A survey on 802.11n over 802.11g

Madhu Vinod Diwakar, Divya Pathiramanna

Abstract
The world of wireless telecommunications is fast evolving. Technologies under research and development promise to deliver more services to more users in less time[3].A Wireless local area network (WLAN) is a local-area network in which digital devices communicate through a wireless medium such as high frequency radio or infrared instead of cables. Most WLAN equipment today is based on the Institute of Electrical and Electronics Engineers (IEEE) 802.11 series of standards, popularly known as Wi-Fi technology [1]. A wireless LAN (WiFi) is a data transmission system intended to provide location-independent network access between computing devices by using radio waves rather than a cable infrastructure. Wi-Fi is meant to be used basically when referring to any type of 802.11 network, whether 802.11b, 802.11a, 802.11g etc.[3]This paper presents an overview survey of emerging wireless LAN technology – 802.11n standard and provides a comparison of 802.11n over 802.11g standard. **802.11n** is an emerging industry standard for high-speed Wi-Fi networking. 802.11n is designed to replace the 802.11a, 802.11b and 802.11g Wi-Fi standards for local area networking [2]. 802.11n offers a higher bandwidth. It also assures both higher data rates and increased reliability [3]. 802.11n offers somewhat better range over earlier Wi-Fi standards due to its increased signal intensity. 802.11n equipment will be backward compatible with 802.11g.

Key words: IEEE, 802.11n, 802.11g, WLAN

I. Introduction

In 2002 and 2003, WLAN products supporting a newer standard called *802.11g* emerged on the market. 802.11g combines the best of both 802.11a and 802.11b. 802.11g supports bandwidth up to 54Mbps, and it uses the 2.4 Ghz frequency for greater range. 802.11g is backward compatible with 802.11b, meaning that 802.11g access points will work with 802.11b wireless network adapters and vice versa [2].

Demand for wireless LAN hardware has experienced amazing growth during the past several years, evolving quickly into inevitability. Wi-Fi technology is most commonly found in notebook computers and internet access devices such as routers and DSL or cable modems. The growing ubiquity of Wi-Fi is helping to extend the technology beyond the PC and into consumer electronics applications like Internet telephony, music streaming, gaming, and even photo viewing and in-home video transmission. These new uses, as well as the growing number of WLAN users, increasingly combine to strain existing Wi-Fi networks. Fortunately, a solution is close at hand. The industry has come to an agreement on the components that will make up 802.11n, a new WLAN standard that promises both higher data rates and increased reliability.

COMPARISON OF THE PRIMARY IEEE 802.11 SPECIFICATIONS

	802.11a	802.11b	802.11g	802.11n
Standard Approved	July 1999	July 1999	June 2003	Not yet ratified
Maximum Data Rate	54 Mbps	11Mbps	54 Mbps	600 Mbps
Modulation	OFDM	DSSS or CCK	DSSS or CCK or OFDM	DSSS or CCK or OFDM
RF Band	5 GHz	2.4 GHz	2.4 GHz	2.4 GHz or 5 GHz
Number of Spatial Streams	1	1	1	1,2,3, or 4
Channel Width	20 MHz	20 MHz	20 MHz	20 MHz or 40 MHz

II. Overview of IEEE 802.11n

IEEE 802.11n is the latest development to the 802.11 WLAN specifications promising major improvement in the transmission throughput to at least 130 Mbps for a standard 20-MHz channel in the 2.4 GHz and 5 GHz frequency band. IEEE 802.11n utilizes numerous new efficient techniques for the physical (PHY) and medium access control (MAC) layers of the specifications in order to obtain the enhanced performance. For example, IEEE 802.11n utilizes a more effective OFDM scheme with 52 data sub-carriers in the 20-MHz channel, instead of 48 sub-carriers used in IEEE 802.11g that improves the highest data rate per stream to 65 Mbps from 54 Mbps supportable in IEEE 802.11g.

Apple product	Standard	Speed	Range	Frequency
Airport	802.11b	11 Mbps	150 feet	2.4 Ghz
Airport Extreme	802.11g	54 Mbps	50 feet	2.4 Ghz
Airport Extreme	802.11a	54 Mbps	50 feet	5 Ghz
Airport Extreme	802.11n	300 Mbps	175 feet	2.4/5 Ghz

III. Why do we need a standard like 802.11n?

The **802.11g** wireless standard is the latest in existence by IEEE for WLANs. 802.11g, the basis of the majority of WLANs in existence today is the combination of the best from both 802.11 a & b. 802.11g broadens 802.11b's practically achievable data rates to 54 Mbps within the 2.4 GHz band using OFDM (orthogonal frequency division multiplexing) technology.

Though the current **802.11g** wireless networking products available theoretically promise data rates up to 54 Mbps, the practical, or "actual," data rate is more likely to be in the range of 10 – 12 Mbps.

From the tests conducted on 802.11g, it is observed that farther the distance from the access point, the lower the performance, higher the power better is the performance.

Even though WiFi products are useful, they do have few limitations as well. Firstly, Wi-Fi is designed for medium-range data transfers, and most versions of 802.11 works up to about 250-300 feet away from the access point indoors, and about 1,000 feet away outdoors, and with more distance between our computer/laptop and the access point, the speed and the quality falters tremendously. They do suffer from interference from Microwave Ovens and cordless phones which operate in the same frequency range of 2.4GHz. Another disadvantage for WiFi products is their security system. The Wired Equivalent Privacy (WEP) is the common wireless encryption standard which is easily broken even when configured accurately. In addition to the above reasons 802.11g throughput performance will be affected by the following reasons:

(1) 802.11g mandates 20 us slot time in order to be compatible with current 802.11b devices; use of a 9 us slot time as is used in 802.11a is optional.

(2) 802.11g shares the same 2.4 GHz spectrum as 802.11b devices; the performance impact may be significant if no coordination is employed.

(3) Frequency-dependent propagation loss favors 802.11g. However, the prevalence of non-WLAN devices in the 2.4 GHz ISM band, e.g., Bluetooth and microwave ovens.

IV. Characteristics of 802.11n

802.11n specification differs from its predecessors in that it provides for a variety of optional modes and configurations that exhibits different maximum raw data rates. This empowers the standard to provide baseline performance parameters for all 802.11n devices, while allowing manufacturers to enhance or tune competencies to accommodate different applications and price points. With every possible option enabled, 802.11n could offer raw data rates up to 600 Mbps. But WLAN hardware does not need to support every option to be compliant with the standard. The current draft-n WLAN hardware available is expected to support raw data rates up to 300 Mbps [1]. In comparison, every 802.11b-compliant product support data rates up to 11 Mbps, and all 802.11a and 802.11g hardware support data rates up to 54 Mbps.

MAJOR COMPONENTS OF DRAFT 802.11N [1]

Feature	Definition
Better OFDM	Supports wider bandwidth & higher code rate to bring maximum data rate to 65 Mbps
Space-Division Multiplexing	Improves performance by parsing data into multiple streams transmitted through multiple antennas.
Diversity	Exploits the existence of multiple antennas to improve range and reliability. Typically employed when the number of antennas on the receiving end is higher than the number of streams being transmitted.
MIMO Power Save	Limits power consumption penalty of MIMO by utilizing multiple antennas only on as-needed basis.
40 MHz channels	Effectively doubles data rates by doubling channel width from 20 MHz to 40MHz.
Aggregation	Improves efficiency by allowing transmission bursts of multiple data packets between overhead communications.
Reduced Inter-frame Spacing (RIFS)	One of several draft-n features designed to improve efficiency. Provides a shorter delay between OFDM transmissions than in 802.11a or g.
Greenfield Mode	Improves efficiency by eliminating support for 802.11a/b/g devices in an all draft-n network.

1) Better OFDM

In the 802.11n draft, the first gear is to support an OFDM implementation that improves upon the one employed in the 802.11a/g standards, using a higher maximum code rate and slightly wider bandwidth. This alteration improves the highest attainable raw data rate to 65 Mbps from 54 Mbps in the existing standards.

2) MIMO Improves Performance

Among its main innovations, 802.11n supplements technology called multiple-input multiple-output (MIMO), a signal processing and smart antenna technique for transmitting multiple data streams through multiple antennas. A MIMO system has N number of transmitters and M number of receivers, which is normally represented as NxM. The result is that it has five times the performance and up to twice the range compared to the earlier 802.11g standard MIMO employs a technique called Spatial Multiplexing to transmit two or more parallel data streams in the same frequency channel. IEEE 802.11n utilizes the benefit of

MIMO and Spatial Multiplexing to double the transmission capacity of the system to 130 Mbps by transmitting and receiving two parallel spatial data streams over two transmitters at the same time. With 4 transmitters, the maximum throughput of 260 Mbps can be achieved. MIMO exploits a radio-wave phenomenon called multipath- transmitted information bounces off walls, doors, and other objects, reaching the receiving antenna multiple times through various routes and at slightly different times. MIMO increases both the range and throughput of a wireless network. Uncontrolled, multipath distorts the original signal, making it more difficult to decode and degrading Wi-Fi performance. 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. The current 802.11n draft provides for up to four spatial streams, even though compliant hardware is not required to support that many [5]. Doubling the number of spatial streams from one to two efficiently doubles the raw data rate. There are trade-offs, however, such as increased power consumption and, to a lesser extent, cost. The draft-n specification includes a MIMO power-save mode, which alleviates power consumption by using multiple paths only when communication would benefit from the additional performance.

3) Reduced Guard interval

Another optional support is the reduction in the guard interval (GI) for each OFDM symbol. As same as the legacy IEEE 802.11a and 802.11g, the IEEE 802.11n also use 800 nanoseconds as the default guard interval. However, it also provides an option for the transmitter and receiver to use a short guard interval of 400 nanoseconds, which corresponding to the higher data rate. For 20-MHz channel with 400-nanosecond guard interval, the maximum data rate for two transmitters is 144 Mbps. For 40MHz channel with this short guard interval, the maximum throughput of 600 Mbps can be achieved by using the 4x4 MIMO systems

4) Improved Throughput and Higher Data Rates

Another optional mode in the 802.11n draft efficiently doubles data rates by doubling the width of a WLAN communications channel from 20 MHz to 40 MHz The key trade-off here is fewer channels available for other devices. In the case of the 2.4-GHz band, there is enough room for three non-overlapping 20-MHz channels. A 40-MHz channel does not leave much room for other devices to join the network or transmit in the same airspace. This means intelligent, dynamic management is critical to ensuring that the 40-MHz channel option improves overall WLAN performance by balancing the high-bandwidth demands of some clients with the needs of other clients to remain connected to the network.

5) Increased channel bandwidth

An additional technique employed by 802.11n involves increasing the channel bandwidth. As in 802.11a/b/g networking, each device uses a predetermined Wi-Fi channel on which to transmit. Each 802.11n channel will use a larger frequency range than these earlier standards, also increasing data throughput.

6) Frame aggregation and block acknowledgement

IEEE 802.11n uses the new efficient frame aggregation and block acknowledgement mechanisms to greatly enhance the throughput of the system. For frame aggregation, IEEE 802.11n presents two new frame aggregation mechanisms, namely A-MSU and A-MPDU that greatly reduce the overhead of IEEE 802.11n packets. The AMSDU is more efficient of the two aggregation methods. The idea is to combine the payload of several PHY or MAC frames into one aggregated frame so that size of the required header is relatively smaller compared with the size of the combined payload. A-MSDU associates with the aggregation of payload of several MAC frames while A-MPDU translates each MAC frame to IEEE 802.11 format and then assembles IEEE 802.11 frames for a common destination. Therefore, the A-MPDU has the extra overhead of the individual 802.11 frame headers for each constituent frame. IEEE 802.11n has also increased the maximum size of PHY frames on the wireless link from the legacy 23k to 64k bytes with A-MPDU and the maximum size of MAC frames from 2.3k to 8k bytes with A-MSDU.

Fig.1:A-MSDU Frame Format

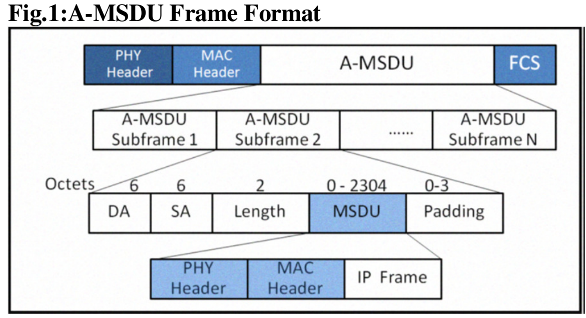
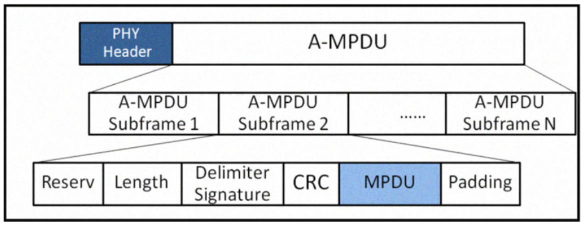


Fig.2:A-MPDU Frame Format



V. Applications of 802.11n

Because it promises far greater bandwidth, better range, and reliability, 802.11n is beneficial in a variety of network configuration. Some of the current and emerging applications that are motivating the need for 802.11n are listed below:

Voice over IP (VoIP)*:* VoIP is expanding as consumers and businesses alike realize they can save money on long distance phone calls by using the Internet instead of traditional phone service. An increasingly popular way to make Internet calls is with VoIP phones, which are battery powered handsets that connect to the Internet with built-in 802.11b or 802.11g. Telephony does not demand high bandwidth, though it does require a reliable network connection to be usable. Both 802.11b and 802.11g consume less power than 802.11n in MIMO modes, but single-stream 802.11n may become prevalent in VoIP phones.

Streaming video and music

As with voice, streaming music is an application that requires a highly reliable connection that can reach throughout the home. Masses of consumers are building libraries of digital music on their personal computers by shredding their CD collections and buying digital recordings over the Internet. In addition, growing numbers are streaming music directly from the Internet. Though higher bandwidth is not undeniably necessary, the additional range and reliability that 802.11n-draft offers may be better suited to streaming music than older generation WLAN hardware.

Gaming: Gaming is an application that gradually is making use of home WLANs, whether users connect wirelessly to the Internet from their computers and portable gaming devices or use the network to compete with others in the home.

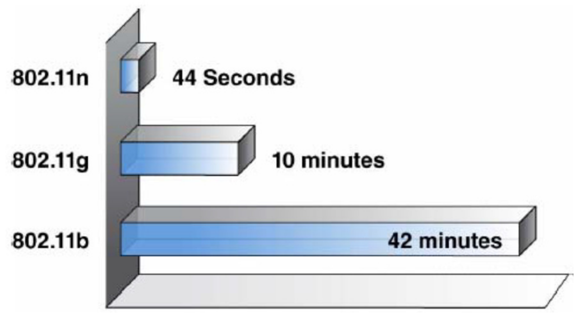
Network attached storage

Another application that demands all that 802.11n has to offer high data rates as well as range and reliability is Network-Attached Storage (NAS). NAS has become popular as a low-priced, easy-to-install alternative for data backup. More recently, NAS is taking hold in small offices and even some homes, as users want to safeguard their growing digital photo albums from hard drive failure, and as the price of self-contained NAS backup systems falls below $1,000. New exciting applications for NAS are emerging, such as video storage centers that demand reliable, high-bandwidth connections to stream prerecorded TV shows, music videos and full-length feature films to televisions and computers throughout the house.

Transferring large files

Transferring large files such as prerecorded TV shows from a personal video recorder into a notebook computer or portable media player for viewing outside the home takes planning and patience on an older WLAN. Fig.3 compares the time it would take to transfer a 30-minute video file. At the best data transfer rate, it would take 42 minutes to copy the file using 802.11b, and less than a minute with a two antenna 802.11n client.

Fig.3:



VI. Available results of tests conducted

In real world tests, 802.11n base station is established to be 3.8 times faster than the 802.11g setup.802.11a offers the same theoretical speed (54 Mbps) as 802.11g, but it operates in a different frequency (5 GHz) and is not backwards compatible with 802.11b. 802.11n can operate on either the 5 GHz frequency at full speed or on the 2.4 GHz frequency in "mixed mode" which will support systems only capable of using 802.11b or 802.11g, but it slows down the entire network to the maximum speed of the earliest standard connected.

Results show that the usual throughput performance for the UDP traffic over the 20-MHz IEEE 802.11n channel is about 60 Mbps for a downlink flow and 30 Mbps for an uplink flow and the throughput performance for the TCP traffic is around 40 Mbps for both uplink and downlink flows. Additionally, when the 40MHz channel width is used, the performance results only improve very slightly. In addition, it is found that unlike for the case of IEEE 802.11g, the performance of the IEEE 802.11n devices from different manufacturers as well as the performance of the uplink and downlink flows can be fairly varied. In order to analyze this issue, in packets transferred over the air during the tests, which are captured by the Air Magnet Wi-Fi Analyzer tool, it was observed that the performance variations depend on how the devices may be differently programmed by the manufacturers to employ different modulation rates, frame aggregation schemes, and block acknowledgement mechanisms for different wireless environments and conditions. The performance improvements of IEEE 802.11n are measured to be approximately about 850/0 for the downlink UDP traffic, 680/0 for the downlink TCP traffic, 50% for the uplink UDP traffic, and 90% for the uplink TCP traffic.

Fig.4:

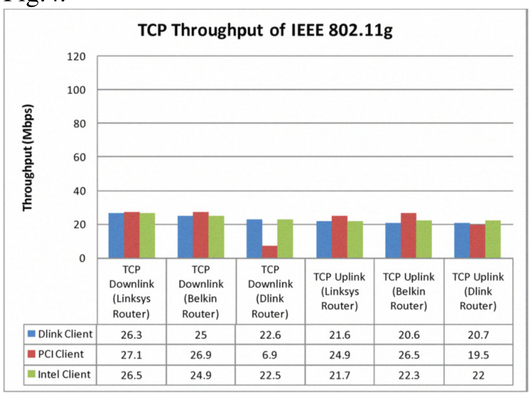
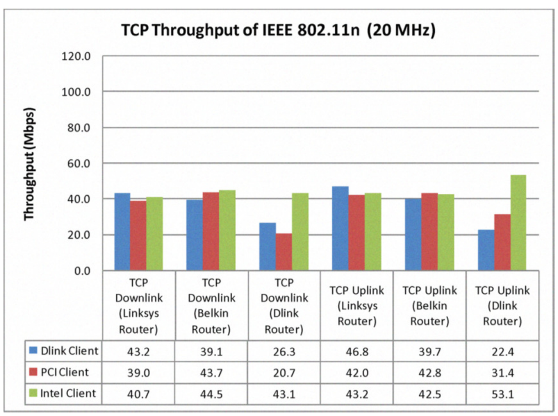


Fig.5:



VII. Limitations of 802.11n

Though 802.11n has many advantages it is not free from limitations. Main being that 802.11n - standard is not yet finalized. Other most important demerits of 802.11n are its cost and interference. Use of multiple signals greatly interferes with nearby 802.11b/g based networks.

VIII. Conclusion

In this paper, we provide an overview of the improvements and advantages of 802.11n over 802.11g. The advantages and disadvantages in operating them in different modes is also detailed. It can be seen that the performance of IEEE 802.11n is significantly higher than the performance of IEEE 802.11g with the same standard 20-MHz channel width configuration. Though 802.11n is not yet standardized, in view of the applications requiring higher data rates, it should be soon introduced with few modifications to mitigate the limitations.

References

[1] http://www.searchtwice.com/wirelesslan_technology.asp

[2] http://compnetworking.about.com/od/wireless80211/g/bldef_80211n.htm

[3] Sidhu, B.,Singh,H.,Chhabra,A. (2007),Emerging Wireless Standards - WiFi, ZigBee and WiMAX, World Academy of Science, Engineering and Technology 25 2007, 308-313.

[4] Visoottiviseth, V. , Piroonsith, T. ,Siwamogsatham, S., (2009), An empirical study on achievable throughputs of IEEE 802.11n devices, 7th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks, 2009. WiOPT 2009.

[5] Broadcom, 802.11n: Next-Generation Wireless LAN Technology, White Paper dated April 2006.

[6] http://www.gsmarena.com/wireless_n_bluetooth_3_speed_test-review-551.php

[7] http://networking.anandsoft.com/802.11g.html

[8] http://www.techrepublic.com/article/evaluating-the-wireless-networking-options/5054011

[9] Marco Domenico Aime; Giorgio Calandriello; Antonio Lioy; Politecnico di Torino, (2007), Dependability in Wireless Networks: Can We Rely on WiFi?, Security & Privacy, IEEE,5(1):23-29

[10] Dhawan, S., (2007),Analogy of Promising Wireless Technologies on Different Frequencies: Bluetooth, WiFi, and WiMAX , The 2nd International Conference on Wireless Broadband and Ultra Wideband Communications, 2007. AusWireless 2007.

[11] Boulmalf.M.,El-Sayed.H.,Soufyane.A.,2005(2): 1333 - 1337

Measured Throughput and SNR of IEEE 802.11g in a Small Enterprise Environment
[12] G.Akbar and W. Mansoor, "Testing the performance of wireless LAN," Asia-Pacific Conf. on Communications, October 2005.
[13] T.Wang, H.H.Refai, "Empirical network performance analysis on IEEE 802 .11g with different protocols and signal to noise ratio values," IFIP Inter.Conf. on Wireless and Optical Commun. Networks, March 2005 .
[14] http://mason.gmu.edu/~fkondolo/page3
[15] IEEE 802.11g OFDM WLAN Throughput Performance, Ming-Ju Ho, Jing Wang, Kevin Shelby and Herman Haisch