Network Security - ISA 656
Firewalls & NATs

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Types of Firewalls

- Packet Filters
- Dynamic Packet Filters
- Application Gateways
- Circuit Relays
- Personal and/or Distributed Firewalls

Many firewalls are combinations of these types.
Schematic of a Firewall

Firewalls
Types of Firewalls
Schematic of a Firewall
Conceptual Pieces
Packet Filters
Stateless Packet Filtering
UDP Filtering
Stateful Packet Filters

Inside

Filter

Gateway(s)

Filter

Outside

DMZ
Conceptual Pieces

- An “inside” — everyone on the inside is presumed to be a good guy
- An “outside” — bad guys live there
- A “DMZ” (Demilitarized Zone) — put necessary but potentially dangerous servers there
Packet Filters

- Usually Router-based (and hence cheap).
- Individual packets are accepted or rejected; no context or connection information is used.
- Advanced filter rules are hard to set up; the primitives are often inadequate, and different rules can interact.
- Packet filters a poor fit for ftp and X11.
- Hard to manage access to dynamic services.
Stateless Packet Filtering

- We want to permit out-bound connections
- We have to permit reply packets
- For TCP, this can be done without state
- The very first packet of a TCP connection has just the SYN bit set
- All others have the ACK bit set
- Solution: allow in all packets with ACK turned on
Firewall Rules Setup

- **Action:**
  - Permit (Pass) Allow the packet to proceed
  - Deny (Block) Discard the packet

- **Direction:**
  - Source (where the packet comes from) <IP Address, Port> or network
  - Destination (where the packet goes) <IP Address, Port> or network

- **Protocol:**
  - TCP
  - UDP

- **Packet Flags:**
  - ACK
  - SYN
  - RST
  - etc.
Sample Rule Set

We want to block a spammer, but allow anyone else to send email to our mail server.

**block:**
Source IP Address = SPAMMER

**allow:**
Source IP Address = any

and
Source Port = any

and
Destination IP Address = OUR-MAIL

and
Destination Port = 25
Incorrect Rule Set

We want to allow all TCP connection to mail servers.

allow: Source IP Address = any
and
Source Port = 25
and
Destination IP Address = any
and
Destination Port = any

We don’t control port number selection on the remote host. Any remote process on port 25 can call in.
The Right Choice

allow: Source IP Address = any
and Source Port = 25
and Destination IP Address = any
and Destination Port = any
Flag (ACK) = Set

Permit outgoing calls.
Your Own Filter

Your company has decided that web browsing is not permitted for the employees. It is your task to create a filter that denies web browsing for all the machines inside the company. Assume that all the company IP addresses are known.

Outgoing packets to port 80, Web servers.
Filtering In-bound Packets

Outside

Firewall

DMZ

Inside

If you filter out-bound packets to the DMZ link, you can't tell where they came from.
UDP Filtering

UDP Example: DNS
ICMP Problems
The Problem with
RPC
Incorrect Approach
FTP, SIP, et al.
Saving FTP
The Role of Packet Filters
Application: Point
Firewalls
Application: Address Filtering
Sample Configuration
Sample Rules
Stateful Packet Filters
UDP Filtering

- UDP has no notion of a connection. It is therefore impossible to distinguish a reply to a query—which should be permitted—from an intrusive packet.

- Address-spoofing is easy — no connections

- At best, one can try to block known-dangerous ports. But that’s a risky game.

- The safe solution is to permit UDP packets through to known-safe servers only.
UDP Example: DNS

- Accepts queries on port 53
- Block if handling internal queries only; allow if permitting external queries
- What about recursive queries?
  - Bind local response socket to some other port; allow in-bound UDP packets to it
  - Or put the DNS machine in the DMZ, and run no other UDP services
- (Deeper issues with DNS semantics; stay tuned)
ICMP Problems

- Often see ICMP packets in response to TCP or UDP packets
- Important example: “Path MTU” response
- Must be allowed in or connectivity can break
- Simple packet filters can’t match things up
The Problem with RPC

- RPC services bind to random port numbers
- There’s no way to know in advance which to block and which to permit
- Similar considerations apply to RPC clients
- Systems using RPC cannot be protected by simple packet filters
Incorrect Approach

Block a range of UDP ports.

```
astavrou@ise:~$> rpcinfo -p ise.gmu.edu
program vers proto port service
 100000  4  tcp  111  rpcbind
 100000  2  udp  111  rpcbind
 390113  1  tcp  7937
 100005  1  udp  32800  mountd
 100005  3  tcp  32776  mountd
 100003  3  udp  2049  nfs
 100227  2  udp  2049  nfs_acl
 100003  2  tcp  2049  nfs
 100227  2  tcp  2049  nfs_acl
 100011  1  udp  36613  rquotad
 100008  1  udp  36614  walld
 100001  2  udp  36615  rstatd
```

The precise patterns are implementation-specific
FTP, SIP, et al.

- FTP clients (and some other services) use secondary channels
- Again, these live on random port numbers
- Simple packet filters cannot handle this
- Trying to create rules simple, packet-based rules will NOT work
Saving FTP

- By default, FTP clients send a PORT command to specify the address for an in-bound connection.
- If the PASV command is used instead, the data channel uses a separate out-bound connection.
- If local policy permits arbitrary out-bound connections, this works well.
The Role of Packet Filters

- Packet filters are not very useful as general-purpose firewalls
- However, they are very efficient and can be applied even in high capacity links (why?)
- Several special situations where they’re perfect
- Can be used to drop connections we don’t want to reach the more expensive application-level firewall
Allow in ports 80 and 443. Block *everything* else. This is a Web server appliance — it shouldn’t do anything else! But — it may have necessary internal services for site administration.
Application: Address Filtering

- At the border router, block internal IP addresses from coming in from the outside.
- Similarly, prevent address spoofing (fake IP addresses) from going out.
Sample Configuration

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Application: Address Filtering

Sample Configuration
Sample Rules
Stateful Packet Filters

Outside

Firewall

DMZ: 192.168.42.0/24

Mail
DNS

Inside: 10.0.0.0/16
## Sample Rules

<table>
<thead>
<tr>
<th>Interface</th>
<th>Action</th>
<th>Addr</th>
<th>Port</th>
<th>Flags</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside</td>
<td>Block</td>
<td>src=10.0.0.0/16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outside</td>
<td>Block</td>
<td>src=192.168.42.0/24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outside</td>
<td>Allow</td>
<td>dst=Mail</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Outside</td>
<td>Block</td>
<td>dst=DNS</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>Outside</td>
<td>Allow</td>
<td>dst=DNS</td>
<td>UDP</td>
<td></td>
</tr>
<tr>
<td>Outside</td>
<td>Allow</td>
<td>Any</td>
<td></td>
<td>ACK</td>
</tr>
<tr>
<td>Outside</td>
<td>Block</td>
<td>Any</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMZ</td>
<td>Block</td>
<td>src≠192.168.42.0/24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMZ</td>
<td>Allow</td>
<td>dst=10.0.0.0/16</td>
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<td>ACK</td>
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<tr>
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<td>Allow</td>
<td>dst=Mail</td>
<td>993</td>
<td></td>
</tr>
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<td>Allow</td>
<td>dst=DNS</td>
<td>53</td>
<td></td>
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Stateful Packet Filters

Stateless Packet Filtering

UDP Filtering

Stateful Packet Filters
Stateful Packet Filters
Keeping State
Problems Solved
Remaining Problems
Network Address Translators (NATs)
Basic NAT operation
Comparison
Stateful Packet Filters

- Most common type of packet filter
- Solves many — but not all — of the problems with simple packet filters
- Requires per-connection state in the firewall
Keeping State

- When a packet is sent out, record that in memory
- Associate in-bound packet with state created by out-bound packet
Problems Solved

- Can handle UDP query/response
- Can associate ICMP packets with connection
- Solves some of the in-bound/out-bound filtering issues — but state tables still need to be associated with in-bound packets
- Still need to block against address-spoofing
Remaining Problems

- Still have problems with secondary ports
- Still have problems with RPC
- Still have problems with complex semantics (i.e., DNS)
- The amount of state we can keep is limited
Network Address Translators (NATs)

- Translates source address (and sometimes port numbers)
- Primary purpose: coping with limited number of global IP addresses
- Sometimes marketed as a very strong firewall — is it?
- It’s not really stronger than a stateful packet filter
Basic NAT operation

- Firewalls
- Stateless Packet Filtering
- UDP Filtering
- Stateful Packet Filters
- Keeping State
- Problems Solved
- Remaining Problems
- Network Address Translators (NATs)
- Basic NAT operation
- Comparison

<table>
<thead>
<tr>
<th>Private Address</th>
<th>Public Address</th>
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<tbody>
<tr>
<td>10.0.1.1</td>
<td>129.174.93.21</td>
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Basic NAT operation

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- **Firewalls**
  - Stateless Packet Filtering
  - UDP Filtering
  - Stateful Packet Filters
  - Keeping State Problems Solved
  - Remaining Problems
  - Network Address Translators (NATs)

- **Basic NAT operation**

- **Comparison**

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## Comparison

<table>
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<tr>
<th>Stateful Packet Filter</th>
<th>NAT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Out-bound</strong></td>
<td>Create state table entry.</td>
</tr>
<tr>
<td><strong>In-bound</strong></td>
<td>Look up state table entry; drop if not present.</td>
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<td><strong>Out-bound</strong></td>
<td>Create state table entry. Translate address.</td>
</tr>
<tr>
<td><strong>In-bound</strong></td>
<td>Look up state table entry; drop if not present. Translate address.</td>
</tr>
</tbody>
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The lookup phase and the decision to pass or drop the packet are identical; all that changes is whether or not addresses are translated.