System Security

Waltzing Access Control in Unix 1/2

Mohamed Sabt

Univ Rennes, CNRS, IRISA

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Part I

Introduction

What is Access Control

- The ability to allow only authorized users, programs or processes.

- The granting or denying, according to a particular security model, of certain permissions to access a resource.

- An entire set of procedures performed by hardware and software to
  - Identify users requesting access,
  - Record access attempts,
  - Monitor access,
  - Grant or deny access based on pre-established rules.

Examples of Access Control

- Operating Systems:
  - One user cannot arbitrarily access another user's files; a normal user cannot kill another user's processes.

- Web Browsers:
  - For instance, a code from one website cannot access the cookies from another website.

- Firewalls:
  - Firewalls inspect every incoming (sometimes outgoing) packet. If a packet matches with certain conditions, it will be dropped by the firewalls.

- Memory Protection:
  - In modern processors, code in Ring 3 cannot access the data in another more privileged region (e.g. Ring 0).

Overview of System Access Control

- All operating systems have an access control component.
- The system must first authenticate a user seeking access.
- Then, the access control function determines if the specific requested access by this user is permitted.
  - The access control function consults a database to determine whether to grant access.
- An auditing function monitors and keeps a record of user accesses to system resources (logs).

What is a Security Model

- A model describes the system
  - A high level specification or an abstract machine description of what the system does.

- A security policy
  - Defines the security requirements for a given system.

- Verification techniques that can be used to show that a policy is satisfied.

- System Model + Security Policy = Security Model

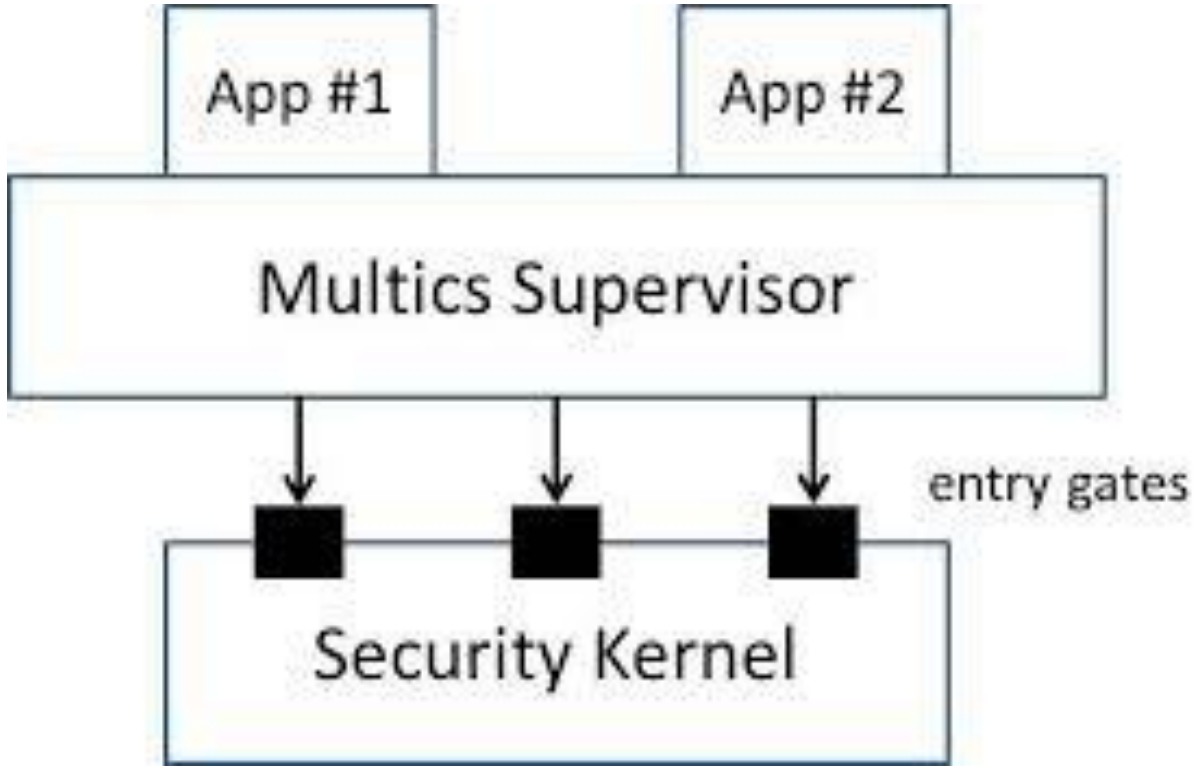
Policy Vs Mechanisms

- Access Control Policy Models:
  - pre-established rules:
    - All users should be treated equally.
    - Preferred users should be treated better.
  - Discretionary Access Control (DAC)
  - Mandatory Access Control (MAC)

- Mechanisms: tools to implement policies
  - Access control matrices
  - Access control list
  - Capability

Reference Monitor 1/2

- The Reference Monitor was introduced by James Anderson et al. in 1972 in the *Computer Security Technology Planning Study*.



- It provides an abstract model of the necessary properties that must be achieved by any system claiming to enforce access controls.

Reference Monitor 2/2

The three properties of Reference Monitor are:

- The access control mechanism is always invoked:
  - The access control cannot by bypassed.

- The access control mechanism is tamperproof
  - It is impossible for an attacker to break into the access mechanism.

- It must be small enough to be subject to analysis and tests
  - Its completeness can be assured.

Design Vocabulary

- Subject/Object:
  - A *subject* is any entity that requests access to an *object*.
  - The Subject/Object inherits from the same terms as used in grammar.
  - In System, all verbs are transitive: subject implies object. In other words, there is no subject without an object.

- Principle:
  - Principles are the keys we use in access control.
  - Principles are what subjects resolve to.
  - A subset of *subject* that is represented by a unique identifier.

Design Principles 1/2

- Complete Mediation:
  - Every access to every object must be checked.
- Economy of mechanism:
  - keep the designs as simple and small as possible.
- Fail-safe defaults:
  - Access decisions are based on permission rather than exclusion.
- Open Design:
  - The design should not be secret.

Design Principles 2/2

- Separation of Privilege:
  - Breaking up a single privilege into multiple independent components.

- Least privilege:
  - Every program and every user of the system should operate using the least set of privileges necessary to complete the job.

- Psychological acceptability:
  - Therefore, users happily apply the protection mechanisms correctly.

Part II

The UNIX DAC
(Discretionary Access Control)

DAC

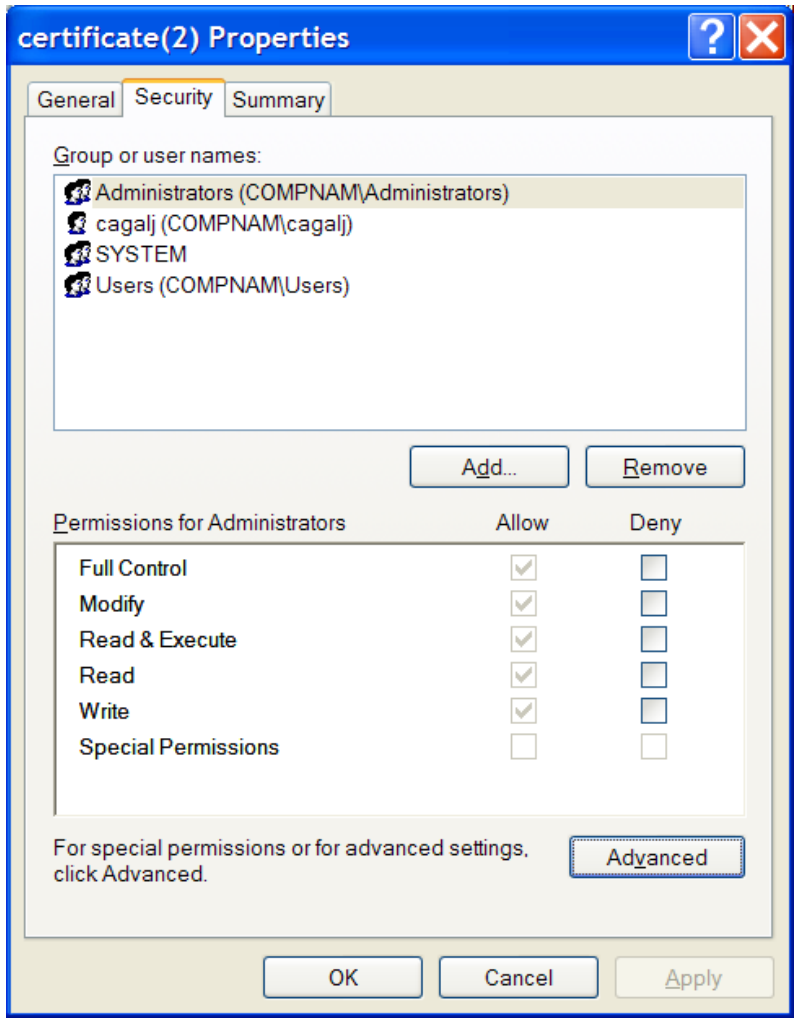
- Discretionary / Discrétionnaire:
  - Cambridge: decided by officials and not fixed by rules.
  - Larousse: Se dit du pouvoir de l'Administration lorsque cette dernière est libre de porter une appréciation sur l'utilité et l'opportunité d'une décision à prendre.

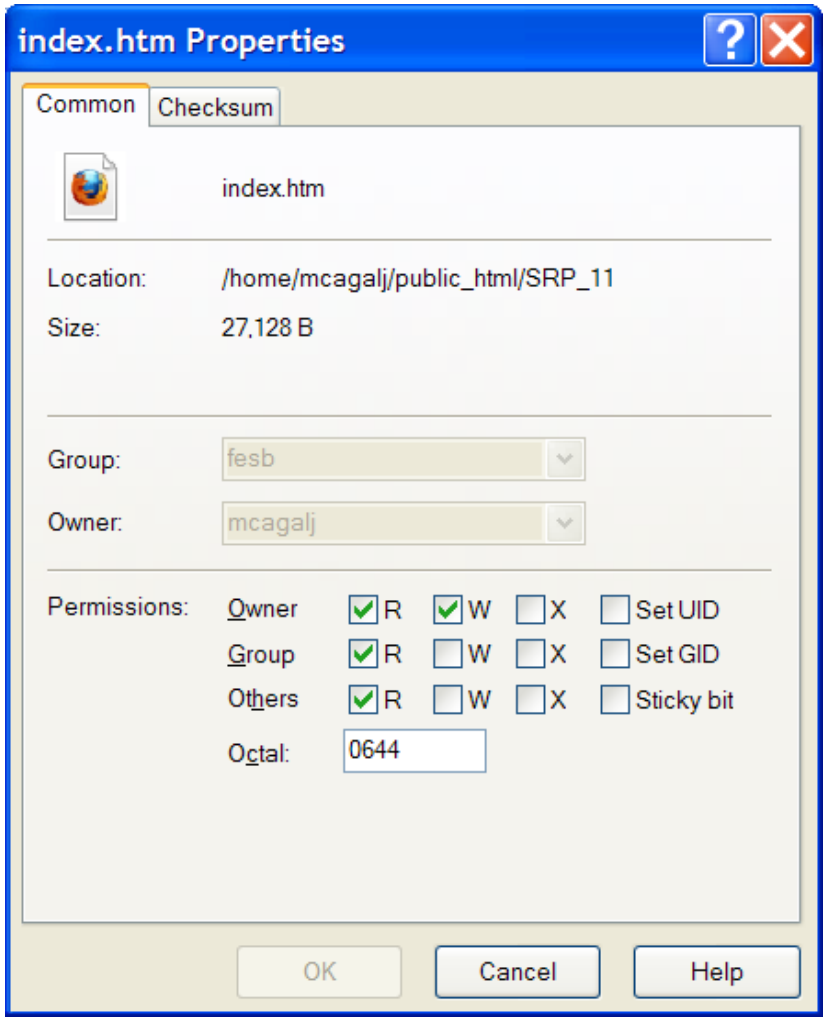
- In Computer Systems:
  - An individual user can set an access control mechanism to allow or deny access to an object.

- It relies on the object owner to control access.
- DAC is widely implemented in most operating systems.

Examples: Unix and Windows

Windows





Unix (WinSCP view)

Principles

- The Principles are **users** and **groups**.
- Users have username and **user identifier (UID)**.
- Groups have group name, **group identifier (GID)**.

- UID and GID are usually 16-bit numbers:
  - 0: root.
  - 1 – 99: predefined accounts.
  - 100 – 999: reserved for administrative and system accounts/groups.

- Both names and identifiers are permanent:
  - UID values often differ from system to system.

Superuser

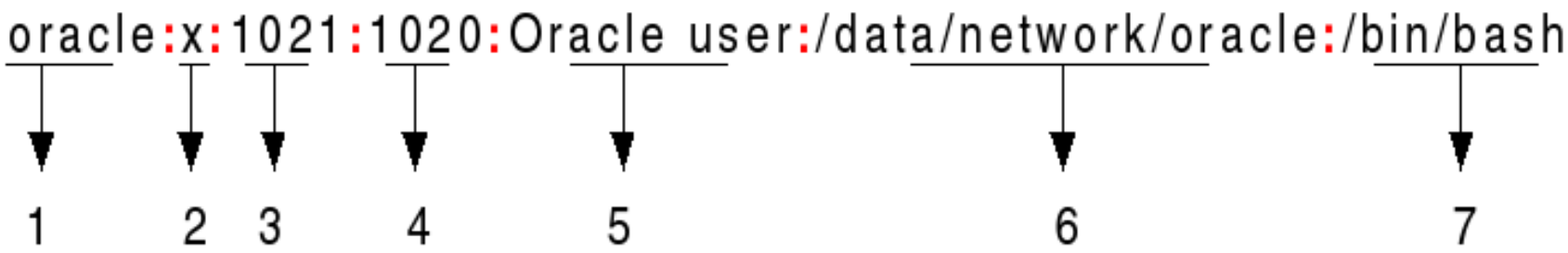
- The superuser is a special privileged principal with **UID zero** and usually the user name **root**.

- There are few restrictions on the superuser:
  - All security checks are not turned off for the superuser.
  - The superuser can become any other user.

- Examples:
  - Execute non-executable script.
  - The superuser cannot get passwords in plaintext, but can reset them.

User Accounts 1/2

- User accounts are stored in ***/etc/passwd***.
- User account format:
  - Username:password:UID:GID:name:homedir:shell



User Accounts 2/2

1. **Username**: It is used when user logs in. It should be between 1 and 32 characters in length.
2. **Password**: An x character indicates that the password is stored in ***/etc/shadow*** file.
3. **User ID (UID)**: Each user must be assigned a user ID (UID).
4. **Group ID (GID)**: The primary group ID (stored in /etc/group file)
5. **User ID Info**: The comment field. It allow you to add extra information about the users such as user's full name, phone number etc.
6. **Home directory**: The absolute path to the directory the user will be in when they log in. If this directory does not exist, then users directory becomes /.
7. **Command/shell**: The absolute path of a command or shell (/bin/bash). Typically, this is a shell. Please note that it does not have to be a shell.

The Shadow File

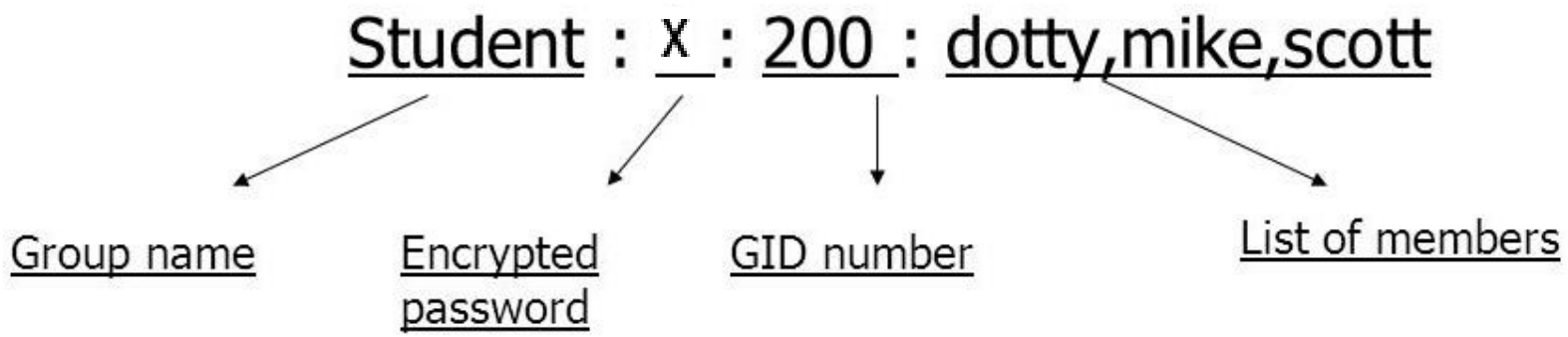
- Most modern Linux distributions use the **/etc/shadow** file to store encrypted password data.
- The **/etc/shadow** file is typically not readable by ordinary users.
  - The file is only accessible by root.

- Passwords are stored using a **hash** (a one-way type of scrambling).
- Here is how an entry in the **/etc/shadow** file looks like:

```
vivek:$1$fnfffc$pGteyHdicpGOfffXX4ow#5:13064:0:99999:7:::
```

Groups

- Users belong to one or more groups at the same time.
- The file ***/etc/group*** contains a list of all groups; entry format:
  - groupname:password:GID:list of users



- Every user belongs to a primary group; the group ID (GID) of the primary group is stored in /etc/passwd.
- Use the **`groups`** command to see your groups

Group Passwords

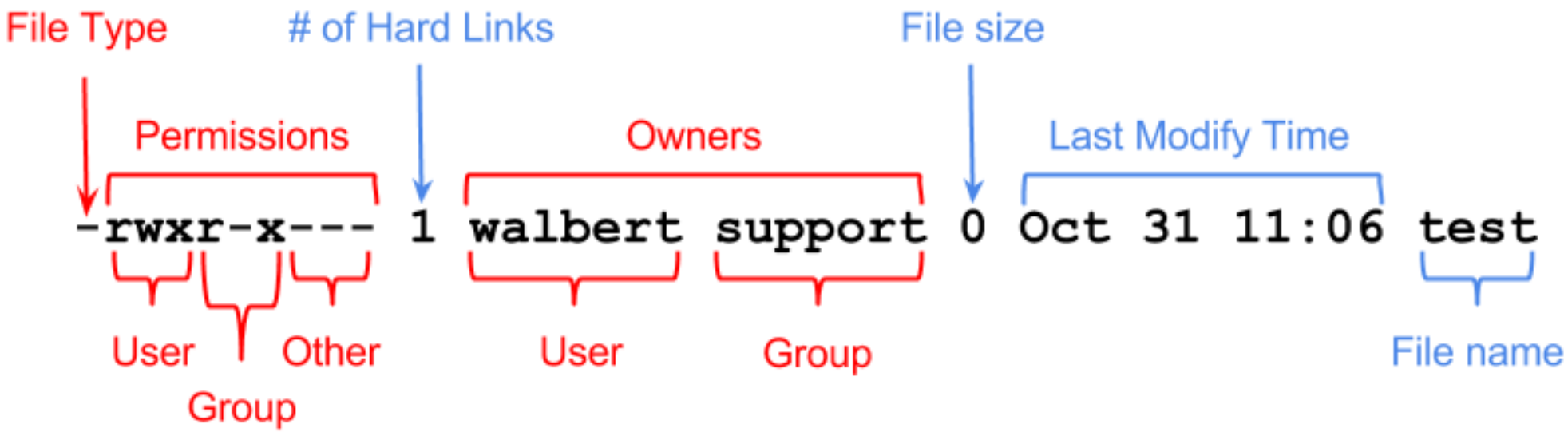
- Every group can have administrators, members and a password.
  - This can be managed with ***gpasswd*** (group passwords are in /etc/gshadow)

- Group passwords are an inherent security problem, since more than one person is permitted to know the password.
  - However, they can be useful in some contexts.

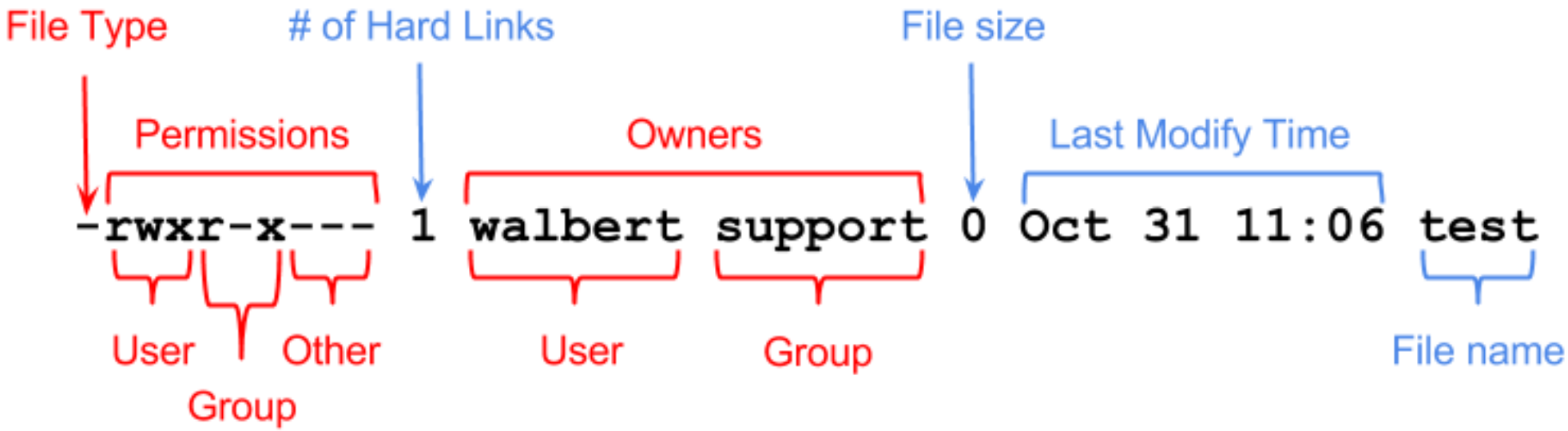
- The ***newgrp*** command
  - It is used to change the current real group ID (GID) to the specified group.
  - If the user is not root, they will be prompted for a group password if the user is not listed as a group member.
  - If there is NO group password set, and the user is not listed as a member of the group, the user will be denied access after asking them for a password.

Information about Files 1/2

- File type:
  - - file
  - d directory
  - b block device file
  - s socket
  - i symbolic link
  - p FIFO pipe
- File permissions: nine characters



Information about Files 2/2



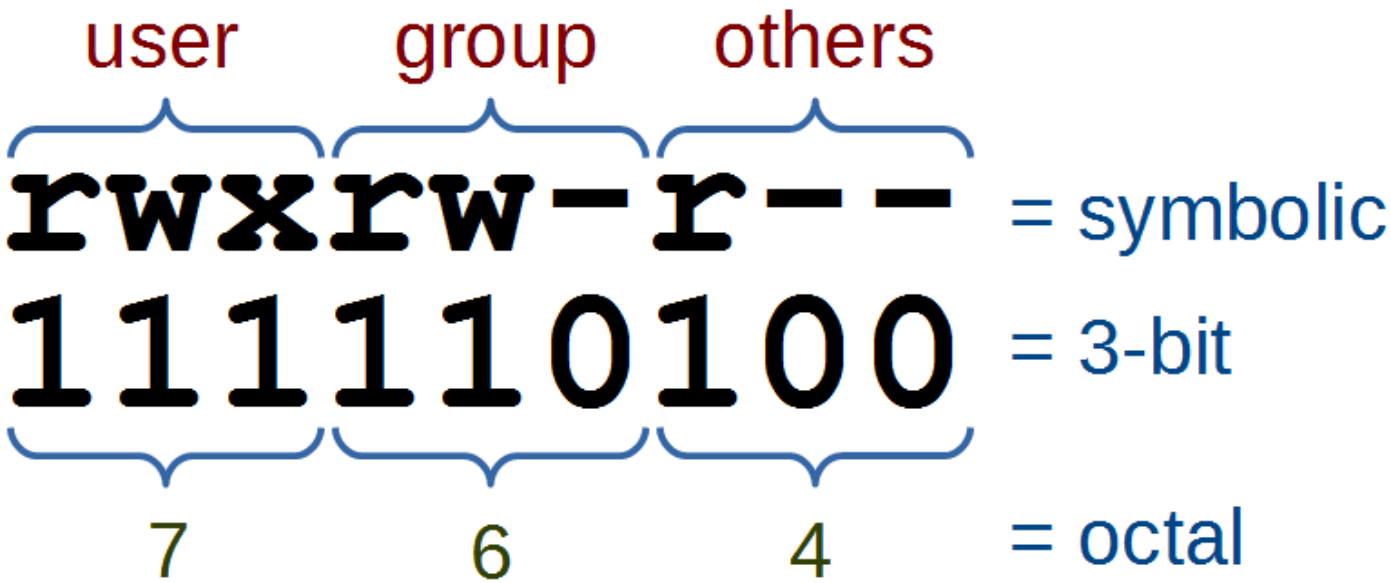
- Owners and root can change permissions.
- Only root can change the file owner and group.
- Owners can change the file group to one of its own group.

Permissions bits

- Permission bits are grouped in three triplets that define **read**, **write**, and **execute** for **owner**, **group** and **other**.
- Users:
  - Owner
  - Group
  - Other
- Operations:
  - Read: r
  - Write: w
  - Execute: x
- Permissions semantics are different between files and directories.

Octal Representation

- File permissions can also be specified as octal numbers.



Permissions Semantics

- Read:
  - File: to view the contents of the file.
  - Directory: to find which files are in the directory, e.g. for executing ls.

- Write:
  - File: to modify and delete the contents of the file.
  - Directory: to add and delete files.

- Execution:
  - File: to the run the file as a program.
  - Directory: to open files and make it the current directory (cd).

Access Control Decision

- Access control uses the effective UID/GID:
  - If the subject's UID owns the file, the permission bits for owner decide whether access is granted
  - If the subject's UID does not own the file but ones of its groups' GIDs does, the permission bits for group decide whether access is granted
  - If the subject's UID and no GID do not own the file, the permission bits for other (also called world) decide whether access is granted

- Note that the owner can always change the permissions.

Unix Access Control -- Discussions

- Unix permissions have been standardized by IEEE as part of the POSIX standards.
  - Fairly universal across Unix systems.
- Advantages:
  - Relatively simple and widely understood.
  - Relatively easy to check the protection state.
- Limitations:
  - Files have only one owner and one group.
  - Superuser needed for maintaining groups.
  - Complex policies, e.g. access several groups, are impractical to implement.
  - All access rights (e.g. shutdown) must be mapped to file access.

Umask

- Consider default behavior of file and directory creation
  - 666 & 777 respectively
  - To change this default behavior – use **umask**

- Defines the permissions to be masked while object is created
- Examples: umask 002
  - File creation: (666 – 002 = 664) = rw-rw-r--
  - Directory creation: (777 – 002 = 775) = rwxrwxr-x

Special Permissions

- Setgid: stands for SET Group ID.
  - Numerical value: 2000
  - Represented by an s in place of x, or S in place of - in the group permission.
  - Assigned to directories, makes all created files and directories belong to the group owning the setgid directory, instead of the GID.

- Sticky bit: meaningful when assigned to directories.
  - Numerical value: 1000
  - Represented by an t in place of x, or T in place of - in the other permission.
  - Prevents users from deleting each other’s file in a shared writeable directory.
  - Example: /tmp where any user can store files, but only owner of file has rights to modify or delete the file.

Extended ACL for Finer-Grain Control

- Extended ACLs provide:
  - Beyond simple user/group/other ownership.
  - Contain any number of named user & groups.
  - Contain mask entry.

- Utility/Library Functions
  - **getfacl**: check the current state of ACL on file/directory.
  - **setfacl**: modify/add ACL to additional user or group.
  - **chacl**: changes the ACL of file or directory.

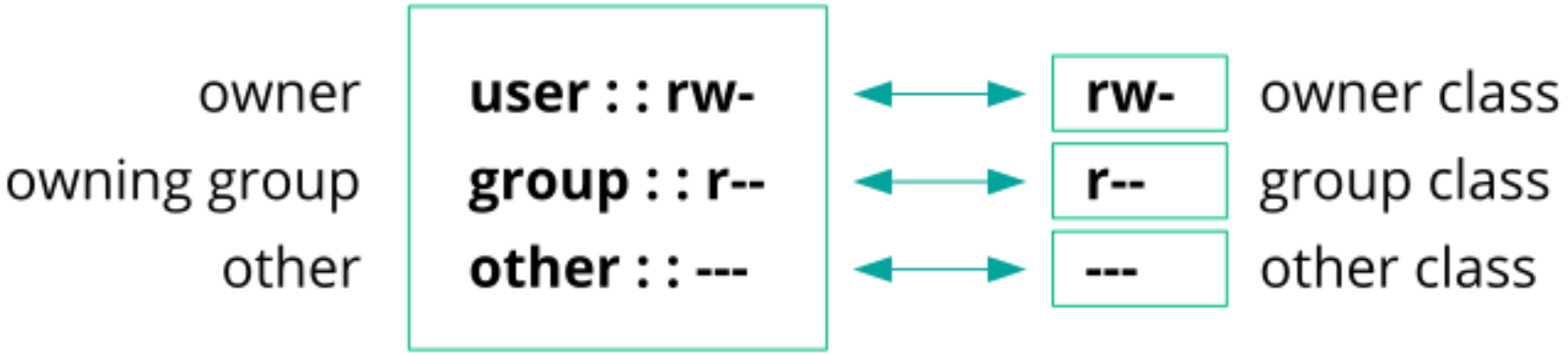
ACL Entry Types

Type	Text Form
Owner	user::rwx
Named user	user:name:rwx
Owning group	group::rwx
Named group	group:name:rwx
Mask	mask::rwx
Other	other::rwx

- The mask entry
  - Limits the permissions granted by named user, group and named group.
  - Permissions contained only in the mask or only in the actual entry are not effective.

Classes of ACLs

- Minimum ACL:
  - contains only the entries for the owner, the owning group and other, which correspond to the conventional permissions bits.
- Extended ACL
  - Contains several named user and group.



Example

user *heidi*, group *family* owns file with permissions:

```
user::rw-
user:skyler:rwx
group::rw-
group:child:r--
mask::rw-
other::r--
```

- *heidi* can read, write file (first line)
- *matt*, not in group *child*, can read file (last line)
- *skyler* can read, write file (second line masked by fifth line)
- *sage*, in group *family*, can read, write the file (third line masked by fifth line)
- *steven*, in group *child*, can read file (fourth line masked by fifth line)

Default ACL

- Directories can have a default ACL, which is a special kind of ACL defining the access permissions that objects in the directory inherit when they are created.

- Effects of a Default ACL
  - A file inherits the default ACL as its ACL.
  - A subdirectory inherits the default ACL of the parent directory both as its default ACL and as an ACL.

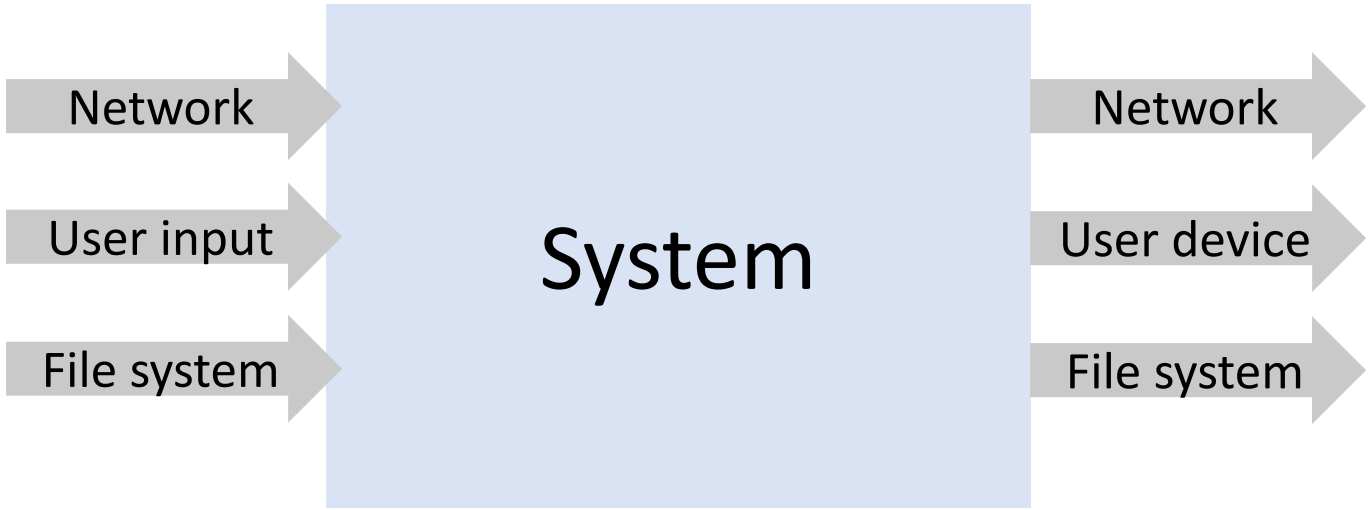
- The umask is disregarded in case default ACLs are used.

Principle of Least Privilege

A subject should be given only those privileges that it needs in order to complete its task.

- **Privilege**: ability to access or modify a resource.
- Each system component or process should have the least authority necessary to perform its duties.
- This helps reduce the "attack surface" of the computer by eliminating unnecessary privileges that can result in security exploits.

Monolithic Design



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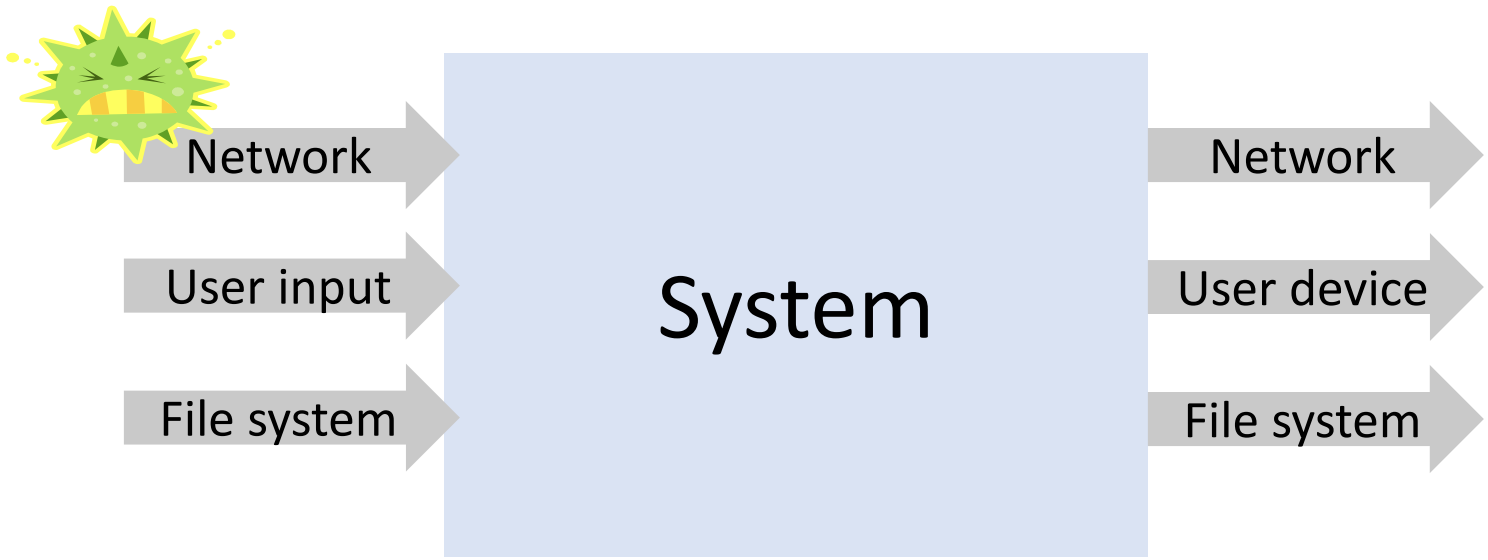
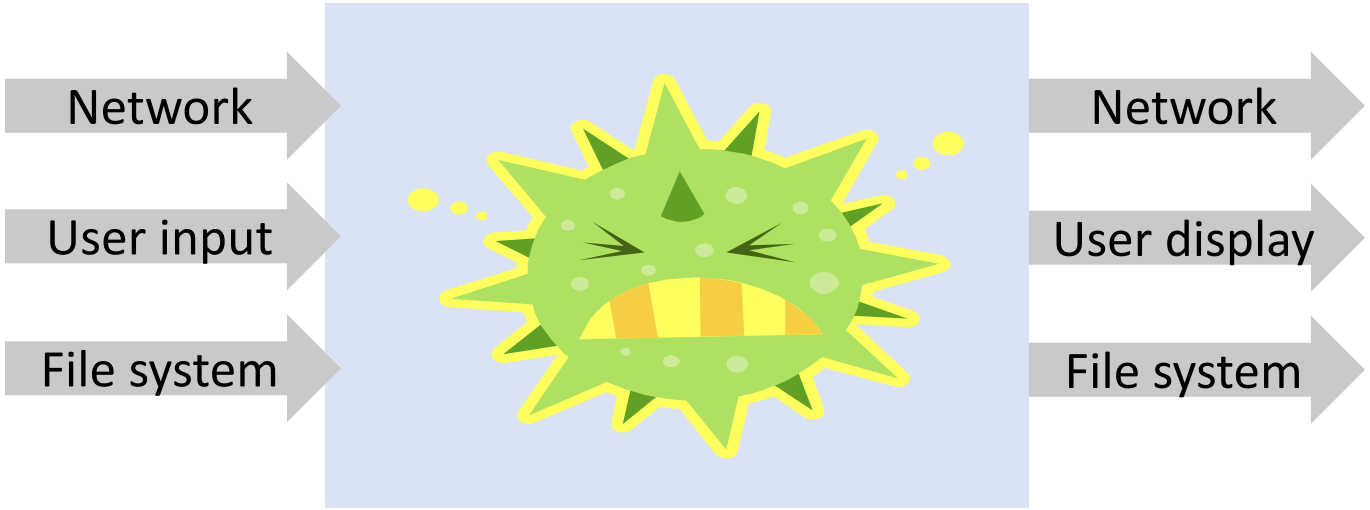
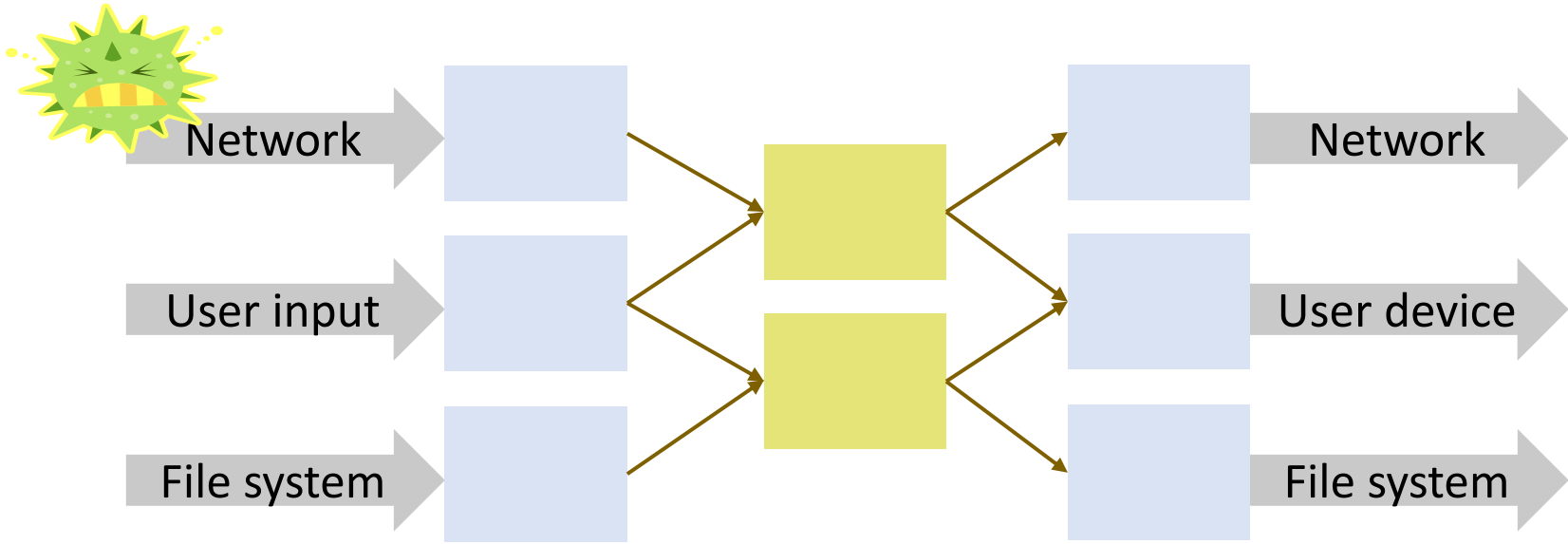


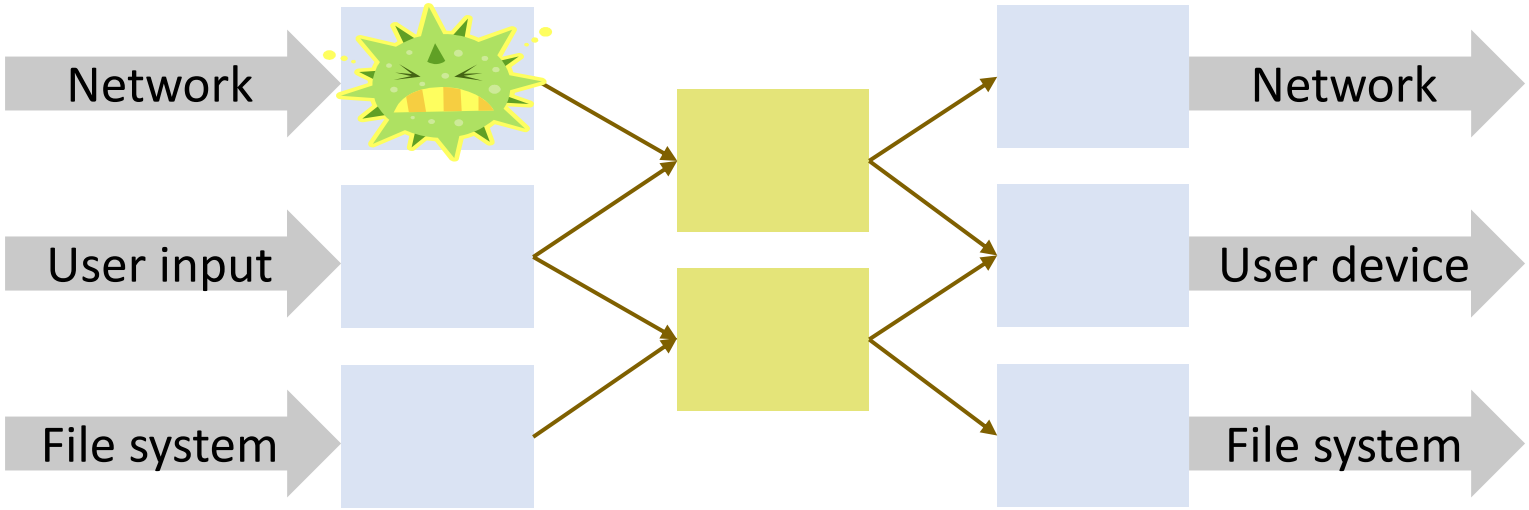
Monolithic Design



Component Design



Component Design



The Need of Superuser (The Unix Case)

- Users need to change their passwords.
  - Passwords are stored in the **/etc/shadow** file.
  - The permission of the file rw-r----- and its owned by root.

- Therefore, users need to be **root** to change their passwords.
  - Root, the superuser, has unlimited power.
  - Consequently, any user should have unlimited power to change their passwords.

The Need of Superuser (The Unix Case)

- Exercise: Noticing that you can change your password without root privilege in Linux, how does Unix solve this problem?

A Deputy to the Rescue

- A Deputy is a program that can be called by any user and performs a particular task requiring an escalated privilege.

- A user should be able to run programs on behalf of a different user.
  - Technical problem: when a user runs a program, the program gets its privilege by the UID/GID associated to the user.
  - Security impact: users must not be able to run arbitrary programs performing arbitrary tasks on behalf of any user, especially the root.

- Proposed Solution:
  - The root defines some programs runnable by other users.
  - These programs have the root privilege when they are called.

SUID and SGID Programs

- SUID programs run with the effective UID of the owner of the executable file.
- For a SUID program, the execute permission of the owner is given as **s** instead of **x**, and **S** instead of **-**.

- SGID programs run with the effective GID of the owner of the executable file.
- For a SGID program, the execute permission of the group is given **s** instead of **x**, and **S** instead of **-**.

SUID to root

- When root owns an executable file and the SUID bit is set, the process will get superuser status during execution.
- Important SUID programs:
  - /bin/passwd: change password.
  - /bin/su: change UID program.

- SUID programs need to be written very carefully so that their privileges cannot be misused and they only do what is intended.