CPSC 441 L01
COMPUTER NETWORKS

MIDTERM EXAM SOLUTION

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

It is a 45 minute exam, with a total of 50 marks. There are 14 questions, and 8 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. The main components of the Internet are:

(a) hosts

(b) links

(c) switches

(d) **all of the above**

(e) none of the above

1 2. File transfer is an example of a network application that is:

(a) delay-sensitive and loss-sensitive

(b) delay-sensitive and loss-tolerant

(c) **delay-tolerant and loss-sensitive**

(d) delay-tolerant and loss-tolerant

(e) none of the above

1 3. Which of the following protocols or applications is transaction-oriented?

(a) electronic mail (SMTP)

(b) file transfer (FTP)

(c) secure shell (ssh)

(d) **Domain Name Service (DNS)**

(e) video streaming (DASH)

1 4. Which one of the following is an email access protocol?

(a) DNS

(b) **IMAP**

(c) SMTP

(d) FTP

(e) two (but not all) of the above

1 5. Modern Web browsers achieve high performance on the Internet by:

(a) using persistent connections

(b) launching multiple connections in parallel

(c) exploiting Web object caching whenever possible

(d) **all of the above**

(e) none of the above

1 6. The data rate supported by dialup modems on the early Internet was:

(a) a few bits per second (bps)

(b) **a few kilobits per second (kbps)**

(c) a few Megabits per second (Mbps)

(d) a few Gigabits per second (Gbps)

(e) all of the above

1 7. The "best effort" service model provided by the Internet is an example of:

(a) time-division multiplexing

(b) frequency-division multiplexing

(c) code-division multiplexing

(d) space-division multiplexing

(e) **statistical multiplexing**

1 8. In the "Internet food chain", most residential customers deal with:

(a) **an Internet Service Provider (ISP)**

(b) an Internet Exchange Point (IXP)

(c) a backbone Network Service Provider (NSP)

(d) BGP peering agreements

(e) international peering agreements

Internet Protocol Stack

8 9. Use your knowledge of the Internet protocol stack to answer the following questions, by filling in the blanks with the appropriate word, phrase, or number.

(a) (1 mark)

The top-most layer of the Internet protocol stack is the Application Layer.

The fundamental data unit exchanged at this layer is called a message.

(b) (2 marks)

Whether connection-oriented or connection-less, the Transport Layer protocol must provide a means to multiplex/demultiplex among many possible different network applications.

In TCP and UDP, this is done using ports, which provide 16-bit Transport Layer addresses for data delivery on an end-to-end basis.

(c) (2 marks)

At the Network Layer, the basic unit of information exchange is called a datagram.

This layer operates on a host-to-host basis, dealing with issues such as internetworking, addressing, and routing.

The classic protocol used here is the Internet Protocol, with 32-bit NL addresses.

(d) (2 marks)

At the Data Link Layer, the two main types of links are wired and wireless.

This layer exchanges data units called frames, doing so on a hop-by-hop basis.

(e) (1 mark)

The Physical Layer supports the raw transmission of bits via a network interface.

One example of a transmission medium used at this layer is twisted pair/coax/fiber.

HyperText Transfer Protocol (HTTP)

4 10. Suppose that you are updating your silly HTTP proxy from Assignment 1 to replace the text string “Happy Birthday” on Web pages with “Happy Anniversary” instead. What changes (if any) would be needed in your code to do this, and why?

```
- modify text strings to search/replace
- each such replacement increases text size by 3 bytes (11 vs 8 bytes)
- need to shift text, increase buffer size, and send more bytes to client
- must update Content-Length: header in HTTP response to reflect this
```

Networking Delays

6 11. Answer the following numerical questions. Please show your work.

(a) (2 marks) Suppose that former U of C Chancellor Dr. Robert Thirsk wants to download Floppy.jpg (1 MegaByte in size) from the CPSC 441 Web site, doing so from his home in Calgary. Assuming that his data rate for Internet downloads is 1.5 Mbps (Megabits per second), what is the transmission time for this file? (Recall that $T_{xmit} = \frac{L}{R}$)

```
T_xmit = L / R = size_in_bits / data_rate

            1 x 2^20 bytes x 8 bits/byte       8,388,544 bits
         =  ----------------------------   =  ------------------  =  5.59 seconds
               1.5 x 10^6 bits/sec            1,500,000 bits/sec
```

(b) (2 marks) Suppose that Dr. Thirsk now wishes to upload Floppy.jpg to his astronaut colleagues on the moon, which is 385,000 km away. If the first bit of Floppy.jpg leaves his house at time 0.0 seconds, at what time does the first bit of Floppy.jpg arrive at the moon? (Recall that $T_{prop} = \frac{d}{s}$, and assume $s = 3\text{x}10^8$ m/second)

```
T_prop = d / s = distance / speed

            385,000 km x 10^3 m/km       385,000,000 m
         =  ----------------------  =  -----------------  =  1.28 seconds
              3 x 10^8 m/sec           300,000,000 m/sec
```

(c) (2 marks) Assuming a single large packet containing all of Floppy.jpg (and minimal header info), and an upload speed of 1.5 Mbps, at what time would the final bit of Floppy.jpg arrive at the moon? And when would a one-bit acknowledgement be received back at his house?

```
T_lastbit = T_xmit + T_prop = 5.59 sec + 1.28 sec = 6.87 sec

T_ack = T_lastbit + T_prop = 6.87 sec + 1.28 sec = 8.15 sec
```

Networking Concepts and Definitions

9 12. 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) "connection-oriented" and "connection-less"

```
CO: stateful protocol design              CL: stateless protocol design
Explicit setup phase (handshake)          No setup phase required
  prior to data exchange                    before exchanging data
Explicit teardown phase to close          No closing handshake needed
Suitable for any amount of data           Suitable for small amounts of data
This choice of protocol design applies at every layer of the protocol stack!
```

(b) (3 marks) "TDM" and "FDM"

```
  TDM: Time-Division Multiplexing          FDM: Frequency-Division Multiplexing
 - static resource allocation to N users  - static resource allocation to N users
 -  time slot allocated per user          - frequency range allocated per user
 -  all of the channel, part of the time  - part of the channel, all of the time
```

(c) (3 marks) "iterative DNS query" and "recursive DNS query"

```
I: a form of DNS query resolution in      R: a form of DNS query resolution in
  which the onus is on the initiator to     which one DNS server performs query
  perform successive queries at each        on your behalf, like a nested RPC
  different level of the DNS hierarchy    Result returned and cached on DNS path
Multiple queries required by local DNS    Single query required by local DNS
```

Reliable Data Transfer (RDT)

7 13. Briefly describe each of the following generic protocols for Reliable Data Transfer (RDT). Do so by describing what assumptions they make, what mechanisms they use for RDT, why those mechanisms are needed, and how they work. Make sure to mention what state information is involved in each protocol, and where that state information is stored.

(a) (3 marks) RDT 2.0

```
- sender follows stop and wait flow control paradigm
- assumes NL can corrupt data segments, but not ACKs/NAKs; no losses
- sender computes and adds checksum to outgoing data segments
- receiver computes and verifies checksum prior to delivery
- positive ACK if successful; negative ACK (NAK) if corrupted
- sender retransmits upon NAK, else can send new data segment
```

(b) (4 marks) RDT 3.0

```
- sender follows stop and wait flow control paradigm
- assumes NL can corrupt and/or lost segments (data or ACKs; no NAKs needed))
- similar mechanisms to above for data integrity checking
- sequence numbers 0/1 on outgoing data segments for duplicate detection
- ack numbers 0/1 to indicate what arrived successfully (or expected next)
- timer at sender; seqnum at sender; expected seqnum at receiver
- loss of data or ACK segment results in timeout and retransmission by sender
```

Transmission Control Protocol (TCP)

8 14. Suppose that you are uploading a 12 Megabyte video into D2L using TCP. Assume that each TCP data segment holds exactly 1 Kbyte of data, and that the headers are small. Processing times at both ends are negligible, but the *one-way* latency between you and D2L in Montreal is 20 milliseconds. The link transmission rate is 1 Gbps. Assume that the TCP connection is already established, and that the connection starts in the slow start phase with $cwnd = 1$ segment. Use your knowledge of TCP to answer the following:

(a) (2 marks) How long does it take to complete the first Round Trip Time (RTT) of DATA-ACK exchange in slow start? What is the throughput achieved at this point?

```
RTT = 2 * one-way-delay = 2 * 20 msec = 40 msec = 0.040 seconds

Throughput = 1 KB/40 ms = 8,192 bits/0.040 sec = 204,800 bps
```

(b) (3 marks) Assuming no packet losses, how many RTT rounds does it take before reaching TCP's maximum window size of 64 KB? How many data segments would have been delivered by this point in time?

```
cwnd evolution (in segments): 1, 2, 4, 8, 16, 32, 64
Takes 6 rounds to get from 1 seg to 64 segs, with 64 KB in the 7th round
TCP sends a total of 63 segments in the first 6 rounds
```

(c) (3 marks) If TCP operates loss-free at a maximum window size of 64 KB for the rest of the upload, what is the (approximate) average throughput that will be achieved?

```
Throughput = 64 KB/40 ms = 524,288 bits/0.040 sec = 13.1 Mbps
```

*** THE END ***