Internet of Things, June 7, 2022

1 – Exercise (7 points)

A IEEE 802.15.4 network is composed of a PAN Coordinator and five motes. Each mote is assigned 2 slots in the Collision Free Part, and each slot can carry packets of 128 [byte]. The nominal rate is R=250 [kb/s] and the active part is composed of the beacon slot and the CFP only. The network is operated with a duty cycle η=1%. The motes have the following traffic pattern: mote 1 and mote 2 generate packets according to a Poisson process with parameter λ_1=0.2 [packets/s], mote 3 and mote 4 generate packets according to a Poisson process with parameter λ_2 = 0.5 [packet/s], mote 5 generates packets deterministically at a rate r=2[packets/s]
Find: the duration of the Beacon Interval, the duration of a slot, the equivalent rate defined as "one slot per Beacon Interval", the average energy consumed by one mote 1 assuming that it is not in range of the other motes.

Solution

The total number of slots in the active part is Nactive=5 x 2 + 1= 11.
The slot duration is Ts = 128[byte] / 250[kb/s] = 4.096[ms]
The beacon interval can be written as: BI = (Nactive x Ts)/ η = 4,505[s].
The equivalent rate defined as "one slot per Beacon Interval" is r = 128[byte] / = 227,2[bit/s].

The probabilities that mote 1 has 0, 1, >=2 packets available in a BI are:

$P_0 = P(k=0) = e^{-\lambda_1 BI}$
$P_1 = P(k=1) = \lambda_1 BI\, e^{-\lambda_1 BI}$
$P_2 = 1 - P_0 - P_1$

The energy consumed by mote 1 is:

$E = E_{rx}$ (beacon reception) + $8\, E_{idle}$ (idle in the 8 slots of the other 4 motes) + $2E_{idle}\, P_0 + (E_{idle} + E_{tx})\, P_1 + 2E_{tx}\, P_2 + E_{sleep}\, xN_{sleep}$

1 – Exercise (7 points)

A IEEE 802.15.4 network is composed of a PAN Coordinator and five motes. Each mote is assigned 2 slots in the Collision Free Part, and each slot can carry packets of 128 [byte]. The nominal rate is R=250 [kb/s] and the active part is composed of the beacon slot and the CFP only. The network is operated with a duty cycle η=2%. The motes have the following traffic pattern: mote 1 and mote 2 generate packets according to a Poisson process with parameter λ1=0.2 [packets/s], mote 3 and mote 4 generate packets according to a Poisson process with parameter λ2 = 0.5 [packet/s], mote 5 generates packets deterministically at a rate r=2[packets/s]
Find: the duration of the Beacon Interval, the duration of a slot, the equivalent rate defined as "one slot per Beacon Interval", the average energy consumed by one mote 1 assuming that it is not in range of the other motes

Solution

The total number of slots in the active part is N_{active}=5 x 2 + 1= 11.
The slot duration is T_s = 128[byte] / 250[kb/s] = 4.096[ms]
The beacon interval can be written as: BI = ($\boldsymbol{N_{active}}$ x T_s)/ η = 2,252[s].
The equivalent rate defined as "one slot per Beacon Interval" is r = 128[byte] / = 454,5[bit/s].

The probabilities that mote 1 has 0, 1, >=2 packets available in a BI are:

$P_0 = P(k=0) = e^{-\lambda_1 BI}$

$P_1 = P(k=1) = \lambda_1 BI\, e^{-\lambda_1 BI}$
$P_2 = 1 - P_0 - P_1$

The energy consumed by mote 1 is:

$E = E_{rx}$ (beacon reception) + $8\, E_{idle}$ (idle in the 8 slots of the other 4 motes) + $2E_{idle}\, P_0 + (E_{idle} + E_{tx})\, P_1 + 2E_{tx}\, P_2 + E_{sleep}\, xN_{sleep}$

2 – Exercise (6 points)

A multi-frame Dynamic Frame ALOHA collision resolution protocol has an initial population of n=4 tags and an initial frame size r=2. Answer to the following (truncate to the third decimal when needed and use "." as decimal separator). Find the probabilities that 0,1,2,3,4 tags are resolved. Find the average throughput. Assuming that all the slots in the first frame are collided, find the duration of the second frame if Schoute is applied.

Solution
P(0)=1/2
P(1)=1/2
P(2)=0
P(3)=0
P(4)=0
E(S)=1/2
$r_2=5$

3 – Exercise (4 points)

A MQTT client (Client 1) is subscribed to the topic /temp. The MQTT broker is connected to 3 additional MQTT clients which publish messages on the topic /temp according to the following traffic processes:

• Client 2 publishes one message on topic /temp according to a Poisson process with parameter λ_2= 0.5 message/second
• Client 3 publishes one message on topic /temp according to a Poisson process with parameter λ_3= 1 message/second
• Client 4 publishes one message on topic /temp deterministically every 2 seconds.

All the transmissions between broker and Client 1 work with QoS 1; transmissions from Client 2 to broker work with QoS 0; transmissions from Client 3 to broker work with QoS 1; Transmissions Client 4 to broker work with QoS 2.

Messages received by Client 1 in 10 minutes: $(\lambda_2 + \lambda_3) \times 600 + 600/2 = 1200$
Messages sent by Client 1 in 10 minutes: 1200 (Client 1 sends PUB ACK back to the broker, QoS1)

Messages sent by Client 2 in 10 minutes: $\lambda_2\ 600 = 300$ (Client 2 sends only PUB messages to the broker, QoS0)
Messages received by Client 1 in 10 minutes: 0 (QoS0)

Messages sent by Client 3 in 10 minutes: $\lambda_3\ 600 = 600$ (Client 3 sends only PUB messages to the broker, QoS1)
Messages received by Client 3 in 10 minutes: 600 (Client 3 receives PUB ACK from Broker, QoS1)

Messages sent by Client 4 in 10 minutes: 600/2 + 600/2= 600 (Client 4 sends PUB messages and PUB rel messages to the broker, QoS2)

Messages received by Client 4 in 10 minutes: 600 (Client 4 receives PUB REC and PUB COMP from Broker, QoS2)

3 – Exercise (4 points)

A MQTT client (Client 1) is subscribed to the topic /temp. The MQTT broker is connected to 3 additional MQTT clients which publish messages on the topic /temp according to the following traffic processes:
• Client 2 publishes one message on topic /temp according to a Poisson process with parameter \lambda_2 = 1 message/second
• Client 3 publishes one message on topic /temp according to a Poisson process with parameter \lambda_3 = 4 message/second
• Client 4 publishes one message on topic /temp deterministically every 4 seconds.
All the transmissions between broker and Client 1 work with QoS 1; transmissions from Client 2 to broker work with QoS 0; transmissions from Client 3 to broker work with QoS 1; Transmissions Client 4 to broker work with QoS 2.
Find the total number of messages (PUB messages + signalling messages, if any) sent by Client 1,2,3 and 4 in a period of 10 minutes

Messages received by Client 1 in 10 minutes: $(\lambda_2 + \lambda_3)$ x 600 + 600/4 = 3150
Messages sent by Client 1 in 10 minutes: 3150 (Client 1 sends PUB ACK back to the broker, QoS1)

Messages sent by Client 2 in 10 minutes: λ_2 600 = 600 (Client 2 sends only PUB messages to the broker, QoS0)
Messages received by Client 2 in 10 minutes: 0 (QoS0)

Messages sent by Client 3 in 10 minutes: λ_3 600 = 2400 (Client 3 sends only PUB messages to the broker, QoS1)
Messages received by Client 3 in 10 minutes: 2400 (Client 3 receives PUB ACK from Broker, QoS1)

Messages sent by Client 4 in 10 minutes: 600/4 + 600/4= 300 (Client 4 sends PUB messages and PUB rel messages to the broker, QoS2)
Messages received by Client 4 in 10 minutes: 300 (Client 4 receives PUB REC and PUB COMP from Broker, QoS2)

3 – Exercise (4 points)

A MQTT client (Client 1) is subscribed to the topic /temp. The MQTT broker is connected to 3 additional MQTT clients which publish messages on the topic /temp according to the following traffic processes:
• Client 2 publishes one message on topic /temp deterministically every 4 seconds
• Client 3 publishes one message on topic /temp according to a Poisson process with parameter \lambda_3 = 4 message/second
• Client 4 publishes one message on topic /temp /temp according to a Poisson process with parameter \lambda_4 = 1 message/second
All the transmissions between broker and Client 1 work with QoS 1; transmissions from Client 2 to broker work with QoS 0; transmissions from Client 3 to broker work with QoS 1; Transmissions Client 4 to broker work with QoS 2.

Find the total number of messages (PUB messages + signalling messages, if any) sent by Client 1,2,3 and 4 in a period of 10 minutes

Messages received by Client 1 in 10 minutes: $(\lambda_4 + \lambda_3) \times 600 + 600/4 = 3150$
Messages sent by Client 1 in 10 minutes: 3150 (Client 1 sends PUB ACK back to the broker, QoS1)

Messages sent by Client 2 in 10 minutes: 600/4 = 150 (Client 2 sends only PUB messages to the broker, QoS0)
Messages received by Client 1 in 10 minutes: 0 (QoS0)

Messages sent by Client 3 in 10 minutes: λ_3 600 = 2400 (Client 3 sends only PUB messages to the broker, QoS1)
Messages received by Client 3 in 10 minutes: 2400 (Client 3 receives PUB ACK from Broker, QoS1)

Messages sent by Client 4 in 10 minutes: 600+ 600= 1200 (Client 4 sends PUB messages and PUB rel messages to the broker, QoS2)
Messages received by Client 4 in 10 minutes: 1200 (Client 4 receives PUB REC and PUB COMP from Broker, QoS2)

4 – Questions (9 points)

1. Three RFID tags are arbitrated by Dynamic Frame ALOHA. Tell if the following statements are true or false. **MOTIVATE THE ANSWER. UNMOTIVATED ANSWER WILL NOT BE CONSIDERED**
   a. The lower the dimension of the first frame the higher the collision probability. TRUE
   b. The optimal size of the first frame is 2 FALSE is 3
   c. In LoraWAN the lower the Spreading Factor the higher the transmission range TRUE
   d. In LoraWAN the higher the Spreading Factor the lower the transmission time FALSE

2 A COAP client periodically retrieves every second the latest reading of the resource /test/pressuse from a COAP server. Observation mode is active. Choose the correct statement

The COAP client automatically receives an usolicited reply from COAP server every second

2bis A COAP client periodically retrieves every second the latest reading of the resource /test/pressuse from a COAP server. Observation mode is NOT active. Choose the correct statement

The COAP client issues a COAP request for resource /test/pressure every second and the COAP server replies back

2. A MQTT Broker receives a subscription message with the following content: what is the action of the Broker (choose among the following, motivate the answer)?

packeId	2
topicName	“matteo/temp”
QoS	1
retainFlag	false
Payload	“temperature:30”
dupFlag	false

The broker relays the PUB message to all the clients subscribed to topic "matteo/temp" and send back a PUB ACK"