Chapter 6
System Data Files and Information

Cheng-Hsin Hsu

National Tsing Hua University

Department of Computer Science

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Outline

- Overview
- Password
- Group
- Accounting
- System Identification
- Time and Date Routines

Overview

- A UNIX system requires numerous data files for normal operation
  - Password file: /etc/passwd
  - Group file: /etc/group
  - Many other system configuration files are placed in /etc as well
- These data files are usually ASCII text files, and can be accessed with standard I/O library
- A number of portable interfaces to these files are also provided for application programs
  - Developers does not need to handle the underlying design and implementations
  - Increase the program portability

Who Am I?

- The `id` program

```
$ id
uid=1000(chuang) gid=1000(chuang)  groups=4(adm), 20(dialout),
24(cdrom), 46(plugdev), 108(lpadmin), 123(admin),
124(sambashare), 1000(chuang)
```

The /etc/passwd File

Description	struct passwd member	POSIX.1	FreeBSD 8.0	Linux 3.2	Mac OS X 10.6.8	Solaris 10
User name	`char *pw_name`	•	•	•	•	•
Encrypted password	`char *pw_passwd`		•	•	•	•
Numerical user ID	`uid_t pw_uid`	•	•	•	•	•
Numerical group ID	`gid_t pw_gid`	•	•	•	•	•
Comment field	`char *pw_gecos`		•	•	•	•
Initial working dir	`char *pw_dir`	•	•	•	•	•
Initial shell	`char *pw_shell`	•	•	•	•	•
User access class	`char *pw_class`		•		•	
Next time to change password	`time_t pw_change`		•		•	
Account expiration time	`time_t pw_expire`		•		•	

The /etc/password File (Cont’d)

```
root:x:0:0:root:/root:/bin/bash squid:x:
23:23::/var/spool/squid:/dev/null nobody:x:
65534:65534:Nobody:/home:/bin/sh sar:x:
205:105:Stephen Rago:/home/sar:/bin/bash
```

- A simple example from Linux system
- Password fields are separated by colons (:)
- Fields can be empty
- Many UNIX services have their own user id and group id
- The shell is the first process that a user logs in
  - Use something like /dev/null or /bin/false to prevent users from logging into the system
- Valid shells (for users to choose from) are listed in /etc/shells

The finger Command

- Read user information from password database
- finger command may be not available in your system
- You can still read passwd files to obtain the information

```
sar:x:205:105:Steve Rago, SF 5-121, 555-1111, 555-2222:/home/sar:/bin/sh
```

```
$ finger -p sar
Login: sar           Name: Steve Rago
Directory: /home/sar     Shell: /bin/sh
Office: SF 5-121, 555-1111  Home Phone: 555-2222
On since Mon Jan 19 03:57 (EST) on ttyv0 (messages off) No Mail.
```

Functions to Retrieve Password Info.

- Get password information for a specific user

```
#include <pwd.h>
struct passwd *getpwuid(uid_t uid);
struct passwd *getpwnam(const char *name);
```

- Iteratively retrieve all password information

```
#include <pwd.h>
struct passwd *getpwent(void);
void setpwent(void);      // rewind
void endpwent(void);      // close the password file
```

User and Shadow Passwords

- Historically, encrypted passwords are stored in /etc/passwd file
- But modern UNIX systems move the encrypted password into another secret file, which is only readable by system administrators
  - FreeBSD: /etc/master.passwd
  - Linux: /etc/shadow
- Only a few programs need to access encrypted passwords, for example, login(1) and passwd(1)
- There is not a shadow structure for FreeBSD and Mac OS X

Linux's Shadow Structure

```
#include <shadow.h>
struct spwd *getspnam(const char *name);
struct spwd *getspent(void);
void setspent(void);
void endspent(void);
```

Description	struct spwd member
User login name	`char *sp_namp`
Encrypted password	`char *sp_pwdp`
Date of last password change (Days since Epoch)	`long sp_lastchg`
Min # of days between changes	`long sp_min`
Max # of days between changes	`long sp_max`
# of days before password expires to warn user to change it	`long sp_warn`
# of days after password expires until account is disabled	`long sp_inact`
Date when account expires (Days since Epoch)	`long sp_expire`
Reserved	`long sp_flag`

Example: Linux Username and Password

- Files
  - /etc/passwd and /etc/shadow

```
root:x:0:0:root:/root:/bin/bash
bear:x:1000:1000:Cheng-Hsin Hsu,,,:/home/bear:/bin/bash
```

```
root:!:14265:0:99999:7:::
bear:$6$TwU0GSrB$x3tYfrE3E.sB3Tfpqrsffp1WP.to4x.sqHUuCkcDaw/
L8.bgmJrnyLDVg9L1dP6kM2hzHujhHGZo5w7zQU.qz1:17056:0:99999:7:::
```

More on User Passwords

```
root:!:14265:0:99999:7:::
bear:$6$TwU0GSrB$x3tYfrE3E.sB3Tfpqrsffp1WP.to4x.sqHUuCkcDaw/
L8.bgmJrnyLDVg9L1dP6kM2hzHujhHGZo5w7zQU.qz1:17056:0:99999:7:::c
huang:$1$.oJz4T5J$XmVX77WOdYDHxyvTEcaLc1:14265:0:99999:7:::
```

- Passwords are *encrypted*, see `crypt(3)`
- Binary data are converted to ASCII texts
  - Each byte represents 6-bit data
  - `const char map[] = "ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz0123456789./";`
- Salt + Encrypted password
- Algorithm id + Salt + Encrypted password
- Common password algorithms
  - DES, MD5, SHA256, SHA512

Example: Password Algorithms

- The password is 'hello'
- DES: enc(salt, key = password):
  - 56-bit key, 64-bit input, 64-bit output (11 bytes)
  - mOeHQ3re1ro8s
- MD5: hash(salt, password)
  - 128-bit output (22 bytes)
  - $1$l8g4a5kf$.92G5ZJvtDF/.WJbM.ef31
- SHA256: hash(salt, password)
  - 256-bit output (43 bytes)
  - $5$aKM2MaGt$NmJnlxu8kup8jlg5SxJPBDhmFLH50nwQATB/
    72zVuH5
- SHA512: hash(salt, password)
  - 512-bit output (86 bytes)
  - $6$CaP7vQ/f$Puo5/
    OmR7P21D0BvqEl5ZW4bqW4wPNKBGhj.kTUSwcfqj18wMdl36h2sm
    X0ZUaT6buYKSeXhw13RR6oBpIfZv0

The crypt(3) Function

- The built-in password encryption function

```
#include <unistd.h>
char *crypt(const char *key, const char *salt);
```

- Your program may have to link with the crypt library (`-lcrypt`)

```
printf("%s\n", crypt("password", "ab"));
printf("%s\n", crypt("password", "$1$abcdefgh$"));
printf("%s\n", crypt("password", "$5$abcdefgh$"));
printf("%s\n", crypt("password", "$6$abcdefgh$"));
```

The /etc/group File

Description	struct group member	POSIX.1	FreeBSD 8.0	Linux 3.2	Mac OS X 10.6.8	Solaris 10
Group name	`char *gr_name`	●	●	●	●	●
Encrypted password	`char *gr_passwd`		●	●	●	●
Numerical group ID	`gid_t gr_gid`	●	●	●	●	●
Array of pointers to individual user names	`char **gr_mem`	●	●	●	●	●

- An example: /etc/group

```
adm:x:4:bear
dialout:x:20:bear
cdrom:x:24:bear
plugdev:x:46:bear
lpadmin:x:108:bear
admin:x:123:bear
bear:1000:bear
sambashare:x:124:bear
```

Functions to Retrieve Group Information

- Get group information for a specific group

```
#include <grp.h>
struct group *getgrgid(gid_t gid);
struct group *getgrnam(const char *name);
```

- Iteratively retrieve all group information

```
#include <grp.h>
struct group *getgrent(void);
void setgrent(void);     // rewind
void endgrent(void);     // close the group file
```

Supplement Group IDs

- In the past, a UNIX user is belong to a single group at any time
- Use the `newgrp(1)` command to switch between allowed groups
  - Change the current effective GID
- Later we have the concept of "supplement group IDs"
  - A user has a default group ID (given in the /etc/passwd file)
  - A user is also belong to a number of additional groups – the supplement group IDs
  - The permission check are performed based on all the group IDs that the user belongs to
  - The number of additional groups has a limit (`NGROUPS_MAX`), and a common value is 16

Group Setup Functions

- Standard POSIX.1 functions

```
#include <unistd.h>
int getgroups(int gidsetsize, gid_t grouplist[]);
```

- Not in POSIX.1, but very common to most platforms
  - `initgroups(3)` setup gid and supplement group IDs for a user based on /etc/group
  - `setgroups(2)` setup supplement group IDs, usually called by `initgroups(3)`

```
#include <grp.h>    /* on Linux */
#include <unistd.h> /* on FreeBSD, Mac OS X, and Solaris */
int setgroups(int ngroups, const gid_t grouplist[]);

#include <grp.h>    /* on Linux and Solaris */
#include <unistd.h> /* on FreeBSD and Mac OS X */
int initgroups(const char *username, gid_t basegid);
```

Implementation Differences

Information	FreeBSD 8.0	Linux 3.2.0	Mac OS 10.6.8	Solaris 10
Account information	/etc/passwd	/etc/passwd	Directory Services	/etc/passwd
Encrypted passwords	/etc/master.passwd	/etc/shadow	Directory Services	/etc/shadow
Hashed password files?	yes	no	no	no
Group information	/etc/group	/etc/group	Directory Services	/etc/group

- The storage of users, groups, and passwords could be different on different platforms
- Some UNIX systems implements user and group database using network information service (NIS) or lightweight directory access protocol (LDAP)
  - You may have a look at /etc/nsswitch.conf

Other Data Files

- We have a number of other data files in the system
- They have similar lookup functions to passwords and groups

Description	Data file	Header	Structure	Lookup functions
passwords	`/etc/passwd`	`<pwd.h>`	`passwd`	`getpwnam, getpwuid`
groups	`/etc/group`	`<grp.h>`	`group`	`getgrnam, getgrgid`
shadow	`/etc/shadow`	`<shadow.h>`	`spwd`	`getspnam`
hosts	`/etc/hosts`	`<netdb.h>`	`hostent`	`gethostbyname, gethostbyaddr`
networks	`/etc/networks`	`<netdb.h>`	`netent`	`getnetbyname, getnetbyaddr`
protocols	`/etc/protocols`	`<netdb.h>`	`protoent`	`getprotobyname, getprotobynumber`
services	`/etc/services`	`<netdb.h>`	`servent`	`getservbyname, getservbyport`

Login Accounting

- utmp: Record the currently logged in users
- wtmp: Record the history of user login, logout, and system (up, down, or reboot) activities
- The format and the location of utmp and wtmp records are diverse
  - See utmp(5)
  - Parts of a utmp record (textbook example)

```
struct utmp {
    char ut_line[8]; /* tty line: "ttyh0", "ttyd0", "ttyp0", ... */
    char ut_user[8]; /* login name */
    long ut_time;    /* seconds since Epoch */
};
```

- Relevant commands
  - `w(1)` and `who(1)`
  - `last(1)`

System Identification

- The uname function

```
#include <sys/utsname.h>
int uname(struct utsname *name);
```

- The utsname structure

```
struct utsname {
    char sysname[];  /* name of the operating system */
    char nodename[]; /* name of this node */
    char release[];  /* current release of operating system */
    char version[];  /* current version of this release */
    char machine[];  /* name of hardware type */
};
```

System Identification

- The uname command
  - System
  - Node
  - Release
  - Version
  - Machine
  - Processor
  - Hardware platform
  - Operating system

```
$ uname -a
Linux ubuntu-vm 3.16.0-62-generic #83~14.04.1-Ubuntu SMP
Fri Feb 26 22:52:39 UTC 2016 x86_64 x86_64 x86_64 GNU/
Linux
```

Time and Date Routines

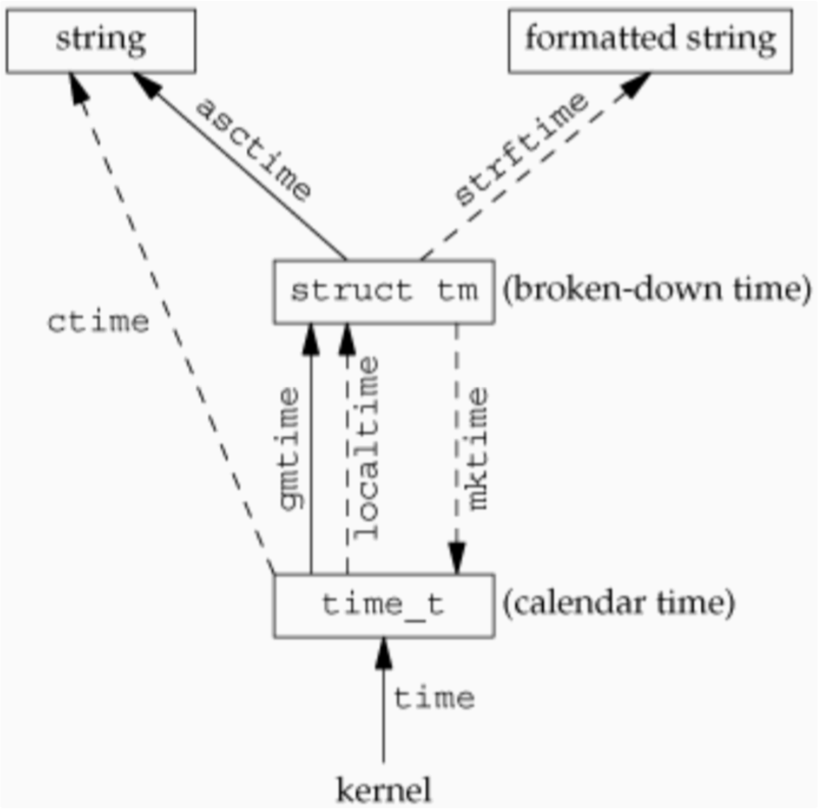
- We have introduced several time and date time routines
  - `time(2)` get current time, in the unit of seconds from Epoch
  - `gettimeofday(2)` get current time, in the unit of milliseconds from Epoch

```
#include <time.h>
time_t time(time_t *calptr);

#include <sys/time.h>
int gettimeofday(struct timeval *tv, struct timezone *tz);
```

Relationship between Time and Time Functions

- Blocks
  - Time format
- Solid arrows
  - Functions get time in UTC time zone
- Dashed arrows
  - Functions get time base on the TZ environment variable
  - Can be any customized time zone



The tm Structure (1/4)

- `gmtime(3)` and `localtime(3)` break down a `time_t` value into a structure
- `mktime(3)` does the reverse

```
struct tm {
    int tm_sec;         /* seconds */
    int tm_min;         /* minutes */
    int tm_hour;        /* hours */
    int tm_mday;        /* day of the month */
    int tm_mon;         /* month */
    int tm_year;        /* year */
    int tm_wday;        /* day of the week */
    int tm_yday;        /* day in the year */
    int tm_isdst;       /* daylight saving time */
};
```

The tm Structure (2/4)

- Break down time_t value

```
#include <time.h>
struct tm *gmtime(const time_t *calptr);
struct tm *gmtime_r(const time_t *calptr, struct *tm result);
struct tm *localtime(const time_t *calptr);
struct tm *localtime_r(const time_t *calptr, struct *tm result);
```

- Print out time in a string

```
#include <time.h>
char *asctime(const struct tm *tmptr);
char *asctime_r(const struct tm *tmptr, char *buf);
char *ctime(const time_t *calptr);
char *ctime_r(const time_t *calptr, char *buf);
```

- mktime

```
#include <time.h>
time_t mktime(struct tm *tmptr);
```

The tm Structure (3/4)

- Formatted output using `strftime(3)`

```
#include <time.h>
size_t strftime(char *buf, size_t maxsize, const char *format,
                const struct tm *tmptr);
```

- The format string

Fmt	Description	Example	Fmt	Description	Example
%a	Abbr. weekday name	Tue	%d	Day of the month	10
%A	Full weekday name	Tuesday	%D	Date [MM/DD/YY]	02/10/04
%b	Abbr. month name	Feb	%e	Day of month	10
%B	Full month name	February	%F	ISO 8601: YYYY-MM-DD	2004-02-10
%c	Date and time	Tue Feb 10 18:27:38 2004	%g	Last two digits of a year	04
%C	Year/100	20	%G	ISO 8601 year	2004
			%h	Same as %b	Feb

The tm Structure (4/4)

Fmt	Description	Example	Fmt	Description	Example
%H	Hour of the day (24-hr)	18	%u	ISO 8601 weekday: 1-7	2
%I	Hour of the day (12-hr)	06	%U	Sunday week number: 00-53	06
%j	Day of the year : 001-366	041	%V	ISO 8601 week number	07
%m	Month: 01-12	02	%w	Weekday: 0-6	2
%M	Minute: 00-59	27	%W	Monday week number: 0-53	06
%n	Newline character		%x	date	02/10/04
%p	AM/PM	PM	%X	time	18:27:38
%r	Locale’s time (12-hr)	06:27:38 PM	%y	Last two digits of a year	04
%R	Same as "%H:%M"	18:27	%Y	Year	2004
%S	Second: 00-60	38	%z	Offset from UTC	-0500
%t	Horizontal tab character		%Z	Time zone name	EST
%T	Same as "%H:%M:%S"	18:27:38	%%	Percent sign	%

Time Function Examples

- (times.c)

```
time_t t = time(0);
struct tm tm1, tm2;
char buf[256];

gmtime_r(&t, &tm1);
localtime_r(&t, &tm2);

printf("                 time: %ld\n", t);
printf("                ctime: %s", ctime_r(&t, buf));
printf("    gmtime -> asctime: %s", asctime(&tm1));
printf(" localtime -> asctime: %s", asctime(&tm2));
strftime(buf, sizeof(buf), "%c %Z (%z)", &tm1);
printf("   gmtime -> strftime: %s\n", buf);
strftime(buf, sizeof(buf), "%c %Z (%z)", &tm2);
printf("localtime -> strftime: %s\n", buf);
```

Running the Example

```
$ ./times
                 time: 1457769624
                ctime: Sat Mar 12 16:00:24 2016
    gmtime -> asctime: Sat Mar 12 08:00:24 2016
 localtime -> asctime: Sat Mar 12 16:00:24 2016
   gmtime -> strftime: Sat Mar 12 08:00:24 2016 GMT (+0000)
localtime -> strftime: Sat Mar 12 16:00:24 2016 CST (+0800)
```

Time Zone (1/3)

- The TZ environment variable
- Formats: from `tzset(3)`
- Standard:
  - `std offset`
  - Example: `CST-08:00:00, PST08:00:00, NSDT-13:00:00`
- Daylight saving time:
  - `std offset dst [offset],start[/time],end[/time]`
  - Example: `NZST-12:00:00NZDT-13:00:00,M10.1.0,M3.3.0`
- Predefined: files stored in `/usr/share/zoneinfo`
  - `:filename` (relative path to /usr/share/zoneinfo)
  - Example: `:Asia/Taipei, :America/Vancouver, :NZ`

Time Zone (2/3)

- The times.c example with time zone settings (New Zealand)

```
$ TZ=":NZ" ./times
                 time: 1457771092
                ctime: Sat Mar 12 21:24:52 2016
    gmtime -> asctime: Sat Mar 12 08:24:52 2016
 localtime -> asctime: Sat Mar 12 21:24:52 2016
   gmtime -> strftime: Sat Mar 12 08:24:52 2016 GMT (+0000)
localtime -> strftime: Sat Mar 12 21:24:52 2016 NZDT (+1300)


$ TZ="NZST-12:00:00NZDT-13:00:00,M10.1.0,M3.3.0" ./times
                 time: 1457771128
                ctime: Sat Mar 12 21:25:28 2016
    gmtime -> asctime: Sat Mar 12 08:25:28 2016
 localtime -> asctime: Sat Mar 12 21:25:28 2016
   gmtime -> strftime: Sat Mar 12 08:25:28 2016 GMT (+0000)
localtime -> strftime: Sat Mar 12 21:25:28 2016 NZDT (+1300)
```

Time Zone (3/3)

```
$ TZ="NSDT-13:00:00" ./times
                 time: 1457771162
                ctime: Sat Mar 12 21:26:02 2016
    gmtime -> asctime: Sat Mar 12 08:26:02 2016
 localtime -> asctime: Sat Mar 12 21:26:02 2016
   gmtime -> strftime: Sat Mar 12 08:26:02 2016 GMT (+0000)
localtime -> strftime: Sat Mar 12 21:26:02 2016 NSDT (+1300)
```

```
$ TZ="ABC-13:00:00" ./times
                 time: 1457771300
                ctime: Sat Mar 12 21:28:20 2016
    gmtime -> asctime: Sat Mar 12 08:28:20 2016
 localtime -> asctime: Sat Mar 12 21:28:20 2016
   gmtime -> strftime: Sat Mar 12 08:28:20 2016 GMT (+0000)
localtime -> strftime: Sat Mar 12 21:28:20 2016 ABC (+1300)
```

Assignment #4 (5% + 2% Bonus)

- Please write a tool to break a /etc/shadow line using dictionary attack. Download the dictionary file at https://nmsl.cs.nthu.edu.tw/images/courses/CS5432_2016/john.txt . Your tool will load this dictionary into memory, and tries to concatenate three words into the plaintext password candidate. Use the crypt library to find the actually password of a person. You need to submit both your source file and library. The TA will time how fast your code can break the password. The top 10% of the student will receive 2 bonus points.
- Sample test data:
  - bear:$6$naIJPKfO
    $SMkeSkFM36M6u3mZIyf2hAtt31WxuYtoTwLMjF9Fv49cprYPKtR1K88
    Ox5xvQdLdoBrAOmCnomRvaHc7VDiqQ0:17099:0:99999:7:::