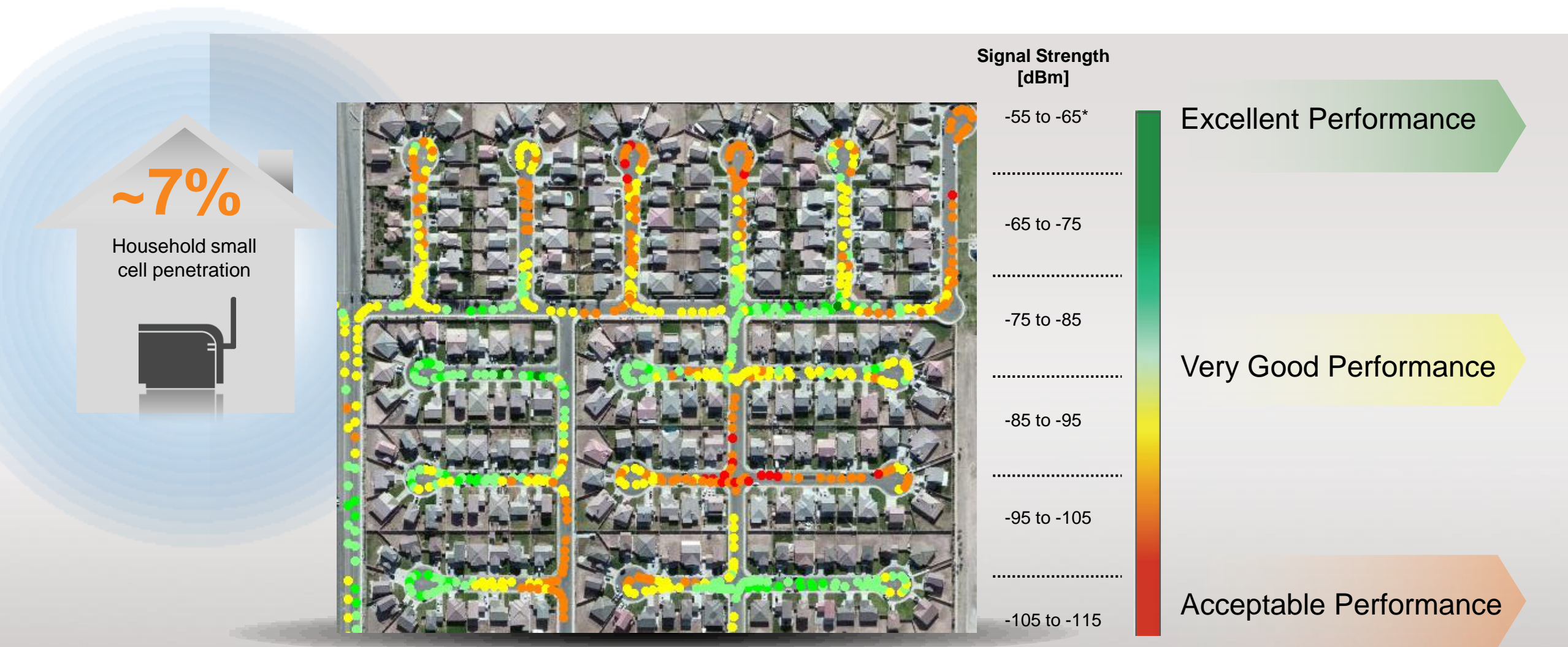
Neighborhood Small Cells

Indoor small cells, leveraging available backhaul

Unplanned deployments, managed by the operator

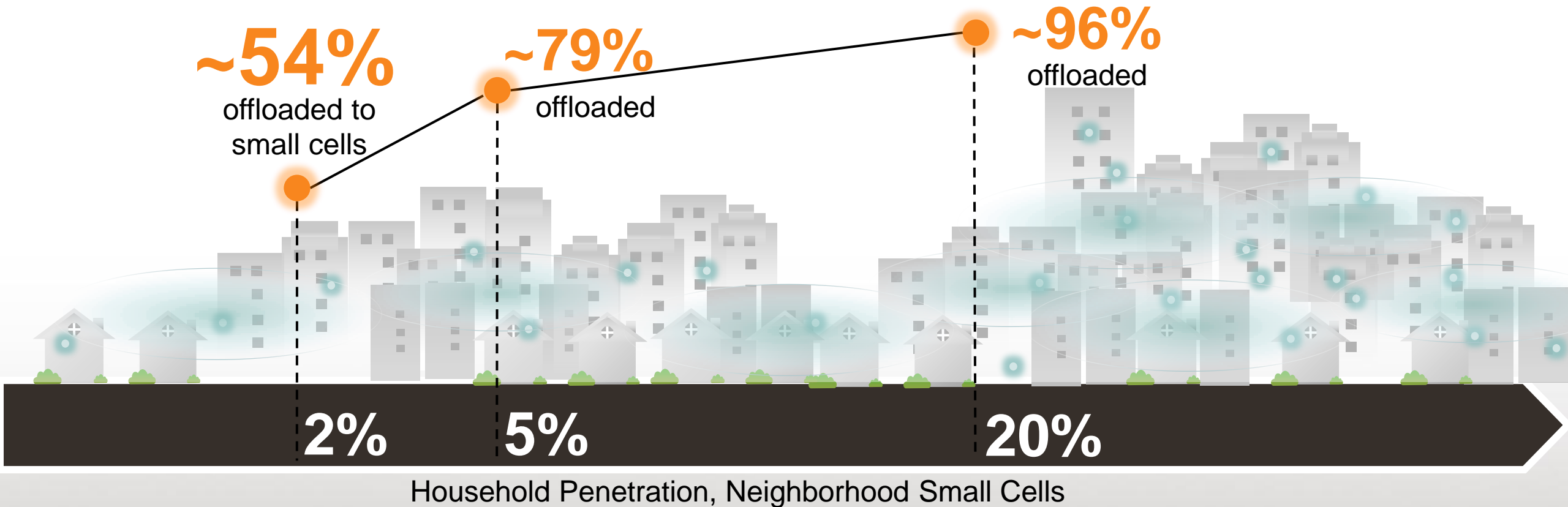


Tests Show Indoor Small Cells Providing Coverage Outside



Shows actual measured received pilot strength for a small cell deployment: -115dBm results in ~700kbps for Rel-7 5MHz in thermal noise limited case; Points less than -115dBm are not shown on the plots.

Even Low Small Cell Penetration Provides Good Performance

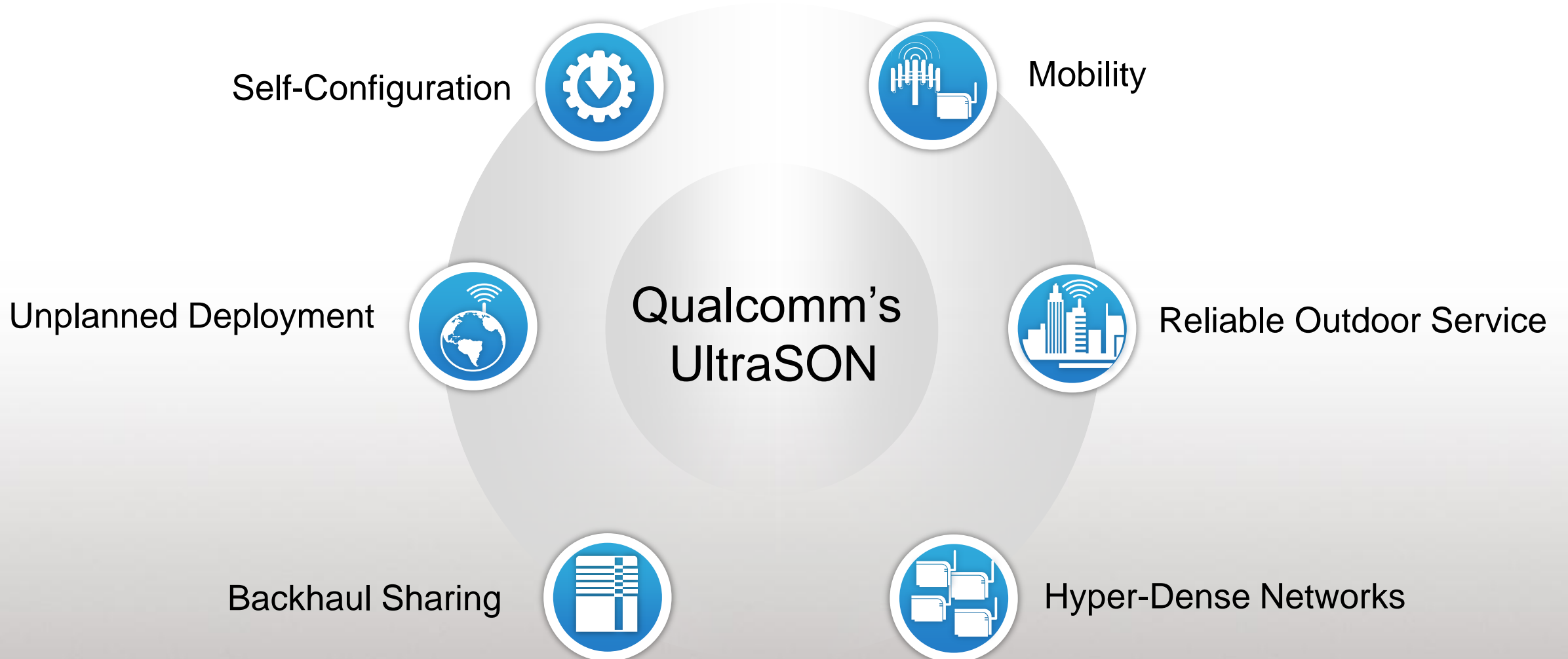


► Low Transmit Power Sufficient¹

► Gain not sensitive to external wall loss

UltraSON Enables Neighborhood Small Cells

Solves Multiple Challenges

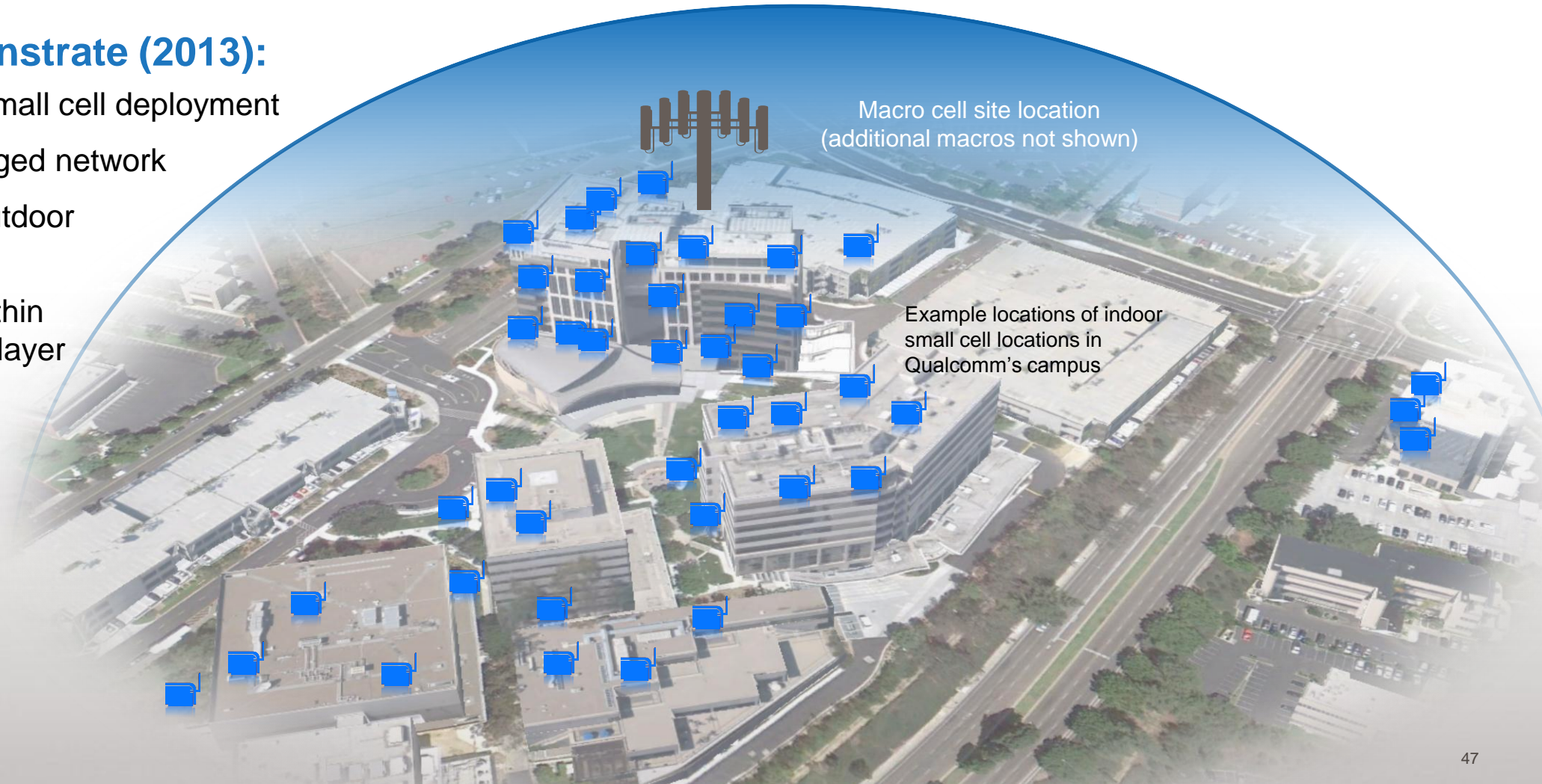


Taking Real World Neighborhood Small Cells to The Next level

Our over-the-air network will be expanded to a hyper dense network

We Plan To Demonstrate (2013):

- ▶ Unplanned, ad-hoc small cell deployment
- ▶ Controlled and managed network
- ▶ Robust indoor and outdoor operation
- ▶ Seamless mobility within small cell and macro layer
- ▶ Capacity gain



Examples of Neighborhood Small Cells Enhancements

1000x¹

Add 10x
Spectrum



~ 20 %
Household
Penetration

- ▶ Higher order MIMO (e.g. from 2x2 to 4x4) especially beneficial indoor/hotspot
- ▶ Higher order modulation (e.g. 256 QAM) can be used more often indoor/hotspot
- ▶ Opportunistically turn small cell on/dormant with usage, beneficial for hyper dense deployments
- ▶ And more...

1000x

With Less
Spectrum



And/or
Fewer
small cells

Median throughput gain versus Macro only baseline

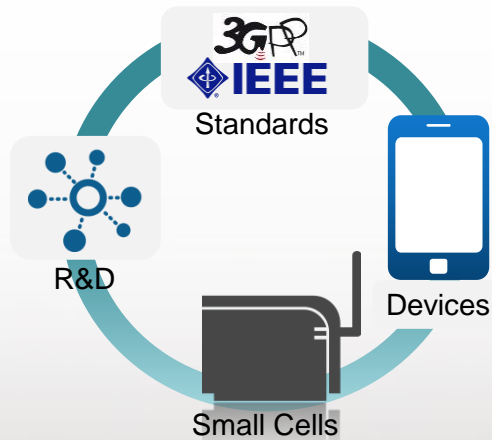
¹Example for LTE FDD, 2x2 MIMO baseline. Assumptions: 70% indoor users, 200 Active users per macro, small cells randomly dropped in households in a mix of 2 to 6 story apartments. 20% household penetration equals ~ 144 small cells per macro.

Summary: Qualcomm Enables Small Cell Solutions for 1000x

Multiple paths to 1000x with different small cell types, indoor, outdoor, ...

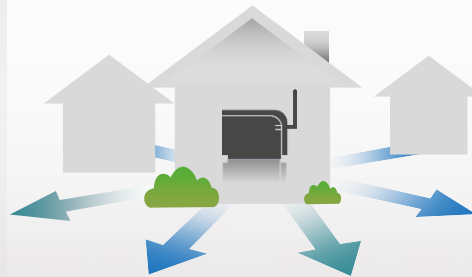
1000X

End-to-End Approach



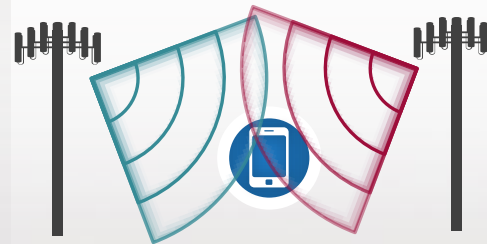
Demonstrating hyper-dense HetNets in 2013

New Inside-Out Deployment Models



Neighborhood Small Cells

Enabling Technologies



Interference Management
UltraSON

Enabling Small Cell Product Solutions



3G/4G+Wi-Fi
chipset solutions

2.15pm Product Solutions

Powering 1000x



A scenic view of a park, likely Central Park in New York City, with many people sitting on the grass. In the background, a dense city skyline with various skyscrapers is visible under a clear sky. The foreground shows a large tree on the right side, and the grass is a mix of green and yellow, suggesting autumn. The overall atmosphere is bright and sunny.

Qualcomm Atheros Small Cell Products

4G World, October 2012



Qualcomm Driving Small Cell Technology

Investment in enabling technologies

- Extensive small cell system on chip (SoC) development
- Initiatives in HetNet, SON, HotSpot 2.0
- Wi-Fi leadership

3G

4G

Wi-Fi

DesignArt provides immediate access to field tested LTE & backhaul SoC

- Single SoC supports LTE access and LOS/NLOS wireless backhaul

DesignArt
Networks

Qualcomm SoC roadmap leverages UE leadership & scale

- Qualcomm is leader in 28nm process node
- Low power processors including Snapdragon™

QUALCOMM

Qualcomm Small Cell Value Proposition

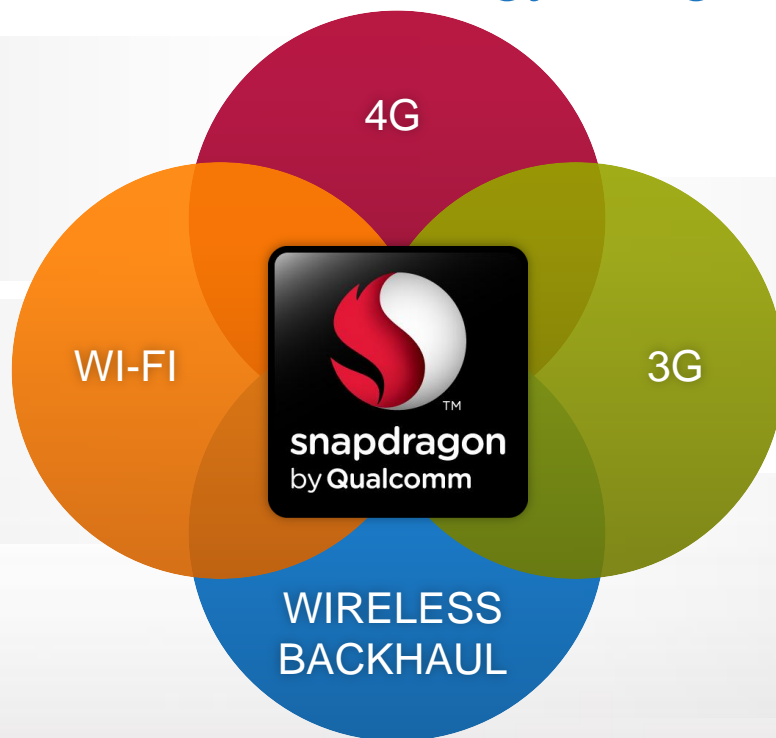
Industry's highest level of small cell technology integration

LTE

- FDD/TDD
- Carrier aggregation

802.11n/ac

- Dual-band, dual concurrent
- 3x3 MU-MIMO



UMTS/HSPA+

- Rel. 10

Unified Mobile Backhaul

- LOS/NLOS
- 10/20 MHz TDD/FDD
- 2x2 MIMO

- ▶ Concurrent 3G/4G access
- ▶ Complete RF solution: RFICs, DPD/CFR, Network Listen, digital I/Q
- ▶ Comprehensive supporting portfolio: Wi-Fi 802.11n/ac, Gbit Ethernet, Bluetooth, GNSS, power management

Qualcomm's Small Cell Differentiation



Systems expertise: Silicon and firmware/software; market leadership in UE silicon enables synergies (interoperability, features)



Best-in-class performance: Modem, RF, GPS, Snapdragon processor, security, low power, and dedicated network listen



Multiple technologies: Small cell SoC supports both 3G and 4G



Complete RF solution: Global 3GPP bands; Rx/Tx Diversity, High Performance Rx Sensitivity; optimized for enterprise use



Wi-Fi integration: Optimized reference designs, connectivity manager, systems design, and algorithm for cellular and Wi-Fi interworking



Fully validated and field tested UltraSON™ and HetNet solutions

- Interference management for shared & dedicated carrier deployments (3G and 4G)
- Mobility management in active and idle states (active and idle hand in)
- HetNet algorithms to enable multi-vendor deployments and Wi-Fi integration



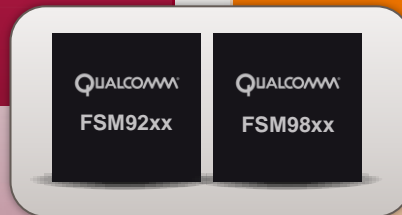
Qualcomm Engineering Services provides field and RF optimization

Small Cell Vision

NEIGHBORHOOD SMALL CELL

Provide Low Cost Access

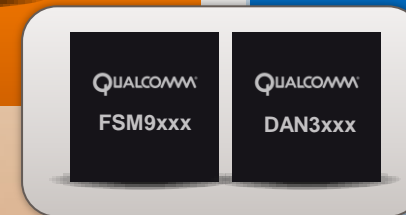
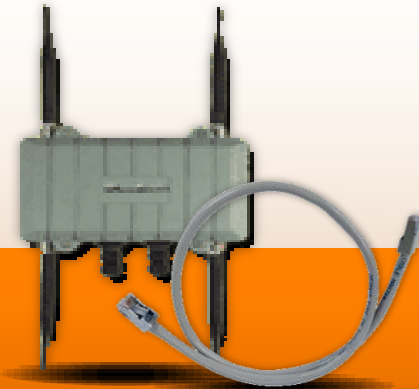
- LCA with 3G/4G/Wi-Fi
- UltraSON
- Coexistence & AP Connection Mgmt



ENTERPRISE

Provide in Building Coverage

- 3G/4G/Wi-Fi
- UltraSON
- Coexistence & AP Connection Mgmt



METRO/PICO/MICRO

Outdoor Hotspots

- 3G/4G/Wi-Fi
- UltraSON and HetNet
- HotSpot 2.0
- Coexistence & AP Connection Mgmt
- Wireless Backhaul



Convergence of Cellular and Wi-Fi Infrastructure



Convergence of Cellular and Wi-Fi Infrastructure

CHALLENGES

- Efficient cellular offload
- Seamless mobility and user experience
- QoS management
- Security
- Radio coexistence

QUALCOMM DIFFERENTIATION

- Wi-Fi and 3G/4G cellular SoCs & RF
- Complete reference designs
- End-to-end connection management
- Mobile IP
- Self configuration



Foundations: Hotspot 2.0, UltraSON, HetNet

Converged Access Points

- ▶ Complete reference designs
 - Flexible, modular
 - 3G/4G/Wi-Fi RF band flexibility
- ▶ RF considerations:
 - Radio coexistence
 - Power consumption (e.g., Power over Ethernet)

Qualcomm is Developing Reference Designs for Converged Access Points

- ▶ Radio and connection management
 - Best radio link selection (Wi-Fi vs. cellular)
 - QoS management
 - Scheduling
- ▶ Hotspot 2.0
 - Seamless Wi-Fi connectivity for mobile devices
 - User access to information without having to associate with the Wi-Fi AP
 - Improved information security between STA and AP
 - Traffic offload from cellular to Wi-Fi

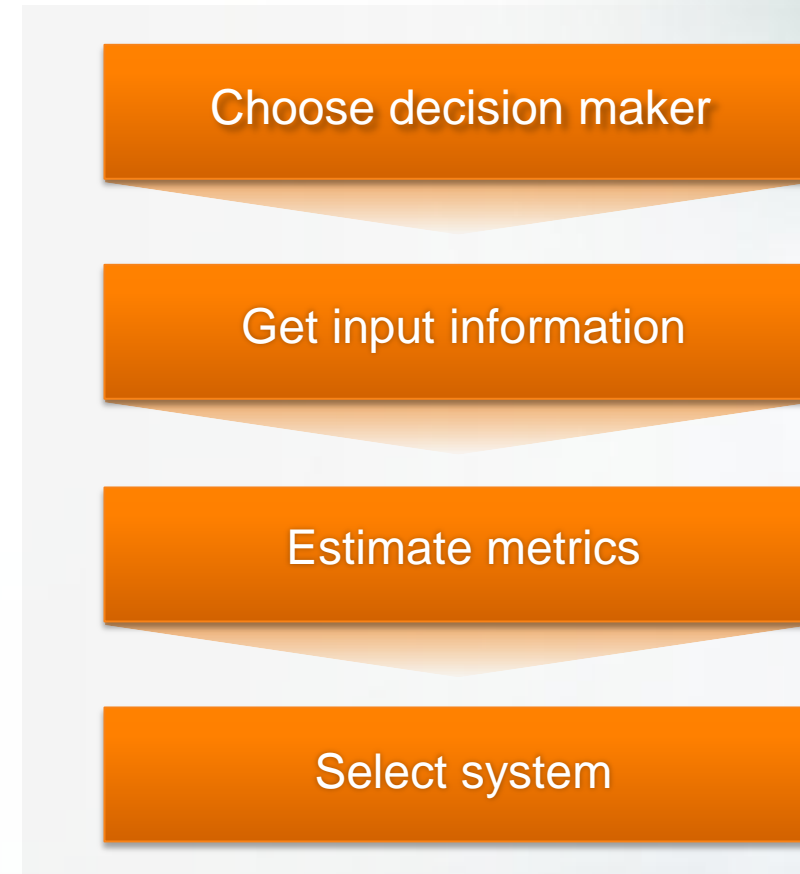
Multi-Technology Connection and Radio Resource Management

- ▶ Smartphones will associate themselves with known Wi-Fi access point whenever discovered.
- ▶ This is not always the best choice.
 - May result in Wi-Fi congestion
 - May cause excessive interference or high activity on other Wi-Fi APs in the vicinity
 - There may be areas where Wi-Fi signals are much weaker than cellular.



AP Connection Management

- ▶ **Decision maker**
 - AP or mobile
- ▶ **Input info per system (Wi-Fi/small cell/macro)**
 - Backhaul rate, Internet connectivity, available OTA and hardware resources
 - Available resources monitored both for cellular and Wi-Fi
 - Macro info can be collected via network listen
 - Mobile info: applications, path loss, rate category
- ▶ **Estimate performance metrics per system**
 - Metrics: throughput, delay/jitter, load
 - Throughput prediction prior to connection
 - End-to-end throughput estimate during connection
- ▶ **Select system**
 - Pick best system for each mobile at admission or during connection





AP Connection Management

- ▶ Seamless traffic and mobility management across licensed and unlicensed systems
- ▶ Joint system selection software can utilize network and mobile based information.
- ▶ The combination of enhanced AP and Qualcomm's Connectivity Engine (CnE) at UEs

	Enhanced AP	Non Enhanced AP
UE with CnE	Best optimization with complete information	Intelligent selection based on UE info and network estimation
UE without CnE	Intelligent selection based on AP info and standardized UE reports	No optimization

Qualcomm is developing enhanced AP methods for system selection that can operate with mobiles with CnE and without CnE

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