COMP 445 Final Review

Chapter 1,2,3: Intro, Application, Transport

- Chapter 1: What is the Internet
  - Switching: Circuit, Message, Packet
  - Delay: processing + queuing + transmission + propagation delay
  - OSI Model, TCP/IP Reference Model, Encapsulation
- Chapter 2: Application Layer
  - Client-Server, P2P
  - Service Requirements (TCP vs UDP, loss, latency, bandwidth)
  - HTTP, SMTP, DNS (records and lookups), and a bunch of others
  - Socket programming (listen, connect, accept, send, recv, bind, sendto, recvfrom)
- Chapter 3: Transport Layer
  - Multiplexing, UDP (checksums)
  - Reliable Data Transfer (corruption, loss, duplicates, out of order, pipelining)
  - Congestion Control (Saturated Links lead to lost packets)
  - TCP (SYN/ACK, FIN/ACK, Flow Control, Congestion Control, Fairness)

Chapter 4: Network Layer (Data Plane)

- Move data between hosts via routers, exists on every hop
  - Data Plane handles forwarding, Control Plane handles routing
  - Service Models (bandwidth, loss, order, timing, congestion feedback)
- What's inside a router?
  - Processor
  - Input and Output ports
    - Line termination, Link Layer protocols, Queue
  - High-speed switching fabric
    - Memory, Bus, Crossbar
- Destination Based Forwarding
  - Longest Prefix Matching
- Scheduling: FIFO, Priority, Round Robin, Weighted Fair Queueing

Chapter 4: Network Layer (Data Plane)

- IPv4 (fields: TTL, protocol, source & destination addresses…)
  - Fragmentation & MTU
  - Addresses, Subnets and CIDR: 192.0.2.7/28 (255.255.255.240)
  - 11000000 00000000 00000010 00000111
- DHCP: Dynamic Host Configuration Protocol (for IP Address, Subnet, Default Router, Local DNS Server)
- NAT: Network Address Translation (Private IP addresses)
- IPv6 (longer addresses, fewer fields)
- OpenFlow and Generalized Forwarding
  - Rule, Action, Stats
  - Forward, Capture, Drop, Normal Processing, Alter
  - Switch Port #, VLAN, MACs, IPs, TCP/UDP Ports, Counters

Chapter 5: Network Layer (Control Plane)

- Network Layer: Forwarding (Data Plane) and Routing (Control Plane)
  - Control Plane can be per router or logically centralized
  - Routing Protocols find the “cheapest” path to destination host
  - Network can be modeled as a Graph (hosts has nodes, links as edges with costs)
- Link State Routing Protocols
  - Requires a global view of the whole network per devices
    - Link state broadcast
  - Uses Dijkstra’s algorithm to create a shortest path tree
  - Generates forwarding table from shortest path tree
  - Oscillations are possible given multiple paths
- Distance Vector Routing Protocols
  - Only needs to know about neighbors and their cost to destinations
    - Recalculate table on update from neighbor, update neighbors only if table changed
  - Uses Bellman-Ford algorithm (min{link cost + neighbor cost})
  - Link cost increases take time to to propagate

Chapter 5: Network Layer (Control Plane)

- OSPF (Open Shortest Path First)
  - Used for intra-domain routing (all withing the same AS)
  - Uses Link State algorithm
  - Router floods the AS with link state advertisements.
    - Link state is all attach links to router
    - Messages are carried over IP directly rather than in a transport layer protocol
  - Messages are authenticated
  - Multiple cost metrics permitted for different service levels
  - Hierarchical
    - backbone area, transit area, stub area
    - backbone router, area border router, AS boundary routers

Chapter 5: Network Layer (Control Plane)

- BGP (Border Gateway Protocol)
  - Used for inter-domain routing (AS to AS)
  - Uses Distance Vector algorithm
  - Router advertises existence and connected neighbors and costs
    - eBGP communicates to another AS
    - iBGP communicates connectivity withing the same AS
  - AS may choose not to advertise connectivity based on policy
    - Don’t tell A that B is connected to C
  - Routers use OSPF to find closest gateway (hot potato routing)
  - Gateways use BGP to determine connectivity
  - OSPF for internal routing, iBGP to sync gateways
- Why different protocols? Policy, Scale, Performance

Chapter 5: Network Layer (Control Plane)

- Software defined networking
  - Replace monolithic hardware with programmable software
  - Logically centralized control plane
  - Handle difficult routing problems
    - Load balance across many links
    - Route same destination differently for different sources
  - Distinctive features
    - Generalized flow-based forwarding
    - Control/Data plane separation
    - Control plane functions on remote controller
    - Applications on controller for roles such as routing or NAT
- ICMP: the protocol used for ping and traceroute
- SNMP: used to manage information on network equipment

Chapter 6: Link Layer

- Send data within Link Segment (Ethernet, Wireless, ...)
  - Nodes send Frames over Links
- Services: Flow Control, Error Detection & Correction, Full/Half-Duplex
- Link Layer is the bridge between hardware and software
- Error Detection & Error Correction
  - Parity (Single, 2D), Checksum, Cyclic Redundancy Check (CRC)
- Multiple Access Links and Protocols (PPP vs Broadcast)
  - Ideally: full link utilisation (one node or all nodes), decentralized, simple
  - Channel Partitioning: TDMA, FDMA, CDMA
  - Random Access: ALOHA, Slotted ALOHA, CSMA(/CD, /CA)
  - Taking Turns: Polling, Token Passing

Chapter 6: Link Layer

- Ethernet
  - Addressing (MAC vs IP), ARP
  - Default Routers and Link Segments
  - Legacy “Bus” Ethernet, Modern “Star” Ethernet
  - Switches and Switching Tables and larger Link Segments
  - Frame Format, 802.1q, VLANS
- MPLS: add labels to traffic for forwarding
- Data Center Networking
- Webpage Load Example
  - Connect, DHCP, Switch Table, ARP, DNS, TCP, HTTP

Chapter 7: Wireless

- Wireless Hosts connect over Wireless Links to Base Stations
  - Or in ad hoc mode, other wireless hosts (as opposed to infrastructure mode)
- Protocols: 802.11(a, b, g, n, ac, ax) 2G, 2.5G, 3G, 4G LTE, 5G
  - Speed vs. Range
  - Link Characteristics: Signal Strength, SNR and BER, Multipath
  - Hidden Terminal Problem
- CDMA (not the phone protocol with the same name)
- 802.11: 2.4GHz and 5-ish GHz, Channels, Speed, CSMA/CA (RTS/CTS)
  - Wireless hosts “Associate” to the Access Point
  - 802.11 frame (address 3, …), Power Management
- 802.15 / Bluetooth

Chapter 7: Wireless

- Cellular Networks
  - Mobile users connect to Base Station over Air-Interface
  - Base Station connects to Mobile Switching Center to wired networks (PSTN)
  - Combined FDMA/TDMA/CDMA (large number of slots)
- 2G: MSC to PSTN (data over PSTN, think dial-up)
- 3G: Two networks PSTN and GPRS
- 4G: Packet core, PSTN and IP over packet core

Chapter 8: Security

- Alice, Bob and everyone else
- Confidentiality, Authentication, Message Integrity, Access Control
- Symmetric Key Cryptography
  - Same key used for both sides, key distribution problem
  - ROT-13, DES, AES
- Asymmetric Key Cryptography
  - Two key, one public
  - Relies on hard to reverse math problems
  - **RSA**, Elliptic Curves
- Cryptographic Hash Functions
  - MD5, SHA-1, SHA-256
- Session Keys
- Message Integrity and Authentication
- Certificate Authorities

The End

That’s it, Good Luck on the Final