Wireless System Design Experience: Case Study of a Manufacturing Factory

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Abstract

The purposes of this work were to perform a case study of designing the wireless network in manufacturing under SOA404 policy which includes the design of wireless networks, design of the security for wireless network, and computer related crime act.b.e. 2550. However, in this paper, we focus on the wireless network design. We develop two design models include high performance of signal and high coverage of signal. Each model has equipment standard 802.11g and 802.11n. To compare the cost, signal coverage as well as the advantages and disadvantages for each model are studied. The instruments used in the design were AirMagnet [17] Survey Professional software. The signal obtained by the design software and real signals measured by the software are compared.

Keywords: *SOA404, Wireless network design, IEEE802.11, Wireless network in manufacturing*

1. Introduction

A typical manufacturing factory is facing the problem in computerizing a system. For a case study, the truck factory contains thousands of employees and hundreds of electronic machines and very large working area. To computerize the system, the networking is usually mandatory. Especially wireless networking is an advantage to save cost of installation, to be flexible in equipment relocation, *etc.*

In this paper, we demonstrate the case study of installing wireless networking in a large factory which considers the compliance of SOA404. Criteria are studied and the various design choices are explored and compared in many aspects to suggest to proper one.

The paper is organized as follows. The next section presents some backgrounds in IEEE 802.11 standards and some previous work. Section 3 presents our research methodology. Section 4 presents the wireless network model designs and the evaluation. Finally, Section 5 concludes the paper.

2. Backgrounds

One of the wireless network standards which was becoming popular is IEEE 802.11 developed about ten years ago by IEEE. Nowadays there are many variations of it. In this work, we study two versions which is IEEE802.11g and IEEE802.11n.

IEEE802.11g uses the OFDM (Orthogonal Frequency Division Multiplexing) technology at 2.4GHz which has the bandwidth upto 54Mbs. IEEE802.11n is better technology with the MIMO (Multiple Input and Multiple Output) technology. It contains many antennas and integrates signal processing algorithms to merge signals

and makes the transfer faster. It can achieve the bandwidth upto 600Mbps. Comparison between various standards can be found in [1].

Wireless network can be in many forms such as ad-hoc network or a network with infrastructure. What we are using in the case study is the network with an infrastructure that should contain the access points, hub and switching, LAN / Ethernet which can be connected to the servers as shown in Figure 1.

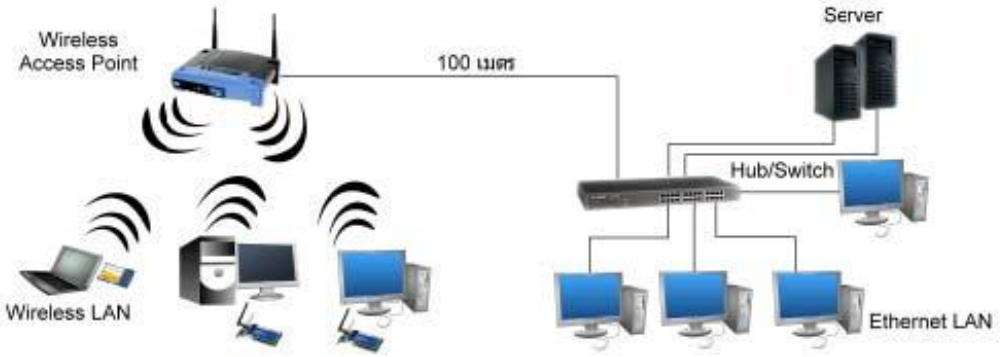

Figure 1. Infrastructure Network Example [2]

Gibney, Klepal, Pesch [3] mentioned that the user demand to use the access points is growing. They suggested the method called Self Growing Neural Gas, to determine the proper access point installation locations which considers obstacles such as walls, areas, *etc*. Prommak, Kabara, Tipper, Charnsripinyo [4] used the Capacity based WLAN constraint satisfaction problem (Cap-WLAN CSP) to design the wireless network. It is based in the user satisfactory, the number of access points, the number of channels, power consumptions, *etc.*

Kouhbor, Ugon, Mammadov, Rubinov, Kruger used a new Global Optimization Algorithm (AGOP) to determine the number of access points and locations considering obstacles and the number of users [5]. Lee, Kim, and Choi developed a tool to search for access point locations and minimize the channel usage to cover the area considering the number of users [6]. Mateus, Loureiro and Rodrigues also developed tools for wireless network installation considering base station installation and channel selection to minimize the overlapping signals in the building [7].

There are many works proposed about the case study of wireless network designs. The work in [8] gave the general tips on designing cases. It is suggested that the area is needed to be surveyed extensively, design choices are needed, the financial aspects need to be considered as well as the training issue.

From [9], the design of the wireless network principles is mentioned. The aspects considered are architecture design which includes the topology, physical design, services. Also, the applications of the network, security of the network, and physical landscapes should be considered. Four cases are presented in the book. In [10], the case study of wireless sensor design is presented. The work includes the decision system where the rule base and optimization, learning are used.

The work by R. A. Stanley [11] presented a case study of wireless system design in a city in the United States. The city has a dense population with a uniform load. The case in by Aughenbaugh and Call [12] is the demonstration of the wireless network design in a university, BYU-Hawaii. Khatani and Saleem presented the case study of designing wireless network services in Mehran, Pakistan. It is based on 802.11g standard [13].

Mitra, *et.al.*, demonstrated a case study of wireless sensor design for healthcare [14]. Particularly, the body area is considered. The biosensors are used to detect the health situations and certain behaviors in real-time. For such a type of network, the emphasis are on the correctness of real-time data, robustness, the number of sensors, *etc*.

Hurni, Braun, Bhargava, and Zhang proposed a multi-hope cross lay design for wireless sensor networks [15]. It attempts to handle communications between different protocols for wireless sensor networks.

Kuo, Perrig, and Walker [16] used the user study method to the security application in the wireless network. The study focuses on the correctness of the users and devices are interacted. It is interesting that each case may handle different environments and scenarios. Costs are considered as one of the major aspects.

3. Research Methodology

To design the wireless network, we first begin with the study of SOA404, laws of IT, and then design the wireless network and security system. Then we estimate the budget used.

For the SOA404, the scope of IT and its auditing are as in Table 1.

Table 1. Scope of IT in SOA 404

Topic areas	No. of controls
1. IT policy and administrations	16
2. Develop and improvement of IT system	15
3. IT operations	21
4. System security	17
Total	69

In particular, the details that are related to the wireless network are the security measure and access control.

Then we study about computer related crime ACT (2006 version). It is found that in Sections 3, the control numbers 14, 15, 26 need to be considered. Section 3 mentions that our factory is in the class of computer network services. Sections 14-15 are about the policy and planning about the penalty on the security violation of the abused users. Section 26 mentions that the computer traffic data should be maintained by at least 90 days and the clock of the systems should be synchronized with the referenced clocks such as NIST etc.

Next, we design the wireless network system. We consider two version of the standards: 802.11g and 8021.11n. In doing so, we divide and survey the installation area. Then we gather the requirement of the users and current status. We determine the locations of access points using AirMagnet [17] software to test the signal strength and coverage.

After that, we design the security system. It covers the following: the design of network security, the usage of basic security such as MAC filtering, Radius server installation with user access control design, design the data security, and the usage of WPA2. At last, we determine the cost of the system design which covers the cost of equipment, the cost of changing the old system to the new system and the cost of security system.

4. Wireless Network Design Strategies

According to Section 3, we survey the area of installation. The factory area is divided into regions as shown in Figure 2. There are three regions. MARU W is the part production management department covered the area of 12,800 square meters. MARU T is another area of part production management department. This area covers 11,200 square meters but there is no need for the wireless signal in this area. MARU A is the vehicle production management covered the area 2,400 square meter. When surveying the current coverage area of MARU W, there is no signal at all while in the area of MARU A, there are some signals from other factories nearby.

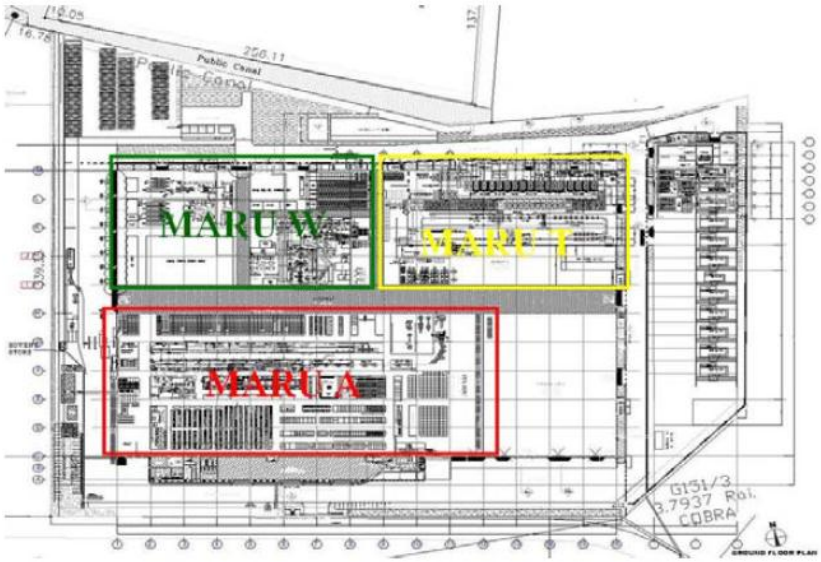

Figure 2. Area Division

We show the results from the design of the MARU W and MARU A. The two styles of the designs are focused. First, it is the style where the efficiency of the access point usage which considers the frequency and bandwidth of the hardware. In the second style, it considers the area coverage. In both design, we consider two types of standards IEEE 802.11g and IEEE 802.11n.

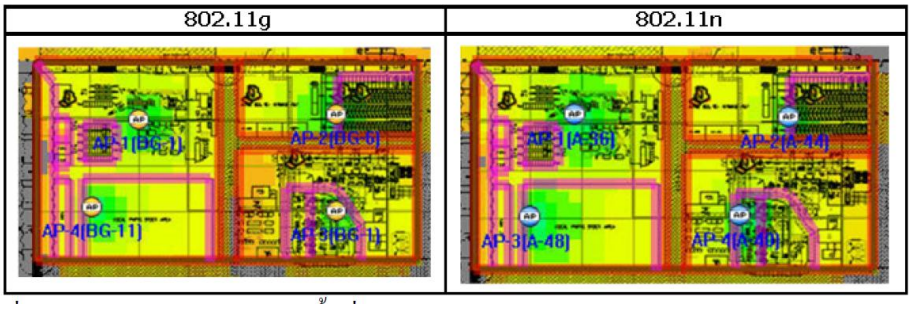

Figure 3. Two Designs for MARU W Focusing on Efficiency

Figure 3 shows the resulting design for MARU W which focuses on efficiency on both standards. The number of access points used is about the same. The difference is in the equipments used as shown in Figure 4. The left table is for the design of 802.11g and the right table is for the design of 802.11n. The tables compare the equipments used and prices in both cases, as of the year 2010 in Thai Baht. The second design seemed to be more expensive.

MARU W -TypeA 2.4

No	Detail	Price	Quantity	Total Price
1	Cisco AIR-AP1242AG-E-k9	20,000	4	80,000
2	Power Injector for 1242AG	1,400	4	5,600
3	AIR-ANT2422DG Dipole Antenna	800	8	6,400
4	Wireless G Adapter for PC	1200	11	13,200
			Total	105,200

MARU W -TypeA 5

No	Detail	Price	Quantity	Total Price
1	Cisco AIR-AP1252AG-E-k9	33,000	4	132,000
2	Power Injector for 1252AG	3,300	4	13,200
3	AIR-ANT2422DG Dipole Antenna	800	12	9,600
4	AIR-ANT5135DG Dipole Antenna	600	12	7,200
5	Wireless N Adapter for PC	1,900	11	20,900
6	Cisco-C2960G-8TC-L	28,500	1	28,500
Tota				211,400

Figure 4. The Cost of the Two Designs for MARU W Focusing on Efficiency

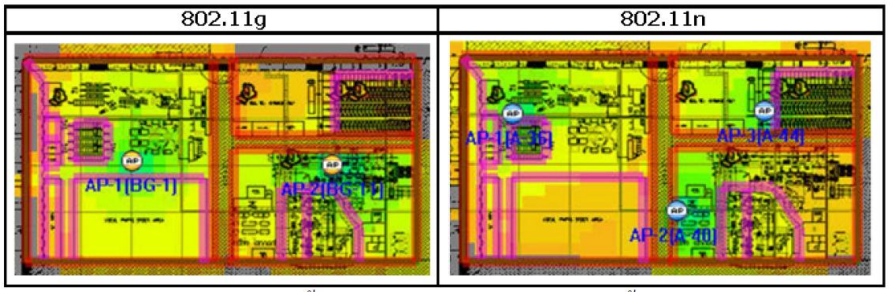

Figure 5. Two Designs for MARU W Focusing on Area Coverage

MARU W -TypeB 2.4

No	Detail	Price	Quantity	Total Price
1	Cisco AIR-AP1242AG-E-k9	20,000	2	40,000
2	Power Injector for 1242AG	1,400	2	2,800
3	AIR-ANT2422DG Dipole Antenna	800	4	3,200
4	Wireless G Adapter for PC	1200	11	13,200
			Total	59,200

MARU W -TypeB 5

No	Detail	Price	Quantity	Total Price
1	Cisco AIR-AP1252AG-E-k9	33,000	3	99,000
2	Power Injector for 1252AG	3,300	3	9,900
3	AIR-ANT2422DG Dipole Antenna	800	9	7,200
4	AIR-ANT5135DG Dipole Antenna	600	9	5,400
5	Wireless N Adapter for PC	1,900	11	20,900
6	Cisco-C2960G-8TC-L	28,500	1	28,500
			Total	170,900

Figure 6. The Cost of the Two Designs for MARU W Focusing on Area Coverage

Figure 5 shows the design that focuses on the area coverage for MARU W. The number of access points used is different: 2 for 802.11g and 3 for 802.11n. The 802.11n design uses more number of access points. Also, Figure 6 shows the cost of both designs. The design with 802.11g is less expensive. Thus, it is shown that the design with 802.11g is better in term of performance and cost.

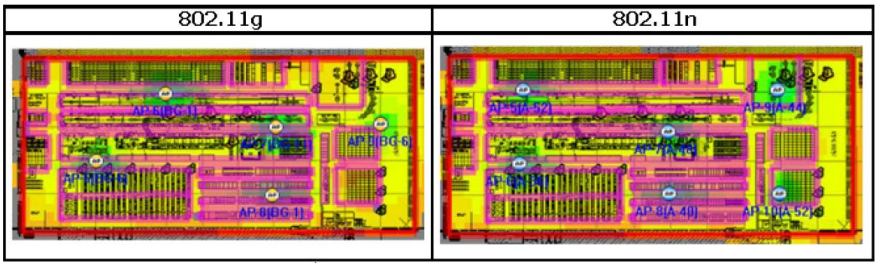

Figure 7. Two Designs for MARU A Focusing on Efficiency

Figure 7 is the design for MARU A for both standards. The design with 802.11g uses 5 access points while that of 802.11n uses 6 access points. Figure 7 presents the signal strength of the design for each test case for some specific location in the area. We measure by using AirMagnet [17] software and the real testing on MARU W. We also test the throughput of each standard design. It is confirmed that the maximum users we can accept is about 10 users. For the security testing, the radius server can help handle access control of the users for the users with limited knowledge of computers.

Figure 8 shows that the design with 802.11g is much cheaper.

MARU A -TypeA 2.4

No	Detail	Price	Quantity	Total Price
1	Cisco AIR-AP1242AG-E-k9	20,000	5	100,000
2	Power Injector for 1242AG	1,400	5	7,000
3	AIR-ANT2422DG Dipole Antenna	800	10	8,000
4	Wireless G Adapter for PC	1200	8	9,600
5	Wireless Adapter for Print Server D-L	3,900	9	35,100
			Total	159,700

MARU A -TypeA 5

No	Detail	Price	Quantity	Total Price
1	Cisco AIR-AP1252AG-E-k9	33,000	6	198,000
2	Power Injector for 1252AG	3,300	6	19,800
3	AIR-ANT2422DG Dipole Antenna	800	18	14,400
4	AIR-ANT5135DG Dipole Antenna	600	18	10,800
5	Wireless N Adapter for PC	1,900	8	15,200
6	Wireless Adapter for Print Server D-L	3,900	9	35,100
7	Cisco-C2960G-8TC-L	28,500	2	57,000
			Total	350,300

Figure 8. The Cost of the Two Designs for MARU A Focusing on Efficiency

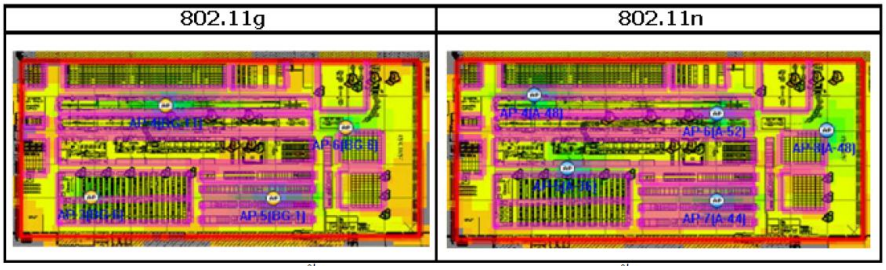

Figure 9. Two Designs for MARU A Focusing on area Coverage

MARU A -TypeB 2.4

No	Detail	Price	Quantity	Total Price
1	Cisco AIR-AP1242AG-E-k9	20,000	4	80,000
2	Power Injector for 1242AG	1,400	4	5,600
3	AIR-ANT2422DG Dipole Antenna	800	8	6,400
4	Wireless Adapter for PC	1200	8	9,600
5	Wireless Adapter for Print Server D-L	3,900	9	35,100
			Total	136,700

MARU A -TypeB 5

No	Detail	Price	Quantity	Total Price
1	Cisco AIR-AP1252AG-E-k9	33,000	5	165,000
2	Power Injector for 1252AG	3,300	5	16,500
3	AIR-ANT2422DG Dipole Antenna	800	15	12,000
4	AIR-ANT5135DG Dipole Antenna	600	15	9,000
5	Wireless N Adapter for PC	1,900	8	15,200
6	Wireless Adapter for Print Server D-L	3,900	9	35,100
7	Cisco-C2960G-8TC-L	28,500	2	57,000
			Total	309,800

Figure 10. The Cost of the Two Designs for MARU A Focusing on Area Coverage

Figure 9 shows the design of MARU A considering the coverage. The design of 802.11g uses 4 access points while the design with 802.11n uses 5 access points. The cost of the design using 802.11g totally is less than that of 802.11n more than half. It is clear that the design with 802.11g is potentially a good solution.

Table 2.The Measurement of the Signal Coverage of Both Standards

Area	Signal Strength 802.11g		Signal Strength 802.11n	
	Airmagnet	Real value	Airmagnet	Real value
MARU A	-55 dbm	-50 dbm	-55 dbm	-52 dbm
	-65 dbm	-60 dbm	-65 dbm	-62 dbm
	-75 dbm	-67 dbm	-80 dbm	-72 dbm
MARU W	-55 dbm	-51 dbm	-55 dbm	-50 dbm
	-65 dbm	-57 dbm	-65 dbm	-61 dbm
	-75 dbm	-60 dbm	-80 dbm	-70 dbm

Table 2 compares the signal strength for each standard measured by the software AirMagnet[17] and the real value. The signal strength of 802.11n is a little better than that of 802.11g.

Table 3. Comparison of the Data Transfer Rate

No. of Computers	Avg. Data Transfer rate (MB)	
	IEEE 802.11g	IEEE 802.11n
1	12.5	87.4
2	12.3	87.2
3	11.7	87.3
4	11.6	86.8
5	10.9	87.1
6	9.7	86.8
7	9.5	86.7
8	9.4	86.5
9	9.1	83.1
10	9.1	81.8

Table 3 compares the data transfer rate for each standard in MB. When the number of computers using wireless are more the rate drop fast especially for the 802.11g one.

Table 4. Comparison of Both Designs in Both Aspects for MARU A and MARU W

ตารางที่ 26 เปรียบเทียบการออกแบบระบบเครือข่ายไร้สาย

Location	Type	Signal		AP	Client	Client Signal Quality (unit)			Cost (Baht)			
		Coverage	Interfere	(unit)	(unit)	<= -60 dbm	<= -70 dbm	> -70 dbm	Installing	Security	Upgrade Equipment	Total
MARU A	แบบเน้นคุณภาพสัญญาณ											
Efficiency		○	●	5	17	11	6	-	159,700	154,900	-	314,600
	มาตรฐาน 802.11n	○	○	6	17	15	2	-	293,300	154,900	57,000	505,200
	แบบเน้นครอบคลุมพื้นที่											
	มาตรฐาน 802.11g	○	○	4	17	5	10	1	136,700	154,900	-	291,600
Area Coverage		○	○	5	17	4	11	2	252,800	154,900	57,000	464,700
MARU W	แบบเน้นคุณภาพสัญญาณ											
	มาตรฐาน 802.11g	○	●	4	11	4	7	-	105,200	154,900	-	260,100
	มาตรฐาน 802.11n	○	○	4	11	5	6	-	182,900	154,900	28,500	366,300
Efficiency												
	แบบเน้นครอบคลุมพื้นที่											
	มาตรฐาน 802.11g	○	○	2	11	1	7	3	59,200	154,900	-	214,100
	มาตรฐาน 802.11n	○	○	3	11	3	2	6	142,400	154,900	28,500	325,800

○ nal coverage all / Signal not interfere
Area Coverage ● nal not coverage / Signal Interfere

Table 4 summarizes the comparison of both designs in all aspects. For signal coverage, for efficiency, the design with 802.11g has more interference than that with 802.11n. Column "AP" is the number of access points used for each case for each MARU. Column "Client" is the number of clients supported that are tested. Column "Client Signal Quality" is the number of clients tested for each signal strength case. Column "Cost" is the cost of each design for

each MARU dividing by types of the cost. It is shown that the design with 802.11g for the area coverage is cheaper by more than half compared to the most expensive design.

In Figure 11, we show the comparison of the previous system and the new system. It is noted that the access points are added and the radius server is added to handle the log of users.

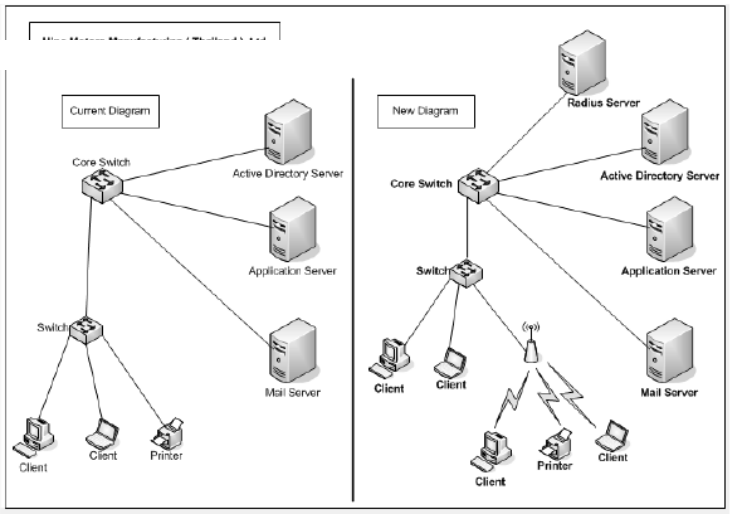

Figure 11. The Comparison of the Design Architecture for the Existing One and the New One

5. Conclusion

In this paper, we describe the design experience on the wireless network installation for a typical manufacturing factory. We start from surveying the area and user requirements. Then two selections of standards are trial: 802.11g and 802.11n. The design considers the SOA404 compliance and the computer crime laws. Two designs are presented as well as their costs. Finally, the effectiveness of each design is test by the signal strength and coverage. Also, the authentication is handled by Radius server.

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