# 521150A Introduction to Internet

Exercise 3A

# Welcome to calculation exercises

## In this non-mandatory part of the course, you will learn to

- answer concrete, numerical questions on the subject matter
- model different network scenarios
- use the presented algorithms and methods

## Contact info for issues with these exercises

- email: lauri.haverinen@oulu.fi
- room: TS387 (prefer email for contacting)

# Before the session

## Complete pre-exercises in Moodle

- you will be better prepared for the exercise
- you can earn up to **1 point for final grading** (in Moodle, the points are scaled by 10)

# During the session

## Follow, participate and solve

- revisiting pre-exercises
- solving example problems together
- describing and going through how to solve the advanced problems

# After the session

## Solve the rest of the problems presented in this document

- return a scanned version (or good photo) as PDF of your hand-written solutions **with your name on it** to Moodle **before the next exercise**
- you can earn up to **0.5 points for each solved problem**, so a maximum of 1.5 points per exercise (in Moodle, the points are scaled by 10)

# Pre-assignments

1. **You are downloading a web page using a browser. To resolve the web server domain name to IP address, three DNS queries are required; one to each server: 0, 1 and 2.**

   **DNS server 0: RTT = 5 ms (including DNS query and response transmission delays)**
   **DNS server 1: RTT = 10 ms (including DNS query and response transmission delays)**
   **DNS server 2: RTT = 20 ms (including DNS query and response transmission delays)**
   **Web server: RTT = 8 ms**

   **Assuming that only one web page is downloaded, that does not have references to external objects. How much time it takes from resolving IP address to until your browser has downloaded the web page? Ignore all transmission delays (DNS request and response transmission times and HTML page transmission time)! Assume that DNS uses UDP. Express your answer in milliseconds without decimals.**

   5ms + 10ms + 20ms + 8ms + 8ms = 51ms

# Pre-assignments

**You are downloading a website from a web server. RTT is 10ms and the server IP address is already known. The website consists of a negligibly small HTML file that refers to three other objects, each also negligibly small - each fits into one TCP segment. Also you can ignore transmission times of all requests (i.e. you can ignore all transmission delays).**

2. **How long does it take to download all four files when using non-persistent HTTP without parallel TCP connections? Give your answer is milliseconds without decimals.**

   Requires 2RTT per object (initiate TCP connection + request object) = 80ms

3. **How long does it take to download all four files when using non-persistent HTTP with parallel TCP connections? Give your answer is milliseconds without decimals.**

   2RTT for fetching first object, 2RTTs for fetching the rest (with parallel connections) = 40ms

4. **How long does it take to download all four files when using persistent HTTP with parallel TCP connections? Give your answer is milliseconds without decimals.**

   2RTT for fetching first object, RTT for fetching the rest (with parallel connections) = 30ms

# Pre-assignments

**You are downloading a website from a server whose IP address is known. The site consists of 10KB HTML file that refers to 10 JPEG images. The size of each image is 50KB. The download link from the server is 10Mbps and RTT is 100ms.**

- Assume, that TCP can send at full speed immediately after the connection has been initialised (no congestion control/slow-start)
- No congestion
- No processing delays
- No additional delays from layers below L3 (network)
- Transmission delay of request sent to the server can be ignored
- Ignore additional delays caused by headers on any layer

**Give your answer is milliseconds without decimals.**

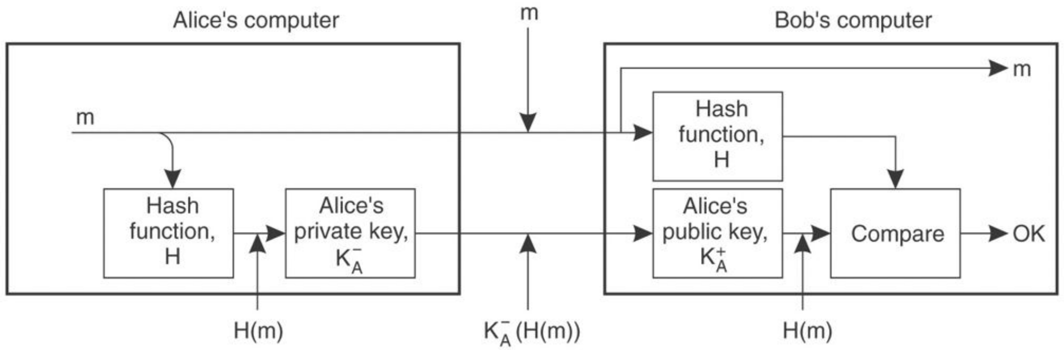
5. **Calculate the total time when using non-persistent HTTP without parallel TCP connections?**

   100ms + 100ms + [10KB*8/10Mbps=8ms] + 10 * (100ms + 100ms + [50KB*8/10Mbps=40ms]) = 2608ms

6. **Calculate the total time when using persistent HTTP with pipelining?**

   100ms + 100ms + 8ms + 100ms + 10*40ms = 708ms

# Pre-assignments

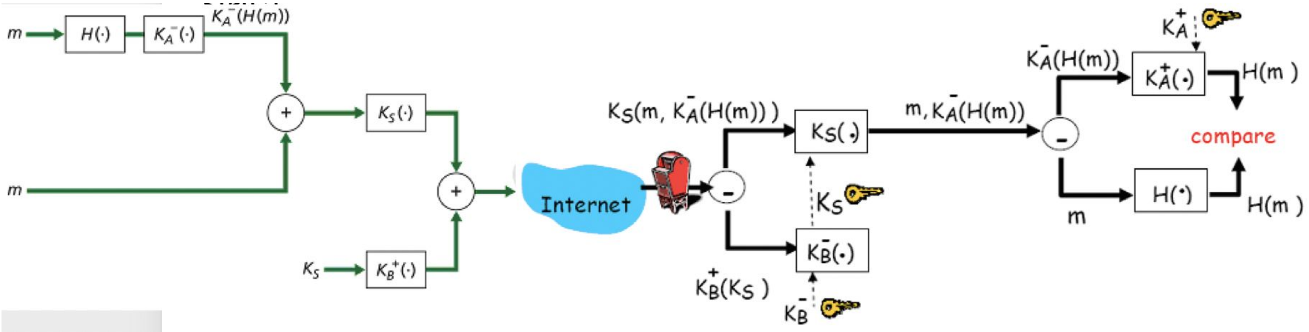



**7. Hashing - which are correct?**

- Jotta Alicen digitaaliseen allekirjoitukseen voidaan luottaa, tiiviste- eli hashfunktio H on oltava sellainen, että on liki mahdotonta löytää järkevä m', jolla H(m') = H(m) - Probability of hash collision (H(m') = H(m)) must be negligible, otherwise the digital signature of Alice cannot be trusted
- Kuvan tarkoituksena on esitellä, miten digitaalisella allekirjoituksella varmistetaan lähettäjän identiteetti - The diagram illustrates how digital signature can be used to verify the identity of the sender

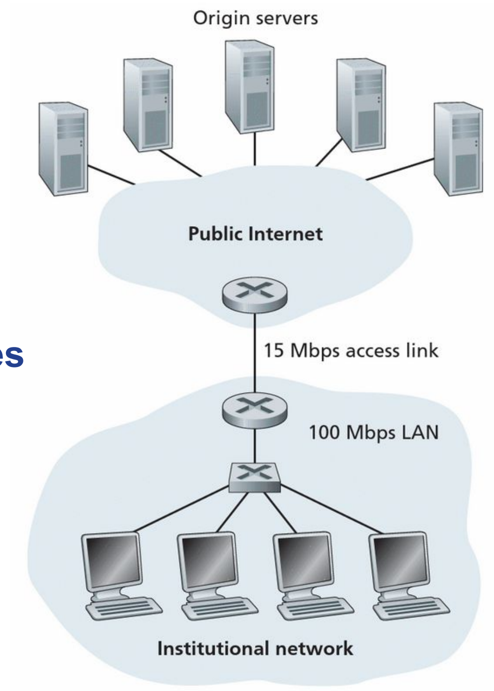
**8. Message encryption - which are correct?**

- Trudy kaappaa viestin sen ollessa matkalla. Lukeakseen viestin sisällön, hän tarvitsee B:n salaisen avaimen.
- Mikäli avaimet eivät ole vuotaneet ja käytetyt algoritmit ovat (edelleen) turvallisia, kuvan järjestely takaa viestin luottamuksellisuuden (confidentiality), lähettäjän henkilöllisyyden (authentication) ja viestin muokkaamattomuuden (integrity).



# Problem #F

Consider the figure right, where an institutional network is connected to the Internet. Suppose that the average object size is 900,000 bits and that the average request rate from the institution's browsers to the origin servers is in total 15 requests per second. Suppose that the amount of time from when the router on the Internet side of the access link forwards an HTTP request to the origin servers until it receives the response is two seconds on average.

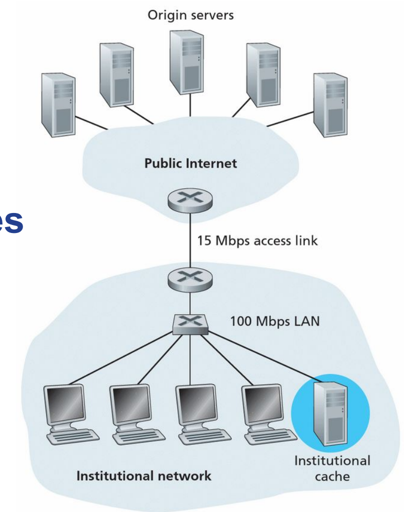



a) What is the traffic intensity at the link from the internet router to the the institutional network?

b) Given that the average access delay is Δ/(1 – Δβ), where Δ is the average time required to send an object over the access link and β is the arrival rate of objects to the access link, what is the average access delay for that link?

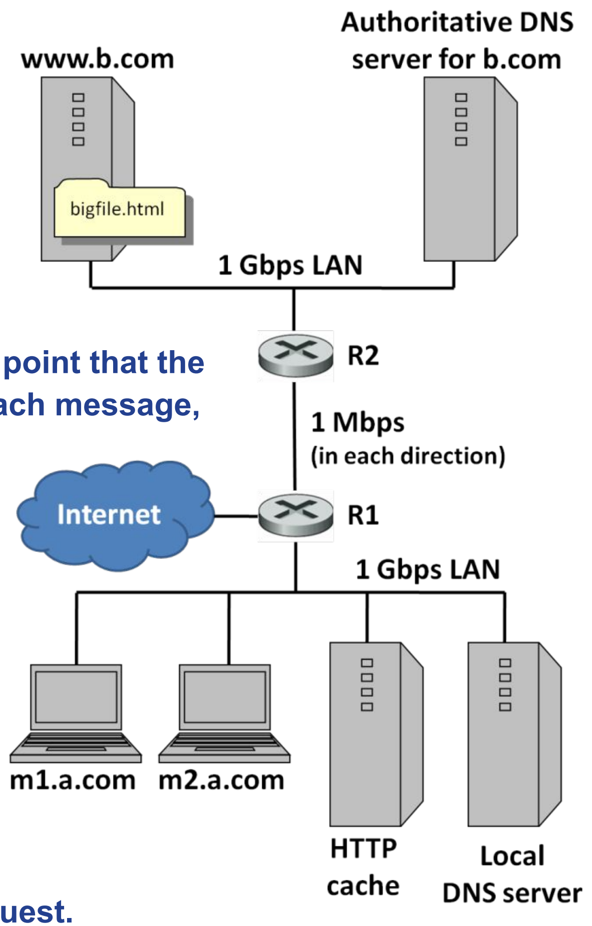
c) What is the the total average time from request to finish, assuming that all propagation delays inside the institutional network are negligible, there is no propagation delay in the access link and that the transmission delay of requests are negligible?

d) Finally, suppose a web proxy server (cache) is installed in the institutional LAN. Suppose that the hit rate of the proxy server (the proportion of the HTTP requests satisfied by the proxy server) is 40%. How does i) the traffic intensity and ii) the total average time change as a result, assuming that the proxy causes no additional processing delays.



# Problem #10

Consider the network on the right. There are two user machines, m1.a.com and m2.a.com in the network a.com.




**a)** **Suppose the user at m1.a.com types in the URL http://www.b.com/bigfile.html into a browser to retrieve the 100 Mbit file. List the sequence of DNS and HTTP messages sent/received from/by m1.a.com, as well as any other messages that leave/enter the a.com network that are not directly sent/received by m1.a.com, from the point that the URL is entered into the browser until the file is completely received. Indicate the source and destination of each message, associated delays and provide a brief explanation for each message. You can assume the following:**

- Every HTTP request from m1.a.com (and m2.a.com) is first directed to the HTTP cache in a.com.
- The HTTP cache is initially empty.
- All DNS queries are iterative queries.
- The packets containing DNS/HTTP commands are very small compared to the size of the file retrieved. Therefore, their transmission times can be ignored (but not their propagation times).
- Propagation delays within the LANs are so small that they can be ignored. The propagation time from router R1 to router R2 is 100 ms.
- The one-way propagation delay from anywhere in a.com to any other site in the Internet (except b.com) is 500 ms.

**b)** **Now assume that after machine m1.a.com has fully retrieved the file, machine m2.a.com makes the same request. Make the same table as above, highlighting the differences to the previous case.**

**c)** **Now suppose there is no HTTP cache in network a.com. What is the maximum rate (requests/s) at which machines in a.com can make requests for the file http://www.b.com/bigfile.html, so that the response time to complete a request will not become infinite in the long run?**

# Problem #11

Consider an Ethernet LAN consisting of N nodes interconnected by a switch. Suppose node A wants to establish a TCP connection with node B using the three-way handshake. Assume the switch's forwarding table is initially empty, all ARP tables are initially empty, node A knows the hostname of node B, node A knows the IP address of the DNS server residing in node C, and there are no other traffic or packet errors or loss. How many frames in total will be transmitted in the LAN in the process of establishing the TCP connection? Justify your answer by showing the sequence of transmitted frames in a table of five columns (source, destination, type of frame, brief explanation for the frame, and amount of sent frames).

| SOURCE | DESTINATION | TYPE | EXPLANATION | AMOUNT OF FRAMES |
|---|---|---|---|---|
| … | … | … | … | … |

# Problems 3A

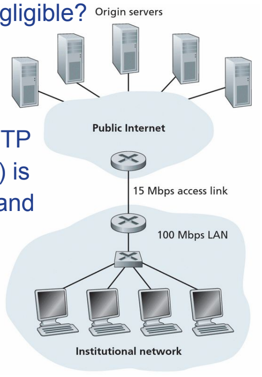
**Problem #F: Consider the figure right, where an institutional network is connected to the Internet. Suppose that the average object size is 900,000 bits and that the average request rate from the institution's browsers to the origin servers is in total 15 requests per second. Suppose that the amount of time from when the router on the Internet side of the access link forwards an HTTP request to the origin servers until it receives the response is two seconds on average.**

a) What is the traffic intensity at the link from the internet router to the the institutional network?

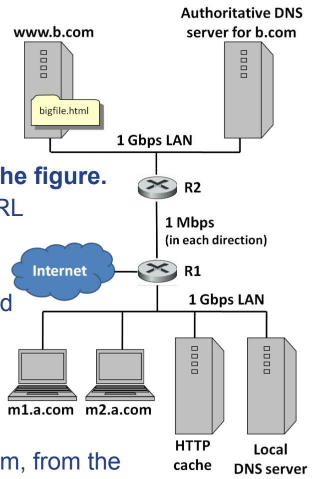
b) Given that the average access delay is Δ/(1 – Δβ), where Δ is the average time required to send an object over the access link and β is the arrival rate of objects to the access link, what is the average access delay for that link?

c) What is the the total average time from request to finish, assuming that all propagation delays inside the institutional network are negligible, there is no propagation delay in the access link and that the transmission delay of requests are negligible?

d) Finally, suppose a web proxy server (cache) is installed in the institutional LAN. Suppose that the hit rate of the proxy server (the proportion of the HTTP requests satisfied by the proxy server) is 40%. How does i) the traffic intensity and ii) the total average time change as a result, assuming that the proxy causes no additional processing delays.




**Problem #10: Consider the network in the figure.**




a) User at m1.a.com types in the URL *http://www.b.com/bigfile.html* into a browser to retrieve a 100 Mbit file. List the sequence of DNS and HTTP messages sent/received from/by m1.a.com,as well as any other messages that leave/enter the a.com network that are not directly sent/received by m1.a.com, from the point that the URL is entered into the browser until the file is completely received. Indicate the source and destination of each message, associated delays and provide a brief explanation for each message. You can assume the following:

- Every HTTP request from m1.a.com (and m2.a.com) is first directed to the HTTP cache in a.com.
- The HTTP cache is initially empty.
- All DNS queries are iterative queries.
- The packets containing DNS/HTTP commands are very small compared to the size of the file retrieved. Therefore, their transmission times can be ignored (but not their propagation times).
- Propagation delays within the LANs are so small that they can be ignored. The propagation time from router R1 to router R2 is 100 ms.
- The one-way propagation delay from anywhere in a.com to any other site in the Internet (except b.com) is 500 ms.

b) Now assume that after machine m1.a.com has fully retrieved the file, machine m2.a.com makes the same request. Make the same table as above, highlighting the differences to the previous case.

c) Now suppose there is no HTTP cache in network a.com. What is the maximum rate (requests/s) at which machines in a.com can make requests for the file http://www.b.com/bigfile.html, so that the response time to complete a request will not become infinite in the long run?

**Problem #11: Consider an Ethernet LAN consisting of N nodes interconnected by a switch. Suppose node A wants to establish a TCP connection with node B using the three-way handshake. Assume the switch's forwarding table is initially empty, all ARP tables are initially empty, node A knows the hostname of node B, node A knows the IP address of the DNS server residing in node C, and there are no other traffic or packet errors or loss. How many frames in total will be transmitted in the LAN in the process of establishing the TCP connection? Justify your answer by showing the sequence of transmitted frames in a table of five columns (source, destination, type of frame, brief explanation for the frame, and amount of sent frames).**

| SOURCE | DESTINATION | TYPE | EXPLANATION | AMOUNT OF FRAMES |
|---|---|---|---|---|
| … | … | … | … | … |

**Notes for #F**

a) I=β*L/R (intensity = arrival rate * object size / transmission rate)
b) Δ = average time to send object to link (= L/R)
c) router-server RTT + average access delay
d) how does intensity decrease affect the average time?

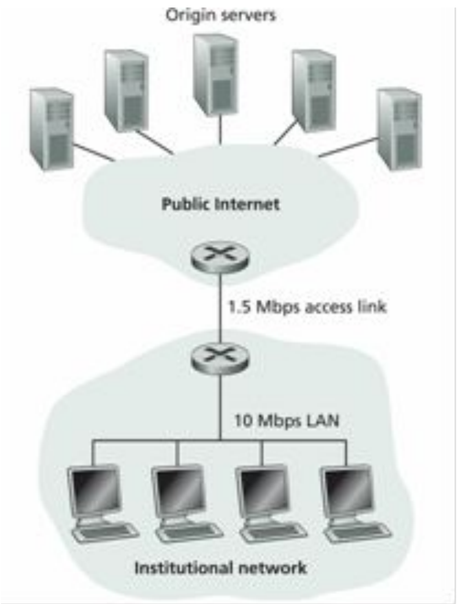
**Notes for #10**

a) check lecture 11 for DNS, you must take root DNS server and TLD DNS server into account as well!
b) how does local DNS and HTTP cache affect?
c) R1-R2 limits

**Notes for #11**

- message types: Address Resolution Protocol (ARP) request/reply, Domain Name System (DNS) query/reply, SYN(chronization), SYN-ACK, ACK(nowledgement)
- one frame from node to switch, one frame from switch to node
- in total 9 steps and 2N+14 frames are sent!

# Examples




**Problems**

a) Consider the institutional network in the top right corner connected to the internet. Suppose the average object size is 100kb and on average 12 requests are made each second to get these objects. Suppose that it takes on average 3 seconds for the internet router from forwarding an HTTP request to the origin servers to receive a response. Assume all RTTs inside the institutional network are 10ms.
   i) What is the traffic intensity on the LAN?
   ii) What is the traffic intensity on the access link?
   iii) Solve the total average response time as the sum of average LAN delay, average access delay (Δ/(1 – Δβ)) and average Internet delay.
   iv) How does the total average response time change, if a web cache capable to respond on average 20% of requests is installed to the institution LAN?

b) Consider an Ethernet LAN consisting of client A, web server B, and DNS server C, all connected to each other via switch. Suppose node A wants to establish a TCP connection with node B using the three-way handshake. Assume the following:
   - switch's forwarding table is initially empty
   - all ARP tables are initially empty
   - node A knows the hostname of node B, and IP address and MAC address of node C
   - there are no other traffic or packet errors or loss

   Describe the process and the amount of frames transmitted in the LAN in the process of establishing the TCP connection.

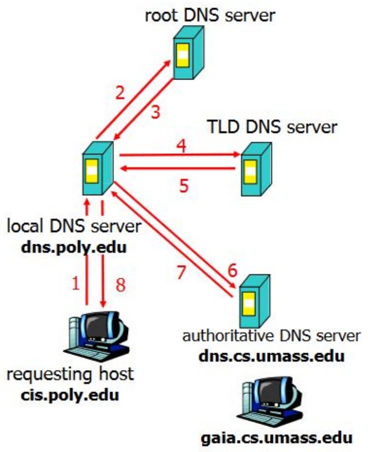
c) From lecture 11: host at cis.poly.edu wants the IP address for gaia.cs.umass.edu

**Solutions**

a)
   i) (12 requests/s)*(100 kb/request) / 10 Mbps = 0.12
   ii) (12 requests/s)*(100 kb/request) / 1.5 Mbps = 0.8
   iii) Δ = average time required to send an object over the access link
   β = arrival rate of objects to the access link
   average LAN delay = 10 ms, average internet delay = 3 s
   average access delay = Δ / (1 – Δβ) = (100kb/1.5Mbps) / (1-(100kb/1.5Mbps)*12)
   = 0.333... s -> total average response time =~ 3343 ms
   iv) 0.2 * 10 ms + 0.8 * 3343 ms =~ 2676 ms

b)
1. A sends DNS query to C to get B's IP address (1 frame to switch +1 frame to C)
2. C sends B's IP address in DNS reply to A (1+1 frame)
3. A sends ARP request to all nodes to get B's MAC address (1+2 frames)
4. B sends its MAC address in ARP reply to A (1+1 frames)
5. A sends SYN to B to initiate TCP connection (1+1 frames)
6. B sends SYN-ACK to A (1+1 frames)
7. A acknowledges B's response and the connection is formed (1+1 frames)

c) Iterative name resolution




Recursive name resolution