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COMP 4320: Assignment (1)

**Problem 1.**

Imagine you are tasked with designing a new communication network for a mid-sized city. Using your understanding of packet-switching and circuit-switching, access networks (DSL, cable, fiber, etc.), and the Internet's structure as a "network of networks," answer the following questions:

1. **Describe your approach to designing the communication network for this mid-size city.**

The network will most importantly depend on packet-switching. This allows for greater efficiency and scalability. It can support services such as voice, video, and data. This is better for the city compared to circuit-switching because it allows for sharing and does not require the entire path to be used which frees up more space and resources to use. There needs to be multiple pathways for data transmission to enhance reliability and fault tolerance. Internet Protocol (IP) based routing would create communication that is flawless throughout the city. Also, network monitoring and automation tools would be used to discover issues ahead of time to ensure no issues to the network.

Residential users would have access to fiber. In more remote areas and places where fiber is expensive cable could be introduced. Finally, in businesses there can be distinct fiber links with Ethernet-based connections which creates stable and secure connectivity for business operations.

The core network structure would consist of multiple interconnected data centers, central offices, and Internet Exchange Points. By placing servers in high traffic places this allows for a result. Backup routes and failover systems would be integrated to strengthen network reliability and ensure uninterrupted service in case of disruptions.

1. **Discuss how you would ensure efficient data transmission while minimizing delays and packet losses.**

To make sure that both fair and efficient use of networking resources, bandwidth would allocate based on different user needs and traffic types. Residential users will have flexible speeds that allows for multiple needs such as streaming, gaming, and basic browsing. Business users will get designated bandwidth to support critical applications such as online tools and video conferencing. Overall, important activities such as video calls and emergency communication will be given priority to avoid delays to important uses. Actions like downloading a large file are pushed back in line and given a lower priority.

In order to have high performance and affordability it includes delicate planning. Fiber-optic connections are shown to offer the fastest and most reliable service, but they are expensive to install most importantly is pricier in more rural areas. The solution is to create a combination of fiber, cable, and wireless solutions. Fiber will serve the high populated areas and wireless or cable connectivity will be provided in suburban and rural areas. Also, you can store frequently used content closer to the users will help prevent delays and allow for a faster speed.

1. **Explain how you would design the network to provide both reliable Internet access for residential and business users.**

A fiber-optic makeup with multiple pathways would make sure that services run continuous by rerouting traffic in case of failures. There must be backup power sources available to not allow for outages. These backup power sources can be generators to keep the network structure running smooth. High populated businesses can have certain backup connections like secondary fiber lines and wireless failover options. There also has to be management that priorities services like video conferencing and business uses to precent congestion.

As discussed earlier, fiber provides the best speed and reliability, but it comes at a higher cost. Implementing a cable network in less populated areas allows it to serve a larger group of people at a lower cost. For example, one neighborhood junction can support up to 5,000 homes. Additionally, wide-area cellular access networks can be deployed across the city to reach a larger number of people, and this can be complemented with wireless local area networks (Wi-Fi). For businesses, dedicated fiber connections are essential to guarantee high speeds and consistent performance. For companies requiring even higher performance, private network solutions can be implemented, with the flexibility to add additional bandwidth as are needed.

**Problem 2.**

Imagine you are building a large-scale video streaming platform (e.g., similar to YouTube or Netflix) that serves millions of users worldwide. Using your understanding of throughput, bottlenecks, protocol layering, application-layer protocols, and security considerations, answer the following:

1. **Describe how you would design the network to maximize throughput and minimize bottlenecks. (e.g., Throughput Management, Bottleneck Mitigation, and Caching) (one paragraph)**

One way to ensure high throughput and minimize bottlenecks is to implement Content Delivery Network (CDN) with globally distributed edge servers to cache and serve video content closer to users. This is an essential way to help stop congestion. The main part of the video streaming infrastructure will include bandwidth fiber-optic connections. To help stop buffering the platform will adjust the video quality based on the user's connection.

1. **Identify the key requirements for the application-layer protocol you would use. Discuss how you would implement features like persistent connections, adaptive streaming, session management (e.g., cookies), and data compression to optimize the user experience. (one paragraph)**

The streaming platform uses a protocol that uses both TCP and UDP. This makes sure that there is low latency and that the content will make it to the user. UDP is used for real-time, low-latency playback, while TCP will be in use when there is buffering or error connections. These persistent connections are in place to prevent handshake overhead and slow loading times. In order for the streaming session to be saved and transferred easily the use of cookies will be put in place.

1. **Reflect on the trade-offs between performance and scalability in your design. Discuss the challenges of balancing these factors and propose strategies to address them effectively. (one paragraph)**

It is difficult to balance performance and scalability when increasing a server capacity for high-speed performance. This is because it is extremely pricey to do. Another issue is keeping low latency while dealing with a large number of users at the same time. To fix this issue there can be on premises data centers for places that are highly populated. The servers being placed in populated areas help to keep the video content close to the user.

**Problem 3.**

Calculate the total time required to transfer a 1000-KB file in the following cases, assuming an RTT of 50 ms, a packet size of 1 KB data, and an initial 2×RTT of “handshaking” before data is sent. We define the total time of transferring the file as the time elapsed from the start of initial handshaking to the instant when the last bit arrives at the receiver. (Please include both the calculation process and a corresponding diagram to demonstrate your understanding; Not including the diagram will result in a deduction of 30% of the points.)

1. **The bandwidth is 5 Mbps, and data packets can be sent continuously.**

Bandwidth = 5 Mbps = 5,000,000 bits per second

Packet size = 1 KB = 8,000 bits

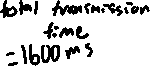
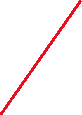
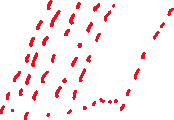
Transmission time per packet = Packet size/bandwidth = 8,000 bits/5,000,000 bit/sec = 0.0016 sec = 1.6 ms

Total number of packets = 1000 KB /1KB = 1,000 packets

Total transmission time = 1000 x 1.6 ms = 1600 ms

Total time = Initial handshaking time + total transmission time

100ms + 1600ms = 1700ms = 1.7sec



1. **The bandwidth is 1.5 Mbps, but after we finish sending each data packet we must wait one RTT before sending the next.**

Bandwidth = 1.5 Mbps = 1,500,000 bits per second

Packet size = 1 KB = 8,000 bits

Transmission time per packet = 8,000 bits/1,500,000 bit/sec = 2/375 sec = 16/3 ms

Total number of packets = 1000 KB/1KB = 1000 packets

Time to send all packets = 1000 x (16/3ms + 50ms(RTT)) = 166,000/3ms

Total time = initial handshaking time + time to send all packets = 100ms +166,000/3ms = 166,300/3ms » 55,433.33ms = 55.43sec



1. **The bandwidth is “infinite,” meaning that we take transmission time to be zero, and up to 20 packets can be sent per RTT.**

Transmission time = 0ms

20 packets/1 RTT

Total number of packets = 1000 KB/1KB = 1,000 packets

Number of RTTs required = 1,000 packets/20 packets/RTT = 50 RTT

Total time = handshake time + Number of RTTs required X RTT = 100ms + 50 x 50ms = 100ms + 2500ms = 2600ms = 2.6sec



1. **The bandwidth is infinite, and during the first RTT we can send one packet (21-1), during the second RTT we can send two packets (22-1), during the third we can send four (23-1), and so on.**

Transmission time = 0ms

Packets sent per RTT = 1st RTT 1 packet, 2nd RTT 2 packets, 3rd RTT 4 packets,…

Total number of packets = 1000 KB/1KB = 1000 packets

Total number of packets sent after n RTTS = 2n-1

|  |  |  |
| --- | --- | --- |
| RTT | Packets Sent | Total Packets Sent |
| 1 | 21-1=1 | 0+1=1 |
| 2 | 22-1=2 | 1+2=3 |
| 3 | 23-1=4 | 3+4=7 |
| 4 | 24-1=8 | 7+8=15 |
| 5 | 25-1=16 | 15+16=31 |
| 6 | 26-1=32 | 31+32=63 |
| 7 | 27-1=64 | 63+64=127 |
| 8 | 28-1=128 | 127+128=255 |
| 9 | 29-1=256 | 128+256=511 |
| 10 | 210-1=512 | 511+512=1023 |

Total time = initial handshake time + 10 x RTT = 100ms + 10ms x 50ms = 100ms + 500ms = 600ms = 0.6sec



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| --- | --- | --- | --- |
| Q1: 1.7sec | Q2: 55.43sec | Q3: 2.6sec | Q4: 0.6sec |

**YouTube Links:**

Question 1:

<https://youtu.be/Aze4bZGf7K0?si=h9MfqjMUNOkJCzGL>

Question 2:

<https://youtu.be/0BctO1I1AKU?si=HF9g0Qrgucvhy6Tj>

Question 3:

<https://youtu.be/z1sZGoeflSE?si=5PX5prfp8qUMM9ET>