

Coexistence of WiFi and LAA: Detection Thresholds

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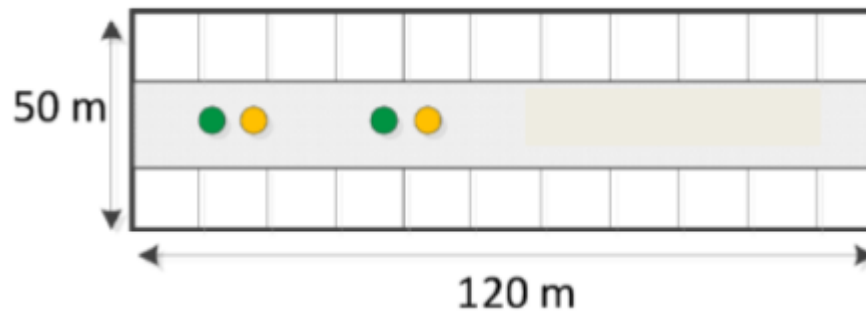
Nov. 12, 2015

- ❖ Problem Review
- ❖ Performance of Delay
- ❖ A problem in the simulation
- ❖ How to avoid collisions caused by “hidden nodes”?
- ❖ Next Steps

Problem Review

❖ Simulation setting

- ✓ 2 WiFi APs (green) and 2 LAA eNBs (yellow) are equally spaced [1]



- ✓ Transmit power: 18 dBm, with path loss (shadowing and Rayleigh fading)
- ✓ Load rate of 0.8
- ✓ WiFi: CCACS = -82 dBm, CCAED = -62 dBm;
- ✓ LAA: CCAED = -65/-70/-75 dBm
- ✓ $q_{\text{WiFi}} = [15, 63]$, $q_{\text{LAA}} = [15, 63]$

Problem Review (Cont'd)

❖ Transmission “range”

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	2,3	1,4	1	3
-70	2,3	1,2,4	1	3
-75	2,3,4	1,2,4	1,4	2,3

❖ Number of blocks due to others' transmission

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	2	2	1	1
-70	2	2	2	1
-75	2	2	3	3

Problem Review (Cont'd)

❖ When will collisions happen among WiFi/LAA pairs? (-70 dBm)

- ✓ If WiFi #3 transmit first, LAA #2 will be blocked (No collision, LAA's uplink data, like ACK, is transmitted via licensed band.)



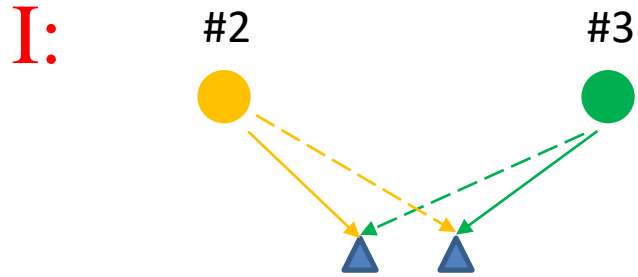
- ✓ If LAA #2 transmit first, WiFi #3 will sense the channel to be idle and start to transmit. (Collisions may happen, a “hidden node” problem due to asymmetric threshold setting?)



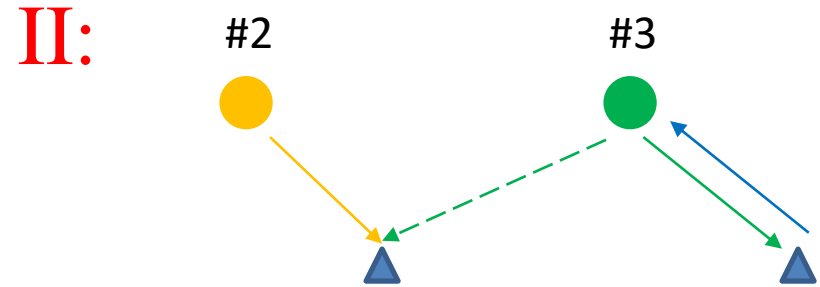
- ✓ If LAA # 2 and WiFi #3 transmit simultaneously (collisions may happen)



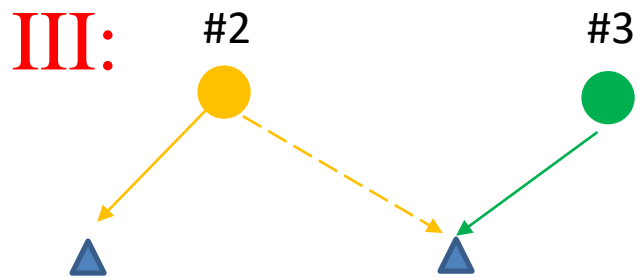
Problem Review (Cont'd)



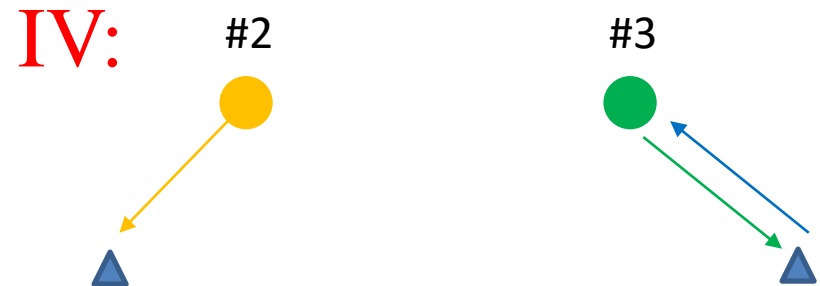
Collisions for LAA #2 user and AP #3's client



Collision for LAA #2's user



Collision for AP #3's client



No collisions

Performance of Delay: Case II

❖ Only collisions to LAA, load rate of 0.8

✓ Percentage of time occupation (successful transmission)

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	0.4019	0.4022	0.4450	0.4420
-70	0.4474	0.3752	0.0639	0.4440
-75	0.4455	0.4500	0.0066	0.0078

✓ Average delay (in seconds)

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	6.5686	7.6698	0.0073	0.0073
-70	0.0472	11.6686	64.4340	0.0072
-75	0.0829	0.0801	76.9641	79.1500

✓ Number of collisions

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	1052	567	1101	608
-70	1316	1161	4428	451
-75	1294	1259	3359	3445

Performance of Delay: Case II (Cont'd)

- ❖ For the percentage of time occupation, WiFi may decrease and then increase due to the interactions: 1) limitations among WiFi pairs; 2) collision probability increases.
- ❖ The delay for WiFi is so large even at -65 dBm, and it looks strange.
 - ✓ For a particular packet, delay = the time when the packet is popping out of the buffer - the time when the packet is pushing into the buffer.
 - ✓ For -65 dBm, at the beginning, both WiFi and LAA's delay is very small. However, the number of packets for WiFi pairs (#1 & #3) in their buffers keeps increasing, even though at a slow speed. For example, at the time of 150 seconds, the number of packets for WiFi pairs (#1 & #3) in their buffer is 1026 & 1112, and for LAA pairs (#2 & #4), they are 2 & 1.

Performance of Delay: Case II (Cont'd)

- ❖ WiFi pairs' performance may decrease and then increase.
 - ✓ For -70 dBm, at the time of 150 seconds, the number of packets for WiFi pairs (1 & 3) in their buffer is 8 & 1780 , and for LAA pairs (2 & 4), they are (>5000) & 0. So the buffer length will increase more quickly at -70 dBm for WiFi #3 and LAA #2, this leads to a larger delay compared to the case of -65 dBm.
 - ✓ For -75 dBm, LAA #2 and #4 has few opportunities to transmit, WiFi #2 and #3's performance get improved.

- ❖ What should be a suitable buffer size? (I set as 5,000 packets in my simulation) In the case of a small buffer, how to calculate the delay for the lost packets?

Performance of Delay: Case II (Cont'd)

❖ Only collisions to LAA, load rate of 0.5

✓ Percentage of time occupation (successful transmission)

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	0.3330	0.3303	0.3314	0.3329
-70	0.3321	0.3333	0.2023	0.3327
-75	0.3334	0.3329	0.1014	0.1007

✓ Average delay (in seconds)

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	0.0048	0.0047	0.0017	0.0017
-70	0.0095	0.0063	28.6761	0.0018
-75	0.0051	0.0049	52.3055	51.6315

✓ Number of collisions

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	421	414	207	196
-70	1224	601	9045	277
-75	692	682	7160	7106

Similar trend. Better delay performance due to low load rate.

Performance of Delay: Case I

❖ Collisions to both, load rate of 0.8

✓ Percentage of time occupation (successful transmission)

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	0.4019	0.4022	0.4450	0.4420
-70	0.4379	0.1553	0.0910	0.4450
-75	0.3260	0.3114	0	0

✓ Average delay (in seconds)

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	6.5686	7.6698	0.0073	0.0073
-70	0.0189	43.3610	61.0801	0.0047
-75	19.2728	23.7517	N.A.	N.A.

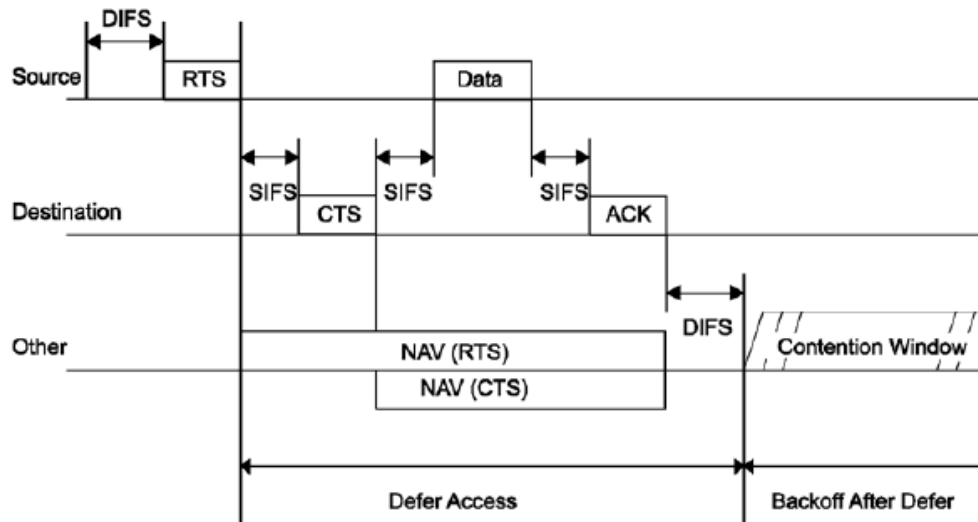
✓ Number of collisions

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	1052	1101	567	608
-70	884	5972	5966	315
-75	4662	4749	4233	4164

Similar trend. Worse delay performance due to collisions to both.

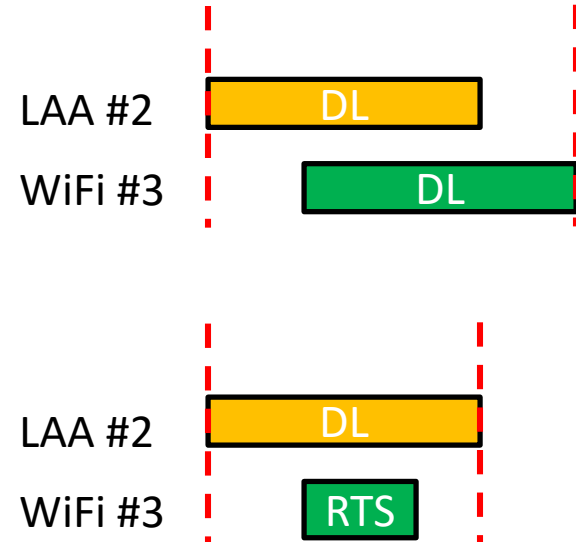
Performance of Delay with RTS/CTS

- ❖ If we include RTS/CTS for WiFi, can we decrease the collision probability and improve the efficiency?



Case I

Collision



- ✓ WiFi #3 will backoff without CTS back from clients.
- ✓ RTS packets are small, will they cause a corruption to LAA #2?

[1] IEEE 802.11TM-2012, “Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications.”

Performance of Delay with RTS/CTS: Case I

❖ Not a corruption to LAA data, load rate of 0.8

✓ Percentage of time occupation (successful transmission)

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	0.4293	0.4287	0.4390	0.4442
-70	0.4122	0.1251	0.4450	0.4414
-75	0.1788	0.1785	0.2946	0.2938

✓ Average delay

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	3.4103	2.4619	0.0056	0.0055
-70	5.5523	53.9792	0.0315	0.0011
-75	46.6016	43.9051	24.2726	24.6315

✓ Number of collisions

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	0	0	0	0
-70	0	0	0	0
-75	0	0	1028	1028

LAA's performance is improved compared to the case of without RTS/CTS.

Performance of Delay with RTS/CTS: Case I

❖ A corruption to LAA data, load rate of 0.8

✓ Percentage of time occupation (successful transmission)

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	0.4293	0.4287	0.4390	0.4442
-70	0.4426	0.3888	0.0773	0.4422
-75	0.4435	0.4447	0.0230	0.0249

✓ Average delay

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	3.4103	2.4619	0.0056	0.0055
-70	0.0466	9.0699	61.7935	0.0041
-75	0.0230	0.0207	74.5587	66.8954

✓ Number of collisions

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	0	0	0	0
-70	0	0	4702	0
-75	0	0	3844	3766

Both WiFi and LAA's performance are improved compared to the case of without RTS/CTS.

A problem in the simulation

- ✓ When we consider the location of users, we may have to consider the impact of interference if we adopt high thresholds; it makes more sense to find an “optimal” (adaptive) threshold in this case.
- ✓ What’s the problem if we set CCAED for LAA to be -62 dBm?
- ✓ In my current simulation, except the asymmetric threshold cases, I assume there is no interference to one pair if its received power is below the threshold, and this pair will be totally blocked if its received power is above the threshold. For example, if we set the LAA threshold to be -30 dBm, the performance will only be better (at least not worse). This may be one of the reasons why my results prefer high threshold.
- ✓ Thus, we may need to consider SIR for users in different locations.

How to avoid collisions caused by “hidden nodes”?

- ❖ Can we also introduce RTS for LAA? RTS's power will be higher, depending on the difference between WiFi and LAA's CCAEDs. Also, RTS needs to inform the packet length.
- ❖ Adaptive threshold: CCAED for LAA increases if collisions happen (based on the past records).

Next steps

- ✓ Consider the location and SIR for users;
- ✓ Continue study this threshold problem with some theoretic analysis.