UNLICENSED LTE & WI-FI COEXISTENCE CONSIDERATIONS

Itai Dadon
Christopher Szymanski

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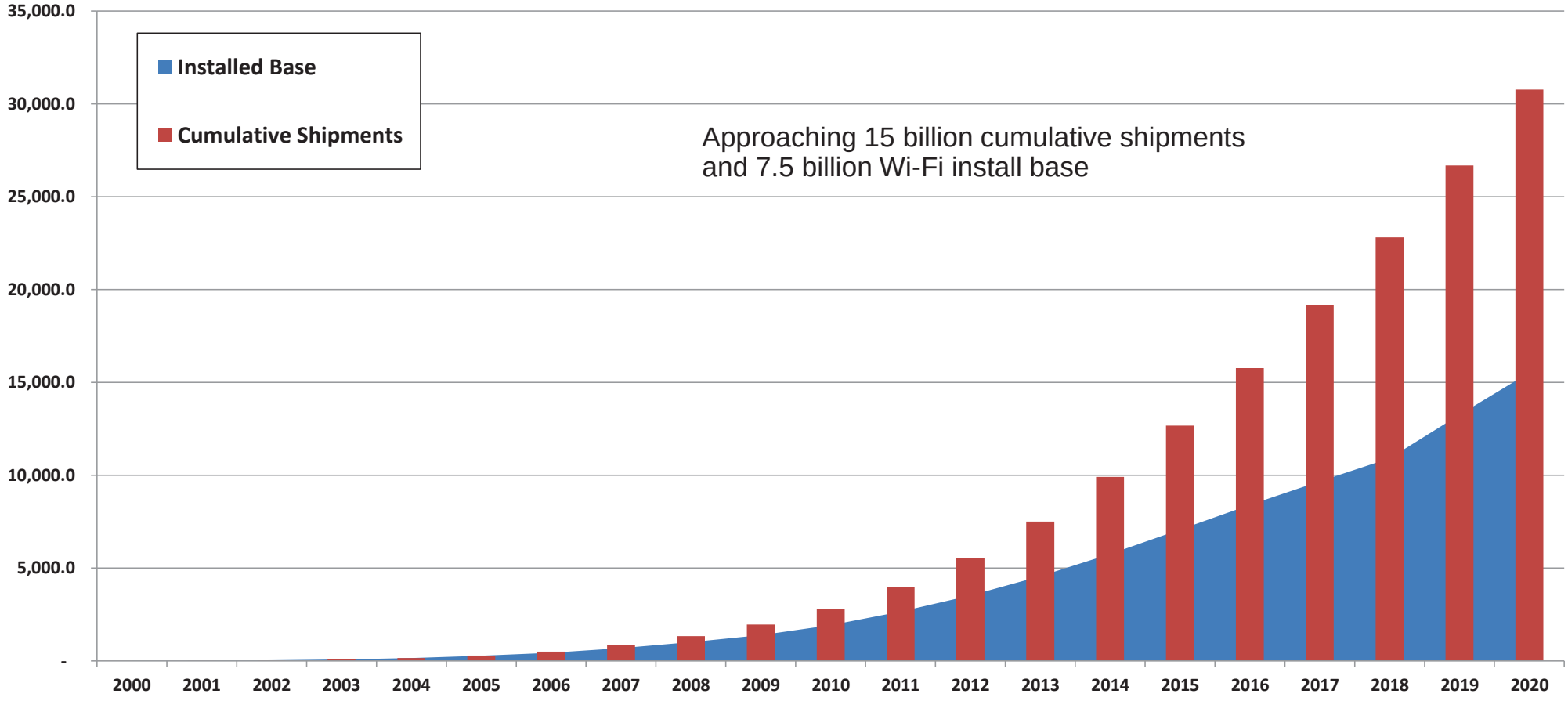
WI-FI DEMAND HUGE & EVER-INCREASING



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

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WI-FI IS THE PREDOMINATE & PREFERRED WAY PEOPLE ACCESS INTERNET

- **Over 80% of mobile data traffic goes over Wi-Fi**
  - Wi-Fi traffic grew at over 2X the rate of cellular traffic from 2H13 to 1H15, accounting for ~83% of wireless traffic [1]
  - 81% of smart phone traffic is carried over Wi-Fi [2]
  - "Wi-Fi dominating monthly data usage" [3, 4]
  - "Almost all wireless data usage (80-90%) is "Quasi-static/In Wi Fi coverage," due to device capabilities, relative pricing, and quality-of-experience versus cellular"

[1] Strategy Analytics' Telemetry Intelligence Platform: http://www.wirelessweek.com/news/2015/08/study-cellular-wi-fi-data-usage-among-smartphone-users-tripled-under-two-years
[2] Analysys Mason: Research Report**:** Consumer smartphone usage 2014: mobile data usage *April 2015*
[3] Mobidia**:** http://www.mobidia.com/insights/topic/whitepapers;
[4] Paul de Sa, Bernstein, A New LTE/5G order: https://owncloud.cablelabs.com/public.php?service=files&t=0384b653d14da1120ad740136de327a9

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WI-FI IS SOMETIMES THE ONLY MEANS FOR INTERNET ACCESS

- **Outdoor Wi-Fi Hotspots Providing Outdoor Coverage**
  - LinkNYC will soon replace over 7,500 payphones across the five boroughs with high speed Wi-Fi hotspot kiosks [5]
- **Indoor Wi-Fi Hotspots Providing Outdoor Coverage**
  - The Web-Deprived Study at McDonald's: Students go to the parking lots of businesses that offer free Wi-Fi in order to do their homework [6]
  - Students use local schools' and libraries' Wi-Fi to finish homework after class [7]

[5] https://www.link.nyc/index.html;
[6] http://www.wsj.com/articles/SB10001424127887324731304578189794161056954;
[7] http://www.nytimes.com/2016/02/23/technology/fcc-internet-access-school.html?_r=0

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WI-FI (802.11) CONTINUES TO EVOLVE & INNOVATE

2012

802.11AC

- 1.3 Gbps
- Improved range

2014/15

Advanced AC

- 7 Gbps
- Better, faster, and more secure, roaming within a network
- Better in dense user environments

2016/17

Carrier Grade AC

- Seamless association and roaming
- Enhanced traffic prioritization
- Greater network manageability, reliability, and efficiency

2017/18

802.11AX

- 10 Gbps
- Designed for dense indoor/outdoor environments
- Further improvements in association and roaming
- 4X increased spectral efficiency over AC, allowing even more simultaneous users
- Reduced latency
- Enhanced range

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WHAT IS UNLICENSED LTE AND HOW WILL IT BE DEPLOYED?

- LTE has been modified by a few companies so that it can operate in the same unlicensed spectrum that Wi-Fi uses (called LTE-U)
- License Assisted Access (LAA) and eLAA are modifications of the LTE protocol being standardized in 3GPP
- LTE-U / LAA deployments will target high densely populated urban areas, where Wi-Fi is already widely used

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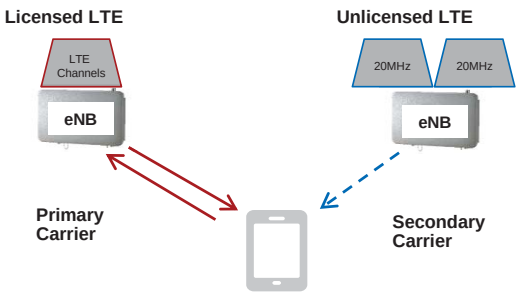
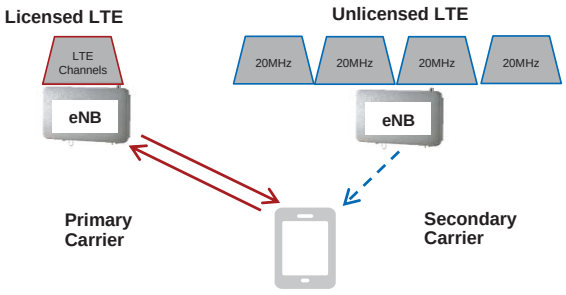
WHAT ARE THE DIFFERENCES BETWEEN LTE-U / LAA / eLAA?

NON STANDARD LTE-U



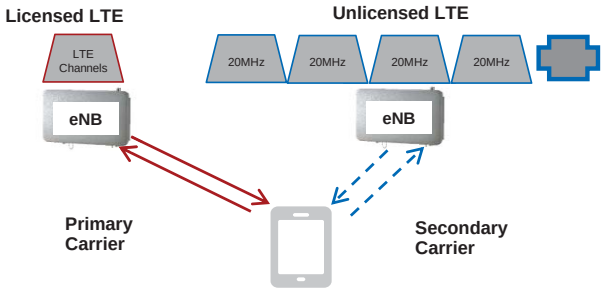
- Proprietary technology
- Downlink only
- For use in countries with no listen-before-talk (LBT) regulatory requirement (e.g., USA, China, South Korea, India)
- Claims coexistence using duty cycle

LICENCE ASSISTED ACCESS (LAA)



- 3GPP Rel 13
- Downlink only
- Meets LBT regulatory requirements (e.g., EU, Japan)
- Allows aggregation of up to 4 unlicensed channels
- Expected June 2016

LAA WITH UPLINK (eLAA)



- 3GPP Rel14
- Adds uplink over unlicensed spectrum
- Likely will use more than four unlicensed channels
- Expected March 2017

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LTE-U INTERFERES WITH WI-FI

- Broadcom's tests demonstrate that Wi-Fi links will be severely degraded by interference from LTE-U based networks
  - Proprietary LTE-U will be the most disruptive to Wi-Fi
  - Standards based version of LTE-U, called LAA, should protect some Wi-Fi traffic
  - Unless more work is done to make LAA more friendly within 3GPP, existing Wi-Fi coverage areas will shrink and throughput and latency will be significantly compromised[8]

*[8] See IEEE and Wi-Fi Alliance Liaison Letters to 3GPP (R1-163375 & R1-163388)

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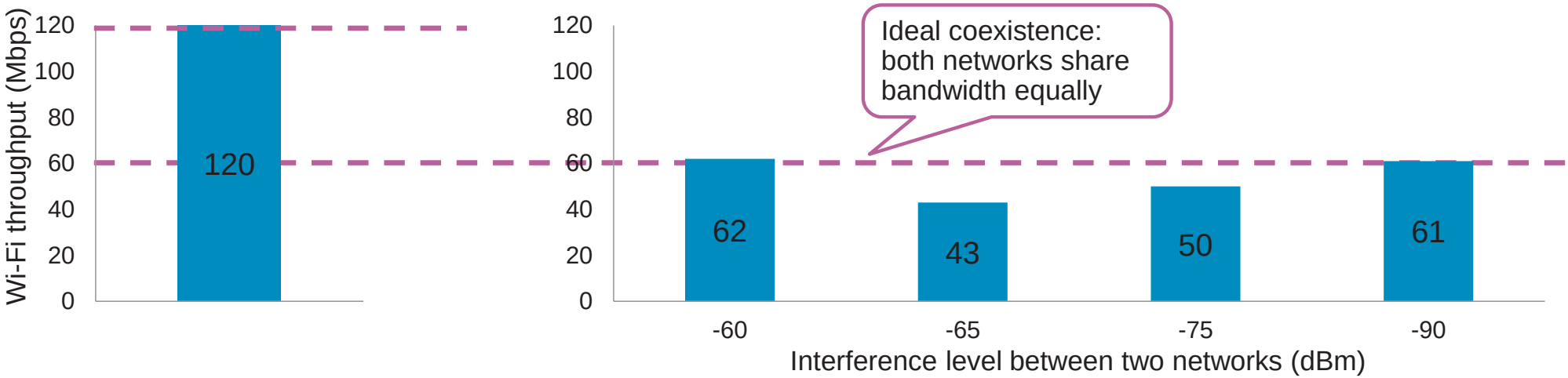
BASELINE: WI-FI + WI-FI



1 Wi-Fi network

2 Wi-Fi networks coexisting

- Wi-Fi + Wi-Fi coexistence is basically robust over a wide range of interference levels
- The two networks defer to each other and share the available airtime and bandwidth
  - At -60 dBm interference, OBSS frame detection is accurate and collisions are very rare
  - At -65 and -75 dBm interference, occasional OBSS frame misdetection causes collisions that modestly reduce throughput
  - At -90 dBm interference, some OBSS misdetections occur but lower interference means some collisions can still be decoded

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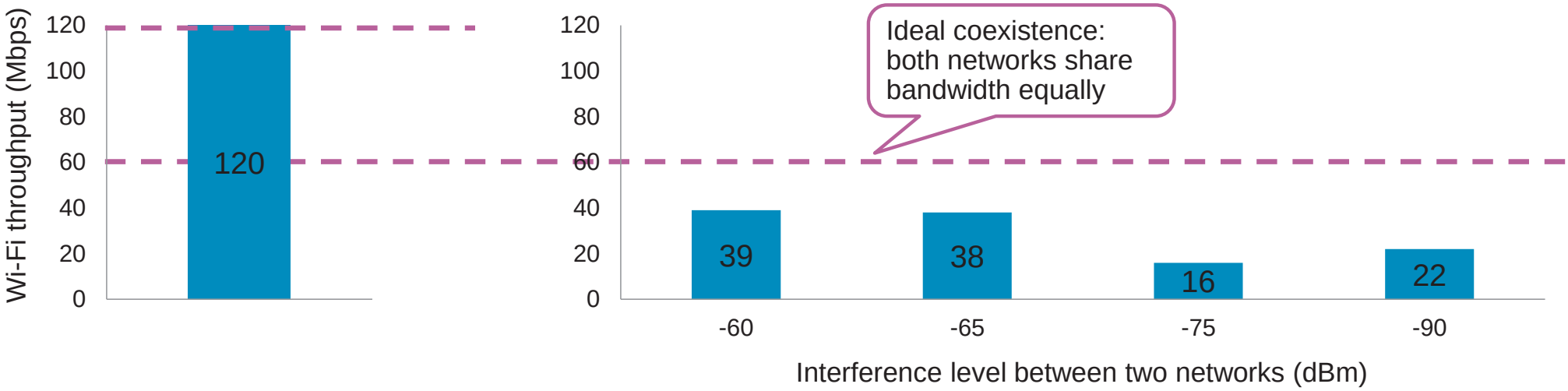
WI-FI + LTE-U 50% DUTY CYCLE (NEIGHBOR DETECTION)



1 Wi-Fi network

1 LTE-U + 1 Wi-Fi network interacting

- Even when LTE-U detects Wi-Fi neighbor and limits its duty cycle to 50%, throughput of the Wi-Fi network is substantially degraded compared to Wi-Fi + Wi-Fi case
  - At all interference levels, LTE-U ON cycles interrupt Wi-Fi transmissions and cause retransmits, with a knock-on effect on Wi-Fi rate adaptation implementations in response to unexpected interference
  - At -75 dBm interference, degradation is worst since LTE-U interference is low enough that Wi-Fi cannot always detect it and back-off its own transmissions, yet high enough that the SINR of the resulting collisions is very poor

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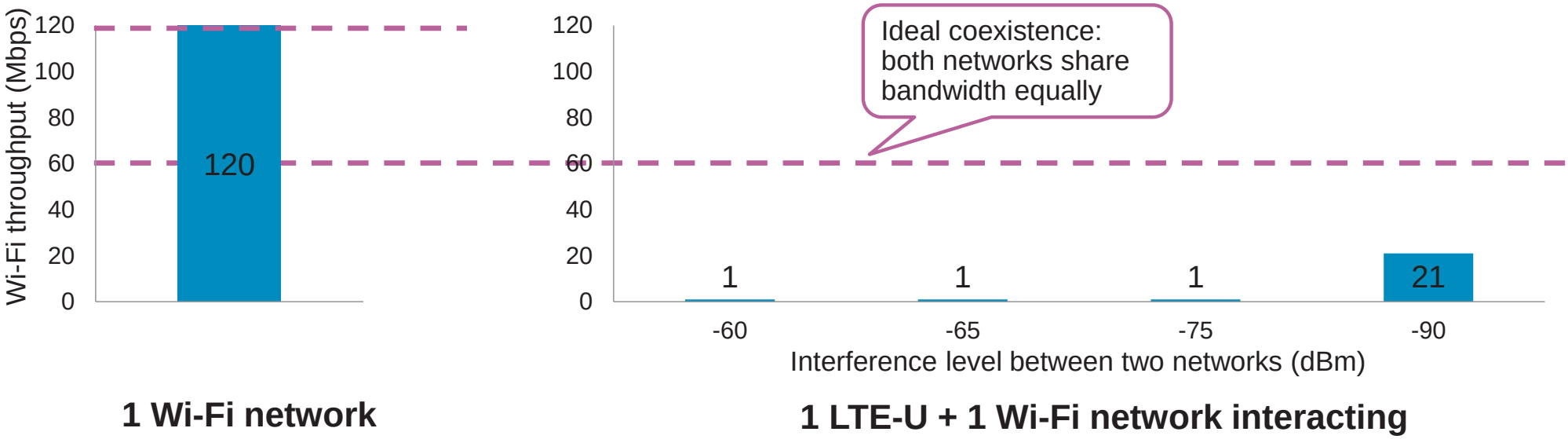
WI-FI + LTE-U 90% DUTY CYCLE (FAILED NEIGHBOR DETECTION)



- If LTE-U doesn't detect Wi-Fi neighbor and raises its duty cycle to 90%, the impact on the Wi-Fi throughput is catastrophic
  - Still substantial degradation even when the interference level is as low as -90 dBm

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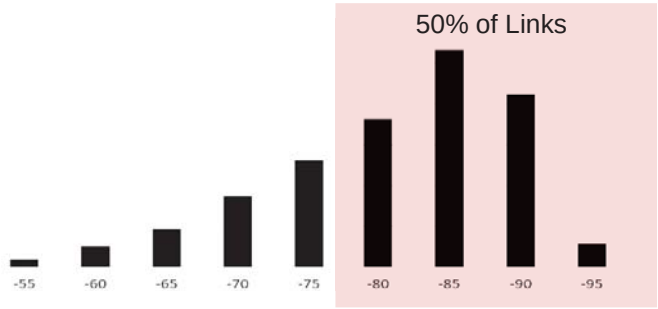
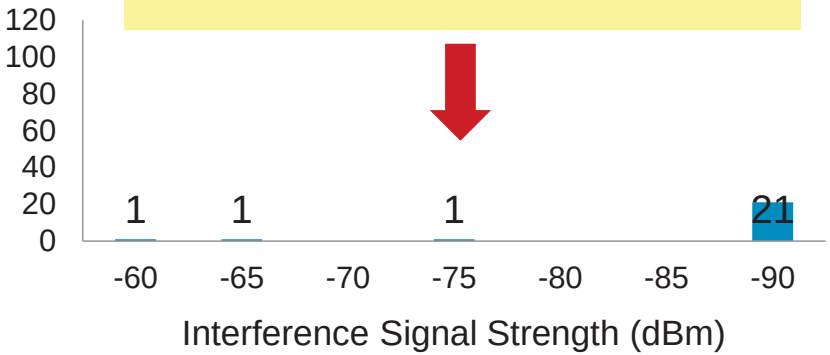
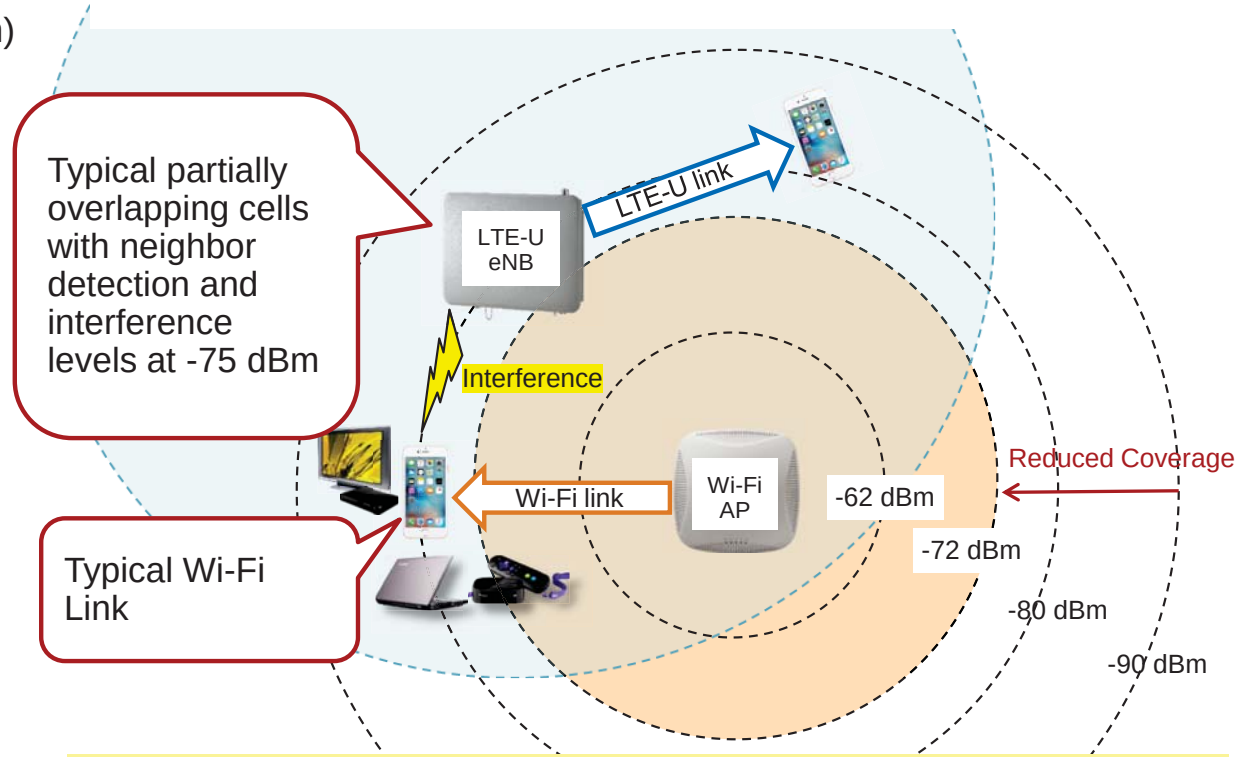
REDUCED WI-FI AP COVERAGE FROM LTE-U INTERFERENCE

Distribution of Outdoor Wi-Fi Link Strengths (dBm)



In this very typical coexistence scenario…





Wi-Fi throughput may fall to <u>almost zero.</u> LAA coexistence with Wi-Fi signals ≥ -72 dBm is expected to be better than LTE-U, but signals below -72?

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LAA FRIENDLIER THAN LTE-U, BUT IT STILL FALLS SHORT

✔ LAA 20MHz channel rules have adopted Wi-Fi like coexistence

- Listen before talk at -72 dBm energy detect level
- Exponential backoff
- Initial defer

? Multichannel, slot alignment, and other rules have not been finalized and may be detrimental to Wi-Fi

✘ 3GPP declined to incorporate coexistence mechanisms in LAA to protect Wi-Fi signals below -72 dBm

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WITH OVER 7 BILLION WI-FI DEVICES OPERATING WORLDWIDE, MUST WE RELY SIMULATIONS?

- Significant field data has been contributed by independent sources that demonstrates links below -72 dBm are typical[9]
  - Boingo: 33% of airport links below -72 dBm
  - Broadcom: - 80 dBm is the typical Wi-Fi link for outdoor hotspots
  - CableLabs: median Wi-Fi signal strength for uplink is -85 dBm, and -80 dBm for downlink
- Analysis of LAA coexistence simulations, and the underlying assumptions, explains the disparity in simulation data and in-field measurements
- Based on the substantial evidence provided from active Wi-Fi devices, assumptions should be revisited, and coexistence should be defined as protecting typical Wi-Fi links

[9] https://www.wi-fi.org/downloads-public/Wi-Fi_LTE-U_Test_Workshop_Presentations_201604.zip/30328

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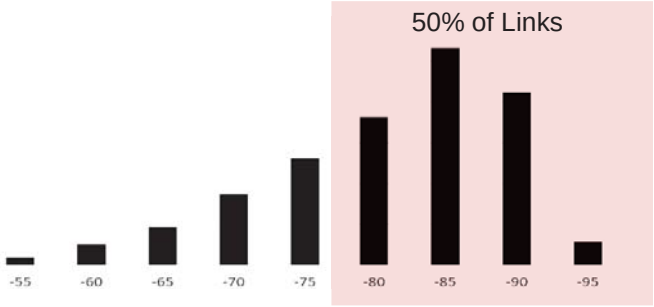
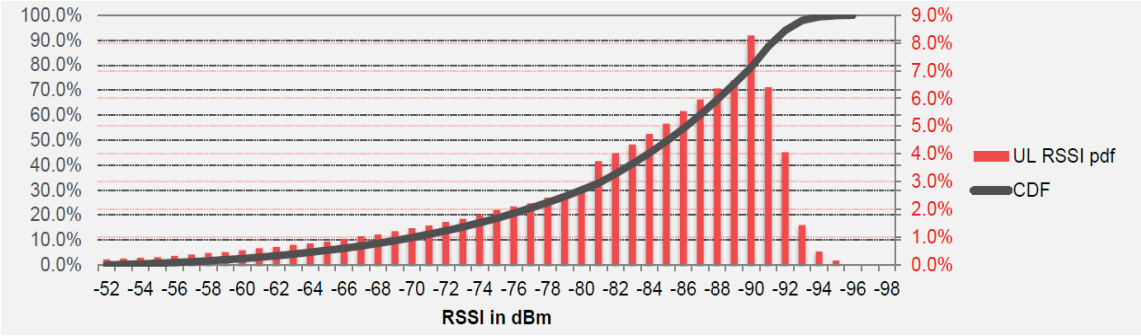
REAL WORLD WI-FI SIGNAL DISTRIBUTIONS



- Broadcom obtained operating data from enterprise deployments and outdoor hotspots
  - Found that the median signal was -80 dBm

- CableLabs provided a data set containing uplink RSSIs
  - From over one million samples
  - Connecting to 13,000 different outdoor APs
  - Demonstrating that the median uplink for data transmissions was -85 dBm [10]



[10] https://www.wi-fi.org/downloads-public/Wi-Fi_LTE-U_Test_Workshop_Presentations_201604.zip/30328

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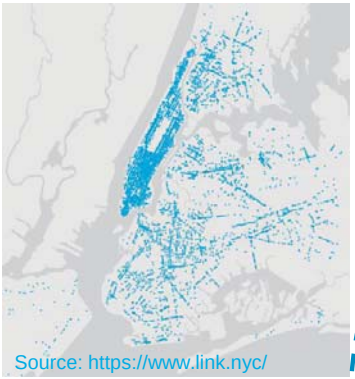
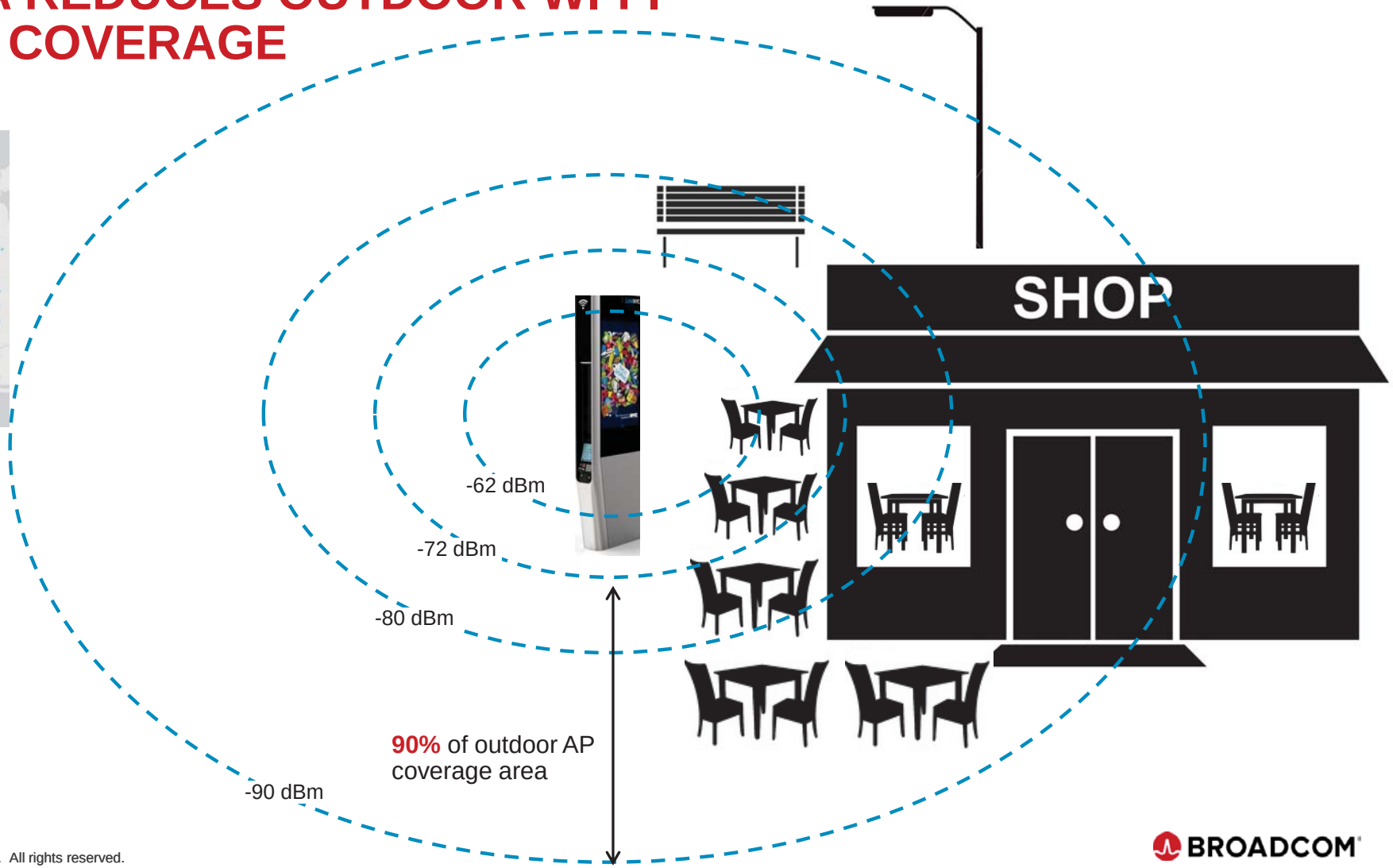
LTE-U/LAA REDUCES OUTDOOR WI-FI HOTSPOT COVERAGE





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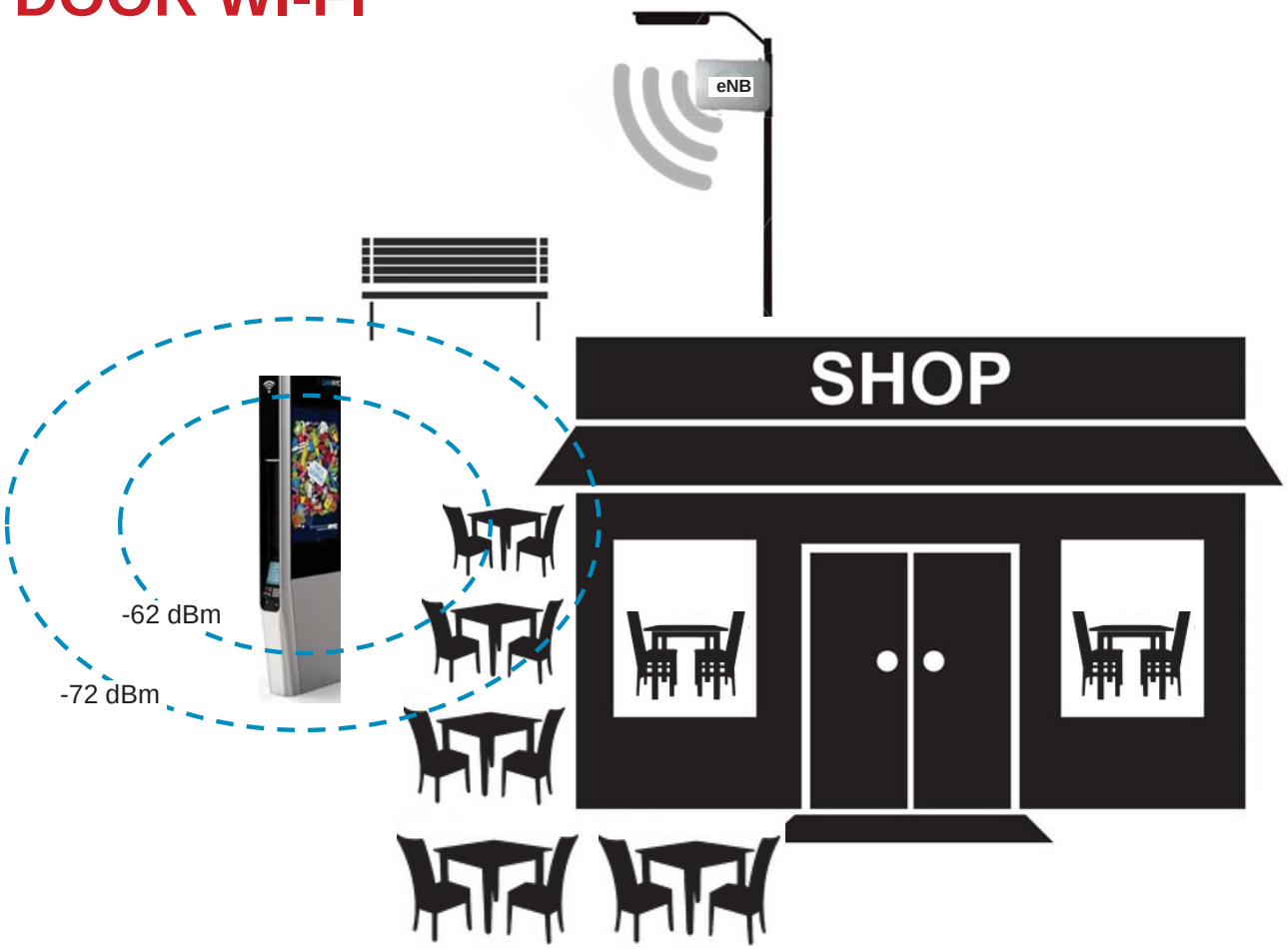
LTE-U/LAA REDUCES OUTDOOR WI-FI HOTSPOT COVERAGE

Wi-Fi AP coverage area may shrink to 10% of its original size

- Reducing broadband access, or
- Requiring increased investment



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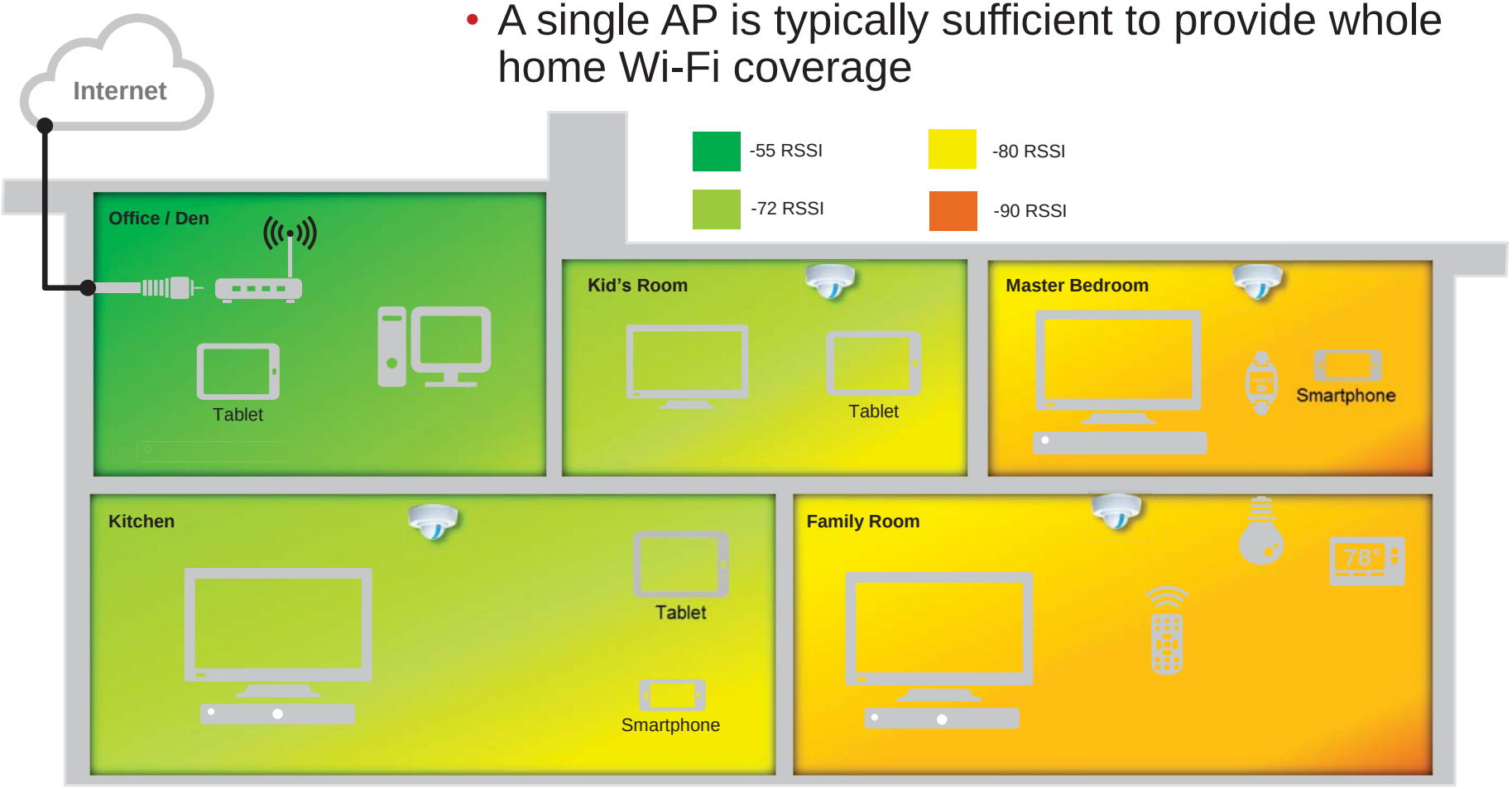
LTE-U / LAA INTERFERES WITH WI-FI LINKS IN THE HOME

- A single AP is typically sufficient to provide whole home Wi-Fi coverage



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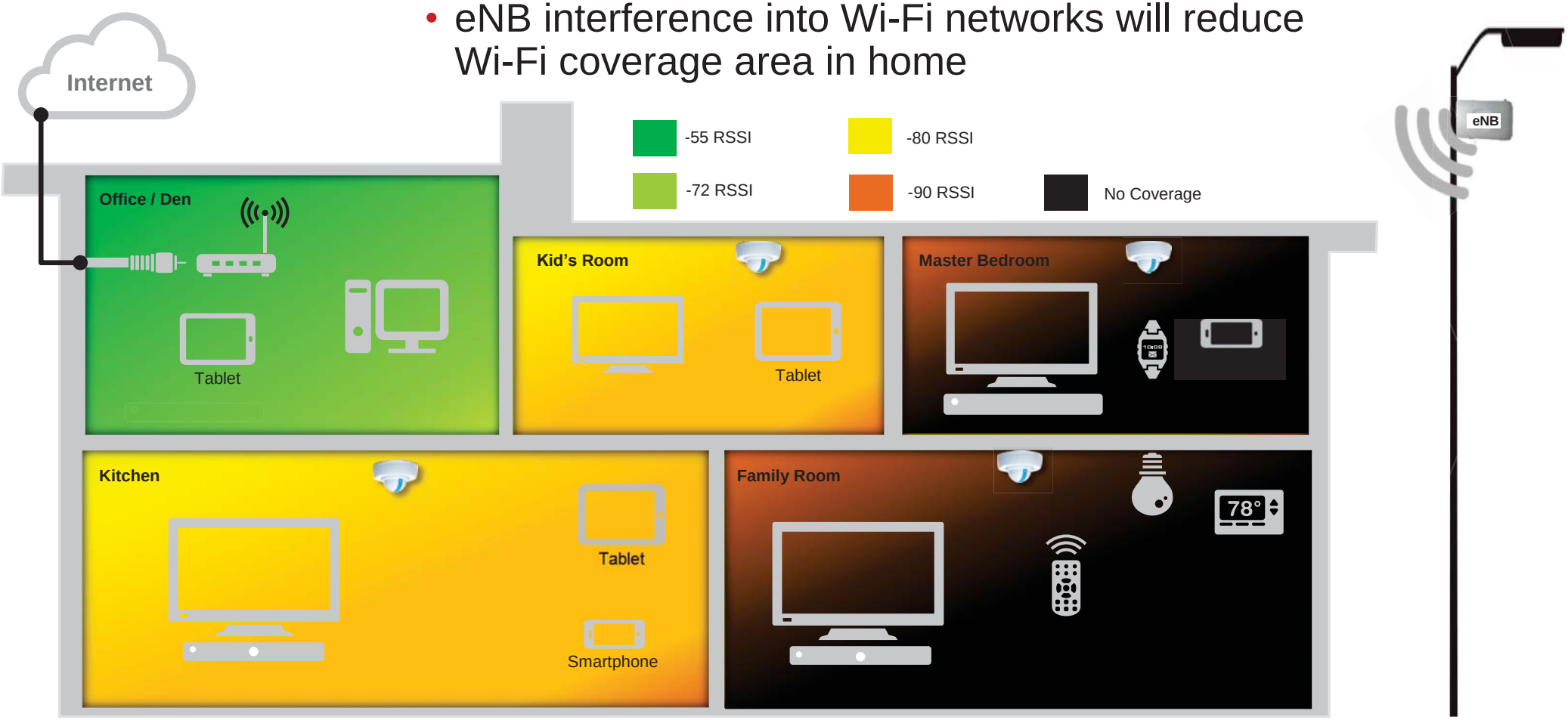
LTE-U / LAA INTERFERES WITH WI-FI LINKS IN THE HOME

- eNB interference into Wi-Fi networks will reduce Wi-Fi coverage area in home



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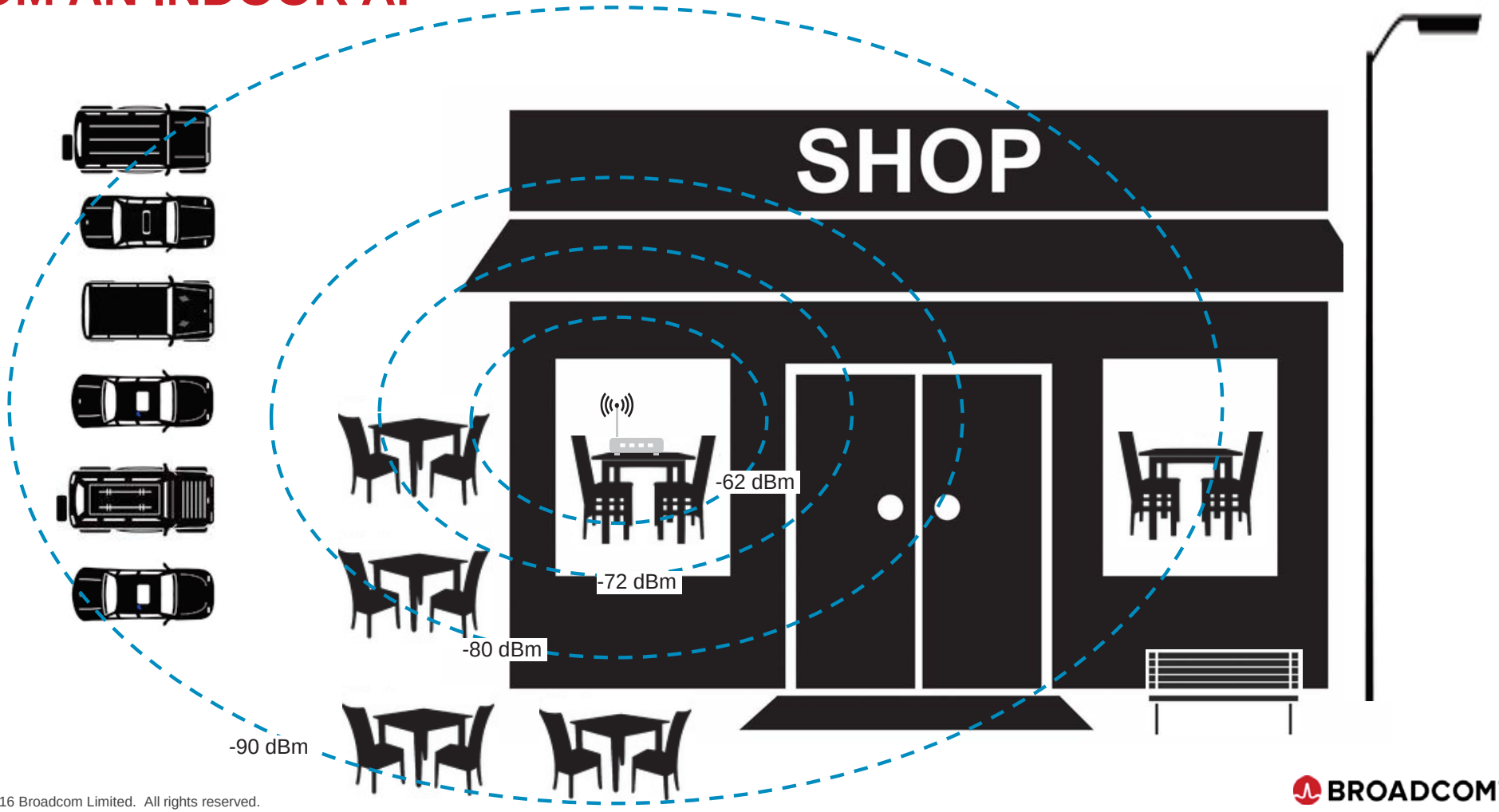
MANY ESTABLISHMENTS PROVIDE OUTDOOR WI-FI COVERAGE FROM AN INDOOR AP



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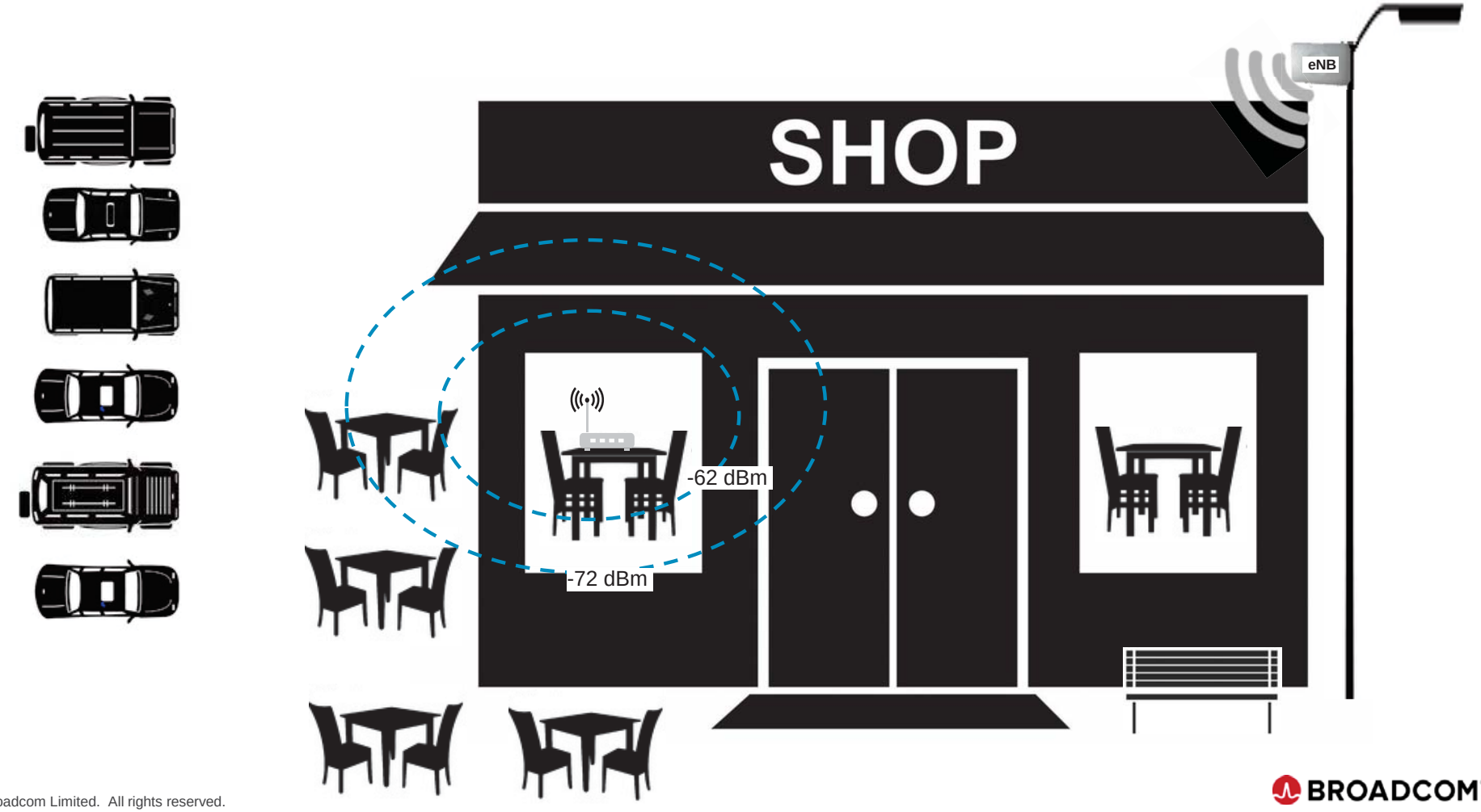
LTE-U/LAA REDUCES WHOLE PREMESIS WI-FI COVERAGE



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CONCLUSIONS

- Proprietary LTE-U would be a disaster for Wi-Fi
- Even standardized LTE-U (e.g., LAA) is likely to significantly reduce Wi-Fi coverage area unless specific coexistence mechanisms are adopted for typical Wi-Fi signals
- The issue is being framed as a technology vs technology or cable vs carrier dispute, but poor coexistence will be felt by cities, businesses, and consumers
  - Cities and businesses have already made significant investments in Wi-Fi as a part of their broadband access strategies
  - There are billions of Wi-Fi devices used around the globe today, many of which may be the only means of broadband access
- Specifications for LTE-U and LAA must be fixed to operate more fairly with Wi-Fi prior to deployment

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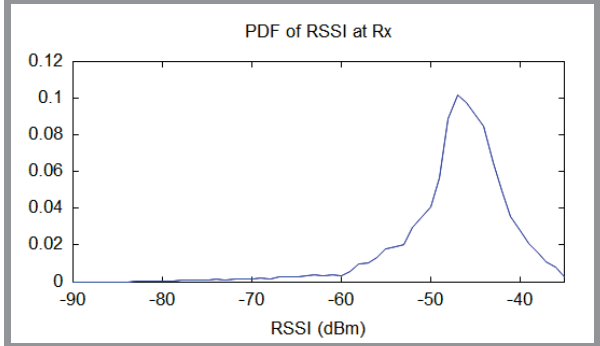
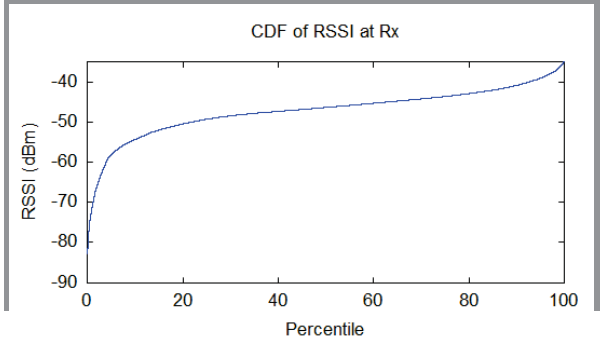
WHY DOESN'T LAA LISTEN TO WI-FI SIGNALS BELOW -72 DBM?

- 3GPP models that served as the basis for LAA coexistence studies generated the following distribution models:

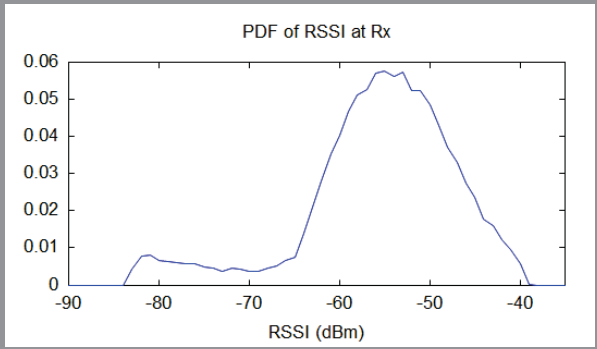
Indoor Simulation Model

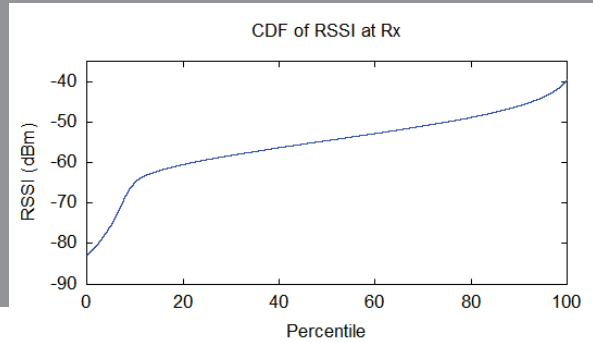




- median signal of -47 dBm
- only 1% of signals below -72 dBm

Outdoor Simulation Model





- median signal of -55 dBm
- only 7% of signals below -72 dBm

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3GPP SIMULATIONS AND ASSUMPTIONS DO NOT REPRESENT REAL-WORLD WI-FI DEPLOYMENTS

- No penetration losses are modeled
  - Outdoor model: 100% of STAs are outdoors (i.e. no outdoor → indoor penetration loss)
  - Indoor model: no in-building wall/ceiling penetration loss ("open warehouse" model)
- STA Tx Power is +18 dBm (higher than average for current Wi-Fi STAs)
- All STAs with RSSI < -82 dBm are (artificially) excluded from the simulations
- Maximum distance from AP is limited (e.g. 70m outdoors)
  - Does not represent many Wi-Fi deployments where usable coverage extends well beyond this
- Most Wi-Fi links are modeled as Line-of-Sight (LoS)
  - 100% of STAs <18m from AP are LoS; 50% of STAs 37m (indoor) or 52m (outdoor) from AP are LoS
    - Based on 10m (outdoor) or 6m (indoor) eNB height – not clear if appropriate for many Wi-Fi deployments
  - LoS path loss is much lower than NLoS (e.g. 20 dB difference for outdoor model at 25m range)

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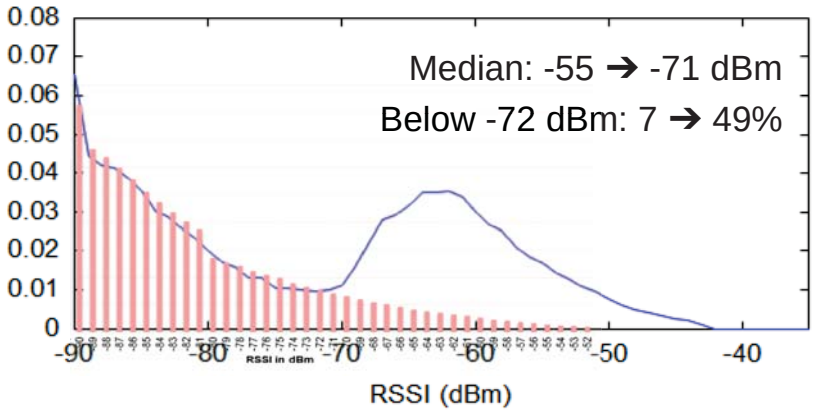
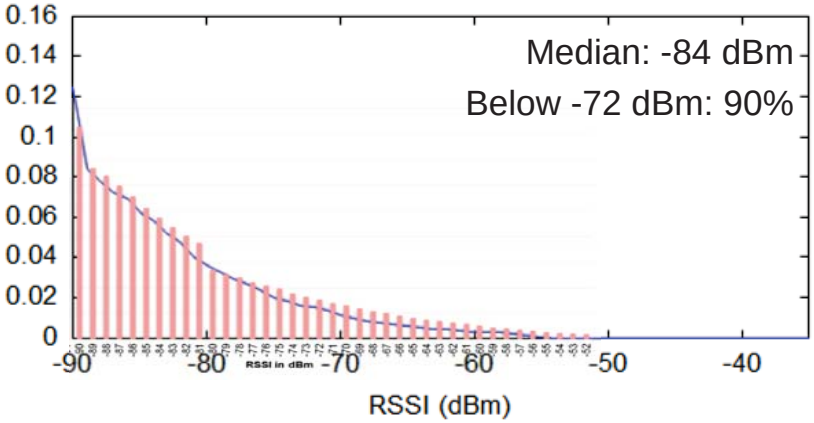
IF 3GPP MODELS WERE RUN USING MORE WI-FI APPROPRIATE ASSUMPTIONS, WOULD THIS REPRESENT FIELD DATA?

- Indoor STAs: 0➔50% (per UMi model)
- RSSI cutoff: -82 ➔-90 dBm
- Cluster radius: 70 ➔ 100m
- STA Tx Power: +18 ➔ +15 dBm
- Associate with one of the two APs with highest RSSI



Overlaid With CableLabs Field Data



- Field data suggests outdoor Wi-Fi hotspots are closer to NLoS model
  - LoS Probability: UMi model ➔ 100% NLoS
  - All other parameters as above

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