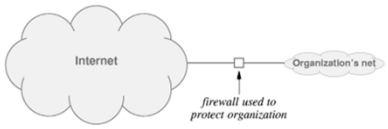
CSIS 4222

Ch 27: Internet Routing

Ch 30: Packet filtering & firewalls

Internet Firewall

A combination of hardware and software that isolates an organization's internal network from the Internet at large



Placing a firewall on each external network connection defines a secure perimeter.

Internet Firewall

- Used by a network administrator to manage traffic flow in and out of the internal network
- Implements a security policy and rejects any traffic that doesn't adhere to it
- Primary means of accomplishing this is through *packet filtering*

Packet Filtering

Filtering decisions typically based on fields in a packet's header:

- IP source or destination address
- TCP or UDP source and destination port
- ICMP message type
- Connection initialization datagrams using the TCP SYN or ACK bits

Examples

To block all telnet connections

Block TCP segments whose source or destination port number is 23

To block streaming video

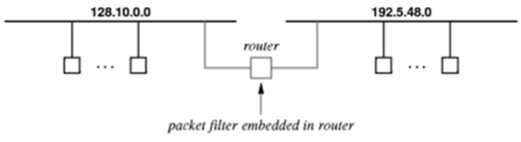
Block all UDP segments

To prevent external clients from connecting to internal servers

Block incoming TCP segments with ACK=0 (all other segments have ACK=1)

Routers can implement packet filtering

Specify which packets can pass through and which should be blocked



Linux Packet Filtering

The Linux `iptables` program acts as a packet filter

- Used to design a firewall to protect a single computer
- Filters traffic based on port numbers, addresses, and flags
- Organizes rules into groups called chains
  Input, *output*, and *forward* are built-in chains
- Rules are applied in order, first match is the one used
- A policy specifies how to handle packets that do not match any rules.

Adding Filtering Rules

Accept incoming TCP packets on interface eth0 from any IP address destined for 192.168.1.1

```
iptables -A INPUT -i eth0 -d 192.168.1.1 -p TCP -j ACCEPT
```

Reject ping packets from 192.168.1.5

```
iptables -A INPUT -s 192.168.1.5 -p icmp -j REJECT
```

Stateful Firewalls

A *stateful* firewall allows traffic from inside the network to exit but doesn't allow general traffic from outside to enter

Outside packets can enter only if they match a request from within the network

Keeps track of packet flow

Maintains information about recent history of *traffic on a connection*

Stateful Firewalls

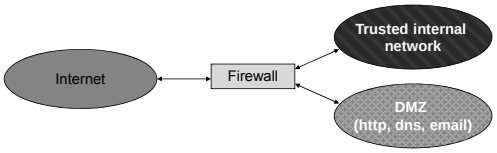
Example: Host requests a page from a web server outside the network

- Firewall recognizes SYN packet from host and creates a state w/source and destination IP addresses
- Web server returns a SYN-ACK which the firewall allows to pass through
- State is maintained until connection ends

Stateful Firewalls

Are outside users ever allowed access?

- Firewalls generally must open ports for incoming traffic to web servers, DNS, email
- Create demilitarized zones (DMZ) to isolate these servers from the rest of the network



Intrusion Detection Systems (IDS)

- Monitors all arriving packets and notifies the site administrator if a security violation is detected
- Provides an extra layer of security awareness even if a firewall prevents an attack
- Can be configured to watch for specific types of attacks
  - Example: port scanning

Content Scanning and Deep Packet Inspection

A firewall only examines fields in a packet header
- Cannot test the payload of a packet for viruses, etc.
- This requires content analysis:
  - File scanning
  - Deep Packet Inspection (DPI)

Content Scanning

Take a file as input and looks for suspicious byte patterns
- Many virus scanners look for strings of bytes known as a fingerprint
- Virus scanner software searches files for such sequences

File scanning can make mistakes
- *false positive*
- *false negative*

Deep Packet Inspection

Operates on packets
- Examines the data in the packet payload
- Includes the header fields
- In many cases, the payload cannot be interpreted without examining fields in the packet header

Disadvantage of DPI is computational overhead

Routing Terminology

Forwarding
- Refers to datagram transfer
- Uses routing table
- Performed by host or router

Routing
- Refers to propagation of routing information
- Inserts / changes values in routing table
- Performed by routers

Routing Issues

A routing algorithm must provide:

Correctness and simplicity: Networks are never taken down; individual parts (e.g., links, routers) may fail, but not the whole network

Stability: Handle topology and traffic changes without aborting jobs, rebooting, etc.

Fairness and optimality: Often in conflict. Fairness is not part of definition of optimality.

Two Forms of Internet Routing

Static routing
- Forwarding table initialized when system boots
- No further changes

Dynamic routing
- Table is initialized when system boots
- Routing software learns routes and updates table
- Continuous changes are possible

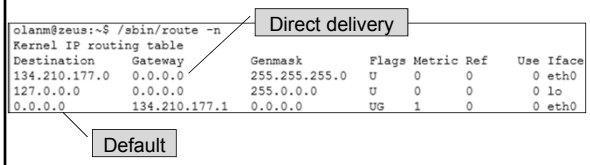
Static Routing

Used by most Internet hosts

Typical routing table has two entries for:

Local network → direct delivery

Default → nearest router



Dynamic Routing

- Used by IP routers
- Requires special software
- Each router communicates with its neighbors by passing routing information
- Uses a route propagation protocol

Dynamic Routing and Routers

- Router R_1 knows about networks 1 and 3
- Router R_2 knows about networks 2 and 3

Router exchanges information about connected networks

Dynamic Routing and Routers

- Routing software updates the local forwarding table when it learns about changes in routes
- Routers exchange information periodically
- In the example:
  - R_2 will install a route to `network 1` and R_1 will install a route to `network 2`
  - If R_2 crashes, the route propagation software in R_1 will detect that `network 2` is no longer reachable and will remove the route from its forwarding table
  - Later, when R_2 comes back on line, the routing software in R_1 will determine that `network 2` is reachable again and will reinstall the route

Routing in the Global Internet

A route propagation protocol allows one router to exchange routing information with another

- But this cannot scale to the entire Internet
  - Routers and networks in the Internet are divided into groups
  - All routers within a group exchange routing information
  - Then, at least one router (possibly more) in each group summarizes the information and passes it to other groups

Routing in the Global Internet

How big is a group?

- To accommodate organizations of various size, no exact group size is dictated

What protocol do routers use within a group?

- Each organization can choose a routing protocol independently

What protocol do routers use between groups?

- Interconnected groups must agree

Autonomous Systems

An autonomous system is a region of the Internet (networks and routers) that is administered by a single authority

Examples:

- UUNet (Verizon) backbone network
- Regional Internet Service Provider
- A big university

Each AS chooses a routing protocol

Internet Routing Protocol Classes

Interior Gateway Protocols (IGPs)

- Used by routers within an autonomous system
- Destinations lie within same AS

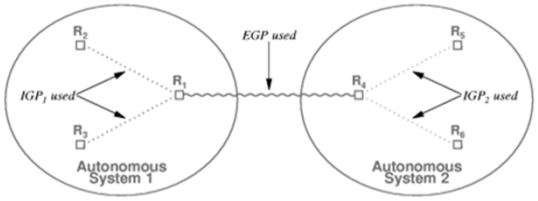
- Example protocols
  - RIP (old but simple)
  - OSPF (better)

Exterior Gateway Protocols (EGPs)

- Used between autonomous systems
- Destinations lie throughout Internet

- Example protocols
  - EGP
  - BGP (more recent)

Illustration of IGP / EGP Use



Routing software should find all possible paths and choose one that is optimal

How to measure the optimal path between any source and destination?

For a remote desktop application

- a path with least delay

For a browser downloading a large graphics file

- a path with maximum throughput

For a real-time audio webcast application

- a path with least jitter

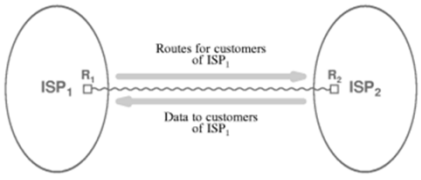
Optimal Routes and Routing Metrics

Typical Internet routing uses a combination of two metrics:

Hop count and Administrative cost

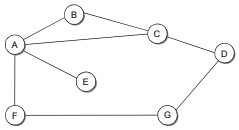
- Hop count gives the number of intermediate networks on the path to the destination
- Administrative costs are assigned manually
  - Often to control which paths traffic can use
  - Routing software chooses the least cost path

Routes and Data Flow



- Each Tier 1 ISP is an autonomous system that advertise its customers' networks to other ISPs.
- Datagrams destined for network D can begin to arrive after the ISP advertises it

Distance Vector Routing



All nodes start by building a local view of what nodes are 1 hop away.

Every node sends its vector to its directly connected neighbors.

F tells A that it can reach G at cost 1. A knows it can reach F at cost 1, so it updated its own vector to indicate that it can reach G at cost 2.

Higher cost routes to G will be ignored, finding a lower cost route will replace the route currently in the vector.

After a few iterations of these exchanges, the routing table ***converges*** to a consistent state.

Periodic updates: Every *t* seconds, send local info to your neighbors. This informs other nodes that you are running.

Triggered updates: Every time you learn new info from a neighbor that makes you to update your local vector, send the recomputed vector to all your neighbors.

Internet Routing Protocols (Interdomain)

Border Gateway Protocol (BGP-4)

- Currently the EGP of choice for the Internet
- Provides routing between autonomous systems
- Gives path of autonomous systems for each destination
- Uses reliable transport (TCP)
- Distance vector algorithm

BGP Tracing: http://www.routeviews.org/

Internet Routing Protocols (Intradomain)

Routing Information Protocol (RIP)

- Routing within an autonomous system (IGP)
- Hop count metric
- Distance vector algorithm
- Unreliable transport (uses UDP)
- Implemented by the Unix program `routed`

Link State Routing

- Each node knows the distance to its neighbors
- The distance information (link state) is broadcast to all nodes in the network
- Each node calculates its routing table independently
  - Route calculations based on Dijkstra's shortest-path first algorithm

Internet Routing Protocols (Intradomain)

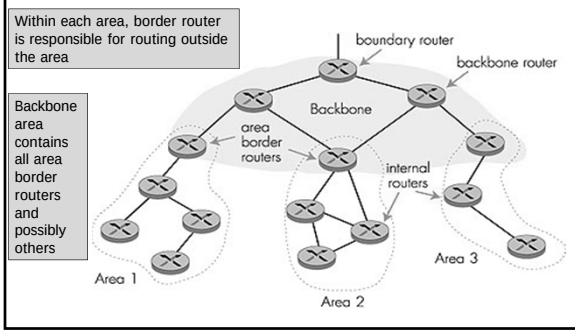
Open Shortest Path First Protocol (OSPF)

- Routing within an autonomous system (IGP)
- More powerful but more complex than RIP
- Can scale to handle a much larger number of routers than other IGPs
- Uses SPF algorithm

OSPF Areas and Efficiency

- Allows subdivision of AS into areas
- Link-status information propagated within area
- Routes summarized before being propagated to another area
- Reduces overhead (less broadcast traffic)

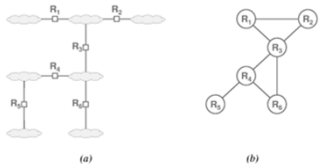
OSPF AS Organized in a 2-level Hierarchy



Link-Status in the Internet

- Router corresponds to a node in a graph
- Network corresponds to an edge
- Adjacent pair of routers periodically
  - Test connectivity
  - Broadcast link-status information to area
- Each router uses link-status messages to compute shortest paths

Illustration of OSPF Graph



(a) an interconnection of routers and networks

(b) an equivalent OSPF graph