Firewalls and NAT
Firewalls

By conventional definition, a firewall is a partition made of fireproof material designed to prevent the spread of fire from one part of a building to another.

Firewalls isolates organization’s internal net from larger Internet, allowing some packets to pass, blocking others.

privately administered

222.22/16
Firewalls: Goals

- All traffic from outside to inside and vice-versa passes through the firewall
- Only authorized traffic, as defined by local security policy, will be allowed to pass
- Firewall itself is immune to penetration
Firewalls: Taxonomy

1. Traditional packet filters
   - Filters often combined with router, creating a firewall
2. Stateful filters
3. Application gateways

Major firewall vendors:
- Checkpoint
- Cisco PIX
Firewall

- Firewall == system that filters TCP/IP UDP/IP packets according to rules
- Either software on user machine or network router
Firewall

- Rules
- Router
- (Global IP addresses)
Traditional packet filters

Analyzes each datagram going through it; makes drop decision based on:

- Source IP address
- Destination IP address
- Source port
- Destination port
- TCP flag bits
  - SYN bit set: datagram for connection initiation
  - ACK bit set: part of established connection
- TCP or UDP or ICMP
  - Firewalls often configured to block all UDP
- Direction
  - Is datagram leaving or entering internal network?
- Router interface
  - Decisions can be different for different interfaces
## Filtering rules - examples

<table>
<thead>
<tr>
<th>Policy</th>
<th>Firewall Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>No outside Web access.</td>
<td>Drop all outgoing packets to any IP address, port 80</td>
</tr>
<tr>
<td>Outside connections to public Web server only.</td>
<td>Drop all incoming TCP SYN packets to any IP except 130.207.244.203, port 80</td>
</tr>
<tr>
<td>Prevent Web-radios from eating up the available bandwidth.</td>
<td>Drop all incoming UDP packets - except DNS and router broadcasts.</td>
</tr>
<tr>
<td>Prevent your network from being used for a Smuft DoS attack.</td>
<td>Drop all ICMP packets going to a “broadcast” address (e.g. 130.207.255.255).</td>
</tr>
<tr>
<td>Prevent your network from being tracerouted</td>
<td>Drop all outgoing ICMP unreachable</td>
</tr>
</tbody>
</table>
## Access control lists

Apply rules from top to bottom:

<table>
<thead>
<tr>
<th>action</th>
<th>source address</th>
<th>dest address</th>
<th>proto</th>
<th>source port</th>
<th>dest port</th>
<th>flag bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>allow</td>
<td>222.22/16</td>
<td>outside of 222.22/16</td>
<td>TCP</td>
<td>&gt; 1023</td>
<td>80</td>
<td>any</td>
</tr>
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<td>allow</td>
<td>222.22/16</td>
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<td>UDP</td>
<td>&gt; 1023</td>
<td>53</td>
<td>---</td>
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<td>allow</td>
<td>outside of 222.22/16</td>
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<td>UDP</td>
<td>53</td>
<td>&gt; 1023</td>
<td>----</td>
</tr>
<tr>
<td>deny</td>
<td>all</td>
<td>all</td>
<td>all</td>
<td>all</td>
<td>all</td>
<td>all</td>
</tr>
</tbody>
</table>
Access control lists (2.)

- Each router/firewall interface can have its own ACL
- Most firewall vendors provide both command-line and graphical configuration interface
Traditional packet filters

Advantages

- One screening router can protect entire network
- Can be efficient if filtering rules are kept simple
- Widely available. Almost any router, even Linux boxes

Disadvantages

- Can be penetrated
- Cannot enforce some policies. For example, permit certain users.
- Rules can get complicated and difficult to test
Network or host firewall

Network firewall:

Internet \rightarrow \text{Network firewall} \rightarrow \text{protected network}

Host firewall:

Internet \rightarrow \text{host with firewall}
Example: Iptables – chain types

Internet → Linux host w/ iptables → protected network
INPUT chain (to iptables host)

Internet ← Linux host w/ iptables ← protected network
OUTPUT chain (from iptables host)

Internet → Linux host w/ iptables → protected network
FORWARD chain
Iptables: Example command

```
iptables -A INPUT -i eth0 -s 232.16.4.0/24 -j ACCEPT
```

- Sets a rule
  - Accepts packets that enter from interface eth0 with source address in 232.16.4/24

- Kernel applies rules in order
  - First matching rule determines action for packet

- Append: -A
  - Adds rule to bottom of existing rules
Stateful filters

- Stateless filters: Any packet with ACK=1 and source port 80 gets through
  - Attack with malformed packets: send ACK=1 segments

- Stateful filter: Adds more intelligence to decision-making process
  - Stateful = remember past packets
  - Needs very dynamic state table
Stateful filters: Example

- Log each TCP conn initiated through firewall: SYN segment
- Timeout entries without activity after, e.g., 60 seconds

<table>
<thead>
<tr>
<th>source address</th>
<th>dest address</th>
<th>source port</th>
<th>dest port</th>
</tr>
</thead>
<tbody>
<tr>
<td>222.22.1.7</td>
<td>37.96.87.123</td>
<td>12699</td>
<td>80</td>
</tr>
<tr>
<td>222.22.93.2</td>
<td>199.1.205.23</td>
<td>37654</td>
<td>80</td>
</tr>
<tr>
<td>222.22.65.143</td>
<td>203.77.240.43</td>
<td>48712</td>
<td>80</td>
</tr>
</tbody>
</table>

Rule table indicates check of stateful table:
See if there is a connection entry in stateful table
Stateful filters can remember outgoing UDP segments
Stateful example: Example (2.)

1) Pkt arrives from outside: src=37.96.87.123, src port=80, dst=222.22.1.7, dst port=12699, SYN=0, ACK=1

2) Check filter table ➔ check stateful table

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<th>source address</th>
<th>dest address</th>
<th>proto</th>
<th>source port</th>
<th>dest port</th>
<th>flag bit</th>
<th>check conn</th>
</tr>
</thead>
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<td>all</td>
<td>all</td>
<td>all</td>
<td>all</td>
<td>all</td>
<td></td>
</tr>
</tbody>
</table>

3) Connection is in connection table ➔ let packet through
Application gateways (aka proxy servers)

- App gateway between user (inside) and server (outside)
- User and server talk through proxy
- Allows fine grained/sophisticated control
- Hinders protocol attacks
- E.g.: ftp server may not allow files $\geq$ size X
Mail servers and proxy Web servers

- Local mail server is application gateway
  - Virus detection and removal
- So is Web proxy cache
  - E.g.: virus detection and removal
Proxy gateways

- Advantages
  - Can log all connections, activity in connections
  - Can provide caching
  - Can do intelligent filtering based on “content”
  - Simplifies service control
    - Can perform user level authentication
    - Simplifies firewall rules

- Disadvantages
  - Not all services have proxied versions
  - Need different proxy server for each service
  - Requires modification of client
  - Performance
  - Hinders end-to-end encryption
Demilitarized Zone (DMZ)

- Used for: Gateways and public services
- Advantage: Hacked server – limited damage
IP traceback

Problem: How do we determine where malicious packet came from?

- Why? Attackers can spoof source IP address
- Benefits:
  - Determine attacker
  - Determine zombie machine participating in DDoS attack
- Alternative: Use ingress filtering
Methods for finding source

- Manual using current IP routing
  - Link testing: how?
    - Start from victim and test upstream links
    - Recursively repeat until source is located
    - Assume attack remains active until trace complete
  - Link testing: problem
    - Handle ISPs
    - Located zombie...
  - Logging

- Automatic using marking algorithms
Logging

- Key routers log packets (useful for forensics)
- Use data mining to find path

Pros

- Post mortem – works after attack stops

Cons

- High resource demand: need to store and process tons of data
Marking algorithms

- Mark packets with router addresses
  - Deterministically or probabilistically
- Trace attack using marked packets

Strengths
- Independent of ISP management
- Little network overhead, traffic
- Trace distributed attacks, attacks post-mortem
Marking: Assumptions

- Most routers remain uncompromised
- Attacker sends many packets
- Route from attacker to victim remains relatively stable
Marking: Summary

- Can determine attack path with a relatively small number of attack packets
- Need to include addresses, counter in IP datagram (e.g., via fragment fields)
- E.g.: “Practical Network Support for IP Traceback” by Savage et al.

- Status:
  - Lots of RFCs
  - But not ?yet? deployed...
Network address translation (NAT)

- Also known as
  - Network masquerading
  - IP masquerading

- Re-writes source and/or destination address as they pass through NAT gateway

- Why
  - IPv4 address shortage
  - Standard feature
  - Some believe it enhances privacy, security, ...
Simple NAT

(Public IP addresses)

Main Internet

NAT

(Public IP addresses)

(Private IP addresses)
Multiple NAT

156.148.70.32

(Public IP addresses)

ISP NAT

192.168.2.12

ISP network

192.168.2.99

Home NAT

Home network

10.0.0.12

(Private IP addresses)
NAT traversal: Relay

Relay S

Main Internet

NAT

Local network

10.0.0.12

host B

192.168.2.99

host A

NAT

1

2
NAT traversal: Connection reversal

1. host A (192.168.2.99) in Local network
2. NAT device
3. host B (1.1.1.4) in Main Internet

Connections:
- 1: host A to NAT
- 2: NAT to Main Internet
- 3: Main Internet to host B

Rendezvous S
TURN protocol

- Protocol for UDP/TCP relaying behind NAT
- Data is bounced to a public TURN server
- No hole punching
- TURN works even behind symmetric NAT
Hole punching

- Technique to allow traffic from/to a host behind a firewall/NAT without collaboration of the NAT itself
- UDP: simple 😊
- TCP:
  - Berkeley sockets allows TCP socket to initiate an outgoing or listen for an incoming connections but not both
  - Solution: bind multiple sockets to same local endpoint
STUN (RFC 3489)

- Defines operations and message formats to understand type of NAT
- Discovers presence and type of NAT and firewalls between them and Internet
- Allows applications to determine their public NAT IP address
STUNT

- Simple Traversal of UDP Through NATs and TCP too (STUNT)
- Extends STUN to include TCP functionality
NAT traversal: Cooperating NAT

- SOCKS
  - Client server protocol
  - Enables client (behind firewall) to use server (in public Internet)
  - Relays traffic
  - Widely adopted
    - E.g.: Mozilla can use SOCKS
NAT traversal: UPnP

- Defines:
  Internet Gateway Device (IGD) protocol

- Enables:
  - Learning of ones public (external) IP address
  - Enumeration of existing port mappings
  - Adding and removing port mappings
  - Assigning lease times to mappings
  - Applications to automatically configure NAT routing