(302) Network

An Exploration of Transmission Power Optimization Method for Concurrently Communicating Two Access-Points in Wireless Local-Area Network

Hendy Briantoro Nobuo Funabiki Md Manowarul Islam Rahardhita Widyatra Sudibyo
Kwenga Ismael Munene Minoru Kuribayashi
Graduate School of Natural Science and Technology, Okayama University

Abstract

Nowadays, *IEEE 802.11n wireless local-area network (WLAN)* has become popular around the world due to advantages in capacity, reachability, and affordability. In *WLAN*, any host or terminal device is connected with an *access-point (AP)* using wireless signal. Thus, the *AP transmission power* should be optimized for improving the performance in WLAN, considering the capacity and interference. Previously, we proposed an AP transmission power optimization method for a single AP considering the link capacity to a host. In this paper, we explore an *AP transmission power optimization method* for two concurrently communing APs in WLAN. Unlike the single AP case, it needs to consider the interference between two APs, too. As a simple method, either the maximum or minimum power is selected for each AP such that it maximizes the *signal-to-noise ratio (SNR)* among the four combinations. The accuracy of this proposal is investigated through extensive experiments using *Raspberry Pi* APs in eight network fields with various host locations. The results show that it provides the best performance except for three cases among 144 cases.

1 Introduction

Nowadays, *IEEE 802.11n wireless local-area network (WLAN)* has been widely used around the world, including homes, schools, and offices, due to advantages in capacity, reachability, and affordability. Through WLAN, people can connect laptops, printers, and smartphones with the Internet without cables.

In *WLAN*, any host or terminal device is connected with an *access-point (AP)* using wireless signal. Thus, the *AP transmission power* should be optimized for improving the performance in WLAN, considering the capacity and interference. As the power increases, the link capacity increases. However, the interference to other devices also increases, which gives negative impacts to them [1]. Previously, we proposed an AP transmission power optimization method for a single AP, considering only the link capacity to a host [2].

In this paper, we explore an *AP transmission power optimization method* for two concurrently communing APs in WLAN. Unlike the previous single AP case, this case needs to consider the interference between two APs at the same time. Then, a simple method is presented here, where either the maximum or minimum available transmission power is selected for each AP such that the selection can maximize the *signal-to-noise ratio (SNR)* at the APs among the four possible combinations.

To investigate the accuracy of this method, we conducted extensive experiments using *Raspberry Pi* APs in eight network topologies with various host locations in two buildings at Okayama University. The results confirm that the proposed method provides the best throughput performance except for three cases among the 144 cases of different AP locations and host locations in them. In future works, we will analyze the reasons of the three error cases and study improvements of the proposal.

2 Transmission Power Optimization Method

In this section, we present our preliminary work of the *AP transmission power optimization method* for two concurrently communing APs in WLAN.

2.1 Idea

Normally, any transmission power in the range of the available maximum and minimum one can be selected for an AP device including the one in this paper. To avoid the complexity, the proposed method only selects either the maximum or minimum power, because our previous study shows either the maximum or minimum power exhibits the best performance in any experiment case [3]. Then, the task becomes the selection of one combination from the four possible ones such that the total throughput performance is highest. As the selection index, we adopt the *signal-to-noise ratio (SNR)* at the APs. SNR can consider the interference and the link capacity at the same time, where the signal strength is closely related with the capacity and the noise is to the interference. Besides, SNR at an AP can be easily measured using Linux commands at *Raspberry Pi*.

2.2 Transmission Power Optimization Procedure

Here, assuming the situation where AP_1 is communicating with H_1, AP_2 is communicating with H_2, and these links are within the interfered distance, the procedure of the AP transmission power optimization method is presented as the following steps:

1. Assign the transmission power for each AP by selecting one of the following four combinations one by one:
   - $P_{AP1} = P_{min}$ and $P_{AP2} = P_{min}$.
   - $P_{AP1} = P_{min}$ and $P_{AP2} = P_{max}$.
   - $P_{AP1} = P_{max}$ and $P_{AP2} = P_{min}$.
   - $P_{AP1} = P_{max}$ and $P_{AP2} = P_{max}$.

   where P_{AP1} and P_{AP2} represent the transmission power of AP1 and AP2 respectively, and $P_{min} = 0dBm$ and $P_{max} = 20dBm$ are used for *Raspberry Pi* with *TP-Link Wi-Fi adapter*.
2. Measure the following *receiving signal strength (RSS)* at an AP from other AP and a host for this combination:
   - $RSS_{AP1,AP2}$: RSS at AP2 of the signal from AP1
   - $RSS_{AP2,AP1}$: RSS at AP1 of the signal from AP2
   - $RSS_{H1,AP1}$: RSS at AP1 of the signal from H1
   - $RSS_{H2,AP1}$: RSS at AP1 of the signal from H2
   - $RSS_{H1,AP2}$: RSS at AP2 of the signal from H1
   - $RSS_{H2,AP2}$: RSS at AP2 of the signal from H2

   $RSS_{H1,AP1}$ and $RSS_{H2,AP2}$ are necessary signals to transmit data, and the others become noises to them.
3. Calculate SNR for the link between AP1 and H1 by Eq. (1):
$$SNR_{AP1,H1} = \frac{RSS_{H1,AP1}}{(RSS_{H1,AP2} + RSS_{H2,AP1} + RSS_{AP2,AP1})} \quad (1)$$
4. Calculate SNR for the link between AP2 and H2 by Eq. (2):
$$SNR_{AP2,H2} = \frac{RSS_{H2,AP2}}{(RSS_{H2,AP1} + RSS_{H1,AP2} + RSS_{AP1,AP2})} \quad (2)$$
5. Calculate the average SNR by Eq. (3):
$$aveSNR = \frac{1}{2}(SNR_{AP1,H1} + SNR_{AP2,H2}) \quad (3)$$
6. Select the best combination that has the largest $aveSNR$ after applying the four combinations, and setup P_{AP1} and P_{AP2} to the corresponding power.

3 Evaluation of Algorithm

In this section, we evaluate the proposed method through extensive experiments in two buildings.

3.1 Experiment Setup

In our experiments, eight network topologies are considered using two buildings, namely Engineering Building #2 and Graduate School Building at Okayama University. We use two *Raspberry Pi 3 B+* with *TP-Link TL-WN722N wireless NIC adapter* for APs and four laptop PCs for two servers and two hosts. The *channel bonding (CB)* at $2.4GHz$ is used, where AP1 is assigned *channels 1+5* and AP2 is *channels 9+13* as the least interfered ones. *iperf 2.0.5* is used to generate TCP traffics and measure the throughput. At the same time, the RSS is measured using *iw commands*.

3.1.1 First Topology

Figure 1 shows the first topology in Engineering Building #2, where D307 room of size $7m \times 6m$, and corridor of size $30m \times 2.3m$ are used. The triangle represents the AP and the circle does the host. *AP1* is located in front of D307 and *H1* is moved from *H1-1* to *H1-5* in the corridor. *AP2* and *H2* are located in D307 with the $3m$ distance. The two links are concurrently communicating.

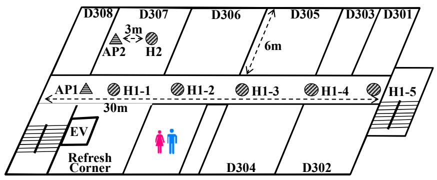

Figure 1: First topology.

Table 1 shows the average SNR and the total throughputs for the four combinations of transmission powers. The results show that the proposed method can select the best combination that provides the highest total throughput except for *H1-2*. This error may be caused by the fluctuation of RSS. From the throughput results, the best transmission power for *AP1* is the maximum and the one for *AP2* is the minimum at any *H1* location. It is noted that *AP2* and *H2* are located in the same room. On the other hand, the average SNR becomes largest only at *H1-2* when the both powers are minimum.

Table 1: Results in first topology.

P_{AP1},P_{AP2}	average SNR (proposal)					total throughput (Mbps) (measurement)				
	H1-1	H1-2	H1-3	H1-4	H1-5	H1-1	H1-2	H1-3	H1-4	H1-5
min,min	44.8	45.7	33.9	33.8	35.2	96	86.3	76.3	66.6	58.6
min,max	6.3	23.4	34	35.9	35.3	83.3	73.6	65	56.4	55.9
max,min	214	43.6	50	39.3	35.7	96.9	90.6	84.6	81.6	78
max,max	18.8	12.9	10.6	9.7	15.1	81.3	73	70.1	64.3	59.4

3.1.2 Second Topology

Figure 2 illustrates the second topology. *AP2* and *H2* are located in D307 and D306 separated by a wall, with the $8m$ distance. The results in Table 2 confirm that the proposal can select the best combination at any *H1* location that uses the maximum for both APs.

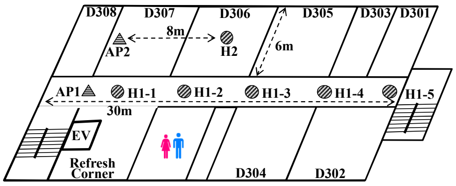

Figure 2: Second topology.

Table 2: Results in second topology.

P_{AP1},P_{AP2}	average SNR (proposal)					total throughput (Mbps) (measurement)				
	H1-1	H1-2	H1-3	H1-4	H1-5	H1-1	H1-2	H1-3	H1-4	H1-5
min,min	21.9	2.3	0.7	0.1	0.08	59.4	51.8	50	48.2	32.6
min,max	2.5	7.5	19.9	22.1	14.2	71.7	62.5	64.8	61.4	42
max,min	73.3	75.3	38.3	31.5	25.1	63.1	59.2	54.6	50.3	34.7
max,max	73.5	85.8	39.6	33.7	25.9	79.4	71.2	67.1	65.4	47.1

3.1.3 Third Topology

Figure 3 illustrates the third topology. *AP2* and *H2* are located in D307 again, but *AP1* is located in front of D301 that is the most distant from D307 in the corridor. The results in Table 3 confirm that the proposal can select the best power combination at any *H1* location, although it is changed by the location.

In this topology, as the distance between the two APs is large, the minimum power for the APs can remove the interference. However, the best power for *AP1* becomes the maximum when *H1* is located at *H1-3* or farther ones, as $RSS_{H1,AP1}$ becomes smaller there.

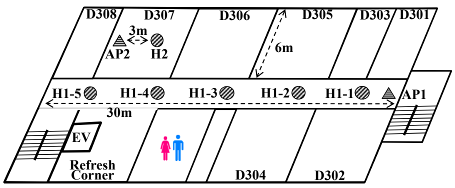

Figure 3: Third topology.

Table 3: Results in third topology.

P_{AP1},P_{AP2}	average SNR (proposal)					total throughput (Mbps) (measurement)				
	H1-1	H1-2	H1-3	H1-4	H1-5	H1-1	H1-2	H1-3	H1-4	H1-5
min,min	4806	1449	369	103	33.7	119	116	98	78	62
min,max	510	207	75.9	7.9	2.4	89	81.7	77.7	59.1	54.2
max,min	3258	966	489	249	48.8	109	107	105	97	83
max,max	1065	299	110	12.3	2.8	86	83.5	82	77.7	72.9

3.1.4 Fourth Topology

Figure 4 illustrates the fourth topology. As in the third topology, *AP1* is located in front of D301, but *AP2* and *H2* are located in different rooms. The results in Table 4 confirm that the proposal can select the best power combination at any *H1* location, where the power for AP2 is always the maximum because of the wall between *AP2* and *H2*.

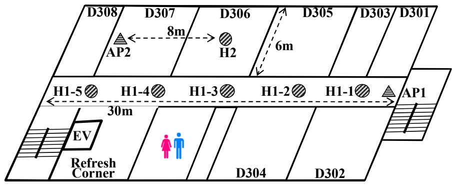

Figure 4: Fourth topology.

Table 4: Results in fourth topology.

P_{AP1},P_{AP2}	average SNR (proposal)					total throughput (Mbps) (measurement)				
	H1-1	H1-2	H1-3	H1-4	H1-5	H1-1	H1-2	H1-3	H1-4	H1-5
min,min	217	18.7	1.3	0.2	0.02	64.7	47.1	32.7	30.9	27.7
min,max	223	36.6	24.7	12.3	3.8	89.2	81.6	64.7	62.2	59.6
max,min	97.7	28.8	24.9	12.1	5.3	63.4	45	39.7	36.8	31.1
max,max	98.9	29	25.5	13.2	5.4	80.1	75.9	70.4	66.3	64.1

3.1.5 Fifth Topology

Figure 5 shows the fifth topology in Graduate School Building. *AP1* and *AP2* are located at distance positions, and *AP2* and *H2* are located in the same room, which is the similar situation to the third topology. *H1* is moved from *H1-1* to *H1-4*. The results in Table 5 confirm that the proposed method can select the best combination except for *H1-2*. Again, this error may be caused by the fluctuation of RSS.

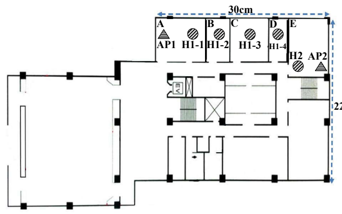

Figure 5: Fifth topology.

Table 5: Results in fifth topology.

P_{AP1},P_{AP2}	average SNR (proposal)				total throughput(Mbps) (measurement)			
	H1-1	H1-2	H1-3	H1-4	H1-1	H1-2	H1-3	H1-4
min,min	835.6	84.8	75.9	16.2	86.1	70.25	46.07	44.03
min,max	545.5	74.9	46.3	15.2	85.1	61.5	44.04	47.31
max,min	678.5	57.8	82.6	30.5	74.32	65.05	64.3	60.25
max,max	399.1	88.6	43.3	15	76.15	56.8	56.9	57.05

3.1.6 Sixth Topology

Figure 6 shows the sixth topology. *AP2* and *H2* are located at distance positions. The results in Table 6 confirm that the proposed method can select the best combination for any *H1* location. In this topology, the best power for *AP1* is the minimum except *H1-4*, where there are three walls between them. For *AP2*, the best power is the maximum, because *H2* is distant.

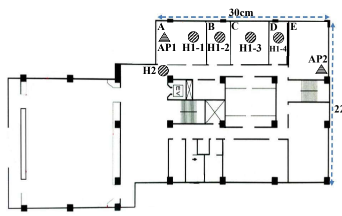

Figure 6: Sixth topology.

Table 6: Results in sixth topology.

P_{AP1},P_{AP2}	average SNR (proposal)				total throughput(Mbps) (measurement)			
	H1-1	H1-2	H1-3	H1-4	H1-1	H1-2	H1-3	H1-4
min,min	0.76	0.02	0.01	0.01	40.77	27.6	24.04	18.67
min,max	1.61	0.68	0.56	0.07	52.9	47.1	35.44	20.21
max,min	0.91	0.05	0.03	0.03	38.07	24.62	22.34	22.03
max,max	0.94	0.08	0.06	0.08	48.73	46	33.93	22.54

3.1.7 Seventh Topology

Figure 7 shows the seventh topology. *AP1* and *AP2* are closely located, separated by one wall. *AP2* and *H2* are also closely located in the corridor. The results in Table 7 confirm that the proposed method can select the best combination for any *H1* location. The best power for *AP1* is the maximum except *H1-1* where they are located in the same room. The best power for *AP2* is the minimum.

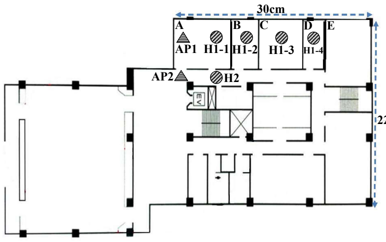

Figure 7: Seventh topology.

Table 7: Results in seventh topology.

P_{AP1},P_{AP2}	average SNR (proposal)				total throughput(Mbps) (measurement)			
	H1-1	H1-2	H1-3	H1-4	H1-1	H1-2	H1-3	H1-4
min,min	2.17	0.27	0.38	0.39	70.5	60.26	53.03	53.6
min,max	1.04	1.14	1.32	0.81	65.4	56.13	55.3	49.47
max,min	1.62	1.28	1.35	0.86	63.6	63	58.9	56.2
max,max	0.49	0.51	0.55	0.56	59.52	58.2	56.54	52.8

3.1.8 Eighth Topology

Figure 8 shows the eighth topology. Again, *AP1* and *AP2* are closely located, separated by one wall. But, *AP2* and *H2* are located with a long distance, separated by one wall. The results in Table 8 confirm that the proposed method can select the best combination except for *H1-2*. Again, this error may be caused by the fluctuation of RSS. The best power for *AP1* is the minimum at *H1-1* and *H1-2*, and the maximum at other locations. The best power for *AP2* is the maximum.

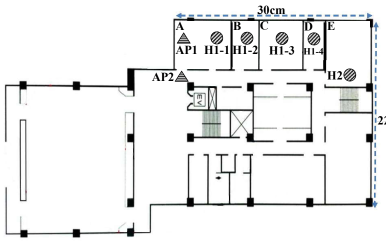

Figure 8: Eighth Topology.

In this topology, the best transmission power of *AP1* is minimum value when *H1* positions are *H1-1* and *H1-2* and maximum value for other *H1* positions. For *AP2*, the best transmission power is maximum value because the distance between *AP2* and *H2* is far.

Table 8: Results of Eighth Topology

P_{AP1},P_{AP2}	average SNR (proposal)				total throughput(Mbps) (measurement)			
	H1-1	H1-2	H1-3	H1-4	H1-1	H1-2	H1-3	H1-4
min,min	0.61	0.04	0.02	0.01	53.9	48.6	33.3	29.47
min,max	1.04	0.57	0.57	0.38	68.72	55.4	40.9	38.12
max,min	0.98	0.54	0.61	0.49	49.7	41.82	40.7	34.05
max,max	0.35	0.59	0.62	0.62	53.8	48	43.43	41.41

3.2 Evaluation Summary

The above experiment results in the eight network topologies show that the proposed method selected wrong transmission power combinations in only three cases among 144 cases of different AP locations and host locations in them. Therefore, the accuracy for selecting the correct transmission powers by the proposal is 97.92% in our experiments.

4 Conclusion

This paper explored the *AP transmission power optimization method* for two concurrently communing APs in WLAN. The experiment results using *Raspberry Pi* APs in eight network topologies confirmed that the proposed method provides the best throughput performance except for three cases among the 144 cases of different AP and host locations. In future works, we will analyze the reasons of the error cases, investigate extensions of the proposal to deal with the dynamic nature of a host, concurrently communing multiple hosts with an AP, and three or more APs in a field, and will evaluate the proposal in various topologies.

References

[1] D. Qiao, S. Choi, and K. G. Shin, “Interference analysis and transmit power control in IEEE 802.11a/h wireless LANs,” IEEE/ACM Trans. Networking, vol. 15, no. 5, pp. 1007-1020, Oct. 2007.

[2] M. M. Islam, N. Funabiki, M. Kuribayashi, M. Saha, K. I. Munene, R. W. Sudibyo, and W.-C. Kao, ”A proposal of transmission power minimization extension in active access-point configuration algorithm for elastic wireless local-area network system,” Int. J. Comput. Soft. Eng., vol. 4, Feb. 2019.

[3] H. Briantoro, N. Funabiki, M. M. Islam, R. W. Sudibyo, K. I. Munene, and M. Kuribayashi, “An investigation of transmission power optimization for performance improvement at concurrent communications of multiple access-points in wireless local-area network,” in Proc. IEICE Gen. Conf., pp. S-66-67, March 2019.