Performance Evaluation of a Campus HotSpot Network in Baghdad

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Abstract: Wi-Fi evolving towards increase throughput and reduce delay enables providing reliable and seamless internet in a public and private venue or what is addressed as hotspots. The widespread of internet paves the road for smart cities and E-government systems development. This includes the educational sector, where internet becomes an integral part of the educational process. Deploying wireless Local Area Networks (LANs) in university campuses helps to provide the students with knowledge and academic information. In this work, a site survey for a large scale WiFi network deployed in Baghdad University College of Arts campus is conducted in order to evaluate the network performance in terms of; coverage, interference, Quality of Services (QoS). The statistical results obtained from the walk test are used to overcome the main problems and suggest solution for performance enhancement.

Key words: Wi-Fi, IEEE 802.11n, Coverage, dead zone, hotspot, access point.

1. Introduction
The era of 5G wireless communication is materialized by Internet of Things (IoT) as its salient features. IoT refers to control and monitor remotely all devices via internet and moreover, these devices can communicate with each other and negotiate to organize their works efficiently providing of knowing smart cities. Smart City provides a high speed and reliable internet connection to the end users all over the city in order to increase their life quality. This requires deploying a highly dense and wide scale networks all over the city's enterprises, universities, hospitals and other public places (or what is known also as hotspots) to leverage information from different data sources at the city scale. The International Electrotechnical and Electronics Engineering Society (IEEE) has been established 802.11 group, which represents the routing protocol for wireless local area networks (WLAN) and based on WiFi technology [1]. WiFi networks are proved to be a valuable solution to get the full fitment of smart cities because of this technology features; high bandwidth, ease of installation, unlicensed band and economic infrastructure [2]. The evolving in WiFi technology offers a reliable internet connection. Nowadays WiFi Access Points (APs) are densely deployed and become an integral part of all business daily life. From other point of view, large scale WiFi networks could provide load balancing by taking off the load from 3G mobile network [3]. For all the above mentioned, many city governmental enterprises have been adopted such WiFi large scale networks and become the backbone for their daily business. At the higher education sector, many universities campuses employed these networks to provide various learning services for their students [4]. WiFi hotspot networks represent promising solution to provide a large number of users with the internet
services based on the latest 802.11 standards. As an example, IEEE 802.11n, is widely adopted due to its powerful features. It is designed to work with dual band (2.4GHz and 5GHz), aims to enhance IEEE 802.11 standard for higher throughputs equals to 600Mbps. Moreover, IEEE 802.11n utilizes MIMO (Multiple Input Multiple Output) often within to carry very high data rates. These two features enable 802.11n to handle highly loaded cells in crowded environment.

Verification the aims of hotspot networks start from these network installations, where the significant metric that evaluates the network performance is the coverage. Proper coverage of the network can be achieved by proper deployment of access points. Authors, in this paper, focus on determining the coverage problems of an already installed hotspot network in a university campus in Baghdad. By conducting a walk test employing WiFi tool analyzer at various locations in the campus, it is possible to identify weak signal areas and dead zones in terms of signal strength, interference and QoS.

WiFi hotspot networks have been widely adopted by the researchers to study, analyze and then enhance their performance from different points of view. The main aspect that must be considered first is how to provide the user with reliable signal strength. There are many researchers worked on enhancing the coverage of WiFi signal in a particular area. Others investigated the effective factors to be simultaneously optimized. Some of these works will be presented below:

In [5], Aashi Srivastava et al employed NetSpot software to measure WiFi signal strength in VIT, Pune campus. The authors analyzed the measured data all over the campus in order to determine the dead zone area over which the WiFi signal strength is weak. The authors also studied the wall effect in attenuating the signal strength. Several solutions are being proposed to enhance the coverage such as; redistributing the APs in optimal manner using particle swarm optimization (PSO), besides extending the coverage area based on repeaters deployment.

The assessment of WiFi network based on 802.11g deployed in industrial environment is presented in [6]. The assessment is based on comparing the collected data in terms of WiFi signal strength with the estimated one by adopting log-distance path loss model. The difference between experimental and theoretical values is depended to predict the interferences caused by machine crowded environment.

In [7], Siddhesh Shinde et al continuously measured the WiFi signal strength in a campus. The network coverage in indoor environment of two campus' buildings is analyzed in order to determine the existence of dead zone and suggest the techniques to the enhance Wi-Fi signal strength; study related to Wi-Fi signal strength of the college and its effects on the different access points available in campus. The author concluded that, omnidirectional nature of single antenna routers caused wastage of energy and also provided signal strength reduction in desired direction, so that dead zones could be eradicated, and signal strength could be evenly distributed throughout the campus based on directional antenna. Acrylic WiFi analyzer has being employed for collecting the data. In addition, the effect of students’ connections on the internet download speed was investigated.

The investigation of IEEE 802.11 protocol usage in different environment has been studied in [8]. Two different environments were adopted; inside and outside a university campus. The researchers analyzed the network traffic in terms of frame delivery for different application types and variant 802.11 protocol standardization (i.e. a/b/g/n/ac/ad). The results showed that, as limiting the retransmission ratio, the IEEE 802.11 protocol could be more efficient. In addition, it was concluded that the network traffic varies largely according to different users' applications in different environments.

Alessandro E. Redondi, et. al. in [9] analyzed the of traffic of technical university campus network. The analyses represent the traffic correlation at three levels, The analysis of WiFi traffic can give fundamental insights on how to optimize and manage the network and it can also reveal patterns on how the end users behave for each AP, for a set of APs and overall the campus network. A database was collected, and a supervised learning approach was proposed to classify the students according to their traffic. The students' attendance percentage and their classes technical types was being predicted based on spatio-temporal analysis of the WiFi traffic successfully with about 6-8% of errors.

Most of the researchers’ works investigate the wide scale networks performance from signal strength aspect only. In this paper, a large scale WiFi network deployed in Baghdad University College of Arts is adopted to evaluate its performance through conducting a walk test. Based on the
collected data, this work introduces a comprehensive study for identifying dead zones. This study not only concentrates on Wi-Fi signal strength as above-mentioned works, but also explains how other factors can affect the performance and may cause the loss of some of the important and critical information. The Wi-Fi signal strength, throughput and delay are represented by heat maps with statistical analyses to identify the weak signal areas and dead zones. Rest of the paper is organized as follows: comprehensive survey of Material and Software is presented in section II. Discussion in section is presented in section III, in section concluded in section IV, Finally the paper is Future Works V.

2. Material and Software
A real WiFi hotspot network is adopted in this work as a case study to characterize the peculiarity of Baghdad environment. A walk test by the aid of hardware and software tools is performed to evaluate the performance of a wide scale WiFi network. The network model and software used will be explained through next sections.

2.1. Network Model and Software Description:
A test bed is conducted for Baghdad University College of Arts WiFi hotspot network, which is located at Bab Al-Muatham neighborhood in Baghdad. The data collected through a walk test is in terms of Received Signal Strength (RSS), latency and throughput based on Acrylic software tool [10]. Baghdad campus houses the Departments; English Language, Arabic language, Psychology, Sociology, Geography and Geoinformatics Systems, History, Philosophy, Archaeology, and many research centers. The adopted WiFi hotspot network is installed by orient company for internet services. The network infrastructure provides data connectivity via the air fiber 2.4 GHz Point-to-Point Gigabit Radio (AF24) (broadband wireless backhaul radios). Four Ubiquiti NanoStation M2 - Wireless Access Point - (NSM2) are deployed in the campus outdoor. In addition, the fifth one is indoor installed as depicted by figure (1). Wi-Fi base stations runs with 802.11n in 2.4 GHz, 2x2 MIMO, and two spatial data streams, Power Supply 24v, 0.5A, (NSM2) base stations can offers theoretical 150 Mbps data speeds. Table (1) illustrates the APs characteristics and configuration. An active Wi-Fi site survey is performed by interacting with the network APs in order to obtain all information necessary to evaluate the performance such as; signal strength, bandwidth (transmission speed) and latency. In order to conduct Wi-Fi site survey, Acrylic software is employed. This software is a complete suite of WiFi analysis programs designed for providing wireless network coverage mapping and RF spectrum analysis. Moreover, Acrylic tool helps the network engineer to measure TCP and UDP throughput and latency between two end points by employing Iperf and Ping command [10]. In this work, the measured RSS is used to reflect the network coverage via heat map. Also, interference can be concluded from measuring the received RSS from all detected APs. While, bandwidth and delay are measured by uploading a file to the laptop on which the software will record all collected data at each test point on the survey root.

![Figure 1. Orient APs' locations in Baghdad University College of Arts](image-url)
Table 1. Wireless access points description

| BSSID     | F0:9F:C2:E2:E1 | F0:9F:C2:E2:E3 | F0:9F:C2:E2:E4:8D | F0:9F:C2:E2:E4 | B8:69:F4:13:05 |
|-----------|----------------|----------------|-------------------|----------------|----------------|
| BSSID     | R1:0F:C2:E2:E1 | R1:0F:C2:E2:E3 | R1:0F:C2:E2:E4:8D | R1:0F:C2:E2:E4 | R1:0F:C2:E2:E4 |
| Channel   | 2              | 4              | 2                 | 7              | 7802.11        |
| Frequency(MHz) | 2417          | 2427           | 2417              | 2442           | 2442           |
| VENDOR    | Ubiquiti Networks Inc. | Ubiquiti Networks Inc. | Ubiquiti Networks Inc. | Ubiquiti Networks Inc. | Routerboard.co m |
| SECURITY  | Open           | Open           | Open              | Open           | Open           |
| Article 1, ACCESS POINT # 5 | 2              | 4              | 3                 | 1              |
| OUTPUT POWER | 28dBm         | 28dBm          | 28dBm             | 28dBm          | default |
| ANTENNA   | Built-11dBi    | Built-11dBi    | Built-11dBi       | Built-11dBi    | 2.5 dBi |
| MAX TX RATE, MBPS | 144.4         | 144.4          | 144.4             | 144.4          | 54 |
| Frequency | 2.4GHz         | 2.4GHz         | 2.4GHz            | 2.4GHz         | 2.4GHz |
| Power Supply (PoE) | 24V, 0.5A   | 24V, 0.5A      | 24V, 0.5A         | 24V, 0.5A      | 24V, 0.5A |
| Location  | Outdoor        | Outdoor        | Outdoor           | Outdoor        | Indoor         |

2.2. Walk test Description:
In order to perform the network test bed, a map of Baghdad University College of Arts is uploaded to the adopted Acrylic software in the form of AutoCAD file. Then a survey root is determined around the campus' buildings as depicted in figure (2). 288 points represent the points where the data are collected, and the network is tested. The test points are separated by 1 meter and the data are measured by a laptop that was located at a height of one meter above the ground. The data is measured at four directions, then the average is stored in a data base for further analyses.

![Figure 2. Survey Root of walk test](image)

3. Results and Discussion
Network QoS addresses many important aspects such as; coverage, interference, throughput, latency and others. Network QoS is governed by many factors which can be generally classified into environmental effects and network configuration. Since environmental effects cannot be controlled, the internet service provider should introduce a reliable planned network which is convenient with the
area of interest specifications. In order to obtain the adopted WiFi network QoS, many tests were conducted in terms of coverage, interference, throughput and latency as will be explained through next sections.

3.1. Coverage Analysis:
WiFi coverage is materialized by a WiFi Signal Strength Indicator (RSSI) which must be more or equals to a predefined threshold value. From the result of walk test through the root survey depicted by figure (2), it is found that there are 5 APs, where each one covers a specific area of Baghdad University College of Arts. Figure (3) depicts the WiFi signal strength distribution through an area of 23834 m². The color bar indicates that the signal strength is ranged from the highest signal strength (-10 dBm) to the lowest signal strength (-91dBm ) as explained by figure (4) for each AP.

![Figure 3. RSSI heatmap](image)

![Figure 4. RSS range for each network AP](image)

It can be noticed from figure(4) that all the five APs average power all over the network area are ranged from (-60 dBm) to (-70dBm). Despite of equally transmitted power for all APs, the maximum RSS can be gained near the location of AP4 equals to (-10dBm). This of course relevant to environmental effect including the multipath effect. On the other side, the minmum RSS equals about (-90dBm) for all APs.

The WiFi coverage is usually classified according to the RSS which is the main factor to evaluate the network QoS as adopted by [11-12] and illustrated in table (2). According to these RSS levels, the adopted network QoS can be assessed as shown in figure (5). The analysis result shows the unplanned deployment of the network's APs. It can be noticed that about 35% of the covered area receives the best signal strength in the range of (-30dBm to -40dBm). On the other side, about 30% of the covered area receives unrelaible signal quality in the range below (-70dBm). Accordingly, most of the covered area
gained either high or low signal quality, which indicates the unevenly power distribution due to unproper APs deployment. The most important drawback point concluded from the coverage analysis is the existance of dead zone, where the WiFi signal is below the the receiver sensitvity, which is the least value required for internet connection as dipected by figure (3).

Table 2. Signal Strength Quality for Each RSS level

| RSS  | Signal Strength Quality                                      |
|------|-------------------------------------------------------------|
| -30dBm | Signal strength is very strong, you are most likely standing in front of an access point (AP). |
| -40 dBm | Signal strength is not strong.                             |
| -50 dBm | Signal strength is excellent.                              |
| -60 dBm | Signal strength is good and reliable.                      |
| -67 dBm | Signal strength is reliable.                               |
| -70 dBm | Signal strength is not strong.                             |
| -80 dBm | Signal strength is unreliable as it will not suffice for most services. |
| -90 dBm | The chance connection at this level is very low.           |

Figure 5. Coverage percentage in terms of signal quality

Another metric to quantify the WiFi coverage is by assessing the network in terms of APs overlapping as depicted in figure (6) and analyzed in figure (7). It is obviously shown that about 40% of the covered area (at the university boundaries) senses only one AP signal which result in 0% overlapped. 20% of the APs overlapped is covered about 37% of the campus area, which means only two APs signals can be sensed across this area. Three APs are overlapped over 20% of the covered area and finally only about 3% of the area can received 5 WiFi signals.
3.2. Interference Analysis:
Wireless networks are prone to different types of interference such as; Co Channel Interference (CCI) and adjacent Channel Interference (ACI). CCI is sensed at the part of the network area which receives signals from two or more APs utilize the same channel. If the difference between these two signals are not at an acceptable value, a sever signal distortion will be occurred and hence the connection is lost. The other Type, ACI results from the overlapping between two or more signals working at different but overlapped channels. For the adopted network, the coverage area of five APs work at three channels (2, 4, 7) (which are overlapped as defined by 802.11n standard) is analyzed. Figure (8) explains the channel overlapping taken into account all APs in the adopted environment including the indoor private APs detected by the Acrylic software. The simulation results are analyzed at the cost of 20dBm (assumed as threshold value). In term of CCI the result show that, channel 2 is provide the significant interference area which is distributed over 21% of the covered area followed by channel 7 with 15% of the covered area. While, channel 4 has the least CCI equals to 0.6% of the coverage area. Since channel 4 and 7 are the most widely utilized and overlapped, this led also to ACI between them over 19% of the covered area as depicted by figure (10). A small portion of covered area equals to 3% is also prone to ACI between channel 2 and channel 4.
3.3. **Network Services Quality Analysis:**

**Figure 8.** Orient network Channels overlapped

**Figure 9.** Co Channel interference analysis.

**Figure 10.** Adjacent Channel interference analysis.
WiFi network service quality means providing end user with reliable signal in order to maintain continuous network connection and high-speed internet services. Service quality is governed by three major factors which are; signal strength, bandwidth grantees, and latency as explained in [12] and [13], which are based in this work to analyze the network performance. In order to quantify the services of the adopted network, Figure 11 and Figure 12 are obtained through walk test to present the network performance in terms of latency and bandwidth. The statistical analyses for the above-mentioned factors are depicted in Figure 13. It can be shown that, about 55% of the network-covered area can serve students with voice and light video streaming at signal strength threshold equals to (-67dBm). Moreover, browsing service can be offered over about 90% of the covered area. In addition, in terms of latency, the voice and light video streaming can be offered for 50% of the covered area, while data services is distributed over 89% of the covered area. From the bandwidth point of view, about 29%, 38% and 89% of the covered area can support video, voice and data services respectively. As a result, each user location must satisfy all above-mentioned ruling factors (signal strength, bandwidth grantees, and latency). Accordingly, at moderate load, the network can offer 20%, 30% and 89% of its coverage for video, voice and data services respectively.

Figure 11. Orient network latency.

Figure 12. Orient Wi-Fi network Bandwidth
4. Conclusions
In this work, a large scale WiFi network deployed in Baghdad University College of Arts campus is adopted as a case study to evaluate the network performance. The evaluation is based on statistical results obtained from the walk test in terms of; coverage, interference, QoS. Based on the walk test measurements it can be concluded that the most of the covered area gained either high signal quality (-30dBm over 35% of the covered area) or low signal quality (less than -70dBm over 30% of the covered area). This indicates the unevenly power distribution due to the unplanned APs deployment. In terms of CCI, the result shows that, channel 2 is prone to the significant interference which is distributed over 21% of the covered area. On the other side, the highest ACI is noticed between channels 4 and 7 over 19% of the covered area. Finally, signal strength, bandwidth grantee and latency are based to quantify the services of the adopted network. It can be concluded that 20%, 30% and 89% of the coverage area can provide the user by video, voice and data services respectively.

5. Future Works
A relay station (RS) is a low-cost alternative to upgrading a conventional communication infrastructure, hence a Relay Stations (RSs) are suggested. To satisfy the stringent requirement of capacity enhancement in wireless networks and coverage area of a Base Station (BS) can be extended by RSs. taking into account the frequency reuse concept and the inter-cell interference. Moreover, the access point settings may be modified to reduce different types of interference such as Co Channel Interference (CCI) and adjacent Channel Interference (ACI).

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