OPTIMAL POSITION TO PLACE WI-FI RANGE EXTENDER TO IMPROVE ITS PERFORMANCE

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ABSTRACT

An extender (Wi-Fi range extender) is a device that takes the radio signal of an access point (AP) of Wi-Fi and rebroadcasts it to create a new group of Extended Service Set Identifier. It is useful for extending the range of an AP to where the wired network cannot reach since installation of AP needs both commercial power supply and the wired network line to serve as the last mile of the Internet. Based on our preliminary experiments, although the extender itself offers slower connection compared to the original AP, it could offer more stable connection at hard to reach places. One of the significant factors that affect the internet speed is where the extender is set. Therefore, we investigated extender usage based on the correlation between distance, Received Signal Strength Indicator (RSSI), and the speed of the connection. Through our control experiment for the extender usage, we found that just placing an extender might degrade the performance compared to the direct association to an AP in the service area in the AP. We also found that the optimal position of the extender was not centered equidistant from the AP and the client, but rather shifted toward the AP.

Keywords: Wi-Fi range extender, Connectivity, RSSI.

1. INTRODUCTION

The statistic by Japan National Tourism Organization (JNTO, 2018) reveals that the number of visitors to Japan from other country (here after inbound visitors) is increasing by almost every year with few exceptions caused by serious concerns such as the global impact of bankruptcy of Lehman Brothers after late 2008 and the national-wide impact of the Great East Japan Earthquake in 2011. Tokyo 2020 (TOCOG, 2020) is one of the examples of the upcoming event that will bring more inbound visitors. Although some of the sightseeing areas including public transportations start offering multi-lingual information for inbound visitors using English, Chinese or other languages with pictograms, it is very difficult to provide information for all local languages in public. Using the Internet is one of the current solutions to cover such an inconvenient problem caused by language barrier. Inbound visitors need the Internet services for supporting their trip to Japan, such as translation service and online map one for reaching to their destination for example. Therefore, we should stress that more Wi-Fi Access Points (APs) with good Internet access lines are needed for visitors to enjoy even at smaller local train stations where reconstructions rarely happen for better supporting for inbound visitors. Japan Tourism Agency together with the Ministry of Internal Affairs and Communications of Japan set up a council named “Free Wi-Fi in Japan” that offers free Wi-Fi for foreign visitors in Japan (NTTBPI, 2019).

However, installing new APs is quite costly because of the wired infrastructure to connect APs to the Internet as backhaul. On the other hand, a Wi-Fi range extender (or wireless range extender; here after extender) is a device that takes the radio signal of an AP of Wi-Fi and rebroadcasts it to create a new group of Extended Service Set Identifier (ESSID). It is useful for extending the range of an AP to where the wired network cannot reach without wired backhaul. For example, Ali *et al.* (2014) analyzed the relationship between several IEE802.11 series standard and power consumption of each implementation for designing solar powered backhaul using IEEE 802.11 extenders without wired backhaul. An extender currently commercialized is portable in size and easy to set up for increasing the distance over which a Wi-Fi signal can spread. It is also economically better and less time-consuming than making a new infrastructure of APs, for events like this which is one-time only. So we investigate the performance of Wi-Fi range extenders in this paper.

2. PRELIMINARY EXPERIMENT ON WI-FI RANGE EXTENDER

The motivation of this research was based on our preliminary experiment in our PBL (Project Based Learning) class for the first grade students in their second semester. We, the instructor of the class and three students, was trying to struggle with an extender to extend the Wi-Fi area from an AP in the instructor’s laboratory located on the 7th floor of our research building to the ground. The floor height of this building is about 4m (meters) so the AP’s height from the ground is about 25m. The project was planned by the instructor who already implemented the similar Wi-Fi networks using cascading WDS (Wireless Distribution System) AP (Kaede, 2008). Figure 1 illustrates the settings of the environment on the ground. The building has two wings, the north one and the south. For each floor, a crossing corridor covered by glass connects the same level of the two wings. The client on the ground in front of the building entrance was used to check the wireless link of the Wi-Fi network.

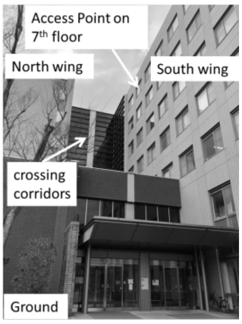

Fig. 1. The building's overview from the ground in front of the entrance

Although just placing the AP on the laboratory's window at first might be used for broadcasting ESSID to a Wi-Fi client on the ground in PBL class, it was unstable in communication. The Received Signal Strength Indication (RSSI) was -55 dB (decibel) at the Wi-Fi client on the ground and it could be associated with the AP, but the connection was unstable and the speed test site the Internet later described would not measure the speed of the Internet connection.

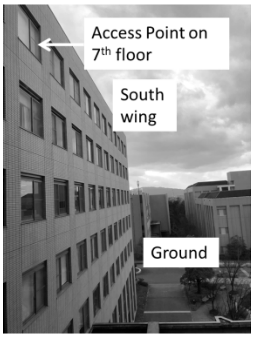

Fig. 2. The view from the crossing corridor of the 5th floor

Since introducing an extender on the ground would not help for improving performance nor stability of connection, we tried several floors for placing one extender, or tried three cascading extenders for different floors for descending in steps, but none of them could reach to the ground with superior performance than the specific "hot spot" where the stable direct association to the AP was possible on the ground. At the hot spot, the download speed in bit rate, upload one, and RSSI for AP to the client were about 20.5Mbps, 3.58Mbps, and -73dB respectively. On the other hand, the only possible connection on the ground using an extender was accomplished by placing the extender on the crossing corridor of the 5th floor to the adjacent buildings although the download speed, upload one, and RSSI for AP to the client were about 4.62Mbps, 2.02Mbps, and -57dB respectively and the performance was worse compared to the direct association to the AP.

The figure 2 illustrates the settings of the environment from the best position of the extender in the preliminary experiment. We can clearly see that the extender in the best position is much closer to the AP near the window than the client on the ground in front of the building even without precise surveying. This led us to doubt about the symmetry between AP-extender link and extender-client one. These were the tales regarding our motivation to focus on an extender for better performance. In order to clarify the usage of extender for better performance, we conducted the following control experiment.

3. EXPERIMENT FOR WIFI RANGE EXTENDER PERFORMANCE

The Shannon–Hartley theorem (Shannon, 1949) combined with the inverse-square law suggests us the attenuation of radio wave in the unshielded normal environment will degrade the maximum communication bit rate through distance. Hasegawa *et al.* (2011) showed that it is also true for WLAN (Wireless Local Area Network) system by measuring the inverse relationship between RSSI and average throughput, which means the lower the RSSI is by path loss phenomenon, the worse the throughput. So we focus on the attenuation through distance and the quality of Wi-Fi link. They also measured the correlation between RSSI and attenuation through the distance in the real building hallway. However, their hallway was 30 meters long at most and the attenuation longer than their maximum distance is unknown although the service area of WLAN is wider than their measurement area.

The objective of this experiment is to clarify the nature of extender by measuring its performance in the different distance from AP. In the preliminary experiment, it seemed using extender made performance degraded in some cases although the cover area might be extended. So we conducted a control experiment in the fixed distance between an AP and its client laptop computer and measure the total performance of the Internet access at the client side by moving the place of the extender that repeats the radio wave between the AP and the client.

We chose the distance between the AP and the client as 70m long in a straight hallway in our building. This distance was chosen since it was around the area where stable communication was possible without extender in this environment. This condition was adopted in order for the client to emulate our preliminary experiment at the edge of the APs service area. The download speed in bit rate, upload speed, and RSSI for AP to the client at 70m were about 4.4 Mbps (mega bit per second), 1.86 Mbps, and -73dB respectively. These measurement results supported our supposition regarding the stability of communication.

In this environment, we placed an extender between the AP and the client and set the client to connect to the ESSID from the extender. Then we changed the position of the extender from the 0m point from the AP to 70m, *i.e.* 0m point from the client, linearly in 10 meters increments measuring the AP's RSSI and its noise at the extender via the extender's management web interface, Round Trip Time (RTT) as ping output, upload speed and download one on the Internet speed test site Speedtest.net by Ookla at the client. The measurement procedure was repeated three times on different days to reduce problems depending on a particular day or a particular location of the device. We believe that this performance measurement especially for sampling in numbers is enough for comparisons ones for each position of the extender since the bit rate in this measurement is not mere the average rate of one transfer but based on the average rate of multiple sampling data during each trial discarding the two fastest results (Ookla, 2019). Figure 3 illustrates the visualized methodology of our experiment above.

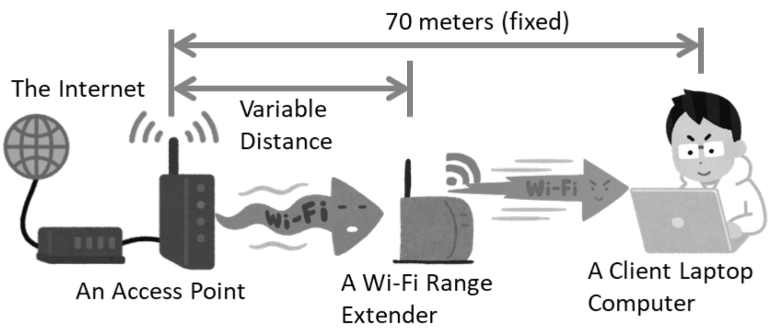

Fig. 3. The methodology of our experiment

The devices used in this experiment are WRC-1167GHBK2-S (by ELECOM Co. Ltd.) as an AP, TL-WA850RE (by TP-LINK Technologies Co., Ltd.) as a Wi-Fi range extender, and MacBook Air (2018) as a client laptop computer. Only the 2.4GHz band was used as Wi-Fi link in this experiment so that we can directly apply our result for operating an extender outdoors. This is because some of the 5GHz bands of Wi-Fi are inhibited to emit outdoors in Japan to avoid interference with other stations such as weather radar (Hou, 2013). Usage of 5G band was separately excluded in our experiment by setting up an independent 5GHz ESSID from 2.4GHz one. Thus, the standard IEEE 802.11n should be used in our experiment and is the same standard discussed in Hasegawa *et al.* (2011).

The internet connection from the AP was stable and fast enough (around 60Mbps) compared to the speed obtained over the Wi-Fi links so we can conclude that the degrading of the client performance in this experiment is only caused by the Wi-Fi links.

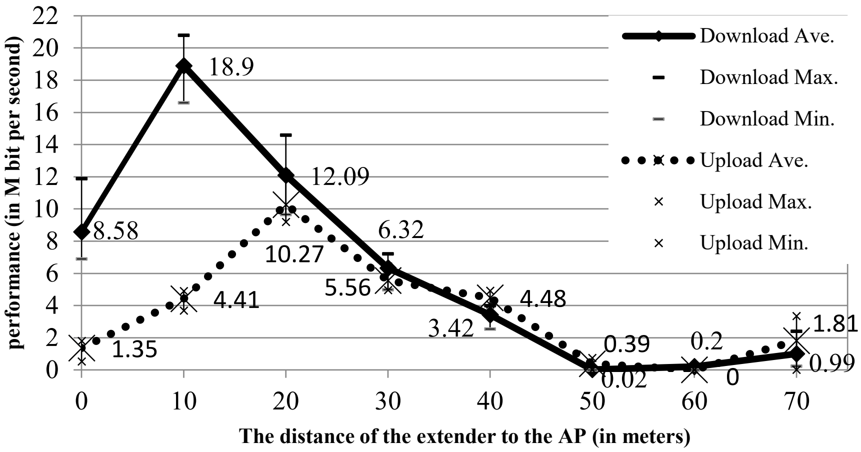

Fig. 4. The Extender Performance as Download and Upload Speed of the Extender line graph

4. RESULT

The RTTs as the ping output ranged from 9ms (millisecond) to 15 ms and were almost fixed values during trials from 0m position to 50m. This shows that the communication was stable both for internet and Wi-fi link for the measurement. In one trial out of three for each distance from 50m to 70m, the connection to the speed test site became unstable and only RTT was measured although it could be measured performance at other trials. In later discussion, the connection speed results in these failure trials are regarded as 0 Mbps.

Figure 4 shows correlation between the Wi-Fi link performance through the extender and the distance between the AP and the extender. All the performance measures over 40m distance are bad compared to the direct link between the AP and the client in our environment. It clearly shows that just placing an extender in the cover area of an AP might degrade the performance and that the placement of an extender is an important problem for better performance of an extender. The user manual of the extender we used (Tp-Link, 2018) instructs how to place the product as follows and no explanation for best position. So we continue with this position problem.

Plug the extender into an electrical outlet between your host router and the Wi-Fi"dead" zone. The location you choose must be within the range of your existing host network (Section 2. 2. Position Your Extender).

The download speed at 0 meter using the extender was faster than the one in the direct link between the AP and the client. This means the extender's Wi-Fi link was better than the AP's one through 70m distance for the client at least in our environment and the degrading of the performance in the above discussion is not mainly caused by the extender itself nor the Wi-Fi link between the extender and the client.

In our environment, the download speed peaked at 10m averaging at 18.9 Mbps and the upload one peaked at 20m with 10.3 Mbps. Although this result only shows the rough position of the extender for maximum performance, the distance between the AP and the extender is much smaller than that between the extender and the clients in these points (only 40% at 20m position and even 1/6 at 10m). This means that the optimum position for maximum performance is greatly shifted to the AP side from the center which is equidistant from the both ends, the AP and the client. This result supports our doubt about the symmetry of the AP extender link and the extender client link discussed in section two. The performance near the center ranges from 3.42Mbps at 40m position to 6.32Mbps at 30m for download link and is significantly worse than the minimum speed at 20m, 9.67Mbps.

Figure 5 shows correlation between the RSSI at the extender and the distance between the AP and the extender. From 0m position to 40m, the RSSI gradually decreased through distance from -37db to -66.33db. It is a natural phenomenon obeying to the inverse-square law and is similar to the result by Hasegawa *et al.* (2011). As we discussed in the first part in section three, the maximum performance of wireless link is heavily dependent on the RSSI, both the result by by Hasegawa *et al.* (2011) and our one are quite natural.

Although the degrading of average RSSI from 20m position to 40m is only 2.66db (decreasing to about 54% in power), the result from figure 2 suggests sensitive degrading of download performance from 12.1Mbps to 3.42Mbps in the same positions. From this result, we can infer that the extender will degrade its performance at least under the situation where RSSI is under around -64db threshold and users of the extender should keep the threshold for better performance if we believe the Shannon–Hartley theorem and the IEEE 802.11n adaptation functions such as modulation and coding for air interface.

The RSSIs at 50m position or over are rather disturbed compared to the less distance results described above. The RSSI at 50m position was stronger than the RSSI at 20m one, the best position for uploading. Moreover, the RSSI at 60m position significantly dropped to -72dB with almost disconnected situation but the one at 70m breathed back again to -68dB and the connection resumed.

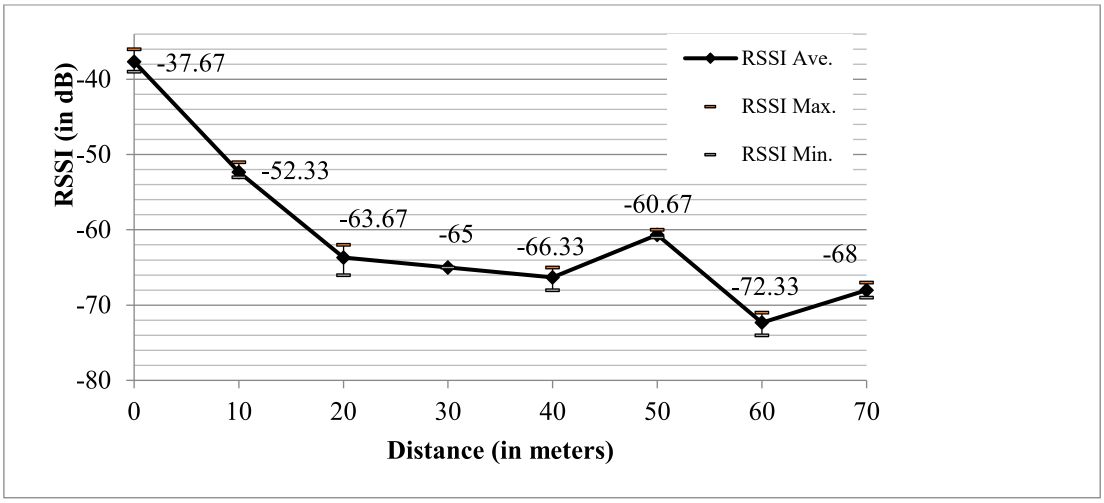

Fig. 5. RSSI at the Extender

Excluding path loss, radio wave might be mainly affected by two types of phenomenon, shadowing loss and multipath fading. Since the experiment was done through the straight hallway and all devices were placed on the line of sight, so it would be impossible to argue that shadowing loss was the main cause. These results might suggest us the RSSI anomaly caused by multipath fading by walls facing to the hallway. However, the half-wavelength of 2.4GHz band is rather small (about 6 centimeters) and accidentally placing Wi-Fi devices multiple times at the location of a multipath standing wave node rarely occurs from a probability point of view. We fear that further investigation is needed to determine the root cause of this issue.

Hassan (2013) discussed the similar problem where to place cascading extenders in series, but the author's model to predict the RSSI for best performance was mainly discussed on shadowing loss phenomenon assuming the home usage and it is hard to apply the model in our experiment directly.

5. CONCLUSION

The objective of this paper is to support tourist for through better Wi-Fi experience with less cost using extenders. The most optimal distance for the placement of the Extender is between 10 – 20m away from the AP (around -64dB RSSI). The optimal distance is different compared to the manufacturer's recommendation, which is to put the extender about halfway between the client and AP. Based on the data, both RSSI and the distance need to be put into consideration for the best possible performance.

Although the maximum performance of the radio link between AP and a client was discussed in this paper on the control experiment, the multiple clients are supported for an AP in real usage scenario and the influence of the multiple clients is based on the IEEE 802.11 standard. So the interference among multiple clients and an extender might be surveyed for better performance in real world usage. For future work, we would like to investigate both extenders cascading and mesh networks. The reason being from our previous experiment while cascading improves internet stability at longer ranges, the speed was reduced by almost half. On the other hand, mesh network which is a group of devices that act as a single Wi-Fi network could be more efficient. This is because in extender a separate network is created, while network mesh is not, which means that the setup process could be more straightforward.

REFERENCES

Ali, Q.I., and Jalal, J.K. (2014). Practical Design of Solar-Powered IEEE 802.11 Backhaul Wireless Repeater, In: *Proc. 6th International Conference on Multimedia, Computer Graphics and Broadcasting*, Haikou, China, 9-12. doi: 10.1109/MulGraB.2014.9.

Hasegawa, T., Takeno, H., Nakatsu, Y., and Omiya, M. (2011). Relations of RSSI and Average Throughput of IEEE802.11n Wireless LAN System. *Trans. IPSJ*, 52(9), 2329-2840. (in Japanese). doi: 10.1109/TENCON.2011.6129030.

Hassan, S.A. (2013). Optimal throughput analysis for indoor multi-hop wireless networks in IEEE 802.11n, In: *Proc. of WAMICON 2013 (The 12th annual IEEE Wireless and Microwave Technology Conference)*, Orlando, FL, United States of America, 2013, 1-5. doi: 10.1109/WAMICON.2013.6572772.

Hou, C. (2013). IEEE Std 802.11ac Deployment in Japan, https://wifiamateur.blogspot.com/2013/04/80211ac-device-deployment-in-japan.html (last accessed on Mar. 21, 2020).

Japan Tourism Statistics (JNTO, 2018). Data list | Japan Tourism Statistics | Japan National Tourism Organization (JNTO), Japan Tourism Statistics, Trends in Visitor Arrivals to Japan, https://statistics.jnto.go.jp/en/graph/#graph--inbound--travelers--transition/ (last accessed on Mar. 21, 2020).

Kaede, K., and Nishimura, T. (2008). The implementation of disaster prevention/recovery network appliances using unified authentication system for wireless LAN, In *Proc. IEICE Gen. Conf. '07*, 169. (in Japanese).

NTT Broadband Platform Inc. (NTTBPI, 2019). Japan Connected-free Wi-Fi, http://www.ntt-bp.net/jcfw/en.html (last accessed on Mar. 21, 2020).

Ookla (2019). How does Speedtest measure my network speeds?, https://help.speedtest.net/hc/en-us/articles/360038679354-How-does-Speedtest-measure-my-network-speeds-? (last accessed on March 21, 2020).

Shannon, C.E. (1949). Communication in the presence of noise, *Proc. the Institute of Radio Engineers* 37(1), 10–21.

The Tokyo Organising Committee of the Olympic and Paralympic Games (TOCOG, 2020). Tokyo 2020 Olympic Games – Homepage, https://tokyo2020.org/en/ (last accessed on Mar. 21, 2020).

TP-Link Technologies Co., Ltd. (TP-Link, 2018). User Guide 300Mbps Wi-Fi Range Extender TL-WA850RE. https://static.tp-link.com/2018/201805/20180509/1910012385_TL-WA850RE_UG_REV6.0.1.pdf. (last accessed on Mar. 21, 2020).