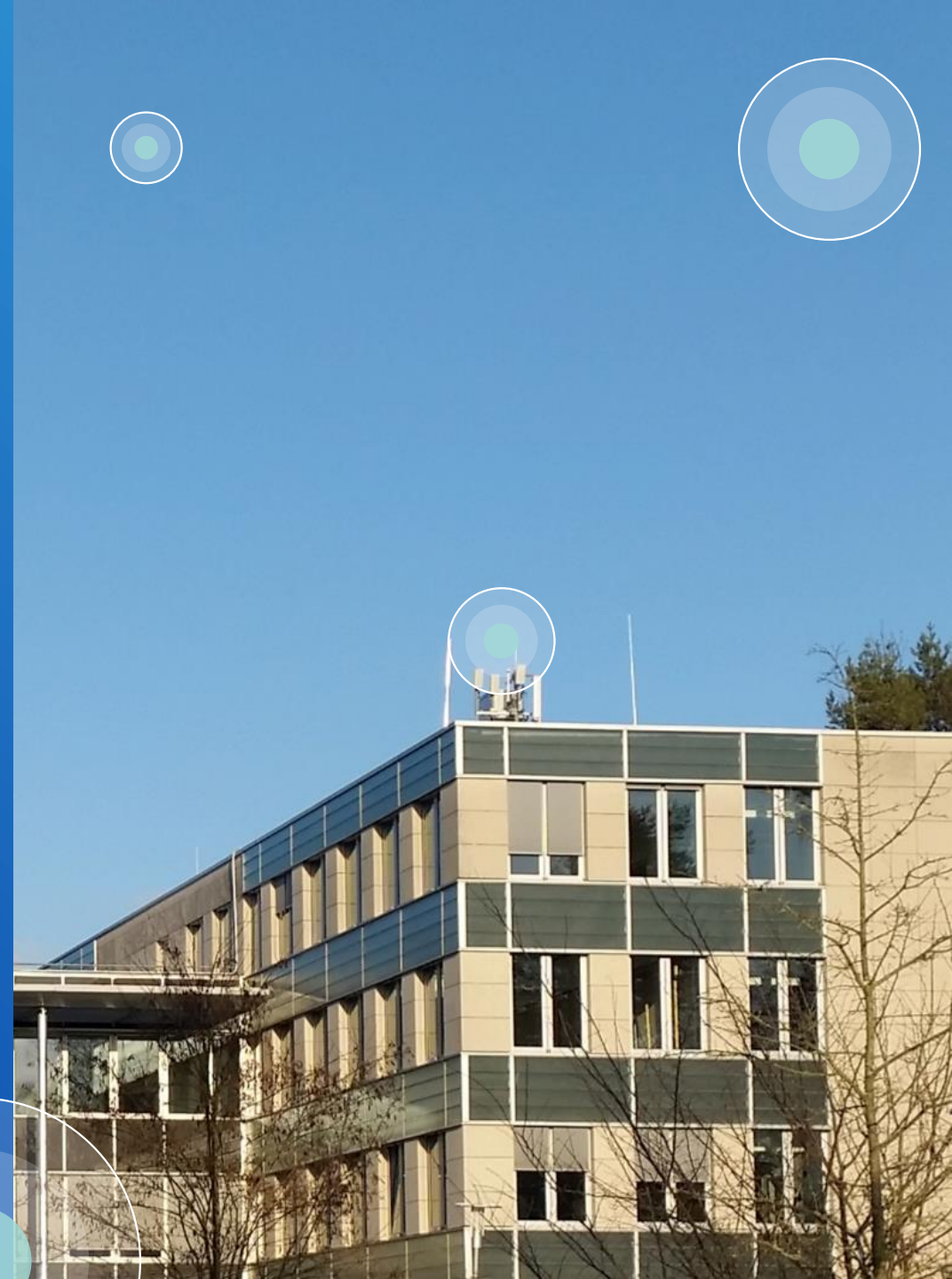


World's first over-the-air LAA trial

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.

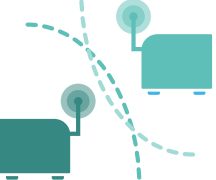
Co-existence benefiting everyone


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)

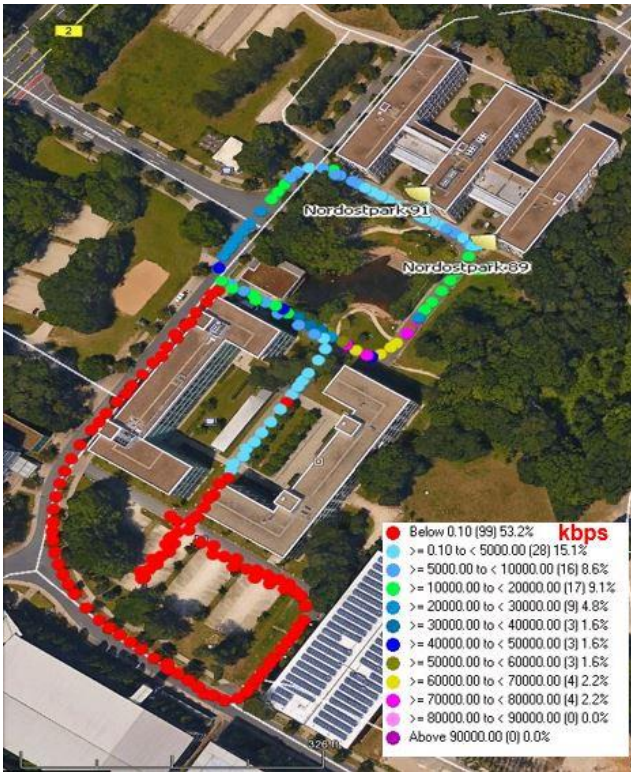
Same configuration for LAA and Wi-Fi: radio channel, 2x2 MIMO, antennas, transmit power, mobility...



~2X coverage improvement outdoors

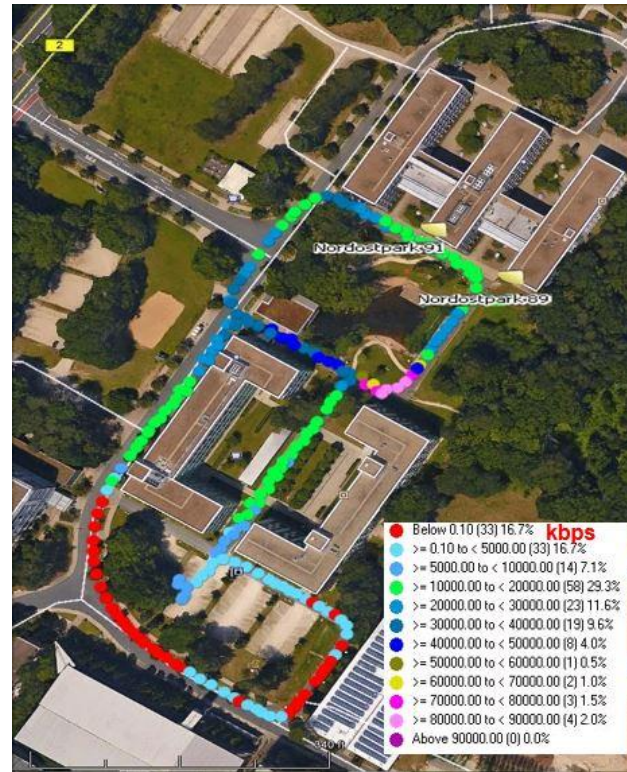
Downlink throughput in unlicensed spectrum for each location on test route¹

LWA (Wi-Fi)



©2009 GeoBasis-DE/BKG, ©2016 Google

LAA



©2009 GeoBasis-DE/BKG, ©2016 Google

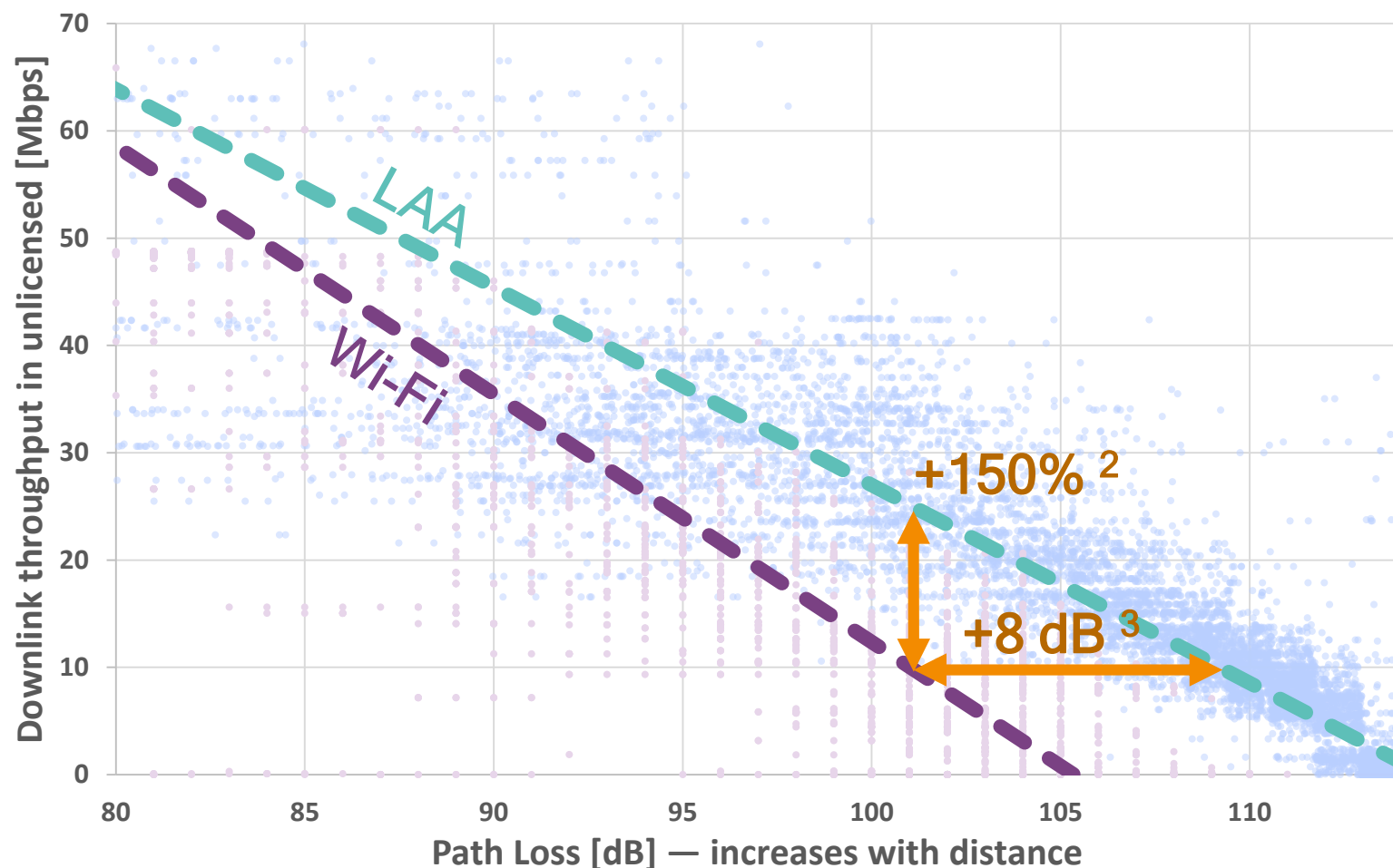
Coverage² in unlicensed

Mbps	Wi-Fi	LAA
>10	24% of route	60% of route
>1	39% of route	71% of route
>0	47% of route	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 mobility¹



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.

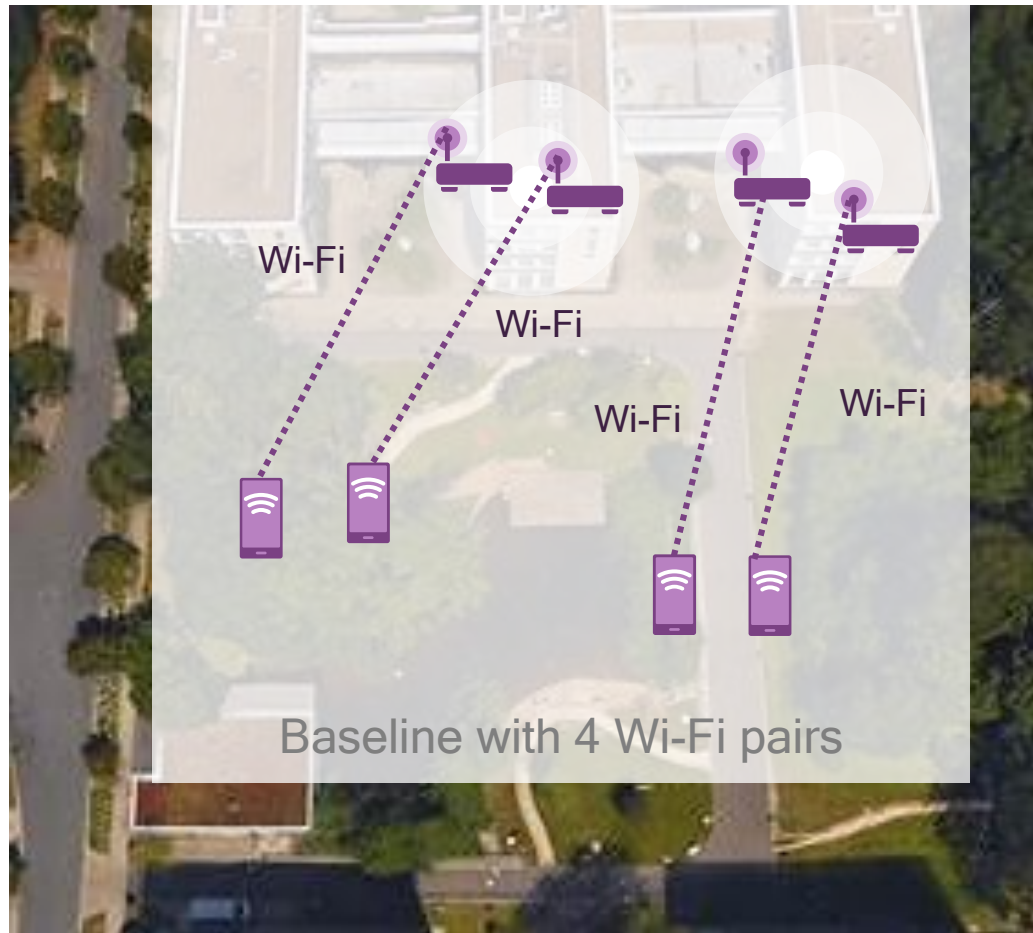
Higher averaged throughput

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

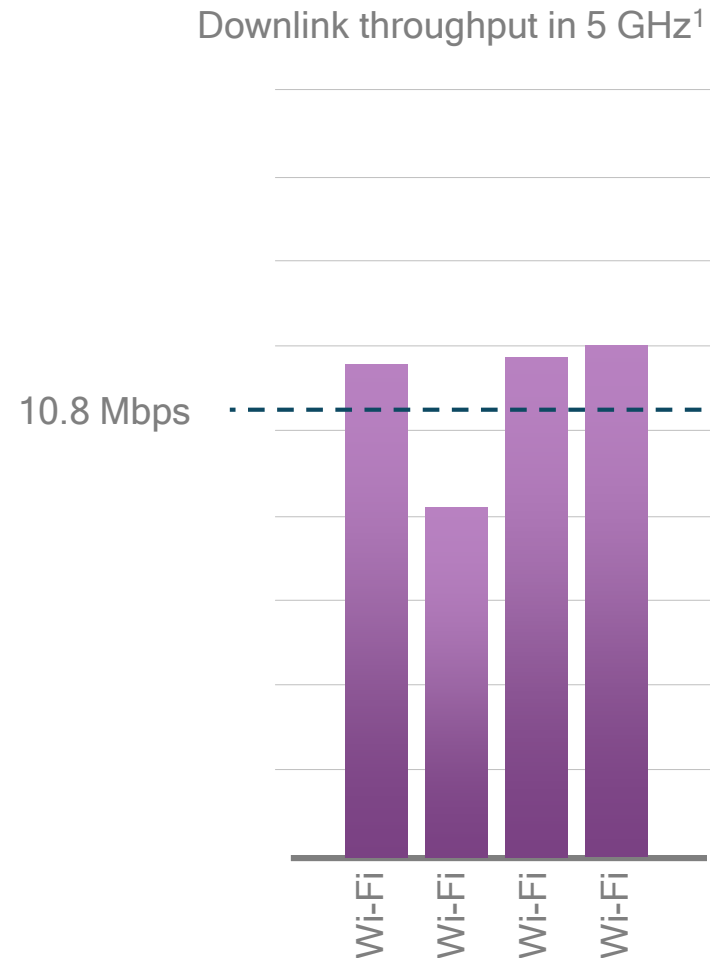
¹ Dual cells with handover, LAA based on 3GPP release 13; LWA using 802.11ac; LTE on 10 MHz channel in 2600 MHz licensed spectrum with 4W transmit power; the following conditions are identical for LAA and Wi-Fi: 2x2 downlink MIMO, same 20 MHz channel in 5 GHz unlicensed spectrum with 1W transmit power. 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



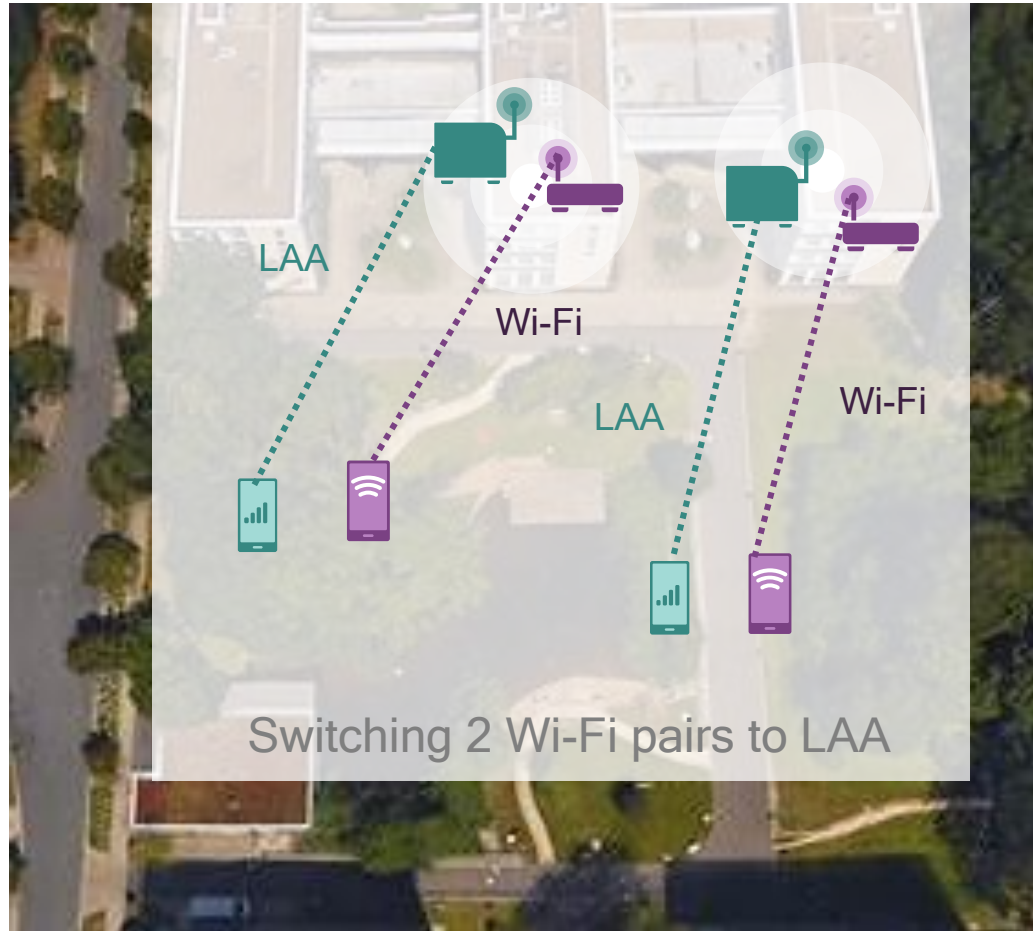
Imagery ©2016 Google. Map data ©2016 GeoBasis-DE/BKG (©2009). Google



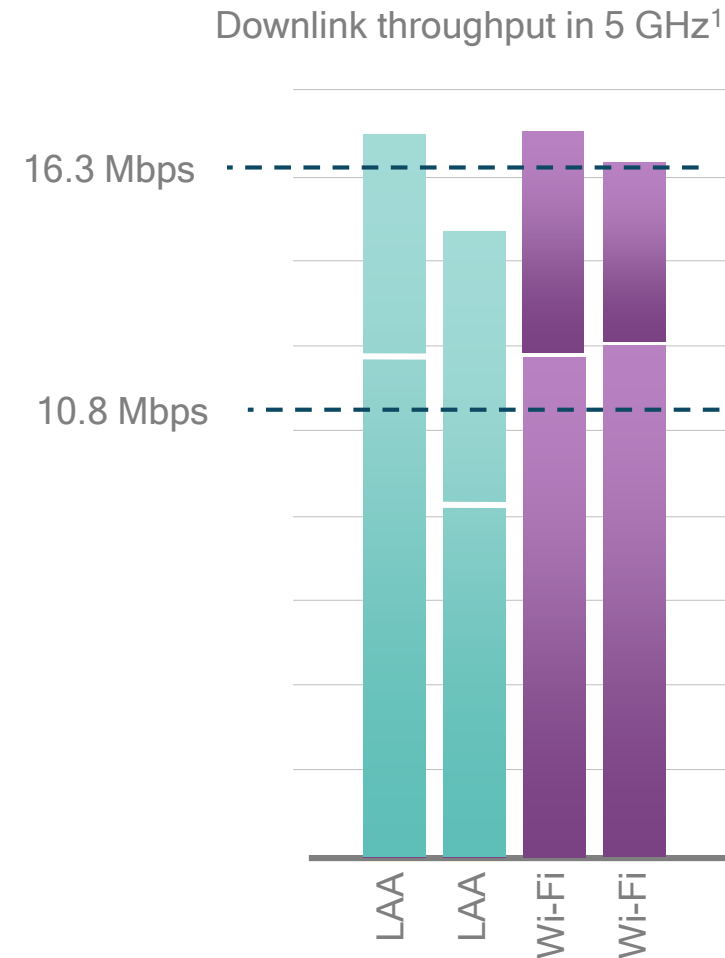
¹ Outdoor, 4 users on 4 different AP/cells, Mix of above and below ED, strong signal level with some interference, LAA based on 3GPP rel. 13; LWA using 802.11ac; LTE on 10 MHz channel in 2600 MHz licensed spectrum with 4W transmit power; the following conditions are identical for LAA and Wi-Fi: 2x2 downlink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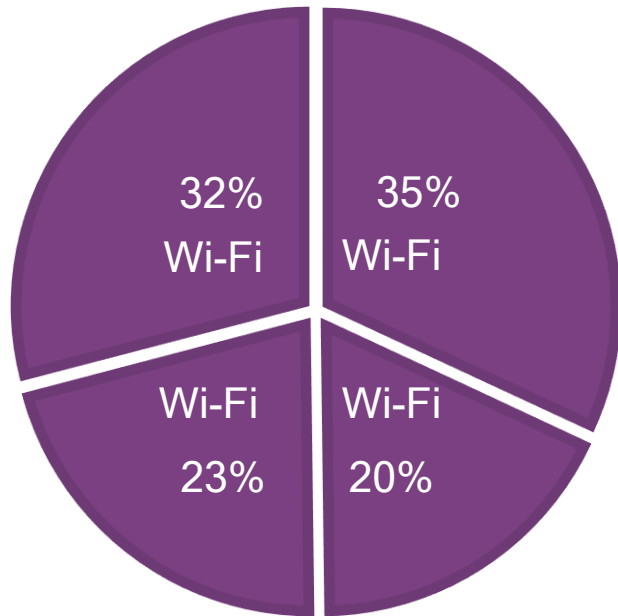


¹ Outdoor, 4 users on 4 different AP/cells, Mix of above and below ED, strong signal level with some interference, LAA based on 3GPP rel. 13; LWA using 802.11ac; LTE on 10 MHz channel in 2600 MHz licensed spectrum with 4W transmit power; the following conditions are identical for LAA and Wi-Fi: 2x2 downlink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

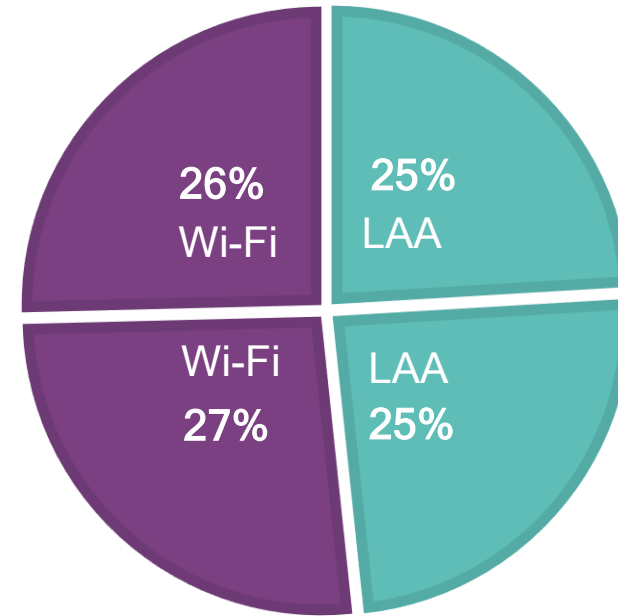
LAA benefits everyone sharing the same 5 GHz channel

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 occupancy¹,
the total is not 100% due to over utilization.

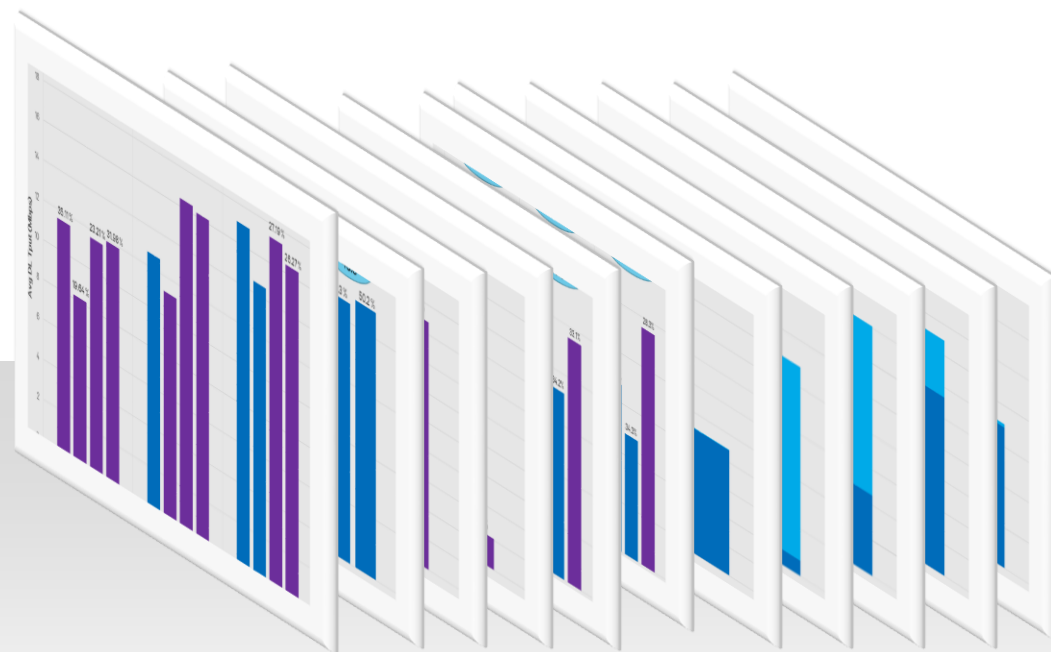
¹ Outdoor, 4 users on 4 different AP/cells, Mix of above and below ED, strong signal level with some interference, LAA based on 3GPP rel. 13; LWA using 802.11ac; LTE on 10 MHz channel in 2600 MHz licensed spectrum with 4W transmit power; the following conditions are identical for LAA and Wi-Fi: 2x2 downlink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

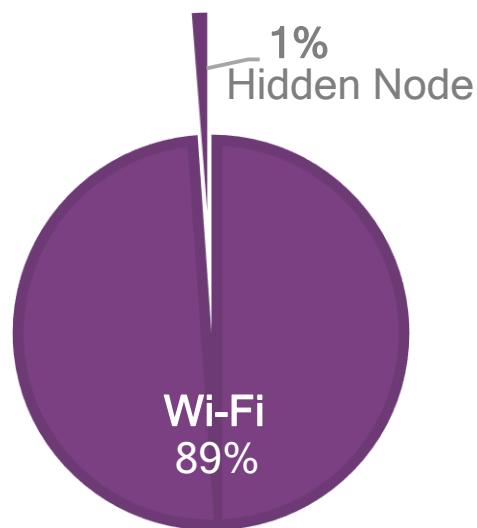
2 LBT ensures that the channel is **shared fairly between the users** and LAA is overall a better neighbor to Wi-Fi than Wi-Fi itself.



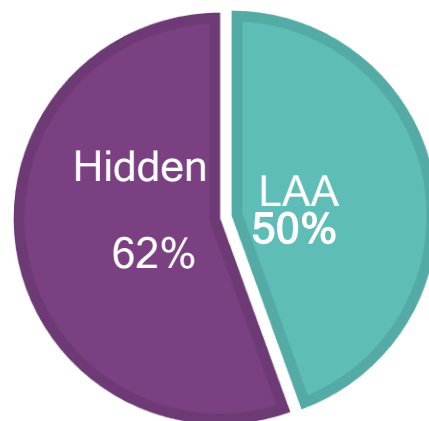
LAA shares the channel fairly also in corner cases

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

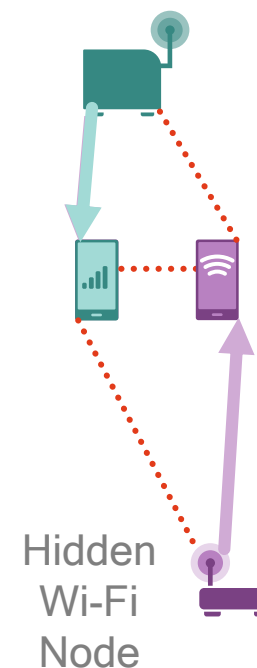
Baseline with 2 Wi-Fi pairs



Switching 1 Wi-Fi pair to LAA



Numbers in pie charts show channel occupancy¹, the total is not 100% due to over/under-utilization.



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.

Thank you



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