Process Relationship

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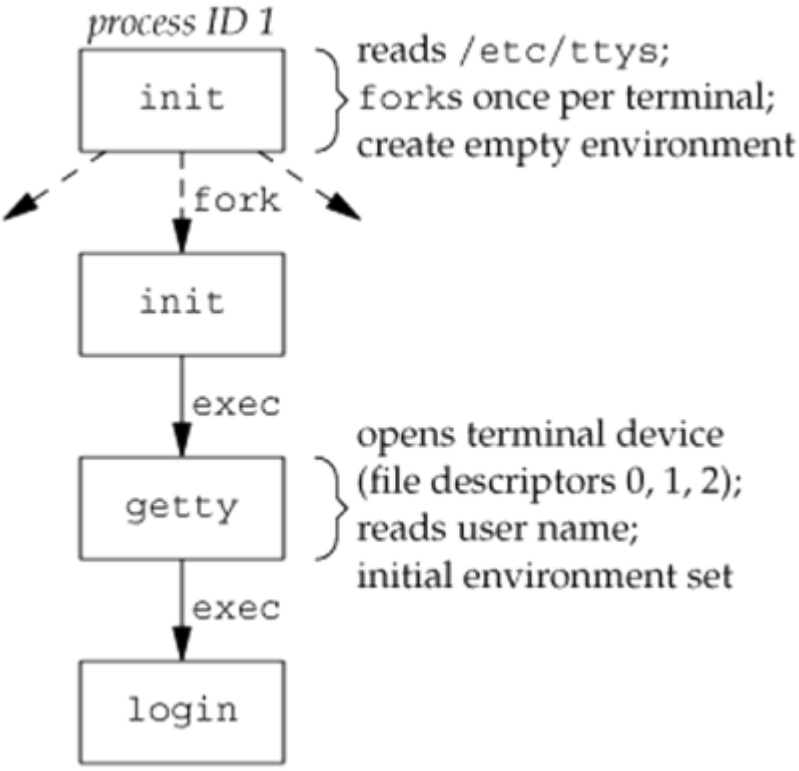
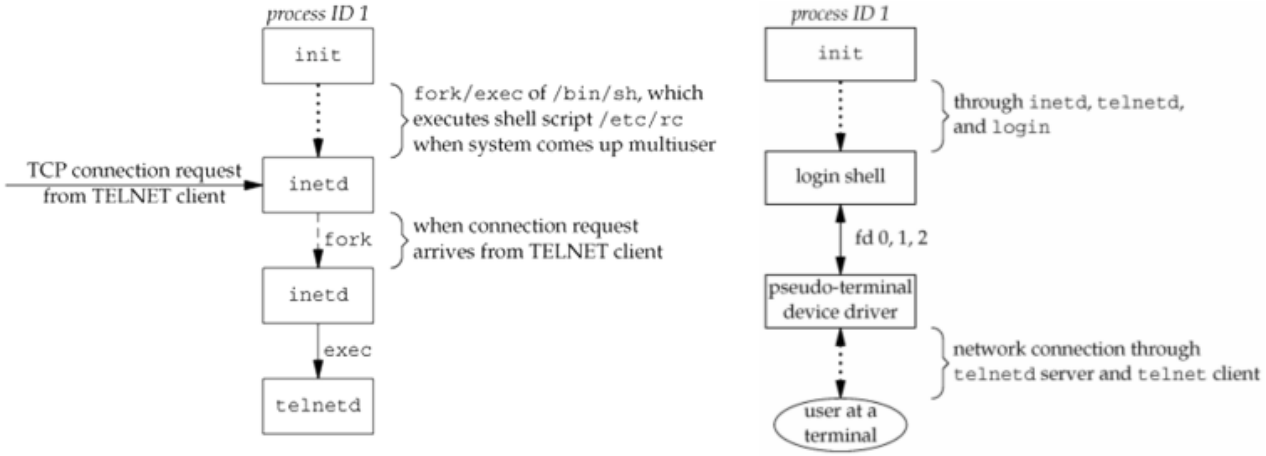
Login

- Linux Booting Process
  - first process: `/sbin/init`
    - PID is 1
    - configurations: `/etc/inittab`, `/etc/event.d/*`, or `/etc/init/*`
  - run levels
    - 0: halted
    - 6: reboot
    - 1 to 5 can be customized
      - default run level often set to 2, 3 or 5
  - enable console logs
- Linux Terminal Logins (e.g. Ubuntu)
  - start 6 consoles terminals for login
  - can be switched by Alt + F1 to F6
  - `getty` program
    - call open for `/dev/tty1`, `/dev/ttyS0`, ...
    - create file descriptor 0, 1 and 2
    - show login prompt
    - when user provide name, invoke `/bin/login` program
      - `execle("/bin/login", "login", "-p", username, (char *)0, envp);`
  - `login` program
    - display `Password` prompt
    - read password by `getpass(3)`
    - read encrypted password
    - encrypt input and compare password
    - if fails, the program terminates and `init` restart `getty`
  - after successful `login`

    - `chdir` to user's home directory
    - `chown` the terminal device owner to user
    - set the access permissions for the terminal device
    - `setgid` set group IDs
    - `initgroups` initialize the supplementary group access list
    - initialize the environment variables
    - `setuid` set user ID and invoke a login shell



- Network Logins – via the `telnetd` Program
    - open a pseudo-terminal device
        - `/dev/pts/N`
    - splits into two processes using fork
        - parent handles the communication across the network connection
        - child does an exec of the login program
    - whether we log in through a terminal or a network connection ...
        - we have a login shell
        - std in/out/err are connected to either a terminal device or a pseudo-terminal device



Process Groups

- Definition
  - a collection of one or more processes, usually same jobs
- Properties
  - parent process can wait children in a process group
  - signals can be sent to processes in a process group
- `getpgid(2)`: `pid_t getpgid(pid_t pid);`
- `getpgrp(2)`: `pid_t getpgrp(void);` = `getpgid(0)`
- Group Leader
  - leader process group ID equals its process ID
  - leader can create a group, create processes in the group, and then quit
- Process Group Lifetime
  - start on the creation of the group
  - end when the last process in the group leaves
- Create/Join a Process Group
  - `setpgid(2)`: `int setpgid(pid_t pid, pid_t pgid);`
    - set process group ID of process `pid` to `pgid`
    - if `pid` equals `pgid`, then process `pid` becomes leader
    - if `pid` equals 0, then `pid` is replaced by the caller `pid`
    - if `pgid` equals 0, then `pgid` is replace by the value `pid`
  - `setpgid` limitations
    - process can only perform `setpgid` to itself or its children
    - process can not perform `setpgid` after its child calls `exec`
  - use of `setpgid` function
    - called after `fork`, parent sets child process group ID
    - child sets its own process group ID
    - above two actions are redundant, but they guaranteed that the child is placed into its own process group

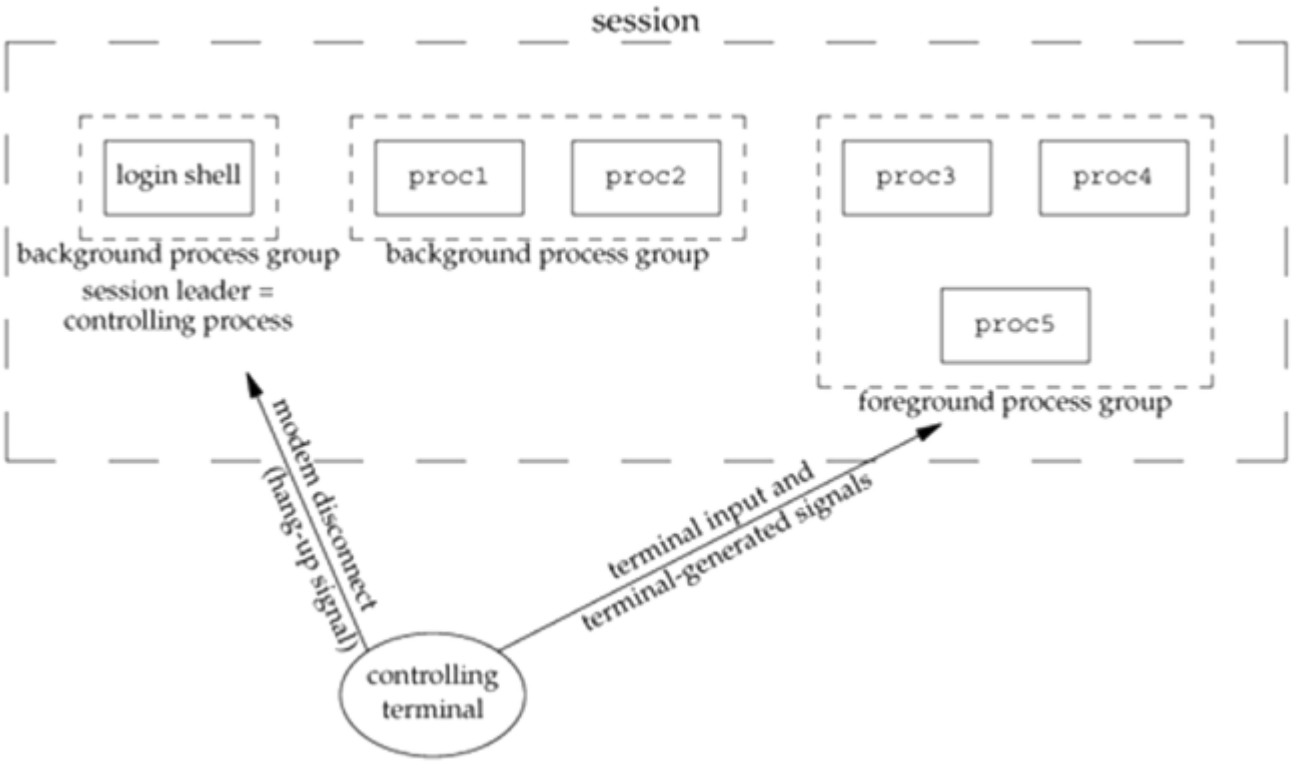
Sessions

- Definition
  - a collection of one or more process groups
  - pipes are used to generate process group

        - `$ prog1 | prog2 | prog3`
        - these three programs are in the same process group
- Create a Session
    - `setsid(2)`: `pid_t setsid(void);`
    - return: `pgid` or -1 if caller is process group leader
    - if the process is not a process group leader, the function creates a new session
        - the process becomes session leader
        - the process is the only process in the 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 Current Session ID
    - `getsid(2)`: `pid_t getsid(pid_t pid);`
    - return: the session leader's process group ID, -1 on error
    - if `pid` is 0, `pid` is replaced by caller process ID
- when user login, the session leader is usually the shell

Controlling Terminal

- a session can have a single controlling terminal
    - terminal device or 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
    - one or more background process groups
- if a session has a controlling terminal
    - it has a single foreground process group
    - all other process groups in the session are background process groups
- 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



- Whom to Send Signals
  - `tcgetpgrp(3)`: `pid_t tcgetpgrp(int fd);`
    - get terminal foreground process group
  - `tcsetpgrp(3)`: `int tcsetpgrp(int fd, pid_t pgrp);`
    - only set by controlling process
  - most applications don't call above two functions
    - normally called by job-control shells
- Direct Access to the Controlling Terminal
  - even stdin or stdout is redirected
  - this can be done by open file `/dev/tty`
    - synonym within the kernel for the controlling terminal
    - the program must have a controlling terminal, otherwise open will fail

Job Control

- start multiple jobs from a single terminal
- requirements
  - a shell that supports job control
  - the terminal driver in the kernel must support job control
  - the kernel must support certain job-control signals
- start a job in background: `&` operator
- stop job running in foreground
  - Ctrl + z
  - `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
  - but background process is restricted to do so
  - signal will send to the background process

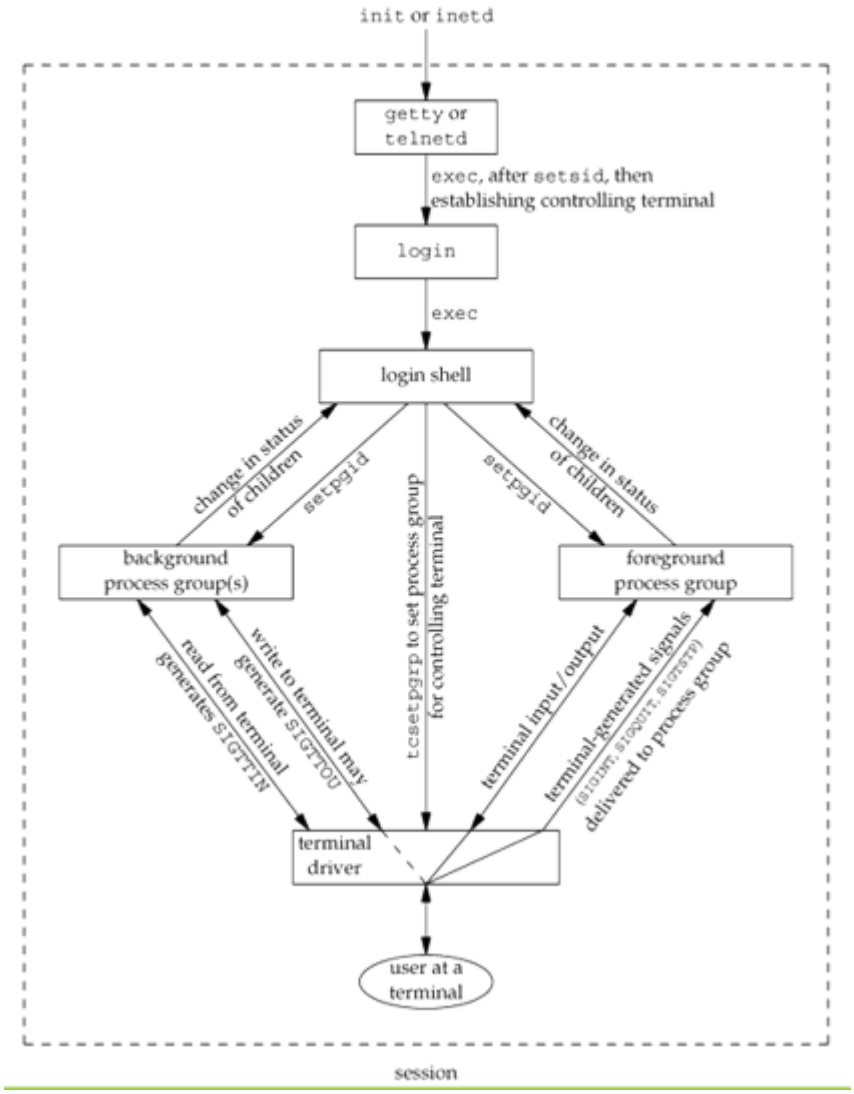
- SIGTTIN: signal of reading from terminal

```
$ 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
```

- SIGTTOU: signal of writing to terminal

```
$ 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
```

- job control summary



Shell Execution of Programs

- `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
```

Orphaned Process Groups

- Definition
    - the parent process of every member is either
        1. a member of the group or
        2. not a member of the group's session
- In contrast, 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

- Example

```
int main() {
  char c;
  pid_t pid;
  pr_ids("parent");
  if ((pid = fork()) < 0) {
    err_sys("fork error");
  } else if (pid > 0) {
    sleep(5);
  } else {
    pr_ids("child");
    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 %d on controlling TTY\n", errno);
  }
  exit(0);
}
```

```
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
```

1. the parent and the child prints out their own information
2. the parent then sleeps for 5 seconds
3. the child stopped itself
4. when the parent terminates, the child received `SIGHUP` and `SIGCONT`
5. since the child has assigned the `SIGHUP` handler, it is not terminated
6. the child is now in background, so read from TTY got the `EIO` error