TD INF567

IoT Protocols

Version: Feb. 2024

1 Battery Life Time in LoRa

In this exercice, we estimate the battery lifetime of a LoRa device as a function of its transmission period. We have the following assumptions: $I_{sleep} = 0.1\ \mu$A, $I_{tx} = 125$ mA, $I_{rx} = 10$ mA, $T_{sleep} = T - T_{tx} - T_{rx}$, $C = 2500$ mAh, where T is the transmission period and T_{tx} is the packet transmission time. The channel bandwidth is $B = 125$ kHz and the spreading factor is $SF = 12$. Every transmission is made of a preamble ($q = 12$ symbols), a packet payload of $p = 51$ Bytes protected by a channel code of rate $r = 4/5$ and a PHY+MAC overhead of $o = 324$ bits. In Class A, we assume an unacknowledged mode without any traffic on the downlink. Still, the device has to listen to the two receive windows. The duration of a receive window is the time required to detect a preamble.

Question 1 *Compute T_{tx} as a function of p, r, o, q, SF and B and give the numerical application.*

Question 2 *Compute the receive window duration. Deduce T_{rx}^{A}.*

Question 3 *What is the battery lifetime in years when the device transmits a packet every 2 hours with Class A.*

In Class B, on top of the process described for class A, we assume that the device listens every second ($t_p = 1$ s) to a ping slot (without transmission) and every $t_b = 128$ s to a beacon (10 symbol preamble + 17 Bytes sent with $SF = 9$, $B = 125$ kHz and coding rate $r = 4/5$). We assume that the ping slot duration is the time required to detect a 12 symbol preamble with $SF = 12$ and $B = 125$ kHz.

Question 4 *Compute the duration of a beacon, of a ping slot, and finally an approximation for T_{rx}^{B}.*

Question 5 *Deduce the battery lifetime in years when the device transmits a packet every 2 hours with Class B.*

Question 6 *Compute T_{rx}^{C} in Class C.*

Question 7 *Deduce the battery lifetime in years when the device transmits a packet every 2 hours with Class B.*

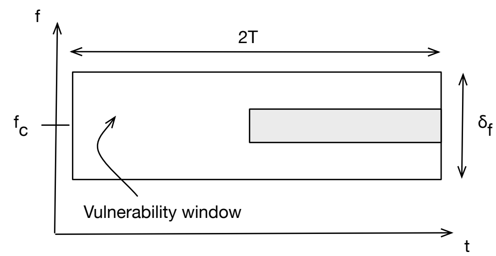

Figure 1: Vulnerability window in Sigfox.

2 Sigfox MAC Performance

In this exercice, we model and evaluate the performance of the MAC protocol of Sigfox. Assume that N nodes are transmitting packets of duration T at a rate of λ packets/s. System bandwidth is W. Carrier frequency f_c is chosen uniformly random in W. Any transmission in $f_c \pm \delta_f/2$ implies a collision. Messages are repeated r times (r identical packets are sent and they are supposed to be sent independently). Figure 1 shows the vulnerability window, i.e., the time-frequency area around a current transmission within which a new transmission implies a collision. Recall that for Poisson arrivals of rate λ, the probability to have k arrivals in a time interval of T is $\frac{(\lambda T)^k}{k!}e^{-\lambda T}$.

Question 8 *What is the arrival rate of packets in the vulnerability window?*

Question 9 *What is the probability to have at least one arrival from this new process in the vulnerability window?*

Question 10 *What is the failure probability when r transmissions are allowed?*

3 LoRa Coverage

We want to estimate the LoRa coverage. We have the following assumptions:

- Thermal noise spectral density is $N_0 = -174$ dBm/Hz, noise factor is $NF = 6$ dB.
- System bandwidth is $W = 125$ kHz.
- Target SNR is around -20 dB (for $SF = 12$ obtained from [Georgious'16]).
- The transmit power is bounded by the regulation: $P_{tx} = 16.15$ dBm
- The typical antenna gain at the BS is $G_r = 6$ dBi (provides a benefit on the uplink but does not allow to increase the ERP on the downlink). We assume that there are two receive antennas for diversity.
- Cable losses are $L_c = 3$ dB and penetration loss for indoor propagation is $L_p = 18$ dB.
- The shadowing standard deviation is $\sigma = 7$ dB. We require an outage probability of $P_{out} = 0.9$.

- Hata model valid for 150-1500 MHz can be applied with $f = 868$ MHz. With $h_B = 30$ m, $h_m = 1$ m, we have $A = 127.3$ dB, $B = 35.2$, and $C = 0$ in a urban area. We have $A = 127.3$ dB, $B = 35.2$, and $C = 28.3$ in a rural area.

Question 11 *Compute the noise power and the receive sensitivity in dBm.*

Question 12 *Compute the sum of all the gains and losses and compute the shadowing margin.*

Question 13 *Compute the MAPL and the cell range in a urban area and in a rural area.*