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PERFORMANCE ANALYSIS FOR WIRELESS G (IEEE 802.11G) AND WIRELESS N (IEEE 802.11N) IN OUTDOOR ENVIRONMENT

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ABSTRACT

This paper described an analysis the different capabilities and limitation of both IEEE technologies that has been utilized for data transmission directed to mobile device. In this work, we have compared an IEEE 802.11/g/n outdoor environment to know what technology is better. The comparison consider on coverage area (mobility), throughput and measuring the interferences. The work presented here is to help the researchers to select the best technology depending of their deploying case, and investigate the best variant for outdoor. The tool used is Iperf software which is to measure the data transmission performance of IEEE 802.11n and IEEE 802.11g.

Keywords: 802.11g, 802.11n, performance comparison, throughput, coverage area, interference.

INTRODUCTION

The common set of implementing WLAN is the IEEE 802.11 standards. Positive growth of mesh network deployments that currently based on Wi-Fi technology shows that human nowadays depends on a wireless network. Previously, the best available data speeds being dominating by 802.11a, -b or -g standards reach data rates of 54 Mbps. However, over the past year, the arriving of new standard of 802.11n technology has become industry, manufacturer, media and consumer discussion and debate. The positive acceptance of 802.11n Wi-Fi in the enterprise and consumer markets is increase rapidly, with many customers changing older networks to meet new standards [1]. However, well planning wireless network is needed in order to deliver full coverage WLAN which offers, the flexibility to consumer and equipment and in expanding wireless devices in a future. Usually, an IEEE 802.11 standard is chosen based on their bandwidth and their coverage area. Sometimes there are cases where the best technology is not the latest one for indoor or outdoor environment installation [2]. One of the major issues in Wireless Local Area Network (WLAN) is the changes of physical environment [3]. This paper concern in comparing IEEE 802.11/g/n outdoor environments to know what technology is better. This comparison will look through the coverage area, throughput and measuring the interferences between channels. Several works in [2] [8] [9] have empirically investigated each one of them providing their drawbacks and benefits. But, it is not practical to model all wireless coverage area for each site when we are setting up a WLAN [6]. Moreover different 802.11 variants (a, b, g and n) provide different coverage areas and even, different signal strength inside the coverage area. The work presented here is to help researchers to select the best technology depending on their deploying case, and investigate the best alternative for outdoor between 802.11g and 802.11n.

BACKGROUND

Demand for more bandwidth access and wireless LAN equipment has experienced a phenomenal growth in recent times. The growing deployment of protocols from the Wi-Fi alliance is helping consumers take advantage of new electronic application such as VOIP telephony or video streaming. Officially known as 802.11n and often referred to as "Wireless N," this standard from the Wi-Fi (Wireless Fidelity) alliance paves the way for blazing fast high definition video and data. It is a new standard that promises both higher data rates and increased performance. This N wireless standard has also the ability to have up to four simultaneous streams of high-definition video, voice and data. It also promises easy backward compatibility which means new devices will work smoothly with older product.

Unlike wireless G (802.11g), the Wireless N (802.11n) standard promises more bandwidth and high throughput to help consumers and businesses benefit from the Voice over IP (VoIP) technology. It is evidently known that huge amount of moneys can be saved on long distance calls trough VoIP as against traditional telephony, which is why individuals and corporate businesses are leered into using wireless N today and also migrating from existing wireless G to wireless N.

The 802.11n standard is a successor to the 802.11g Wi-Fi protocol and therefore offers an improvement such as speeds of up to 54 Mbps. 802.11n supports much faster wireless connections over longer distances. The most important addition is the multiple-input multiple-output (MIMO) capability, alternatively called. MIMO allows for multiple antennas to resolve more information more quickly and improves the reliability, range and performance of connection that is almost close to Ethernet quality. This means users can get at least six (6) times the speed of Wireless G with Wireless N and high definition video can be transmitted across multiple rooms in large house with just a single access point. MIMO also increases the performance of 802.11g present on a network. Chips like WCN 1320 that do this are available in Wireless N routers and set-top boxes. Another helpful feature is the inclusion of an intrusion detector on the Buffalo wireless-N-infinity; which constantly looks for unwanted attempts at accessing the network and once found, alerts you to those attempts.

Orthogonal frequency-division multiplexing OFDM implementation is a major change to the physical layer of 802.11n to improve performance. By adapting the way it is set-up, the data rate can be increased from 54 Mbps for 802.11a/g to 65 Mbps. Antenna technology associated with 802.11n have been significantly improved by the introduction of beam forming and diversity. Beam forming focuses the radio signals directly along the path for the receiving antenna to improve the range and overall performance whiles diversity uses the multiple antennas available and combines the best subset from a larger number of antennas to obtain the optimum signal conditions. 802.11n comes with an optical mode chips that runs using a double sized channel bandwidth. 802.11g used 20MHz bandwidth whilst 802.11n has an option of using 40 MHz. The backward compatibility of Wireless N is removed when all the devices operating on the network are 802.11n standard, thereby removing overheads that are not required and consequently maintaining maximum efficiency. This feature is reinstalled when earlier devices such as 802.11b and 802.11g are joined to the network. Wireless N offers a considerable advantage when operated on a network with older standards.

IEEE 802.11n

IEEE 802.11n is a proposed amendment to the IEEE 802.11-2007 standard [10] to improve the network performance of the previous 802.11a/b/g with the adding of Multiple-Input Multiple-Output (MIMO) and binding of network interfaces (Channel Bonding). It works on 2.4 GHz or 5.0 GHz frequency band. In order to optimize the theoretical maximum rate of 600 Mbps of data transfer, it also adds frames to the MAC layer. Moreover, it increases system performance by using MIMO multiple transmit and receive antennas. However, this technology increases the implementation costs compared to the systems without MIMO technology because it requires a separated radio-frequency chain and an analog to digital converter for each MIMO antenna [2]. 802.11n access points are expected to have less range than 802.11b and g models, so organizations must consider whether the extra speed is worth the expense of the additional APs needed to provide coverage.

IEEE 802.11g

In 2003, IEEE 802.11g was introduced in the market. It is an evolution of IEEE 802.11a and IEEE 802.11b. It works on 2.4 GHz frequency band and it is compatible with IEEE 802.11b. Its theoretical transfer is 54 Mbps, although it is reduced to 22 Mbps when the receiver is some meters far from the AP in a real scenario. The modulation scheme used in 802.11g is orthogonal frequency-division multiplexing (OFDM). In this standard, there is also a speed decrease according to the signal quality. IEEE 802.11g suffers from the same interference as IEEE 802.11b and other 2.4 GHz range devices. IEEE 802.11g may seem to be the competence of 802.11a, but it delivers the bandwidth advantages of 802.11a without the range and reliability limitations of 5 GHz technology [2]. 802.11g is more mature than 802.11n and more proven in industrial. Table below summarizes the main characteristics of the IEEE 802.11 standard:

Table-1. Wireless standard comparison.

	IEEE 802.11g	**IEEE 802.11n**
Date release	June, 2003	October,2009
Technology	OFDM (orthogonal frequency division multiplexing)	OFDM/MIMO(Multi input Multi output)
Frequency Band	2.4	2.4(backward compatible)/ 5.0 (for 802.11n only)
MIMO stream	1	1,2,3 and 4
Channels width	20MHz	20/40 MHz
Maximum data rate	54Mbps	600Mbps
Range	Indoor: 38 meters or 125 feet Outdoor: 140 meters or 460 feet.	Indoor: 70 meters or 230 feet Outdoor: 250 meters or 820 feet
Channels	3	14

MEHODOLOGY

In this section, we described the scenario where the measures have been taken and the hardware and software used to perform our research. In order to keep testing between all the sample tests obtaining any advantages over each other based on location, orientation,

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it was required that the following conditions were met before testing could begin:

- Each computer must be placed in the same spot and follow the strict orientation guideline. The PCs are situated at a distance of approximately 1 m from the AP which is associated to.
- In this simulation, it was taken into consideration the principal difference between 802.11g and 802.11n, i.e. MIMO and the option of 40 MHz channel instead of 20 MHz. The experiment was performed using 2.4 GHz frequency spectrum which is compatible to both standards (802.11n and 802.11g). Three location distances of 50, 100, 150, 200, 250 and 300 meter were selected. In each location, files were sent from one point to another with the client devices, each time measuring the speed and the throughput.

Table-2. Description of experiment.

Activity	File sharing between client and server and copying 8.61GB file from server to client
Software used	Iperf on both client and server
IP address Client	192.168.1.101
IP address server	192.168.1.100
Internet	Internet was disconnected along the test to ensure the accuracy result

Place of measurements

Testing was conducted in a 968256 square foot field environment with a mix of walled houses.

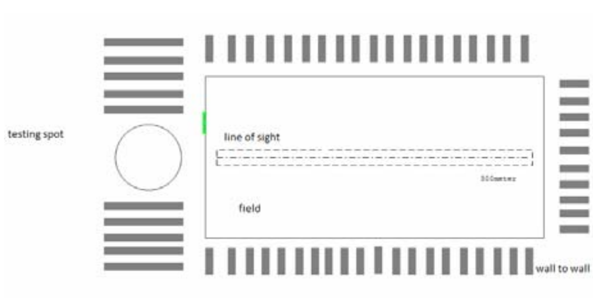

Figure-1. Experiment location.

Hardware used in the test bench

2 mobile devices (laptops), 1 Wireless Modem Routers and 1 USB Wireless Network

Table-3. Mobile device (laptops) description.

Brand	ASUS K40AE Series (server)
RAM	1024MB
Processor	Sempron M120
OS	Window 7
Standard	802.11g (plus USB wireless N)
Brand	ASUS N82Jq (client)
RAM	DDR3 1066 MHz SDRAM,
Processor	Intel® Core™ i7 Processor 720QM
OS	Window 7
Standard	802.11b/g/n

Table-4. Wireless modem router description.

Standard	ANSI T1.413, ITU G.9992.1/ G.992.2/ G.992.3/G.992.5, I.EEE 802.3/802.3u,IEEE 802.11b/g/n
Interfaces	1 RJ11 line port, 410/100M RJ45 Auto MDI/MDIX LAN ports
Frequency Ranges	2.4~2.4835GHz (Backward Compatible)
Wireless Data Rates	Up to 300Mbps
Antenna Type	Detachable, RP-SMA Connector (omni-directional)
Security	WEP/WPA/WPA2 encryptions, SSID Control, Built-in Firewall, MAC/IP/URL Filter
Advanced Features	Support up to 10 IPSec VPN Tunnels
LED	Power, Internet, ADSL, WLAN, 1, 2, 3, 4

Software used

Iperf is a simple server-client based tool for measuring TCP and UDP performance between two endpoints. By running the Iperf software on two computers over a network, data flows are sent between the computers and measurements returned regarding the performance between the endpoints. These measurements are then useful to identify how a network will perform for a specific application. There are Iperf versions for UNIX, Linux, BSD, MAC OS X, and Solaris. The Windows application is a simple executable run from the command line, thus no software has to be installed or configured [5].

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MEASUREMENT DESCRIPTION

Coverage Measurement

Quality of the transmission depends on distance and other factors. The further a device is from its access point, the weaker the signal it can send and receive and the lower the physical rate that it can reliably achieve because the frame error rate increases as the distance increases. The measurement will be conducted by transmitting data in difference distance up to 300meter with ignoring interference factor.

Interference Measurement

Interference test is a test to analyze the impact of 802.11g and 802.11n to interference. In this case we use IEEE 802.15.4 which utilizes same 2.4GHz band like 802.11g and 802.11n. Due to supporting same complimentary applications, they are likely to be collocated within the interfering range of each other. WLANs on the other hand are striving to achieve the increasing higher data rate demand and its performance under the interference from such networks needs to be evaluated. The problem here is that a lot of the 802.11n and 802.11g adapters are only the 2.4 GHz range. This means it interferes with phones, wireless mice, speakers, microwaves, and baby monitors. The measurement will be conducted by transmitting data in difference distance up to 300meter with the different condition of with interference (by using microware as interference factor) and without interference. In this paper, the effect of interference on the throughput will be investigated.

Throughput Measurement

The Throughput vs. Distance test is designed to measure the speed of downstream, TCP traffic between the access point and client. With wireless, clients can theoretically be anywhere within a facility, so it is important to measure throughput not just when a client is next to an access point but when other obstacles, such as distance and intervening walls, are introduced as well. This competitive analysis comparing the performance of wireless configurations in throughput testing between IEEE.802.11g and 802.11n, using Iperf, to find which wireless configuration had the greatest throughput performance. The tests were designed to be objective by ensuring that each test configuration was affected by the same or similar environmental factors. The measurement will be conducted by transmitting data in difference distance up to 300meter with the different locations.

Table-5. Locations description.

Location Type	Description
Location Without Obstacles (line of sight)	Location A marked the best-case scenario for this test, with distance client increase to 50 meter until 300 meter from the access point and also within the same field so that there were no obstacles for the wireless signal between the access point and client to overcome.
Location With Obstacles (wall to wall)	Location B was a bit more challenging, with the distance between the client and access point increased to 50 meter until 300 meter and plus with 10 walls in between the access point and the client.

RESULT AND DISCUSIONS

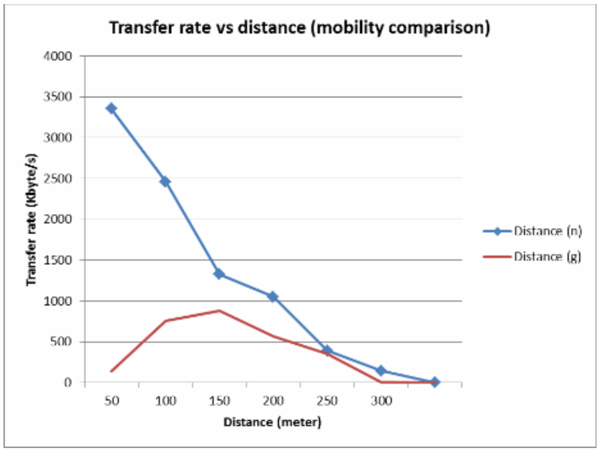

Figure-2. Coverage (mobility) graph result.

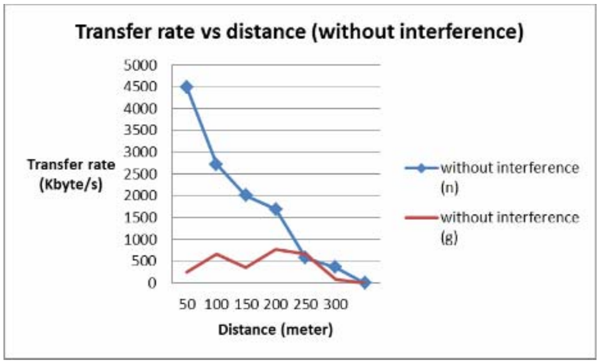

Figure-3. Interference graph result (without interference).

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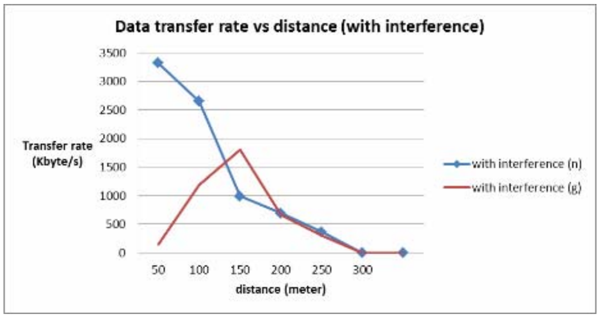

Figure-4. Interference graph result (with interference).

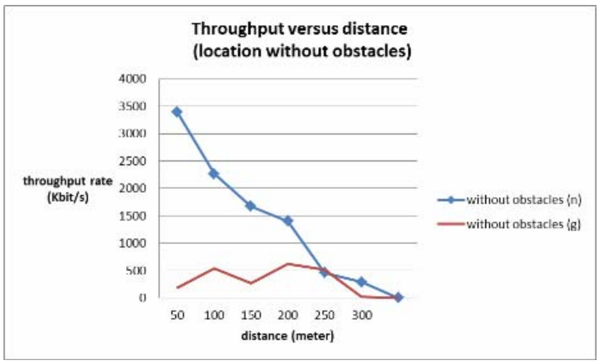

Figure-5. Throughput graph result (without obstacles).

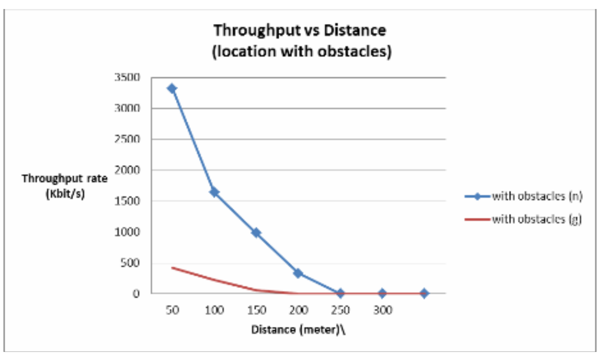

Figure-6. Throughput graph result (with obstacles).

Coverage Measurement Discussion

Figure-2 shows how distance can affect the transmit rate that can be achieved between two radios, in this case an access point and a mobile device using 802.11 g/n. Average data transfer above is ignoring the interference factor. As distance increase, the average data transfer slowly decreases for both IEEE 802.11g and 802.11n. The difference is the value data transfer 802.11n is higher compared 802.11g with 4240 Kbytes at distance of 1 meter before it terminates its signal at distance of 300 meter. While average throughput 802.11g is only 192 Kbyte at distance of 1 meter before it increase to 1076 Kbytes at distance of 100 meter and terminates its signal at 250 meter. Obviously, average data transfer 802.11g is unstable because their throughput values also unstable as distance increase.

An important aspect to know about radio frequency is as the power level of the electromagnetic field decreases when the distance from the source of transmission increases. This means that each time the distance from the source doubles, the power level is reduced. Yet, the power level is reduced by a factor of roughly 160 times within 1 wavelength of the antenna. The energy available in the radio wave decreases, as the distance between the transmitter and the receiver increases. When the energy present in a radio wave decreases, the more susceptible to noise and distortion the transmission becomes. Lower data rates are used to overcome the effects of noise and distortion. Therefore, as distance increases, less energy is available, and lower data rates are used in 802.11g and 802.11n. However, 802.11n performance is better than 802.11g in coverage area analysis. This is because 802.11n coding scheme for 802.11n is better than earlier versions of the standard, and that results in more data bits being transmitted in the same size channel.

Interference Measurement Discussion

Figures 3 and 4 show the data transfer value for both 802.11n and 802.11g with and without interference. The result shows transfer rate with interference of 802.11g not stable until it terminates signal at 250m. Wireless n gets the higher transfer rate if got no interference. When interference interferes, the transfer rate n slightly decreases with the value only 988Kbit/s at distance of 100 meter (with interference) compared 1670Kbit/s at same distance (without interference). Wireless n maintains highest transfer rate compared wireless g across every distance. Wireless n maintained a strong and reliable connection in heavy interference or long range conditions compared Wireless g. Both Wireless n and wireless g terminate signal at the same distance of 200 meter (with interference) with transfer rate value 368Kbit/s and 189Kbit/s. Data transfer for 802.11n is better compared 802.11g but 802.11n transfer rate value will drop badly with interference.

The results above confirm that the performance of 802.11n is better than 802.11g in the presence of interference from other sources such as IEEE 802.15.4 in the 2.4GHz ISM band. This result is also intuitive as the spatial diversity using MIMO in IEEE 802.11n makes it more robust and increases its probability of a correct detection due to less dependence on channel and noise conditions. The better performance is also because of the ability of IEEE 802.11n to improve its throughput using multiple data streams. As the throughput of IEEE 802.15.4 (250Kbps) is much less than the throughput of IEEE 802.11n (30Mbits/s for BPSK) this means that IEEE 802.11n can pump more data in the spectrum before it encounters interference from IEEE 802.15.4 traffic. Throughput of IEEE 802.11g (6Mbitss for BPSK) is less than IEEE802.11n and hence more traffic is obstructed by interference from IEEE 802.15.4 traffic

Throughput Measurement Discussion

Both graphs in Figure 5 and 6 above show the different throughput result between 802.11g and 802.11n with obstacles of walls and without obstacles of walls. The throughput rate for both 802.11n/g produce better result in Location 'A' compared throughput rate result in Location 'B'. Besides that, in Location 'A', signal termination of 802.11n happened at distance of 300 meter, while 802.11g at distance of 250 meter, but in Location 'B', signal termination of 802.11n happened at distance of 200 meter and 802.11g at distance of 150 meter. This show distances without any obstacles of wall produce higher throughput rate at long range compared long distances with walls. Indeed, 802.11n produce higher throughput rate and longer range in both locations without obstacles with obstacles.

802.11 n maintains high and stable throughput even at long distances. 802.11g throughput often becomes unstable or disconnects at long range of 150 meter (with obstacles of walls) and 250 meter (no obstacles) with throughput reduced to zero. 802.11n throughput only disconnects at long range of 200 meter (with obstacles of walls) and 300 meter (no obstacles) with throughput reduced to zero. 802.11n maintains highest throughput compared to wireless G across every distance. 802.11n performs the best at long range compared to 802.11g. Performance is best at long distances where throughput really matters. The last throughput G value before it terminates signal is 22.1Kbit/s (no obstacles) and 57Kbit/s (with obstacles).

The IEEE 802.11n throughput performance still better than 802.11g because MIMO in 802.11n exploits a radio-wave phenomenon called multipath: transmitted information bounces off walls, doors, and other objects, reaching the receiving antenna multiple times via different routes and at slightly different times. The transmitting WLAN device actually splits a data stream into multiple parts, called spatial streams, and transmits each spatial stream through separate antennas to corresponding antennas on the receiving end.

CONCLUSIONS

In this paper we reported on measurements between IEEE 802.11n and IEEE 802.11g performance in various conditions, especially focusing on coverage, interference and throughput. The results obtained vary. While the enhancements in IEEE 802.11n clearly result in better performance compared to earlier Wireless LAN technologies especially in IEEE 802.11g, the results are significantly lower than the theoretical maxima. The results above confirm that the performance of 802.11n is better than 802.11g in the presence of interference from other sources such as IEEE 802.15.4 in the 2.4GHz ISM band. This result is also intuitive as the spatial diversity using MIMO in IEEE 802.11n makes it more robust and increases its probability of a correct detection due to less dependence on channel and noise conditions It was conspicuous from the experiment that, 802.11n could change the way people access the internetwork in their daily life by enjoying an improved throughput and wider coverage compared 802.11g. In addition, it can also be said that to measure the ideal performance of 802.11n routers, an environment without interfering signal is much appreciated. The ability to change the signal between the 802.11n Access Point (AP) and the clients' devices could also lead to repeatable increased throughput. It was also ascertained that, the connection speed with 802.11n is increased over a certain distance. It was established also that 802.11n routers can provide connection until 200 feet, which means several office within a specified distance can share the same connection if it well implemented.

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