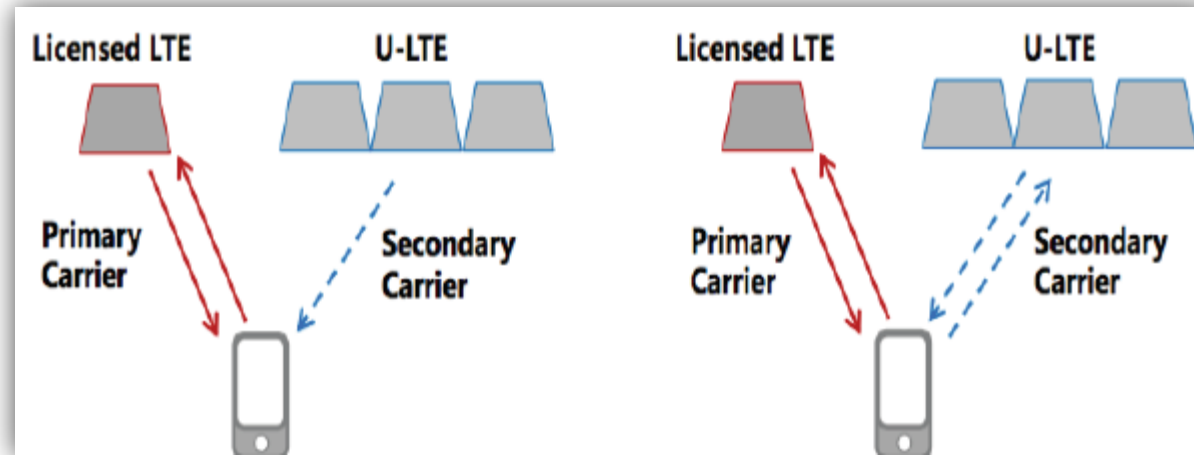


UNLICENSED LTE & WIFI COEXISTENCE

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August 18, 2015



LTE-U & LAA are envisioned to complement existing LTE networks with carriers in unlicensed band (5 GHz)

- LTE-U: Pre standard version
- LAA: Version currently being standardized in 3GPP

Initially LTE-U & LAA deployments are expected to be for downlink traffic only on LAA carriers, but later to encompass uplink

Only best effort data to be serviced by the unlicensed band

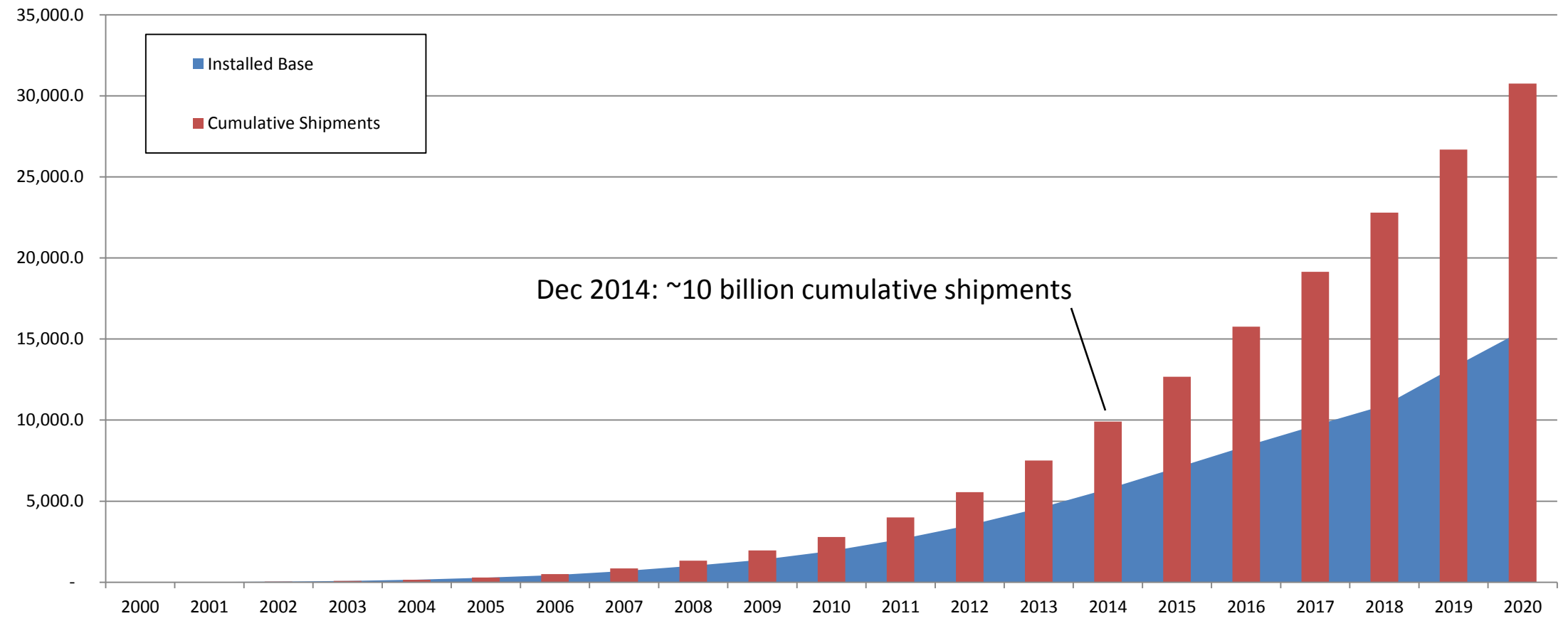
- QoS sensitive applications such as video and voice continue to use licensed band

Primarily restricted to small-cell usage models

WI-FI DEMAND EVER-INCREASING; LTE-U/LAA NEEDS TO ENSURE FAIRNESS IN DENSE WI-FI DEPLOYMENTS



Wi-Fi Cumulative Product Shipments and Installed Base of Products 2000-2020



Source: ABI Research: Cumulative Wi-Fi-enabled Product Shipments and Installed Base of Wi-Fi-enabled Products World Market, Forecast: 2000 to 2020.

WI-FI SERVICE PROVIDERS NEED LTE-U/LAA IN HARMONY WITH WI-FI IN 5 GHZ FOR QUALITY VIDEO AND VOICE



- LTE-U/LAA providers have licensed airwaves for voice and video; Other service providers rely solely on Wi-Fi
- Voice and video quality over Wi-Fi must be preserved
- So, are LTE-U/LAA polite enough?



WI-FI DENSIFICATION CONTINUES...

802.11N

2009
450 Mbps
20/40 MHz

802.11AC

2012
1.3 Gbps
80 MHz

Devices use two
80 MHz channels

Advanced 802.11AC

2015
160 MHz
MU-MIMO

3x deployment
density

802.11AX

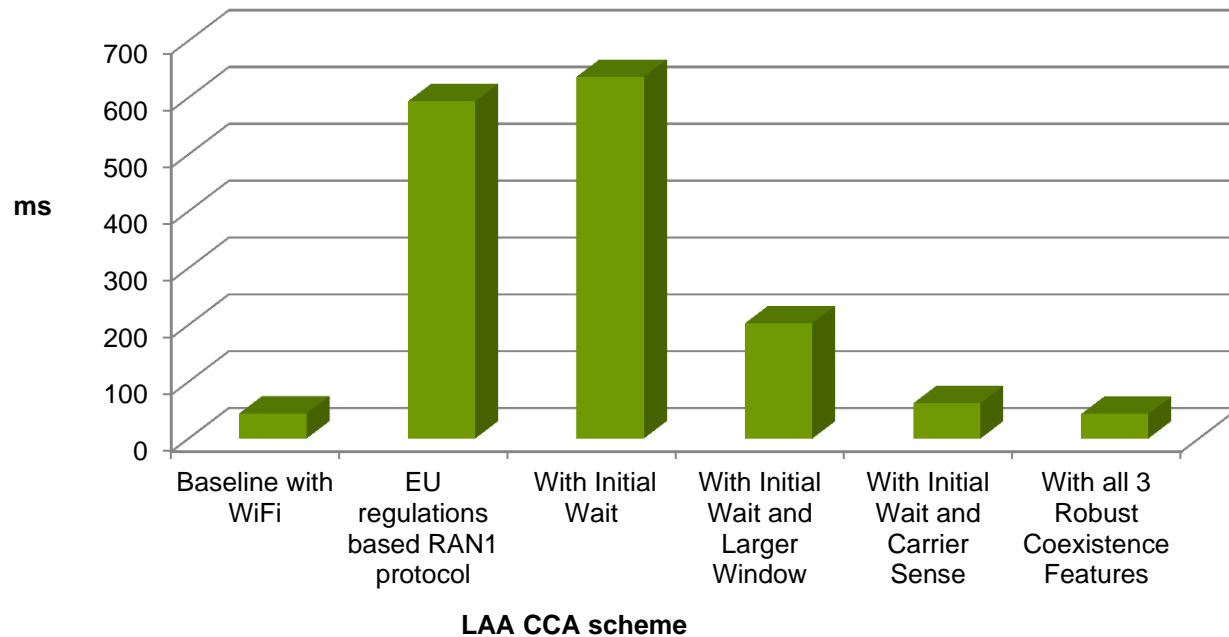
2017
7.2 Gbps
High efficiency
MAC

High density and
efficiency WLAN

But higher Wi-Fi
deployment
density using
wider
transmission
bandwidths
increases
channel
congestion -
**mandates polite
behavior from
LTE-U/LAA**

“Old” Wi-Fi configurations are being used
in some of the coexistence studies

Average latency of VoIP packets on Wi-Fi A



Wi-Fi VoIP Average 98%ile Latency (ms)
For LAA protocol alternatives

Objective: Test VoIP latency when LTE-U and Wi-Fi operate simultaneously

Scenario: Moderately dense indoor deployment

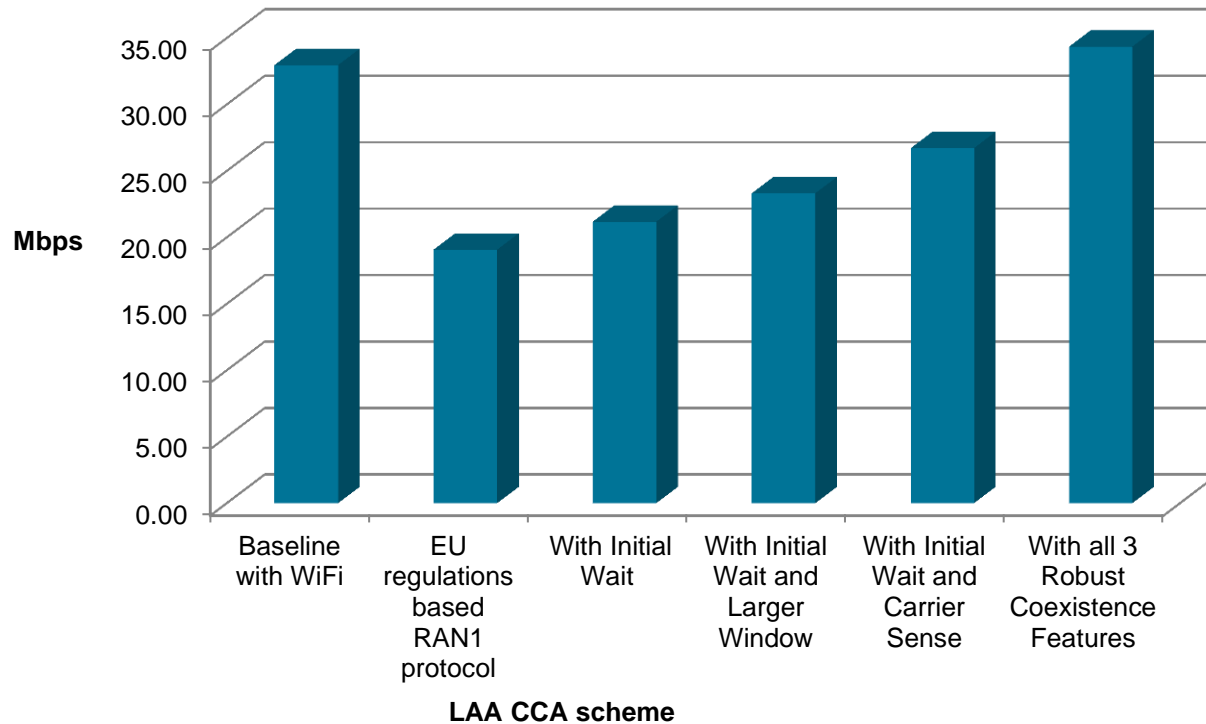
- 4 Wi-Fi AP's in network A
- 4 LAA nodes (or Wi-Fi nodes) in network B
- 10 data users in each network
- 2 Wi-Fi VoIP users in network A

Results: Average 98 %ile Latency (ms) measured as nominal user requirement

- 44ms when both networks are on Wi-Fi
- 600ms when LAA is active and using only baseline coexistence protocols adhering to EU regulations
- 43ms if robust coexistence is implemented

Robust coexistence mechanism needed to guarantee VoIP quality (~50 ms latency)
in Wi-Fi deployments

Wi-Fi A Throughput



Wi-Fi Aggregate Data Throughput
For LAA protocol alternatives

Objective: Test if Wi-Fi speeds can exceed video needs of 20 Mbps when LTE-U and Wi-Fi operate simultaneously

Scenario: Moderately dense indoor deployment

- 4 Wi-Fi AP's in network A
- 4 LAA nodes (or Wi-Fi nodes) in network B
- 10 data users in each network
- 2 Wi-Fi VoIP users in network A

Results: Average Wi-Fi speeds

- 33 Mbps when both networks are on Wi-Fi
- 19 Mbps when LAA is active and using only baseline coexistence protocols adhering to EU regulations
- 34 Mbps if robust coexistence is implemented

Without Robust coexistence mechanisms, throughput needs for video data (~20 Mbps) will not be met for moderately dense deployments

Broadcom suggests standardization of at least a three-pronged approach to healthy coexistence among broadband unlicensed technologies:

- **Let other data transmissions and handshake mechanisms complete before transmitting; be adaptive to current occupants**
 - Solution: LTE-U/LAA should deliberately wait for a nominally acceptable time before transmissions
 - Possible Technical solution: Initial wait for ~43 microseconds prior to arbitration - similar to Wi-Fi
- **Back-off transmissions rapidly when significant interference with other users is detected; be adaptive to congestion**
 - Solution: LTE-U/LAA should implement technologies similar to those in Wi-Fi such as “Exponential Back-off” which defer transmissions upon detection of interference
- **Detect signals that are far below regulatory requirements to maintain thriving unlicensed ecosystem**
 - Solution: Match Wi-Fi mechanisms, which detect signals as weak as 1000 times below regulatory requirements
 - Possible Technical solution: LTE-U/LAA should operate at -82 dBm to -92 dBm for preamble or carrier sense detection and at -62 dBm energy detection assuming 20 MHz signal bandwidth

THANK YOU