UNIVERSITY OF CANBERRA
AUSTRALIA'S CAPITAL UNIVERSITY

Assignment Cover Sheet

Network Architecture - Semester 2, 2019

Course Code, UG/PG: 11484

Lecturer/Tutor Name: Ahmed

Workshop /Tutorial Day & Time: Thursday 12:30pm

Assignment: Semester Assignment

Date & Time Submitted: 25/10/19

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Student Name	Student ID	Group
Lovevish Beessoo	U3177028	28
Thanh Phan	U3175008	

"Only one member of the group submits the assignment. However, each group members must keep a photocopy or electronic copy of their assignments."

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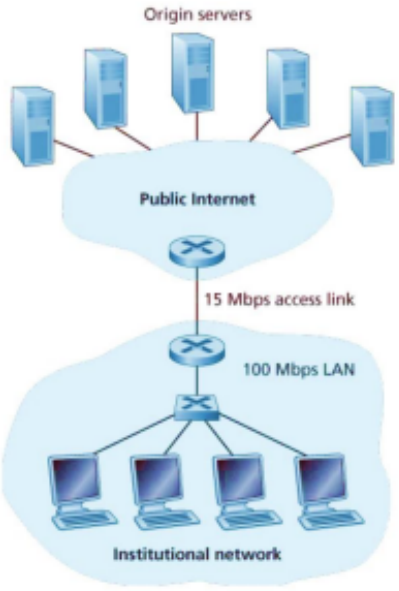
Question 1:

Part A: Review Questions (12 marks)

Q1 [8 marks, Network delay & performance]

Requirements analysis includes gathering, analysing, and developing requirements for the network. This question addresses the problem of developing and measuring the delay performance of an institution network.



Consider the institutional network shown in the figure to the right. Assume that each device within the institution requests an average of 16 objects per second from the origin servers. The average object size requested by the devices within the institution is 850,000 bits. Ignore other types of traffic flows and answer the following questions.

a) What is the average time required to transmit ($\mathbf{d_{tran}}$) an object over the 15 Mbps access link? *(1 mark)*

b) What is the traffic intensity ($\mathbf{t_{int}}$) of the 15 Mbps access link? *(2 marks)*

c) What is the average access delay of the 15 Mbps access link? Hint: the average access delay of the 15 Mbps access link can be computed as $\mathbf{d_{tran}/(1-t_{int})}$. *(2 marks)*

d) The institution wants to upgrade the 15 Mbps access link, i.e., replace the access link with a higher-speed link. What is the minimum throughput (or link capacity) of the new access link to achieve an average access delay of 300 ms? *(3 marks)*

Assume 1 Mbits = 10^6bits. Show your working steps for all questions and provide the measurement units.

Object size: 850 000 bits
Request: Number of objects = 16 object/s

Part A – Solution:

Throughput = 15Mbps = 15×10^6 bits

dTrans = $\frac{\text{Object Size}}{\text{Throughput}} = \frac{850\,000}{15\times10^6}$ = 0.056s

Part B – Solution:

Traffic intensity of 15Mbps access link

T int = dTrans x Number of objects

= 0.056 x 16
= 0.91

Part C – Solution:

Access Delay of 15Mbps

$$\text{Access Delay} = \frac{\text{dTrans}}{(1-\text{t int})} = \frac{0.056}{(1-0.91)} = 0.607\text{s}$$

Part D – Solution:

Access Delay of 300ms = 300×10^{-3}s

$$\text{Access delay A} = \frac{\text{dTrans}}{(1-\text{t int})} = \frac{\text{dTrans}}{1-(\text{dTrans x Number of object})}$$

$$\text{Access delay A} = \frac{\frac{\text{Object Size}}{\text{Throughput}}}{1-(\frac{\text{Object Size}}{\text{Throughput}} \text{ x Number of object})}$$

$$300 \times 10^{-3} = \frac{\frac{850\,000}{\text{Throughput}}}{1-(\frac{850\,000}{\text{Throughput}} \text{ x } 16)}$$

$$0.3 = \frac{\frac{850\,000}{\text{Throughput}}}{1-(\frac{850\,000}{\text{Throughput}} \text{ x } 16)}$$

$$\frac{850\,000}{\text{Throughput}} = 0.3 - 0.3\,(\frac{850\,000}{\text{Throughput}} \text{ x } 16)$$

$$\frac{850\,000}{\text{Throughput}} = 0.3 - \frac{408\,000\,0}{\text{Throughput}}$$

$$0.3 = \frac{850\,000}{\text{Throughput}} + \frac{408\,000\,0}{\text{Throughput}}$$

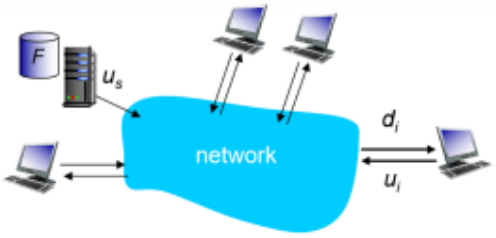
$$0.3 = \frac{493\,000\,0}{\text{Throughput}}$$

Throughput = $\frac{493\,000\,0}{0.3}$ 164 333 33.33 bits = 16.43Mbps

Question 2:

Q2 [4 marks, Flow models]

Flow models describe the degrees of hierarchy and diversity of flows for the network applications. Peer-to-peer and client-server are widely adopted flow models.



As shown in the figure to the right, consider an organization network where a file of size **F=15,360 Mb** must be sent to **100** employees. The file is initially stored in the server device. Each employee uses a computer device that has a download rate of $\mathbf{d_i}$**=2 Mbps** and an upload rate of $\mathbf{u_i}$**=2 Mbps**.

a) To achieve a minimum distribution time of **20,480** seconds in the client-server distribution architecture, compute the minimum required upload rate of the server $\mathbf{u_s}$? *(2 marks)*

b) Assume that the upload rate of the server is $\mathbf{u_s}$**=100 Mbps**. Can the P2P distribution architecture achieve a minimum distribution time of 5120 seconds? Justify your answer. *(2 marks)*

File size: 15360Mb
Destinations: 100 employees
Download rate: d_i= 2 Mbps
Upload rate: u_i= 2 Mbps

Part A – Solution:

Minimum required upload rate of the server u_s to achieve distribution time of 20480 s

Minimum distribution time: $D_{c\text{-}s} = \max\left\{\frac{N\,x\,F}{us}\,;\ \frac{F}{di}\right\}$

$$20480 = \max\left\{\frac{100\times 15360}{u_s}, \frac{15360}{2}\right\}$$

$$= \max\left\{\frac{100\times 15360}{u_s}, 7680\right\}$$

$$= \max\left(\frac{1536000}{U_s}\right) = 20480$$

⇨ Min U_s = $\frac{1536000}{20480}$ = 75 Mbps

➔ The minimum required upload rate of the server u_s to achieve distribution time of 20480 s is 75 Mbps

Part B – Solution:

Upload rate of the server u_s= 100 Mbps

$$D_{P2P} \geq \max\left\{\frac{F}{us}\,;\ \frac{F}{di}\,;\ \frac{N\,x\,F}{us+\sum ui}\right\}$$

$$\geq \max\left\{\frac{15360}{100}, \frac{15360}{2}, \frac{100.15360}{100+(100X2)}\right\}$$

$$\geq \max\ \{153{,}6, 7680, 5120\}$$

$$\geq 7680$$

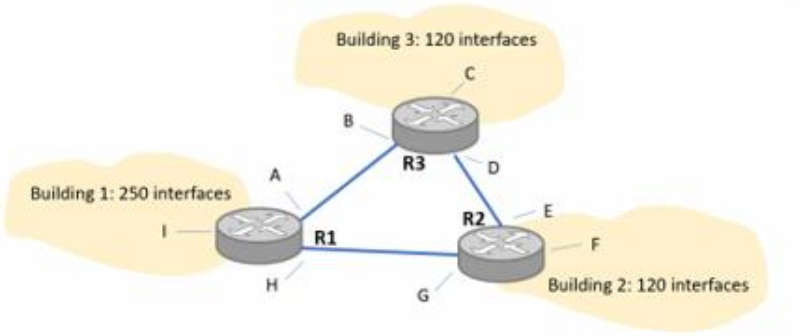
➔ So, 7680 > 5210, the P2P distribution architecture cannot achieve a minimum distribution time of 5120 seconds

Question 3:

Part B: Network design (8 marks)

Q3 [8 marks, Network architecture and design]

Component architectures of a network describes its major functions, e.g., addressing and routing, and their mechanisms.



Consider the network of a university campus shown in the figure above that connects three buildings using three routers (R1, R2, and R3). Each router has three interfaces, e.g., R1 has interfaces A, H, and I. The requirement specification has the following entries:

Requirements Specification							
ID	Date	Type	Description	Gathered/Derived	Locations	Status	Priority
1	05/09/19	User	User distribution: 250 interfaces in Building 1, 120 interfaces in Building 2, and 120 interfaces in Building 3	Gathered from management	See Map	Info	TBD
2	08/09/19	Network	To maintain high speed connection, all devices within each building must be connected using the same subnet	Gathered from network staff and users	All buildings	TBD	TBD
3	09/09/19	Network	The address space available for the network is 137.92.254.0/23	Gathered from network staff	All buildings	Info	TBD
4	09/09/19	Network/ Application	Existing security tools require that all routers must use the longest prefix matching for data forwarding	Gathered from network staff	All buildings	Info	TBD

Answer the following questions.

a) How many subnets exist in this campus network? Justify your answer and list all subnets. *(2 marks)*

b) Assign the address space to the subnets and compute the maximum number of interfaces that can be connected in each subnet. The address space must not be wasted, and the address allocation must be optimized e.g., it is not acceptable to assign 4 addresses to a subnet that only connects 2 interfaces. Use the address naming convention of a.b.c.d/x or a.b.c.d/x-e.f.g.h/y. *(3 marks)*

c) Create the forwarding tables of routers R1, R2, and R3. *(3 marks)*

Part A – Solution:

As per the given figure of the buildings within the campus, it can be said that each building is a subnet comprising of a certain allocated interface. Further stated in row 2 in the Requirements Specification table, “To maintain high speed connection, all devices within each building must be connected using the same subnet”. Hence, since there are 3 buildings, it would be adequate for there to be a single subnet within each building. The difference in the number of interfaces per building indicates the requirement of variable-length subnetting. Below is listed each subnet followed by the building number, allocated interface and their respective address count.

- Subnet 1:
  - Building 1
  - 250 interfaces
  - 256 (2^8) addresses (A 256 address space has been allocated as 2 extra address are required to make network connection and broadcast)

- Subnet 2:
  - Building 2
  - 120 interfaces
  - 128 (2^7) addresses (A 128 address space has been allocated as 2 extra address are required to make network connection and broadcast)

- Subnet 3:
  - Building 3
  - 120 interfaces
  - 128 (2^7) addresses (A 128 address space has been allocated as 2 extra address are required to make network connection and broadcast)

As stated in row 3 of the Requirement Specification table, “The address space available for the network is 137.92.254.0/23”. By utilising the CIDR notation and with reference to the above, each subnet can be written in their CDIR notation.

- Subnet 1: 137.92.254.0/24
- Subnet 2: 137.92.255.0/25
- Subnet 3: 137.92.255.128/25

Part B – Solution:

As seen above in part A each subnet comprises of a different number of interfaces. Therefore, there will be a different amount of addresses space for each subnet. Below are conditions that explain the number of address space.

- In the above figure the stated number of interfaces for the individual building is a multiplication of 10 and after the addition of the address space, the total number produced can be a power of 2. In this case it can be seen that 250 and 120 are not a power of 2.

- As seen in part A the total number of interfaces can be calculated to be 490 and after adding the needed address space it increases to a total address space of 512 for the whole network.

Hence, creating room for spare addresses for each subnet. Defined below are the number of address space in each subnet.

Table 1: Subnet Details

No.	Subnet	Total Interface Addresses	Valid Interface Addresses	Network Address	Broadcast Address	Host/ Interface Addresses
1	Subnet 1	256	254	137.92.254.0/24	137.92.254.255/24	137.92.254.1/24 – 137.92.254.254/24
2	Subnet 2	128	126	137.92.255.0/25	137.92.255.127/25	137.92.255.1/25 – 137.92.255.126/25
3	Subnet 3	128	126	137.92.255.128/25	137.92.255.255/25	137.92.255.129/25 – 137.92.255.254/25

In according to the created table above it can be depicted that there will be 4 spare addresses for building 1 since there are 250 interfaces and 254 available spaces in subnet 1. Moreover, there will be 6 spare addresses for building 2 and 3 since there are 120 interfaces and 126 available spaces in subnet 2 and 3.

Part C – Solution:

As per the Requirement Specification table it states in row 3 “Existing security tools require that all router must use the longest prefix matching for data forwarding”. Hence, the forwarding tables of R1, R2 and R3 must utilise the longest prefix.

Step 1: Convert subnet addresses to binary

- Subnet 1:
  - From: 10001001 01011100 11111110 00000000
  - To: 10001001 01011100 11111110 11111111

- Subnet 2:
  - From: 10001001 01011100 11111111 00000000
  - To: 10001001 01011100 11111111 01111111

- Subnet 3:
  - From: 10001001 01011100 11111111 10000000
  - To: 10001001 01011100 11111111 11111111

In obtaining the address in binary form of each subnet, the longest prefix for each subnet and their respective building is (in green):

- Subnet 1 and Building 1: 10001001 01011100 11111110 ********
- Subnet 2 and Building 2: 10001001 01011100 11111111 0*******
- Subnet 3 and Building 3: 10001001 01011100 11111111 1*******

With reference to the figure of all the buildings, the forwarding table for each router can be constructed.

Forwarding Table – R1:

Interface	Prefix Match
I	10001001 01011100 11111110 ********
A	10001001 01011100 11111111 1*******
H	10001001 01011100 11111111 0*******

Forwarding Table – R2:

Interface	Prefix Match
G	10001001 01011100 11111110 ********
E	10001001 01011100 11111111 1*******
F	10001001 01011100 11111111 0*******

Forwarding Table – R3:

Interface	Prefix Match
B	10001001 01011100 11111110 ********
C	10001001 01011100 11111111 1*******
D	10001001 01011100 11111111 0*******

Question 4:

Part C: Case Study (5 marks)

Q4 [5 points, Australia's broadband access network (NBN)]

NBN[1] is a monopolist, government-owned corporation in Australia. It provides wholesale broadband access services to retail broadband providers, e.g., Telstra, Optus, TPG group. Since it was established in 2009, there have been many controversial discussions on the performance, pricing, and development cost of NBN. As of September 2019, Australia is ranked 60th worldwide in the ranking of fixed broadband speeds[2]. In 2017, NBN claimed that only 1% of the complaints on activated NBN premises were forwarded to NBN for solution[3]. Consider the following points that may affect the performance of the NBN network:

- To reduce deployment cost, NBN has adopted a multi-technology mix[4] that includes FTTN (fibre to the node) and FTTdp (fibre to the distribution point) instead of FTTP (fibre to the premises).
- Australia has a total area of 7,692,024 km^2. It has deserts in the center, tropical rainforests in the northeast, and mountains in the southeast parts.

Develop a *questionnaire to gather requirements* from

a) NBN end users; *(at least 5 questions, 2 marks)*
b) retail broadband providers; and *(at least 5 questions, 2 marks)*
c) NBN staff *(at least 3 questions, 1 mark)*

to better understand the possible shortcomings of the NBN network?

Part A – Solution:

Australia's Broadband Access Network (NBN) – End User Questioner

As per the launch of the NBN upgrade across all of Australia which includes the upgrade of existing land line phone and internet network, NBN would like to gather your honest thoughts on the services provided. Upon taking this questionnaire all provide information will be kept confidential, completely anonymous and only used towards the improvement of the launch of the NBN switch. Below are five questions that we would like you to attempt. Please ensure to fill all questions unless sated otherwise before submitting. Thank you for your time.

Age: _____
State/ Region: _____
Suburb/ City: _____
Current Internet Provider: _____
Current Broadband Technology (if known): _____
The Stated Internet Speed by Provider: _____

1. How satisfied with your current internet service?
   - ☐ Very Satisfied
   - ☐ Satisfied
   - ☐ Neutral
   - ☐ Dissatisfied
   - ☐ Very Dissatisfied
2. How is your internet utilised?
   - ☐ Downloading large files
   - ☐ Streaming Movies
   - ☐ Uploading Content
   - ☐ Social Media
   - ☐ Voice or Video Calls
   - ☐ Online Researching
   - ☐ Other: _____
3. Will you need extra support when switching to NBN?
   - ☐ Yes
   - ☐ No
4. On average how many devices share the same internet connection at once?
   _____
5. How reliable is your internet connection?
   - ☐ Very Reliable
   - ☐ Reliable
   - ☐ Unreliable
   - ☐ Very Unreliable

Part B – Solution:

Australia's Broadband Access Network (NBN) – Retail Broadband Providers Questioner

This questionnaire attempts to gather data on the honest thoughts of the retail broadband providers that are responsibly to client service in the NBN community. Upon taking this questionnaire all provide information will be kept confidential, completely anonymous and only used towards the improvement of the launch of the NBN switch. Below are five questions that we would like you to attempt. Please ensure to fill all questions unless sated otherwise before submitting. Thank you for your time.

1. How will this upgrade affect the market of internet providers?
   _____

2. How can we better promote this upgrade on the market?
   _____

3. Which region of Australia do you find more challenging to provide services to?
   - ☐ Western Australia
   - ☐ Northern Territory
   - ☐ Queensland
   - ☐ South Australia
   - ☐ New South Wales
   - ☐ Australia Capital Territory (ACT)
   - ☐ Victoria
   - ☐ Tasmania

   Once selected state the reason why: _____

4. How will certain regions be affected by the NBN upgrade?
   _____
   _____

5. How can we improve the transition of clients when making the switch to NBN?
   _____
   _____

Part C – Solution:

Australia's Broadband Access Network (NBN) – NBN Staff Questioner

This questionnaire attempts to gather data on the honest thoughts of the staff at NBN. Upon taking this questionnaire all provide information will be kept confidential, completely anonymous and only used towards the improvement of the launch of the NBN switch. Below are three questions that we would like you to attempt. Please ensure to fill all questions unless sated otherwise before submitting. Thank you for your time.

Position: _____
Branch: _____
Department: _____

1. What are the problems and stakes when launching a large-scale upgrade?
   _____
   _____

2. How can the reliability of service to regional areas be guaranteed after the NBN upgrade?
   _____
   _____

3. NBN has planned to implement a wireless NBN connection instead of fibre (FTTP) cables in remote areas, what are contingency plans or alternatives if the wireless internet is temporary unavailable?
   _____
   _____