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Analyzing the basic performance of IEEE802.11g/n

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Abstract **- This paper describes a new standardization effort – IEEE 802.11n, and its comparison with legacy standard. In this paper we present the results of a measurement campaign evaluating the performance of both standards IEEE802.11g/n. We concentrate our evaluation on wireless communication in the outdoor scenario. We found that distance, throughput and signal/noise ratio characterize the basic performance of standards.**

Keywords: **IEEE802.11g/n, outdoor measurment, throughput, goodput, distance, signal to noise ratio.**

I. INTRODUCTION

The IEEE802.11 technology with -a,-b,-g extensions are highly popular and widely available at low-cost for free commercial hotspots and home networking. This technology has potential to grow and new versions were recently produced. The latest standard of wireless local area network (WLAN) is IEEE802.11n, which supports the original concepts of IEEE802.11 and contains many new options to improve the quality of the wireless link and thereby to increase data rate and data range.

The IEEE802.11n is a new solution and its performance is several times greater than legacy standards. The main goal of this paper is an evaluation of IEEE802.11n standard using commercially available Off-The-Shelf (COTS) equipment without additional tuning and with diminished settings compare to IEEE802.11g standard in outdoor scenario. The basic performance of the standards we characterized with such features as distance, throughput and signal to noise ratio.

The main component of Intelligent Transportation Systems (ITS) is the provision of adequate mobile communication infrastructure to support vehicular communication. In connection with this there have been also extending interests from industry and research communities in using wireless communication technologies to provide Internet access to ITS.

We were interested to understand the basic performance of these standards for further studies to provide Internet access to users in the vehicles.

This paper we divided into four main sections. In this paper we firstly study the related works. Then we describe IEEE802.11n standard main features and theoretical limits. In section four and five we present our practical measurements' setup and our results. At the end of the paper we conclude our paper.

II. RELATED WORKS

We can find a lot of information about IEEE802.11n technical concept in comparison with legacy standards, advantages and challenges.

T. Paul and T. Ogunfunmi[1] have described the benefits of current generation wireless LAN devices, offers advantages of new generation wireless standard - 802.11n. The authors also did some simulations and discussed about the benefits of all existing structures.

F. Heereman et al. [2] did path loss (PL) measurements of IEEE802.11n in large conference rooms. In this research, it was found that two PL models predict some basically different effects concerning throughput and radiated power.

S. Fiehe et al.[3] studied the performance of IEEE802.11n in two office environments – typical office and interference controlled office. The results show that in a typical office environment important performance improvement compared to former standards can be achieved.

Evaluations of a low-cost WLAN in different scenarios are currently a topic research area in academia and industry. Remarkable efforts in the research field are achieved to provide comprehensive tests results which are COTS technologies mostly based on the widely deployed IEEE802.11a/b/g standards.

Our work is different in that we have made a basic outdoor performance evaluation of IEEE802.11n devices with diminished setting compered to legacy standard. Next, we describe the result in outdoor. In particular, we tested IEEE802.11g/n in real outdoor scenario to show the throughput performance and outdoor coverage range of our tested IEEE802.11g/n devices.

III. THEORETICAL APPROACH

The main contributions of this section are to give an overview on the latest standard like IEEE802.11n improvements and experimental results from trial tests. The field test was performed in absence of other conventional wireless signals in order to be able to perform WLAN root cause analysis in mobile environment.

The significant improvement of IEEE802.11n standards comparing to legacy standards is the raw data rate of the wireless channel up to 600 Mbps[4] – more than ten-fold improvement over 54 Mbps of IEEE802.11 a/g maximum data speed. Table 1 shows the maximal data rate of the standard. This capacity has been gained through different features.

At the Physical (PHY) layer of the standard is applied the multiple antennas at the receiver and transmitter, called MIMO (Multiple Input Multiple Output) together with signal processing and the use spatial division multiplexing (SDM) at a channel width of 40MHz. At the sub-layer of Data Link layer, Medium Access Control (MAC) data communication protocol extensions like Frame Aggregation (FA) and Block Acknowledgement (BACK).

TABLE I. IEEE802.11N STANDARD RELATIONSHIP RAW DATA THROUGHPUT IN SEQUENCE

Description of improvements in sequence	Data rate up to (Mbps)
IEEE802.11n legacy mode	54
Increasing useful number of OFDM subcarriers from 48 to 52	58.5
Additional coding rate (5/6)	65
Reducing OFDM symbol guard interval from 0.8µs to 0.4 µs	72.2
Doubling channel bandwidth from 20Mhz to 40MHz	150
MIMO option	600

Energy consumption by using protocols IEEE802.11n and IEEE802.11g is shown in Figure 1. Respectively laptop battery life will be extended by using IEEE802.11n standard. These benefits together provide the ability to transfer data into an IEEE802.11n handheld at greater energy efficiency than into a legacy standards' device. Energy is saved because the handheld device can enter low-power standby state when the data transmission is done – this works can be done much faster with IEEE802.11n settings [5].

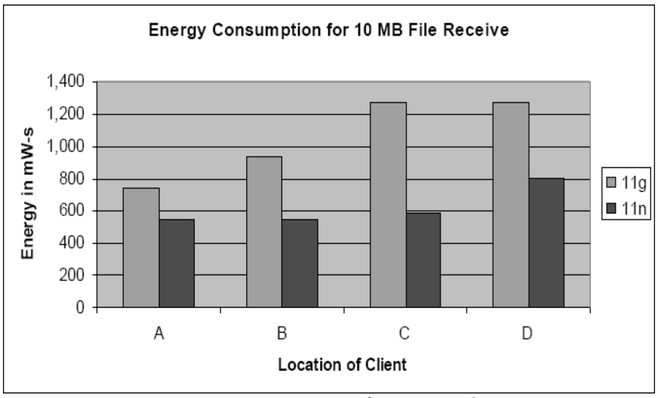

Figure 1. Energy Consumption for 10MB File Receive

A. MIMO

One of the most significant components of the IEEE802.11n specification is Multiple Input-Multiple Output (MIMO). MIMO is the most practical method to increase the raw data rate and to improve the transmission range of the standard. MIMO uses multiple receive and transmit antennas to create multiple spatial channels between a receiver and transmitter. Figure 2 shows MIMO usage to exploit a radio-wave phenomenon known as multipath: transmitted information bounces off doors, walls, other objects, reaching the receiving antenna multiple times via different routes and at slightly different times [6].

In general, the more antennas an IEEE802.11n device users at the same time, the higher is its maximum data rate. But multiple antennas do not maximize data range or data rate themselves.

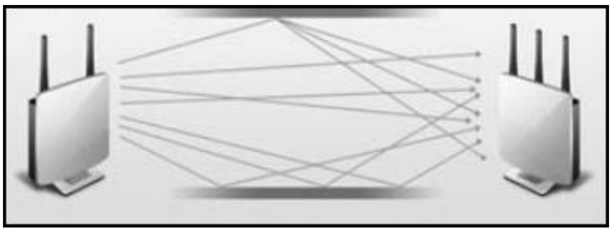

Figure 2. MIMO system.

These improvements come from how the MIMO device actually uses its multiple antennas. MIMO is used to improve range of reception, depending on the environment, or to extend the dramatically throughput over single antenna systems by two to four times using different signal processing techniques.

B. Doubling of data rates

Another optional mode in the IEEE802.11n effectively doubles data rates by doubling the width of a WLAN communications channel from 20 MHz to 40 MHz. The primary trade-off there is that fewer channels are available for other devices. In the case of the 2.4-GHz band, there is enough space for three non-overlapping 20-MHz channels [8]. A 40-MHz channel does not leave much space for other devices to join the network or transmit in the same airspace. The 40-MHz channel option improves overall WLAN performance by balancing the high bandwidth requirements of some clients with the needs of other clients connecting the network [6]. Three new formats are defined in the IEEE802.11n system for the Physical Layer: the Legacy mode, the Mixed Mode and the Green Field Mode.

C. Frame aggregation to the MAC layer

The medium access control (MAC) layer provides addressing and channel access control allowing multiple stations in the network to communicate. Frame Aggregation increases the payload that can be provided by each IEEE802.11 frame, reducing MAC layer. The legacy standards - IEEE802.11a/g devices can send no more than 2304 payload bytes per frame. But new IEEE802.11n devices have the option of bundling frames together for transmission, increasing the payload size to reduce the significance of the fixed overhead caused by inter-frame spacing and preamble [8].

IV. MEASURAMENT IN OUTDOOR

A. Measurement Description

To analyze the current wireless the basis performance standards, we used the COTS equipment with following settings.

Equipment:

Computer 1 (IEEE802.11g):
Operating System: Windows Vista Home Premium (6.0, Build 6002);
Processor: AMD Turion (tm) 64x2 (2CPUs), ~2,0GHz;
Memory: 2046MB RAM;
Wireless g adapter: Atheros AR5007EG Wireless Network Adapter.

IEEE802.11g settings: additional channel coding speed up to 3/4, OFDM symbol guard interval 800ns and 20 MHz wide channel.

Computer 2 (IEEE802.11n):
Operating System: Windows 7 Home Premium 64-bit (6.1, Build 7601);
Processor: Intel(R) Core(TM) i3 CPU M380 @2.53GHz (4 CPUs), ~2,5GHz;
Memory: 3072MB RAM;
Wireless n adapter: The Broadcom BCM4329 802.11 network adapter.

IEEE802.11n limited settings without MIMO and 40MHz wide channel. In this research we used channel coding speed up to 5/6, OFDM symbol guard interval 400ns and for the OFDM symbol formation were used 52 sub-carrier frequencies (see Fig.4). With these limitations WLAN card support only up to 72.2 Mbps data transmission. The result is the application-level goodput, the real throughput, which user can get through data transmission.

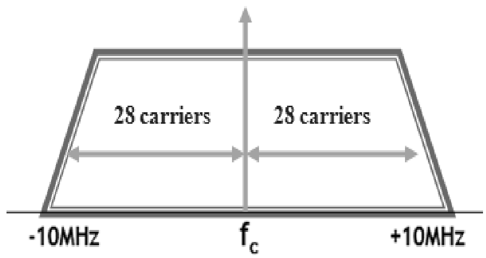

Figure 4. 56 sub-carriers (52 usable) for a 20 MHz channel [9]

In our research effort, we are interested in the behavior and performance of User Datagram Protocol (UDP) over wired and wireless networks with following setup: UDP Buffer Size: 41Kbytes, UDP Packet Size: 1500 Bytes.

Base station (WLAN access point):
Ultra Range Plus Wireless-N Broadband Router (WRT160N), Cisco Linksys.

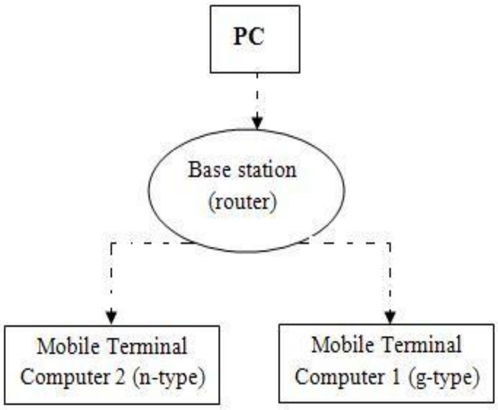

Figure 5. Testing Network architecture

Tools of measurement:

Programs Vistumbler and Jperf were installed on both computers. Signal to noise ratio we have used Vistumbler program, but throughput – used Jperf program.

Settings:

To understand the basic performance of the IEEE802.11n during the test we disabled Dynamic Host Configuration Protocol (DHCP), firewalls and other security settings. We used static stetting to avoid the additional resource consumption, which is required to create a secure and flexible wireless connection.

Test place:

Our approach was to find the test place with less reflecting surfaces and to get a power supply for the access point (base station). Test place was country wooden house and field around it. Two more wooden houses, some trees and tillage are in that area too. Figure 6 shows the testing place from the different point of view.

Figure 6. Testing place

Weather during the test:
Overcast, temperature ~+5°C, drizzle for a short time.

Testing process:

The base station was placed on the window. We walked away from it with both computers, looked how far we are and fixed the results. Three measurements were made: first time we fixed throughput, second time – distance. Third time one person was standing exactly 50 m distance from the base station, another person was increasing the distance between himself and a base station till reaching the minimum level of the signal. Settings of 802.11n were not changed in all three situations.

Figure 7. Testing process

B. Measurement results

The evident from the graphs (Fig.8) is that increasing distance from the base station decreases the data rate. IEEE802.11n (computer 2 solutions) is relatively better, as it is possible to cover a greater distance. If the IEEE802.11g covers the 250 m distance, then the IEEE802.11n covers 300 meters. Data rates of both protocols in closer distances from base station are about the same, but more the distance increases than more perceptible difference was found in the protocols.

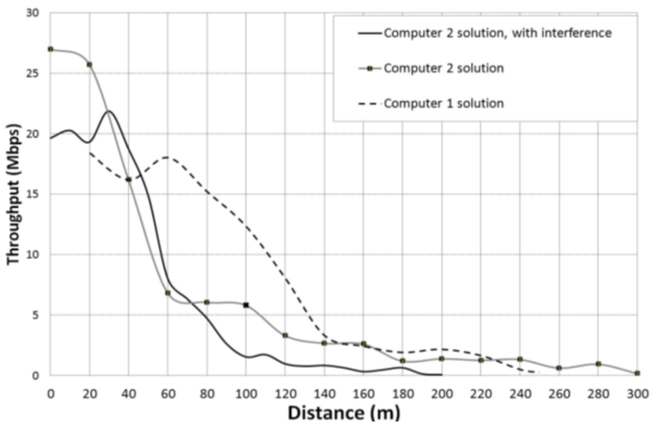

Figure 8. Throughput (Mbit/sec) versus distance (m); for Computer 1 and Computer 2

The experiment's results did not confirm the linear dependence (which was expected), and changes can be defined as 1/d, where d – distance. If there is interference (another mobile user), then the maximum transmission distance is rapidly decreasing.

The period where all three graphs form something like a "hill" (up and down distance from 20m to 100m), can be explained so that there was an obstacle (wooden house) between base and laptops.

Theoretically the data rate should be 600Mbits/sec, but during the experiment there was reached maximum 28Mbits/sec.

It can be concluded that IEEE802.11n outdoor performance is not significantly different from the IEEE802.11g. Only further distances show the difference in performance.

Next Figure 9 shows signal to noise Ratio (SNR) depends on distance of access point and mobile devices.

The minimum signal level matches -100dBm. An interesting observation was noted – the period where graphs form something like a "hills" again (there was an obstacle (wooden house) between base and laptops) – IEEE802.11g has better SNR, but at the same time the data speed rate is lower (it can be seen from the previous graphs also). Minimum signal level IEEE802.11g reaches at a shorter distance from base station than the IEEE802.11n computer.

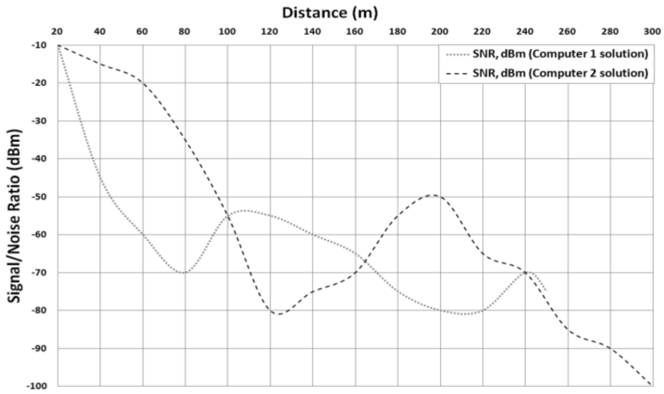

Figure 9. SNR(dBm) versus distance (m); for Computer 1 and Computer 2

The measurement was carried out with the following observations: 1) The IEEE802.11g standard provides acceptable signal till 250 m distance, but the IEEE802.11n - 300 meters; 2) The data rate at closer distances from base station are about the same, but increasing the distance, the noticeable difference accurse between the standards; 3) The minimum signal level matches -100dBm; 4) The minimum signal level IEEE802.11g reaches at a shorter distance than the IEEE802.11n equipped computer; 5) The minimal improvements of IEEE802.11n show significant differences between legacy standards in outdoor measurement.

V. Measurment in mobile environment

The main goal of field test is to investigate the possibility of IEEE802.11n standard with limited settings in vehicular to infrastructure mode using cost effective and COTS equipment.

In order to reach this goal we have been performed set of measurements with access point (APs) and a mobile user's device which was located in vehicle, which moved at a constant speed of 20 kilometer per hour (km/h), 40 km/h, 60 km/h, 80 km/h and 100 km/h. The constant vehicle speed we maintained using cruise control.

Goodput is defined [10] as the application throughput, i.e. the number of bits per unit of time excluding protocol overhead and retransmission packet. In this case, it is calculated by multiplying size of sending file by transferred file quantity and dividing by useful connectivity window.

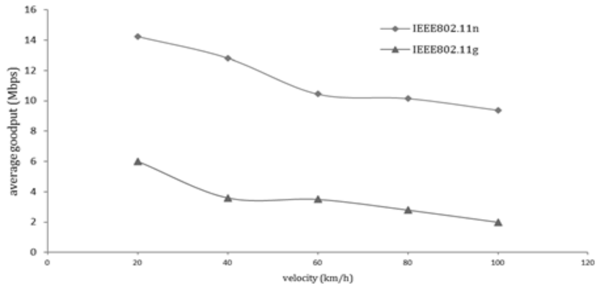

Figure 10. Basic performance comparison of IEEE802.11g/n standards in mobile environment

In fact, average goodput rate of TCP is dependent on the vehicle speed and decreasing proportionally with the vehicle speed. In Figure 10 shows the goodput of the IEEE802.11n standard with limited settings in comparison with IEEE802.11g. Despite diminished setting of improved standard it presents up to 5 time preferably performance of goodput in vehicular environment then legacy standard.

CONCLUSION

In this paper we presented field test evaluations of the IEEE802.11n standard with diminish settings comparing with IEEE802.11g standard using off-the-shelf equipment in the vehicle environment. The basic concept of our research is to compare the IEEE802.11n standard with legacy standards through a practical test in outdoor. In our paper we analyze outdoors practical measurements, fixing such parameters as distance, throughput and signal/noise ratio that characterize IEEE 802.11n performance.

It is important to note that results were showed in this article serve as information for future analyzes and vehicle wireless network systems designers to be aware of the system's possible improvements and limitations.

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