# CSCI 476: Computer Security

Lecture 5: Set-UID and Environment Variables

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Spring 2023

# Announcements

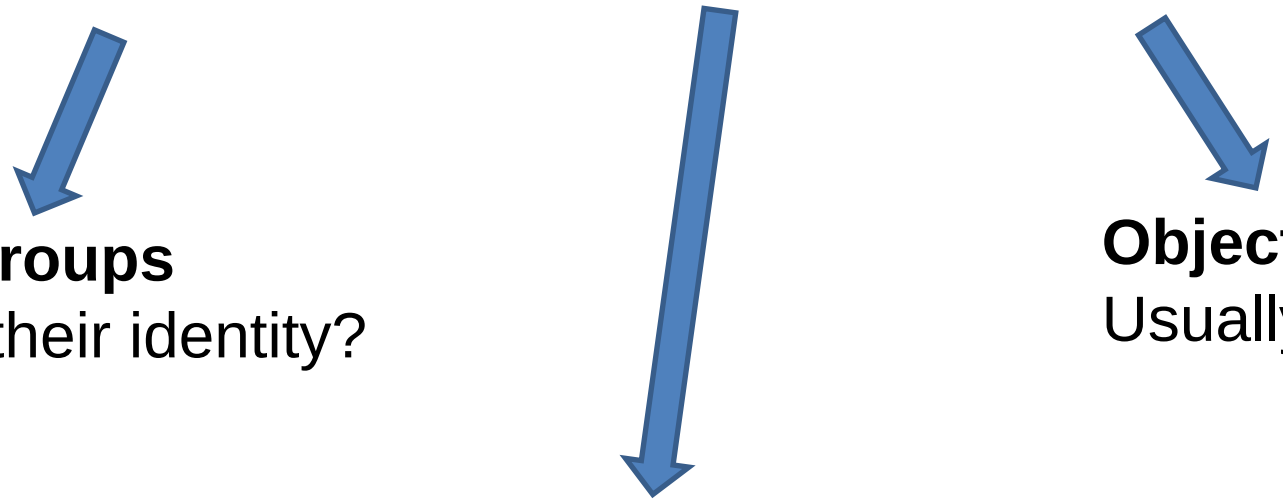
No in-person lecture on Wednesday
→ I will post a video to the course website

Lab 1 posted, due **Sunday** February 12th

How would you protect your computer and its resources?

# Access Control

**who** can do **what** to **whom?**



**users/groups**
what is their identity?

**Objects**
Usually things on a filesystem

**permissions (read/write/execute)**
Ok, I know the who– what are ***you*** permitted to do?

# **who** can do **what** to **whom?**

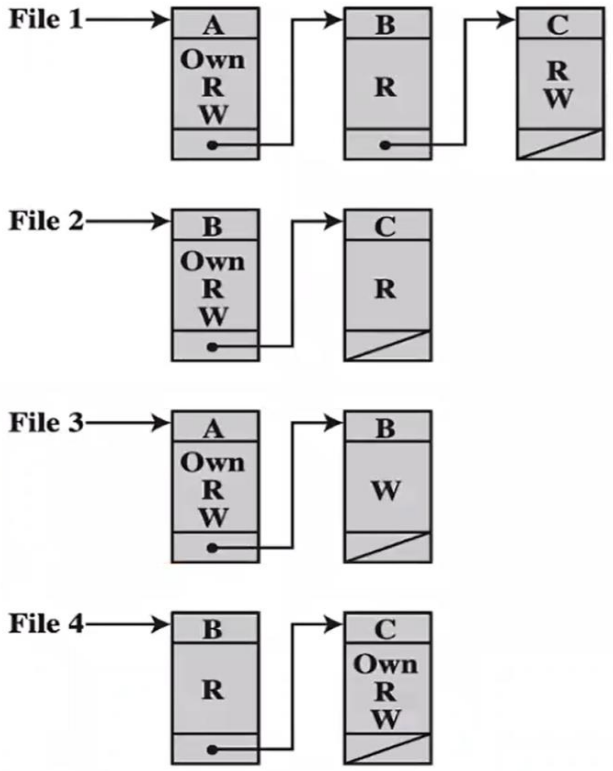
| | | OBJECTS | | | |
|---|---|---|---|---|---|
| | | File 1 | File 2 | File 3 | File 4 |
| SUBJECTS | User A | Own<br>Read<br>Write | | Own<br>Read<br>Write | |
| | User B | Read | Own<br>Read<br>Write | Write | Read |
| | User C | Read<br>Write | Read | | Own<br>Read<br>Write |

*Access Control Matrix*

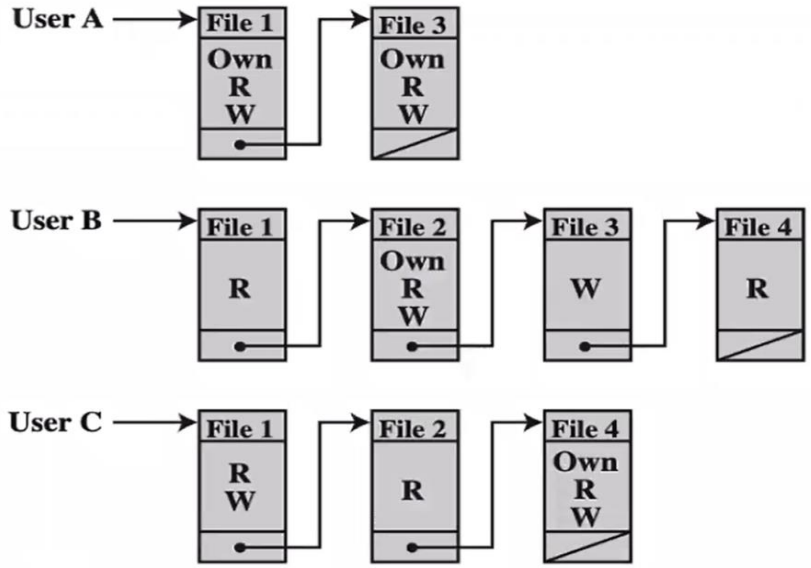
***What are some issues with this?***

# Access Control

**who** can do **what** to **whom?**




*Access Control list (ACL)*




Wont take up as much memory!

# Unix File Modes and Permissions

Every Unix file has a set of permissions that determine whether someone can read, write, or run the file

```
ls -l ~
ls -l /dev
```

```
[09/13/22]seed@VM:~$ ls -l ~
total 44
drwxr-xr-x 2 seed seed 4096 Nov 24  2020 Desktop
drwxr-xr-x 2 seed seed 4096 Nov 24  2020 Documents
drwxr-xr-x 2 seed seed 4096 Nov 24  2020 Downloads
drwxrwxr-x 2 seed seed 4096 Sep  1 14:37 lab0
drwxr-xr-x 2 seed seed 4096 Nov 24  2020 Music
drwxrwxr-x 2 seed seed 4096 Sep  6 15:23 os-review
drwxr-xr-x 2 seed seed 4096 Nov 24  2020 Pictures
drwxr-xr-x 2 seed seed 4096 Nov 24  2020 Public
drwxrwxr-x 2 seed seed 4096 Aug 25 13:41 shared
drwxr-xr-x 2 seed seed 4096 Nov 24  2020 Templates
drwxr-xr-x 2 seed seed 4096 Nov 24  2020 Videos
```

# Unix File Modes and Permissions

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```

Permissions for the file

# Unix File Modes and Permissions

Every Unix file has a set of permissions that determine whether someone can read, write, or run the file

```
ls -l ~
ls -l /dev
```

Owner/group information

Permissions for the file

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```

# Unix File Modes and Permissions

Every Unix file has a set of permissions that determine whether someone can read, write, or run the file

```
$ ls -l file
-rw-r--r-- owner group date/time file
```

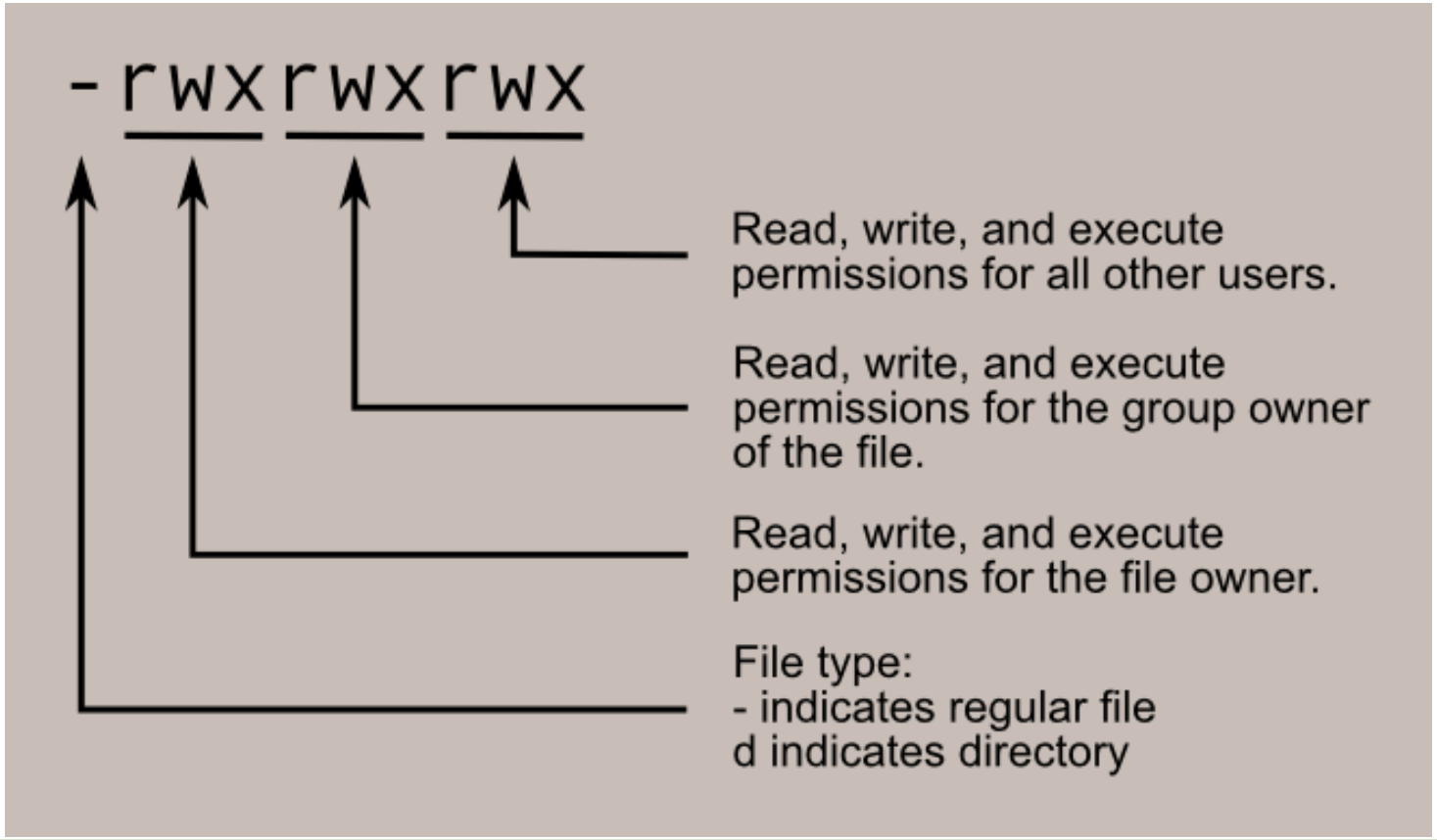
File permissions (4 parts)

- [file type][user][group][other]

# Unix File Modes and Permissions

File permissions (4 parts)

- [file type][user][group][other]



# Unix File Modes and Permissions

- [file type][user][group][other]

Suppose you have the following file:

```
$ ls -l F
-rw-rw-r--  B  G  ...  F
```

If user **A** asks to perform some operation **O** on a file object **F**, the OS checks:

- Is **A** the owner of **F**?

# Unix File Modes and Permissions

- [file type][user][group][other]

Suppose you have the following file:


If user **A** asks to perform some operation **O** on a file object **F**, the OS checks:

- Is **A** the owner of **F**?

  No, B is the owner

# Unix File Modes and Permissions

- [file type][user][group][other]

Suppose you have the following file:

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If user **A** asks to perform some operation **O** on a file object **F**, the OS checks:

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- [file type][user][group][other]

Suppose you have the following file:


If user **A** asks to perform some operation **O** on a file object **F**, the OS checks:

- Is **A** the owner of **F**?
- Is **A** a member of **F**'s group? Suppose G = {B,C,F}

  A is not in F's group

# Unix File Modes and Permissions

- [file type][user][group][other]

Suppose you have the following file:

```
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If user **A** asks to perform some operation **O** on a file object **F**, the OS checks:

- Is **A** the owner of **F**?
- Is **A** a member of **F**'s group?
- Otherwise, what can they do?

# Unix File Modes and Permissions

- [file type][user][group][other]

Suppose you have the following file:


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- Is **A** the owner of **F**?
- Is **A** a member of **F**'s group?
- Otherwise, what can they do?

Everyone can **read** file F

# Unix File Modes and Permissions

- [file type][user][group][other]

Suppose **user C** asks to **execute** a **file object F2**. Will they be able to do so?

```
$ ls -l F
-rwxrwxrwx   B H   ...   F1
-rwxr-xr--   D G   ...   F2
-rw-r-----   D H   ...   F3
-rw-rw-rw-   B G   ...   F4
```

Note:

- Group = G = {A, C, K, M, Q, Z}
- Group = H = {A, B, C, Q}

# Unix File Modes and Permissions

- [file type][user][group][other]

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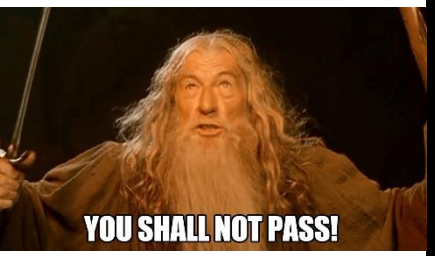
Changing password!




```
[seed@VM][~]$ ls -al /etc/passwd
-rw-r--r-- 1 root root 2886 Nov 24 09:12 /etc/passwd

[seed@VM][~]$ ls -al /etc/shadow
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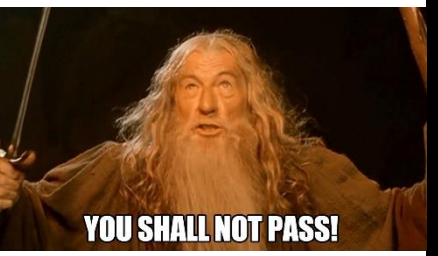


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**`/etc/passwd`** and **`/etc/shadow`** hold encrypted passwords for the user, in order to change our password, we will need to have access to those directories

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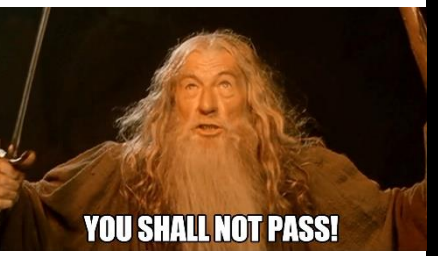


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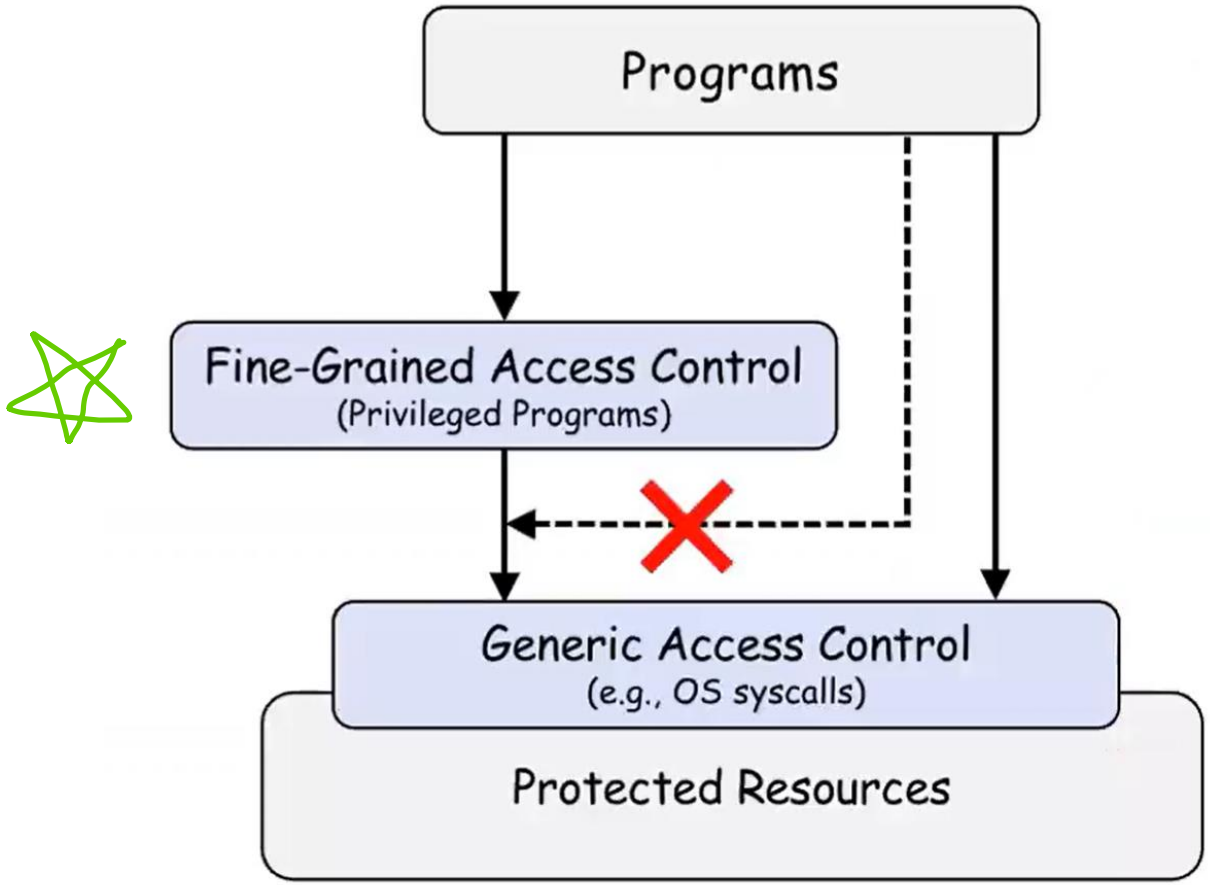
**`/etc/passwd`** and **`/etc/shadow`** hold encrypted passwords for the user, in order to change our password, we will need to have access to those directories

*root (aka admin) is the only person that has write permissions!*

# Limitations of File-Based Access Control

Instead of having a user deal with sensitive actions, lets have a privileged program do it for us!



# Types of Privileged Programs

- **Daemons**
  - Computer program that runs in the background
  - Needs to run as root or other privileged users

- **Set-UID Programs**
  - Widely used in UNIX systems
  - A normal program… but marked with a special bit

# The superman story

Superman got tired of saving the city every day

So, he decided to create a “super suit” that would give normal people his powers

**Problem:** Not all super people are good……

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## Super suit 2.0

Super suit with a dope computer
Programmed to perform a specific task
No way to deviate from the pre-programmed task

# The superman story


Task: Stop Bowser

1. Fly North
2. Turn left and move forward
3. Punch

Super suit 2.0

People can hop in, and do the specific task to stop bowser

# The superman story


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**Exploitable?**

# The superman story


Task: Stop Bowser

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Suppose I come along,
and I see the power suit

And I decide to flip the suit around

Now what happens???

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Suppose I come along,
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And I decide to flip the suit around

**I still followed the steps, but now we have a totally different outcome**

My plan was to rob the bank, and I had friends waiting this whole time!

# Set-UID In a Nutshell

**Set-UID** allows a user to run a program with the program owner's privilege

- User runs a program w/ temporarily elevated privileges

Created to deal with inflexibilities of UNIX access control

Example: The **`passwd`** program

```
[seed@VM][~]$ ls -al /usr/bin/passwd
-rwsr-xr-x 1 root root 68208 May 28  2020 /usr/bin/passwd
```

# Set-UID In a Nutshell

**Set-UID** allows a user to run a program with the program owner's privilege
- User runs a program w/ temporarily elevated privileges

Every process has two User IDs
- Real UID (RUID)– Identifies the **owner** of the process
- Effective UID (EUID)– Identifies **current privilege** of the process

When a normal program is executed
- RUID == EUID

When a Set-UID program is executed
- RUID != EUID
- EUID == ID of the program's owner

**If a program owner == root,**
**The program runs with root privileges**

# Set-UID Program Demo

```
[seed@VM][~]$ cp /bin/cat ./mycat
[seed@VM][~]$ sudo chown root mycat
[seed@VM][~]$ ls -al mycat
-rwxr-xr-x 1 root seed 43416 Jan 25 21:15 mycat
```

**Change the owner** of a file to root

# Set-UID Program Demo

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**Change the owner** of a file to root

```
[seed@VM][~]$ mycat /etc/shadow
mycat: /etc/shadow: Permission denied
```

Running to program (normally)

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**Change the owner** of a file to root

```
[seed@VM][~]$ mycat /etc/shadow
mycat: /etc/shadow: Permission denied
```

Running to program (normally)

```
[seed@VM][~]$ sudo chmod 4755 mycat
[seed@VM][~]$ ls -al mycat
-rwsr-xr-x 1 root seed 43416 Jan 25 21:15 mycat
[seed@VM][~]$ mycat /etc/shadow
root:!:18590:0:99999:7:::
daemon:*:18474:0:99999:7:::
```

**Enable the Set-UID bit**

We have successfully made a Set-UID program!

A Set-UID program is just like any other program, except that is has a *special* bit set

```
[09/15/22]seed@VM:~/lab2$ cp /usr/bin/id ./myid
[09/15/22]seed@VM:~/lab2$ chown root myid
chown: changing ownership of 'myid': Operation not permitted
[09/15/22]seed@VM:~/lab2$ sudo chown root myid
[09/15/22]seed@VM:~/lab2$ /myid
bash: /myid: No such file or directory
[09/15/22]seed@VM:~/lab2$ ./myid
uid=1000(seed) gid=1000(seed) groups=1000(seed),4(adm),24(cdrom),27(sudo),30(dip
),46(plugdev),120(lpadmin),131(lxd),132(sambashare),136(docker)
```

Steps for creating a set-uid program

1. Change file ownership to root (`chown`)
2. Enable to Set-uid bit (`chmod`)

*If the set-uidbit is enabled, the EUID is set according to the file owner*

```
[09/15/22]seed@VM:~/lab2$ chmod 4755 myid
chmod: changing permissions of 'myid': Operation not permitted
[09/15/22]seed@VM:~/lab2$ sudo chmod 4755 myid
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(sudo),30(dip),46(plugdev),120(lpadmin),131(lxd),132(sambashare),136(docker)
```

| | |
|---|---|
| 4755 | 4 = setuid bit<br>755 = owner r/w/x, group/others can r/w |

Access control decisions made based on EUID, not RUID !

# So…. Is Set-UID secure?

Allows normal users to escalate privileges

➢ This is different from directly giving escalated privileges (such as **sudo**)

➢ Restricted behavior (think **power suit 2.0**)

Are there any programs that **should not** be Set-UID programs?

# So…. Is Set-UID secure?

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Are there any programs that **should not** be Set-UID programs?

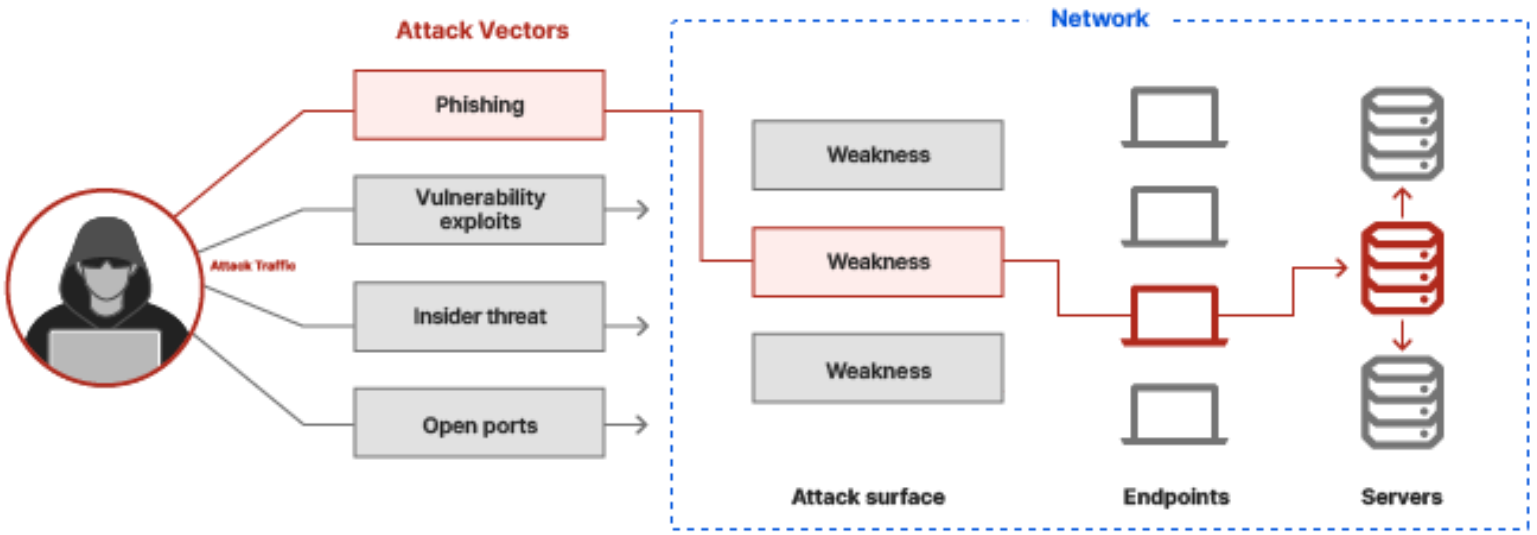
/bin/sh

"root shell"

```
[09/15/22]seed@VM:~/lab2$ sudo /bin/sh
# cat /etc/shadow
root:!:18590:0:99999:7:::
daemon:*:18474:0:99999:7:::
bin:*:18474:0:99999:7:::
sys:*:18474:0:99999:7:::
```

# Attack Surface of (Set-UID) Programs

An **attack surface** is the aggregation of all exposed entry points/weaknesses into the system to gain unauthorized access



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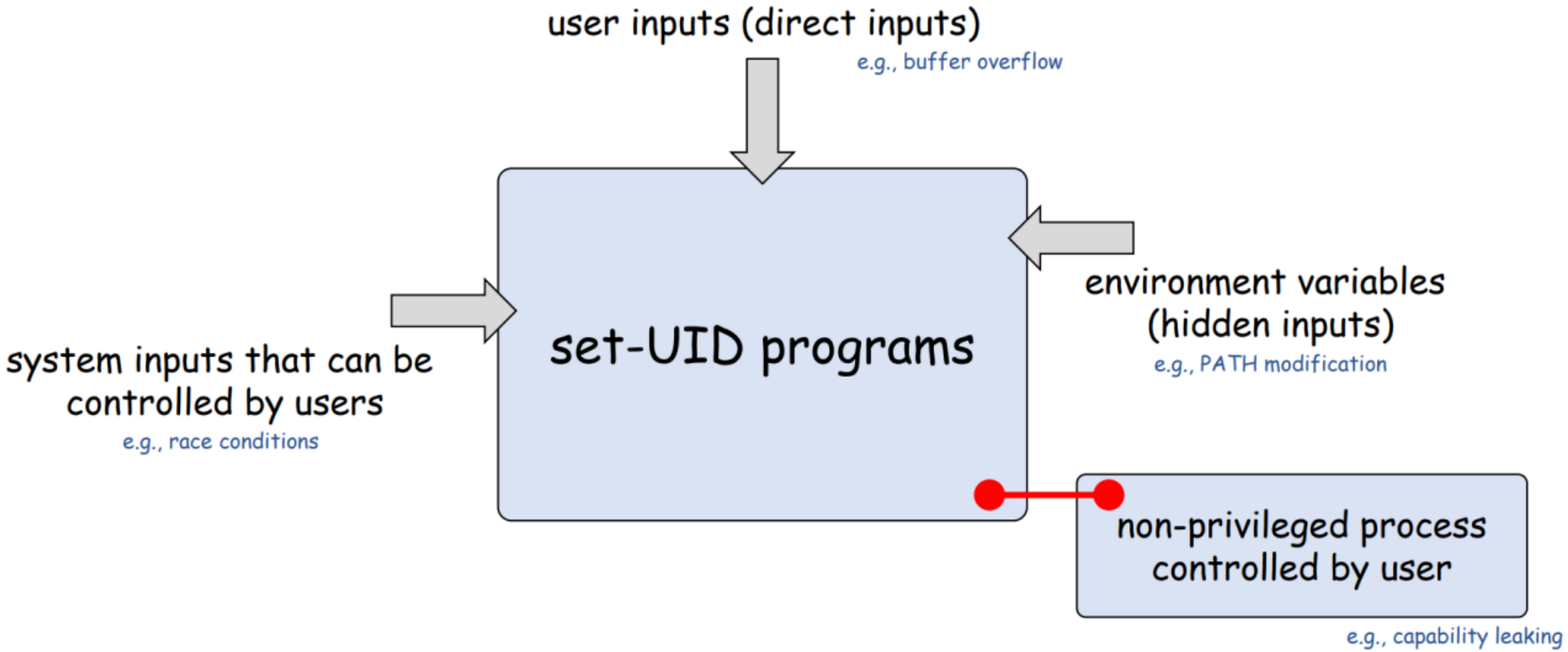

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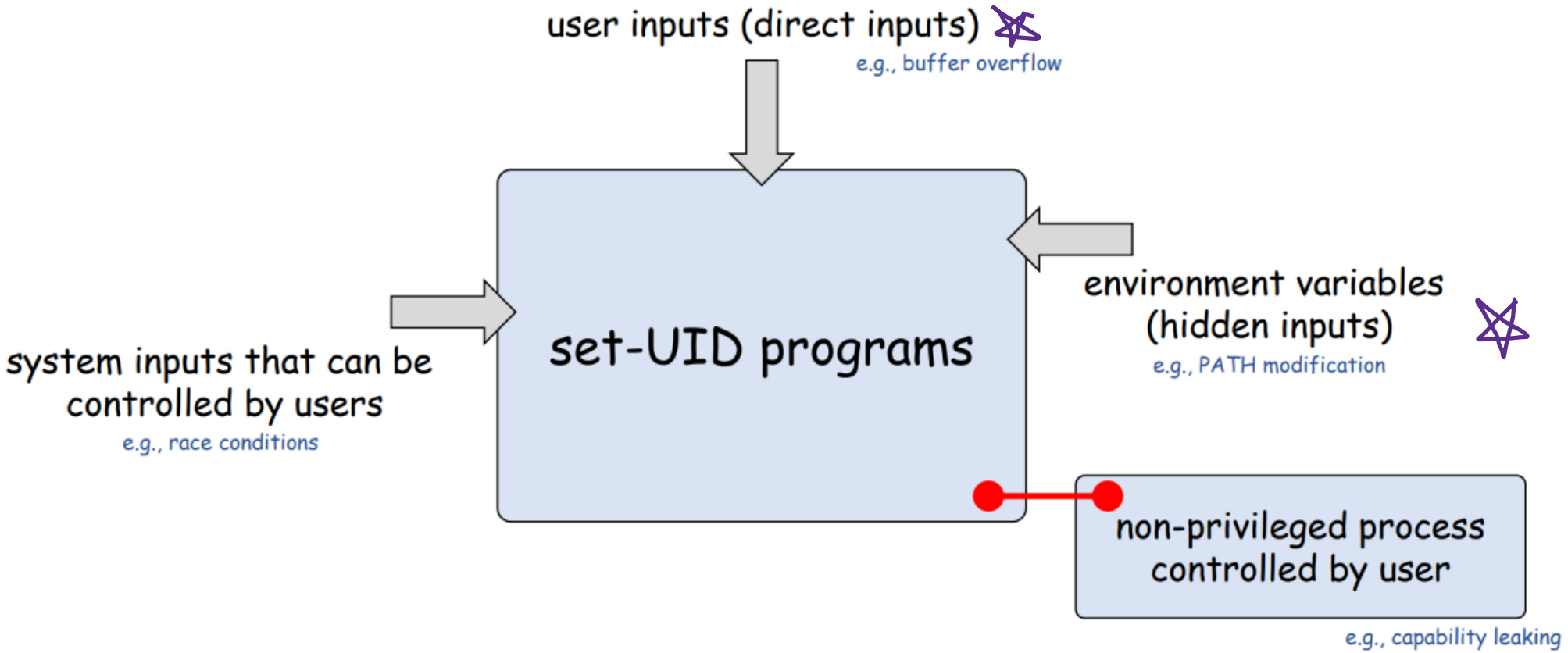

# Invoking Programs from within programs

# Before we get started….

We need to disable a countermeasure on our OS, and set our shell (`/bin/sh`) to be an unsafe version

```
[seed@VM][~]$ sudo ln -sf /bin/zsh /bin/sh   # set shell to zsh (no countermeasure)
[seed@VM][~]$ sudo ln -sf /bin/dash /bin/sh  # set shell to dash (has countermeasure)
```


`/bin/sh` is an alias for `/bin/dash`. `/bin/dash` has countermeasures for some of our attacks

# Invoking a program with a program

We can invoke external commands/programs from INSIDE another program

- `system()`
- `exec()-family`

# System()

usage: **system**(*command*)

- Spawns a new process that executes the shell command that is specified in *command*

```
#include <stdlib.h>
#include <stdio.h>

int main()
{
    printf("I am going to start the calculator program! \n");
    system("/bin/bc");
}
```

# `audit` Set UID program

- Suppose you are preparing for an audit. An auditor may need the access to view certain files.
- Instead of giving them total access to everything on the system, we will create a privileged program that will the auditor view the content of some file

Set-UID program name

Name of file the auditor will view

```
./audit company_data.csv

./audit ../lab0/solution.docx
```

# catall.c

```c
#include <string.h>
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>

int main(int argc, char *argv[])
{
    char *v[3];

    if (argc < 2) {
        printf("Audit! Please type a file name.\n");
        return 1;
    }

    v[0] = "/bin/cat"; v[1] = argv[1]; v[2] = 0;
    char *command = malloc(strlen(v[0]) + strlen(v[1]) + 2);
    sprintf(command, "%s %s", v[0], v[1]);

    /*
     * Use only one of the following (comment out the other):
     */

    system(command);
    //execve(v[0], v, 0);

    return 0;
}
```

The command line argument (file path) is appended to the string "/bin/cat"

*Spawns a new process that executes:*

`/bin/cat [FILE_PATH]`

ex. `/bin/cat my_file.txt`

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```
./audit company_data.csv  ➡ /bin/cat company_data.csv

./audit ../lab0/solution.docx
                                  ↘
                                    /bin/cat ../lab0/solution.docx
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```

↘

```
/bin/cat ../lab0/solution.docx
```

**!!!** We have some control over the behavior of this program

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Program Input: `./audit company_data.csv`

Command Executed `/bin/cat company_data.csv`

Because this is a SET-UID program, things can get *very interesting*

```c
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    v[0] = "/bin/cat"; v[1] = argv[1]; v[2] = 0;
    char *command = malloc(strlen(v[0]) + strlen(v[1]) + 2);
    sprintf(command, "%s %s", v[0], v[1]);

    /*
     * Use only one of the following (comment out the other):
     */

    system(command);
    //execve(v[0], v, 0);

    return 0;
}
```

`system()` is a **very unsafe** function

We can exploit this by maliciously constructing the input to this program

Hint: the string passed to `system()` can include *multiple* commands

```c
#include <string.h>
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>

int main(int argc, char *argv[])
{
    char *v[3];

    if (argc < 2) {
        printf("Audit! Please type a file name.\n");
        return 1;
    }

    v[0] = "/bin/cat"; v[1] = argv[1]; v[2] = 0;
    char *command = malloc(strlen(v[0]) + strlen(v[1]) + 2);
    sprintf(command, "%s %s", v[0], v[1]);

    /*
     * Use only one of the following (comment out the other):
     */

    system(command);
    //execve(v[0], v, 0);

    return 0;
}
```

`system()` is a **very unsafe** function

We can exploit this by maliciously constructing the input to this program

Hint: the string passed to `system()` can include *multiple* commands

**`./audit "my_info.txt; /bin/sh"`**