Design and Implementation of an Efficiently Managed Wireless Internet Service Providing (WISP) System

Dr.Qutaiba Ibraheem Ali
Mosul University

Ahmed Zuhair Al-wattar
Mosul University

Abstract:

In this paper, a comprehensive study to the structure, behavior and management of a Wireless Internet Service Provider (WISP) system is presented. The structure of the system is investigated and the importance of the different parts of the system is clearly determined. Also, WISP system was subjected to different tests such as load test, user behavior and page response time. The design methodology and data given here could be used by the planners, developers and researchers of such a sophisticated network field.

1.INTRODUCTION

Wireless technologies are playing an increasingly prominent role in the global Internet infrastructure. One of the popular technologies is the IEEE 802.11 standard. This popular "WiFi" (Wireless Fidelity) technology provides low-cost wireless Internet capability for end users. Recently, Wi-Fi has become one of the most popular standards for wireless Internet access technology. Using radio frequency connections between a base station and devices with add-on or built-in 802.11 wireless cards, Wi-Fi gives access to the Internet and remote corporate and personal data without using the wires and cables of conventional wired networks in public places, homes, and offices. The global push to adopt 802.11 is based largely on its high bandwidth (up to 54 Mbps) and rich user experience that is comparable to being on a wired company LAN. This standard is open, unlicensed, internationally adopted, interoperable, and supported by every major player in the wireless LAN industry. WLAN options are available today for most consumer devices and the current technology of laptops, handheld PCs and PDAs are WLAN enabled [1]-[4].

The Institute of Electrical and Electronic Engineers (IEEE) ratified the original 802.11 specification in 1997 as the standard for wireless LANs (WLANs). That version of 802.11 provides for 1 and 2 Mbps data rates and a set of fundamental signaling methods and other services. Some disadvantages with the original 802.11 standard are the data rates that are too slow to support most general business requirements. Recognizing the critical need to support higher data transmission rates, the IEEE ratified the 802.11b standard for transmissions of up to 11 Mbps. With 802.11b (also known as WiFi), WLANs are able to achieve wireless performance and throughput comparable to wired 10-Mbps Ethernet. 802.11a offers speeds of up to 54 Mbps, but runs in the 5-GHz band, so products based on this standard are not compatible with those based on 802.11b[5]. Several task groups are working on further developments for the 802.11 standard[6], as shown in Table 1.

TABLE (1): ACTIVITIES OF THE TASK GROUPS WORKING ON THE 802.11 STANDARD

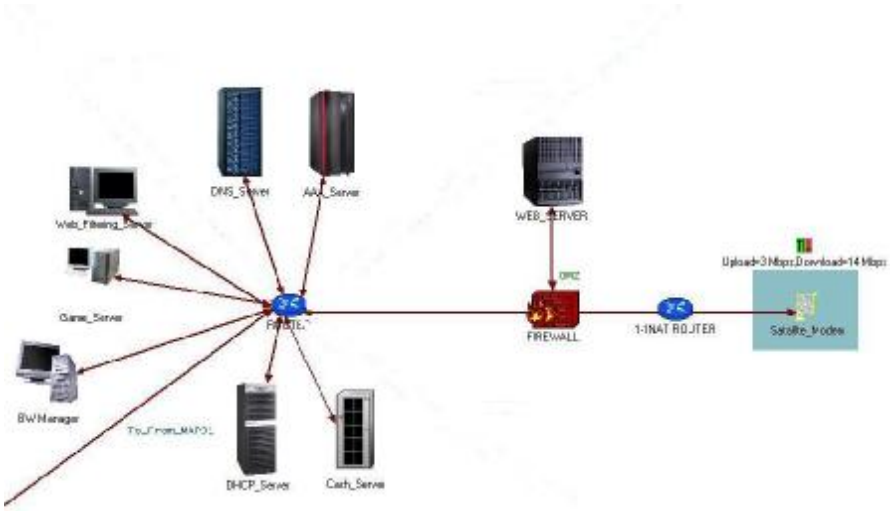
Task Group	Activities
802.11	Initial standard, 2.4-GHz band, 2 Mbps
802.11a	High speed PHY layer in the 5-GHz band, up to 24 or 54 Mbps
802.11b	High speed PHY layer in the 2.4-GHz band, up to 11 Mbps
802.11d	New regulatory domains (countries)
802.11e	Medium access control (MAC) enhancements: Multimedia, QoS, enhanced security
802.11f	Interaccess point protocol for AP interoperability
802.11g	Higher data rate extension in the 2.4-GHz band, up to 22 Mbps
802.11h	Extensions for the 5-GHz band support in Europe

The main contribution of this work relies on giving a clear method to build an efficiently managed WISP system.

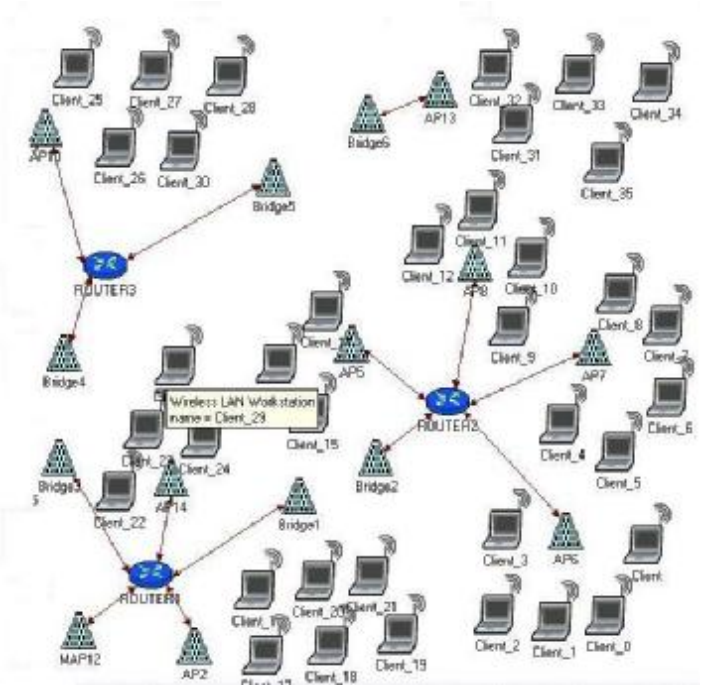
2. SYSTEM DESCRIPTION

The WISP system under study is considered the major internet service provider in the city of Mosul/Iraq. Its establishment begins in the second half of 2003 and witnesses a wide expansion, in terms of coverage area and number of users, since then. The system gives various services to its clients, such as, Internet browsing, E-mail services, web hosting, HTML pages design, distributed gaming and numerous commercial activities.

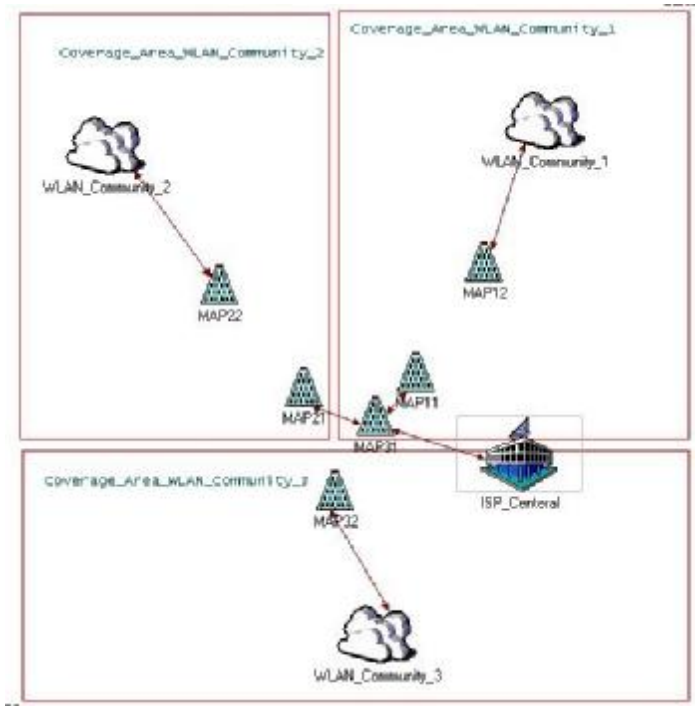
From the technical point of view, home Internet services providing is considered to be the major activity of the system. It uses multiple wireless/wired network techniques to cover the different areas of the city. Fig. (1) gives a clear picture of the network


DNS_Server
AAA_Server
WEB_SERVER
Web_Filtering_Server
Game_Server
BW Manager
DHCP_Server
Cash_Server
FIREWALL
1-1NAT ROUTER
Satellite_Modem

(a)


ROUTER3
ROUTER2
ROUTER1
Bridge1
Bridge2
Bridge3
Bridge4
Bridge5
AP5
AP7
AP13
AP14
MAP12
AP2
Wireless LAN Workstation
name = Client_29

(b)



(c)

Fig. (1): Structure of WISP System: (a) ISP (Management) Center (b) Distribution Network (c) The Whole System

The network spans about (25×25 Km) of the city area. The major elements of the system are the distribution network and the ISP center.

● The distribution network: It is the various links between the clients and the ISP center. The traffic to/from the center is forwarded through three pairs of point to point bridges, we called Major Access points (MAP); each one of them is responsible of covering certain areas of the city. The wireless links between MAPs are subjected to IEEE802.11g WLAN standard, running at a speed of (22 Mbps). It is worthwhile to mention that two of the MAPs are connected through a Fast Ethernet LAN to the third MAP, which is the gateway between the WLAN communities and the ISP center.

The rest of the network consists of local access points (working at 11 Mbps data rate of IEEE 802.11b WLAN standard) installed in different sections of the city to serve certain number of users.

The local access points were segmented into different VLAN groups to prevent inter-traffic between them. Fig. (2) Shows the installed access points with their relative users.

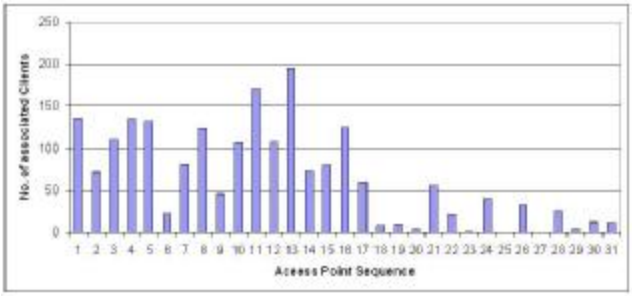


Fig. (2): Installed access points with their relative users.

It is clear that local access points have different number of users with an average of (63 client/AP). When the number of clients exceeds certain limit, additional access points are installed to serve the growing number of users. The coverage area of each access point is maintained through the use of proper antennas and if necessary, suitable signal boosters.

● The ISP Center: It consists of various network devices and servers to manage and provide internet services. Their functions could be summarized as follows:

♦Satellite Modem: It is the link between the ISP and the rest of the internet. It has a data rates of (15 Mbps) for download and (3 Mbps) for upload operations.

♦1-1 NAT Router: The system has an (1500) public IP addresses pool available to the clients on the *one to one* Network Address Translation basis (i.e., each public IP is given to a private IP address during user log in time). Address translation substitutes the real address in a packet with a mapped address that is routable on the destination network. NAT is comprised of two steps: the process in which a real address is translated into a mapped address, and then the process to undo translation for returning traffic [7].

The security appliance translates an address when a NAT rule matches the traffic. If no NAT rule matches, processing for the packet stops. The benefits of NAT are preventing private addresses from being routable on the Internet and

NAT hides the real addresses from other networks, so attackers cannot learn the real address of a host.

♦A Firewall supported with Intrusion Detection System (IDS) capabilities provides certain level of security to the system. It is known that IDS monitors and performs real-time analysis of network traffic by looking for anomalies and misuse based on an extensive, embedded signature library. When the system detects unauthorized activity, it can terminate the specific connection, permanently block the attacking host, log the incident, and send an alert to the **device manager.**

Other legitimate connections continue to operate independently without interruption[1]. the company's web server is connected to the *demilitarized zone* (DMZ) portion of the firewall device. The firewall allows limited access to the DMZ, but because the DMZ only includes the public servers, an attack there only affects the servers and does not affect the other inside networks[3].

♦AAA Server: AAA is the acronym for authentication, authorization, and accounting Authentication controls access by requiring valid user credentials, which are typically a username and password. Authorization controls access *per user* after users authenticate. Accounting tracks traffic that passes through the security appliance, gives the ability to have a record of user activity. The security appliance supports a variety of AAA server types and a local database that is stored on the security appliance. Examples of these types are: RADIUS Server, TACACS+ Server, SDI Server, NT Server, Kerberos Server, LDAP Server Support and Local Database Support.

Depending on the size of the network and available resources, AAA can be implemented on a device locally or can be managed from a central server running RADIUS or TACACS+ protocols. The AAA server first checks to see if the user has been authenticated.

If a valid authentication entry exists for the user, the session is allowed and no further intervention is required by the authentication proxy. If no entry exists, the authentication proxy responds to the connection request by prompting the user for a username and password. If the authentication fails, the AAA server reports the failure to the user and prompts the user for a configurable number of retries. The most functionally server type is the TACACS+ Server and it is chosen here for that purpose. Terminal Access Controller Access Control System Plus (TACACS+) is an industry standard protocol specification, RFC 1492, that forwards username and password information to a centralized server [4].

♦Game server provides distributed game network between network clients.

♦ Web filtering server together with the Squid cache server frees more bandwidth for the benefit of the most important needs. As known[8], these servers have a great influence on the system performance and our measurements shows that a *Hit Ratio* of 0.35 is achieved (i.e., 35% of the traffic is acquired from the cache server rather than from the internet). Squid is a caching proxy for the Web supporting HTTP, HTTPS, FTP, and more. It reduces bandwidth and improves response times by caching and reusing frequently-requested web pages. Squid has extensive access controls and makes a great server accelerator. Squid can also route content requests to servers in a wide variety of ways to build cache server hierarchies which optimize network throughput.

On the other hand, filtering server frees 40% of the available bandwidth from the less important applications. Its decision is based on *Content plus Database filtering* algorithms according to pornography, spyware and viruses categories.

♦Bandwidth Management Server: It is responsible for giving a certain level of service to the different clients according to their individual subscriptions. Table (2) lists the various types of subscriptions.

TABLE (2): SUBSCRIPTION TYPES

Subscription Type	Number of Clients
1.2 GB 64 Kb/s Home 1-PC	205
1.2 GB 64 Kb/s Home 2-PC	82
1.2 GB 64 Kb/s Home 3-PC	160
2.4 GB 64 Kb/s Home 1-PC	399
2.4 GB 64 Kb/s Home 2-PC	146
2.4 GB 64 Kb/s Home 3-PC	292
3 GB 160 Kb/s Home 1-PC	219
6 GB 160 Kb/s Home 1-PC	9
9 GB 160 Kb/s Home 1-PC	1
6 GB 256 Kb/s Home 1-PC	2
1.5 GB 160 Kb/s Home-Hours 1-PC	24
3 GB 160 Kb/s Home-Hours 1-PC	213
64 Kb/s Café-IP-Unlimited	5
128 Kb/s Cafe-Band	23
160 Kb/s Cafe-Band	48
192 Kb/s Cafe-Band	8
224 Kb/s Cafe-Band	5
256 Kb/s Cafe-Band	1
600 MB 64 Kb/s Home 2-PC	1
600 MB 64 Kb/s commercial 1-PC	51
600 MB 64 Kb/s commercial 2-PC	11
600 MB 64 Kb/s commercial 3-PC	18
1.5 GB 64 Kb/s commercial 1-PC	18
1.5 GB 64 Kb/s commercial 2-PC	1
1.5 GB 64 Kb/s commercial 3-PC	1

1.5 GB 160 Kb/s commercial 1-PC	42
3 GB 160 Kb/s commercial 1-PC	5
4.5 GB 160 Kb/s commercial 1-PC	4
3 GB 160 Kb/s commercial 1-PC Full-time	31
6 GB 160 Kb/s commercial 1-PC Full-time	1
9 GB 160 Kb/s commercial 1-PC Full-time	1
3 GB 160 Kb/s commercial-Hours 1-PC	39
3GB 160 Kb/s Cafe-IP 5 to 9-PC	9
3GB 160 Kb/s Cafe-IP 10 to 14-PC	1
3GB 160 Kb/s Cafe-IP More than 14-PC	19
600 MB 64 Kb/s Home 1-PC	5
Total Number of Clients	2104

Each client is given a certain amount of bandwidth using several bandwidth management techniques. Also, many subscriptions have a pre defined amount of transferred data per month.

♦The WEB Server contains the web site of the company and hosted web sites for some individuals.

♦Domain Name System(DNS): DNS uses a hierarchical naming scheme known as domain names. The mechanism that implements a machine name hierarchy for TCP/IP is called DNS. DNS has two conceptual aspects: the first specifies the name syntax and rules for delegating authority over names, and the second specifies the implementation of a distributed computing system that efficiently maps names to addresses. DNS is a protocol that can be used in different platforms. In the Internet, the domain name space is divided into three different sections: generic domain, country domain and inverse domain. A DNS server maintains a list of hostnames and IP addresses, allowing computers that query them to find remote computers by specifying hostnames rather than IP addresses. DNS is a distributed database and therefore DNS servers can be

configured to use a sequence of name servers, based on the domains in the name being looked for[9]-[10].

♦Dynamic Host Configuration Protocol(DHCP) servers provide their usual tasks which allows both manual IP address assignment and automatic assignment. DHCP is based on the idea of a special server that assigns IP addresses to hosts asking for one[3].

The last issue to discuss in this section is the Service Level Agreement (SLA) of the system. It can be defined as the level of the services given to the user as given in the contract [6]-[7]. For the current system, SLA has the following criterion:

♦Average web page response time(Time needed to completely download a web page[8]) less than or equal to (14 sec.) for 80 % of the time.

♦The bandwidth given to a user is *full* for 80% of the time.

♦System (or network) failure rate (Availability) ≤ 12 day/year

3. SYSTEM MEASUREMENTS

In order to evaluate the performance of the installed system, various tests were made.

● Load Tests: different Load tests were implemented at different points on the network to give the maximum level of knowledge about the system. These points are: the satellite modem, content (http traffic) filter, Major Access Points(MAPs), a highly loaded local access point (AP4) and a lightly loaded access point (AP28). The data were collected for a year, month and day periods. The following remarks could be extracted from the these tests:

1. The yearly average value of the downloaded traffic occupy (58.5%) of the available (15 Mbps) bandwidth, while it consumes (60%) of the available (3 Mbps) upload bandwidth. This result indicates the possibility of successful future expansion which is expected due to the load increment throughout the year.

2. Http traffic occupies (85%) of the whole download bandwidth. Other applications are: file transfer applications (FTP), E-mail applications (SMTP), Domain Name Server Protocols(DNS) and Chatting protocols which share the remaining bandwidth.

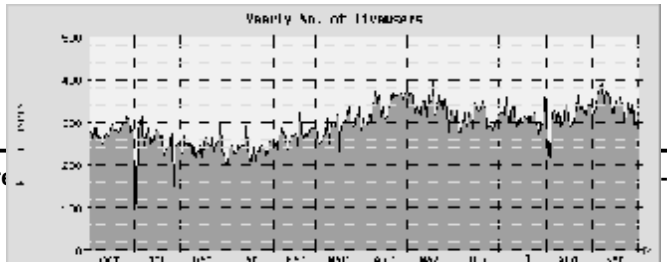
3. The resultant traffic load applied to the system changes periodically between a low load period (16% of the available download bandwidth, from 3 to 8 am) and high load periods(78% of the available bandwidth) for the rest of the day.

4. The game server traffic witnesses a notable increase during the summer holiday as compared to other seasons. Also, a similar daily load distribution to that mentioned earlier is noticed here.

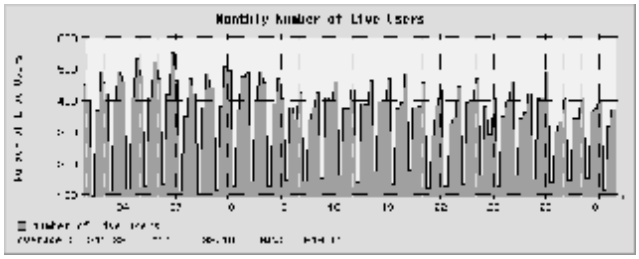
5. The traffic directed from the infrastructure network is gathered via the three major access points and forwarded to the ISP center. In addition to the traffic received from the major access point (MAP3), ISP center receives an extra load from some local access points connected to it directly.

6. The average throughput of the local access points indicates an average user throughput of (4 kbps).

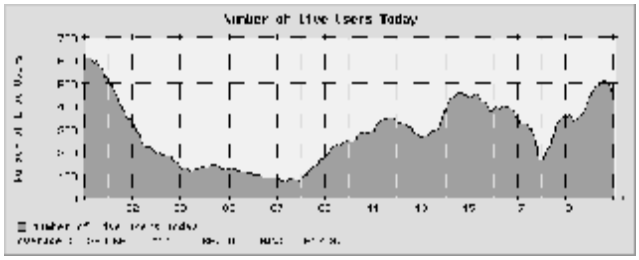
Not far from the above results is the statistical data gathered about the number of live (active) users of the system. This factor has a direct impact on the load applied to the network. Fig. (3) illustrates the number of active users during different time units.



(a)



(b)



(c)

Fig. (3): Number of Live Users: (a) Yearly (b) Monthly (c) Daily

●. Investigating users behavior: It was shown earlier that http is the internet major application and its traffic occupies most on the available bandwidth. This result gives a motive to discover the user behavior relating to this application. A better look to the users' activities in a typical work day could be created, as listed in table (3) below.

TABLE (3) : TYPICAL DAILY USERS ACTIVITIES

Average number of live users	**300 out of 2104**
Average downloaded data/day	**69.8 GByte**
Average downloaded data/user/day	**232.6 MByte**

Average number of TCP Connections/day	**4.77 M**
Average number of TCP connections/user/day	**15.9 K**
Average log time/user	**10 hours**

●Page Response Time: to complete the picture, another test is done, page response time. It can be defined as the time needed to completely download a web page from an HTTP server to the claimed client Yahoo web site is chosen to be the tested sample because of its popularity (it was the home page for 70% of the users) and the objects richness of its web pages. The purpose of this test is to assure system fulfillness to its service level agreement criteria mentioned earlier. The test procedure lasts for 24 hours and includes configuring one of AP4 (high load) clients to repeat the download operation of the page with and without the use of the cache server. The properties of the web page under test is listed in table (4) and the page response time is shown in Fig.(4).

TABLE (4): YAHOO WEB PAGE PROPERTIES

No. of Objects	**23**
No. of Image Objects	**17`**
No. of Java Script Objects	**4**
No. of Style Sheet Documents	**1**
No. of Flash Objects	**1**
HTML Code Size(kBytes)	**133**
Total Page Size(kBytes)	**566**

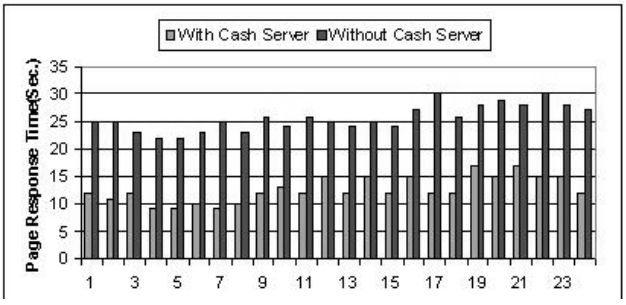


Fig.(4): Page Response Time Measurements

The average value of the page response time is (12.6 Sec.) when using cache server and (25.6 Sec.) without it. This is a clear indication to the importance of web cache technique and its great influence on the system performance. Also, Fig.(4) assures the ability of the WISP system to respond successfully to the SLA criteria.

5. CONCLUSIONS

This paper highlights the necessary steps to build an efficiently managed WISP system. It is important to take into consideration scalability issue, because the accurate plan prior to build the infrastructure network enhances system performance and allows a smooth future expansion. Also, the performance of the system could be greatly enhanced using proper system servers. The techniques used by these servers have influence on both optimizing the used bandwidth, minimizing page response time and free more bandwidth to the profit of the most important applications.

ACKNOWLEDGMENT

We thank AL MEHRAB for Internet and communications for the facilities provided during the preparation of this study.

REFRENCES

[1] Dixit S. and Prasad R.," Wireless IP and Building the Mobile Internet", Artech House, 2002.

[2] Kikta R., Michael A. And Courtney P. , "Wireless Internet Crash Course", McGraw-Hill Inc.,2002.

[3] Gutérrez J. , "Business Data Communications and Networking: A Research Perspective", IDeA Group Publishing, 2007.

[4] Camponovo G., and Cerutti D., "WLAN communities and Internet access sharing: a regulatory overview" , International Conference on Mobile Business, 11-13 July 2005 Page(s):281 – 287.

[5] Tang D. and Baker M., "Analysis of a Metropolitan Area Wireless Network", Proceedings of ACM MOBICOM, Seattle, WA, pp. 13-23, August 1999.

[6] Tang D. and Baker M., "Analysis of a Local-Area Wireless Network", Proceedings of ACM MOBICOM, Boston, MA, pp. 1-10, August 2000.

[7] Balachandran A., Voelker G., Bahl P., and Rangan P., "Characterizing User Behavior and Network Performance in a Public Wireless LAN", *Proceedings of ACM SIGMETRICS*, Marina Del Rey, CA, pp. 195-205, June 2002.

[8] Kotz D. and Essein K., "Analysis of a Campus-Wide Wireless Network", Proceedings of ACM MOBICOM, Atlanta, GA, September 2002.

[9] Bai G. , Oladosu K., Performance and Robustness Testing of Wireless Web Servers, M.Sc. Thesis, University of Calgary, September 2003.

[10] Narbutt M. and Davis M., "Experimental investigation on VoIP performance and the resource utilization in 802.11b WLANs", Proceedings 2006 31st IEEE Conference on Local Computer Networks, Nov. 2006 Page(s):397 – 403.

تصميم و تنفيذ مزود خدمة انترنيت لاسلكي مدار بشكل كفوء

د. قتيبة إبراهيم علي
جامعة الموصل

أحمد زهير سعيد
جامعة الموصل

المستخلص :

يتناول هذا البحث إجراء دراسة عملية معمقة و شاملة لمزود لاسلكي لخدمة الانترنيت. تم إجراء دراسة مستفيضة لتركيب النظام و دراسة خواصه لفترات زمنية مختلفة تراوحت مابين يوم إلى سنة لإعطاء أفضل تصور عن تصرف النظام. كنتيجة لعملية القياس , تم تحديد تأثير و مساهمة العوامل المختلفة المؤثرة على أداء النظام. الهدف من هذه الدراسة إعطاء صورة واقعية لتصرف الأنظمة من هذا النوع و تقديم منهجية لبناء أنظمة كفوءة من هذا النوع.