POLITECNICO
MILANO 1863

SCUOLA DI INGEGNERIA INDUSTRIALE
E DELL'INFORMAZIONE

Course: Internet of Things - 5 CFU

Professor: Matteo Cesana
Students: Bruno Arena, Matteo Cavalleri
Personal IDs: 10806605, 10768765

Challenge 2 - Exercise

Abstract

A smart building system includes a battery-powered temperature sensor (transmits every 2 minutes), a battery-powered fan-controller actuator, and a mains-powered MQTT gateway.
Communication parameters:
payload 12 B, topic/resource length 8 B. Message sizes (header + payload already included): CoAP CON PUT = 70 B,
PUT ACK = 15 B; MQTT CONNECT/DISCONNECT = 60 B, CONNACK = 50 B, PUBLISH = 75 B, PUBACK =
50 B, SUBSCRIBE = 65 B, SUBACK = 55 B.

Assumptions: ETX = 50 nJ/bit, ERX = 58 nJ/bit; CoAP uses CON messages; MQTT uses QoS 1; ideal channel (no losses); devices start disconnected; MQTT connections closed during sleep (non-acknowledged DISCONNECT); gateway energy ignored.

Question #1 – Total communication energy in CoAP and MQTT

Answer EQ1a

The sensor transmits every 2 minutes; it is 30 cycles of transmission per hour.
With CoAP CON PUT there is the following scheme:

- Sensor sends
- Actuator receives
- Actuator sends back ACK
- Sensor receives ACK

In the table are shown all the energy consumptions of the transmission:

Message	***Device***	***TX/RX***	***Bits***	***Cost [nJ/bit]***	***Energy [nJ]***
CON PUT	Sensor	TX	560	50	28.000
CON PUT	Actuator	RX	560	58	32.480
PUT ACK	Actuator	TX	120	50	6.000
PUT ACK	Sensor	RX	120	58	6.960

The total energy consumption over 1 hour in CoAP (direct communication) is:

$$E_{CoAP} = (28.000 + 32.480 + 6.000 + 6.960)\frac{nJ}{cycle} * 30\ cycles * 10^{-3}$$

$$E_{CoAP} = 2.203{,}2\ \mu J$$

Answer EQ1b

By using the protocol MQTT (via gateway) with QoS 1 and devices disconnecting during sleep periods every hour there are 30 cycles with:

- CONNECT
- CONNACK
- PUBLISH
- PUBACK
- DISCONNECT

Sensor per cycle

Message	***TX/RX***	***Bits***	***Cost [nJ/bit]***	***Energy [nJ]***
CONNECT	TX	480	50	24.000
CONNACK	RX	400	58	23.200
PUBLISH	TX	600	50	30.000
PUBACK	RX	400	58	23.200
DISCONNECT	TX	480	50	24.000

$$E_{sensor} = 124.400\ nJ$$

Actuator per cycle

Message	***TX/RX***	***Bits***	***Cost [nJ/bit]***	***Energy [nJ]***
CONNECT	TX	480	50	24.000
CONNACK	RX	400	58	23.200
SUBSCRIBE	TX	520	50	26.000
SUBACK	RX	440	58	25.520
PUBLISH	RX	600	58	34.800
PUBACK	TX	400	50	20.000
DISCONNECT	TX	480	50	24.000

$$E_{actuator} = 177.520\ nJ$$

The total energy consumption over 1 hour in MQTT (via gateway) is:

$$E_{MQTT} = (E_{sensor} + E_{actuator}) * 30\ cycles * 10^{-3} = 9.057{,}6\ \mu J$$

Summary:
EQ1a: Total consumption over CoAP = 2.203,2 μJ
EQ1b: Total consumption over MQTT = 9.057,6 μJ

Question #2 – Best protocol for long term operation

Assumption: The actuator wakes up only once every 30 minutes. It translates in 2 times per hour.

The assumption changes dramatically the energy consumption of the system.
The recommended protocol for the transmission in this case is:

MQTT with retain=True (sensor) + clean_session=True (actuator)

When the sensor publishes with retain = True, the broker stores the last measurement.
When the actuator wakes and connects, it subscribes once; the broker immediately delivers the retained message without waiting for the next sensor transmission. The actuator receives the latest temperature value on every wake up regardless of when the sensor last published.
Actuator energy with MQTT retain (2 cycles/hour):

$$E_{actuator} = 177.520 \frac{nJ}{cycle} * 2\ cycles = 355{,}04\ \mu J$$

Otherwise, with CoAP Observe, the actuator must stay registered (or re-register on each wake-up).
If it sleeps, it misses all CON notifications sent while it was off — the server retransmits up to MAX_TRANSMISSIONS = 3 times (wasting sensor + server energy), then deregisters the observer. On the next wake, the actuator must re-subscribe. The overhead is equivalent to a new connection per wake-up, like MQTT without retain, but with additional retransmission waste.

Protocol parameters:

MQTT QoS 1, retain = True on sensor PUBLISH, clean_session = True on actuator CONNECT.

Performance metric optimised: total communication energy of the actuator.