COAP		MQTT	
GET Request	60 B	Subscribe	58 B
GET Response	55 B	Sub Ack	52 B
PUT Request	77 B	Publish	68 B
PUT Response	58 B	Pub Ack	51 B
Empty ACK	14 B	Connect	54 B
		Connect Ack	47 B
		Ping Req	52 B
		Ping Resp	48 B

- Topic/resource length = 10 bytes
- Payload size = 8 bytes

- $E_{TX} = 50 \frac{nJ}{bit}$ • $E_{RX} = 58 \frac{nJ}{bit}$ • $E_C = 2,4$ mJ

- Sensor time = 5 minutes • Valve_time = 30 min • Total time = 24 h

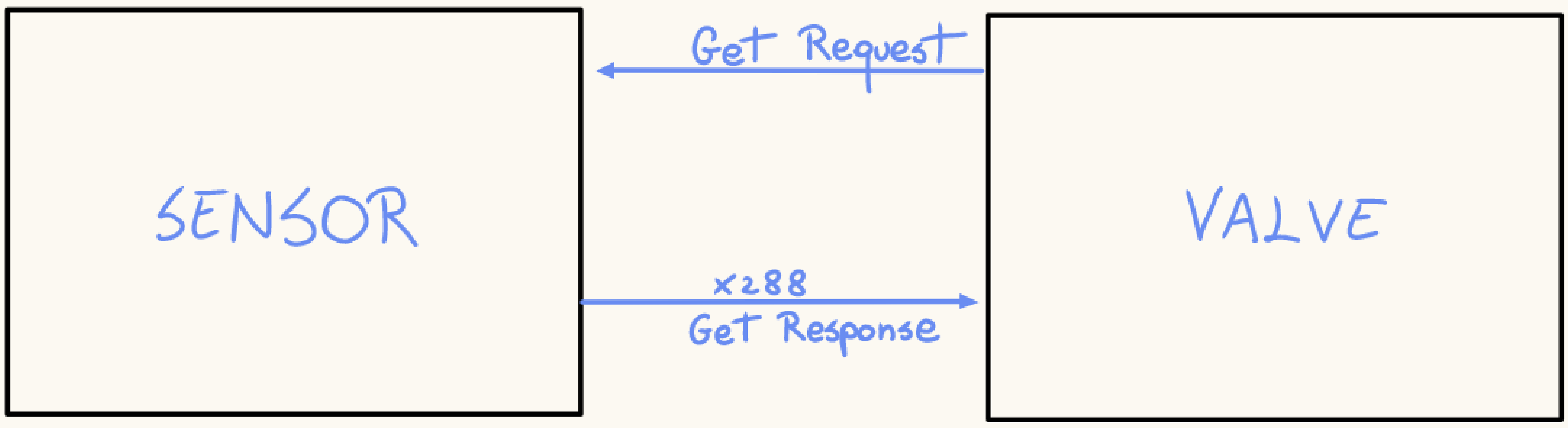
Total messages from valve: $\frac{24 \cdot 60}{5} = 288$

Total operations of the valve: $\frac{24 \cdot 60}{30} = 48$

EQ1a (CoaP) Using CoaP as OBSERVE, the valve sends an unique get request to the sensor.

	SENSOR	VALVE
GET REQUEST	$60 \cdot 8 \cdot 58 = 27840$ nJ	$60 \cdot 8 \cdot 50 = 24000$ nJ
GET RESPONSE (×288)	$55 \cdot 8 \cdot 50 \cdot 288 = 6336000$ nJ	$55 \cdot 8 \cdot 58 \cdot 288 = 7349760$ nJ
VALVE OPERATION		$2,4 \cdot 48 = 115,2$ mJ

Total energy $= (27840 + 6336000 + 24000 + 7349760) \cdot 10^{-6} + 115,2 = 128,9376$ mJ



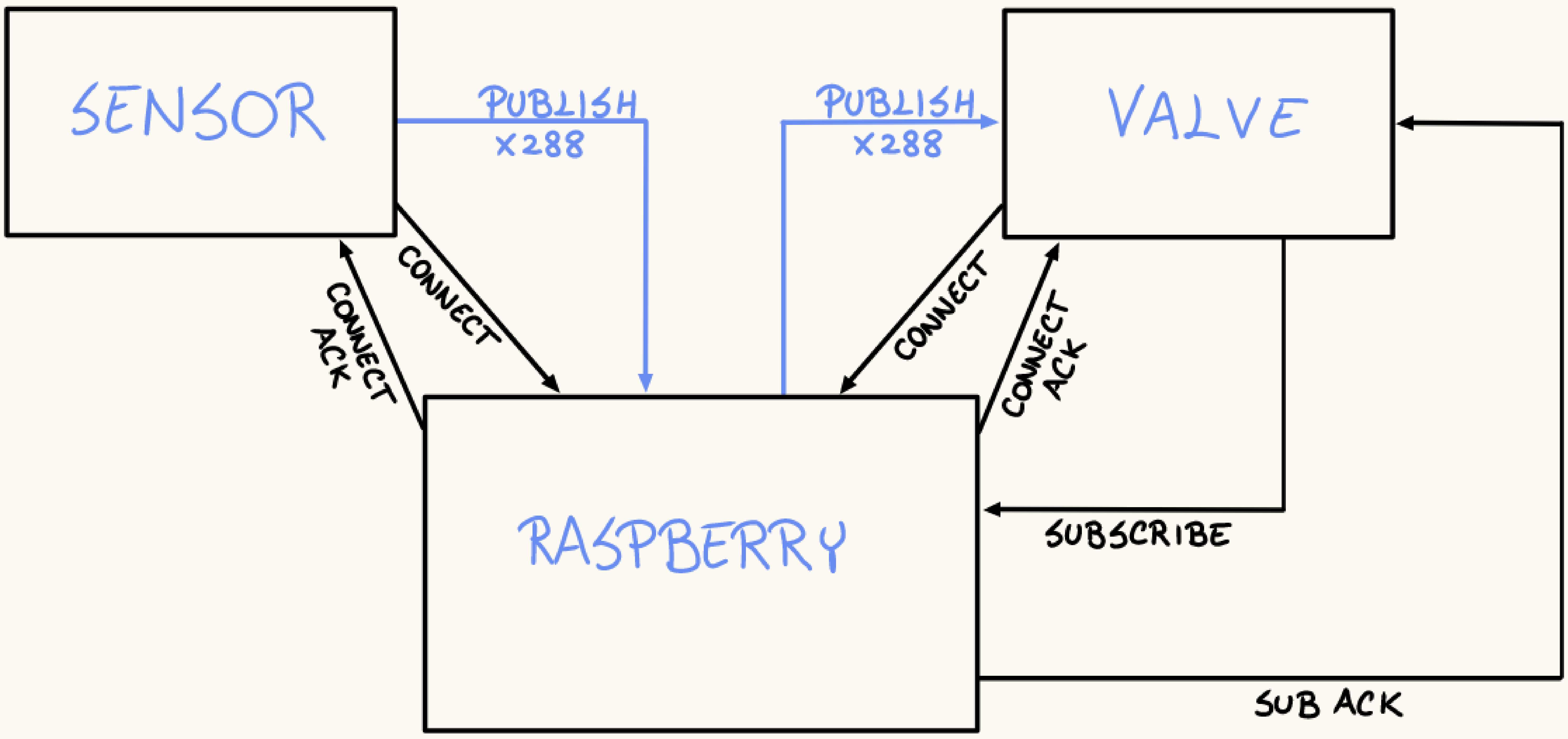
EQ1b MQTT

In MQTT, we have the raspberry as broker. The initialization must be considered before starting the communication. In order to save some energy we considered the communication of type QoS(0)[Quality-Of-Service]

	SENSOR	VALVE
Connect Connect Ack Subscribe Sub Ack	$54 \cdot 8 \cdot 50 = 21600\ nJ$ $47 \cdot 8 \cdot 58 = 21808\ nJ$ ////// ////////	$54 \cdot 8 \cdot 50 = 21600\ nJ$ $47 \cdot 8 \cdot 58 = 21808\ nJ$ $58 \cdot 8 \cdot 50 = 23200\ nJ$ $52 \cdot 8 \cdot 58 = 20800\ nJ$
Publish (x288)	$68 \cdot 8 \cdot 50 \cdot 288 = 7833600\ nJ$	$68 \cdot 8 \cdot 58 \cdot 288 = 9086976\ nJ$
Valve operation	// / // /	$2{,}4 \cdot 48 = 115{,}2\ mJ$

$$\text{Total energy} = (2 \cdot 21600 + 2 \cdot 21808 + 23200 + 20800 + 7833600 + 9086976) \cdot 10^{-6}$$

$$+ 115{,}2 = 132{,}2513\ mJ$$



EQ2

OPTION 1

Regarding the possibles improvements, we could consider to modify the logic for the storage of the measurations. We could consider to store in the sensor the last six measurations and then, each 30 minutes, transmit all this measurations toghetez to the valve to compute the average temperature.

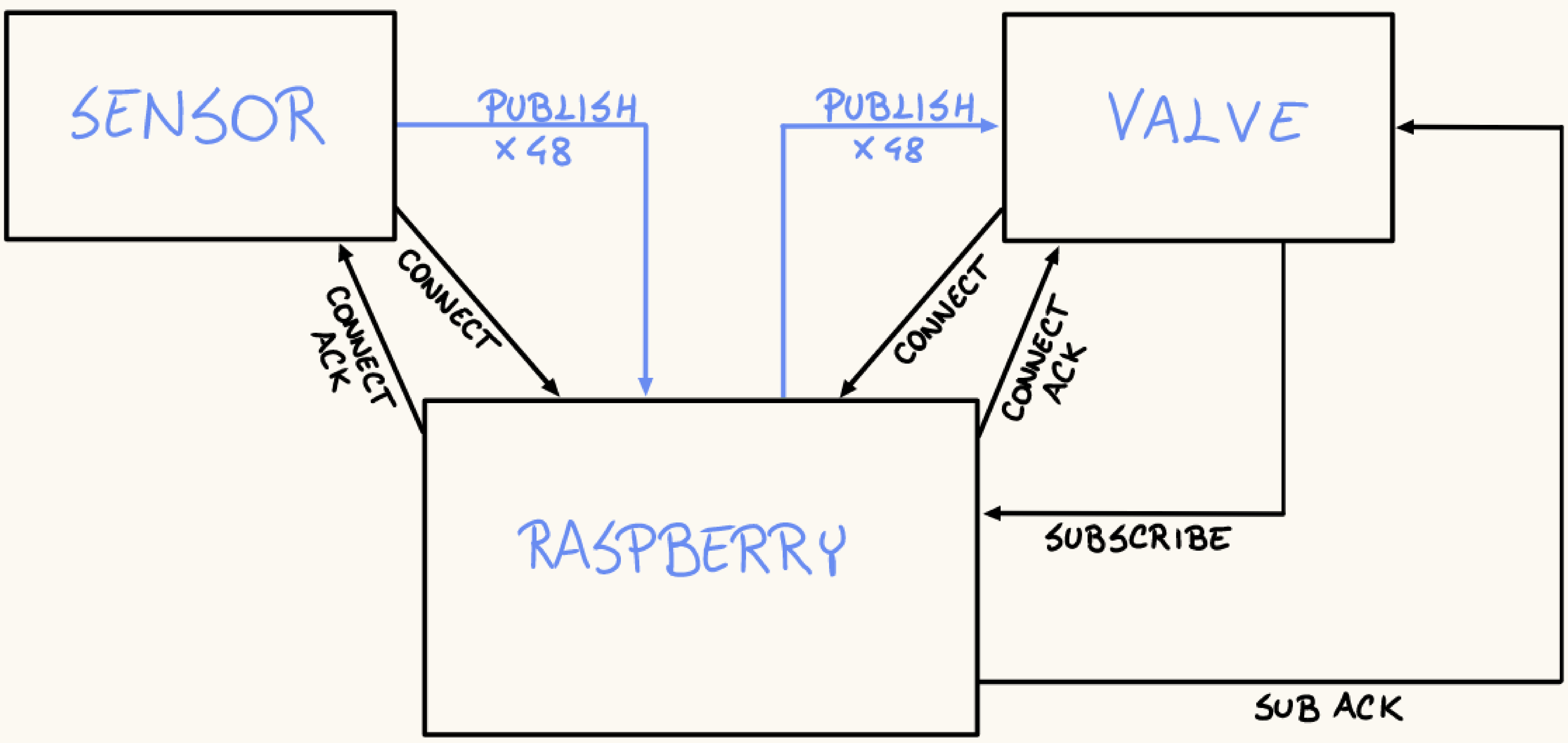
Considering the previous scenario, we had 288 PUBLISH operations of 68 B each. In this different solution we can have only 48 PUBLISH.

Considering the topic/resource length of 10 bytes and the payload of 8 bytes, each packet will have a size of : $60 + (\text{PAYLOAD} \cdot \text{Num-of-misurations}) =$
$= 60 + (8 \cdot 6) = 108\ B$

The energy consumed in the communication will be: $108 \cdot 8 \cdot 48 \cdot (\overset{E_{Tx}}{50} + \overset{E_{Rx}}{58}) = 4478976\ nJ$

$\Rightarrow$ 4,478976 mJ. Is easy to see that the total energy consumed by the system, now is $(2 \cdot 21600 + 2 \cdot 21808 + 23200 + 20800) \cdot 10^{-6} + 4{,}478976 + 115{,}2 =$

$\Rightarrow$ 119,8097 mJ which is less than the previous case



OPTION 2

An other possible improvement could be implementing MQTT-SN with QoS -1
This version of the protocol, lighter than the canonical one, is specific for sensors communication and allows to save energy, "bypassing" the CONNECTION phase of the clients. QoS -1 allows, in fact, to communicate using a short-topic-name of 2 byte which doesn't need to be registered first.
In this case, each packet can be reduced by 8 bytes, simply reducing the topic's size to 2 bytes. In this scenario, the energy consumption would be:

- SUBSCRIPTION (VALVE): $\underbrace{50}_{\text{SUBSCRIPTION - 8 bytes}} \cdot 8 \cdot \overset{E_{TX}}{50} = 0{,}02\ mJ$

- SUBACK (VALVE): $\underbrace{44}_{\text{SUB ACK - 8 bytes}} \cdot 8 \cdot \overset{E_{RX}}{58} = 0{,}020416\ mJ$

- 288 SENT AND RECEIVED PUBLISH: $\underbrace{60}_{\text{PUBLISH - 8 bytes}} \cdot 8 \cdot (50+58) \cdot 288 = 14{,}92992\ mJ$

- Valve operation: $115{,}2\ mJ$

$\Rightarrow$ Total energy = $130{,}17\ mJ$