Birla Institute of Technology & Science, Pilani
Work-Integrated Learning Programmes Division
Second Semester 2015-2016

Comprehensive Examination
(EC-3 Regular)

Course No.	: CS ZG525 (A)
Course Title	: ADVANCED COMPUTER NETWORKS
Nature of Exam	: Open Book
Weightage	: 50%
Duration	: 3 Hours
Date of Exam	: 09/04/2016 (FN)

No. of Pages = 2
No. of Questions = 5

Note:
1. Please follow all the *Instructions to Candidates* given on the cover page of the answer book.
2. All parts of a question should be answered consecutively. Each answer should start from a fresh page.
3. Assumptions made if any, should be stated clearly at the beginning of your answer.

Q.1. Consider the following graphs related to "*short-flow and long-flow network share*".

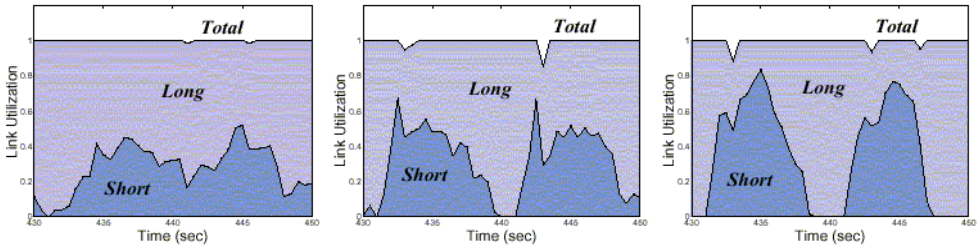


Fig. 2. Impact of Preferential Treatment— Link utilization under Drop Tail (left), RED (middle), and RIO-PS (right)

(a) Explain the reasons for under performance of short flows in Drop-tail routers.

Short flows have short congestion windows, long flows have large congestion windows. Long flows may fast retransmit (detecting loss through Trip Dup ACKs), small flows may have to wait for timeout.

(b) Explain the reasons why short and long flows get roughly equal share in routers using Random Early Detection (RED) scheme .

RED uses randomization in choosing which arriving packets to mark for dropping. With this method, the probability of marking a packet from a particular connection is roughly proportional to that connection's share of the bandwidth through the gateway. Number of packets dropped in short flows will be much less than that of long flows. Long flows will undergo window reduction at the sender more often than short flows.

(c) Explain the reasons why short-flows get higher share in Routers with RED with In/Out bit (RIO) scheme. [3 + 3 + 3 = 9]

Dropping probability for short flows is based on average backlog of short packets. Dropping probability for long flows is based on total average queue size. Short flows are not affected by long flows but long flows are affected by short flows.

Q.2. Explain the rationale behind the following design decisions in Multipath TCP. Be to the point.

(a) Every subflow should initiate a 3-way handshake.

Middle boxes drop packets if they detect TCP data segments without first noticing TCP 3-way handshake. By keeping a separate TCP connection for each subflow, middle boxes restrictions are satisfied.

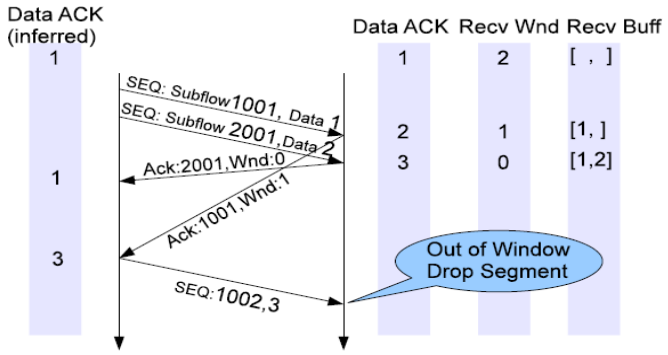
(b) Apart from sequence numbers, there should be global data sequence number.

- Packets received out-of-order from different subflows due to RTT differences. To combine them into a continuous flow, a global sequence number is required.
- Some middleboxes rewrite sequence numbers of TCP flow. So TCP seuence numbers can't be completely relied on.
- If we use TCP sequence numbers to order packets across subflows, there will be gaps in sequence numbers in a particular flow. Middleboxes upset by discontinuous TCP byte stream and may drop such packets.
- Need to retransmit lost packets on a different subflow.

(c) There will be one receiver window for all sub-flows.

Each subflow having its own receive window may lead starvation of some subflows in a connection.

(d) Explicit data acknowledgements



Reordering of ACKs is possible when RTTs are different in subflows. When cumulative ACKs are received in subflows, it can't be inferred how much of data is received by the receiver.

Due to out of order delivery of ACKs, advertised window size will be stale.

(e) using TCP options instead of using TCP payload for sharing data acknowledgements.

Problems with using TCP payload:
Flow control may keep receiver from sending a data ACK.
Excluding the data-ACKs from flow control is not possible because any middlebox that buffers data can foil this.
When return path is lossy, decoding DATA ACKs will be delayed until retransmissions.
Therefore, DATA ACKs can't be safely encoded in the payload.
The only real alternative is to encode them in TCP options (on a pure ACK packet which are not subject to flow control.

[5 X 2 = 10]

Q.3. Many of the mechanisms discussed in the course use some constant values (as thresholds, limits etc). For the following parameters, explain what will happen (i) if we chose a value that is too small and (ii) if we chose a value that is too large?

(a) In Random Early Detection(RED), *maxThreshold* is used as a limit on average queue length.

Too large: there will not be enough spare space to accommodate bursty traffic.
Too small: if it is too small, there will not be enough time for the sender to react and reduce traffic.

(b) Half-life parameter in route damping algorithm.

Too large: if it is too large, it will take lot of time to bring penalty to normal range.
too small: if it is too small, penalty may not grow to exceed suppress limit so that announcements can be stopped.

(c) γ parameter in compound TCP (CTCP)

if it is too large, cwnd will be incremented more often than decrementing i.e. it can't detect network capacity accurately.
if it is too small, cwnd will be decremented more often than incrementing i.e. it can't detect network capacity accurately.

(d) number of duplicate acknowledgements (default value is 3) to detect loss.

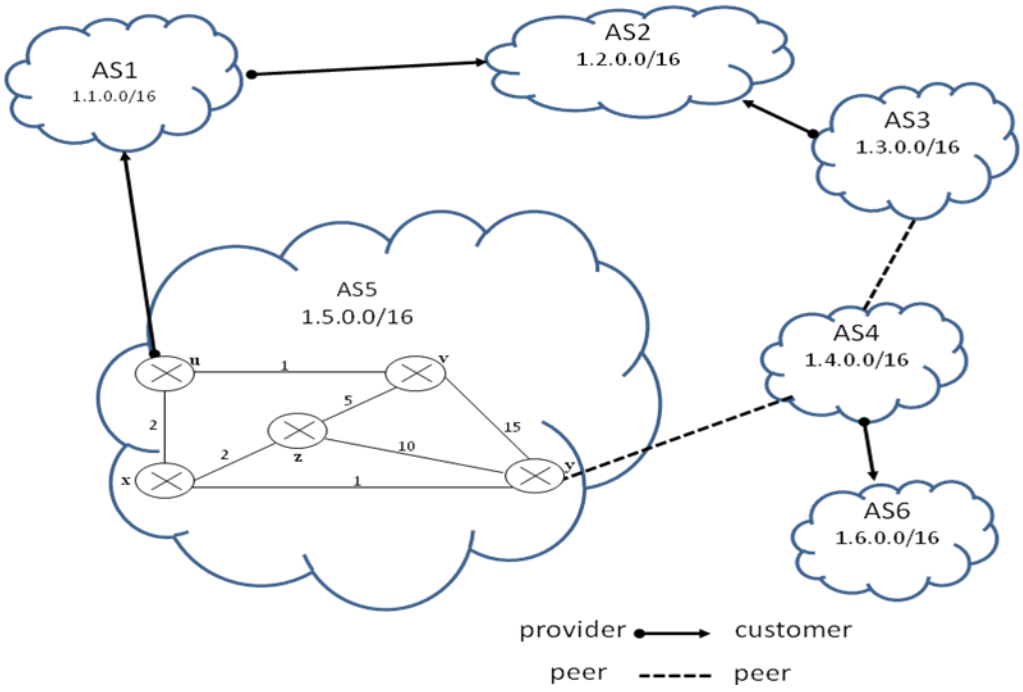
if it is too small(<3), a packet reaching through a different path will be inferred as lost.
if it is too large(>3), many packets have to be received to detect a packet loss.

(e) queue size of a router.

if it is too large, latency of packets will increase.
if it is too small, link utilization will be reduced.

[5 * 2 = 10]

Q.4. Consider following AS topology.



(a) Identify the BGP route advertisements (prefix, AS-PATH) received by router *u*, router *y*, AS 1, AS6 and AS4.

```
at router u:
1.2.0.0/16 AS1, AS2
1.1.0.0/16 AS1
at router y:
1.4.0.0/16 AS4
1.6.0.0/16 AS4, AS6
at AS1:
1.2.0.0/16 AS2
1.5.0.0/16 AS5
1.4.0.0/16 AS5, AS4
1.6.0.0/16 AS5, AS4, AS6

at AS6:
1.4.0.0/16 AS4
1.3.0.0/16 AS4, AS3
1.2.0.0/16 AS4, AS3, AS2
1.5.0.0/16 AS4, AS5
1.1.0.0/16 AS4, AS5, AS1
1.2.0.0/16 AS4, AS5, AS1, AS2

at AS4:
1.3.0.0/16 AS3
1.2.0.0/16 AS3, AS2
1.5.0.0/16 AS5
1.1.0.0/16 AS5, AS1
1.2.0.0/16 AS5, AS1, AS2
```

(b) For each prefix received at router u and router y, assign local_pref values in order to enforce business relationships.

at router u:
1.2.0.0/16 AS1, AS2 local pref value=<90-99> any value in the range
1.1.0.0/16 AS1 local pref value=<90-99>
at router y:
1.4.0.0/16 AS4 local pref value=<80-89> any value in the range
1.6.0.0/16 AS4, AS6 local pref value=<80-89> any value in the range

(c) What routes does AS5 announce to AS1 and AS4?

to AS1:
1.5.0.0/16 AS5
1.4.0.0/16 AS5, AS4
1.6.0.0/16 AS5, AS4, AS6

to AS4:
1.5.0.0/16 AS5
1.1.0.0/16 AS5, AS1
1.2.0.0/16 AS5, AS1, AS2

(d) If AS2 wants to receive all its traffic through AS1, keeping link with AS3 as backup link, which of the following techniques it can use to make it happen? List limitations if any for each.

(i) AS-PATH manipulation

AS2 can add duplicate copies of its own AS number and announce to AS3. During BGP decision process, if local preference is same and then length of AS-PATH is considered. Shorter paths are given more preference.

But if local preference itself is different, then AS-PATH manipulation will not work.

(ii)community attribute

With prior agreements with providers, AS2 can use community attribute to make AS3 assign low preference or high preference to routes going through it. This gives flexibility to AS2 to shift its traffic to AS3 whenever it wants.

(iii) local preference

Local preference is used to control outgoing traffic. So here it can't be used to control inbound traffic.

[5 + 4 + 2 + 4 = 15]

Q.5. Write what will be the response of the following ad-hoc network protocols in the event of link failure.

(a) DSR

Node which detected link failure sends a route error message (RERR) to sender along reverse route. Nodes hearing RERR update their route cache to remove error link. Sender tries another if it had otherwise rediscovers the path.

(b) AODV

When node X is unable to forward packet P (from node S to node D) on link (X,Y), it generates a RERR message. Node X increments the destination sequence number for D cached at node X. The incremented sequence number N is included in the RERR. When node S receives the RERR, it initiates a new route discovery for D using destination sequence number at least as large as N.

(c) TORA

If node i loses last outgoing link due to a link failure (Case Generate), set ref level to (current time, i, 0), do a full reversal and update neighbors.
When a node receives an update due to a height change and its nbrs don't have same ref level (Case Propagate), adopt max ref level and set delta to effect a partial reversal.
When a node receives an update due to a height change and its nbrs have same ref level with r = 0 (Case Reflect), adopt new ref level, set r to 1, set delta to 0 (full reversal).
When a node receives an update due to a height change and its nbrs have same ref level with r = 1 and oid = i (Case Detect), detected as Partition. Start process of erasing routes.

[6]

Birla Institute of Technology & Science, Pilani
Work-Integrated Learning Programmes Division
First Semester 2017-2018

Comprehensive Examination
(EC-3 Regular)

Course No.	: CS ZG525/ CSI ZG525/ ES ZG526
Course Title	: ADVANCED COMPUTER NETWORKS
Nature of Exam	: Open Book
Weightage	: 45%
Duration	: 3 Hours
Date of Exam	: 04/11/2017 (AN)

No. of Pages = 3
No. of Questions = 6

Note:
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3. Assumptions made if any, should be stated clearly at the beginning of your answer.

Q.1 (a) Assume a MPTCP connection comprises of two subflows (i.e. *Subflow-1* and *Subflow-2*). *Subflow-1* is passing through a bottleneck link i.e. *Link-1* and *Subflow-2* is passing through a bottleneck link i.e. *Link-2*. You can assume that there is no other traffic flows through these links.
Links characteristics are as follows:
Link-1: RTT = 20 millisec, Loss rate = 5%
Link-2: RTT = 100 millisec, Loss rate = 2%
What will be the throughput of MPTCP connection if:
(i) Subflows are treated as two independent TCP flows.
(ii) Coupled congestion control algorithm is used.
(iii) Equal Weight Congestion Protocol (EWTCP) algorithm is used

Q.1 (b) Data transfer scenario for a Multipath TCP connection between A and B, which comprises of two sub-flows is shown in Fig.1. The middle-box M presents in the path of the upper sub-flow buffers small TCP segments and it sends combined segment to the receiver. It copies one of the segment's (which are combined) option field (i.e. Dseq) in the combined segment. This creates desynchronization between byte stream (seq) and data sequence numbers (Dseq).
Suggest a solution to avoid de-synchronization between the byte stream (seq) and data sequence number (Dseq). [4 + 3 = 7]

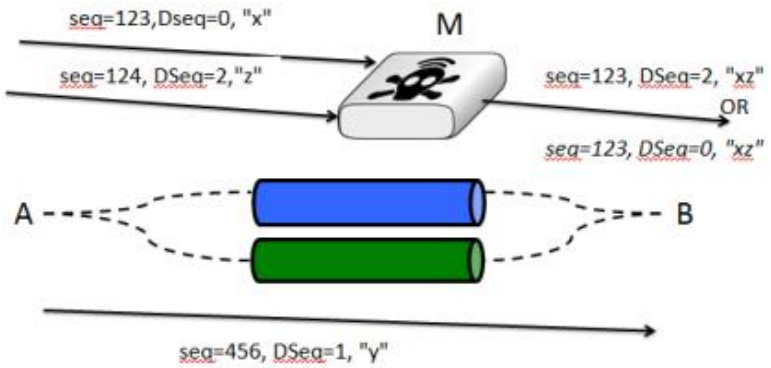

Fig. 1

Q.2. Consider the AS network topology shown in the Fig.2. For parts i) and ii), assume that if a customer has an equally good choice of providers to send outbound traffic through, the customer will pick the provider with the lowest AS number. [1.5 + 1.5 + 2 + 3 = 8]

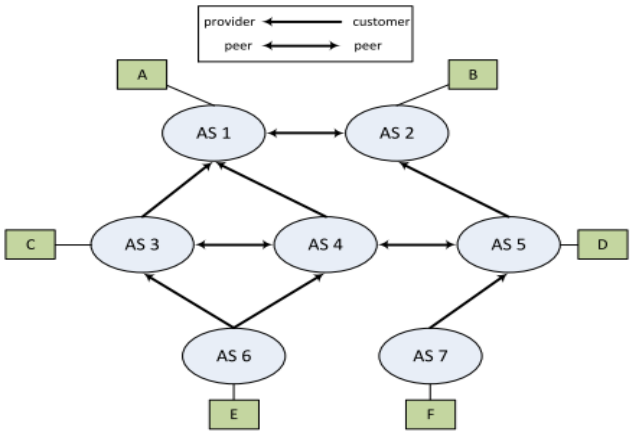

Fig. 2

i. What path would E take to reach B? Explain with reason.

ii. What path would F take to reach C? Explain with reason.

iii. Suppose AS 3 and AS 4 become engaged in a bitter corporate rivalry. AS 3 wishes to implement a policy where any of its outbound traffic will avoid traversing AS 4. How it can be achieved using BGP?

iv. Network operators typically like to equalize the amount of traffic coming from multiple providers. Suppose AS 6 owns prefix 123.4.0.0/16, and all IP addresses in this prefix receive approximately the same amount of traffic. AS 6 have two options for announcing this prefix. In the first option, AS 6 sends the same announcement to both AS 3 and AS 4. In the second option, AS 6 announces 123.4.0.0/17 to AS 3 and 123.4.128.0/17 to AS 4. Discuss the pros and cons of both approaches.

Q.3 Two flows F1 and F2 are sharing a common bottleneck link of capacity C (assume C= 10Mbps). The round trip time of F1 is 0.2 sec and that of F2 is 0.3 sec. Let r1 and r2 denote the rates obtained by the two flows, respectively.
The hosts use AIMD to regulate their flows in the following manner:
As long as r1 + r2 < C, the window of a flow increases by one packet every round trip time.
As soon as r1 + r2 > C, the hosts reduce their rates r1 and r2 by the factor of 0.1

(a) Draw the evolution of the r1 and r2 (i.e. bandwidth share of flows) over time using two phase plot.

(b) Calculate the approximate values of steady state rates r1 and r2. [4 + 2 = 6]

Q.4 (a) In Snoop protocol, Base Station (BS) protects TCP sender (Fixed Host) from wireless losses by dropping duplicate ACKs and performs link layer retransmissions locally.

(i) Write any two drawbacks of the Snoop protocol.

(ii) Suggest appropriate modifications in Snoop protocol to overcome the drawbacks mentioned by you. Also mention the drawbacks of suggested approaches, if any.

Q.4 (b) Assume a wireless user is connected to the Internet via an access point which runs a Web proxy.
Explain why this may improve Web performance for the wireless user, even if the cache miss rate is 100%. [5 + 2 = 7]

Q.5. Give a comparative performance analysis of the following queuing algorithms for providing protection against non-cooperative flows (i.e. the flows which do not obey congestion control signals/rules). [5]
(i) FQ (ii) CSFQ (iii) RED

Q.6. Answer the following questions.

(a) Argue on the soundness of the following statement: "Open flow based SDN decouples data and control plane and provides hardware independent network control".

(b) The domain name system is a directory service mapping hierarchical, human-readable names to IP addresses. Traditionally, the DNS is a hierarchical system. Let us consider an alternative design based on DHT called as Chord-DNS.

Let's assume you want to implement Chord-DNS to store 2^{32} records on 1024 servers spread around the world. Explain briefly how you would implement Chord-DNS? In particular, your answer must cover the following aspects:

i. What would be the keys?
ii. What would be the values?
iii. How would you decide where to place the (key, value) objects?
iv. What is the average number of records a server needs to store?

(c) Do overlay networks violate the end-to-end principle? Comment on this. If you conclude that they do violate the end-to-end principle, what does this imply for their eventual impact in the Internet? If you conclude that they do not violate the end-to-end principle, explain why not. (Note: Deliberate end to end principle at packet level as well at application level)

Does a content distribution network such as Akamai, which creates a large infrastructure that sits "between" an end user and an origin server, violate the end-end principle?

[4 + 4 + 4 = 12]

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Birla Institute of Technology & Science, Pilani
Work-Integrated Learning Programmes Division
Second Semester 2017-2018
Comprehensive Examination (EC-3 Regular)

Course No.	: CS ZG525
Course Title	: ADVANCED COMPUTER NETWORKS
Nature of Exam	: Open Book
Weightage	: 45%
Duration	: 3 Hours
Date of Exam	: 21/04/2018 (AN)

No. of Pages = 2
No. of Questions = 4

Note:
1. Please follow all the *Instructions to Candidates* given on the cover page of the answer book.
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Q.1. Answer the following questions?

(a) Why does Data Center TCP (DCTCP) use instant queue length of the switch instead of average queue length to mark congestion bit in the packets?

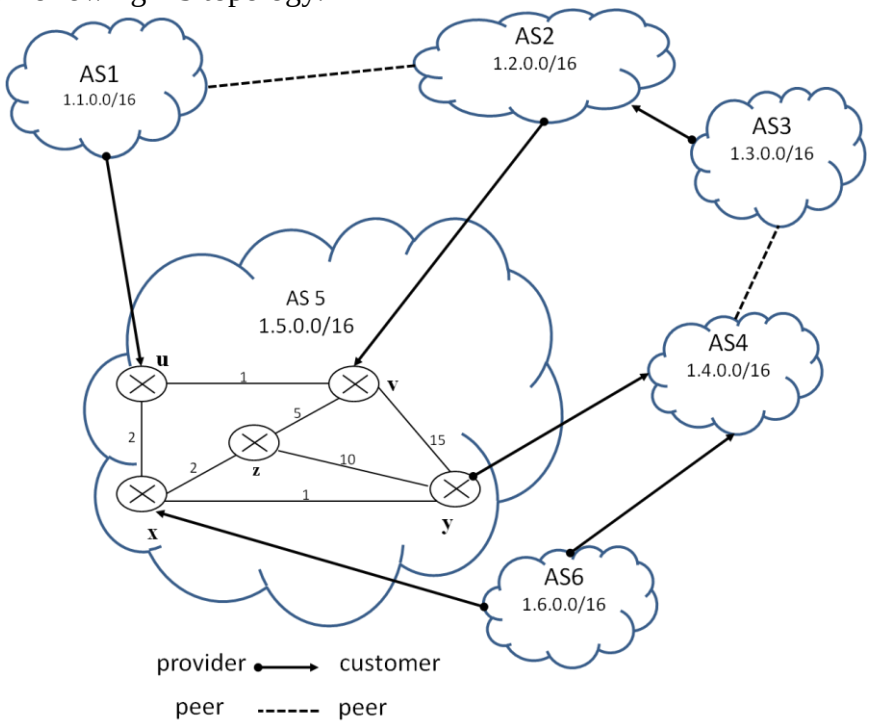
(b) Why can't Multipath TCP use ip and port number of the first TCP connection to tie all subflows together?

(c) "Multipath TCP requires existing applications to be re-written". State true or false with justification.

(d) "Multipath TCP is made of multiple TCP connections". State true or false with justification

(e) "Incast problem can be solved by adjusting parameters in TCP Reno". State true or false with justification. [3 + 3 + 2 + 2 + 2 =12]

Q.2. Consider following AS topology.



(a) Identify the BGP route advertisements (prefix, AS-PATH) received by router u, router v, and router *y*. Which of these advertisements will be exported by AS 5 and to whom?
(b) For each prefix received by AS5, assign local_pref values to the route advertisements in order to enforce business relationships.
(c) If AS4 wants to receive all its traffic through AS5, keeping link with AS6 as backup link, which of the following techniques it can use to make it happen? List limitations if any for each.
 (i) AS-PATH manipulation
 (ii) Community attribute
 (iii) Local preference

(d) For AS5, identify the iBGP and eBGP connections on its routers.
(e) Of the following paths which are valley-free paths? Write justification for each answer.
 i. AS6-AS5-AS2-AS1
 ii. AS5-AS4-AS3-AS2-AS1

[6 + 3 + 6 + 3 + 2 = 20]

Q.3. Answer the following questions briefly.
(a) Within an autonomous system, why is it stated that an advertisement received through iBGP session can't be advertised on another iBGP session?
(b) Explain an attack on BGP which RPKI will not be able to stop? How can BGPSEC stop such an attack?
(c) How SDN controller can put a limit on bandwidth used by a flow using OpenFlow?

[2 + 3 + 2 = 7]

Q.4. Explain how does VL2 architecture use the following to achieve its goals? . *[For MTech (Computing Systems & Infrastructure)]*
(a) Link-state routing
(b) Equal-cost multi-path(ECMP) forwarding
(c) IP Anycasting

[6]

OR

Explain the following in the context of CDNs. *[For MTech (SW Engg) / MTech (SW Systems)]*
(a) How is Proxy level caching different from CDN?
(b) How does design of Akamai CDN differ from that of Lime Light?
(c) What is the role of CNAME DNS records in CDNs?

[6]

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Birla Institute of Technology & Science, Pilani
Work Integrated Learning Programmes Division
First Semester 2018-2019
Comprehensive Examination (EC-3 Regular)

Course No.	:	CS ZG525
Course Title	:	Advanced Computer Networks
Nature of Exam	:	Open Book
Weightage	:	45%
Duration	:	3 Hours
Date of Exam	:	24/11/2018 (AN)

No. of Pages = 1
No. of Questions = 3

Note to Students:
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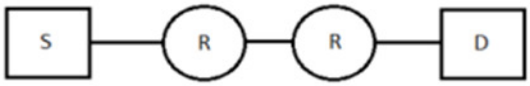
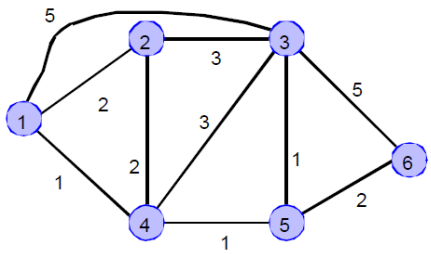
Q.1 (a) Assume that source S and destination D are connected through two intermediate routers labeled R (shown in the figure below). Determine how many times each packet has to visit the network layer and the data link layer during a transmission from S to D. [5]



Q.1 (b) Assume node 1(as shown in the figure below) has obtained the entire network topology using some link state routing protocol Construct the routing table at node 1 using Dijkstra's algorithm to determine shortest paths from node 1 to all other nodes in the network. [10]

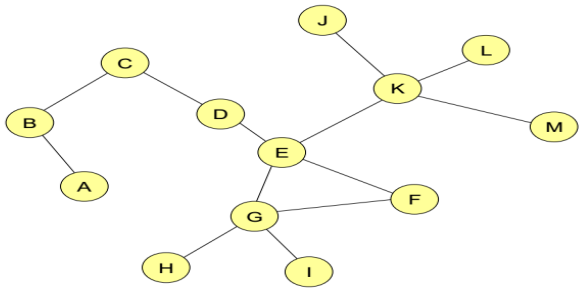


Q.1 (c) What is ProgrammableFlow? What are the main advantages of ProgrammableFlow? [5]

Q.2. Briefly explain the Zone Routing Protocol (ZRP) for advanced routing. [10]

Q.3 (a) What are the differences between dynamic-routing mobility and session location mobility? [5]

Q.3 (b) Given is an ad-hoc network which has initially the following topology (as shown in the figure below):



Connected nodes are in transmission range and can forward messages along the edges. For routing, DSR should be used. The caches of all nodes are empty. Now, D wants to send some packets to H. Give the sequence of messages exchanged for finding a path (also the "unnecessary" messages). For each message, describe sender, receiver, and the list of used nodes as written in the header by the routing protocol. Assume that the paths are symmetrical. What happens if the connection between E and G breaks down? [7 + 3 = 10]

Birla Institute of Technology & Science, Pilani
Work-Integrated Learning Programmes Division
Second Semester 2018-2019
Comprehensive Examination (EC-3 Regular)

Course No.	: CSI ZG525
Course Title	: ADVANCED COMPUTER NETWORKS
Nature of Exam	: Open Book
Weightage	: 45%
Duration	: 3 Hours
Date of Exam	: 03/05/2019 (FN)

No. of Pages = 2
No. of Questions = 5

Note:
1. Please follow all the *Instructions to Candidates* given on the cover page of the answer book.
2. All parts of a question should be answered consecutively. Each answer should start from a fresh page.
3. Assumptions made if any, should be stated clearly at the beginning of your answer.

Q.1. Design a communication network for smart automotive (e.g. cars) that can support following function/application:

- Support 'on-demand' download of digital content to vehicles (e.g. digital help manuals, movies/videos, audio streaming, etc) from remote cloud-hosted application servers. The downloaded digital content can then be used/seen by driver/passengers using 'in-vehicle' multimedia devices (e.g. display units, speakers etc).

The solution proposed MUST cover following aspects of network design:

1.1. What **networking** equipment is required to enable such a network? Show a diagram of the end-to-end network, including the key solution components

1.2. How would information routing/ forwarding be performed in such a dynamic network where vehicles are constantly on the move? Consider both uplink (vehicle to server) and downlink (server to vehicle) traffic.

1.3. How can QoS be maintained for different types of application traffic (e.g. help manual download vs video streaming)?

1.4. How can load balancing be done on remote application servers so that overall latency can be maintained in terms of server response time as well as network transmission delay be minimized? [12]

Q.2. "*In a network where pre-scheduled bandwidth allocation / resource reservation / admission control is done, policing (or traffic shaping) has no role*".

Justify or refute the statement with reasons. [8]

Q.3. An organization has an existing communication network that is setup as a wired fixed infrastructure network. However, to allow greater mobility to its employees when roaming within the office premise, the organization wishes to migrate to using wireless communication/ networking in the last mile (i.e employee devices to support wireless communication and connect to enterprise networking equipment over wireless links).

3.1. Which layers of the OSI reference model shall undergo impact due to this change from wired to wireless in last mile connectivity?

3.2. How will the protocols get modified for the impacted layers?

3.3. What are the key reasons/ factors driving these protocol changes? What are the problems if the existing wired network protocols are used without change? [12]

Q.4. With the help of suitable diagram(s), explain how SDN and NFV technologies are impacting the design of modern-day Data Center Networks enabling more efficient cloud platforms for running server-side applications. [8]

Q.5. For a point-to-point link of length 20 km, at what value of link throughput (in Mbps or *Megabits-per-sec*) would the link propagation delay (at a speed of 2×10^8 m/sec) equal the transmit delay for 100-byte packets? Will this computation change if the point-to-point link were a wireless link instead of a wired link, all other values/factors remaining the same? [5]

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Birla Institute of Technology & Science, Pilani
Work-Integrated Learning Programmes Division
Second Semester 2018-2019

Comprehensive Examination
(EC-3 Make-up)

Course No.	: CSI ZG525
Course Title	: ADVANCED COMPUTER NETWORKS
Nature of Exam	: Open Book
Weightage	: 45%
Duration	: 3 Hours
Date of Exam	: 10/05/2019 (FN)

No. of Pages = 2
No. of Questions = 6

Note:
1. Please follow all the *Instructions to Candidates* given on the cover page of the answer book.
2. All parts of a question should be answered consecutively. Each answer should start from a fresh page.
3. Assumptions made if any, should be stated clearly at the beginning of your answer.

Q.1. Design a communication network connecting smart utility meters (electricity meters, water meters and gas meters) that can support following function/application:

- Support 'on-demand' reading of consumption information recorded at meter (e.g. kilo-liters of water consumed, electricity units consumed etc) from remote cloud-hosted application servers.
- Support Over-The-Air (OTA) upgrade of utility meter firmware/software from cloud-servers.
- Support remote control of meters from cloud-based application servers e.g. remote disconnection of supply, etc

The solution proposed MUST cover following aspects of network design:

1.1. What **networking** equipment is required to enable such a network? Show a diagram of the end-to-end network, including the key solution components

1.2. How would information routing/ forwarding be performed in such a network where certain utility meters could be far-off from any infrastructure node? How can mesh networking help solve reachability/connectivity to such remote meters?

1.3. How can QoS be maintained within the network for different types of application traffic (e.g. control command vs OTA firmware/software upgrade traffic)?

1.4. Since every residential unit (or home) has at least one meter deployed (e.g. electricity, water or gas), how can such a network help remotely control other appliances at home (e.g. a networked coffee machine, or a WiFi-enabled Air Conditioner)? [Hint: Think of meter as a home gateway for other appliances]. [12]

Q.2. "*Constant Bit Rate (CBR) traffic in a packet-switched network is same as having TDM channels in a circuit-switched network*".

Justify or refute the statement with reasons. [8]

Q.3. An organization in the business of delivering digital content (e.g. video-on-demand, songs-on demand etc) has their content server setup in Pittsburgh, USA. Lately, the organization is facing severe criticism from its customers, since the latency in serving to customer requests has increased beyond acceptable levels. Also, the digital content download latency has increased beyond limits, impacting user experience. In what way would you recommend this organization to re-design their network so as to meet customer expectations? [6]

Q.4. An organization having their head-office in Chennai, India has a lot of employees in their Sales Team who are always travelling. These employees frequently need to access corporate information available on head-office enterprise servers.

4.1 Design a secure access network for such employees to connect to their head-office and access information just like they would if they were physically located at the head-office.

4.2 Further, since all sales employees connect using wireless networks (e.g. using cellular modems / data cards), what changes are required to the transport layer of the networking stack to enable higher performance, instead of simply relying on TCP? [6]

Q.5. "*SDN technology cannot exist in the absence of NFV technology, and vice-versa*"

Justify or refute this statement with reasons for your answer. [8]

Q.6. On a link with 1.5 Mbps (*Mega-bits per sec*) bandwidth, what will be the total time required to transmit a file of 1500 KB (*Kilo-Bytes*) in below scenario:

- Each packet carries 1 KB of data, and
- Round Trip Time (RTT) is 25 ms, and
- A wait time of 1 RTT is required after sending each packet and before the next packet can be sent.
- Every alternate packet needs to be sent twice for successful transmission (i.e. every alternate packet that is transmitted is required to be re-transmitted due to loss or errors in the network.) [5]

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