Security Part 3

Live Anonymous Q&A:
https://tinyurl.com/cs1670feedback

Recap: Access Control

- Two approaches
  - who you are
    - subjects' identity attributes determine access to objects
  - what you have
    - capabilities possessed by subjects determine access to objects

today

revisit later

Who-You-Are-Based Access Control

- Discretionary access control (DAC)
  - objects have owners
  - owners determine who may access objects and how they may access them
- Mandatory access control (MAC)
  - system-wide policy on who may access what and how
  - object owners have no say

Access Control in Traditional Systems

- Unix and Windows
  - primarily DAC
  - file descriptors and file handles provide capabilities
  - MAC becoming more popular
    - SELinux
    - Windows

will discuss in later lecture

Case Study 1: Unix Permissions

Unix

- **Process's security context**
  - user ID
  - set of group IDs
  - more discussed later
- **Object's authorization information**
  - owner user ID
  - group owner ID
  - permission vector

Permissions Example

adm group:
malte, katie

```
$ ls -lR
.:
total 2
drwxr-x--x  2 malte    adm    1024 Dec 17 13:34 A
drwxr-----  2 malte    adm    1024 Dec 17 13:34 B

./A:
total 1
-rw-rw-rw-  1 malte    adm     593 Dec 17 13:34 x

./B:
total 2
-r--rw-rw-  1 malte    adm     446 Dec 17 13:34 x
-rw----rw-  1 katie    adm     446 Dec 17 13:45 y
```

Quiz 1

Recall that in Unix, each file/directory has an owner and a group (e.g., owner “joe”, group “adm”).

Is there a means in Unix to specify that members of *two* different groups have read access to a file, without resorting to features we haven’t yet discussed?

a) No, it can’t be done.

b) Yes, but it’s complicated.

c) Yes, it can be done in a single command just like setting the file readable by just one group.

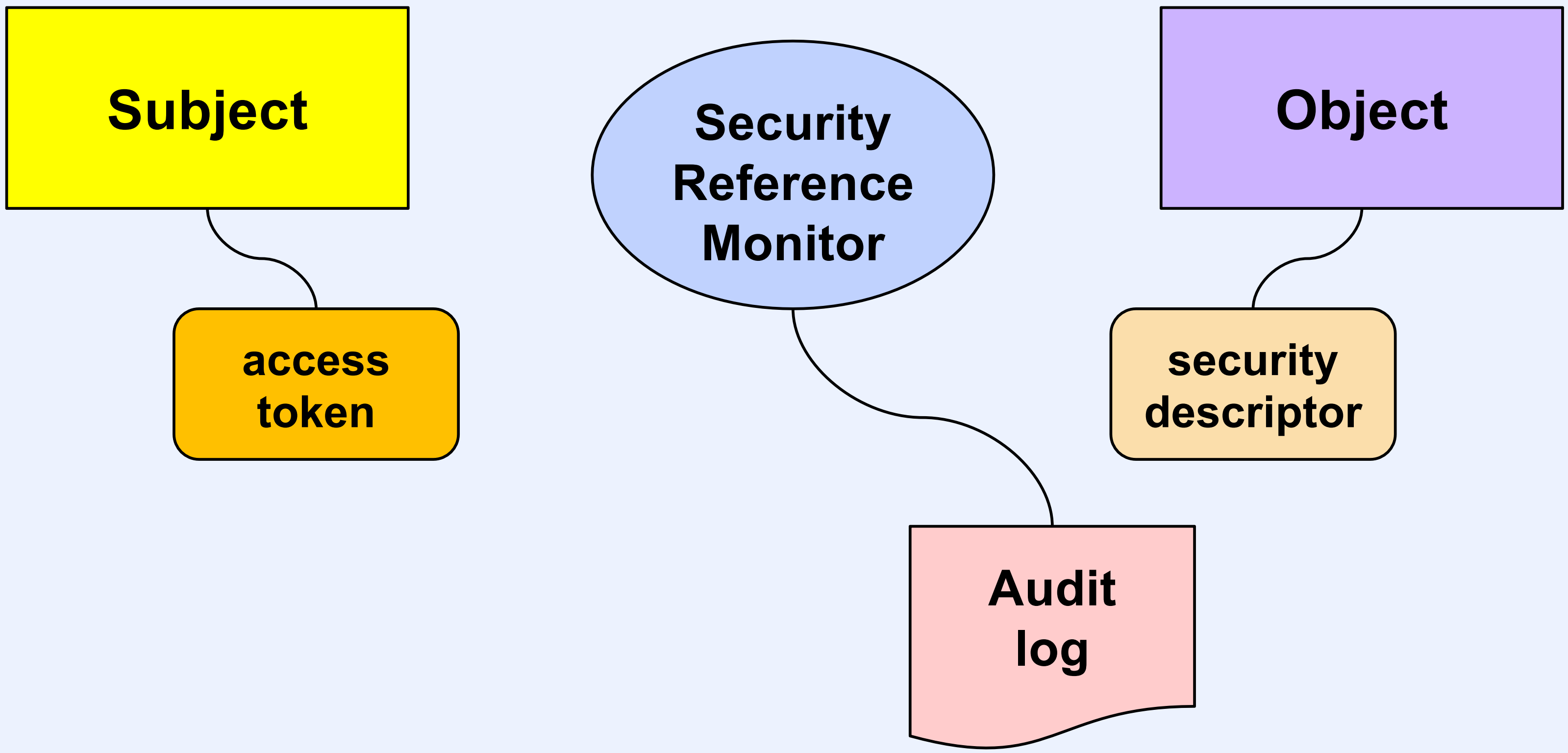
Solution

Initializing Authorization Info

- permission_vector = mode & ~umask
  - mode is from `open`/`creat` system call
  - umask is process-wide, set via `umask` syscall
- Owner user ID
  - effective user ID of creating process
- Group owner ID
  - "set either to the effective group ID of the process or to the group ID of the parent directory (depending on file system type and mount options, and the mode of the parent directory, see the mount options *bsdgroups* and *sysvgroups* described in mount(8))"
    - Linux man page for open(2)

Case Study 2: Windows Security Architecture

Windows


Subject
Security Reference Monitor
Object
access token
security descriptor
Audit log

Security Identifier (SID)

- Identify principals (users, groups, etc.)
- S-V-Auth-SubAuth$_1$-SubAuth$_2$-…-SubAuth$_n$-RID
  - S: they all start with "S"
  - V: version number (1)
  - Auth: 48-bit identifier of agent who created SID
    - local system
    - other system
  - SubAuth: 32-bit identifier of subauthority
    - subsystem, etc.
  - RID: relative identifier
    - makes it unique
    - user number, group number, etc.
- E.g., S-1-5-123423890-907809-43

Security Descriptor

- Owner's SID
- DACL
  - discretionary access-control list
- SACL
  - system access-control list
    - controls auditing
- Flags

DACLs

- Sequence of Access-Control Entries (ACEs)
- Each indicates
  - who it applies to
    - SID of user, group, etc.
  - what sort of access
    - bit vector
  - action
    - permit or deny

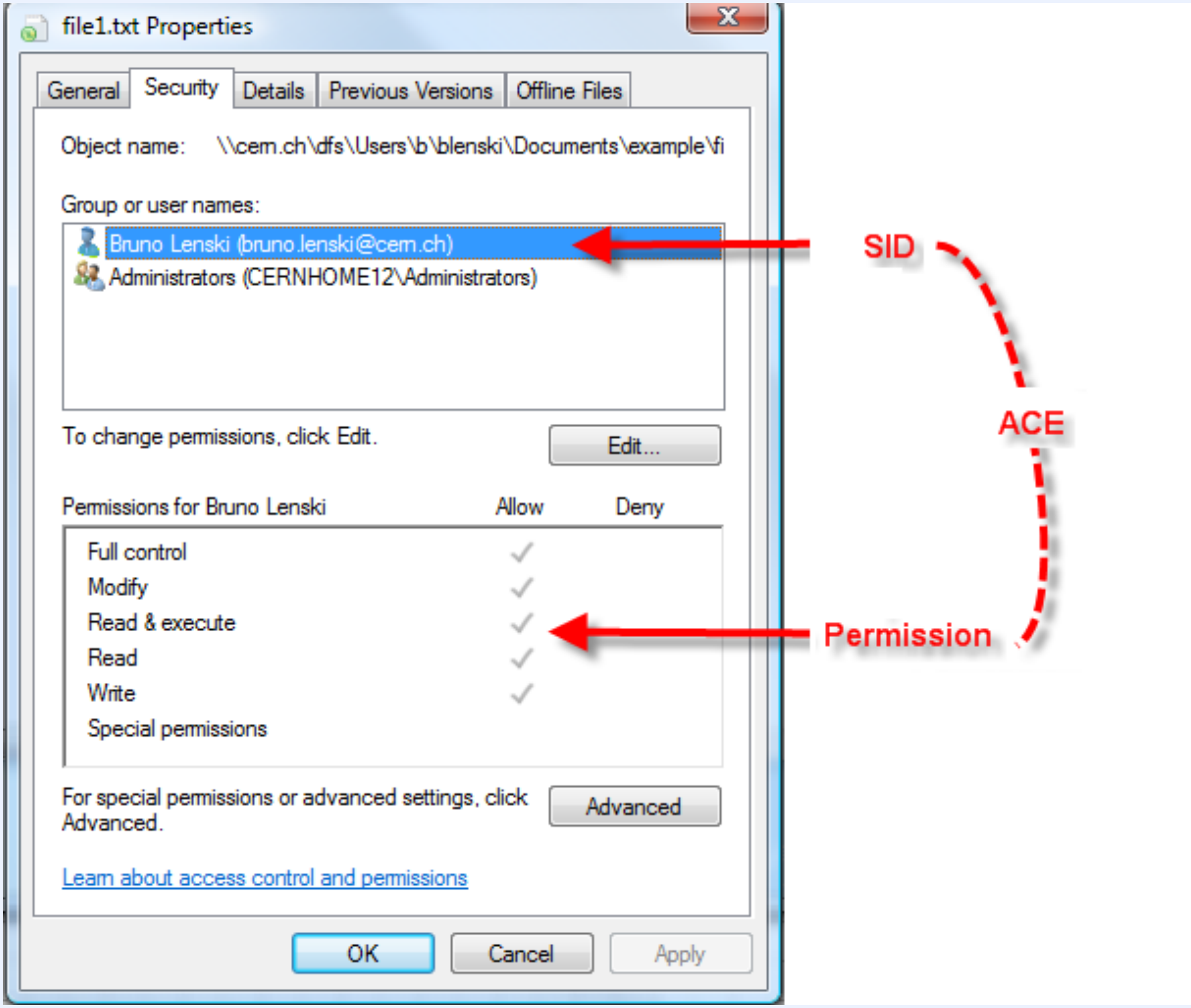


Image credit: https://devices.docs.cern.ch/devices/windows/permissions/

Initializing DACLs

- Individual ACEs in directories may be marked inheritable
- When an object is created, DACL is initialized
  – explicitly provided ACEs appear first
  – then any ACEs inherited from parent
  – then any ACEs inherited from grandparent
  – etc.

Decision Algorithm

accesses_permitted = null
walk through the ACEs in order
    if access token's user SID or group SID match ACE's SID
        if ACE is of type access-deny
            if a requested access type is denied
                Stop — access is denied
        if ACE is of type access-allow
            if a requested access type is permitted
                add access type to *accesses_permitted*
                if all requested accesses are permitted
                    Stop — access is allowed
if not all requested access types permitted
    Stop — access is denied

Order Matters …

allow
inGroup
read, write
deny
Mary
read, write

deny
Mary
read, write
allow
inGroup
read, write

Preferred Order

- *Access-denied* entries first
- *Access-allowed* entries second
- However …
  - not enforced
  - system GUIs don't show order
  - only way to find out is to ask for "effective permissions"

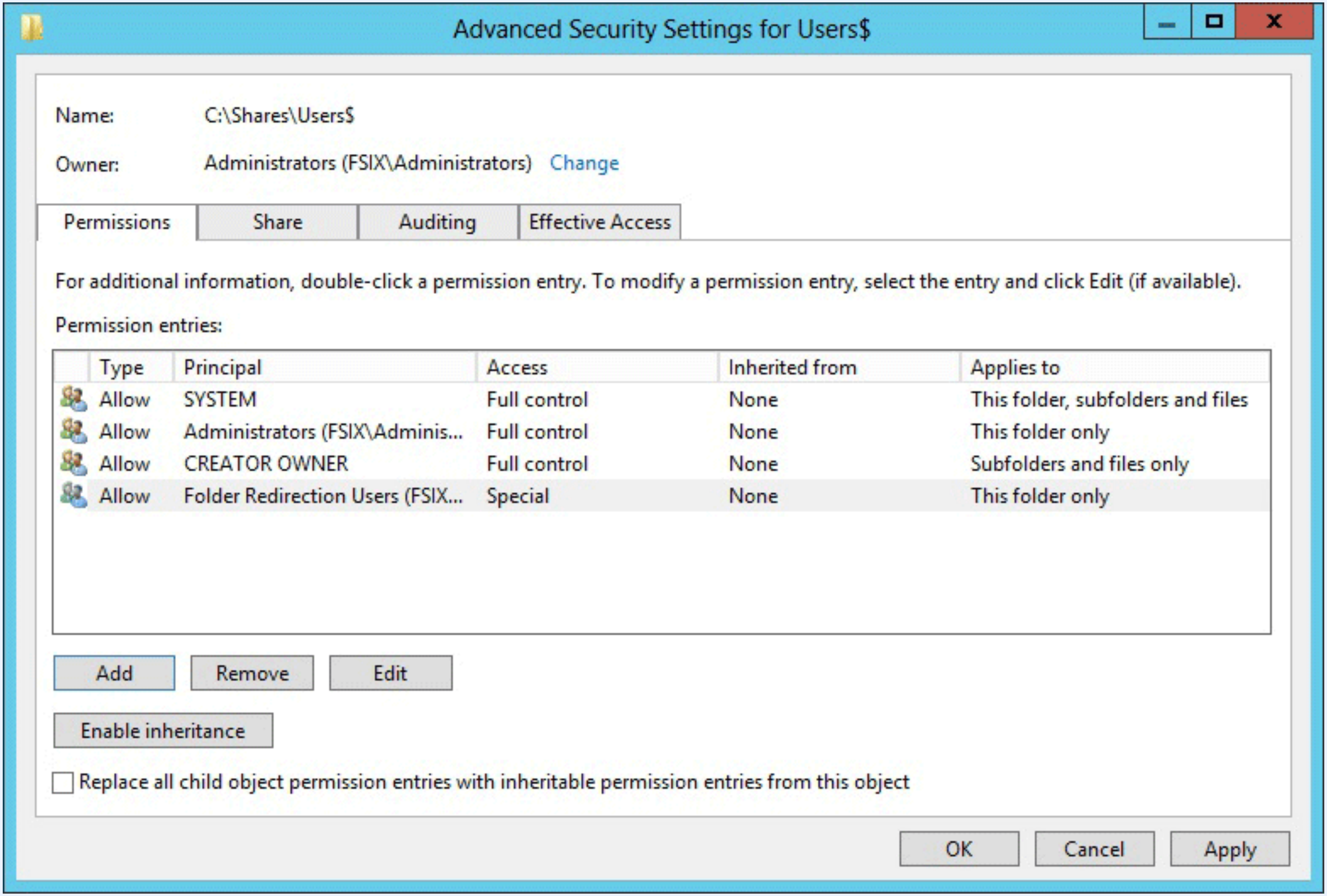


Image credit: https://superuser.com/questions/1186187/command-line-to-open-the-advanced-security-settings-dialogue

There's More

- ACE inheritance
  - designated ACEs propagate down tree
  - an object's ACL can be flagged "protected"
    - no inheritance
  - an object may have an "inherit-only" ACL
    - applies to descendants, not to itself
  - revised preferred order
    - first explicit ACEs
    - then ACEs inherited from parent
    - then ACEs inherited from grandparent
    - etc.
    - within group, first access-denied, then access permitted

Case Study 3: POSIX Advanced ACLs

Unix ACLs

- POSIX 1003.1e
  - deliberated for 10 years
    - what to do about backwards compatibility?
  - gave up …
  - but implemented, nevertheless
    - setfacl/getfacl commands in Linux

Unix ACLs

- ACEs
  - user_obj: applies to file's owner
  - group_obj: applies to file's group
  - user: applies to named user
  - group: applies to named group
  - other: applies to everyone else
  - mask: maximum permissions granted to user, group_obj, and group entries

Unix ACLs

- Access checking
  - if effective user ID of process matches file's owner
    - *user_obj entry* determines access
  - if effective user ID matches any *user ACE*
    - *user entry* ANDed with *mask* determines access
  - if effective group ID or supplemental group matches file's group or any *group ACE*
    - access is intersection of *mask* and the union of all matching group entries
  - otherwise, *other ACE* determines access

Example

```
% mkdir dir
% ls -ld dir
drwxr-x--- 2 twd fac 8192 Mar 30 12:11 dir
% setfacl -m u:floria:rwx dir
% ls -ld dir
drwxr-x---+ 2 twd fac 8192 Mar 30 12:16 dir
% getfacl dir
# file: dir
# owner: twd
# group: cs-fac
user::rwx
user:floria:rwx
group::r-x
mask::rwx
other::---
```

Example (continued)

```
% setfacl -dm u::rwx,g::rx,u:floria:rwx dir
% getfacl dir
# file: dir
# owner: twd
# group: cs-fac
user::rwx
user:floria:rwx
group::r-x
mask::rwx
other::---
default:user::rwx
default:user:floria:rwx
default:group::r-x
default:mask::rwx
default:other::---
```


Example (continued)

```
% cd dir
% cp /dev/null file # creates file with mode = 0666
% ls -l
total 0
-rw-rw----+ 1 twd fac 0 Mar 30 12:16 file
% getfacl file
# file: file
# owner: twd
# group: cs-fac
user::rw-
user:floria:rwx                  #effective:rw-
group::r-x                       #effective:r--
mask::rw-
other::---
```

Example (continued)

```
% new file 0466 # creates file with mode = 0466
% ls -l
total 0
-rw-rw----+ 1 twd fac 0 Mar 30 12:16 file
% getfacl file
# file: file
# owner: twd
# group: cs-fac
user::rw-
user:floria:rwx                    #effective:rw-
group::r-x                         #effective:r--
mask::rw-
other::---
```


Example (and still continued)

```
% setfacl -m o:rw file
% getfacl file
# file: file
# owner: twd
# group: cs-fac
user::rw-
user:floria:rwx
group::r-x
mask::rwx
other::rw-
```

Example (and still continued)

```
% setfacl -m g:cs1670ta:rw file
% getfacl file
# file: file
# owner: twd
# group: cs-fac
user::rw-
user:floria:rwx
group::r-x
group:cs1670ta:rw-
mask::rwx
other::rw-
```


Example (end)

```
% setfacl -m m:r file
% getfacl file
# file: file
# owner: twd
# group: cs-fac
user::rw-
user:floria:rwx                    #effective:r--
group::r-x                         #effective:r--
group:cs1670ta:rw-                 #effective:r--
mask::r--
other::rw-
```

Quiz 2

Unlike Windows ACLs, UNIX ACLs have no deny entries. Is it possible to set up an ACL that specifies that everyone in a particular group has rw access, except that a certain group member has no access at all?

a) No, it can't be done

b) Yes, it can be done in two commands

c) Yes, but it's complicated and requires more than two commands

Real-world Problem:
Cross-OS ACL Interoperability

NFSv4 ACLs

- NFSv4 designers wanted ACLs
  – on the one hand, NFS is used by Unix systems
  – on the other hand, they'd like it to be used on Windows systems
  – solution:
    - adapt Windows ACLs for Unix
    - NFSv4 servers handle both Unix and Windows clients
    - essentially Windows ACLs plus Unix notions of file owner and file group

ACLs at Brown CS (Up Till Fall 2019)

- Linux systems support POSIX ACLs
- Windows systems support Windows ACLs
- Servers run GPFS file system and handle NFSv3 and SMB clients
  - GPFS supports NFSv4 ACLs
  - translated to POSIX ACLs and Unix bit vectors for NFSv3 clients
  - translated to Windows ACLs for SMB clients

ACLs at Brown CS (What was Planned for Fall 2019)

- Switch to Isilon servers managed by CIS
  - support NFSv4 and SMB clients
- Linux and Mac clients use NFSv4
  - switch to NFSv4 ACLs
- Windows clients use SMB

OSX (Macs)

- Native support for NFSv4 ACLs
  - no setfacl/getfacl commands, but built into chmod
- No NFSv4 client support
  - third-party implementations exist, but they don't work

ACLs at Brown CS (Fall 2019 – Present)

- Isilon servers managed by OIT
  - support NFSv4 and SMB clients
- Linux clients use NFSv4
  - switch to NFSv4 ACLs
- Windows clients use SMB
- OSX clients use SMB
  - no groups – just the authenticated user
  - all remote files seen as allowing 0700 access
  - clients can't observe or modify access protection
    - (though still enforced on server)

Advanced Access Control

setuid and friends

Extending the Basic Models

- Provide a file that others may write to, but only if using code provided by owner
- Print server
  - pass it file names
  - print server may access print files if and only if client may
- Password-changing program (`passwd`)

Superuser (Unix)

- User ID == 0
  - bypasses all access checks
  - can send signals to any process

Attaining Super (or Lesser) Powers

- Setuid protection bit
  - the exec'ing process's UID is set to owner of file

User and Group IDs

- *Real* user and group IDs — usually used to identify who created the process
- *Effective* user and group IDs — used to determine access rights to files
- Saved user and group IDs — hold the initial effective user and group IDs established at the time of the *exec*, allowing one to revert back to them

Exec

- Normally the real and effective IDs are the same
  - they are copied to the child from the parent during a *fork*
- *execs* done on files marked *setuid* or *setgid* change this
  - if the file is marked *setuid*, then the effective and saved user IDs become the ID of the owner of the file
  - if the file is marked *setgid*, then the effective and saved group IDs become the ID of the group of the file

Exercise of Powers

- **Permission to access a file depends on a process's effective IDs**
  - **the *access* system call checks permissions with respect to a process's real IDs**
    - **this allows *setuid*/*setgid* programs to determine the privileges of their invokers**
- **The *kill* system call makes use of both forms of user ID; for process *A* to send a signal to process *B*, one of the following must be true:**
  - ***A*'s real user ID is the same as *B*'s real or saved user ID**
  - ***A*'s effective user ID is the same as *B*'s real or saved user ID**
  - ***A*'s effective user ID is 0**

Race Conditions

```
// a setuid-root program:

if (access("/tmp/mytemp",
    W_OK) == 0) {
  // ... fail
}
fd = open("/tmp/mytemp",
    O_WRITE|O_APPEND);
len = read(0, buf,
    sizeof(buf));
write(fd, buf, len);
```

```
// another program:

unlink("/tmp/mytemp");
symlink("/etc/passwd",
    "/tmp/mytemp");
```

- **TOCTTOU vulnerability**
  - **time of check to time of use …**