IS 2150 / TEL 2810
Introduction to Security

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Lecture 2
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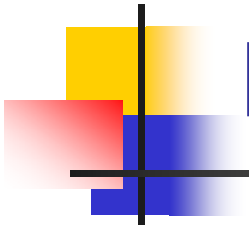
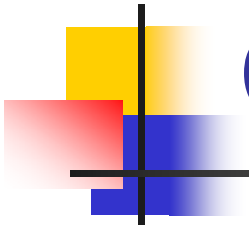
Secure Design Principles
OS Security Overview

Design Principles



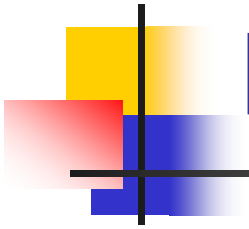
Design Principles for Security

- Principles
  - Least Privilege
  - Fail-Safe Defaults
  - Economy of Mechanism
  - Complete Mediation
  - Open Design
  - Separation of Privilege
  - Least Common Mechanism
  - Psychological Acceptability
- Based on the idea of *simplicity* and *restriction*



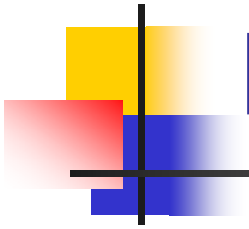
Overview

- Simplicity
  - Less to go wrong
  - Fewer possible inconsistencies
  - Easy to understand
- Restriction
  - Minimize access power (need to know)
  - Inhibit communication



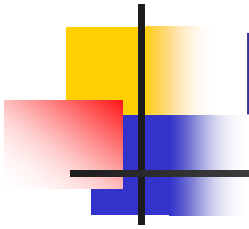
Least Privilege

- A subject should be given only those privileges necessary to complete its task
  - Function, not identity, controls
    - Role Bases Access Control!
  - Rights added as needed, discarded after use
    - Active sessions and dynamic separation of duty
  - Minimal protection domain
    - A subject should not have a right if the task does not need it



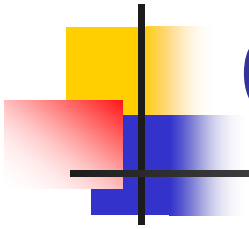
Fail-Safe Defaults

- Default action is to deny access
- If action fails, system as secure as when action began
  - Undo changes if actions do not complete
  - Transactions (commit)



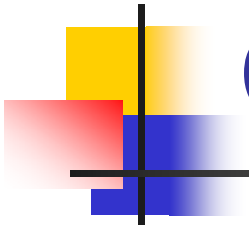
Economy of Mechanism

- Keep the design and implementation as simple as possible
  - KISS Principle (Keep It Simple, Silly!)
- Simpler means less can go wrong
  - And when errors occur, they are easier to understand and fix
- Interfaces and interactions



Complete Mediation

- Check every access to an object to ensure that access is allowed
- Usually done once, on first action
  - UNIX: Access checked on open, not checked thereafter
- If permissions change after, may get unauthorized access

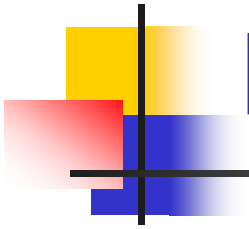


Open Design

- Security should not depend on secrecy of design or implementation
  - Popularly misunderstood to mean that source code should be public
  - “Security through obscurity”
  - Does not apply to information such as passwords or cryptographic keys

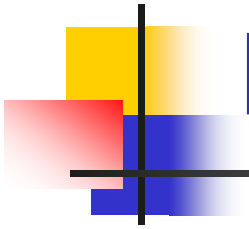
Separation of Privilege

- Require multiple conditions to grant privilege
  - Example: Checks of $70000 must be signed by two people
  - Separation of duty
  - Defense in depth
    - Multiple levels of protection



Least Common Mechanism

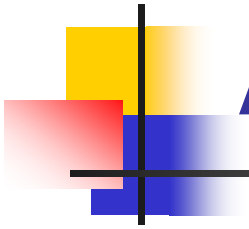
- Mechanisms should not be shared
  - Information can flow along shared channels
  - Covert channels
- Isolation
  - Virtual machines
  - Sandboxes



Psychological Acceptability

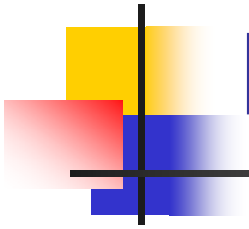
- Security mechanisms should not add to difficulty of accessing resource
  - Hide complexity introduced by security mechanisms
  - Ease of installation, configuration, use
  - Human factors critical here

Access Control Matrix



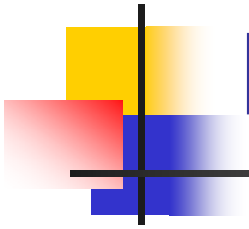
ACM Background

- Access Control Matrix
  - Captures the current protection state of a system
- Butler Lampson proposed the first Access Control Matrix model
- Graham and Denning refined it
- Harrison, Russo and Ulman modified it and presented some theoretical results



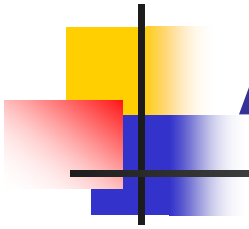
Protection System

- State of a system
  - Current values of
    - memory locations, registers, secondary storage, etc.
    - other system components
- Protection state (P)
  - A system state that is considered secure
- A protection system
  - Captures the conditions for state transition
  - Consists of two parts:
    - A set of generic rights
    - A set of commands



Protection System

- Subject (S: set of all subjects)
  - Active entities that carry out an action/operation on other entities; Eg.: users, processes, agents, etc.
- Object (O: set of all objects)
  - Eg.:Processes, files, devices
- Right (R: set of all rights)
  - An action/operation that a subject is allowed/disallowed on objects
  - Access Matrix A: a[s, o] $\subseteq$ R
- Set of Protection States: (S, O, A)



Access Control Matrix Model

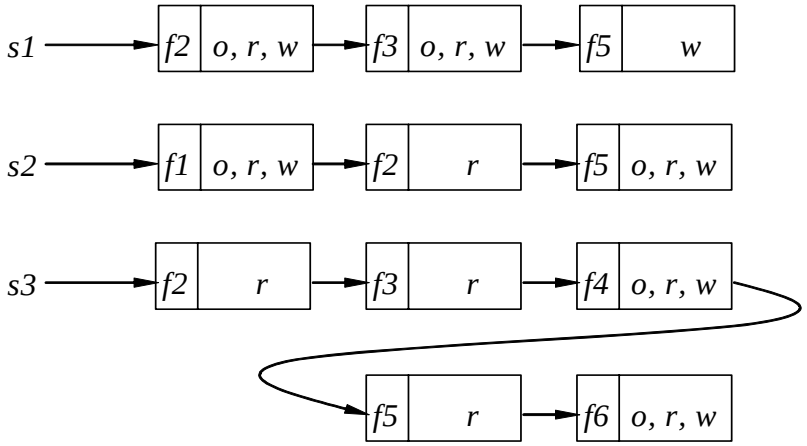
- Access control matrix
  - Describes the protection state of a system.
  - Elements indicate the access rights that subjects have on objects
- ACM is an abstract model
  - Rights may vary depending on the objects involved
- ACM is implemented primarily in two ways
  - Capabilities (rows)
  - Access control lists (columns)

o: own
r: read
w:write

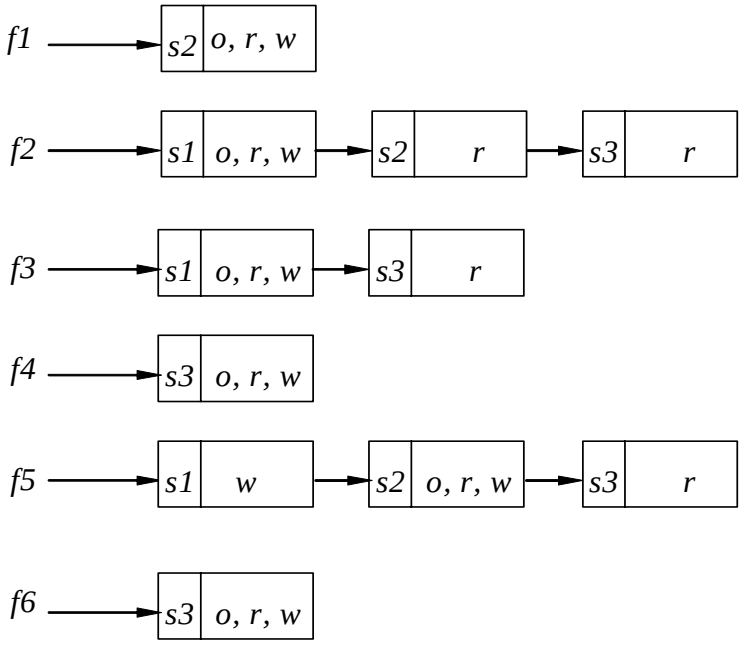
	f1	f2	f3	f4	f5	f6
s1		o, r, w	o, r, w		w	
s2	o, r, w	r			o, r, w	
s3		r	r	o, r, w	r	o, r, w

Access Matrix

Capabilities



Access Control List

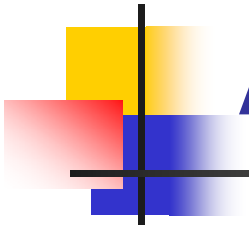


Access Control Matrix

Hostnames	*Telegraph*	*Nob*	*Toadflax*
Telegraph	*own*	*ftp*	*ftp*
Nob		*ftp, nsf, mail, own*	*ftp, nfs, mail*
Toadflax		*ftp, mail*	*ftp, nsf, mail, own*

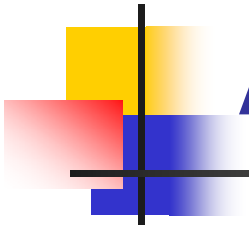
- *telegraph* is a PC with ftp client but no server
- *nob* provides NFS but not to Toadfax
- *nob* and *toadfax* can exchange mail

	Counter	*Inc_ctr*	*Dcr_ctr*	*Manager*
Inc_ctr	+			
Dcr_ctr	-			
manager		*Call*	*Call*	*Call*



Attenuation of privilege

- Principle of attenuation
  - A subject may not give rights that it does not posses to others
- Copy
  - Augments existing rights
  - Often attached to a right, so only applies to that right
    - *r* is read right that cannot be copied
    - *rc* is read right that can be copied
      - Also called the *grant* right



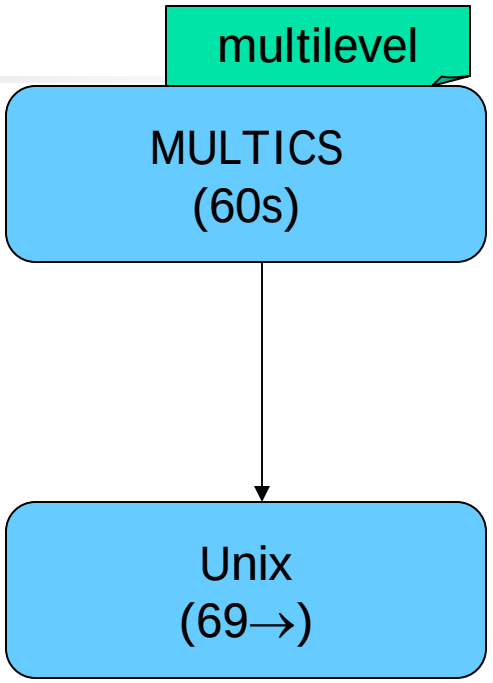
Attenuation of privilege

- Own
  - Allows adding or deleting rights, and granting rights to others
  - Creator has the *own* right
  - Subjects may be granted *own* right
  - Owner may give rights that he does not have to others on the objects he owns
    - Example: John owns file *f* but does not have *read* permission over it. John can grant *read* right on *f* to Matt.

Unix Security
Overview

Unix

- Kernel
  - I/O, Load/Run Programs, Filesystem; Device Drivers ...
- Standard Utility Programs
  - /bin/ls, /bin/cp, /bin/sh
- System database files
  - E.g, /etc/passwd; /etc/group



Multi-user

Multi-tasking

Developed at
AT&T Bell Labs

Users and password

- Each user has a
  - unique *account* identified by a *username*
  - Each *account* has a *secret password*
    - Standard: 1-8 characters; but varies
    - Passwords could be same – bad choice!
- /etc/passwd contains
  - Username, Identification information
  - Real name, Basic account information

```
root:x:0:1:System Operator:/:/bin/ksh
daemon:x:1:1::/tmp:
uucp:x:4:4::/var/spool/uucppublic:/usr/lib/uucp/uucico
rachel:x:181:100:Rachel Cohen:/u/rachel:/bin/ksh
arlin:x.:182:100:Arlin Steinberg:/u/arlin:/bin/csh
```

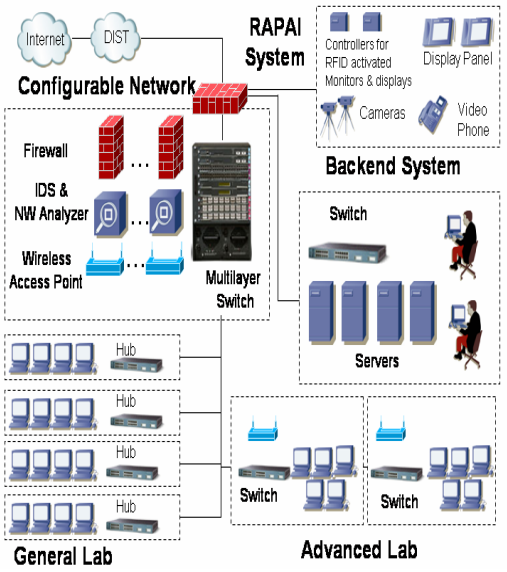
Account info

Field	Contents
rachel	Username.
x	Holding place for the user's "encrypted password." Newer Unix systems store encrypted passwords in a separate file (the *shadow password file*) that can be accessed only by privileged users.
181	User's user identification number (UID).
100	User's group identification number (GID).
Rachel Cohen	User's full name
/u/rachel	User's home directory.
/bin/ksh	User's shell (empty field means default shell)

rachel:x:181:100:Rachel Cohen:/u/rachel:/bin/ksh

Account over a network

- Current systems are networked and grouped in client/server environment
  - Accounts setup to allow using any workstation
  - Automatic account creation and password synchronization
  - Typical info in /passwd available over the network
- Network authorization systems in use
  - Sun's Network Information System (NIS) and NIS+
  - MIT Kerberos - part of DCE and Windows XP (and others)
  - NetInfo – part of Mac OS X
  - RADIUS (remote authentication Dial-In User Service)
  - Authentication systems using Lightweight Directory Access Protocol (LDAP) server



Pluggable Authentication Module

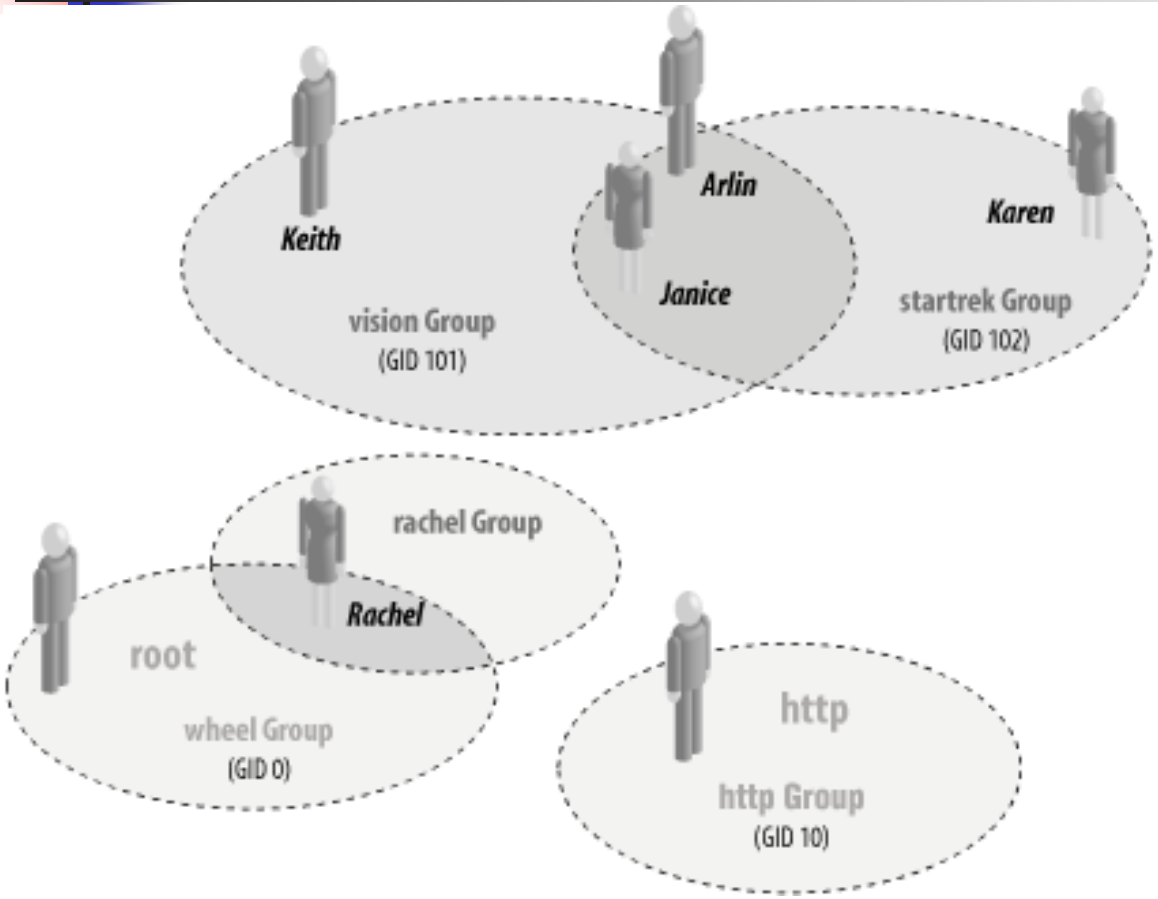
Users and Groups

- Each user is uniquely identified by a UID
  - Special user names
    - Root; Bin; Daemon; Mail; Guest; ftp
- Every user belongs to one or more groups
  - A *primary group*
  - */etc/group*
    - Gname, Gpassword, GID, Users

16 bits: 1 – 65535
UID 0: superuser
(More bits too)

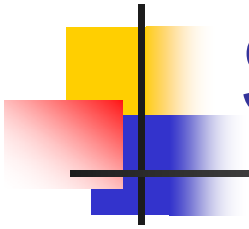
wheel:*:0:root,rachel
http:*:10:http
users:*:100:
vision:*:101:keith,arlin,janice
startrek:*:102:janice,karen,arlin
rachel:*:181:

Users and Groups



Some useful commands
- groups
- id
- newgrp
- su

wheel:*:0:root,rachel
http:*:10:http
users:*:100:
vision:*:101:keith,arlin,janice
startrek:*:102:janice,karen,arlin
rachel:*:181:

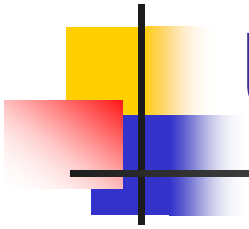


Superuser

- root; UID = 0 ..... Complete Control
  - Used by OS itself for basic functions
    - Logging in/out users
    - Recording accounting info
    - Managing input/output devices
  - Security controls are bypassed
  - There are few things not allowed
    - Decrypt passwords shadow-file, ...

Key Security Weakness in Unix

Processes can run with Effective UID = 0



User ids

- Each process has three Ids
  - Real user ID (RUID)
    - a user's "real identity"
    - same as the user ID of parent (unless changed)
    - used to determine which user started the process
  - Effective user ID (EUID)
    - from set user ID (SUID) bit on the file being executed
    - Can use su command to assume another's RUID
    - determines the permissions for process
  - Saved user ID (SUID)
    - Allows restoring previous EUID
- Similarly we have
  - Real group ID, effective group ID, ..

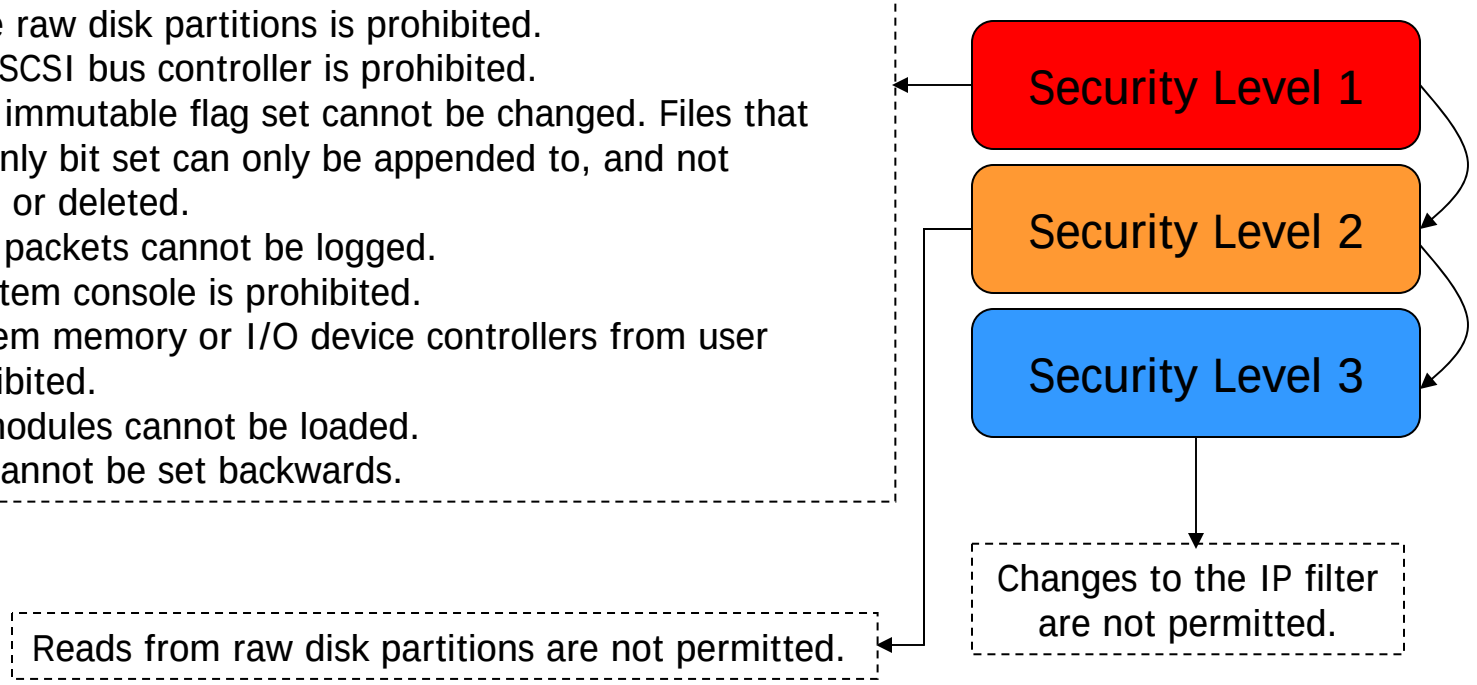
One should always use the full path /ls/su if changing to root
... WHY?

Kernel security Levels (BSD, Mac OS ..)

Restricts power of superuser

`sysctl kern.securelevel=1`

- Write access to the raw disk partitions is prohibited.
- Raw access to the SCSI bus controller is prohibited.
- Files that have the immutable flag set cannot be changed. Files that have the append-only bit set can only be appended to, and not otherwise modified or deleted.
- The contents of IP packets cannot be logged.
- Raw I/O to the system console is prohibited.
- Raw writes to system memory or I/O device controllers from user programs are prohibited.
- Additional kernel modules cannot be loaded.
- The system clock cannot be set backwards.



Not a comprehensive list

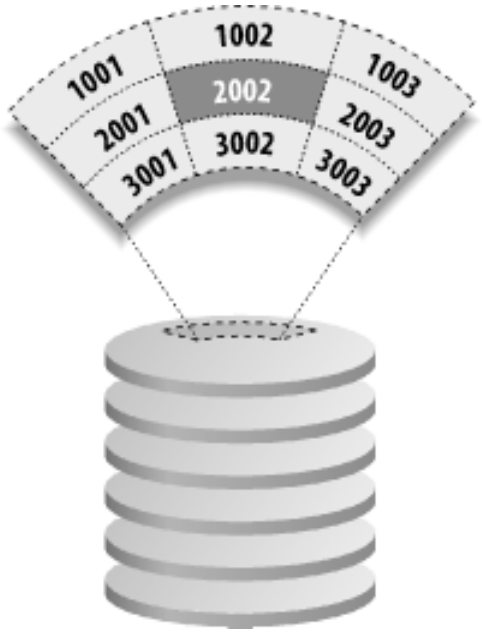
Unix file system

- File systems store
  - information in files and metadata about files.
  - tree-structured

A file is a block of information that is given a single name and can be acted upon with a single operation.

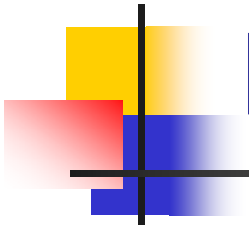
"everything is a file"

Finenames stored in director and Have pointers to *inodes*



inode 2002

Item Location	Item Type	Item Size *(bytes)*
Time Inode Modified *(ctime)*	Time Contents Modified *(mtime)*	Time File Accessed *(atime)*
File's Owner *(UID)*	File's Group *(GID)*	Per-missions *(mode bits)*
Reference Count	Location of Data on Disk	



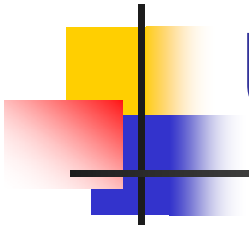
Directory

- A Unix directory is
  - a list of names
    - files, directories,.
  - associated inode numbers.
  - Special entries

    “.” and its inode # (self)

    “..” and its inode # (parent)

r	Read	Listing files in the directory.
w	Write	Add, rename, or remove entries in that directory.
x	Execute	Stat the contents of a directory (e.g., you can determine the owners and the lengths of the files in the directory). Required to make directory your current directory or to open files inside the directory (or in any of the directory's subdirectories).



Unix file security

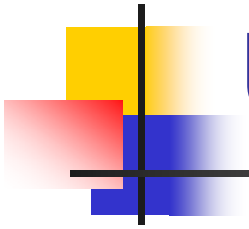
- Each file/directory has owner and group
- Permissions set by owner
  - Read, write, execute
  - Owner, group, other
  - Represented by vector of four octal values
- Only owner, root can change permissions
  - This privilege cannot be delegated or shared

Unix File Permissions

- File type, owner, group, others

```
drwx------   2 jjoshi  isfac  512  Aug 20  2003 risk management
lrwxrwxrwx   1 jjoshi  isfac   15  Apr  7 09:11 risk_m->risk management
-rw-r--r--   1 jjoshi  isfac 1754  Mar  8 18:11 words05.ps
-r-sr-xr-x   1 root    bin   9176  Apr  6  2002 /usr/bin/rs
-r-sr-sr-x   1 root    sys   2196  Apr  6  2002 /usr/bin/passwd
```

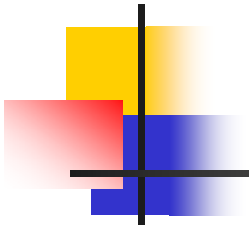
  - File type: regular -, directory d, symlink l, device b/c, socket s, fifo f/p
  - Permission: r, w, x, s or S (set.id), t (sticky)
- While accessing files
  - Process EUID compared against the file UID
  - GIDs are compared; then Others are tested



Umask

- Four digit octal
- Specifies the permission you do not want given by default to new files
  - Bitwise AND with the bitwise complement of the umask value

Umask	User Access	Group Access	Other Access
0000	All	All	All
0002	All	All	Read, Execute
0007	All	All	None
0022	All	Read, Execute	Read, Execute
0027	All	Read, Execute	None
0077	All	None	None

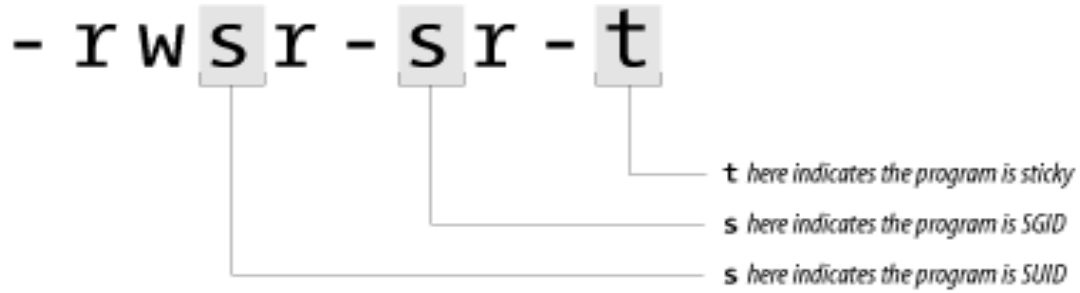


IDs/Operations

- Root can access any file
- Fork and Exec
  - Inherit three IDs,
    - except exec of file with setuid bit
- Setuid system calls
  - seteuid(newid) can set EUID to
    - Real ID or saved ID, regardless of current EUID
    - Any ID, if EUID=0
  - Related calls: setuid, seteuid, setgid, setegid

Setid bits

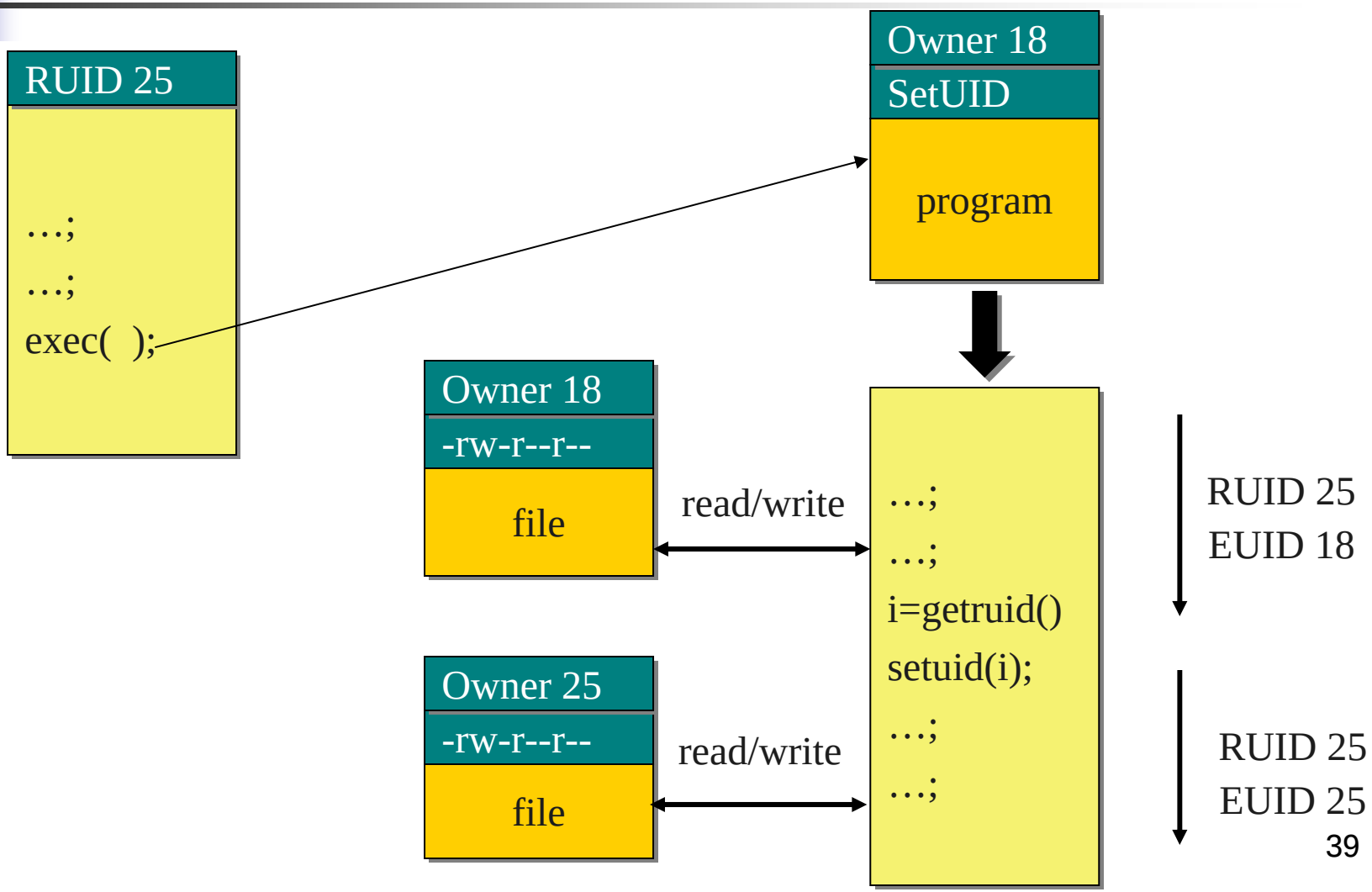
- Three setid bits
  - suid
    - set EUID of process to ID of file owner
  - sgid
    - set EGID of process to GID of file
  - suid/sgid used when a process executes a file
    - If suid(sgid) bit is on – the EUID (EGID) of the process changed to UID (GUID) of the file
  - Sticky
    - Off: if user has write permission on directory, can rename or remove files, even if not owner
    - On: only file owner, directory owner, and root can rename or remove file in the directory

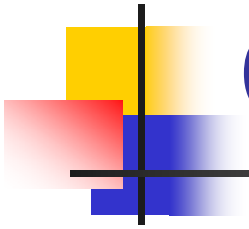


If SUID is set but execute is not

-r--r-Sr-T 1 root user 12324 Mar 26 1995 /tmp/example

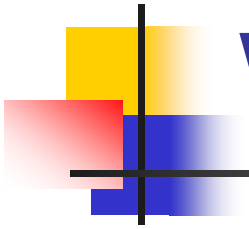
SUID – dangerous!





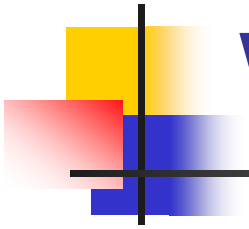
Careful with Setuid !

- Can do what owner of file is allowed to do
- Be sure not to
  - Take action for untrusted user
  - Return secret data to untrusted user
- Principle of least privilege
  - change EUID when root privileges no longer needed
- Setuid scripts (bad idea)
  - Race conditions: begin executing setuid program; change contents of program before it loads and is executed



Windows NT

- Windows 9x, Me
  - Never meant for security
  - FAT file system – no file level security
  - PWL password scheme – not secure
    - Can be simply deleted
- Windows NT
  - Username mapped to Security ID (SID)
  - SID is unique within a domain
    - SID + password stored in a database handled by the Security Accounts Manager (SAM) subsystem

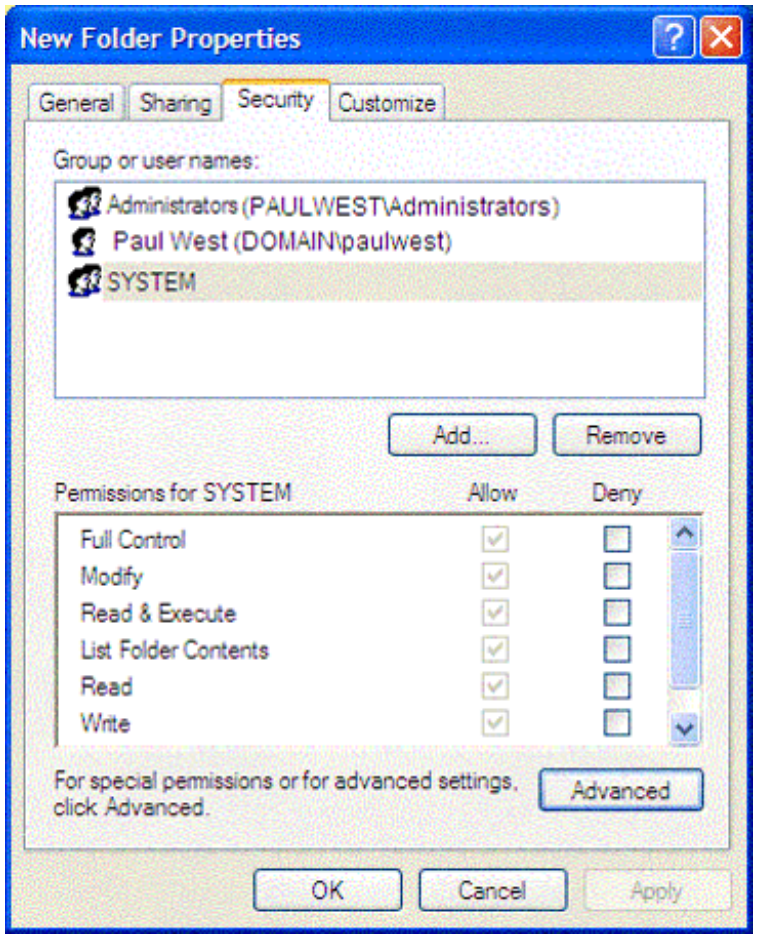


Windows NT

- Some basic functionality similar to Unix
  - Specify access for groups and users
    - Read, modify, change owner, delete
- Some additional concepts
  - Tokens
  - Security attributes
- Generally
  - More flexibility than Unix
    - Can define new permissions
    - Can give some but not all administrator privileges

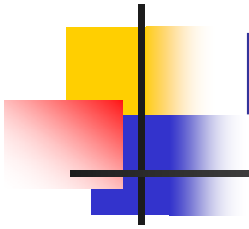
Sample permission options

- SID
  - Identity (replaces UID)
    - SID revision number
    - 48-bit authority value
    - variable number of Relative Identifiers (RIDs), for uniqueness
  - Users, groups, computers, domains, domain members all have SIDs



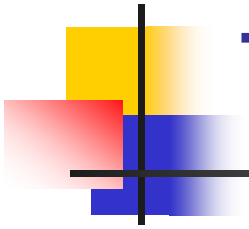
Permission Inheritance

- Static permission inheritance (Win NT)
  - Initially, subfolders inherit permissions of folder
  - Folder, subfolder changed independently
  - *Replace Permissions on Subdirectories* command
    - Eliminates any differences in permissions



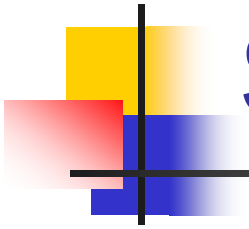
Permission Inheritance

- Dynamic permission inheritance (Win 2000)
  - Child inherits parent permission, remains linked
  - Parent changes are inherited, except explicit settings
  - Inherited and explicitly-set permissions may conflict
    - Resolution rules
      - Positive permissions are additive
      - Negative permission (deny access) takes priority



Tokens

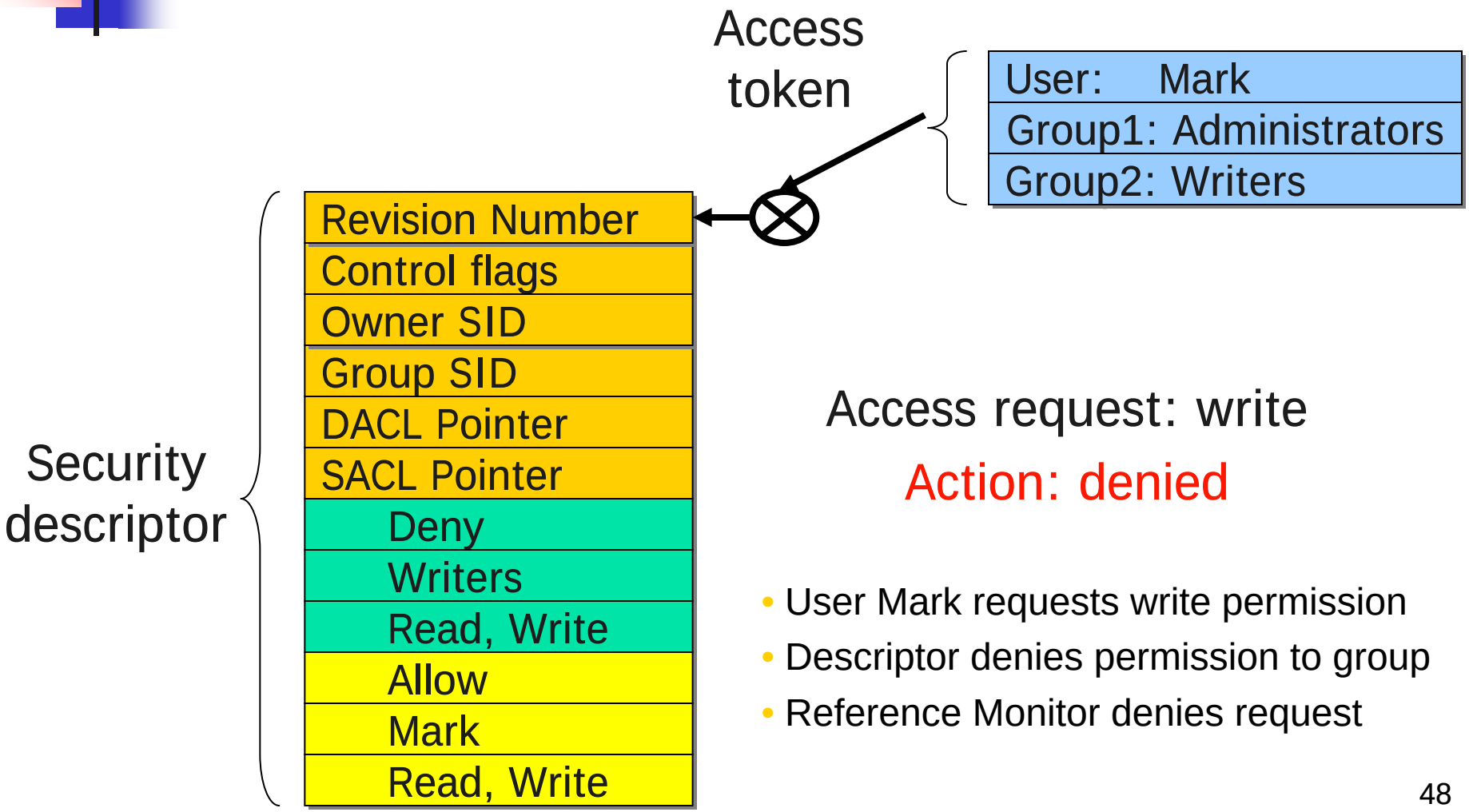
- Security context
  - privileges, accounts, and groups associated with the process or thread
- Security Reference Monitor
  - uses tokens to identify the security context of a process or thread
- Impersonation token
  - Each thread can have two tokens – primary & impersonation
  - thread uses temporarily to adopt a different security context, usually of another user



Security Descriptor

- Information associated with an object
  - who can perform what actions on the object
- Several fields
  - Header
    - Descriptor revision number
    - Control flags, attributes of the descriptor
      - E.g., memory layout of the descriptor
  - SID of the object's owner
  - SID of the primary group of the object
  - Two attached optional lists:
    - Discretionary Access Control List (DACL) – users, groups, ...
    - System Access Control List (SACL) – system logs, ..

Example access request

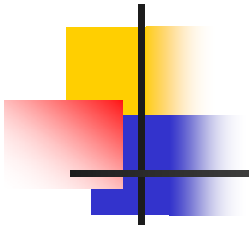


Access request: write

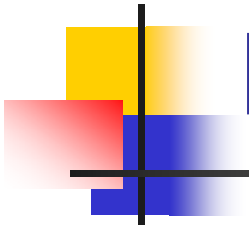
Action: denied

- User Mark requests write permission
- Descriptor denies permission to group
- Reference Monitor denies request

Impersonation Tokens (setuid?)



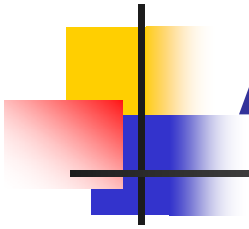
- Process uses security attributes of another
  - Client passes impersonation token to server
- Client specifies impersonation level of server
  - Anonymous
    - Token has no information about the client
  - Identification
    - server obtains the SIDs of client and client's privileges, but server cannot impersonate the client
  - Impersonation
    - server identifies and impersonate the client
  - Delegation
    - lets server impersonate client on local, remote systems



Encrypted File Systems (EFS)

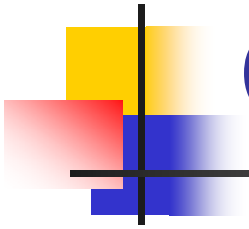
- Store files in encrypted form
  - Key management: user's key decrypts file
  - Useful protection if someone steals disk
- Windows – EFS
  - User marks a file for encryption
  - Unique file encryption key is created
  - Key is encrypted, can be stored on smart card

SELinux Security Policy Abstractions



- Type enforcement
  - Each process has an associated domain
  - Each object has an associated type
  - Configuration files specify
    - How domains are allowed to access types
    - Allowable interactions and transitions between domains
- Role-based access control
  - Each process has an associated role
    - Separate system and user processes
  - configuration files specify
    - Set of domains that may be entered by each role

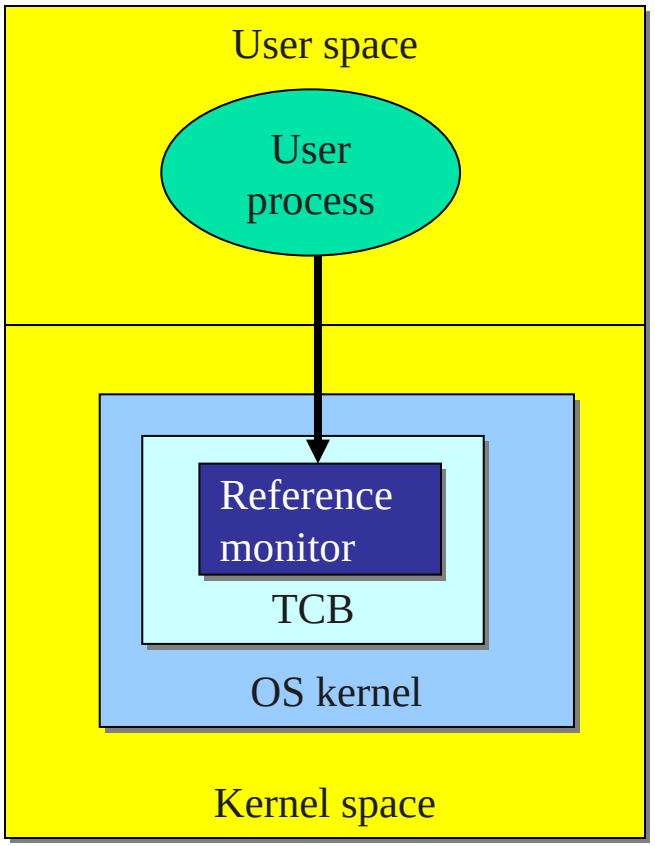
Sample Features of Trusted OS

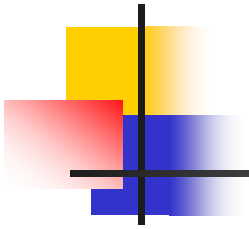


- Mandatory access control
  - MAC not under user control, precedence over DAC
- Object reuse protection
  - Write over old data when file space is allocated
- Complete mediation
  - Prevent any access that circumvents monitor
- Audit
  - Log security-related events
- Intrusion detection
  - Anomaly detection
    - Learn normal activity, Report abnormal actions
  - Attack detection
    - Recognize patterns associated with known attacks

Kernelized Design

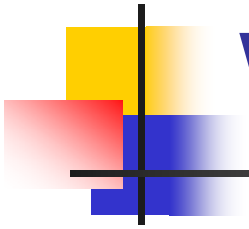
- Trusted Computing Base
  - Hardware and software for enforcing security rules
- Reference monitor
  - Part of TCB
  - All system calls go through reference monitor for security checking
  - Most OS not designed this way
- Reference validation mechanism –
  1. Tamperproof
  2. Never be bypassed
  3. Small enough to be subject to analysis and testing – the completeness can be assured





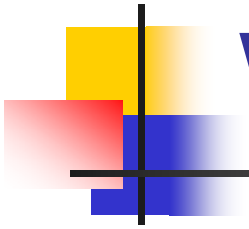
Is Windows “Secure”?

- Good things
  - Design goals include security goals
  - Independent review, configuration guidelines
- But ...
  - “Secure” is a complex concept
    - What properties protected against what attacks?
  - Typical installation includes more than just OS
    - Many problems arise from applications, device drivers
    - Windows driver certification program



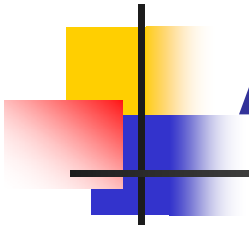
Window 2000

- Newer features than NT
- NTFS file system redesigned for performance
- Active directory
  - Kerberos for authentication
  - IPSec/L2TP



Windows XP

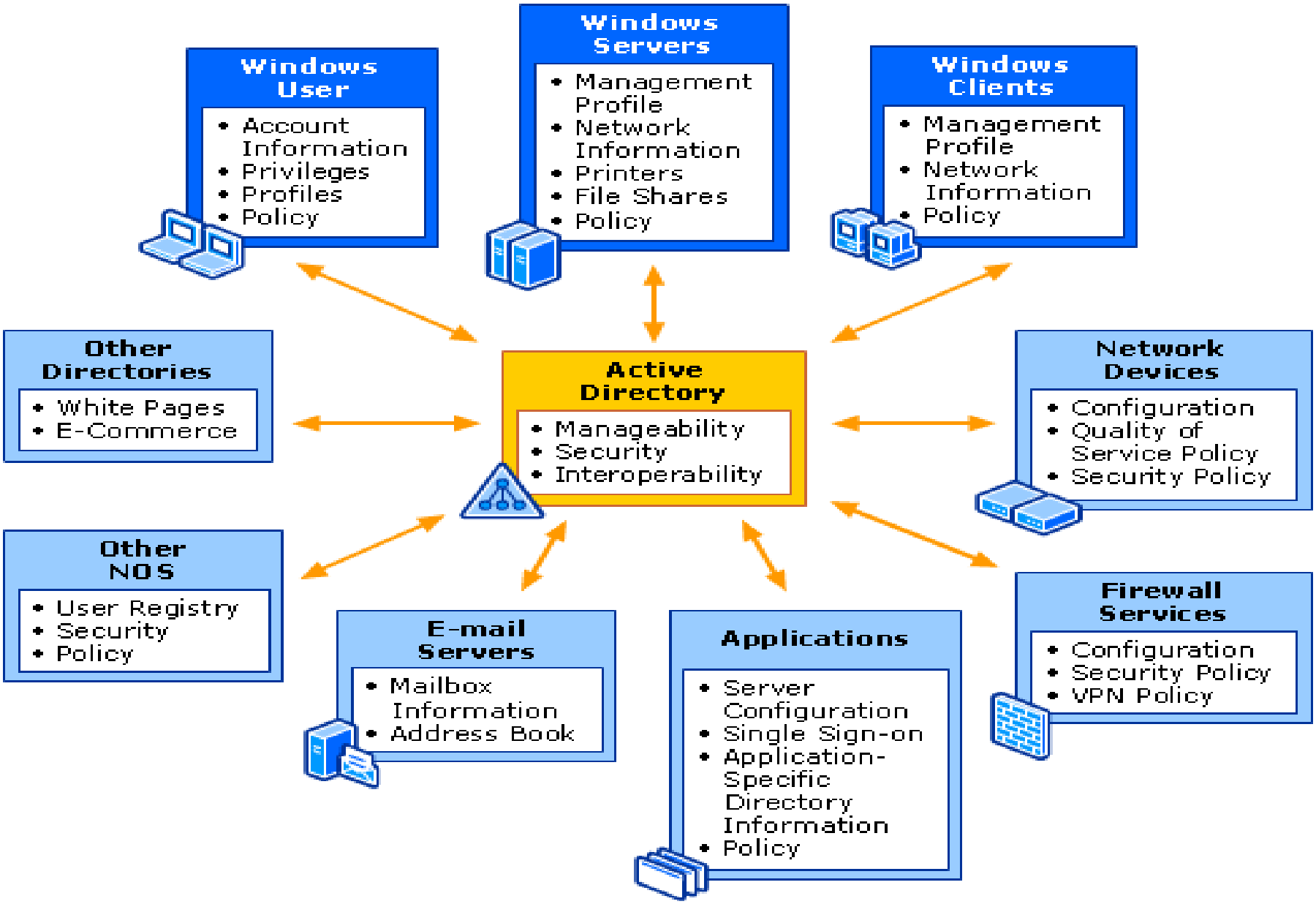
- Improvement over Win 2000 Professional
  - Personalized login
    - Multiple users to have secure profiles
  - User switching
    - Multiple users to be logged in
  - Internet connection firewall (ICF)
    - Active packet filtering
  - Blank password restriction (null sessions)
  - Encrypting File System (EFS) using PKI
  - Smart card support (uses X.509 certificate for authentication)



Active Directory

- Core for the flexibility of Win2000
  - Centralized management for clients, servers and user accounts
- Information about all objects
- Group policy and remote OS operations
- Replaces SAM database
  - AD is trusted component of the LSA
- Stores
  - Access control information – authorization
  - User credentials – authentication
- Supports
  - PKI, Kerberos and LDAP

Win 2003


Windows User
• Account Information
• Privileges
• Profiles
• Policy
Windows Servers
• Management Profile
• Network Information
• Printers
• File Shares
• Policy
Windows Clients
• Management Profile
• Network Information
• Policy
Other Directories
• White Pages
• E-Commerce
Active Directory
• Manageability
• Security
• Interoperability
Network Devices
• Configuration
• Quality of Service Policy
• Security Policy
Other NOS
• User Registry
• Security
• Policy
E-mail Servers
• Mailbox Information
• Address Book
Applications
• Server Configuration
• Single Sign-on
• Application-Specific Directory Information
• Policy
Firewall Services
• Configuration
• Security Policy
• VPN Policy