Name ..... ID ..... Section ..... Seat No .....

Sirindhorn International Institute of Technology
Thammasat University

Final Exam: Semester 1, 2012

Course Title: ITS323 Introduction to Data Communications

Instructor: Steven Gordon

Date/Time: Monday 15 October 2012; 9:00–12:00

Instructions:

- This examination paper has 21 pages (including this page).
- Conditions of Examination: Closed book; No dictionary; Non-programmable calculator is allowed
- Students are not allowed to be out of the exam room during examination. Going to the restroom may result in score deduction.
- Students are not allowed to have communication devices (e.g. mobile phone) in their possession.
- Write your name, student ID, section, and seat number clearly on the front page of the exam, and on any separate sheets (if they exist).
- Assume bits are ordered from left to right. For example, for the data 00001111, the first (1st) bit is 0 and the last (8th) bit is 1.
- Assume the speed of transmission is 3×10^8 m/s
- Reference material included at the end of the exam may be used.

Question 1 [15 marks]

For each question fill in the blank space with the most appropriate term from the list below. For each blank space you must give only one answer. However, there may be more than one correct answer. You may use a term from the table in more than one question. You must not use terms that are not in the table. Each correct answer is worth 1.5 marks.

- adaptive routing
- addressing
- application
- automatic repeat request
- circuit switching
- congestion control
- datagram packet switching
- data link
- fixed routing
- flooding
- flow control
- Go-Back-N ARQ
- host
- internet
- LAN
- neighbours
- PCM
- physical
- router
- sampling period
- sampling frequency
- segmentation of data
- Selective-Reject ARQ
- sliding window
- station
- Stop-and-Wait ARQ
- subnet
- switch
- topology
- transport
- virtual circuit packet switching

(a) _____ is a simple, but inefficient mechanism for sending data to all nodes in a network.

(b) If a source node sends too fast it is possible for the buffer at the destination node to become full and subsequent received packets are dropped/lost. _____ is a mechanism that aims to prevent this from happening.

(c) In _____ if a node indicates frame i was lost, then the source retransmits frame i, as well as all frames in the window that it has previously sent after frame i.

(d) In _____ the least-cost paths are calculated when the network is designed and built; in _____ the least-cost paths are calculated on a regular basis, e.g. every 5 minutes.

(e) An advantage of _____, which was built for telephone networks, is that resources are reserved for the duration of the connection, meaning the application performance is guaranteed.

(f) When using _____, data at the source is sub-divided into packets, and packets may take different paths to the destination.

(g) To calculate least-cost paths, a node needs to know the current network _____, including costs.

(h) A feature provided by TCP, but not by IP, is _____.

(i) An IP _____ is a datagram packet switch that forwards IP datagrams.

(j) A(n) _____ is composed of multiple LANs and WANs, each using possibly different data link and physical layer technologies.

Question 2 [12 marks]

Assuming classless IP addressing is used, answer the following questions by writing your answers in the table on the next page. Unless otherwise stated, give all IP addresses in dotted decimal notation.

(a) For a host with IP address `43.109.168.14/22`: [3 marks]

i. What is the network address?

ii. What is the directed broadcast address?

(b) For a host with IP address `108.16.4.200` and subnet mask `255.255.0.0`: [4.5 marks]

i. What is the network address?

ii. What is the directed broadcast address?

iii. What is the maximum number of IP devices that can attach to this subnet?

(c) A host does not yet have an IP address configured, nor does it know its network address. [4.5 marks]

i. Give an IP address that the host can send to in order to send to itself.

ii. Give an IP address that the host can send to in order to deliver an IP datagram to all nodes on its subnet.

iii. For the case of part (ii), give the source address of the IP datagram.

Question	*Answer*
(a) i.	
(a) ii.	
(b) i.	
(b) ii.	
(b) iii.	
(c) i.	
(c) ii.	
(c) iii.	

Question 3 [13 marks]

Consider the network in Figure 1.

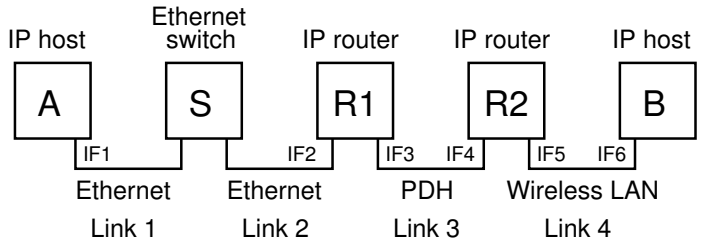

Figure 1: An internet

The addresses on each interface, IF, are given in Table 1. All subnet masks are `/24`.

Table 1: Interface Addresses

Interface	*MAC Address*	*IP Address*
IF_1	`01:23:45:67:89:AB`	`10.10.10.1`
IF_2	`AA:BB:CC:DD:EE:FF`	`10.10.10.2`
IF_3	`22:44:66:88:AA:CC`	`20.20.20.3`
IF_4	`11:33:55:77:99:BB`	`20.20.20.4`
IF_5	`FE:DC:BA:98:76:54`	`30.30.30.5`
IF_6	`00:00:11:11:22:22`	`30.30.30.6`

A user on host B is using their web browser to access a website. There are web servers running on all hosts and routers. Router R2 also acts as a DNS server. A DNS server maintains a database of mappings between domain names and IP addresses. The DNS protocol involves a client sending a DNS Query containing a domain name to the server, and the server sending a DNS Response containing the corresponding IP address back to the client. The DNS protocol uses UDP as a transport layer protocol. Assume the current values in the DNS server database are:

- `www.siit.com` → `10.10.10.1`
- `www.example.com` → `10.10.10.2`
- `www.sandilands.com` → `20.20.20.4`

The user on host B types the URL `http://www.example.com/index.html` into the address bar of their browser and presses Enter.

Assume the transport layer protocols can send the application layer data in a single segment. All requested URLs exist and are accessible on the server. Assume optional fields are not used in transport or network layer headers.

Assume you can intercept any packet on any link in the internet and see the entire contents of the packet. For the following packets and locations, complete the corresponding tables giving the value of the header fields. Some values are already given.

(a) The packet containing the DNS Query sent by host B, on link 4. [2 marks]

Layer	*Field*	*Value*
Network	Protocol	
Network	Source Address	
Network	Destination Address	
Transport	Destination Port	

(b) The 1st packet of the TCP connection setup, intercepted on link 3. [2.5 marks]

Layer	*Field*	*Value*
Network	Destination Address	
Transport	Source Port	51078
Transport	Destination Port	
Transport	Flags	
Transport	Sequence Number	415

(c) The 2nd packet of the TCP connection setup, intercepted on link 3. [2.5 marks]

Layer	*Field*	*Value*
Transport	Source Port	
Transport	Destination Port	
Transport	Flags	
Transport	Sequence Number	960
Transport	Ack Number	

(d) The 3rd packet of the TCP connection setup, intercepted on link 4. [1 mark]

Layer	*Field*	*Value*
Transport	Flags	
Transport	Ack Number	

(e) The packet containing the HTTP request sent by B, intercepted on link 3. [3.5 marks]

Layer	*Field*	*Value*
Data Link	Source Address	
Data Link	Destination Address	
Network	Destination Address	
Network	Protocol	
Network	Total Length	165
Transport	Destination Port	
Transport	Sequence Number	

(f) The packet containing the TCP acknowledgment, acknowledging the HTTP request, intercepted on link 4. [1.5 marks]

Layer	*Field*	*Value*
Transport	Ack Number	

Question 4 [12 marks]

Stop-and-wait ARQ is used on a link from A to B. A has 1,200,000 Bytes of data to send to B. Assume:

- The link propagation delay in both directions is 50 ms.
- The link data rate from A to B is 1 Mb/s.
- The link data rate from B to A is 400 kb/s.
- Frames can carry a maximum of 1200 B of data.
- Each frame has a 50 B header; an ACK does not contain any data.
- A has a timeout value of 200 ms. The timer starts immediately after the transmission of an entire data frame (i.e. after the last bit is transmitted).

(a) What is the value of the transmission delay of a DATA frame? [1 mark]

(b) What is the value of the transmission delay of an ACK frame? [1 mark]

(c) Consider a single DATA frame that is lost, and then the retransmitted frame is successfully delivered. How long does it take from the start of transmission of the original DATA frame, until when the ACK is received for the retransmitted frame? [4 marks]

(d) Now consider all DATA frames. If 100 of the transmitted DATA frames are lost, what is the throughput for the data delivery? Assume no retransmitted DATA frames, nor ACK frames, are lost. That is, of all original DATA frames transmitted, 100 are lost. [4 marks]

(e) What is the optimal timeout value for this link? Explain your answer. [2 marks]

Question 5 [21 marks]

Consider the network in Figure 2. The nodes/circles are packet switches.

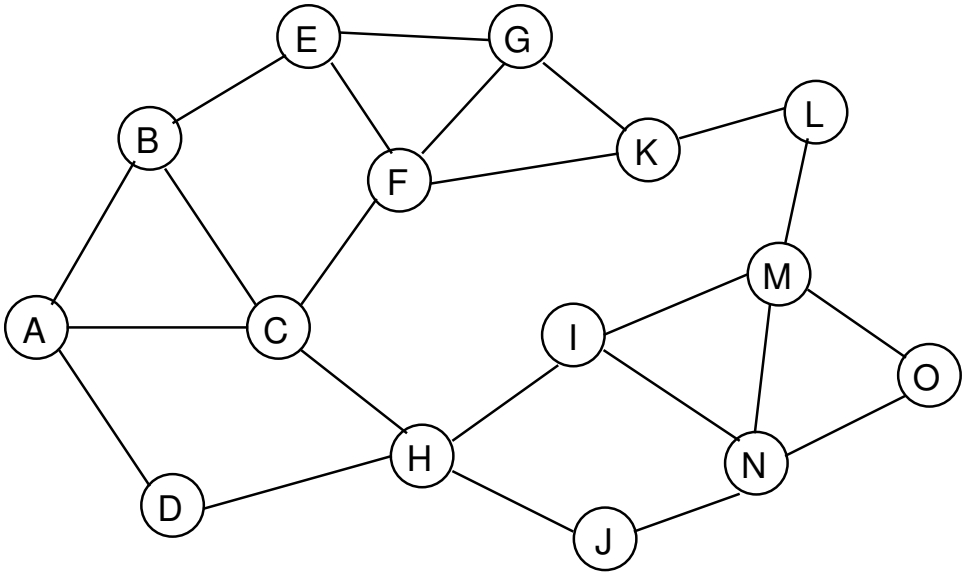

Figure 2: Network Topology

Assume flooding is to be used in the network to deliver a data packet from node A to node M.

(a) What is the optimal value of the hop limit that source node A should use? Explain your answer. [2 marks]

(b) If a sequence number is used when flooding, how many copies of the packet will node H transmit? Explain your answer. Assume the delay to deliver a packet across a link is the same for all links. [2 marks]

Assume instead of flooding, adaptive routing is to be used in the network to deliver data packets. The routing metric is not hops. The cost of a link is identical in both directions. The following least-cost paths have already been determined:

- M—L—K—G—E—B
- B—E—F—C—H—I—N—O
- J—H—C—F—E—B
- B—A—D
- G—F—C—A—D
- M—L—K—F

(c) List three (3) performance/cost metrics, other than hops, that could be used for determing the least-cost routes. [1 mark]

(d) What is the least-cost path from node E to node H? [1 mark]

(e) Draw the optimal routing tables for nodes B and F. An optimal routing table is one with the least number of rows. Each row must contain only one value for the destination and next router, with the exception that you can use * in the *destination* column to indicate "any value". In forwarding, assume the table is processed row-by-row: if one row matches, then the subsequent rows are ignored. [6 marks]

Consider virtual circuit packet switching being used to deliver packets on the path A—B—E—G—K. Assume the following:

- All packets (data, connection request, ACK) contain a header that has a transmission time of 1 ms. Data packets also contain data with an additional transmission time of 9 ms. That is, it takes a total of 10 ms to transmit a data packet.
- Link propagation delay is 2 ms in each direction.
- All links are the same, i.e. same propagation and transmission delays.
- There are 1000 data packets to be sent from A to K.
- Node A initiates the connection/circuit at time 0 seconds.

(f) At what times does node A know the connection is setup (and can start transferring data)? [2 marks]

(g) At what time has K received all the data? [4 marks]

Consider datagram packet switching being used to deliver packets on the path A—B—E—G—K. All packets must contain a 20 Byte header. They may contain a varying amount of data. The source A has 4,000 Bytes of data to send to K.

(h) Explain three (3) factors that are important in node A selecting the amount of data that should be carried in each packet. [3 marks]

Question 6 [8 marks]

(a) What organisation is responsible for developing and maintaining the standards for the most popular wireless LAN technology? [1 mark]

(b) Draw the protocol stack, labelling the layers with specific protocols (not just names of layers) of a laptop accessing a web site using wireless LAN. [2 marks]

CSMA is used in the MAC layer of wireless LAN. The basic procedure can be described as follows:

- A station senses if anyone is transmitting. If no-one else is transmitting for a period of *DIFS* then move to next step. Otherwise, wait until they stop transmitting and restart from first step.
- Choose a random integer, R, between 0 and 15 (inclusive), and wait for $R \times SlotTime$ (this is called *Backoff*). If no-one else is transmitting during this time then move to next step. Otherwise, wait until they stop transmitting and restart from first step.
- Transmit DATA frame.
- Upon complete reception of a DATA frame, the receiver waits for a period of *SIFS* and then transmits an ACK frame.

These steps, in the case that no-one else is transmitting, are summarised in Figure 3.

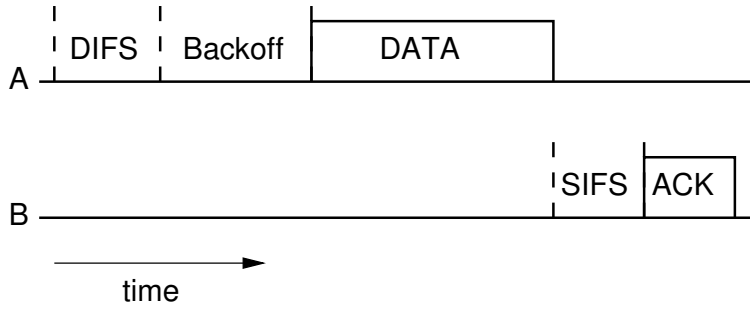

Figure 3: Basic operation of CSMA

A common set of values used for the parameters is given in Table 2.

Table 2: CSMA Parameter Values

Parameter	*Value*
Data rate	54 Mb/s
DIFS	28 μs
SIFS	10 μs
SlotTime	9 μs
DATA frame header	34 Bytes
DATA frame maximum payload (data)	1500 Bytes
ACK frame	14 Bytes

(c) What is the best-case throughput, with one station transmitting to one other station, that can be achieved using CSMA? [5 marks]

Question 7 [7 marks]

Analog data, with amplitude ranging from 0 to some maximum amplitude, is to be encoded using PCM. A portion of the analog data for the first X seconds is shown in Figure 4.

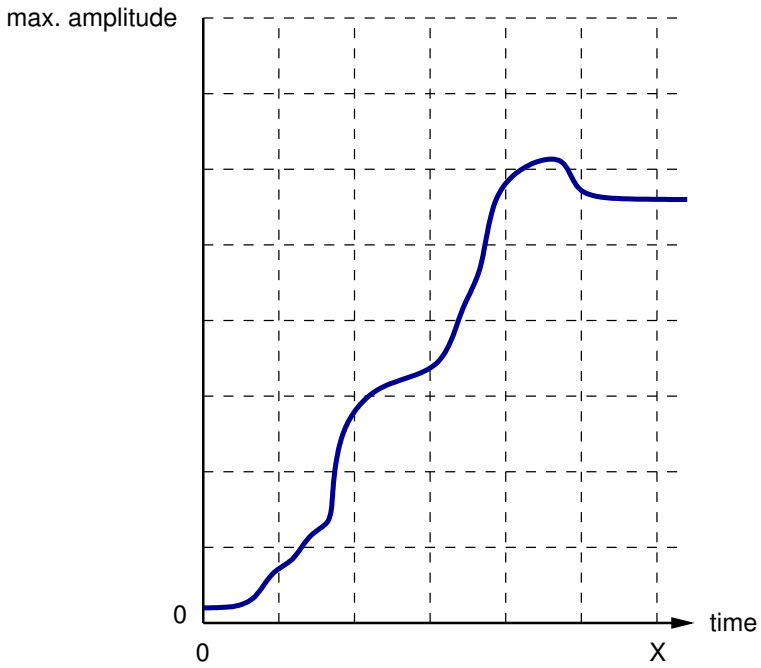

Figure 4: Analog data

Assume $X = 6\mu$s, and a sampling frequency of 500 kHz with 3-bit samples is used.

(a) What is the data transmitted? Consider only the analog input from time 0 to X, inclusive. [3 marks]

(b) At what data rate should the data be sent so that the receiver can receive and re-construct the analog data with the same timing? [2 marks]

(c) Give an advantage and disadvantage of increasing the sampling frequency to 1 MHz: [2 marks]

i. Advantage:

ii. Disadvantage:

Question 8 [6 marks]

A sliding window protocol is used over an error free link, with a window size of 6 data frames. Each data frame has a transmission delay of 110 us, and the header is 10% of the total size (the remaining 90% of the data frame is payload, i.e. real user data). ACK transmission time is 5 us, while the link propagation delay is 290 us.

Assuming the source always has data to send, what is the maximum efficiency, expressed as a percentage, that can be achieved in delivering user data across the link?

Question 9 [6 marks]

TCP includes two error control mechanisms: basic retransmit and fast retransmit.

(a) What ARQ scheme is basic retransmit most similar to? [1 mark]

(b) Explain how basic retransmit works in TCP. [2 marks]

(c) Explain how fast retransmit works in TCP. [2 marks]

(d) Explain an advantage of fast retransmit (compared to basic retransmit). [1 mark]

Reference Material

Selected well-known ports:

- FTP 20 and 21
- SSH 22
- Telnet 23
- SMTP 25
- DNS 53
- HTTP 80
- HTTPS 443

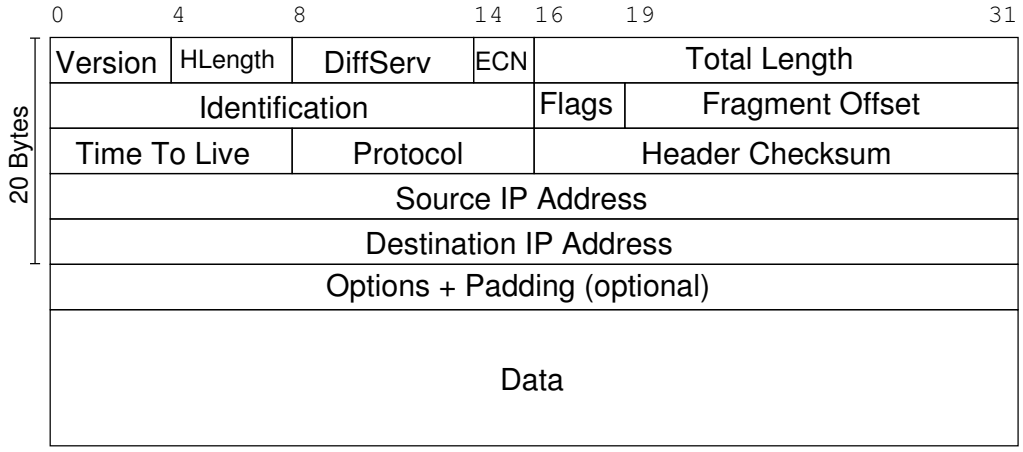

Figure 5: IP Datagram Format. Flags: Reserved, Don't Fragment, More Fragments

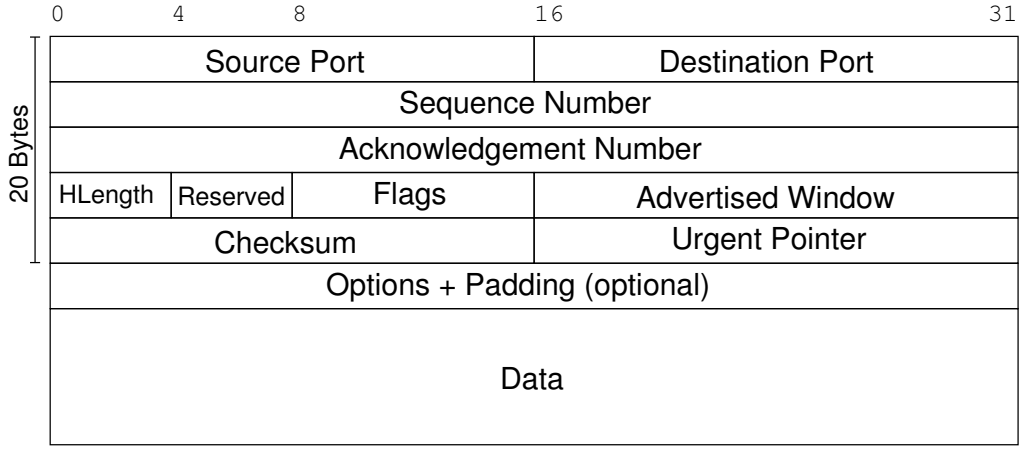

Figure 6: TCP Segment Format. Flags: CWR, ECE, URG, ACK, PSH, RST, SYN, FIN

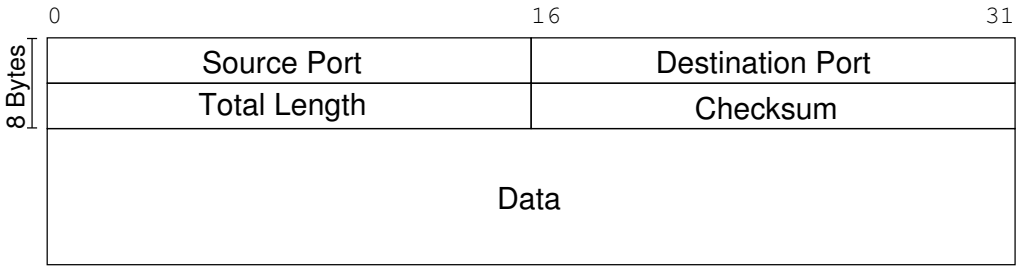

Figure 7: UDP Datagram Format

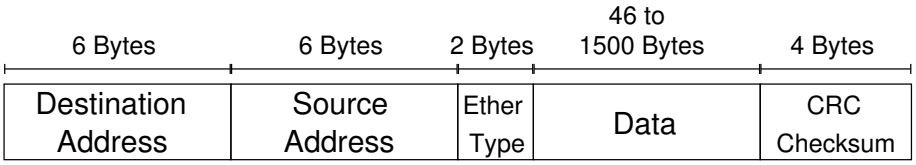

Figure 8: Ethernet Frame Format

Selected Protocol numbers:

- 1 ICMP
- 6 TCP
- 17 UDP

Selected HTTP Status Codes:

- 200 Ok
- 304 Not Modified
- 401 Unauthorized
- 404 Not Found