Unix (and Linux) Security

- Identification and Authentication
- Access Control
- Other security related things:
  - Devices, mounting filesystems
  - Search path
  - Race conditions
- NOTE: filenames may differ between OS/distributions

Users

- Principals have unique UID
  - System cares about ID, not name
  - Several users can have different names but same ID. Then they are treated as the same.
- Superuser (root) has UID = 0
  - There is only one superuser
- Stored in /etc/passwd

- Processes are subjects.

UIDs for Processes

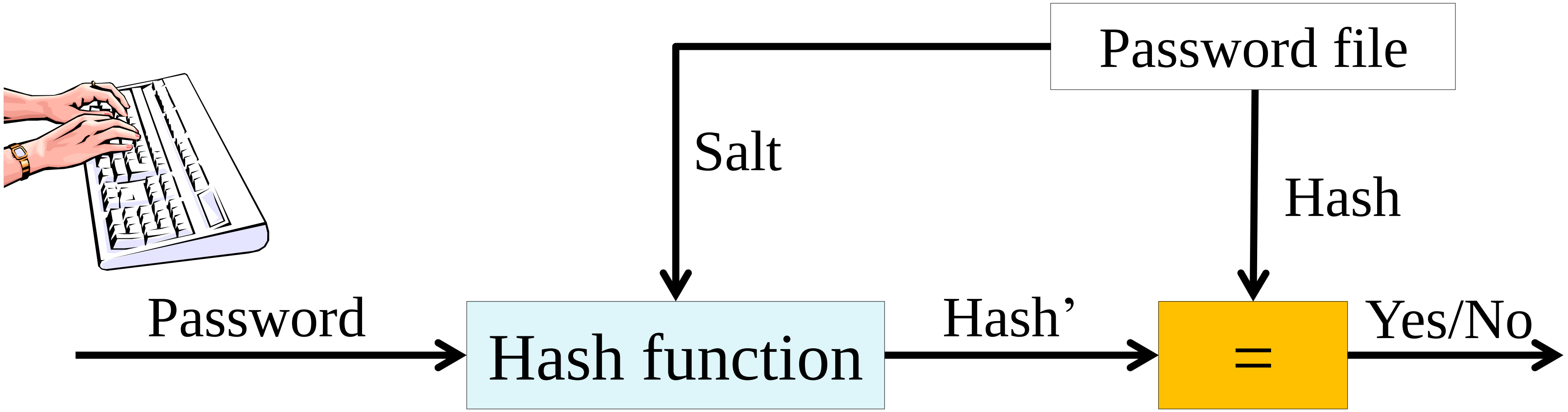
- Real user ID – The ID of the logged in principal
  - Can only be changed by root (effective user ID = 0) → this is how login works
- Effective user ID – The ID used for access control
  - Can be changed by root (effective user ID = 0) to anything
    - Used by processes with effective user ID = 0 when they temporarily access files as a less privileged user
  - Can be changed by anyone (any effective user ID) to real user ID
    - This process has to be able to get back to effective user ID = 0
- Same rules apply to group ID

Groups

- Can not associate multiple user IDs with one file
  - We have to put users in groups if we want several users to have access to the file
- Every user belongs to a primary group.
- Older Unix: Can only be in one group at a time
- Newer Unix and Linux: Can be in several groups at the same time
  - New files are associated with current group ID of user
  - Process group ID is the current group ID of user running the process
- Change group (newgrp)
- Primary group given in /etc/passwd
- Other groups in /etc/group
  - A group can not belong to a group

```
users:x:100:
Students:x:1000:alice,bob
```

Authentication



- Salt is always used
- Hash function and salt will depend on OS
- We look at three variants

Traditional crypt (Password Hashing)

- Design dates back to 1976
- Based on DES
- Password up to 8 characters, salt 12 bits
  - Take least significant 7 bits → 56 bit key
  - Encrypt zero string 25 times with DES
  - If bit i = 1 in salt, swap bits i and i + 24 in E-box output
  - Output 12 + 64 = 76 bits. Encode to 13 characters.

- Problems: Short passwords, short salts, constant cost (and fast function)

Other Alternatives – MD5 crypt

- MD5 crypt
  - Developed for FreeBSD to avoid export restrictions and allow longer passwords (up to 2^{64} bits)
  - Algorithm uses 1000 iterations → slow
  - Salt 12-48 bits
  - Output: 1 'salt' $ 128 bit hash output

- Problem: Constant cost

Other Alternatives – bcrypt

- Based on block cipher blowfish
- Password up to 72 characters, 128 bit random salt
- Internal loop with variable cost
- Output $2a$cost$salt + 192 bit hash output
- Default in OpenBSD
- All problems solved

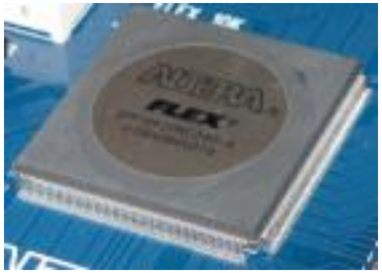
Comparison

	DES crypt	MD5 crypt	bcrypt
Password length	max 8 chars	virtually any	max 72 chars
Salt length	12 bits	12-48 bits	128 bits
Variable cost	No	No	Yes
Eval/sec	8 000 000	140 000	500

- Eval/sec based on 3.4 GHz processor with 4 cores, approximate values given
- The given performance for bcrypt is for a cost of 8

Final words on our password discussion

- ”All problems solved” is kind of bullshit
- Some devices can be really fast to a low cost
  - With enough money they are really really really fast
  - Several instances can be implemented in parallel
- Can no longer compare
  - CPU – ”needed” when verifying password
  - GPU, FPGA, ASIC – used by attackers



FPGA/ASIC

GPU

- Make this more fair by making hashing more difficult (costly) for GPUs, FPGAs and ASICs

- **Example**: scrypt – requires *memory* as well as CPU cycles

The File /etc/passwd

- Store user (principal) information

Format:

```
Username:password:UID:GID:ID string:home directory:login shell
```

- File is world readable
- Example:

```
alice:x:1004:100:Alice:/home/alice:/bin/bash
bob:x:1005:100:Bob:/home/bob:/bin/bash
```

The File /etc/shadow

- Save passwords in a non-world readable file
  - Username
  - (hashed) password
  - Date of last change (days since Jan 1, 1970)
  - Minimum days between password changes (0 means anytime)
  - Maximum days of validity
  - Days in advance to warn user about change
  - Days account is active after password expired
  - Date of account disabling (days since Jan 1, 1970)
  - Last entry is reserved

```
alice:9SuDfhDz3l12U:13920:30:180:7:2:14609:
bob:IBDXWbkBirMfU:13920:0:99999:7:::
```

Access Control

- Discretionary access control – owner of file can change permissions
- Three categories: User (owner), Group, Other (world)
- Three access rights: Read, Write, Execute

```
alice@home:>ls -l
totalt 8
drwxr-xr-x 2 alice Students 48 2008-02-13 16:36 directory
-rw-rw-r-- 1 alice Students 22 2008-02-13 16:37 file1
-rw-r--r-- 1 alice Students  9 2008-02-13 16:37 file2
```

<u>Other info from ls -l</u>

Link counter, owner, group, size, date of last change, name

Order of Checking

1. Owner
2. Group
3. Other

Consequence:

if owner = r and other = rw then owner has no write permission

```
alice@home:>ls -l
totalt 0
-r--rw-rw- 1 alice Students 0 2008-02-13 16:52 file
alice@home:>echo hello > file
bash: file: Åtkomst nekas
```

```
bob@home:>ls -l
totalt 0
-r--rw-rw- 1 alice Students 0 2008-02-13 16:52 file
bob@home:>echo hello > file
bob@home:>
```

Permissions For Directories

- Read = list the directory
- Write = Delete, rename and insert files in directory
- Execute = access directory and access files in directory

```
alice@home:>ls -la
totalt 0
dr-xr-xr-x 2 alice Students  72 2008-02-14 05:19 .
drwxr-xr-x 8 alice Students 384 2008-02-14 05:19 ..
-rw-rw-rw- 1 alice Students   0 2008-02-14 05:19 file
alice@home:>rm file
rm: kan inte ta bort "file": Åtkomst nekas
```

```
alice@home:>ls -la
totalt 0
drwxr-xr-x 2 alice Students  72 2008-02-14 05:26 .
drwxr-xr-x 8 alice Students 384 2008-02-14 05:19 ..
-rw-r--r-- 1 root  root       0 2008-02-14 05:26 file
alice@home:>rm -f file
alice@home:>
```

Change Permissions – chmod

- Used to change permissions on files
- Mnemonics can be used: user, group, other, all, read write execute.
- Examples:

  chmod u+rw file

  chmod u=r file

  chmod a+rwx file

  chmod u-w,g+r,o+r file

  chmod a-rwx,u+r file1 file2

Change Permissions – chmod

- Alternatively, numbers can be used.
- See each group of permissions as one number.
  - Read = 4
  - Write = 2
  - Execute = 1

Sum gives permission

- Example:

  chmod 754 file

Read permission for others
Read and execute for group
Read, write and execute for user

```
alice@home:>chmod 754 file; ls -l file
-rwxr-xr-- 1 alice Students 46 2008-02-13 12:02 file
```

Setuid and Setgid (programs)

- Controlled invocation
- Effective ID of process is ID of program owner (usually root)
  - Here is the situation when RUID ≠ EUID
- Used to temporarily change access rights
- *x* is replaced by *s*

```
alice@home:>ls -l
totalt 16
-rwxr-sr-x 1 root root 6378 2008-02-13 15:16 prog_setgid
-rwsr-xr-x 1 root root 6378 2008-02-13 14:58 prog_setuid
alice@home:>./prog_setuid &
[1] 12189
alice@home:>./prog_setgid &
[2] 12190
alice@home:>ps -C prog_setgid,prog_setuid -o pid,ruser,euser,rgroup,egroup,args
  PID RUSER    EUSER    RGROUP   EGROUP   COMMAND
12189 alice    root     Students Students ./prog_setuid
12190 alice    alice    Students root     ./prog_setgid
```

Setuid and Setgid (Directories)

- Setuid on directory usually ignored
- Setgid on directory causes new files to get the same group as directory

```
alice@home:>ls -l
totalt 0
drwxr-s--- 2 alice root 48 2008-02-13 15:37 directory
alice@home:>cd directory; touch file; ls -l
totalt 0
-rw-r----- 1 alice root 0 2008-02-13 15:37 file
```

Without setgid, file would get the group which is current group ID for user (set by newgrp and defaults to primary group).

<u>Allows users to share files more easily</u>

Important SUID Programs

- **/usr/bin/passwd** change password
- **/usr/bin/at** batch job submission
- **/bin/su** change UID program

```
alice@home:>ls -l /usr/bin/passwd /bin/su /usr/bin/at
-rwsr-xr-x 1 root root    31668 2006-04-23 08:48 /bin/su
-rwsr-xr-x 1 root trusted 43940 2006-05-02 09:47 /usr/bin/at
-rwsr-xr-x 1 root shadow  72836 2006-05-02 10:50 /usr/bin/passwd
```

Setuid and setgid:
chmod u+s file or chmod 4XXX file
chmod g+s file or chmod 2XXX file

Sticky Bit

- Historically used to keep program code in memory when exiting program (still the case in, e.g. HP-UX)
- Now used to only let owner delete file
  - directory owner and superuser can also delete it

```
bob@home:>ls -la
totalt 0
drwxrwxr-t 2 alice Students 72 2008-02-13 16:17 .
drwxr-x--- 3 alice Students 80 2008-02-13 16:00 ..
-rw-rw-r-- 1 alice Students  0 2008-02-13 16:17 file
bob@home:>rm file
rm: kan inte ta bort "file": Operationen inte tillåten
bob@home:>ls -la
totalt 0
drwxrwxr-x 2 alice Students 72 2008-02-13 16:17 .
drwxr-x--- 3 alice Students 80 2008-02-13 16:00 ..
-rw-rw-r-- 1 alice Students  0 2008-02-13 16:17 file
bob@home:>rm file
bob@home:>
```

- Typical example: the directory /tmp has sticky bit set

Default Access Rights (umask)

- Control default permissions, stored in /etc/profile
- Override in ~/.profile or in prompt
- `umask` tells which permissions to exclude by default
- Access = full access AND NOT(umask)
  - Full access for programs and directories: 0777
  - Full access for files: 0666

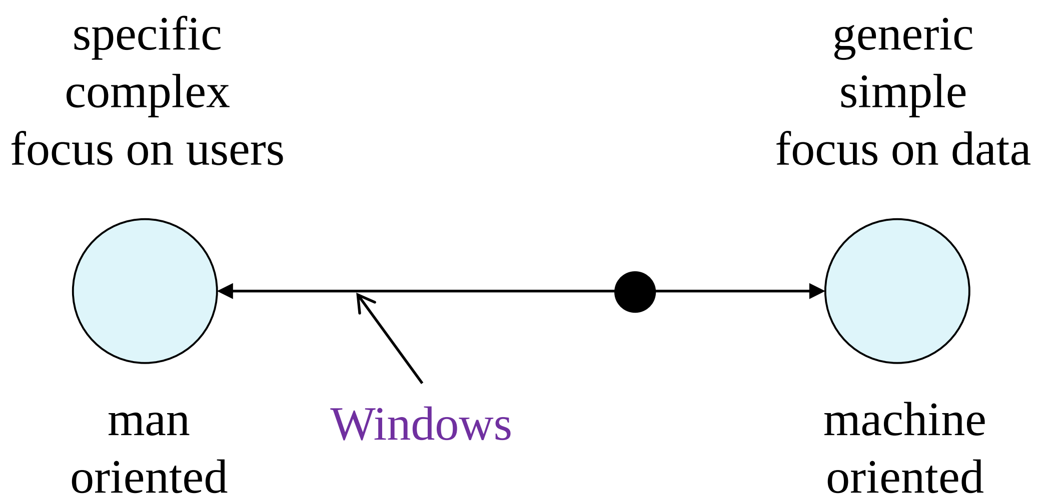
```
alice@home:>umask 0027; mkdir directory; touch file; ls -l
totalt 0
drwxr-x--- 2 alice Students 48 2008-02-13 12:33 directory
-rw-r----- 1 alice Students  0 2008-02-13 12:33 file
```

Change Owner and Group (chown and chgrp)

- chown is used to change the owner of a file (or directory)
- chgrp is used to change the group of a file (or directory)
  - chown can set group also
- Possible problem: A user creates a suid program and owner gets changed to root
- Common solution:
  - Only root can change owner and setuid and setgid bits are removed when owner is changed
  - Anyone can change group to a group they are member of, but setuid and setgid bits are removed when group is changed
- Other solutions possible
  - Let only root use chown, but preserve setuid and setgid bits
  - Let any user change owner on his/her own files, but remove setuid and setgid bits

Unix security on the Man-Machine Scale

- Lack of ”flexibility” puts it more to the machine end of the scale
- Limited to read, write and execute
  - E.g., ”shutdown computer” does not exist but may exist in more user-focused environments
  - Can still be implemented though, using the basic access rights



Example: Shutdown in Unix/Linux

- Shutdown can be done with
  - /sbin/shutdown
  - /sbin/halt
  - /sbin/reboot
- Only root can use these
- Problem: Allow some users to shutdown
- Solution (one of several):
  - Add group ”shutdown” in /etc/group
  - Add users to this group

    shutdown:x:1500:alice,bob
  - Use chown or chgrp to change group of /sbin/shutdown

chown root:shutdown /sbin/shutdown or chgrp shutdown /sbin/shutdown
  - Allow group shutdown to execute and set SUID bit since only root is allowed to execute this command

    chmod u+s,g+x /sbin/shutdown

The inode

- Stores file information
- Directory contains filename and inode number

```
alice@home:>ls -i
133143 file1  133144 file2  133145 file3  133143 file4
```

Note that file1 and file4 points to the same inode

- inode contains e.g.:
  - Access rights
  - Owner (UID)
  - Group (GID)
  - Time of latest access, modification and change
  - Size of file
  - Pointers to block of data

inode Information (stat)

- Some information about an inode can be found using `stat`

Size in bytes

Inode number

```
alice@home:>stat file
  File: "file"
  Size: 102              Blocks: 8           IO Block: 4096   normal fil
Device: 802h/2050d       Inode: 133060       Links: 1
Access: (0644/-rw-r--r--)  Uid: ( 1004/    alice)   Gid: ( 1000/Students)
Access: 2009-02-03 12:30:50.000000000 +0100
Modify: 2009-02-03 12:12:00.000000000 +0100
Change: 2009-02-03 12:30:59.000000000 +0100
alice@home:>
```

Last access

Access rights given to this file

Last modification of file

Last modification of inode

Copy files

- Files can be copied in two ways
- `cp src dest`
  - Creates a new inode and new physical file owned by user running cp
- `ln target linkname`
  - Creates filename and pointer to target's inode. No new file is created.
  - When one filename is deleted the other is still there and the file is not deleted
  - rm subtracts the number of links in the inode by 1. If it becomes zero the corresponding data block is freed
- `ln –s target linkname`
  - Creates a symbolic link, not a real link
  - When opening symbolic link for reading or writing link is automatically dereferenced
  - If file is deleted, the symbolic link remains, pointing to nothing

Race conditions

- Assume process ”proc” with effective user ID = 0 writes to files in /tmp directory
  - Process creates e.g., /tmp/file and writes temporary data to this file
- What if malicious user creates /tmp/file as symbolic link to /etc/passwd?
  - The file /etc/passwd will be overwritten since ”proc” has write access to this file
  - System is damaged
- Race condition: Who creates the file first

Solutions To This Race Condition

- Create files with unpredictable filenames in /tmp
  - Still, attacker can try thousands of filenames and will succeed with probability > 0
- Use O_EXCL flag when opening file
  - Then open fails if file already exists

Function mkstemp() will do this

- Check if file was opened through a symbolic link
  - Can be done with lstat()

- All of the above should be used

Protection of devices

- Devices are treated as files
- **Example:** If you can read/write physical memory all access control is overruled!
- **/dev/mem** is the physical memory
- **/dev/kmem** is the virtual memory

Mounting File Systems

- Different physical devices put under a single root “/”
- The mounted file system may contain unwelcome programs
  - nosuid – turn off SUID and SGID bits
  - noexec – no binaries can be executed
  - nodev – no devices can be accessed
  - ro – read-only
- UIDs and GIDs are local identifiers that need not be interpreted the same on different Unix systems
  - Use *global unique* identifiers

Searchpath

- When executing programs, system needs to know where to look for it → PATH tells system where to look
- PATH=. : $HOME/bin:/usr/bin:/bin:
  - Programs can be located in current directory + 3 bin directories
  - Trojan horse
- Can be a bad idea to put your current directory in the search path (especially for programs executed by root)
- Alternatively, call program by full name

TCP Wrapper (not included in course from 2015)

- inetd is a super-server deamon (starts other servers)
- Config file inetd.conf maps port numbers to programs

```
ftp     stream  tcp  nowait  root   /usr/sbin/in.ftpd      in.ftpd
telnet  stream  tcp  nowait  root   /usr/sbin/in.telnetd   in.telnetd
```

- Put intermediate program with access control and logging

```
ftp     stream  tcp  nowait  root   /usr/sbin/tcpd         in.ftpd
telnet  stream  tcp  nowait  root   /usr/sbin/tcpd         in.telnetd
```

- The TCP wrapper (tcpd) will have process name (in.ftpd and in.telnetd) and thus know where to go after security controls are done

Network Access Control (not included in course from 2015)

- /etc/hosts.allow: (deamon, client) pair that is allowed access
- /etc/hosts.deny: (deamon, client) pair that is denied access

Example

file: /etc/hosts.allow

```
ALL : localhost
ALL : 192.168.1.2
sshd : ALL EXCEPT .somedomain.com
```

file: /etc/hosts.deny

```
ALL : ALL
```

Priority:

1. Check hosts.allow
2. Check hosts.deny
3. Allow access

Compare with allow/deny in Windows!