Written exam for
EE2T21 (Part B) – Data Communications Networking

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July 6th, 2018

Friday 6th of July, 13:30 – 15:30.

Responsible teacher: dr. Jaron Sanders MSc

Material: This examination covers Chapters 1 – 7.5 of the book "Data Communications Networking", by professor Piet Van Mieghem. This is a closed book examination.

This exam consists of multiple choice and open questions. Note that for each multiple choice question that you answer incorrectly, points will be deducted. When answering one of the open questions, always indicate all of your intermediate steps in detail.

<u>Instructions:</u>

(i) Write down your **name** and **student number** legibly and on **all** answer sheets.

(ii) **Carefully** read each question before answering.

(iii) **Motivate** your answers to the open questions in detail.

(iv) You can score a total of **100 points** on this exam.

(v) You are **not** allowed to have any reference material with you.

(vi) You **are** allowed to use a non-programmable calculator.

(vii) Hand in your answers to the **invigilators** at the end of this exam.

(viii) You are **not** allowed to keep or distribute copies of this exam.

As we say in Dutch: Veel succes!

Multiple choice questions (60 points in total)

Chapter 1

4 or −1 points

1. Which of the following is **not** an advantage of connection-oriented (CO) forwarding over connectionless (CL) forwarding?
   - A. When doing CO forwarding, capacity can be guaranteed.
   - B. Interference hardly plays a role in CO forwarding, so there is hardly any quality variation.
   - C. In CO forwarding, network resources and intermachine connections are shared.
   - D. CO forwarding is less susceptible to delay, because the queueing dynamics in the network generally imply that delay increases superlinearly with load.

4 or −1 points

2. The Open System Interconnect (OSI) model is a conceptual framework that organizes the functionalities of any type of communication in a layered structure. Which of the following is **false**?
   - A. The Data Link Layer transforms bit streams into data streams, and handles the sequential transmission of these frames by regulating flows and handling errors.
   - B. Higher layers use services provided by lower layers, and interface with them via Protocol Data Units (PDUs).
   - C. Foregoing several of the intermediate layers, we encounter *in order* from top to bottom the Presentation Layer, Transport Layer, Data Link Layer, and Physical Layer.
   - D. The OSI model was introduced by the International Standards Organization (ISO).

4 or −1 points

3. Which of the following is **not** a strength of the OSI model?
   - A. The layering in the OSI model divides the complex problem of communication into smaller, more manageable pieces that may be treated independently or executed in parallel from one another.
   - B. When installing a full-fledged, wide-area telecommunication system and when discussing about improvements or new services, the layering concept is particularly valueable.
   - C. When data is send over a network using the OSI framework, intermediate nodes only need to execute a subset of the OSI layers.
   - D. Because each layer only has access to the information of adjacent layers, we can more easily design protocols that operate optimally within each of those layers: this ultimately leads to the best overall operation of a network.

Chapter 2

4 or −1 points

4. Ethernet is a 1-persistent CSMA/CD scheme with a binary exponential back-off policy. This means that:
   - A. Sensing times are chosen at random in the range $[0, 2^{16} - 1]$, and data is sent immediately when the channel is free.
   - B. Since the probability of success for p-persistent CSMA is $Np(1-p)^{N-1}$, no frames can be sent successfully.
   - C. Continuous sensing, but sending at a random time interval in the range of $[0, (2^j - 1)]$ with j the number of collisions.
   - D. The probability of one of N stations successfully transmitting during a time interval is $(1 - 1/N)^{N-1}$.

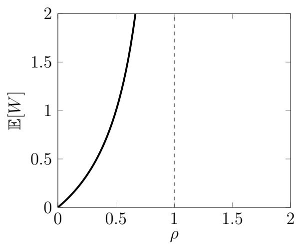
4 or −1 points

5. The average waiting time of a packet is reasonably well approximated by the average waiting time in an M/G/1 queue. Specifically,

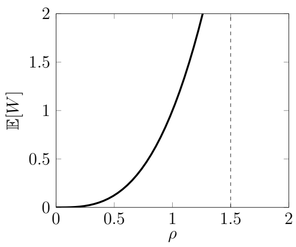
$$\mathbb{E}[W] = \frac{\rho\big(\mu \mathrm{Var}[X] + \frac{1}{\mu}\big)}{2(1-\rho)}.$$

Here, X denotes the random service time of a packet, $\mu = 1/\mathbb{E}[X]$, and $\rho = N\lambda/\mu \geq 0$ is a dimensionless variable that describes the load on the local area network.

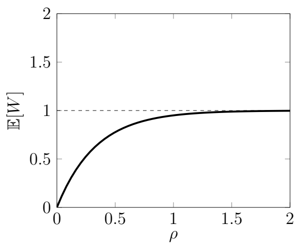
Now suppose that the random variable X is such that $\mathrm{Var}[X] = \mathbb{E}[X] = 1$. Which of the following schematic plots and fundamental capacity upper bounds is **correct**?



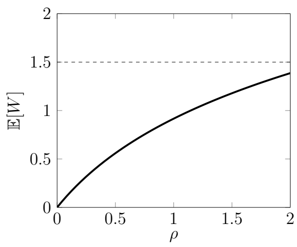
A. $\lambda < \mu/N$



B. $\lambda < \frac{3}{2}\mu/N$



C. $\mu < N\lambda$



B. $\mu < \frac{3}{2}N\lambda$

4 or −1 points

6. Consider CSMA/CA. Which is **false**?
   - A. A sender sends a Request-To-Send (RTS) message that contains the length of the message.
   - B. The receiver replies with a Clear-To-Send (CTS) message that echoes the length of the message.
   - C. All stations in range of the receiver always wait for a time corresponding to the length of message in the CTS.
   - D. Answers A – C in fact describe the pure ALOHA protocol, and not CSMA/CA.

4 or −1 points

7. Which is **true**? The hidden-terminal problem...
   - A. was first noticed by Kleinrock and Tobagi in 1975.
   - B. is the problem of a node unnecessarily refraining from sending.
   - C. can be resolved by agreeing that any node that hears a sender remains silent, no matter what.
   - D. does not occur when using CSMA/CA without reservation, because this is a MAC protocol in which nodes in the sender's range are prohibited to transmit.

Chapter 3

4 or −1 points

8. A Cyclic Redundancy Check (CRC) is an error-detecting code that is attached to the end of a message so the recipient may use it to verify authenticity of the received message. Let $G = 11011$ denote the generator agreed upon between you and the recipient. Compute $C = (M, R)$, that is, the concatenation of the message $M = 11100101$ in binary and the result R of the CRC.
   - A. The correct codeword is $C = 11100101\,100$.
   - B. The correct codeword is $C = 11100101\,101$.
   - C. The correct codeword is $C = 11100101\,0100$.
   - D. The correct codeword is $C = 11100101\,0101$.

Chapter 4

4 or −1 points

9. Consider a host with IP address 175.133.27.25, on a network using subnet mask 255.255.240.0. Which class network is this?

   A. Class A. B. Class B. C. Class C. D. Class D. E. Class E.

4 or −1 points

10. Consider a host with IP address 175.133.27.25, on a network using subnet mask 255.255.240.0. How many addresses are available in each subnet *for hosts* – so excluding one address for the subnet and one address for broadcasting?
    A. There are between 1 and 2047 addresses available for hosts.
    B. There are between 2048 and 4095 addresses available for hosts.
    C. There are between 4096 and 9191 addresses available for hosts.
    D. There are between 9192 and 18384 addresses available for hosts.

4 or −1 points

11. What is **not** an improvement over IPv4 that was introduced in IPv6?
    A. The fixed format given to all headers.
    B. The omission of the header checksum field.
    C. The removal of the hop-by-hop fragmentation fields, including the identification, flags and fragmentation offset fields.
    D. The total size of the header.

Chapter 5

4 or −1 points

12. "TCP is self-clocking" refers to:
    A. The rate of sending new packets (segments) is adjusted to the rate at which acknowledgments are received.
    B. The fact that TCP is a connection-oriented protocol over a connectionless medium (IP), and therefore it can still deliver packets in time and in sequence.
    C. The end devices being synchronized via the network time protocol (NTP)
    D. The hour-glass shape of the TCP-IP protocol suite.

Chapter 6

4 or −1 points

13. How many different undirected graphs $G = (V, E)$ exist with n vertices, so $V = \{1, \ldots, n\}$?

    A. $n - 1$ B. $\frac{1}{2}n(n-1)$ C. $2^{\binom{n}{2}}$ D. 2^{n^2}

Chapter 7

4 or −1 points

14. In selective flooding:
    A. Each incoming packet is sent out on every outgoing interface, except for the interface it came in on.
    B. Packets are only flooded to a pre-defined selected set of nodes.
    C. A minimum spanning tree is used to distribute information.
    D. Only specific time slots can be used for flooding information.

4 or −1 points

15. Which of the following statements is **incorrect**?
    A. The Border Gateway Protocol (BGP) is a distance vector protocol enhanced with path vectors.
    B. BGP is an inter-domain routing protocol that facilitates the routing between autonomous systems.
    C. BGP exchanges routing tables via TCP.
    D. None of the above is correct.

Next up are the open questions!

Open questions (40 points in total)

16. In this assignment, you are going to consider TCP's three-way handshake and TCP's graceful close.

3 points (a) Create **two** sketches: one that schematically depicts TCP's three-way handshake, and one that schematically depicts TCP's graceful close.

5 points (b) Write **one** detailed paragraph of at most 80 words that either explains TCP's three-way handshake, or TCP's graceful close. You can choose either, you need **not** explain both.

17. Consider p-persistent CSMA/CD. Let T denote the random number of transmitters that simultaneously transmit in one timeslot. Suppose that N stations are operating independently on a complete graph topology, and that each station has the same probability p of transmitting during each time slot. Under these assumptions, T is *binomially* distributed, i.e., $T \sim \mathrm{Bin}(N,p)$. This means that

$$\mathbb{P}[T=t] = \binom{N}{t} p^t (1-p)^{N-t}.$$

2 points (a) Let S be the event of a successful transmission. Why is S equal to the event $\{T=1\}$?

5 points (b) Prove that

$$\lim_{N\to\infty} \max_{p\in[0,1]} \mathbb{P}[S] = \frac{1}{\mathrm{e}}.$$

Hint: Use the Taylor expansion $(1-1/N)^{N-1} = 1/\mathrm{e} + O(1/N)$ for $N \to \infty$.

15 points 18. Apply Bellman–Ford's algorithm to the network of Figure 2, starting from node S. Show all of your intermediate steps by producing the activity table.
Hint: Recall that an activity table is a schematic depiction of the algorithm's updates to the depth vector $d[v]$, as well as to the preceding node vector $\pi[v]$.

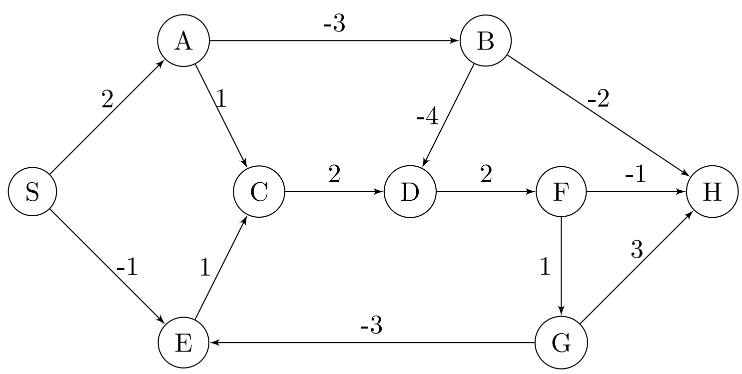


Figure 2: A directed graph with negative weights.

One final, challenging assignment

19. TCP maintains an estimator of the round-trip time of packets, and uses it to set an appropriate retransmission time-out. Specifically, every $(k+1)$-st ACK provides TCP with one sample of the round-trip time M_{k+1}, and with it, TCP updates

$$R_{k+1} = gM_{k+1} + (1-g)R_k, \quad R_0 = gM_0, \tag{1}$$

for some $g \in (0,1)$. In this assignment, you will prove that this estimator converges to the mean of the round-trip time, i.e.,

$$\lim_{t\to\infty} \mathbb{E}[R_t] = \mathbb{E}[M_0]$$

if all sample round-trip times have the same mean.

You will first solve the stochastic recursion. You will be using the *generating function method.*

3 points (a) Define $R(z) \triangleq \sum_{k=0}^{\infty} R_k z^k$ and $M(z) \triangleq \sum_{k=0}^{\infty} M_k z^k$. Use these functions together with (1) and verify that

$$R(z) = gM(z) + (1-g)zR(z).$$

2 points (b) Next perform the following three actions consecutively: use (a) to solve for $R(z)$, then substitute the definition of $M(z)$, and finally recall the geometric series $\sum_{k=0}^{n-1} ar^k = a(1-r^n)/(1-r)$ for $|r| < 1$, to show that

$$R(z) = g\Big(\sum_{k=0}^{\infty} M_k z^k\Big) \sum_{k=0}^{\infty} (1-g)^k z^k \quad \text{for} \quad |z| \le 1.$$

2 points (c) Now apply Cauchy's product rule for power series $\sum_{k=0}^{\infty} a_k z^k \sum_{k=0}^{\infty} b_k z^k = \sum_{k=0}^{\infty} \Big(\sum_{j=0}^{k} a_j b_{k-j}\Big) z^k$ to (b), then substitute the definition of $R(z)$, and finally equate all corresponding terms in front of the equivalent powers of z, to show that

$$R_k = g\sum_{j=0}^{k} M_j (1-g)^{k-j}. \tag{2}$$

Now that you have solved the stochastic recursion, all that remains is to take the expectation and then the limit.

2 points (d) Recall that by assumption $\mathbb{E}[M_0] = \mathbb{E}[M_1] = \cdots$. Now take the expectation of (2), and use the geometric series to show that

$$\mathbb{E}[R_k] = \mathbb{E}[M_0]\big(1 - (1-g)^{k+1}\big).$$

1 point (e) Finally show that

$$\lim_{k\to\infty} \mathbb{E}[R_k] = \mathbb{E}[M_0].$$

This completes your proof!

Well done, that was it!