INSTITUT NATIONAL DES SCIENCES APPLIQUÉES DE TOULOUSE
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Zigbee-WiFi Interference

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Introduction

Assignment on studying interference of a WiFi signal on a Zigbee receiver. The Zigbee network is located inside a 1-floor building, and should co-exist with a WiFi network whilst ensuring a packet error rate (PER) lesser than 1%. In this example the WiFi transmitter and Zigbee transmitter will be initially placed 5m apart. We will be studying the range degradation caused by the WiFi signal on our Zigbee network.

1 Part 1

The WiFi transmitter and Zigbee are placed 5m apart as shown in 2.

1.1 Calculating Zigbee range without WiFi interference

Using the available data and some assumptions, we can compute the link budget associated to a transmission without WiFi interference.

Transmitter	Electrical power (dBm)	0 (extracted from annex 2)
	Gain emitter antenna (dB)	0 (Assumption)
	Transmitter losses (dB)	0 (Assumption)
	EIRP (dBm)	0
Receptor	Bandwidth (MHz)	2 (extracted from annex 2)
	Throughput (kbps)	250 (Zibgee standards)
	Noise floor (dBm)	-95dBm (extracted from annex 2)
	Noise figure (dB)	0 (Assumption)
	SNR % (dB)	2 (extracted from annex 2)
	Sensitivity receiver (dBm)	-93
	Losses receiver (dB)	0 (Assumption)
	Gain receiver antenna (dB)	0 (Assumption)
	Minimal input power (dBm)	-93
	Path loss (dB)	93

Table 1: Link budget without WiFi interference

We will be using the one slope model to compute the path loss induced by the environment. In this case, we suppose that we are in a dense area on one floor. The following empirical formula will be used:

$$Lp(dB) = Lp_0 + 10N\log_{10}(\frac{r}{r_0}) \tag{1}$$

In our case, $Lp_0 = 33.3$, N=4 and r_0=1. We are looking for the maximum value of r, D_{max} ensuring a correct Zigbee transmission (with a PER1%). Hence, we will be equating the maximum path loss to the one found in the link budget. We have the following equations:

$$Path\ Loss = Lp_0 + 10N\log_{10}(D_{max}) \tag{2}$$

$$
\begin{aligned}
Lp_0 + 10N\log_{10}(D_{max}) &= Path\ Loss \\
10N\_10(D_{max}) &= Path\ Loss - Lp_0 \\
\log_{10}(D_{max}) &= \frac{Path\ Loss - Lp_0}{10N} \\
D_{max} &= 10^{\frac{Path\ Loss - Lp_0}{10N}}
\end{aligned}
$$

Calculating the value of D_{max}:

$$
\begin{aligned}
D_{max} &= 10^{\frac{93-33.3}{11\times 4}} \\
&= 31.08m
\end{aligned}
$$

1.2 Calculating Zigbee range with WiFi interference

We will now consider a nearby WiFi transmitter, disturbing the communication between the two Zigbee entities. In order to do that, we will place a Wifi hotspot 5m behind the Zigbee antenna, so that it will not be between the two Zigbee devices. All other environmental conditions are maintained.

Emitter	Electrical power (dBm)	0 (same as previously)
	Gain emitter antenna (dB)	0 (same as previously)
	Losses emitter (dB)	0 (same as previously)
	EIRP (dBm)	0
Receptor	Bandwidth (MHz)	2 (same as previously)
	Throughput (kbps)	250 (same as previously)
	Thermal noise floor at 300 K + Noise induced by environment (dBm)	-95
	Noise induced by the Wifi hotspot (dBm)	Nw
	Sum of noises	$10\log_{10}(10^{\frac{Nw}{10}} + 10^{\frac{-95}{10}})$
	Noise figure (dB)	0 (same as previously)
	SNR (dB)	2 (same as previously)
	Sensitivity receiver (dBm)	$10\log_{10}(10^{\frac{Nw}{10}} + 10^{\frac{-95}{10}}) + 2$
	Losses receiver (dB)	0 (same as previously)
	Gain receiver antenna (dB)	0 (same as previously)
	Minimal input power (dBm)	$10\log_{10}(10^{\frac{Nw}{10}} + 10^{\frac{-95}{10}}) + 2$
Path loss (dBm)		$-(10\log_{10}(10^{\frac{Nw}{10}} + 10^{\frac{-95}{10}}) + 2)$

Table 2: link budget with Wifi interference

We need to evaluate the noise induced by the Wifi hot-spot a distance of D m from the transmitter. In order to do that we need to determine the power from the Wifi that can interfere with the Zigbee signal, and then calculate the attenuation of the WiFi signal overa distance of D m. To calculate the noise, we will be considering thermal noise and the overlapping WiFi signal as additive white noise. Since we will be considering the same environmental conditions, the previous noise floor will still be applicable. Assuming an even power transmission spectrum over the WiFi's bandwidth, the power of WiFi signal transmitted overlapping with the Zigbee signal will be :

$$
\begin{aligned}
P_{TX\_WiFi\_Interfering} &= \frac{Bandwidth_{Zigbee}}{Bandwidth_{WiFi}} \times P_{TX\_WiFi} \\
&= \frac{2MHz}{22MHz} \times 10^{\frac{20}{10}} mW \\
&= 9.0909mW \\
&= 9.586dBm
\end{aligned}
$$

As done previously, the path loss for the Wifi signal for a distance of (D+S) m shoulbe be computed, with D being the distance between the WiFi transmitter and the Zigbee transmitter, and S the distance between the Zigbee transmitter and Zigbee receiver.

$$Nw = Lp_0 + 10N\log_{10}(\frac{D+S}{r0}) \tag{3}$$

$$\begin{aligned} L_{P0}(r_0) + 10N\log_{10}(\frac{D_{max}}{r_0}) &= EIRP(dBm) + SNR(dB) - P_{Noise}(dBm) \\ &= EIRP(dBm) - SNR(dB) \\ &- (10\log_{10}(10^{\frac{Initial\_noise}{10}} + 10^{\frac{P_{TX\_WiFi\_Intefering} - L_{P0}(r_0) - 10N\log_{10}(\frac{D_{max}+S}{r_0})}{10}})) \end{aligned}$$

$$33.3 + 10Nlog_{10}(D_{max}) = -2 - (10\log_{10}(10^{\frac{-95}{10}} + 10^{\frac{9.58-33.3-40\log_{10}(D_{max}+5)}{10}})) \tag{4}$$

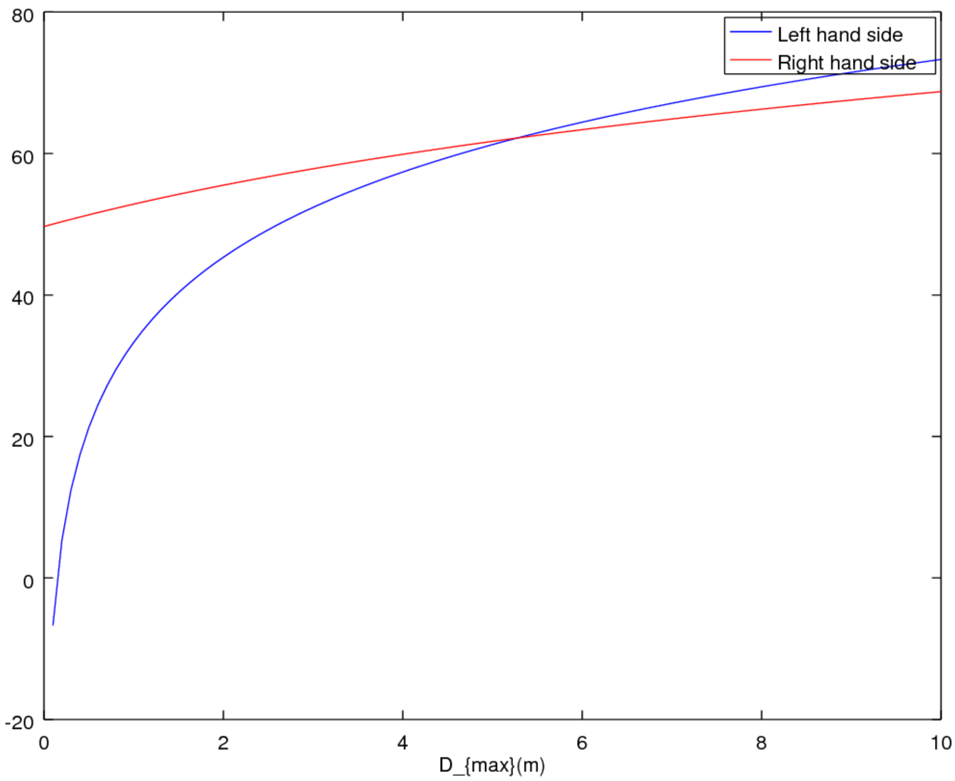


Figure 1: Graphical solution to equation 4

$D_{max} = 5.28$m

The range of action for Zigbee will be degraded to 5.28m if there is a WiFi hot-spot nearby.

2 Part 2

The aim of this section is to calculate the minimum distance between the Zigbee transmitter and WiFi transmitter, to achieve a range of 20m.

Emitter	Electrical power (dBm)	0
	Gain emitter antenna (dB)	0
	Losses emitter (dB)	0
	EIRP (dBm)	0
Receptor	Bandwidth (MHz)	2
	Throughput (kbps)	250
	Thermal noise floor at 300 K (dBm)	-95
	Noise induced by the Wifi hotspot (dBm)	Nw
	Sum of noises (dBm)	$10\log_{10}(10^{\frac{Nw}{10}}+10^{\frac{-95}{10}})$
	Noise figure (dB)	0
	SNR (dB)	2
	Sensitivity receiver (dBm)	$10\log_{10}(10^{\frac{Nw}{10}}+10^{\frac{-95}{10}})+2$
	Losses receiver (dB)	0
	Gain receiver antenna (dB)	0
	Minimal input power (dBm)	$10\log_{10}(10^{\frac{Nw}{10}}+10^{\frac{-95}{10}})+2$
Path loss (dB)		$-10\log_{10}(10^{\frac{Nw}{10}}+10^{\frac{-95}{10}})-2$

Table 3: Link budget with Wifi interference

Besides, we can compute the path loss at the Zigbee receiver using the one slope model:

$$L_P = L_{P0}(r_0) + 10N\log_{10}(\frac{D}{r_0})$$

Numerical application:

$$\begin{aligned} L_P &= 33.3 + 40\log_{10}(20) \\ &= 85.34dB \end{aligned}$$

$$\begin{aligned} L_{P0}(r_0) + 10N\log_{10}(\frac{D}{r_0}) &= Path\ loss \\ &= EIRP(dBm) - Minimal\ input\ power(dBm) \\ &= EIRP(dBm) - SNR(dB) - P_{Noise}(dBm) \text{ (see table 3)} \\ &= EIRP(dBm) - SNR(dB) \\ &- (10\log_{10}(10^{\frac{Initial\_noise}{10}} \\ &+ 10^{\frac{P_{TX\_WiFi\_Intefering} - L_{P0}(r_0) - 10N\log_{10}(\frac{D+S_{max}}{r_0})}{10}})) \end{aligned}$$

$$S_{max} = -D + r_0 \times 10^{\frac{10\log_{10}(10^{\frac{L_{P0}(r_0)+10N\log_{10}(\frac{D}{r_0})-EIRP(dBm)+SNR(dB)}{-10}} - 10^{\frac{Initial\_noise}{10}}) - P_{TX\_WiFi\_Intefering} + L_{P0}(r_0)}{-10N}} \tag{5}$$

$$S_{max} = -D + r_0 \times 10^{\frac{10log(10^{\frac{Path\ loss - EIRP(dBm) + SNR(dB)}{-10}} - 10^{\frac{Initial\_noise}{10}}) - P_{TX\_WiFi\_Intefering} + L_{P0}(r_0)}{-10N}}$$

$$= -20 + 10^{\frac{10\log_{10}(10^{\frac{Path\ loss+2}{-10}} - 10^{\frac{-95}{10}}) - 9.58 + 33.3}{-10\times 4}}$$

Applying the path loss of 85.34dB found above :

$$\Rightarrow S_{max} = -20 + 10^{\frac{10\log_{10}(10^{\frac{85.34+2}{-10}} - 10^{\frac{-95}{10}}) - 9.58 + 33.3}{-10\times 4}}$$

Applying D = 20m, r_0 = 1m, $L_{P0}(r_0)$ = 33.3 dB, N = 4, Initial_noise = -95 dBm, $P_{TX\_WiFi\_Intefering}$ = 9.58 dBm to equation 5, we get a value of 20.82m for S_{max}.

The minimum distance between the WiFi transmitter and Zigbee transmitter must be 20.8 m, in order to ensure a good reception from Zigbee receiver.

Conclusion

After analysing the interference of a WiFi signal on the range of a Zigbee network, we may conclude that the Zigbee network is degraded. Hence deploying a Zigbee network coexisting with a WiFi network can prove to be tricky as the WiFi signal can stomp the Zigbee receivers with noise. Should both networks be deployed on the same area, the Zigbee nodes will have to be significantly closer to each other if WiFi transmitters are placed nearby.

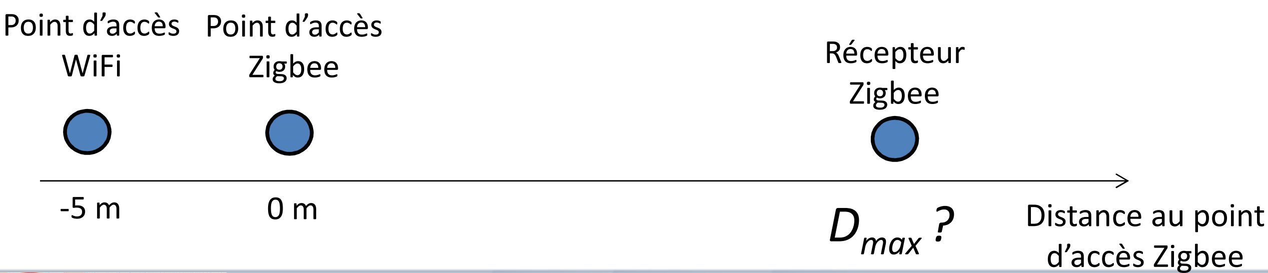
3 Annex

3.1 Part 1

Exercice 2 – Interférences Zigbee – WiFi

Un réseau Zigbee a été réalisé à l'intérieur d'un bâtiment. Celui-ci doit coexister avec un réseau WiFi IEEE 802.11.b. La réception Zigbee est supposée satisfaisante tant que le Packet Error Rate (PER) est inférieur à 1 %. Dans cet exercice, on considère une installation donnée, où les points d'accès WiFi et Zigbee sont initialement séparés de 5 m. On s'intéresse à l'effet de l'interférence du WiFi sur la réception du Zigbee, notamment la dégradation de la portée radio du Zigbee.

1. Calculez la portée radio du Zigbee en présence ou non d'interférences WiFi. On considèrera un modèle de propagation du type One Slope pour un environnement dense sur un étage.



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3.2 Data

Exercice 2 – Interférences Zigbee – WiFi

Caractéristiques radio

	Zigbee	WiFi
Fréquence centrale	2405 MHz	2412 MHz
Bande passante	2 MHz	22 MHz
Puissance d’émission	0 dBm	15 – 20 dBm
Seuil de bruit	-95 dBm	N/A
SNR minimum (PER < 1%)	2 dB	N/A

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3.3 Part 2

Exercice 2 – Interférences Zigbee – WiFi

2. En considérant le schéma ci-dessous, calculez la séparation maximale Smax entre les points d'accès Zigbee et WiFi pour assurer une portée de 20 m du réseau Zigbee. On conserve les mêmes hypothèses que précédemment.