ICS 351: Today's plan

- ARP protocol
- `arp` command
- internet packet forwarding
- IP routing table and routing cache
- proxy ARP
ARP protocol

- when communicating over the local network, the routing table only records the IP address of the next (or final) interface
- one advantage of this is that the next hop (e.g. a router) can be replaced relatively easily
- an ARP request (ARP who-has) is broadcast whenever the MAC address is needed for a local IP address
- the ARP reply is unicast back to the sender, and carries both IP and both Ethernet addresses
- the ARP reply could be sent by an ARP proxy if the intended destination does not support ARP
- ARP packets are not IP packets (ping packets are IP packets)
arp command

- always use "-n" in the lab for all these commands, to request numerical output rather than domain name resolution
- `arp -a -n`: print all the entries in the ARP table
- `arp -d address`: remove the table entry corresponding to the given IP address
- `arp -s address MAC`: add a table entry mapping the given IP address to the given MAC address (use temp at the end of the command to install a normal temporary translation)
Internet packet forwarding

- the IP protocol alone is involved in forwarding packets on the Internet
- forwarding needs a gateway/next hop reachable through a given interface
- different steps:
  1. check routing cache for an exact match. If found, use corresponding gateway and interface
  2. otherwise, find all the routing table entries for which the network part of the address matches the IP destination address
  3. if found, use the match *with the most bits in its network part* (the longest match)
  4. if there is no matching route, the packet is discarded
Internet packet forwarding, details

- since the netmask is stored in the routing table, the same IP destination address will (typically) match routing table entries with different masks
- the default route simply has a mask of 0.0.0.0, so is the shortest match
- a router receiving a packet for destination D may issue an ICMP redirect that says "use router R instead of me for destination D"
- for example, if a packet is sent to the default router, but the router R directly attached to the destination D is connected on the same network as the sender of the packet
- ICMP redirects only affect the routing cache
IP routing table metric

- it is fine for a routing table to have more than one (equal-length) route for a given destination
- each routing table entry has a metric
  - can be thought of as “cost”, or “distance”
  - less metric is better!
- if they have different metrics, the one with the smallest metric is used
- if they have the same metric, any one can be used, possibly even in round-robin fashion
IP routing table issues

- the routing tables of different routers/hosts should be such as to deliver packets to their destination in the least number of hops.
- when routing tables of different routers/hosts can deliver every packet to its destination, they are consistent
- inconsistent routing tables will lead a packet back to a router which has already seen it: this is a routing loop
- an IP packet will go around the loop a few times
- no IP packet can be sent over more than its maximum number of hops, or time-to-live (TTL)
- the time to live in the IP header is decremented each time the packet is forwarded
Proxy ARP

- given a router connected to two networks
- e.g. 192.168.10.0/24 and 192.168.11.0/24
- the router can forward everything between the two networks by simply replying to ARP requests for the "other side"
- in-class exercise: which MAC address does the ARP give in its replies?
- this generalizes to more than two networks
- but only works for networks directly connected to a single router
Static routing

- routing tables can be built by hand
- this works well when:
  - the routes are not changed very often, and
  - the network is small
- whenever equipment is configured manually, it is possible that there will be an error, e.g. a routing loop
- tools such as traceroute (tracert on windows) can be used to debug this
Lab 3

- errata: p. 113, "clear arp-cache" instead of "clear arp"
- class uses minicom instead of kermit
- using a Linux PC as a router (a Windows PC or MAC works just as well)
- using a Cisco router
- verifying network routing setup
- ICMP route redirect
- routing loops
- network prefixes