INVESTIGATION OF 802.11 N WLAN THROUGHPUT

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Abstract

The latest generation of high-speed wireless LAN solutions, based on the Institute of Electrical and Electronics Engineers (IEEE) Draft 802.11n standard, are available for more than a year.

The 802.11n standard offers several advantages over previous wireless LAN technologies. The most notable advantages are substantially improved reliability and greater application data throughput.

The aim of this paper is to analyze the WLAN throughput through measurements based on real wireless network with 11N devices and special monitoring and measurement software.

1. INTRODUCTION

IEEE 802.11 n offers dramatic improvements in speed, range, and reliability. However, understanding its design and configuration requirements is crucial if organizations are to take advantage of its full potential. Current wireless solutions operate in the 2.4-GHz radio frequency band (802.11g and 802.11b) or the 5-GHz radio band (802.11a). Solutions based on the 802.11n standard will operate in the 2.4-GHz, the 5-GHz radio band, or both bands, offering backward compatibility with preexisting 802.11a/b/g deployments. The 802.11n standard is expected to deliver data rates of up to 300 Mbps per radio in 2.4 Ghz spectrum and up to 600 Mbps in 5Ghz spectrum. The industry is working aggressively to try to ensure that existing 802.11n draft 2.0 products will be able to be software upgraded to the final 802.11n standard. Now, the prestandart 802.11 n is in Draft 4.0, the official TGn workgroup is not expected to finalize the amendment until December 2009.

The important characteristics of the 802.11 n are: Orthogonal Frequency Division Multiplexing; Multiple Input Multiple Output technology; packet aggregation; channel bonding; wider coverage and backward compatibility with existing platforms.

Unlike the highest encoder rate in 802.11a/g is 3/4, this is increased to 5/6 in 802.11n, i. e. 11 percent increase in data rate. With the improvement in radio frequency technology, it was demonstrated that two extra frequency subcarriers could be squeezed into the guard band on each side of the spectral waveform and still meet the transmit spectral mask. This increased the data rate by 8 percent over 802.11a/g. Lastly, the waveform in 802.11a/g and mandatory operation in 802.11n contains an 800 ns guard interval between each orthogonal frequency-division multiplexing (OFDM) symbol. An optional mode was defined with a 400 ns guard interval between each OFDM symbol to increase the data.

Multiple Input Multiple Output- MIMO enabled access points use spatial multiplexing to transmit different bits of a message over separate antennas, providing much greater data throughput and allowing for more robust, resilient wireless LANs. Whereas previous wireless technologies had problems dealing with signal reflections, MIMO actually uses these reflections to increase the range and reduce “dead spots” in the wireless coverage area. This performance gain is a result of MIMO smart antenna technology, which allows wireless access points to receive signals more reliably over greater distances (and allows clients to operate at higher data rates) than with standard diversity antennas. Multipath scenario, or multiple transmission paths of the same data in a wireless broadcast begin to interfere with each other, degrading network performance and shrinking the coverage area of the network. MIMO aims to change all that by using multipath to its advantage. The smart antennas on a MIMO AP can hand off reception and transmission dynamically to each other, adjusting for the clearest data path on the fly. This increases both range and throughput at any given distance in an indoor setting, especially in multipath or interference-phone environments.

In conventional wireless transmission methods, the amount of channel access overhead required to transmit each packet is fixed, regardless of the size of the packet itself. As data rates increase, the time required to transmit each packet shrinks, but the overhead cost remains the same, potentially becoming much greater than the packet itself at the high speeds delivered with 802.11n.

802.11n technologies increase efficiency by aggregating multiple packets of application data into a single transmission frame. In this way, 802.11n networks can send multiple data packets with the fixed overhead cost of just a single frame. *Packet aggregation* is more beneficial for certain types of applications such as file transfers due to the ability to aggregate packet content.

The most straightforward way to increase the capacity of a network is to increase the operating bandwidth. However, conventional wireless technologies are limited to transmitting over one of several 20-MHz channels. 802.11n networks employ a technique called *channel bonding* to combine two adjacent 20-MHz channels into a single 40-MHz channel. The technique more than doubles the channel bandwidth. Channel bonding is most effective in the 5-GHz frequency given the far greater number of available channels. The 2.4-GHz frequency has only 3 non overlapping 20-MHz channels. Therefore, bonding two 20-MHz channels uses two thirds of the total frequency capacity. Therefore, the IEEE has defined rules on when a device can operate in 40MHz channels in the 2.4GHz space to ensure optimal performance.

The aim of this paper is to analyze the WLAN throughput through measurements based on real wireless network with 11N devices and special monitoring and measurement software.

This paper is divided into two parts, the first part describes the experiments in 802.11n WLAN infrastructure mode, and the second – the generalized results.

2. 802.11N THROUGHPUT TESTING AND MEASURMENT

All tests and measurements are accomplished in laboratories in South-West University – Bulgaria. The wireless network equipment which is used is D-Link and Trendnet 802.11 n Draft 1.0 devices as follows [7]:

D-link	DIR-655 Extreme Wireless N Router
	DIR-635 Rangebooster Wireless N router
	DAP-1353 Wireless N Access Point
	DWA-547 Wireless N Desktop Adapter - PCI
	DWA-140 Wireless N USB Mini Adapter
	DWA-643 Wireless N Express Card Notebook Adapter
	DWA-650 Wireless Rangebooster Cardbus Notebook Adapter
	ANT24-600 – 2.4GHz 6dBi Directional Indoor Antenna
	DWL-R60AT – 2,4 GHz 6 dBi Directional Patch Indoor Antenna
	DWL-50AT -2.4 GHz 5 dBi Gain Dipole Indoor Antenna
	ANT-24 -2.4 GHz 5 dBi Omni-directional Indoor Antenna
Trendnet	TEW-621PC – 300 Mbps Wireless N-Draft PC Card

Table 1. WLAN hardware

All N devices work in 2.4 GHz (2.4-2.4835 GHz) spectrum, compatible with IEEE 802.11 b/g/n , max EIRP Power – 100 mW, theoretical data rate -300 Mbps.

The PC-s used in tests are full compatible with the minimum system requirements of the WLAN devices. The operation system is MS Windows XP Professional SP2.

Software used for measurements, monitoring and site survey is shown in tabl. 2.

AirMagnet Laptop Analyzer Pro	Ver.7.6 Build10264
Passmark Performance Test	Ver. 6.1
Celetrio Covera Zone	Ver. 2.1
DU Meter	Ver.4.0Build R3009

Table 2. WLAN software

Configurated test wireless network in infrastructure mode – Independent Extended Service Set (IESS) with two access points and wireless hosts (clients) is shown in fig. 1.

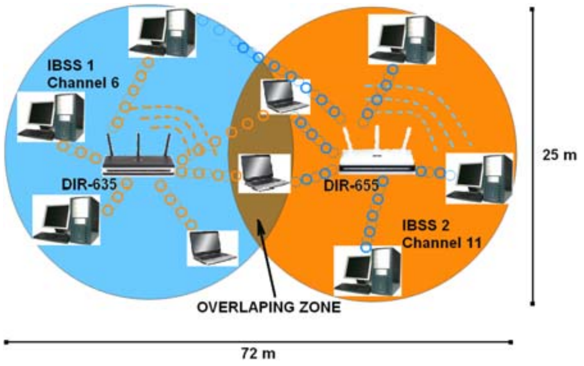

Figure1. Block diagram of tested IESS

The 2.4 GHz band is broken down into 11 channels for North America and 13 channels for Europe. These channels have a center frequency separation of only 5 MHz and an overall channel bandwidth (or frequency occupation) of 22 MHz. The 22 MHz channel bandwidth combined with the 5 MHz separation between center frequencies means there is an overlap between successive channels. Best practices for WLANs that require multiple access points are set to use non-overlapping channels. If there are three adjacent access points, use channels 1, 6, and 11.We use in our test 6 (2427MHz) and 11(2452MHz) channels.

The channel bonding is 40 MHz. The distance between APs is 45 m. Between IBSS1 and IBSS2 is important to have a 15% (or more) overlapping zone for best communication and data transfer.

Overhead is the major fundamental issue for WLAN inefficient, and it includes MAC and PHY headers, frame check sequence- FCS, interframespaces- IFSs, backoff time, and ACKs. Define normalized overhead as overhead divided by data rate. Let T_{slot}, T_{SIFS}, T_{DIFS}, and $CW_{\min}$ denote a slot time, a short IFS (SIFS) time, a differentiated IFS (DIFS) time, and the minimum backoff contention window size, respectively. Let T_P and T_{PHY} denote transmission times of a physical preamble and a PHY (Physical Layer) header, respectively.Let T_{DATA} and T_{ACK} denote transmission times of a data frame and an ACK, respectively. Assume that all data frames are the same size, and at all times frames are concatenated. The Maximum Throughput [1] is given as:

$$MT_a = \frac{8k * L_{DATA}}{kT_{DATA} + T_{ACK} + T_{DIFS} + T_{SIFS} + (CW_{\min} - 1)T_{slot}/2} \qquad (1)$$

With Airmagnet Laptop Analyzer Pro [10] are measured throughput, utilization, signal strength on MAC sublayer on the base of the network traffic (downlink and uplink) passing through special full compitable WLAN adapter TEW-621PC installed on notebook. The test duration is 3 hours. Performance Test [11] measures the average and maximum throughput on TCP ports: 80 (HTTP), 21 (FTP), 23 (Telnet), 25 (SMTP), 53 (DNS) and on UDP ports: 53(DNS), 69 (TFTP), 161 (SNMP), 520 (RIP).Each test duration is 200 s. The transmitted frames can be with fixed or variable block size. Unlike Transmission Control Protocol- TCP which is a connection-oriented and reliable transfer protocol, User Datagram Protocol- UDP is a connectionless protocol, which means it is an unreliable means of data transfer. UDP provides no checking of the transferred or received data.

In tests are used different types of antennas and different distances between the transmitter and the receiver (see bellow).

3. RESULTS

Summary of the results are presented at this section. The highest throughput that is measured is 293,7 *MBps* for interval of 11,2 sec., but this data rate is not constant, and the transmission of this rate is still impossible in Draft 1.0 on 2.4 GHz. The throughput is strongly dependent of the building infrastructure, walls material, signal fading, SNR, RF interference and antennas gain and diversity.

Having a standard configuration of WLAN devices, at the same distance of 52m between transmitter (DWA-140) and the receiver (DWA-547), at 2.4 GHz, on 11 channel is measured with Performance Test 6.1 the following throughput:

Port Number	Throughput , Kbps
TCP	
80	2638,9
21	1703,5
23	1575,4
25	1298,9
53	1586,8
UDP	
53	5290,9
69	5354,8
161	5243,2
520	4408,8

Table 3. TCP and UDP Throughput

It is used variable block size of data frames (from 20÷100 Bytes). Each test transmission lasts 200 sec.

In the same conditions, but with changed gain antennas of the router DIR-655 and the receiver DWA-547 is measured the throughput. On the DIR-655 are installed one directional antenna DWL-R60AT and two omni-directional antennas DWL-50AT. The receiver DWA-547 is with one ANT24-600 and two ANT-24. The achievable throughput on UDP is about 10 times higher than devices with standard antennas (2 dBi).The directional antennas are on the same line, one opposite another. The gain of the directional antennas is 6 dBi. The results are shown in the Table 4.

UDP	Throughput, Kbps	
Port Number	Variable Block Size	Fixed Block Size - 16384 B
53	42183,0	51306,0
69	53726,0	50777,0
161	54177,0	52087,0
520	53851,0	51342,3
1040	54696,9	22749,1

Table 4. UDP Throughput at 5 dBi Antennas Gain

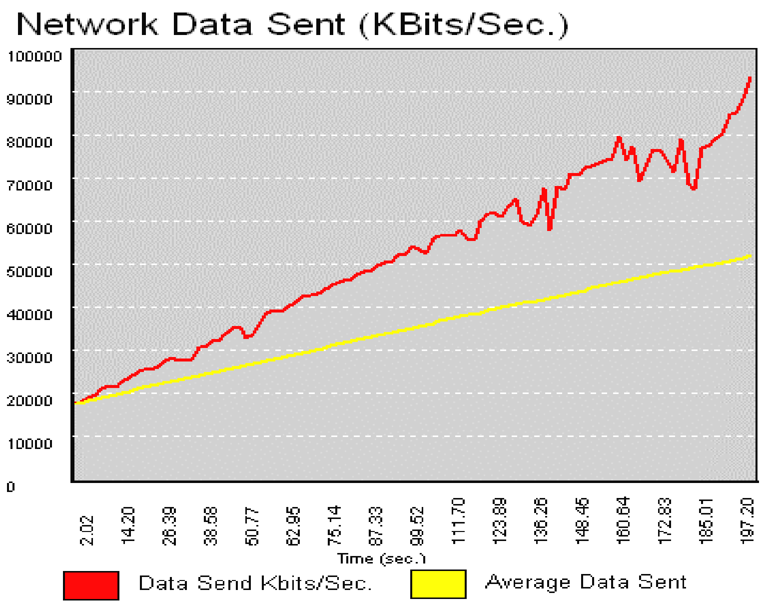

Figure 2. UDP Throughput (Port 161).

The values shown in Table 3 and 4 are average. The highest throughput measured with Performance Test 6.1 is 94 Mbps (fig. 2).

On Figure 3. is shown the percentage distribution of the transmitted frames between the transmitter and the receiver at different data rates. The distance between them is 52m. Most of the all frames - 14,4% are transmitted on 24,0Mbps.But it is important to mark that 20,82% of all data is transmitted on data rates 127.0÷263.7 Mbps. – 802.11 n.

On the application layer of the TCP/IP model, is realised file transfer (on FTP) of 6,58 GB (7070469411 bytes). The transferred data contains different by size and type files (mpeq, avi, mp3, cda, doc, html pages, jpeg, ets.).The distance is 20 m between the transmitter and the receiver and the radio signal is transmitted through one brick-built wall.

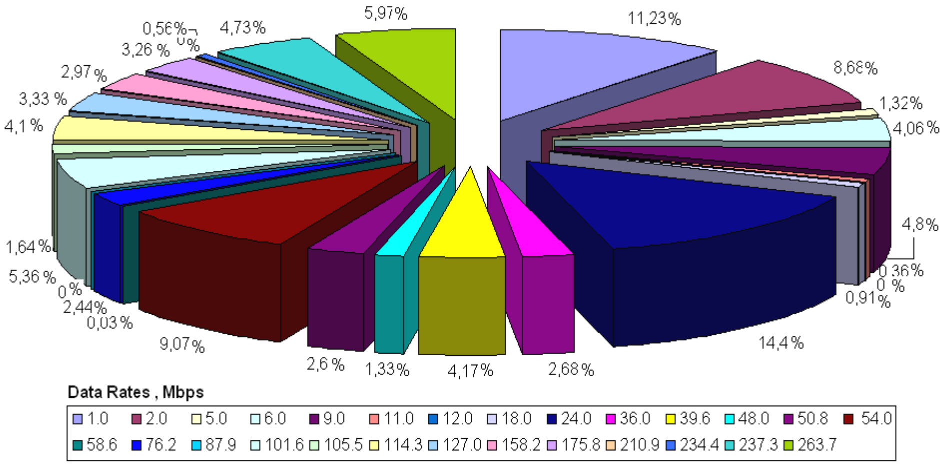

Figure 3. Percentage distribution of transmitted data

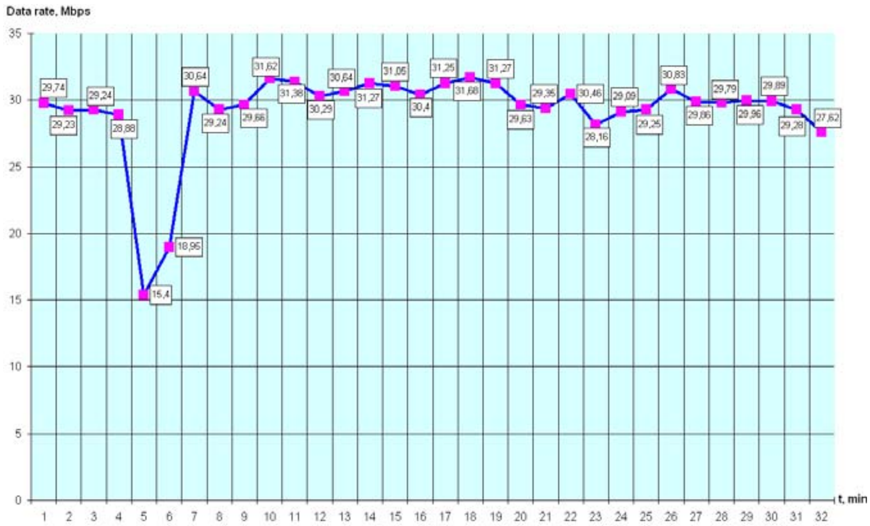

Figure 4. FTP Downlink

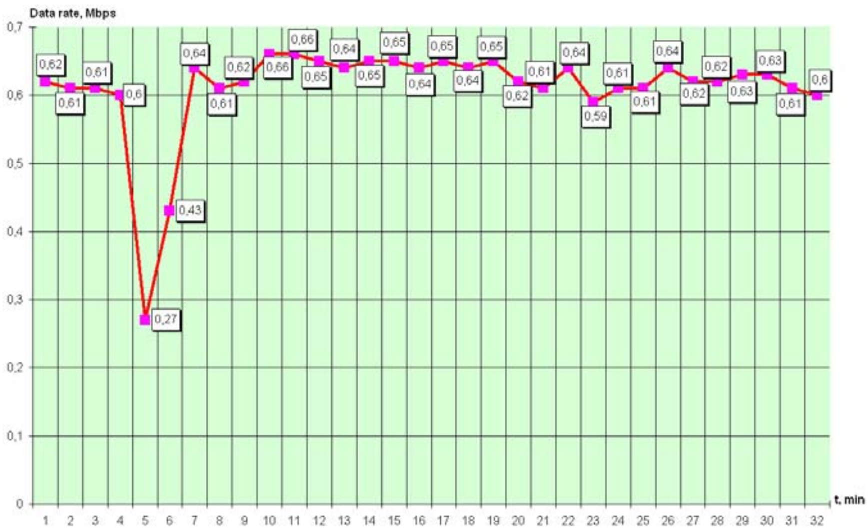

Figure 5. FTP Uplink

The average downlink and uplink data rate of the file transfer are 29,22 Mbps and 0,61 Mbps. The total time of transfer is 32.10 min. The utilization of the wireless network at the time of transfer was very low – 6.83%.There is no fluctuation in the data rate except one drop. FTP is often used from the users of the WLANs and this test shows real data rates between two nodes.

As can see from experimental results the throughput is not very high. Based on analysis of many proposals [1-8] for 802.11n enhancements we can conclude to break the 100 Mbps throughput barrier:

– Frame aggregation must be added to the 802.11n MAC as the key method of increasing efficiency. The issue is that as the data rate increases, the time on air of the data portion of the packet decreases. However, the PHY and MAC overhead remain constant. This results in diminishing returns from the increase in PHY data rate. Frame aggregation increases the length of the data portion of the packet to increase overall efficiency;

– Using of the reverse direction protocol, which allows a station to share its transmit opportunity (TXOP) with another station. This increases throughput with traffic patterns that are highly asymmetric, for example, when transferring a large file with FTP operating over TCP. Time is borrowed during the TXOP to send the short TCP Acknowledgment in the reserve direction. Depending on the usage model, TCP traffic throughput may improve up to 40 percent [1];

– Using of the greenfield format- By eliminating the components of the preamble that support backward compatibility, the greenfield format preamble is shorter than the mixed format preamble. This difference in efficiency becomes more pronounced when the packet length is short, as in the case of VoIP traffic.

4. CONCLUSION

This paper presents some experimental results and analyze of throughput of 802.11n network. The achievable throughput in test is fine for many applications, interconnection devices with higher data rates, particularly HDTV and streaming video and audio in short indoor distance not more then 50 m. The MIMO technology and multiple antennas extends the network coverage and is one of the main factors of higher throughput. The 802.11 n network devices are full compatible of 802.11 a/b/g devices and it is possible to work in a mixed mode.

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