Computer Security: Principles and Practice

Fourth Edition

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Chapter 9

Firewalls and Intrusion Prevention Systems

The Need For Firewalls

- Internet connectivity is essential
  - However it creates a threat
- Effective means of protecting LANs
- Inserted between the premises network and the Internet to establish a controlled link
  - Can be a single computer system or a set of two or more systems working together
- Used as a perimeter defense
  - Single choke point to impose security and auditing
  - Insulates the internal systems from external networks

Firewall Characteristics

Design goals

All traffic from inside to outside, and vice versa, must pass through the firewall

Only authorized traffic as defined by the local security policy will be allowed to pass

The firewall itself is immune to penetration

Firewall Access Policy

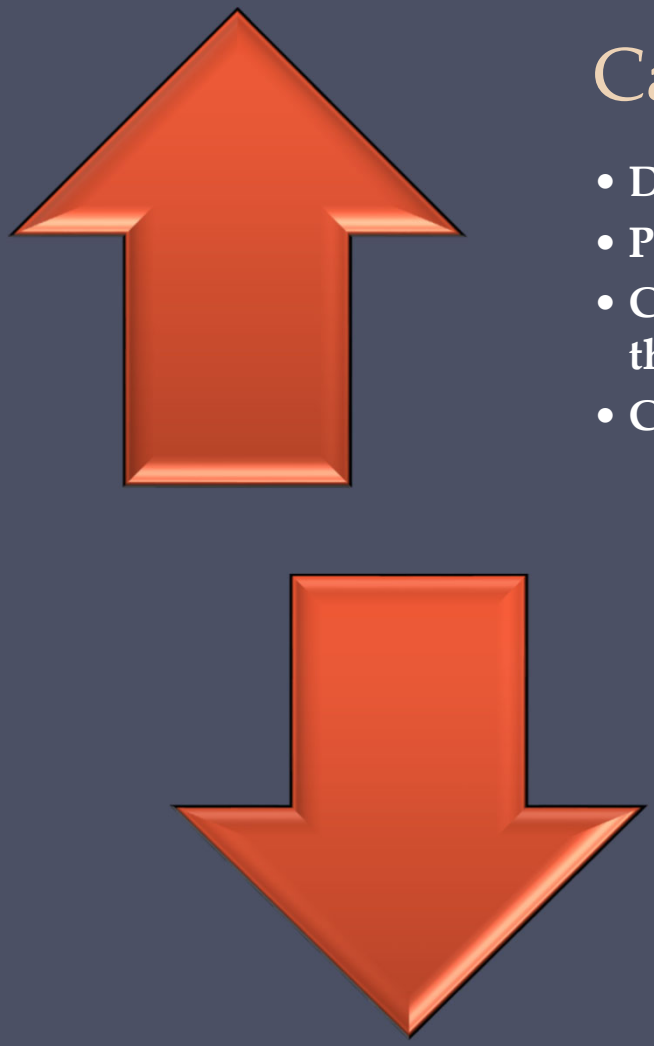
- A critical component in the planning and implementation of a firewall is specifying a suitable access policy
  - This lists the types of traffic authorized to pass through the firewall
  - Includes address ranges, protocols, applications and content types
- This policy should be developed from the organization's information security risk assessment and policy
- Should be developed from a broad specification of which traffic types the organization needs to support
  - Then refined to detail the filter elements which can then be implemented within an appropriate firewall topology

Firewall Filter Characteristics

- Characteristics that a firewall policy could use to filter traffic include (not an exhaustive list):

IP address and protocol values	Application protocol	User identity	Network activity
This type of filtering is used by packet filter and stateful inspection firewalls	This type of filtering is used by an application-level gateway that relays and monitors the exchange of information for specific application protocols	Typically for inside users who identify themselves using some form of secure authentication technology	Controls access based on considerations such as the time of request, rate of requests, or other activity patterns
Typically used to limit access to specific services			

Firewall Capabilities And Limits

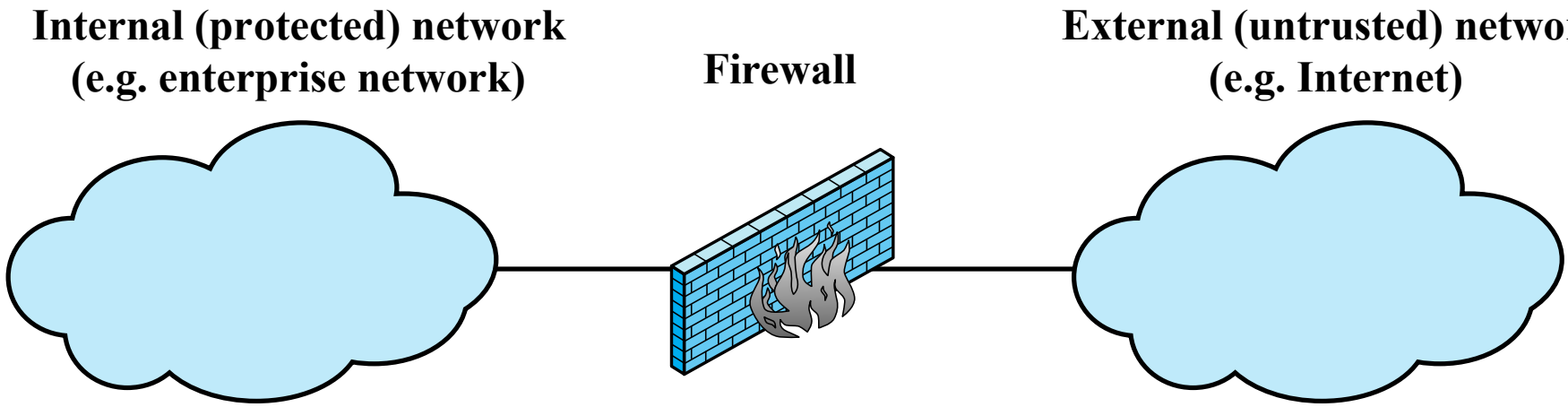


Capabilities:

- Defines a single choke point
- Provides a location for monitoring security events
- Convenient platform for several Internet functions that are not security related (NAT/DNS, logging)
- Can serve as the platform for IPSec (VPNs)

Limitations:

- Cannot protect against attacks bypassing firewall
- May not protect fully against internal threats
- Improperly secured wireless LAN can be accessed from outside the organization
- Laptop, PDA, or portable storage device may be infected outside the corporate network then used internally (BYOD)



(a) General model

Figure 9.1 Types of Firewalls

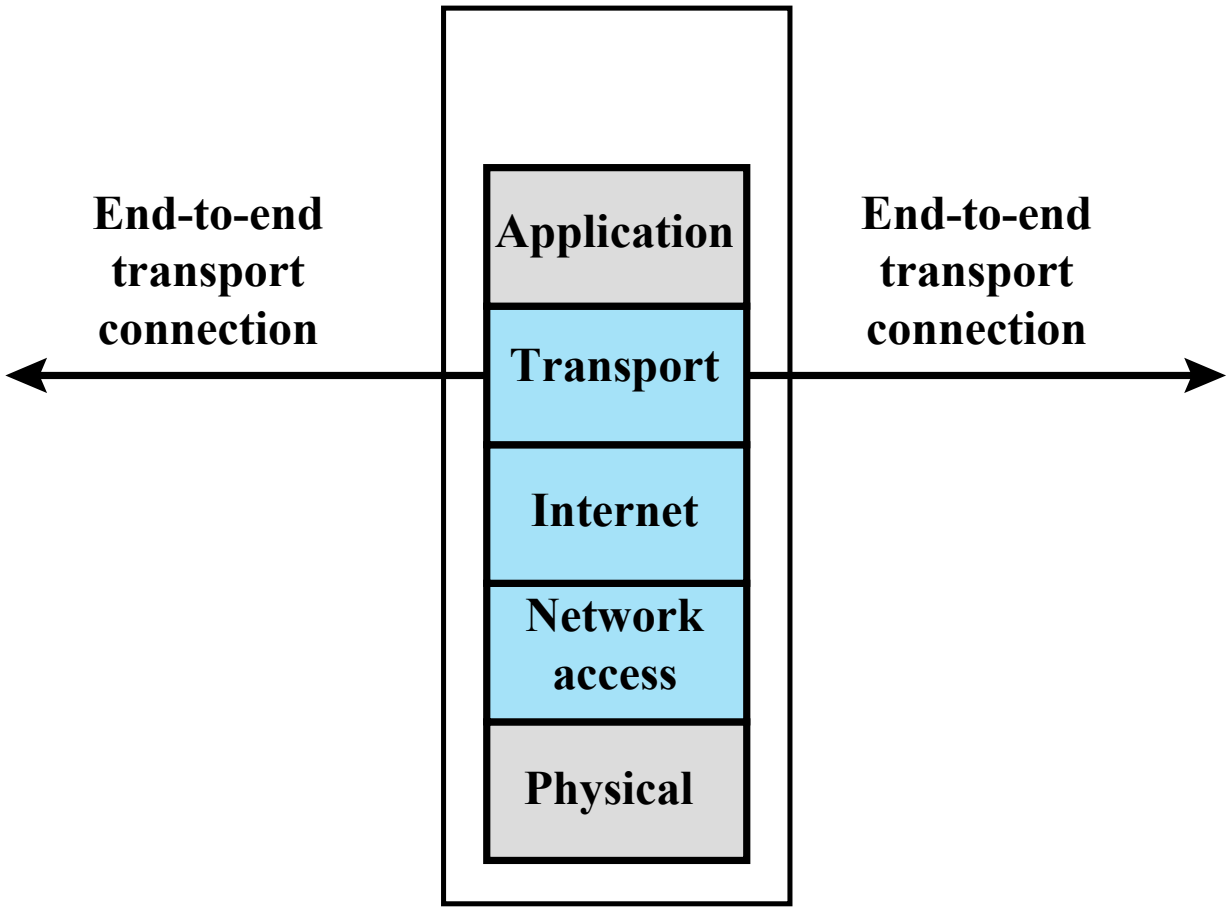


Figure 9.1 Types of Firewalls

Packet Filtering Firewall

- Applies rules to each incoming and outgoing IP packet
  - Typically a list of rules based on matches in the IP or TCP header
  - Forwards or discards the packet based on rules match

Filtering rules are based on information contained in a network packet
• Source IP address • Destination IP address • Source and destination port-level address • IP protocol field • Interface

- Two default policies:
  - Discard - prohibit unless expressly permitted
    - More conservative, controlled, visible to users
  - Forward - permit unless expressly prohibited
    - Easier to manage and use but less secure

Table 9.1
Packet-Filtering Examples

Rule	Direction	Src address	Dest addresss	Protocol	Dest port	Action
1	In	External	Internal	TCP	25	Permit
2	Out	Internal	External	TCP	>1023	Permit
3	Out	Internal	External	TCP	25	Permit
4	In	External	Internal	TCP	>1023	Permit
5	Either	Any	Any	Any	Any	Deny

Packet Filter Advantages And Weaknesses

- Advantages
  - Simplicity
  - Typically transparent to users
  - Very fast
- Weaknesses
  - Cannot prevent attacks that employ application specific vulnerabilities or functions
  - Limited logging functionality
  - Does not support advanced user authentication
  - Vulnerable to TCP/IP spoofing
  - Improper configuration can lead to breaches

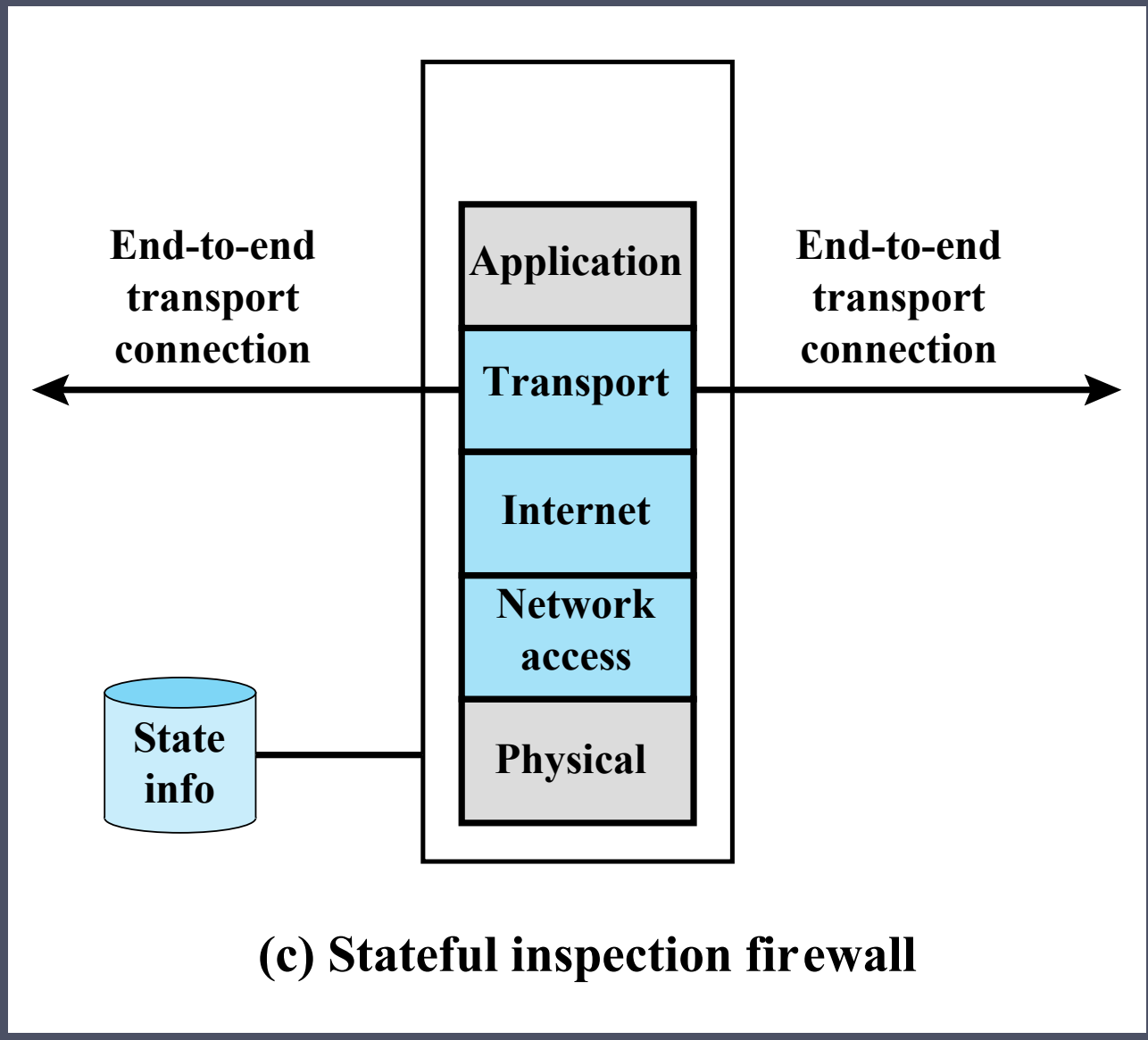


Figure 9.1 Types of Firewalls

Stateful Inspection Firewall

Tightens rules for TCP traffic by creating a directory of outbound TCP connections

- There is an entry for each currently established connection
- Packet filter allows incoming traffic to high numbered ports only for those packets that fit the profile of one of the entries in this directory

Reviews packet information but also records information about TCP connections

- Keeps track of TCP sequence numbers to prevent attacks that depend on the sequence number
- Inspects data for protocols like FTP, IM and SIPS commands

Table 9.2
Example Stateful Firewall Connection State Table

Source Address	Source Port	Destination Address	Destination Port	Connection State
192.168.1.100	1030	210.9.88.29	80	Established
192.168.1.102	1031	216.32.42.123	80	Established
192.168.1.101	1033	173.66.32.122	25	Established
192.168.1.106	1035	177.231.32.12	79	Established
223.43.21.231	1990	192.168.1.6	80	Established
219.22.123.32	2112	192.168.1.6	80	Established
210.99.212.18	3321	192.168.1.6	80	Established
24.102.32.23	1025	192.168.1.6	80	Established
223.21.22.12	1046	192.168.1.6	80	Established

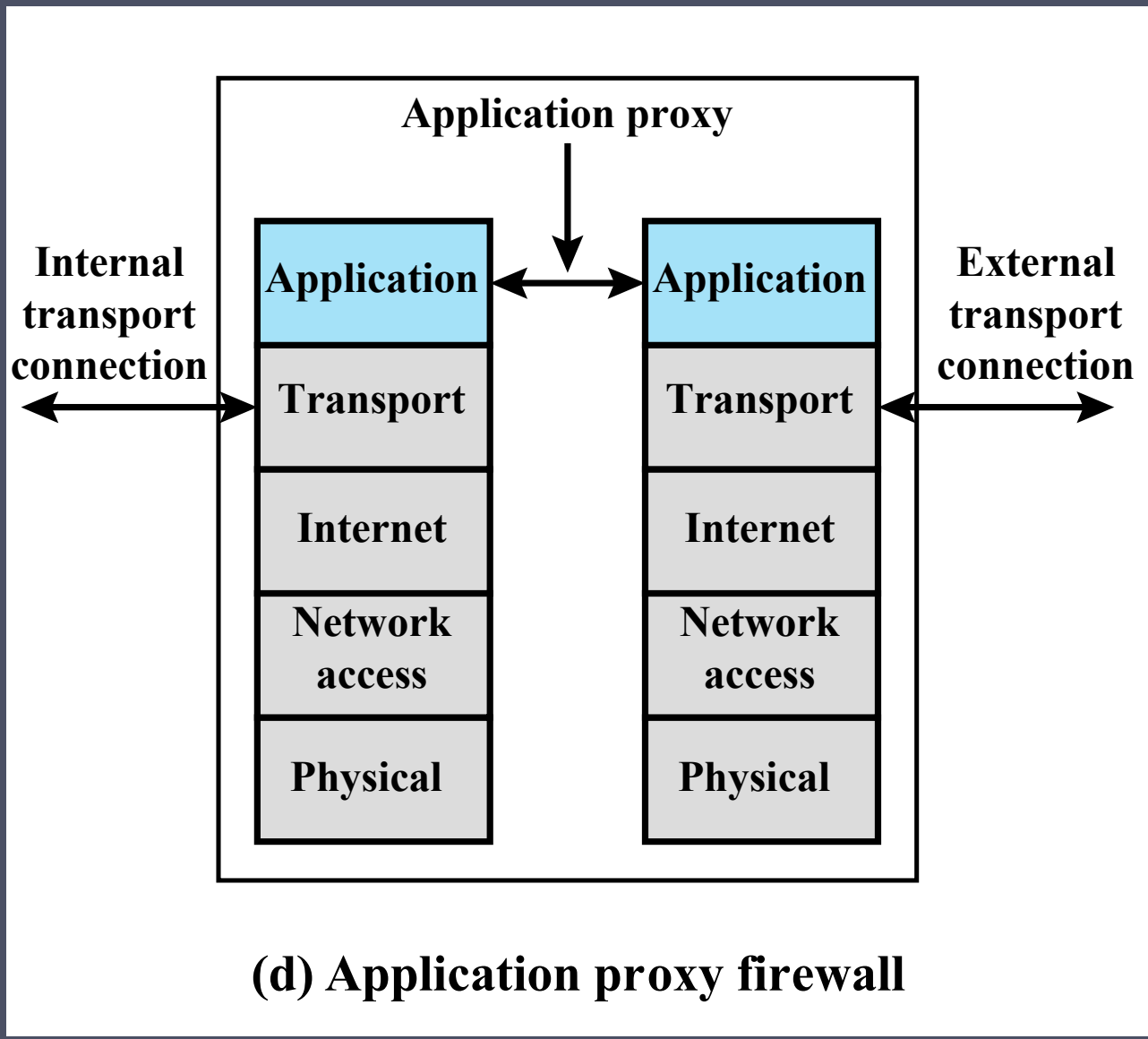


Figure 9.1 Types of Firewalls

Application-Level Gateway

- Also called an application proxy
- Acts as a relay of application-level traffic
  - User contacts gateway using a TCP/IP application
  - User is authenticated
  - Gateway contacts application on remote host and relays TCP segments between server and user
- Must have proxy code for each application
  - May restrict application features supported
- Tend to be more secure than packet filters
- Disadvantage is the additional processing overhead on each connection

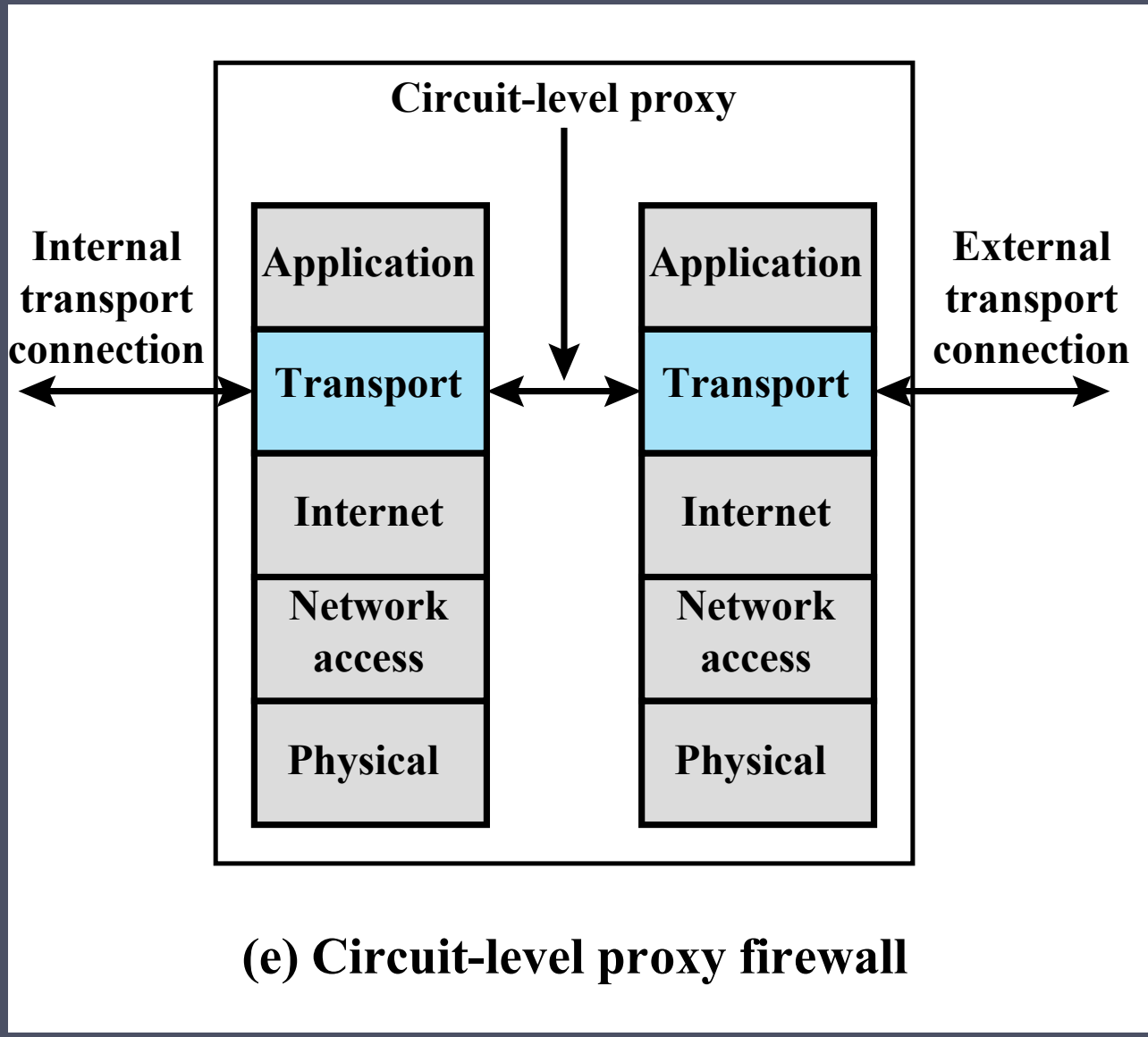


Figure 9.1 Types of Firewalls

Circuit-Level Gateway

Circuit level proxy

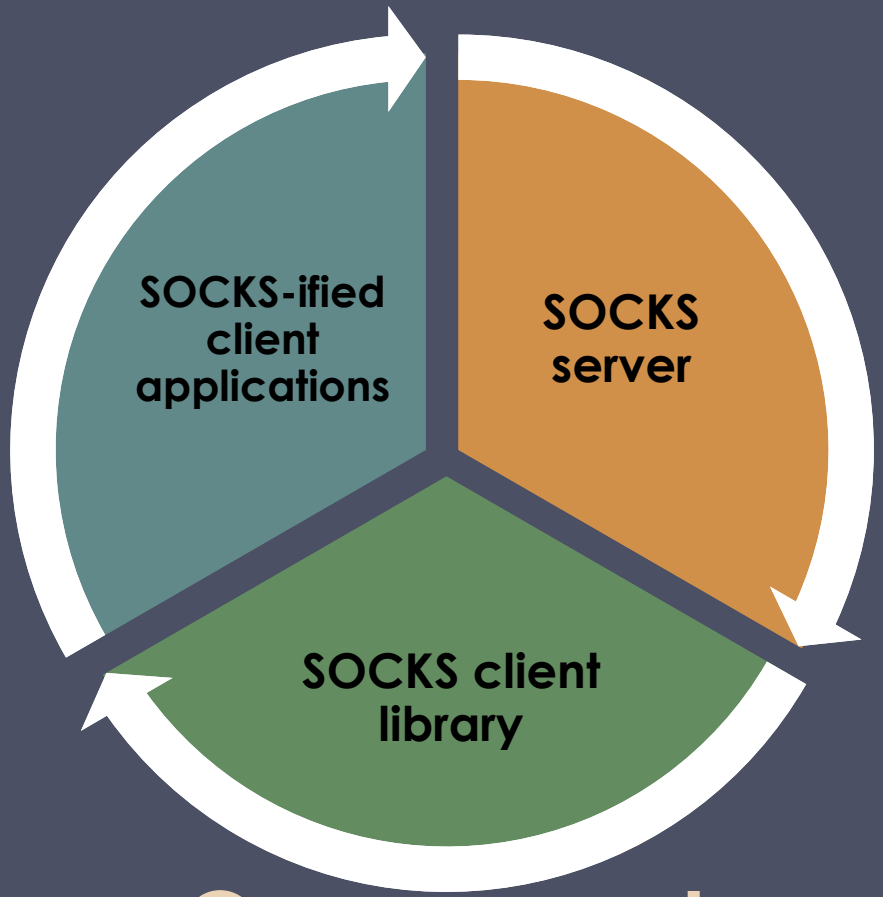
- Sets up two TCP connections, one between itself and a TCP user on an inner host and one on an outside host
- Relays TCP segments from one connection to the other without examining contents
- Security function consists of determining which connections will be allowed

Typically used when inside users are trusted

- May use application-level gateway inbound and circuit-level gateway outbound
- Lower overheads

SOCKS Circuit-Level Gateway

- SOCKS v5 defined in RFC1928
- Designed to provide a framework for client-server applications in TCP/UDP domains to conveniently and securely use the services of a network firewall
- Client application contacts SOCKS server, authenticates, sends relay request
  - Server evaluates and either establishes or denies the connection



Components

Bastion Hosts

- System identified as a critical strong point in the network's security
- Serves as a platform for an application-level or circuit-level gateway
- Common characteristics:
  - Runs secure O/S, only essential services
  - May require user authentication to access proxy or host
  - Each proxy can restrict features, and hosts accessed
  - Each proxy is small, simple, checked for security
  - Each proxy is independent, non-privileged
  - Limited disk use, hence read-only code

Host-Based Firewalls

- Used to secure an individual host
- Available in operating systems or can be provided as an add-on package
- Filter and restrict mainly packet flows
- Common location: could be on a server

Advantages:

- Filtering rules can be tailored to the host environment
- Protection is provided independent of network topology
- Provides an additional layer of protection

Personal Firewall

- Controls traffic between a personal computer or workstation and the Internet or enterprise network
- For both home or corporate use
- Typically is a software module on a personal computer
- Can be housed in a router that connects all of the home computers to a DSL, cable modem, or other Internet interface
- Typically much less complex than server-based or stand-alone firewalls
- Primary role is to deny unauthorized (inbound) remote access
- May also monitor outgoing traffic to detect and block worms and malware activity

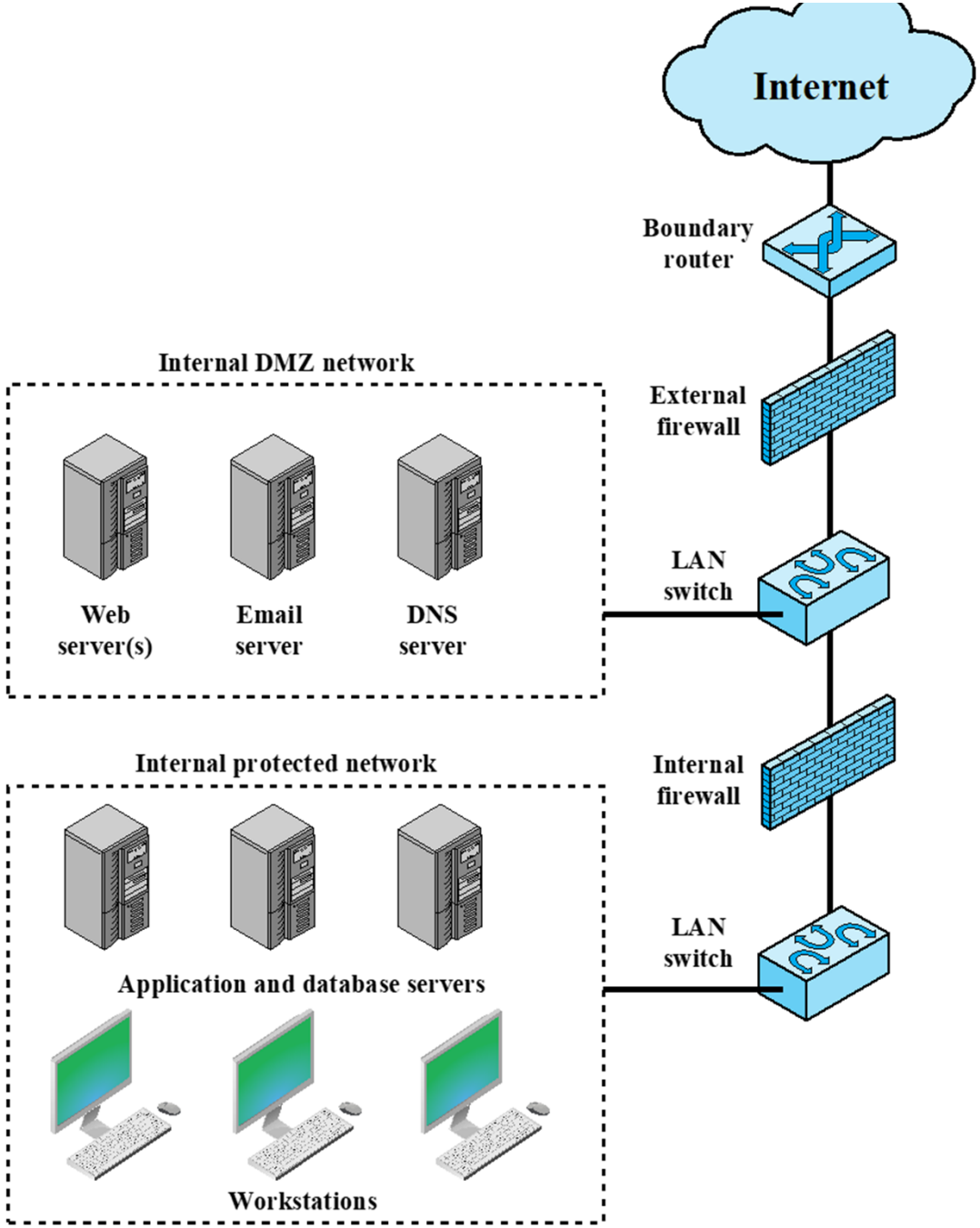


Figure 9.2 Example Firewall Configuration

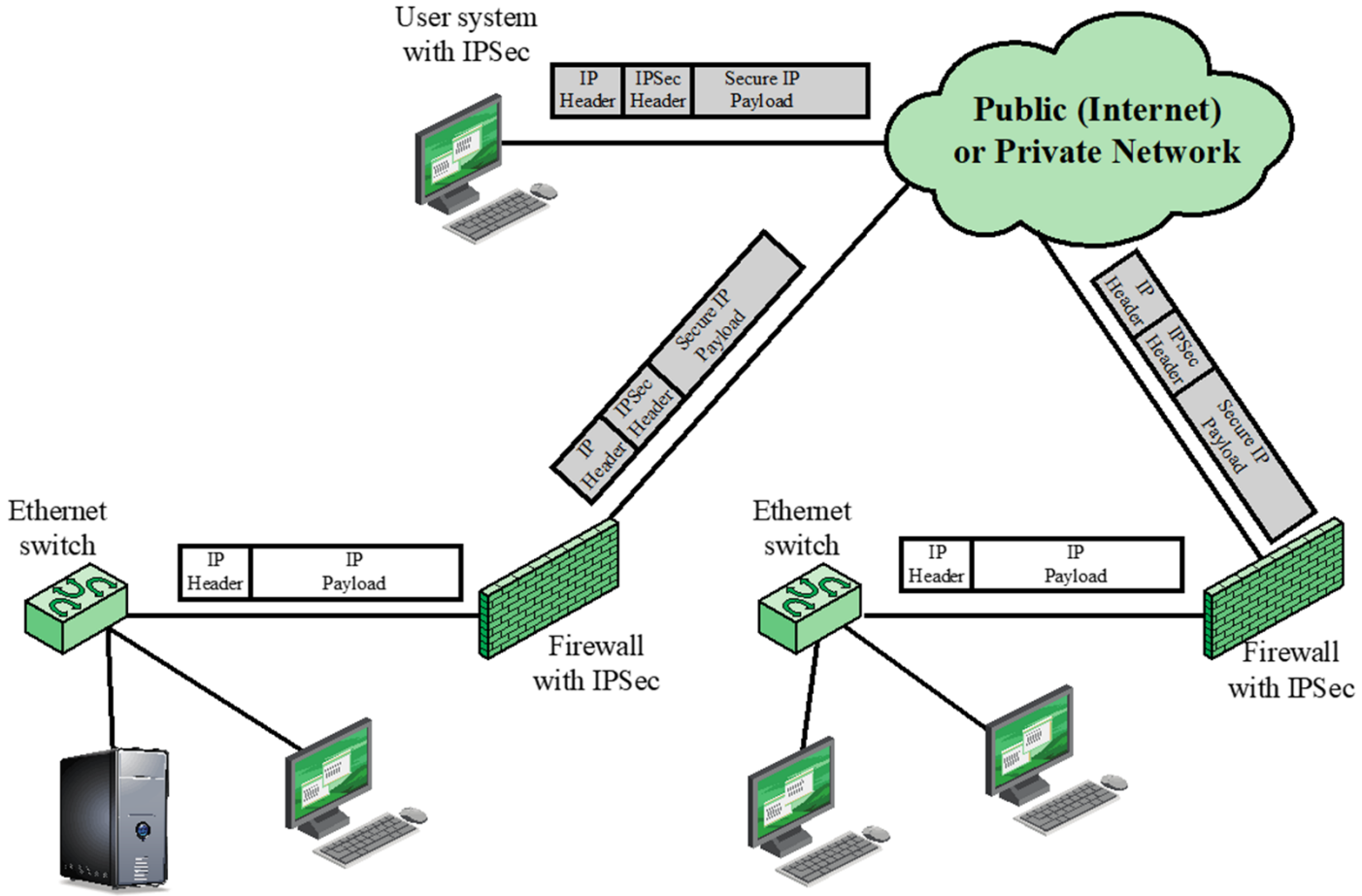


Figure 9.3 A VPN Security Scenario

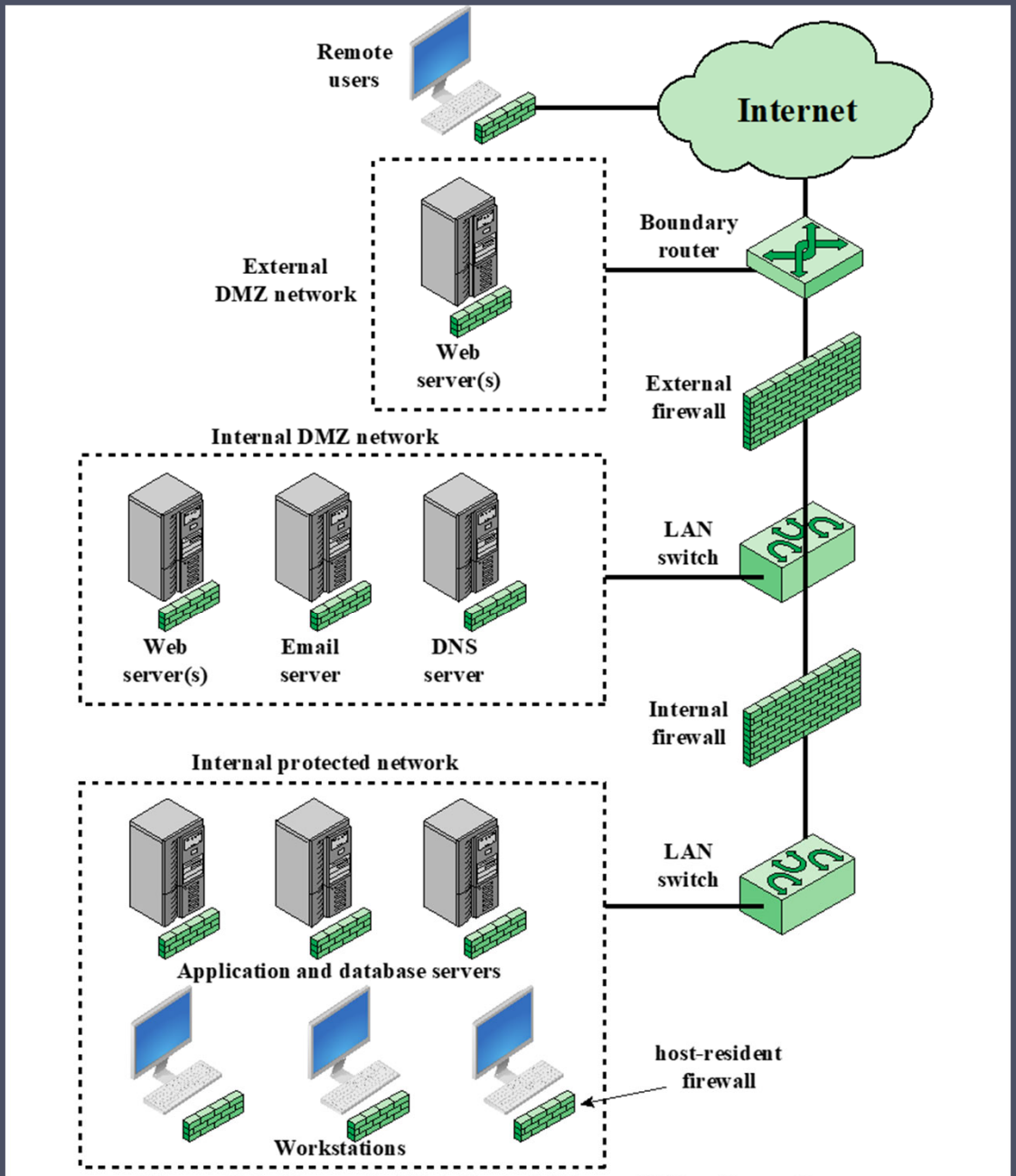
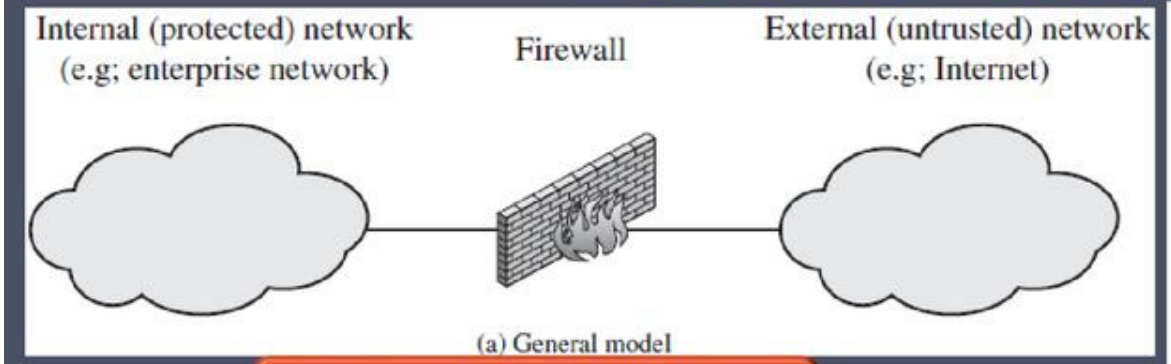


Figure 9.4 Example Distributed Firewall Configuration

Firewall Topologies

Host-resident firewall	• Includes personal firewall software and firewall software on servers
Screening router	• Single router between internal and external networks with stateless or full packet filtering
Single bastion inline	• Single firewall device between an internal and external router (hardened)
Single bastion T	• Has a third network interface on bastion to a DMZ where externally visible servers are placed
Double bastion inline	• DMZ is sandwiched between bastion firewalls
Double bastion T	• DMZ is on a separate network interface on the bastion firewall
Distributed firewall configuration	• Used by large businesses and government organizations

Bastion Configs



(a) General model

Single bastion inline

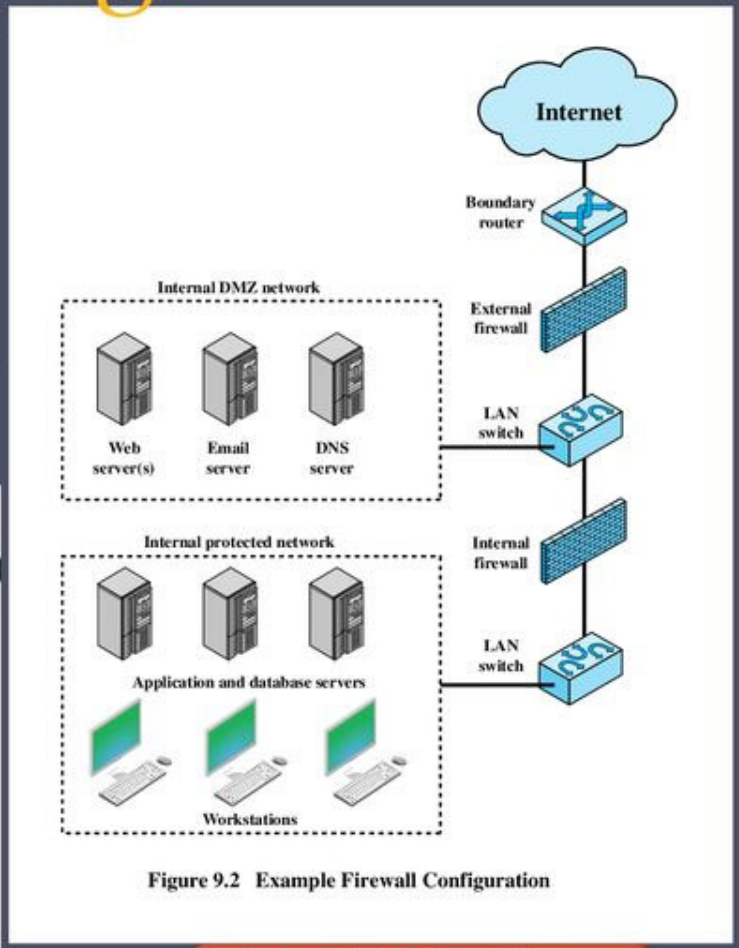
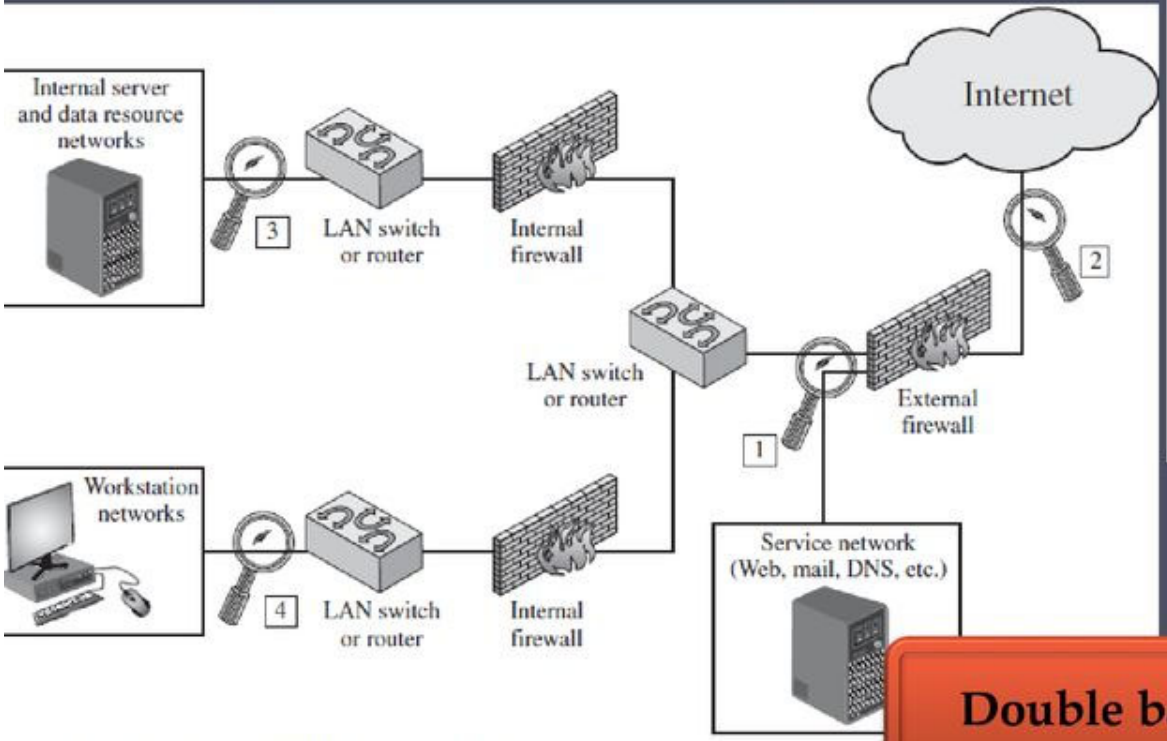


Figure 9.2 Example Firewall Configuration

Double bastion inline



igure 8.5 **Example of NIDS Sensor Deployment**

Double bastion T

Intrusion Prevention Systems (IPS)

- Also known as Intrusion Detection and Prevention System (IDPS)
- Is an extension of an IDS that includes the capability to attempt to block or prevent detected malicious activity
- Can be host-based, network-based, or distributed/hybrid
- Can use anomaly detection to identify behavior that is not that of legitimate users, or signature/heuristic detection to identify known malicious behavior can block traffic as a firewall does, but makes use of the types of algorithms developed for IDSs to determine when to do so

Host-Based IPS (HIPS)

- Can make use of either signature/heuristic or anomaly detection techniques to identify attacks
  - Signature: focus is on the specific content of application network traffic, or of sequences of system calls, looking for patterns that have been identified as malicious
  - Anomaly: IPS is looking for behavior patterns that indicate malware
- Examples of the types of malicious behavior addressed by a HIPS include:
  - Modification of system resources
  - Privilege-escalation exploits
  - Buffer-overflow exploits
  - Access to e-mail contact list
  - Directory traversal

HIPS

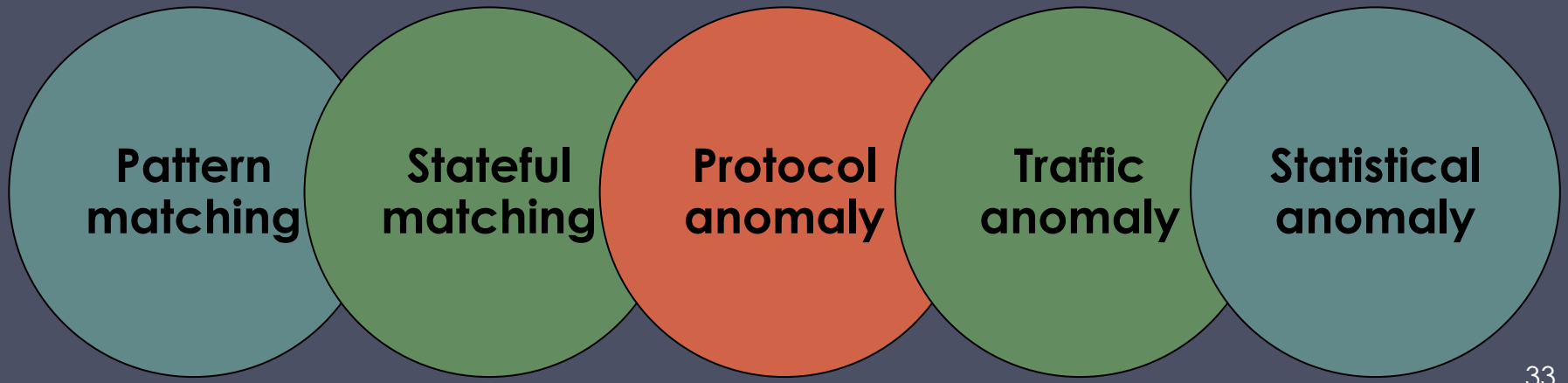
- Capability can be tailored to the specific platform
- A set of general purpose tools may be used for a desktop or server system
- Some packages are designed to protect specific types of servers, such as Web servers and database servers
  - In this case the HIPS looks for particular application attacks
- Can use a sandbox approach
  - Sandboxes are especially suited to mobile code such as Java applets and scripting languages
  - HIPS quarantines such code in an isolated system area then runs the code and monitors its behavior
- Areas for which a HIPS typically offers desktop protection:
  - System calls
  - File system access
  - System registry settings
  - Host input/output

The Role of HIPS

- Many industry observers see the enterprise endpoint, including desktop and laptop systems, as now the main target for hackers and criminals
  - Thus security vendors are focusing more on developing endpoint security products
  - Traditionally, endpoint security has been provided by a collection of distinct products, such as antivirus, antispyware, antispam, and personal firewalls
- Approach is an effort to provide an integrated, single-product suite of functions
  - Advantages of the integrated HIPS approach are that the various tools work closely together, threat prevention is more comprehensive, and management is easier
- A prudent approach is to use HIPS as one element in a defense-in-depth strategy that involves network-level devices, such as either firewalls or network-based IPSs

Network-Based IPS (NIPS)

- Inline NIDS with the authority to modify or discard packets and tear down TCP connections
- Makes use of signature/heuristic detection and anomaly detection
- May provide flow data protection
  - Requires that the application payload in a sequence of packets be reassembled
- Methods used to identify malicious packets:



Digital Immune System

- Comprehensive defense against malicious behavior caused by malware
- Developed by IBM and refined by Symantec
- Motivation for this development includes the rising threat of Internet-based malware, the increasing speed of its propagation provided by the Internet, and the need to acquire a global view of the situation
- Success depends on the ability of the malware analysis system to detect new and innovative malware strains

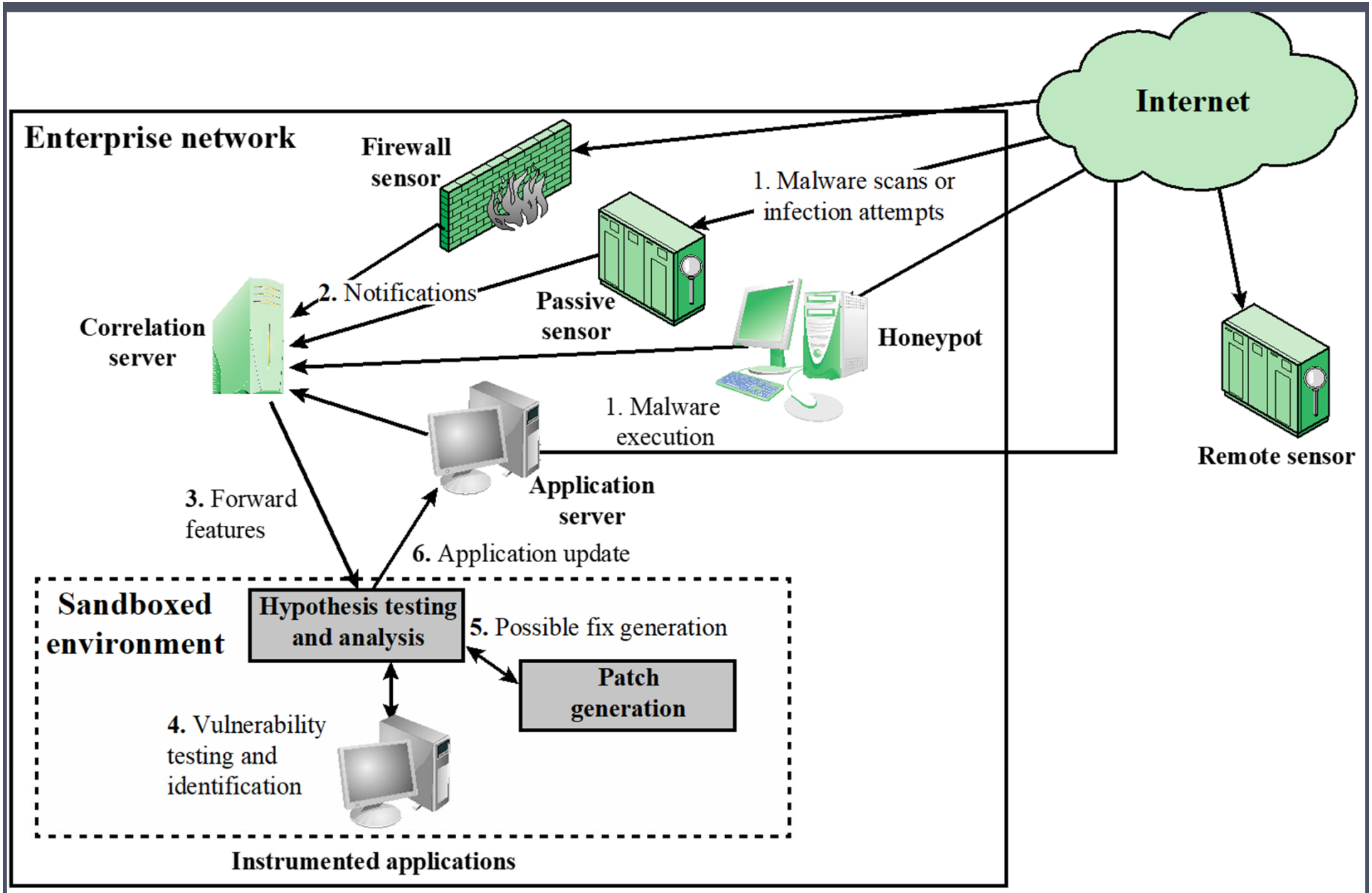
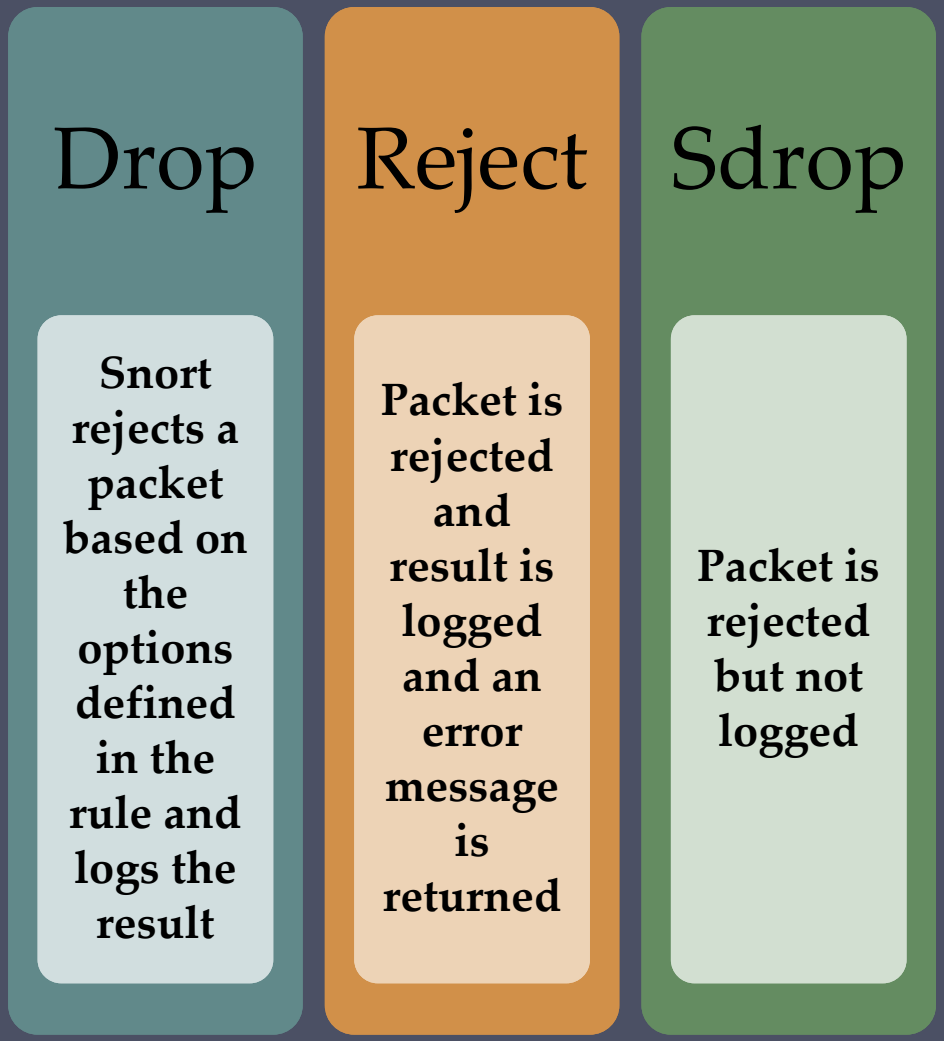


Figure 9.5 Placement of Worm Monitors

Snort Inline

- Enables Snort to function as an intrusion prevention system
- Includes a replace option which allows the Snort user to modify packets rather than drop them
  - Useful for a honeypot implementation
  - Attackers see the failure but cannot figure out why it occurred



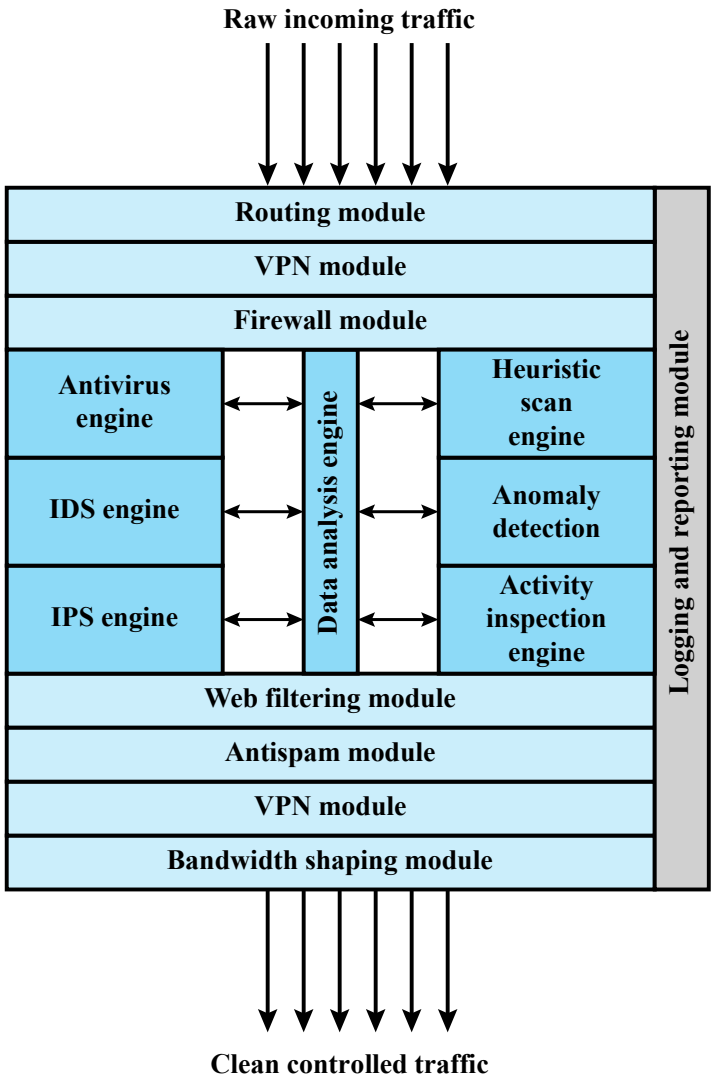


Figure 9.6 Unified Threat Management Appliance (based on [JAME06])

Table 9.3

Sidewinder G2 Security Appliance Attack Protections Summary - Transport Level Examples

Attacks and Internet Threats		Protections	
TCP			
•Invalid port numbers •Invalid sequence •numbers •SYN floods •XMAS tree attacks •Invalid CRC values •Zero length •Random data as TCP •header	•TCP hijack attempts •TCP spoofing attacks •Small PMTU attacks •SYN attack •Script Kiddie attacks •Packet crafting: different TCP options set	•Enforce correct TCP flags •Enforce TCP header length •Ensures a proper 3-way handshake •Closes TCP session correctly •2 sessions, one on the inside and one on the outside •Enforce correct TCP flag usage •Manages TCP session timeouts •Blocks SYN attacks	•Reassembly of packets ensuring correctness •Properly handles TCP timeouts and retransmits timers •All TCP proxies are protected •Traffic Control through access lists •Drop TCP packets on ports not open •Proxies block packet crafting
UDP			
•Invalid UDP packets •Random UDP data to bypass rules	•Connection prediction •UDP port scanning	•Verify correct UDP packet •Drop UDP packets on ports not open	

(Table can be found on page 312 in the textbook)

Table 9.4

Sidewinder G2 Security Appliance Attack Protections Summary - Application Level Examples (page 1 of 2)

(Table can be found on pages 313-314 In the textbook)

Attacks and Internet Threats	Protections
DNS	
Incorrect NXDOMAIN responses from AAAA queries could cause denial-of-service conditions.	•Does not allow negative caching •Prevents DNS Cache Poisoning
ISC BIND 9 before 9.2.1 allows remote attackers to cause a denial of service (shutdown) via a malformed DNS packet that triggers an error condition that is not properly handled when the rdataset parameter to the dns_message_findtype() function in message.c is not NULL.	•Sidewinder G2 prevents malicious use of improperly formed DNS messages to affect firewall operations. •Prevents DNS query attacks •Prevents DNS answer attacks
DNS information prevention and other DNS abuses.	•Prevent zone transfers and queries •True split DNS protect by Type Enforcement technology to allow public and private DNS zones. •Ability to turn off recursion
FTP	
•FTP bounce attack •PASS attack •FTP Port injection attacks •TCP segmentation attack	•Sidewinder G2 has the ability to filter FTP commands to prevent these attacks. •True network separation prevents segmentation attacks.
SQL	
SQL Net man in the middle attacks	•Smart proxy protected by Type Enforcement Technology •Hide Internal DB through nontransparent connections
Real-Time Streaming Protocol (RTSP)	
•Buffer overflow •Denial of service	•Smart proxy protected by Type Enforcement technology •Protocol validation •Denies multicast traffic •Checks setup and teardown methods •Verifies PNG and RTSP protocol, discards all others •Auxiliary port monitoring
SNMP	
•SNMP flood attacks •Default community attack •Brute force attack •SNMP put attack	•Filter SNMP version traffic 1, 2c •Filter Read, Write, and Notify messages •Filter OIDs •Filter PDU (Protocol Data Unit)

Table 9.4

Sidewinder G2 Security Appliance Attack Protections Summary – Application Level Examples

(page 2 of 2)

SSH			
•Challenge-Response buffer overflows •SSHD allows users to override "Allowed Authentications" •OpenSSH buffer_append_space buffer overflow •OpenSSH/PAM challenge Response buffer overflow •OpenSSH channel code offer-by-one		Sidewinder G2 v6.x's embedded Type Enforcement technology strictly limits the capabilities of Secure Computing's modified versions of the OpenSSH daemon code.	
SMTP			
•Sendmail buffer overflows •Sendmail denial of service attacks •Remote buffer overflow in sendmail	•Sendmail address parsing buffer overflow •SMTP protocol anomalies	•Split Sendmail architecture protected by Type Enforcement technology •Sendmail customized for controls	•Prevents buffer overflows through Type Enforcement technology •Sendmail checks SMTP protocol anomalies
•SMTP worm attacks •SMTP mail flooding •Relay attacks •Viruses, Trojans, worms	•E-mail Addressing spoofing •MIME attacks •Phishing e-mails	•Protocol validation •Anti-spam filter •Mail filters – size, keyword •Signature antivirus	•Anti-relay •MIME/Antivirus filter •Firewall antivirus •Anti-phishing through virus scanning
Spyware Applications			
•Adware used for collecting information for marketing purposes •Stalking horses •Trojan horses	•Malware •Backdoor Santas	•SmartFilter® URL filtering capability built in with Sidewinder G2 can be configured to filter Spyware URLs, preventing downloads.	

(Table can be found on pages 312 - 313 In the textbook)

Summary

- The need for firewalls
- Firewall characteristics and access policy
- Types of firewalls
  - Packet filtering firewall
  - Stateful inspection firewalls
  - Application-level gateway
  - Circuit-level gateway
- Firewall basing
  - Bastion host
  - Host-based firewalls
  - Personal firewall
- Firewall location and configurations
  - DMZ networks
  - Virtual private networks
  - Distributed firewalls
  - Firewall locations and topologies
- Intrusion prevention systems
  - Host-based IPS
  - Network-based IPS
  - Distributed or hybrid IPS
  - Snort inline
- Example: Unified Threat Management Products