

# Free Download Adjacent Channel Interference In Ieee 802 11n Networks

## Reinvestigating Channel Orthogonality - Adjacent Channel Interference in IEEE 802.11n Networks

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**Abstract**—In this paper we analyze the adverse effects of Adjacent Channel Interference (ACI) on 802.11 with a focus on new 802.11n standard. ACI is causing problems that are related to the carrier sensing mechanism in 802.11. On the one hand, the carrier sensing is sometimes too restrictive thus preventing concurrent transmissions which leads to a variant of the exposed terminal problem. On the other hand, the carrier sensing is sometimes too optimistic thus causing packet collisions which is a form of the hidden node problem. Both problems are especially severe in multi-radio systems, where the radios are very closely spaced. Such problems already investigated in 802.11a/b/g still remain with 802.11n. Our results show that the number of available orthogonal channels in IEEE 802.11n depends on the spatial spacing between the radios, channel width (HT20 vs. HT40), RF band (2.4 vs. 5 GHz) and traffic pattern. In a multi-radio system the situation is worst, e.g. in the 2.4 GHz we were not able to find more than 1 orthogonal channel. The adverse effect of ACI can be reduced in two ways. First, by increasing the spatial separation between the radios, a spacing of less than 1 meter already improves the situation significantly, e.g. 90 cm are sufficient to get 2-3 orthogonal 20 MHz channels in the 2.4 GHz band with reduced transmission power. Furthermore, a distance of 90 cm is also sufficient so that a 40 and a 20 MHz channel can be used simultaneously without any interferences. However, in a multi-radio system the spatial spacing between the radios cannot be increased due to space limitations. The only option to overcome ACI related problems is to reduce the transmit power making power control essential. Finally, our analysis revealed that 802.11 is an inappropriate protocol for multi-channel MAC/ Routing protocols based on multi-radio systems where an explicit MAC layer link-scheduling is more promising.

**Index Terms**—Wireless Networks, IEEE 802.11n, Multi Channel, Multi Radio, Adjacent Channel Interference, Orthogonal Channels, Measurements

### I. INTRODUCTION

Wireless networks based on standards like IEEE 802.11 are an important research topic in industry and academia. To increase the network capacity lots of work was done on multi-channel MAC and routing protocols that simultaneously use the multiple channels available in IEEE 802.11 [1]. The majority of multi-channel protocol designers assume the existence of several non-overlapping and therefore non-interfering (orthogonal) channels, e.g. 3 for 802.11b/g and 12 for 802.11n, when evaluating their protocols. While implementing real-world prototypes of their multi-channel protocols, some authors realized that Adjacent Channel Interference (ACI) between supposedly non-overlapping channels causes serious problems when used with 802.11. The impact from ACI was

much higher in multi-radio systems where network devices are equipped with multiple 802.11 radios, since the spacing between antennas of different radios is small due to space constraints.

In contrast to strictly using only non-overlapping channels it is also possible to further increase the available network capacity by simultaneously using overlapping channels. However, this requires a careful planning of channel assignment taking into account aspects like spatial spacing between radios, and PHY modulation and RF band as well as traffic pattern [2]. Otherwise problems like the hidden and exposed terminal problem would significantly increase due to ACI and waste a large amount of the available radio resources (ref. to III-C). Thus there is a tradeoff between spectral efficiency and impact from ACI related problems as depicted in Fig. 1.

The majority of multi-channel protocol research is based on the outdated 802.11a/b/g standard. However, the updated 802.11n standard [3] offers lots of improvements like the use of wider channels (channel bonding) and the use of less guard carriers which have an effect on channel orthogonality. Moreover, the signal filtering was improved, i.e. less energy is bleeding over to adjacent channels. Finally, earlier studies have shown that some hardware and software solutions based on the legacy 802.11a/b/g standard showed incorrect behavior [2]. Therefore, it is necessary to examine the influence of ACI in 802.11n again using state-of-the-art hardware and software.

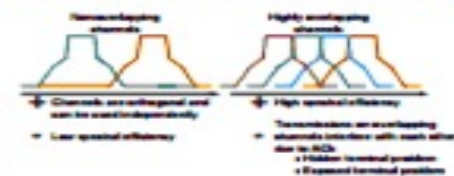


Fig. 1. Tradeoff, which occurs with simultaneous use of multiple channels when using a Carrier Sense Multiple Access (CSMA) protocol (e.g. 802.11).

The main contributions of this paper are as follows. First, we describe the adverse effects of Adjacent Channel Interference (ACI) on 802.11 like the increased probability for hidden and



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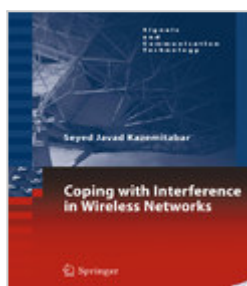
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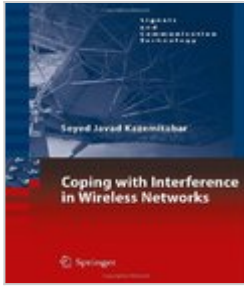
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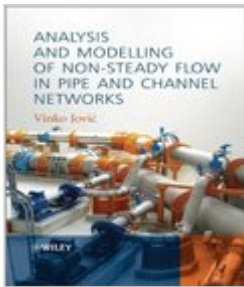
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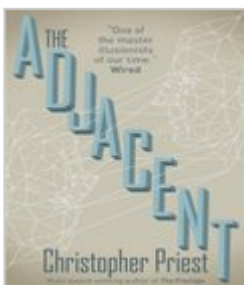
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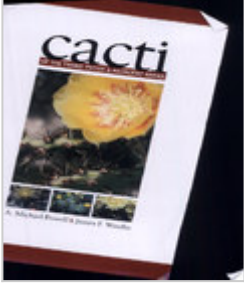
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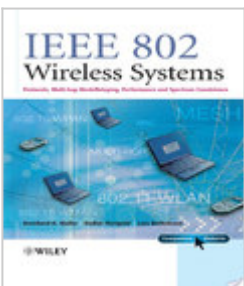
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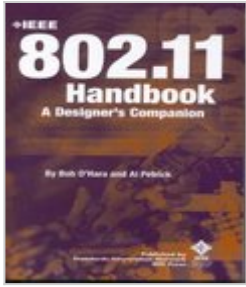


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