UNIVERSITY OF DELAWARE

Cisco Cooperative Project

Coexistence of WiFi and LAA: Detection, Multi-Carrier LBT

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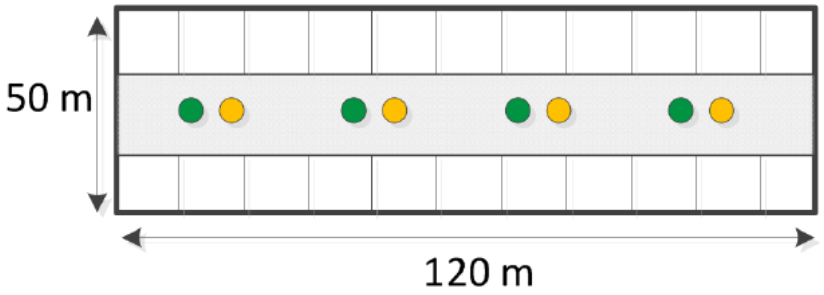
Outline

- Energy detection for LAA
- Multi-Carrier LBT
  - ✓802.11ac & LAA
  - ✓802.11ac & LAA & 802.11b
- Next Steps

Energy Detection for LAA

❖ Simulation setting

- ✓ 4 APs (green) and 4 eNBs (yellow) are equally spaced [1]



- ✓ Transmit power: 18 dBm, with path loss, shadowing (sigma = 4) and Rayleigh fading
- ✓ FTP traffic with load rate of 0.5
- ✓ WiFi: CCACS = -82 dBm, CCAED = -62 dBm; LAA: CCAED = -65/-70/-75 dBm
- ✓ q_WiFi = [15,63], q_LAA = [15,63]

Energy Detection for LAA (cont'd)

- Shadowing for indoor scenario, in Table B.1.2.1-1 and Table A.2.1.1.5-1 [1]:
  - ✓ If UE is inside a different building or outside, $\sigma = 10$
  - ✓ If UE is inside the same building, 1) $\sigma = 3$ for LOS case; 2)$\sigma = 4$ for NLOS case.

- What about the Shadowing in Cisco's simulation?

[1] 3GPP TR 36.814 v9.0.0, "*Technical Specification Group Radio Access Network*," Mar.2010.
[2] IST-WINNER II Deliverable 1.1.2 v.1.2, *WINNER II Channel Models, IST-WINNER2, Tech.* Rep., 2007.

Energy Detection for LAA (cont'd)

❖ LAA CCAED: -65 dBm

✓ Radius in average

WiFi		LAA	
1	2,3	2	1
3	1,4,5	4	3
5	3,6,7	6	5
7	5,8	8	7

✓ Block times

WiFi		LAA	
1	2	2	1
3	3	4	1
5	3	6	1
7	2	8	1

❖ LAA CCAED: -75 dBm

✓ Radius in average

WiFi		LAA	
1	2,3,4	2	1,4
3	1,2,4,5,6	4	2,3,6
5	3,4,6,7,8	6	4,5,8
7	5,6,8	8	6,7

✓ Block times

WiFi		LAA	
1	2	2	3
3	3	4	5
5	3	6	5
7	2	8	3

Energy Detection for LAA (cont'd)

❖Only path loss, if all nodes are independent

LAA threshold (dBm)	WiFi (1,3,5,7)				LAA (2,4,6,8)			
-60	2	3	3	2	1	1	1	1
-65	2	3	3	2	1	1	1	1
-70	2	3	3	2	2	2	2	1
-75	2	3	3	2	3	5	5	3
-80	2	3	3	2	3	5	5	3
-85	2	3	3	2	5	7	6	5

✓ Decreasing LAA threshold: WiFi nodes keep the same, LAA nodes are easily blocked.

Energy Detection for LAA (cont'd)

❖Only path loss, load rate of 0.5 (Time occupation/Block times)

LAA threshold (dBm)	WiFi (1,3,5,7)				LAA (2,4,6,8)			
-60	14217	20732	21016	14255	6338	6971	6756	6427
-65	14475	21203	21197	14088	6438	6985	6685	6440
-70	15085	20019	19821	14513	10853	11871	12008	6501
-75	14708	17155	17393	15186	12398	47146	45950	12139
-80	15264	17311	17373	14894	12253	48504	45463	12478
-85	13777	15969	17024	15002	21091	87044	57450	12729

LAA threshold (dBm)	WiFi				LAA			
-60	0.3323	0.3331	0.3297	0.3338	0.3320	0.3331	0.3321	0.3335
-65	0.3320	0.3343	0.3350	0.3330	0.3328	0.3342	0.3301	0.3338
-70	0.3332	0.3190	0.3349	0.3310	0.3338	0.3301	0.3324	0.3347
-75	0.3322	0.3348	0.3360	0.3302	0.3337	0.1325	0.1377	0.3359
-80	0.3309	0.3379	0.3319	0.3333	0.3327	0.1335	0.1369	0.3332
-85	0.3306	0.3328	0.3362	0.3327	0.2639	0.0329	0.1099	0.3356

Energy Detection for LAA

- ✓ The block times by simulation basically follows the block times with independent assumption at high thresholds. For example, 1) ratio for -60 dBm; 2) for some cases, like -60 and -65 dBm, the performance are the same (also works for -75 and -80 dBm).

- ✓ At high thresholds, there are more interactions and less concurrent transmission?? For example, at the threshold of -65 dBm, node 2 and 3 can transmit simultaneously, but node 3 will block node 2 at the threshold is -75 dBm.

- ✓ LAA nodes' performance keep decreasing, and WiFi nodes can always send their data out in this load rate.

Energy Detection for LAA (cont'd)

❖Only path loss, load rate of 0.8 (Time occupation/Block times)

LAA threshold (dBm)	WiFi (1,3,5,7)				LAA (2,4,6,8)			
-60	11893	23593	22932	12339	7958	5846	5873	7918
-65	12117	23893	22930	12063	7960	5796	5925	7767
-70	10338	23978	24282	11025	9570	7234	6995	7441
-75	9903	16776	16426	10235	15547	37250	36460	15547
-80	10078	16659	16499	10142	15184	37845	36587	15527
-85	10767	14098	18273	9934	27050	62079	41347	15425

LAA threshold (dBm)	WiFi				LAA			
-60	0.4383	0.3147	0.3218	0.4351	0.4469	0.4444	0.4415	0.4451
-65	0.4388	0.3175	0.3164	0.4374	0.4421	0.4455	0.4465	0.4431
-70	0.4209	0.2672	0.2482	0.4423	0.3454	0.4429	0.4114	0.4435
-75	0.4383	0.3505	0.3504	0.3504	0.2661	0.0923	0.1019	0.2621
-80	0.4370	0.3492	0.3515	0.4382	0.2669	0.0965	0.1007	0.2603
-85	0.4392	0.3989	0.3288	0.4421	0.1685	0.0195	0.0903	0.2769

Energy Detection for LAA

- ✓ WiFi nodes in the middle suffer performance loss due to more competitions at the load rate of 0.8.

- ✓ LAA's performance always decreases; WiFi's performance generally increases, but some nodes may decrease first and then increase. 1) Decreasing LAA thresholds will make the LAA nodes become easily blocked; this may give WiFi more opportunities to transmit; 2) Decreasing LAA thresholds will decrease the opportunities of concurrent transmissions; this may both decrease WiFi and LAA's performance??

- ✓ Decreasing LAA thresholds, LAA nodes suffer a lot, but WiFi nodes only improve a bit. Only WiFi: (0.4413, 0.4035, 0.4027, 0.4465). The performance of WiFi are limited by their own nodes?

Energy Detection for LAA (cont'd)

❖With fading, load rate of 0.5 (Time occupation)

LAA threshold (dBm)	WiFi				LAA			
-65	0.3278	0.2454	0.2534	0.2924	0.3320	0.3242	0.3185	0.3303
-70	0.3295	0.2430	0.2492	0.2963	0.3238	0.2750	0.2776	0.3246
-75	0.3246	0.2467	0.2663	0.2987	0.3147	0.1912	0.2144	0.3095

❖With fading, load rate of 0.8 (Time occupation)

LAA threshold (dBm)	WiFi				LAA			
-65	0.3780	0.2400	0.2480	0.3292	0.4176	0.4207	0.3912	0.4381
-70	0.3947	0.2399	0.2475	0.3155	0.3643	0.3190	0.3191	0.4069
-75	0.4077	0.2415	0.2629	0.3239	0.2936	0.2219	0.1870	0.3742

- ✓ The performance trend is similar, LAA nodes keep decreasing, WiFi nodes generally become a bit better.
- ✓ What about Cisco's results?

Multi-carrier LBT

❖ Option 1: WiFi-like (same location, load rate of 0.5, 4 pairs)

✓ Single subchannel, effective bandwidth

WiFi		LAA	
4.24	4.17	4.18	4.21

✓ 4 subchannels, AC PC: 1,2; LAA PC: 3,4

WiFi		LAA	
17.2	16.8	17.1	17.8

✓ 4 subchannels, AC PC: 1,2; LAA PC: 1,2

WiFi		LAA	
17.1	16.8	17.3	17.5

✓ Both 802.11ac and LAA will occupy the entire bandwidth or not work.

Multi-carrier LBT (cont'd)

- Option 1: including 802.11b nodes same location, load rate of 0.5, 3 pairs.
  - ✓ Single subchannel, effective bandwidth

802.11ac	LAA	802.11b
6.65	6.63	4.78

  - ✓ 4 subchannels (802.11 PC:1, LAA PC: 4)

802.11b subchannel	802.11ac	LAA	802.11b
1	22.92	23.21	6.69
2	19.14	22.80	6.74
3	21.55	22.01	6.67
4	20.12	24.24	6.69

Multi-carrier LBT (cont'd)

- Option 1: including 802.11b nodes same location, load rate of 0.5, 6 pairs.

  - ✓ Single subchannel, effective bandwidth

802.11ac		LAA		802.11b	
3.17	3.16	3.14	3.21	1.75	1.69

  - ✓ 4 subchannels (802.11 PC:1,2, LAA PC: 3,4, 801.11b: 2,3)

802.11ac		LAA		802.11b	
11.84	12.93	19.12	15.35	5.89	5.20

Multi-carrier LBT (cont'd)

❖ Option 1: Bandwidth, load rate of 0.5, 6 pairs.

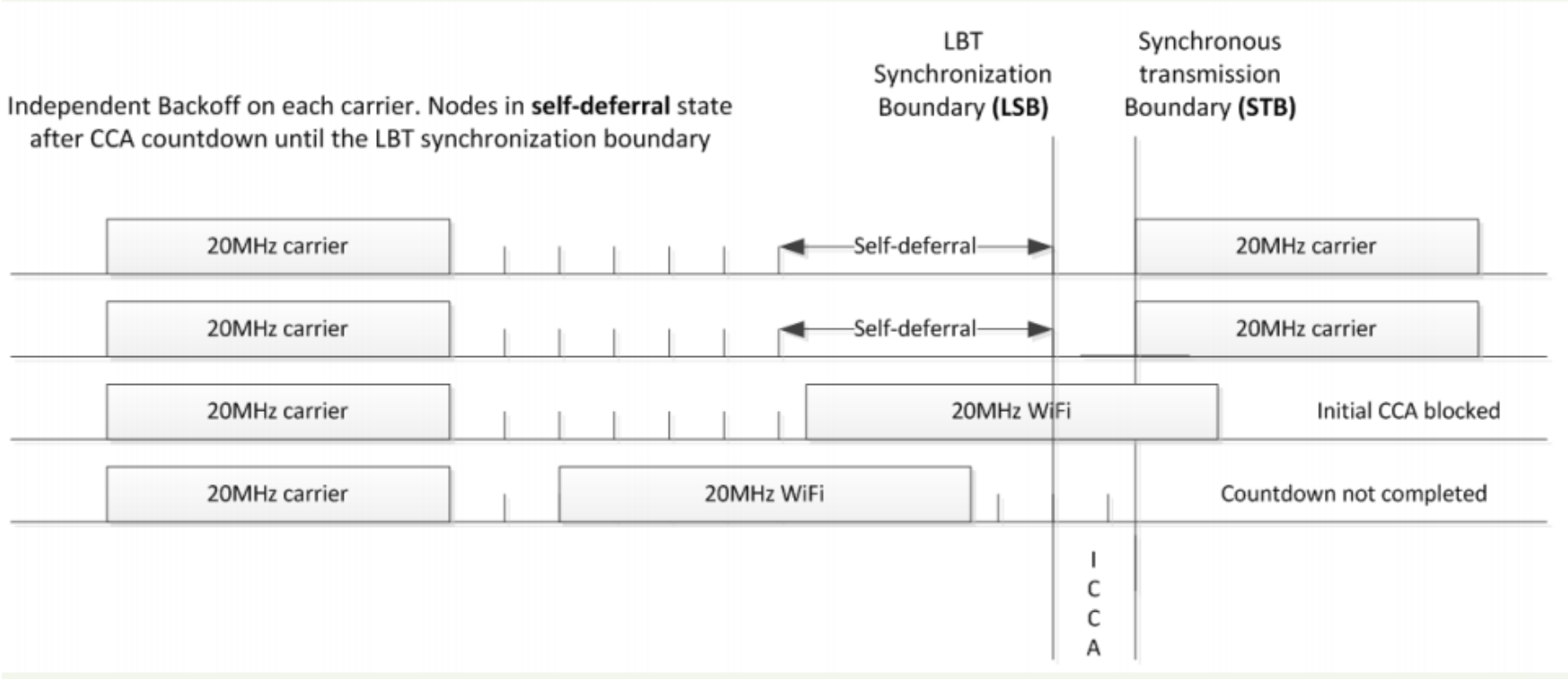
✓ 4 subchannels (802.11 PC:1,2, LAA PC: 3,4, 801.11b: 2,3)

Bandwidth	802.11ac		LAA		802.11b	
80	622	658	680	611	0	0
60	0	0	2172	1394	0	0
40	1512	2117	3626	2285	0	0
20	6324	5694	1963	3747	5900	5326

✓ LAA is more aggressive in this case due to its flexibility in carrier aggregation.

Multi-carrier LBT (cont'd)

❖ Option 2: Self-deferral for synchronization



Next steps

- ✓ Continue to study the detection threshold problem.
- ✓ Simulate multi-carrier LBT with more limitations and at different locations; continue to study the channel selection problem.