Q1 (10 points).

(a) (**True** / False)

(b) (**True** / False)

(c) (True / **False**)

(d) (True / **False**)

(e) (**True** / False)

(f) (True / **False**)

(g) (True / **False**)

(h) (**True** / False)

(i) (**True** / False)

(j) (**True** / False)

Q2 (5 points).

*(a) Consider a request for a connection is sent from A to B. B receives the request and acknowledges the connection. If the B to A packet gets lost on the way **(1 point)**, A never knows that B accepted the connection **(1 point)**, and B remains with a half-open connection **(1 point)**.*
*(b) Three-way handshake adds one more acknowledgement round. Therefore, if A does not receive the acknowledgement, there will not be a connection as B also waits for another acknowledgement to actually establish the connection **(1 point)**.*
*(c) TCP **(1 point)***

Q3 (5 points).

*(a) It sits as a local server. Receives the content requested by clients from original servers, caches the contents in a local storage when responded by original server to the local client **(1 point)**. In following requests, it responds to the requests to the same resource using the local copy and does not send the request to the original server if the resource is previously cached and locally available (Satisfy the client request without contacting the original server) **(1 point).***

*(b) **Improving Performance:** It can save the repeatedly requested content, removing the need to request it from the source server again and again.*

***Eavesdropping/Monitoring:** Proxy is sitting in between the communication, receiving at one side and sending to the other side. It knows the requested and returned resource.*

***Content Control:** Proxy is sitting in between the communication, receiving at one side and sending to the other side. It can block the unwanted content when responding to the client.*
***Bypassing a filter**: E.g. in case a client is filtered, a filter can be bypassed using the proxy server as the proxy has a different address.*

Any three out of the four above is ok ***(each 1 point)***.

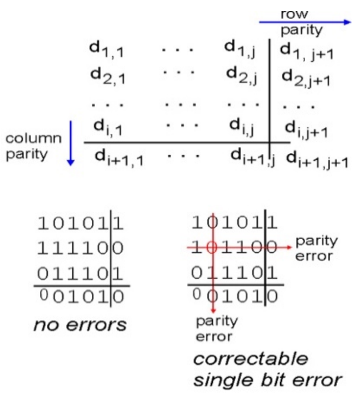
Q4 (5 points).

(a) Content distribution networks are networks used to bring the servers hosting the contents (e.g. multimedia, steaming resources) closer to the users. They are needed to solve the load-balancing the servers, as well as not jamming the core of the network. ***(1 point)***

(b) ***CDN****: Enter deep – Access ISPs* ***(2 points)*** *and bring home - IXPs* ***(2 points)***

Q5 (5 points).

(a) for a given number of bits, the number of ones should be either even (Even parity) or odd (odd parity). We have a parity bit, and if this condition does not hold, a one is added so that it can hold with the parity bit together with the given bits. ***(1 point)***



(b) When we put together same length tokens, party checking could be done horizontally (on same token of the bits) and vertically (on same index on put together tokens). ***(1 point)***

(c) Yes, A bit flip will cause a parity check fail on a row and a column, put together they give the location of the flip ***(2 points)***

Yes, 2x2 square bit flip ***(1 point)***

Q6 (10 points).

(a) Lost packets and long delays caused by more packets than what could be handled by the buffers of the routers sent to the core of the network at the same time. ***(1 point)***
(b) No perfect knowledge about loss and state of the network. ***(1 point)***
(c) TCP Congestion Control: AIMD ***(1 point)***
*Slow start (cwnd=1, beginning or after timeout, cwnd=cwnd+MSS until reach ssthresh)****(3 points)***
*Congestion avoidance (cwnd=cwnd+MSS. MSS/cwnd until triple duplicate acks or timeout)****(2 points)***
Fast recovery (start from ssthresh=cwnd/2, cwnd=cwnd+MSS until reach ssthresh or timeout) ***(2 points)***

Q7 (10 points).

(a) Intra-AS routing*: Routing among hosts and routers in the same AS (network)*
All routers in AS must run ***same*** *intra-domain protocol*
Routers in ***different*** *AS can run* ***different*** *intra-domain routing protocol*
Gateway router: At ***edge*** *of its own AS, has link(s) to router(s) in other ASes*

Inter - AS routing*: Routing among ASes. Gateways perform inter-domain routing (as well as intra-domain routing)*

Policy: (1 point)
Inter-AS: Admin wants control over how its traffic routed, who routes through its net
Intra-AS: Single admin, so no policy decisions needed

Scale: (1 point)
Hierarchical routing saves table size, reduced update traffic. Inter-AS is still in a scale to be able to handle LS. Intra-AS can focus on policy.

Performance: (1 point)
Intra-AS: Can focus on performance
Inter-AS: Policy may dominate over performance

Intera-AS: OSPF (1 point)

Inter-AS: BGP (1 point)

(b) *Implementing Control Plane functionalities in a central location instead of per-router control.* ***(1 point)***
Incentive*: Traffic Engineering (flow flexibility), easier configuration* ***(1 point)***

Protocol: *Open Flow. Between SDN Controller and Switches to configure, get information to controller from the switch, or occasionally send packets out from control plane.* ***(1 point)***

Q8 (15 points).

(a) Carrier Sense Multiple Access:*, listens before transmit* ***(1 point)***
If channel sensed idle: *transmit entire frame* ***(1 point)***
If channel sensed busy, *defer transmission* ***(1 point)***
Human analogy: do not interrupt others
It is a Random-Access shared medium MAC Protocol ***(2 points)*** *. In Link Layer* ***(1 point)***

(b) Collision: *Multiple sources start sending on the same shared medium on the same time. Random Access Protocols on shared mediums do not have timing, or other pre-defined specific allocation for sharing mechanisms* ***(1 point)****. They attempt to gain access to the medium when it is not in use. If it is attempted to be used by another source at the same time, collision happens.* ***(1 point)***

(c) *In CSMA/CD, if NIC senses channel idle, starts frame transmission. If NIC senses channel busy, waits until channel idle, then transmits. If NIC detects another transmission while transmitting, aborts and sends jam signal. After aborting, NIC enters* ***binary (exponential) backoff*** *which means after mth collision, chooses a number K at random from $\{0,..., 2^m-1\}$ waits $K\cdot 512$ bit times, returns to sensing the channel and attempting again.* ***(2 points)***

(d) Either:
In context of Random Access: *Slotted Aloha, and Pure Aloha* ***(2 points)****. Pure Aloha has lower efficiency due to start not scheduled in the beginning of the slot and collision can happen in more occasions* ***(2 points).*** *In general lower efficiency to CSMA, due to no sensing in the channel* ***(1 point).***

In General Shared Access: *Partitioning (TDMA, and FDMA)* ***(1 point)*** *and Taking Turn protocols****(1 point)****. Partitioning protocols are efficient and high throughput at high loads, but inefficient in low loads.* ***(2 point)*** *Taking Turn protocols have the best of the two worlds (from Partitioning and Random Access), but they need mechanisms to implement the turn* ***(1 point).***

Q9 (15 points).

(a) ***Packet Switching:*** *Hosts break messages into packets. Packets go from one router to the next (store and forward) across links on path from source to destination. Each packet transmitted* ***at full link capacity****. Important Functionalities:* ***Routing*** *and* ***Forwarding****.* ***(3 points)***

(b) ***Circuit Switching****: End to end resources reserved and allocated between source and destination. Two important ways to implement for communication resources:*

TDM: Time-Division Multiplexing

FDM: Frequency-Division Multiplexing

If nothing to send, channel idle, no one else can use ***(3 points)***

(c)Packet Switching*: Internet.* ***(1 point)*** *Unpredictable variable rate usage.* ***(1 point)***

(d) Circuit Switching*: Home Telephony* ***(1 point)****. Predictable, full rate, or CBT traffic.* ***(1 point)***

(e) *10000*

(f)

$$\sum_{n=N+1}^{M} \binom{M}{n} p^n (1-p)^{M-n}$$

Q10 (20 points).

(a) Either the pseudo code or detailed explanation.

Initiation ***(2 points)****, Definition of Cost* ***(1 point),*** *Definition of Algorithm Step* ***(2 points)***
*Definition of D****(1 point)***

M = {s}
for each *n* **in** *N − {s}*
 if n adjacent to s, D(n)=Cost(s,n) otherwise D(n)= ∞

while *(N != M)*
 M = M ∪ {w} **such that** ***D****(w)* **is the minimum for all** *w* **in** *(N − M)*
 for each *n* **in** *(N − M)*
  D(n) = MIN(D(n), D(w) + Cost(w,n))

(b) Link State ***(1 point)***

(c) Control Plane ***(1 point)***

(d) Could be used in either centralized or traditional ***(1 point)***

	D(u),p(u)	D(v),p(v)	D(w),p(w)	D(x),p(x)	D(y),p(y)	D(z),p(z)
u	-	9,u	9,u	9,u	infty	infty
u v	-	-	9,u	9,u	infty	infty
u v w	-	-	-	9,u	18,w	15,w
u v w x	-	-	-	-	18,w	15,w
u v w x z	-	-	-	-	17,z	-
u v w x z y	-	-	-	-	-	-

The links in the least cost routing tree from node u to all destinations are: u-to-v, u-to-w, u-to-x, z-to-y, w-to-z.