POLITECNICO
MILANO 1863

Internet of Things
Challenge 2

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1 Packet Sniffing

1.1 Problem Data

The system consists of three devices communicating over Wi-Fi:

- A battery-powered temperature sensor that sends temperature values every 5 minutes.
- A battery-powered valve that receives these values and computes an average every 30 minutes to decide actions.
- A grid-powered Raspberry Pi that only supports MQTT and acts as a broker.

Communication can occur using either CoAP or MQTT. Payloads are 8 bytes, and topic/resource names are 10 bytes long.
Message Sizes:

- CoAP GET Request: 60 bytes
- CoAP GET Response/Notification: 55 bytes
- MQTT Connect: 54 bytes, Connack: 47 bytes
- MQTT Subscribe: 58 bytes, Suback: 52 bytes
- MQTT Publish: 68 bytes, Puback: 51 bytes

Energy Costs:

- Transmit: $E_{TX} = 50\,nJ/bit$
- Receive: $E_{RX} = 58\,nJ/bit$
- Processing: $E_C = 2.4\,mJ$ (valve only, every 30 min)

1.2 EQ1

1.2.1 CoAP

Energy Calculation (24 hours):

- Number of notifications: 287.
- Sensor transmitted bits:

$$bits_{TX,sensor} = (60 + 287 \times 55) \times 8 = 126760\, bits$$

- Sensor transmission energy:

$$E_{sensor,TX} = 126760 \times 50\, nJ = 6.338\, mJ$$

- Sensor received bits (initial GET Response only):

$$E_{sensor,RX} = 55 \times 8 \times 58\, nJ = 0.02552\, mJ$$

- Total sensor energy:

$$E_{sensor,total} = 6.338 + 0.02552 = 6.3635\, mJ$$

- Valve received bits:

$$bits_{RX,valve} = (55 + 287 \times 55) \times 8 = 126720\, bits$$

- Valve reception energy:

$$E_{valve,RX} = 126720 \times 58\, nJ = 7.3498\, mJ$$

- Valve computation energy:

$$E_{valve,C} = 48 \times 2.4\, mJ = 115.2\, mJ$$

- Total energy (sensor + valve):

$$E_{CoAP,total} = 6.3635 + (7.3498 + 115.2) = \boxed{128.9133\, mJ}$$

1.2.2 MQTT

Communication Overview:

- **Sensor**: transmits CONNECT, SUBSCRIBE, and 288 PUBLISH; receives CONNACK and SUBACK.
- **Valve**: transmits CONNECT and SUBSCRIBE; receives CONNACK, SUBACK, and 288 PUBLISH.

Energy Calculation (24 hours):

- Sensor energy:

$$E_{sensor} = (54 + 58 + 288 \times 68) \times 8 \times E_{TX} + (47 + 52) \times 8 \times E_{RX} = 7.9243\,mJ$$

- Valve energy:

$$E_{valve} = (54{+}58){\times}8{\times}E_{TX}{+}(47{+}52{+}288{\times}68){\times}8{\times}E_{RX}{+}48{\times}E_C = 124.3777\,mJ$$

- Total energy (sensor + valve):

$$E_{MQTT,total} = 7.9243 + 124.3777 = \boxed{132.3020\,mJ}$$

1.3 EQ2

Proposed Solution: Use MQTT-SN with QoS = -1 and delegate the computation of the average to the broker (Raspberry Pi).
Improvements introduced:

- Using MQTT-SN with QoS = -1 removes all acknowledgment and subscription overhead (CONNECT, CONNACK, SUBSCRIBE, SUBACK, PUBACK).
- Delegating the computation of the average temperature to the Raspberry Pi reduces computational energy consumption entirely on the valve, significantly decreasing overall energy usage.
- The valve receives significantly fewer messages, only 48 averaged values instead of 288 raw values.

Energy Calculation:

- Sensor energy (only transmission of 288 Publish messages):

$$E_{sensor} = 288 \times 68 \times 8 \times E_{TX} \approx 7.8336\,mJ$$

- Valve energy (receiving only 48 averaged messages from the broker, no computation):

$$E_{valve} = 48 \times 68 \times 8 \times E_{RX} \approx 1.5145\,mJ$$

- Total energy (sensor + valve):

$$E_{MQTTSN,total} = 7.8336 + 1.5145 = \boxed{9.3481\,mJ}$$