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Performance Evaluation of WirelessLocal Area Network

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ABSTRACT

The enormous growth of public mobile communications and the tendency to provide similar wireless services in indoor environment reacts on the activities in the area of wideband wireless local access, and Wireless Local Area Networks (WLAN) architectures and protocols. The IEEE 802.11 WLAN standard has been developed to provide high bandwidth to mobile users in a short-range indoor environment. Apart from mobility, it should provide some QoS guarantees, for certain set of services.

In this paper, wireless computer network was constructed and analyzed according to standard IEEE 802.11b with its two channel rates 1Mbps and 11Mbps using OPNET IT Guru Simulator. The physical layer at the radio-interface supports three different coding techniques: Frequency Hopping Spread Spectrum (FHSS), Direct Sequence Spread Spectrum (DSSS) and Infrared (IR). The present model considers DSSS coding.

The system utilizes the behavior of the IEEE 802.11b WLAN within single Basic Service Set (BSS). The BSS consists of 5-20 stations, which is a reasonable size of the WLAN. Each station performs access to the network using the Distributed Coordination Functionality only.

The observed performance measures are defined as follows:

- Throughput is the average number of successfully transmitted bits per second.

- Delay is defined to be the elapsed time between the moments of packet arrival at the station queue and positive acknowledgment reception for the corresponding frame, averaged over all successfully transmitted frames.

It is concluded that, the simulation's results show that the model performs as expected and demonstrates the performance of different traffic types under different network configurations for the selected workload.

1. Wireless Local Area Network Technologies

WLAN indicates a grouping of network components connected by electromagnetic (radio) waves instead of wires. WLANs are used to augment or replace wired computer networks, adding flexibility and freedom of movement within the workplace [1]. The WLAN base standard, IEEE 802.11, is divided into two layers: The Medium Access Control (MAC) layer which defines WLAN access methods and Physical (PHY) layer. The MAC protocol may be fully distributed or controlled by a central coordination function housed in the access point. The Point Coordination Function (PCF) is an optional extension to DCF. It is only useable in infrastructural operation mode. PCF has lower transfer delay variations to support Time Bounded Services [2, 3]. Fig. 1 shows the IEEE 802.11 protocol architecture.

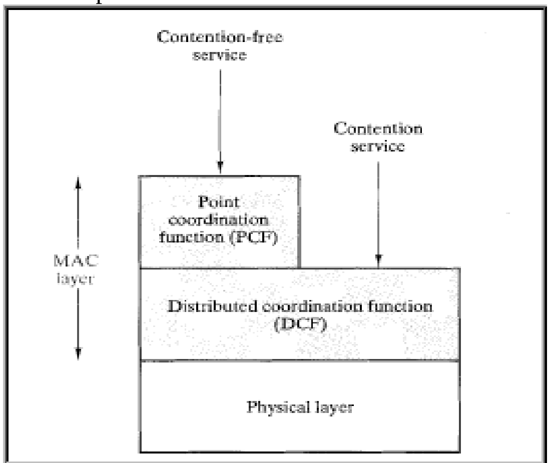

Figure (1) IEEE 802.11 protocol architecture.

The Physical (PHY) layer has the Spread Spectrum specification. It is designed to modulate a signal for transmission, to avoid interference from licensed and other non-licensed users, and to avoid noise [4]. IEEE 802.11 defines three physical characteristics for wireless LAN systems: Diffused Infrared (IR), Direct Sequence Spread Spectrum (DSSS), and Frequency Hopping Spread Spectrum (FHSS) [5]. WLAN has two operation modes: infrastructure mode and ad-hoc mode. The 802.11 networks are flexible by design. There are three types of WLAN topologies [6]:

1. Independent basic service sets (IBSSs)
2. Basic service sets (BSSs)
3. Extended service sets (ESSs)

A service set is a logical grouping of devices. WLANs provide network access by broadcasting a signal across a wireless radio frequency (RF) carrier. A receiving station can be within range of a number of transmitters. The transmitter prefaces its transmissions with a service set identifier (SSID). The receiver uses the SSID to filter through the received signals and locate the one it wants to listen to [6].

- IBSS

An IBSS consists of a group of 802.11 stations communicating directly with one another. An IBSS is also referred to as an ad-hoc network because it is essentially a simple peer-to-peer WLAN. Fig.2 illustrates how two stations equipped with 802.11 network interface cards (NICs) can form an IBSS and communicate directly with one another [3].

- BSS

A BSS is a group of 802.11 stations communicating with one another. A BSS requires a specialized station known as an access point (AP). The AP is the central point of communications for all stations in a BSS. The client stations do not communicate directly other client stations. Rather, they communicate with the AP, and the AP forwards the frames to the destination stations. The AP might be equipped with an uplink port that connects the BSS to a wired network (for example, an Ethernet uplink). Because of this requirement, a BSS is also referred to as an infrastructure BSS. Fig.3 illustrates a typical infrastructure BSS [3].

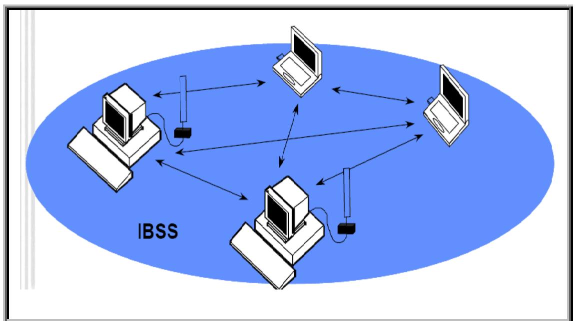

Figure (2) IBSS

- ESS

Multiple infrastructure BSSs can be connected via their uplink interfaces. In the world of 802.11, the uplink interface connects the BSS to the distribution system (DS).

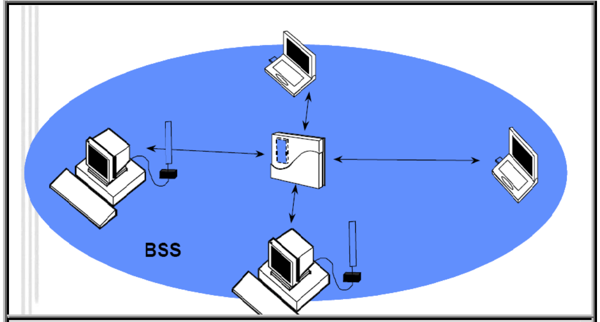

Figure (3) BSS

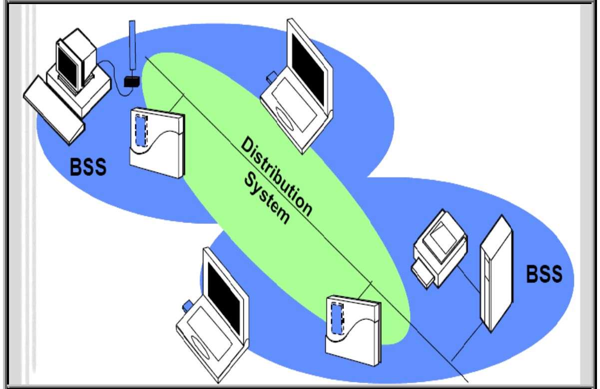

Figure (4) ESS

The collection of BSSs interconnected via the DS is known as the ESS. Fig.4 shows a practical implementation of an ESS. The uplink to the DS does not have to be via a wired connection. The 802.11 specification leaves the potential for this link to be wireless. For the most part, DS uplinks are wired Ethernet.

A set of wireless LAN standards has been developed by the IEEE 802.11 committee [3] as shown in table 1.

2. 802.11 LAN Medium Access Mechanism

802.11-based WLANs use a mechanism known as carrier sense multiple access with collision avoidance (CSMA/CA). CSMA/CA is a listen before talk (LBT) mechanism. The transmitting station senses the medium for a carrier signal and waits until the carrier channel is available before transmitting. If the node question finds that the medium is free, then that node will begin transmission [3].

CSMA/CA algorithm also mandates a delay between contiguous frame sequences. Transmitting node will make sure that the medium is idle for this required duration. Nodes will each select a random back-off interval to initialize a counter, and will decrement this counter while the medium remains idle [4].

The time interval between frames is known as the Inter Frame Space (IFS). Once node has determined that the medium is idle, two IFSs (Distributed IFS and Short IFS) defined, to provide delays between sending and receiving RTS, CTS, DATA and ACK packets [7]. The way CSMA/CA works is illustrated through the diagram shown in Fig.5. When a node needs to transmit a DATA packet, and it detects that the medium is idle, it will first broadcast a small packet called a Request To Send (RTS) packet. The RTS packet contains relevant information for the destination node. The receiving node, if it is within range, will wait SIFS units of time, and then respond to the sender with another small packet called Clear To Send (CTS).

Table 1 IEEE 802.11 wireless LAN standards

WiFi	Speed	Frequency Range	Modulation Method
802.11b	11 Mbps	2.4 GHz	HR-DSSS: High Rate Direct Sequence Spectrum
802.11a	54 Mbps	5 GHz	OFDM: Orthogonal frequency division Multiplexing
802.11g	54 Mbps	2.4 GHz	OFDM

The CTS packet indicates that the intended recipient of the data is both within range, and ready to receive data. Upon receipt of the CTS packet, the sender waits another SIFS unit of time before sending the DATA packet. Once the receiver has heard the DATA successfully, it will wait SIFS units of time, and then send an (ACK) Acknowledgement packet back to the sender. If the sender does not receive an ACK before a set timeout interval, it will try again by sending out another RTS packet. If a node is within range of the sender, hears an RTS packet, and is not the intended recipient, it will refrain from sending DATA or RTS packets for a random period of time, known as the back-off interval. This is done to prevent packet collisions within the network [6, 7, 8].

3. NETWORK SIMULATION

In the last decade the simulation became a powerful approach for analyzing and design of complex network systems. According to simple definition the simulation is the imitation of the real process or system over the time. The behavior of a network system is studied by developing a simulation model. The one is a physical, mathematical, or logical representation of network processes and systems [9,10]. A simulation model presents a set of assumptions about the network behavior.

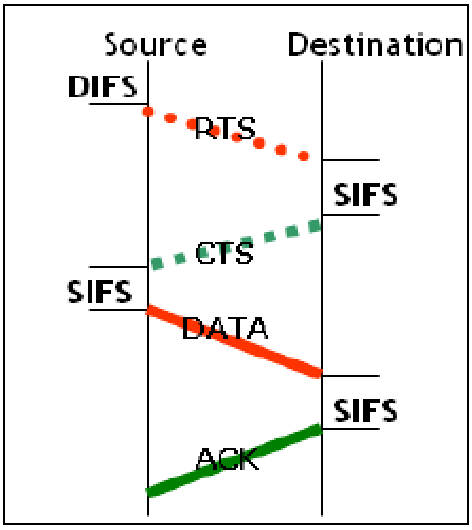

Figure (5) Collision avoidance using the RTS and CTS frames

Generally, there are two forms of network simulation: analytical modeling and computer simulation [11]. The first one uses mathematical analysis to predict the effect of changes to the existing systems or to investigate the performance of the new systems under different circumstances. The main disadvantage of this approach is that many real network systems are so sophisticated and they cannot be presented by a set of equations. In edition to this, the analytical modeling is inappropriate to simulate the dynamic nature of a network. In this instance, the investigation of the system behavior over time always requires a computer simulation.

With computer simulation approaches to performance evaluation, network systems can be modeled with almost any level of detail desired and the design space can be explored more finely than is possible with analytical-based approaches or measurements. Computer simulation can combine mathematical and empirical models easily, and incorporate measured characteristics of network devices and actual signals into analysis and design [12].

The network simulators are one of the most complex software tools that provide comprehensive development environment for simulation and performance analysis of communication networks. The main advantages of the simulators can be summarized in the following points [10]:

- Simulators enable the study of complex network systems;
- The effects of information and environmental changes on the model's behavior can be analyzed;
- Simulators can be used to verify analytical models;
- Simulators are appropriate tools for test interoperability between network nodes;
- Network Simulators can be used with pedagogical purposes for training new operators, administrators, and users that can experiment in a simulated environment knowing that their mistakes couldn't cause any problems.

The above considerations show that network simulators are appropriated tools to obtain adequate information on functionality and performance of communication networks and protocols [10]. Some examples of Network simulators include: OPNET, REAL, INSANE, NetSim, Maisie, BONES, NESSY, TOPNET, NETMOD [11].

4. OPNET Simulator

OPNET (Optimized Network Engineering Tool) is a simulation tool for analyzing communication networks. The model description is done hierarchically. The user of OPNET graphically specifies the topology of his network which consists of nodes and links. Each node includes processors, queues, and traffic generators. The user also has to describe the data flow between components in a node. Finally, the behavior of each process is described using state diagrams. OPNET provides a comprehensive development environment for the specification, simulation and performance analysis of communication networks. A large range of communication systems from a single LAN to global satellite networks can be supported. Discrete event simulations are used as the means of analyzing system performance and their behavior. OPNET can simulate a wide variety of different networks which are linked to each other [11].

5. Simulating IEEE 802.11b using OPNET IT Guru

This section shows the constructing and analyzing the wireless local area network according to standard IEEE 802.11b after the installing and the activation of OPNET IT Guru - 1997 academic version.

Two scenarios were built to construct the WLAN within the office range of scale 100mx100m, the first one for the data rate 1Mbps and the second for 11 Mbps. Meanwhile, the rest of the network variables were kept on assumption variables except the type of modulation which was changed to Direct Sequence.

The network consists of one server, an Access Point, and variable number of workstations (from 5 to 20).

After adding traffic to the network by setting application(s) the network works on it like Web Browsing, File Transfer, Email, etc.., every station in this LAN can communicate directly with each other. However transmission medium degradations due to multipath fading or interference from nearby BSSs reusing the same physical-layer characteristics can cause some stations to appear 'hidden' from other stations. In this simulation, WLAN constructed with only one BSS, a clean channel without errors and fading effects etc., and a static configuration of nodes, so all stations can indeed communicate directly with each other. At each station, a Poisson process simulates the arrival of frames for transmission. Fig. 6 shows the constructed network.

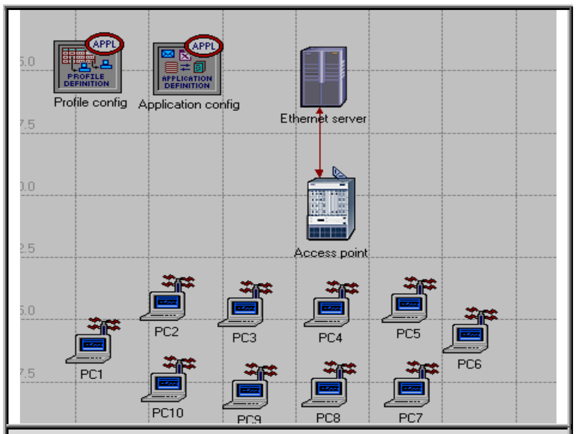

Figure (6) the constructed IEEE 802.11b WLAN

After adding the traffic to the network, some of the important global statistics were chosen (Delay and throughput statistics) to analyze the network behavior.

6.Results and Discussions

Fig. 7, Fig. 9, and Fig. 11 show that the throughput increases with increasing load until it reaches a maximum value then remains unchanged for relatively high offered loads; such throughput stability is result of the implementation of the Binary Exponential Backoff procedure. Actually, the station queue in each station equalizes the throughput for moderate and high traffic loads. At low loads, the curves also coincide because there are almost no collisions.

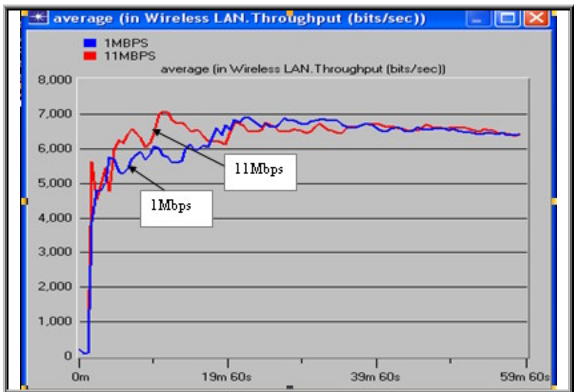

Figure (7) The average throughput for data rates 1&11Mbps with (5) stations

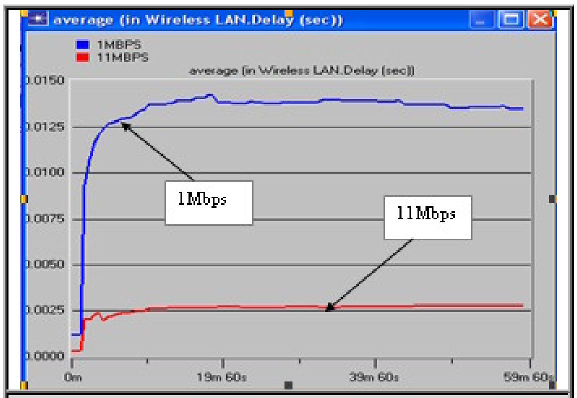

Figure (8) The average Delay for data rates 1&11Mbps with (5) stations

It is evident from Fig. 8, Fig. 10, and Fig. 12 that the delay increases dramatically as the maximum throughput is reached. For relatively low throughput, which is at low offered load, delay is estimated to be several tens of milliseconds. Delay dramatically increases as the throughput reaches its upper ceiling.

Certainly the performance characteristics for 10 stations would be different than that for 20 stations, all stations are contending for access to the medium. As more stations are added to the simulation the probability that two or more stations will calculate the same backoff window is increased. Thus, the chance for collision increases.

Finally, it is obviously seen from the figures obtained that the higher transmission speeds yielded lower average throughput and delay results.

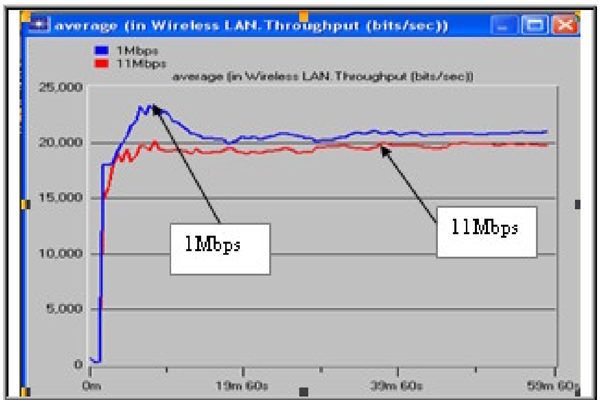

Figure (9) The average throughput for data rates 1&11Mbps with (15) stations

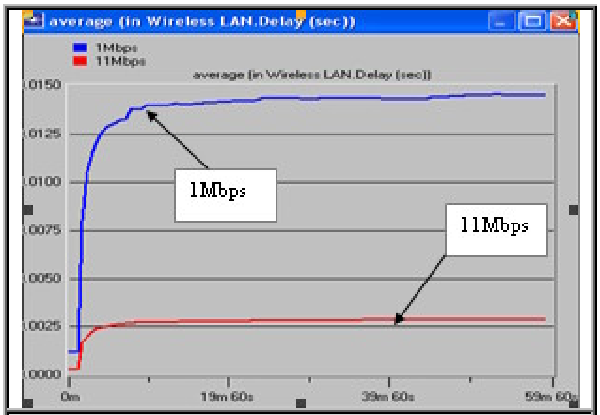

Figure (10) The average Delay for data rates 1&11Mbps with (15) stations

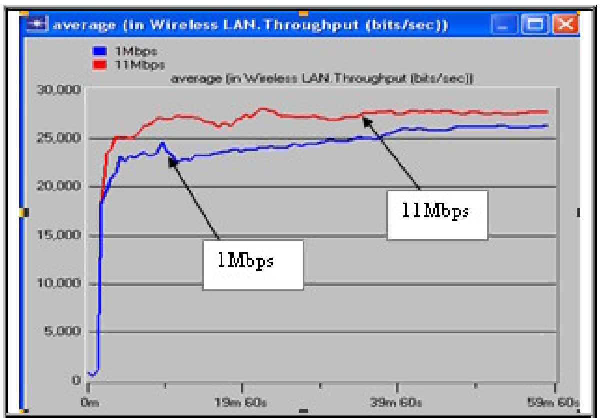

Figure (11) The average throughput for data rates 1&11Mbps with (20) stations

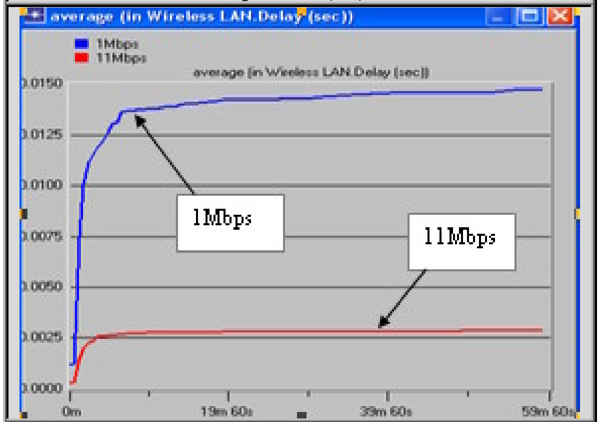

Figure (12) The average delay for data rates 1&11Mbps with (20) stations

7. Conclusions

The work presents a simulation study that considers how the main network parameters (packet delay, throughput, network speed, and number of network nodes) affect the Wireless LAN performance. The simulation results will help administrators make well-informed decisions on how to manage Wireless LAN networks and fine-tune the network parameters.

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الخــــــــــــلاصة:

ان النمو المتزايد لاستخدم الاتصالات العامة المتنقلة و كذلك الميل لتوفير خدمات لاسلكية مماثلة في بيئة داخلية تفعَل النشاطات في استخدامات الحزم العريضة اللاسلكية المحلية و معمارية و بروتوكولات استخدام الشبكات الاسلكية (WLAN).
ان مواصفات IEEE 802.11 WLAN قد طورت لتجهيز مستخدمي الحاسبات المحمولة بسرع عالية في بيئة داخلية ذات مدى قصير و اضافة الى خاصية التنقل يجب ان تعطي بعض الضمانات لجودة الخدمة (QOS) لنوع معين من الخدمات.
لقد تم في هذا البحث انشاء شبكة حاسبة و تحليلها حسب المواصفات IEEE 802.11b بسرعتين 1 ميغابت في الثانية و 11 ميغا بت في الثانية و باستخدام المحاكي OPNET IT Guru. ان الطبقة الفيزيائية للتداخل الراديوي تدعم ثلاث تقنيات مختلفة للتشفير : Frequency Hopping Spread Spectrum (FHSS), Direct Sequence Spread Spectrum (DSSS) and Infrared (IR). ان النموذج الحالي يعتمد على مبدأ DSSS. وان النظام يستخدم سلوك IEEE 802.11b WLAN من خلال مجموعة خدمية واحدة (BSS). تحتوي هذه المجموعة على 5 الى 20 محطة والتي تشكل حجما معقولا للشبكات المحلية اللاسلكية. ان كل محطة تستطيع الوصول الى الشبكة بأستخدام تقنية تنسيق الوظائف الموزعة فقط (Distributed Coordination Functionality).
ان معايير الاداء التي يجب ملاحظتها هي:
سرعة الوصول (Throughput): و هي معدل عدد البتات التي ترسل بنجاح في الثانية الواحدة.
وقت الارسال (Delay): يعَرف بالزمن المستغرق بين لحظات و صول البيانات في طابور الحاسبة و الايعاز بالاستلام الايجابي للبيانات بالمعدل الكلي للبيانات الناجحة الارسال.
ان انتائج المحاكاة تبين بأن النموذج المستخدم يعطي الاداء المتوقع و يوضح الاداء لانواع السير المختلفة تحت شبكات مختلفة التصميم للاحمال المختارة.