Aalto University
School of Electrical
Engineering

ELEC-E7120 Wireless Systems

Homework for Unit 5

Released on 6.10.2023
Due date 13.10.2023 (by 9:00 AM - Finnish Time)

Guidelines:

- Return the electronic version of your answers before the deadline using the corresponding homework link in MyCourses.
- Homework is individual.
- Some references to do the homework are found in
  - Slide-sets covered in “Lec9” and “Lec10” (@ MyCourses)

Problem 5.1 (1 point). *Wi-Fi vs Bluetooth*

We need to download a file of one recorded lecture whose size is 100 MB (*Megabytes*) through two different wireless technologies, namely: *Wi-Fi* (IEEE 802.11g) and *Bluetooth*.

a) Assume that the raw bit data for the Wi-Fi (IEEE 802.11g) access point is 54 Mbps (*Megabits-per-second*) and transmit power is 20 dBm. Let us neglect for the moment any antenna gains and cable losses. For simplicity, we assume a transmission efficiency of 100%: That is, we consider that there is no signalling overhead, and that delays introduced by the contention-based multiple access protocol (i.e., CSMA-CA) do not exist. How long would does it take, in this ideal situation, to download this file? How much energy would it be consumed in this process?

b) Let us now consider that we use a pair of Bluetooth (class 3) devices for the wireless link, which can provide a (raw) data rate at 1 Mbps (*Megabit-per-second*) with a transmission power of 0 dBm. How much time do we now need download the same file? And how much energy would be now consumed? For simplicity, we neglect again the PHY- and MAC-layer overhead and assume that the download speed is equal to the raw data rate that is transmitted.

c) Compare the spectral efficiency (in *bps/Hz*) and the energy efficiency (in *bits/joules*) for both technologies. For this, consider that the bandwidth of the Wi-Fi (IEEE 802.11g) transmission is 20 MHz and the bandwidth of the Bluetooth transmission is 1 MHz. What is the effect that you observe when comparing these two Key Performance Indicators Parameters (KPIs) for both wireless technologies? Are they aligned with your expectations, keeping in mind their target key applications?

Problem 5.2 (1.5 points). *Bluetooth throughput in scatternet*

Bluetooth devices hop in frequency following a pseudo-random sequence of 79 channels (1 MHz each) on the license-free 2.4 GHz ISM band. Each Bluetooth piconet is synchronized to a frequency hopping sequence defined by the master device, so that all the slave devices in the same piconet are tuned at the correct channel at any transmission time instant.

Let us assume that *'N'* independent Bluetooth piconets are coexisting in the same area. For simplicity, the internal clocks of all master devices are synchronized, such that only full overlapping collisions may take place when two different piconets select the same frequency channel for the given hop. Moreover, let us assume that all piconets are using Data High-rate packets type-1 (DH1) in both directions (*i.e.*, master-to-slave and slave-to-master), alternating one DH1 packet from master-to-slave and one DH1 packet from slave-to-master sequentially. Note that each DH1 packet transport 27 bytes of useful data in every time slot of duration of 0.625 milliseconds.

For sake of simplicity, we consider that the full packet is lost if a collision takes place (this is a reasonable assumption, since DH1 packets do not use Forward Error Correction). Note that for a successful transmission using DH1 packets, there should be no collision neither in the transmission slot (when the data is sent from source to the destination) and the following reception slot (where the ACK of correct reception issued from the destination).

Find the throughput that each Bluetooth piconet can support in each direction of communication when *'N'* equals *'1'*, *'10'* and *'100'*. Express the result in kbps.

What is the effect that you observe in the aggregate data rate of the *Scatternet* for *N = 1, 10, 100*? (Note: the aggregate data rate of the Bluetooth scatternet is the sum of the individual data rates of the piconets). Give a short but clear justification of this observation.

Problem 5.3 (1.5 points). *Optical Wireless Communication*

Make a table comparing *Visible Light Communication* (VLC) and *Free-Space Optical* (FSO) technologies for optical wireless communications, making emphasis on the following points:

- Highlight similarities and differences considering, *e.g.*, the portion of the Electro-Magnetic spectrum that is used in each case, the kind of light sources that is utilized in each situation, the target data rate and coverage range that is expected, among other things that you consider relevant.
- Which of both technologies is more suitable for wireless access (point-to-multipoint)? And which one for wireless point-to-point connectivity? Why? Justify your answer properly.
- Propose two use cases (application scenarios) in which the use of VLC would have notable advantages with respect to FSO, and two use cases in which FSO would be more convenient to use when compared to VLC? Justify your answers.