Mobile Communication
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Matthias Frank, Peter Martini;
Christoph Barz, Christoph Fuchs, Lukas Pustina, Christian de Waal

Assignment Sheet #3

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Exercise 6: (Free-space signal propagation)

Acquaint yourself with the Decibel unit (dB)! The dBm unit specifies a signal strength (in dB) in relation to 1 mW, i.e. y dBm = 10 log(x mW / 1 mW).

According to the Friis free space model (see lecture chapter 3, slide 10), what is the strength of signals transmitted with 50mW, 100mW at the free space distances 50m, 500m, if the signal's carrier frequency is 2.4GHz and $G_r = G_t = L = 1$? Express all values (including transmission powers) in dBm!

Explain why the received signal strength is assumed to be proportional to $1/d^2$ in free space, where d is the distance from the sender to the receiver!

Exercise 7: (Large-scale fading)

In the data sheet of an IEEE 802.11b wireless LAN card, we find the following specifications:

Data rate	**11 MBit/s**	**5.5 MBit/s**	**2 MBit/s**	**1 MBit/s**
Transmission power	15 dBm			
Receiver sensitivity	-82 dBm	-87 dBm	-91 dBm	-94 dBm
Transmission range (open)	160 m	270 m	400 m	550 m
Transmission range (semi-open)	50 m	70 m	90 m	115 m
Transmission range (closed)	25 m	35 m	40 m	50 m

The "receiver sensitivity" is the minimum signal strength at the receiver required for a successful reception (with a predefined, sufficiently high probability). In the following subtasks, the log-distance model (cf. chapter 3, slide 12) will be used to take a closer look at the communication, carrier sense and interference ranges.

a) For each of the given data rates, calculate the maximum path loss (cf. chapter 3, slide 10) that allows for successful decoding of a signal modulated at this rate. Using these values and the distance values in the data sheet, estimate the path loss exponent of the log-distance model for the three environments "open", "semi-open", and "closed". (Resolve the formula to n for this purpose!) How well is the log-distance formula applicable to the data?

b) Suppose that a carrier can be sensed if the signal strength at the receiver is at least -98 dBm. How large are the "carrier sense ranges" in the different environments?

c) Suppose that a successful reception requires the Signal-to-Interference-and-Noise Ratio (SINR, see lecture chapter 3, slide 4) to be above the following values:

Data rate	**11 MBit/s**	**5.5 MBit/s**	**2 MBit/s**	**1 MBit/s**
SINR	6.99 dB	5.98 dB	1.59 dB	-2.92 dB

How large is the "interference range" with the different data rates in different environments (disregarding possible background noise)? In other words, what conditions must be fulfilled for the distance d_I between interferer and receiver such that

1. the interferer's signal prevents successful decoding of the sender's signal at the receiver and
2. the interferer is not able to sense the sender's signal (and therefore assumes the transmission medium to be free)?

For which data rate / environment combinations might a potential interferer be unable to sense the sender's carrier? How sensible is the notion of an "interference range" in your opinion?

Hints:

- Begin subtask c) by showing that there exists some constant k with $P_r(d) = k / d^n$.
- Make your calculation in dependence of the distances d_I (interferer-receiver distance) and d_S (sender-receiver distance), but avoid additional use of the sender-interferer distance: When considering a worst-case scenario, this distance can be substituted by other variables.

Exercise 8: (Rayleigh Fading)

A classical small-scale fading model is the Rayleigh model (cf. chapter 3, slides 17 and 18). According to this model, the received signal's amplitude follows a Rayleigh distribution. This distribution is defined for $x \geq 0$, and its cumulative distribution function (cdf) is

$$F(x) = 1 - \exp\left(-\frac{x^2}{2s^2}\right).$$

As small-scale fading model, the Rayleigh model is used to model the variation of the signal strength around a given mean (originating from a large-scale fading model, e.g. the log-distance model). The deviation from the mean signal strength is given by $X^2 / E\left(X^2\right)$, where X is the random variable modelling the signal's amplitude (this is because the signal strength is related to the squared amplitude).

Deduce the cdf for this deviation (in dB)! What is the probability for the signal strength to drop more than 6dB / more than 12dB below the mean? What is the probability for the signal strength to rise more than 3dB / more than 6dB above the mean?

What is the motivation to expect received signals' amplitudes to be Rayleigh distributed?

Hints:

- The second (raw) moment of the Rayleigh distribution is $2s^2$, i.e. for a Rayleigh distributed random variable X, it is $E\left(X^2\right) = 2s^2$.
- In case you want to experiment with the Rayleigh distribution, a simple way to generate a random number based on this distribution is to take two independent samples x and y from a Gaussian distribution with mean 0 and variance s^2 and to calculate $\sqrt{x^2 + y^2}$.

Exercise 9: (Multiple Access Schemes)

Chapter 3.3 introduced several concepts to achieve multiple access on a shared medium to allow for parallel wireless communication of several devices in spatial proximity: TDMA, FDMA, and CDMA.

These concepts can be illustrated by a real world analogy, the “cocktail party”. At such a cocktail party, usually there are several guests involved in parallel conversations. If all guests would speak at the same time, none of them would understand anything. Therefore, medium access has to be controlled in some way.

a) How does this usually work in our real world “cocktail party”? Also think about “transmission ranges” and issues of “power control”!

b) How can you apply TDMA, FDMA or CDMA at the cocktail party?

c) Discuss strengths and weaknesses of TDMA, FDMA and CDMA.

Exercise 10: (Duplex Schemes)

Chapter 3.3 mentioned “FDD” (Frequency Division Duplex) in the context of FDMA as one possible example of achieving full duplex communication between a sender and a receiver.

a) Which duplex concept is used in wired networking technologies (like Ethernet, Token Ring) and wireless networking technologies (like Bluetooth, WLAN)?

b) GSM uses FDD for duplex (beside a combination of FDMA and TDMA for multiple access). Is it really possible to communicate “full-duplex”, i.e. sending and receiving in parallel at the same point in time? What do you have to consider for a simple wireless device (like a mobile phone)?