CPSC 441
COMPUTER NETWORKS

MIDTERM EXAM SOLUTION

Department of Computer Science
University of Calgary
Professor: Carey Williamson

October 26, 2018

This is a CLOSED BOOK exam. Textbooks, notes, laptops, personal digital assistants, tablets, and cellular phones are NOT allowed. However, **calculators are permitted**.

It is a 50 minute exam, with a total of 50 marks. There are 13 questions, and 7 pages (including this cover page). Please read each question carefully, and write your answers legibly in the space provided. You may do the questions in any order you wish, but please USE YOUR TIME WISELY.

When you are finished, please hand in your exam paper and sign out. Good luck!

Student Name: _____

Score: _____ / 50 = _____ %

Optional Privacy Fold Here

Student ID: _____

Multiple Choice

Choose the best answer for each of the following 8 questions, for a total of 8 marks.

1 1. Which of the following was one of the "big three" applications on the early Internet?

(a) BitTorrent

(b) World Wide Web

(c) secure shell

(d) file transfer

(e) Crypto-Tweet

1 2. The leased transmission lines used to build the early Internet had data rates of about:

(a) 56 kbps

(b) 256 kbps

(c) 1.5 Mbps

(d) 10 Mbps

(e) 100 Mbps

1 3. What did Sir Tim Berners-Lee invent?

(a) TCP/IP

(b) electronic mail

(c) the Internet

(d) hyper-text documents

(e) the World Wide Web

1 4. Fiber optic cables are superior to WiFi for physical-layer transmission because:

(a) the signals stay primarily within the guided media

(b) signals can propagate much further distances

(c) the data transmission rate is much higher

(d) the error rate is much lower

(e) all of the above

1 5. In a TCP-based server, some typical system calls used are:

(a) `socket()` and `connect()` (in that order)

(b) `connect()` and `socket()` (in that order)

(c) `accept()` and `listen()` (in that order)

(d) `listen()` and `accept()` (in that order)

(e) `recvfrom()` and `sendto()` (in that order)

1 6. How many "root" name servers are there in the Domain Name System?

(a) only 1

(b) about 10

(c) about 100

(d) about 1,000

(e) about 1,000,000

1 7. Which of the following statements is true about TCP's "Slow Start" algorithm?

(a) the congestion window size `cwnd` increases linearly

(b) `cwnd` increases exponentially

(c) `cwnd` remains constant

(d) `cwnd` decreases linearly

(e) `cwnd` decreases exponentially

1 8. With TCP Reno, the average throughput achieved by a TCP flow is:

(a) directly proportional to the average packet loss rate

(b) directly proportional to the square root of the average packet loss rate

(c) inversely proportional to the average packet loss rate

(d) inversely proportional to the square root of the average packet loss rate

(e) none of the above

Internet Protocol Stack

8 9. List, in order, the five layers of the Internet protocol stack. For each layer, provide a brief description (1-2 sentences) of what that layer does, and provide an example of a protocol or specific networking technology associated with that layer.

```
5. Application Layer: user-to-user exchange of messages (e.g., SMTP)
                      (useful network applications and services)

4. Transport Layer: end-to-end exchange of segments (e.g., TCP)
                    (process to process, using sockets)

3. Network Layer: host-to-host movement of packets (e.g., IPv4)
                  (datagrams)

2. Datalink Layer: hop-by-hop exchange of frames (e.g., WiFi)


1. Physical Layer: raw transmission of bits (e.g., optical fiber)
```

Networking Delays

5 10. Suppose that a lunar rover robot on the Moon takes a 2 MB "selfie" photo and transmits it home to its parent robot on Earth. The transmission uses an error-free direct link with a data transmission rate of $R = 4$ Megabits per second (Mbps).

(a) (3 marks) Using the relationship $t_{trans} = \frac{L}{R}$, calculate the transmission time for this file, which has size L (in bits). Recall that 1 MB = 2^{20} bytes, and that 1 Mbps = 10^6 bits per second. Show your work.

$$t_{trans} = \frac{L}{R} = \frac{2 \cdot 2^{20}\ bytes \cdot 8\ bits/byte}{4 \cdot 10^6\ bits/sec} = \frac{16,777,216\ bits}{4,000,000\ bits/sec} = 4.19\ seconds$$

(b) (2 marks) Assuming that the Moon is approximately 385,000 kilometers from the Earth, at what time would the very first bit of the photo arrive? Recall that propagation delay $t_{prop} = \frac{distance}{speed}$, and that the speed of light is approximately 3 x 10^8 meters per second. Show your work.

$$t_{prop} = \frac{distance}{speed} = \frac{385,000\ km \cdot 10^3\ m/km}{3 \cdot 10^8\ m/sec} = \frac{385,000,000\ m}{300,000,000\ m/sec} = 1.28\ seconds$$

Networking Concepts and Definitions

9 11. For each of the following pairs of technical terms, **define** each term, and **clarify** the key difference(s) between the two terms. Be clear and concise. If in doubt about your definition, feel free to supplement with a relevant example.

(a) (3 marks) "circuit-switched" and "packet-switched"

Circuit-switched: traditional telephone network design; end-to-end call setup; single path for duration of call; switches maintain important state about calls; dumb devices at network edge; all the smarts are in the network core.

Packet-switched: data network design for Internet; data is split into packets, which are independently addressed and routed through the network; simple core; routers maintain minimal state about active calls; smarts are at network edge.

(b) (3 marks) "client-server" and "peer-to-peer"

Client-server: traditional paradigm for network applications; server is special and well-resourced; clients are simple and numerous; client requests service from the server. Example: World Wide Web

Peer-to-peer: alternative paradigm for network applications; all nodes are equal; each node can function both as a client (requesting service or resources) and as a server (providing service or resources). Example: BitTorrent.

(c) (3 marks) "positive ACK" and "negative ACK"

Positive ACK: a control packet that conveys "good news" about the successful delivery of data; used in the PNA protocol for RDT.

Negative ACK: a control packet that conveys "bad news" about the unsuccessful delivery of data; used in the PNA protocol for RDT to indicate corrupted data.

Key difference: ACK triggers new data, while NAK triggers retransmission.

Application Layer Protocols

10 12. In some respects, many application-layer protocols are conceptually similar, in that they are moving a set of bytes from one computer to another. Three such protocols that we discussed in class are FTP (File Transfer Protocol), SMTP (Simple Mail Transfer Protocol), and HTTP (Hyper-Text Transfer Protocol).

Using the tabular format below, and your knowledge of application-layer protocols, identify the main similarities and/or differences between these three protocols. For example, you might comment on their design, communication paradigm, protocol state information, service requirements, implementation details, or other features of these protocols.

Point form is sufficient, but try to make at least 4 relevant comments about each protocol, and have a mix of similarities and differences across the columns.

FTP (3 marks)	SMTP (3 marks)	HTTP (4 marks)
client-server	client-server/peer-to-peer	client-server
TCP	TCP	TCP
session-oriented	session-oriented	transaction-oriented (1.0)
files	email messages (+attachments)	Web objects (pages)
1970's	1970's	1990's
plain text	plain text	plain text
push/pull	push	pull
ports 20 and 21	port 25	port 80
separate data/control	inband data/control	inband data/control
stateful	stateful	stateless (1.0); state (1.1)
loss-sensitive	loss-sensitive	loss-sensitive
delay-tolerant	delay-tolerant	interactive

Transport Layer Protocols

10 13. In class, we discussed two different examples of Transport Layer protocols in the Internet protocol stack, namely TCP and UDP.

(a) (2 marks) What do the acronyms "UDP" and "TCP" stand for?

```
UDP: User Datagram Protocol
TCP: Transmission Control Protocol
```

(b) (2 marks) Give **two** examples of similarities between TCP and UDP.

```
- both are transport-layer protocols
- both use 16-bit port numbers in headers for TL multiplexing
- both use 16-bit Internet checksum in headers for error detection
- both allow variable size segments (up to 64 KB)
```

(c) (3 marks) Give **three** distinct examples of differences between TCP and UDP.

```
- TCP is connection-oriented (stateful); UDP is connection-less (stateless)
- TCP uses 3-way handshake for connection setup; UDP does not
- TCP does flow control; UDP does not
- TCP does congestion control; UDP does not
- TCP has sequence numbers and ACKs; UDP does not
- TCP does timeouts and retransmissions; UDP does not
```

(c) (3 marks) Give **three** specific examples of state variables within a TCP Control Block (i.e., Connection State Record) that would not be present in the case of UDP, and indicate what each of these state variables is used for.

```
- sequence number: numerical value associated outgoing data being sent
- expected: numerical value associated with incoming data being received
- send window: flow control window size for sender
- receive window: flow control window size for receiver
- RTT: Round Trip Time estimate
- RTO: Retransmission TimeOut value used when a segment is lost
- cwnd: congestion window for dynamic congestion control
- ssthresh: slow start threshold for TCP congestion control algorithm
...
```

*** THE END ***