Private and Public Networks

- Internet addresses are public; globally unique and meaningful
  - e.g., for routing purposes
  - servers want to be found, and clients want to be reachable
- Some people want private addresses! Why? ...
  - provides flexibility in re-assigning addresses
  - conceals internal network configuration / topology
  - protects hosts

Interconnecting Private Networks

- Choice #1: dedicated (leased) lines
  - Internet (public network)
  - Private Network N1
  - Leased line
  - Private Network N2

- Features
  - excellent reliability, availability, predictability
  - excellent protection, isolation from the public Internet

- Expensive! Is there a lower-cost way?
Choice #2: VPNs

- VPN = Virtual Private Networks
- Establish a connection through the Internet that “acts like” a leased line!
- VPNs = tunneling + encryption

VPN Example

- Tunnel endpoints (gateways) needed for encapsulation / decapsulation
  - sit at the boundary between public/private networks
- Definitely lower cost than leased lines

Some Tunneling Choices

- Application layer?
- IP layer?
- Lower layers (MPLS, optical, ...)?
- Where should the gateway be located
  - host
  - router?

Some Uses of Tunneling

- VPNs
- Multicast over Unicast (MBONE)
- IPv6 over IPv4 (6BONE)
- X-BONE (generalized IP-in-IP)
- Application-layer (overlay) networks
  - e.g., peer-to-peer

Challenges in Tunneling

- Overhead introduced (extra header)
- Routing Inefficiency (why?)
- Gateway expense, administration
  - if gateways aren’t used, then hosts have to be upgraded
- Can the Internet provide other leased-line properties…
  - guaranteed bandwidth for tunnels?
  - guaranteed reliability / availability for tunnels?
APPLICATION LAYER GATEWAYS

Connecting Private to Public Networks

- Even people in private networks (wishing to remain anonymous) want access to public services
  - e.g., web, mail, ftp, ...
- How can you establish communication without revealing your private address?
  - (i.e., how correspond with someone without giving away your home address?)

Connecting Private to Public (cont’d)

- Analogy: use a post-office box
  - a "public delivery service" gets mail to your PO box
  - a "private delivery service" gets mail from your PO box to you
  - key point: you must be able to trust the provider of the PO box (why?)

Application Gateways (Proxies)

1. For service Y at H2, user at private address H1 sends request to Proxy X
2. X forwards H1's request to H2, after substituting X's public address for H1's address
3. H2 responds to X
4. X "remembers" this is a response to a request from H1, forwards the response back to H1

Application Gateway Examples

- Web proxy
- Mail relays and servers
- "Anonymizers"
- Transcoders
- ...

Other Benefits of Application Gateways

- May do some transformation of requests and/or responses, e.g.,
  - remove pop-up ads
  - remove spam
  - compress images
- A gateway can also be a translator
  - between versions of a protocol or application
- Another potential benefit... load balancing
  - gateway redirects requests among a set of servers
Drawbacks of Application Gateways

- Expense
- Extra latency
- Application specific; a gateway for every application?

Network Address Translation (NAT) (RFC3022)

- NAT translates private addresses to public addresses, and vice versa
  - a cheaper, more general solution than application gateways
  - however, less functionality
- Instead of translating at the application layer, translates at the IP layer

Example

Address translator for IP addresses only

Permanent NAT

- Permanent means one private IP address ⇔ one public IP address
- Address bindings may be created...
  - statically: configured manually by administrator or DHCP
  - dynamically: when a packet is sent from the private to the public network
  - on demand: when a host in the public network requests a DNS translation for a server hostname to a server public address
- When is it safe to terminate an address binding?

Reducing the Number of Public Addresses

- If there are \( n \) hosts in the private network, but only \( m \leq n \) need public addresses at the same time, the NAT only needs to provide \( m \) public addresses
Network Address Port Translation (NAPT)

- What if \( m = 1 \)?
- Solution: do port-mapping
  - host on private network generates packet with private SrcIP=a, SrcPort=p
  - NAPT maps this to the public SrcIP=A, SrcPort=P

- Example:

<table>
<thead>
<tr>
<th>Private IP Addr</th>
<th>Private IP Port</th>
<th>Public IP Addr</th>
<th>Public IP Port</th>
</tr>
</thead>
<tbody>
<tr>
<td>192.168.0.3</td>
<td>2004</td>
<td>152.14.62.55</td>
<td>13135</td>
</tr>
<tr>
<td>192.168.0.3</td>
<td>4471</td>
<td>152.14.62.55</td>
<td>13147</td>
</tr>
<tr>
<td>192.168.0.6</td>
<td>1942</td>
<td>152.14.62.55</td>
<td>13151</td>
</tr>
<tr>
<td>192.168.0.6</td>
<td>2004</td>
<td>152.14.62.55</td>
<td>13158</td>
</tr>
</tbody>
</table>

NAPT (cont’d)

- Reminder: how many TCP and UDP ports are there?
  - is this enough?
  - what if there are thousands of connections to a single server?
  - what if there are multiple servers using the same source port?

Challenges of NAT

- Some application payloads contain IP addresses and/or port numbers
  - ex.: FTP, SIP, ICMP, ...
- The NAT/NAPT box has to understand the payload format and do translations there, too 😊
  - greatly complicates NAT/NAPT
  - how many should you support, and how upgrade?
- What if the payload is encrypted / authenticated?
- IP “purists” dislike NAT

Summary

- Tunneling is a powerful concept with many uses
  - incurs overhead, but provides great flexibility
- Tunneling + encryption = VPN
- NAT / NAPT are very handy for getting more “mileage” out of current IPv4 address space
  - but they make life more difficult for protocol designers

Next Lecture

- IPv6