PTP Innovative Smart Systems

Wireless digital communications for connected objects - Exercises

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Exercise

The purpose of the proposed exercises is the study of the physical layer of some famous IoT protocols. Questions deals with frame structures, throughput evaluation, radio access, link budget and coverage estimation. Your answers must rely on scientific and technical literature, that you must cite in your report.

<u>Instructions:</u>

- ✓ Choose one exercise per project group
- ✓ Answer to the questions and write a report
- ✓ Send it to alexandre.boyer@insa-toulouse.fr before January 10th 2020

Exercise 1

Study of physical layer of Sigfox protocol

1. What are the frequency ranges used by Sigfox (in Europe) ?
2. What is the modulation used by Sigfox ? What is the binary data rate ? What is the bandwidth ?
3. Define the packet structure. What is the actual throughput of Sigfox (precise all the hypothesis for this evaluation) ? What is the time on air ?
4. What are the features used by Sigfox to reduce the effect of interferences ?
5. What is the maximum transmitted power ? Wat should be the theoretical sensitivity of a Sigfox receiver? What is the typical sensitivity of a Sigfox receiver ? Compute the typical link budget of a Sigfox wireless network.
6. If a free space environment is considered, what is the radio range of Sigfox ?
7. For an outdoor application, evaluate the radio range of Sigfox. The model COST231-Hata will be used for this purpose (see next slide). The following parameters could be used: Hb = 15 m, Hm = 1 m.

Exercise 1

Study of physical layer of Sigfox protocol – model COST231-Hata

- Model for urban environment, with transmitting antenna above roof top. Frequency range = 800 – 1800 MHz
- Path loss Lu estimated by:

$$L_u(dB) = 69.55 + 26.16\log(f) - 13.82\log(H_b) - A(H_m) + (44.9 - 6.55\log(H_b)) \times \log(d) - B$$

With f the frequency in MHz, Hb and Hm the height to the floor of base station and end-node antenna, d the separation between antennas in m

- Correction factors:

$$A(H_m) = (1.1\log(f) - 0.7) \times H_m - (1.56\log(f) - 0.8)$$

$$B = 30 - 25.\log(Building\_Area\,\%)$$

Exercise 2

Study of physical layer of Bluetooth Low Energy (BLE) protocol

1. What are the frequency ranges used by BLE (in Europe) ?
2. What is the modulation used by BLE ? What is the binary data rate ? What is the bandwidth ?
3. Define the packet structure. What is the actual throughput of BLE (precise all the hypothesis for this evaluation) ? What is the time on air ?
4. What are the features used by BLEto reduce the effect of interferences ?
5. What is the maximum transmitted power ? Wat should be the theoretical sensitivity of a BLE receiver? What is the typical sensitivity of a BLE receiver ? Compute the typical link budget of a BLE wireless network.
6. If a free space environment is considered, what is the radio range of BLE ?
7. For an indoor application, evaluate the radio range of BLE. The model IEEE P802.11 will be used for this purpose (see next slide).

Exercise 2

Study of physical layer of Bluetooth Low Energy (BLE) protocol – model IEEE P802.11

- Model for different indoor test environments, validated on the ISM band at 2400 MHz
- Path loss L estimated by:

$$L(dB) = L_0(d),\ d \le d_{BP}$$

$$L(dB) = L_0(d_{BP}) + 35\log\left(\frac{d}{d_{BP}}\right),\ d > d_{BP}$$

With d the distance between emitter and receiver (in m), d_{BP} the breakdown distance (in m) and L0(x) the free space path loss at distance x

- <u>Model parameters:</u> (shadowing modeled by a log-normal distribution)

Model	Environment	Delay (ns)	d_{BP} (m)	Shadowing σ (dB) for LOS / NLOS
B	Residential	15	5	3 / 4
C	Small office	30	5	3 / 5
D	Typical office	50	10	3 / 5
E	Large office	100	20	3 / 6
F	Large open space	150	30	3 / 6