UNIVERSITY OF SOUTHAMPTON ELEC3227W1

SEMESTER 1 EXAMINATIONS 2022-2023

EMBEDDED NETWORKED SYSTEMS

Duration 120 mins (2 hours)

This paper contains 3 questions.

Answer **ALL** questions in this paper**.**

Only University approved calculators may be used.

A foreign language dictionary is permitted ONLY IF it is a paper version of a direct ‘Word to Word’ translation dictionary AND it contains no notes, additions or annotations.

9 page examination paper

 Version 1

Answer ALL questions

Question 1

(a) Consider a network of 100 battery-powered IoT devices, which monitor and report data on changes in PM2.5 pollutant levels across the university campus. All of the IoT devices are a single hop away from a mains-powered receiver, which provides a gateway to publish data via the Internet. On average, each device sends a frame once every minute, and each frame takes 30 ms to transmit. The DLL provides an unacknowledged connectionless service, and none of the other layers implement acknowledgements.

You have been asked to select an appropriate MAC sublayer for the network. **Explain** the positive and negative aspects of both of the following MAC protocols, including a timing diagram to illustrate the operation of each. Your answer should comment on the implications on 1) the average power consumption of the IoT devices, 2) the number of frames successfully received at the gateway, and 3) the end-to-end latency of received frames.

(i) ALOHA
(ii) Non-persistent CSMA

[8 marks]

(iii) In summary, **state** and **justify** whether you'd recommend ALOHA or non-persistent CSMA for this network.

[2 marks]

(b) (i) **Encode** the 11-bit word 01101100101_2 using a Hamming(15,11) code. Show all your working.

[3 marks]

(ii) Using your answer to (i), **show** how the Hamming(15,11) code can correct a transmission error which flips the 7^{th} bit.

[3 marks]

(iii) Using your answer to (i), **show** whether or not the Hamming(15,11) code can detect or correct transmission errors if both the 7^{th} and 15^{th} bits are flipped. **Explain** whether a Hamming code can correct 1-bit errors at the same time as detecting 2-bit errors.

[3 marks]

(iv) Consider the scenario where 64-bit frames are communicated across a channel with a Bit Error Rate (BER) of 1×10^{-3} (you should assume that a maximum of 1 bit error occurs per frame, and that ACKs/NAKs are instantaneous and of zero length). **Estimate** and **discuss** which is a better choice: the Hamming(15,11) code, or a single even parity bit. You should consider this from the perspective of (1) the total number of bits transmitted, and (2) latency.

[6 marks]

(c) A network architecture uses Selective Repeat for flow control at the DLL, with a 3-bit sliding window and maximum window size of 4. **Show**, using a fully annotated sequence diagram, the frames communicated between the sender and receiver. 10 frames need to be sent, but frame 3 is lost during transmission, and the sender never receives the acknowledgement for frame 7. Assume that the Round Trip Time (RTT) is significantly greater than the time taken to transmit a series of frames.

[8 marks]

TURN OVER

Question 2

(a) Alice wishes to send a confidential design to Bob, but is worried that Trudy may intercept the file. She wishes to use public key cryptography, but Alice and Bob have not communicated in this way before, so they have no prior knowledge of each other's encryption keys.

Initially, Bob's public key is requested by Alice. He supplies it to Alice in a certificate signed by the root CA. Alice already has the public key of the root CA. Alice sends her public key to Bob using the same method.

(i) **Explain** the major difference between symmetric and asymmetric encryption schemes. **State** whether public key cryptography is symmetric or asymmetric.

(ii) **State** whether Alice should encrypt the data using her private key or Bob's public key, and **explain** why.

(iii) **Explain** how Alice can have confidence that she has been supplied with the correct public key for Bob, and that Trudy is not impersonating Bob. What information does the certificate contain?

(iv) If Alice and Bob are concerned that Trudy could try and impersonate Alice, **explain** what could be done to enable Bob to confirm whether messages have originated from Alice.

[11 marks]

(b) You know that some links in your network (shown in Figure 1) are unreliable, but that your nodes will generate their own packets at a relatively low rate (e.g. a maximum of one packet every few seconds).

You decide to use flooding to get packets to their destination as quickly and reliably as possible. After considering your network topology, you configure your nodes to send packets with a hop limit of 2.

Other than ensuring that nodes do not retransmit on incoming lines, **no other intelligence** is built into the flooding algorithm.

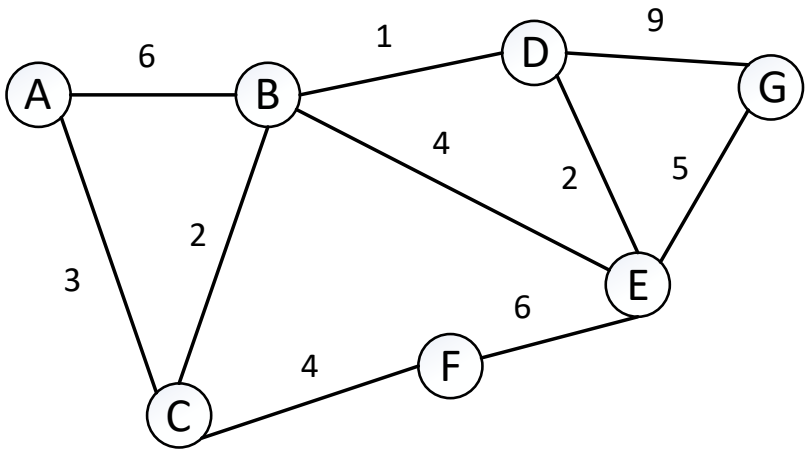

Figure 1 – Network topology used in Question 2(b)

You send an **unacknowledged** packet through your network from node A, addressed to node E.

(i) **List** each of the transmissions made by nodes in the network delivering this packet. You should also **state** how many transmissions are made in total.

(ii) **Discuss** the suitability of this routing scheme, and its configuration, to this application (considering the requirements outlined above), along with its efficiency.

[8 marks]

TURN OVER

(c) The traffic on the network described in part (b) increases significantly. You decide to modify it to use a different routing scheme, either Link State Routing or Distance Vector Routing. The other properties of this network remain unchanged.

(i) **Explain** which alternative routing scheme would be most appropriate, clearly justifying your answer.

(ii) **Explain** what information would be held by each node for your preferred scheme, for this network. **Describe** what computation would need to be done by each node in order to calculate the best route (but you do not need to carry out this computation).

[7 marks]

(d) An excerpt of a DNS resource record is shown in Table 1.

(i) A user attempts to access `www.soton.ac.uk` **Explain** how the name server computes the address to return. What is the advantage of defining it in this way?

(ii) A sender wishes to transmit an email to `bob@soton.ac.uk`. **Explain** how the name server returns the address(es), and what may happen if the chosen mail server later fails.

(iii) **Explain** the significance of the “86400” listed on each line. What does this mean for systems accessing these addresses?

[7 marks]

soton.ac.uk.	86400	IN	SOA	admin@soton.ac.uk (20221022, 3600, 1800, 604800, 86400)
soton.ac.uk.	86400	IN	NS	alpha
soton.ac.uk.	86400	IN	MX	1 beta
soton.ac.uk.	86400	IN	MX	2 gamma
alpha	86400	IN	A	152.78.130.111
beta	86400	IN	A	152.78.130.251
gamma	86400	IN	A	131.41.231.180
delta	86400	IN	A	152.78.130.102
www	86400	IN	CNAME	delta

Table 1 – Excerpt of a DNS resource record used in Question 2(d)

TURN OVER

Question 3

(a)

(i) In the context of wireless networking, **explain** the purpose of the MAC sublayer.

[2 marks]

(ii) **Explain** what is meant in this context by a hidden terminal and an exposed terminal. Your answer should include a diagram.

[2 marks]

(b) A company has installed a peer-to-peer/mesh network of low-power wireless sensor nodes. The designers have identified that the MAC protocol is consuming too much energy (at both the receiving and transmitting nodes). **State** and **explain** three typical sources of wasted power/energy in the MAC sublayer.

[3 marks]

(c) Suggest and **discuss** a modification that could be made to the ALOHA MAC protocol to reduce the average power consumption at the MAC sublayer for (i) transmitting frames, and (ii) receiving frames. Your answer should **explain** the effect of each modification on 1) average power consumption, 2) frame latency, and 3) throughput.

[8 marks]

(d) Consider a network of low-power wireless sensor nodes. **Explain** why a star-network (where nodes communicate directly to a central mains-powered sink node) might offer a lower power consumption for the sensor nodes than a peer-to-peer mesh network.

[2 marks]

(e) A ZigBee network may be built from RFDs and FFDs.

(i) **State** what RFD and FFD stands for.

(ii) **Explain** what network roles are supported by each type of device.

(iii) **State** which roles, if any, are appropriate to power from a small battery, and **explain** why.

[7 marks]

(f) TCP uses the “slow start” method of congestion control.

(i) **Explain** the operation of the slow start method of congestion control used by TCP.

For parts (ii) and (iii) below, assume that the slow start algorithm is being used, the RTT (Round Trip Time) is given by 2 x (propagation time + queueing delay), that there is no limit to the TCP packet length, the receive buffer is 1 Mbyte, and no packets are lost.

(ii) If the initial congestion window is 1 Kbyte, **calculate** how many RTTs it takes until the sent packet size reaches 1 Mbyte.

(iii) **Calculate** how many RTTs it takes to transfer a 10 Mbyte file. Show your workings.

[9 marks]

END OF PAPER