Kate Moreland
kem0149
COMP 4320: Assignment 7

Problem 1:

Imagine you are responsible for designing a high-performance wireless communication system that ensures efficient access to the medium, reliable data transmission, and minimal interference. Using your understanding of wireless network architectures, multiple access protocols (CSMA/CA, CDMA), and wireless link characteristics, answer the following questions:

1. **Explain the key differences between infrastructure-based and ad hoc wireless networks, including their advantages and use cases. Describe how a mobile device transitions between base stations (handoff process) in infrastructure mode. Discuss how path loss, interference, and multipath propagation impact wireless link performance and propose strategies to mitigate these effects.**
   In infrastructure-based networks devices are able to talk through a central access point. It creates a much easier management style. There are better coverages and is much more scalable. The infrastructure-based network is used in Wi-Fi in homes and offices. It is also used in cellular networks and infrastructure. The ad hoc network allows for communication without a central access point. This allows for a faster deployment of the model. There is less infrastructure needed in the model. Ad hoc is used in military situations and recovery areas from disasters. The handoff process with a mobile device begins when a device is located outside of a central access point area. The device will then look for any access points around. The device will then select an access point that has a stronger signal because it is closer. It will then authenticate with it and use it. The data connection will resume with the new connection. Wireless links struggles with path loss. When there is a greater distance between connections the signal will decrease. To solve this, one can implement power control, repeaters, and antennas. The idea of interference in the signal caused by other signals are seen in wireless connections. To solve this, take use of different frequencies and interference cancellation. Lastly, reflected signals mess with direct signals. Spead-spectrum modulation can solve this issue.

2. **Compare CSMA/CA (Collision Avoidance) and CDMA (Code Division Multiple Access) in terms of collision handling, efficiency, and reliability. Explain how CSMA/CA uses RTS/CTS handshaking to reduce collisions in high-traffic environments like Wi-Fi (802.11). Given a scenario where multiple devices are contending for a wireless medium, propose an optimal medium access strategy and justify why it is the best choice.**
   CSMA/CA will avoid collision via RTS/CTS. CDMA will spread signals and will not have any traditional collisions. CSMA/CA works well with a normal amount of traffic but will struggle with a higher amount of traffic. CDMA works with high efficiency and has the ability to works with multiple users at the same time. CSMA/CA is moderately reliable with RTS/CTS. CDMA is a highly reliable implementation. The

CSMA/CA RTS/CTS handshake begins with a RTS and it is delivered to an access point. That access point will send back a CTS. When devices that are not included see the CTS will stop transmission which will help stop collisions. The optimal medium access strategy will include a hybrid implementation. There will be a use of CSMA/CA along with RTS/CTS to stop collisions. There will also be a use of backoff algorithms. In a large infrastructure there will be the idea of scheduled access including CDMA which will assist in congestion prevention.

3. **Explain how CDMA encoding and decoding work, ensuring that multiple users can communicate over the same frequency spectrum without interference. Discuss the importance of orthogonal CDMA codes in minimizing inter-user interference and how improper code selection can degrade performance. Given a scenario where multiple senders are transmitting using CDMA, analyze the received chip sequence and determine which stations were active.**
CDMA encoding with multiple users occurs by each user being assigned a spreading code that is orthogonal to others. The bits of data are spread by multiplying the code by the bits. Decoding is when the receiver multiplies the user's code and the received signal. It will them add that to the original data. Orthogonal codes help reduce the cross-talk with different users. Code that doesn't use orthogonal code can result in inter-user interference and lowers the overall performance. The scenario involves analyzing each chip sequence. To analyze them you should multiply by each code that is seen. If there is either a strong positive or a negative sum it means that the sender is active. When there is a weak or zero sum it means that the sender is inactive.

Problem 2:

Imagine you are responsible for optimizing Wi-Fi (802.11) and cellular (4G/5G) networks to ensure seamless connectivity, efficient mobility management, and high data rates. Using your understanding of Wi-Fi multiple access mechanisms, mobility management, and cellular network architecture, answer the following questions:

1. **Explain the architecture of Wi-Fi networks, including Basic Service Sets (BSS), Access Points (APs), and ad hoc mode. Discuss the passive vs. active scanning mechanisms that enable a device to associate with an access point. Given a scenario where a dense Wi-Fi deployment suffers from interference and congestion, propose an optimal channel allocation and access control strategy to minimize interference and improve performance.**
   BSS is a group of devices that use an access point to communicate. An access point is the main nod that other devices connect to. Ad hoc mode is where devices talk peer-to-peer and do not take advantage of an access point. When there is passive scanning they are trying to locate access point beacon frames. When there is active scanning the device will send out multiple probe requests and will get probe responses in return. The optimal strategy should be taking use of non-overlapping channels. They should also put into effect dynamic channel selection. Next implement band steering to change devices up to 5 GHz. Finally, put into use access point load balancing to make sure users are evenly distributed.

2. **Describe the key components of a 4G LTE network, including User Equipment (UE), eNodeB (base station), Mobility Management Entity (MME), and Packet Data Network Gateway (P-GW). Explain the handover process in 4G networks, including the role of the serving gateway (S-GW) and tunneling mechanisms. Given a scenario where a mobile device is moving between base stations while maintaining an active video call, analyze how the handover process ensures seamless connectivity without packet loss or major disruptions.**
   The UE are the end devices such as a smartphone. The eNodeB is an LTE base station that monitors any wireless communication. MME is watches user mobility and session connection. P-GW will connect any mobile network to their external IP networks. The handover process involves processes as the UE moves. The eNodeB will check the signal strength. The MME will monitor and control handover signaling. The S-GW will keep up the data path by transferring packets from old eNodeB to new eNodeB via tunneling. There will be switching without any packet loss.

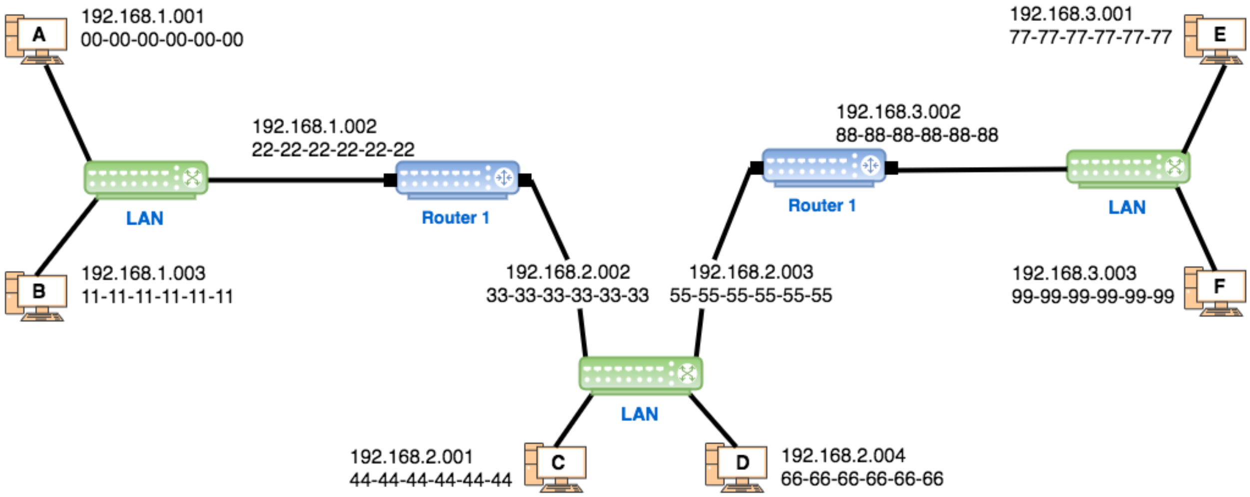
3. **Compare Wi-Fi (802.11) and 4G/5G cellular networks in terms of architecture, mobility support, and medium access mechanisms (CSMA/CA vs. scheduled**

access). Explain how 4G/5G cellular networks handle congestion differently from Wi-Fi and why cellular networks are better suited for large-scale, high-density deployments. Given a scenario where a smart city requires ubiquitous high-speed wireless connectivity, propose a hybrid networking solution that integrates both Wi-Fi and 5G to balance cost, coverage, and performance.

The architecture of Wi-Fi is very decentralized due to multiple access points, but 4G/5G cellular is centralized by base stations and cores. The mobility support of Wi-Fi is restricted due to the access point handoffs, but 4G/5G is protected due to resources. The medium access of Wi-Fi is CSMA/CA and for 4G/5G cellular takes used of scheduled access. Wi-Fi takes use of reactive congestion handling and the 4G/5G cellular is proactive and uses QoS. Wi-Fi has a lower end density suitability. 4G/5G cellular takes use of high-density. For congestion handling, Wi-Fi will have devices move back and redo whenever a collision happens. The network takes over access scheduling which helps lower collisions and makes sure of QoS for 4G/5G. The solution for the smart city should take advantage of 5G which will ensure that the whole city is covered. While, 5G is very expensive it has amazing coverage. For small indoor spaces they should use Wi-Fi 6 which will create a high-capacity access hotspot for a small localized area. The Wi-Fi 6 will assist in lowering the cost since it is much cheaper. In order to move between Wi-Fi and 5G they should use Hotspot 2.0 and network slicing.

Problem 3:

Consider three LANs interconnected by two routers as shown in the Figure.



1. **Consider sending an IP datagram from host E to Host B. Suppose all of the ARP tables are up-to-date. Enumerate all the steps, as done for the single router example in section 6.4.1.**

   Host E will check its routing table. Since destination IP (192.168.1.003) is not on the same network there must be packets sent to its default gateway (Router 2). Host E discovers the MAC address of Router 2 in the ARP table. Host E will encapsulate the IP datagram: Source IP: IP_E, Destination IP: IP_B, Source MAC: MAC_E, Destination MAC: MAC_Router2_E_LAN. Host E will send the frames to Router 2.

   Router 2 will then receive the frame. It then decapsulates the Ethernet frame and glances at the IP datagram. Router 2 will check the routing table so Destination IP (IP_B) is with LAN of Router 1. Router 2 will then send the datagram to Router 1. Router 2 encapsulates the IP datagram: Source IP: IP_E, Destination IP: IP_B, Source MAC: MAC_Router2_Router1_LAN, Destination MAC: MAC_Router1_Router2_LAN. The Router 2 will then send out the frame to Router 1.

   Router 1 gets the frame from Router 2. It will decapsulate the Ethernet frame and looks at the IP datagram. Router 1 will check the routing table to see that Destination IP (IP_B) is located in LAN where Host B is. Router 1 discovers Host B's MAC address in Router 1's ARP table. Router 1 encapsulates the IP datagram: Source IP: IP_E, Destination IP: IP_B, Source MAC: MAC_Router1_B_LAN, Destination MAC: MAC_B. Router 1 then sends the frame to Host B.

   Finally, Host B will get the frame. It will extract the IP datagram and turn it to the IP layer. Then the delivery is done.

2. **Now repeat the previous steps assuming that the ARP table in the sending host is empty and the other tables are up to date.**

   Starting at Host E, it will check its ARP table and since it is empty it is unable to discover Router 2's MAC address. Host E will send out an ARP request: "Who has IP_Router2_E_LAN? Tell IP_E.". Router 2 will send back an ARP reply: "IP_Router2_E_LAN is at MAC_Router2_E_LAN. Host E will then update its own ARP table. Then the rest of the steps from above occur.

YouTube Videos:

Problem 1: https://youtu.be/z3UwaQtxygY

Problem 2: https://youtu.be/DJmjlfFATSc

Problem 3: https://youtu.be/lg3VnNWKE7k