CPE5021
Advanced Network Security

--- Firewalls: Design, Implementation, and Configuration Principles---

Lecture 4

Outline

- Firewall concepts
- Firewall design principle
- Firewall types
- Firewall implementation
- Firewall configuration

What is a Firewall? and Why we need it.

- A firewall is a “choke point/guard box” of controlling and monitoring the network traffic.
- It allows interconnections between different networks with some level of trust.
- It imposes restrictions on network services (only authorized traffic is allowed).
- It enforces auditing and controlling access (alarms of abnormal behavior can be generated).
- It provides perimeter defence.

Terminology

- DeMilitarized Zone (DMZ): a portion of a network that is not fully protected and separates an internal network from an external network.
- Guard: a host that mediates access to a network to allow or disallow certain types of access on the basis of a predefined policy.
- Filtering firewalls: firewalls that perform access control based on the attributes of packet headers, rather than the content.
- Proxy: an intermediate agent or server that acts on behalf of an endpoint without allowing a direct connection between two end points.
- Proxy Firewall: is a firewall that uses proxies to perform access control. It uses on content and/or header information.
- Network security domain: is a contiguous region of a network that operates under a single security policy.

Security Policies

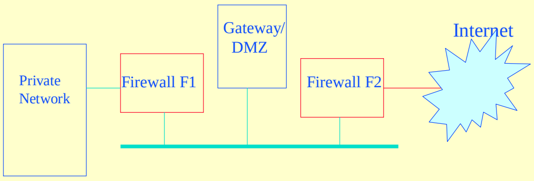
Before a firewall is designed, implemented and configured, an organisation must define a security policy related to firewalls. E.g:

- Servers in an DMZ are not allowed to make direct connections to an intranet of the private network.
- Network systems of the same organisation across the Internet are not allowed to directly contact any systems in the organisation’s intranet.
- Intranet systems are not allowed to directly contact any systems in the Internet.
- Systems in an DMZ serve as mediators (go-between).
- Do not allow dual interface from DMZ servers directly to intranet systems except inner firewalls.

DMZ and Security Policy

- Complete mediation principle: inner firewalls mediate every access involved with DMZ and intranets.
- Separation of privileges: different DMZ servers running different network functions and firewall machines are different entities than the DMZ servers.
- The outer firewall allows HTTP/HTTPS, anonymous FTP and SMTP access to DMZ server.

Firewall Example



Firewall properties

All firewalls must have the following three properties:

(1) All traffic between the networks must pass through it.

(2) Only authorized traffic, as defined by the *local* security policy, is allowed to pass through a firewall.

(3) The firewall machine/system itself SHOULD be immune to penetration.

Firewall Design Principle (1)

Before you start to design your firewall, it is important to study:

- the existing network architecture carefully. (do not create a mess when you think you are a firewall expert while you do not understand the architecture of the existing network.)
- what kind of services your organisation will provide and how often those services are changed (updated, removed, moved).
- what need to be protected (services, data or systems).
- the affect of new technology. (an old firewall may not be able to protect your network with new technology attacks)
- the possibility of your network update, expansion, or restructure. What is the security implication to your next work if one or more of those things will eventually happen?
- the possibility of disaster and recovery. What if your firewall has to be moved or shutdown; or it is dead.

Firewall Design Principle (2)

Before you design your firewall, it is also important to understand :

- for a firewall to work, it must be a part of a consistent overall organisational security architecture.
- that you can either allocate
  (1) all firewall functions on one host or
  (2) distribute those functions among a small number of hosts
- the advantages and disadvantages of each approach (1) and (2). E.g:
  - (1)
    - disadvantage: susceptive to implementation flaws or configuration errors
    - advantage: cost effective; suitable to a simple network
  - (2)
    - disadvantage: more expensive; one may compromise the others.
    - advantage: allows more flexibility in defence with diff. technologies; can reduce risks.
- how to work out how many firewall hosts your organisation need.
- that firewalls can impose performance penalty on your system.
- the advantages and disadvantages of using different firewall technologies.

Study of organisation services

- Which Internet services does the organisation plan to use or provide?
  - Telnet
  - WWW
  - Ftp
  - Email
  - DNS
  - X-windows
  - Video Conferencing

Study of organisation services

- Where will the services be used?
  - on a local network
  - across the Internet
  - dial-in from home
  - on one subnet
  - on different subnets
  - totally on a wired environment
  - mobile

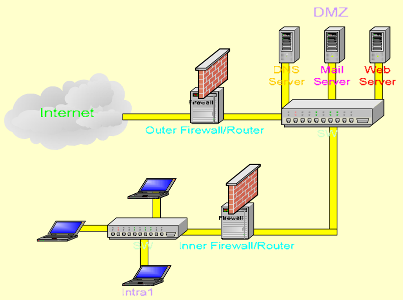
Study of organisation services

- What additional needs, such as encryption, authentication or dial-in support, may be supported?
- What risks are associated with providing these services and access?
- What is the cost, in terms of controls and impact on network usability, of providing full services with protection?
- Who are going to look after those services?
- Are there any other security servers on your existing network?

Firewall Basic Design : Examples

- Address filtering
  - Based on source and/or destination address in IP packets
  - Allowing packets with certain IP addresses to go through
  - Blocking packets with certain IP addresses
- Traffic type filtering
  - Based on the type of traffic in IP header (TCP/UDP port numbers)
  - Allowing certain types to go through. E.g http (port# 80)
- Content filtering
  - Based on the content of packets. Blocking packets with some patterns in the content.
- Specific filtering: ICMP message type, TCP SYN and ACK bits

Firewalls: Example



Borrowed from Chow - other university

Firewalls: Examples

- firewall (p: packet) { /* general form */

```
 if (allow (p)) forward (p);
else drop (p);
}
```

- firewall (p: packet) { /* more specific form */

```
 if (p->IP in allowed-domain) forward (p);
else drop (p);
}
```

- firewall (p: packet) { /* combine between filtering and content based */

```
 if ((p->IP NOT in allowed-domain) & p->content contains “write”)
  drop (p);
else forward (p);
}
```

Firewall Design Policies

- Generally speaking there are two basic design policies:

  (a) Permit any service unless it is expressly denied

  (b) Deny any service unless it is expressly permitted
- Option (b) is more secure but harder to implement

Firewall Design Basic Guidelines –Eg.

Step 1: Assume denial of all services except those that are expressly permitted.

Step 2: Answer local security policy questions.

Step 3: Study and understand the firewall design principle (1) and (2)

Step 4: Select a firewall product or build your own firewall that can implement your organisation’s firewall policy.

Firewall Types – Packet Filtering Firewalls

- Packet filtering firewalls (PFF) are the simplest form of firewalls.
- A PFFs examine each IP packet (based on information in the packet header) and permit or deny according to predefined rules. They use:
  - Send/Receive Address
  - Protocols
  - Protocol Ports
  - User-defined Bitmasks
- PFFs' possible default policies
  - that not expressly permitted is prohibited
  - that not expressly prohibited is permitted

A Simple PFF : Example

```
boolean allow (packet) {
   if (! match (packet.source,
   “130.194.*.*”))
      return false;
   /* Only allow packets from 130.194.*.*     */
   else if (match (packet.source,
                   “140.194.225.*”))
       return false;
   /* Allow all packets from 130.194.*.*, except from subnet
   225.*/
   else
      return true;
}
```

Example of Packet Filtering Rules

Incoming:

```
permit 0.0.0.0 130.194.57.*
     TCP src >= 1024 dst = 25
permit 0.0.0.0 130.194.56.19
     TCP src = 25 dst >= 1024
```

Outgoing:

```
permit 130.194.226.* 0.0.0.0
     TCP src = 25 dst >= 1024
permit 130.194.227.19 0.0.0.0
     TCP src = 80 dst = 25
```

Stateful Packet Filtering Firewalls

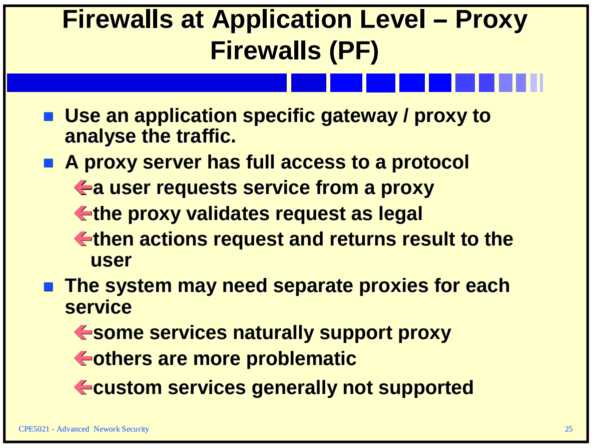
- A *stateful* packet filtering firewall (SPFF) looks at each packet and applies rules or tests, but the rules or tests applied to each packet may be modified depending on packets that have already been processed or in the case of an application relay it will maintain state by definition.
- A SPFF examines each packet in context
  - keeps tracks of client-server sessions
  - checks each packet if it belongs to one session
- These firewalls are able to detect bogus packets out of context

Firewalls at Transport Layer- Circuit Level Gateway Firewalls

- A circuit level firewall doesn't simply allow or disallow packets but also determines whether the connection between both ends is valid according to the predefined rules
  - Relays two TCP connections without examining contents
  - Enforces security by limiting which such connections are allowed
  - Allowing general outbound connections
  - SOCKS is commonly used for this

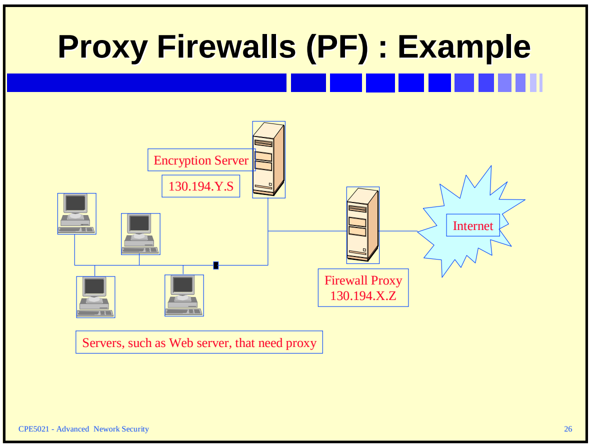
Circuit Level Gateway Firewalls

- Whether a connection is valid may be based upon the predefined rules. Eg:
  - Valid destination IP address and/or port
  - Valid source IP address and/or port
  - Allowed time of day (*)
  - Valid protocol (**)
  - Agreed information (***)

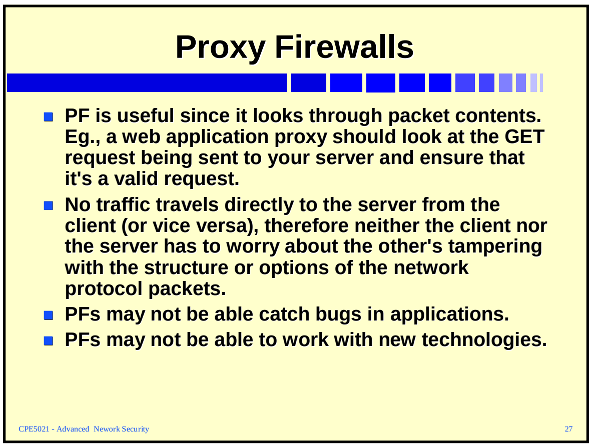


Firewalls at Application Level – Proxy Firewalls (PF)

- Use an application specific gateway / proxy to analyse the traffic.
- A proxy server has full access to a protocol
  - a user requests service from a proxy
  - the proxy validates request as legal
  - then actions request and returns result to the user
- The system may need separate proxies for each service
  - some services naturally support proxy
  - others are more problematic
  - custom services generally not supported

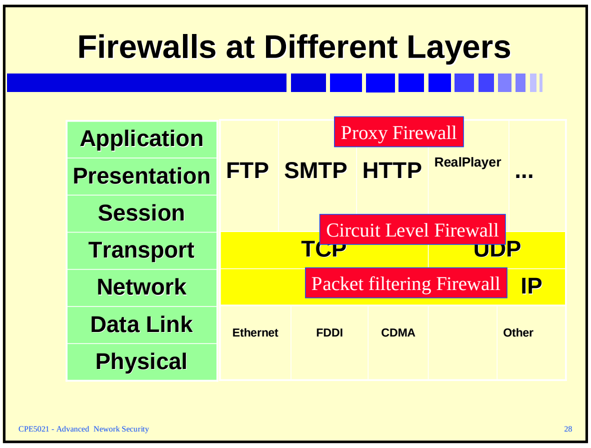


Proxy Firewalls (PF) : Example



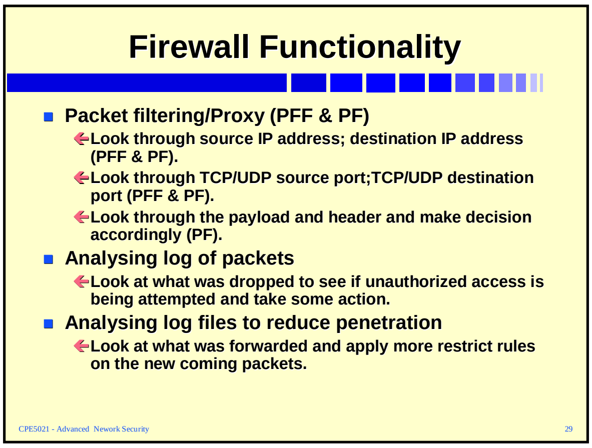
Proxy Firewalls

- PF is useful since it looks through packet contents. Eg., a web application proxy should look at the GET request being sent to your server and ensure that it's a valid request.
- No traffic travels directly to the server from the client (or vice versa), therefore neither the client nor the server has to worry about the other's tampering with the structure or options of the network protocol packets.
- PFs may not be able catch bugs in applications.
- PFs may not be able to work with new technologies.



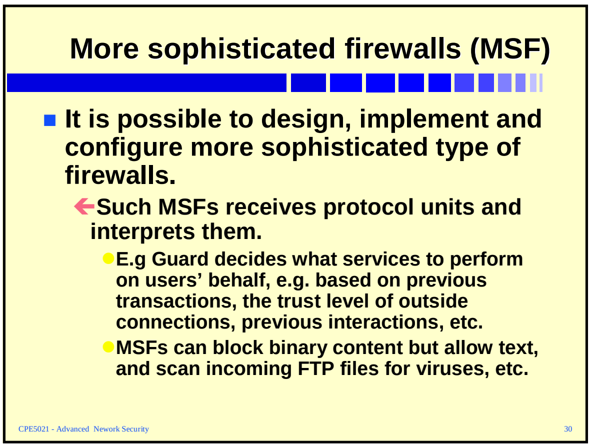
Firewalls at Different Layers

Application			Proxy Firewall		
Presentation	FTP	SMTP	HTTP	RealPlayer	...
Session					
Transport		Circuit Level Firewall TCP		UDP	
Network		Packet filtering Firewall			IP
Data Link	Ethernet	FDDI	CDMA		Other
Physical					



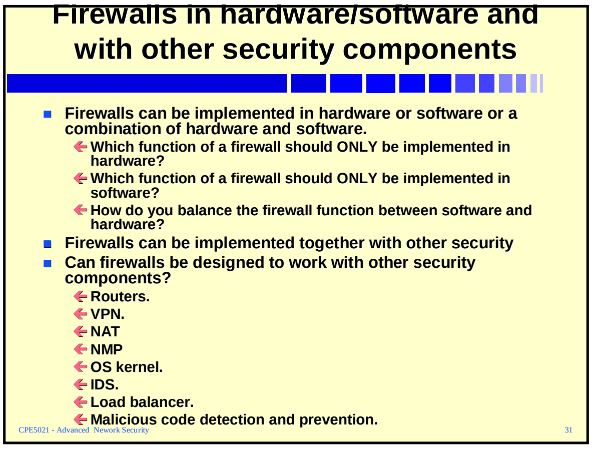
Firewall Functionality

- Packet filtering/Proxy (PFF & PF)
  - Look through source IP address; destination IP address (PFF & PF).
  - Look through TCP/UDP source port;TCP/UDP destination port (PFF & PF).
  - Look through the payload and header and make decision accordingly (PF).
- Analysing log of packets
  - Look at what was dropped to see if unauthorized access is being attempted and take some action.
- Analysing log files to reduce penetration
  - Look at what was forwarded and apply more restrict rules on the new coming packets.



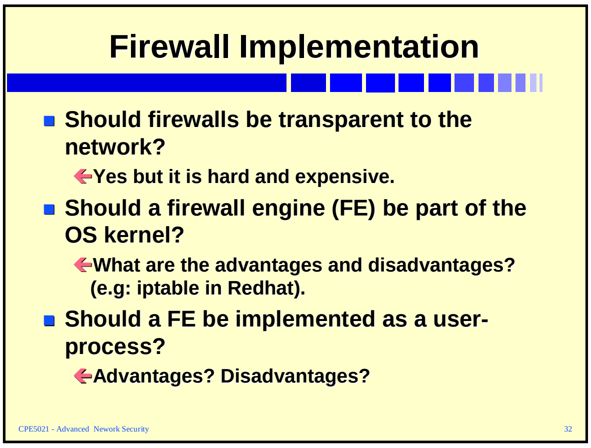
More sophisticated firewalls (MSF)

- It is possible to design, implement and configure more sophisticated type of firewalls.
  - Such MSFs receives protocol units and interprets them.
    - E.g Guard decides what services to perform on users' behalf, e.g. based on previous transactions, the trust level of outside connections, previous interactions, etc.
    - MSFs can block binary content but allow text, and scan incoming FTP files for viruses, etc.



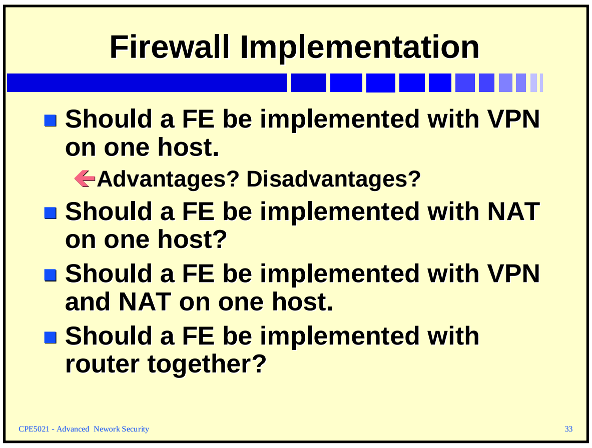
Firewalls in hardware/software and with other security components

- Firewalls can be implemented in hardware or software or a combination of hardware and software.
  - Which function of a firewall should ONLY be implemented in hardware?
  - Which function of a firewall should ONLY be implemented in software?
  - How do you balance the firewall function between software and hardware?
- Firewalls can be implemented together with other security
- Can firewalls be designed to work with other security components?
  - Routers.
  - VPN.
  - NAT
  - NMP
  - OS kernel.
  - IDS.
  - Load balancer.
  - Malicious code detection and prevention.



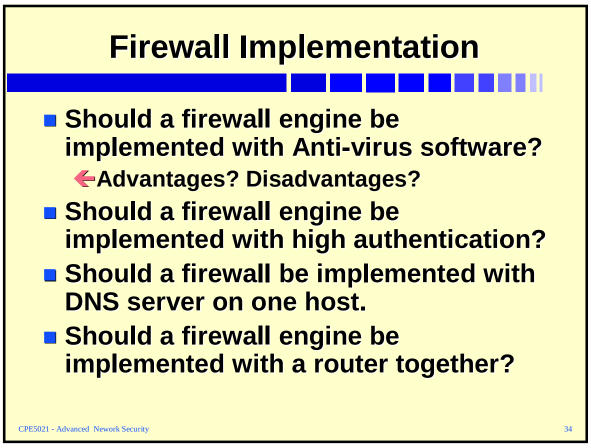
Firewall Implementation

- Should firewalls be transparent to the network?
  - Yes but it is hard and expensive.
- Should a firewall engine (FE) be part of the OS kernel?
  - What are the advantages and disadvantages? (e.g: iptable in Redhat).
- Should a FE be implemented as a user-process?
  - Advantages? Disadvantages?



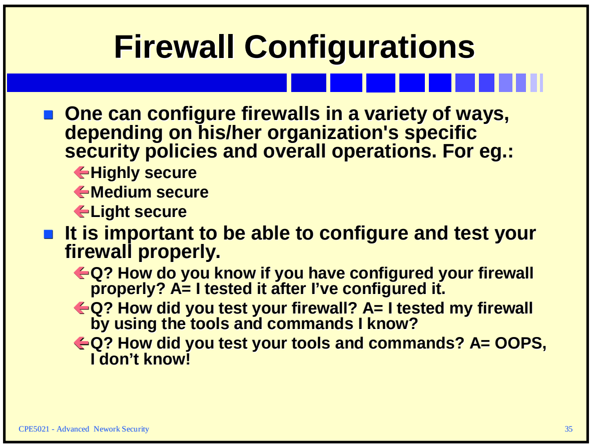
Firewall Implementation

- Should a FE be implemented with VPN on one host.
  - Advantages? Disadvantages?
- Should a FE be implemented with NAT on one host?
- Should a FE be implemented with VPN and NAT on one host.
- Should a FE be implemented with router together?



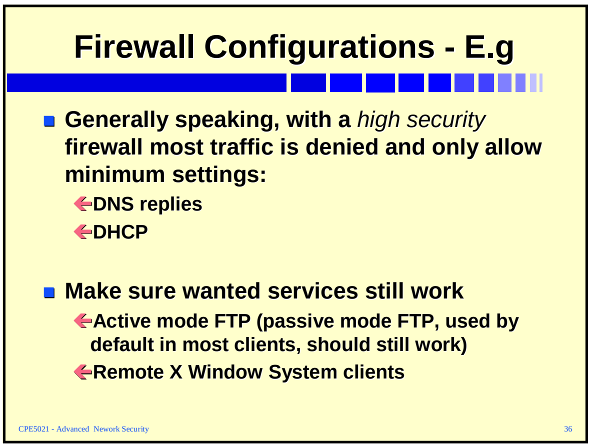
Firewall Implementation

- Should a firewall engine be implemented with Anti-virus software?
  - Advantages? Disadvantages?
- Should a firewall engine be implemented with high authentication?
- Should a firewall be implemented with DNS server on one host.
- Should a firewall engine be implemented with a router together?



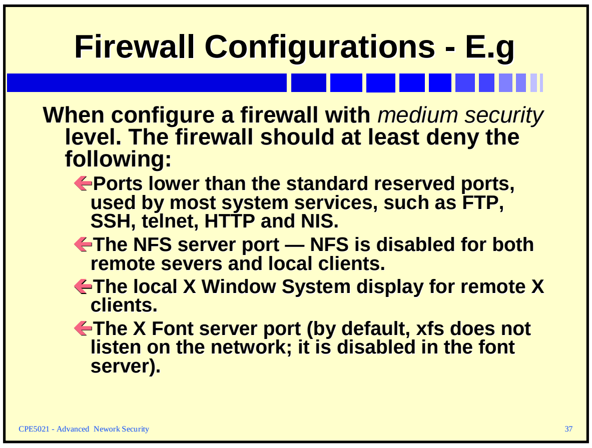
Firewall Configurations

- One can configure firewalls in a variety of ways, depending on his/her organization's specific security policies and overall operations. For eg.:
  - Highly secure
  - Medium secure
  - Light secure
- It is important to be able to configure and test your firewall properly.
  - Q? How do you know if you have configured your firewall properly? A= I tested it after I've configured it.
  - Q? How did you test your firewall? A= I tested my firewall by using the tools and commands I know?
  - Q? How did you test your tools and commands? A= OOPS, I don't know!



Firewall Configurations - E.g

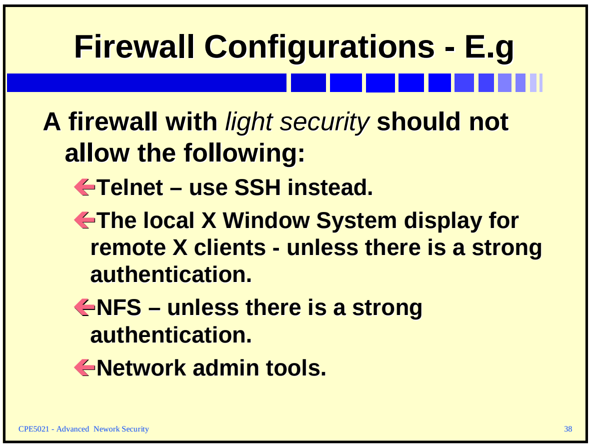
- Generally speaking, with a *high security* firewall most traffic is denied and only allow minimum settings:
  - DNS replies
  - DHCP
- Make sure wanted services still work
  - Active mode FTP (passive mode FTP, used by default in most clients, should still work)
  - Remote X Window System clients



Firewall Configurations - E.g

When configure a firewall with *medium security* level. The firewall should at least deny the following:

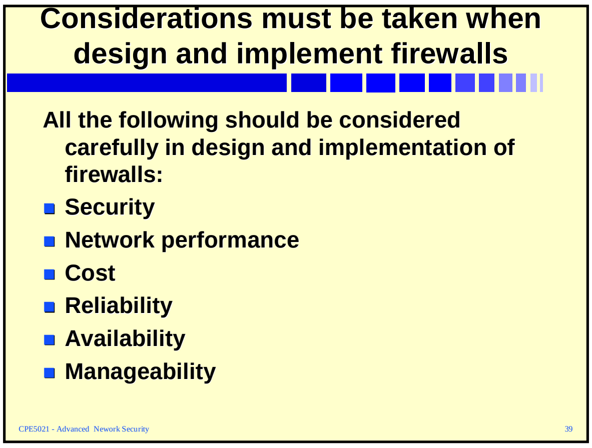
- Ports lower than the standard reserved ports, used by most system services, such as FTP, SSH, telnet, HTTP and NIS.
- The NFS server port — NFS is disabled for both remote severs and local clients.
- The local X Window System display for remote X clients.
- The X Font server port (by default, xfs does not listen on the network; it is disabled in the font server).



Firewall Configurations - E.g

A firewall with *light security* should not allow the following:

- Telnet – use SSH instead.
- The local X Window System display for remote X clients - unless there is a strong authentication.
- NFS – unless there is a strong authentication.
- Network admin tools.



Considerations must be taken when design and implement firewalls

All the following should be considered carefully in design and implementation of firewalls:

- Security
- Network performance
- Cost
- Reliability
- Availability
- Manageability