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Firewalls

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Overview

- In old days, brick walls (called **firewalls**) built between buildings to prevent fire spreading from building to another
- Today, when private network (i.e., intranet) connected to public network (i.e., Internet), users communicate with outside world, and outside world with private network and its computer systems
- Intermediate system(s) placed between private network and public network to establish a controlled link, and a security wall or **perimeter** providing single point where security and audit may be imposed
- These intermediate systems called **firewall systems** or **firewalls** (alternative terms comprise **security gateways** and **secure Internet gateways**)

Overview

- According to RFC 2828 and 2979, term **firewall** refers to inter-network gateway that restricts data communication traffic to and from one of the connected networks, protecting that network's system resources against threats from other network
- It should have following properties
  - All traffic from inside to outside, and vice versa, must pass through the firewall
  - Only authorized traffic, as defined by local security policy, will be allowed to pass
  - Firewall itself immune to penetration (use of trusted system with secure operating system)

Benefits and Limitations

Pros

- controlled and logged interaction with external Internet; can enforce security policy
- internal machines can be administered with varying degrees of care
- Focal point for security decisions

Cons

- services through firewall introduce vulnerabilities
- performance may suffer
- single point of failure
- useless against insider attacks

Firewall Characteristics

Four general techniques:

- Service control
  - Determines the types of Internet services that can be accessed, inbound or outbound
- Direction control
  - Determines the direction in which particular service requests are allowed to flow
- User control
  - Controls access to a service according to which user is attempting to access it
- Behavior control
  - Controls how particular services are used (e.g. filter e-mail)

Firewall Evaluation Criteria 1

- **Performance:** Firewalls always impact performance - compare delays with respect to functions offered.
  - Authentication of connections
- **Requirements Support:** Should support the applications that are to be used across the network (SMTP, TELNET, FTP, HTTP, etc.)
- **Access Control:** handled with IP addresses or user-based? How many users can be supported?
- **Authentication:** How hard is this to administrate and how is it accomplished? Inbound and outbound?

Firewall Evaluation Criteria 2

- **Auditing:** What gets audited? any audit reduction tools available?
- **Logging/Alarms:** How is this accomplished? How is administrator notified?
- **Customer Support:** Training courses, installation, help desk, 24x7 availability?
- **Damage**: if compromised or destroyed, what outside threats can interfere with the ‘protected’ network, and how easy is this to detect and diagnose?
- **Physical Security Requirements**: Location requirements

Firewall Design Philosophies

Default deny:

- *Everything not expressly permitted is prohibited*
  - Firewall designed to block everything
  - Services enabled case-by-case after careful analysis
  - Users more restricted and cannot easily breach security

Default permit:

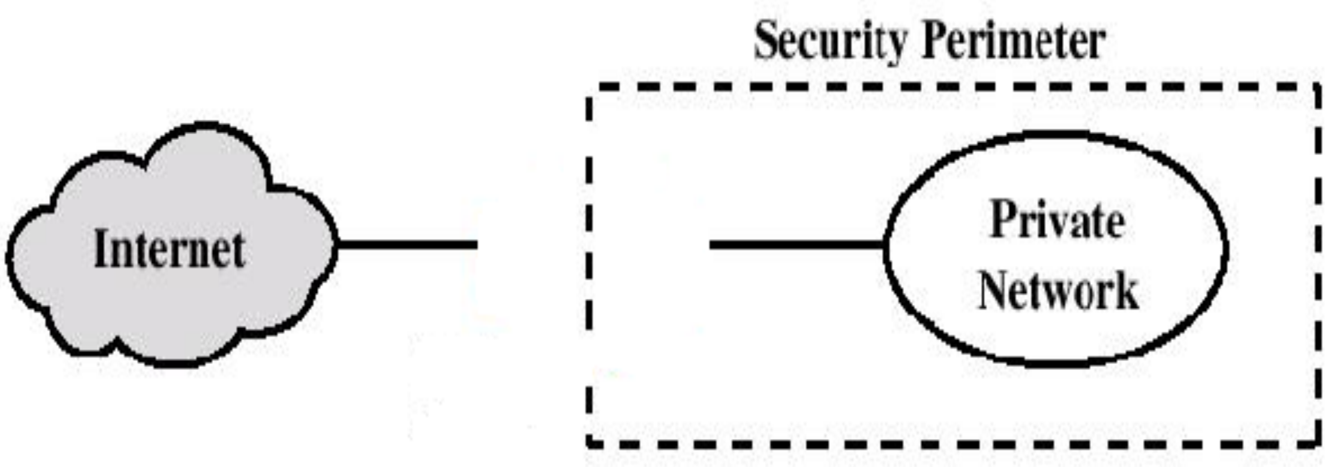
- *Everything not expressly prohibited is permitted*
  - System administrator reacts to threats as discovered
  - Services are removed/limited when proven dangerous
  - Users are less restricted

Components

- Firewall policy
  - Service access policy
  - Firewall design policy
- Packet filters
  - Statically (stateless) filtering devices
  - Dynamically (stateful) filtering devices
- Application gateways
  - Circuit-level gateways
  - Application-level gateways or proxy servers

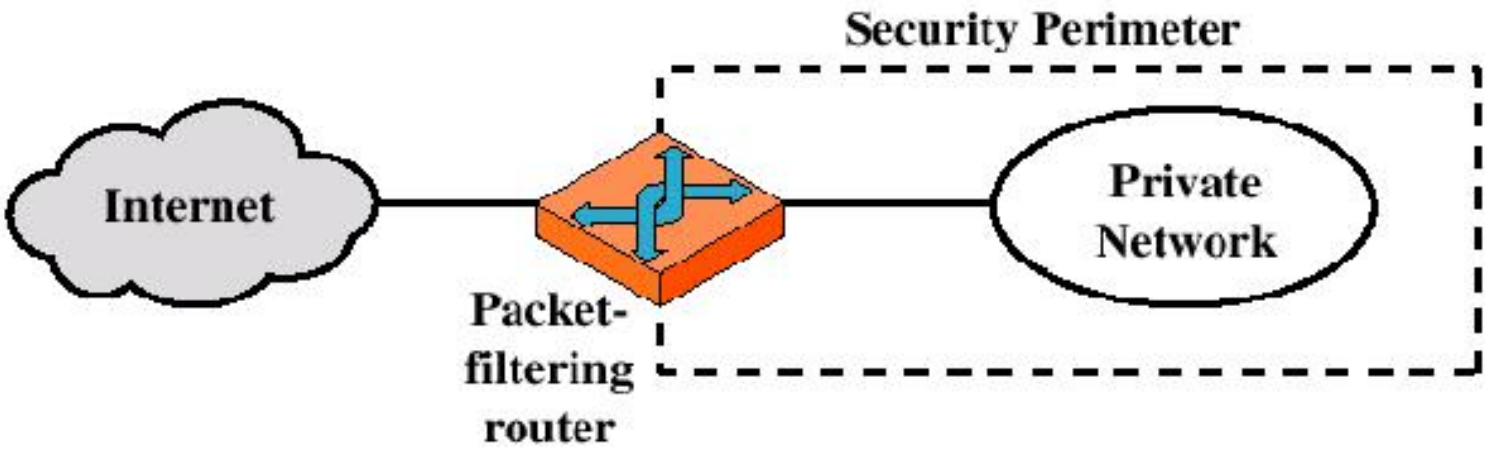
Types of Firewalls

Ultimate Firewall



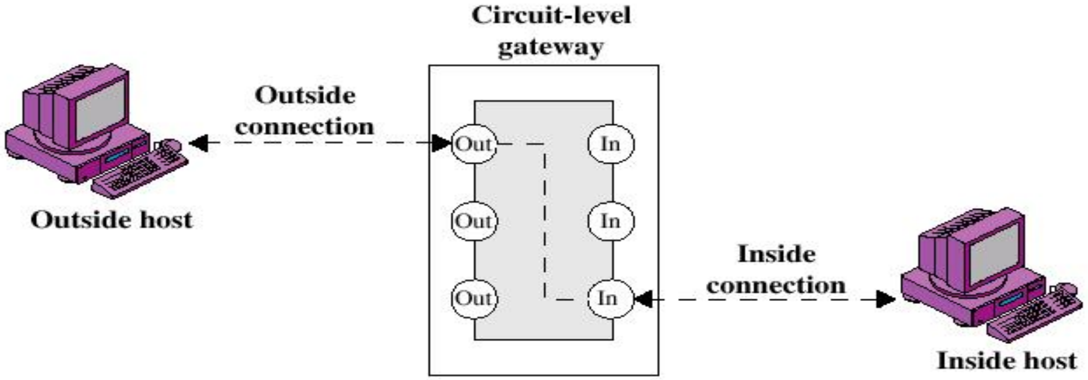
Types of Firewalls

Packet-filtering Router

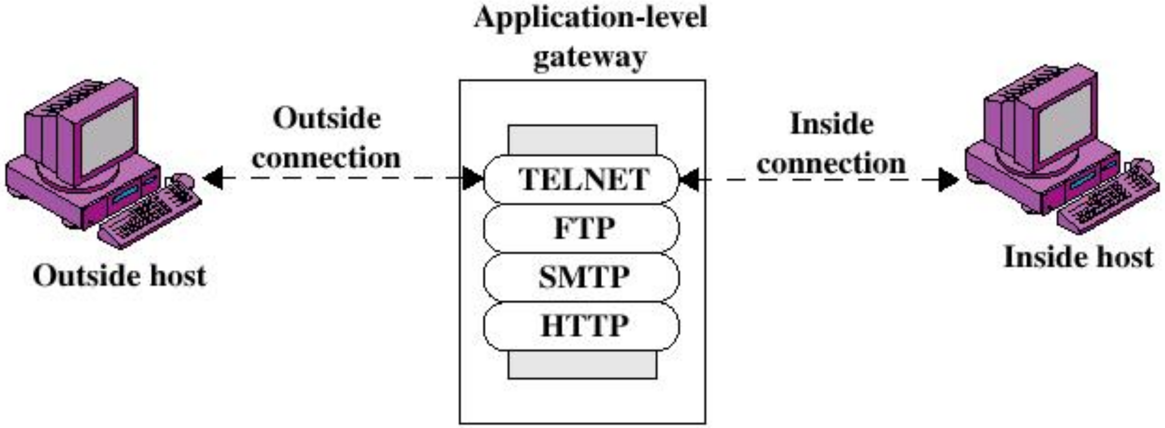


Types of Firewalls

Circuit-level Gateway



Application-level Gateway



Packet-filtering Router

- Security function consists of filtering (forward or drop) packet based on transport-layer information only
- These routers are sometimes called **screening routers**
- The following fields (usually) taken into account by any packet-filtering device
  - Network interface
  - IP header: Source address, Destination address
  - TCP or UDP header: Source and Destination ports
  - TCP connection flags (SYN,ACK,FIN, …)
  - ICMP messsage type

Packet filtering

Advantages:

- Simplicity
- Transparency to users
- High speed

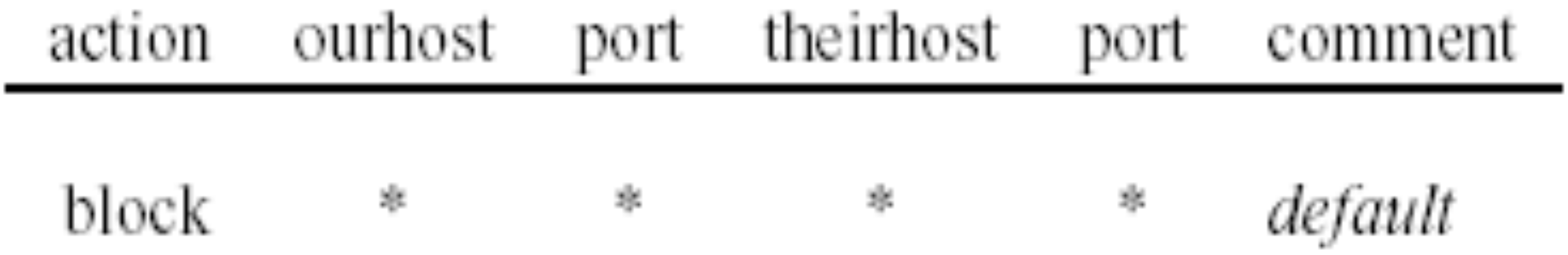
Disadvantages:

- Difficulty of setting up packet filter rules
- Lack of Authentication
- Protect against amateur hackers only

to Configure a Packet Filter

- Start with a security policy
- Specify allowable packets in terms of logical expressions on packet fields
- Rewrite expressions in syntax supported by the vendor
- General rules - least privilege
  - All that is not expressly permitted is prohibited
  - If you do not need it, eliminate it

Every ruleset is followed by an implicit rule reading like this.

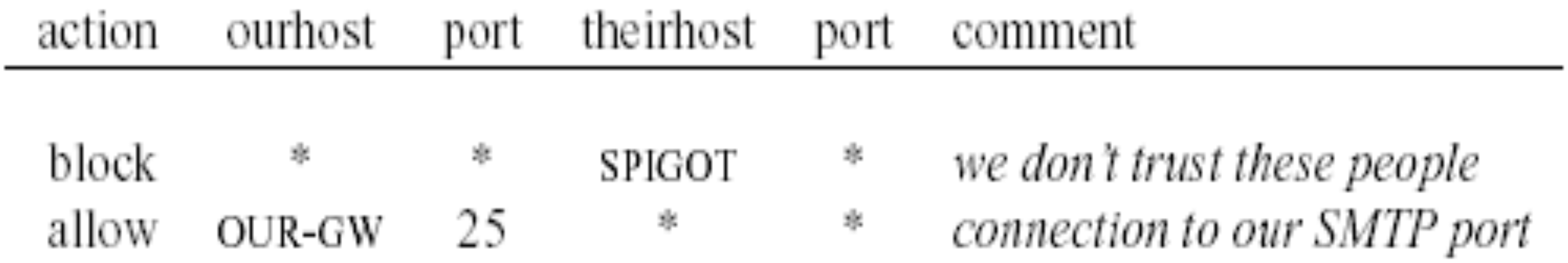


action	ourhost	port	theirhost	port	comment
block	*	*	*	*	*default*

Example 1:

Suppose we want to allow inbound mail (SMTP, port 25) but only to our gateway machine. Also suppose that mail from some particular site SPIGOT to be blocked.

Solution 1:

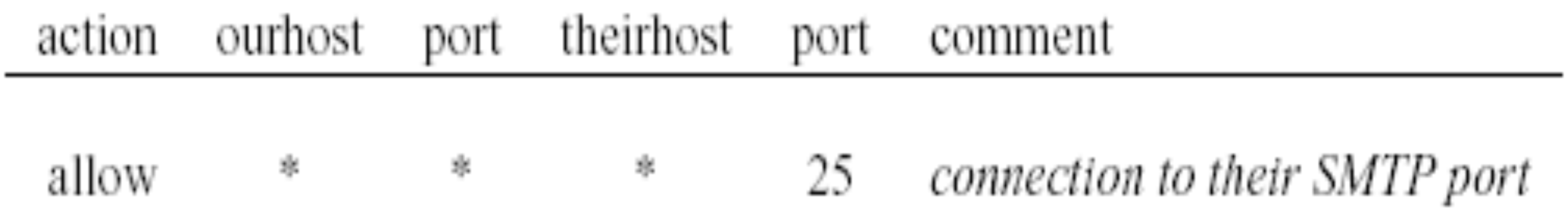


action	ourhost	port	theirhost	port	comment
block	*	*	SPIGOT	*	*we don't trust these people*
allow	OUR-GW	25	*	*	*connection to our SMTP port*

Example 2:

Now suppose that we want to implement the policy “any inside host can send mail to the outside”.

Solution 2:



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

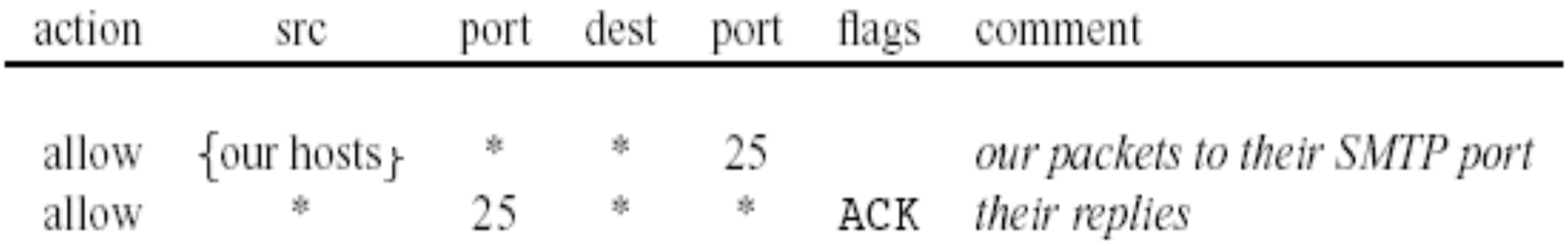
This solution allows calls to come from any port on an inside machine, and will direct them to port 25 on the outside. Simple enough…

So why is it wrong?

- Our defined restriction is based solely on the outside host’s port number, which we have no way of controlling.
- Now an enemy can access any internal machines and port by originating his call from port 25 on the outside machine.

What can be a better solution ?

better Solution 2:



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

- The ACK signifies that the packet is part of an ongoing conversation
- Packets without the ACK are connection establishment messages, which we are only permitting from internal hosts

Packet filtering

- Order rules so that most common traffic is dealt with first
- Correctness is more important than speed

- Possible attacks
  - IP address spoofing
  - Source routing attacks
  - Tiny fragment attacks

Packet filtering

- A packet filter can be **stateless**, meaning that each IP packet is treated individually
- Practical problems occur if inbound connections must be established to dynamically assigned port numbers (e.g., FTP data connection): request may be rejected. In case of FTP, **passive mode FTP** solves the problem, as FTP data connection is also established outbound (from client to server)
- Underlying problem is more general and applies to increasingly large number of applications
- One way to address the problem is to have packet filters establish and maintain state information

Stateful Packet filtering

- filters based on:
  - Information contained in the current packet
  - Information contained in previous packet transmitted
- Accomplished using state table
  - Maintains state information about the communication from previous packet (client-server session)
- Information comes from any part of the packet
- Advantages
  - Can deal with most of the problems that can rise from using stateless filtering
    - Can handle UDP packets
    - Can handle fragmented packets
    - Can prevent TCP Open SYN Flood Attacks
- Disadvantages
    - Not easy to configure
    - Less secure than Application level gateways???

Types of Firewalls

Circuit-level Gateway

- Stand-alone system or specialized function performed by an Application-level Gateway
- Sets up two TCP connections
- The security function consists of determining which connections will be allowed
- The gateway typically relays TCP segments from one connection to the other without examining the contents
- Typical use is a situation in which the system administrator trusts the internal users
- An example is the SOCKS package

Circuit-Level Gateways

- The goal of SOCKS was to provide a general framework for TCP/IP applications to securely use (and traverse) a firewall
- When a client requires access to a server on the Internet, it must first open a TCP connection to the appropriate port (1080) on the SOCKS server residing on the firewall system. Then the client uses the SOCKS protocol to have the SOCKS server establish a second TCP connection to the origin server

Types of Firewalls

Application-Level Gateways

- Acts as a relay of application-level traffic
  - Does not provide the service itself. It only acts as the client to the real server
- It interprets the application protocol, and therefore checks or filters the content
- works at the application layer, is specific and generally able to proxy only one TCP-based application protocol
- A firewall needs specific application-level gateways (or **proxy servers**) for every application protocol that must traverse the firewall (a serious disadvantage for, e.g., proprietary protocols)

Application-Level Gateways

- Advantages:
  - Higher security than packet filters
  - Only need to scrutinize a few allowable applications
  - Easy to log and audit all incoming traffic
- Disadvantages:
  - Additional processing overhead on each connection (gateway as splice point)

Application-Level Gateways

- In general, the use of an application gateway requires some modification of either the user procedures or the client software (not convenient either way)
- Useful to have a firewall that maintains all software modifications required for application gateway support in the firewall
- Solution: **transparent firewalls,** configured to listen on the network segment of the firewall for outgoing TCP connections and to relay these connections on the behalf of the client.

Application-Level Gateways

- Transparency is not necessarily in both directions (e.g., inbound transparency is seldom used)
- A transparent firewall requires that all messages to and from the Internet be transmitted through the firewall
- Similar functionality is required for **network address translation (NAT)**
- The application-level gateway must be able to authenticate and authorize user requests
  - List of IP addresses allowed inbound or outbound
  - Weak authentication schemes (e.g., password)
  - Strong authentication schemes

Application-Level Gateways

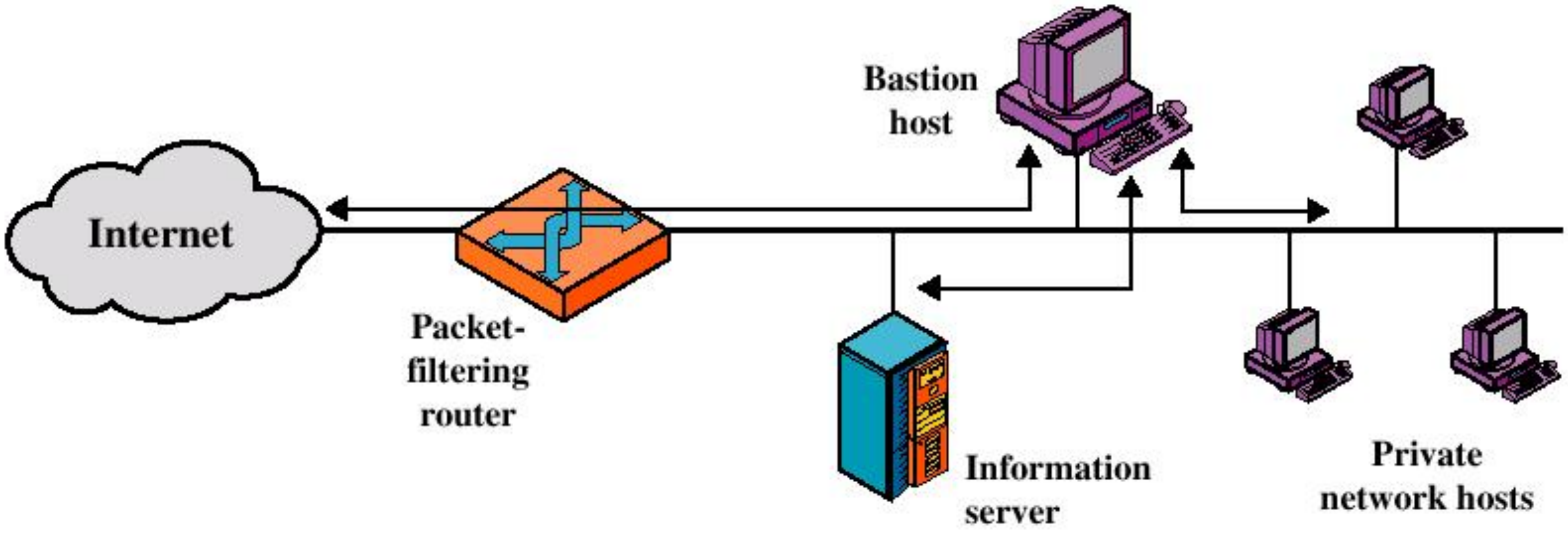
- In practice, the firewall policy must define the authentication and authorization schemes that must be used in either direction and for each service
- Many policies use the simplest scheme mentioned above for outbound connections and a strong authentication scheme for inbound connections
- Need for access to reference information to verify the authentication of information provided by client (e.g., hash value of user password or public key certificate for a specific user)
- The reference information can be stored either locally or remotely: the latter is preferable since it makes it possible to aggregate at a single point security information for several firewall systems and network access servers

Firewall Configurations

- More complex configurations than a simple system (single packet filtering router or single gateway) are possible.
- Three common configurations, all using the notion of **Bastion Host**
  - A system identified by the firewall administrator as a critical strong point in the network´s security
  - The bastion host serves as a platform for an application-level or circuit-level gateway

Firewall Configurations

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

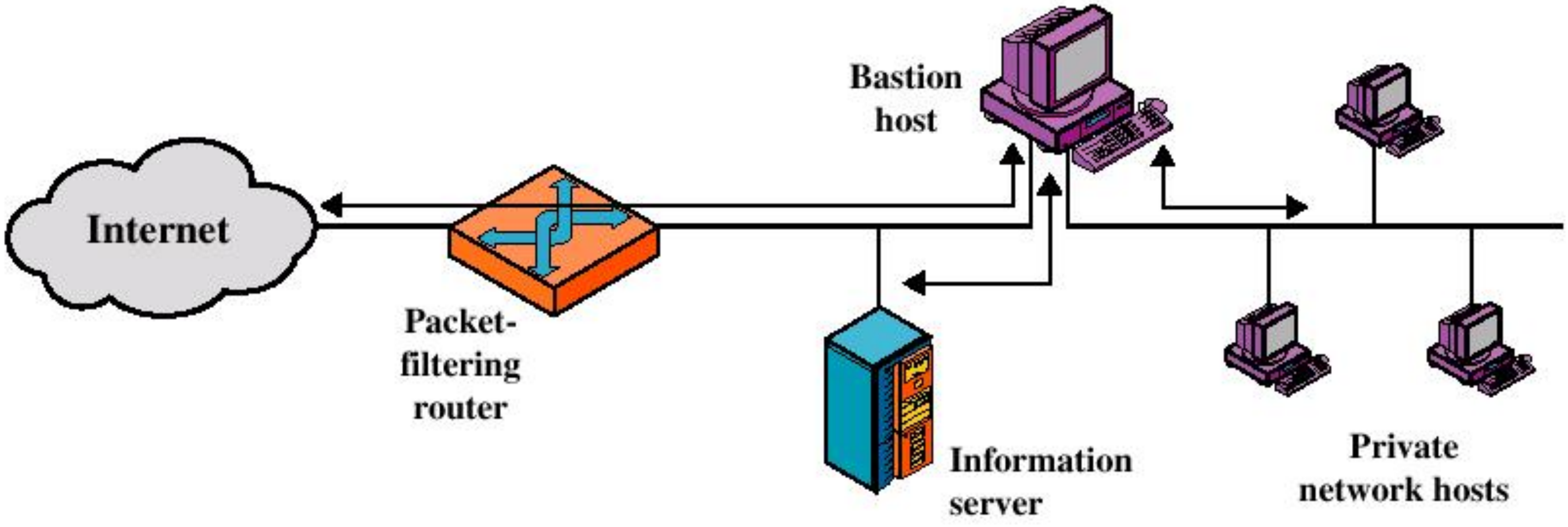


Screened host single-homed

- Firewall consists of two systems:
  - A packet-filtering router
    - only packets from and to bastion are allowed to pass through the router
  - A bastion host
    - performs authentication and proxy functions
- Greater security than single configurations because:
  - This configuration implements both packet-level and application-level filtering (allowing for flexibility in defining security policy)
  - An intruder must generally penetrate two separate systems to compromise network
- This configuration also affords flexibility in providing direct Internet access (public information server, e.g. Web server) by allowing packets through

Firewall Configurations

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

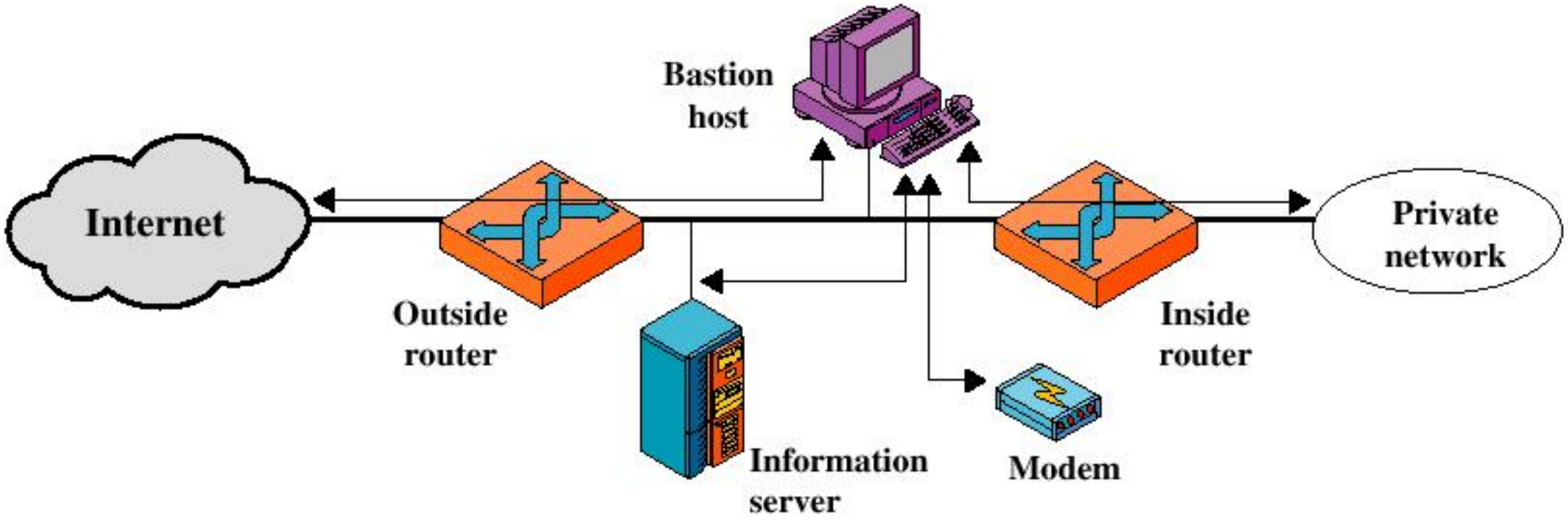


Screened host dual-homed

- In single-homed, if packet-filtering router is completely compromised, traffic flows directly to private network
- In dual-homed, traffic between the Internet and other hosts on the private network has to flow through the bastion host too

Firewall Configurations

- Screened-subnet firewall system



Screened subnet

- Most secure configuration of the three
  - Three levels of defense to thwart intruders
- Two packet-filtering routers are used
- Creation of an isolated sub-network
  - *Inside* router advertises only existence of screened subnet to internal network (systems on the inside cannot construct direct routes to Internet)
  - *Outside* router advertises only existence of screened subnet to the Internet (internal network invisible to the Internet)

Conclusions

If properly designed, implemented, deployed and administered, a firewall can provide effective access control services

The firewall technology is the most widely deployed security technology on the Internet

- It cannot protect
  - from attacks bypassing it, e.g., utility modems, trusted organisations, trusted services (SSL/SSH)
  - against internal threats e.g., disgruntled employee
  - against transfer of all virus-infected programs or files