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IOT Challenge 2 - Exercise

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1.1. EQ1.a

In this scenario, the temperature sensor acts as the CoAP server, as it holds the temperature measurement resource.

The valve initiates communication by sending a GET request to the sensor, enabling observe mode. This allows the sensor to automatically push updated temperature values to the valve every 5 minutes, without requiring additional requests from the valve.

The GET request is sent as a non-confirmable message to minimize energy consumption, which is feasible given the fact that the Wi-Fi network is ideal.

1.1.1. Energy Consumption of the Valve

To compute the energy E_V used by the valve, we take into account:

- the transmission of the first GET request ($60B$), where the observation mode is set
- the receptions of the GET responses ($55B$) from the valve, that happen every 5 minutes: $60/5 = 12$ receptions per hour
- the 2 processing per hour of the average temperature (1 every 30 minutes)

$$E_V = E_{TX} * 60 * 8[nJ] + 12 * 24 * E_{RX} * 55 * 8[nJ] + 2 * 24 * E_c[mJ] = 122.57[mJ] \tag{1.1}$$

1.1.2. Energy Consumption of the Temperature Sensor

To compute the energy E_S of the temperature sensor, we take into account:

- the reception of the first GET request $(60B)$
- the 12 GET response transmissions per hour containing the new temperature value $(55B)$

$$E_S = E_{RX} * 60 * 8[nJ] + 12 * 24 * E_{TX} * 55 * 8[nJ] = 6.36[mJ] \tag{1.2}$$

1.1.3. Total Energy Consumption

The total energy consumed by the valve and the temperature sensor is given by:

$$E = E_V + E_T = 128.93[mJ] \tag{1.3}$$

1.2. EQ1.b

In this scenario, the Raspberry Pi acts as an MQTT broker.

The temperature sensor sends data every 5 minutes to the MQTT broker, so a 7-minute keepalive interval should be sufficient. This way, no PING messages are necessary, as the broker will assume the sensor has failed if it doesn't receive a message within that time frame.

On the other hand, the valve needs to send ping messages, since once it subscribes to the temperature topic, it won't communicate with the broker again. A 5-minute keepalive interval is sufficient to guarantee that the valve gets the updates of the temperature needed to compute the average temperature.

We use QoS 0 because the network is reliable, which helps reduce energy consumption. Consequently, the broker won't send PUBACK messages to the temperature sensor every time it receives a PUBLISH message.

For both the valve and the sensor, the first messages exchanged with the broker will be the CONNECT and CONNACK messages.

1.2.1. Energy Consumption of the Valve

To compute the energy E_V used by the valve, we take into account:

- the transmission of the CONNECT message ($54B$)
- the reception of the CONNACK message ($47B$)
- the transmission of the SUBSCRIBE message ($58B$)
- the reception of the SUBACK message ($52B$)
- the transmission every 5 minutes of the PINGREQ message ($52B$): $60/5 = 12$ messages per hour
- the reception every 5 minutes of the PINGRES message ($48B$)
- the reception of the PUBLISH message containing the updated value of the temperature 12 times per hour ($68B$)
- the 2 processing per hour of the average temperature (1 every 30 minutes)

$$\begin{aligned} E_V = E_{TX} * 54 * 8[nJ] + E_{RX} * 47 * 8[nJ] + \\ E_{TX} * 58 * 8[nJ] + E_{RX} * 52 * 8[nJ] + \\ 12 * 24 * (E_{TX} * 52 * 8 + E_{RX} * 48 * 8) + \\ 12 * 24 * E_{RX} * 68 * 8 + \\ 2 * 24 * E_c[mJ] = 136.78[mJ] \end{aligned} \quad (1.4)$$

1.2.2. Energy Consumption of the Temperature Sensor

To compute the energy E_S of the temperature sensor, we take into account:

- the transmission of the CONNECT message ($54B$)
- the reception of the CONNACK message ($47B$)
- the transmission of the PUBLISH message containing the updated value of the temperature 12 times per hour ($68B$)

$$E_S = E_{TX} * 54 * 8[nJ] + E_{RX} * 47 * 8[nJ] + 12 * 24 * E_{TX} * 68 * 8[nJ] = 7.88[mJ] \quad (1.5)$$

1.2.3. Total Energy Consumption

The total energy consumed by the valve and the temperature sensor is given by:

$$E = E_V + E_T = 144.66[mJ] \quad (1.6)$$

2 | EQ2

2.1. Methodology

Since computing the average temperature every 30 minutes is the most energy-intensive task, energy consumption could be reduced by offloading this computation to the Raspberry Pi (which is likely connected to a constant power source).

In this setup, the Raspberry Pi would run both the MQTT broker and an MQTT client. The sensor publishes temperature readings to a specific topic (for example sensor/temp), which the Raspberry Pi's client subscribes to to collect and process the average.

The client running on the Raspberry Pi computes the average temperature every 30 minutes and publishes a control message (OPEN or CLOSE) to another topic (for example valve/control).

The valve subscribes to this control topic. This way, it no longer performs any computation, but only reacts to commands, significantly reducing its energy usage.

2.1.1. Energy Consumption of the Valve

In this new scenario, the energy consumption of the temperature sensor remains the same as before (7.88 mJ), while the new energy E_V of the valve takes into account:

- the transmission of the CONNECT message ($54B$)
- the reception of the CONNACK message ($47B$)
- the transmission of the SUBSCRIBE message ($58B$)
- the reception of the SUBACK message ($52B$)
- the transmission every 5 minutes of the PINGREQ message ($52B$): $60/5 = 12$ messages per hour
- the reception every 5 minutes of the PINGRES message ($48B$)
- the reception of the PUBLISH message containing the command to either close or open 12 times per hour ($68B$)

$$
\begin{aligned}
E_V = E_{TX} * 54 * 8[nJ] + E_{RX} * 47 * 8[nJ]+ \\
E_{TX} * 58 * 8[nJ] + E_{RX} * 52 * 8[nJ]+ \\
12 * 24 * (E_{TX} * 52 * 8 + E_{RX} * 48 * 8)+ \\
12 * 24 * E_{RX} * 68 * 8 = 21.58[mJ]
\end{aligned}
\tag{2.1}
$$

2.1.2. Total Energy Consumption

The total energy consumed by the valve and the temperature sensor is given by:

$$E = E_V + E_T = 29.46[mJ] \tag{2.2}$$