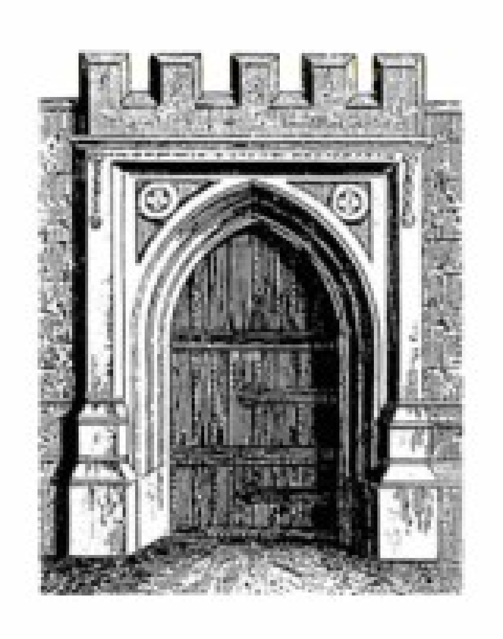
Network Security

Firewalls

Just because you're paranoid, doesn't mean they're not out to get you!
- *Anonymous*



Firewalls Make It To The Movies

Why Firewalls?

- Internet connectivity is no longer an option for most corporations
- The Internet allows you access to worldwide resources, but…
  …the Internet also allows the *world* to try and access your resources
- This is a grave risk to most organizations

Why Firewalls?

- A firewall is inserted between the premises network and the Internet
- Establishes a perimeter
- Provides a choke point where security and audits can be imposed
- Single computer system or a set of systems can perform the firewall function

Good Fences Make Good Neighbors – Robert Frost, “Mending Wall”

Design Goals

- All traffic, from inside to outside and vice versa, must pass through the firewall
- Only authorized traffic (defined by the security policy) is allowed to flow
- Firewall is immune to penetration – uses a trusted system

Access Control Techniques

- Service Control – types of Internet service accessed inbound and outbound
- Direction Control – direction in which particular services may be initiated
- User Control – access to a service is controlled according to users
- Behavior Control – controls how particular services are used

Scope of Firewalls

- Single choke point - to protect vulnerable services from various kinds of attack (spoofing, DOS)
- Singular monitoring point – location for monitoring, auditing and event triggering

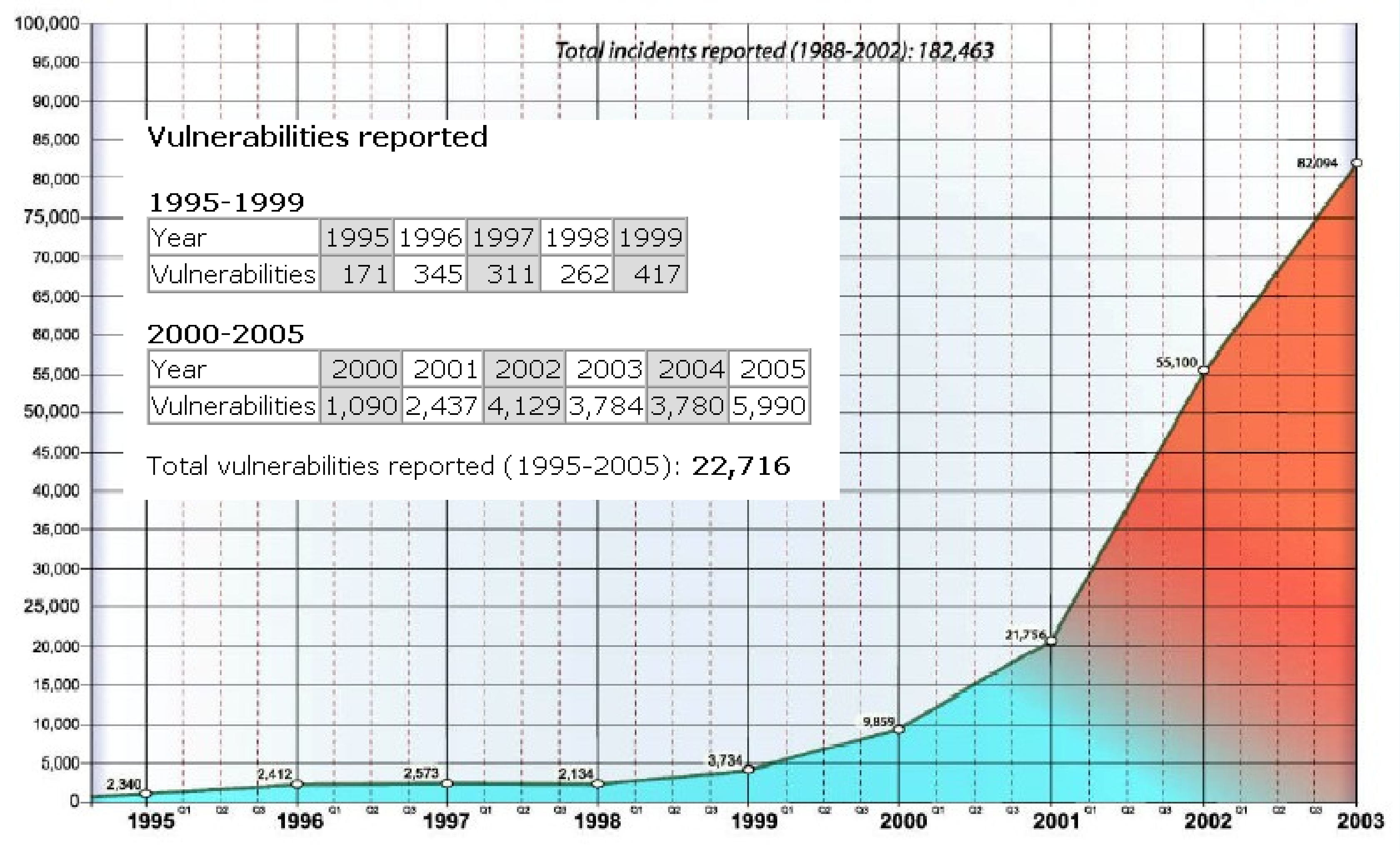
Scope of Firewalls

- Platform for non-security functions – can be used for network address translation and network management
- Platform for IPSec – implements VPN via tunnel mode

Limitations of Firewalls

- Cannot protect against attack that bypasses the firewall – bypass attack
- Does not protect against internal threats
- Cannot protect against the transfer of virus-infected programs

CERT/CC Incidents Reported



Total incidents reported (1988-2002): 182,463

Vulnerabilities reported

1995-1999

Year	1995	1996	1997	1998	1999
Vulnerabilities	171	345	311	262	417

2000-2005

Year	2000	2001	2002	2003	2004	2005
Vulnerabilities	1,090	2,437	4,129	3,784	3,780	5,990

Total vulnerabilities reported (1995-2005): **22,716**

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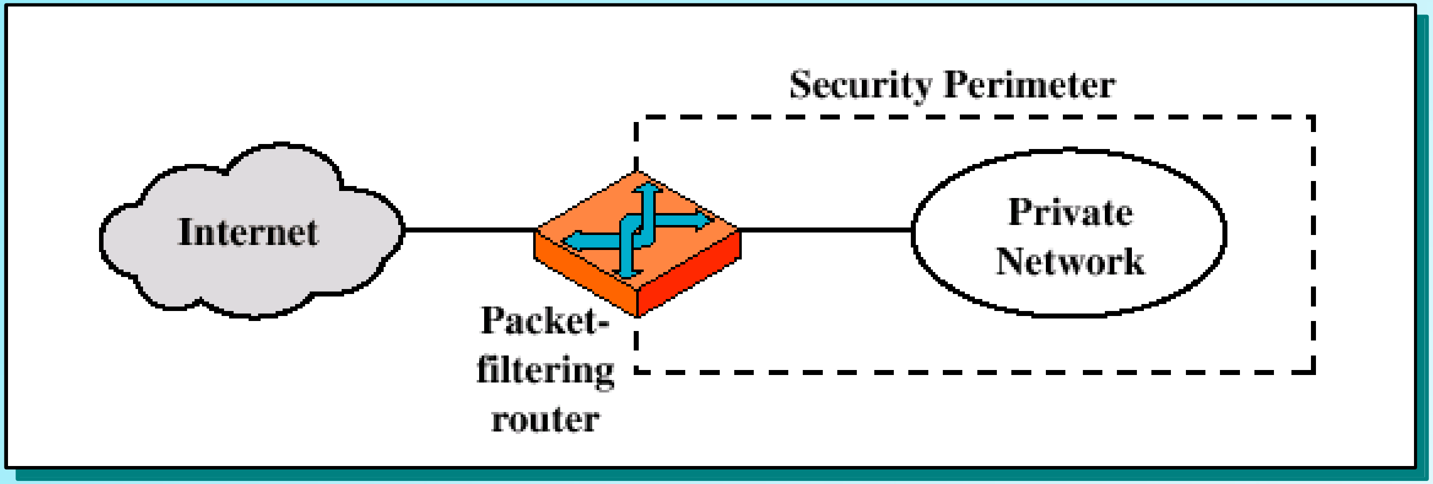
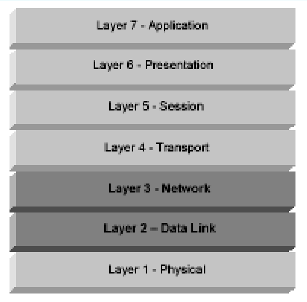
Types of Firewalls

- Packet Filtering Router
- Application Level Gateway
- Circuit Level Gateway

Packet Filtering



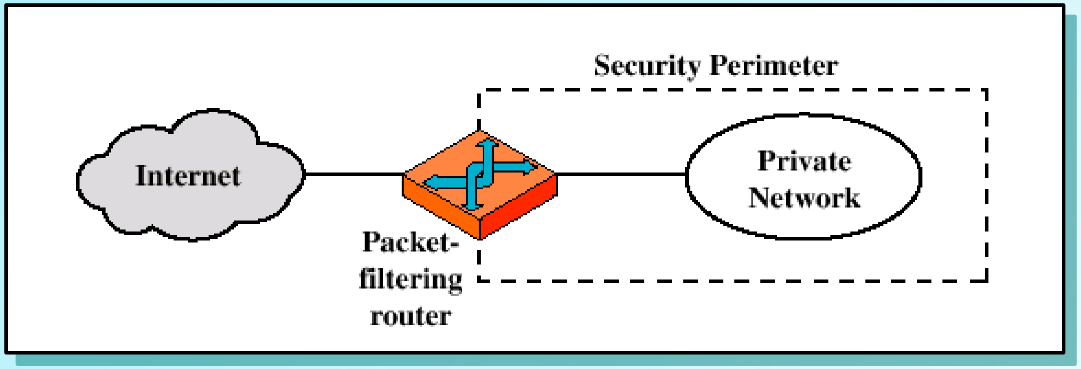


OSI Layers Addressed

Packet Filtering Router

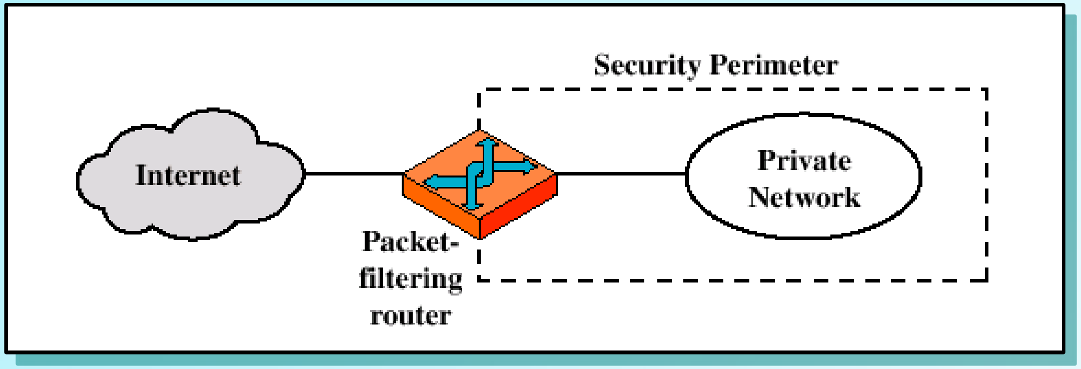
- Applies a set of rules to each incoming IP packet and *forwards* or *discards* the packet

- Filters packets in *both directions*



Packet Filtering Router

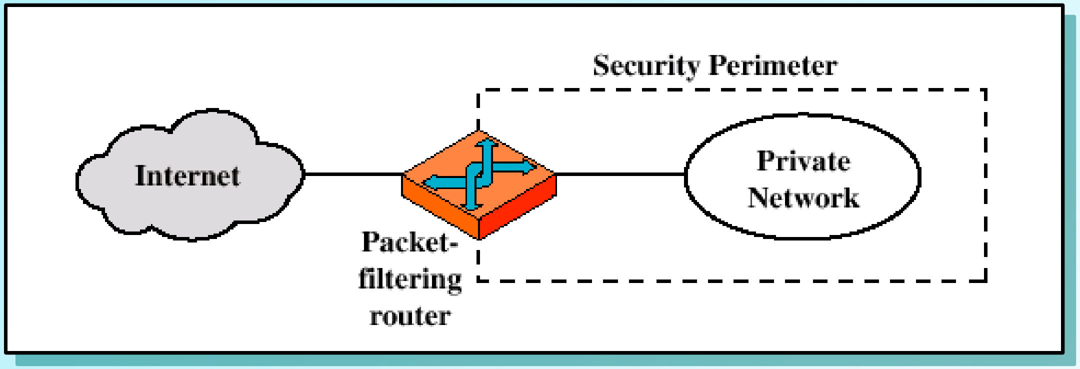
- Rules based on *source* and *destination* address and *port* number
- *List of rules* looking for a match
- If no match, *default* action is taken



Packet Filtering Router

Two default policies:

- **default = discard:**
  That which is not expressly permitted is prohibited
- **default = forward:**
  That which is not expressly prohibited is permitted



Packet Filtering Rules

action	ourhost	port	theirhost	port	comment
block	*	*	SPIGOT	*	we don’t trust these guys
allow	OUR-GW	25	*	*	connection to our SMTP port

- Inbound mail is allowed (port 25), but only to a gateway host
- Everything from SPIGOT is blocked

Packet Filtering Rules

action	ourhost	port	theirhost	port	comment
block	*	*	*	*	default

- This is the *default policy*
- It is usually the *last* rule
- This rule *drops everything*

Packet Filtering Rules

action	ourhost	port	theirhost	port	comment
allow	*	*	*	25	Connection to their SMTP port

- Inside host can send mail to the outside
- Some other application could be linked to port 25
- Attacker could gain access through port 25

Packet Filtering Rules

action	src	port	dest	port	flags	comment
allow	our hosts	*	*	25		connection to their SMTP port
allow	*	25	*	*	ACK	their replies

- This improves on the last situation
- Internal hosts can access SMTP anywhere
- ACKs from any SMTP server are permitted

Packet Filtering Rules

action	src	port	dest	port	flags	comment
allow	our hosts	*	*	*		outgoing calls
allow	*	*	*	*	ACK	replies to our calls
allow	*	*	*	>1024		Traffic to nonservers

- This handles FTP connections
- Two connections are used: one for control and the other for data transfer; different port numbers (20,21)
- Outgoing calls use a higher number port (above 1023)

Packet Filtering

- *Advantage:* simple, transparent and very fast
- *Disadvantage:* difficulty in setting up rules correctly and authentication

Packet Filtering Attacks

- IP address spoofing – packets from the outside have internal addresses in their source IP address field
- Source routing attacks – route of packet is specified to bypass security measures
- Tiny fragment attack – designed to circumvent filtering rules that depend on TCP header information

Real Life Example

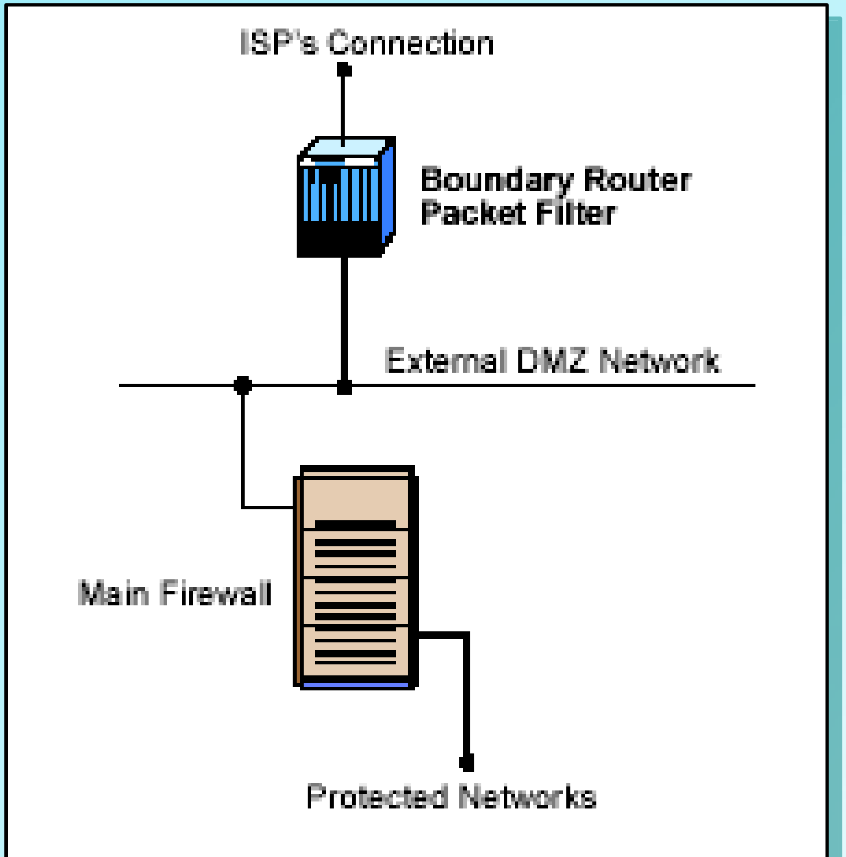
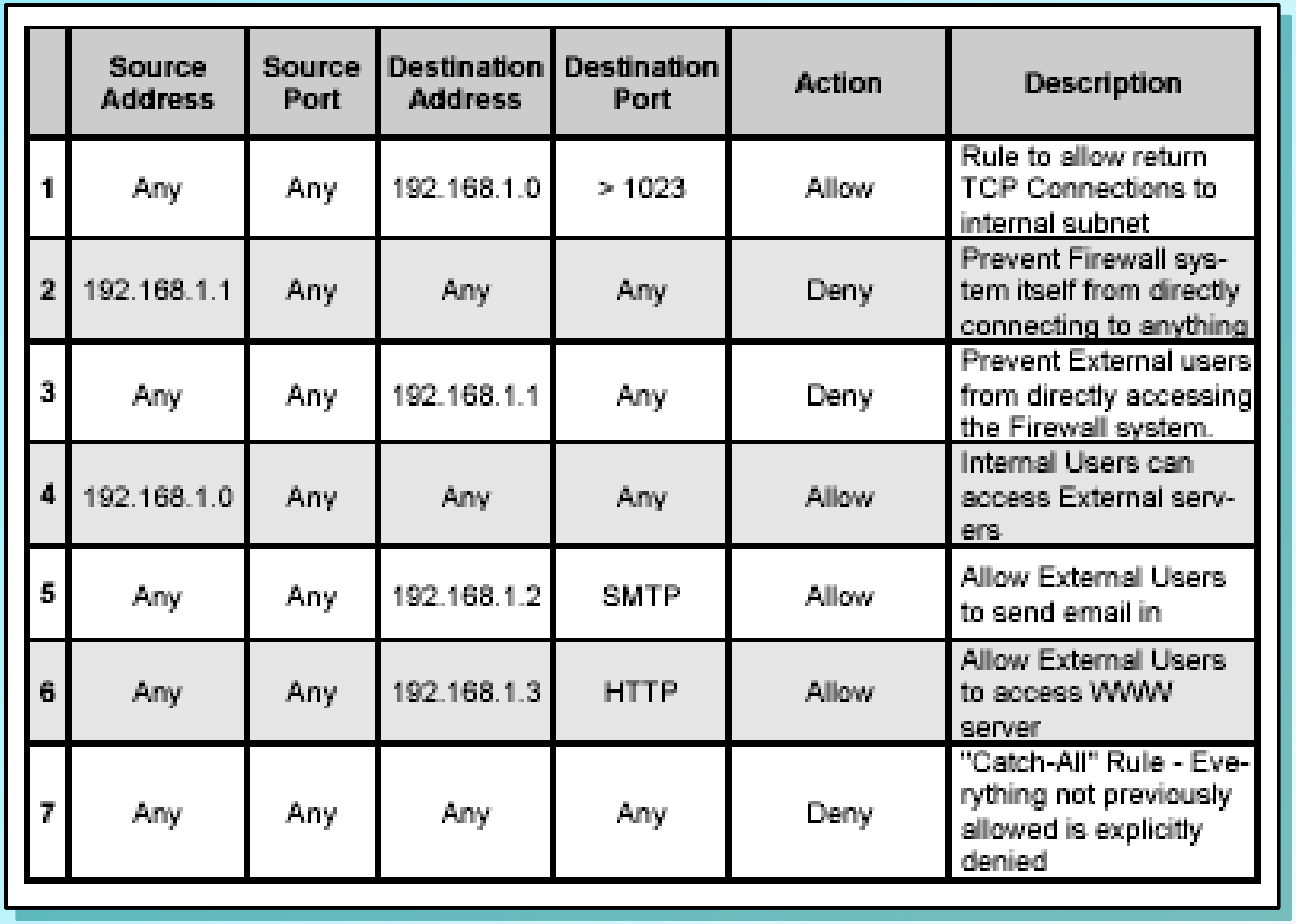


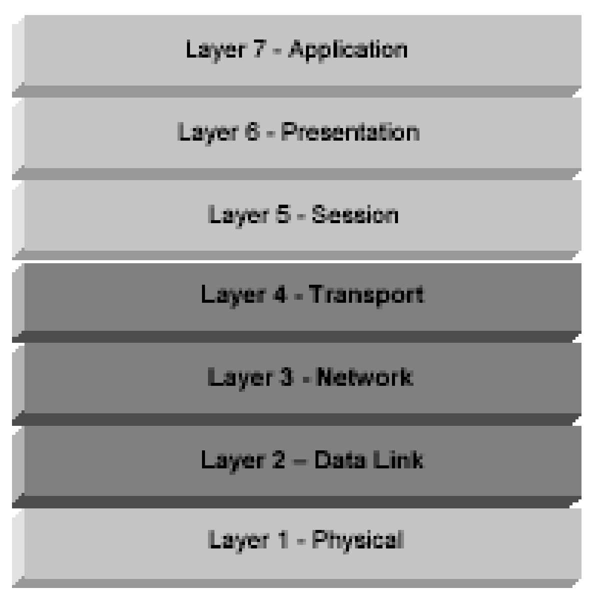
Figure 2.4: Packet Filter used as Boundary Router

Real Life Example



	Source Address	Source Port	Destination Address	Destination Port	Action	Description
1	Any	Any	192.168.1.0	> 1023	Allow	Rule to allow return TCP Connections to internal subnet
2	192.168.1.1	Any	Any	Any	Deny	Prevent Firewall system itself from directly connecting to anything
3	Any	Any	192.168.1.1	Any	Deny	Prevent External users from directly accessing the Firewall system.
4	192.168.1.0	Any	Any	Any	Allow	Internal Users can access External servers
5	Any	Any	192.168.1.2	SMTP	Allow	Allow External Users to send email in
6	Any	Any	192.168.1.3	HTTP	Allow	Allow External Users to access WWW server
7	Any	Any	Any	Any	Deny	"Catch-All" Rule - Everything not previously allowed is explicitly denied

Stateful Inspection



Layers Addressed By Stateful Inspection

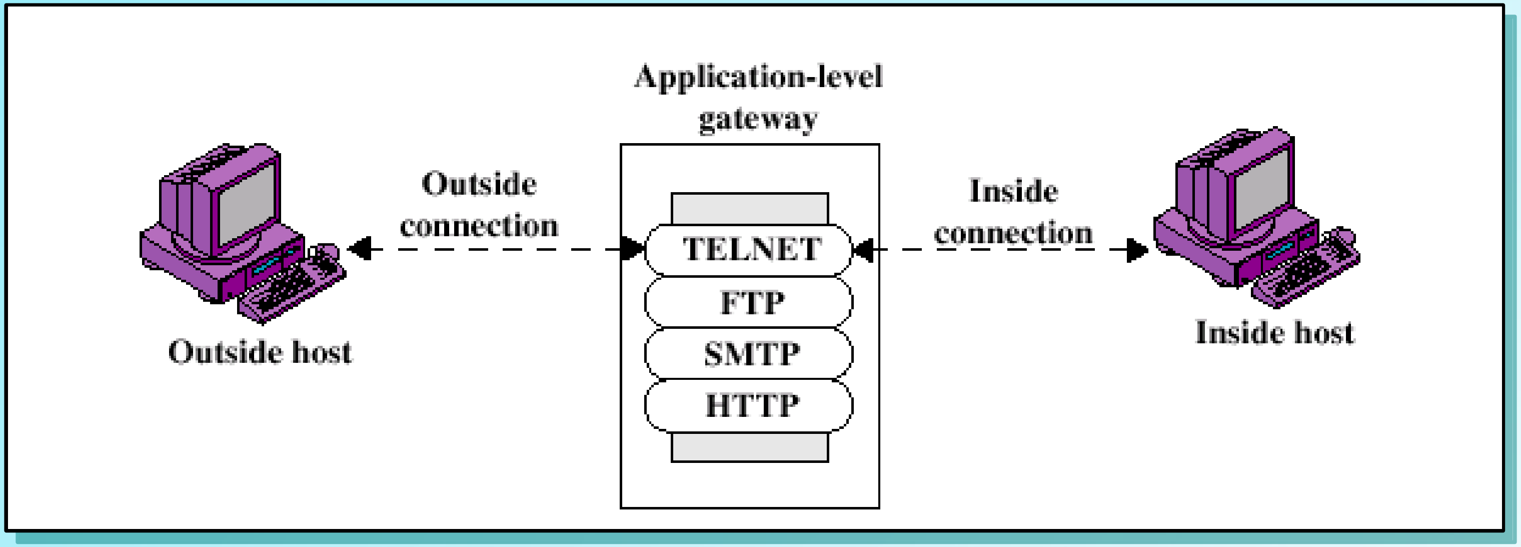
Stateful Inspection

- Inbound connections are above port 1023
- Solve this problem by creating a directory of outbound TCP connections, along with each session’s corresponding high-numbered client port
- State Table - used to validate any inbound traffic.

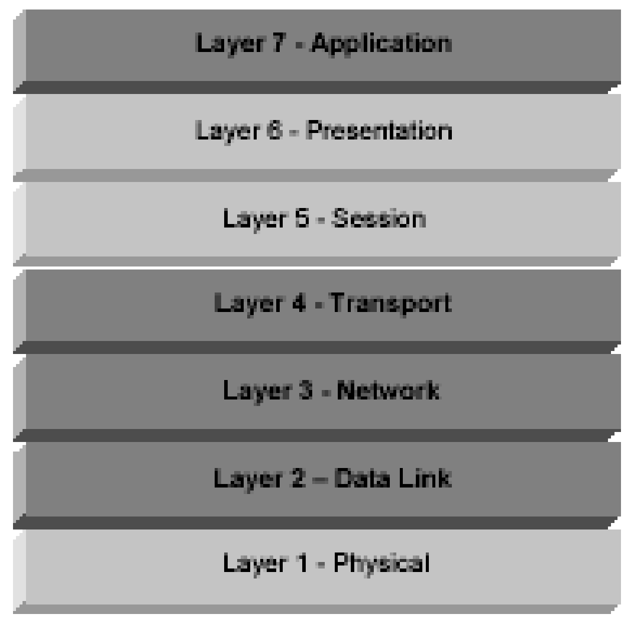
Stateful Inspection

- More secure because the firewall tracks client ports individually rather than opening all high-numbered ports for external access.
- Adds Layer 4 awareness to the standard packet filter architecture.
- Useful or applicable only within TCP/IP network infrastructures
- Superset of packet filter firewall functionality

Application Level Gateway



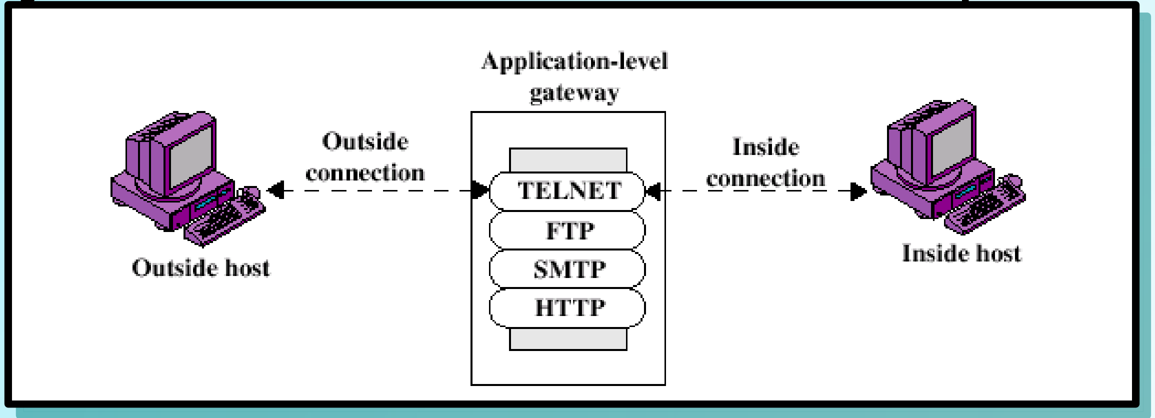
Application Gateway Firewalls



Layers Addressed by
Application-Proxy Gateway Firewalls

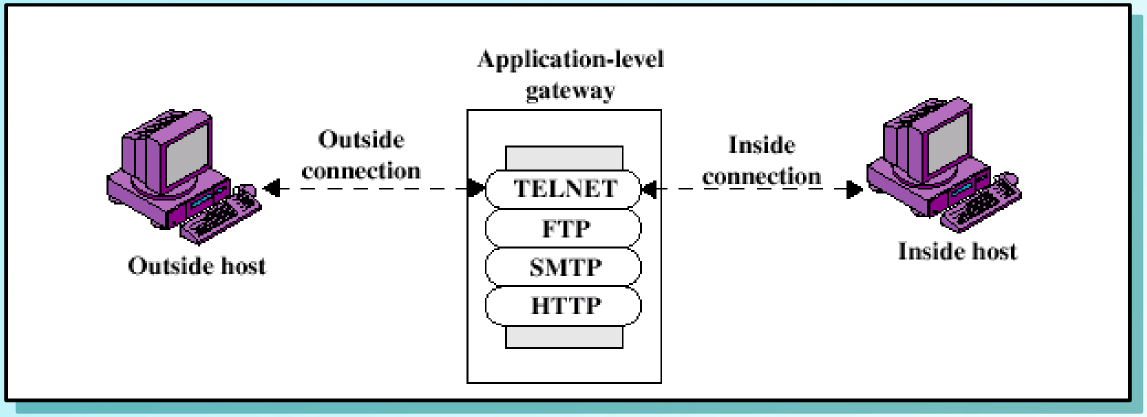
Application Level Gateway

- Acts as a relay of application level traffic
- Also called a proxy
- User contacts gateway for TELNET to remote host, user is authenticated, then gateway contacts remote host and relays info between two end points

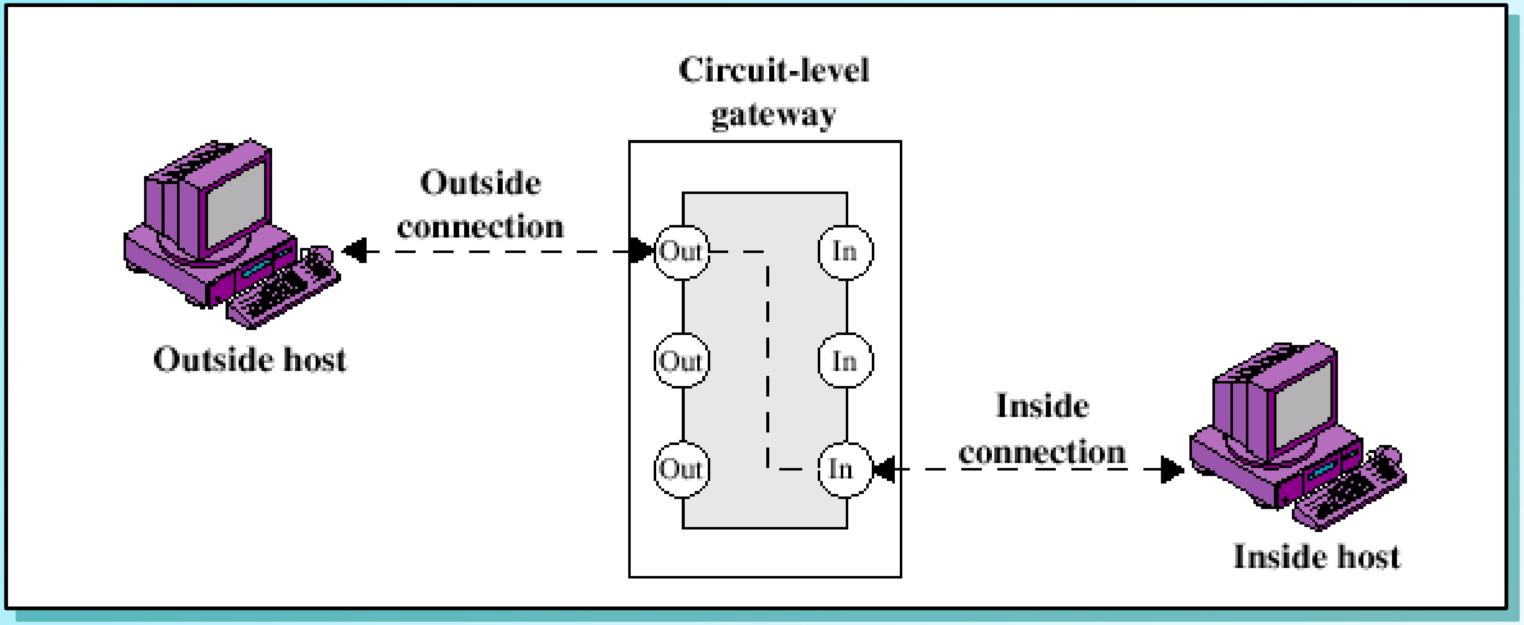


Application Level Gateway

- If proxy code for application is not supported, no forwarding of packets
- Can examine the packets to ensure the security of the application – full packet awareness
- Very easy to log since entire packet seen
- *Disadvantage:* additional processing overhead for each connection – increase load

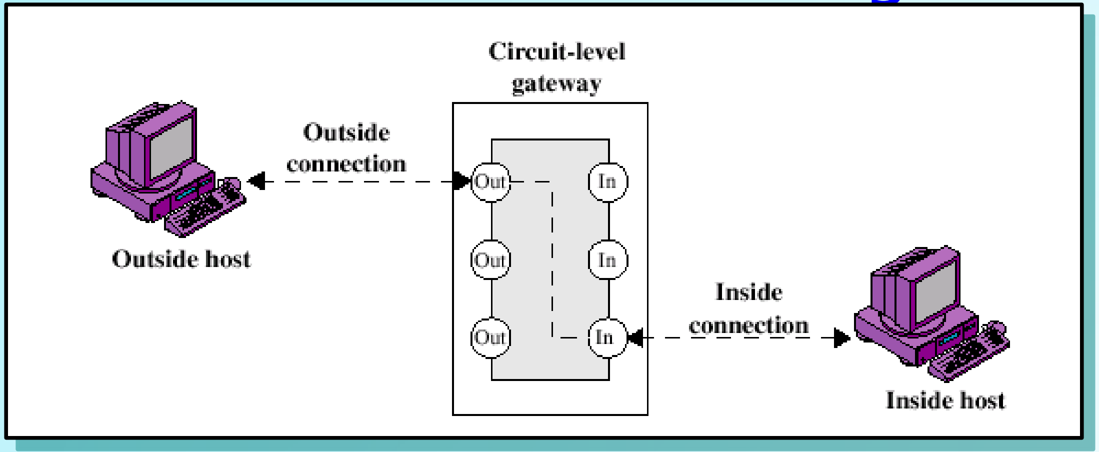


Circuit-Level Gateway



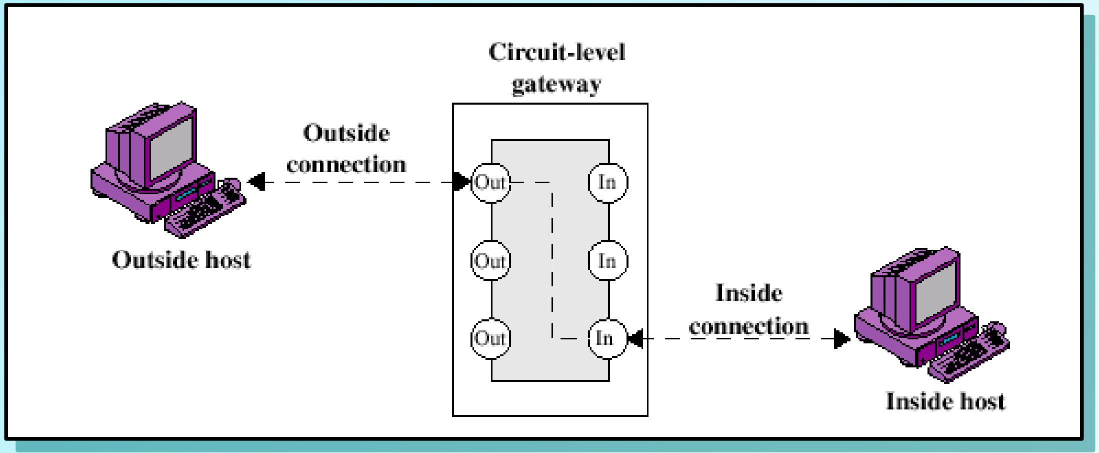
Circuit Level Gateway

- *Does not* permit an end-to-end TCP connection
- Sets up *two TCP connections* one between itself and a TCP user on the inside and one between itself and a TCP user on the outside
- *Relays TCP segments* from one connection to the other without examining the contents



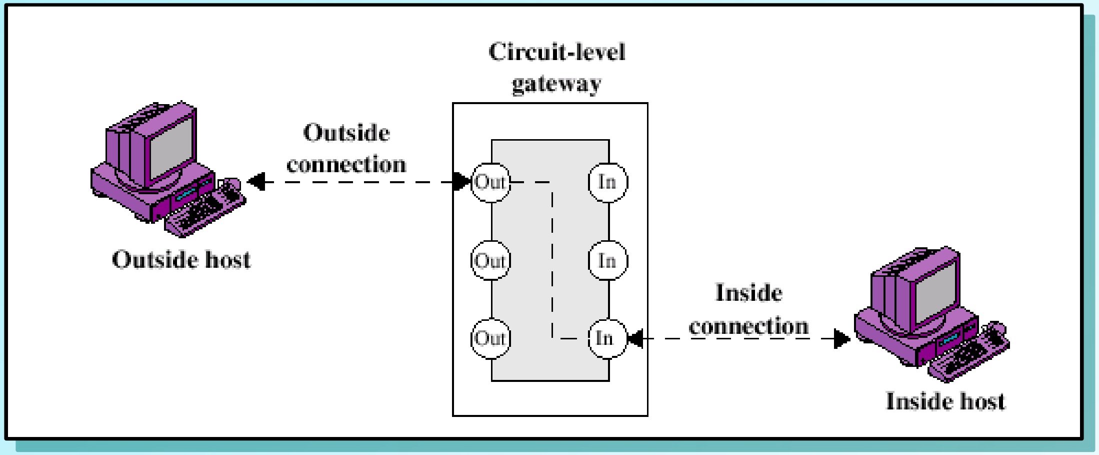
Circuit Level Gateway

- *Security function* (implements policy) determines which connections will be allowed
- Used where *internal users are trusted* for all outbound services
- Often *combined with a proxy* for inbound services

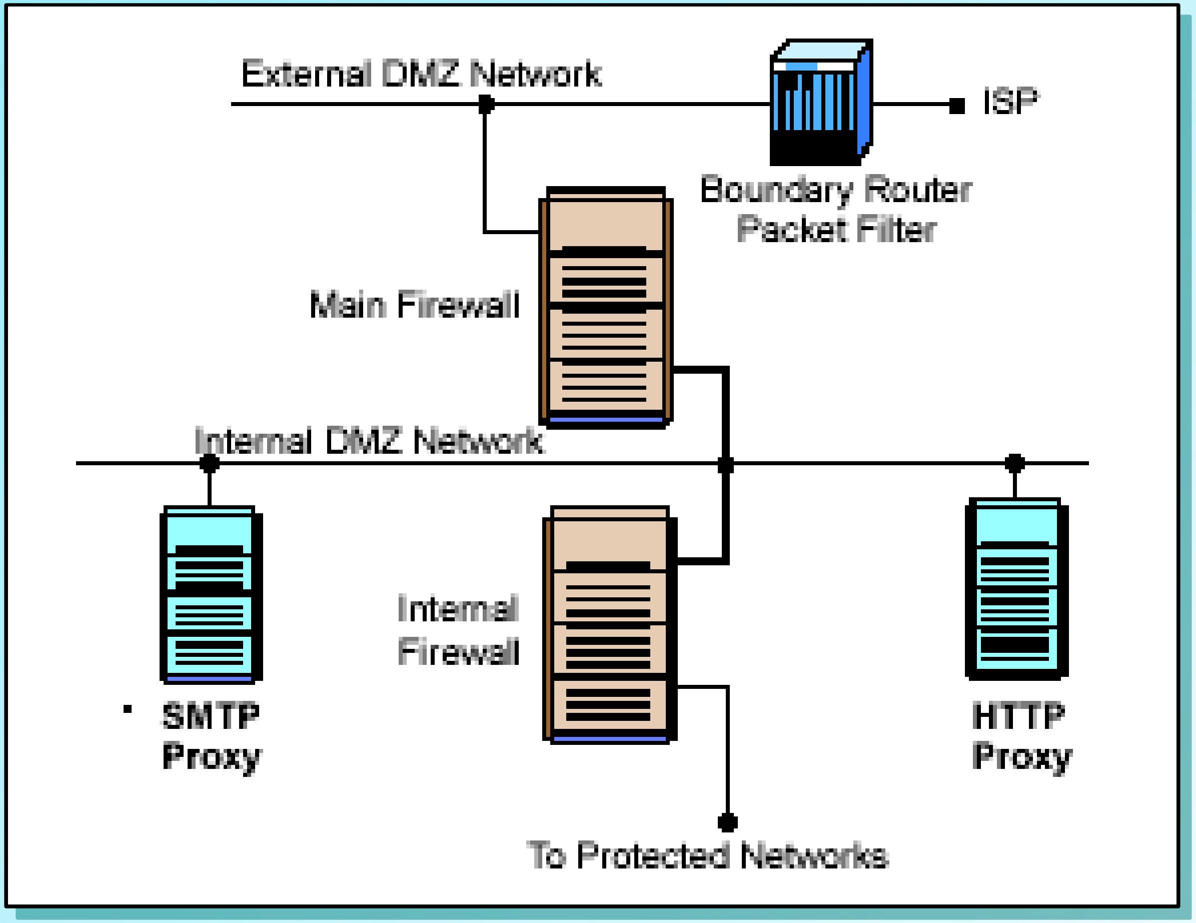


Circuit Level Gateway

- **SOCKS** package V5 – RFC 1928
- **Shim** between application and transport layers
- Uses port 1080
- Requires *SOCKS-ified client*
- *Disadvantage:* some implementations require a special client



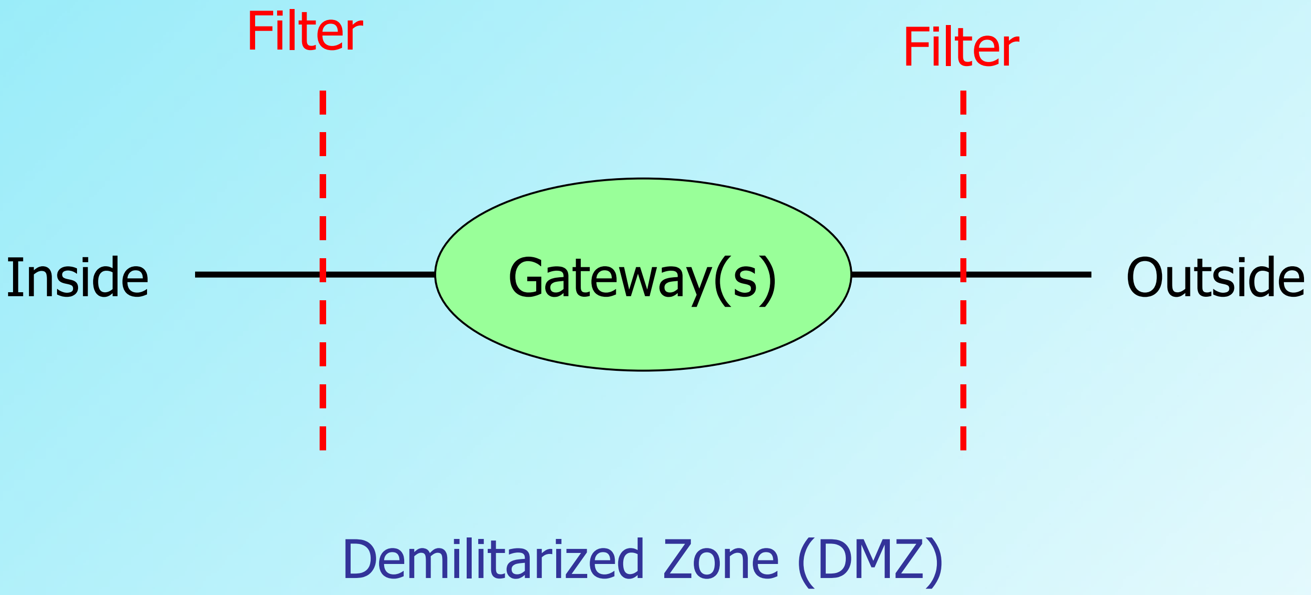
Dedicated Proxy Servers



Hybrid Firewalls

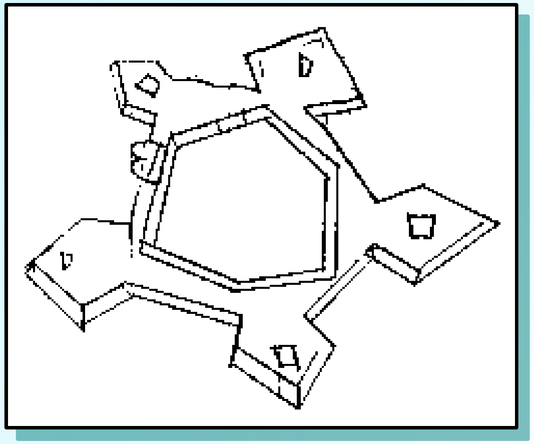
- "blurring of lines" that differentiate types of firewalls
- Application proxy gateway firewall vendors have implemented basic packet filter functionality in order to provide better support for UDP based applications
- Stateful inspection packet filter firewall vendors have implemented basic application proxy functionality to offset some of the weaknesses associated with packet filtering

Schematic of a Firewall



Bastion Host

- *Exposed* gateway is called the bastion host
- Sits in the *DMZ*
- Usually a platform for an application or circuit level gateway
- Hardened, *trusted system*
- Only essential services



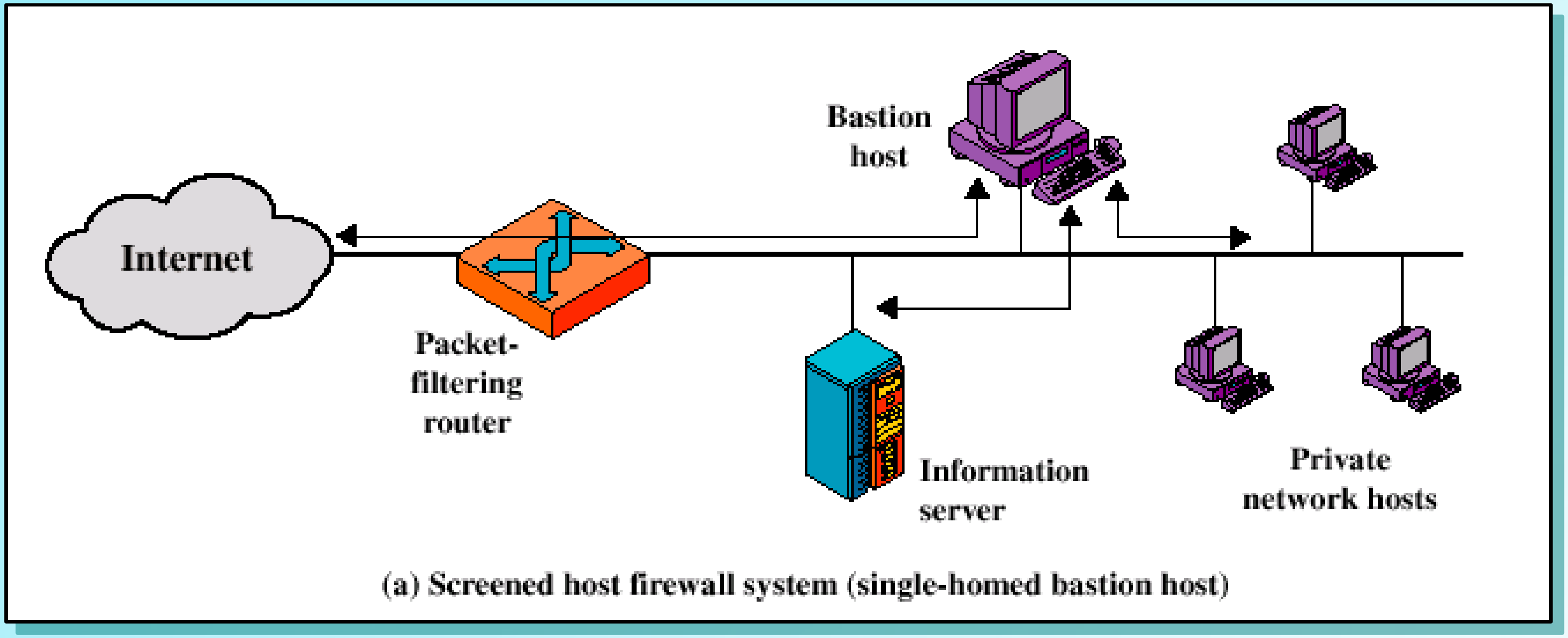
Bastion Host

- Allows *access only* to *specific hosts*
- Maintains detailed *audit information* by logging all traffic
- *Choke point* for discovering and terminating intruder attacks
- Each proxy is a *small, highly secure network software package* that is a subset of the general application

Bastion Host

- *Proxies* on bastion host are *independent* of each other
- *No disk access* other that to read initial configuration
- Proxies *run* as *non-privileged* users
- *Limited access* to bastion host

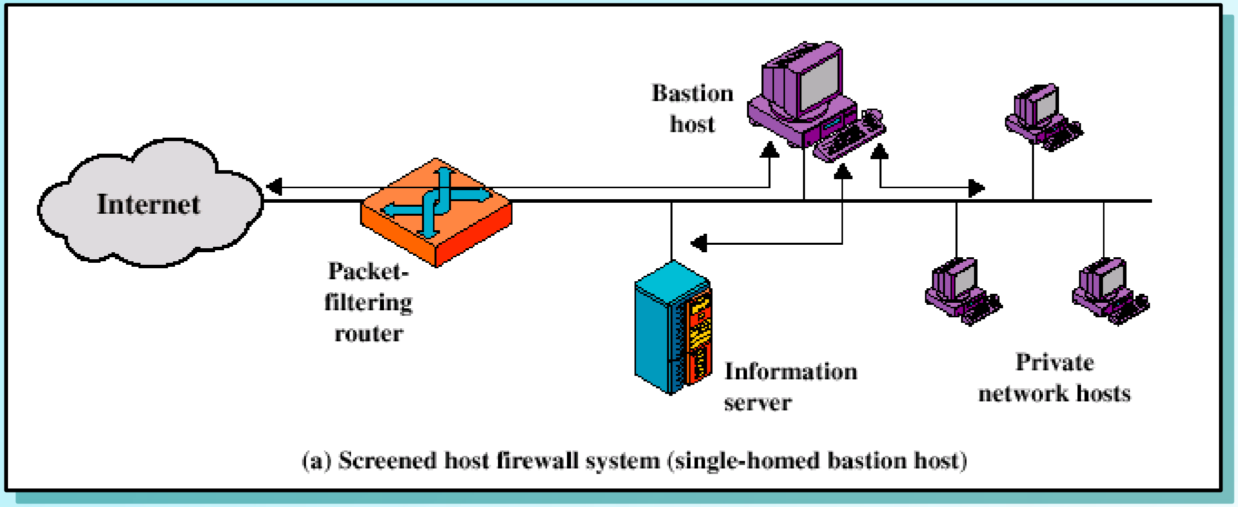
Bastion Host, Single-Homed



(a) Screened host firewall system (single-homed bastion host)

Bastion Host, Single-Homed

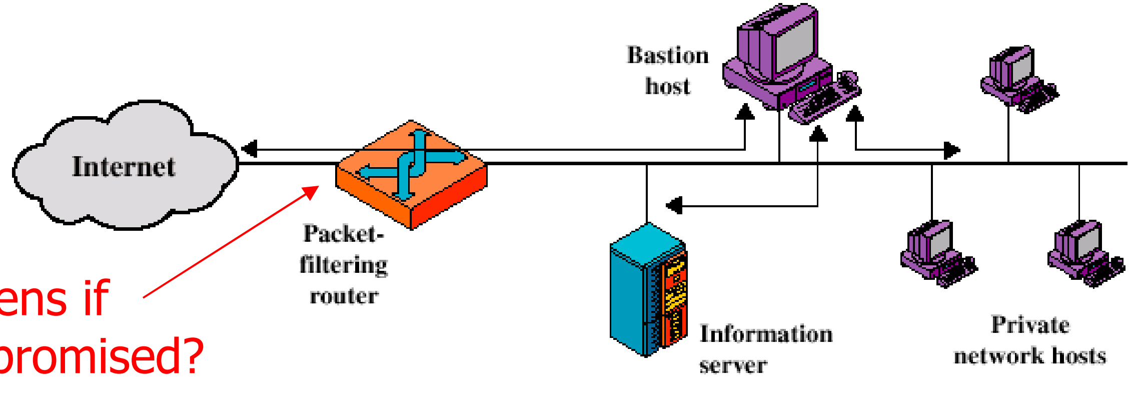
- *Two systems:* packet filtering router and bastion host
- For traffic from the *Internet*, only IP packets *destined* for the *bastion* host are allowed
- For traffic from the *internal network*, only relayed packets *from* the *bastion* host are allowed out



(a) Screened host firewall system (single-homed bastion host)

Bastion Host, Single-Homed

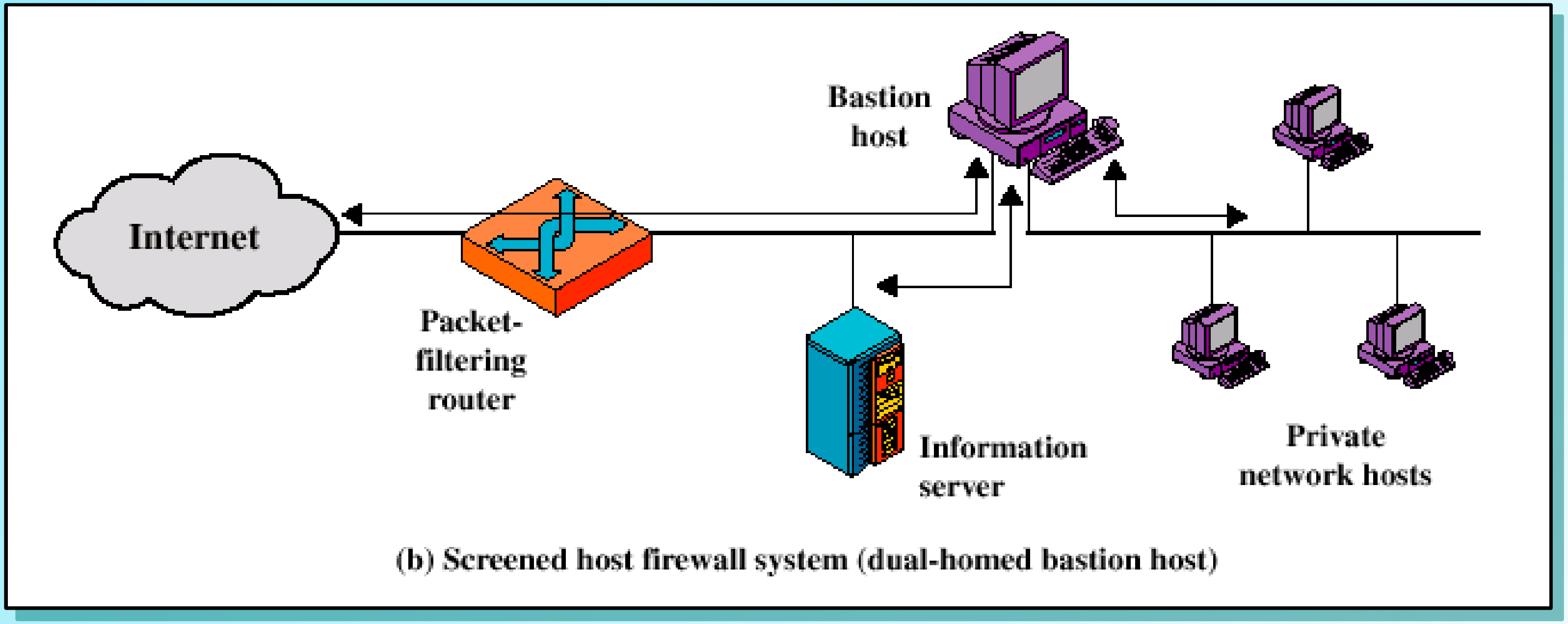
- Bastion host *performs authentication* Implements *both* packet level and application level filtering
- Intruder *penetrates two separate systems* before internal network is compromised
- May contain a *public information* server



(a) Screened host firewall system (single-homed bastion host)

What happens if this is compromised?

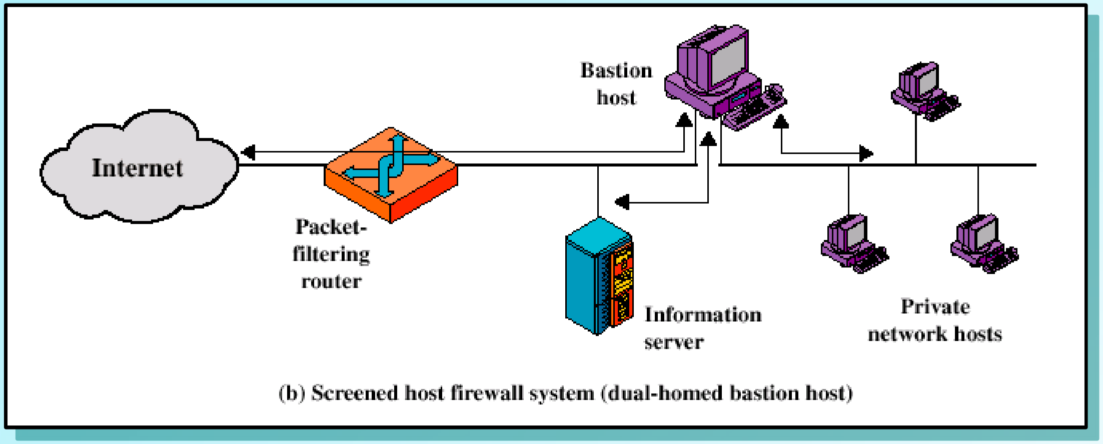
Bastion Host, Dual-Homed



(b) Screened host firewall system (dual-homed bastion host)

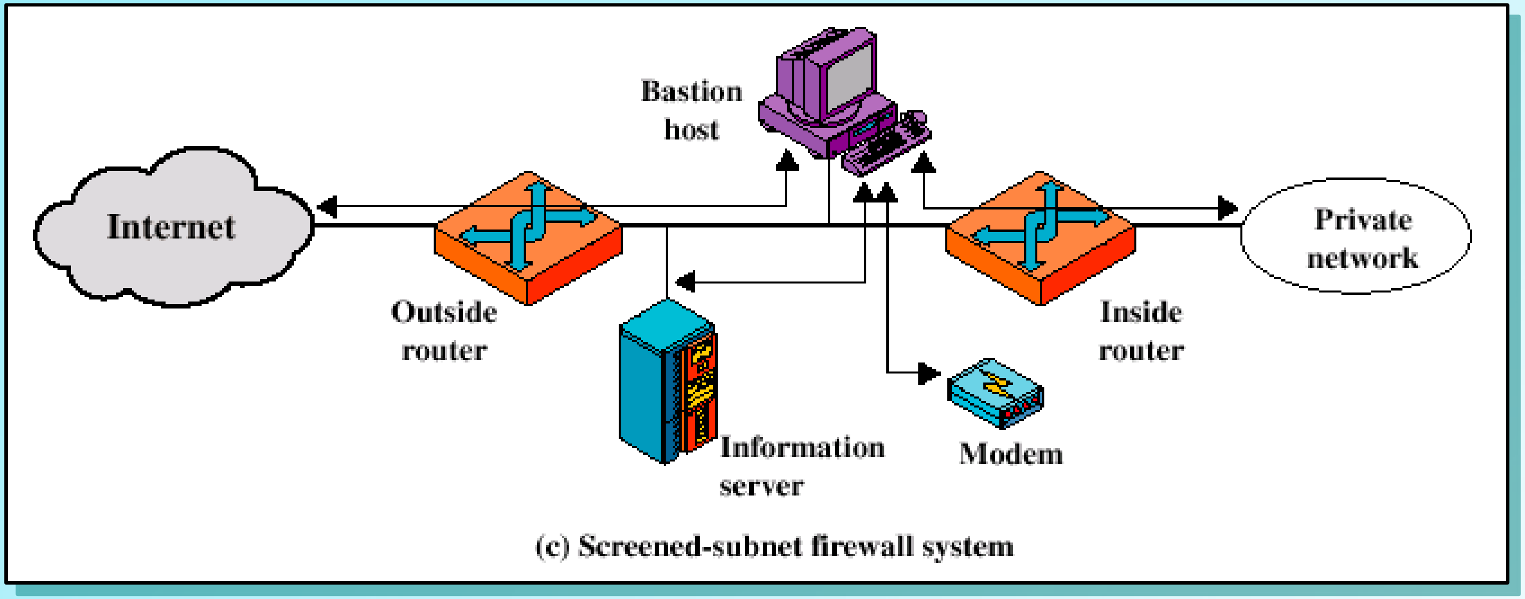
Bastion Host, Dual-homed

- Bastion host *second defense layer*
- Internal network is completely isolated
- Packet forwarding is turned off
- More secure



(b) Screened host firewall system (dual-homed bastion host)

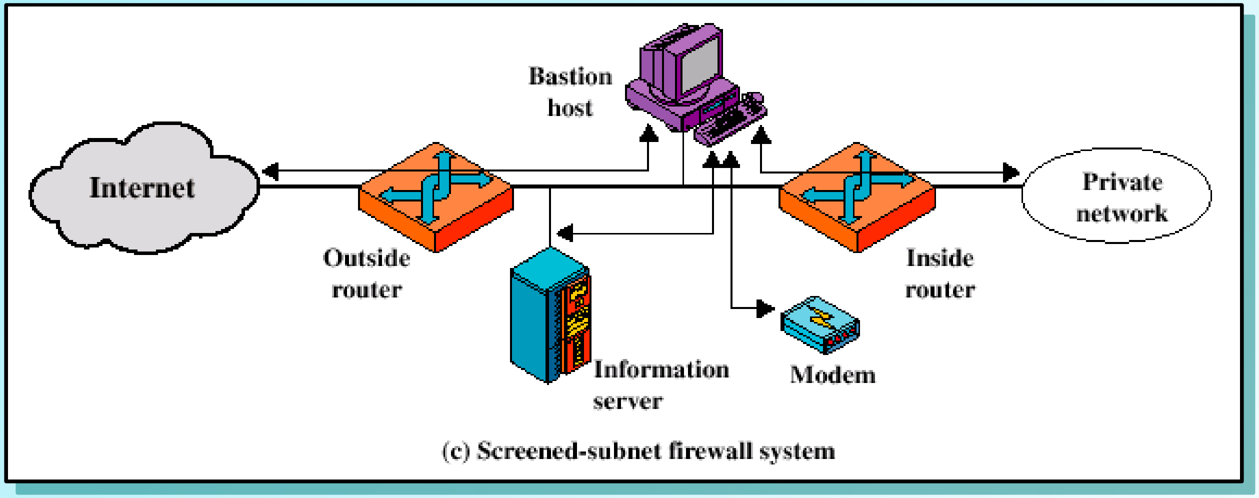
Screened Subnet



(c) Screened-subnet firewall system

Screened Subnet

- Most secure
- Isolated subnet with bastion host between two packet filtering routers
- Traffic across screened subnet is blocked
- Three layers of defense
- Internal network is invisible to the Internet



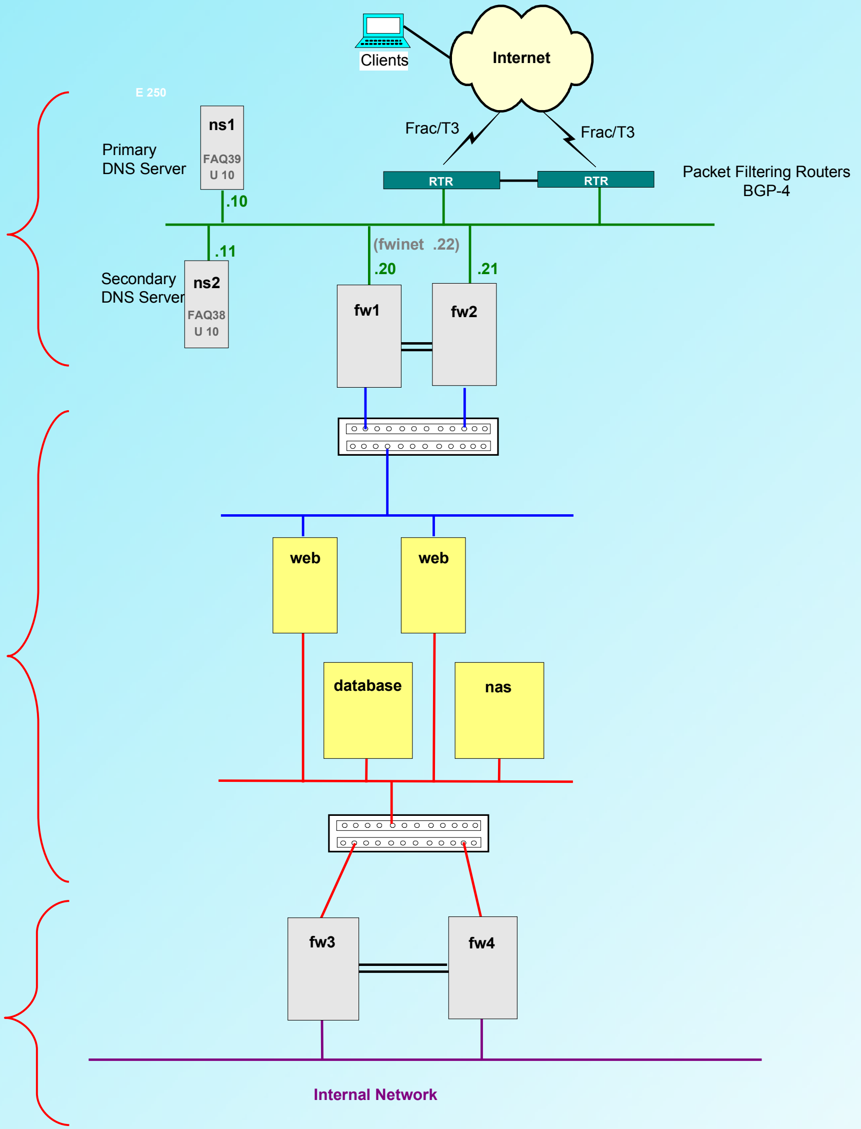
(c) Screened-subnet firewall system

Typical DMZ

external network

DMZ

internal network



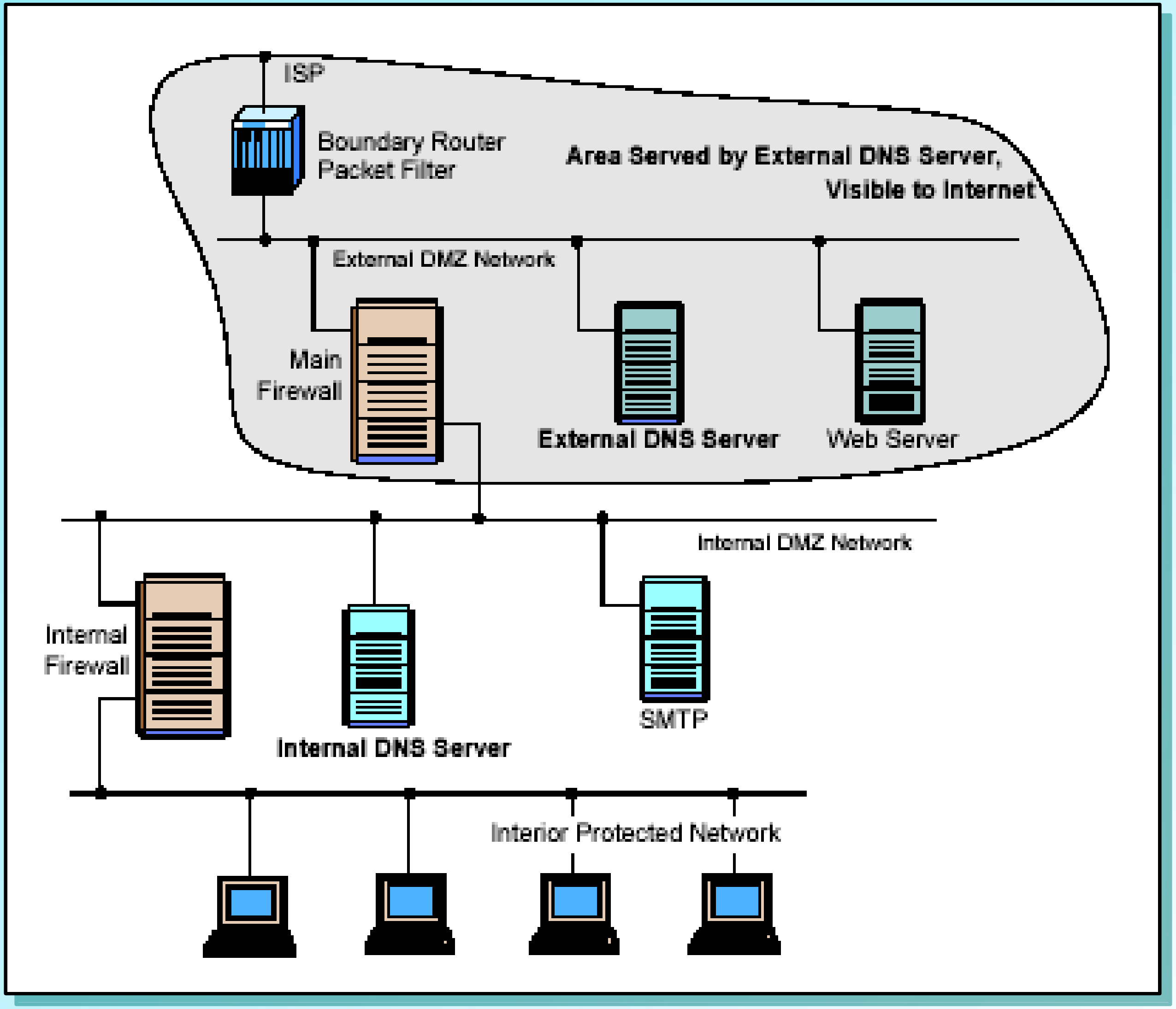
DMZ Building Guidelines

- Keep It Simple - KISS principle - the more simple the firewall solution, the more secure and more manageable
- Use Devices as They Were Intended to Be Used – don’t make switches into firewalls
- Create Defense in Depth – use layers, routers and servers for defense
- Pay Attention to Internal Threats – “crown jewels” go behind internal firewall – adage: “all rules are meant to be broken”

Taming the DNS

- Need *two* DNS servers
- Don’t want to reveal internal names and addresses
- Internal network has an isolated, pseudo-root DNS
- *Forwards* requests to the external DNS
- “Split DNS” or “Split Brain”

Taming the DNS



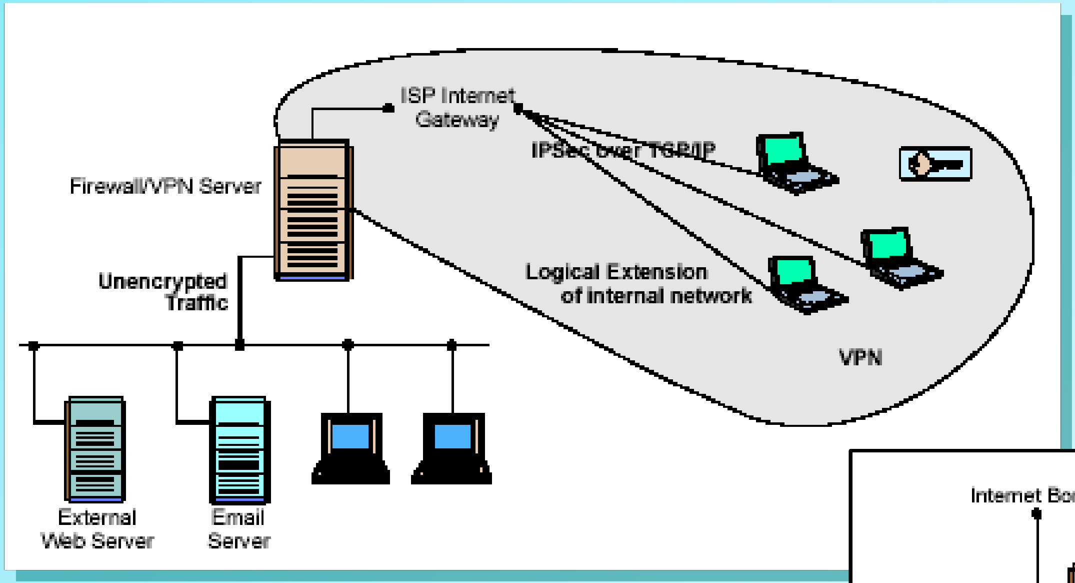
Network Address Translation

- Solves address depletion problems with IPv4
- RFC 2663 – IP Network Address Translator Terminology and Considerations, 1996
- Gateways to disparate networks
- Hides internal addresses
- Port Address Translation (PAT) – a variation using ports

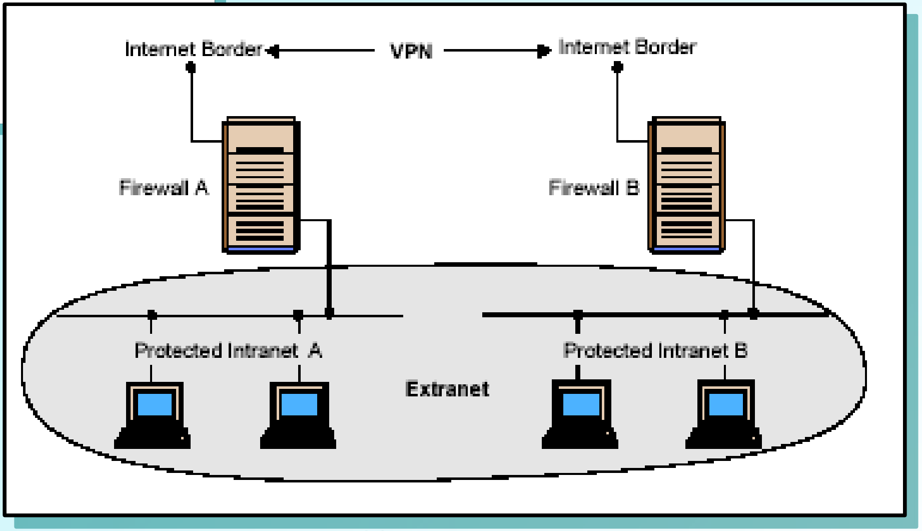
Secure Shell (SSH)

- Eliminates “Crunchy Cookie” DMZ
- Everything is encrypted
- Used for system administration and remote access
- SSH2 – www.ssh.com

VPN's Another Type of Firewall



Connecting remote users across the Internet



Connecting offices across Internet

Other Types Of Firewalls

- Host Based Firewalls – comes with some operating systems (LINUX, WIN/XP) – ipfilter is a popular one http://coombs.anu.edu.au/~avalon/
- Avoids Crunchy Cookie Syndrome – hard and crunchy on the outside, soft and chewy on the inside

Other Types Of Firewalls

- Personal Firewalls Appliances – personal firewall appliances are designed to protect small networks such as networks that might be found in home offices
- Provide: print server, shared broadband use, firewall, DHCP server and NAT

Wireless 2.4GHz (802.11b)
Router plus Print Server
DI-713P
Up to 11Mbps and fully compatible with 802.11b

(NB: This is not an endorsement of any product)

Network Security

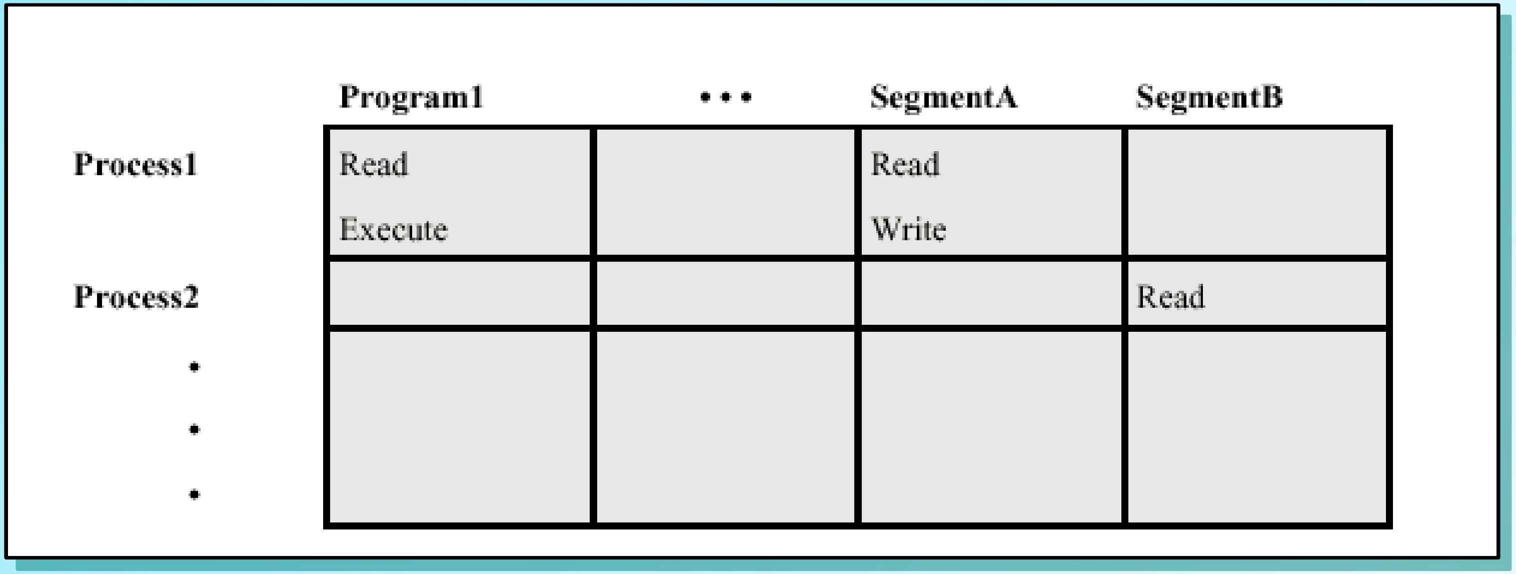
Trusted Systems

Access Matrix

General model of access control:

- Subject – entity capable of accessing objects (user = process= subject)
- Object – anything to which access is controlled (files, programs, memory)
- Access right – way in which an object is accessed by a subject (read, write, exe)

Access Matrix



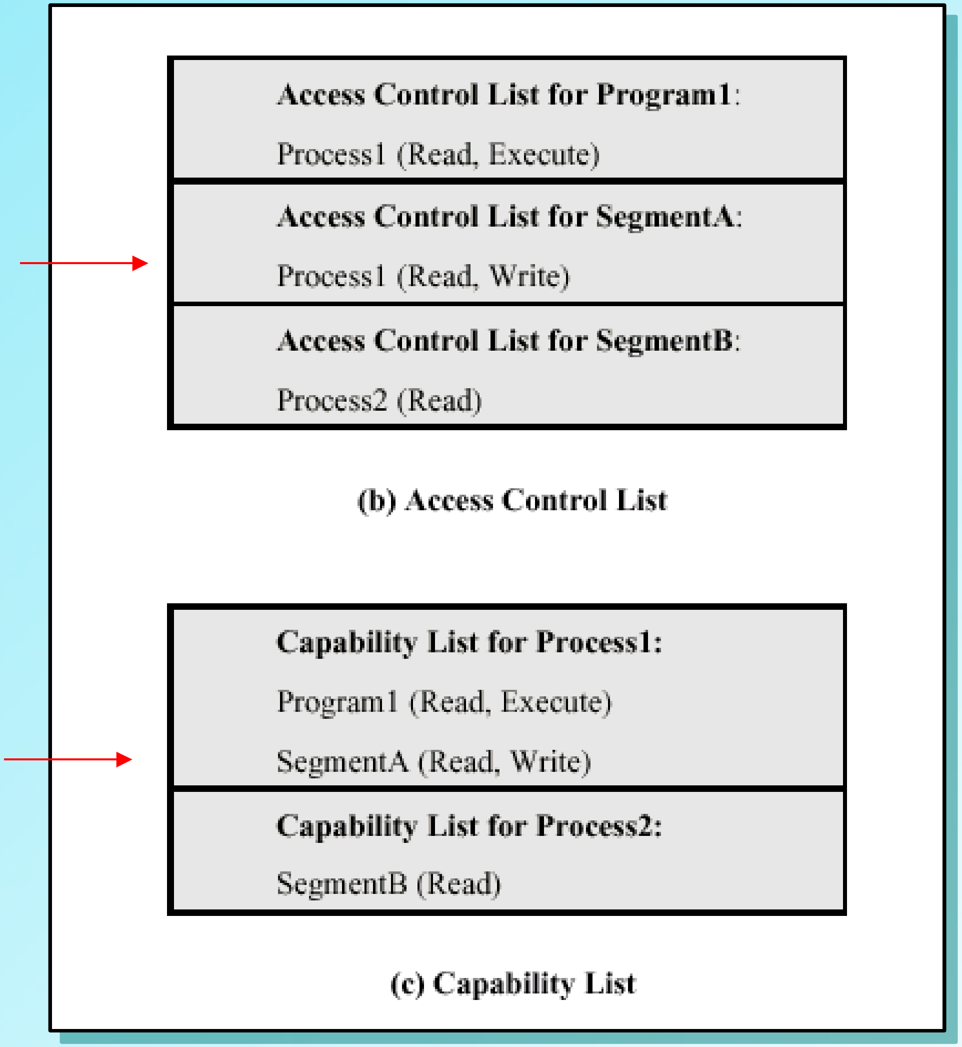
	Program1	• • •	SegmentA	SegmentB
Process1	Read Execute		Read Write	
Process2				Read
• • •				

Access Control List

decomposed by columns

decomposed by rows

“compability ticket”



Access Control List for Program1:

Process1 (Read, Execute)

Access Control List for SegmentA:

Process1 (Read, Write)

Access Control List for SegmentB:

Process2 (Read)

(b) Access Control List

Capability List for Process1:

Program1 (Read, Execute)

SegmentA (Read, Write)

Capability List for Process2:

SegmentB (Read)

(c) Capability List

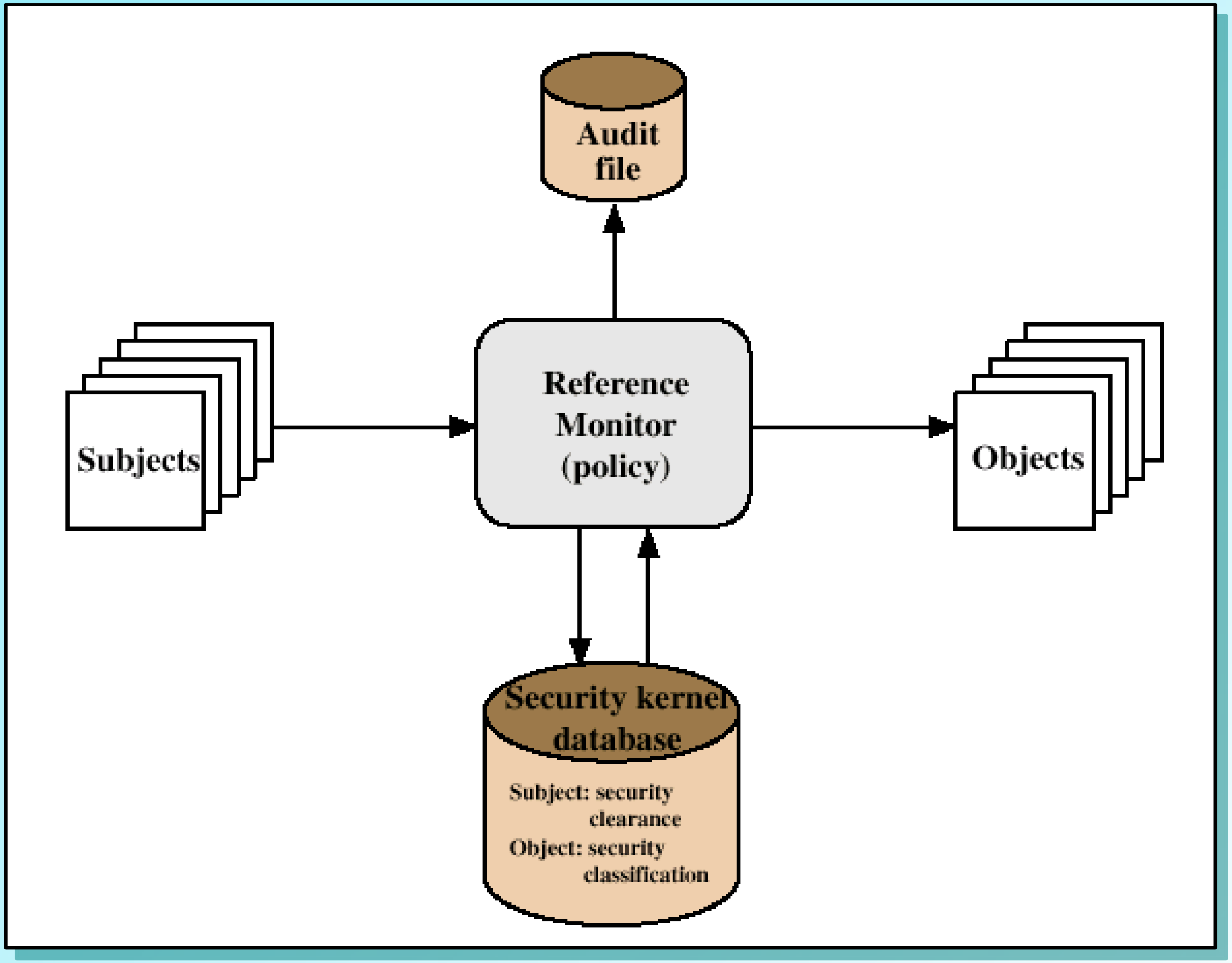
Concept of Trusted Systems

- We’ve been concerned with protecting a message from active or passive attack by given user
- Different requirement is to protect data or resources on the basis of security levels (unclassified, confidential, secret and top secret)

Concept of Trusted Systems

- Multilevel security – subject at a high level may not convey information to a subject at a lower or non-comparable level unless that flow accurately reflects the will of an authorized user
- No read up: Subject can only read an object of less or equal security level
- No write down: Subject can only write into an object of greater or equal security level

Reference Monitor


Audit file
Subjects
Reference Monitor (policy)
Objects
Security kernel database
Subject: security clearance
Object: security classification

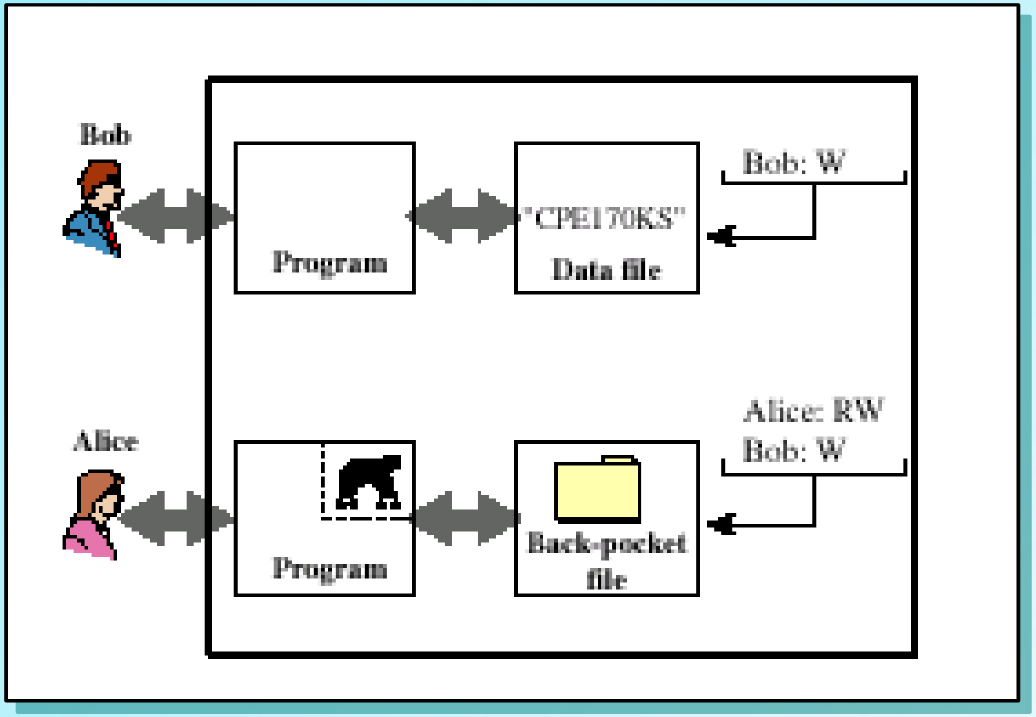
Reference Monitor

- Reference monitor is a controlling element in hardware and OS
- Enforces the security rules in the security kernel database (no read up, no write down)

Trusted System Properties

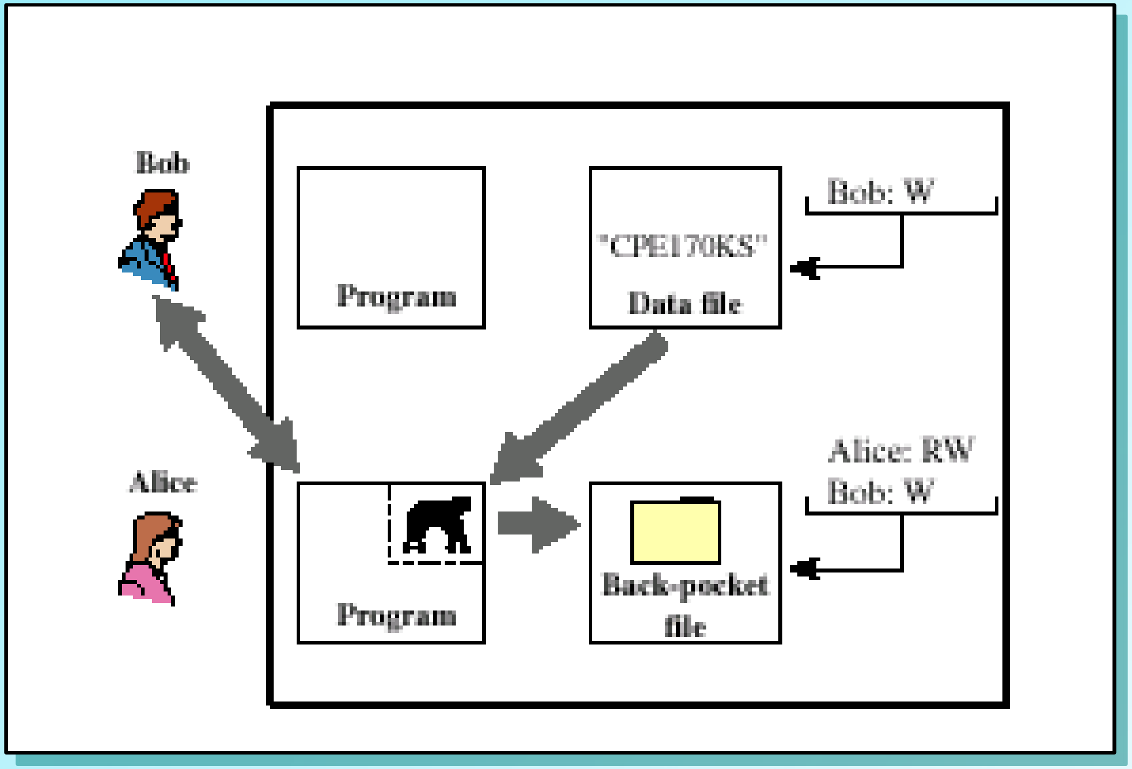
- Complete mediation – security rules enforced on every access
- Isolation – reference monitor and database are protected from unauthorized modification
- Verifiability – reference monitor's correctness must be mathematically provable

Trojan Horse Defense



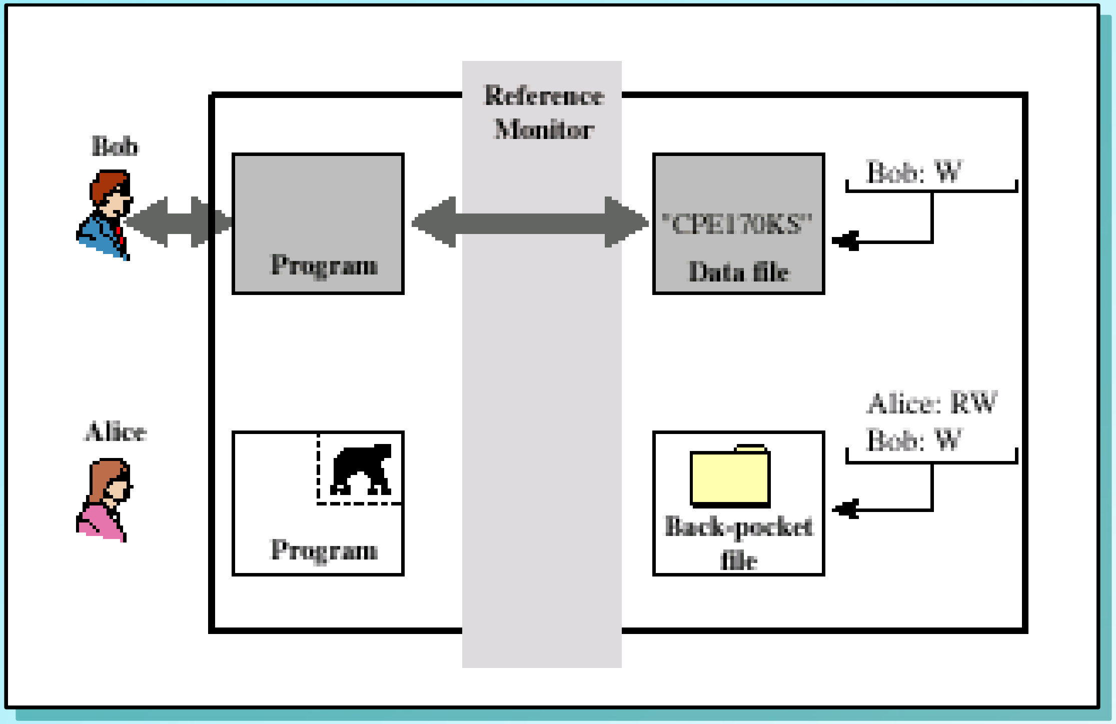
Alice installs trojan horse program and gives Bob write only permission

Trojan Horse Defense



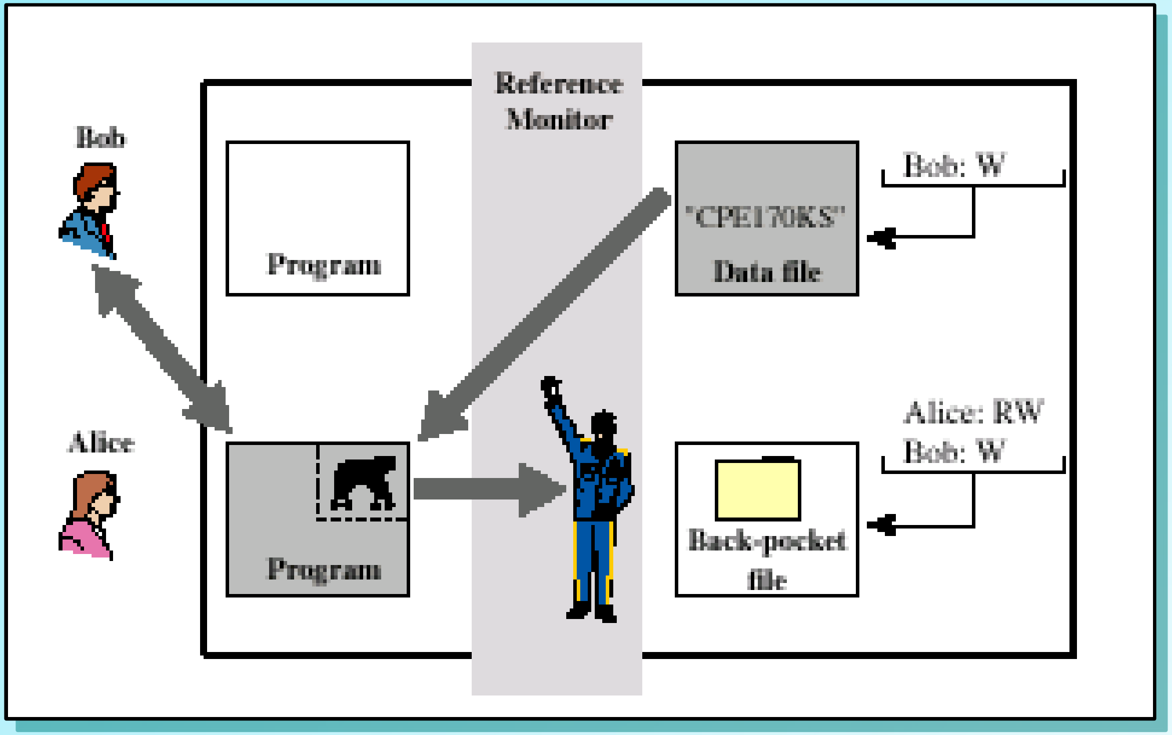
Alice induces Bob to invoke the trojan horse. Program detects it is being executed by Bob, reads the sensitive character string and writes it into Alice's back-pocket file

Trojan Horse Defense

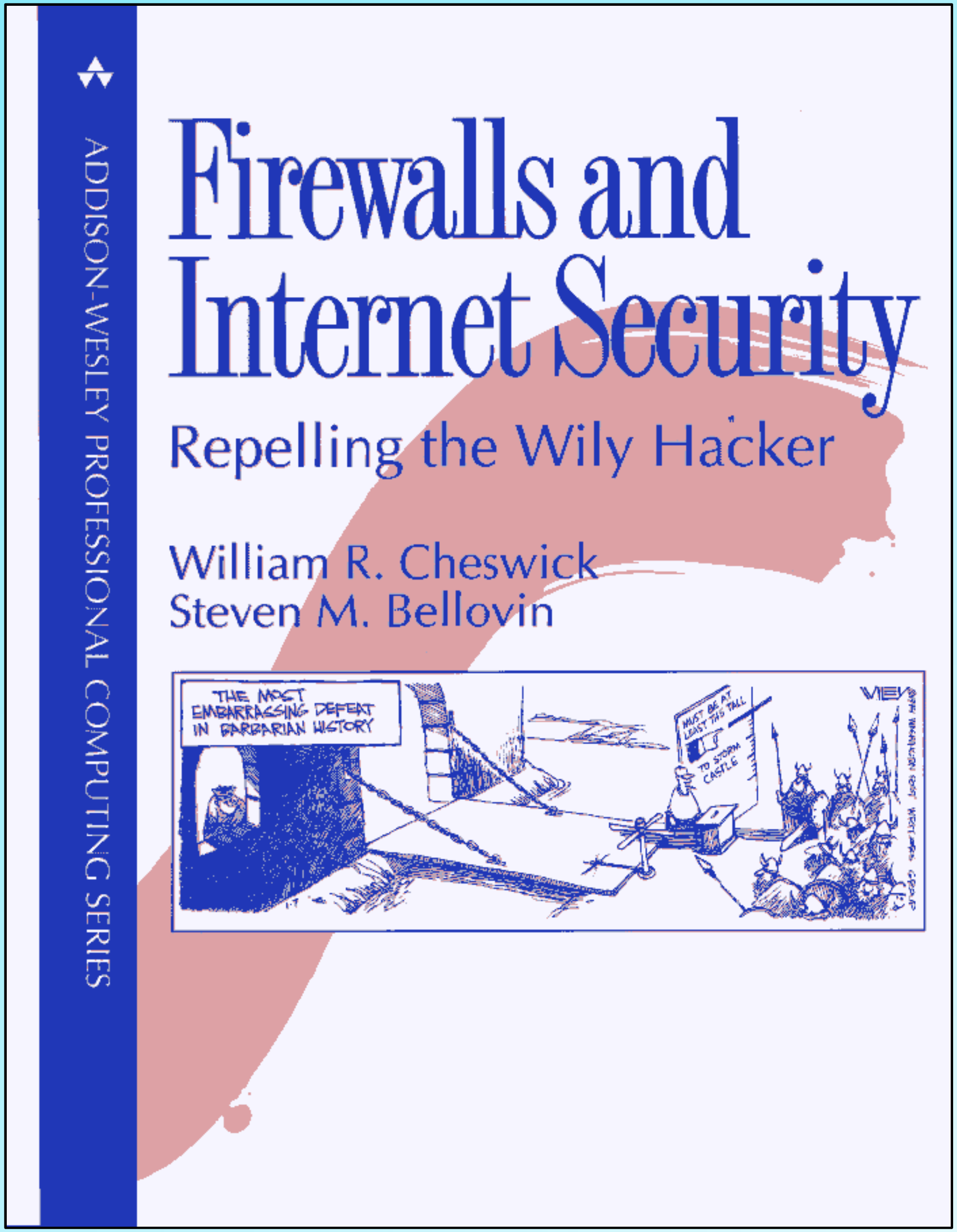


Two security levels are assigned, sensitive(higher) and public. Bob's stuff is sensitive and Alice's stuff is public.

Trojan Horse Defense



If Bob invokes the trojan horse program, that program acquires Bob’s security and is able to read the character string. However, when the program attempts to store the string, the no write down policy is invoked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Firewalls and Internet Security
Repelling the Wily Hacker
William R. Cheswick
Steven M. Bellovin
THE MOST EMBARRASSING DEFEAT IN BARBARIAN HISTORY
MUST BE AT LEAST THIS TALL TO STORM CASTLE

A classic in the field published in 1994. Know for its 💣 “bombs” which indicated a serious risk

Important URLs

- Evolution of the Firewall Industry - Discusses different architectures and their differences, how packets are processed, and provides a timeline of the evolution
- http://csrc.nist.gov/publications/nistpubs/800-41/ NIST Guidelines On Firewalls and Firewall Policy
- Trusted Computing Group Vendor group involved in developing and promoting trusted computer standards

Homework

- Read Chapter Ten
- Read “An Evening With Berferd” – notice the techniques used (traces, protocols, etc.) – Do not attempt this at home

Remember Hans Brinker…

… 1st Firewall Administrator