Chapter 9
Process Relationships

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Outline

- Logins
- Process groups
- Sessions
- Controlling terminal
- Job control
- Shell execution of programs
- Orphaned process groups

Linux Boot Process

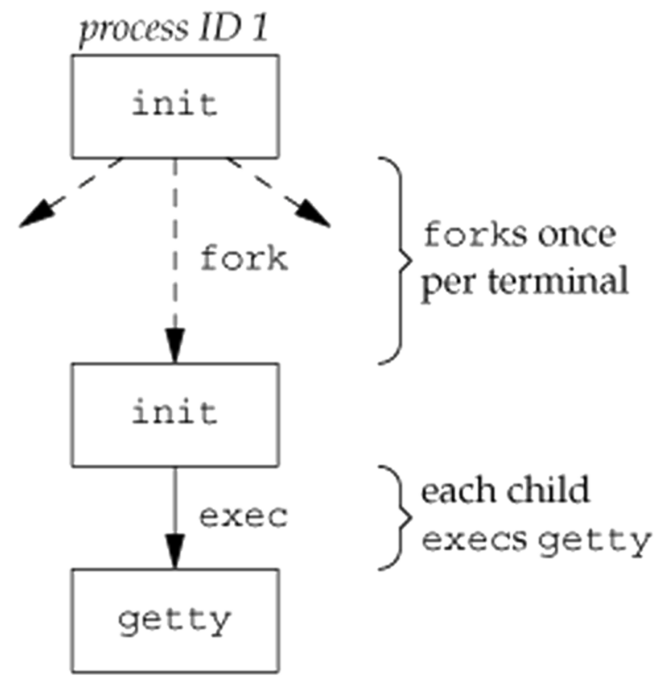
- The first process after system boot /sbin/init
  - The parent of all processes
  - Has a PID of 1
- /sbin/init configurations
  - /etc/inittab, /etc/event.d/*, or /etc/init/*
- Run levels
  - sysinit
  - 0 (halted), 6 (reboot), 1-5 (can be customized)
    - Default run levels – often set to 2, 3, or 5
- Enable console logins

Run Level	Mode
0	Halt / Shutdown
1	Single User
2	Multi-user without NFS
3	Full multi-user mode
4	Not used
5	GUI (X11)
6	Reboot

Linux Terminal Logins

- Terminal setups, an example from Ubuntu 14
  - Start 6 consoles terminals for login
  - Can be switched using hotkey Alt+F1 ~ F6
- /etc/init/tty1.conf (on Ubuntu…)

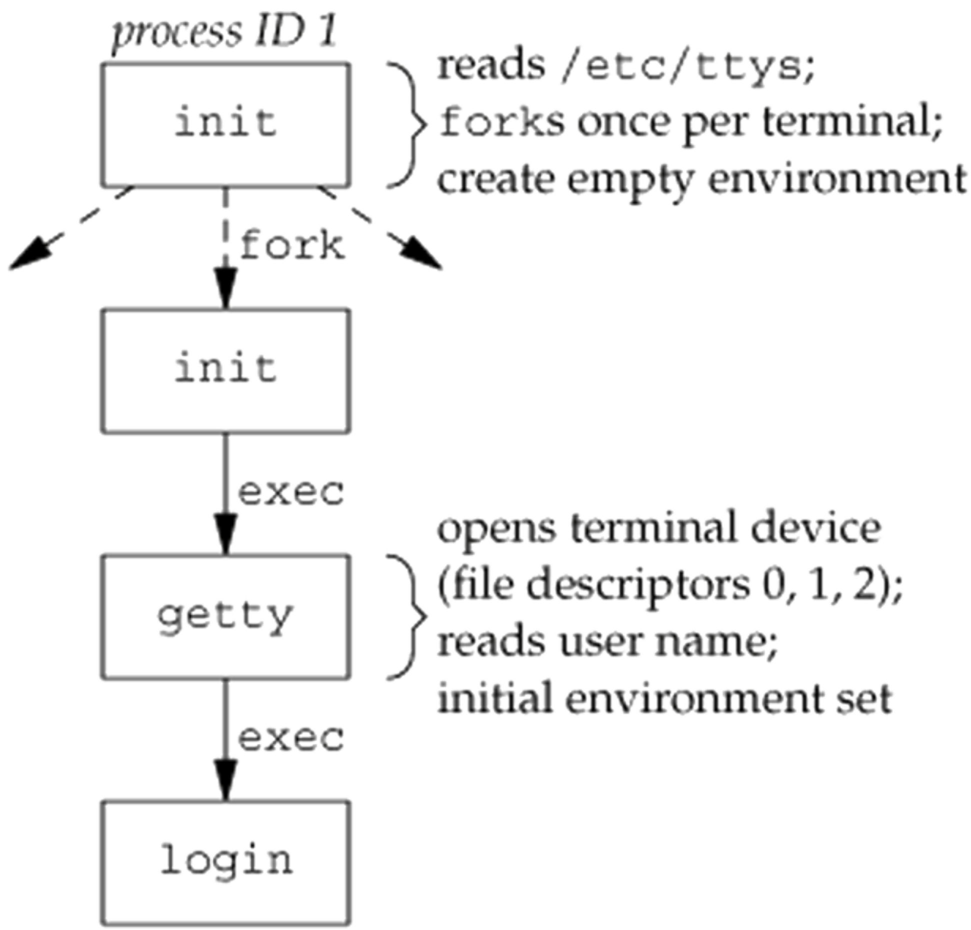
```
start on stopped rc RUNLEVEL=[2345] and (
            not-container or
            container CONTAINER=lxc or
            container CONTAINER=lxc-libvirt)

stop on runlevel [!2345]

respawn
exec /sbin/getty -8 38400 tty1
```



The getty Program

- Calls open for the terminal device
  - /dev/tty1, /dev/ttyS0, …
- Create file descriptors 0, 1, and 2
- Show the "login:" prompt
- When a user provides his/her username, invoke the "/bin/login" program
  - execle("/bin/login", "login", "-p", username, (char *)0, envp);

The getty Program (Cont'd)



The login Program

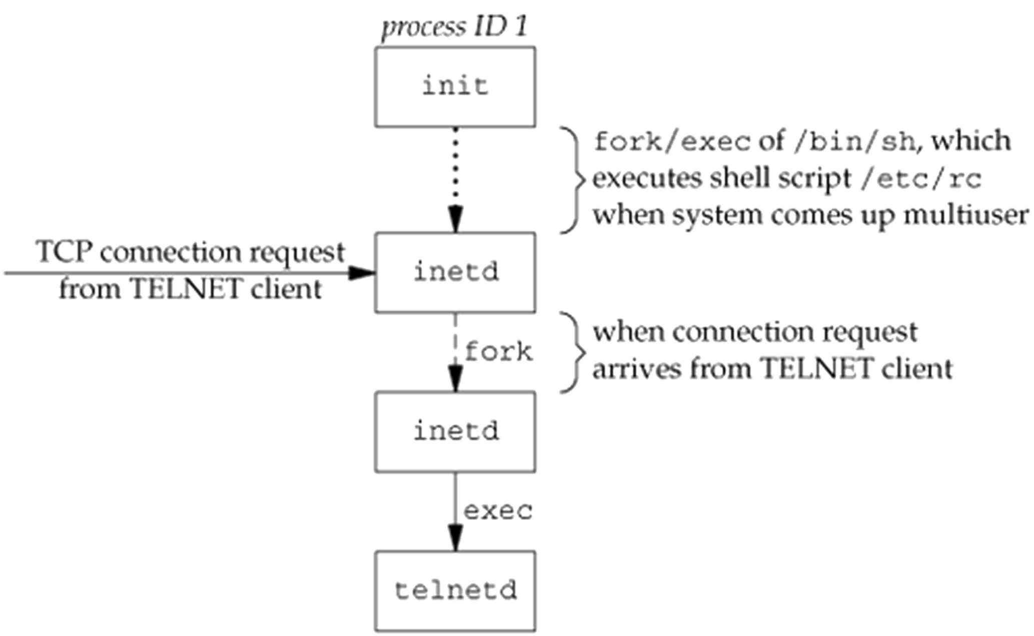
- Display the "Password:" prompt
  - Read user password using getpass(3)
  - Read encrypted password, e.g., from /etc/shadow
  - Encrypt user input password, and compare the encrypted with that stored in /etc/shadow
- If a user login fails …
  - The login program terminates and the init restarts getty
- If a user login succeeds …
  - There are a lot tasks to be performed

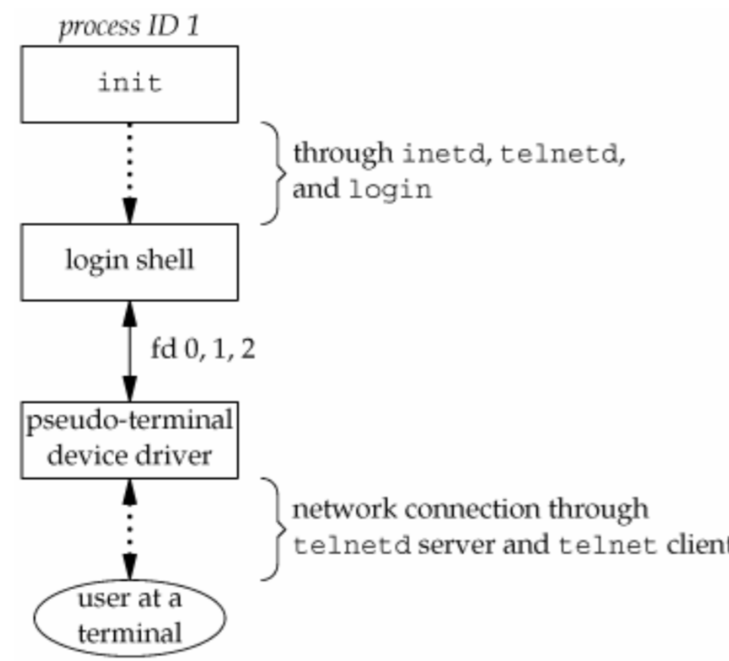
Actions for a Successful Login

- Set CWD to the user's home directory (chdir)
- Set the ownership of the user's terminal device (chown)
- Set the access permissions for the terminal device so the user have permission to read from and write to it
- Set group IDs by calling setgid (real group) and initgroups (for supplementary groups)
- Initialize the environment variables
  - HOME, SHELL, USER, LOGNAME, PATH, …
- Set user ID (setuid) and invoke a login shell

Network Logins – via the telnetd Program

inetd: Internet Superserver





The telnetd Program

- Opens a pseudo-terminal device
  - /dev/pts/N
- Splits into two processes using fork
- The parent handles the communications across the network connection
- The child does an exec of the login program – it is the same as terminal logins
- Whether we log in through a terminal or a network connection …
  - We have a login shell
  - Its standard input/output/error are connected to either a terminal device or a pseudo-terminal device

The Purpose of Process Group

- Every process has a parent process
- The parent is notified when its child terminates
- The parent can obtain the child's exit status
  - The waitpid function
  - In addition to wait a single child, the parent process can wait children in a *process group*
  - Signals (covered in the next chapter) can be also sent to processes in a process group
- So, what is a process group?

What is a Process Group

- Each process belongs to a process group
- A process group is a collection of one or more processes
  - Usually associated with the same job
- Each process group has a unique process group ID
- Process group IDs are similar to process IDs
  - They can be stored in a pid_t data type
- Retrieve of the process group ID
  - `#include <unistd.h>`
  - `pid_t getpgid(pid_t pid);`
  - `pid_t getpgrp(void);`
    - Is equivalent to `getpgid(0);`

What is a Process Group (Cont'd)

- Each process group *can* have a process group leader
  - The leader is identified by its process group ID being equal to its process ID
  - A group leader can create a group, create processes in the group, and then quit
  - The process group still exists, as long as at least one process is in the group
- The process group lifetime
  - Start on the creation of the group
  - End when the last process in the group leaves

Create/Join a Process Group

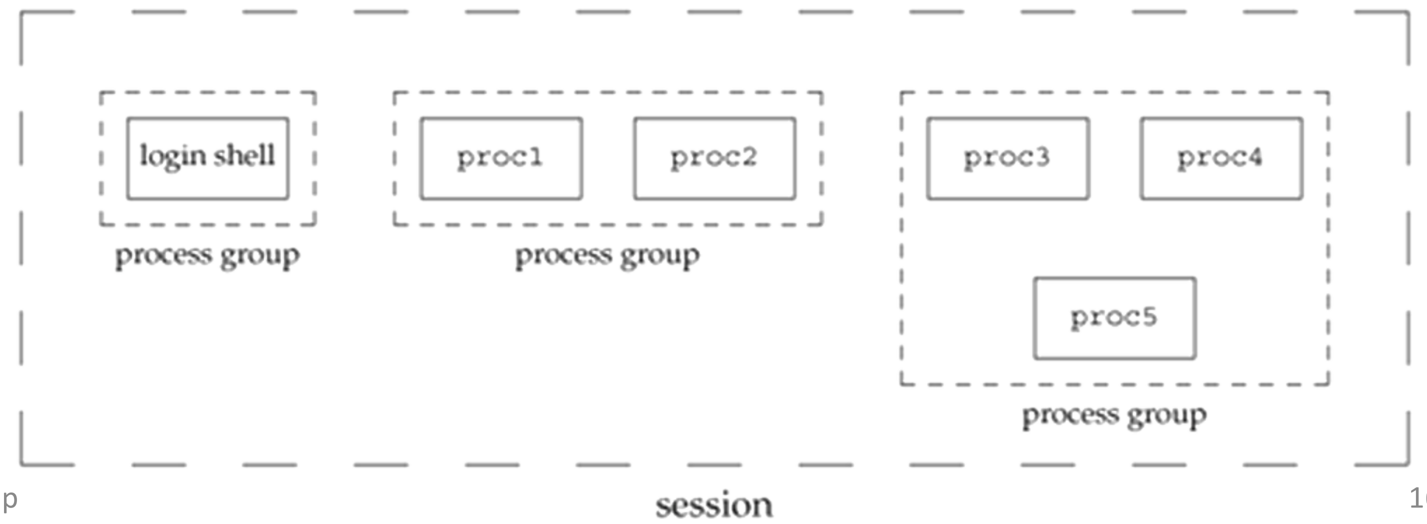
- Synopsis
  - `#include <unistd.h>`
  - `int setpgid(pid_t pid, pid_t pgid);`
- Explanations
  - Sets the process group ID to pgid in the process whose process ID equals pid
  - If pid = pgid, the process specified by pid becomes a process group leader
  - If pid is 0, the process ID of the caller is used
  - If pgid is 0, pgid = pid

Create/Join a Process Group (Cont'd)

- setpgid Limitations
  - A process can set the process group ID of only itself and any of its children
  - Furthermore, it can not change the process group ID of one of its children after that child has called one of the exec functions.
- The use of setpgid function
  - It is called after a fork to have the parent set the process group ID of the child, and
  - Have the child set its own process group ID
  - The above two actions are redundant, but they guaranteed that the child is placed into its own process group ← to avoid race conditions

Sessions

- A session is a collection of one or more process groups
- The processes in a process group are usually placed there by a shell pipeline
- An example
  - $ proc1 | proc2 &
  - $ proc3 | proc4 | proc5 &



Create a Session

- Synopsis
  - pid_t setsid(void);
  - Returns pgid or -1 if the caller is already a process group leader
- If the calling process is not a process group leader, this function creates a new session
  - The process becomes the session leader of this new session
  - The process is the only process in this new session
  - The process becomes the process group leader of a new process group.
  - The new process group ID is the process ID of the calling process
  - The process has no *controlling terminal*

Get the Current Session ID

- Synopsis
  - pid_t getsid(pid_t pid);
  - Returns the session leader’s process group ID, or -1 on error
  - If pid is 0, getsid returns the process group ID of the calling process's session leader
- The session ID is the process ID of the session leader
- When a user logged in, the session leader is usually the shell

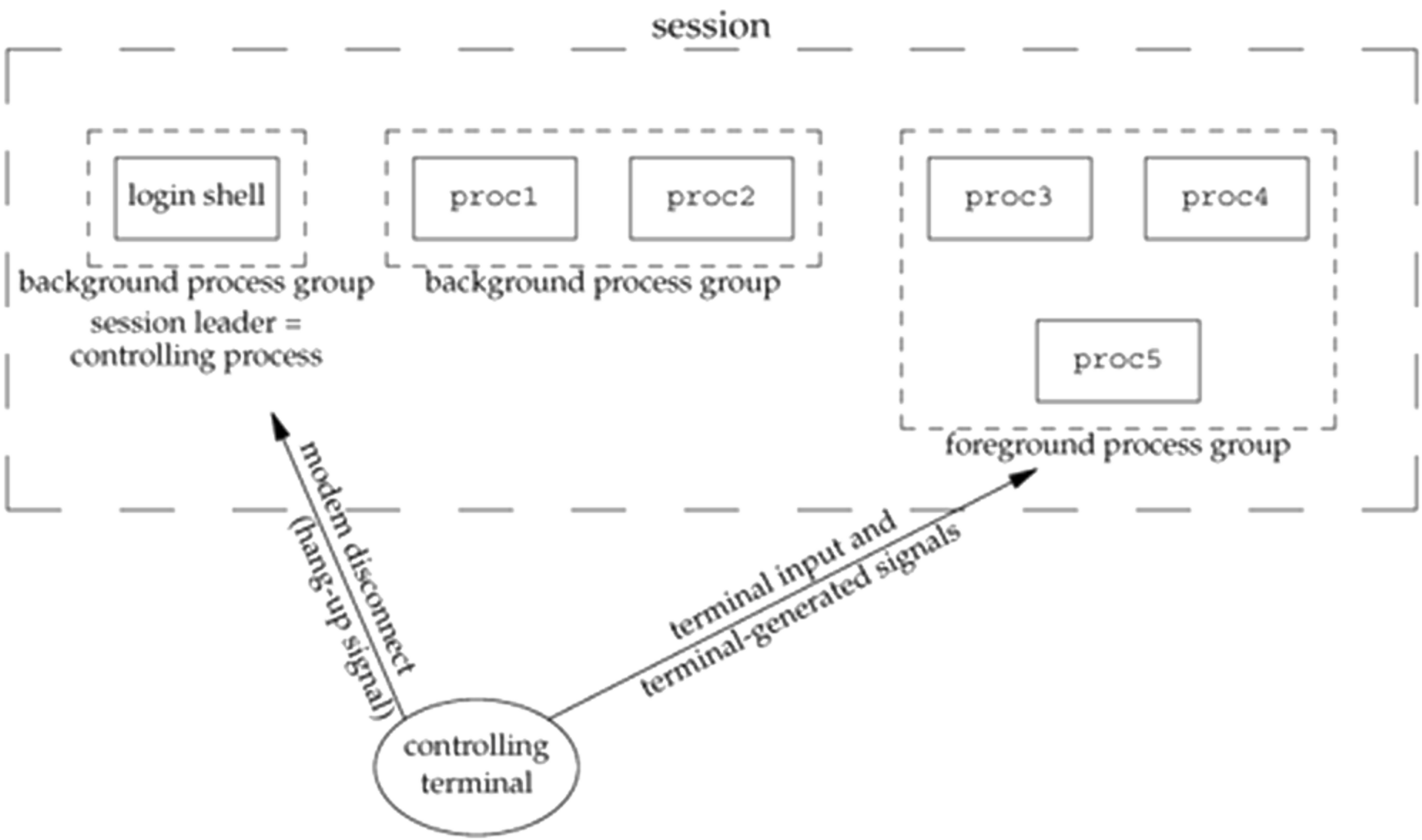
Controlling Terminal (1/3)

- A session can have a single controlling terminal
  - It is usually a terminal device or a pseudo-terminal device
- The session leader that establishes the connection to the controlling terminal is called the controlling process
- The process groups within a session can be divided into:
  - A single foreground process group, and
  - One or more background process groups
- If a session has a controlling terminal,
  - It has a single foreground process group, and
  - All other process groups in the session are background process groups

Controlling Terminal (2/3)

- User control keys
  - Send signals to all processes in the foreground process group
  - Interrupt key (often Ctrl-C): Send SIGINT
  - Quit key (often Ctrl-Backspace): Send SIGQUIT
- If a network disconnect is detected by the terminal interface, the SIGHUP is sent to the controlling process (the session leader)

Controlling Terminal (3/3)



Whom to Send Signals?

- How does the terminal device know the foreground process group?
- It can be set using the tcgetpgrp and tcsetpgrp functions
- Synopsis
  - `pid_t tcgetpgrp(int filedes);`
  - `int tcsetpgrp(int filedes, pid_t pgrpid);`
- It can be only set by the controlling process, who knows the descriptor of the controlling terminal
- Most applications don't call these two functions directly
- They are normally called by job-control shells

Direct Access to the Controlling Terminal

- Usually, a controlling terminal is established automatically when we log in
- There are times a program wants to talk to the controlling terminal directly
  - For example, ask a user to input his/her password from the terminal even if the standard input or standard output is redirected
- This can be done by opening the file /dev/tty
  - This special file is a synonym within the kernel for the controlling terminal
  - If the program doesn't have a controlling terminal, the open of this device will fail

Direct Access to the Controlling Terminal, an Example

```
#include <unistd.h>
#include <stdio.h>
int main() {
    FILE *fp;
    if((fp = fopen("/dev/tty", "w")) == NULL) {
        fprintf(stdout, "cannot open the controlling terminal.\n");
        return(-1);
    }
    fprintf(fp, "write to /dev/tty\n");
    fprintf(stdout, "write to stdout\n");
    return(0);
}
```

```
$ ./a.out
write to /dev/tty
write to stdout
$ ./a.out > xxx
write to /dev/tty
$ cat xxx
write to stdout
```

- Another example: getpass.c
  - Read password from a user without ECHO

Job Control

- This feature allows us to start multiple jobs from a single terminal
- Control which jobs can access the terminal and which jobs are to run in the background
- Job control requires three forms of support
  - A shell that supports job control
  - The terminal driver in the kernel must support job control
  - The kernel must support certain job-control signals
  - (and also applications….)

Job Control (Cont'd)

- Start a job in background – the & operator

```
$ ps auxw | grep ps &
[1] 30554
$ bear 30553 0.0 0.0 2744 1016 pts/1 R 12:26 0:00 ps auxw
bear 30554 0.0 0.0 3240  812 pts/1 S 12:26 0:00 grep ps
```

(Just press enter)

```
[1]+  Done                    ps auxw | grep ps
```

- Stop a job running in foreground
  - A user can press Ctrl-Z to stop a running foreground job
  - The SIGTSTP is sent to all processes in the foreground process group

SIGTTIN and SIGTTOU

- Processes in the foreground process group is always able to read from and write to the terminal
- However, background processes is restricted to do so
- An example of reading from the terminal – received SIGTTIN

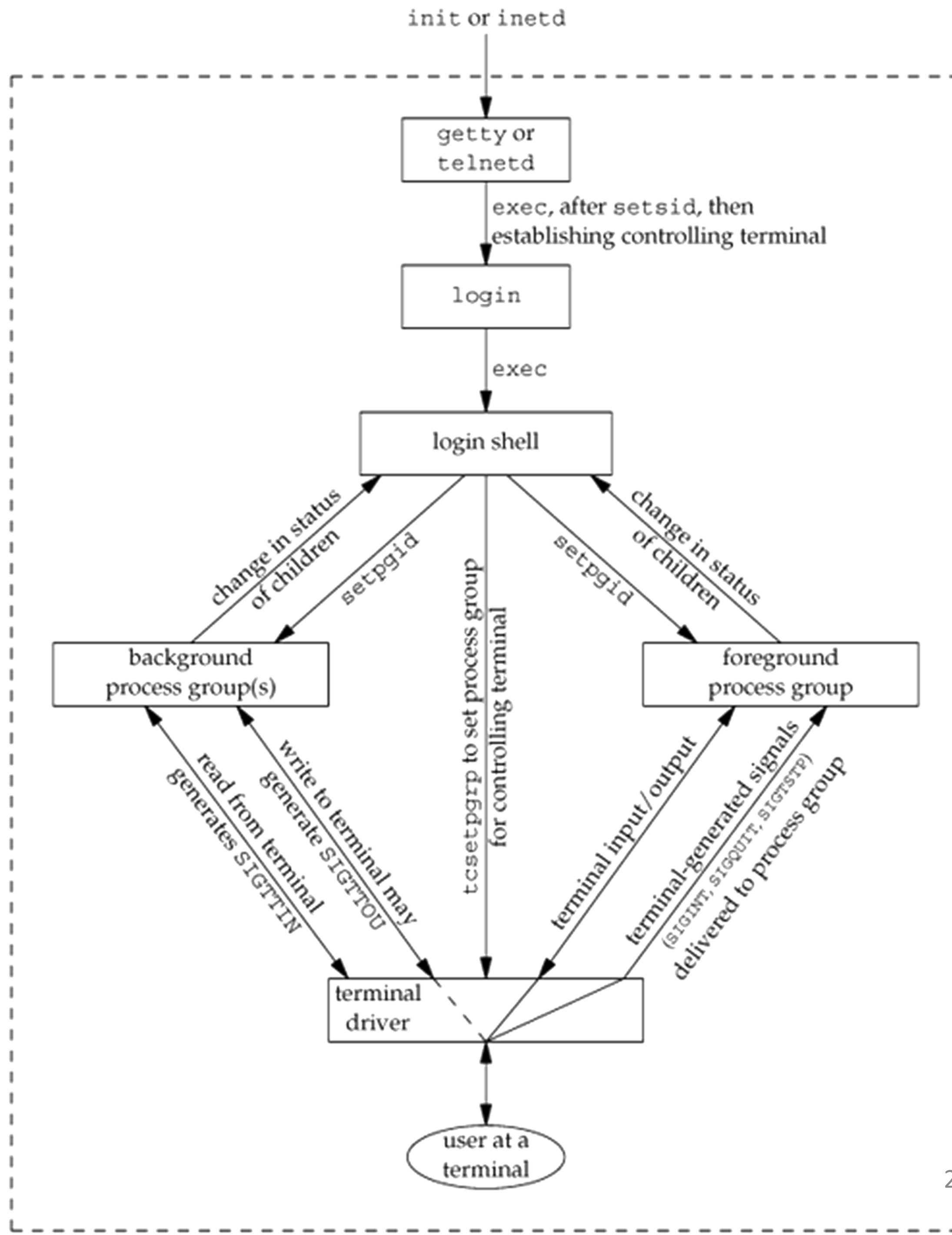
`$ cat > temp.foo &`	*start in background, but it'll read from standard input*
`[1] 1681`	
`$`	*we press RETURN*
`[1] + Stopped cat > temp.foo`	
`$ fg %1`	*bring job number 1 into the foreground*
`cat > temp.foo`	*the shell tells us which job is now in the foreground*
`hello, world`	*enter one line*
`^D`	*type the end-of-file character*
`$ cat temp.foo`	*check that the one line was put into the file*
`hello, world`	

SIGTTIN and SIGTTOU (Cont'd)

- An example of reading from the terminal – received SIGTTOU

`$ cat temp.foo &`	*execute in background*
`[1] 1719`	
`$ hello, world`	*the output from the background job appears after the prompt*
	we press RETURN
`[1] + Done cat temp.foo`	
`$ stty tostop`	*disable ability of background jobs to output to the controlling terminal*
`$ cat temp.foo &`	*try it again in the background*
`[1] 1721`	
`$`	*we press RETURN and find the job is stopped*
`[1] + Stopped(SIGTTOU) cat temp.foo`	
`$ fg %1`	*resume stopped job in the foreground*
`cat temp.foo`	*the shell tells us which job is now in the foreground*
`hello, world`	*and here is its output*

Summary of Job Control Features



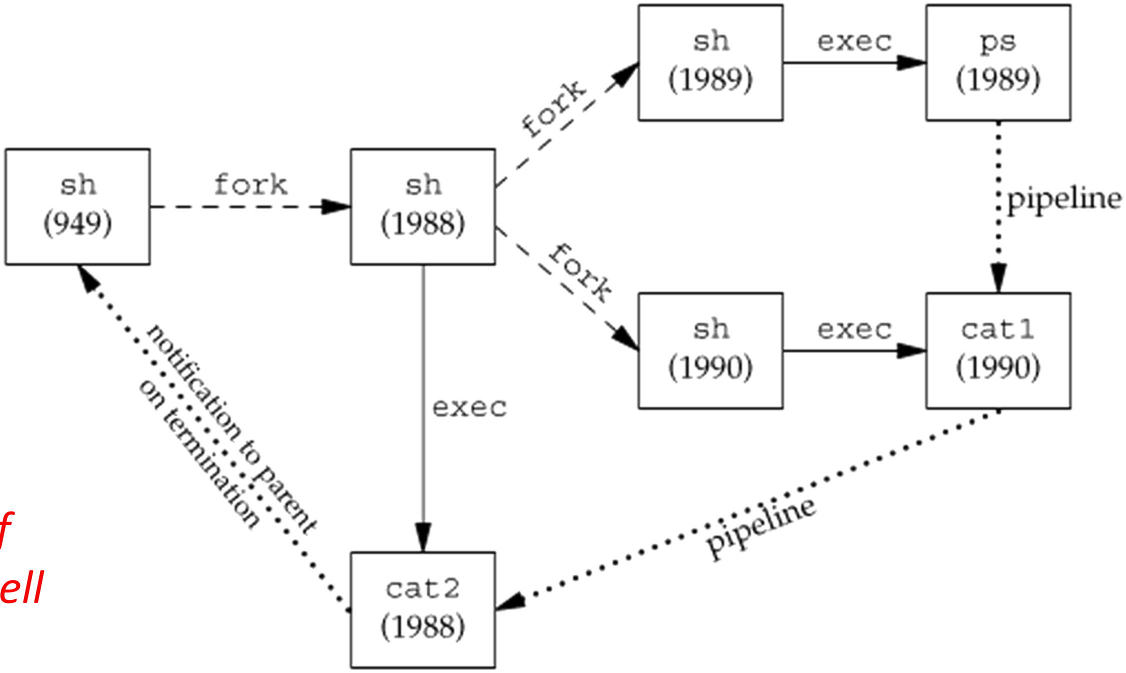
Shell Execution of Programs

- $ ps -o pid,ppid,pgid,sid,comm

```
 PID PPID PGID SID COMMAND
 949  947  949 949 sh
1774  949  949 949 ps
```

- $ ps -o pid,ppid,pgid,sid,comm | cat1 | cat2

```
 PID PPID PGID SID COMMAND
 949  947  949 949 sh
1988  949  949 949 cat2
1989 1988  949 949 ps
1990 1988  949 949 cat1
```



**** This example comes from the textbook and it might be different if you are working with a different shell*

Shell Execution of Programs (Cont'd)

- On Ubuntu 16.04
- $ ps -o pid,ppid,pgid,sid,comm

```
  PID  PPID  PGID   SID COMMAND
19064 19060 19064 19064 bash
19237 19064 19237 19064 ps
```

- $ ps -o pid,ppid,pgid,sid,comm | cat1 | cat2

```
  PID  PPID  PGID   SID COMMAND
19064 19060 19064 19064 bash
19238 19064 19238 19064 ps
19239 19064 19238 19064 cat1
19240 19064 19238 19064 cat2
```

Orphaned Process Groups

- A process whose parent terminates is called an orphan and is inherited by the init process
- A entire process group can be orphaned
- Definition of an orphaned process group
  - A process group is orphaned if the parent process of every member is either a member of the group or not a member of the group's session
  - In contrast, a process group is not orphaned if a process in the group has a parent in a different process group but in the same session
- If a process group becomes orphaned
  - Every stopped process in the group is sent the SIGHUP followed by the SIGCONT
  - The default action on receipt of a SIGHUP is to terminate the process

Orphaned Process Group, an Example

```
main(void) {
    char    c;
    pid_t   pid;
    pr_ids("parent");                       /* parent: pid, ppid, pgrp, and tpgrp */
    if ((pid = fork()) < 0) { err_sys("fork error"); }
    else if (pid > 0) {                     /* parent */
        sleep(5);                           /* sleep to let child stop itself */
        exit(0);                            /* then parent exits */
    } else {                                /* child */
        pr_ids("child");                    /* child: pid, ppid, pgrp, and tpgrp */
        signal(SIGHUP, sig_hup);            /* establish signal handler */
        kill(getpid(), SIGTSTP);            /* stop ourself */
        pr_ids("child");                    /* prints only if we're continued */
        if (read(STDIN_FILENO, &c, 1) != 1)
           printf("read error from controlling TTY, errno = %d\n",
               errno);
        exit(0);
    }
}
```

Orphaned Process Group, an Example (Cont'd)

```
$ ./fig9.11-orphan3
parent: pid = 6099, ppid = 2837, pgrp = 6099, tpgrp = 6099
child: pid = 6100, ppid = 6099, pgrp = 6099, tpgrp = 6099
(sleep for 5 seconds)
SIGHUP received, pid = 6100
child: pid = 6100, ppid = 1, pgrp = 6099, tpgrp = 2837
read error from controlling TTY, errno = 5
```

- The parent and the child prints out their own information
- The parent then sleeps for 5 seconds
- The child stopped itself
- When the parent terminates, the child received SIGHUP and SIGCONT
  - Since the child has assigned the SIGHUP handler, it is not terminated
  - The child is now in background, so read from TTY got the EIO error

Assignment

No assignment this time.

The points will be merged with the next Chapter’s assignment!