Information Security
CS 3002

Dr. Haroon Mahmood

Assistant Professor

NUCES Lahore

Disclaimer: The contents of these slides have been taken from the book of Computer Security by William Stallings.

Intrusion

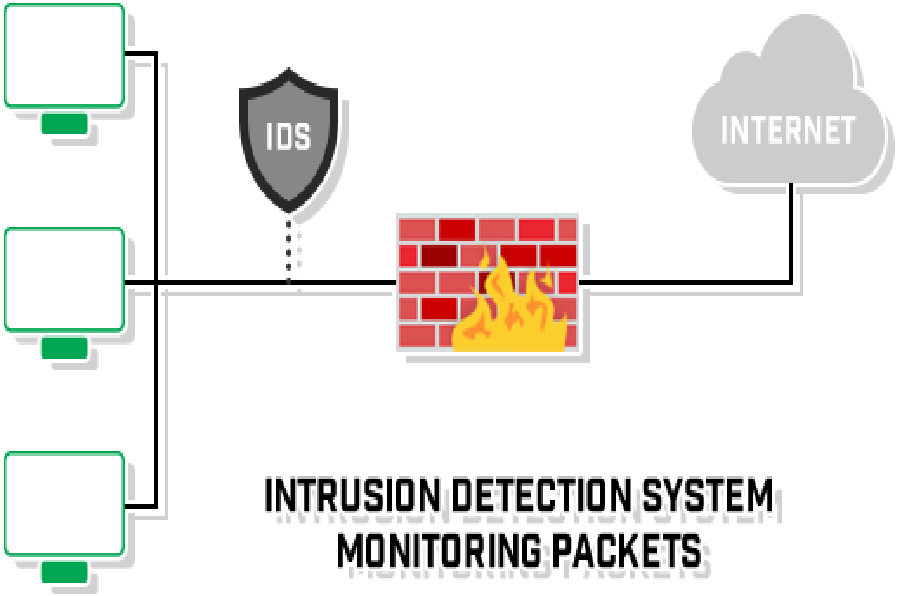
- Attempt to break into or misuse a system
- Intruders may be from outside the network or legitimate users of the network
- Three classes of intruders:
  - Masquerader: an individual who is not authorized to use the computer and who penetrate a system’s access controls to exploit a legitimate user’s account. (usually outside)
  - Misfeasor: A legitimate user who access data, program, or resources for which such access is not authorized , or who is authorized for such access but misuses them. (usually inside)
  - Clandestine user: An individual who seizes supervisory control of the system and uses this control to evade auditing and access controls or to suppress audit collection.(can be either inside or outside)

Types of attacks using Intrusion

- Performing a remote root compromise of an e-mail server
- Defacing a Web server
- Guessing and Cracking passwords
- Copying a database containing credit card numbers
- Viewing sensitive data (i.e. Payroll records and media without authorizations)
- Running a packet sniffer on a workstation to capture usernames and passwords
- Using an unattended, logged-in workstation without permission

Intrusion Detection System

- A security service that monitors and analyzes system events for the purpose of finding, and providing real-time or near real time warning of, attempts to access system resources in an unauthorized manner.
- Intrusion Detection Systems look for attack signatures (patterns that usually indicate malicious or suspicious intent)



Components of an IDS

- An IDS comprises of three logical components:
  - Sensors: sensors are responsible for collecting data (i.e. network packets, log files, and system call traces)
  - Analyzers: analyzers receive inputs from one or more sensors or from other analyzers. The analyzer is responsible for determining if an intrusion has occurred.
  - User Interface: it enables a user to view output from the system or control behavior of the system. (i.e. UI may associate to a manager, director, or console component)

Basic Principles of IDSs

1) If an intruder is detected quickly enough, the intruder can be identified and ejected from the system before any damage. Even if the detection is not that quick, sooner the intrusion is detected, the less the amount of damage and more quickly the recovery can be achieved.

2) An effective IDS can serve as a deterrent, thus acting to prevent intrusion.

3) Intrusion detection enables the collection of information about intrusion techniques that can be used to strengthen intrusion prevention measures.

Intrusion Detection System

- Different ways of classifying an IDS
  - Anomaly based detection
  - Misuse detection or signature based detection
  - Hybrid detection
    - Specification based detection

Anomaly based detection

- At involves a collection of information about legitimate user's behavior over a period of time. Then, statistical tests are applied to observe them.
- Anything distinct from the usual behavior is assumed to be an intrusion activity.
  - E.g flooding a host with lots of packet.
- The primary strength is its ability to recognize novel attacks.
- Such IDS generate many false alarms and hence compromise the effectiveness of the IDS.

Signature based detection

- Involves an attempts to define a set of rules or attack patterns that can be used to decide that a given behavior is that of an intruder.
- The question of what information is relevant to an IDS depends upon what it is trying to detect.
  - E.g DNS, FTP etc.
- Most signature analysis systems are based simple pattern matching algorithms. For example, the IDS simply looks for a sub string within a stream of data carried by network packets. When it finds this sub string (for example, the ``phf'' in ``GET /cgi-bin/phf?''), it identifies those network packets as vehicles of an attack.

Signature based detection

- Signature techniques detect intrusion by observing events on system & apply rules to decide if activity is suspicious or not.

Rule-based anomaly detection:

- analyze historical audit records to identify usage patterns & auto-generate rules for them
- then observe current behavior & match against rules to see if conforms
- like statistical anomaly detection does not require prior knowledge of security flaws
- It requires to have a large database of rules to be effective.

Specification-based intrusion detection

- **The desirable behavior of a system is described through its functionalities and through the security policy. Any sequence of operations executed outside of the system's specifications is considered to be a security violation**
- **Use of manually specified program behavioral specifications is the basis to detect attacks**
- **It has been proposed as a promising alternative that combine the strengths of misuse detection (accurate detection of known attacks) and anomaly detection (ability to detect novel attacks)**
- **The development of the specifications is an expensive and tedious process and specifications are often very difficult to evaluate and verify.**

Effectiveness of an IDS

- Practically an intrusion detection system needs to detect a substantial percentage of intrusions while keeping the false alarms rate at acceptable level.
  - if too few intrusions detected -> false security
  - if too many false alarms -> ignore / waste time while analyzing the false alarm
- Achieving this fate is very hard to achieve
- existing systems seem not to have a good record

Types of IDS

- Intrusion Detection Systems (IDSs) can be classified into:

  - **Host-based IDS:**

    Monitors the characteristics of a single host and the events occurring within that host for suspicious activity.

  - **Network-based IDS:**

    Monitors network traffic for particular network segments or devices and analyzes network, transport, and application protocols to identify suspicious activity.

Host/Applications based IDS

- **The host operating system or the application logs in the audit information.**

- **These audit information includes events like the use of identification and authentication mechanisms (logins etc.) , file opens and program executions, admin activities etc.**

- **This audit is then analyzed to detect trails of intrusion.**

Drawbacks of the host based IDS

- **The kind of information needed to be logged in is a matter of experience.**

- **Unselective logging of messages may greatly increase the audit and analysis burdens.**

- **Selective logging runs the risk that attack manifestations could be missed.**

Strengths of the host based IDS

- Attack verification
- System specific activity
- Encrypted and switch environments
- Monitoring key components
- Near Real-Time detection and response
- No additional hardware

Network based IDS

- A network-based IDS monitors traffic at selected points on a network or interconnected set of networks.

- It examines the traffic packet by packet in real time or close to real time in order to detect intrusion patterns.

- A filter is usually applied to determine which traffic will be discarded or passed on to an attack recognition module. This helps to filter out known un-malicious traffic.

Strengths of Network based IDS

- Cost of ownership reduced
- Packet analysis
- Evidence removal
- Real time detection and response
- Malicious intent detection
- Complement and verification
- Operating system independence

Honey Pots

- Decoy systems that designed to lure a potential attacker away from critical systems
- An asset that solely exists to be attacked
- It could be an individual item, a system or entire network
- It could be a real system or emulated.

Purpose

- Divert an attacker from accessing critical systems
- Collect information about the attacker’s activity
- Good at detecting new or unknown threats
- Engage the attacker to stay on the system long enough for administration to respond

Deception Technology

- Honeypots are limited in scope
  - it uses static decoys due to which adversary starts to understand the decoys
  - requires expensive resources to implement and maintain

Deception technology is a proactive cyber defense system through the use of decoys to lure, detect and defend, without the issues of scalability, skilled and available resources.

- Uses automated dynamic traps generated by AI
- Immediate alerts with minimum false positive rates.
- Deploy traps according to the behavioral patterns of the hacker
- Provide detailed reports for post cyber defense investigation

Deception technology

- Decoy Files
  - Used as a “marker”
  - In case of an access, read, copy, or deletion, it serves as an alert to monitors
  - It could be anything: file, database, picture, email, account, etc
  - Normally used to deliver bogus information to attackers
- Honey net
  - Collection of two or more honeypots/decoy devices
  - Could be at the same location or distributed
  - Managed by same entity

Interaction level

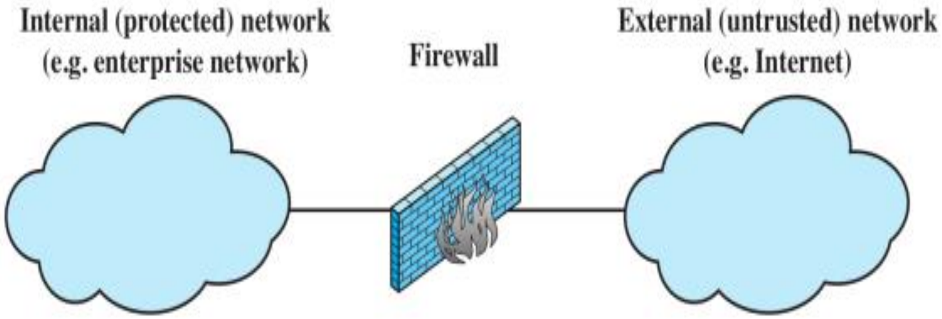
It is the capability to mimic a real asset or object

- High – More Realistic that mimics real, legitimate computer or device with applications, activity, and changing content
  - Needed for more hacker interaction, intent, etc.
  - More involved setup and maintenance
- Low – Does very little to mimic real, legitimate device
  - Usually just TCP/IP port advertising or basic logon prompts
  - For early warning honeypots • Quicker setup, less ongoing maintenance, less risk
- If you can actually logon to a decoy, then you're at least at Medium interaction

Firewalls

The Need for Firewalls

- Internet connectivity is essential for organizations
  - However it creates a threat
- Firewalls are effective means of protecting LANs
  - Protection at single point, rather on every computer within LAN
- Inserted between the premises network and the Internet to establish a controlled link
- Used as a perimeter defense
  - Single choke point to impose security and auditing
  - Insulates the internal systems from external networks


Internal (protected) network
(e.g. enterprise network)
Firewall
External (untrusted) network
(e.g. Internet)

Firewall Characteristics

Design Goals

- All traffic from inside to outside 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

General Techniques

- Service control, e.g. filter based on IP address, port number
- Direction control, e.g. to internal LAN, to external Internet
- User control, e.g. student vs faculty
- Behaviour control, e.g. filter email with spam

Capabilities & Limitations

Capabilities

- Defines a single choke point
- Provides a location for monitoring security events
- Convenient platform for several Internet functions that are not security related
- Can serve as platform for VPN end point

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, phone, or USB drive may be infected outside the corporate network then used internally

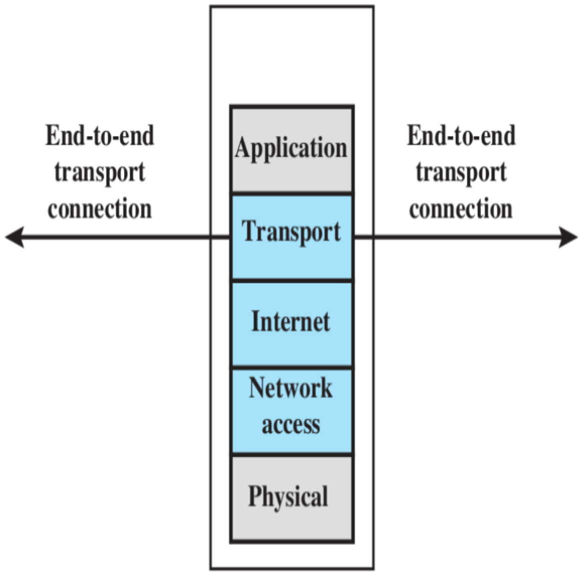
Types of Firewalls

- Packet Filtering accepts/rejects packets based on protocol headers
- Stateful Packet Inspection adds state information on what happened previously to packet filtering firewall
- Application Proxy relay for application traffic
- Circuit-level Proxy relay for transport connections

- Normally a firewall is implemented on a router
- That router may perform other (non-)security functions, e.g. VPN end-point, accounting, address and port translation (NAT)

Packet Filtering Firewall

- Security policy implemented by set of rules
- Rules define which packets can pass through the firewall
- Firewalls inspects each arriving packet (in all directions), compares against rule set, and takes action based on matching rule
- Default policies: action for packets for which no rule matches
- Accept (allow, forward)
- Drop (reject, discard) - recommended


End-to-end transport connection
Application
Transport
Internet
Network access
Physical
End-to-end transport connection

Packet Filtering Rules

Packet Information

- IP address: identifies host or network
- Port number: identifies server, e.g. web (80), email (25)
- Protocol number: identifies transport protocol, e.g. TCP or UDP
- Firewall interface: identifies immediate source/destination
- Other transport, network, data link packet header fields

Rules

- Conditions defined using packet information, direction
- Wildcards (*) support to match multiple values
- Actions typically accept or drop
- List of rules processed in order

Packet Filtering Firewalls

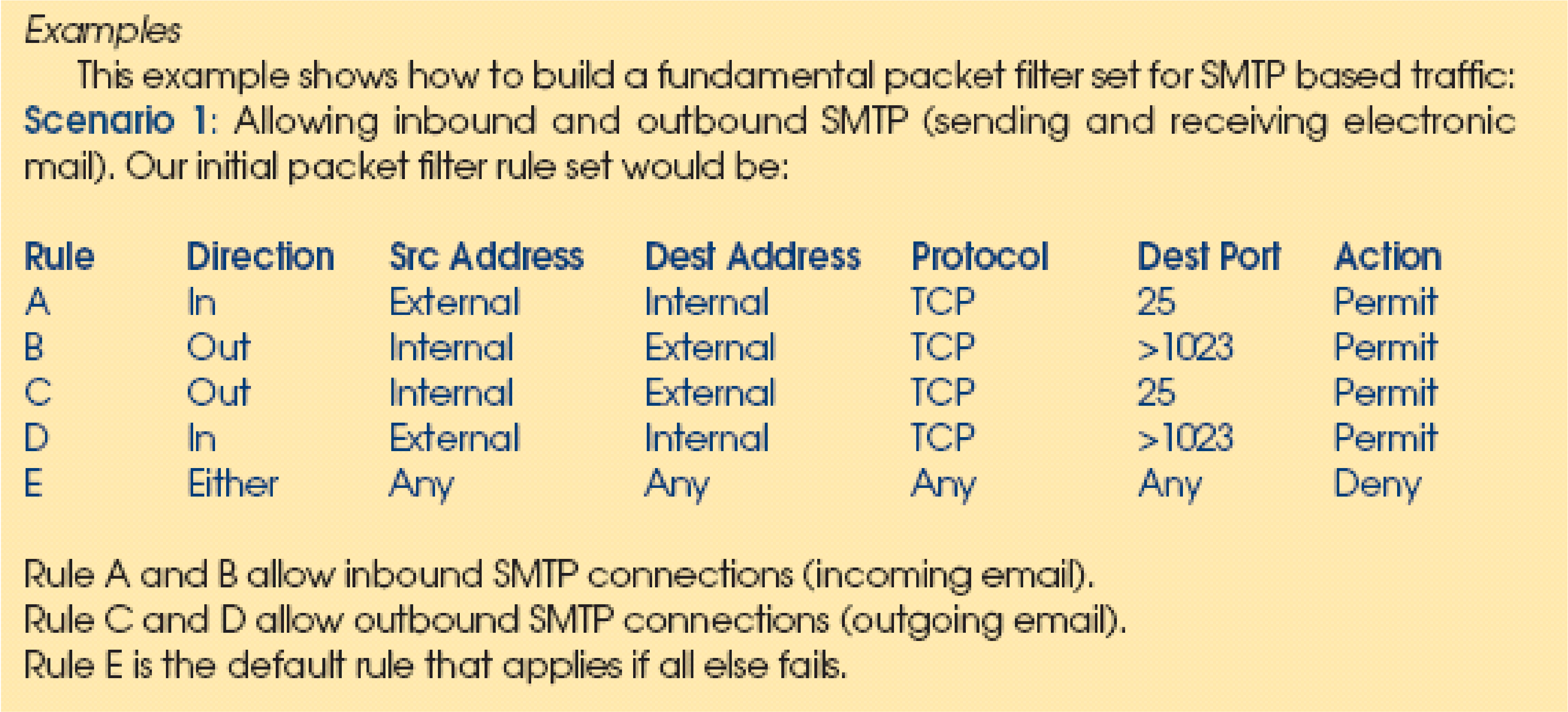
Advantages

- Simplicity
- Transparent to users
- Very fast

Disadvantages

- Cannot prevent attacks that employ application specific vulnerabilities or functions
- Limited logging functionality
- Do not support advanced user authentication
- Improper configuration can lead to breaches

Example



Examples

This example shows how to build a fundamental packet filter set for SMTP based traffic:

Scenario 1: Allowing inbound and outbound SMTP (sending and receiving electronic mail). Our initial packet filter rule set would be:

Rule	Direction	Src Address	Dest Address	Protocol	Dest Port	Action
A	In	External	Internal	TCP	25	Permit
B	Out	Internal	External	TCP	>1023	Permit
C	Out	Internal	External	TCP	25	Permit
D	In	External	Internal	TCP	>1023	Permit
E	Either	Any	Any	Any	Any	Deny

Rule A and B allow inbound SMTP connections (incoming email).
Rule C and D allow outbound SMTP connections (outgoing email).
Rule E is the default rule that applies if all else fails.

Packet Filtering Firewalls

- Uses transport-layer information only
  - IP Source Address, Destination Address
  - Protocol/Next Header (TCP, UDP, ICMP, etc)
  - TCP or UDP source & destination ports
  - TCP Flags (SYN, ACK, FIN, RST, PSH, etc)
  - ICMP message type

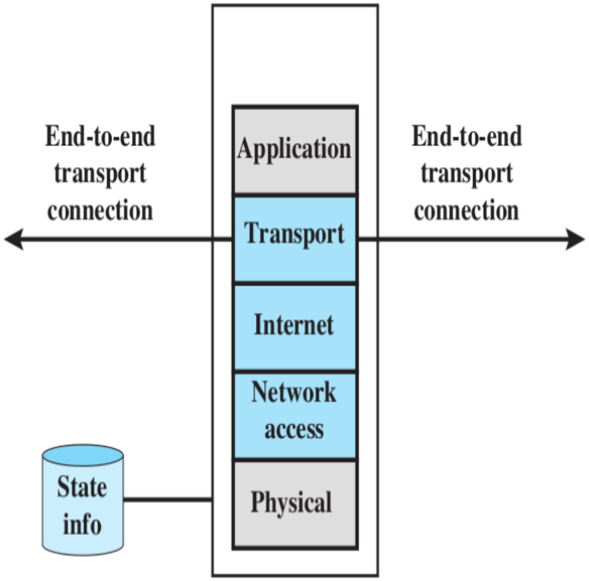
- Examples
  - DNS uses port 53
    - No incoming port 53 packets except known trusted servers

Stateful Packet Inspection

- Traditional packet filtering firewall makes decisions based on individual packets; don’t consider past packets (stateless)
- Many applications establish a connection between client/server; group of packets belong to a connection
- Often easier to define rules for connections, rather than individual packets
- Need to store information about past behavior (stateful)
- Stateful Packet Inspection (SPI) is extension of traditional packet filtering firewalls
- Issues: extra overhead required for maintaining state information

Stateful Packet Inspection

- For connections accepted by packet filtering firewall, record connection information
    - src/dest IP address, src/dest port, sequence numbers, connection state (e.g. Established, Closing)
- Packets arriving that belong to existing connections can be accepted without processing by firewall rules


End-to-end transport connection
Application
End-to-end transport connection
Transport
Internet
Network access
State info
Physical

Application Proxy

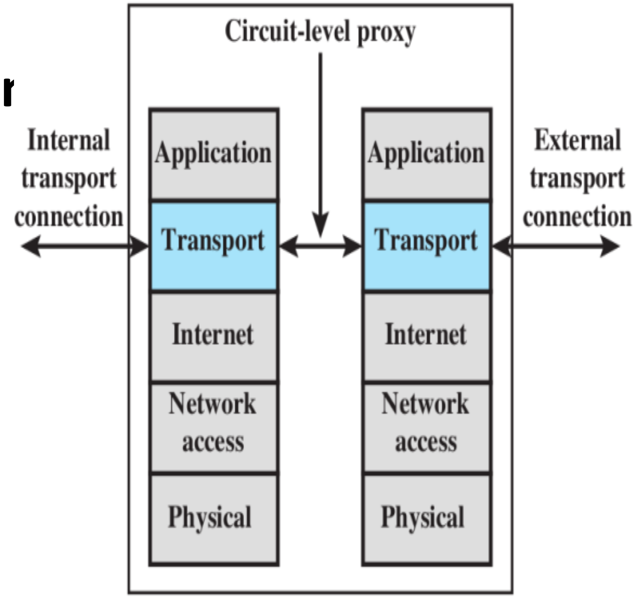
- Also called Application-level Gateway
  - Allows data into/out of a process based on that process’ type
  - Can act on a single computer or at the network layer
    - e.g. allowing only HTTP traffic to a website
  - Log access – attempted access and allowed access

- Tend to be more secure than packet filters
- Disadvantage is the additional processing overhead on each connection

Circuit-level Proxy Firewall

- Also called Circuit-level Gateway
- Sets up two TCP connections, one between itself and a TCP user on an inner host and one on an outside host
    - For incoming data
        - Proxy is server to internal network clients
    - For outgoing data
        - Proxy is client sending out data to the internet

- 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



Firewall Locations

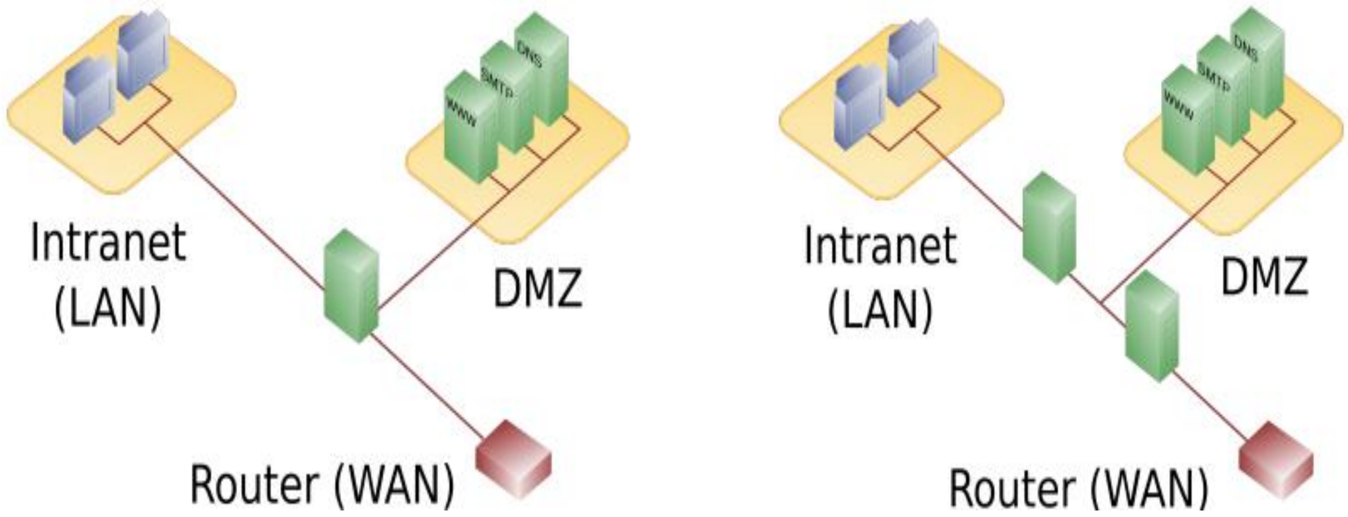
- Firewalls can be located on hosts: end-users computers and servers
- With large number of users, firewalls located on network devices that interconnect internal and external networks

- Common to separate internal network into two zones:

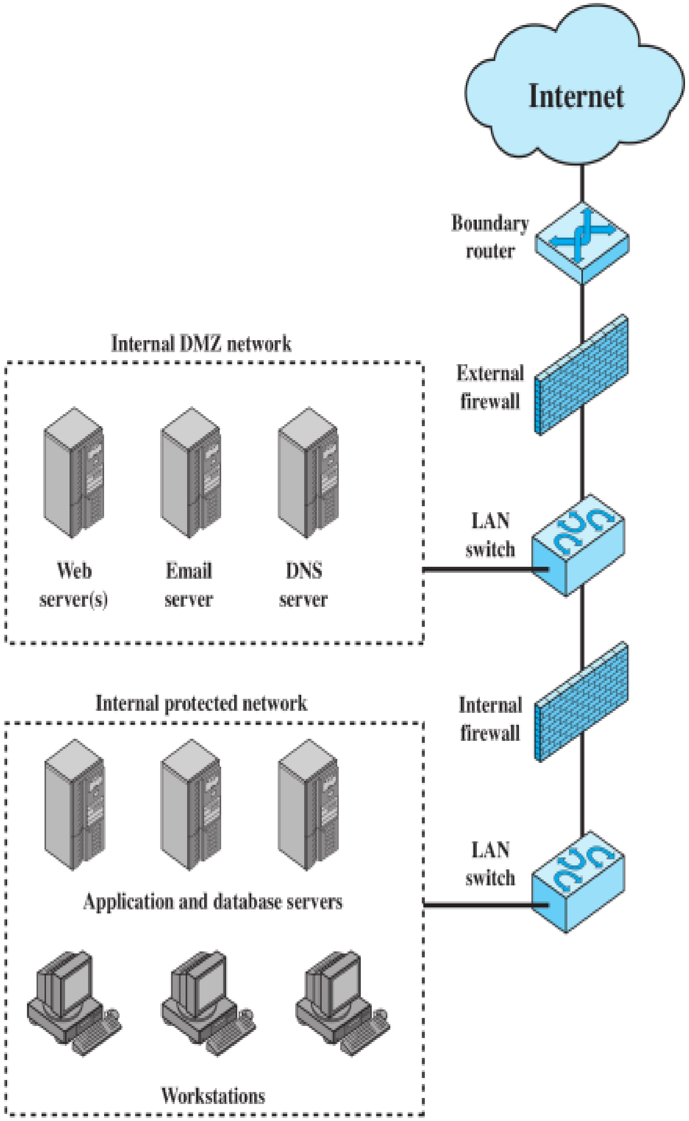
1. Public-facing servers, e.g. web, email, DNS
2. End-user computers and internal servers, e.g. databases, development web servers

- Public-facing servers put in De-Militarized Zone (DMZ)

DMZ with 1 or 2 Firewalls



Example DMZ with 2 Firewalls



Security Issues

- Complexity and human error: writing firewall rules that implement the security policy is difficult for large networks
- Bypassing security policies using tunnels
- Bypassing firewalls using other networks (WiFi, mobile) or devices (laptop, USB)