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SINR Simulation in 802.11n Networks

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***Abstract*— *Two factors determine the possibility of transmitting on 802.11 networks. The first is the level of the signal received by the receiving station. Depending on this parameter system can select the appropriate modulation and coding scheme. As the power level increases, the maximum theoretical bit rate increases. This is related to the modulation type change. In 802.11 n the highest bit rates are obtained for 64QAM modulation. The literature standard specifies the received power levels necessary to obtain a given bit rate, but there is no detailed information on the power characteristics of the power above and below the threshold. In addition, this level is a function of the channel width and it is higher for a 40 MHz channel. The second parameter that determines the choice of MCS for transmission is SINR (Signal to Noise and Interference Ratio). It is defined as function of type and modulation scheme and does not depend directly on signal level. Also in this case there is no information about the operation of the system in the vicinity threshold values. The author performed a series of simulations using the newest 3.26 release of NS-3 Simulator to determine the behavior of the standard for threshold SINR values. The NS-3.26 version allows to analyze the effect of interference on the resulting throughput using the new SpectrumWifiPhy physical layer model.*

Keywords—*Network Simulator, NS-3.26, interference, throughput, SINR thresholds.*

I. INTRODUCTION

The current throughput of 802.11 networks is variable over time as it depends on a very large number of factors. While the maximum momentary theoretical throughput of a given device is usually defined for a given standard (Juniper 2011), the actual bit rate can be defined rather using statistical methods and assumptions: eg time of day (relevant for large-scale links), number of concurrent users or average load per user. For 802.11n, the theoretical bandwidth varies from 6.5 Mb/s to 150 Mb/s for SISO transmissions, depending on: MCS modulation scheme, coding factor, channel width, guard interval, and modulation type. Fig. 1 shows the maximum bit rate limitation in 802.11n as a function of selected parameters.

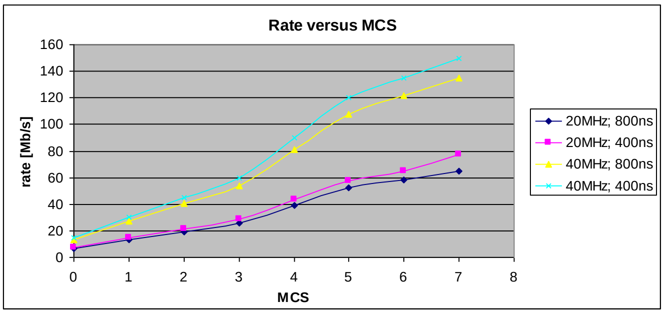


Fig. 1. Maximal theoretical transmission rate in 802.11n standard for following parameters: guard interval 400/800 ns, channel width 20/40 MHz and modulation type BPSK (MCS=0), QPSK (MCS=1;2), 16 QAM (MCS=3;4) i 64 QAM (MCS=5;6;7).

Source: Juniper Networks, (2011), Coverage or Capacity-Making the Best Use of 802.11n, Juniper Networks Inc. 2011.

The ability to achieve a given level of bit rate is related to the level of received power and the level of noise and interference. The highest signal level is required for 40 MHz channel bandwidth and MCS = 7 (64QAM) and its power value is -62 dBm. The other end of the range is determined by the channel width of 20 MHz and MCS = 0 (BPSK). In this case the signal power value is -82 dBm. The minimum required SINR values are shown in Fig. 2.

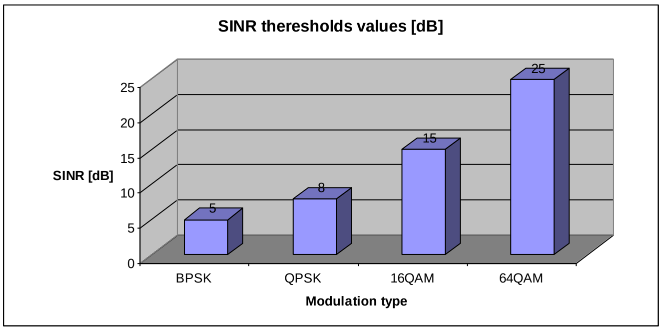


Fig. 2. Minimal SINR values in 802.11 standards.

To estimate the possibility of receiving packets, the SINR (Signal to Interference and Noise Ratio) factor is used. This factor for one transmitted station and one interference source is expressed in terms of:

$$SINR = \frac{P_{signal}}{P_{noise} + P_{interference}} [dB] \quad (1)$$

Where

Psignal	signal power level (dBm),
Pnoise	white Gaussian noise (dBm),
Pinterference	interference Power level (dBm),

while in general case interference could be produced by *n-1* stations or non-communication sources:

$$SINR = \frac{P_{1signal}}{P_{noise} + \sum_{1=2}^{n} P_{i\,interference}} [dB] \quad (2)$$

Interference can come from other stations 802.11, or other devices which also operate on frequencies used by this standard.

II. NS-3 SIMULATOR

NS-3 simulator is an advanced network simulator that is recognized as the primary test tool for LAN, WAN and Wi-Fi

(The NS-3 network simulator 2016, Ryu et al.) One of the most important devices (NetDevice) on the NS-3 is a Wi-Fi device. It is the largest module in NS-3. WifiNetDevice implements the IEEE 802.11 standard. Allows you to perform simulations with different versions of MAC and PHY. The IEEE 802.11 architecture implemented in NS-3 was based on the YANS simulator developed by Tom Henderson's Mathieu Lacage (Lacage, Henderson 2006). The model used in NS-3 is very extensive and contains 75 objects and a number of variables and functions. Works on the development of the simulator are ongoing and the new versions are made available virtually every year. The current version of the simulator is 3.26. A number of new models can be used with this version. Version 3.26 has a new physical layer model implemented. In addition to YansWifiPhy you can now use SpectrumWifiPhy (Baldo Miozzo 2009). The new physical layer model allows for consideration of radio channel parameters, interference from other stations, or other systems. The SINR (Signal to Interference and Noise Ratio) is used to assess the correct reception of the channel. Interference may come from other 802.11 standard or from other devices that also work on frequencies used by this standard.

SpectrumWifiPhy has implemented a number of tools to support the analysis of the physical layer of the radio channel. Fig. 3 shows the structure of the Phy layerAn easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.

A number of new objects have been introduced in this structure. WaveformGenerator is a simple device that generates an electromagnetic signal of a certain frequency that is a source of interference. The device is not a device for communication, but only for interference. The generator may be in an active state in which it is transmitting or in wait. The second source of interference is MicrowaveOven. Like the Generator, the Oven is not a communications device and only serves to produce interference in the 2.4 GHz ISM band (Taher et al. 2008). The SpectrumAnalyzer allows you to measure and store PSD (Power Spectral Density) power distribution in the frequency and time domain. This is an analyzer with functionality similar to real measuring instruments.

ShannonSpectrumWifiPhy calculates the maximum capacity Ct within a given time interval t using the Shannon-Hartley theorem, i.e.:

$$C_t = \sum_{n=1}^{N} B_n (\log_2 + \gamma_{n,t}) \quad (3)$$

where *Bn* is the bandwidth of sub band *n*.

Some calculations are made to find out if the reliable or successful transmission could be possible. First the amount of bits in time interval *t* taking into account available *Ct*. Then total amount of bits in the transmission time *T*. Finally this amount of bits are compared with the present packet size. If this size is larger then previously calculated theoretical possible throughput the transmission is not possible.

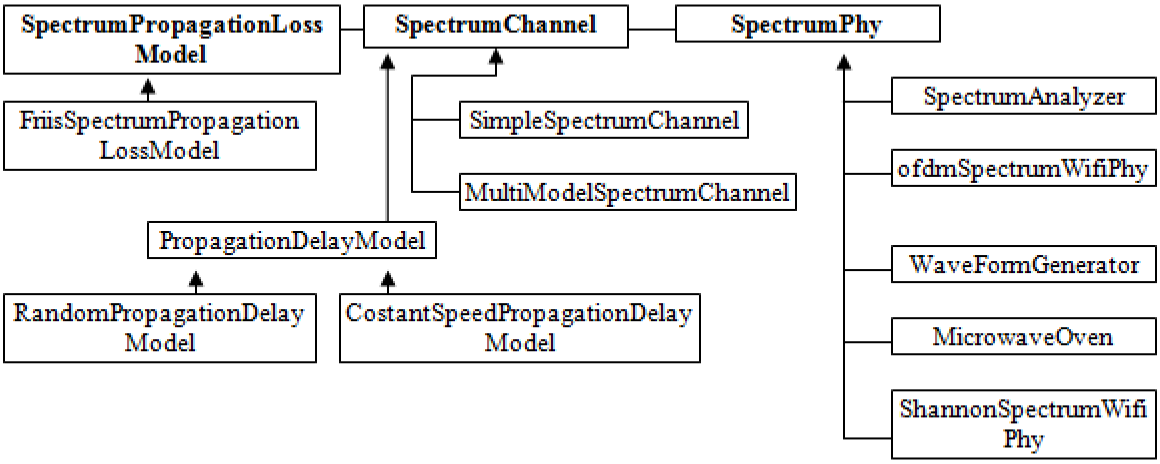


Fig. 3. UNL diagram of PHY layer of radio channel.

III. BER/PER ANALYZE IN NS-3 SIMULATOR

The SINR value criterion requires that the SINR value should be less than the minimum value specified in Fig. 2 for the entire transmission of the packet according to Fig. 4.

The currently available SpectrumWifiPhy model allows you to set the level of interference and SINR. The basis for calculating interference is AWGN (Additive White Gaussian Noise). This noise also called white noise, thermal, Nyquist, Johnson is constant in function of the Fourier frequency and is the background of each signal, or we can say that it is added to every signal in the channel.

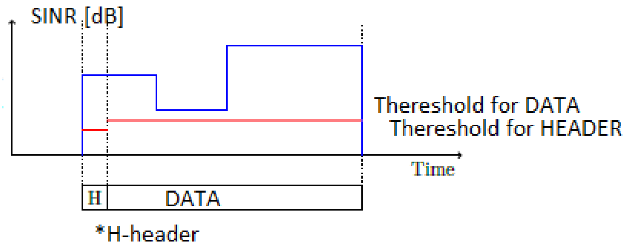
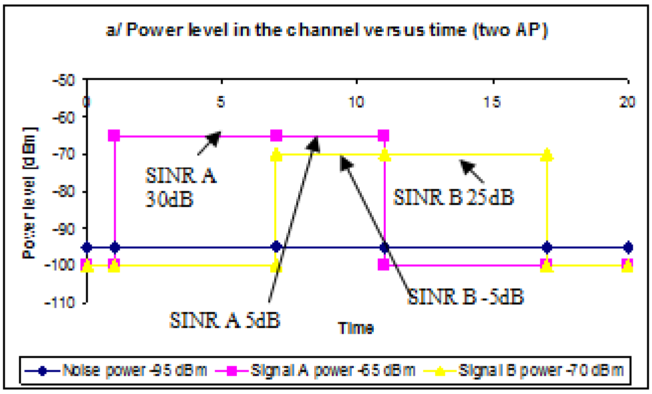


Fig. 4. Comparison of theoretical SINR requirements with the Real SINR value during the packet transmission.

Source: Bingman 2009.

If there are multiple signals sent simultaneously in the timeline, then the level of interference must be taken into account in order to properly evaluate the conditions in the channel. The thermal noise in the simulator channel NS-3 is calculated at 290° K, taking into account the channel bandwidth. It is possible to set a constant noise level. The typical white noise level in Wi-Fi systems is -105 ÷ -95 dBm.
For each packet sent, the received power is calculated taking into account transmit power. Power is received constant during the transmission of the entire package in the simulator, in real conditions, the received power is constantly changing due to the influence of noise and other factors affecting the transmission and reception parameters. When two packets are sent simultaneously to one receiver, hidden station scenario or when two access point operates on the same radio channel two AP scenario, there is a transmission interference. Figure 5 shows possible interference scenarios where two packets simultaneously reach the Node, which is the receiving station.
The following power level value were assumed for calculation: Noise power -95 dBm, Signal A power -65 dBm, signal B power -70 dBm.



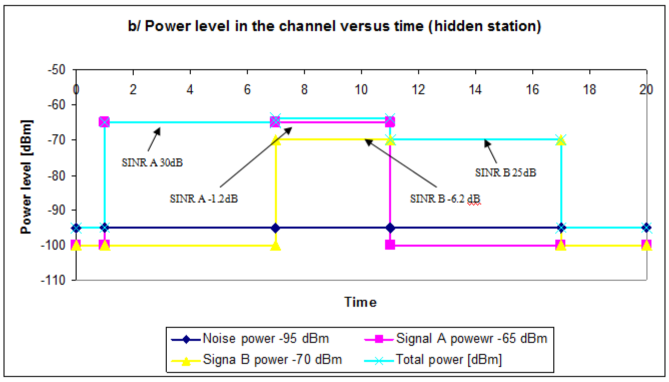


Fig. 5. Possible scenarios of packets receiving
a/ two AP
b/hidden station

In the first scenario we have two independent AP however they transmitted on the same channel and as a result Signal B is treated as interference for Signal B and vice versa. At least Signal A has positive SINR value which is equal 30 dB for some time and then 5 dB when two signals overlap in time domain. Second scenario is different. There is a situation when the hidden station exists and it is represented by Signal B [13, 14]. The hidden station is associated with the same network as the station with signal A but because of the distance influence both station haven't seen each other. As both signal are transmitted within the same network the power in channel is the sum of all signals. We have the total power which in practice is equal -65dBm when only Signal A is transmitted, -63.8 dBm when both signal are transmitted and -70 dBm when only signal B is transmitted. Both signals have negative SINR at time period when both signals are transmitted. It is means that the transmissions are blocked.

Calculated cumulative noise and SINR were implemented in the NS-3 simulator. Noise interference issues are analyzed by the InterferenceHelper module. For each packet received, a list of input data is created to evaluate the various parameters associated with the given signal. The list includes information such as arrival time, t-start, and, tendency end time, and, power level Pi received, packet size, and other parameters. The list is arranged according to the time of receipt of the package. Using the list, it is possible to design continuous interference. However, for evaluating two other parameters used in NS-3 such as bit error rate (BER) and packet error rate (PER), it is necessary to know about changes in the transmission interference level of the packet.

The WirelessPhyExt module uses SINR as the criterion for receiving the packet. First, the checksum (CRC32) is checked for each 802.11 packet header. Secondly, it is assumed that the packet was received correctly if the SINR packet is still above the minimum level of noise (threshold) as shown in Fig. 4.

During transmission, the SINR value may change significantly due to the interference effect (the appearance of other signals in the timeline). In this case, the SINR value must be recalculated.

Frame Capture Effect is related to the way the chipsets operate, which can switch during packet reception to a stronger signal (Ryu et all 2008). The weak signal is disturbed by the stronger signal.

Due to the increase in the level of interference SINR falls for the first packet and fails to receive correct reception. If the receiver does not support the frame capture option, the weak packet reception continues, but after the indicators are calculated, the packet is disqualified. The stronger package is lost, will remain undeleted.

Higher intelligence receivers will signal a weak packet reception error and receive a stronger packet. This improves the actual realized bit rate in the channel. The final decision to change the package received depends on the agreed delivery rules. The YansWifiPhy module is available in the NS-3 simulator. It allows the reception criteria based on PER / BER. This module works closely with two sub-modules: InterferenceHelper and YansWifiStateHelper. This first manages the cumulative noise calculation and places all received packets in the list as an Event. By using the list, all SINR changes during package receipt can be calculated. The set of these changes is represented as a vector: Interference-Helper :: NiChanges and is used to calculate the BER / PER value of functions included in the YansErrorRateModel

model. The final decision on acceptance is made by YansWifiPhy :: EndReceivePacket () based on the PER value.

IV. Simulation Assumptions and Results

The model *wifi-spectrum-per-interference* model available at www.nsnam.org in the examples / wireless tab was used after minor modifications for simulations . Because the model enables the use of both PHY, YansWifiPHy and SpectrumWifiPhy models, the use of the latest version of the ns-3.26 simulator is required. The model consists of three signal sources, two of which the Access Point and the Workstation represent a Wi-Fi network. The third signal source is the source of the interference. It is possible to change two source parameters: the power level and the position on the XY plane. The distribution of objects is shown in Fig.6.

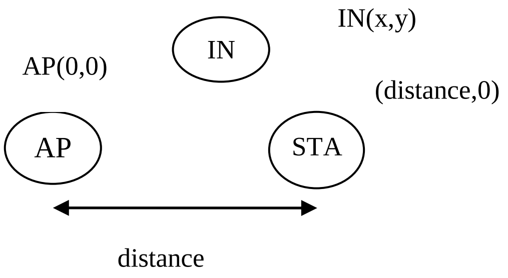


Fig. 6. Objects location on X, Y plane.

With a power level of 0.0001 [W], the interference source is virtually disabled. The interference power at the receiving point, which is the AP, can be controlled by the interference power level, which is waveformPower=[value] or by selecting the source position in the plane, or by changing the value of both parameters. The test network has a number of parameters that are summarized in Table 1.

Table 1. Basic parameters of simulated network.

Parameter	Value	Options
Network ssid	ns380211n	
Channel frequency [MHz]	5180	
Standard	802.11n	
Band [GHz]	5	
Channel width [MHz]	20	40
Guard interval [ns]	800	400
Number of streams	1	
Modulation	BPSK;QPSK;16/64QAM	
MCS	0-7	
Network IP address	192.168.1.0	
Flow	tcp	udp
Phy model	SpectrumWifiPhy	YansWifiPhy
Loss model	FriisPropagationLossModel	
STA Tx [dBm]	16	

A number of factors affect the throughput achieved in practice, and the most important of them include: station distance from the access point (AP), the frequency of the radio channel, inter and adjacent channel interference, the number of stations connected to the AP, the amount of traffic, the number of collisions and the conditions in the radio channel, which in turn, are associated with numerous parameters. The basic theoretical Friis model of losses in the channel is basically an ideal model. To reflect the real conditions, dozens of models were built and a number of amendments to the Friis model were introduced [3, 4]. Several models have been designed within the framework of the simulator NS-3, among others, Friis Propagation Loss Model and Log Distance Propagation Loss Model [6]. The balance of power at the receiving point in free space according to the Friis model [4], using a logarithmic scale can be determined by the following formula:

$$P_{Rx}(r) = P_{Tx}[dBm] + G_{Tx}[dB] + G_{Rx}[dB] - L_{fspl}[dB] \qquad (4)$$

where: $P_{Rx}(r)$ is the received power level, P_{Tx} transmitted power level, G_{Tx} i G_{Rx} transmitting and receiving antenna gains, L_{fspl} free space loss. L_{fspl} value can be calculated for r in kilometers and f in megahertz using the following formula:

$$L_{fspl}[dB] = 32.44 + 20\log r[km] + 20\log f[MHz] \qquad (5)$$

The Friis model assumes a change in signal level with a square of distances.

During the simulation it is possible to change a number of attributes. Some of them can be changed using commands available from the command line, some require changes at program code level. A number of simulations were performed as a function of the selected parameters. The functionality of the changes was determined by the practically reached rate near the transmission thresholds determined by the received power level and the SINR value. Table 2 lists the range of variance of analysis attributes.

Table 2. Range of simulation attributes.

Parameter	Range
Guard interval [ns]	400; 800
Channel width [MHz]	20; 40
Distance [m]	2÷1150
waveformPower [W]	0.0001÷0.015
Index	0-31
Modulation	BPSK, QPSK, 16QAM, 64QAM

The simulation results are presented in figures from 8 to 13.

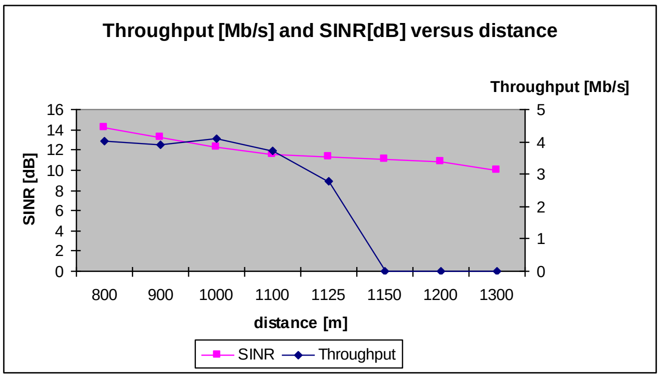


Fig. 8. Throughput and SINR versus distance for the following attributes: simulationTime=2s, index=0 (MCS=0, BPSK, 20MHz channel width, 800ns guard interval), Friis loss model. waveformPower=0.00001W.

The throughput characteristics versus distance between AP and STA were shown in Fig. 8, 9, 11 and 12. As the distance increased the received power decreased and when the critical level is achieved the throughput for given set of attributes start to drop dawn rapidly. The change of SINR from 11.5 to 11.1 dB in Fig. 8 cause the fact that transmission fails completely.

The corresponding distance is about fifty meters. The coverage for low index used for simulation presented in Fig.8 is equal about 1100 meters while for high MCS the coverage drop to about 100 meters and SINR increased to 30 db what is shown in Fig. 9. SINR values for attributes set for Fig. 11 and 12 are respectively about 15 and 20 dB.

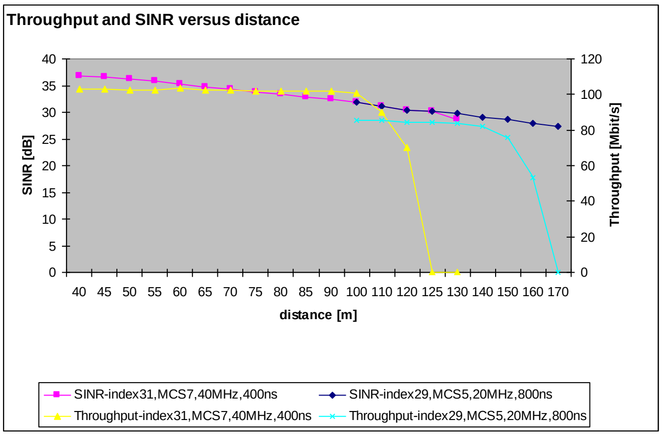


Fig. 9. Throughput and SINR versus distance for the following attributes: simulationTime=2s, 64QAM, Friis loss model. waveformPower=0.00001W.

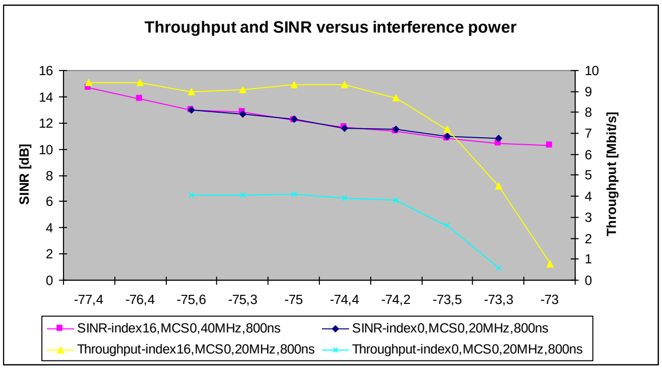


Fig. 10. Throughput and SINR versus interference power level for the following attributes: simulationTime=2s, BPSK, Friis loss model, distance=50 m, Rx=-62,6 dBm.

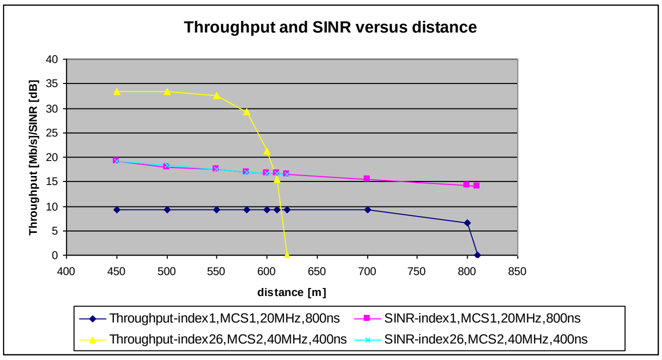


Fig. 11. Throughput and SINR versus interference power level for the following attributes: simulationTime=2s, QPSK, Friis loss model, waveformPower=0.00001W.

Throughput characteristics versus interference power were shown in Fig. 10 and 13. The effect of interference power increased is similar to distance increased in both scenarios SINR value decreased and when the critical level was achieved the transmission is terminated.

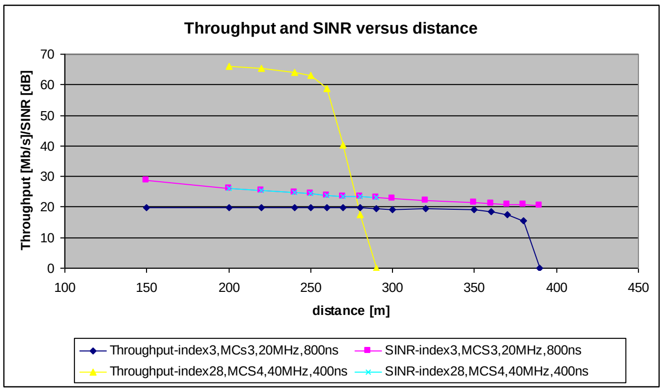


Fig. 12. Throughput and SINR versus interference power level for the following attributes: simulationTime=2s, 16QAM, Friis loss model, waveformPower=0.00001W.

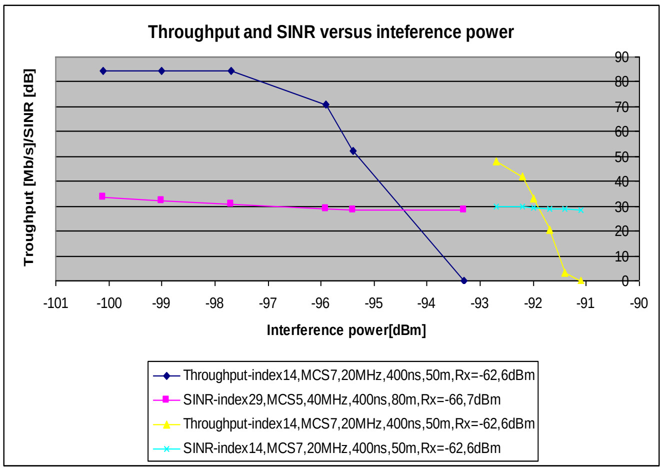
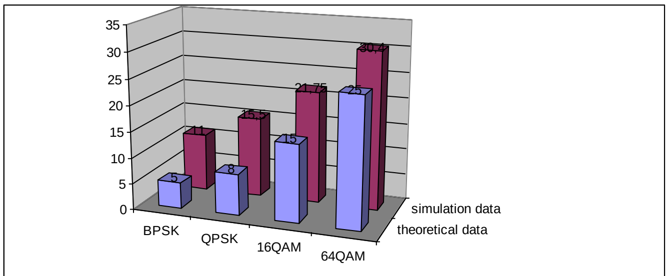


Fig.13 Throughput and SINR versus interference power level for the following attributes: simulationTime=2s, 64QAM, Friis loss model

SINR value depends on the transmission index which is a function of MCS, channel width and interval guard. Practical and theoretical SINR values are compared in Fig. 14.



	BPSK	QPSK	16QAM	64QAM
theoretical data	5	8	15	25
simulation data	11	15,5	21,75	30,4

Fig. 14. Comparison of theoretical and simulation data of SINR values.

SINR values are within the range of 6 to 25 dB according to literature and 11 to 30 for NS-3.26 simulation.

V. CONCLUSIONS

Simulation confirm the strong SINR value dependence on the different attributes especially: MCS, channel width and interval guard. The final effect of SINR decreasing is the collapse of transmissions. The transmissions however don't stop immediately but we have some slope. Typical range of SINR change which stop the communication vary from a part of dB to few dB and strongly depend on transmissions schemes.

SINR values obtained through NS-3 simulation are higher in the range from 5.5 to 7.5 dB fro theoretical data.

New PHY implementation as Spectrum WifiPhy give more possibilities of interference analysis. The WaveForm Generator device enabled analysis concerning interference power level.

REFERENCES

[1] I. Dolińska , A. Masiukiewicz, and G. Rządkowski, "Collisions in DCF scheme used In 802.11 standard networks," *Telecommunications Review*, vol. 2-3, pp. 44-46, 2014.
[2] Juniper Networks, "Coverage or capacity-making the best use of 802.11n," *Juniper Networks Inc.* 2011.
[3] T. G. Hodgkinson, "Wireless communications- the fundamentals," *BT Technology Journal*, vol. 25, no. 2, pp. 11-26, 2007.
[4] R. L Freeman, *Radio System Design for Telecommunication*, J. Willey & Sons, 2007.
[5] T. Bingmann, "Accuracy enhancements of the 802.11 model and EDCA QoS extensions in ns-3," Diploma Thesis at the Institute of Telematics Faculty of Computer Science University of Karlsruhe, 2009.
[6] NS-3 Network Simulator, "NS-3 Model Library," Release ns-3 dev, NS-3 Project, February 01.2017, www.nsnam.org access 02.2017.
[7] N. Baldo, M. Miozzo, "Spectrum-aware channel and PHY layer modeling for ns3," *NSTOOLS Conference Proceedings*, Italy, 2009.
[8] The ns-3 network simulator, http://www.nsnam.org access 02.2017
[9] M. R. Akhavan, "Study the performance limits of IEEE 802.11 WLAN's," Master Thesis, Lulea University of Technology, Sweden 2006.
[10] L. Deek, E. Garcia-Villegas, E. Belding, Sung-Ju Lee, and K. Almeroth, "The impact of channel bonding on 802.11n network management," *ACM CoNEXT 2011 Conference Proceedings*, Tokyo, Japan, 2011.
[11] I. Dolińska, A. Masiukiewicz, and G. Rządkowski, "Channel selection in home 802.11 standard networks," *Proceedings of IEEE sponsored Digital Technologies Conference*, Żylina, 2014.
[12] T. Taher, M. Misurac, J. LoCicero, and D. Ucci, "Microwave oven signal modelling," *in IEEE WCNC Conference Proceedings*, 2008.
[13] C. L. Fuller, and J. J. Garcia-Luna-Aceves, "Solutions to hidden terminal problems in wireless networks," *ACM SIGCOMM Computer Communication Rewie*, vol. 27, issue 4, pp. 39-49, 1997.
[14] L. Boroumand, R. H. Khokhar, L. A. Bakhtiar, and M. Pourvahab, "A review of techniques to resolve the hidden node problem in wireless networks", *Smart Computing Review,* vol. 2, no. 2, pp. 95-110, 2012.