CTIA May 22 2013

What's Next for LTE

QUALCOMM®

Prakash Sangam

1000x, Spectrum Innovation & Chipset Evolution

- 1:00pm - 1:30pm **The 1000x mobile data challenge**
  Innovations in small cells, spectrum and higher efficiency
- 1:30pm - 2:00pm **What is next for HSPA+?**
  And related evolutions; WCDMA+ and S-UMTS

Speaker: Rasmus Hellberg,
Sr Director, Technical Marketing

- 2:00pm - 2:30pm **What is next for LTE?**
  LTE Advanced, opportunistic HetNets and LTE Direct
- 2:30pm - 3:00pm **What is next for Wi-Fi?**
  The Wi-Fi evolution, its role in 1000x, connected home and new frontiers

Speaker: Prakash Sangam,
Director, Technical Marketing

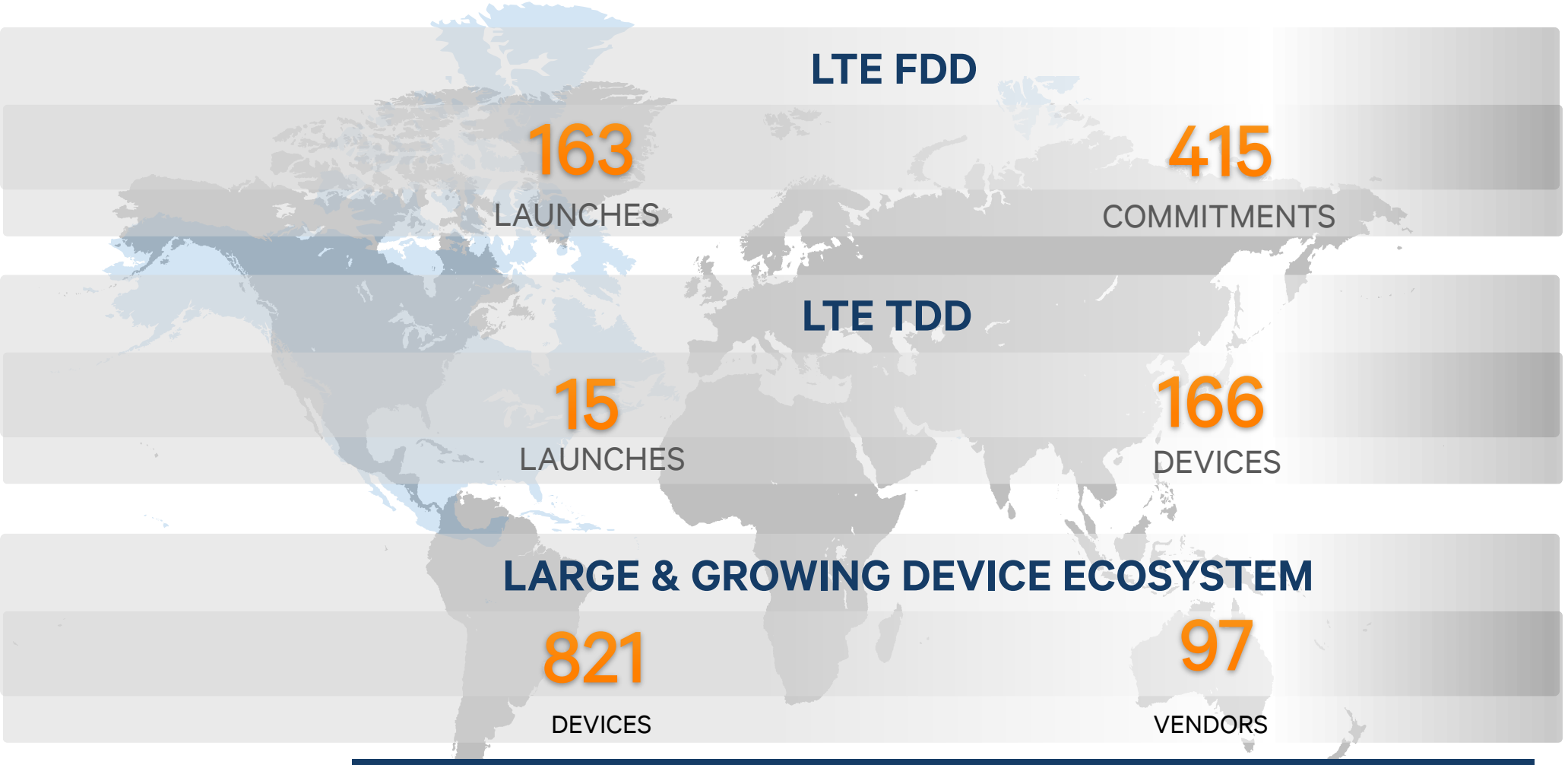
- 3:00pm - 3:15pm Break
- 3:15pm - 4:00pm **How do we access more spectrum for 1000x?**
  Cleared, Licensed Spectrum (Voluntary Incentive Auction)/Authorized Shared Access (3.5 GHz)/Unlicensed Spectrum (5 GHz)

Speaker: Dean Brenner,
Sr VP, Government Affairs

- 4:00pm - 4:30pm **Addressing LTE Band Fragmentation**
  RF360 progress, carrier aggregation and more
- 4:30pm - 5:00pm **The 3G/4G multimode roadmap**
  Including LTE Broadcast, VoLTE and voice interworking

Speaker: Sunil Patil,
Director, Product Management

LTE - Strong Global Growth



LTE FDD

163
LAUNCHES

415
COMMITMENTS

LTE TDD

15
LAUNCHES

166
DEVICES

LARGE & GROWING DEVICE ECOSYSTEM

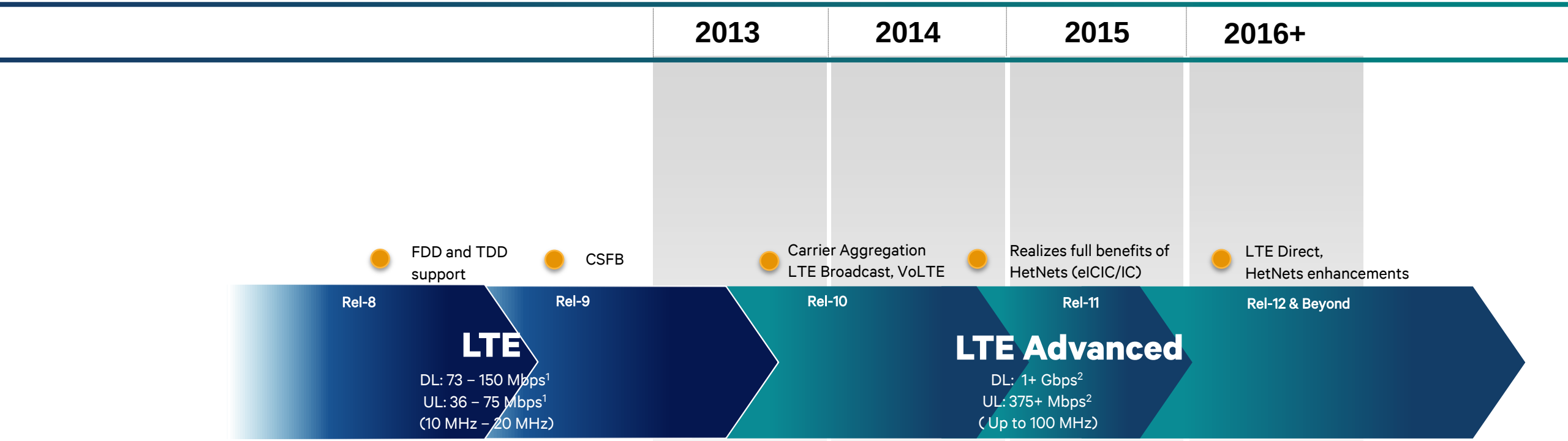
821
DEVICES

97
VENDORS

Global LTE connections reached 100 Million in May 2013
– Wireless Intelligence

Source: www.gsacom.comJ Apr 2013

LTE continues to evolve



[1]Peak rates for 10 and 20 MHz FDD using 2x2 MIMO, standard supports 4x4 MIMO enabling peak rates of 300 Mbps. Peak data rates takes overhead into account, per standards172 Mbps is achievable in 20 Mhz.
[2]Peak rates can exceed 300 Mbps by aggregating multiple 20 MHz carriers planned for LTE Advanced (LTE Rel-10). Peak data rate can exceed 1 Gbps using 4x4 MIMO and at least 80 MHz of spectrum.

Commercial
Note: Estimated commercial dates.

Created 4/16/2013

Qualcomm LTE Advanced leadership

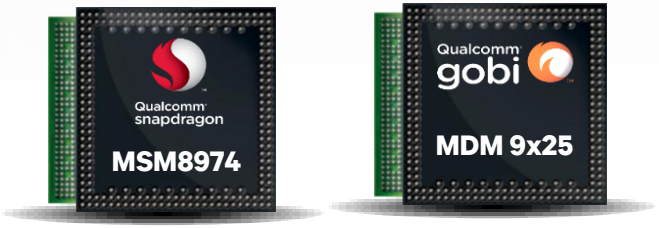
STANDARDS LEADERSHIP

- A main contributor to key LTE Advanced features
- Major contributor for ITU IMT-Advanced submission

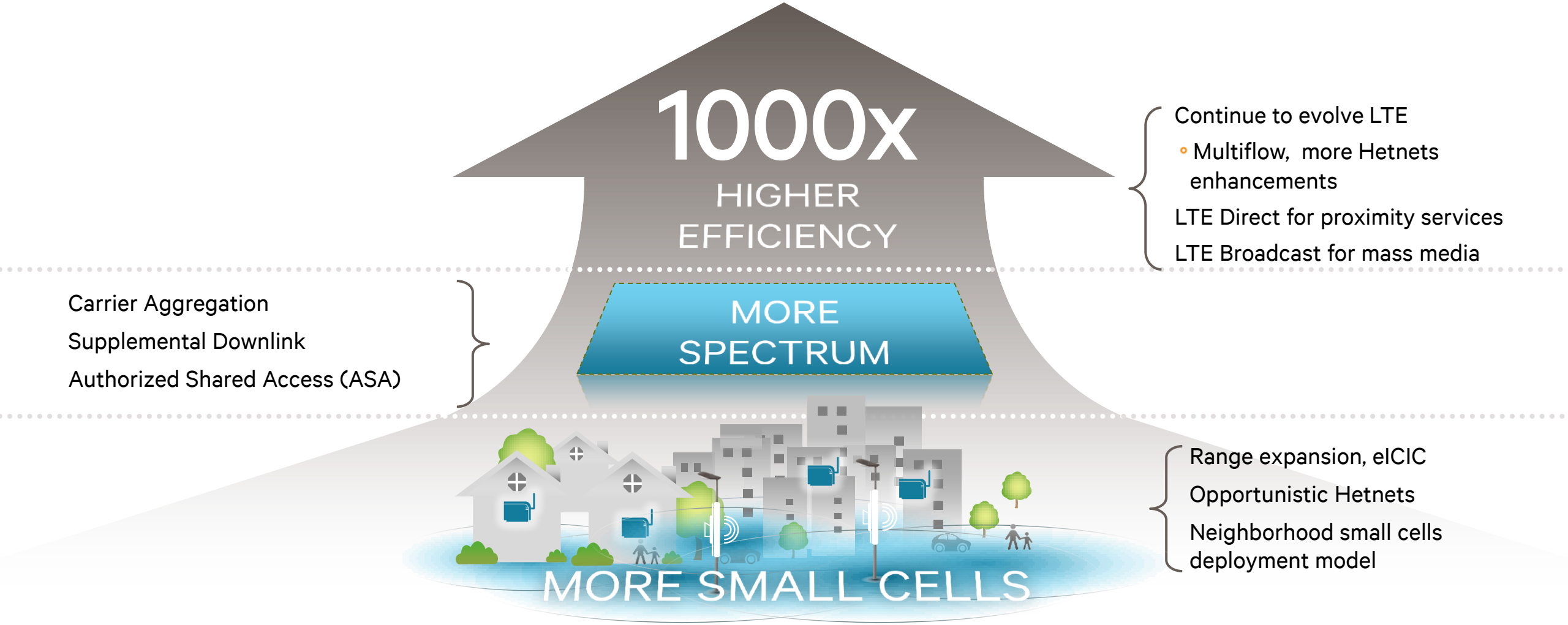
INDUSTRY-FIRST DEMOS

- MWC 2013: Live Opportunistic Smallcells
- MWC 2012: Live Over-The-Air HetNet Demo with Mobility
- MWC 2013: Live Over-The-Air opportunistic HetNet Demo with VoIP Mobility

INDUSTRY-LEADING LTE/3G CHIPSETS



LTE Advanced is key to 1000x



Continue to evolve LTE
- Multiflow, more Hetnets enhancements

LTE Direct for proximity services

LTE Broadcast for mass media

Carrier Aggregation

Supplemental Downlink

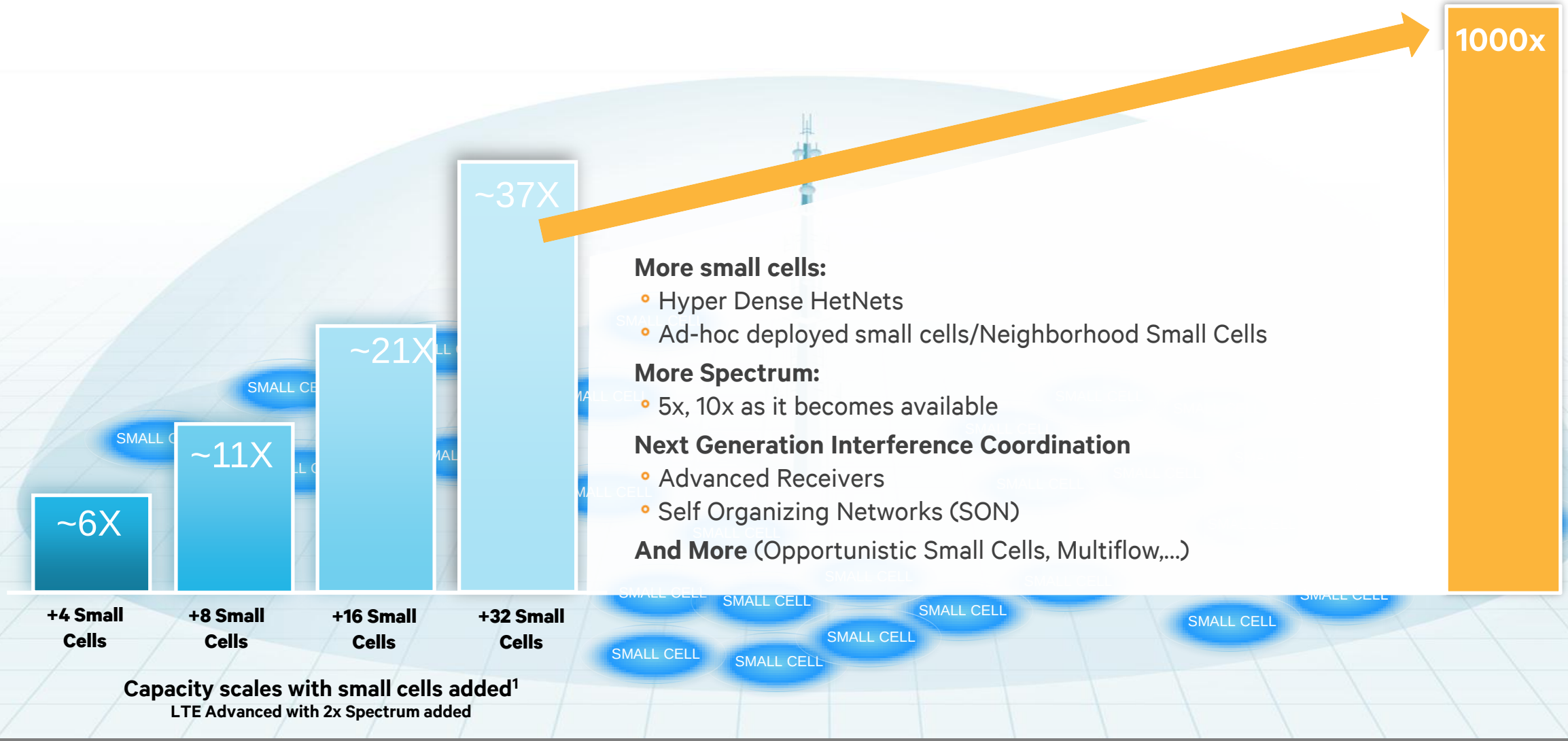
Authorized Shared Access (ASA)

Range expansion, eICIC

Opportunistic Hetnets

Neighborhood small cells deployment model

Note: neighborhood small cells and ASA are not covered in this presentation, see www.qualcomm.com/hetNets and www.qualcomm.com/spectrum for more details.



Capacity scales with small cells added[1]
LTE Advanced with 2x Spectrum added

The roadmap to 1000x:
more small cells, more spectrum and improved techniques

[1] Assumptions: 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)

LTE Advanced opportunistic small cells for dense HetNets

Reduces energy consumption

Reduces interference to further improve capacity

Possible today[1]

Device triggered small cells (on/dormant)

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

LTE Direct

Operator enabled proximity services

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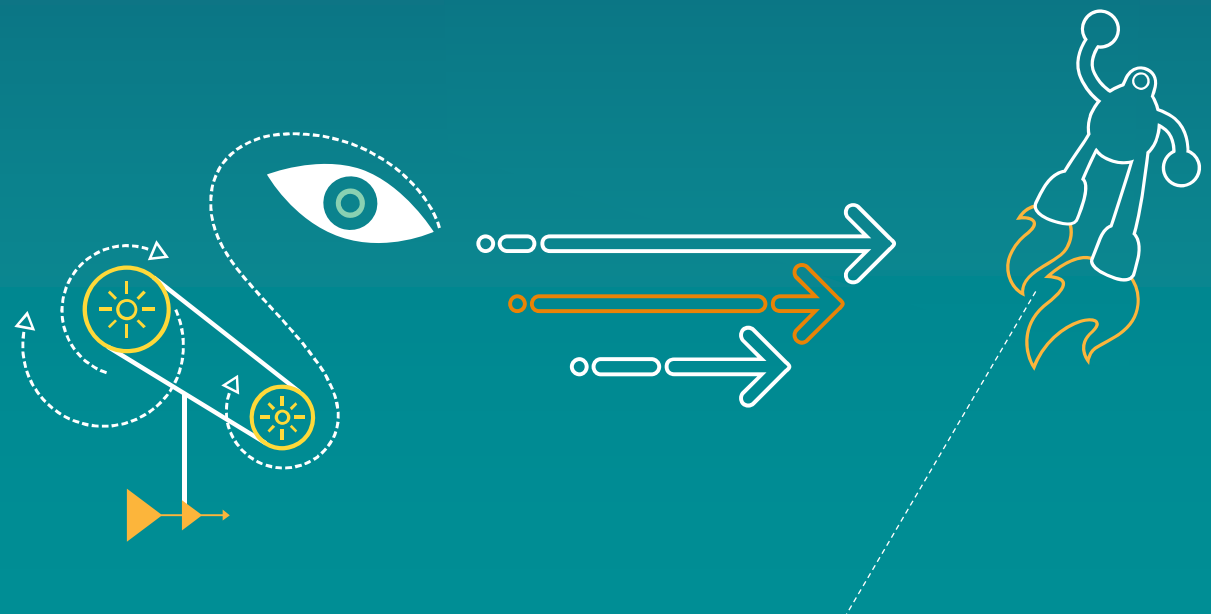


Hyper connected world around you

- WHO'S AROUND?
- WHAT'S NEAR BY?
- IS IT RELEVANT NOW?

Stores / Restaurants

Connected Home

Family, Friends & Pets

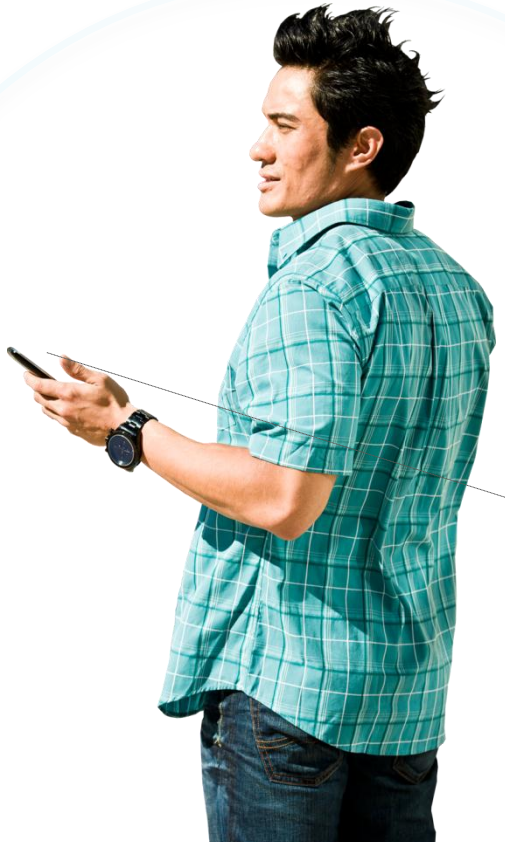
Professional Contacts

Hyper connected world around you

You need a “Wireless Sense”

Stores / Restaurants

Family, Friends & Pets



Professional Contacts

Connected Home

LTE Direct – An illustration

All devices broadcast their needs/services via “*Expressions*”

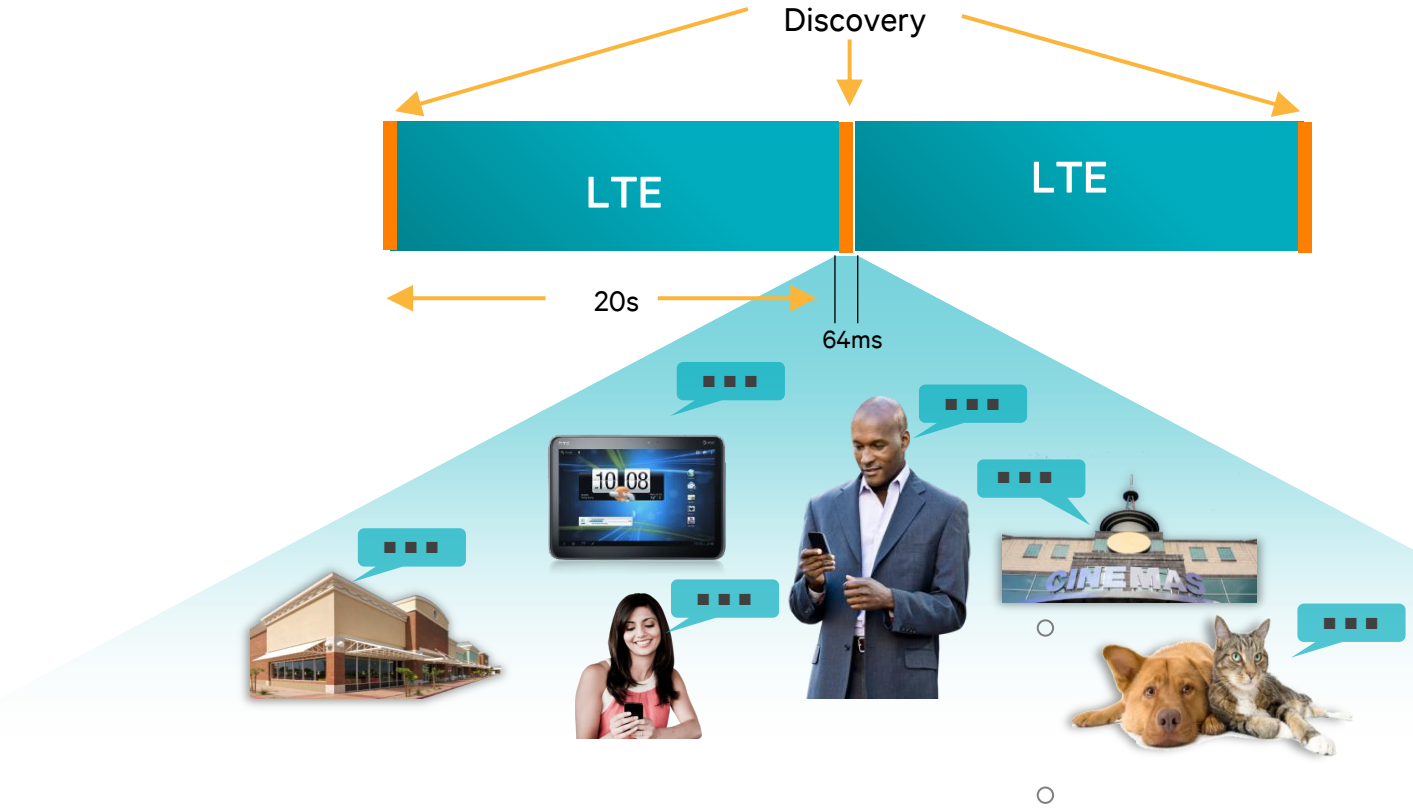
Services are *passively* identified (no user intervention)

Relevance is determined

Communication with the desired service

Designed for autonomous “Always-ON” discovery

Low-overhead with extremely low battery consumption



- All devices either broadcast their needs/services or listen to others
- Switch between broadcast and listen based on services/applications

Short “wake-up” time

All devices synchronously “wake-up” for discovery

Very high discovery capacity

E.g. Can discover 2816 services in 64msec

Highly scalable

Overhead scales with the capacity;
Easy to configure resources to suit demand

Negligible LTE capacity impact

E.g. 0.3% reduction in uplink capacity for 2816 expressions

Source: Qualcomm simulations; Assumptions:10MHz bandwidth,64 discovery sub frames every 20s; Operator or some other entity has to manage a database of expressions and services they represent

Privacy sensitive, connectionless discovery

All devices broadcast 64 or 128 bit service identifier called "***Expression***" for each service they offer

Devices in the proximity read "Expressions" to determine relevance

Fast and Easy

Expressions are easy to read & decode, no connection needed

Anonymous

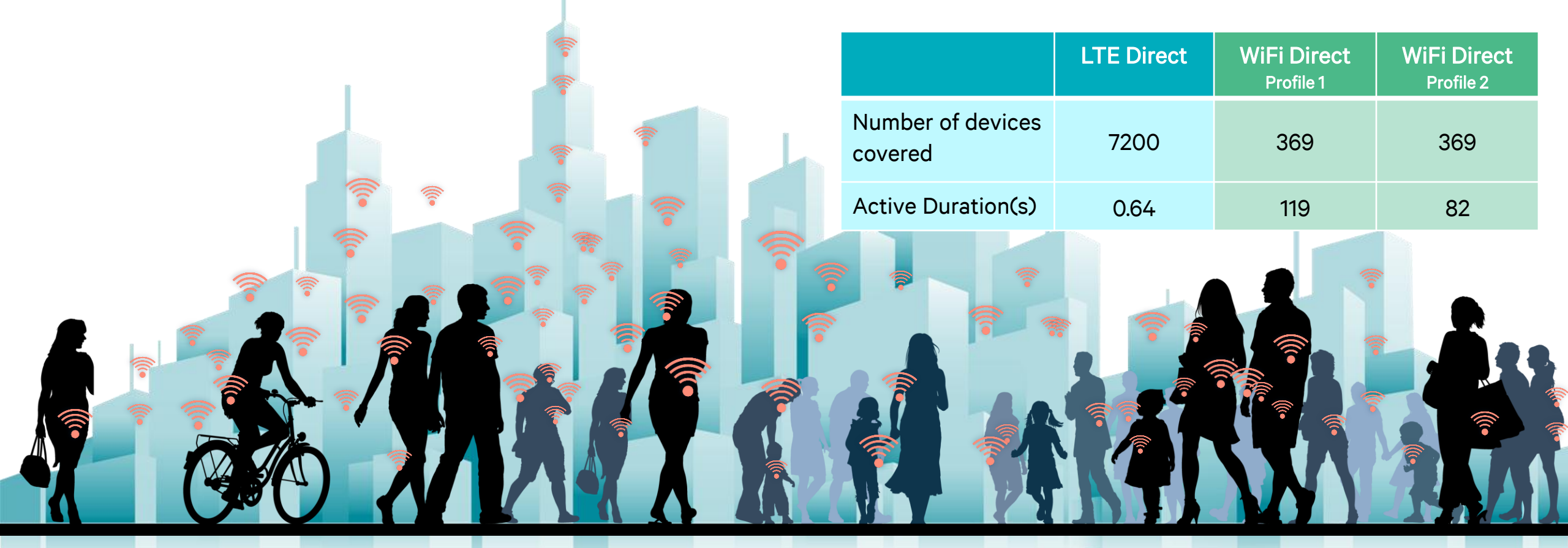
Devices do not need to reveal their identity or location

Operator or some other entity has to manage a database of expressions and services they represent ; Device to device contact needed for communication, but not for discovery

Unparalleled scalability

Superior discover capacity and latency than other device-to-device technologies

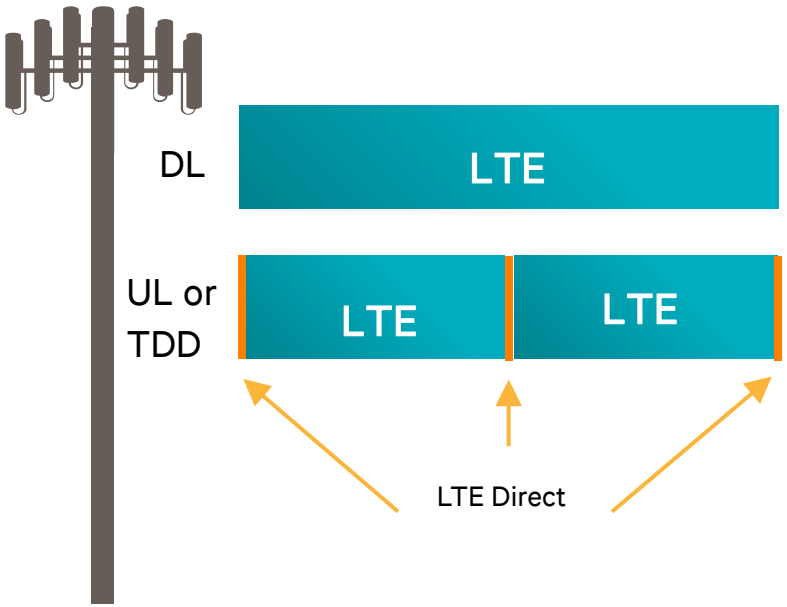
	LTE Direct	WiFi Direct Profile 1	WiFi Direct Profile 2
Number of devices covered	7200	369	369
Active Duration(s)	0.64	119	82



Source – Qualcomm simulations; Assumptions: Outdoor dense deployment scenario (e.g Times Square); Ped A channel model, ITU-1411 NLOS model; Wi-Fi Direct – 10dB shadowing and 20dB wall penetration loss; BW - LTE Direct 10 MHz, Wi-Fi Direct – Synchronous operation with 20 MHz @ 5 GHz; 23dBm tx power, -5dB antenna gain, 7dB noise figure ; WiFi Direct Profile 1 – 100 % Service Discovery; WiFi Direct Profile 2 – 10 % Service Discovery;

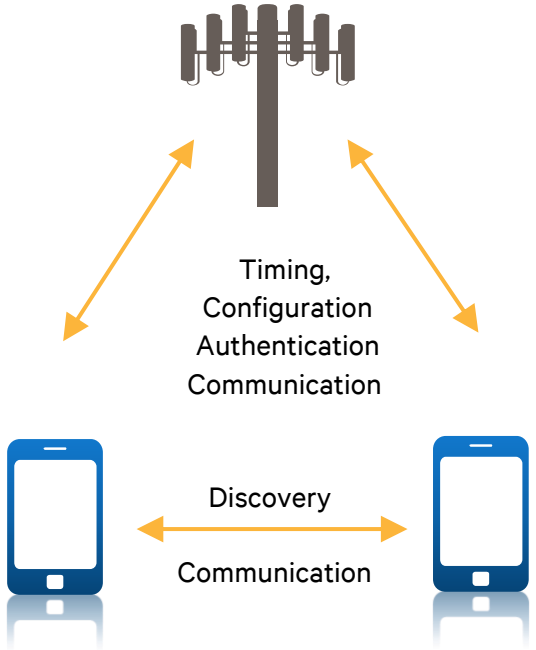
LTE Direct is a “Native” LTE solution

Uses LTE Uplink



- For discovery and optionally also for communication

Leverages LTE Infrastructure



- LTE network used for configuration and authentication
- Communication can be either through network or direct device to device

Proposed to be part of LTE Standard

Study item in Rel. 12

3GPP™

A GLOBAL INITIATIVE

Differentiated app/services enabled by proximate discovery

LTE Direct

Discover

Social Matching -
- Friends/family discovery

Push Advertising -
- Hyper-relevant notifications

Venue Services -
- e.g. tourist bulletins, crime alerts

Leash

Geo-Fencing -
- Child, pet, elderly, etc.

Dwell Time -
- Auto notification

Credentialing -
- Qualify within a boundary

Trigger

Auto-Authentication-
- Proximity triggered automation

Loyalty Services -
- Autonomous ‘check-in’

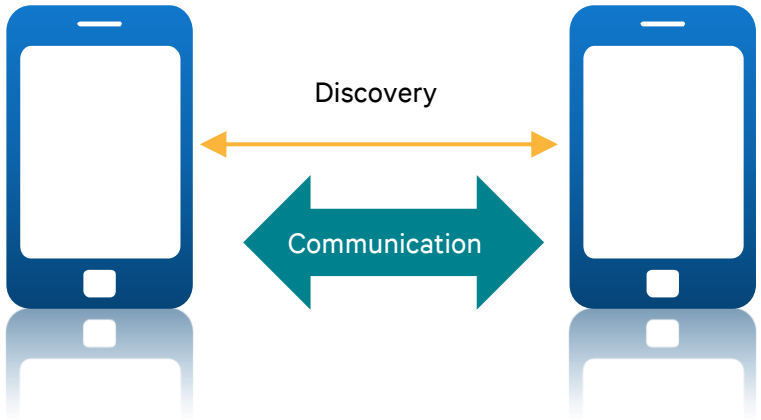
Gaming –
- e.g. scavenger hunts, multi-payer games

Search

Query-Response -
- User initiated and ad-hoc

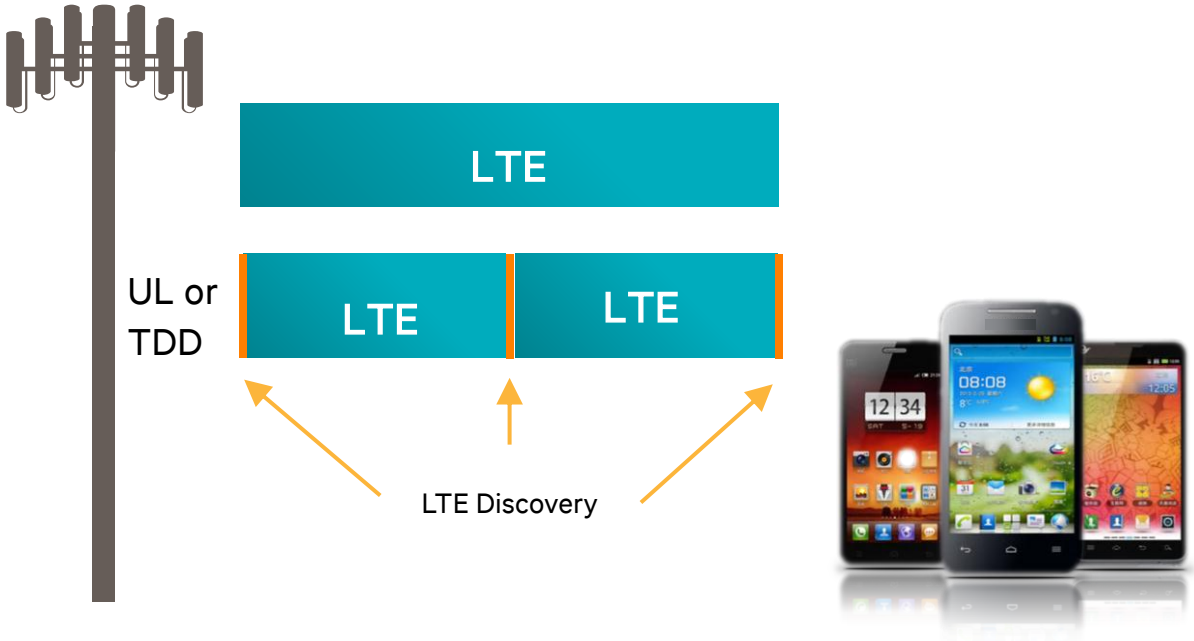
Next-Gen solution for emergency services

Robust



- Licensed spectrum ensures no interference & very-high reliability
- Works even during extreme situations like infrastructure failure
- Scalable to address small emergencies to natural disasters

Cost-effective



- Utilizes commercial LTE network and spectrum
- Leverages huge LTE device ecosystem
- Offers flexibility and customization to suit emergency services' needs

LTE Direct : Operator enabled proximity services

LTE “Native” Direct Device-to-Device Solution

Uses LTE spectrum, and network; Candidate feature in 3GPP R12

“Always-ON” Privacy Sensitive Discovery

Autonomously discovers 1000s of relevant devices/services in a battery–efficient way

Enables New and Enhances Existing Apps/Services

Differentiated app/services enabled by proximate discovery; Opportunities for operators to monetize

Next-Gen Solution for Emergency Services

Robust; Cost-effectively leverages commercial LTE infrastructure and ecosystem

Thank you

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www.qualcomm.com & www.qualcomm.com/blog

CTIA May 22 2013

What's Next for Wi-Fi

QUALCOMM®

Prakash Sangam

Wi-Fi: An integral part of the wireless landscape

Part of the solutions to “1000x mobile data challenge”

Wi-Fi supported in all smart devices

At the center of connected home

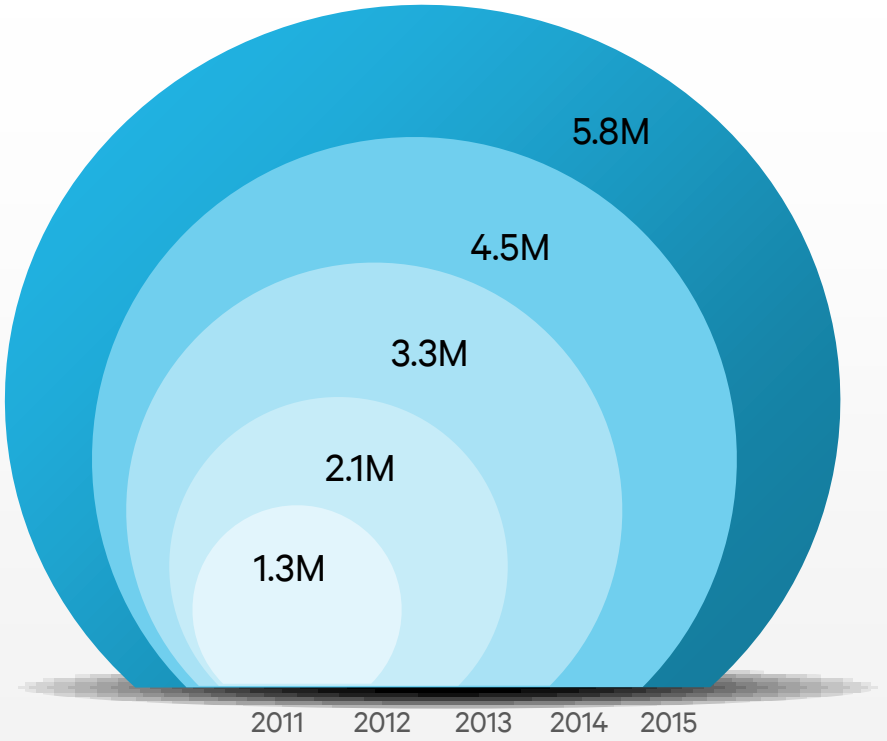
The universal technology in smart connected homes

Opening new frontiers for wireless connectivity

Leveraging ubiquity of indoor Wi-Fi for many new applications and services

Wi-Fi is becoming ubiquitous

Growing Global Reach



Number of public hotspots worldwide.

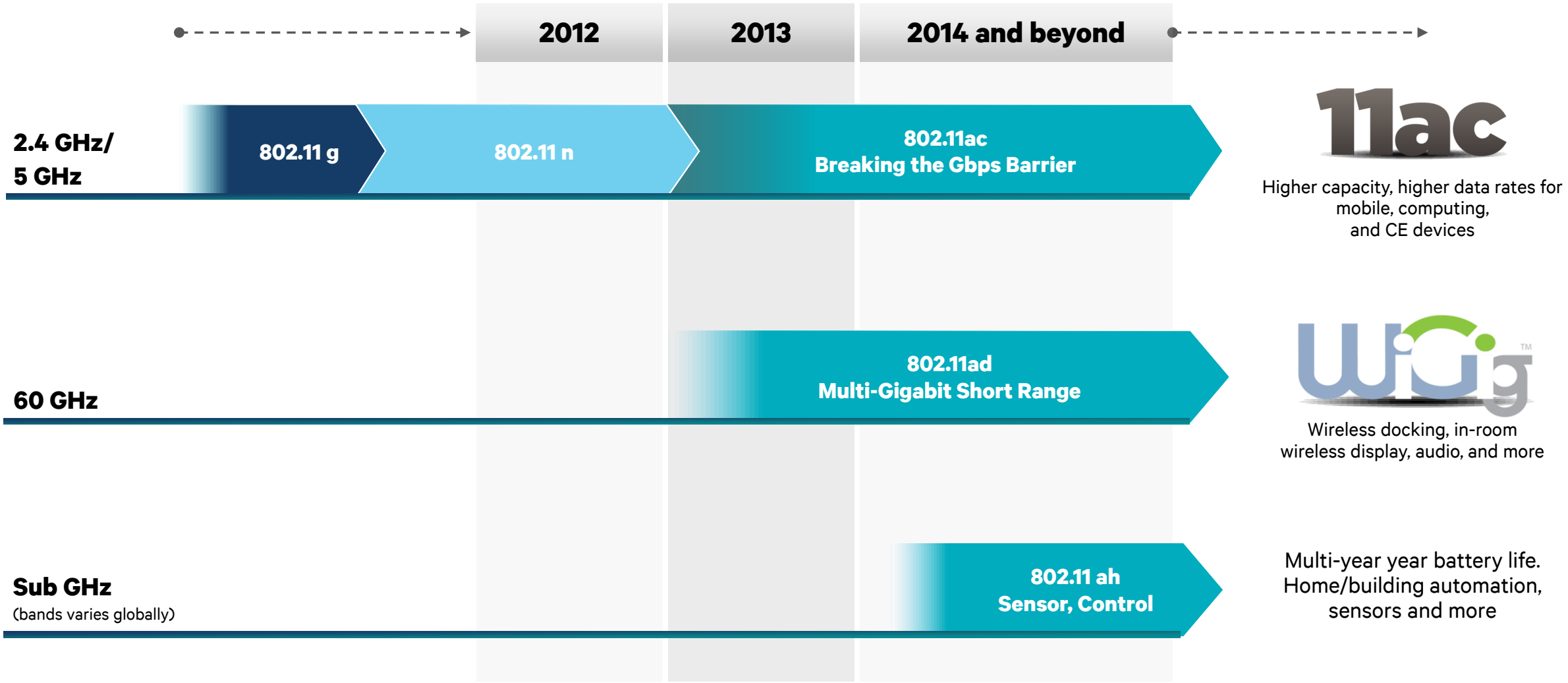
Source: Wireless Broadband Alliance (WBA) and Informa Telecoms & Media.

Expanding Device Support

Wi-Fi Enabled Devices Shipped	2012 MU	2015 MU
Phones/Accessories	685	1,459
Tablets, E-Readers, Media Players, etc	199	360
Laptops, Desktops, Peripherals, etc.	392	717
Connected Home	107	287
Others	39	338
TOTAL	**1,422**	**3,161**

Source: ABI Research forecast, December 2012. “Connected Home” category includes Flat Panel TVs, Set-top Boxes, Gaming Consoles, Gaming Console Controllers, DVD/Blu-ray Players/Recorders, OEM Remote Controls,3D Glasses, Digital Photo Frames. “Others” include Automotive Health, Fitness and Medical, Smart meters, automation, industrial

A strong Wi-Fi evolution path



Qualcomm VIVE™: Enabling end-to-end 11ac ecosystem

Driving 11ac in migration in mobile through pin compatible solutions

Extending industry leading Wi-Fi performance[1]

~6x lower power consumption (v/s our own 11n)

[1]AnandTech -The HTC One X for AT&T Review by Brian Klug on 5/1/2012; “Unsurprisingly the One X posts the highest WLAN throughput I’ve seen from a smartphone to date.” ; This devices uses Qualcomm’s 802.11n solution

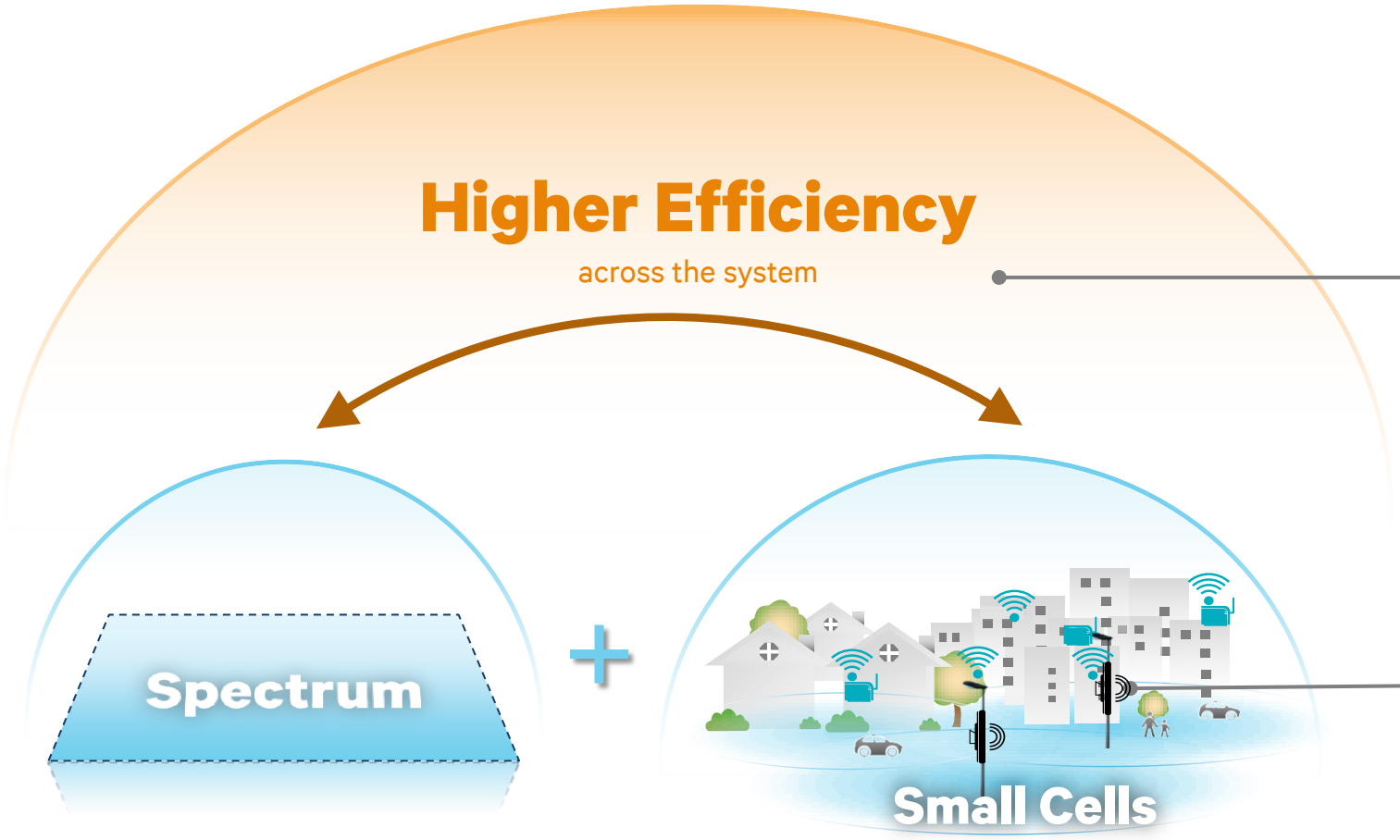
11ac

3G/4G/Wi-Fi
Smallcells/Hetnet

Seamless
3G/4G/Wi-Fi Interworking

Wi-Fi: Part of the solutions to the "1000x Mobile Data Challenge"

Multiple efforts needed to address 1000x – Wi-Fi is an integral part of the solutions



11ac

Next-Gen Wi-Fi with
3x more throughput (per stream)

Wi-Fi/3G/4G Seamless interworking
for selecting best access

Wi-Fi to be integrated into
virtually all 3G/4G small cells

802.11ac: Up to 3x increase in throughput per stream

3x more in the future with MU-MIMO

3x throughput now*

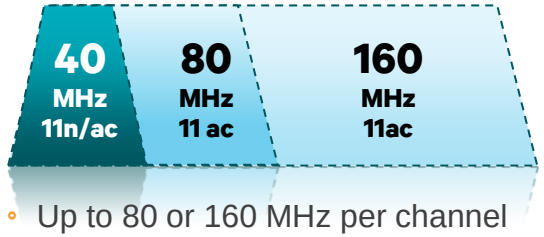
3x more aggregate throughput with MU-MIMO**

Higher data rates at all ranges

Lower latency

11ac

Wider Bandwidth



- Up to 80 or 160 MHz per channel
- Less crowded 5GHz band
- Higher order modulation (256 QAM)

Dynamic Bandwidth Management

- Improved interference detection and avoidance
- Bandwidth allocation based on interference

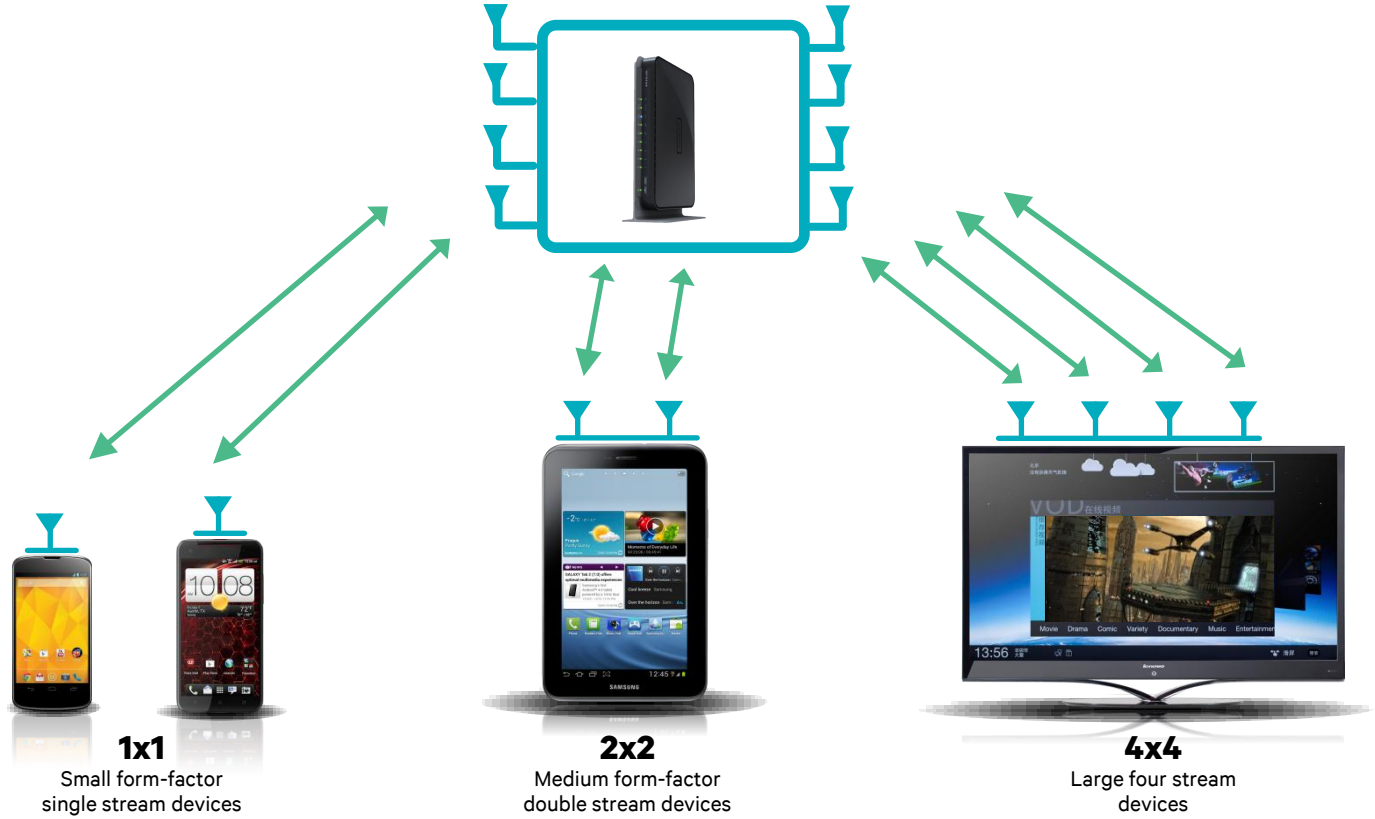
Multi User MIMO

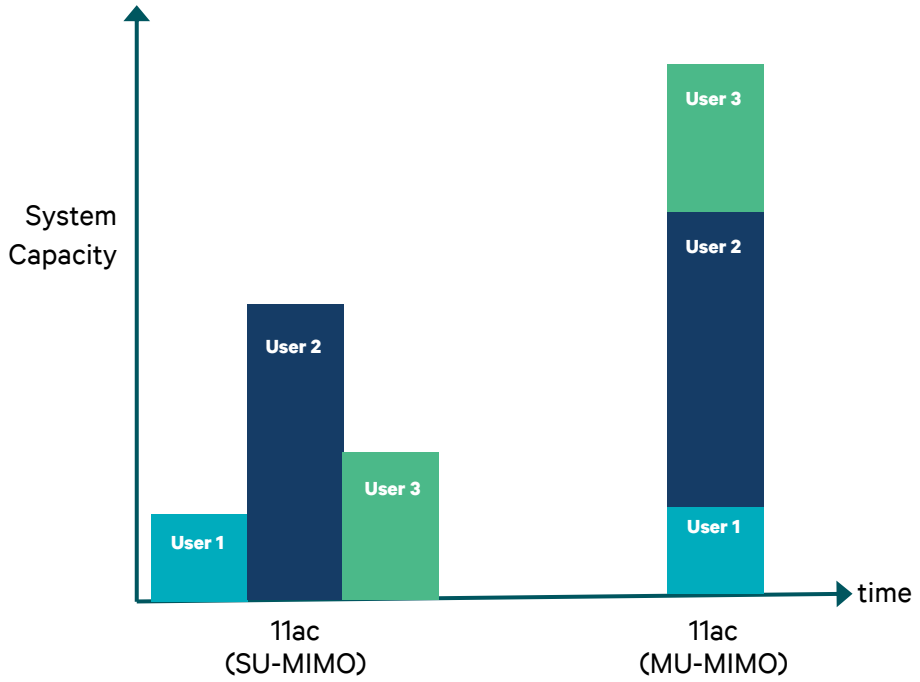
Serves up to 4 devices simultaneously

* As compared to 802.11.n; **When compared to 3-stream 11ac SU-MIMO, considering only single stream mobile devices; 802.11ac standard supports up to 8-stream MIMO

MU-MIMO: Higher capacity with mix of devices

Simultaneously serving multiple devices by reusing resources



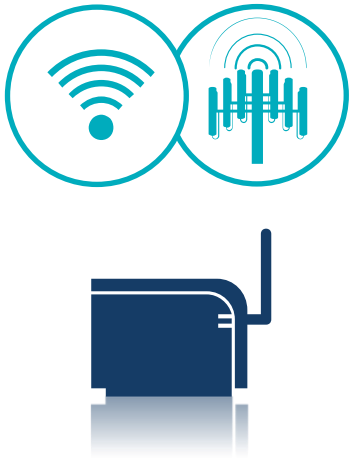


Simultaneously serves up to 4 devices

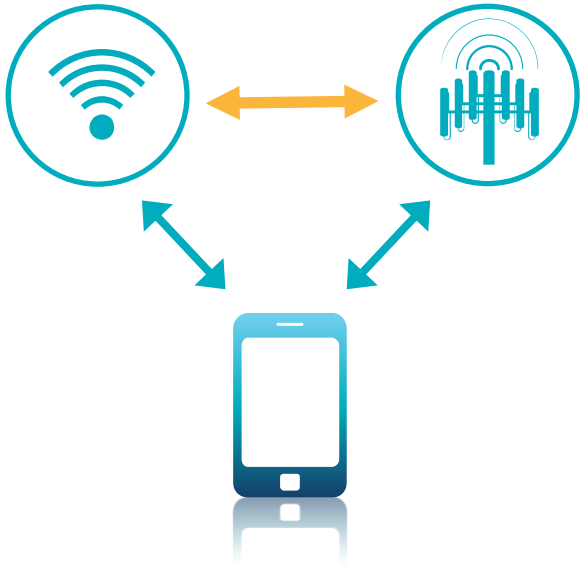
Up to 3x more aggregate throughput*

*When compared to 3-stream 11ac SU-MIMO, considering only single stream mobile devices

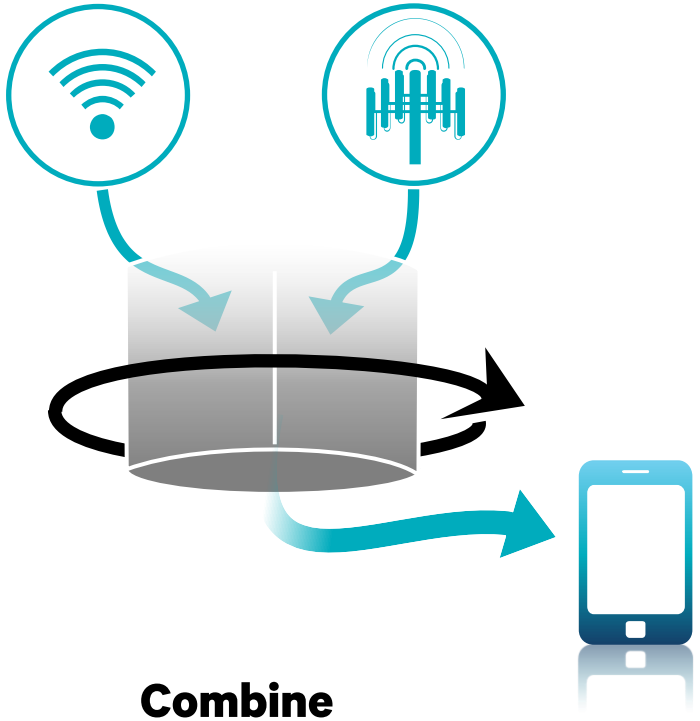
Tighter Wi-Fi—3G/4G interworking



Convergence of Cellular and Wi-Fi Infrastructure

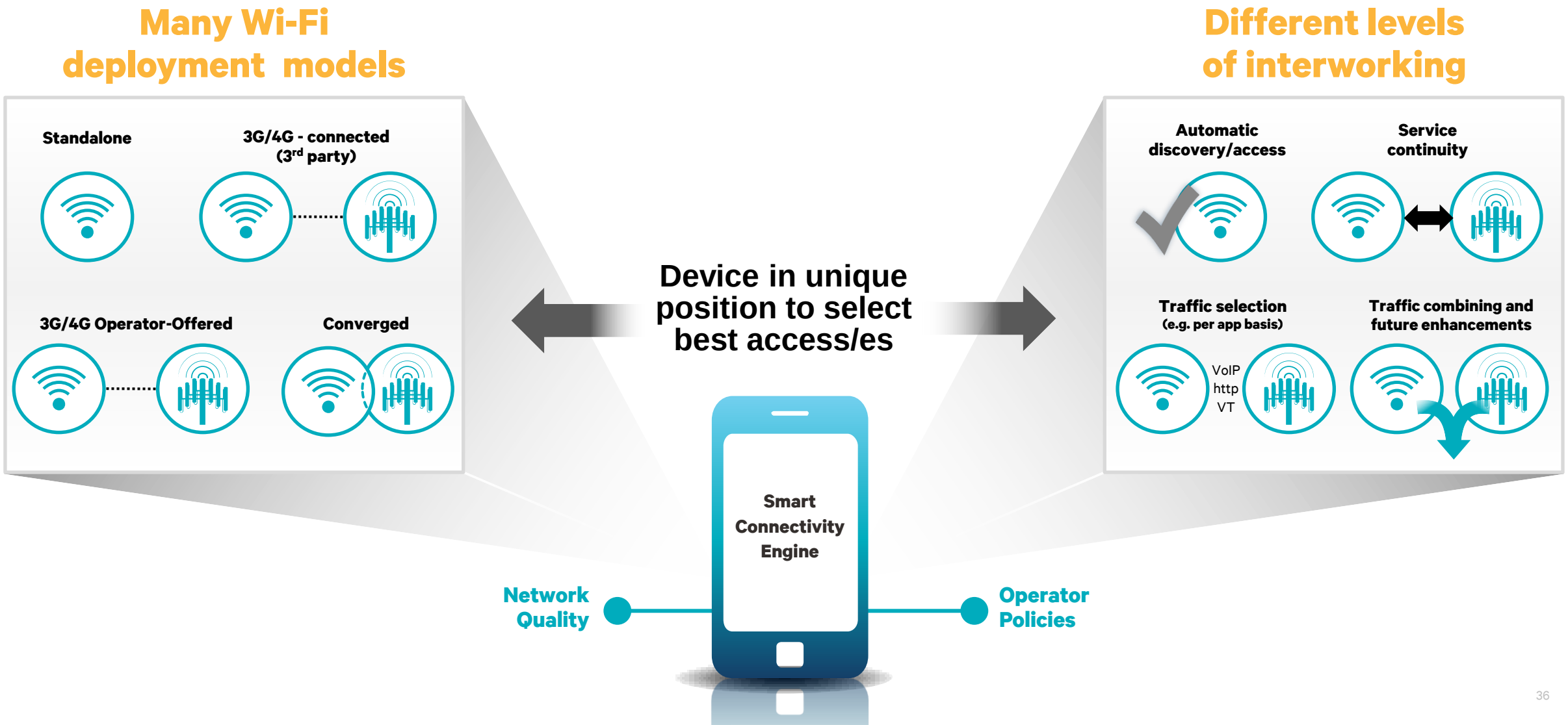


Seamless Access and Connectivity



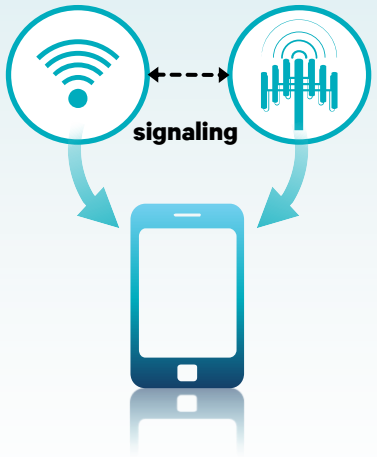
Combine Wi-Fi and 3G/4G

Multi-dimensional Wi-Fi—3G/4G interworking landscape



Seamless Wi-Fi—3G/4G interworking is evolving

Discovery & access



Traffic selection

- Per flow selection

Service continuity

Future enhancements

- Combining data
- Even tighter integration
- 3GPP Rel 11 and beyond

Service continuity & seamless transition

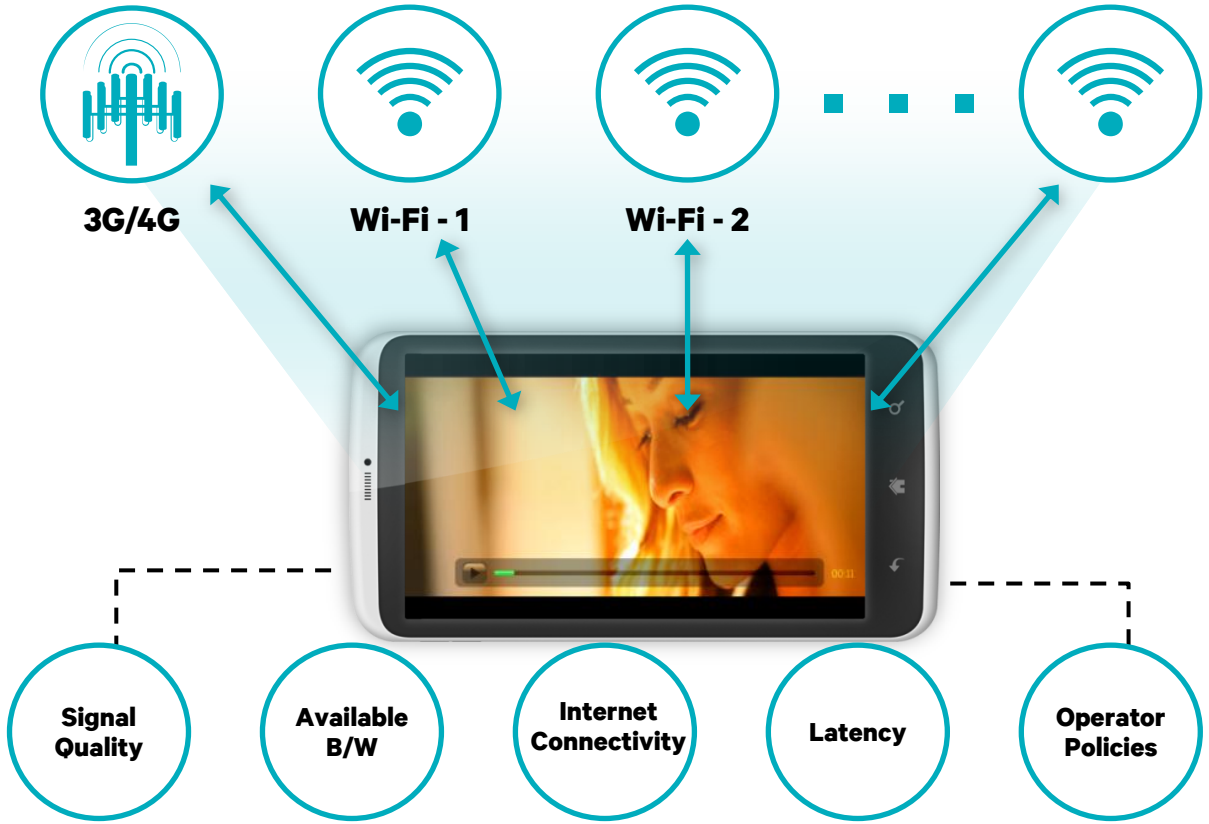
Adherence to operator policies (ANDSF)

Passpoint / Hotspot 2.0 + some features from ANDSF

Notes: 1) ANDSF - Access Network Discovery and Selection Function defined in 3GPP :
2) The evolution shown here represents the trend in commercialization. 3GPP supports Service continuity in Rel 8 and Traffic selection in Rel. 10

Qualcomm connectivity engine (CnE) – Selecting best access

Based on end-to-end link performance



Standards compliant
(Passpoint/Hotspot2.0, 3GPP (ANDSF), IWAN)

Smart algorithms
(In addition to standards)

Part of Qualcomm chipset solutions

Qualcomm 3G/4G – Wi-Fi converged small cell Solutions

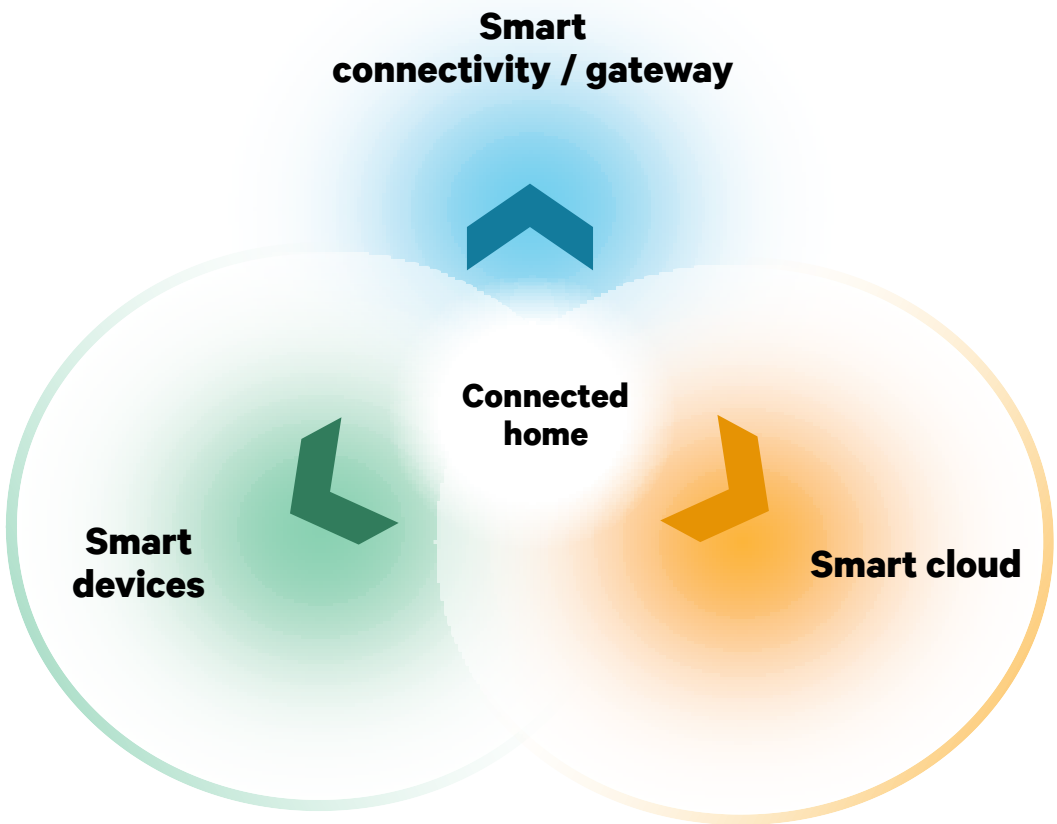
- Wi-Fi and 3G/4G cellular SoCs & RF
- Complete reference designs
  - Modular, Flexible RF band support
  - RF Coexistence considerations fully addressed
- Intelligent end-to-end connection management
  - Hotspot 2.0/Passpoint support
  - Access selection based on information from both Wi-Fi and 3G/4G (QoS, resource constraints, loading, link quality etc)
  - Works even better with Qualcomm's connectivity engine (CnE)

	Qualcomm's Converged Small Cell	Standard Converged Small Cell
Device with CnE	Most optimized selection with end-to-end information	Intelligent selection based only on device info
Device w/o CnE	Intelligent selection based only on AP info	N/A

Wi-Fi: At the center of “Smart Connected Homes”

Connected home vision: Multiple smarts working together

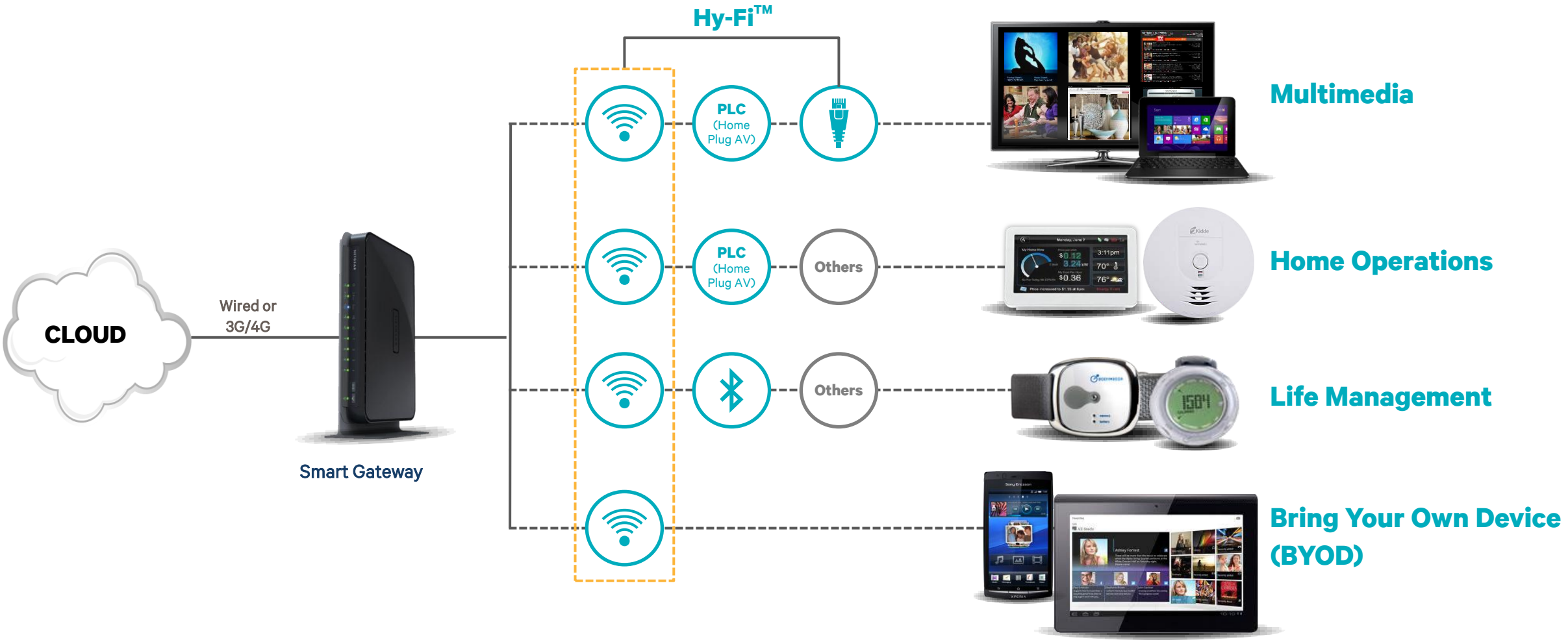
Manage devices/apps to maximize efficiency, and provide homogenized user experience
(e.g. smart bandwidth management based on app requirements)



Deliver a personalized connected home experience
(e.g. smart TV, smart appliances)

Extend resources of the home network when needed, by providing additional data, storage space and computing capabilities

Wi-Fi: Universal technology in “Connected Homes”



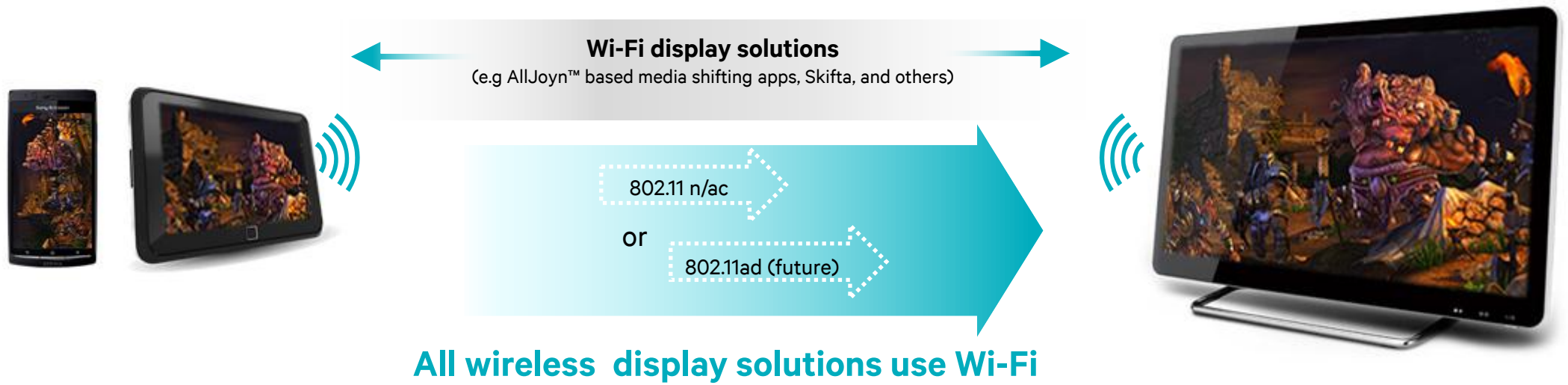
PLC – Power Line Communications
Home Plug AV – Standard for Audio/Video over PLC

Wireless Display

Indoor Location

Wi-Fi: Opening new frontiers

Wi-Fi : Foundation for all wireless display technologies



All wireless display solutions use Wi-Fi

Miracast™

Global industry standard
for Wireless Display

- Mandatorily uses Wi-Fi Direct
- Captures contents of source display and renders on the target
  - Mirrors the entire display, not just “transferring” media

WiGig: Short-distance multi-gigabit connectivity

Leveraging bandwidth-rich 60 GHz spectrum with 802.11ad

Wireless Gigabit Alliance

Globally Harmonized Band
(Up to 9 GHz available in most countries)

Complements 11ac
(for short distance/same-room communication)

Strong Industry Support
(Major players from PC, Mobile & CE segments)

Instantaneous Docking/Synching
(Peer-to-peer)

Internet Access
(complementing 11ac)

High-Performance Wireless Display/Audio
(Uncompressed transfer, Peer-to-peer)

Industry’s first tri-band WiGig solution

- Tri-band - 2.4, 5 and 60 GHz
- 10x more in-room performance*
- Seamless transition with 11n & 11ac
- Commercial now (PC/Docking Station)

Combining Qualcomm’s VIVE™ 11ac solutions with Wilocity’s 802.11ad

Precise indoor positioning – Using Wi-Fi, sensors and more

Wi-Fi network based determination

- Signal strength and delay measurements
- Accuracy 5-7 mts

Device-based determination

- Signal strength and delay measurements
- Sensor augmentation
- Accuracy 3-5 mts

End-to-end solution provides highest accuracy and reliability

Qualcomm IZat™ – Precise positioning everywhere

Comprehensive end-to-end solutions

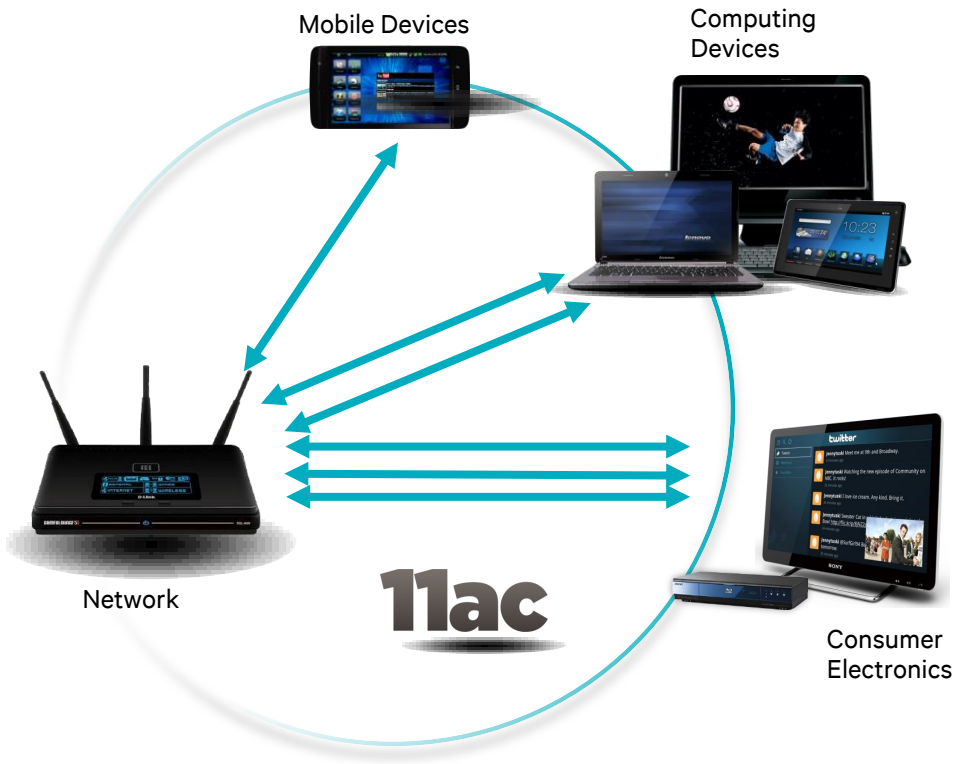
1st to market with GPS + Glonass

Integrated into all MSM, MDM and APQ platforms

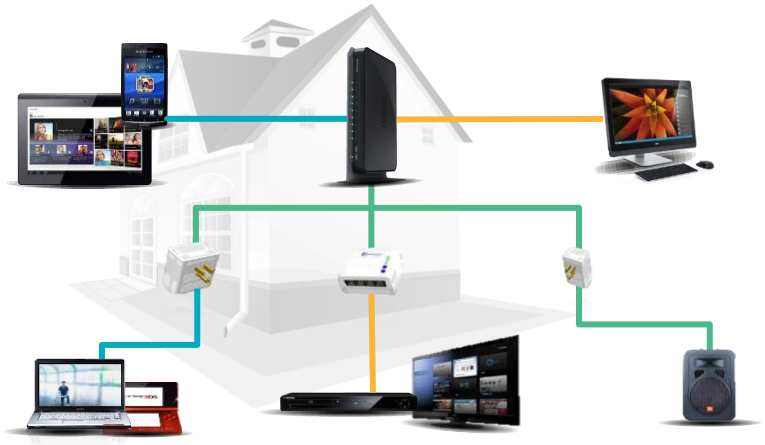
(and discrete solutions)

Qualcomm: Wi-Fi evolution leadership

Enabling robust end-to-end 11ac Ecosystem



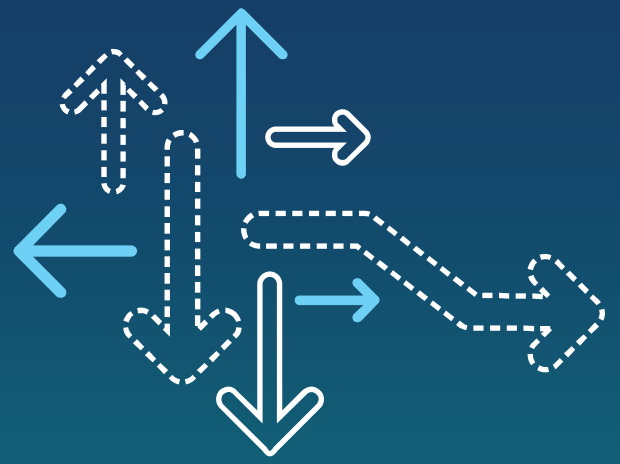
Comprehensive connected-home solutions



Trendsetting in-door positioning & WiGig offerings

Industry leading solutions with end-to-end excellence

Questions? - Connect with Us



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