Adjacent channel interference in a multi-radio wireless mesh node with 802.11a/g interfaces

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Abstract—**In this work we utilize Signal to Interference-plus-Noise (SINR) criterion for reception, and combine it with the model for partial channel overlap presented in [1] and extended for 802.11a/g, to quantify the impact of Adjacent Channel Interference (ACI) in multi-radio 802.11a/g based wireless nodes designed for mesh networking. The nodes we consider are equipped with two to four 802.11a or 802.11g wireless interfaces and a variety of directional antennas.**

Our study focuses mainly on 802.11a, since we expected that the ACI would be almost inexistent in this protocol, due to better frequency allocation. Indeed, adjacent channels in 802.11a are widely considered to be non-overlapping. However, as we have seen in this work, adjacent 802.11a channels have in fact an overlap that produces significant interference whose impact will be noticeable when the antennas are closely co-located on a node, even in the case where directional antennas are used. We examine how this close placement affects the cell radius of such a node with respect to the offered data rates for the uplink, and the 802.11a/g clear channel assessment (CCA) mechanism. Our results are verified by initial short range experiments performed on off-the-shelf 802.11a cards.

Our future work includes both uplink and downlink testing through in-lab experimentation with channel emulation over programmable RF attenuators and through experiments on a metropolitan scale mesh network. We also intend to revisit the model proposed in [1] and refine it, taking into account the partial overlap of the OFMD subcarriers of 802.11a/g.

***Index Terms*— ACI, 802.11a/g, Multi-radio, Mesh Networks.**

I. Introduction

In [2] the authors perform 802.11a testbed experiments to quantify the effect of Adjacent Channel Interference (ACI) on a dual-radio multihop network. In their work they use omnidirectional antennas for their testbed and suggest increasing channel separation and antenna distance as well as using directional antennas in order to mitigate the effects of ACI.

Unlike [2], we have begun our work enhancing the SINR criterion for signal capture with a theoretical model similar to the one presented in [1] that quantifies the ACI of partially overlapping channels. We consider nodes with more than two (and up to four) interfaces and directional antennas. Such a theoretical analysis is important, since it can be readily extended to newer standards, such as 802.11n, and gives initial insight on the adjacent channel interference effects prior to any delicate, time consuming testbed experiments. In our work we indicate quantitatively and through simulations, that adjacent 802.11a channels have such an overlap that produces significant interference, whose impact will be noticeable when antennas are closely co-located on a node, even in the case that directional antennas are used. We also examine how this design affects (i) the cell radius of such a node with respect to the offered data rates for the uplink and the physical distance of the antennas, and (ii) the 802.11a/g clear channel assessment (CCA) mechanism. Our results are verified by initial experiments performed on off-the-shelf 802.11a cards.

II. Using The SINR Criterion in the presence of ACI

According to the SINR model for the successful capture of the transmitted data at a receiver, the Signal to Interference-plus-Noise ratio must be at least equal to a threshold θ which depends on the transmission rate, the modulation scheme, and the required bit-error-rate.

In the presence of adjacent channels that have partial overlap, such as the 802.11a/b/g channels, the interference power can be calculated as proposed by [1], taking into account the spectral mask of the 802.11a PHY amendment and the channelization scheme of 802.11a and 802.11g. As we see in table I for the 802.11g case this interference can be quite significant, whereas in the 802.11a case it is not inexistent as it is widely believed.

TABLE I
Interference power leakage (in mW) from neighboring channels for 802.11a and 802.11g for typical transmission power values

	Standard	802.11a		802.11g				
	Channel distance	+/-1	+/-2	+/-1	+/-2	+/-3	+/-4	+/-5
Transmit power	100mW	n/a	n/a	79.06	52.67	26.51	0.627	0.121
	50mW	0.303	0.0050	39.53	26.34	13.25	0.303	0.061
	25mW	0.152	0.0025	19.76	13.17	6.63	0.152	0.030
	12mW	0.073	0.0012	9.49	6.32	3.18	0.073	0.015
	6mW	0.036	0.0006	4.74	3.16	1.59	0.036	0.007
	3mW	0.018	0.0003	2.37	1.58	0.80	0.018	0.004
	2mW	0.012	0.0002	1.58	1.05	0.53	0.012	0.002
	1mW	0.006	0.0001	0.79	0.53	0.27	0.006	0.001

The 802.11a/b/g standards specify the minimum receiver sensitivity that receivers must have at each of the supported data rates, which is determined by the modulation scheme, for a given bit error rate. For an environment without interference receive sensitivity is defined as:

$$Receive\ sensitivity = ((N_t + 10log(BW)) + N_s) + SNRmin(r)$$

All terms in the sum are expressed in dB and N_t is the power spectral density of the thermal noise, BW is the channel bandwidth, N_s is the noise figure for the receiver and $SNRmin(r)$ is the minimum SNR required by the modulation used at rate r to meet a certain BER. As one can see the receive sensitivity is practically the minimum required received power for the signal of interest. The $SNRmin(r)$ for a given rate r and BER can be calculated, so given the receive sensitivity we can identify the noise $N_p=((N_t + 10log(BW)) + N_s)$ for which devices are required by the standards to be able to operate. To that noise we add any interference we introduce later on and use the SINR criterion with θ the $SNRmin(r)$.

Using the criteria above, we can calculate the link budget for any 802.11a/g mesh node designs. Doing so we are able to estimate the worst case maximum cell radius for the supported data rates and any antenna specifications.

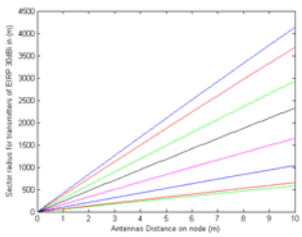


Fig. 1. The scenario assumes a mesh node of 2 back-to-back 802.11a interfaces, tuned to adjacent channels, with 180°,13dBi gain and 20dB f/b antennas, spaced apart as indicated on the x-axis. The Y-axis is the maximum distance for successful reception of a 30bBm EIRP 802.11a client transmitting to one of the interfaces of the mesh node, while the other mesh interface is transmitting at 17dBm. Bottom-up on the plot are the curves for rates of 54, 48, 36, 24, 18, 12, 9 and 6Mbps.

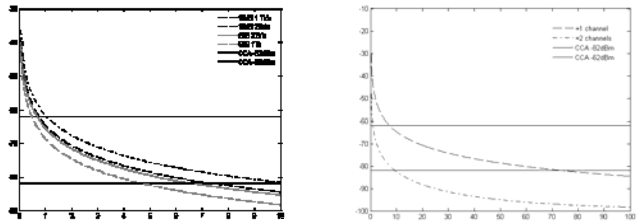
III. CCA Errors due to ACI

In order a node to gain access to the channel and transmit data, an 802.11a/g interface senses the channel and performs a Clear Channel Assessment. In 802.11a a channel is considered busy if a preamble can be decoded at -82dBm. If the preamble cannot be correctly decoded –or missed altogether, but the power detected is above -62dBm then again the medium is considered busy.

Since there is significant power leakage from the nearby channels, in both 802.11g and 802.11a, it will be possible for interfaces transmitting near a sensing interface to cause the CCA of the latter to report a false negative on the clear channel assessment mechanism. This false negative of the CCA mechanism can be caused on an interface either by downlink traffic from the other interfaces of the node, or by the clients sending uplink traffic to one of the other interfaces, even when using directional antennas.

IV. Testbed experiments

In order to verify our work we present one of our initial experiments conducted that indicate the existence of interference in 802.11a adjacent channels and couples its effects with the antenna distance. We used two laptops with MadWifi-driven D-link 108AG pcmcia cards to send udp traffic for 30 sec to distant 802.11a mini-pci Atheros based cards on a linux desktop. The laptops were located in our laboratory, with their wireless cards at a distance of 50cm. Transmission rates were locked on 54Mbps with 16dBm transmit power and the udp packet size was 1000 bytes. Results on the average per node uplink throughput are presented in figure 9.



(a) (b)

Fig. 2. Both figures show the power received in dBm at an 802.11a sensing interface of a node with 3 interfaces using 15dBi 120°sector antennas with 20dB f/b ratio. (a) ACI power from single or two 802.11a transmitters on the mesh node at the adjacent channel. Distance of transmitting interfaces is indicated on the x-axis. (b) ACI power from a client transmitting to one of the other interfaces of the node tuned to the adjacent channel. The client is assumed to be at the distance indicated on the x-axis and uses EIRP of 30dBm.

V. Future work

Our future work includes uplink and downlink testing through in-lab tesbed experimentation with channel emulation over programmable RF attenuators and through experiments on a metropolitan scale mesh network. To a more theoretical twist we intend to revisit the model proposed in [1] and refine it, taking into account the subcarriers of the OFMD scheme used in 802.11a/g..

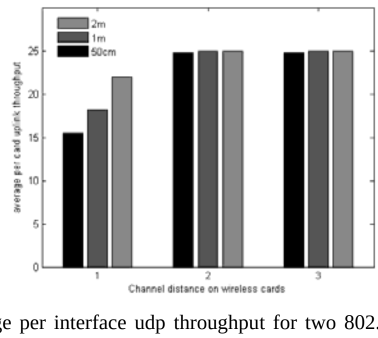


Fig. 3. Average per interface udp throughput for two 802.11a sending udp traffic to two different clients. The two links are tuned at adjacent channels 100 and 104. Physical interface separation is indicated by the color-code of the bars.

References

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