System Data Files and Information

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- portable interfaces to these files are provided
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Password

- `/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`		•		•	

Description	struct passwd member	POSIX.1	FreeBSD 8.0	Linux 3.2	Mac OS X 10.6.8	Solaris 10
Next time to change password	`time_t pw_change`		•		•	
Account expiration time	`time_t pw_expire`		•		•	

  - initial shell is the first process that a user logs in
    - use `/dev/null` or `/bin/false` to prevent users from logging in
    - valid shells are listed in `/etc/shells`
  - use command `finger` to read information of this file

- functions
  - include `<pwd.h>`
  - get `struct passwd` for a specific user
    - `struct passwd *getpwuid(uit_t uid);`
    - `struct passwd *getpwnam(const char *name);`
  - iteratively retrieve all password information
    - `struct passwd *getpwent(void);`
    - `void setpwent(void);` -> rewind
    - `void endpwent(void);` -> close file

- modern UNIX systems move the encrypted password into another file
  - instead of `/etc/passwd` in the past
  - FreeBSD: `/etc/master.passwd`
  - Linux: `/etc/shadow`

- Linux's Shadow Structure
  - include `<shadow.h>`
  - `struct spwd *getspnam(const char *name);`
  - `struct spwd *getspent(void);`
  - `void setspent(void);`
  - `void endspent(void);`

Decription	struct spwd member
User login name	`char *sp_nmap`
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`

Decription	struct spwd member
Date when account expires (days since epoch)	`long sp_expire`
Reserved	`long sp_flag`

- More on User Passwords
    - Algorithm id + Salt + Encrypted password
    - `crypt(3)` function
        - include `<crypt.h>`, link with `-lcrypt`
        - `char *crypt (const char *key, const char *salt)`
        - e.g.
            - `crypt("password", "abcde")`
            - `crypt("password", "$5$abcde$")`

Group

- `/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`	•	•	•	•	•

- Supplement Group IDs
    - in the past, a UNIX user is belong to a single group
    - user is also belong to a number of additional groups
    - command `newgrp(1)` to switch between allowed groups
        - change current effective GID
    - permission check are performed based on all the group IDs
    - the number of additional groups has a limit `NGROUPS_MAX`, usually 16
- functions
    - include `<grp.h>`
    - get `struct group` for a specific group
        - `struct group *getgrgid(gid_t gid);`
        - `struct group *getgrnam(const char *name);`
    - iteratively retrieve all group information
        - `struct group *getgrent(void);`
        - `void setgrent(void);` -> rewind
        - `void endgrent(void);` -> close file

  - `initgroups(3)`: `int initgroups(const char *username, gid_t basegid);`
    - setup gid and supplement groups IDs for a user based on `/etc/group`
  - `setgroups(2)`: `int setgroups(int ngroups, const gid_t grouplist[]);`
    - setup supplement group IDs, usually called by `initgroups(3)`
  - `getgroups(2)`: `int getgroups(int gidsetsize, gid_t grouplist[]);`
    - in `<unistd.h>`
- 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`

  - some UNIX systems implement user and group database by
    - network information service (NIS)
    - lightweight directory access protocol (LDAP)
    - have a look at `/etc/nsswitch.conf`

Other Data Files

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

Accounting

- `utmp(5)`: record the currently logged in users

```
struct utmp {
  short   ut_type;              /* Type of record */
  pid_t   ut_pid;               /* PID of login process */
  char    ut_line[UT_LINESIZE]; /* Device name of tty - "/dev/" */
  char    ut_id[4];             /* Terminal name suffix, or inittab(5)
ID */
  char    ut_user[UT_NAMESIZE]; /* Username */
  char    ut_host[UT_HOSTSIZE]; /* Hostname for remote login,
                                   or kernel version for run-level
messages */
  ...
}
```

- `wtmp(5)`: record the history of user login, logout, and system (up, down, or reboot) activities
- relevant commands
  - `w(1)`
  - `who(1)`
  - `last(1)`

System Identification

- `uname(2)`: `int uname(struct utsname *buf);`
  - return: 0 OK, -1 error

```
struct utsname {
  char sysname[];    /* Operating system name (e.g., "Linux") */
  char nodename[];   /* Name within "some implementation-defined
network" */
  char release[];    /* Operating system release (e.g., "2.6.28") */
  char version[];    /* Operating system version */
  char machine[];    /* Hardware identifier */
};
```

- `uname(1)`

```
$ uanme -a
Linux ee904-itri-pc2 4.15.0-50-generic #54-Ubuntu SMP Mon May 6
18:46:08 UTC 2019 x86_64 x86_64 x86_64 GNU/Linux
```

Field	**Description**
System	`Linux`
Node	`ee904-itri-pc2`
Release	`4.15.0-50-generic`
Version	`#54-Ubuntu SMP Mon May 6 18:46:08 UTC 2019`
Machine	`x86_64`

Field	Description
Processor	`x86_64`
Hardware platform	`x86_64`
Operating system	`GNU/Linux`

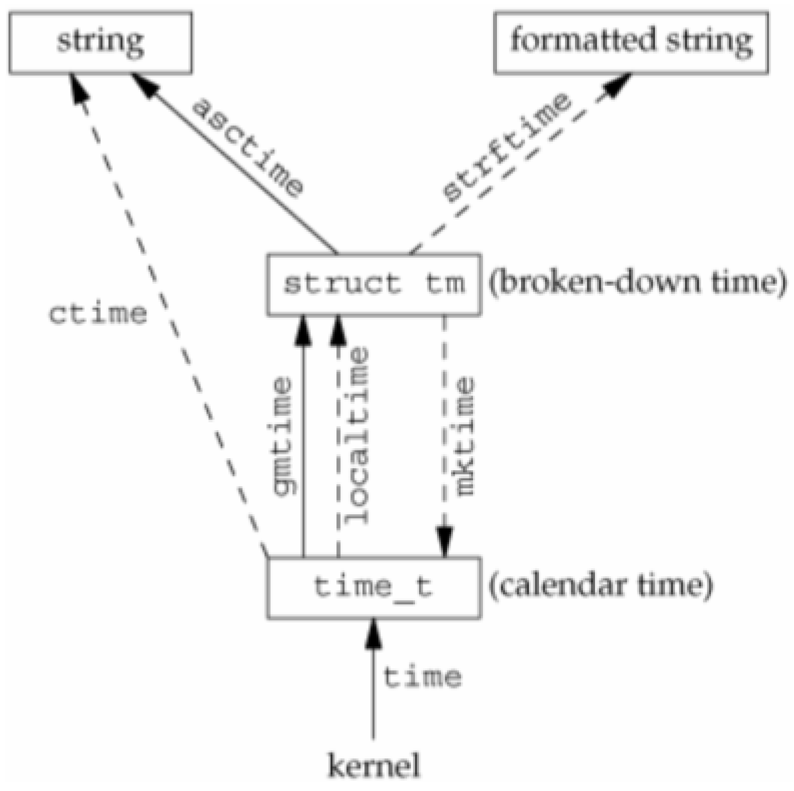
Time and Date Routines

- `time(2)`: `time_t time(time_t *tloc);`
    - return: current time from epoch (seconds)
    - if `tloc` is not `NULL`, `tloc` will also point to the current time
- `gettimeofday(2)`: `int gettimeofday(struct timeval *tv, struct timezone *tz);`
    - return: 0 OK, -1 error
    - `tv` point to current time from epoch (microseconds)
    - `tz` is usually `NULL`, see NOTES in man page

    ```
    struct timeval {
      time_t      tv_sec;     /* seconds */
      suseconds_t tv_usec;    /* microseconds */
    };

    struct timezone {
      int tz_minuteswest;     /* minutes west of Greenwich */
      int tz_dsttime;         /* type of DST correction */
    };
    ```

- Time Functions
    - relationships
        - solid arrow: UTC time zone
        - dashed arrow: time zone base on environment variable `TZ`



- structure `tm`

  ```
  struct tm {
    int tm_sec;     /* Seconds (0-60) */
    int tm_min;     /* Minutes (0-59) */
    int tm_hour;    /* Hours (0-23) */
    int tm_mday;    /* Day of the month (1-31) */
    int tm_mon;     /* Month (0-11) */
    int tm_year;    /* Year - 1900 */
    int tm_wday;    /* Day of the week (0-6, Sunday = 0) */
    int tm_yday;    /* Day in the year (0-365, 1 Jan = 0) */
    int tm_isdst;   /* Daylight saving time */
  };
  ```

- break down `time_t` value
  - `gmtime(3)`
    - `struct tm *gmtime(const time_t *timep);`
    - `struct tm *gmtime_r(const time_t *timep, struct tm *result);`
  - `localtime(3)`
    - `struct tm *localtime(const time_t *timep);`
    - `struct tm *localtime_r(const time_t *timep, struct tm *result);`

- print out time in a string
  - `asctime(3)`

        - `char *asctime(const struct tm *tm);`
        - `char *asctime_r(const struct tm *tm, char *buf);`
    - `ctime(3)`
        - `char *ctime(const time_t *timep);`
        - `char *ctime_r(const time_t *timep, char *buf);`

- make up `time_t` value

    - `mktime(3)`: `time_t mktime(struct tm *tm);`

- formatted output

    - `strftime(3)`: `size_t strftime(char *s, size_t max, const char *format, const struct tm *tm);`

Format	Description	Example
`%a`	Abbr. weekday name	Mon
`%A`	Full weekday name	Monday
`%b`	Abbr. month name	May
`%B`	Full month name	May
`%c`	Date and time	Mon May 27 13:25:57 2019
`%C`	Year/100	20
`%d`	Day of month, leading zero	27
`%D`	Date [MM/DD/YY]	05/27/19
`%e`	Day of month, leading space.	27
`%F`	ISO 8601: `%Y`-`%m`-`%d`	2019-05-27
`%g`	`%G` without century	19
`%G`	ISO 8601 week-based year	2019
`%h`	same as `%b`	May
`%H`	Hour (24-hours)	13
`%I`	Hour (12-hours)	01
`%j`	Day of the year: 001-366	147
`%m`	Month: 01-12	05
`%M`	Minute: 00-59	37
`%n`	New line	
`%p`	AM or PM	PM
`%r`	Locale's time (12-hours)	13:37:13 PM

Format	Description	Example
`%R`	`%H:%M`	13:37
`%S`	Second: 00-60	13
`%t`	Horizontal tab	
`%T`	`%H:%M:%S`	13:37:13
`%u`	ISO 8601 weekday: 1-7	1
`%U`	Sunday week number: 00-53	21
`%V`	ISO 8601 week number	22
`%w`	Sunday weekay: 0-6	1
`%W`	Monday week number: 00-53	21
`%x`	Date	05/27/19
`%X`	Time	13:37:13
`%y`	Year without century	19
`%Y`	Year	2019
`%z`	Offset from UTC	+0800
`%Z`	Timezone name or abbreviation	CST
`%%`	'%' character	%

- Example

```
int main() {
  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("         cime: %s", ctime_r(&t, buf));
  printf(" g -> asctime: %s", asctime(&tm1));
  printf(" l -> asctime: %s", asctime(&tm2));
  strftime(buf, sizeof(buf), "%c %Z (%z)", &tm1);
  printf("g -> strftime: %s\n", buf);
  strftime(buf, sizeof(buf), "%c %Z (%z)", &tm2);
  printf("l -> strftime: %s\n", buf);
}

/* Result:
 *          time: 1558936577
 *          cime: Mon May 27 13:56:17 2019
 *  g -> asctime: Mon May 27 05:56:17 2019
 *  l -> asctime: Mon May 27 13:56:17 2019
 * g -> strftime: Mon May 27 05:56:17 2019 GMT (+0000)
 * l -> strftime: Mon May 27 13:56:17 2019 CST (+0800)
 */
```

- Time Zone
  - `tzset(3)`
  - standard: `std offset`
    - offset
      - `[+|-]hh[:mm[:ss]]`
      - positive: west of the Prime Meridian
      - negative: east of the Prime Meridian
    - e.g.
      - `CST-08:00:00`
      - `PST08:00:00`
      - `NSDT-13:00:00`
  - daylight saving time: `std offset dst[offset][,start[/time],end[/time]]`
    - e.g.
      - `NZST-12:00:00NZDT-13:00:00,M10.1.0,M3.3.0`
  - predefined: files stored in `/usr/share/zoneinfo`
    - `:filename`
    - e.g.
      - `:Asia/Taipei`
      - `:America/Vancouver`
      - `:NZ`