Progress on LAA and its relationship to LTE-U and MulteFire™

Qualcomm Technologies, Inc.

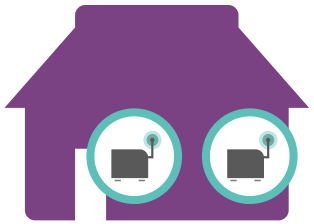
February 22, 2016

Making best use of 5 GHz unlicensed band

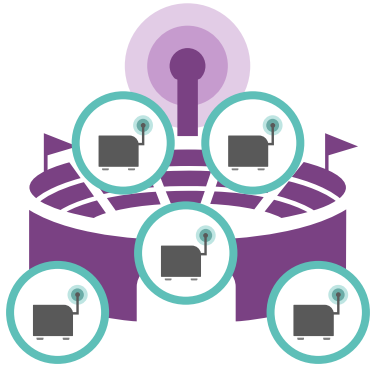
LTE-U/LAA, LWA, MulteFire™ and Wi-Fi will coexist in 5 GHz

Enterprises

Small Businesses



Venues



Residential/ Neighborhood

Large amounts of spectrum available globally (~500 MHz[1])

Ideal for small cells thanks to lower mandated transmit power

Global neutral spectrum that can serve any user with same deployment – neutral hosts

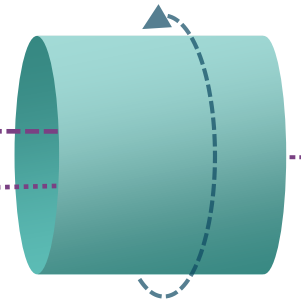
1 Regionally dependent

Multiple technologies will co-exist for different needs

Licensed Spectrum

Exclusive use

anchor



Aggregation with licensed anchor channel

Unlicensed Spectrum

Shared use

LTE-U / LAA (Licensed-Assisted Access)

Targeting mobile operators using LTE in unlicensed spectrum for new small cell deployments

LWA (LTE Wi-Fi Link Aggregation)

Targeting mobile operators leveraging existing carrier Wi-Fi deployments

MulteFire

Broadens LTE ecosystem to enhanced and new deployment opportunities

Wi-Fi (11ac/11ad/11ax/11ay)

Evolving for enhanced performance and expanding to new usage models

LTE Unlicensed developed through industry collaboration

Collaboration with organizations such as Wi-Fi Alliance and IEEE

LTE-U Forum

LTE-U Forum

An industry forum defining coexistence specs **LTE-U** based on 3GPP rel. 12, for early time to market for certain markets (e.g., USA, Korea, India).

3GPP for LAA

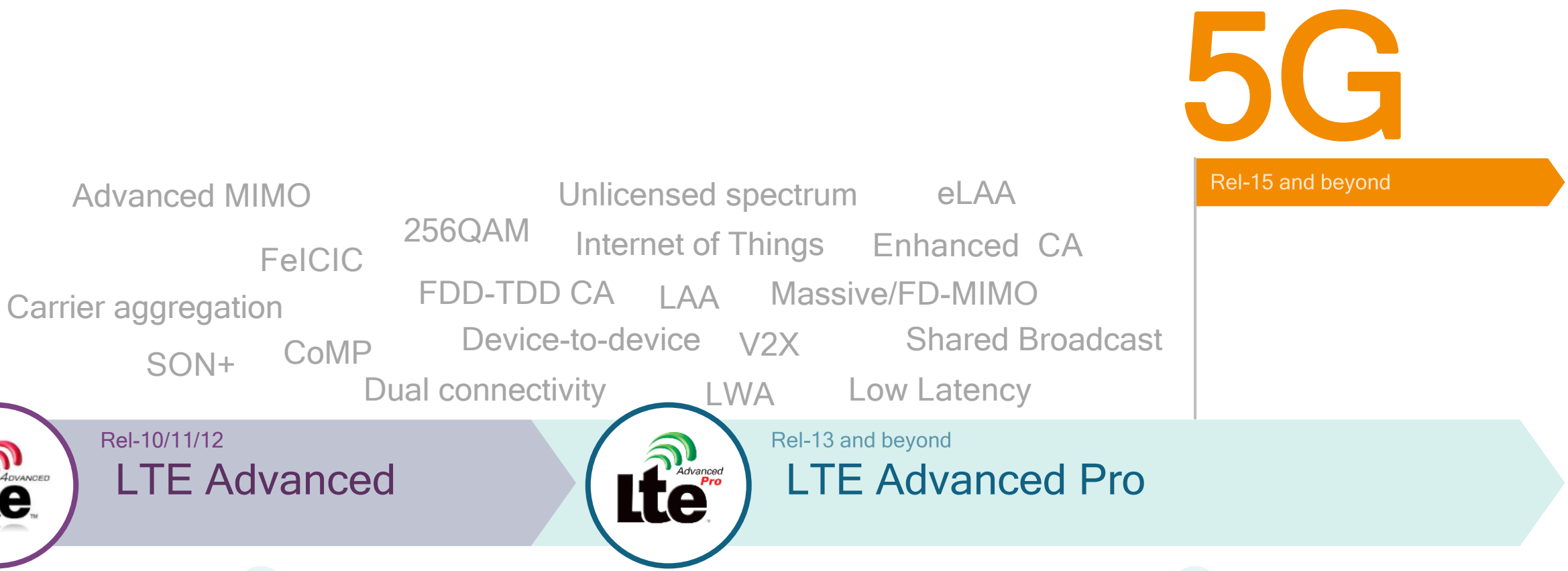
A global standardization organization for cellular network technologies such as LTE, including **LWA** and **LAA** (rel. 13) used for aggregation of unlicensed and licensed spectrum.

MulteFire Alliance

An international association formed in 2015 that will develop global technical specifications and product certification for **MulteFire** based on 3GPP standards.

LAA part of LTE Advanced Pro–a rich roadmap of features

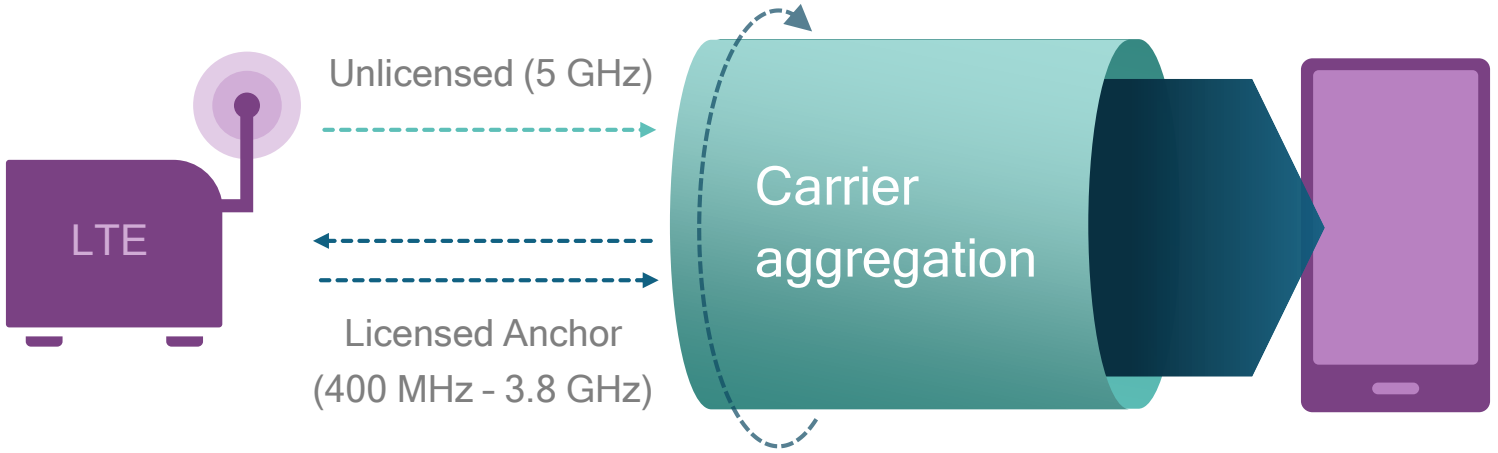
Pushing LTE capabilities towards 5G



Note: Estimated commercial dates. Not all features commercialized at the same time

Extending LTE to unlicensed spectrum

Licensed Assisted Access (LAA)



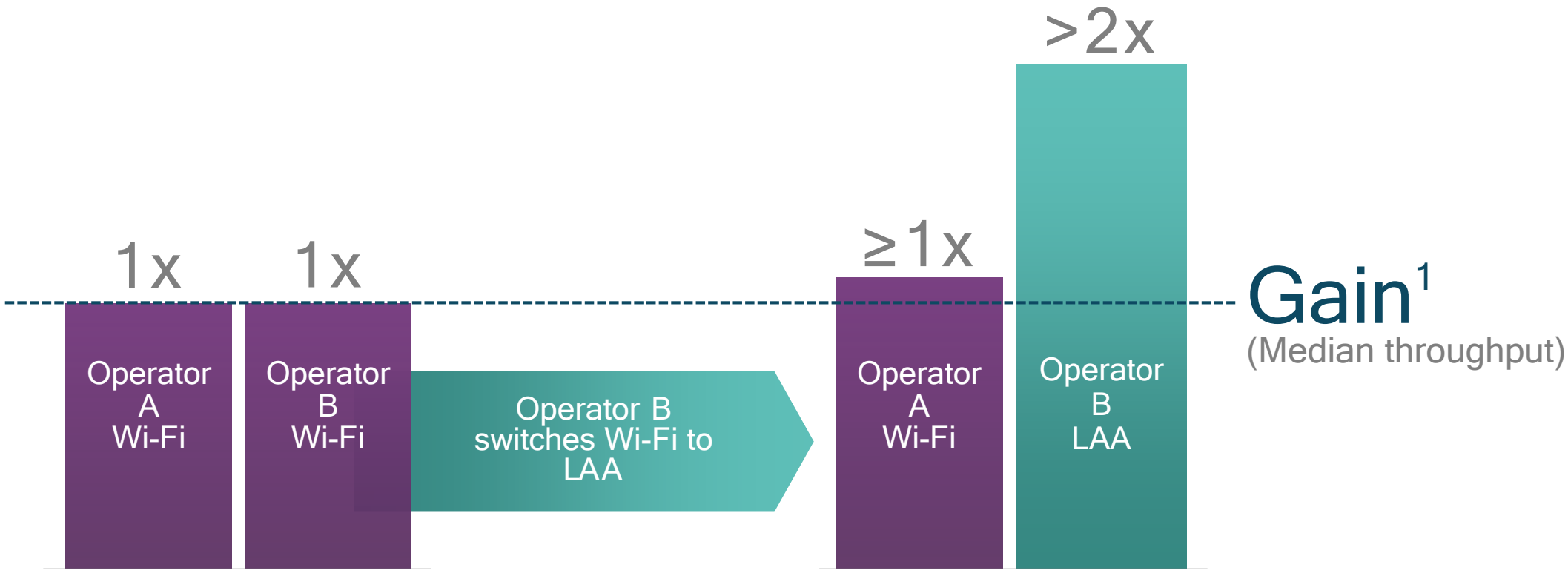
Supplemental Downlink (SDL) to boost downlink[1]

- **Path to Gbps speeds**
  By aggregating as little as 20 MHz licensed spectrum with unlicensed
- **Seamless and robust user experience**
  With reliable licensed spectrum anchor
- **2x capacity and range**
  Over Wi-Fi capacity in dense deployments[2]
- **Single unified LTE network**
  Common management
- **Fair Wi-Fi coexistence**
  Fundamental design principle

[1] Aggregating with either licensed TDD or licensed FDD is possible with SDL; [2] Assumptions: 3GPP LAA evaluation model based on TR 36.889, two operators, 4 small-cells per operator per macro cell, outdoor, 40 users on same 20 MHz channel in 5 GHz, both uplink and downlink in 5 GHz, 3GPP Bursty traffic model 3 with 1MB file, LWA using 802.11ac, DL 2x2 MIMO (no MU-MIMO), 24dBm + 3dBi Tx power in 5 GHz for LAA eNB or Wi-Fi AP.

Fair Wi-Fi coexistence a key principle in LAA design

Extensive over-the-air testing performed in the lab and in the field

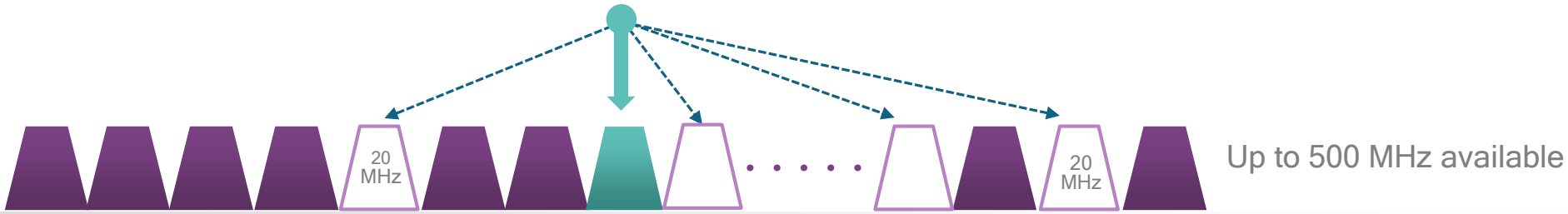


In many cases a better neighbor to Wi-Fi than Wi-Fi itself

[1] Assumptions: 3GPP LAA evaluation model based on TR 36.889 two operators, 4 small-cells per operator per macro cell, outdoor, 40 users on same 20 MHz channel in 5 GHz, both uplink and downlink in 5 GHz, 3GPP Bursty traffic model 3 with 1MB file, LWA using 802.11ac, DL 2x2 MIMO (no MU-MIMO), 24dBm + 3dBi Tx power in 5 GHz for LAA eNB or Wi-Fi AP.

LAA is designed to protect Wi-Fi

Select clear channel: Dynamically avoid Wi-Fi

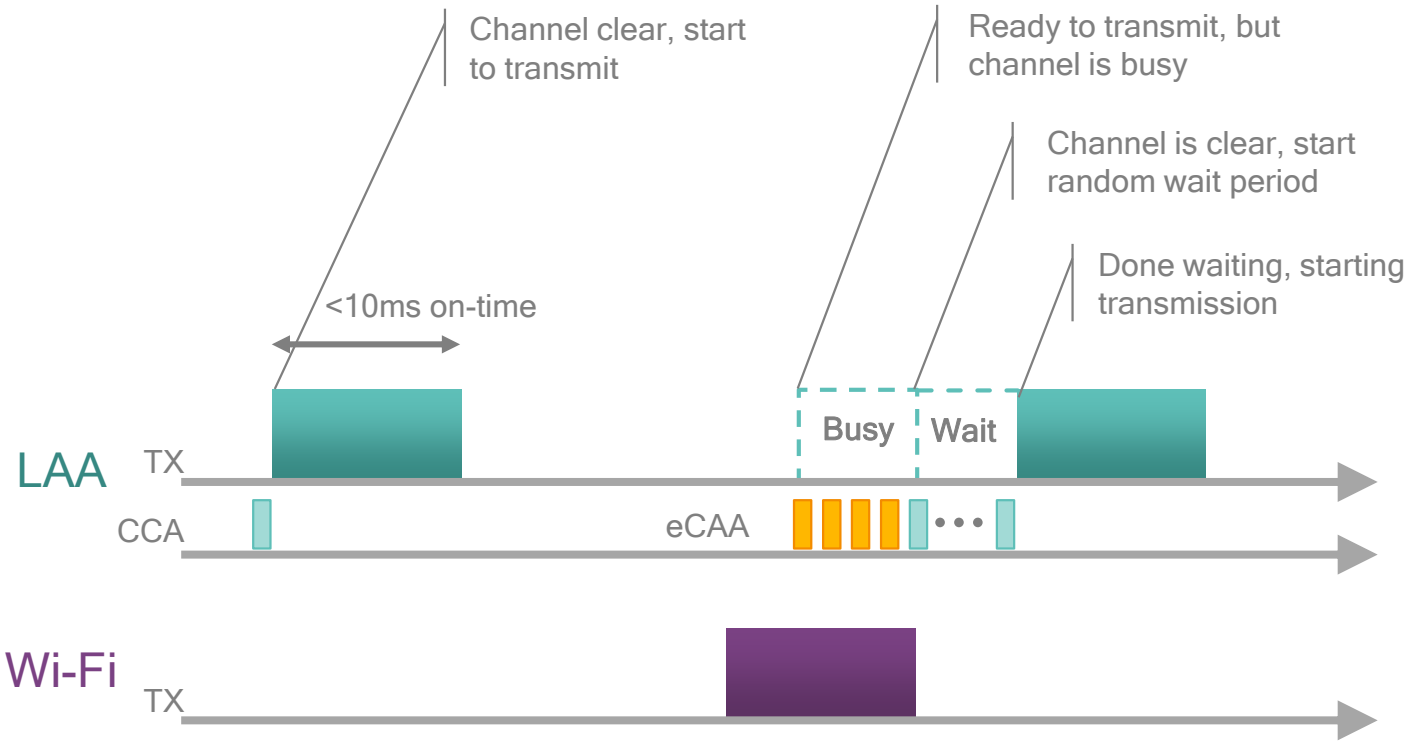


Sharing the channel fairly: “Listen before talk” (LBT)

Release unlicensed channel at low traffic

LBT ensures fair sharing in unlicensed 5 GHz

LBT is standardized in ETSI EN 301 893



ED – Energy Detect Threshold

Introducing[1] a more sensitive threshold that is common for all technologies when sensing each other.

CCA – Clear channel assessment

If no signal is sensed based on ED threshold, then go ahead with transmission right away.

eCCA – Extended CCA

If channel is busy (CCA), then wait for it to become clear. Once it is clear, wait for a random number of additional CCAs indicating that the channel has remained clear before starting transmission.

Designed for fair sharing of 5 GHz	Meets global regulations	Same rule for everyone[1], including Wi-Fi and LTE

1) Proposed in next release of ETSI EN 301 893 with a target release mid 2016.

LTE-U and LAA part of the same evolution

LTE-U

Time to market for certain regions: USA, Korea, India

Based on 3GPP R12

- Supplemental downlink (SDL) to boost downlink
- Dynamic channel selection to avoid Wi-Fi and adaptive duty cycle (CSAT) to fairly coexist
- Support for migration to LAA

LAA

Includes LBT required for global deployments

3GPP R13

- Supplemental downlink (SDL)
- Dynamic channel selection
- Listen before talk (LBT) complying with global regulations

eLAA and beyond

Enhancements to LAA

3GPP R14 and beyond[1]

- Adds uplink aggregation: Boost uplink data rates and capacity[2]
- Dual Connectivity: Aggregation across non-collocated nodes
- Complexity reduction[3]

Qualcomm is showing an eLAA demo at MWC

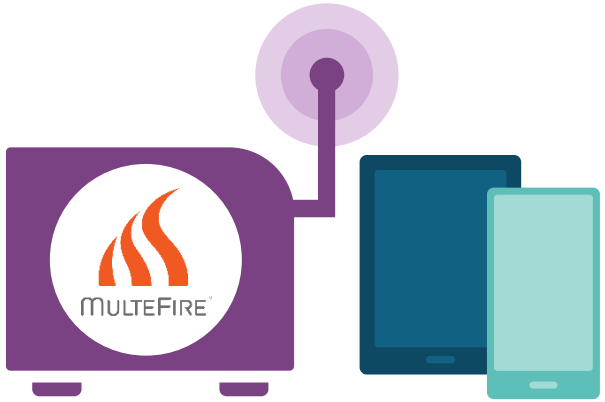
[1] UL aggregation part of Rel. 14–other features proposed; [2] Aggregation of unlicensed downlink and uplink is possible with either licensed TDD or licensed FDD; [3] Complexity/cost reduction is also applicable to licensed LTE

MulteFire: LTE-based technology solely in unlic. spectrum

Targets small-cells in unlicensed spectrum bands such as the global 5GHz band

LTE-like performance

- Enhanced capacity and range
- Improved mobility, quality-of-experience
- Hyper-dense, self-organizing deployments



Harmoniously coexist with Wi-Fi, LTE-U/LAA

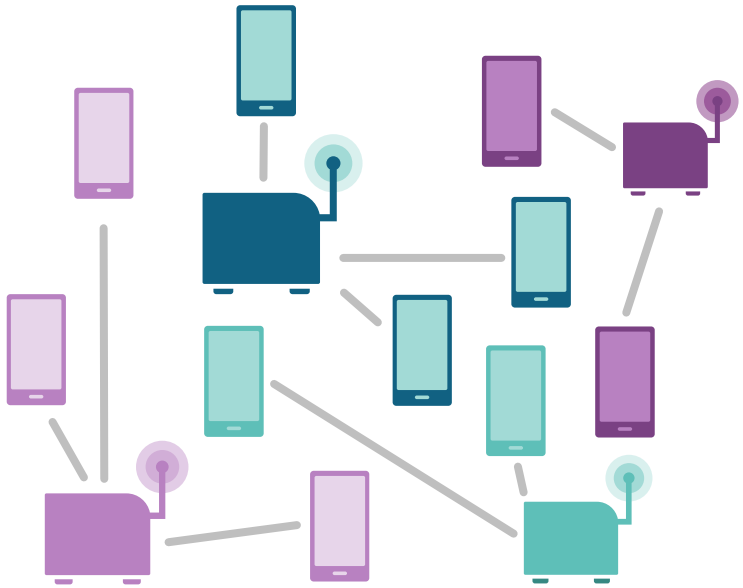
Wi-Fi-like deployment simplicity

- Operates solely in unlicensed spectrum, e.g., 5 GHz
- Leaner, self-contained network architecture
- Suitable for neutral host deployments

Broadens LTE ecosystem to new deployment opportunities

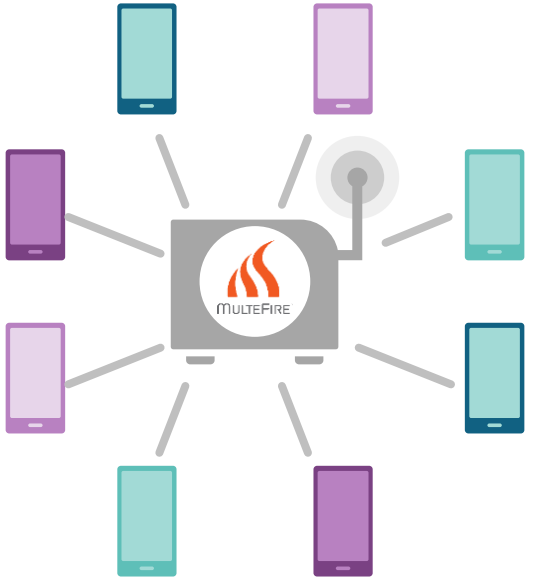
Enhanced offload for mobile networks with MulteFire

High-performance neutral host offload capabilities



Traditional mobile deployments

Separate spectrum bands and deployments may prohibit reaching all venues, enterprises and homes



MULTEFIRE™

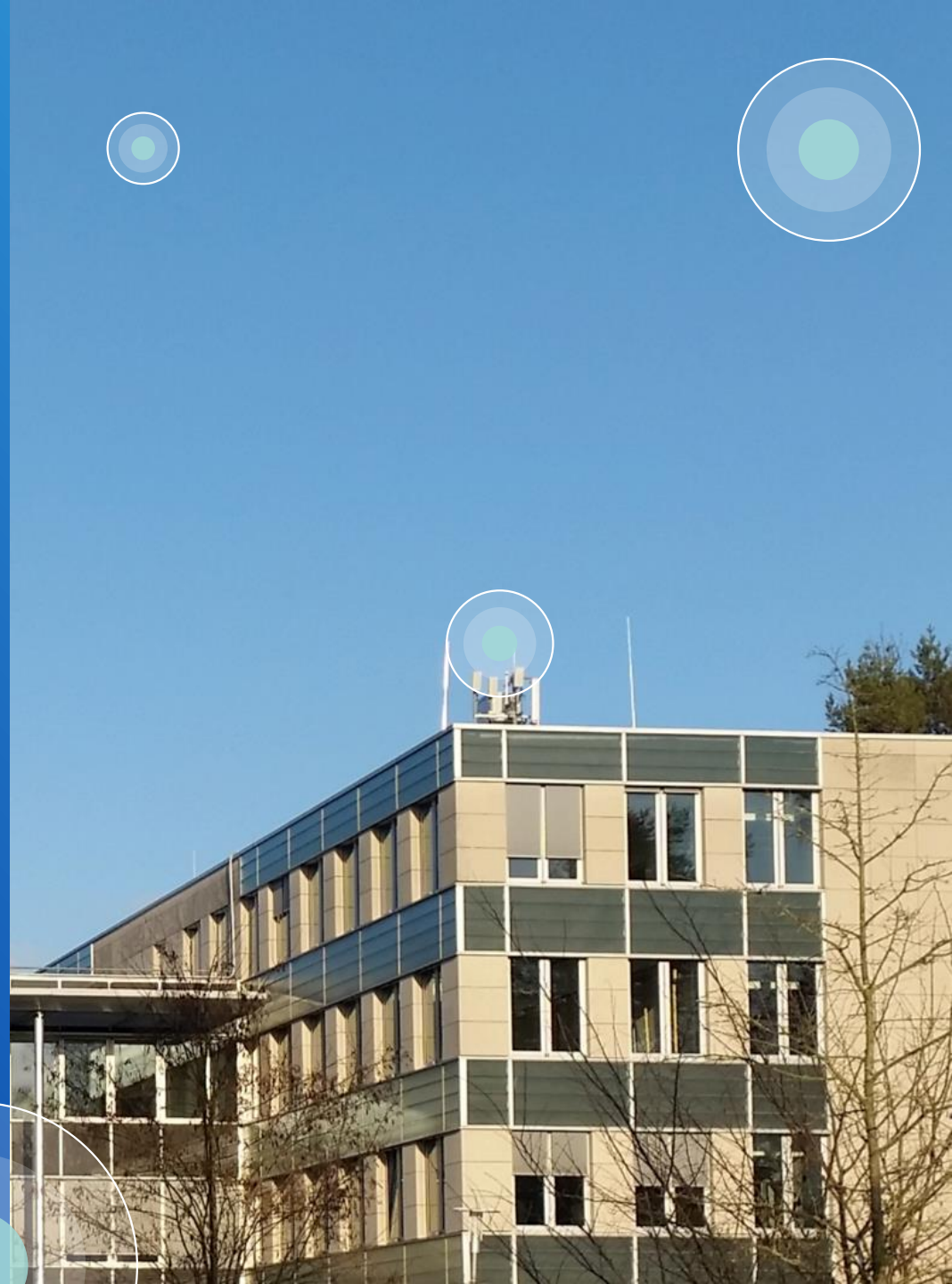
Neutral host deployments

Using common spectrum and common deployment provides neutral host services (Wi-Fi like)

Qualcomm is showing a MulteFire demo at MWC

World’s first over-the-air LAA trial

Joint effort by Qualcomm Technologies, Inc.
and Deutsche Telekom AG
in Nuremberg, Germany
during November 2015



Over-the-air trial demonstrates LAA advantages

Increased coverage

Demonstrated LAA's extended range and improved performance in 5 GHz compared to Wi-Fi

Increased capacity

Demonstrated downlink throughput gains over Wi-Fi.

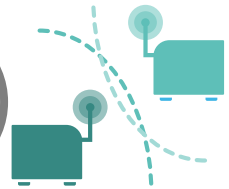
Co-existence benefiting everyone

Demonstrated fair co-existence between LAA, LWA and Wi-Fi with improved performance for everyone.

Completed a wide range of test cases

Covering multiple aspects

1.
   Different combinations of LAA, LWA and Wi-Fi, mix of above and below ED

2. 
   Handover between multiple small cells

3.
   Indoor and outdoor deployment scenarios

4.
   Single or multiple users

5.
   Different radio conditions, including corner cases such as hidden node

6.
   Stationary and mobile users

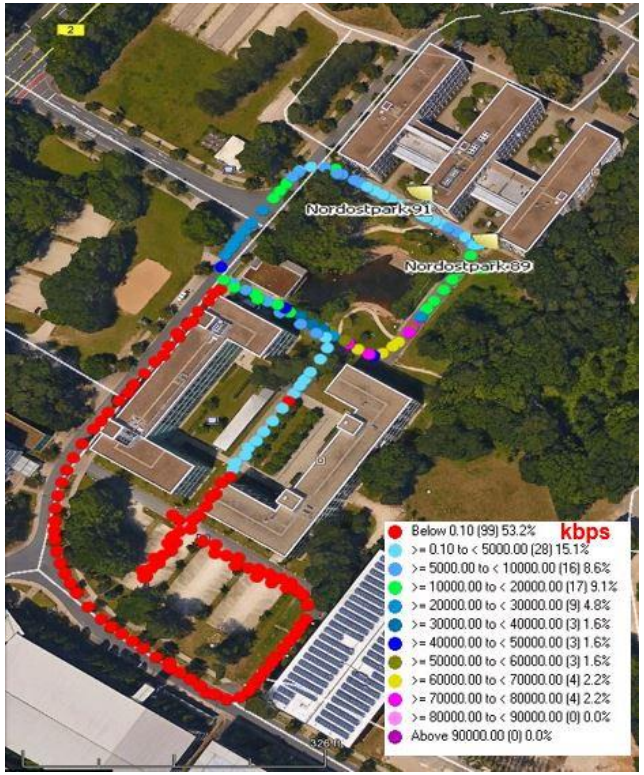
Outdoor test case examples

2 LAA/LWA capable eNB (licensed + unlicensed)
2 Wi-Fi AP (unlicensed)
Same configuration for LAA and Wi-Fi: radio channel, 2x2 MIMO, antennas, transmit power, mobility…

~2X coverage improvement outdoors

Downlink throughput in unlicensed spectrum for each location on test route[1]

LWA (Wi-Fi)



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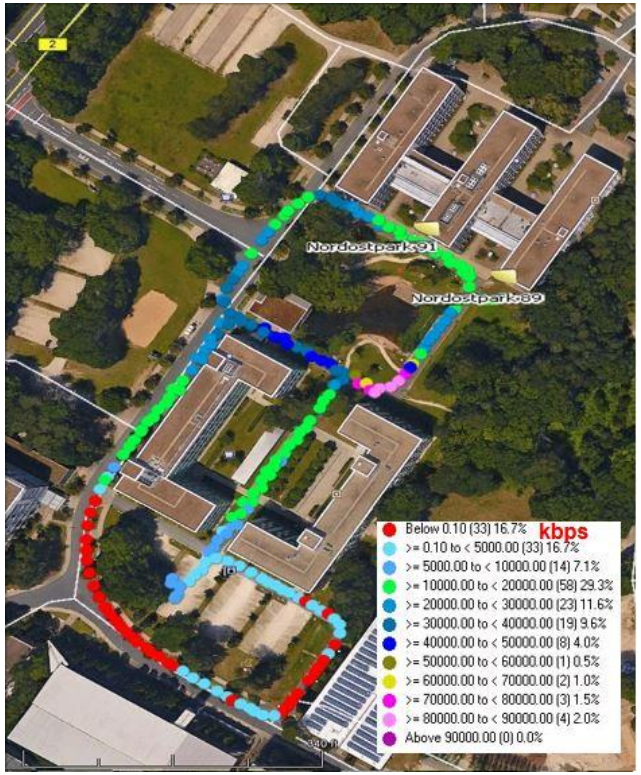
LAA



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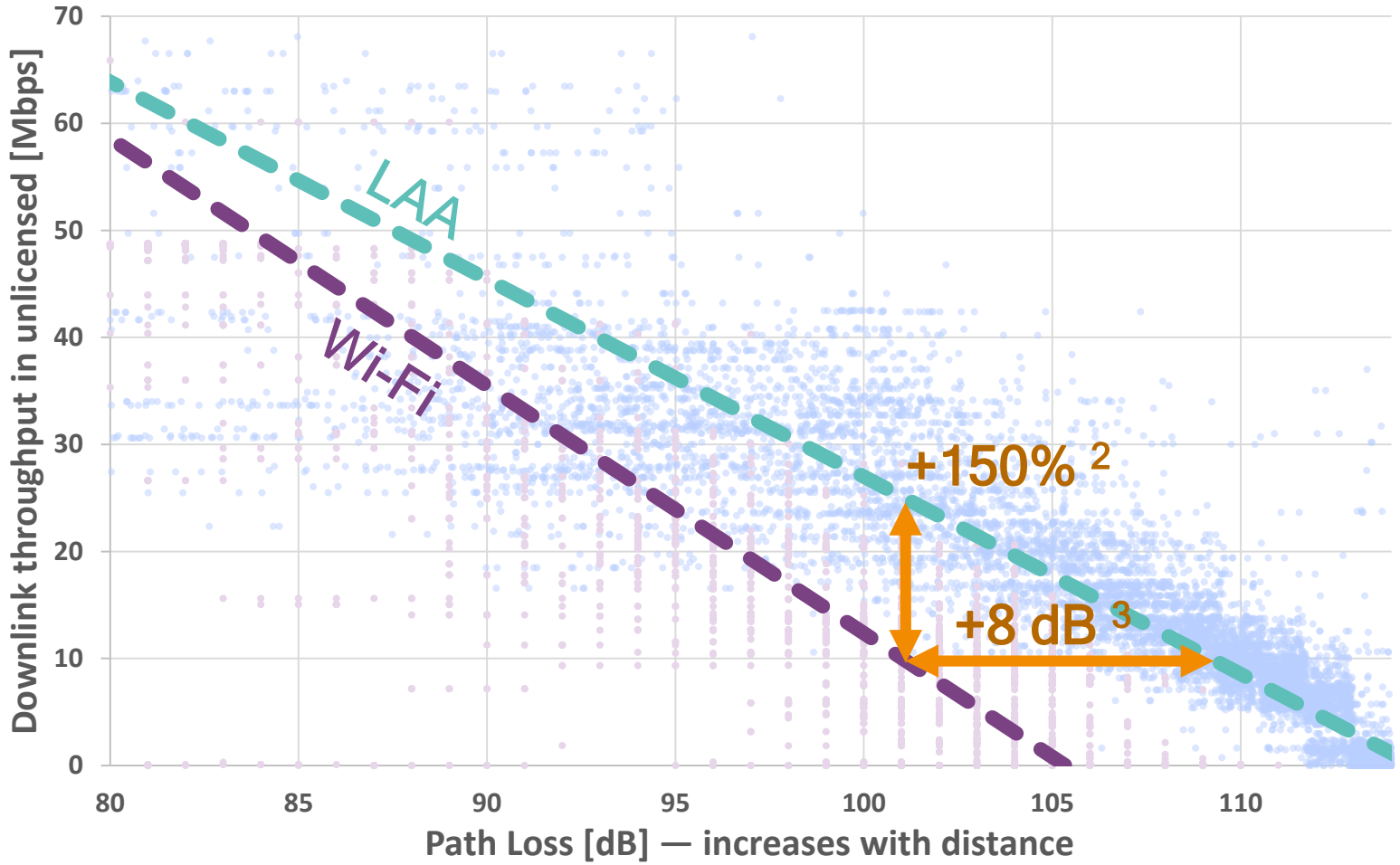
Coverage[2] in unlicensed

Mbps	Wi-Fi	LAA
>10	24% of route	x2.5 60% of route
>1	39% of route	x1.8 71% of route
>0	47% of route	X1.7 82% of route

[1] Single small cell, LAA based on 3GPP release 13; LWA using 802.11ac; LTE on 10 MHz channel in 2600 MHz licensed spectrum with 4W transmit power; the following conditions are identical for LAA and Wi-Fi: 2x2 downlink MIMO, same 20 MHz channel in 5 GHz unlicensed spectrum with 1W transmit power. terminal transmit power 0.2W, mobility speed 6-8 mph; [2] Based on geo-binned measurements over test route

LAA outperforms Wi-Fi in challenging radio conditions

Averaged downlink throughput in 5 GHz during mobility[1]



Performance when it matters

LAA's performance gains grows with more challenging radio conditions, providing more consistent throughput over a larger area.

Increased coverage

Providing same performance at a higher path loss (further distance) contributes to LAA's improved coverage over Wi-Fi.

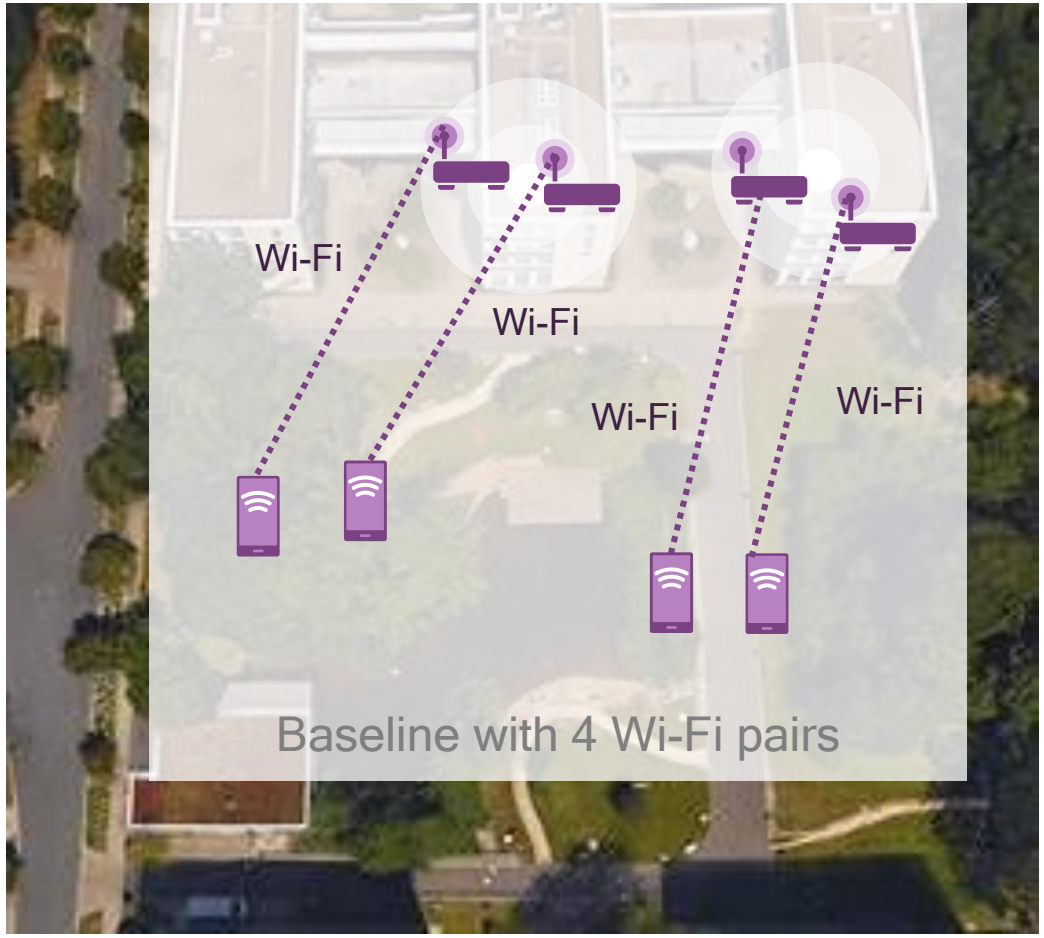
Higher averaged throughput

In challenging radio conditions LAA offers significantly higher averaged throughput at the same distance (same path loss).

[1] Dual cells with handover, LAA based on 3GPP release 13; LWA using 802.11ac; LTE on 10 MHz channel in 2600 MHz licensed spectrum with 4W transmit power; the following conditions are identical for LAA and Wi-Fi: 2x2 downlink MIMO, same 20 MHz channel in 5 GHz unlicensed spectrum with 1W transmit power. terminal transmit power 0.2W, mobility speed 6-8 mph; [2] ~25 Mbps LAA vs ~10 Mbps Wi-Fi at same path loss; [3] At 10 Mbps downlink speed in 5 Ghz

LAA benefits everyone sharing the same 5 GHz channel

A better neighbor to Wi-Fi than Wi-Fi itself



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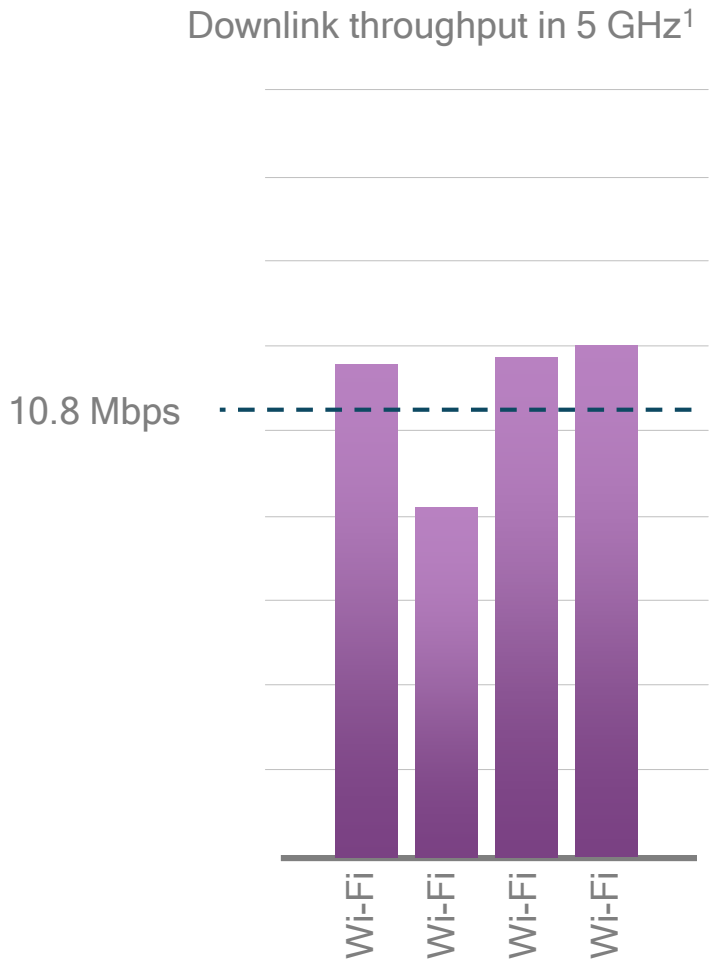
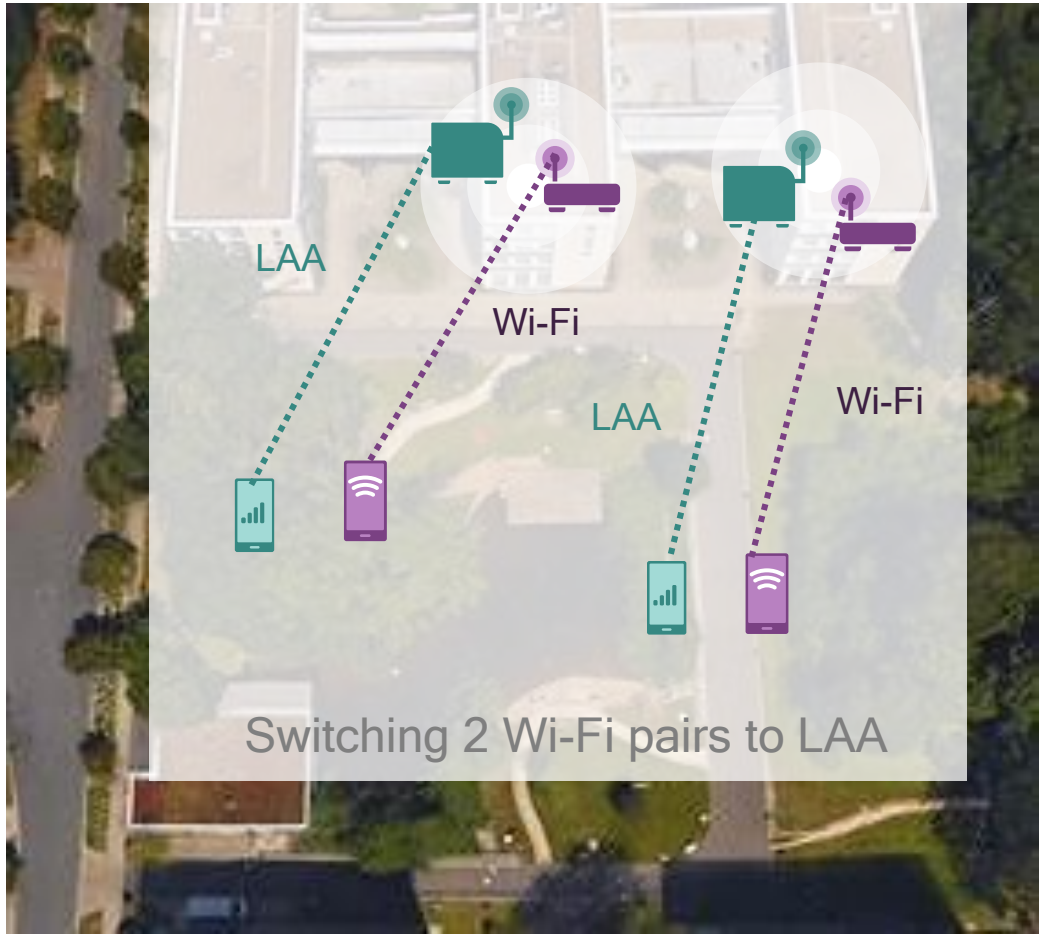


[1] Outdoor, 4 users on 4 different AP/cells, Mix of above and below ED, strong signal level with some interference, LAA based on 3GPP rel. 13; LWA using 802.11ac; LTE on 10 MHz channel in 2600 MHz licensed spectrum with 4W transmit power; the following conditions are identical for LAA and Wi-Fi: 2x2 downlink MIMO, sharing same 20 MHz channel in 5 GHz unlicensed spectrum with 1W transmit power, terminal transmit power 0.2W

LAA benefits everyone sharing the same 5 GHz channel

A better neighbor to Wi-Fi than Wi-Fi itself



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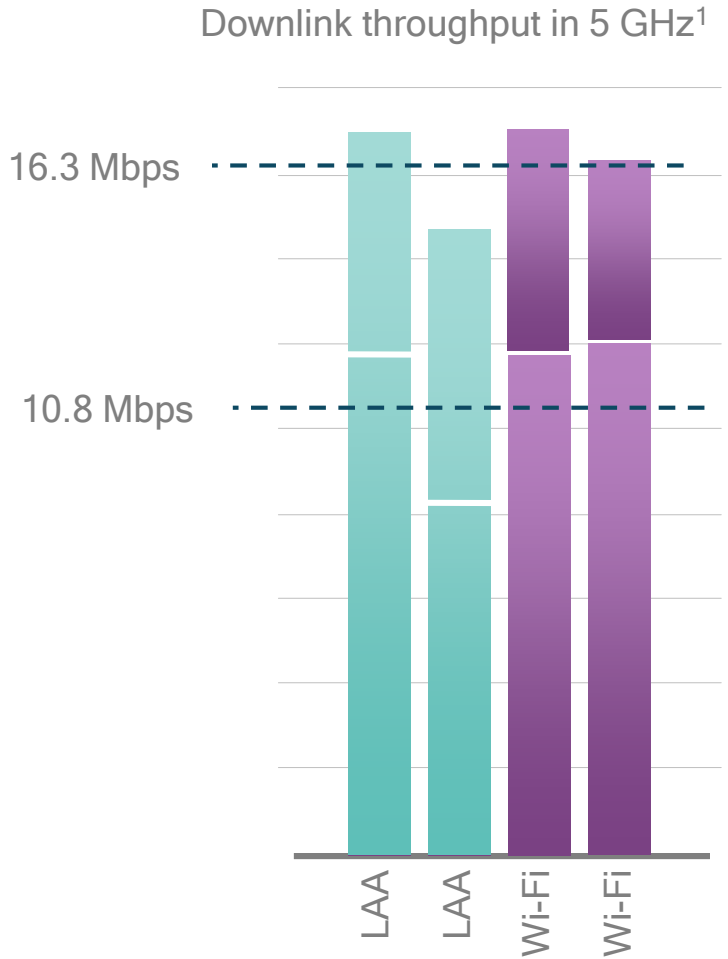

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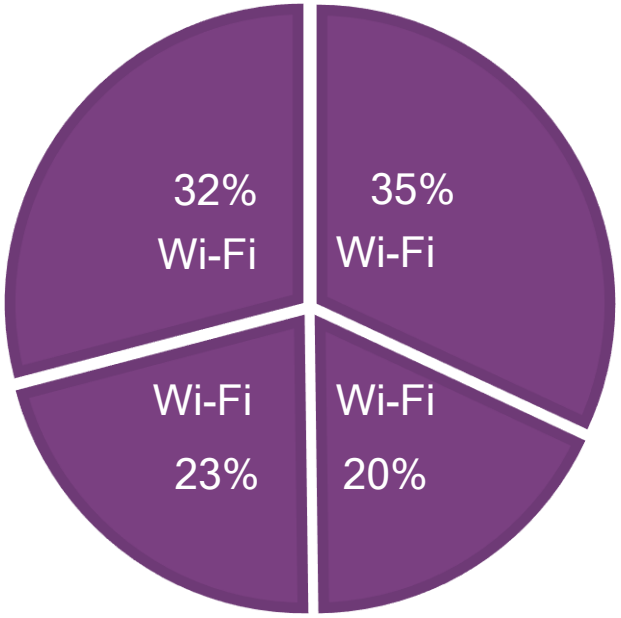
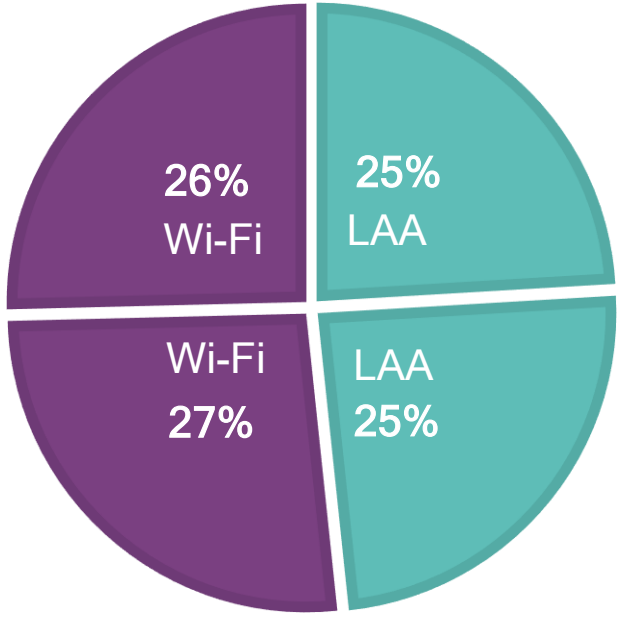
LAA benefits everyone sharing the same 5 GHz channel

LAA promotes fair sharing of the unlicensed channel

Same baseline with 4 Wi-Fi pairs



Switching 2 Wi-Fi pairs to LAA



Numbers in pie charts show channel occupancy[1],
the total is not 100% due to over utilization.

.

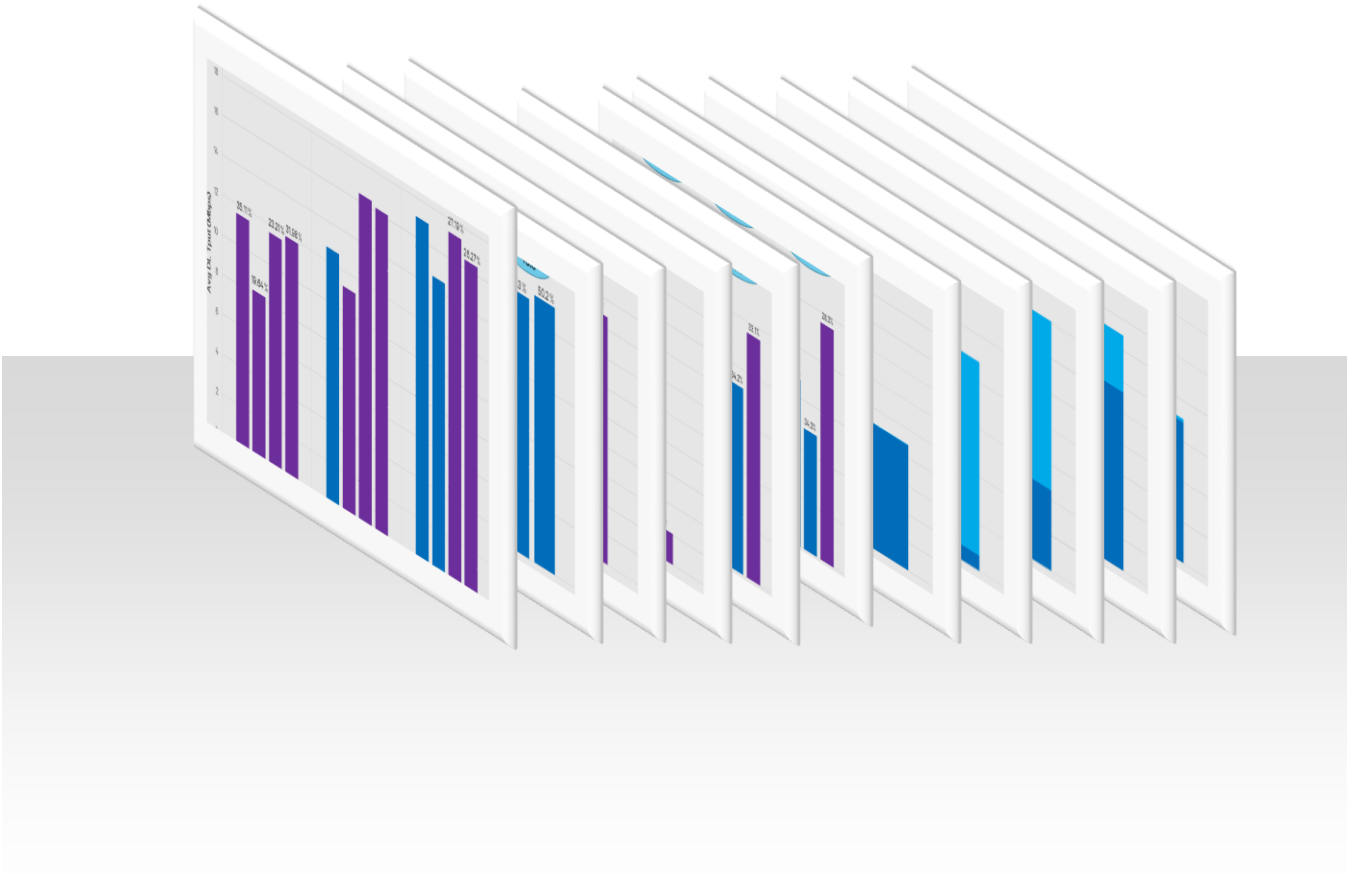
[1] Outdoor, 4 users on 4 different AP/cells, Mix of above and below ED, strong signal level with some interference, LAA based on 3GPP rel. 13; LWA using 802.11ac; LTE on 10 MHz channel in 2600 MHz licensed spectrum with 4W transmit power; the following conditions are identical for LAA and Wi-Fi: 2x2 downlink MIMO, sharing same 20 MHz channel in 5 GHz unlicensed spectrum with 1W transmit power, terminal transmit power 0.2W

LAA fairly coexists with Wi-Fi

Summary from a large number of test cases over a diverse set of conditions

1. Switching a Wi-Fi AP with a LAA small-cell results in overall increased network capacity and higher throughput for all users.

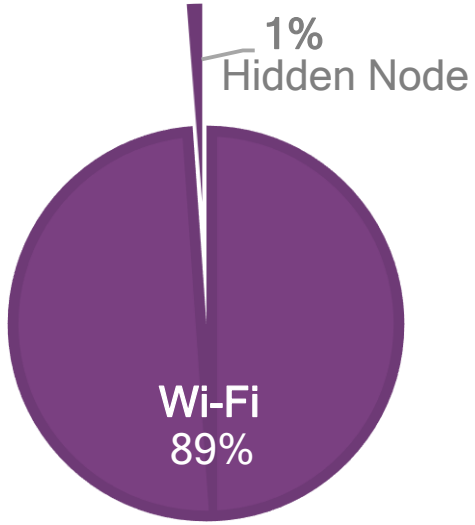
2. LBT ensures that the channel is shared fairly between the users and LAA is overall a better neighbor to Wi-Fi than Wi-Fi itself.



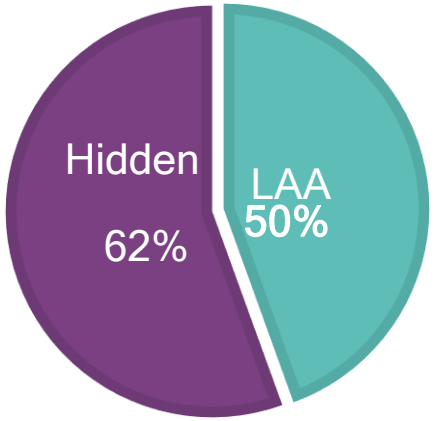
LAA shares the channel fairly also in corner cases

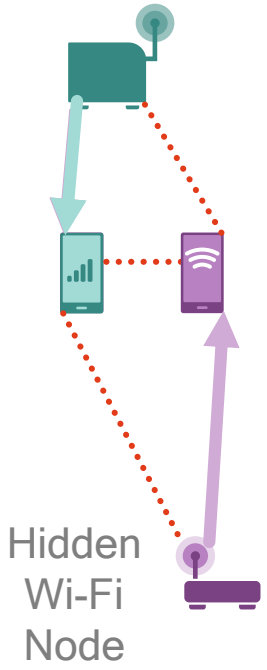
LAA is a better neighbor to a hidden Wi-Fi node

Baseline with 2 Wi-Fi pairs



Switching 1 Wi-Fi pair to LAA





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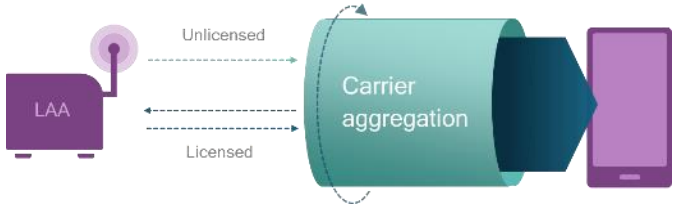
[1] Outdoor, 2 users on 2 different AP/cells, LAA based on 3GPP rel. 13; Wi-Fi using 802.11ac; the following conditions are identical for LAA and Wi-Fi: 2x2 downlink MIMO, sharing same 20 MHz channel in 5 GHz unlicensed spectrum with 1W transmit power, terminal transmit power 0.2W; downlink traffic only in unlicensed; first user has strong signal strength while the second users on the hidden AP has around 20 dB lower signal strength.

Summary

Successful LAA trial – a big milestone towards commercial deployment



MULTEFIRE™

LAA is here with 3GPP Rel. 13

- Path to Gbps speeds with less licensed spectrum
- Improved capacity, range and mobility
- Fair coexistence based on LBT enabling global deployment

OTA trial demonstrates LAA advantages

- Coverage & capacity benefits of LAA over Wi-Fi
- Seamless mobility of both LAA and LWA.
- Fair co-existence of LAA with Wi-Fi over large number of test cases

LAA technology paves the way for MulteFire

- MulteFire is based on LAA with similar performance advantages.
- Combined with Wi-Fi like deployment simplicity, it can offer the best of both worlds.

Introducing the

Qualcomm®
Snapdragon™

X16

LTE Modem

The first* cellular modem to support

Gigabit Class LTE

With Category 16 peak download speeds of up to 1 Gbps

Subject to network availability

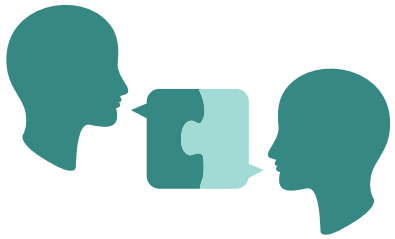
*First commercially announced

Making new mobile experiences possible…

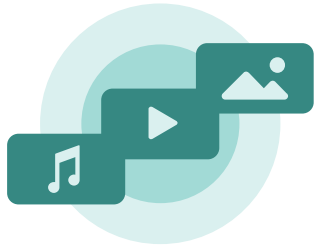
…and enhancing existing ones

Streaming 360° video in virtual reality

Always-on cloud services including “infinite storage”



Higher FPS video communication



Near instant access to entertainment

X16 LTE Modem

Quick Facts

A 14nm FinFET discrete LTE Advanced Pro Modem

Up to 1 Gbps - Cat 16 DL

4x4 MIMO on 2xCA + 2x2 MIMO on 3rd carrier; up to 4x20 MHz CA supported with 2x2 MIMO

Up to 150 Mbps - Cat 13 UL

via 2x20MHz CA and 64-QAM

LTE-U and LAA – Convergence with unlicensed

Globalizing access to LTE in unlicensed spectrum

3.5 GHz band support – New 3GPP bands

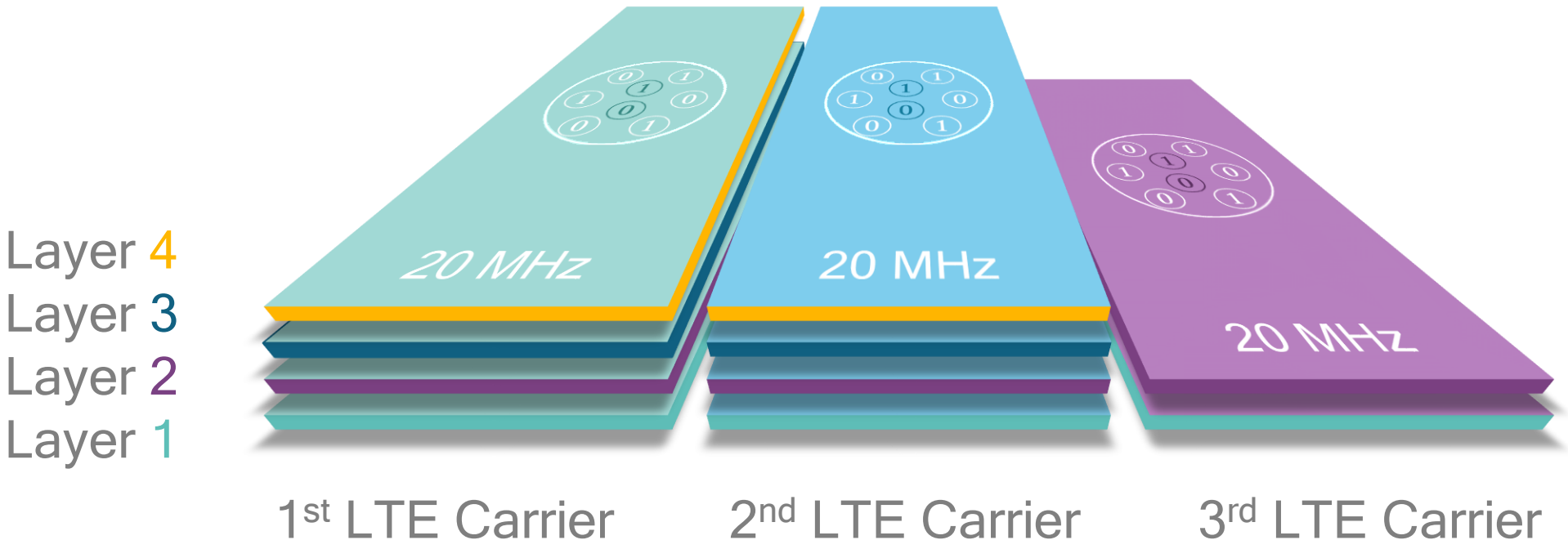
Additional licensed LTE spectrum access

Sampling now
Commercial devices expected in 2H 2016

Subject to network availability.

Gigabit Class LTE with only 60 MHz of spectrum

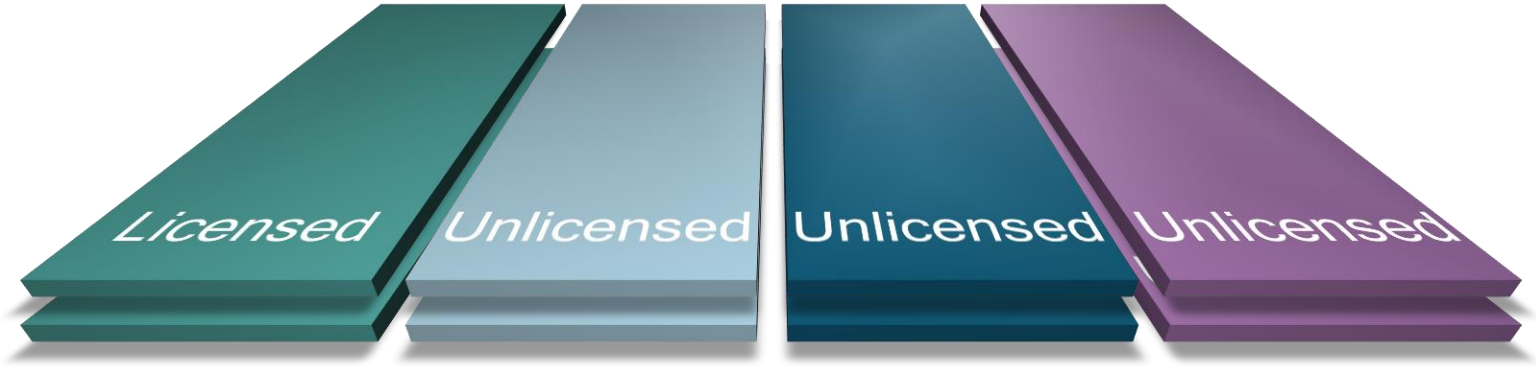
A combination of 3x carrier aggregation, 4x4 MIMO, and 256-QAM



Example configuration. Other RF configurations possible.

Gigabit Class LTE within reach: LTE in unlicensed spectrum

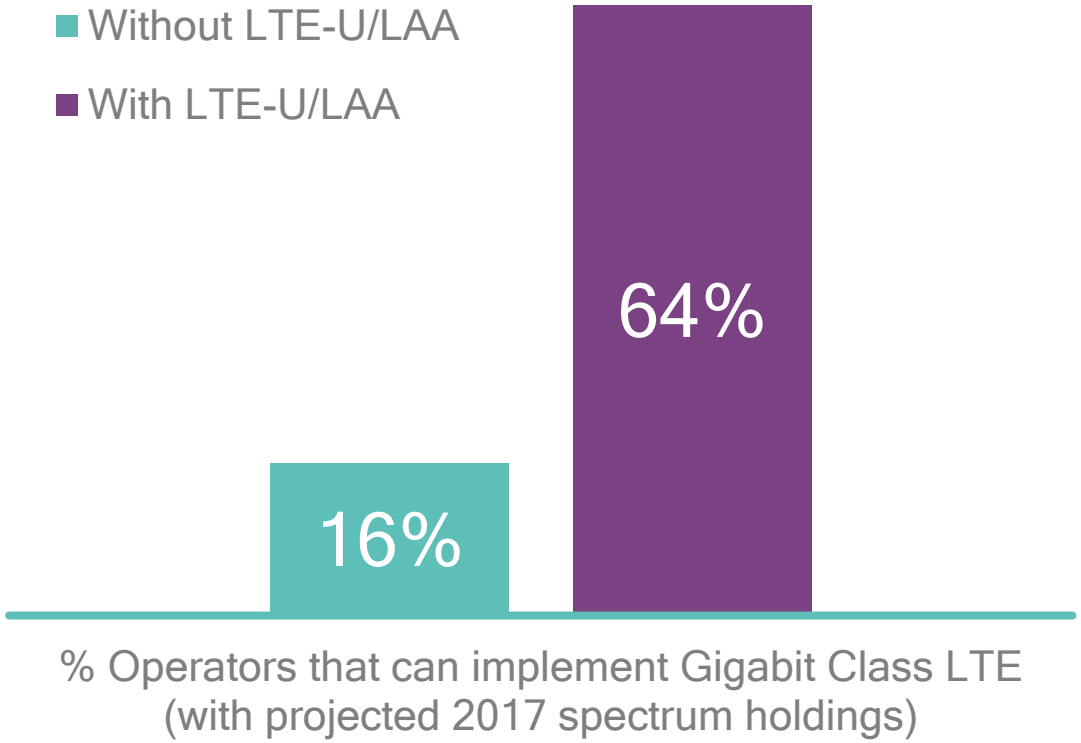
Globalizes possibility of Gigabit Class LTE



Support for LTE in unlicensed spectrum in new geographies with LTE-U and LAA

LTE-U/LAA globalize the possibility of Gigabit Class LTE

Operators with as little one block of 20 MHz licensed spectrum can deploy Gigabit Class LTE



% Operators that can implement Gigabit Class LTE
(with projected 2017 spectrum holdings)

Source: Strategy Analytics “Carrier Aggregation: Essential to Long-Term Operator & OEM Success” report, Exhibit 3 - “Distribution of Operators by Number of 20 MHz Blocks Owned, 2017”, Oct’15.

Snapdragon X16 LTE Modem

Announcement summary

1. First* cellular modem to achieve Gigabit Class LTE speeds
2. First* LTE Advanced *Pro* modem
3. First* LTE discrete modem built on 14nm FinFET process
4. Boosts peak speeds from 450 Mbps to 1 Gbps on the same 60 MHz of spectrum
   By using more antennas (4x4 MIMO) and more sophisticated signal processing (256-QAM)
5. Globalizes the possibility of Gigabit Class LTE with LTE-U and LAA
6. Based on new architecture that scales across tiers and new segments
7. Part of a complete portfolio of modems that address microamp IoT to Gigabit applications

*First commercially announced

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