2020-10-09 - Pearls of Computer Science Core - The Computer Networks and Operating Systems

Course: B-CS Pearls of Computer Science Core 202001022

Dear Students,

Welcome to the test of Computer Networks and Operating Systems.

The test is 60 mins and it is a closed book exam. Laptops, mobile phones, books etc. are not allowed. Please put those in your bag now!

Please note that you may use 1 A4 document with your own notes as a cheat sheet for this exam and a simple calculator. We will give you a 1-page scrap paper.

You can score a total of 100 points for this exam, you need 55 points to pass the exam. Number of questions: 14

Operating systems (total 36 points)

Q1 [5 points]
The European Space Agency (ESA) has recently launched the Solar Orbiter which will spend years in the Solar System to explore the Sun. However, being close to the Sun is not easy, e.g., the Solar Orbiter has to be positioned at a certain angle from the Sun so that it does not get burned!

In case of slight changes in the position of the Solar Orbiter, the Operating System developed by ESA has to take immediate action to reposition the Solar Orbiter: Solar Orbiter is going to have only 50 seconds to complete this repositioning task while there might be other less-urgent tasks to be performed.

Considering this requirement on task completion time, what can you say about the OS of the Solar Orbiter?

a. File system management has the biggest role in ensuring this delay requirement

b. Graphical user interface has the biggest role in ensuring this delay requirement

c. Its CPU scheduler should be designed differently than the scheduler on our personal computers

d. Hard disk capacity has the biggest role in ensuring this delay requirement **e.** Windows OS can be used to meet this delay requirement

f. It has nothing to do with the OS

Answer: c

The mentioned OS has strict time requirements on task completion. Its CPU scheduler must be designed differently than the CPU schedulers on personal computers.

Q2 [5 points]:
Which of the following statements is FALSE?

a. When there are many processes competing for the main memory, processes in “blocked” or “waiting” state can be temporarily copied into slower storage, e.g., hard disk.
b. The Process Control Block stores all the data needed to start or continue execution of a process.
c. Dispatching means using the hard disk as an extension of the main memory.
d. An OS hides the complexity of the underlying hardware from the applications running on the computer.
e. An OS has to be loaded first into the main memory for the OS to perform its operation.

Answer: c
Dispatching is taking a process from the waiting queue for the execution in the CPU whereas option-c defines virtual memory.

While the intended and obvious answer is option-c, we also granted partial credit to option-e as only some essential parts (like the kernel) rather than the whole OS is loaded into the memory.

Q3 [5 points]:

Assume you run a program which performs many mathematical operations and requires 2 GB of main memory. If your computer has only 1 GB main memory, what can you say about this situation?

a. Thanks to the virtual memory, you can run this program, but it would run faster if your physical memory was 2 GB or larger.
b. Thanks to the virtual memory, you can run this program as if you have 2 GB main memory, without any performance difference with the case that your computer has 2 GB main memory.
c. You cannot run this program unless you buy additional memory of at least 1 GB capacity.
d. You can run this program if your computer has a CPU cache.
e. You can run this program if your computer has a CPU register.

Answer: a
It is possible to run such a process using virtual memory. Since virtual memory requires usage of hard disk which is slower storage compared to main memory, you might expect some performance difference.

Q4 [4 points]:

Which of the following is FALSE?

a. File size can be zero if the file is an empty file.

b. File size depends on how many bytes the file has as its content.

c. If two files use exactly the same amount of disk space, then it means they have exactly the same number of bytes as their content.

d. Disk space used by a file depends on both the file size and the disk block size of an OS.

Answer: c

Due to disk space being allocated in blocks, two files storing different number of bytes as their content can use the same amount of disk space.

Q5 [5 points]:

Assume a process is just created as a new process. While being in execution, this process experiences one time-out and it requires I/O from the user only once. Finally, the process completes successfully. How many state transitions (i.e., move from one state to another) does this process experience from the "new state" till completion?

a. 2
b. 3
c. 4
d. 5
e. 6
f. 7
g. 8
h. 9

Answer: g

From New → Waiting → Exec (time-out) → Waiting → Exec (I/O) → Blocked → Waiting → Exec → Finished

So (counting state transitions represented by →), in total 8 state transitions from new to finished state.

Q6 [5 points]

A computer system usually defines at least two operation modes, e.g., privileged (kernel) mode and user mode, to protect the computer system from harm by malicious user programs. Which of the following instructions can be run in *user mode*?

a. Accessing I/O devices directly
b. Reading the current time and date
c. Moving processes out of memory
d. Setting value of timer for CPU scheduling
e. Setting the mode bit to define operation mode

Answer: b

Q7 [7 points]

Assume a system in which the CPU scheduler dispatches the process with the *longest waiting time in the queue* among all the waiting processes and the CPU executes this selected process for a maximum duration of 3 time units. If the process requires a shorter time than 3 time units, the process is successfully completed. Otherwise, the time-out occurs and this process is put into the waiting queue back, the waiting time for this process is set to zero which then starts increasing as the process waits in the queue.

Consider at time T there are three processes P1, P2, P3 waiting in the queue with the respective waiting times 3, 4, 2 time units.

The required CPU time for P1, P2, and P3 are 4, 5, 3 time units, respectively. Assume that CPU time-out occurs after 3 time units of execution time.

Which process is finished *first* and *at what time*?

a. P1, at T+6
b. P1, at T+9
c. P1, at T+12
d. P2, at T+6
e. P2, at T+9
f. P2, at T+12
g. P3, at T+6
h. P3, at T+9
i. P3, at T+12

Answer: **h.**

- At T, P2 will be selected for execution as its waiting time is 4, the longest. The CPU will execute this process for 3 time units.
- At T+3, the waiting times are P1 (3+3=6), P2 (0 because it was executed in the previous round), P3 (2+3 = 5) and the remaining execution times are P1 (4), P2 (5-3 = 2), P3(3).
- At T+3, P1 is selected for execution.
- At T+6, remaining execution times are P1 (4-3 = 1), P2 (2), P3 (3) and the waiting times are P1 (0), P2 (2+3=5), P3 (6 + 3 = 9).
- Finally, at T+6, P3 is selected and it completes at T+9.

Questions on Computer Networks (total 22 points):

Q8 [6 points]:

For each of the following options (a, b, c), find the best matching term (from the possible terms).

a. This network entity lies at the edge of the network and can run network applications.
b. At this level of the Internet hierarchy, there are only a few entities which are connected to each other in mesh mode.
c. This is a physical infrastructure like a building in which the ISPs can connect to each other to exchange traffic.

Possible terms: *Autonomous System, Internet Exchange Point (IXP), Router, Access ISP, End host, Tier-1 ISP, Peering*

Answer:

a: End-Host. Note that routers do not run network applications.

b: Tier-1 ISP. These are also known as global ISPs.

c: Internet Exchange Point (IXP)

Q9 [6 points]:

For each of the following options (a, b, c), find the best matching terms.

a. This layer moves the individual bits within the frame from one node to the next node through a transmission medium, e.g., a copper wire or a wireless radio link.
b. This layer ensures that the packets are moved from the source node towards the destination node in an efficient way.
c. This layer can have connection-oriented or connectionless communication between two application endpoints.

Terms:
Application layer, Network layer, Transport layer, Software layer, Link layer, Physical layer, Hardware layer

Answer:

a: Physical layer
b: Network layer
c: Transport layer

Please note that TCP/IP protocol stack has *Physical Layer, Link Layer, Network Layer, Transport Layer and Application Layer.*

Q10 [5 points]

Which of the following is FALSE?

a. In packet switching, two packets sent by the same transmitter to the same receiver follow exactly the same path, e.g., a set of routers.
b. In circuit switching, a physical path is established between the two communications end points.
c. Internet is a packet switching network.
d. Packet switching might result in packet loss and queuing if many packets arrive at a packet switch.
e. Circuit switching incurs a cost of circuit establishment.
f. In circuit switching, users can be allocated resources by Time Division Multiplexing or Frequency Division Multiplexing.

Answer: a

Packets for the same destination might follow different paths depending on the local forwarding tables of routers at that time. For example, if an outgoing link becomes congested (e.g., resulting in high queuing delay) or a router fails, then a packet might be forwarded to a different outgoing link, resulting in a different path for the packets toward the same destination.

Circuit switching requires first a reservation (referred to as circuit establishment). Remember the analogy: going to a restaurant with a reservation (circuit switching) or without a reservation (packet switching).

Q11 [5 points]

To specify which TCP connection a packet belongs to, which information would you need?

a. Source and destination MAC address, source and destination port numbers
b. Source port number, destination port number
c. Source MAC address, destination MAC address
d. Packet length, packet sequence number, source and destination IP addresses
e. Packet length and packet acknowledgement number
f. Source and destination IP addresses, source and destination port numbers
g. Source IP address, destination IP address
h. Packet length, packet sequence number

Answer: f

Note that a TCP connection is identified by a 4-tuple:
< Source IP, source port number, destination IP, destination port number>

With these four numbers, you can identify which TCP connection a packet belongs to. Packet sequence number and length are needed to identify which application layer bytes a packet carries. But, they do not identify the TCP connection.

Questions on TCP (total 16 points)

Below, you see a few consecutive network packets displayed by Wireshark running on host 130.89.144.74. Use this table for the following three questions.

Packet-nr	Source IP	Destination IP	Source/Destination Port	TCP seq/ack numbers
1	130.89.144.74	128.119.245.12	1161 > 5543	Seq=500, Ack=1270, Len=30
2	130.89.144.74	128.119.245.12	1161 > 5543	Seq=530, Ack=1270, Len=40
3	130.89.144.74	128.119.245.12	1161 > 5543	Seq=570, Ack=1270, Len=30
4	130.89.144.74	128.119.153.13	1389 > 5543	Seq=1270, Ack=580, Len=0
5	128.119.245.12	130.89.144.74	5543 > 1161	Seq=1270, Ack=530, Len=30
6	128.119.153.13	130.89.144.74	5543 > 1389	Seq = 580, Ack=1290, Len=20
7	130.89.144.74	?????	1161 > 5543	??????

Q12.a [5 points]

In the above trace, how many hosts and TCP connections can you recognize?

a. two hosts and one TCP connection
b. two hosts and two TCP connections
c. two hosts and three TCP connections
d. three hosts and two TCP connections
e. three hosts and three TCP connections
f. three hosts and six TCP connections
g. four hosts and four TCP connections

Answer: d

Hosts are identified with their IP addresses while TCP connections are identified with 4-tuples < Source IP, source port number, destination IP, destination port number>. Checking this information in the Wireshark table, you will find three hosts (IP numbers as depicted in the figure below) and two TCP connections (identified by IP addresses of hosts and the port numbers used at both ends).

Q12.b [5 points]

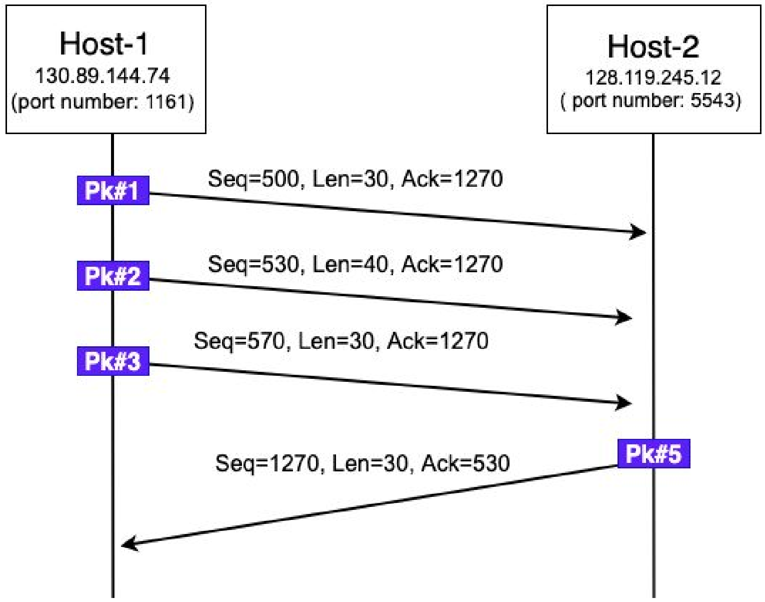
In the above trace, one packet is wrong; it should never have been sent like this. Which packet is it?

a. Packet 2
b. Packet 3
c. Packet 4
d. Packet 5
e. Packet 6

Answer: e.

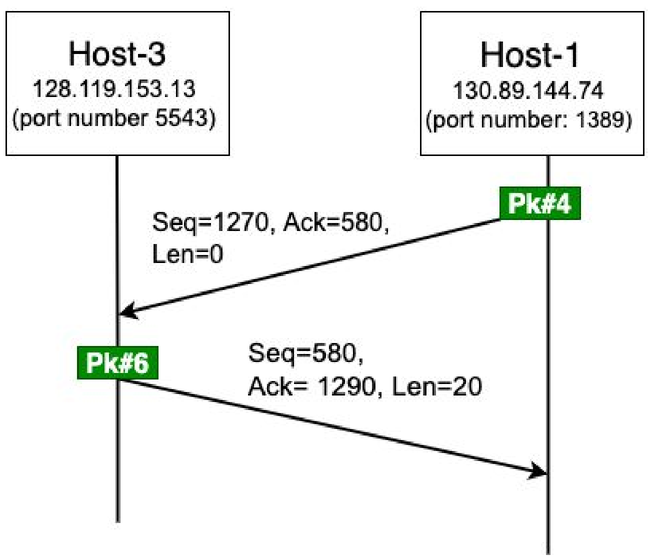
Packet 6, because it acknowledges bytes (from 1270- 1289) that have not been sent yet by 130.89.144.74

As we have identified in the previous question, there are two TCP connections. We need to check each TCP connection separately to see if packets (and associated information) are as expected. Let's start with the first TCP connection (packets 1, 2, 3, 5).



In this diagram, you see the packets flowing between Host-1 and Host-2. Everything seems ok (Packet-5 acknowledges bytes up to 530. It is still a correct entry as this might happen in usual operation of TCP due to packet drops or packet corruption.)

Now, let's check the second TCP connection.



In the above diagram, Pk#4 is an acknowledgement packet (Len=0) and the bytes sent to Host-3 are up to byte number 1270.

But, Pk#6's ACK=1290 which acknowledges bytes that have not been sent yet by Host-1. Since this Wireshark is running on Host-1 (host 130.89.144.74), we know that Host-1 has not sent these bytes from 1270-1289 yet.

Q12.c [6 points]

Which information should packet-7 (sent by host with IP 130.89.144.74) have in it?

a. Dest: 128.119.245.12, Seq=530, Ack=1270, Len=40
b. Dest: 128.119.245.12, Seq=530, Ack=1300, Len=40
c. Dest: 128.119.245.12, Seq=570, Ack=1300, Len=30
d. Dest: 128.119.245.12, Seq=570, Ack=1270, Len=40
e. Dest: 128.119.245.12, Seq=600, Ack=1300, Len=40
f. Dest: 128.119.153.13, Seq=1270, Ack=580, Len=0
g. Dest: 128.119.153.13, Seq=530, Ack=1300, Len=0
h. Dest: 128.119.245.13, Seq=530, Ack=1300, Len=30
i. Dest: 128.119.245.13, Seq=530, Ack=1270, Len=40

Answer: b

Since the port numbers are (1161 > 5543), the destination is Host-2 with IP address 128.119.245.12.

Hence, we check the packets from TCP connection#1.

Since packet-5 has ACK number 530, then Host-1 must send Seq=530 again whose Len is 40 (see packet-2). Since host-1 has received 30 bytes starting from 1270 in packet-5, then host-1 will acknowledge 1270+30=1300. Hence, the packet's details will be as follows:

Dest =128.119.245.12, Seq=530, Len=40, Ack=1300

A common *mistake* is to keep the ack number the same as the previously transmitted packet (i.e, packet-2), resulting in Dest: 128.119.245.12, Seq=530, Len=40, Ack=1270.

Questions on delay calculation (total 4 points)

Q13

Consider a network consisting of an end host A and a router B. The link rate between A and B is 4 Mbps and the distance between these two nodes is 5000 km. The communication signals travel with a speed of 200 000 km/s. There is no other traffic in the network. Consider a packet of 2000 bits.

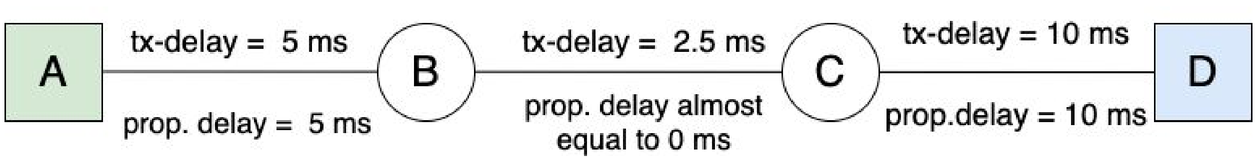
a. [2 points] Calculate the **transmission delay** for this packet when A transmits it to B. Write your answer in milliseconds. For example, if your result is 4.3 ms then write **4.3 (without ms)** to the box below.

Answer:
Transmission delay = Packet length in bits / Link rate in bps
2000 bits/4000000 bps = 0.5 ms

b. [2 points] Now, calculate the **propagation delay** for this packet when A transmits it to B. Write your answer in milliseconds. For example, if your result is 4.3 ms then write **4.3 (without ms)** to the box below.

Answer:
Propagation delay = Distance in km / propagation speed in km/s
5000 km/200 000 km/s = 25 ms

Questions on delays (total 22 points)



Consider a network consisting of an end host A, two routers B and C, and an end host D. The only path from A to D is via B and C.

An application on host A generates 3 packets destined for D as follows:

- **Packet-1** at time 0 ms, size 10000 bits (incl. headers)
- **Packet-2** at time 0 ms, size 10000 bits (incl. headers)

- **Packet-3** at time 3 ms, size 5000 bits (incl. headers)

There is no other traffic in this network. We assume that the computation time needed by routers B and C to decide where to send the packet, is negligible.

When **Packet-1** is transmitted, the delays Packet-1 experiences are as follows (also shown in the figure):

- From A to B: transmission delay 5 ms and propagation delay 5 ms
- From B to C: transmission delay 2.5 and propagation delay is almost 0 ms
- From C to D: transmission delay 10 and propagation delay 10 ms

Q14-a [3 points] : At what time will **Packet-1** have arrived completely **at host D**?

a. 10 ms
b. 12.5 ms
c. 17.5 ms
d. 27.5 ms
e. 30 ms
f. 32.5 ms
g. 42.5 ms
h. 47.5 ms
i. 52.5 ms

Answer: f, at 32.5 ms

Since packet-1 does not experience any queuing delays (as there is no other traffic in the network at the time this packet is generated), the arrival time is simply summation of all transmission and propagation delays from node A to node D:

Transmission delay from A-B + Propagation delay from A-B +
Transmission delay from B-C+ Propagation delay from B-C +
Transmission delay from C-D + Propagation delay from C-D = 5 + 5 + 2.5 + 0 + 10 + 10 = 32.5 ms (arrival time at D)

Q14-b [5 points] At what time will **Packet-2** have arrived completely **at host D**?

a. 27.5 ms
b. 30 ms
c. 32.5 ms
d. 42.5 ms
e. 47.5 ms
f. 52.5 ms

Pk generation time	First bit leaves A (tx time: 5ms) + 5	All bits totally leaves A	From A to B propagation (5 ms) + 5	First bit leaves B (tx: 2.5ms) + 2.5	All bits totally leaves B	From B to C (0 ms)	First bit leaves C (tx-10 ms)	All bits totally leaves C (+10)	From C to D (10) ARRIVES AT D
0	0	5	10	10	12.5	12.5	12..5	**22.5**	**32.5**
0 (waits 5 ms)	5	10	15	15	17.5	17.5 **(waits at C 5 ms)**	**22.5**	32.5	**42.5**
3 (waits till 10 ms)	10 (Tx time: half of packet1)	12.5	17.5	17.5	18.75	**18.75**			

Answer: d.

Packet 2 has the same size as Packet 1. Hence, all transmission times will be the same as Packet-1. It is generated at the same time as Packet-1, hence first it has to wait till node-A transmits packet-1 completely. In the table above, you see that Packet-1's transmission is complete at 5 ms.

So, packet-2's transmission starts at 5 ms and completes at 10 ms. From A to B, 5 ms propagation delay. Hence, packet-2 arrives at B at 15 ms. B is idle at 15 ms (as packet-1 is already completely transmitted at 12.5 ms). This means no queuing at node B.

Packet-2 arrives at node-C at 17.5 ms. But, node-C is busy from till 22.5 ms with transmission of packet-1. Hence, packet-2 experiences delay. The delay is 22.5-17.5 = 5 ms.

Packet 2 experiences queueing 5 ms at node-A, queueing 5 ms at node-C, arrives at D at 42.5 ms.

Q14-c [5 points]

At which node(s) **Packet-2** will experience queuing delays while travelling from A to D?

a. Only at node C
b. Only at node A
c. Node B and node C
d. Node A and node B
e. It does not experience any queuing delays
f. Only at node B
g. Node A, node B, node C
h. Node A and node C

Answer: h

Knowing whether and how much packet-2 experiences delay requires calculating the arrival/transmision times of packet-1 and packet-2 at each node. The second packet will wait at node-A as there is packet-1 to be transmitted. Moreover, the packet-2 will experience queueing delay at node-C.

From the figure, one can also notice that there *might* be some queuing delay at node-C as it has a faster incoming link (a link with a transmission delay of 2.5 ms) than its outgoing link (with transmission delay of 10 ms). Depending on the packet sizes and packet generation times, node-C may or may *not* result in queueing delays (for example, if the second packet was generated 100 ms after the first packet).

Q14-d [5 points]
At what time will **Packet-3** have arrived completely at **router C**?

a. 12.5 ms
b. 17 ms
c. 18.75 ms
d. 20.5 ms
e. 22.75 ms
f. 30.25 ms
g. 45.5 ms

Answer: c.

Packet-3 is half in size (that of packet-1). So, tx delays will be also half. It waits first at A, 7 ms. So starts transmission at 10 ms, experiences 2.5 ms tx delay, 5 ms propagation delay, and 1.25 tx delay. In total, at 18.75 ms, it is completely received at router C.

Q14-e [4 points]
At which nodes Packet-3 will experience queuing delays while travelling from A to **router C**?

a. It does not experience any queuing delays
b. Only at node A
c. Only at node B
d. Node A and node B

Answer: b.

Only at node A

***************************** End of this exam. Have a good day! *****************************