IoT Homework #2

IEEE 802.15.4 Analysis

Giuliano Crescimbeni, 10712403 - Arimondo Scrivano, 10712429
Politecnico di Milano

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1 Output Rate PMF

The number of people per frame follows a Poisson distribution with parameter $\lambda = 0.15$. The output rates are defined as:

- $r_0 = 1$ KB if 0 people
- $r_1 = 3$ KB if 1 person
- $r_2 = 6$ KB if ≥ 2 people

The corresponding probabilities are:

$$\begin{aligned} P(r_0) &= P(0) = e^{-\lambda} = e^{-0.15} = \mathbf{0.8607} \\ P(r_1) &= P(1) = e^{-\lambda} \cdot \lambda = e^{-0.15} \cdot 0.15 = \mathbf{0.1291} \\ P(r_2) &= 1 - P(r_0) - P(r_1) = \mathbf{0.0102} \end{aligned}$$

2 CFP Slot Assignment and Duty Cycle

Assumptions:

- Bitrate: $R = 250\,\text{kbps}$
- Packet size: $L = 128\,\text{byte} = 1024\,\text{bit}$
- Each slot can carry exactly 1 packet
- 3 camera nodes in the system

Slot duration

$$T_s = \frac{L}{R} = \frac{1024}{250\,000} = \mathbf{4.096\,ms}$$

Total number of slots

To ensure reliable operation under all conditions, we adopt a worst-case approach by allocating slots based on the largest possible frame size, i.e., 6 KB. Assuming data is sent every 10 seconds, we compute the required bitrates:

- Worst-case: $\frac{6000 \cdot 8}{10} = 4800\,\text{bps}$
- Best-case: $\frac{1000 \cdot 8}{10} = 800\,\text{bps}$

This yields a ratio of:

$$\frac{4800}{800} = 6$$

Thus, each node in the worst-case needs 6 times the slots required in the best-case. Assuming the best-case would require 1 slot per node, we allocate:

$$N_{\text{cfp}} = 6 \cdot 3 = \mathbf{18\,slots}$$

This approach ensures that even if all nodes transmit 6 KB frames, the system has enough slots to accommodate them within the CFP.

The active time is computed as the total number of slots plus one multiplied by the duration of each slot:

$$T_{\text{active}} = (N_{\text{cfp}} + 1) \cdot T_s = 18 \cdot 4.096\,\text{ms} = \mathbf{77.824\,ms}$$

The Beacon Interval is defined as the time required to transmit one packet at 800 bps:

$$BI = \frac{128 \cdot 8}{800} = 1.28\,\text{s}$$

From this, the inactive time can be computed as:

$$T_{\text{inactive}} = BI - T_{\text{active}} = 1.28\,\text{s} - 77.824\,\text{ms} = \mathbf{1.202\,s}$$

Duty cycle

The duty cycle is calculated as:

$$\text{Duty cycle} = \frac{T_{active}}{B_i} = \frac{77.824}{1.28 \cdot 1000} = \mathbf{6.08\%}$$

3 Maximum Number of Cameras Under 10% Duty Cycle

Case: 5 camera nodes

$$\text{Total slots} = 5 \cdot 6 = 30$$
$$T_{\text{active}} = 30 \cdot 4.096 = 122.88\,\text{ms}$$
$$\text{Duty cycle} = \frac{122.88}{1280} = 9.6\%$$

Case: 6 camera nodes

$$\text{Total slots} = 6 \cdot 6 = 36$$
$$T_{\text{active}} = 36 \cdot 4.096 = 147.456\,\text{ms}$$
$$\text{Duty cycle} = \frac{147.456}{1280} = 11.52\%$$

Conclusion: With 6 nodes, the duty cycle exceeds 10%, thus violating the system constraint. Therefore, the maximum number of supported camera nodes is 5, so we can add a maximum of **2 cameras** to stay below 10%.