IoT Homework 2024/2025
PART 2 – Exercise 2: 802.15.4

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Exercise 2 (1/2)

Consider the following pseudocode for a ESP32-based IoT monitoring system

```
// Global Timer Handle
declare timer_handle as esp_timer_handle_t

// Initialization
function setup_camera():
        initialize_camera(QVGA)


function setup_timer():
    declare timer_config as esp_timer_create_args_t
    set timer_config.callback to process_frame
    set timer_config.name to "10_sec_timer"
    call esp_timer_create(&timer_config,
    &timer_handle)
    call esp_timer_start_periodic(timer_handle,
    10_000_000) // 10s
```

```
function app_main():
    call setup_camera()
    call setup_timer()
    loop forever:
        delay(100 ms)


// Called every 10 seconds
function process_frame(arg):
        image = capture_camera_frame()
        person_count = estimate_number_of_people(image)
        if person_count == 0:
                payload = create_message(size=1KB)
        else if person_count == 1:
                payload = create_message(size=3KB)
        else:
                payload = create_message(size=6KB)
```

Exercise 2 (2/2)

Assuming the system is operated with IEEE 802.15.4 in beacon-enabled mode (CFP only) and that the number of people present in the camera frame at any instant follows a Poisson distribution with an average rate of lambda = 0.15 persons/frame

1. Compute the Probability Mass Function of the output rate of the ESP32 P(r = r_0), P(r = r_1), P(r = r_2), where r_0, r_1 and r_2 are the output rates when there are 0, 1 or more than 1 persons in the captured frame, respectively.

2. Based on the output rate PMF, compute a consistent slot assignment for the CFP in a monitoring system composed of 1 PAN coordinator and 3 camera nodes. Assume nominal bit rate R=250kbps, packets of L=128bytes, 1 packet fits exactly in one slot. Compute Ts (slot time), Number of slots in the CFP, Tactive, Tinactive and the duty cycle of the system.

3. How many additional cameras can be added to keep the duty cycle below 10%?

1. For Poisson distribution we have the formula:
   probability to get k person/ people in the captured frame

   P(X=k) = $\frac{e^{-\lambda} * \lambda^k}{k!}$ For us lambda = 0.15

   So with r_0 = 0, r_1=1, r_2=more than one 1 person.

   P(X=0) = $\frac{e^{-0.15} * 0.15^0}{0!}$ = 0.8607 -> P(r = r_0) = 0.8607

   P(X=1) = $\frac{e^{-0.15} * 0.15^1}{1!}$ = 0.1291 -> P(r = r_1) = 0.1291

   P(X=2) = $\frac{e^{-0.15} * 0.15^2}{2!}$ = 0.0097

So for more than 2 people the probability is less than 1 percent, so we can approximate:
$P(r = r_2) = 0.0097$

2. R=250kps L=128bytes

   Ts = L/R = 128*8/250 = 4.096ms

   Minimum rate: 1KB every 10 second so 1000*8/10 = 800bits/s

   BI = packet size / minimum rate = 128*8 / 800 = 1.28s

   Ncfp = rate of the worst case / min rate = 6KB every 10 seconds / 1KB every 10 seconds = 6
   But this is for each camera, we have 3 cameras so in total 6*3 = 18 for the entire system

   Tactive = (1+Ncfp) * Ts = 19 * 4.096ms = 77.824ms

   Tinactive = BI – Tactive = 1.28s – 77.824ms = 1.202s

   Duty_cycle = Tactive/BI = 77.824ms / 1.28s = 0.0608 = 6.08%

3. With a duty cycle of 10%, we should have a Tactive of 0.1*BI = 0.1*1.28s = 0.128s

   Adding a camera, we have:
   Tactive = (1+18+6(one more camera)) * Ts = 25*4.096ms = 0.1024s < 0.128s that's ok

   Adding two cameras, we have:
   Tactive = (1+18+6*2) * Ts = 31*4.096ms = 0.1269s < 0.128s that's ok

   Adding three cameras we have:
   Tactive = (1+18+6*3) * Ts = 37*4.096ms = 0.1515s > 0.128s the duty cycle would be more than 10%

   So the maximum we can add is 2 cameras