Willkommen zur Vorlesung

Sicherheit:
Fragen und Lösungsansätze

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Vorlesungswebseite (bitte notieren):

http://www-jj.cs.tu-dortmund.de/secse/pages/teaching/ws12-13/sfl/index_de.shtml

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Some basic features of UNIX

- UNIX supports participants in
  - using their own workstation for their specific application tasks
  - cooperating with colleagues in server-based local networks for joint projects
- a participant can manage his own computing resources at his discretion,
  - either keeping them private
  - or making them available to other particular participants or to everybody
- security mechanisms
  - enforce the virtual isolation of identified, previously registered users
  - enable the deliberate sharing of resources
- the mechanisms are closely intertwined with the basic functional concepts of files and processes, which are managed by the UNIX kernel
- the kernel acts as controller and monitor of all security-relevant accesses

Basic blocks of control and monitoring (and cryptography)

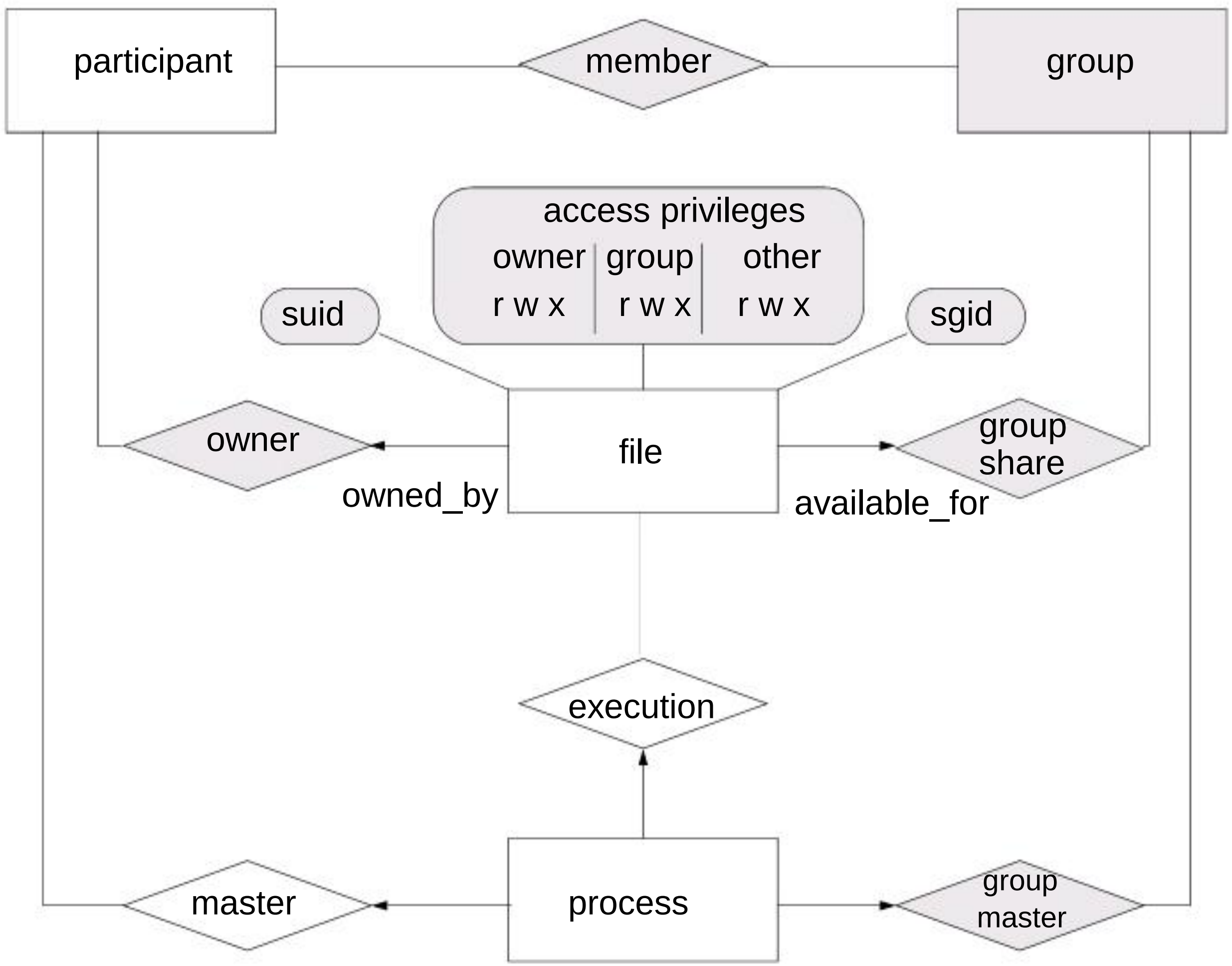
- *identification* of registered users as participants
- *passwords* for user *authentication* at login time
- *a one-way hash function* for storing password data
- *discretionary access rights* concerning *files* as basic objects and three fundamental *operational modes*, read, write and execute
- *owners*, as autonomous grantors of access rights
- owners, *groups* and the full community of all users, as kinds of grantees
- *right amplification* for temporarily increasing the operational options of a user
- a *super-user*, capable of overriding the specifications of owners
- *access control* concerning the commands and the corresponding system calls
- *monitoring* of the functionality
- *kernel*-based implementation of control and monitoring

Conceptual design of the operating system functionality

- UNIX provides a *virtual machine* that offers an external *command* interface with the following fundamental features:
  - identified *participants* can
  - *master processes* that
  - *execute* programs
  - stored in *files*

- the processes, in turn, can operate on files, in particular for *reading* and *writing*

ER model of fundamental functional features and security concepts



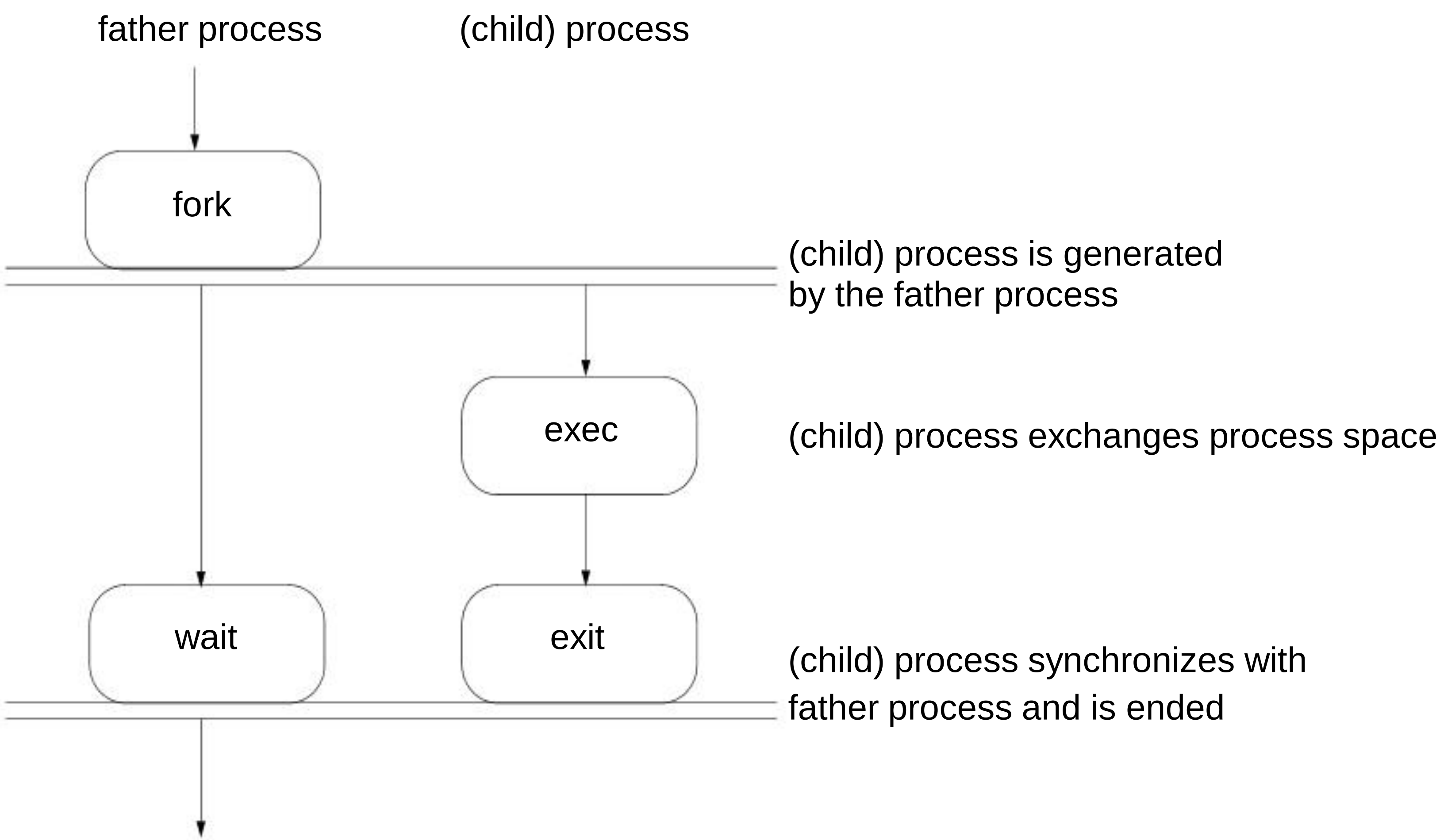
Participants, sessions, and system calls

- a previously *registered participant* can start a *session* by means of the `login` command
- for this the *system*
  - assigns a *physical device* for input and output data to him
  - starts a *command interpreter* as the first process mastered by that participant
- afterwards, the participant can issue *commands*, which may possibly generate additional processes that are also mastered by him
- the commands invoke *system calls* that serve for
  - process management
  - signaling
  - file management
  - directory and file system management
  - protection
  - time management

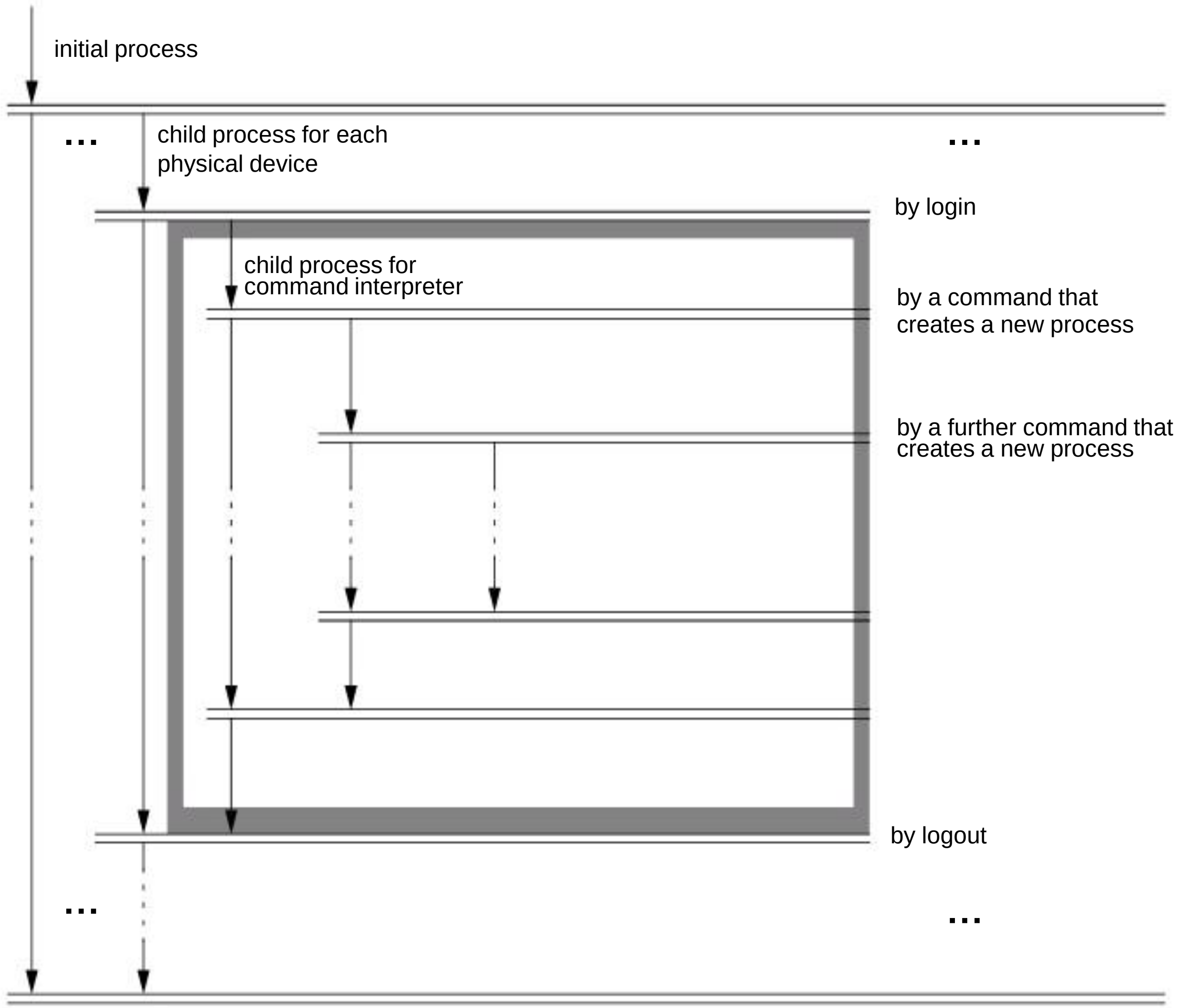
Processes as active subjects

- *execute* (the program contained in) a file, and in doing so
- *read* or *write* in (usually other) files
- *create* new files and *remove* existing ones
- *generate* new (child) processes
- have a *lifespan,*
  starting with the generation by a father process and
  ending with a synchronization with the pertinent father process
- constitute a *process tree*:
  - when the UNIX system is started, an initial process *init* is generated
  - an already running (*father*) *process* can generate new (*child*) *processes*

Lifespan of a process



Growing and shrinking of a process tree



Files as passive objects

- files are uniformly managed by the system using a file tree

- a file is identified by its *path name* within the file tree

- a file that constitutes a branching node in the file tree
is a *directory* listing other files

- a file that constitutes a leaf in the file tree
is a *plain file* containing data,
which might be considered as an executable program

Conceptual design of the security concepts

- a participant acts as the *owner* of the files created by him
- the system administrator assigns participants as *members* of a *group*:
  - a group comprises those participants that are entitled to share files
  - an owner can make a file *available* for a group to *share* it
- for each file, the owner implicitly specifies three *disjoint* participant classes:
  - himself as *owner*
  - the members of the pertinent *group*, except the owner if applicable
  - all *other* participants
- the owner of a file *discretionarily* declares *access privileges* for each of these classes - for the processes mastered - by permitting or prohibiting the operations belonging to an *operational mode*:
  - ***r**ead*
  - ***w**rite*
  - *e**x**ecute*

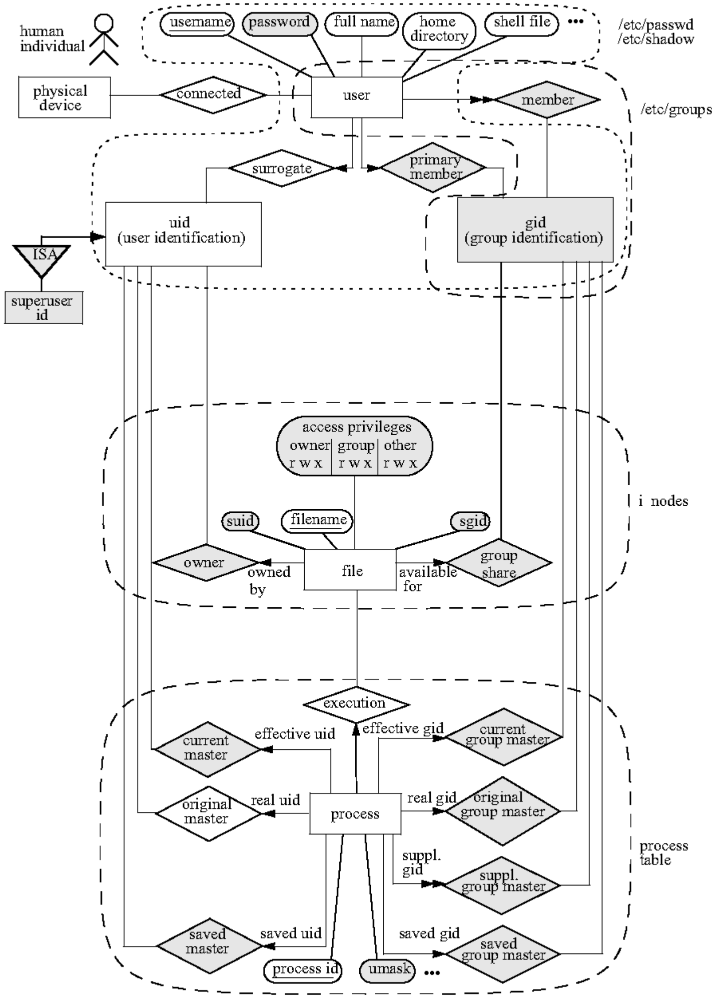
Some operations with commands and their operational mode

Operation with command on plain file	Operation with command on directory	Operational mode
open file for reading: `open( ,o_rdonly)` read content: `read`	open directory for scanning: `opendir` read next entry: `readdir`	read
open file for writing: `open( ,o_wronly)` modify content: `write` delete content: `truncate`	insert entry: `add` delete entry: `remove` rename entry: `rename`	write
execute content as program: `execute`	select as current directory: `cd`	execute

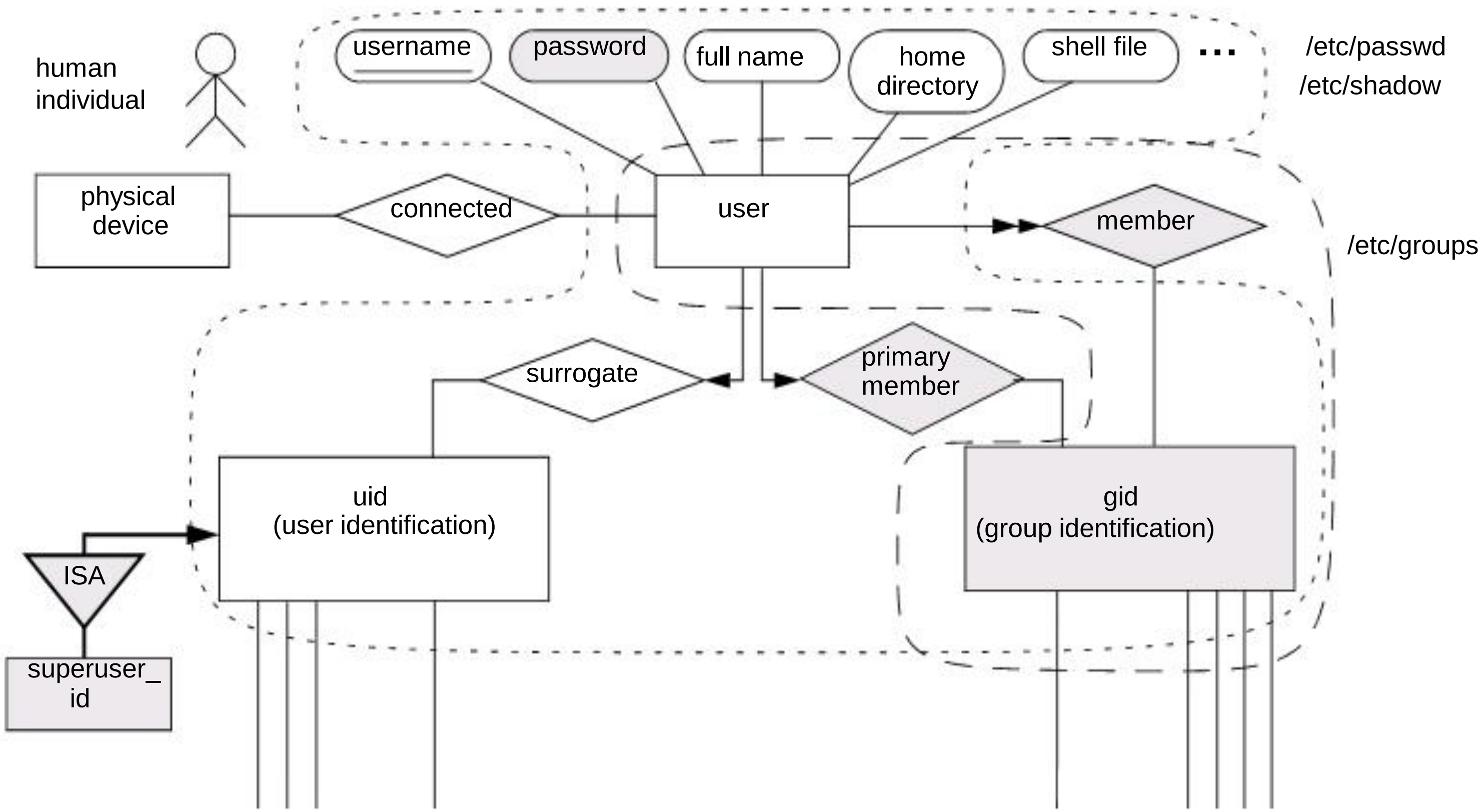
Mastership and group mastership

- normally,
  a user is the *master* of the command interpreter process that he has started,
  and of all its descendants
- additionally, the (primary) group of that user is said to be the
  group master of all those processes
- if a process requests an operation `op` on a file `file`,
  then the access privileges `file.access_privileges`
  are inspected according to the masterships of the process
  in order to take an access decision
- for each file, the owner can additionally set two *execution flags*,
  `suid` and `sgid`,
  that direct its usage as a program, or as a directory, respectively:
  - for a plain file containing an executable program,
    the flag impacts on the *mastership* of an executing process
  - for a directory,
    the flag impacts on the *ownership* of inserted files

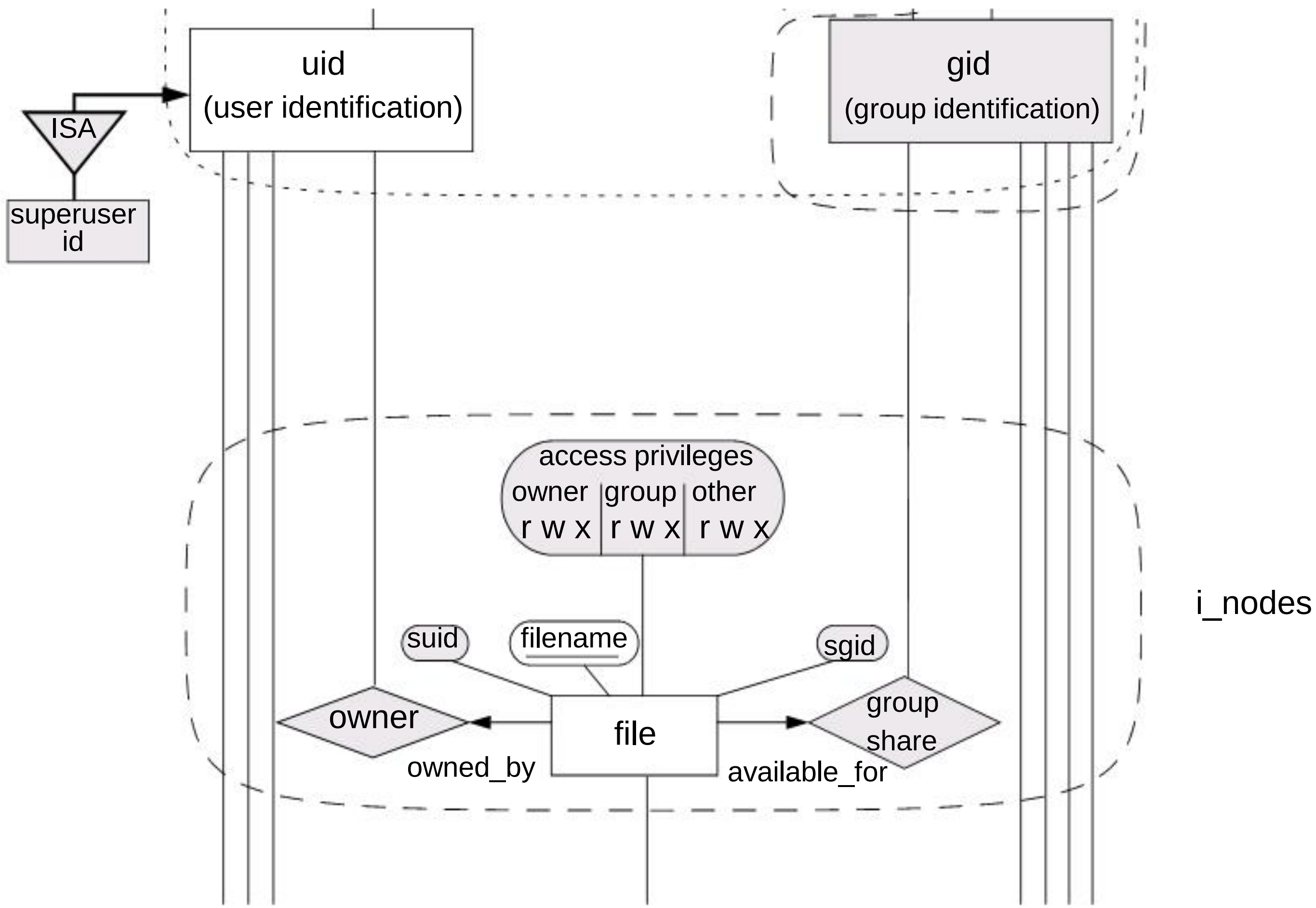
Refined ER model of the functional features and security concepts



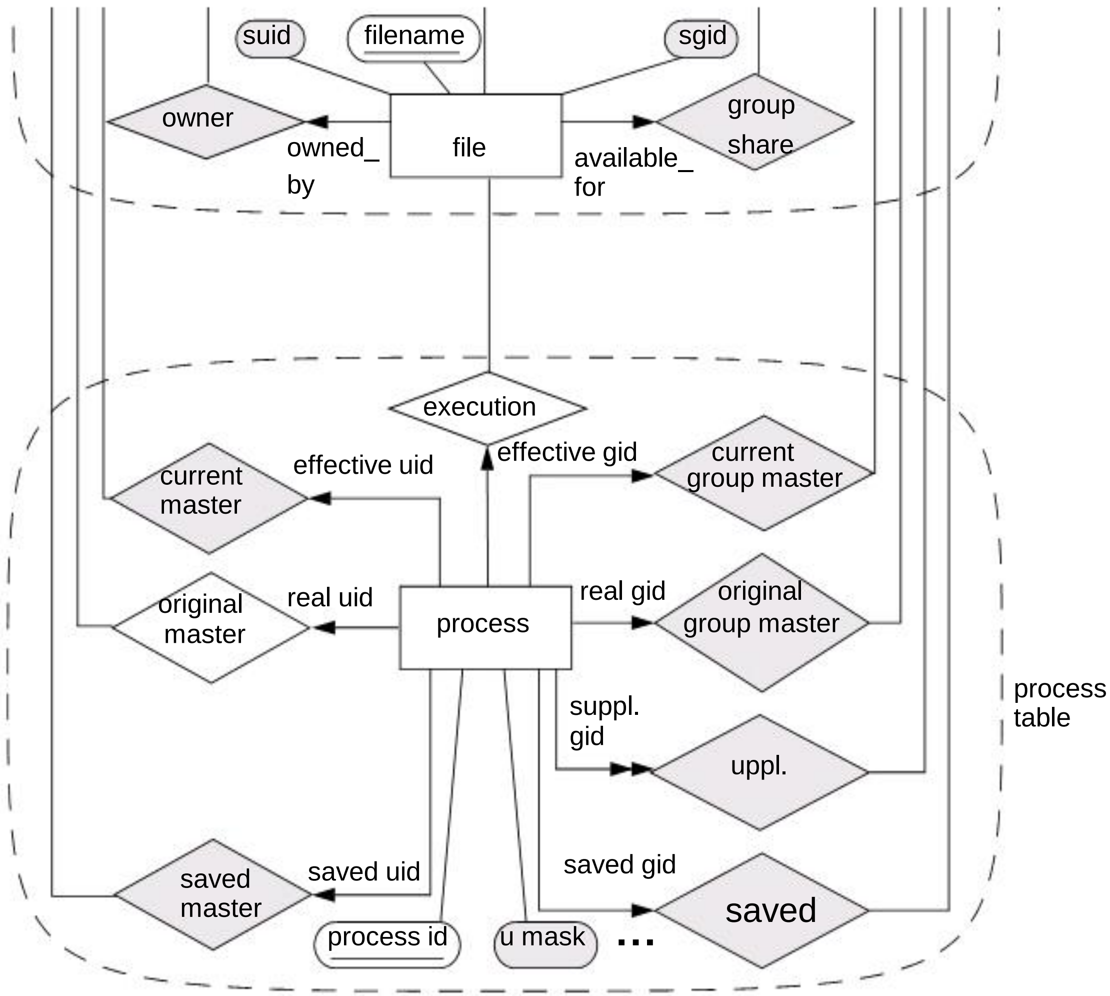
Refined ER model: users



Refined ER model: files



Refined ER model: processes



Different notions of a participant

- a *human individual*
- the *physical device*
  from which the individual issued his last `login` command
- an abstract *user*:
  - representing the previously registered human individual within the system:
    as a result of a successful `login` command,
    the abstract user is *connected* to the
    physical device from which the command was received
  - uniquely identified by a *username*
  - associated with further administrative data, e.g.:
    - *password* data
    - *full name*,
    - (the path name of) *home directory* in the overall file tree
    - (the path name of the file containing) *command interpreter* (*shell file*)
- a *user identification*, i.e., a cardinal number *uid*,
  which serves as a (not necessarily unique) *surrogate* for an abstract user

System administrator

- is a *human individual*,
  typically registered as a distinguished *abstract user*
  whose username is *root* and
  whose surrogate is `superuser_id`
  (in general, represented by `0`)

- enjoys nearly unrestricted operational options
(consequently, so does any human individual
who succeeds in being related to *root*)

Groups

- a group is represented by a *group identification*, *gid*

- each abstract user is a *primary member* of one group,
and can be a *member* of any further groups

Mastership and group mastership refined

- all relationships of files/processes with participants/groups are interpreted as relationships with *user identification/group identifications*
- the *master* and the *group master* relationships are further differentiated in order to enable dynamic modifications
- a user identification *uid*
  (the surrogate of a user connected to a physical device from which a human individual has issued a `login` command)
  is seen as the *original master* of the *command interpreter process* generated during the login procedure
  and of all its descendants
- these processes are also said to have this *uid* as their *real uid*
- correspondingly,
  a group identification *gid*
  is seen as the *original group master* of these processes,
  which are also said to have this *gid* as their *real gid*

Current masterships

- normally, the *original* masterships are intended to determine the access decision when a process requests an operation on a file
- to distinguish between normal and *exceptional* cases,
  - an additional *current mastership* (an *effective uid*) and
  - an additional *current group mastership* (an *effective gid*)

  are maintained and actually employed for access decisions
- the current mastership and the current group mastership of a process are automatically manipulated according

  to the execution flags `suid` and `sgid` of the executed file:
  - normally, if the respective flag is *not* set,
    then the *current mastership* is assigned the *original mastership*, and
    the *current group mastership* is assigned the *original group mastership*
  - exceptionally, if the respective flag is set,
    then the *current mastership* is assigned
    the *user identification of the owner of the file to be executed*, and
    the *current group mastership* is assigned
    the *group identification for which that file has been made available*

Right amplification

- the exceptional case is used for *right amplification*,
  to dynamically increase the operational options of a process
  while it is executing a file with a flag set
- the owner of that file allows all “participants”
  that are permitted to execute the file at all
  to act thereby as if they were the owner himself
- if the owner is more powerful than such a participant
  (e.g., if the owner is the nearly omnipotent abstract user *root*),
  then the operational options of the participant are temporarily increased
- the current masterships and current group masterships
  can also be manipulated by special, suitably protected commands
- for this option, the additional
  saved mastership and *saved group mastership*
  are used to restore the original situation

Identification and authentication

- a human individual can act as a participant of a UNIX installation only if the system administrator has *registered* him in advance as *user*, thereby assigning a *username* to him
- this assignment and further user-related data are stored in the files `/etc/passwd` and `/etc/shadow`
- the usernames serve for *identification* and for *accountability* of all actions
- whenever an individual submits a `login` command, the system
  - checks whether the username is *known* from a registration by inspecting the file `/etc/passwd` : if the username is found, it is considered as known, otherwise as unknown
  - evaluates whether the actual command is *authentic*, relying on:
    - appropriate registrations
    - the integrity of the underlying files

Proof of authenticity by a password procedure

- if the individual can input the agreed password, then the command is seen as authentic
- the system relies on
  - appropriate password agreements
  - the individual's care in keeping his password secret
  - the integrity and confidentiality of the file `/etc/shadow`
- the confidentiality of this file is supported by several mechanisms:
  - passwords are not stored directly, but only their images under a *one-way hash function*
  - on any input of the password, the system immediately computes its *hash value* and compares that hash value with the stored value
- the hash values are stored in a specially protected file `/etc/shadow`:
  - a *write access* to an entry (password modification) is allowed only if the request stems from *root* or from the pertinent user
  - a *read access* to an entry is allowed only for authenticity evaluations

Access decisions

- the kernel has to take *access decisions* concerning
  - a *process* as an active subject
  - a *file* as a controlled passive object
  - arequested*operation*
- given a triple `(process, file, operation)`,
the kernel has to decide whether
  - the process identified by `process` is allowed
  - to actually execute the operation denoted by `operation`
  - on the file named `file`
- two cases according to the *effective user identification* of the process, `process.current_master`:
  - if `process.current_master = superuser_uid`,
    then nearly everything is considered to be allowed
  - otherwise, a decision procedure is called

Access decisions regarding normal users


```
function decide(process, file, operation): Boolean;

if    process.current_master = file.owner
then  return file.access_privileges.owner.mode(operation)

else
   if    process.current_groupmaster = file.group
         OR
         EXISTS process.supplementary_groupmaster:
         process.supplementary_groupmaster = file.group
   then  return file.access_privileges.group.mode(operation)

   else  return file.access_privileges.other.mode(operation)
```

Knowledge base on permitted operational options

- implemented by means of the fundamental functional features of UNIX
- data about *users* and *groups* is stored in the special files
  - `/etc/passwd`
  - `/etc/shadow`
  - `/etc/group`
- these files are owned by the system administrator (under `superuser_id`)
- the access privileges for these files are given by
  - `r--|r--|r--`
  - `rw-|---|---`
  - `r--|r--|r--`
- additionally, modifications of the files `/etc/passwd` and `/etc/group` are specially restricted to processes with the effective uid `superuser_id`
- security-relevant data about *files* is managed in *i-nodes*
- security-relevant data about *processes* is maintained in the *process table*

Main entries of the administration files for users and groups

/etc/passwd	/etc/shadow	/etc/group
username	username	groupname
reference to `/etc/shadow`	hash value of password	group password
user identification (uid)	date of last modification	group identification (gid)
gid of primary group	maximum lifetime	usernames of members
full name, comment	date of expiration	
path name of home directory		
path name of shell file		

Modifications of the knowledge base: user and group administration

- the commands `useradd`, `usermod` and `userdel` manipulate the entries for *users* in the files `/etc/passwd`, `/etc/shadow` and `/etc/group`:

  only executed for a process whose effective user identification is `superuser_uid`

- the commands `groupadd`, `groupmod` and `groupdel` manipulate the entries for *groups* in the file `/etc/group`:

  only executed for a process whose effective user identification is `superuser_uid`

Modifications of the knowledge base: password management

- the command `passwd`
  modifies an entry of a user in the file `/etc/shadow`:

  only executed for a process
  whose effective user identification is

  - `superuser_uid`

  or

  - equal to the user identification of the user
    whose password is requested to be changed

Modifications of the knowledge base: login procedure

- the command `login` tries to identify and authenticate the issuer
- on success, the issuer is recognized as a known registered `user`
- by a system call `fork`, a new process is generated for that user
- that process, by use of a system call `exec`, starts executing the `shell file` of the user as a command interpreter
- the masterships and group masterships are determined as follows:
  - the `real uid`, `effective uid` and `saved uid` are all assigned the user identification of the user, i.e., `user.surrogate`
  - the `real gid`, `effective gid` and `saved gid` are all assigned the primary group of the user, i.e., `user.primary_member`
  - the `supplementary gid` is assigned the set of elements of `user.member`
- subsequently, this process is treated as the original ancestor of all processes that are generated during the session started by the `login` command

Modifications of the knowledge base: mastership assignments

- normally,
  a process inherits its masterships and group masterships from its immediate ancestor

- exceptionally,
  masterships and group masterships are determined differently, namely if
  - the file executed has an execution flag `suid` or `sgid` set,
  or
  - some explicit command modifies the implicit assignment

Modifications of the knowledge base: file management

- the system call
  `create(filename, access_privileges, suid, sgid)`
  creates a new file

- the `owner` and the `group share` of the file are assigned the `effective uid` and the `effective gid`, respectively, of the creating process

- the `access privileges` and the execution flags `suid` and `sgid` are assigned according to the respective parameters of the call, possibly modified according to the mask `umask`

Modifications of the knowledge base: masking access privileges

- the mask `umask` specifies nine truth values,
  one for each value contained in the parameter for the access privileges:
  - each mask value is complemented
  - the conjunction with the corresponding parameter value is taken
- a mask value `true` (or `1`) is complemented into `false` (or `0`) and thus
  always results in the corresponding access privilege being set to `false` (or `0`),
  thereby expressing a *prohibition*
- in general, individuals are strongly recommended
  to prohibit write access to files with an execution flag `suid` or `sgid` set:
  avoids unintended/malicious modification of the program contained,
  resulting in unwanted effects of right amplification
- the system call `umask(new_umask)`
  modifies the current nine truth values of the mask `umask` into
  the values specified by the parameter `new_umask`

Modifications of the knowledge base: process management

- the system call `fork` generates a new process
- a subsequent system call `exec(command_file)` exchanges the content of its address space, thereby loading the program that is contained in the file specified as the parameter `command_file`, whose instructions are then executed
- masterships, group masterships and the mask `umask` of that process:
  - if the flags `suid` and `sgid` of the file `command_file` are *not* set, then the new process inherits all masterships and group masterships from its father process
  - if the flag `suid` is set, then the `effective uid` and the `saved uid` are assigned to `command_file.owner`
  - if the flag `sgid` is set, then the `effective gid` and the `saved gid` are assigned to `command_file.group share`
  - the mask `umask` is inherited from the father process

Modifications of the knowledge base: execution flags

- the system call `setuid(uid)` assigns
  the masterships `real uid`, `effective uid` and `saved uid`
  the parameter value `uid`:
    only executed for a process that satisfies the following precondition:
    the `effective uid` equals `superuser_uid`,
    or the `real uid` equals the parameter value `uid`
    (i.e., in the latter case, the original situation is restored)
- the system call `seteuid(euid)` assigns
  the current mastership `effective uid`
  the parameter value `euid`,
  which might be the `real uid` or the `saved uid`
- thereby, while executing a file with the execution flag `suid` set,
  a process can repeatedly change its `effective uid`:
    the process can select
    the `uid` of that `user` who has generated the original ancestor, or
    the `uid` of the `owner` of the file executed

Modifications of the knowledge base: some further manipulations

- the system calls `setgid(gid)` and `setegid(egid)` manipulate the group masterships
- the command `/bin/su -` changes the `effective uid` of the currently executed process into `superuser_uid` (thus the system administrator can acquire the mastership of any process):
  only executed if the issuer is successfully authenticated
  with the agreed password for the system administrator with username *root*
- the command `chown` changes the `owner` of a file:
  only executed for a process that satisfies the following precondition:
  the `effective uid` equals `superuser_uid` or
  equals the current `owner` of the file
- the command `chmod` changes the `access privileges` of a file:
  only executed for a process that satisfies the following precondition:
  the `effective uid` equals `superuser_uid` or
  equals the current `owner` of the file

Knowledge base on usage history

- basically, UNIX does not maintain an explicit *knowledge base* on the *usage history* for taking *access decisions*, except for keeping track of process generations

- most UNIX versions offer log services for *monitoring* that
  - produce *log data* about issued commands and executed system calls
  - store that data in special *log files*

Examples of UNIX log files

- the file `lastlog` contains the
  date of the last issuing of a `login` command for each of the registered users,
  whether successful or failed

- the file `loginlog` contains
  entries about all failed issuings of a `login` command,
  comprising the username employed, the physical device used and the date

- the file `pacct` contains entries about all issued commands,
  including their date

Examples of UNIX log files, continued

- the file `sulog` contains
  entries about all successful or failed attempts to issue the critical `su` command;
  for each attempt, the following is recorded:
  - success or failure
  - the username employed
  - the physical device used
  - the date

- the files `utmp` or `wtmp` contain
  entries about the currently active participants;
  in particular, the following is recorded:
  - the username employed
  - the physical device used
  - the process identification of the original ancestor process
    that was started by the `login` command
    to execute the user's command interpreter

Audit services

- log services send their log data as *audit messages* to an audit service that unifies and prepares that data for persistent storage or further monitoring
- the audit service `syslog` works on audit messages that are sent
  - by the kernel, exploiting `/dev/klog`
  - by user processes, exploiting `/dev/log`
  - by network services, exploiting the UDP port 514
- the audit messages consist of four entries:
  - the name of the *program* whose execution generated the message
  - a *classification* of the executing process into one of a restricted number of event sources, called *facilities*, which are known as *kern*, *user*, *mail*, *lpr*, *auth*, *daemon*, *news*, *uucp*, *local0*, …, *local7*, *mark*
  - a *priority level*, which is one of *emerg*(ency), *alert*, *crit*(ical), *err*(or), *warning*, *notice*, *info*(rmational), (from) *debug*(ging), *none*
  - the actual notification of the *action* that has occurred

Configuration of an audit service: example

- the system administrator can configure the audit service `syslog` using the file `/etc/syslog.conf`,
  which contains expressions of the form
  `facility.priority destination`
- such an expression determines how an audit message
  - that stems from an event source classified as `facility` and
  - has the level `priority` should be treated, i.e.,
  - to which `destination` it has to be forwarded
- `destination` might denote
  - the path name of a file
  - a username,
  - a remote address,
  - a pipe
  - the wildcard * (standing for all possible receivers)

Overall architecture

- control and monitoring are part of the operating system kernel
- the *kernel* realizes the system calls offered by UNIX
- a *system call* is treated roughly as follows:
  - the kernel checks the operator and the parameters of the call and then deposits these items in dedicated registers or storage cells
  - a software interrupt or trap dispenses the calling process
  - the program determined by the specified operator is executed with the specified parameters
  - if applicable, return values for the calling process are deposited
  - subsequently, the calling process can be resumed
- this procedure needs special hardware support for security: *storage protection*, *processor states*, *privileged instructions*, *process space separation*, ...
- most UNIX installations are part of a *network*, and thus employ various features for *securing the connections* to remote participants and the interactions with them