Andrzej ZANKIEWICZ

Białystok University of Technology

Susceptibility of IEEE 802.11n networks to adjacent-channel interference in the 2.4GHz ISM band

Abstract*. This paper is a practical analysis of effects of mutual interference between Wi-Fi networks that operate in the same area using the newest IEEE 802.11n standard exclusively and also in coexistence with older 802.11 standards. Presented experiments show how this interference deteriorates the network throughput. The obtained results can be used for designing new WLANs and for development of the existing ones.*

Streszczenie. *W artykule przedstawiono praktyczną analizę efektów interferencji pomiędzy pracującymi w tym samym obszarze bezprzewodowymi sieciami w standardzie IEEE 802.11n oraz pomiędzy sieciami 802.11n i starszymi technologiami z rodziny 802.11. Przedstawione wyniki obrazują wpływ tych interferencji na rzeczywistą przepustowość sieci. Otrzymane rezultaty mogą być przydatne przy projektowaniu i rozbudowie sieci Wi-Fi. (**Podatność sieci IEEE 802.11n na interferencje sąsiedniokanałowe w paśmie ISM 2,4GHz**).*

Keywords: WLAN interference, 802.11n, Wi-Fi network throughput.
Słowa kluczowe: interferencje w sieciach WLAN, 802.11n, przepustowość sieci Wi-Fi.

Introduction

At present Wireless Local Area Networks (WLANs) are used in almost every type of environment including offices, industry buildings, private houses and blocks of flats. These networks can be quickly and easily installed almost without any building works and thanks to the newest wireless technologies their throughput and reliability are almost as good as in their wired counterparts.

Consumer WLANs usually use license-free 2.4GHz and 5 GHz radio bands. Especially the most popular standards of WLAN operating in the 2.4GHz ISM radio band are IEEE 802.11b, 802.11g and the newest 802.11n [1]. The whole ISM band is divided into radio channels with frequency spacing of 5 MHz. Due to the current regulations in European countries the first 13 channels are used. Since the consecutive channels are shifted by 5MHz and each of them is 20MHz wide (however some standards can also use 40MHz wide channels) there are only three non-overlapping channels in the whole 2.4GHz ISM band. This is clearly visible in Fig. 1

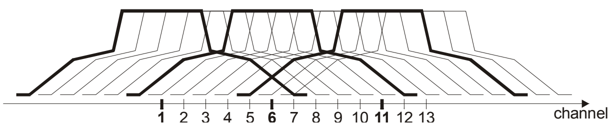

Fig.1. Three non-overlapping 20MHz channels in 2.4GHz band

This property of spectrum characteristic of radio channels can become an important obstacle to development of the 2.4GHz WLAN networks, especially when it comes to the outdoor applications. Theoretically in the particular area only 3 different networks can operate at the same time. In practice there are usually much more networks, especially in the city areas. Because the number of WLANs is still growing, it is important to determine how WLANs operating on the overlapped radio channels influence on each other. This knowledge can be useful for designing new WLANs and for development of the existing ones.

The main goal of this paper is to determine and discuss the mutual influence of coexisting in the same area WLANs on the real throughput (transmission rate), which can be obtained in these networks. The problem is presented from the practical point of view, but mathematically interference can be modelled using state equations [4, 5]. This paper is the continuation of the previous ones [6, 7] and completes them with the newest IEEE 802.11n WLAN standard.

The test environment

The configuration of the test environment, which was used in the experiments, is presented in Fig. 2.

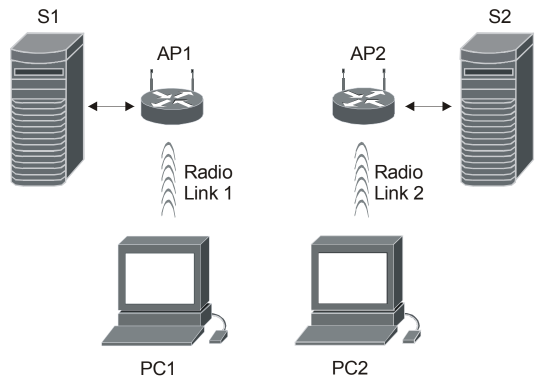

Fig.2. Diagram of the test environment

It consisted of two stations (PC1 and PC2) and two access points (AP1 and AP2) connected to the FTP servers (S1 and S2). The PC1 was equipped with Linksys WMP600N card and the PC2 was equipped with D-Link DWA-547 card. The AP1 was the Linksys WRT320N and the AP2 was the D-Link DIR-655.

Equipment described above can operate in 802.11b, 802.11g and 802.11n (draft 2) standards. The 802.11n devices, which were used, can operate using up to two spatial MIMO streams and 20MHz or 40MHz radio channels. The experiments were carried out using 20MHz channels and thus the maximum data rate was 130Mb/s. Measurements were divided into the following 2 scenarios.

Scenario I – data rate in presence of a foreign AP

The goal of this scenario was to determine a real throughput of the 802.11 2.4GHz radio link in presence of a foreign access point. The measured values are the average throughputs obtained on PC2-AP2 link during transmission a file of size 200MB from S2 to PC2 by FTP. The AP2 was operating on channel 5 and the AP1 (acted as a foreign AP) was operating on channel changed from 1 to 13. The experiments were done in the following configurations:

a. Link PC2-AP2 and AP1 set to the 802.11n standard.
b. Link PC2-AP2 set to 802.11n and AP1 set to 802.11g.
c. Link PC2-AP2 set to 802.11n and AP1 set to 802.11b.
d. Link PC2-AP2 set to 802.11g and AP1 set to 802.11n.
e. Link PC2-AP2 set to 802.11b and AP1 set to 802.11n.

Since the results obtained in all configurations are very similar only those from point “a” are presented in Fig. 3.

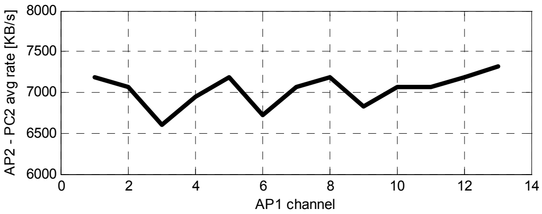

Fig.3. Average throughput of the 802.11n link in presence of a foreign 802.11n access point

As it can be seen in Fig. 3 no influence of foreign 802.11n access point was noticed and the observed changes of the throughput practically did not exceed the measurement error.

Scenario II – influence of a foreign transmission

The goal of this scenario was to determine a real throughput of the IEEE 802.11n 2.4GHz radio link in presence of a foreign transmission. The experiments were done in the same way as in scenario I, and the only difference was that during measurements the link PC1-AP1 was also transmitting a file. The obtained results are presented in Fig. 4.

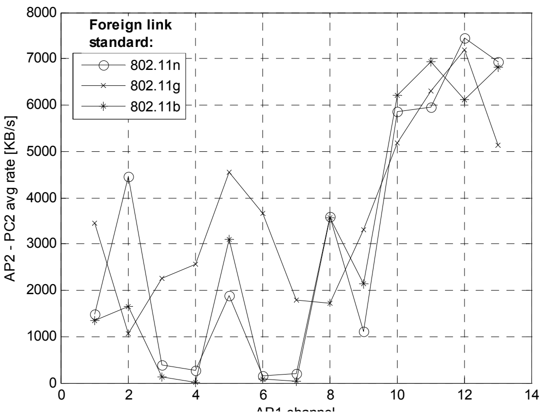

Fig.4. Average throughput of the 802.11n link in presence of a foreign transmission

Obtained results show that there is a significant influence of other (foreign) wireless transmission on throughput of the observed link. The total lack of this influence was noticed only when the foreign link was operating on channels 10, 11, 12 and 13. According to Fig. 1 it covers all the cases when both transmissions were operating using fully non-overlapped channels. When the foreign transmission was present in the frequency range used by other transmission, both links experienced deterioration of their quality. Practically it was noticed as a fall of transmission rate even up to a total cut.

Comparison of the obtained results to the analogous ones obtained for IEEE 802.11g and IEEE 802.11b networks (presented in [6]) allows to draw a conclusion that links which operate using IEEE 802.11n standard are much more susceptible to a foreign transmission than links which use the older 802.11g or 802.11b standard.

The last two experiments were done in order to check how 802.11n transmission influences the throughput of the links that operate using older wireless standards (802.11b and 802.11g). The obtained results are presented in Fig. 5 and 6.

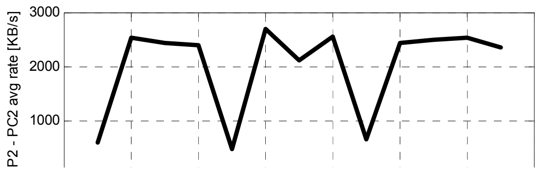

Fig.5. Average 802.11g rate in presence of a foreign 802.11n link

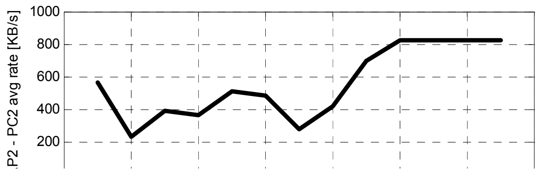

Fig.6. Average 802.11b rate in presence of a foreign 802.11n link

Link, which was operating using IEEE 802.11g standard, appeared as a quite unaffected by a foreign IEEE 802.11n transmission. Only 802.11n link operating on the same channel (channel 5) and on channels situated four positions away from it (channels 1 and 9) deteriorated transmission rate of the 802.11g link by about 75%. On other channels the influence of a foreign 802.11n link on the throughput of 802.11g was almost unnoticeable even in cases when both links were operating on directly adjacent channels (Fig. 5).

For the 802.11b link (Fig. 6) the results were different and were similar to those obtained for 802.11n link (Fig. 4). A foreign 802.11n link causes deterioration of transmission rate of 802.11b link by about 50% practically on every overlapping channel. Only on completely separated channels (10, 11, 12 and 13) the transmission rate of the 802.11b link was unaffected by a foreign 802.11n link.

Conclusions

The analysis of presented results leads to the conclusion that 802.11n links are significantly more sensitive to adjacent-channel interference than older (and slower) WLAN standards since the information included in the spectral sidelobes of 802.11n signal is much more significant than in the previous solutions. However it is possible to point out particular pairs of partially overlapped channels with relatively low interference as well as pairs of frequencies that should be avoid for devices working in the same area due to the extremely high level of interference.

This paper was prepared within the project S/WE/1/10.

REFERENCES

[1] Perahia E., Stacey R., *Next Generation Wireless LANs: Throughput, Robustness and Reliability in 802.11n*, Cambridge University Press, 2008

[2] IEEE Std 802.11 - 2007 (Revision of IEEE Std 802.11 – 1999)

[3] IEEE Std 802.11n – 2009 (Amendment 5: Enhancements for Higher Throughput)

[4] Griszin J., Robust data processing on the presence of outliers, *Przegląd Elektrotechniczny,* 86 (2010), nr 3, 25-27

[5] Jańczak D., An adaptive algorithm of state estimation in the presence of multiplicative interference, *Przegląd Elektrotechniczny,* 86 (2010), nr 3, 30-31

[6] Zankiewicz A., Influence of adjacent-channel interference on the throughput of 2.4GHz WLAN network, XVII EMD Conference, Białystok, 19-21.09.2007, pp. 3.7-1 ÷ 3.7-4

[7] Zankiewicz A., Vulnerability of 5GHz Wi-Fi network to adjacent-channel interference, *Przegląd Elektrotechniczny,* 86 (2010), nr 3, 101-102

Author*: dr inż. Andrzej Zankiewicz, Politechnika Białostocka, Wydział Elektryczny, ul. Wiejska 45D, 15-351 Białystok, E-mail: azankiewicz@pb.edu.pl.*