Optimizing Site Planning and Testing of Wireless Lan Network

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ABSTRACT

In Wireless Local Area Networks (WLAN) deployment, there are several criterions that should be addressed prior to any in-depth planning and implementation. The capacity, the coverage area and the network performance are impacted by several interacting factors that must be considered to meet the requirements of high availability, high performance, and mission critical environment.

This paper discusses how practically optimizing WLAN networks based on methodologies stages for planning, designing, implementing, operating and then using modern techniques for testing WLAN to reach an optimized performance and services of a variety of wireless networks for indoor and outdoor applications by providing appropriate coverage and data throughput to all end users while keeping interference to minimum to insure the successful and efficient deployment of wireless local area networks

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1-Introduction

A Wireless LAN (WLAN) is a network in which the medium for connecting nodes or computers is wireless. A WLAN was designed to serve the functions of a wired LAN network, the breakthrough in both of these networks is that devices on the network do not need to be connected together by a physical wire in order to communicate and instead use radio waves as the communication medium [1].

The basic components of the WLAN are access points (AP)s and the wireless clients, typically a laptop or a Personal Computer (PC) with a WLAN card. To create a wired network infrastructure, Ethernet cables are placed through out the building and then buildings are connected together using fiber optic cables. With a wireless LAN, in order to create the network infrastructure, access points are placed in various locations throughout a building and even outdoors. Various wireless clients then communicate with each other by first communicating with these access points [2]. In the simplest configuration there is one access point at the center and one or more wireless clients spread out around the access point. When additional access points are added the coverage area of the network increases and the wireless client selects to closest access point to communicate with.

When a wireless client talks to an access point, both devices must operate on the same frequency so that they can receive each other's transmissions and both must also use a previously agreed upon bit encoding scheme so that they can "understand" each other. WLAN standardization centers around the protocol called the IEEE (Institute of Electrical and Electronics Engineers) 802.11. There are several specifications in the 802.11 family: 802.11, 802.11a, 802.11b, and 802.11g. Table (1) explains the different versions of 802.11 wireless LAN standards.

Table 1 Wireless LAN 802.11 Standards and Versions

Name	Frequency	Speed	Range
802.11	2.4GHz	Up to 5 Mbps	Up to 100m
802.11b	2.4GHz	Up to 11 Mbps	Up to 100m
802.11b+	2.4GHz	Up to 22 Mbps	Up to 100m
802.11g	2.4GHz	Up to 54 Mbps	Up to 100m
802.11g+	2.4GHz	Up to 108 Mbps	Up to 75m
802.11n	2.4GHz	Up to 600 Mbps	Same range as 802.11g+
802.11a	5GHz	Up to 108 Mbps	Not as good as 802.11b/g

Wireless technology and services must be fully integrated to provide the same level of performance and protection as the wired infrastructure [3]. When integrating modern wireless networking solution with your wired infrastructure, the challenge is to design, build, and operate a wireless network that evolving RF environment and gives an end-to-end services based on proven methodologies for planning, designing, implementing, operating, testing and optimizing the performance of a variety of wireless network solutions and technologies for indoor and outdoor applications. Figure 1 shows the methodology design stages solution for wireless networks.

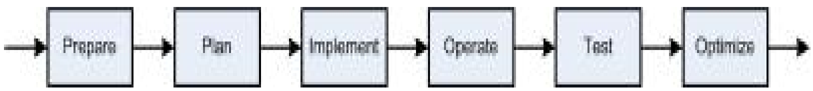


Figure 1: Methodology Design Stages Solution for Wireless Networks

2. Related Work

There are many researches deals with wireless LAN design that discuss the subject from different sides. A comparison with survey summary for other researches shows that some of them such as [5] discuss RF environments and wireless site survey, researches [8] [13] discuss the coverage area and capacity of wireless LAN, other researches deals with Access Points density and distribution such as [9] [11], while some researches like [10] [12] describe frequency planning and channel interference in wireless LAN.

This research specify up-to-date practical strategies to get high performance wireless LAN using multistage solutions techniques that including all the requirements for building wireless LAN and taking into account all RF environments that effects the performance for indoor and outdoor applications. Optimizing performance of wireless LAN can be reach through methodologies of planning, designing, implementing and operating of wireless LAN applied into two case studies sites one for indoor applications and one for outdoor applications, and then using modern techniques for testing wireless LAN [14] to study the performance at different services and applications. The research includes many high technical and scientific terms because the wireless technology and practical side include.

3. Wireless Site Survey and Planning

An important function in design of wireless LAN is site survey; site surveys are used to plan and deploy a new wireless network to provide appropriate coverage and throughput to all end users while keeping interference to a minimum; as well as reconfigure or verify the performance of an existing network. Site surveying methodology may have many phases to ensure best plan and design performance [4][5][6].

Phase I: Preparation Phase

Before purchasing any networking equipment or deploying a completely new wireless technology, the designer should obtain answers to the following questions:

- **How many users require wireless service and what applications will they use?**
- **Is wireless access needed for indoors or outdoors or both?**
- **Are there any known major interfering sources such as high voltage wires, motors?**
- **What are the security policies and requirements for wireless networks?**
- **Are any building/floor blueprints available?**

Phase II: Planning Phase

Where should start the wireless deployment? What equipment should purchase? By knowing the planning capability, the designer can significantly reduce the time and effort needed to deploy a wireless network. The designer should provide quick visibility into these requirements, such as:

- **Estimated number of access points needed and their signal coverage.**
- **Estimated location of the access points.**
- **Estimated interference occurring between the deployed access points.**
- **Radio Frequency (RF) leakage to outside the corporate physical boundaries.**
- **Data speed values for the planned Access Points.**

Phase III: Surveying Phase

After completing the wireless planning to get the required signal and performance, it is recommended that these results be verified with a field survey before any permanent wireless deployment. The actual RF environment can be affected by the presence of interfering devices (802.11 as well as non-802.11). Without an actual field survey, designer won’t be able to determine the true impact of the RF environment on their network’s performance. The Surveying Phase covers several areas:

- **Performing active RF Surveys to managing interference.**
- **Establishing Quality of Service (QoS) for all end users.**
- **Establishing strict security.**
- **Planning for outdoors, if necessary.**

Phase IV: Reporting phase

At the end of the site surveying process, the surveyor is responsible for generating the site survey report. The reports should provide detailed information of all factors necessary for a successful deployment. The report will serve as a map for the current recommendations and can also act as a future reference

for surveys and other deployment changes. The survey report provides the following reports:

- **Overall signal, noise, signal-to-noise information based on channel/name of AP.**
- **Channel Interference and interference between APs.**
- **RF spectrum information.**

• User requirements (speed and user capacity per AP).

4. Factors Affecting Capacity and Performance

The wireless medium is a very dynamic shared environment affected by several interacting factors. Some of these factors can be controlled while others are fundamental limitations of the wireless medium that must be recognized and taken into account when planning a WLAN. The wireless medium is a highly changing environment in which transmission errors are unavoidable and quite common. Wireless signals suffer attenuations as they propagate through space, especially inside buildings where walls, furniture, and other obstacles cause absorptions, reflections, and refractions [7] [8].

The farther a wireless device is from its Access Point, the weaker the signal it receives and the lower the physical rates that it can reliably achieve. WLAN devices constantly monitor the quality of the signals received from devices with which they communicate. When their turn comes to transmit, they use this information to select the *data rate* that is expected to provide the highest throughput (i.e., the best compromise between speed and reliability). In a typical setting where there are walls, cubicles, hallways, etc., the actual achieved data rates will be more random depending on the number and types of obstacles between the wireless unit and the APs at each specific location [9][10]. When multiple devices are simultaneously active in a cell, contention, collisions, and other types of interferences further reduce the medium capacity. The wireless medium is a shared medium and the 802.11 MAC layer must guarantee that all devices get an equal chance to access the medium.

The two main metrics when describing WLAN performance are capacity and coverage. Both of these are directly affected by the inter-AP spacing, or the AP density, in a system. *Capacity* **is the amount of throughput that a WLAN system is able to provide to users, taking into account all the mitigating effects on single AP capacity, and multiple AP capacity. The** *Coverage* **refers to the area over which the wireless signals propagate, and can best be described as the probability that a user will be able to reliably connect to an AP from any location within the WLAN. Capacity and coverage are affected by the inter-AP spacing which is in direct relation to the physical area over which the AP is required to provide connectivity [11].**

When the inter-AP spacing is decreased, the required service area for each AP decreases, and the average distance from a user to the closest AP decreases. Considering that none of the other WLAN parameters have changed, this has two effects. First, it increases the per AP capacity by allowing the clients on the same AP to connect at higher data rates on average. Second, it increases the coverage reliability by increasing margin of safety in the range to achieve the minimum required connect speed even in the case of shadowing.

Coverage reliability is further increased by the fact that, at each location, there are now more likely overlapping RF signals from different APs arriving from different directions and providing more chances for a good signal in the presence of obstacles. Therefore, the coverage, i.e., the probability that a user will be able to associate with at least one AP at the minimum connect speed within the WLAN system, has increased [11] [12].

The capacity of a WLAN composed of multiple access points is essentially the sum of the single AP capacities of the constituent cells. As soon as the number of access points increases beyond the number of available frequencies (channels in access points), care must be taken to minimize the amount of interference between cells using the same frequencies. Co-channel interferences are caused by the transmissions of devices in remote cells using the same frequency channel. These signals are usually too faint to be properly detected outside of the originating cell but are still strong enough to disrupt traffic in the nearby cells using the same frequency. Frequency planning involves reusing frequencies

across a two- or three-dimensional space while positioning cells that use the same frequencies as far away as possible from each other to minimize interferences [12][13]. Figure 2 below illustrates the concept of frequency planning on an ideal hexagonal grid. For deployments requiring fewer frequencies than are available, the range and capacity of a single access point deployment is possible in each of the cells. There is no interference between cells and the total capacity of the network grows linearly with the number of cells.

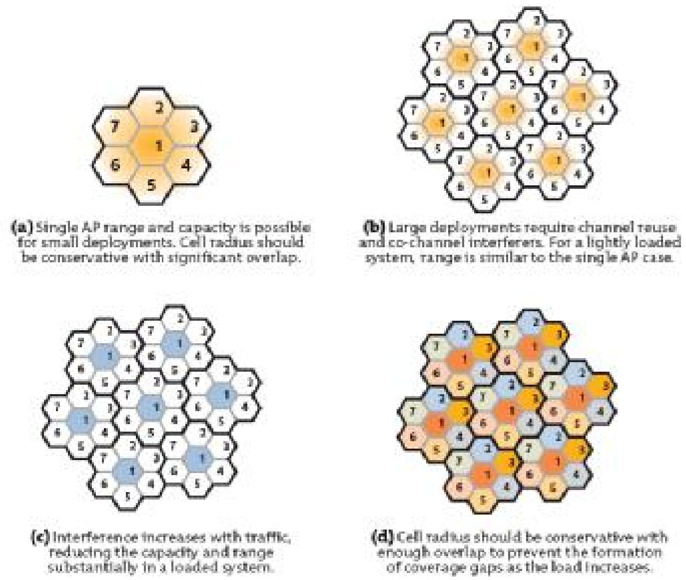


Figure 2: Impact of frequency Planning and Co-channel Interference

5- Wireless LAN Testing

Testing the actual system across the technology stack and from end-to-end is essential to ensure that your WLAN implementation provides the essential capabilities required to deliver the promised business application benefits. Building a WLAN infrastructure from scratch or extending an existing implementation can present issues and risks that need to be addressed through a robust and effective WLAN test strategy. There are many stages and phases to testing the operation of wireless LAN networks to get the high

performance network. The important tests should be taken into account are [14] [15] [16]:

A. Protocol Level Testing

Protocol level testing generally involves comparing network traffic to a specification or standard. Often such specifications or standards include bit-level protocol descriptions. Wireless client adapters and wireless access points need to be tested at this level to ensure compliance with the protocols that the devices are designed to support. In the wireless medium, protocol level testing involves the expert use of wireless protocol analyzers that allow the tester to see what is happening at Layers 2-7 of the OSI model.

B. Security Testing

Wireless networks are becoming more popular in the corporate environment. As such, corporate network administrators need to make the network as secure as possible. A secure wireless strategy includes encryption, authentication, and key management are use. Encryption ranges from static Wired Equivalent Privacy (WEP), Wifi Protected Access (WPA) to rotating keys generated by the access point. The wireless network can authenticate the wireless user or client using a variety of authentication protocols and backend systems. Key management refers to the mechanism being employed to rotate the keys.

C. End-to-End Testing

A comprehensive WLAN test strategy will include full end-to-end application process testing within the test WLAN environment allowing business risk mitigation before WLAN deployment occurs on site. Due to the many configurations that may need to be tested, this is essentially application regression testing, as shown in figure 3. Regression testing is the form of testing most amenable to test automation. Consideration needs to be given to the feasibility of test automation and the potential cost and quality benefits that may be obtained through test automation.

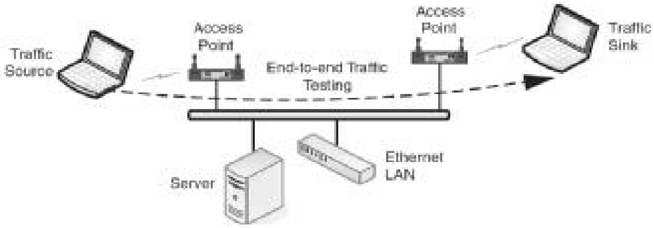


Figure 3: End-to-end Testing

D. Compatibility (Interpretability) Testing

The 802.11 wireless world is governed by standards. However the different wireless components do not always interoperate well. Within a single WLAN infrastructure there may be many combinations of client adapters and wireless access points. Even if the model numbers of the components are the same, there may be different software versions deployed within the devices. Compatibility testing is required to prove that the chosen devices do actually work together as expected, as shown in figure 4.

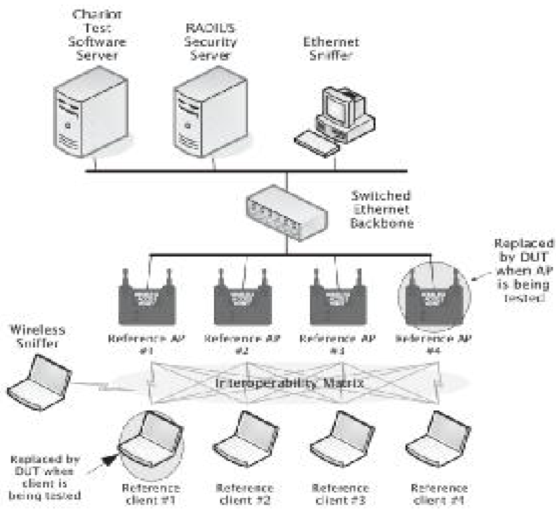


Figure 4: Compatibility Testing Setup

E. Performance Testing

A common measure of wireless performance is the *data rate* or throughput. Regardless of the 802.11 band (a/b/g), wireless client adapter vendors are concerned with throughput as a performance metric and point of comparison. Wireless throughput is a function of multiple factors, most notably:

- **Distance between the client adapter and the access point**
- **Noise in the environment**
- **Relative orientation of the client and access point antennas**

Poor throughput will manifest itself to the end user as increasing response times from their applications. To determine the overall degradation in response times under normal operating conditions, load testing can be performed to simulate multiple concurrent users.

6. Optimizing Wireless LAN Indoor / Outdoor Practical Implementations

To get high performance end to end applications and services in wireless networks we need to increase the speed (data rate), accuracy, and efficiency of deploying a wireless network. This can be done by using design methodology solution of planning, designing, implementing, and operating wireless LAN, then using a modern scientific testing approaches to get an optimize solution of WLAN for indoor and outdoor networks.

6.1 Wireless Indoor Implementation

Indoor environments are basically various types of buildings, such as homes, offices, companies. Every indoor environment is basically unique, especially at microwave frequencies.

The designer should take a map of the building or floor, and customize the space of walls, windows, doors, etc. Different wall characteristics (concrete walls, brick walls, glass/metal doors and windows) and interference areas (cubicles, elevator shafts, warehouse with low/medium/high stock) are marked. Access points with the desired channel, transmitted power, antenna and media-type can then be placed manually on the site floor plan at

places where they are expected. The predicted map of the RF environment is then simulated, enabling users to check access points locations and other configurations until optimal coverage is achieved for all users. Designers further have the option of adding, removing or moving access points to different locations, and the operating channel or the transmitted power can be changed to prevent coverage holes, minimize interference and even reduce security risks by preventing RF spillage outside the corporate physical boundary. A flow chart that explains the practical steps to plan a wireless LAN network is shown in figure 5.

A company in south of Basrah owned by ministry of transport take as an example that shows the design of indoor wireless LAN network. The floor map is shown in figure 6, where figure 6(a) shows the floor plan and the required distribution of wireless clients (which is personal computers with wireless LAN cards and Laptops with wireless LAN capabilities) presented at each room on the map, then we can distribute access points on the map at predetermine location to cover all the wireless network area taking into account using different channels for access points to minimizing interference as low as possible. At first; four access points used to cover area, one at the left side floor, one in the middle and two in the right side plan as shown in figure 6(b). The measurement of the minimum received signal strength (RF signals) for the far side client connected to each access point and transmission speed; (i.e. the rate measurement as a function of distance between client and AP) is explained in Table 2. These measurements are read from the utility of WLAN cards in the clients.

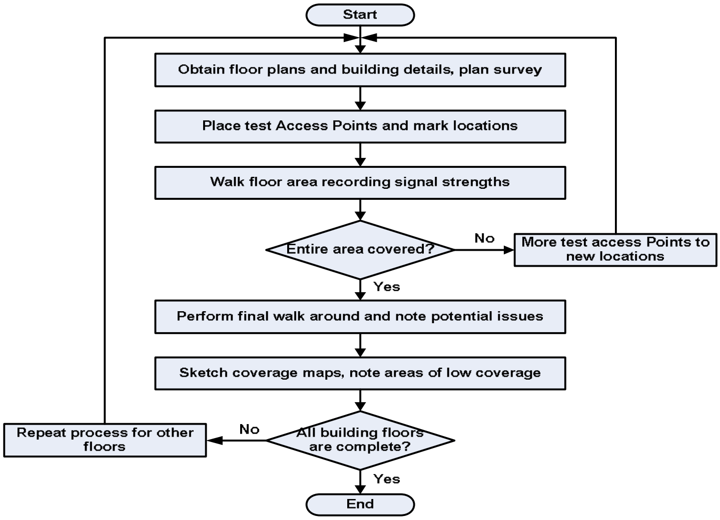


Figure 5: Flow Chart Explains Wireless Site Survey and Planning

Table 2 Weaker Signals for Each Access Points in Figure 6(b)

Access Point No.	AP#1	AP#2	AP#3	AP#4
Frequency Channel	Channel 3	Channel 6	Channel 3	Channel 9
Percentage Received Signal Strength for the far Client from Access Point (%)	45	50	55	40
Transmission Speed (Mbps)	12	16	24	9

The testing of the indoor wireless network shows following characteristics:

1. **It has a good protocol and compatibility tests because all network components are from the same company vender (Linksys Company) which is a division from a Cisco company the most powerful network components provider in the world.**
2. **It has a bad performance and end to end tests because there are some clients receives low level signal strength which then reduces the bandwidth traffic (transmission speed) for the client in the network.**

To improve the design, they can add more access points to the wireless network as shown in figure 6(c) to get good signal strength for clients, and to increase the transmission speed of the clients by minimizing the serviced clients for each access points, so we get a good network performance. Of course there is a limit to how much we can increase number of access points, because increasing number of access points increase interference and this lead to decrease in the speed of data transmission. Table 3 summaries the measured received signal strength for the far side client and transmission speeds for figure 6(c).

Table 3 Weaker Signals for Each Access Points in Figure 6(c)

Access Point No.	AP#1	AP#2	AP#3	AP#4	AP#5	AP#6
Frequency Channel	3	9	6	3	9	6
Percentage Received Signal Strength for far Client from Access Point (%)	65	60	60	65	70	60
Transmission Speed (Mbps)	48	36	36	48	54	36

As we can see from the measurements is that the speed of transmission is increased from minimum data rate as 9 Mbps up to 36 Mbps, which indelicate the improving in the wireless network system performance.

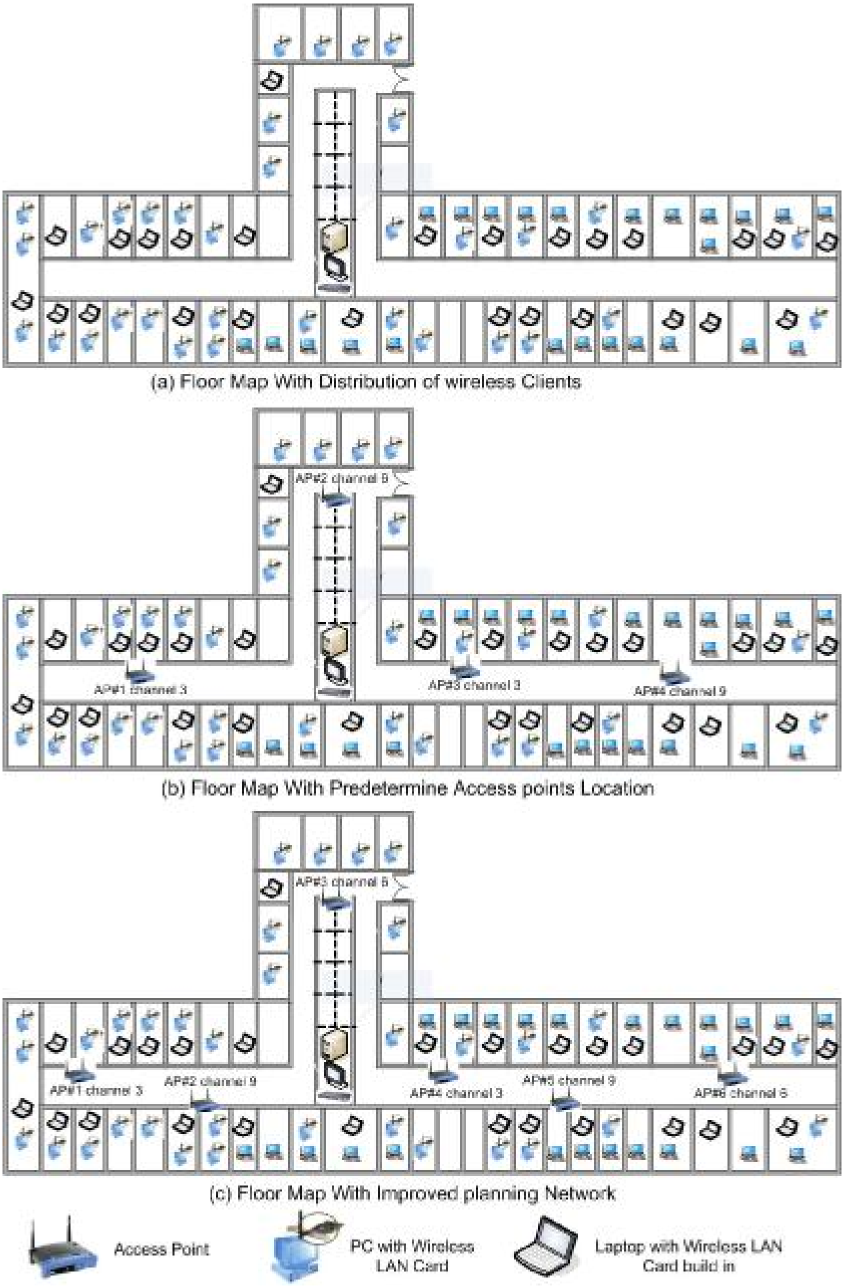


Figure 6: Implementation of Indoor Wireless LAN Network

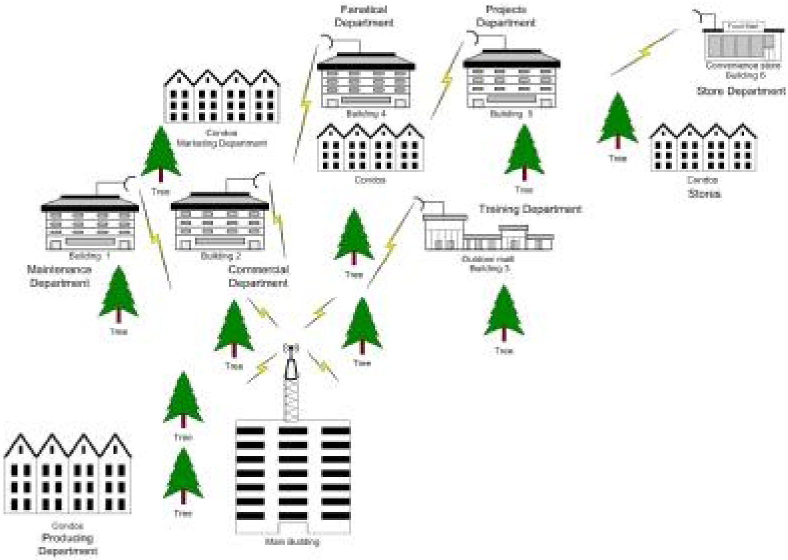
6.2 Wireless Outdoor Implementation

Wirelesses technologies can be a cost effective solution to the problem of connection separate LANs to get wireless *campus network*. The outdoor environment is typically a large open space; the location and size of the space is usually dictated by the access to sufficient outdoor area.

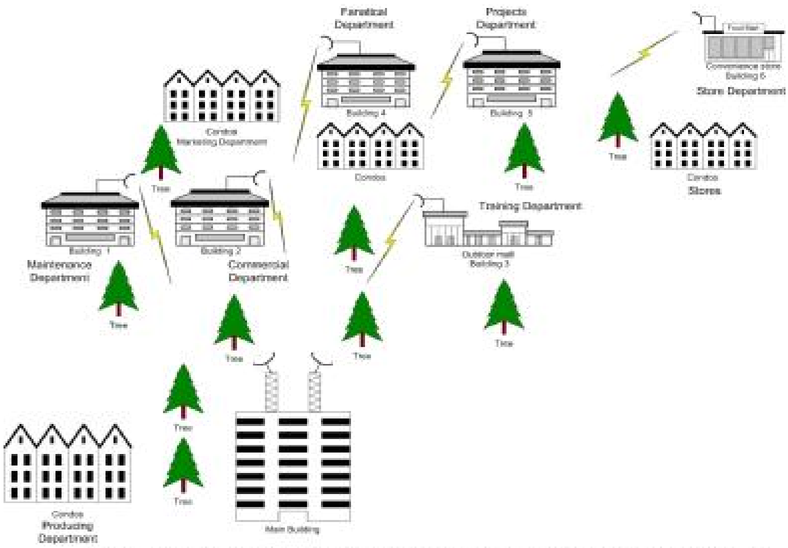
Antennas are the most critical component of any RF system as they convert electrical signals on wires into radio waves, and vice versa. Antennas can be designed with directional preference. Many antennas are omnidirectional, which means they send and receive signals from any direction. Some applications may benefit from directional antennas, which radiate and receive on a narrower portion of the field. For a given amount of input power, a directional antenna can reach farther with a clearer signal. The antenna must also have much higher sensitivity to radio signals in the dominant direction. Overcoming limitations of range can be achieved through properly planning the architecture of a wireless network and using the best antenna type to extend the maximum range for the network.

In a point-to-point WLAN bridge, two LANs can be located far away. The antennas must be in line of site with each other. Obstacles such as buildings, trees and hills will cause communication problems. As the distance increases, the bandwidth decreases, but still have good data rate than many WAN technologies. In this scenario, the Ethernet segments in both buildings act as one LAN. The bridge does not add to the Ethernet hop count, it simply acts as the physical media. For multipoint bridging, an omni-directional antenna can be used at the main site and directional antennas in the remote sites. Line of sight must be maintained between the remote sites and the main site. The remote sites communicate with the main site, but not with each other directly. Traffic from one remote site will be sent to the main site and then forwarded to the other remote site. All sites will appear as one LAN. This configuration was implemented in a figure 7(a), which is a company campus in west of Baghdad owned by ministry of industry and minerals. The rate measurement as a function of distance between far access point bridge and the main

access point in the main building for figure 7(a) is explained in Table 4.



(a) Outdoor Wireless LAN Networks Using one Access Point Bridge and Omnidirectional Antenna



(b) Outdoor Wireless LAN Networks Using Two Access Point Bridges and Two directional Antennas

Figure 7: Implementation of Outdoor Wireless LAN Network

Table 4 Signal Strength in Each Wireless Bridge for Figure 7(a)

Building Number (Bridge No.)	BLD #1	BLD #2	BLD #3	BLD #4	BLD #5	BLD #6
Frequency Channel	6	6	6	6	6	6
Percentage Received Signal Strength from Main Access Point (%)	55	60	55	50	45	40
Transmission Speed Mbps	24	36	24	16	12	9

It's possible to think that one can put up a high-gain antenna and a power amplifier and cover a huge area, thus economizing on access point bridges and serving a large number of users at once. This is not a particularly good idea. The larger the area you cover, the more users your access point bridges must serve. An important note here is to use a limited number of users for each wireless access point (depends on wireless products vender). A good upper bound to aim for is 10 to 20 users per wireless access point bridge. A single access point covering a large area may look like a good idea, and it may even work well while the number of users remains small. However, if a network is successful, the number of users will grow quickly and the network will soon exceed the access point bridges capacity. Once this happens, it is necessary to install more access point bridges and divide the original cell into several smaller ones and lower the power output at all of the cells. This is what happens in network plan shown in Figure 7(a), and become very clear when testing the wireless network as shown in Table 4. To improve the design performance, two directional (Flat Panel) antennas will be use in the main building, one directing to buildings 1,2,3 and the other one directing to 4,5,6 as shown in figure 7(b). By this way we get the following benefits:

1. Directing the entire transmitted signal from main building to the direction of remote building and this overcomes of unused field in other directions and thus increasing the coverage distance in the direction of required remote sites to get high received signal strength and this increases transmission speed in the wireless LAN bridge.
2. Using two access point bridges in the main sites maximizing the processing power to servicing more remote users and decreasing the processing delays, thus leads to increasing of transmission speeds (client bandwidth).

3. Using two different channels in the network to decrease interference and so increasing transmission speed.

Table 5 summaries the measurements of transmission speed as function of received signal strength for the figure 7(b), and its clear from the measurements is that the speed of transmission is increased from low rate as 9 Mbps up to 16 Mbps, which indelicate the improving in the wireless network system performance.

Table 5 Signal Strength in Each Wireless Bridge for Figure 7(c)

Building Number (Bridge No.)	BLD #1	BLD #2	BLD #3	BLD #4	BLD #5	BLD #6
Frequency Channel	3	3	3	9	9	9
Percentage Received Signal Strength from Main Access Point (%)	65	70	65	60	55	50
Transmission Speed Mbps	48	54	48	36	24	16

7. Conclusions and Future Work

Building WLAN remains a complex task and requires dedicated strategies provide end to end applications and services to all end users. Multistage solutions techniques that including all the requirements for building wireless LAN through methodologies of planning, designing, implementing and operating of wireless LAN were applied into two case studies for indoor and outdoor applications. All the RF environments that affects the network such interference and noise are measured through site survey. Site surveys that explained in a flow chart help refine this initial estimate and identify good placements for the access points especially in challenging environments. Based on environment parameters such as network capacity, coverage area size and shape and application requirements, the designer can provide a rough estimate of the number of access points and of the target cell size required to meet the WLAN objectives. In a WLAN deployment, performance and capacity are impacted by many factors ranging from the quality of the physical wireless link to the amount and type of traffic on wireless network. All these factors must be properly characterized in order to meet the requirements of a high-availability and high-performance WLAN.

To get optimum wireless LAN solution, modern testing approaches will be use, where different testing techniques presented and used. Testing is essential to uncover the defects prior to going live. After deployed, the access points should dynamically assign channels and perform power adjustments to minimize interferences, to prevent coverage holes, and dynamically balance the traffic load between access points.

Security issues are very important in WLAN where the radio signal produced can penetrate walls, ceilings, floors and are therefore not confined to a building. Hackers can effortlessly pick up these signals; therefore the security of WLAN is good idea for new researches.

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تحسين تخطيط الموقع و إختبار الشبكات اللاسلكية المحلية

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المستخلص

عند تصميم الشبكات اللاسلكية المحلية هناك العديد من المعايير التي يجب الاخذ بها قبل وضع الخططات التفصيلية و بناء الشبكة (نصب الشبكة). الامور الاساسية في تصميم الشبكات اللاسلكية المحلية مثل سعة الشبكة، مساحة المنطقة التي تغطيها و كفائة الشبكة تتأثر بالعديد من العوامل مثل جودة الاشارة اللاسلكية، نوع و حجم المعلومات المتناقلة بين اجزاء الشبكة و كذلك التداخل الكهرومغناطيسي اللاسلكي بين مختلف الاجهزة العاملة ضمن نفس الترددات. جميع هذه العوامل يجب ان تعرف او تحدد عند تصميم الشبكات اللاسلكية للحصول على متطلبات الجودة المطلوبة و الكفائة العالية لنقل المعلومات اخذين بنظر الاعتبر ظروف الارسال السيئة.

هذا البحث يتناول الخطوات العملية لكيفية تحسين الشبكات اللاسكلية مبنية على الخطوات النظريات للتخطيط، التصميم، البناء والتشغيل و ثم استخدام التقنيات الحديثة لأختبار الشبكات اللاسلكية للحصول على افضل كفائة و خدمة لمختلف انواع الشبكات اللاسلكية للتطبيقات الداخلية و الخارجية بواسطة توفير منطقة التغطية و السرعة المناسبة لكافة مستخمي الشبكة اللاسلكية و في نفس الوقت تقليل التداخل بين الترددات اللاسلكية الى اقل حد ممكن لضمان التوزيع الناجح و الكفوء لاجهزة الشبكة اللاسلكية.

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