SUPPLEMENTARY EXAMINATIONS 2021-2022

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.

7 page examination paper

Answer ALL questions

Question 1

A network architecture uses the *Packet* and *Frame* structures shown in Figure 1.

Packets contain *'Payload'* and *'Checksum'* fields (the latter of which is calculated as the modulo-16 sum of all the 4-bit nibbles in the *'Payload'* field). When passed to the Data Link Layer, the *Packet* is split into a number (specified in the *'Total number of Frames in Packe*t' field) of smaller *Frames*, which are communicated in sequence (indexed using the *'Sequence Number'*). *Frames* use byte stuffing, with a *Flag* byte of `0xFE` and an *Escape* byte of `0xFF`. A single even *'Parity bit'* is calculated over the bits in the *'Payload'* field before byte stuffing is performed.

The sending device creates a single *Packet*, which is split into three *Frames* and transmitted by the Data Link Layer. The following hex strings (where '`0x`' indicates that the symbols following it are in hexadecimal notation) are <u>received</u> by the receiving device's Data Link Layer. Note: any data <u>transmitted</u> by the receiving device, e.g. positive and negative acknowledgements, are not shown here.

```
0xFE0301DECA00FE
0xFE0302FC4F00FE
0xFE0303FFFEE000FE
0xFE0302FC0F00FE
0xFE0303FFFEE000FE
```

<u>Packet Structure (Network Layer)</u>

variable	*1 nibble (4 bits)*
Payload	Checksum

<u>Frame Structure (Data Link Layer)</u>

1 byte	*1 byte*	*1 byte*	*variable*	*7 bits*	*1 bit*	*1 byte*
Flag	Total number of Frames in Packet	Sequence Number	Payload	Padding (all zeros)	Parity bit	Flag

Figure 1 – *Packet* and *Frame* structures used in Question 1.

Question continues on following page

(a) **Calculate** the *'Payload'* data in each *Frame*, and hence **identify** the single *Packet* (as a hexadecimal string) that is passed to the Network Layer

[8 marks]

(b) **Explain** which flow control approach you think is being used at the Data Link Layer. **Draw** a sequence diagram to illustrate your answer, showing all *Frames* communicated.

[7 marks]

(c) Using your answer from part (a), **calculate** the *'Payload'* field contained in the *Packet*, and **explain** whether or not it was correctly received. If you did not answer part (a), assume that the *Packet* passed to the Network Layer was `0xA7B6F137BBCC`.

[5 marks]

(d) If in part (c) you determined that the *Packet* was not correctly received, **explain** what might have happened to cause this. **Explain** what the Network Layer should do to resolve the issue. Alternatively, if in part (c) you determined that the *Packet* was correctly received, **explain** what could happen to cause other *Packets* to be incorrectly received, and what action the Network Layer would then take to resolve the issue.

[4 marks]

(e) **Explain** whether or not the *Packet* would have been received correctly if the *'Parity bit'* field in each *Frame* was replaced with:

(i) A (31,26) Hamming code [2 marks]
(ii) A 32-bit Cyclic Redundancy Check [2 marks]

(f) Based on the limited information that you have, **state** and **justify** which protocols you would choose (at the Data Link Layer) for:

(i) Error Control [3 marks]
(ii) Flow Control [2 marks]

Question 2

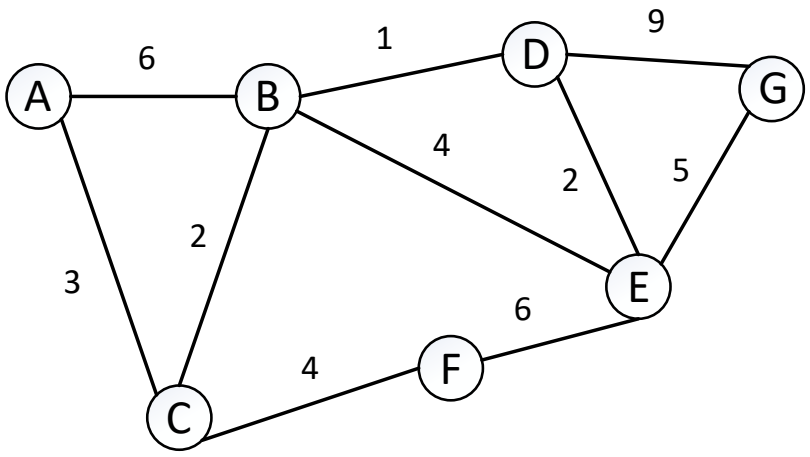

Figure 2 – Network topology used in Question 2

The network topology shown in Figure 2 shows the cost associated with each link.

(a) The network will use Link State Routing. You can assume that the initial neighbour discovery phase has completed successfully.

(i) **List** the Link State Packets (LSPs) that would initially be sent from each node to its neighbours. You should also **describe** any parameters that are sent in the packets.

[5 marks]

(ii) LSPs propagate by *flooding*, which is typically an inefficient routing mechanism. **Explain** how basic flooding algorithms operate, **discuss** why flooding is inefficient, and **describe** how the basic flooding mechanism may be modified for efficient propagation of LSPs.

[4 marks]

(b) **Find** the best (lowest cost) route from all nodes on the network to node A. You should **show** the algorithm you use to find this best route, e.g. using a diagram.

[6 marks]

(c) Node A wishes to send out a broadcast to all nodes in the network. With the aid of a diagram, **sketch** the route(s) that would be taken. How many individual transmissions would be made, and how many nodes would transmit?

[4 marks]

Question continues on following page

(d) The link between node B and node C fails. **Explain** how the network can find new routes, to avoid this link. What could prompt this to happen?

[3 marks]

(e) For general transmissions, a node in the network has a clock-driven method for generating initial sequence numbers, using a 16-bit wide counter. The clock has a 10 ms tick interval, and the maximum packet lifetime is 60 s. **Calculate** how often resynchronization should take place:

(i) in the worst case.
(ii) when data consumes 120 sequence numbers/min.

[5 marks]

(f) **Explain** why packet lifetime is set to a relatively high value.

[2 marks]

(g) To improve reliability, three-way handshakes are often used for connection establishment and release. **Describe** the main difference between the handshakes used for connection *establishment* and *release*, and **explain** why they differ.

[4 marks]

Question 3

A small company is developing a new 'Industry 4.0' *device*, capable of detecting and inspecting the quality of *products* continually passing along a small production line. *Products* pass each *device* at a frequency of 1 Hz. Every time that a *device* detects a new *product*, it wirelessly transmits a 40-byte frame (with an anticipated bit-error-ratio (BER) of $1x10^{-4}$) to a *base-station*. The company anticipates that a single production line is likely to contain many *devices*, all communicating to the same *base-station*. You have been tasked with designing a Data Link Layer which provides a reliable service.

(a) You are trying to decide how to handle errors at the Data Link Layer, and are choosing whether each frame should use a single (255, 247) Hamming code or 3-bit Cyclic Redundancy Check (CRC).

Explain the suitability of each approach in this scenario, considering the impact on frame retransmissions, average latency, energy consumption, and the number of *devices* that the network can reliably support.

[8 marks]

(b) You have decided to use *p*-persistent CSMA for the MAC protocol. **State** and **explain** which value of *p* you would use, assuming that you are optimising the network to:

(i) Minimise latency
(ii) Maximise the number of *devices* that it can reliably support

[4 marks]

(c) You are deciding which flow control approach to use at the Data Link Layer. **State** and **explain** what you would use, assuming that you are optimising the network to:

(i) Minimise latency
(ii) Minimise the cost of each *device*

[4 marks]

(d) It has been decided to use a connectionless networking scheme for this network. However, you wish to have confidence that messages have been successfully received. **Explain** how this can be assured for:

(i) A connection-oriented transport protocol (e.g. TCP).
(ii) A connectionless transport protocol (e.g. UDP).

[4 marks]

Question continues on following page

The company has now decided to use commercially-available transceivers, that are certified standards-compliant. They have seen in sales material that the various technologies claim to be “low-power”. They are considering whether they can power the devices from batteries or energy harvesters, to avoid installing wiring. They have not yet decided whether to use WiFi, Bluetooth, Bluetooth Low Energy, ZigBee/IEEE 802.15.4, LoRa, or another standard. They are looking for your advice.

(e) The production line has good WiFi coverage. **Discuss** whether WiFi is a good choice for this scenario. If not, **recommend** an alternative. You must justify your answer.

[4 marks]

The company have heard about cybersecurity threats, and wish to ensure their systems are as safe as possible.

(f) They have heard that one-time pads are the most secure method of cryptography. **Discuss** whether they are suitable for this application. If not, recommend a suitable scheme.

[4 marks]

(g) You have noticed that most system-on-chip transceivers/processors incorporate AES-128 hardware, which accelerates symmetric key encryption.

(i) **Explain** how encryption keys are configured for this type of wireless device, and **compare** this against public-private key schemes.

(ii) **Describe** how devices can ensure that they use the correct public key to communicate with another device.

[5 marks]

END OF PAPER