What’s most important in Project 1

- gain some experience with the techniques of protocol implementation
  - Learn to design timeouts and resending
  - Peer to peer interface and protocol interface
  - Protocol design: what data needs to be exchanged and kept track of; frame structure
  - Code for handling finite sequence number space
  - What metrics should be used to judge a design
  - How to manage time in a program

Most important (cont’d)

- experience first-hand the effects of different link characteristics and protocol choices on protocol performance
  - Get a real feel of what happens when you send packets over a network that drops and delays packets
  - Experience the significance of protocol parameters such as packet size, window size, delay
- Create a reliable protocol over an unreliable network

Important for individuals

- Using threads, semaphores
- Distributed debugging
- Understand SWP implementation in detail
- 1st experience implementing a protocol
- Network programming experience

From from Most Important

- Advantages and disadvantages of the 3 experimental links, and packet sizes
- Pros/cons of different implementations
- Working with data flow: when to send, when to ack
- How to do repetitive tasks in the most efficient manner
- C language
- Struct timeval
- Different messages in different directions?
- Pointer in sliding window protocol
- Learn about TCP/IP
Far From …

- Difficulties in programming packets
- Use of the emulator interface
- The emulator
- Get SWP to work with as few errors as possible
- How does sliding window work
- Feasible buffering
- How does UDP work
- How to improve sliding window
- How to match send and receive
- Recording unack’ed packets
- How to choose packets for retransmission
- Exception processing
- Appreciation of difficulty of protocol implementation

How to Make Routing Scale

- Flat versus Hierarchical Addresses
- Inefficient use of Hierarchical Address Space
  - class C with 2 hosts \(2/255 = 0.78\%\) efficient
  - class B with 256 hosts \(256/65535 = 0.39\%\) efficient
- Still Too Many Networks
  - routing tables do not scale
  - route propagation protocols do not scale
Different Routing: Interior & Exterior

- Autonomous System (AS)
  - corresponds to an administrative domain
  - examples: University, company, backbone network
  - assign each AS a 16-bit number
- Within an AS (Autonomous System) – interior routing – RIP or OSPF or … (up to AS administrators)
- Between AS’s – exterior routing – formerly EGP, now BGP – internet standard

Route Propagation

- “Know a smarter router” – use default routes
  - hosts know local router
  - local routers know site routers
  - site routers know core router
  - core routers know everything

Subnetting

- Add another level to address/routing hierarchy: subnet
- Subnet masks define variable partition of host part
- Subnets visible only within site

Route Forwarding at router R1

<table>
<thead>
<tr>
<th>Subnet Number</th>
<th>Subnet Mask</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>128.96.34.0</td>
<td>255.255.255.128</td>
<td>128.96.34.1</td>
</tr>
<tr>
<td>128.96.34.128</td>
<td>255.255.255.0</td>
<td>128.96.34.129</td>
</tr>
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</tbody>
</table>

Class B address

```
11111111111111111111111111111111 00000000
```

Subnet mask: 255.255.255.128
Subnet number: 128.96.34.0
128.96.34.15 H1
128.96.34.130 R1
Subnet mask: 255.255.255.128
Subnet number: 128.96.34.128
128.96.34.129 R2
128.96.33.14 H3
128.96.33.14 R2
Supernetting

- Assign block of contiguous network numbers to nearby networks
- Called CIDR: Classless Inter-Domain Routing
- Represent blocks with a single pair
  \((\text{first\_network\_address}, \text{count})\)
- Restrict block sizes to powers of 2
- Use a bit mask (CIDR mask) to identify block size
- All routers must understand CIDR addressing

Forwarding Algorithm

\[
D = \text{destination IP address}\\
\text{for each entry (SubnetNum, NetMask, NextHop)}\\
D_1 = \text{NetMask} \& D\\
\text{if } D_1 = \text{SubnetNum}\\
\quad \text{if NextHop is an interface}\\
\quad \quad \text{deliver datagram directly to } D\\
\quad \text{else}\\
\quad \quad \text{deliver datagram to NextHop}\\
\]

- Use a default router if nothing matches
- Not necessary for all 1s in net mask to be contiguous (but they almost always are)
- Can put multiple subnets on one physical network
- Subnets not visible from the rest of the Internet

EGP: Exterior Gateway Protocol

- Overview
  - designed for tree-structured Internet
  - concerned with reachability, not optimal routes
- Protocol messages
  - neighbor acquisition: one router requests that another be its peer; peers exchange reachability information
  - neighbor reachability: one router periodically tests if the another is still reachable; exchange HELLO/ACK messages; uses a k-out-of-n rule
  - routing updates: peers periodically exchange their routing tables (distance-vector)

BGP-4: Border Gateway Protocol

- AS Types
  - stub AS: has a single connection to one other AS
    - carries local traffic only
  - multihomed AS: has connections to more than one AS
    - refuses to carry transit traffic
  - transit AS: has connections to more than one AS
    - carries both transit and local traffic
- Each AS has:
  - one or more border routers
  - one BGP speaker that advertises:
    - local networks
    - other reachable networks (transit AS only)
    - gives path information
BGP Example

• Speaker for AS2 advertises reachability to P and Q
  – network 128.96, 192.4.153, 192.4.32, and 192.4.3, can be reached directly from AS2

• Speaker for backbone advertises
  – networks 128.96, 192.4.153, 192.4.32, and 192.4.3 can be reached along the path (AS1, AS2).

• Speaker can cancel previously advertised paths

IP Version 6

• Features
  – 128-bit addresses (classless)
  – multicast
  – real-time service
  – authentication and security
  – autoconfiguration
  – end-to-end fragmentation
  – protocol extensions

• Header
  – 40-byte “base” header
  – extension headers (fixed order, mostly fixed length)
    • fragmentation
    • source routing
    • authentication and security
    • other options