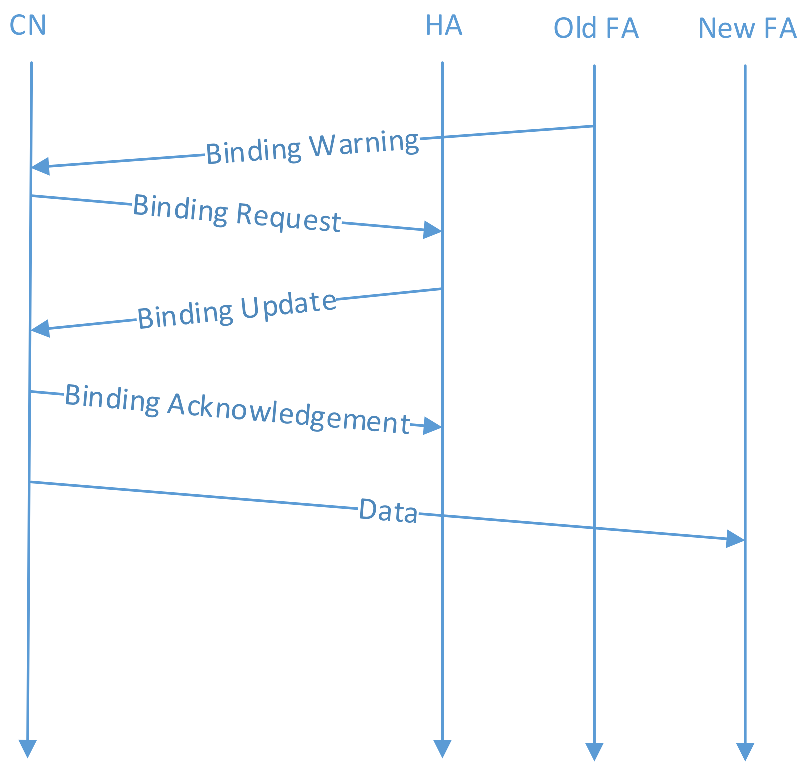
1.

a)

The routing optimization extension allows to avoid data traffic sent by the CN from being routed to the Home Agent first, before being tunneled and routed to the CoA and then to the MN (the CoA corresponds to the MN in case of co-located CoA). It requires the CN to support the MIP protocol, since it must receive information about the CoA from the HA, and must then tunnel the data towards the CoA.

b)



c)

- Packets from CN to MN are routed directly, since we have routing optimization and co-located CoA:

CN > MN/CoA: 45 hops

TTN at MN=100-45=55

- Packets from MN to CN are subject to reverse tunneling and have to be routed through the HA:

MN/CoA > HA >CN: 1+33=34 hops

TTN at CN=100-34=66

d)

CN > MN/CoA			
Outer Header		Inner Header	
Destination Address	Source Address	Destination Address	Source Address
195.137.10.20	146.64.4.6		

MN/CoA > HA			
Outer Header		Inner Header	
Destination Address	Source Address	Destination Address	Source Address
193.154.3.1	195.137.10.20	146.64.4.6	193.154.3.10

HA > CN			
Outer Header		Inner Header	
Destination Address	Source Address	Destination Address	Source Address
146.64.4.6	193.154.3.10		

2.

a)

Unlike MQTT, which features publish/subscribe semantics, CoAP follows a REST paradigm that maps very easily to HTTP. In fact, it supports the GET, PUT, POST and DELETE methods, also present in HTTP.

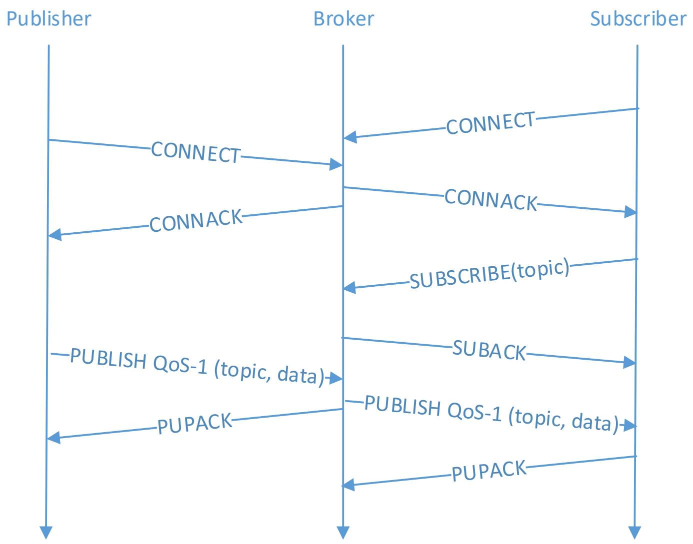
b)

CoAP is structured in two layers: Messages and Request/Response. The Messages layer provides an optionally reliable transmission mechanism, allowing CoAP to operate on top of UDP. The Message ID identifies the messages at this layer, allowing the matching between CON messages and the respective ACK responses. A to the Request/Response layer, it supports GET, PUT, POST and DELETE methods. The Token allows the matching between such requests and their responses. However, there is no requirement for a one-to-one correspondence between each Request/Response exchange and a CON/ACK exchange (and hence between a Message ID and a Token ID). In fact, following the non-confirmed or the separate confirmed response model, a request may be carried in a message whose Message ID is different from that of the message carrying its response.

c)

MQTT requires the TCP transport protocol for sake of transmission reliability, while MQTT-SN is designed for lightweight operation over UDP.

d)



3)

a)

SC-FDMA presents a lower Peak-to-Average-Power-Ratio (PAPR), which is more suitable for mobile phones, since it allows cheaper amplifiers to be employed.

b)

The duration of a Resource Block (RB) is one slot of 0,5s. Each Resource Element (RE) is an elementary resource precisely located in the time and frequency domains, corresponding to a modulation symbol. The number of REs per subcarrier in an RB depends on the size of the Cyclic Prefix (CP). With Normal CP, seven REs are sent per subcarrier in each RB, while with Normal CP, this is reduced to six REs. Since an RB comprises 12 subcarriers, there are $12 \times 7 = 84$ REs per RB with Normal CP, and $12 \times 6 = 72$ REs per RB with Extended CP.

c)

At CQI Index 5, the spectral efficiency is 0,8770. As such, the maximum achieved bitrate with a single MIMO stream is:

$$R_b = B \cdot 0{,}8770 = 20\ MHz\ \times 0{,}8770 = 17{,}540\ \text{Mbit/s}$$

d)

At CQI Index 10, the used modulation is 64 QAM and the code rate is $CR = \frac{466}{1024} \approx 0{,}46$. Each 20 ms (2 frames), a voice packet is generated, whose length can be calculated as follows:

$$l = 253 + 60 \times 8 = 733\ bit$$

When we add the channel coding, the effective number of bits becomes:

$$l_{eff} = \frac{l}{CR} = \frac{733}{0{,}46} \approx 1593{,}5\ bit$$

We must now calculate how many REs are needed to transmit a packet with this size, knowing that the number of bits transmited in each RE (i.e., 64QAM symbol) is $L = log_2(M) = log_2(64) = 6$, and that there are 7 REs per subcarrier, and 12 subcarriers in each RB, this can be calculated as follows:

$$N_{RB}^{20ms} = \left\lceil \frac{1593{,}5}{6 \cdot 7 \cdot 12} \right\rceil \approx 4$$

This is the number of RBs needed per 20 ms. Since each frame has only 10 ms, the average number of RBs needed per frame is $N_{RB}^{10ms} = 2$.

Note: The bandwidth efficiency in the given table is equal to $\frac{L \cdot CR}{1024}$, where L is the number of bits per modulation symbol.

4.

a)

$$F_g = F_c \Leftrightarrow m \cdot g \cdot \left(\frac{R}{r}\right)^2 = m \cdot r \cdot \omega^2 \Leftrightarrow 9.8 \cdot \left(\frac{6370000}{6370000 + 1800000}\right)^2$$
$$= (6370000 + 1800000) \cdot \omega^2 \Leftrightarrow \omega \approx 0{,}854\ mrad/s$$

$$T = \frac{2\pi}{\omega} \approx 7354\ s$$

b)

$$2 \propto = 45° = \frac{\pi}{4}\ rad$$

$$G_{(1plane)} = \frac{2\pi}{2\alpha} = 8$$

$$G = \left(G_{(1plane)}\right)^2 = 64$$

$$A_{eff} = \frac{\lambda^2}{4\pi} G = \frac{\frac{300000000}{2500000000}^2}{4\pi} 64 \approx 0{,}073\ m^2$$

c)

The Latitude is counted from the Equator. As such,

$$\beta = 90° - Lat = 6{,}54°$$

$$\alpha = 90° - \beta - \theta = 90° - 6{,}54° - 61{,}96° = 21{,}5°$$

$$d = \frac{R \cdot \sin(\beta)}{\sin(\alpha)} \approx 1979147{,}5\ m$$

$$P_r(dBm) = P_t(dBm) + 10 \cdot log_{10}\left(\frac{G_t \cdot G_r \cdot \lambda^2}{(4 \cdot \pi \cdot d)^2}\right) - At$$
$$= 40 + 10 \cdot log_{10}\left(\frac{64 \cdot 64 \cdot 0{,}12^2}{(4 \cdot \pi \cdot 1979147{,}5)^2}\right) - 10 \approx -100{,}2\ dBm$$