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Computer Networks

EXAMINERS' REPORT

General Comments

This session is again like the April 2014 session in terms of performance and quality of answers to sections A and B. The performance is improving but slowly as also the quality of answers. Nevertheless, it is worth repeating this message again this year too that candidates need significantly better preparation based on good understanding of concepts to have a realistic chance of getting better marks. The examiners' reports such as this which are available for past 6 sessions will help in examination preparation process for this paper. Good preparation hence, includes studying the topics well, understanding the basic concepts well as well as reading examiners' reports like this so that a student knows what is expected of him/her.

Again this year too, it is also worth saying that candidates still are not reading the questions carefully which leads to poor understanding of what is expected as answers to those questions. There were a good number of borderline cases in this session too.

Section A

A1. This question is about the Transmission Control Protocol (TCP) and User Datagram Protocol (UDP).

a) Explain how a network connection is established between a user and a server over the Internet using the TCP protocol.
(8 marks)

b) Both the TCP and UDP protocols use port numbers. What are these port numbers used for and what is meant by the term well known port?
(6 marks)

c) What is the difference in the quality of service (QoS) offered to applications by the TCP and UDP protocols?
(8 marks)

d) For each of the following three applications, determine whether you would use TCP or UDP.
i. File transfer
ii. Video streaming
iii. An audio conference
(3 marks)

Answer Pointers

a) A TCP connection is uni-directional which means that for two way communications, a connection must be established from the user to the server and separately from the server to the user. Each process does however, follow the same three way handshake procedure. The user will issue a TCP segment with the SYN flag set and the sequence number equal to some initial value – say x. The server – if it wants to accept the connection request – will return a TCP segment with both the SYN and ACK flags set. It will also choose a sequence number starting value – say y. The acknowledgement field of this segment will be set to x+1 to acknowledge receipt of the connection request segment. When the user receives this response it will issue one further TCP segment with the ACK field set. The acknowledgement in this segment will be y+1 and the sequence number will be x+1

(Marking scheme: 2 marks for a need for two uni-directional connections; 2 marks for the connection request (SYN=1); 2 marks for the connection acknowledgement (SYN=ACK=1) and 2 marks for the connection confirm)

b) Both TCP and UDP provide services to higher layer protocols however multiple higher layer protocols can be multiplexed onto a single UDP or TCP layer. Each of these higher layer protocols are then differentiated by means of UDP/TCP port numbers. Port numbers are 16 bits in length. Therefore the port number identifies the particular higher layer protocol to which a given data stream is destined.

Some of these port numbers are pre-defined and are therefore referred to as "well known ports", for example port 80 refers to the higher layer http protocol.

(Marking scheme: 2 marks for recognising that port numbers are 16 bits in length; 2 marks for knowing that they identify the higher layer protocol to which the data stream is destined, 2 marks for explaining what a well known port is)

c) UDP operates above IP and provides a connectionless, unacknowledged service to the upper layers. There is no error detection or recovery and no flow control provided by UDP. It is a best effort service.

TCP operates above IP and provides a connection orientated service in which end to end data transfer is guaranteed with flow control and congestion avoidance capabilities. It is a reliable service.
(Marking scheme: UDP – 2 marks for connectionless, 1 mark for no error control, 1 mark for no flow control. TCP – 2 marks for connection orientated, 1 mark for reliable data transfer, 1 mark for flow/congestion control.)

d)

i. TCP
ii. UDP
iii. UDP

(Marking scheme: 1 mark for each correct answer)

Examiners' Guidance Notes

Question 1 was attempted by the majority of the candidates, 142 (93%), with almost half of them (49%) passing the question. A relatively easy question to answer, however the average mark was about 11 out of 25. The candidates overall demonstrated a good level of understanding of TCP and UDP.

A2. This question is about broadband Internet access using Asymmetric Digital Subscriber Line (ADSL) technology.

a) Explain how ADSL is able to transmit both data and telephone calls over the same twisted pair cable which connects a house to a local exchange.
(8 marks)

b) If a domestic ADSL service was advertised as having a contention ratio of 50:1, what would this mean and how would it affect the download speeds that users experience when accessing the Internet?
(6 marks)
c) Two users located within the same village are using ADSL as their connection to the Internet. However, they each experience widely different download speeds. Suggest why and how the copper cables that connect these users to their local exchange may be the cause of this difference in download speeds.
(6 marks)

d) Many countries are now upgrading broadband access networks to offer customers high speed Internet access. One such technology is called fibre to the cabinet or fibre to the curb (FTTC). Briefly explain how this technology differs from ADSL and hence, is able to offer higher bandwidths than ADSL.
(5 marks)

Answer Pointers
a) ADSL delivers data and telephony over the same twisted pair by using higher frequencies for the data services. Telephony occupies the first 3kHz of a line's bandwidth and ADSL uses frequencies in the range 26kHz to 1.1MHz for data. This bandwidth is then divided into 256 channels, each of 4.3kHz and within these 256 channels, adaptive coding is used (QPSK, QAM) to encode up to 64 kbps per channel.

(Marking scheme: 2 marks for ADSL using frequencies for data higher than the 3kHz voice band; 2 marks for dividing the data frequencies into upstream and downstream; 2 marks for knowing that downstream has more capacity than upstream; 2 marks for reference to adaptive coding)

b) The capacity from a telephone exchange to the core network (backhaul) and hence the Internet is fixed. Therefore, all of the customers connected to the exchange need to share this fixed capacity. This is where contention applies. The capacity of the link from the exchange to the Internet is, in this example, shared across 50 users on the basis that not all of those users will be generating data at the same time. However, if they do, then they will compete for access to a fixed capacity and as such demand will exceed capacity to deliver and the net effect is that each user will observe a reduction in actual Internet bandwidth.

(marking scheme: 2 marks for knowing that the connection from the exchange to the Internet (backhaul) is fixed; 2 marks for knowing that users are competing for access to this fixed link; 2 marks for noting the net effect of a slowing down in Internet access rate)

c) Possible reasons are:
That the customers are at different distances from the exchange. The one who is further away will experience a lower data rate.

The quality of the copper line for the user receiving 3Mbps is poorer (older, lower quality) than the user receiving 8Mbps)

The line for the user receiving a higher download is subject to less interference (cross talk in the local loop) compare to the user receiving the lower download.
(Marking scheme: 2 marks for each of the above possible reasons)

d) Existing telephony networks provide copper cable from the exchange to the roadside cabinet and then onwards from there to each home. The copper path is therefore from the home to the exchange. There are two key problems which limit bandwidth, the length of the copper path and cross-talk caused from the interference from each copper pair when placed in close proximity to each other. Fibre to the cabinet replaces the copper path from the exchange to the cabinet but leaves the copper from the cabinet to homes. However, this does mean that higher capacity data can be delivered to the cabinet and since the copper path has been reduced, increased capacity can also be achieved over the remaining copper from the cabinet to the home.

(Marking scheme: 1 mark for knowing that the copper path extends from the exchange to the home; 1 mark for understanding the performance limits of this; 1 mark for knowing that fibre will replace copper from the exchange to the cabinet; 2 marks for performance improvement due to reduced copper path length and higher capacity to cabinet through fibre)

Examiners' Guidance Notes
Question two was the second most attempted question of section A. It was attempted by 139 (91%) of the candidates, with 65 (47%) providing a correct answer. Candidates from most centres provided reasonable answers demonstrating overall an understanding of the ADSL technology. However, answers from centre B104 were particularly poor. Many candidates incorrectly defined contention, in part B, as the difference between upload and download bandwidths. Answers to part D also varied, most candidates explained the FTTC technology, however, many candidates responded by proving only a definition of fibre optic cables.

A3. This question is about global network services and specifically, the use of Multi- Protocol Label Switching.

a) Global network services are provided by Telecommunications companies (Telcos). When a customer purchases such a service from a Telco, it will be defined in terms of a Service Level Agreement (SLA). Why are SLAs important and briefly explain what is described within them.
(7 marks)

b) Many organisations who wish to interconnect their offices around the world are doing so using Multi-Protocol Label Switching (MPLS) services. Briefly explain how MPLS works.
(9 marks)

c) An alternative to using MPLS for a global company is simply to connect each of its offices to the Internet and then to rely on the Internet itself to carry data between these offices. How does the Quality of Service (QoS) offered by the Internet in such a situation differ from that offered by an MPLS solution?
(9 marks)

Answer Pointers

a) The SLA is an agreement between a customer and a Telco and defines what service is being provided to the customer and what the customer is allowed to do with that service. The SLA would define:

- The data rate being delivered
- QoS parameters such as expected error rates, lost packets, time delays
- availability of the service (including any downtime for maintenance)
- how the service is being charged to the customer
- what the customer is allowed to connect to and use the service (acceptable use
- policy)
- how the customer can complain if they are unhappy with the service being
- provided

(marking scheme: 2 marks agreement between Telco and customer; 1 mark for defining service being offered; 1 mark for a relevant example of what is contained within the SLA up to a maximum of 4 marks)

b) MPLS operates as follows:

- A label switching protocol; a 'label' which is typically a 32 bit number
- Labels are added to data packets by an ingress router based on a classification of the
- incoming traffic
- That virtual circuits are established through the network for different classes of service.
- This ensures that each virtual circuit is able to support the QoS demands of a particular traffic class or type.
- Information about which label identifiers have been assigned to which data flow is exchanged between routers using a Label Distribution Protocol. The label that is added by the ingress router identifies the QoS virtual circuit to use and all routers within the MPLS network route based on this label field.
- All intermediate routers are termed label switching routers and route this data based on its label only.
- On reaching the far end of the connection, the final or egress router, removes the label.

(Marking scheme: 2 marks for label switching protocol; 2 marks that virtual circuits are established through the network for different classes of traffic; 1 mark for the mentioning that labels assigned to these circuits are distributed by a label distribution protocol; 2 marks for incoming traffic being classified and assigned to a specific virtual circuit; 1 mark for labels added and intermediate routers route using only the labels; 1 mark for label being removed by egress router)

c) Internet QoS:

- The Internet is a connectionless network with data being routed towards the destination.
- The Internet is a best effort service which means that there is no guarantee that data will be delivered and if it is delivered, there is no way of predicting how long it will take.
- No prioritisation – all traffic types handled equally which means that you cannot differentiate time critical applications from non time critical ones.
- The volume of traffic on the Internet cannot be predicted which means that the bandwidth being delivered for a service cannot be predicted either.

MPLS QoS:

- MPLS network establish virtual circuits between points.
- MPLS networks seek to differentiate traffic types.
- Each different traffic type is assigned to its own QoS defined by the class of service.
- MPLS is able to guarantee the applied QoS.

(Marking scheme: 2 for Internet being connectionless compared to MPLS which is virtual circuit based; 2 marks for Internet being best effort whereas MPLS applies QoS to each traffic flow; 2 marks for Internet treating all data the same and MPLS classifying traffic by their class of service, 2 marks for the fact that the delivered bandwidth via the Internet is not known and 1 mark for the fact that within MPLS this is guaranteed.)

Examiners' Guidance Notes

The last question in section A was poorly answered. Only 71 (46%) candidates attempted the question, with a mere 39 to obtain a pass mark. The average mark was 10 out 25. Marks were lost across all three parts of the question, particularly in part C, demonstrating that the candidates lacked an understanding of Quality of Service. I found remarkably interesting the answers from three candidates of centre B104 as they were very creative but sadly showed complete lack of understanding of the subject and preparation for this examination.

Section B

B4. This question is about the behaviour of routers within the Internet and Link-State Protocols.

a) Briefly explain the difference between the two tasks of packets forwarding, and routing, which are conducted by routers.

(7 marks)

b) Routers within the networks of large organisations often learn about connectivity using link-state protocols. Describe the general behaviour of link-state protocols.

(6 marks)

c) Open Shortest Path First (OSPF) is an important link-state protocol. Explain how OSPF copes with large networks and the roles of the various types of router within such a deployment.

(12 marks)

Answer Pointers

a). Packet forwarding is the task of dealing with moving individual packets (1) so that they get closer to the destination (1) which must be handled rapidly (1). Routing is the term used to cover the tasks of the creation and maintenance of routing tables (2). The routing task is conducted by exchanging information (1) with other routers (1) and then analysing received information to update tables (1). Routing is done much less often than packet forwarding (1). Other issues could be raised and will be rewarded if appropriate. Other issues could be raised and will be rewarded if appropriate. The total mark for this part of the question will be capped at 7.

b). Link-state protocols operate by generating announcements that contain the state of directly connected links (2). The routers also forward such announcements received from other routers (1) such that routers construct a link-state database (1) containing the state of all links within their network (1). All routers end up with the same link-state database (1) but from that construct their own (1) routing tables which are optimal from their location (1). Link-state routing protocols only transmit information when links change state (1). Other issues could be raised and will be rewarded if appropriate. The total mark for this part of the question will be capped at 6.

c). OSPF operates by splitting the network into areas (1) one of which is the backbone area (1). Routers with all interfaces inside a single area are referred to as Interior Routers (1) and construct a link-state database with detail from that area only (1). Routers with interfaces in more than one area are called Area Border Routers (ABR) (1) and construct multiple link-state databases (1) one for each area to which the router is connected (1). Routers with at least one interface in the backbone area are called Backbone Routers (1). Routers with interfaces within this network but with at least one interface to another administration's network are called Autonomous System Boundary Routers (2). Area Border Routers are also responsible for sending summaries of other areas (1) and knowledge from ASBRs into attached areas (1). Other issues could be raised and will be rewarded if appropriate. The total mark for this part of the question will be capped at 12.

Examiners' Guidance Notes

This question was attempted by about 59% of the candidates of whom only a small proportion (19%) achieved a pass mark.

While a small numbers of good quality answers were submitted, many answers were fairly weak. Many candidates also did not answer the question as set; this was particularly true for part c).

B5. Imagine you have been appointed to design the network to be deployed in three new buildings on a new university campus. Building A contains a dedicated computer room containing 10 very high performance dedicated servers. The servers provide services to students and staff who may need to gain access from the Internet as well as from within the university's own network. Building B contains the offices of 12 lecturers and 8 administrators who only use medium power desktop computers located on fixed desks. Building C contains two lecture rooms and a lounge/coffee shop. The lecture rooms have a desktop computer at the front for use by the lecturers, but some lecturers prefer to use their own laptop or tablet computer. All the students use laptop or tablet computers to take notes and keep in touch with their friends. An underground duct exists between building A and building B which are only 30 metres apart. Building C is 30 metres from building A but no ducts exist and installing one is not possible.

a) What type of network should be deployed in the building that houses the dedicated computer room and what equipment should be installed?

(5 marks)

b) What type of network should be deployed in the second office building and what equipment should be installed?

(5 marks)

c) What type of network should be deployed in the teaching building and what equipment should be installed?

(5 marks)

d) What type of network connections should be used to link the buildings together and where and how should the university's Internet connection be made?

(10 marks)

Answer Pointers

a). It is clear that building A contains fixed (1), high performance computers (1). A cabled network (1) is appropriate probably using high performance switches (1). A minimum of a 1Gbps network should be specified (1) although perhaps a case for 10 Gbps could be made (1). There seems little need for a WiFi network (1) although a case for WiFi to support systems staff using laptops could be argued (1). Other issues could be raised and will be rewarded if appropriate. The total mark for this part of the question will be capped at 5.

b). It is clear that building B contains fixed (1), medium performance computers (1). As in building A, a cabled network (1) is appropriate probably using medium performance switches (1). A minimum of a 100 Mbps network should be specified (1) although perhaps a case for 1 Gbps could be made (1). The text for the other building C does mention that some staff use laptop/tablet computers so perhaps an argument for WiFi to support teaching staff using laptops could be made (1). Other issues could be raised and will be rewarded if appropriate. The total mark for this part of the question will be capped at 5

c). We are told about fixed computers (1) and lots of laptop/tablet use (1). It is clear that we therefore want some cabled network sockets (1) in lecture rooms and perhaps to cash tills in the coffee shop (1) together with a network switch (1). However, it seems that most of the usage in this building is from mobile devices, laptops/tablets (1). A Wifi Network is therefore definitely needed (1) and with multiple access points needed (1). Other issues could be raised and will be rewarded if appropriate. The total mark for this part of the question will be capped at 5.

d). Buildings A and B can clearly be connected by laying some form of cable in the ducts (1). Fibre optic would be the better choice (1). We are told that ducts do not exist to building C and we are not allowed to install one (1) and so a cabled interconnection is not really possible. We can therefore perhaps best connect building C by using WiFi technology (1) and directional aerials (1). Considering all the factors, it seems the best place to make the Internet connection would be via building A. As access from outside the university campus is needed, ADSL is not really appropriate (1) and some form of symmetric service would be better (1). Security needs to be considered in several places (1) WiFi connections should use a good quality security/authentication technique (1) and good practice would see a firewall (1) installed between the Internet and the University networks (1). Other issues could be raised and will be rewarded if appropriate. The total mark for this part of the question will be capped at 10.

Examiners' Guidance Notes

This question was attempted by about 89% of the candidates of whom a large proportion (70%) achieved a pass mark.

While there was a large number of good quality answers submitted, some answers were fairly weak. Many candidates used the term “server” without making it clear what type of server was being referred to (web server, name server, file server, mail server or what?). Some candidates suggested the use of co-axial cable which would not be the cable of choice today. Many answers lacked discussion of security related to wireless LAN access. Some candidates failed to mention the role of firewalls. Many candidates neglected to describe the nature of the connection to the Internet Service Provider. Several candidates used the phrase “wild area network” – we have no idea what this means.

B6. This question is concerned with multicast IP.

a) If an IP datagram has its destination address set to a multicast address, to what places will that packet be delivered?

(4 marks)

b) Briefly explain the role played by the protocol Internet Group Management Protocol (IGMP) in relation to multicast traffic.

(6 marks)

c) Explain the differences between IGMPv1, IGMPv2 and IGMPv3.

(9 marks)

d) What types of application are likely to benefit from the use of IP multicast? Justify your answer.

(6 marks)

Answer Pointers

a). An IP datagram addressed to a multicast address will be sent to all hosts that have expressed an interest in the address specified (2). The hosts concerned could be on the local network (1) but could also be anywhere on the (multicast enabled subset of the) Internet (1).

b). IGMP is a protocol used between hosts (1) and routers (1) within a local area network (1) to exchange membership information (1) of multicast groups (1). Hosts use IGMP to request reception of multicast traffic (1) and routers to query hosts for continued interest in multicast reception (1). Other issues could be raised and will be rewarded if appropriate. The total mark for this part of the question will be capped at 6.

c). IGMPv1 does not possess a mechanism for host to be able to “leave” membership of multicast groups (1). The lack of a leave message could lead to high levels of unwanted traffic (1) if an application started hopping between membership of several groups (“channel hoping”) (1). IGMPv2 gained a leave message (1) and also gained group specific membership messages (1). IGMPv3 gains the ability to support source specific multicast (1) effectively a filtering mechanism (1). IGMPv1 and IGMPv2 suppress their own messages (1) if they see other nodes already expressing interest in groups which they too want (1). IGMPv3 removes message suppression (1). Other issues could be raised and will be rewarded if appropriate. The total mark for this part of the question will be capped at 9.

d). Applications transmitting live audio/video (2) streams to large number of receivers (perhaps a live TV transmission) could gain great benefit from use of multicast (1) as they would then only need to transmit data once (1) even if there were lots of receivers (1). Such a use of multicast would also save network traffic (1) as links would only carry a single copy even if it led to multiple receivers (1). Applications such as sending share prices to multiple traders on a share trading floor would also be a good use (2). Other applications/services could be raised and will be rewarded if appropriate. The total mark for this part of the question will be capped at 6.

Examiners' Guidance Notes

This question was attempted by only 11% of the candidates of whom only a small proportion (11%) achieved a pass mark.

While a very small number of moderate quality answers were submitted, most answers were very weak. Many candidates who submitted an answer to this question submitted answers that were largely empty. It would appear that knowledge of issues related to multicast IP is very poor.