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Advanced office WLAN: a case study

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The purpose of this thesis was to go deeper into WLAN design. First, the theory behind WLAN design is discussed. Second, how to put the theory into practice in a customer case where high-performance WLAN was needed is analyzed.

A portable access point and Ekahau Site Survey was used to survey the site to get as accurate data as possible for the design. The site survey was done before the design showed how the access points would perform in this building.

The results of the survey were of great help to make the design as accurate as possible before implementing it. Finally, this study shows the importance of robust WLAN designing.

Keywords	WLAN, Ekahau, Site Survey, WLAN design

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Tämän opinnäytetyön tarkoituksena oli syventyä WLAN-suunnitteluun. Ensimmäisenä käydään läpi teoriaa WLANin suunnittelusta ja myöhemmin sitä, miten ne toteutetaan asiakkaan tapauksessa, jossa tarvitaan suorituskykyistä WLAN-verkkoa.

Siirrettävää WLAN-tukiasemaa ja Ekahau Site Survey -ohjelmaa käytettiin ensin selvittämään, miten verkossa käyttöön tulevat tukiasemat suoriutuisivat tässä rakennuksessa. Näiden tietojen avulla saatiin mahdollisimman hyvin todellisuutta vastaavaa WLAN-suunnitelma. Suunnitelma tehtiin käyttäen Ekahau Certified Survey Engineer -koulutuksessa sekä Certified Wireless Network Administrator, Official Study Guide -kirjassa esitettyjä menetelmiä.

Mittauksen tulokset auttoivat tekemään mahdollisimman tarkan WLAN-suunnitelman Ekahaussa ennen WLANin toteuttamista. Työ osoittaa WLAN-suunnittelun tärkeyden.

Avainsanat	WLAN, Ekahau, Site Survey, WLAN-suunnittelu

Contents

List of Abbreviations

WLAN	Wireless Local Area Network.
AP	Access point.
IEEE	Institute of Electrical and Electronics Engineers.
VoIP	Voice over Internet Protocol.
VLAN	Virtual Local Area Network.
DHCP	Dynamic Host Configuration Protocol.
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance.
ESS	Ekahau Site Survey.
MCS	Modulations and Coding Scheme index values.
CCI	Co-channel interference.
ACI	Adjacent channel interference.
APOS	Access point on a stick.

1 Introduction

Wireless networks keep getting more and more popular. Companies are relying on wireless technologies for more than just offering Internet access to guests and in meeting rooms. The number of laptops, tablets and smart phones is increasing and the need for high speed wireless access to the Internet increases with it. But with more wireless networks and devices in each network we are met with new challenges such as interference, bad user experience and slow Wi-Fi.

To combat these challenges, we need to go back to the drawing board. How are the wireless networks designed, if at all? How competent are the people implementing these networks? How do other's bad designs affect the networks nearby? All these questions and more will be discussed in this thesis. The need for good WLAN design is increasing and therefore the people designing these networks must follow the same guidelines.

This thesis discusses the technologies of WLAN and how these are taken into consideration when designing WLANs, as well as practical design guidelines. An important tool is the use of Ekahau Site Survey and the Ekahau Sidekick. Lastly all these guidelines are put into practice in a customer case where high-performance WLAN was needed in a big office in busy Helsinki center.

2 Wireless LAN

2.1 WLAN technologies

IEEE 802.11 is a set of standards for implementing WLAN, created and maintained by the Institute of Electrical and Electronics Engineers (IEEE). The first widely accepted standard 802.11b was approved in July of 1999 and delivered up to 11 Mbps data rates. In 2003 802.11g was released, giving data rates up to 54 Mbps thanks to OFDM modulation. [1, p. 166, 169].

Six years later, in 2009, 802.11n was formally made public. With a maximum data rate of up to 600 Mbps it brought several major innovations including, but not limited to, MIMO and wider channel bandwidth. [1, p. 626]. 802.11n provides backwards compatibility, as did 802.11b and 802.11g. [1, p. 182]. When older devices are in the network the network slows down considerably for all devices.

To provide this backwards compatibility there are three modes in which an 802.11n access point can operate:

- Legacy (only 802.11 a, b, and g)
- Mixed (both 802.11 a, b, g, and n)
- Greenfield (only 802.11 n) - maximum performance [2]

In December 2013 the 802.11ac standard was published. Operating on the 5 GHz frequency band, using up to 160 MHz wide channels and 256-QAM modulation it can offer up to 1.69 Gbps data rates per client. With an eight-antenna access point, four two-antenna clients utilizing a 160 MHz wide channel the maximum data rate of the access point is 6.77 Gbps i.e. four times 1.69 Gbps.

The mandatory physical layer specifications for 802.11ac are 20, 40 and 80 MHz wide channels and BPSK, QPSK, 16-QAM and 64-QAM modulation types. There are two versions of 802.11ac, Wave 1 and Wave 2. Wave 2 was released in 2016 and offers higher data rates thanks to multi user MIMO and 160 MHz wide channels. [1, p. 662].

2.2 Antennas

The antenna is what determines in what direction the signal from the AP is sent. There are two main categories for antennas used in APs: omnidirectional and directional. The most commonly used antenna is omnidirectional because it covers the biggest area. [1, p. 117].

An omnidirectional antenna signal pattern can be described as doughnut-shaped and in the commonly used vertical and horizontal plane graphs it’s circular in the horizontal plane and somewhat doughnut-shaped in vertical plane. Antenna signal patterns vary substantially between antennas. [1, p. 118]. The antenna signal patterns of the Aruba IAP-315 access point are illustrated in Image 1.

Directional antennas can be very useful in certain cases. A good example is a warehouse with highly attenuating shelves. Directional antennas in between the shelves can be used here. Because omnidirectional antennas' signal is sent in all directions the risk of channel overlap is greater than when using directional antennas. [1, p. 121].

A good principle to follow in WLAN design regarding signal coverage, and thus antennas, is to only cover what we want to cover. More is not always better and that is seen throughout WLAN design.

Image 1. Aruba IAP-315 antenna pattern plots. [12].

2.3 Airtime

As 802.11 wireless radios can't transmit and receive at the same time, the clients and access points need a way to decide when each gets to use the wireless medium. A protocol called Carrier Sense Multiple Access with Collision Avoidance, CSMA/CA for short, is used for this. [1, p. 265].

The fact that only one client can transmit or receive at the time is a fundamental feature of WLAN. All clients and APs listen to the medium, and when the medium is free, transmission is possible. This is called carrier sense and can be done virtually or physically. [1, p. 268 – 270]. Discussing CSMA mechanism is out of the scope of this paper.

This collision avoidance is what makes WLAN design, more specifically radio settings, so vital. If access point's channels overlap, the medium where collisions must be avoided is expanded to all access points that overlap.

2.4 Client NIC behavior

The association process of a client in any WLAN is of great interest to whoever is designing (or troubleshooting) the network. We like to think that we have designed the placement of AP's such that clients won't have issues associating to the network and staying connected. And yet there we are, with clients that keep losing connection, having trouble associating or getting low throughput. To understand this, we need first need to understand that clients have the last say in which AP to associate with. Manufacturers of the NIC's and their drivers decide how the NIC works, not we who design the WLAN. [3]

Some clients roam very easily, others don't, meaning that some client will hold on to their associated AP longer than others. Comparing a laptop to a smartphone can give some insight to why devices are designed to roam differently. It could be assumed that a laptop is more stationary than a smartphone and that it would benefit from not roaming too quickly.

Clients and APs also continuously discuss what modulation and coding scheme to use, which ultimately determines the speed of the connection. Spatial streams can be used when more than one antenna is available on the AP and client. [1, p. 628] A technology known as multiple-input and multiple-output, or MIMO is what allows the client to use spatial streams. MIMO is also used to improve link quality and reliability. [5]

Modulation is the method by which data is communicated through the air [4]. Illustrated in Image 2 is the signal received using QAM modulation with different signal-to-noise ratios. We can see that for 64-QAM to be reliable in this case a SNR of 20 dB or more is required, otherwise the signal is not distinguishable from the noise.

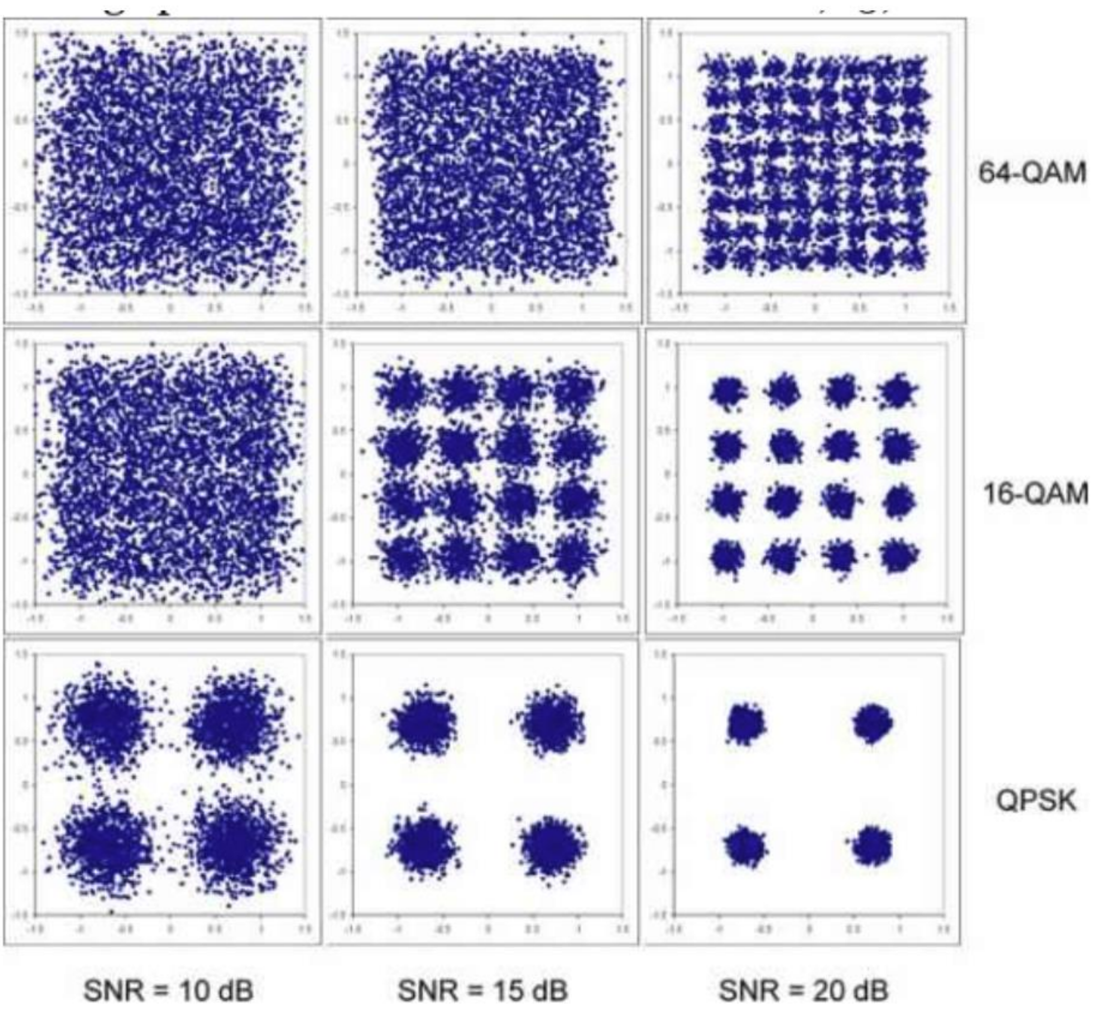

Image 2. Signal received using QPSK and QAM modulation with different signal-to-noise ratios. [8, p. 87].

Coding rate is an indication of how much of the data stream is being used to transmit the client's data versus error correction. This is represented in fractions, with 5/6 or 83,3 % being the most efficient.

Guard interval (GI) is the short pause between packet transmissions. Longer GI allows for more reliable transmission, with speed being the tradeoff. As of 802.11n there are two options: 400 ns (short) and 800 ns (long). [7]

Channel width is very self-explanatory. In 802.11ac there are 4 channel widths available: 20, 40, 80 and 160 MHz wide channels. This is of big interest when designing WLAN, especially in environments with several AP's where the limiting factor is the number of channels that can be used without channel overlap. Narrower channels allow more channels to be used with less overlap. Wider channels offer more bandwidth and thus, higher speeds. The importance of channel widths will be discussed in detail later.

All these factors (spatial streams, modulation, coding rate, guard interval and channel width) can be described in what's called an MCS index value (Modulation and Coding Scheme Index Values). [1, p. 672]. Image 3 shows the MCS Index values in 802.11ac when using 1, 2 or 3 spatial streams.

802.11ac - VHT MCS, SNR and RSSI

VHT MCS	Modulation	Coding	20MHz				40MHz				80MHz				160MHz			
			Data Rate		Min. SNR	RSSI	Data Rate		Min. SNR	RSSI	Data Rate		Min. SNR	RSSI	Data Rate		Min. SNR	RSSI
			800ns	400ns			800ns	400ns			800ns	400ns			800ns	400ns		
1 Spatial Stream																		
0	BPSK	1/2	6.5	7.2	2	-82	13.5	15	5	-79	29.3	32.5	8	-76	58.5	65	11	-73
1	QPSK	1/2	13	14.4	5	-79	27	30	8	-76	58.5	65	11	-73	117	130	14	-70
2	QPSK	3/4	19.5	21.7	9	-77	40.5	45	12	-74	87.8	97.5	15	-71	175.5	195	18	-68
3	16-QAM	1/2	26	28.9	11	-74	54	60	14	-71	117	130	17	-68	234	260	20	-65
4	16-QAM	3/4	39	43.3	15	-70	81	90	18	-67	175.5	195	21	-64	351	390	24	-61
5	64-QAM	2/3	52	57.8	18	-66	108	120	21	-63	234	260	24	-60	468	520	27	-57
6	64-QAM	3/4	58.5	65	20	-65	121.5	135	23	-62	263.3	292.5	26	-59	526.5	585	29	-56
7	64-QAM	5/6	65	72.2	25	-64	135	150	28	-61	292.5	325	31	-58	585	650	34	-55
8	256-QAM	3/4	78	86.7	29	-59	162	180	32	-56	351	390	35	-53	702	780	38	-50
9	256-QAM	5/6			31	-57	180	200	34	-54	390	433.3	37	-51	780	866.7	40	-48
2 Spatial Streams																		
0	BPSK	1/2	13	14.4	2	-82	27	30	5	-79	58.5	65	8	-76	117	130	11	-73
1	QPSK	1/2	26	28.9	5	-79	54	60	8	-76	117	130	11	-73	234	260	14	-70
2	QPSK	3/4	39	43.3	9	-77	81	90	12	-74	175.5	195	15	-71	351	390	18	-68
3	16-QAM	1/2	52	57.8	11	-74	108	120	14	-71	234	260	17	-68	468	520	20	-65
4	16-QAM	3/4	78	86.7	15	-70	162	180	18	-67	351	390	21	-64	702	780	24	-61
5	64-QAM	2/3	104	115.6	18	-66	216	240	21	-63	468	520	24	-60	936	1040	27	-57
6	64-QAM	3/4	117	130.3	20	-65	243	270	23	-62	526.5	585	26	-59	1053	1170	29	-56
7	64-QAM	5/6	130	144.4	25	-64	270	300	28	-61	585	650	31	-58	1170	1300	34	-55
8	256-QAM	3/4	156	173.3	29	-59	324	360	32	-56	702	780	35	-53	1404	1560	38	-50
9	256-QAM	5/6			31	-57	360	400	34	-54	780	866.7	37	-51	1560	1733.3	40	-48
3 Spatial Streams																		
0	BPSK	1/2	19.5	21.7	2	-82	40.5	45	5	-79	87.8	97.5	8	-76	175.5	195	11	-73
1	QPSK	1/2	39	43.3	5	-79	81	90	8	-76	175.5	195	11	-73	351	390	14	-70
2	QPSK	3/4	58.5	65	9	-77	121.5	135	12	-74	263.3	292.5	15	-71	526.5	585	18	-68
3	16-QAM	1/2	78	86.7	11	-74	162	180	14	-71	351	390	17	-68	702	780	20	-65
4	16-QAM	3/4	117	130	15	-70	243	270	18	-67	526.5	585	21	-64	1053	1170	24	-61
5	64-QAM	2/3	156	173.3	18	-66	324	360	21	-63	702	780	24	-60	1404	1560	27	-57
6	64-QAM	3/4	175.5	195	20	-65	364.5	405	23	-62			26	-59	1579.5	1755	29	-56
7	64-QAM	5/6	195	216.7	25	-64	405	450	28	-61	877.5	975	31	-58	1755	1950	34	-55
8	256-QAM	3/4	234	260	29	-59	486	540	32	-56	1053	1170	35	-53	2106	2340	38	-50
9	256-QAM	5/6	260	288.9	31	-57	540	600	34	-54	1170	1300	37	-51			40	-48

Image 3. MCS index values for 802.11ac. [8].

2.5 Channel interference

With the everlasting increase in use of wireless technology comes the inevitable technical limitations. As WLAN uses a limited number of channels, there comes a time when AP's are on the same channel, thus interfering with each other. Two AP's on the same channel leads to clients having to share the bandwidth on that channel. On the 2.4 GHz band this is very commonly seen, especially in bigger environments. With only 3 channels, the risk of co-channel interference (CCI) is big. To make a bad situation worse, AP's on the non-standard channels (2,4,5,7,8,9,10,12,13) interfere with more than one channel. This is called adjacent channel interference (ACI). This is illustrated in Image 4. [1, p. 409].

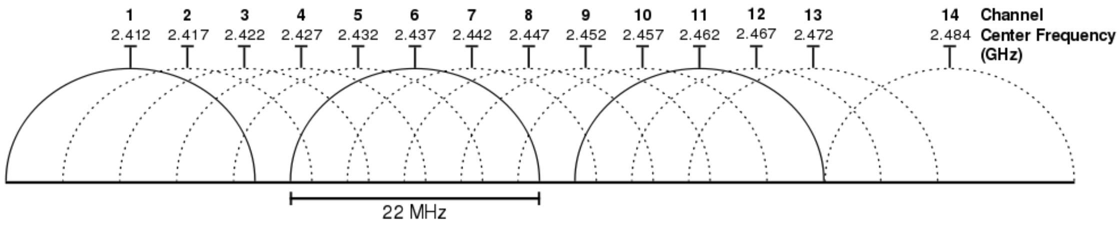

Image 4. Graphical representation of 2.4 GHz band channels overlapping. [11].

On the 5 GHz band using 20 MHz wide channels (UNII-1 – UNII-2 Extended) the number of channels is 20 (Image 5). This makes avoiding channel overlap less challenging and is one of the reasons why the 5 GHz band is preferred over the 2.4 GHz band. Using only 20 MHz channels is preferred especially in crowded areas to lower the risk of CCI and ACI.

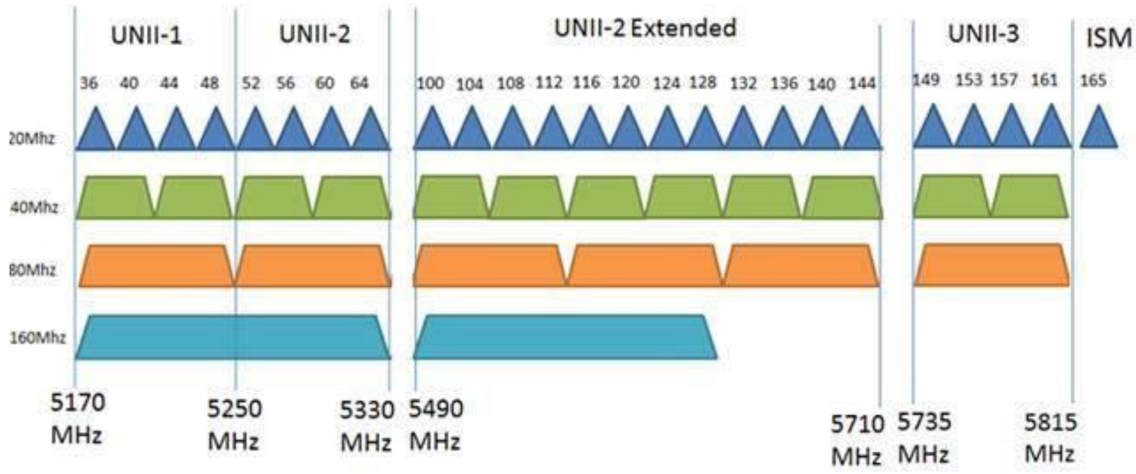

Image 5. Graphical representation of 5 GHz band channels. [10].

Decreasing the transmit power is another way to avoid interference. As discussed earlier, we only want to cover the area we need to cover and avoid interfering with the rest of the APs. Decreasing transmit power from 100 mW to 10 mW only decreases the range of the signal by half in a free environment (Image 6). The clients that are close to the AP won't be affected, but neighboring AP's will have less risk of interference. The threshold for interference is determined by the device receiving the signal.

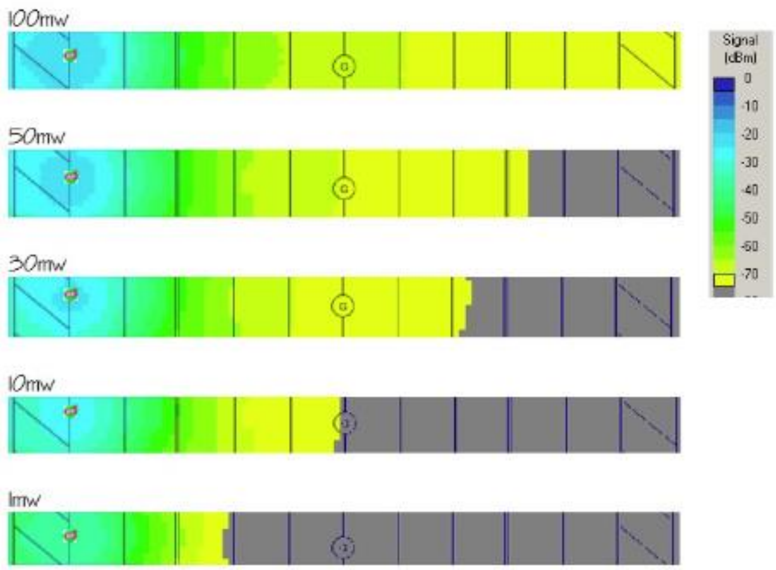

Image 6. Signal strength of AP placed at left side of the (football) field [6, p. 42].

3 WLAN design

3.1 General guidelines

The following is a simplified version of the process of designing WLAN that was presented at ECSE (Ekahau Certified Survey Engineer) training. These guidelines are also presented by Coleman D. and Westcott D. in Chapter 12 and 15 of Certified Wireless Network Administrator, Official Study Guide.

The concept of “least capable, most important device that needs to work in the WLAN” is relatively important. It functions as a framework for what technologies we can and should use. If the network has devices that are only 2.4 GHz capable and need good coverage, that needs to be taken into consideration. Luckily these 2.4 GHz-only devices are getting rarer and 5 GHz can be used as the default, with 2.4 GHz as a backup for less capable devices.

When the least capable, most important device is known, coverage can be discussed. This is also called primary RSSI (Received signal strength indication). Most customers want coverage *everywhere* until they realize that coverage in the cleaning closet, elevator and storage room will cost them three more AP’s. This is an important discussion and the cost-to-benefit ratio should be communicated clearly to the customer.

In environments where seamless roaming for VoIP calls is needed (e.g. hospitals), secondary RSSI also needs to be planned. Clients that can’t afford to lose several packets during roaming need to have a good enough signal to two APs at all times. [1, p. 374].

Another important factor is high-density areas. Some environments have big meeting rooms or auditoriums that have large amounts of devices connect to the network at the same time. These areas need special attention when designing the WLAN. [1, p. 446].

When these requirements are known it’s usually safe to start designing in Ekahau Site Survey.

3.2 Radio planning

Keeping the concepts of coverage and channel overlap in mind, a plan for radio channel and transmit power used in the WLAN is needed. In an isolated environment where the only APs the clients can see are our own, setting channels and transmit power manually is a viable option. With no interference from outside APs using wide channels without overlap is manageable.

Designing WLAN for isolated buildings is a luxury, and interference from outside APs is a reality. A good WLAN design should not have channel overlap on the 5 GHz band in the design phase. Controlling AP radios outside your own network is usually not possible (unless you can contact the administrator and ask them for changes) and that's why it's important that at least the design is free from channel overlap.

When implementing a WLAN in non-isolated, or even crowded areas, the option to let the WLAN controller (or virtual WLAN controller) decide what radio settings to use is a viable option. Interference is seldom static, i.e. an AP that caused channel overlap today might not be a problem tomorrow. With everchanging radio environments, the use of dynamic controller-based radio settings is a clever decision.

3.3 Designing WLAN using ESS

Ekahau Site Survey is a software that allows simulating a WLAN network before implementing it. By using a floor map, drawing everything that attenuates wireless signal (walls etc.) and placing the exact model of AP that will be used, ESS can simulate almost everything needed in WLAN design e.g. signal strength and channel overlap.

After importing a floor map, the walls need to be drawn. Knowing what type of walls that are in the building is important in making a reliable plan. A standard drywall attenuates wireless signal about 3 dB, a window just 1 dB and a concrete wall can attenuate up to 12 dB. Without measuring all the walls, there is no certainty of what the attenuation is, but using these standard values is a good start.

When the walls are drawn APs can be placed on the floor map. There is an automatic planner available, but it tends to overshoot the number of APs needed. With some general rules, experience and trial-and-error, placing APs becomes easier. Some guidelines to keep in mind are:

- Avoid placing APs in the hallway at all cost. The signal will not be attenuated in the hallway, thus interfering with the other APs. APs should be placed in rooms, where the clients are.
- Signal strength is usually not the issue. Take channel overlap into consideration. Adding an AP on the same channel as another AP doesn't improve client experience, it worsens it.
- In environments with several floors, avoid placing AP's in the same spot on floors below or above.

The goal is to have coverage where coverage is needed, while avoiding channel overlap.

3.4 AP on a stick

As mentioned earlier, the only way to know how much the walls attenuate the signal is to measure this. This can be done in several ways. If there are existing access points the simplest way is to measure the signal strength on both sides of the wall and compare these measurements. If there are no existing access points, a smartphone can be set up as a WLAN hotspot.

As most APs have different specifications and parts used, it's best to do these measurements with the model that will be used in the network to get as accurate measurements as possible. To avoid having to install an AP for these measurements, a so-called AP on stick can be used, APOS for short. The APOS is placed somewhere seen useful and a site survey is done with ESS to see how the signal attenuates. A good place would be somewhere where an AP is expected to be placed or somewhere where several wall types can be measured.

Image 7. The APOS used in this project.

A light stand with wheels and a golf club serves as an adjustable mount, an accumulator as the power supply and a Raspberry Pi DHCP server.

An Aruba IAP-215 was used in this APOS survey. It was placed on the 7^{th} floor and a survey was done on the 7^{th} and 6^{th} floor on the side of the building where the AP was located.

Beneath is a comparison of signal strength in three different scenarios. First is the survey done with the APOS, i.e. real life measurements done with an APOS and the Ekahau Sidekick. The second is the calculated signal strength by Ekahau planner with the AP located exactly where the APOS was. The last one is the calculated signal strength of AP-7.6, which was where the AP eventually was installed. The relevant AP is marked with orange in all three pictures, the signal strength is of the 5 GHz frequency and the scale of colors are set so that the grey is where the signal strength is less than -65 dBm.

Image 8.   Comparison of APOS survey and two ESS calculated scenarios.

Comparing the surveyed and calculated APOS scenarios gives us some guidelines of how the ESS plan compares to the actual environment. By changing wall types in ESS and their attenuation values the simulation becomes more accurate.

As shown in the APOS survey, coverage requirements for the area shown are almost met. Most of the area has good (above -67 dBm) signal strength. So why not use just one AP and call it a day? The goal in this environment was to have a robust WLAN with not only good signal, but also great performance. The APs are located inside the rooms for two reasons. The first is that this is where most of the clients are. The second is that we get *more* attenuation of the signal this way. Coverage is seldom the issue, channel overlap is. The principle mentioned earlier of “only cover what we want to cover” is demonstrated here.

The attenuation of the floor can also be measured with an APOS. APs should not be placed in the same spot on floors directly above or below each other. The signal is least attenuated when the signal travels straight through the floor and gets higher further away from the AP because the signal must travel diagonally through the floor. As seen in Image 9, the signal from the APOS carries through the thick concrete floor and is between -67 dBm and -87 dBm on almost half of the area shown.

Image 9. Signal strength of the APOS on the 6th floor.

This is still perceived as noise for the APs on the 6th floor. This can worsen the signal to noise ratio and cause worse client experience due to worse MCS index score i.e. worse throughput. [1, p. 410].

3.5 Surveying using ESS

A design is always a design. Even with APOS measurements and accurate simulations in ESS the design can't represent the real-world scenario. Therefore, verifying the WLAN's performance after implementation with a site survey should be a part of every WLAN project. [1, p. 586].

The survey can be done in the same project as the design. Ekahau uses a WLAN NIC (the computer's or an external) to scan each channel in the intervals the NIC can handle and combines that data to where on the map the data was collected. Ekahau's Sidekick measurement tool is a great tool in surveys. It has two enterprise grade dual-band 802.11ac adapters that allows for fast and accurate scanning of all WLAN channels. It's also a very capable spectrum analyzer. With a spectrum analyzer all traffic, Wi-Fi and non-Wi-Fi, can be seen. [11]

4 Customer case

4.1 Background

The customer’s office is three floors high, located in the fifth, sixth and seventh floor of a busy office building in the center of Helsinki. The hardware used is Aruba IAP-315 and Aruba AP-345. The IAP-315 has one 2.4 GHz and one 5 GHz radio, while the AP-345 is dual 5 GHz radio capable. Some AP-345 models are using the dual 5 GHz capability and are thus not broadcasting on 2.4 GHz frequency. The radio channels shown on the images from ESS are not final, since the APs will use Aruba Adaptive Radio Management (ARM). ARM monitors what channels to use and automatically changes channels on APs to avoid channel overlap. This will be discussed further in the Implementation section.

4.2 The design

Below are the designs for each floor. All images of signal strength are taken from Ekahau Site Survey and of the 5 GHz frequency. The APs transmit power is set to 14 dBm. The maximum user counts are estimates. Taking the customer’s industry into account it is expected that most users have at least two devices and this is reflected in the amount of access points used in this case.

4.2.1 Fifth floor

The fifth floor is half the size of the two other floors. Most walls were standard drywalls or glass, with a few exceptions. There are 3 main areas: the room at the top with approximately 25 users, the middle area with two cabins and two “hanging areas”. This area can hold up to 30 people. Lastly there is the bottom area, with up to 40 users. There are also two private booths and two one-on-one booths. This floor should thus have a maximum user count of approximately 100.

Image 10. AP-5.1 serves the users in the room where it’s placed and some of the users in the middle area.

Image 11. AP-5.2 serves the users in the bottom area.

Image 12. AP-5.3 serves the users in the bottom area and half of the middle area.

This floor is a great example of where the customer needed to decide whether coverage in specific rooms is more important than the cost of an AP.

In Image 9 the signal strength goals are met everywhere but int the upper right corner.

Image 13. 5th floor signal strength on 5 GHz frequency with only 3 APs.

To cover these two rooms, a fourth AP had to be added (AP-5.4).

Image 14. 5th floor signal strength on 5 GHz frequency with 4 APs.

4.2.2 Sixth floor

The sixth floor is split in two by a thick concrete wall. The two sides are in realty two separate buildings and the design reflects that. There are two openings between the two buildings. These openings let the signal travel trough and cause some interference in an otherwise very well planned design. This is seen in Image 15. The left part of the floor is almost the same as on the fifth floor and the max user count is approximately 100. The main difference is AP-6.2 that is placed in the middle area instead of the upper right corner. It is placed in between the cabins so that the signal is attenuated the most and does not leak too much into the right side.

Image 15. AP-6.2 serves the middle area.

The right side has three main areas: upper, middle and bottom. The bottom area can hold up to 40 users, the middle about 10 and the top about 20. Each area has its own AP to guarantee great signal strength and performance.

Image 16. 6th floor signal strength on 5 GHz frequency.

4.2.3 Seventh floor

The seventh floor also spans across the two buildings but has a different floor plan than the sixth floor. The left side is handled by 4 APs.

Image 17. AP-7.1 serves a maximum of approximately 20 users.

Image 18. AP-7.2 serves a maximum of approximately 20 users in the four rooms but also some of the users in the middle area.

Image 19. AP-7.3 serves the top area and some of the middle area. The max user count is approximately 20 users.

The middle area on the seventh floor is an open area with very varying amounts of users. The roof in the middle is very high and the possible installation spots for the AP were limited. By placing it in the middle the signal leak into the right side is also minimized. Typical user count is expected to be less than 20 users, but events are held in this area and user count can thus go up to 100. AP-7.4 is an Aruba AP-345 with both 5 GHz radios enabled. This theoretically doubles the capacity of the AP on the 5 GHz frequency.

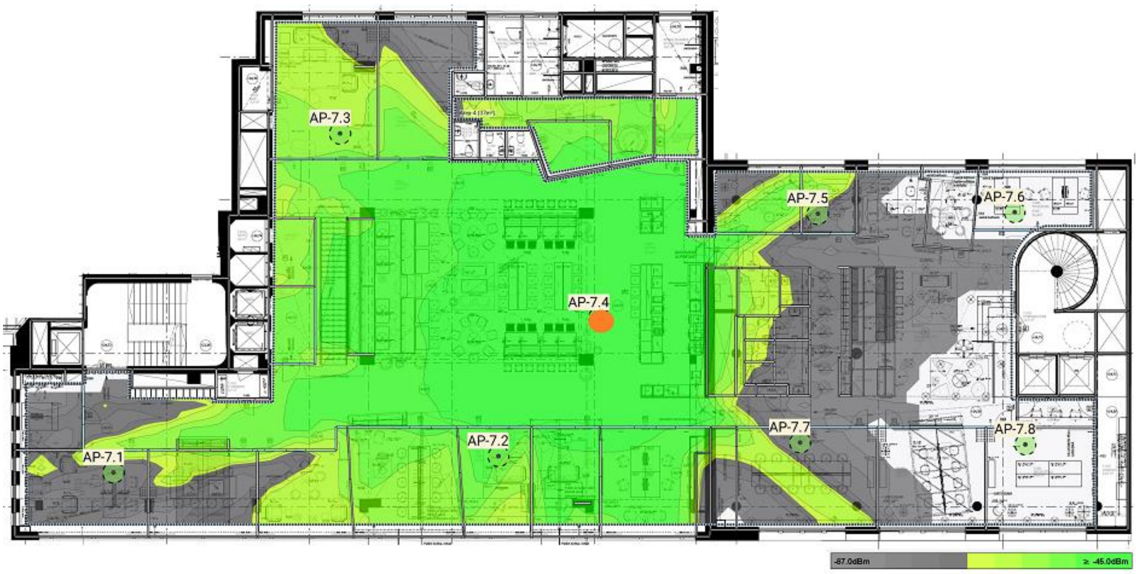

Image 20. Signal strength of AP-7.4.

There are 4 meeting rooms and one office in the top area of the right side. AP-7.5 is placed so that its signal reaches as little of the left side of the floor while still serving the clients in the four meeting rooms.

Image 21. Signal strength of AP-7.5.

AP-7.6 serves the users in the office and reception (middle area).

Image 22. Signal strength of AP-7.6.

The maximum user count in the bottom area is approximately 30 and there are two APs serving these users.

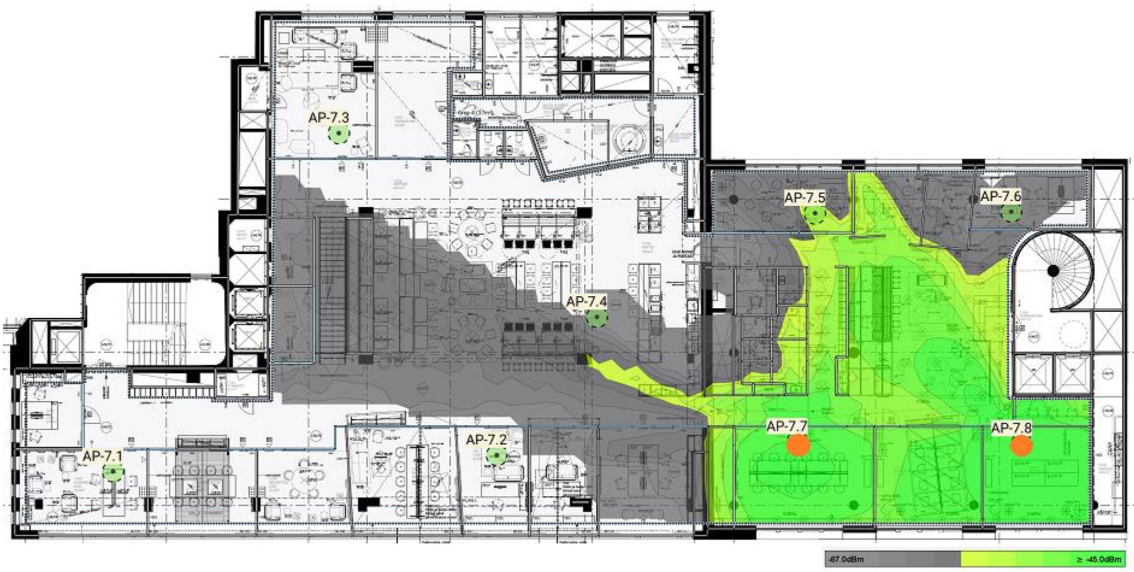

Image 23. Signal strength of AP-7.7 and AP-7.8.

With 8 APs signal strength is excellent even in the sauna area (top right area).

Image 24. Signal strength on the 7th floor.

4.3 Implementation

There were some challenges in the implementation. The office was being renovated and was thus a worksite. The optimal situation would have been to have the WLAN design ready before the renovation and being able to guide construction to have installation points for the APs already taken into consideration with cabling and mounting. Unfortunately, the construction was already in progress when WLAN designing started and therefore not all APs are installed exactly where they were planned to be installed.

4.3.1 Types of installations

APs can be installed in several different ways. This office uses ceiling mounted APs only. Wall-mounted APs and APs with desk stands are the two other common ways to install APs. Because antennas in APs are directed for the specific type of mount, these APs are not inter-changeable i.e. ceiling mounted APs should not be mounted on walls and vice versa.

The least noticeable installation is the ceiling mount kit with a rail adapter. The AP in Image 25 is mounted with the rail adapter and the Ethernet cable is connected through a hole drilled in the ceiling sheet.

Image 25. Ceiling mounted access point with rail adapter.

Some APs where installed near Ethernet plugs. In these installations a ceiling mount kit was used, and the Ethernet cable was simply left visible.

Image 26. Ceiling mounted access point with ceiling mount kit.

Image 27. Ceiling mounted access point with ceiling mount kit.

Another common installation type is on a metal cable railing. Here the cable is not visible.

The ceiling in the office was mostly not covered leaving air conditioning pipes etc. visible. APs were installed with ceiling mounts but brought down using metal cables (commonly used for lamps) to avoid unnecessary signal attenuation and reflection.

Image 28. Ceiling mounted access point with metal cables.

Image 29. Different angle of the access point in Image 28.

4.3.2 Radio settings

As discussed earlier, the wireless environment is seldom static meaning that interference changes and the network needs to adapt to these changes. With Aruba's Adaptive Radio Management, ARM for short, the network can do this. The APs intermittently scan the network for interference and changes settings for channels and transmit power based on these scans.

For this customer case (busy location, lots of interference) Aruba ARM was set to use only 20 MHz wide channels on the 5 GHz band and the transmit power for 5 GHz is 12 dBm to 21 dBm. On the 2.4 GHz band only channels 1,6 and 11 are allowed and the transmit power is set to 3 dBm to 9 dBm. The transmit power settings are set to steer clients to the 5 GHz band.

5 Conclusions

Implementing a wireless network without a strong plan, a design, is a recipe for poor performance and user experience. We must accept our limitations as engineers and use the tools available for designing WLANs. The good news is that these tools are accurate and that by using these we can build great WLANs.

The design is as accurate as the data we use. Therefore, doing measurements at the site is of great help. Knowing the precise attenuation of walls makes the design much more accurate.

The design should always be done before the implementation and the earlier, the better. Knowing the planned locations of the access points before an office or similar is built, or renovated, gives us the chance for easier implementation. If it turns out that a planned installation point can’t be used, this needs to be updated in the design before making changes.

Finally, the customer case was a success. User experience has been great, and this was thanks to a thorough design phase.

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