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
- 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 issues

- it is fine for a routing table to have more than one (equal-length) route for a given destination
- 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
- 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:
- o the routes are not changed very often, and
- o 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