UNIVERSITY OF DELAWARE

Cisco Cooperative Project

Delay Performance and Different Locations for Users

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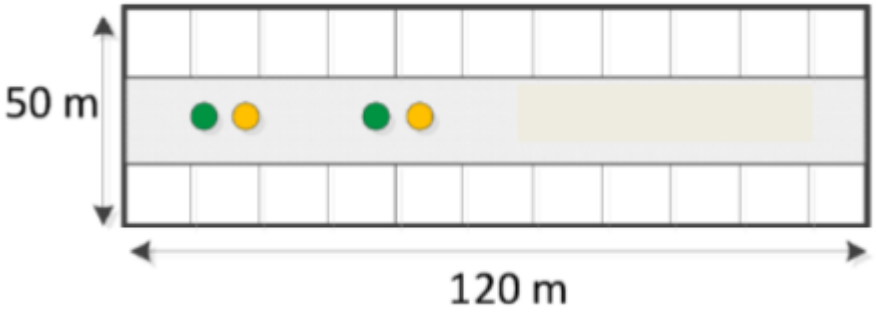
Outline

- Problem Review
- Performance of Delay
- Different Locations of Users
- 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
- ✓ $q\_WiFi = [15,63]$, $q\_LAA = [15,63]$

Problem Review (Cont'd)

❖Performance of delay

- ✓ (Original) Delay definition: For a particular packet, delay = [time of successful transmission – time of arrival], *i.e.*, the time when the packet is popping out of the buffer – the time when the packet is pushing into the buffer.

- ✓ Problem: For some pairs, due to the accumulation of packets in the buffer, the average delay can be very large.

Problem Review (Cont'd)

❖SINR for users

- ✓ In the current simulation, except the asymmetric threshold cases, we 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

- ✓ Problem: Lower CCAED for LAA, better performance (can support more concurrent transmissions).

Performance of Delay

❖Delay definition [1]: The delay for a successfully transmitted packet is defined as the time interval from the time the packet is at the head-of-line of the queue ready to be transmitted, until an acknowledgement for this packet is received. If a packet reaches the specified retry limit then this packet is dropped and its time delay is not included in the calculation of the average packet delay.

❖The delay does not depend on the number of packets that have already existed in the buffer.

[1] P. Raptis , V. Vitsas , K. Paparrizos , P. Chatzimisios , A. C. Boucouvalas , P. Adamidis, "*Packet Delay Modeling of IEEE 802.11 Wireless LANs*".

[2] P. Chatzimisios, V. Vitsas and A. C. Boucouvalas, "*Throughput and delay analysis of IEEE 802.11 protocol*".

[3] M. M. Carvalho, J. J. Garcia-Luna-Aceves, "*Delay Analysis of IEEE 802.11 in Single-Hop Networks*", ICC 2003.

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 (ms)

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	7.4515	7.6062	6.2089	6.2080
-70	7.2500	7.8214	84.0169	6.0435
-75	7.0838	7.2065	822.2832	776.8956

✓ 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

Delay has similar performance trend as percentage of time occupation.

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 (ms)

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	3.8270	3.8211	3.6582	3.6497
-70	4.3241	3.9555	15.6394	3.6744
-75	3.9260	3.9042	32.4506	32.6565

✓ 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

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 (ms)

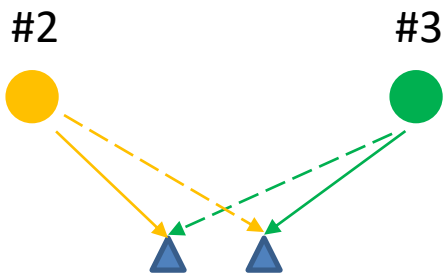
LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	7.4515	7.6062	6.2089	6.2080
-70	6.7257	31.0634	57.9534	5.9407
-75	13.9673	14.6625	N.A.	N.A.

✓ 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

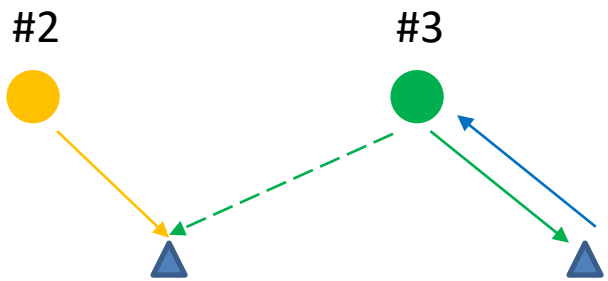
Different Location for Users

I:



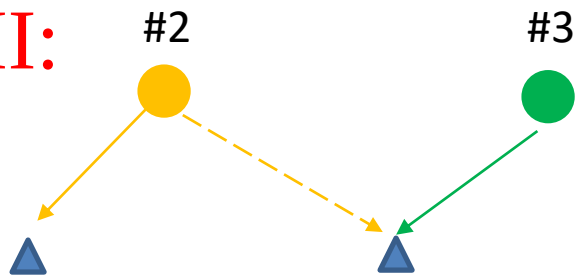
Collisions for LAA #2 user and AP #3's client

II:



Collision for LAA #2's user

III:



Collision for AP #3's client

IV:

No collisions

Different Location for Users

❖Simulation setting

- ✓ Each AP/eNB has only one user.
- ✓ Each user locates in a circle with a uniform distribution: the center is its associated AP/eNB, and the maximum radius is 15 meters.
- ✓ 802.11ac/LTE SNR requirement (theoretical)

Mapping	Code Rate	Bandwidth	AC Min SNR(dB)	LTE Min SNR(dB)
QPSK	1/2	20 MHz	5	2.0
64QAM	3/4	20 MHz	20	17.5

- ✓ Noise floor in 5G band: -90 dBm

[1] https://en.wikipedia.org/wiki/IEEE_802.11ac

[2] http://www.revolutionwifi.net/revolutionwifi/2014/09/wi-fi-snr-to-mcs-data-rate-mapping.html

Different Location for Users (Cont'd)

❖ Collisions

✓ SINR for a particular user:

$$\mathrm{SINR}(i) = 10\log_{10}\frac{S(i,i)}{\sum_{j\in\mathcal{I}} S(j,i) + N}$$

✓ If SINR(i) is less than MinSNR, it is an unsuccessful transmission, and collision happens. (How does WiFi AP know that an unsuccessful transmission is caused by a deep fading or a collision?)

✓ The number of pairs that can transmit simultaneously increases, the interference increases.

Different Location for Users (Cont'd)

- Load rate of 0.8 (average over 20 trials, each trial last 80 s)
  - ✓ Percentage of time occupation (successful transmission)

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	0.3344	0.1779	0.2466	0.3682
-70	0.2804	0.2275	0.2612	0.3441
-75	0.3341	0.2633	0.2176	0.3029

  - ✓ Number of successful transmissions

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	4664	2470	3424	5114
-70	2894	3160	3628	4779
-75	4640	3657	3021	4207

Different Location for Users (Cont'd)

- Load rate of 0.8 (average over 100 trials, each trial last 150 s)
  - ✓ Percentage of time occupation (successful transmission)

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	0.3145	0.1960	0.2827	0.3674
-70	0.2702	0.2782	0.2406	0.3658
-75	0.3591	0.2779	0.1934	0.2953

  - ✓ Number of successful transmissions

LAA threshold (dBm)	WiFi (#1)	WiFi (#3)	LAA (#2)	LAA (#4)
-65	8188	5103	7362	9567
-70	7035	7245	6265	9524
-75	9351	7237	5036	7691

- ✓ WiFi pairs get more improvements, and LAA pairs' performance decreases at a lower speed compared to previous results.
- ✓ Some WiFi pairs' performance may still decrease first and then increase.

Different Location for Users (Cont'd)

❖ Load rate of 0.8, threshold of -75 dBm (20 trials)

0.4419	0.1139	0.3763	0.0021
0.0745	0.0767	0.4165	0.4166
0.4495	0.0769	0.3570	0.3693
0.4413	0.2215	0	0.4258
0.4411	0.2405	0	0.4169
0.4368	0.0938	0.3789	0.0001
0.4378	0.0733	0.3578	0.3772
0.0726	0.4452	0.3746	0.3532
0.1113	0.2567	0	0.4427
0.4416	0.2214	0	0.4239
0.0734	0.0762	0.4153	0.4182
0.0803	0.0721	0.4128	0.4156
0.4491	0.4392	0.2897	0.2898
0.4444	0.4428	0.0361	0.0282
0.4450	0.4463	0.2895	0.2883
0.4416	0.4437	0.2915	0.2882
0.4480	0.4130	0	0.3311
0.0940	0.4470	0.0157	0.3750
0.4458	0.2269	0	0.3966
0.4126	0.4393	0.3398	0.0001

The user's locations has a great impact on the performance.

Next steps

- ✓ Continue to simulate the performance with users at different locations;
- ✓ Try to compute the unsuccessful transmission probability.
- ✓ Continue to study this threshold problem with adaptive threshold and some theoretic analysis.