WLAN IMPLEMENTATION AND PERFORMANCE ANALYSIS

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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Electrical & Electronics Engineering Programme
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Approved:

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June 2007

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Shakinah Yeop Ibrahim

ABSTRACT

Wireless networks are fast becoming ubiquitous in today's highly networked world. New applications based on 802.11 standards are rapidly expanding into corporate, residential, Wireless-Internet-Service-Provider (WISP), and hot-spot applications. With the advent of WLAN technologies, users are increasingly demand for WLAN high performance. Hence, the main focus of this project is to study, observe and experiment the WLAN implementation and performance analysis. The WLAN implementation and performance characteristics are firstly studied and several experiments are conducted. Two major applications are also performed under the wireless network condition that are File Transfer Protocol (FTP) and video streaming. The results show that the WLAN performance depends on location factors, network load and signal strength. The client location will affect the performance of inter-building WLAN file transfer process. The media streaming performance can degrade significantly by signal quality.

ACKNOWLEDGEMENTS

First and foremost I would like to praise God Almighty and thank Him for his blessing and guidance throughout the hard times.

I would like to express sincere gratitude to my supervisor, Mr. Azlan Awang for his constant supervision, support and guidance besides sharing his knowledge and experience throughout the project.

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Throughout the project, I had been exposed to different obstruction and had learned to overcome challenges. Thanks again for the patience and encouragement from those who directly or indirectly involved.

Last but not least, thank you to my family and to all my friends for their support and assistance in completing this project.

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LIST OF ABBREVIATIONS

1. ACU	Aironet Client Utility
2. AP	Access Point
3. CCK	Complementary Code-keying
4. FTP	File Transfer Protocol
5. IEEE	Institute of Electrical and Electronics Engineers
6. LAN	Local Area Network
7. LOS	Line of Sight
8. NLOS	Not Line of Sight
9. OFDM	Orthogonal Frequency Division Multiplexing
10. PC	Personal Computer
11. QoS	Quality of Service
12. RF	Radio Frequency
13. SNR	Signal to Noise Ratio
14. SSID	Service Set Identification
15. WEP	Wired Equivalent Privacy
16. Wi-Fi	Wireless Fidelity
17. WLAN	Wireless Local Area Network
18. WSIP	Wireless-Internet-Service-Provider

CHAPTER 1
INTRODUCTION

1.1 Background of Study

Wireless technologies play a prominent role in today's global communication infrastructure. One popular technology is the IEEE 802.11 WLAN standard. WLAN use spread-spectrum technology based on radio waves to enable communication between devices in a limited area. It has been installed in universities, airports, and other major public places. WLAN technology has transformed from high-tech function into main-street commodity [1].

Wireless technology is becoming more popular, especially with the rapid emergence of portable devices. This is due to the benefits gain by the user in terms of mobility and quality of service of WLAN. WLAN is very convenience, affordable and productive technology to be used [2].

A natural step in the wireless evolution is the convergence of these technologies to support wireless multimedia streaming. Multimedia streaming has been increased demand on the Internet in recent years, and has drawn tremendous attention from both academia and industry. Streaming multimedia over wireless network is becoming an increasingly important service. Users are able to access various services including those which distribute media content anywhere and anytime.

1.2 Problem Statement

1.2.1 Problem Identification

Wired network experiences difficult cabling situations, which lead to wireless network implementation. WLAN offer users a bunch of benefits such as the conveniences and the mobility of devices. With WLAN, user can access shared resources without looking for a place to plug in. A wireless network allows users to be truly mobile as long as the mobile terminal is under the network coverage area.

Without any doubt, each user is expecting the high quality performance of wireless network that helps them to improve their productivity and still provide widely access resource. Needless to say, wireless network are more vulnerable compared to wired network since wireless network uses electromagnetic wave to transmit and receive signals. Proper planning process need to be done in order to implement the WLAN system. The quality of the network is crucial to ensure the stability and the strength of coverage area. WLAN performance is an indicator of how productive a wireless user's connectivity will be.

It is becoming common practice to leverage a wireless connection. In doing so, one could take advantage on the freedom of movement and increased productivity that is provided at work, on a campus and at home. However, the buyer could be quickly turned off by unrealized expectations; particularly when it comes to performance and quality of service. To prevent this from happening, test methodologies and comprehensive test plans must be defined. By simulating real-world conditions in the lab, the true performance of products and services can be ascertained and the enormous potential of WLAN can and will be realized.

1.2.2 Significant of Project

As the technology of wireless communication growth, the need of performance analysis becomes vital. Consequently, it becomes increasingly important to know how network connection will respond and perform in their intended environments.

As the technology moves into the mainstream, a demand is created for more thorough and accurate testing. Concurrent with these developments, wireless technologies have revolutionized the network function by exploring the multimedia streaming in an IEEE 802.11 (WLAN) environment.

The experimental measurements of WLAN performance analysis are observed by simulating several applications in the lab. The inter-building coverage area of WLAN test network setup includes:

- Academic Building 2
- Academic Building 23
- Academic Building 22

Appendix A shows the project layout network of inter-building coverage area diagram for WLAN performance testing.

1.3 Objective and Scope of Work

1.3.1 Relevancy of the Project

The objectives of this project are:

- To analyze the implementation of WLAN development.
- To study and analyze the performance of WLAN.
- Explore multimedia streaming performance in an IEEE 802.11 (WLAN) environment

1.3.2 Feasibility of the project within the scope and the Time frame

Throughout the year, the project emphasizes on:

- Research and study on WLAN technology and performance characteristics
- Research and study on WLAN performance components: interference, multipath fading, network load, location factors.

- Design and implement inter-building WLAN connection that covered building 2, 23 and 22 for testing purposes.
- Carry out experiments and network tests under different of physical condition.
- Configure and analyze experimental measurements of WLAN performance.
- Performing inter-building multimedia streaming under WLAN environment.

CHAPTER 2
LITERATURE REVIEW

2.1 What is WLAN?

A Wireless LAN (WLAN) is a local area network without physical wiring connection. The workstation devices in a WLAN communicate with one another using radio frequency electromagnetic airwaves. WLAN performed the same services as LAN that permits information, application, and files to be accessed on multiple computers among multiple users. Moreover, WLAN allows and provide the mobility of users who can easily move from one place to another and are still connected to the network.

Various WLAN standards or specifications, such as IEEE 802.11a, IEEE 802.11b, Open-Air, HiperLAN, Bluetooth and HomeRF exist today. While WLAN provides greater mobility and flexibility, it also creates several security risks that are not faced in a wired network. Unlike the wired network, the architecture of WLAN does not need physical access because the shared medium is radio frequency.

Mobility is a significant advantage of WLAN. WLAN allows users to keep on connected while moving under the network coverage area. Coverage can be extended, and the user mobility achieved via roaming. WLAN can support large numbers of nodes and large physical areas by adding access points to extend coverage.

2.2 Overview of WLAN performances

The need for higher data rates and techniques to improve performance of wireless LANs becomes crucial. A number of factors will determine Wireless Local Area

Network (WLAN) performance. Some of important WLAN performance parameters are system design, location factors, and network load.

As the technology of wireless communication growth, the need of performance analysis becomes vital. The throughput, data rate, and quality of the signal are some of the figures that are important in WLAN implementation. It is important to understand how the WLAN will perform in the intended environments. The WLAN characteristics are tested in order to create the high quality of WLAN. It would be involved the throughput, data rate, signaling path, delay and etc.

Signal radiates through its environment, it bounces off various barriers like walls, cabinets, and other reflective surfaces. As a result, multiple signal paths arrive at the receiver. Each of those paths will cause to delay and loss. This problem can cause a loss of data or the need for retransmissions. The amount of relative path delay varies based on the environment characteristics.

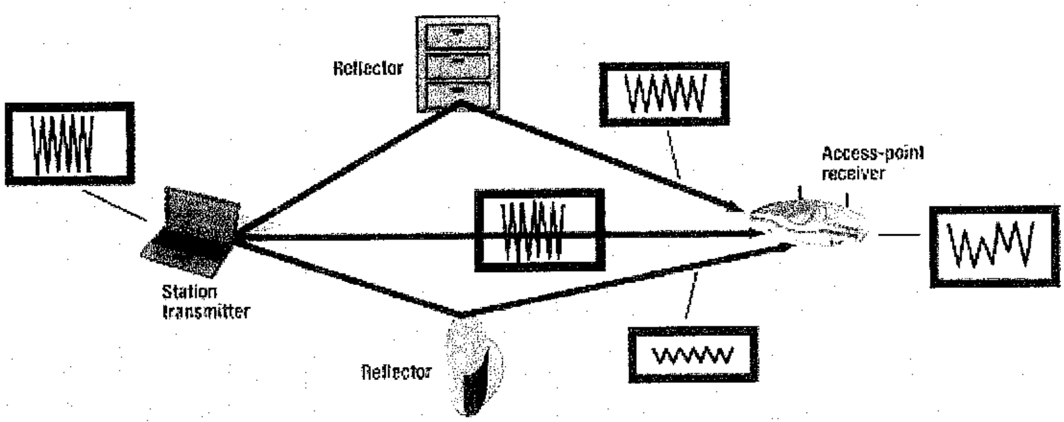

Figure 1: Multipath Fading

2.3 WLAN Standards

Only one working group which is Institute of Electrical and Electronics Engineers (IEEE) that is responsible in developing the worldwide baseline standards for wireless equipment and software for vendors to follow.

802.11a

A physical layer standard in the 5 GHz radio band. It specifies eight available radio channels. The maximum link rate is **54 Mbps** per channel; maximum actual user data throughput is approximately half of it, and the throughput is shared by all users of the same radio channel. The data rate decreases as the distance between the user and the radio access point increases.

802.11b

This is a physical layer standard in the 2.4 GHz radio band. It specifies three available radio channels. Maximum link rate is **11 Mbps** per channel, but maximum user throughput will be approximately half of this because the throughput is shared by all users of the same radio channel. The data rate decreases as the distance between the user and the radio access point increases.

802.11g

This is a physical layer standard for WLAN in the 2.4 GHz and 5 GHz radio band. It specifies three available radio channels. The maximum link rate is **54 Mbps** per channel whereas 11b has 11 Mbps. The 802.11g standard uses orthogonal frequency-division multiplexing (OFDM) modulation but, for backward compatibility with 802.11b, it also supports complementary code-keying (CCK) modulation and, as an option for faster link rates, allows packet binary convolutional coding (PBCC) modulation.

2.4 File Transfer Protocol (FTP)

FTP or File Transfer Protocol is used to transfer data from one computer to another through a network. FTP is a commonly used protocol for exchanging files over any network that supports the TCP/IP protocol. There are two computers involved in an FTP transfer:

- Server
- Client.

The FTP server, running FTP server software, take note on the network for connection requests from other computers. The client computer, running FTP client software, initiates a connection to the server. Once connected, the client can do a number of file manipulation operations such as uploading files to the server, download files from the server, and so on.

2.5 Video Streaming

Video streaming is a server/client technology that allows multimedia data to be transmitted. The main goal of streaming is that the stream should be arrive and play out continuously without interruption.

2.6 WLAN Advantages and Disadvantages

Advantages:

- The cost of employing WLAN is lower compared to LAN. This is due to no need of cables and wires over the buildings.
- The installations processes of WLAN are also easy compared to LAN.
- Major benefit of WLAN is mobility. User can access to the network anywhere as long as within the coverage area.

Disadvantages:

- Electromagnetic propagation. As WLAN use radio waves, it might cause interference with other equipment or components that working at the same frequency.
- Security problem might be occurring due to radio waves propagate through walls.

Wireless networking is important and applicable to all industries; business, education, corporate and etc. WLAN become handy and useful when physical media is not feasible. WLAN provide real-time access to the network. Users are able to connect to the network anywhere within the range of access point.

Nowadays people tend to move a lot from one location to another, wireless networking become practical and popular method to stay connected to the network. The user is able to gain and process information on the spot. It also helps eliminates the paperwork, decrease errors and improves productivity in all activities.

The need of high data rates becomes crucial in modern life. The data rate of WLAN depends on the standard used.

Table 1: Differences of data rate

Protocol	Operation Frequency	Data Rate (Typical)	Data Rate (Maximum)
802.11a	5GHz	25Mbit/s	54Mbit/s
802.11b	2.4GHz	6.5Mbit/s	11Mbit/s
802.11g	2.4GHz	25Mbit/s	54Mbit/s
802.11n	2.4GHz or 5GHz	200Mbit/s	540Mbit/s

CHAPTER 3
METHODOLOGY

3.1 Procedure Identification

A number of main procedures have been identified toward accomplishing the project. It follows the logical order of procedures in completing the project.

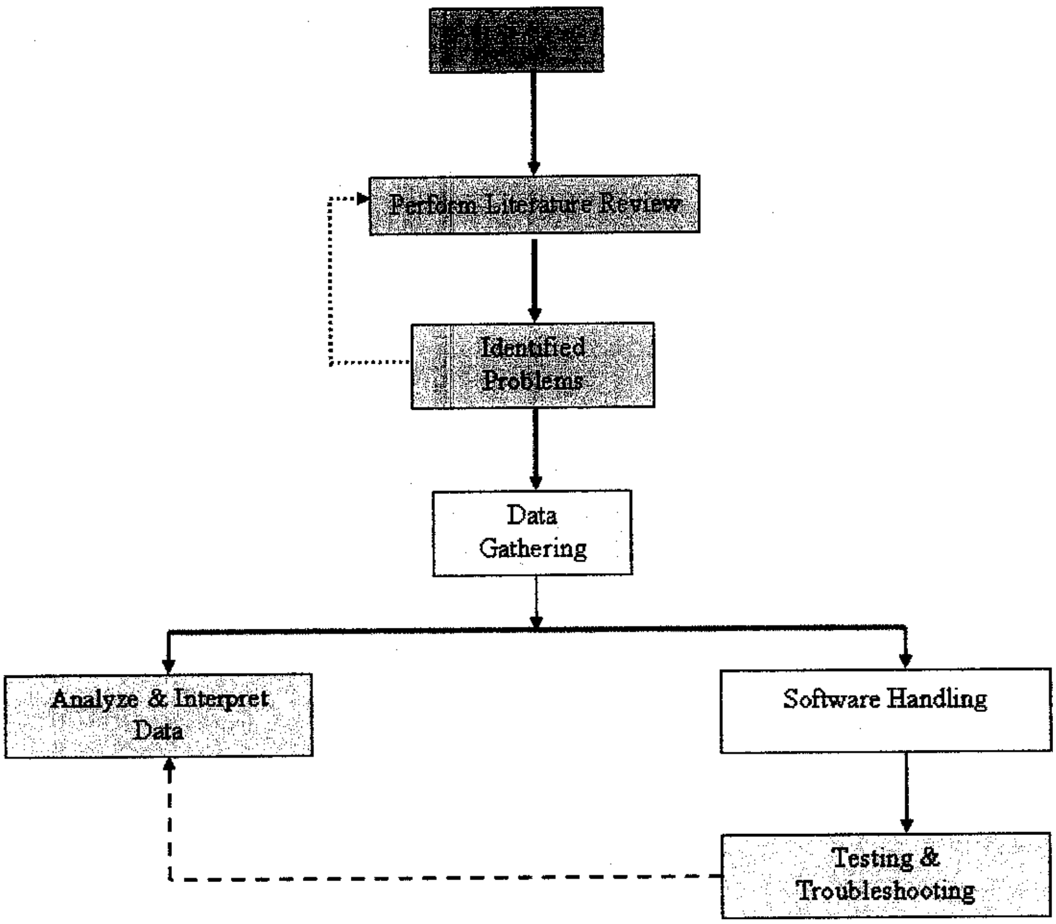

Figure 2: The overall project methodology and process flow.

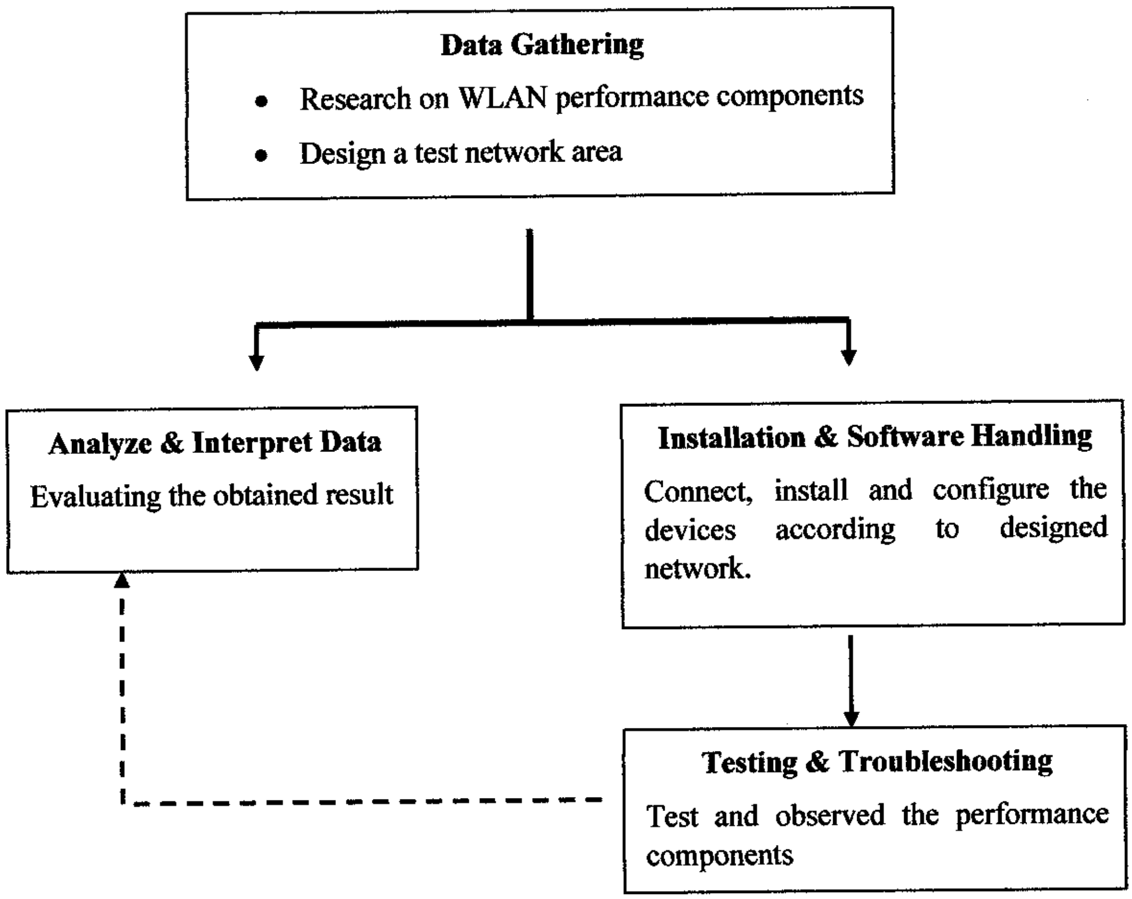

Figure 3: Process flow of WLAN test implementation setup

3.2 WLAN Implementation

The process of planning and implementation of WLAN is illustrated in the implementation cycle below:

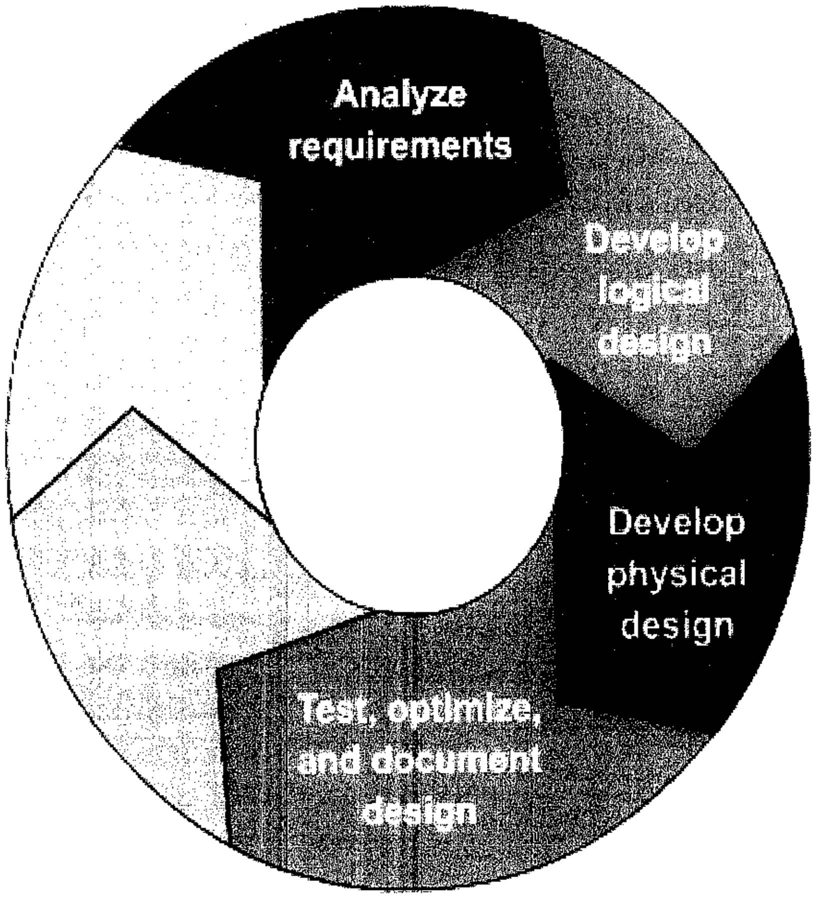

Figure 4: WLAN design & implementation cycle

Figure 4 is taken from Asst. Prof Anan Phonphoem, Ph.D, Computer Engineering Department, Kasetsart University, Bangkok, Thailand, WLAN Design and Implementation, Jan 2004.

3.3 Tools Required

A number of devices and equipments are identified to be utilized in experimental network tests:

- Cisco Aironet 350 Wireless Network Interface Card
- Cisco Aironet 350 Series Remote Wireless Bridge
- AIR-ANT 1949 Yagi Antenna
- D-link Air Plus G Wireless USB adapter
- Network Cables

Where as the following softwares are to be utilized:

- NetStumbler Ver 0.4.0
- FileZilla Server Ver 0.9.23
- Streaming Media Player
- ULive Server
- UMedia Server

3.4 Experimental Methodology

3.4.1 Setting up an Inter-building WLAN bridge Connection

The following explains the steps in creating an infrastructure WLAN for testing purposes:

- Make sure all the devices are working
- Connect the Cisco Aironet 350 Series Remote Wireless Bridge and AIR-ANT 1949 Yagi Antenna by antenna connector.
- Configure the Cisco Aironet 350 Series Remote Wireless Bridge using HyperTerminal application.
- Connect the Cisco Aironet 350 Series Remote Wireless Bridge to the PC using a serial cable to the COM1 port.
- Configure the settings to the assessment shown in Figure 5
- Make all the changes and settings for required network

- System Name
- IP Address
- Subnet mask
- Default Gateway
- Service Set ID (SSID) → wlan-fyp
- Role in Radio Network → Root Bridge & Non-root Bridge W/Clients

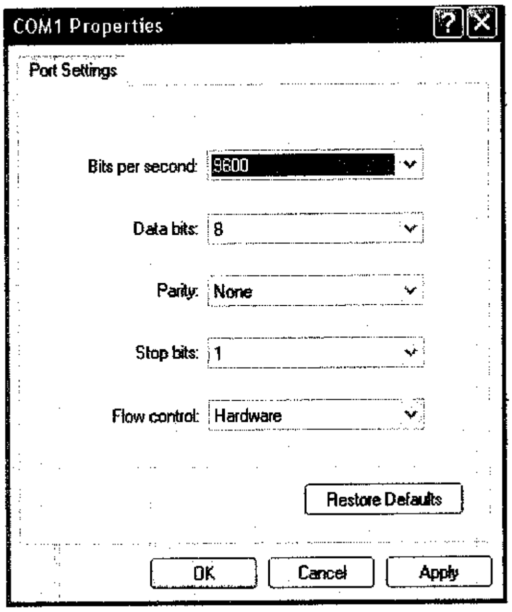

Figure 5: COM1 Port Settings

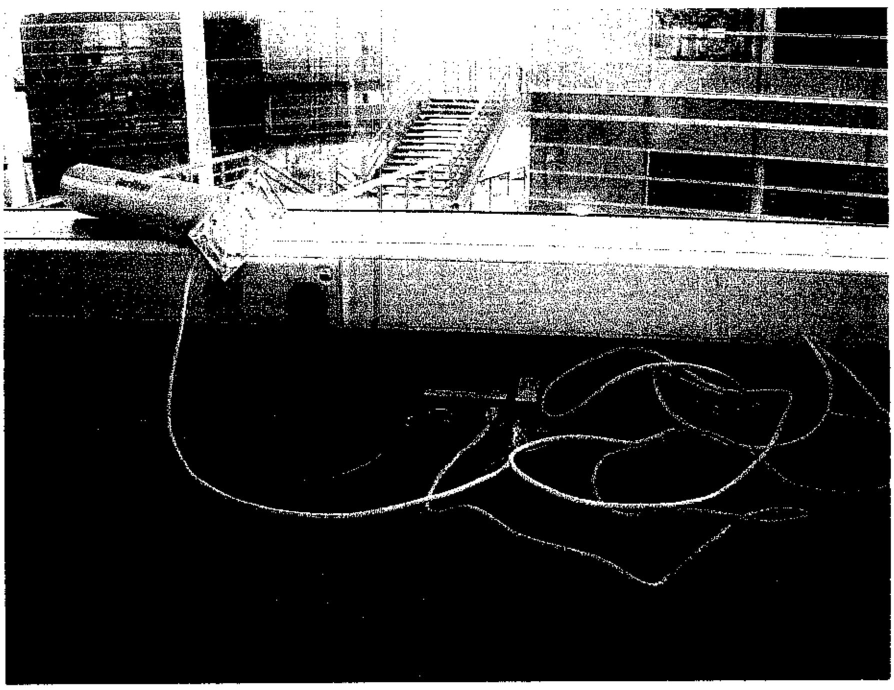

Figure 6: Inter-building WLAN setup

CHAPTER 4

RESULTS AND DISCUSSION

The results from the experiments conducted have been consolidated. The WLAN performance tests were conducted as the results of each testing and experiments helps to improve WLAN implementation process.

4.1 Experimental 1: Signal strength & signal Quality

Compared to the cable-based networks, the testing of wireless-network systems presents new challenges. For example, wireless-network performance can degrade significantly over time due to environmental changes in the signal broadcast area. Thus, the WLAN signal observation test was conducted to identify the differences of signal strength in different locations and conditions.

The inter-building coverage area of WLAN test network setup includes:

- Academic Building 2
- Academic Building 23
- Academic Building 22

Appendix B shows the 5 locations for inter-building WLAN signal strength analysis.

4.1.1 Results

Academic Building 2

Location 1: Building 2 level 2 room 12

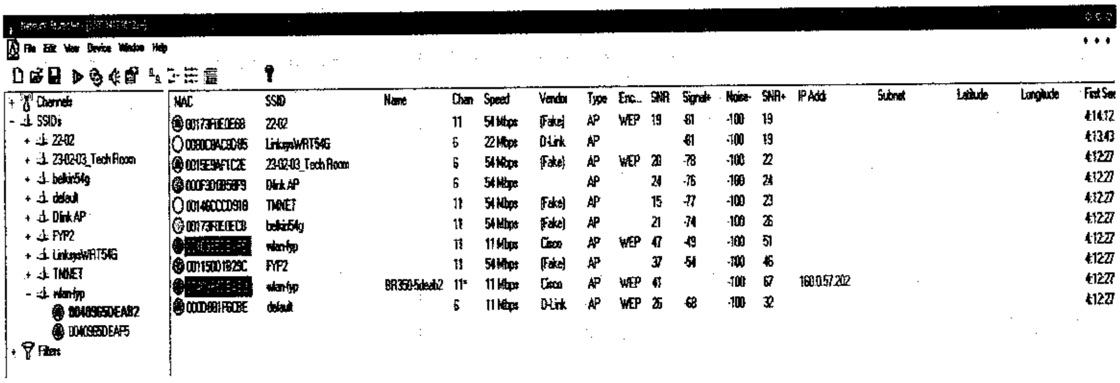

Figure 7: Data of bridge detected by NetStumbler in location 1

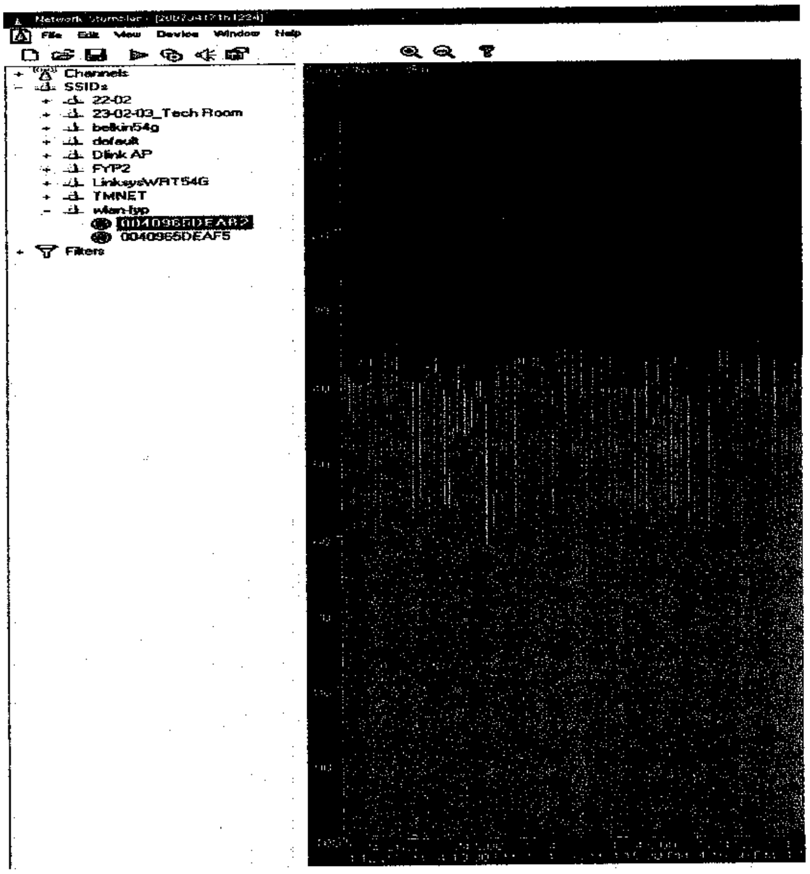

Figure 8: Signal to Noise Ratio (dBm) in location 1

Location 2: Building 2 level 1 room 8

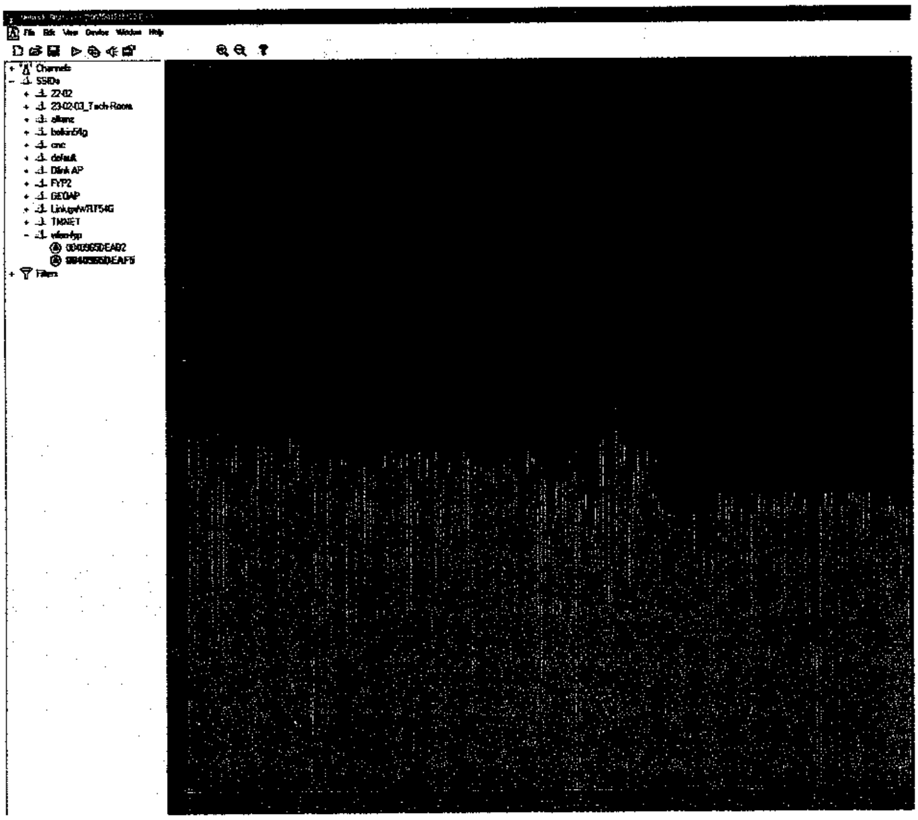

Figure 9: Signal to Noise Ratio (dBm) in location 2

Academic Building 23

Location 3: Building 23 level 1 room 4

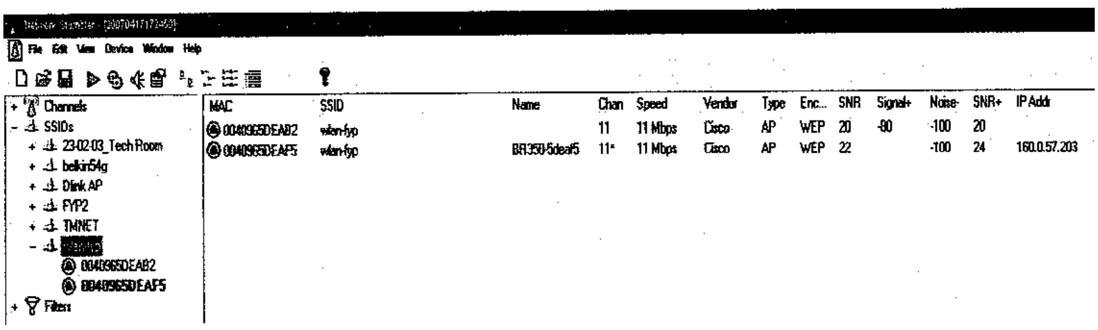

Figure 10: Data of bridge detected by NetStumbler in location 3

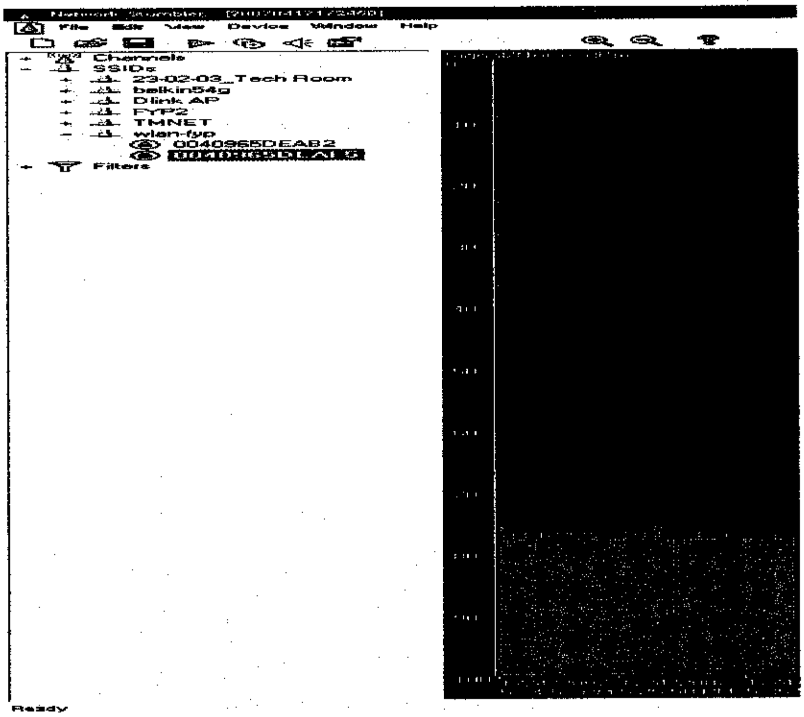

Figure 11: Signal to Noise Ratio (dBm) in location 3

Location 4: Building 23 level 2 room 13

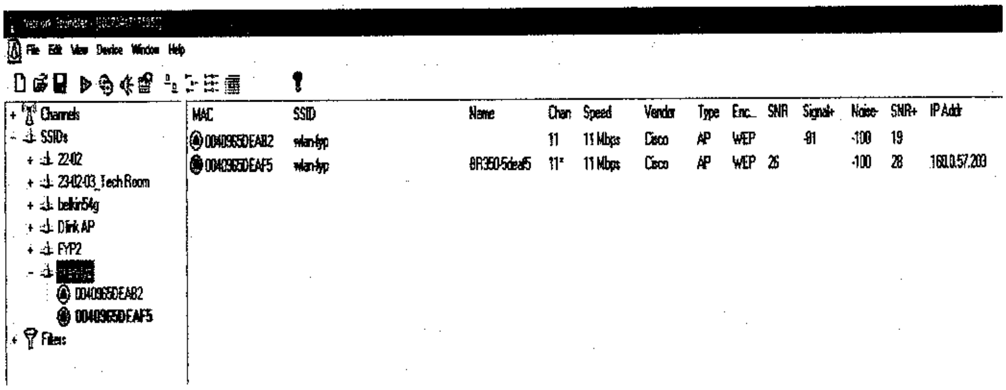

Figure 12: Data of bridge detected by NetStumbler in location 4

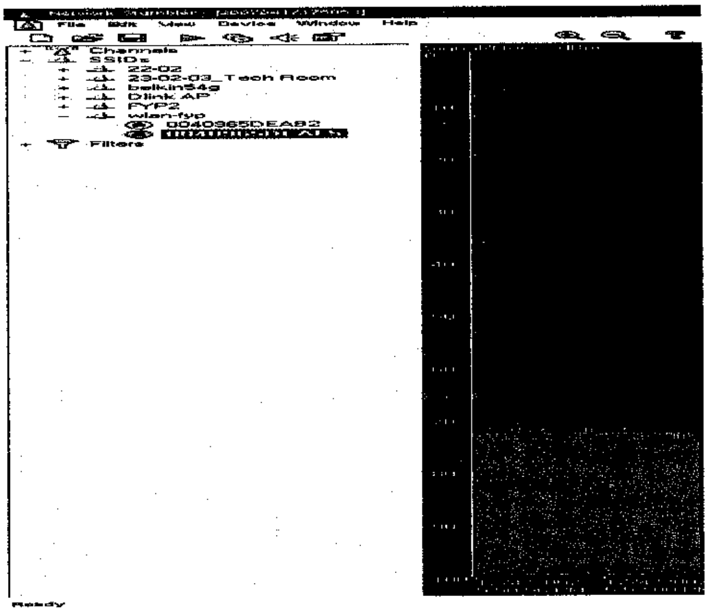

Figure 13: Signal to Noise Ratio (dBm) in location 4

Academic Building 22

Location 5: Building 22 level 2 room 13

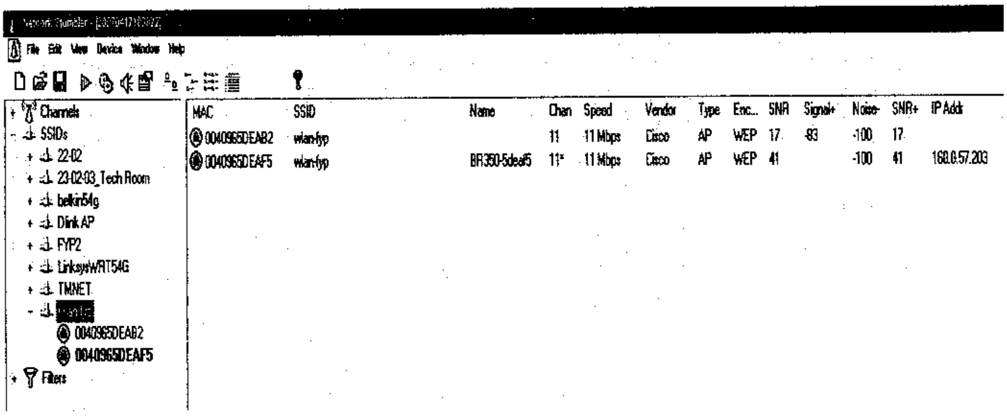

Figure 14: Data of bridge detected by NetStumbler in location 5

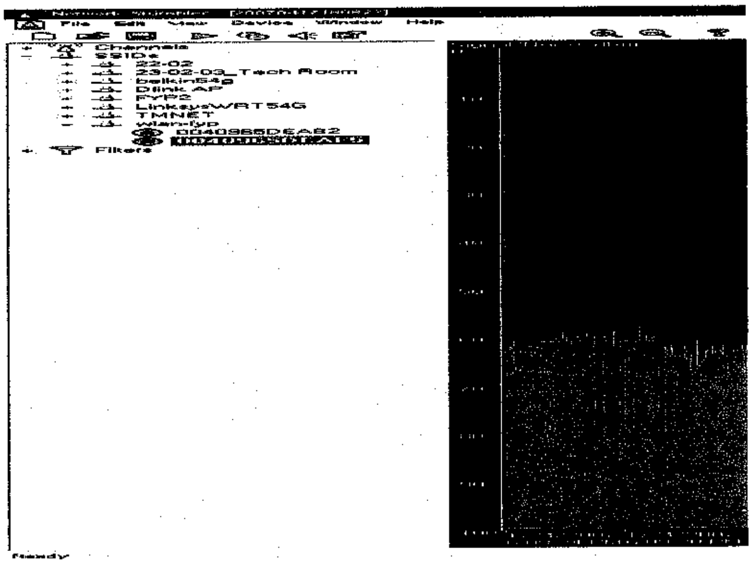

Figure 15: Signal to Noise Ratio (dBm) in location 5

Table 2: Signal Strength in SNR (dBm)

Performance Parameter	Location 1	Location 2	Location 3	Location 4	Location 5
SNR (dBm)	-40	-55	-75	-72	-62

4.1.2 Discussion

The signal strength of inter-building WLAN connection is observed by indicating the SNR level. SNR is the level comparison of a desired signal to level of background noise. The higher the ratio, the less obtrusive of the background noise. Therefore, the WLAN connection is more stable for higher value of SNR.

The summary of the result is presented in Table 2. From the result obtained, it is discovered that excellent inter-building WLAN connection is when SNR was in 0 to -50 dBm range. Any application can easily be perform under this condition. From the experiment, the location 1 and location 2 experienced the excellent WLAN connection.

Location 3, 4 and 5 can be categorized as good WLAN inter-building connection. The SNR value is between -55 to -75 dBm. It shows that the signal strength level decrease and will effect the performance of WLAN connection. Consequently, this condition will cause the lower performance on the application to be performed. It is noted that when the SNR was -80 dBm and lower, the signal strength is low and poor performance of WLAN connection.

The key of WLAN performance is the wireless environment in which the wireless network resides as well as the design of the system and subsystem components such as radio antenna. As a standard WLAN RF signal radiates through its environment, it bounces off various obstructions like walls, file cabinets, and other reflective surfaces. A number of factors will determine WLAN performance:

Interference

Interference occur by the existence of other devices that occupying the same frequency spectrum such as cordless phones and Bluetooth.

Network Load

Network load is depending on the number of users connected to the network at a time. The WLAN performance will be affected as the medium is shared by all the users.

Location Factors

The distance between client and access point will affect the WLAN performance. As distance between the AP and the client increases, the data rate would drop. Besides that, the network performance could also be affected by the orientation of the client depending on the location of the antenna and access point.

4.2 Experimental 2: Inter-building File Transfer Protocol (FTP)

4.2.1 Results

Client 1

Location: Building 2, Level 1, Room 2 (02-01-02)

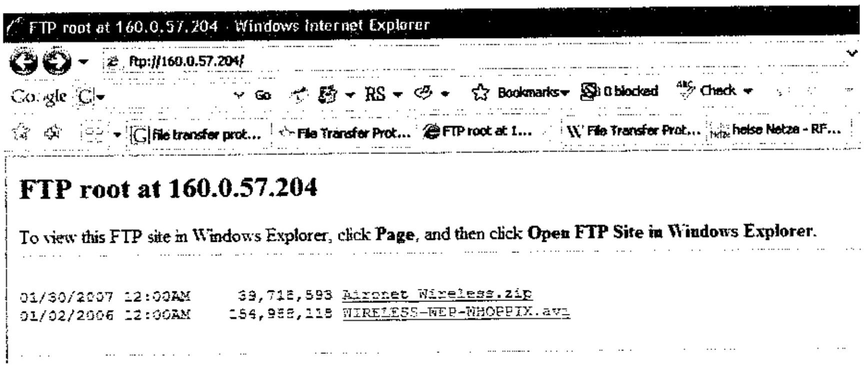

Figure 16: The list of files that can be downloaded by client 1

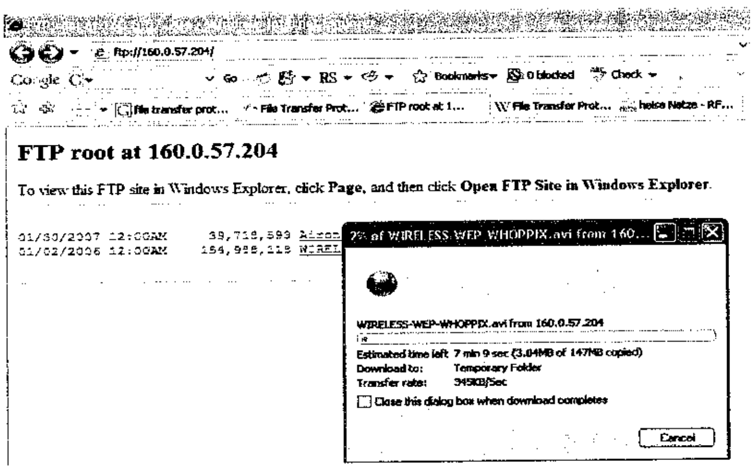

Figure 17: File transfer process by client 1

```
C:\>ping 160.0.57.204
Pinging 160.0.57.204 with 32 bytes of data:
Reply from 160.0.57.204: bytes=32 time=8ms TTL=128
Reply from 160.0.57.204: bytes=32 time=3ms TTL=128
Reply from 160.0.57.204: bytes=32 time=5ms TTL=128
Reply from 160.0.57.204: bytes=32 time=3ms TTL=128
Ping statistics for 160.0.57.204:
   Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
   Minimum = 3ms, Maximum = 8ms, Average = 4ms
C:\>ftp 160.0.57.204
Connected to 160.0.57.204.
220-FileZilla Server version 0.9.18 beta
220 #### WELCOME TO DATACOMM FTP SERVER ####
User (160.0.57.204:(none)): shakina
331 Password required for shakina
Password:
230 Logged on
ftp> ls
200 Port command successful
150 Opening data channel for directory list.
Aironet_Wireless.zip
WIRELESS-WEP-WHOPPIX.avi
226 Transfer OK
ftp: 48 bytes received in 0.01Seconds 4.80Kbytes/sec.
ftp> get
Remote file WIRELESS-WEP-WHOPPIX.avi
Local file second trial
200 Port command successful
150 Opening data channel for file transfer.
226 Transfer OK
ftp: 154988118 bytes received in 462.49Seconds 335.12Kbytes/sec.
ftp>
```

Figure 18: File transfer command by client 1

Client 2

Location: Building 23, Level 2, Room 8 (23-02-08)

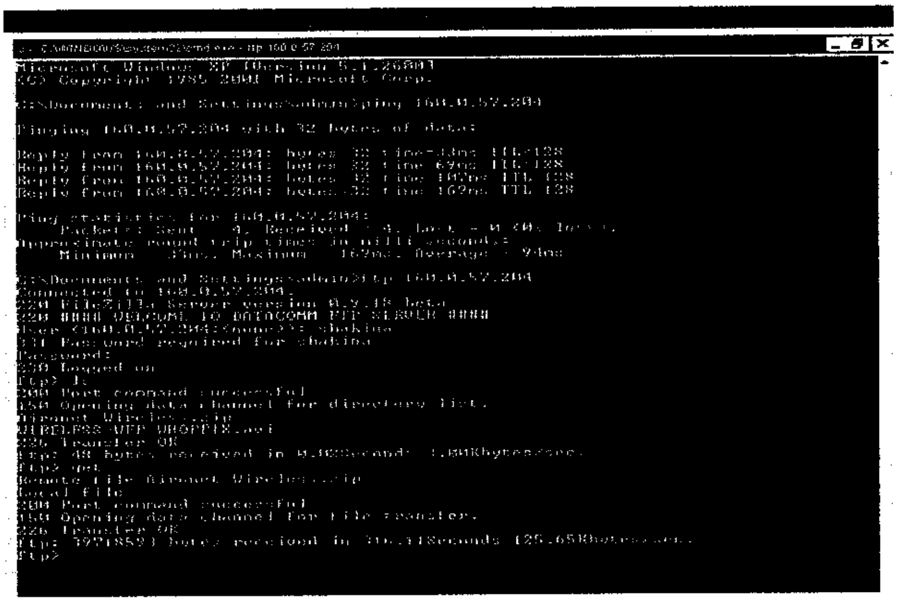

Figure 19: File transfer process by client 2.

Client 3

Location: Building 23, Level 2, Room 4 (23-02-04)

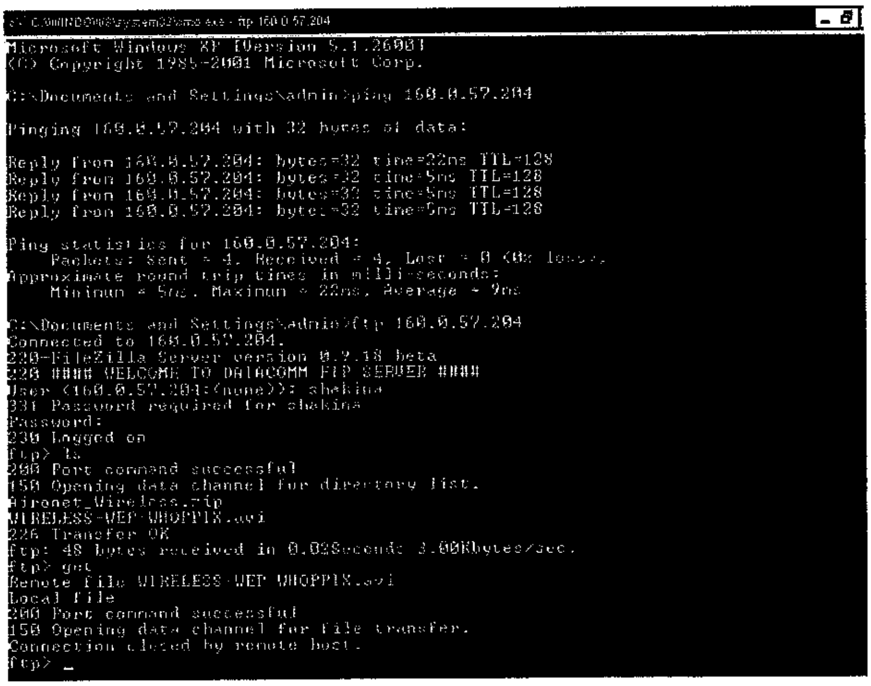

Figure 20: File transfer process by client 3

Table 3: Summary of inter-building FTP

Performance Parameter	Client 1	Client 2
Data rate (Kbytes/sec)	335.12	125.65

4.2.2 Discussion

From the result obtained, it is found that the data rate for client 1 is higher than client 2. The data rate value also shows that the client 2 experienced only half of data rate of client 1. This is due to several factors that caused the performance degradation of WLAN connection.

The client location will affect the performance of inter-building WLAN service. From the experiment, it is observed that client 1 which is located in the same building with the server, experienced higher data rate compared to client 2. The result also shows that the approximate round trip times (in mili-seconds) for client 1 is only 4 ms average, while client 2 is up to 94 ms average. It is found that, the time for data travel of client 1 is much shorter than client 2. Therefore, the data rate performance for client 1 is higher compared to client 2.

Signal strength is also one of the factors that effect file transfer protocol (FTP). With SNR range between -50 to -60 dBm, client 1 experienced excellent WLAN connection and as a result higher data rate can be obtained. It is different condition for client 2 which holds of moderate WLAN connection with SNR range between -70 to -75 dBm. Thus, the degradation of data rate has occurred.

4.3 Experimental 3: Video Streaming

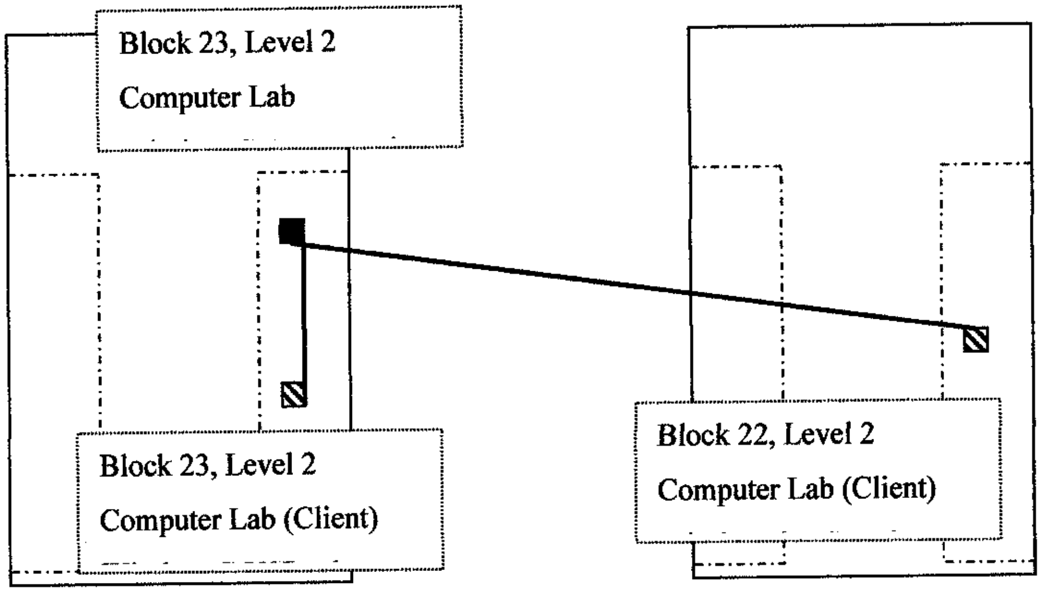

Figure 21: Line of sight video streaming network

4.3.1 Video Streaming (Line of Sight)

Video streaming test for line of sight condition is done between building 23 and building 22 as shown in Figure 21. The streaming server software used in this experiment is Unreal Media Server. Unreal Media Server is a software streaming server for Windows operating systems. The server supports live media sources and recorded media files. Two videos are used for inter-building streaming test that are:

Table 4: Video properties

Video	**Duration**	**File Size**
Dog_smoking	30 sec	2.05MB
Nike-stand_up_speak_up	31 sec	5.06MB

Unreal media server was designed for streaming media over networks that support TCP/IP. The remote files are resided on the computer where Media Server is installed (PC server) Default Media Server TCP port for client connection is 5119.

For a client (computer that runs Streaming Media Player) to request media over Wireless Local Area Network (WLAN) the server machine must have a public IP address. Live Server streams live media to Media Server, which distributes these streams to the clients. Live Server computers communicate to Media Server on TCP only.

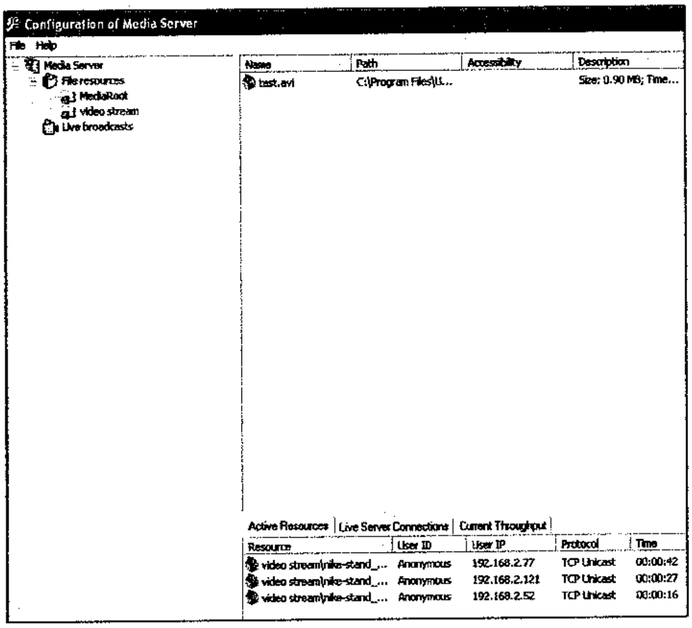

Figure 22: Configuration of Media Server

The video quality received by the client can be categorized as good quality. Despite the fact that, there are a few seconds delay occurs in client view

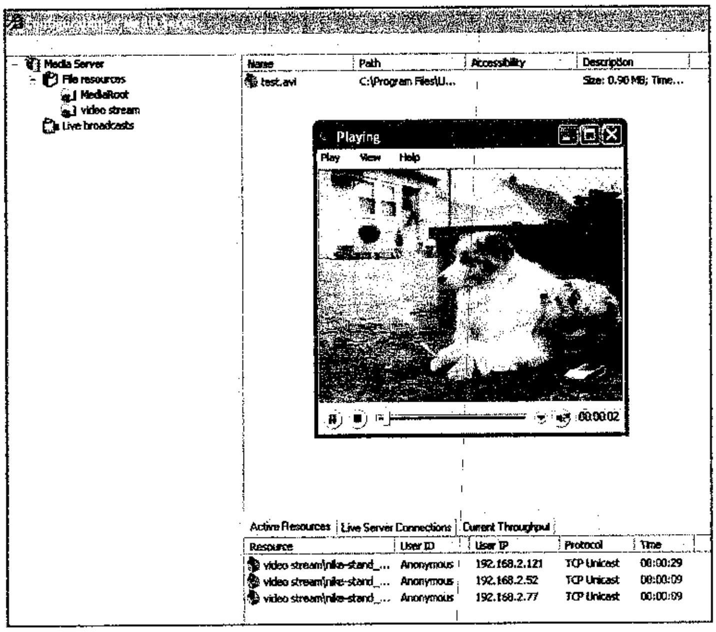

Figure 23: Video quality and server log during video streaming process

4.3.2 Video Streaming (Not Line of Sight)

The experiment for inter-building not line of sight video streaming is performed between building 2 and building 23. The layout of inter-building WLAN is shown in Appendix A.

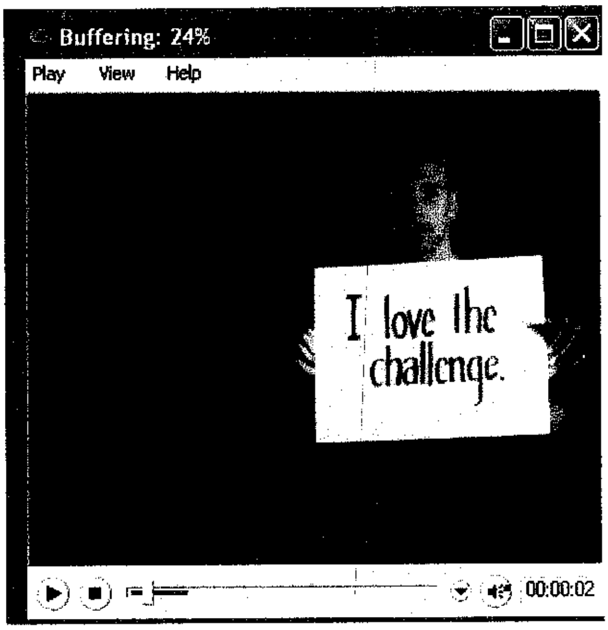

Figure 24: Video quality at Building 23 (buffering)

The outcome video from 'not line of sight' is observed. The video streaming performance is very poor compared to the video for line of sight experiment. The video obtained by the client will experience with delay and buffer which occur more compared to line of sight client.

From the experiment, it is noted that the video quality depends upon many factors, including the distance between client and the access point (AP) and the obstacles between the client and access point (AP).

It is observed that WLAN media streaming performance can degrade significantly by network load signal obstacles. Inconsistent wireless channel quality and intermittent connectivity can lead to excessive retransmission. The delays degrade the performance of wireless streaming application. This problem occurs because of shared queue at access point.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

Nowadays, enterprises are deploying WLAN for larger numbers of users with needs for corporate applications that involve e-mail, video streaming, and access to various server-based databases. The need for higher data rates and techniques to improve performance of wireless LANs is becoming crucial to support these types of applications.

The experimental results illustrate several factors that affect the WLAN performance:

Appropriate 802.11 Physical Layer.

The appropriate choice of 802.11 Physical Layer; a, b or g selection is one of important factors in WLAN implementation. 802.11a offers the highest capacity at 54 Mbps for each of non-overlapping channels and freedom from most potential RF interference. 802.11b provides 11 Mbps data rates, with only three non-overlapping channels. 802.11g will eventually extend 802.11b networks to have 54 Mbps operation, but the three non-overlapping channels limitation will still exist. Of course requirements dictate needs for performance, which will point toward a particular Physical Layer.

Provide adequate WLAN coverage.

The location of access point (AP) is very crucial in WLAN implementation to provide adequate WLAN coverage. As an example; user A who close to an 802.11b access point may be operating at 11 Mbps; whereas, user B who at a greater distance may only have 2 Mbps capability. In order to maximize performance, the WLAN coverage must be spread out and cover all the user areas, especially the locations where the bulk of users reside. The proper setting of transmit power and selection of antennas will also aid in positioning access points for optimum performance.

Avoid RF interference.

Other nearby WLANs such as cordless phones and Bluetooth can offer significant interfering signals that degrade the operation of wireless LAN. These external sources of signal periodically block users and access points from accessing the shared air medium. As a result, the WLAN performance will suffer when interference is present. The site survey process will help in discover interference problems before designing and installing the WLAN.

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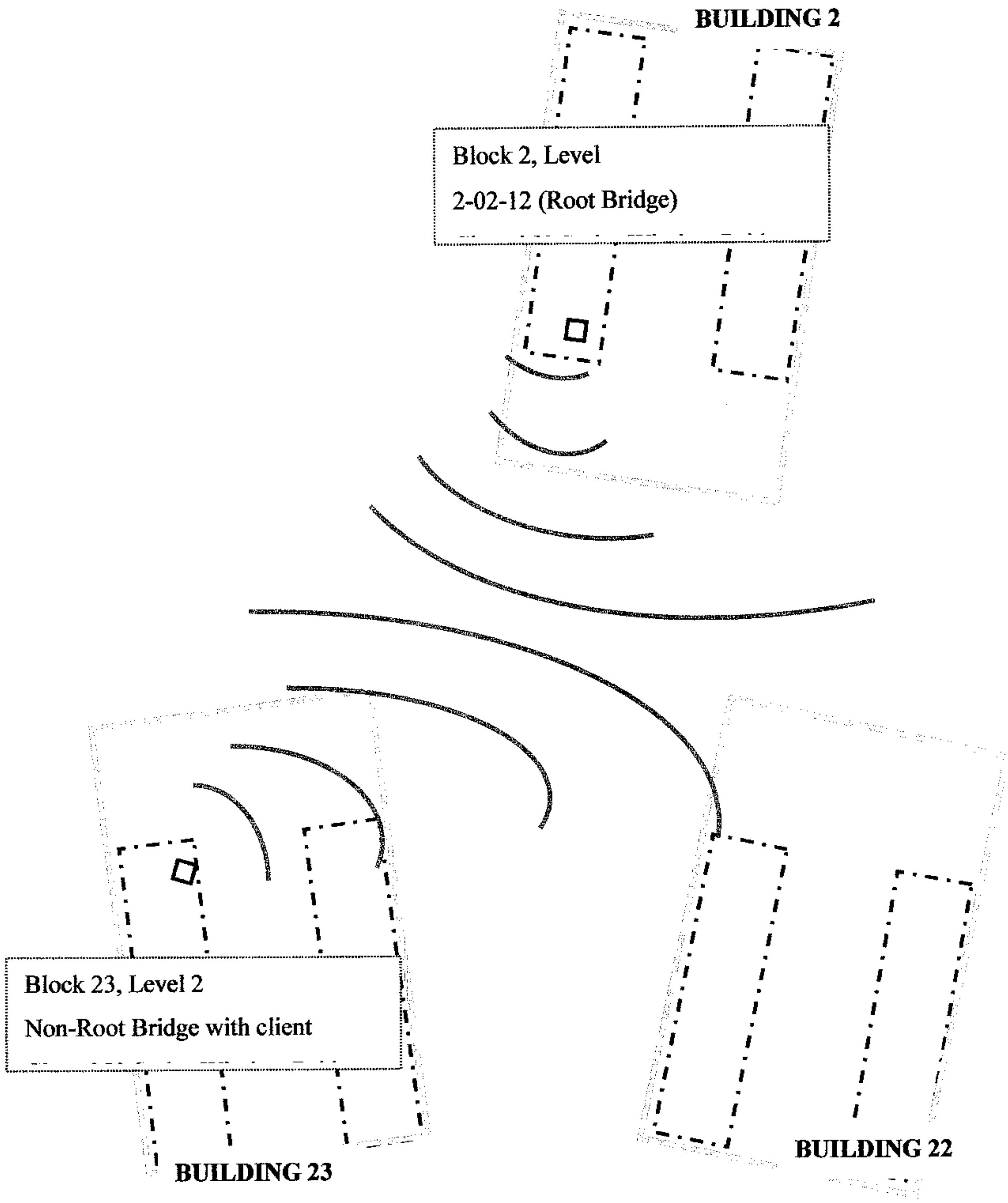
APPENDICES

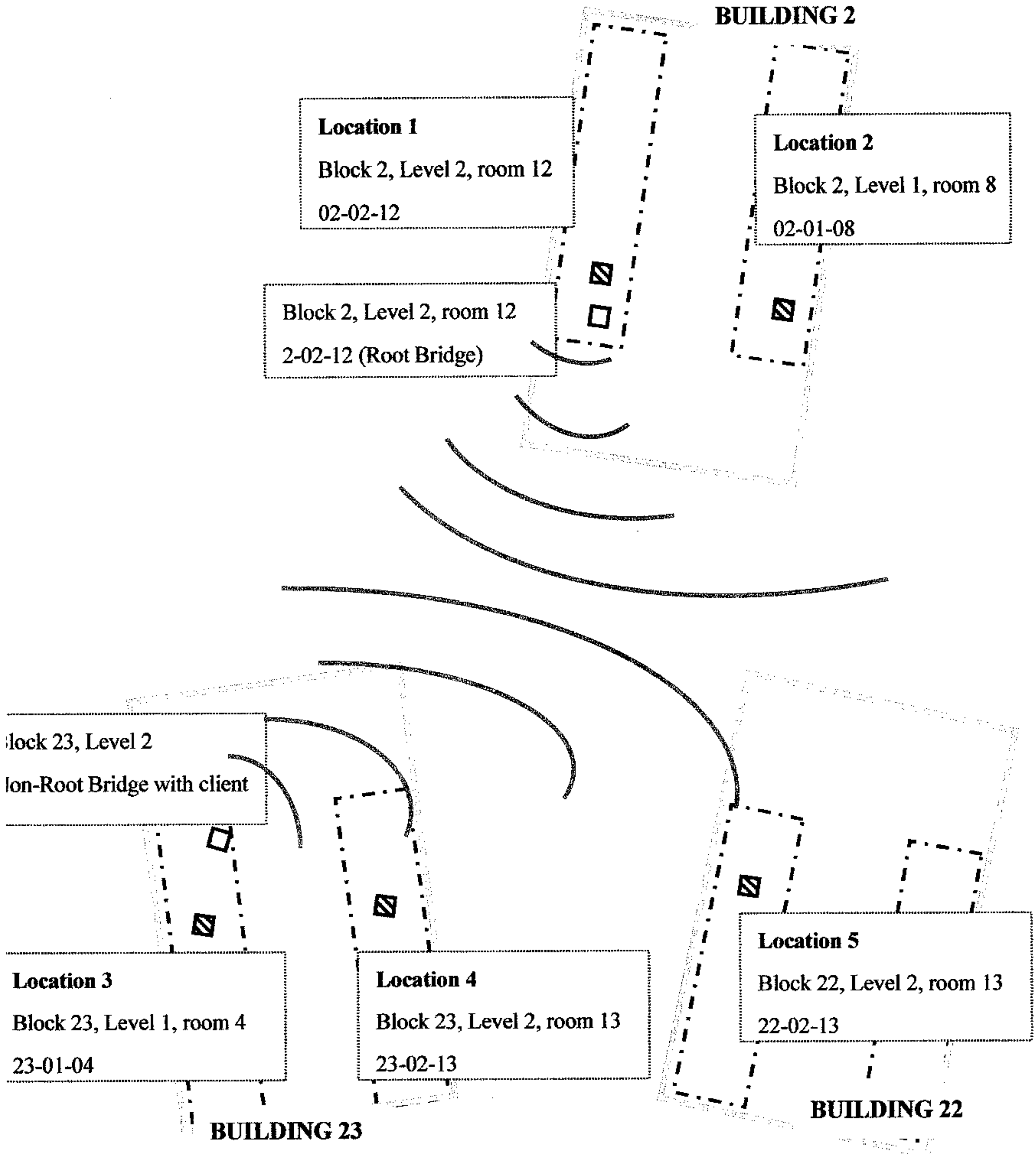
APPENDIX A

PROJECT LAYOUT DIAGRAM



APPENDIX B

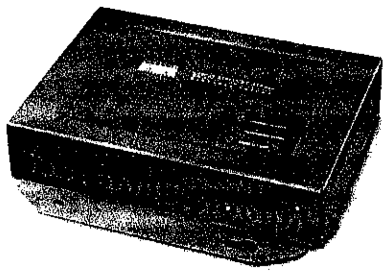
EXPERIMENT LOCATIONS OF SIGNAL STRENGTH ANALYSIS



APPENDIX C

CISCO AIRONET 350 SERIES REMOTE BRIDGE

Cisco **Aironet** 350 Series Wireless Bridge



The Cisco Aironet® 350 Series Wireless Bridge enables high-speed long-range outdoor links between buildings and is ideal for installations subject to plenum rating and harsh environments. It is designed to meet the requirements of even the most challenging applications, with features including:

- High-speed (11-Mbps), high-power (100-mW) radios, delivering building-to-building links of up to 25 miles (40.2 km)
- A metal case for durability and plenum rating and an extended operating temperature rating for harsh environments
- Supports both point-to-point and point-to-multipoint configurations
- Broad range of supported antennas
- Simplified installation, improved performance, and upgradeable firmware, ensuring investment protection

Fixed Wireless Solution

Designed to connect two or more networks (typically located in different buildings), the Cisco Aironet 350 Series Wireless Bridge delivers high data rates and superior throughput for data-intensive, line-of-sight applications. The bridges connect hard-to-wire sites, noncontiguous floors, satellite offices, school or corporate campus settings, temporary networks, and warehouses. They can be configured for point-to-point or point-to-multipoint applications (see Figures 1 and 2) and allow multiple sites to share a single, high-speed connection to the Internet. For functional flexibility, the wireless bridge may also be configured as an access point.

The high-speed links between the wireless bridges deliver throughput several times faster than E1/T1 lines for a fraction of the cost— eliminating the need for expensive leased lines or difficult-to-install fiber-optic cable. Because bridges have no recurring charges, savings on leased-line services quickly pay for the initial hardware investment. Wireless bridges connect discrete sites into a single LAN, even when they are separated by obstacles such as freeways, railroads, and bodies of water that are practically insurmountable for copper and fiber-optic cable. Combining powerful 100-mW radios, industry-leading receive sensitivity, installation tools to assist in bridge placement, delay spread capabilities, and a broad array of directional and omnidirectional antennas, Cisco provides a complete solution for a wide variety of fixed wireless applications.

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Figure 1 Point-to-Point Wireless Bridge Solution

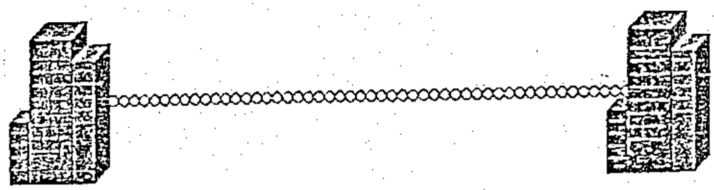
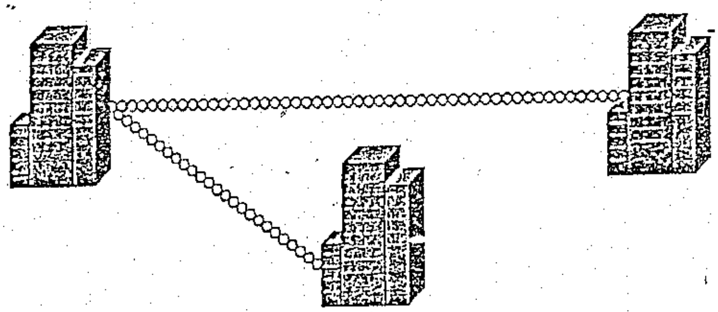


Figure 2 Point-to-Multipoint Wireless Bridge Solution



A Rugged Design

The Cisco Aironet 350 Series Wireless Bridge features an extended operating temperature range of -20 to 55 C, allowing for placement outdoors in a NEMA enclosure or in harsh indoor environments such as warehouses and factories. With a durable metal case, the Cisco Aironet 350 Series Wireless Bridge is UL 2043 certified, and designed to achieve plenum rating as defined by various municipal fire codes.

Simplified Installation and Optimized Performance

The Cisco Aironet 350 Series Wireless Bridge supports a variety of features designed to simplify installation and improve performance. Like Cisco Aironet 350 Series Access Points, Cisco Aironet 350 Series Wireless Bridges obtain their operating power over the Ethernet cable, eliminating the need to run AC power to what are often remotely located wireless devices. (See Figures 3 through 5.)

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Figure 3 The Cisco Aironet 350 Wireless Bridge may obtain power from the Catalyst 3524-PWR-XL Switch

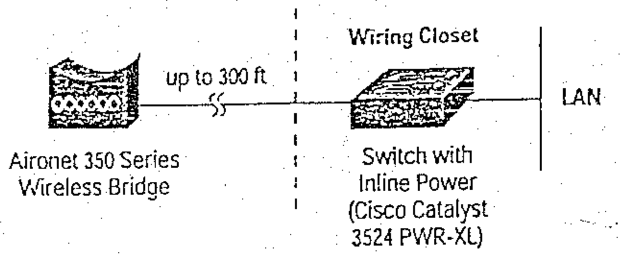


Figure 4 A Cisco Catalyst Inline Power Patch Panel may be used to power the Cisco Aironet 350 Series Wireless Bridge

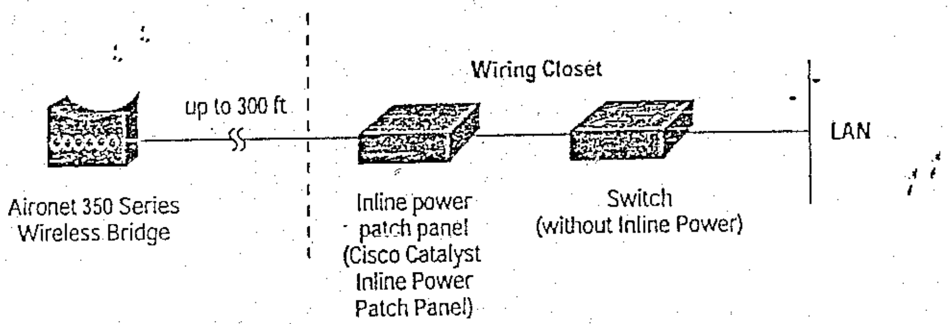
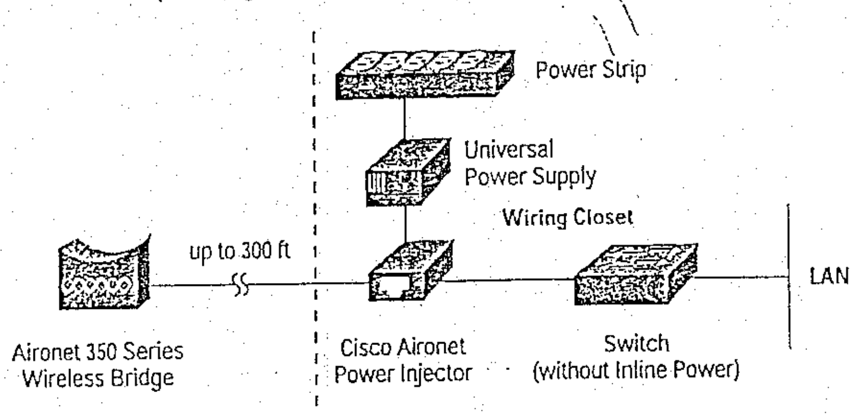


Figure 5 Cisco also offers a power injector to power the Cisco Aironet 350 Series Wireless Bridge



To provide flexibility during installation and configuration, the Cisco Aironet 350 Series Wireless Bridge may be accessed either over the LAN connection or via a console port. The frequency agility option on the Cisco Aironet 350 Series enables the bridges to select the clearest transmission channel, avoiding noise and interference. Frequency agility simplifies installation and, by intelligently avoiding interference and selecting the best transmission channel, maximizes throughput.

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Investment Protection

Cisco will continue to add features, functionality, and enhancements to its bridge firmware. To protect user investment, Cisco Aironet 350 Series Wireless Bridges feature enough storage to handle future firmware upgrades.

Data Rates Supported	1, 2, 5.5, and 11 Mbps
Network Standard (in AP mode)	IEEE 802.11b
Uplink	10/100BaseT Ethernet
Frequency Band	2.4 to 2.497 GHz
Wireless Medium	Direct Sequence Spread Spectrum (DSSS)
Media Access Protocol	Carrier sense multiple access with collision avoidance (CSMA/CA)
Modulation	DBPSK @1 Mbps DQPSK @ 2 Mbps CCK @ 5.5 and 11 Mbps
Operating Channels	North America: 11 ETSI: 13 Japan: 14
Nonoverlapping Channels	Three
Receive Sensitivity	1 Mbps: -94 dBm 2 Mbps: -91 dBm 5.5 Mbps: -89 dBm 11 Mbps: -85 dBm
Delay Spread	1 Mbps: 500 ns 2 Mbps: 400 ns 5.5 Mbps: 300 ns 11 Mbps: 140 ns
Available Transmit Power Settings	100 mW (20 dBm) 50 mW (17 dBm) 30 mW (15 dBm) 20 mW (13 dBm) 5 mW (7 dBm) 1 mW 0 dBm)
Range (typical, contingent upon antenna type selected)	18 miles (28.9 km) @ 11 Mbps Up to 25 miles (40.2 km) @ 2 Mbps
Compliance	Operates license free under FCC Part 15 and complies as a Class B Device; complies with DOC regulations;[1] complies with ETS 300.328, FT 2100, and MPT 1349 standards; complies with UL 2043
SNMP Compliance	MIB I and MIB II
Antenna	Two RP-TNC connectors (antennas optional, none supplied with unit)
Encryption Key Length	128-bit
Security	128-bit WEP in bridge mode IEEE 802.1x (proposal includes EAP and RADIUS) in AP mode

1.The use of this device in a system operating either partially or completely outdoors may require the user to obtain a license for the system according to the Canadian regulations. For further information, contact your local Industry Canada office.

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Status Indicators	Three indicators on the top panel provide information concerning association status, operation, error/warning, firmware upgrade, and configuration, network/modem, and radio status
Automatic Configuration Support	BOOTP and DHCP
Remote Configuration Support	Telnet, HTTP, FTP, TFTP, and SNMP
Local Configuration	Direct console port (with supplied serial cable)
Bridging Protocol	Spanning Tree
Dimensions	6.74 in. (17.1 cm) wide x 6.25 in. (15.9 cm) deep x 1.31 in. (3.3 cm) high
Weight	1.43 lbs (.648 kg)
Environmental	Temperature: –4 to 131 F (–20 to 55 C) 10 to 90% (noncondensing)
Enclosure	Metal case (for plenum rating); UL 2043 certified
Input Power Requirements	24VDC +/- 10% to 60 VDC (Ethernet line power)
Warranty	One year

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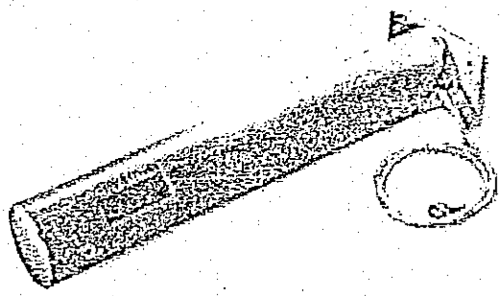
APPENDIX D

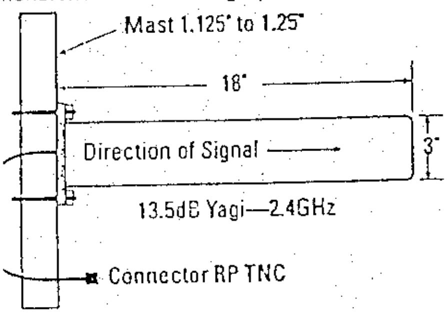
AIR/ANT 1949 WALL MOUNT YAGI ANTENNA

dBi MAST/WALL MOUNT YAGI

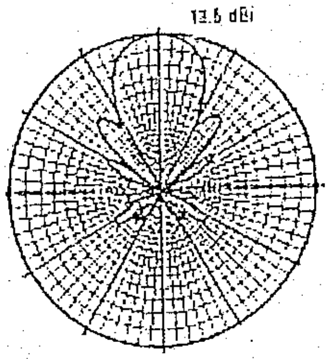
ANT1949



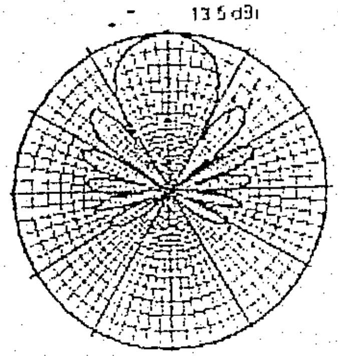
nensions and Mounting Specifications



Horizontal Radiation Pattern



Vertical Radiation Pattern



ɜquency Range	2.4–2.83 GHz
WR	Less than 2:1, 1.5:1 Nominal
in	13.5dBi
ont to Back Ratio	Greater than 30 dB
larization	Vertical
imuth 3dB BW	30 degrees
evations 3dB BW	25 degrees
itenna Connector	RP-TNC
mensions (H x W)	18 x 3 in.
ind Rating	110 MPH
ounting	Mast/Wall Mount

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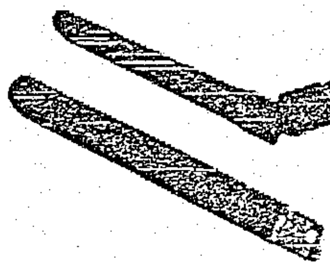
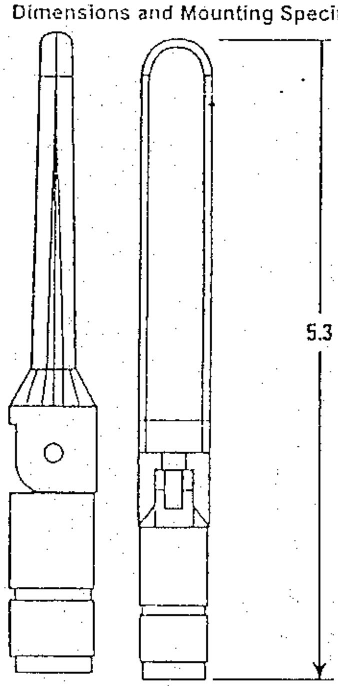
3.5dBi DIPOLE

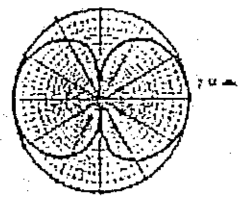
AIR-ANT5135D-R



Dimensions and Mounting Specifications



Vertical Radiation



Frequency Range	5.15–5.85 GHz
VSWR	2:1 or better
Temperature	-30°C to + 70°C
Gain	3.5dBi
Polarization	Linear
Azimuth 3dB BW	Omnidirectional
Elevations 3dB BW	40 degrees
Antenna Connector	RP-TNC
Dimensions (H)	5.3 in.
Mounting	RP-TNC Connector

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