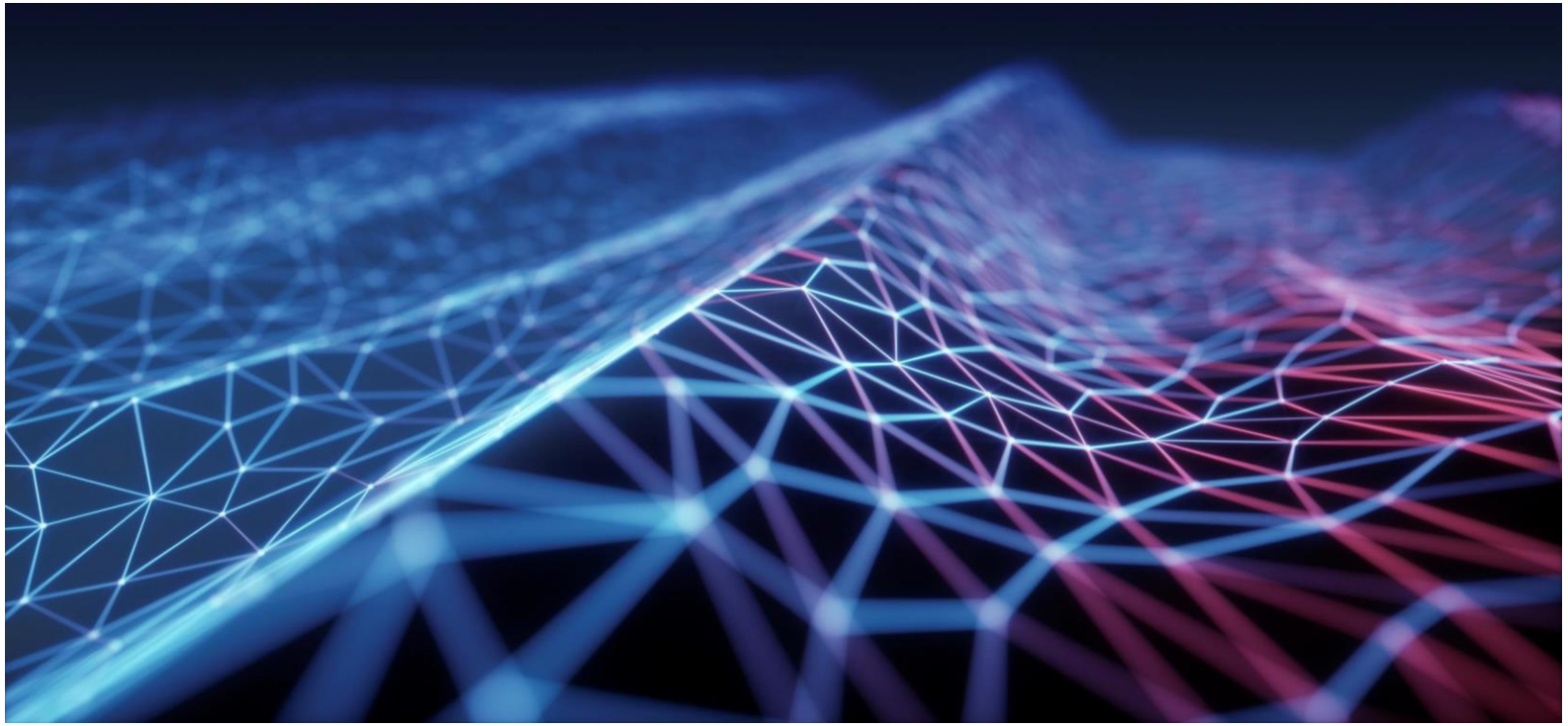


Vidyayāmruthamashnuthe

UNIX PROGRAMMING

AKASH HEGDE

ASSISTANT PROFESSOR

DEPARTMENT OF ISE

MODULE 5

Signals	signal and Signal Mask
	SIGCHLD and waitpid API
	sigsetjmp and siglongjmp
	kill, alarm and Timers
Daemons	Characteristics
	Rules
	Error Logging
	Client-Server Model

SIGNALS

- Triggered by events and posted on a process to notify it that something has happened and requires some action.
- Event can be generated from a process, a user or the UNIX kernel.
- Parent and child processes can send signals to each other for process synchronization.
- Signals are the software version of hardware interrupts.
- Signals are defined as integer flags.
  <*signal.h*> header depicts the list of signals defined for a UNIX system.

SIGNALS

Signal Name	Use	Generates core file at default?
SIGALRM	Alarm timer time-outs. Generated by *alarm()* API.	No
SIGABRT	Abort process execution. Generated by *abort()* API.	Yes
SIGFPE	Illegal mathematical operation	Yes
SIGHUP	Controlling terminal hang-up	No
SIGILL	Execution of an illegal machine instruction	Yes
SIGINT	Process interruption. Generated by the Delete or Ctrl+C keys.	No
SIGKILL	Kill a process. Generated by *kill –9 <pid>* command.	Yes
SIGPIPE	Illegal write to a pipe	Yes
SIGQUIT	Process quit. Generated by Ctrl+\ keys.	Yes

SIGNALS

Signal Name	Use	Generates core file at default?
SIGSEGV	Segmentation fault. Generated by de-referencing a NULL pointer.	Yes
SIGTERM	Process termination. Generated by *kill <pid>* command.	Yes
SIGUSR1/2	Reserved to be defined by users	No
SIGCHLD	Sent to a parent process when its child process has terminated	No
SIGCONT	Resume execution of a stopped process	No
SIGSTOP	Stop a process execution	No
SIGTTIN	Stop a background process when it reads from its controlling terminal	No
SIGTTOU	Stop a background process when it writes to its controlling terminal	No
SIGTSTP	Stop a process execution by the Ctrl+Z keys	No

SIGNALS

- When a signal is sent to a process, it is *pending* on the process to handle it.
- Process can react to pending signals in one of three ways:
  - Accepts the default action of the signal. Usually terminates the process.
  - Ignore the signal. Signal will be discarded, and it has no effect on recipient process.
  - Invoke a user-defined function. The function is known as signal handler routine and signal is said to be *caught* when this function is called.
    If the function finishes its execution without terminating the process, the process will continue execution from the point it was interrupted by the signal.

SIGNALS

- Process may set up per-signal handling mechanisms – ignores some signals, catches some other signals and accepts default action from the remaining signals.
- Process may change handling of certain signals in its course of execution.
- Signal is said to have been *delivered* if it has been reacted to by the recipient process.
- Default action for most signals – terminate a recipient process.
- Some signals will generate a core file for the aborted process – users can trace back the state of the process when it was aborted.
  These signals are usually generated when there is an implied program error in the aborted process.

SIGNALS

- Most signals can be ignored or caught except SIGKILL and SIGSTOP signals.
- Companion signal to SIGSTOP is SIGCONT, which resumes a process execution after it has been stopped.
- Process is allowed to ignore certain signals so that it is not interrupted while doing certain mission-critical work.
- Signal handler function cleans up the work environment of a process before terminating the process gracefully.

KERNEL SUPPORT FOR SIGNALS

- UNIX System V.3 - each entry in kernel process table slot has array of signal flags, one for each signal defined in the system.
- When a signal is generated for a process, kernel will set the corresponding signal flag in the process table slot of the recipient process.
- If recipient process is asleep, kernel will awaken the process by scheduling it.
- When recipient process runs, kernel will check the process U-area that contains an array of signal handling specifications.
  Each entry of the array corresponds to a signal defined in the system.
  Kernel will consult the array to find out how the process will react to the pending signal.

KERNEL SUPPORT FOR SIGNALS

- UNIX System V.2 - when a signal is caught, kernel will first reset the signal handler in the recipient process U-area, then call the user signal handling function specified for that signal.
- Multiple instances of a signal being sent to a process at different points – the process will catch only the first instance of the signal.
  All subsequent instances of the signal – handled in the default manner.
- Continuously catching multiple occurrences of a signal – process must reinstall the signal handler function every time the signal is caught.
  Time between signal handler invoking and re-establishment of signal handler method - another instance of signal may be delivered to the process. Leads to race condition.

KERNEL SUPPORT FOR SIGNALS

- Solving the unreliability of signal handling in UNIX System V.2 - BSD UNIX 4.2 and POSIX.1 use alternate method.
- When a signal is caught – kernel does not reset the signal handler, so there is no need for the process to re-establish the signal handling method.
- Kernel will block further delivery of the same signal to the process until the signal handler function has completed execution.
- Ensures that signal handler function will not be invoked recursively for multiple instances of the same signal.

SIGNAL API

- Used to define the per-signal handling method.
- Prototype of the *signal* API is:

```
#include<signal.h>

void (*signal(int signal_num, void (*handler)(int)))(int);
```

- *signal_num* – signal identifier such as SIGINT or SIGTERM, as defined in <*signal.h*>
- *handler* – function pointer of a user-defined signal handler function.
- Return value of *signal* API – previous signal handler for a signal.
  Can be used to restore the signal handler for a signal after it has been altered.

SIGNAL API

- SIG_IGN and SIG_DFL – manifest constants defined in <*signal.h*>
- SIG_IGN – specifies that a signal must be ignored.
  If the signal is generated to the process, it will be discarded without any interruption of process.
- SIG_DFL – specifies that the default action of a signal must be accepted.

SIGNAL API

- UNIX System V.3 and V.4 support *sigset* API.

```
#include<signal.h>

void (*sigset(int signal_num, void (*handler)(int)))(int);
```

- Arguments and return value of *sigset* are same as that of *signal*.
- Both functions set signal handling methods for any named signal.
- *signal* API is unreliable – race condition due to handling multiple instances of signal. *sigset* API is reliable – one of the multiple instances is handled, whereas remaining instances are blocked.

SIGNAL MASK

- Defines which signals are blocked when generated to a process.
- Blocked signal depends on recipient process to unblock it and handle accordingly.
- Signal is specified to be ignored or blocked – implementation-dependent on whether such a signal will be discarded or left pending when it is sent to the process.
- Process initially inherits the parent's signal mask when it is created, but any pending signals for the parent process are not passed on.

SIGNAL MASK

- Process may query or set its signal mask using *sigprocmask* API:

```
#include<signal.h>

int sigprocmask(int cmd, const sigset_t *new_mask, sigset_t *old_mask);
```

- *new_mask* – defines a set of signals to be set or reset in a calling process signal mask.
- *cmd* – specifies how the *new_mask* value is to be used by the API.
- Returns: 0 if it succeeds, -1 if it fails.
- Possible failure - *new_mask*/*old_mask* are invalid addresses.

SIGNAL MASK

cmd Value	Meaning
SIG_SETMASK	Overrides the calling process signal mask with the value specified in the *new_mask* argument
SIG_BLOCK	Adds the signals specified in the *new_mask* argument to the calling process signal mask
SIG_UNBLOCK	Removes the signals specified in the *new_mask* argument from the calling process signal mask

- If actual argument to *new_mask* argument is NULL pointer – *cmd* argument will be ignored and current process signal mask will not be altered.
- *old_mask* argument – address of a *sigset_t* variable that will be assigned the original signal mask of calling process prior to *sigprocmask* call.
- If actual argument to *old_mask* is NULL pointer, no previous signal mask will be returned.

SIGNAL MASK

- *sigset_t* is a data type defined in <*sigset.h*> - contains a collection of bit flags, with each bit flag representing one signal defined in a given system.
- *sigsetops* functions - set of API defined by BSD UNIX and POSIX.1 to set, reset and query the presence of signals in a *sigset_t* typed variable.

```
#include<signal.h>

int sigemptyset(sigset_t *sigmask);
int sigaddset(sigset_t *sigmask, const int signal_num);
int sigdelset(sigset_t *sigmask, const int signal_num);
int sigfillset(sigset_t *sigmask);
int sigismember(const sigset_t *sigmask, const int signal_num);
```

SIGNAL MASK

- *sigemptyset* - clears all signal flags in *sigmask* argument.
- *sigaddset* - sets the flag corresponding to *signal_num* signal in the *sigmask* argument.
- *sigdelset* - clears the flag corresponding to *signal_num* signal in the *sigmask* argument.
- *sigfillset* - sets all signal flags in *sigmask* argument.
- *sigismember* - checks if the flag corresponding to *signal_num* signal in the sigmask argument is set or not set.

SIGNAL MASK

- One or more signals are pending for a process and are unblocked via *sigprocmask* API – the signal handler methods for those signals that are in effect at the time of *sigprocmask* call will be applied before the API is returned to caller.
- Multiple instances of the same signal pending for the process – implementation-dependent whether one or all the instances will be delivered to the process.
- Process can query which signals are pending for it using *sigpending* API:

```
#include<signal.h>

int sigpending(sigset_t *sigmask);
```

- *sigmask* – address of a *sigset_t* typed variable; assigned the set of signals pending for the calling process by the API.

SIGNAL MASK

- Signal mask manipulation functions –

```
#include<signal.h>

int sighold(int signal_num);
int sigrelse(int signal_num);
int sigignore(int signal_num);
int sigpause(int signal_num);
```

SIGNAL MASK

- *sighold* API – adds the named signal *signal_num* to the calling process signal mask.
- *sigrelse* API – removes the named signal *signal_num* for the calling process signal mask.
- *sigignore* API – sets the handling method for the named signal *signal_num* to SIG_DFL
- *sigpause* API – removes the named signal *signal_num* from the calling process signal mask and suspends the process until it is interrupted by a signal.

SIGACTION

- Replacement for *signal* API in the latest UNIX and POSIX systems.
- *sigaction* API - called by a process to set up a signal handling method for each signal it wants to deal with.
- Passes back the previous signal handling method for a given signal.
- Blocks the signal it is catching, allowing a process to specify additional signals to be blocked when the API is handling a signal.

SIGACTION

- Prototype of *sigaction* API:

```
#include<signal.h>

int sigaction(int signal_num, struct sigaction *action,
              struct sigaction *old_action);
```

- *struct sigaction* data type is defined in <signal.h> as:

```
struct sigaction{
        void (*sa_handler)(int);
        sigset_t sa_mask;
        int sa_flag;
};
```

SIGACTION

- *sa_handler* – corresponds to second argument of *signal* API.
- Can be set to SIG_IGN, SIG_DFL, or user-defined signal handler function.
- *sa_mask* – specifies additional signals that a process wishes to block when it is handling the *signal_num* signal.
- Does not block the signals currently specified in the signal mask of the process and *signal_num* signal.

SIGACTION

- *signal_num* - designates which signal handling action is defined in the *action* argument.
- Previous signal handling method for *signal_num* will be returned via *old_action* argument if it is not a NULL pointer.
- If *action* argument is a NULL pointer, existing signal handling method of the calling process for *signal_num* will be unchanged.

SIGACTION

- *sa_flag* - used to specify special handling for certain signals.
- POSIX.1 defines two values for *sa_flag*: 0 and SA_NOCLDSTOP.
- If *sa_flag* is 0, kernel will send the SIGCHLD signal to the calling process whenever its child process is either terminated or stopped.
- If *sa_flag* is SA_NOCLDSTOP, kernel will send the SIGCHLD signal to the calling process whenever its child process is terminated, but not when it is stopped.

SIGACTION

- Additional flags for the *sa_flag* field in UNIX System V.4 implementation – SA_RESETHAND and SA_RESTART
- SA_RESETHAND – If *signal_num* is caught, *sa_handler* is set to SIG_DFL before the signal handler function is called.
  signal_num will not be added to the process signal mask when the signal handler function is executed.
- SA_RESTART – If a signal is caught while a process is executing a system call, kernel will restart the system call after the signal handler returns.
  If this flag is not set in the *sa_flag* field, the system call will be aborted with a return of -1 after the signal handler returns and *errno* will be set to EINTR.

SIGCHLD SIGNAL AND THE WAITPID API

- When a child process terminates or stops, kernel will generate a SIGCHLD signal to its parent process.
- Three different events may occur depending on how the parent sets up the handling of the SIGCHLD signal.

SIGCHLD SIGNAL AND THE WAITPID API

- *Event 1* – parent accepts the default action of the SIGCHLD signal :
  - SIGCHLD signal does not terminate the parent process.
  - Affects only the parent process if it arrives at the same time when the parent process is suspended by the *waitpid* system call.
  - Parent process will be awakened, *waitpid* will return the child's exit status and PID to the parent, and the kernel will clear up the process table slot for child.
  - With this setup, parent can call *waitpid* repeatedly to wait for each child it created.

SIGCHLD SIGNAL AND THE WAITPID API

- *Event 2* – parent ignores the SIGCHLD signal :
  - SIGCHLD signal will be discarded.
  - Parent will not be disturbed even if it is executing the *waitpid* system call.
  - If parent calls the *waitpid* API, the API will suspend the parent until all its child processes have terminated.
  - Child process table slots will be cleared up by the kernel and API will return a value of –1 to the parent process.

SIGCHLD SIGNAL AND THE WAITPID API

- *Event 3* – parent catches the SIGCHLD signal :
  - Signal handler function will be called in the parent process whenever a child process terminates.
  - If SIGCHLD signal arrives while the parent process is executing a *waitpid* system call, the *waitpid* API may be restarted to collect the child exit status and clear its process table slot after the signal handler function returns.
  - API may be aborted, and the child process table slot is not freed, depending on the parent setup of the signal action for the SIGCHLD signal.

SIGCHLD SIGNAL AND THE WAITPID API

- Interaction between SIGCHLD and *wait* API is the same as that between SIGCHLD and *waitpid* API.
- Earlier versions of UNIX used the SIGCLD signal instead of SIGCHLD.
- SIGCLD signal is now obsolete, but most of the latest UNIX systems have defined SIGCLD to be the same as SIGCHLD for backward compatibility.

SIGSETJMP AND SIGLONGJMP APIs

- *setjmp* and *sigsetjmp* – marks one or more locations in a user program.
- *longjmp* and *siglongjmp* – called to return to any of the marked locations.
- Provision of inter-function *goto* capability.
- Defined in POSIX.1 and on most UNIX systems that support signal masks.
- Function prototypes:

```
#include<setjmp.h>

int sigsetjmp(sigjmpbuf env, int save_sigmask);
int siglongjmp(sigjmpbuf env, int ret_val);
```

SIGSETJMP AND SIGLONGJMP APIs

- *sigsetjmp* and *sigsetjmp* created to support signal mask processing.
- Implementation-dependent on whether a signal process mask is saved and restored when it invokes the *setjmp* and *longjmp* APIs.
- *sigsetjmp* – behaves similarly to the *setjmp* API, but it has a second argument *save_sigmask*.
  - Allows a user to specify whether a calling process signal mask should be saved to the provided *env* argument.
  - If the *save_sigmask* argument is non-zero, the caller's signal mask is saved. Otherwise, signal mask is not saved.

SIGSETJMP AND SIGLONGJMP APIs

- *siglongjmp* – behaves similarly to the *longjmp* API, but it also restores a calling process signal mask if the mask was saved in its *env* argument.
  - *ret_val* argument – specifies the return value of the corresponding *sigsetjmp* API when it is called by *siglongjmp*.
  - *ret_val* value should be a non-zero number.
    If it is zero, *siglongjmp* API will reset it to 1.
- *siglongjmp* API is usually called from user-defined signal handling functions.
- Process signal mask is modified when a signal handler is called – *siglongjmp* should be called to ensure that the process signal mask is restored properly when jumping out from a signal handling function.

KILL

- Process can send a signal to a related process using *kill* API.
- Sender and recipient processes must be related such that either the sender process real/effective UID matches that of recipient process, or sender process has superuser privileges.
- Example: parent and child process sending signals to each other.
- *kill* API function prototype:

```
#include<signal.h>

int kill(pid_t pid, int signal_num);
```

- Returns: 0 if successful, -1 if it fails.

KILL

- *signal_num* – integer value of a signal that must be sent to one or more processes designated by *pid*.
- Possible values of *pid:* positive value, 0, -1, negative value.

***pid* Value**	**Effects *on kill* API**
positive value	*pid* is a process ID. Sends *signal_num* to that process.
0	Sends *signal_num* to all processes whose process GID is same as the calling process
-1	Sends *signal_num* to all process whose real UID is same as the effective UID of calling process. If calling process effective UID is the superuser UID, *signal_num* will be sent to all processes in the system (except process 0 and process 1).
negative value	Sends *signal_num* to all processes whose process GID matches absolute value of *pid*

KILL

- UNIX *kill* command invocation syntax:
  kill [–<signal_num>] <pid>
- Here, <*signal_num*> - integer number or symbolic name of a signal, as defined in <*signal.h*> header.
- <*pid*> - integer number of a PID.
  There can be one or more PID specified – *kill* will send signal <*signal_num*> to each process that corresponds to a <*pid*>.
- Example: *kill –9 1234*

ALARM

- Can be called by a process to request the kernel to send the SIGALRM signal after a certain number of real clock seconds.
- *alarm* API function prototype:

```
#include<signal.h>

unsigned int alarm(unsigned int time_interval);
```

- Returns: number of CPU seconds left in the process timer, as set by previous *alarm* system call.
- *time_interval* – number of CPU seconds elapsed time, after which the kernel will send the SIGALRM signal to the calling process.
  If *time_interval* = 0, it turns off the alarm clock.

ALARM

- Effect of previous *alarm* is cancelled and process timer is reset with new *alarm* call.
- Process alarm clock is not passed on to its *fork*ed child, but an *exec*ed process retains the same alarm clock value as was prior to the *exec* API call.
- *alarm* API is used to implement *sleep* API – suspends a calling process for the specified number of CPU seconds.
- Process will be awakened by either the elapsed time exceeding the *timer* value or when the process is interrupted by a signal.

ALARM

- BSD UNIX – *ualarm* function.
- Same as that of *alarm* API, but argument and return values are in microseconds.
- Useful for time-critical applications where the resolution of time must be in microsecond levels.
- Can be used to implement BSD-specific *usleep* function – similar to *sleep*, but its argument is in microseconds.

INTERVAL TIMERS

- Implemented using the *alarm* API.
- Can be used to schedule a process to do some tasks at a fixed time interval, to time the execution of some operations, or to limit the time allowed for the execution of some tasks.
- *setitimer* API – additional capabilities defined in BSD UNIX. Also available in UNIX System V.3 and V.4, but not specified by POSIX.
- POSIX.1b has new set of APIs for interval timer manipulation.

INTERVAL TIMERS

- Additional features of *setitimer* API:
  - *alarm* resolution time is in seconds.
    setitimer resolution time is in microseconds.
  - *alarm* can be used to set up 1 real-time clock timer per process.
    setitimer can set up 3 - real-time clock timer, timer based on user time spent by a process, timer based on total user time and system times spent by a process.

INTERVAL TIMERS

- *setitimer* and *getitimer* function prototypes:

```
#include<sys/time.h>

int setitimer(int which, const struct itimerval *val,
              struct itimerval *old);
int getitimer(int which, struct itimerval *old);
```

- Return values for both: 0 if successful, -1 if fail.
- Timers set by *setitimer* in a parent process will not be inherited by child processes, but are retained when a process *execs* a new program.

INTERVAL TIMERS

- *which* argument – specifies which timer to process.

***which* Value**	**Timer type**
ITIMER_REAL	Timer based on real-time clock. Generates a SIGALRM signal when it expires.
ITIMER_VIRTUAL	Timer based on user time spent by a process. Generates SIGVTALRM signal when it expires.
ITIMER_PROF	Timer based on total user and system times spent by a process. Generates a SIGPROF signal when it expires.

- ITIMER_VIRTUAL and ITIMER_PROF timers – useful in timing the total execution time of selected user functions, as the timer runs only while the user process is running.

INTERVAL TIMERS

- *struct itimerval* defined in <*sys/time.h*> header as –

```
struct itimerval{
        struct timeval it_interval; //timer interval
        struct timeval it_value; //current value
};
```

- For *setitimer* API – *it_value* is the time to set the named timer, *it_interval* is the time to reload the timer when it expires.
- For *getitimer* API – *it_value* is the named timer's remaining time to expiration, *it_interval* is the time to reload the timer when it expires.

POSIX.1B TIMERS

- Set of APIs for interval timer manipulation defined in POSIX.1b.
- More flexible and powerful than UNIX timers –
  - Users may define multiple independent timers per system clock.
  - Timer resolution is in nanoseconds.
  - Users may specify the signal to be raised when a timer expires, on a per-timer basis.
  - Timer interval may be specified as either an absolute or a relative time.
- Limit on maximum number of POSIX timers per process – TIMER_MAX constant defined in <*limits.h*> header.

POSIX.1B TIMERS

- POSIX timers created by a process are not inherited by its child process, but are retained across the *exec* system call.
- Unlike UNIX timers, POSIX timer can be used safely with *sleep* API if it does not use the SIGALRM signal when it expires.

```
#include<signal.h>
#include<time.h>

int timer_create(clockid_t clock, struct sigevent *spec,
                 timer_t *timer_hdrp);
int timer_settime(timer_t timer_hdr, int flag, struct itimerspec *val,
                 struct itimerspec *old);
int timer_gettime(timer_t timer_hdr, struct itimerspec *old);
int timer_getoverrun(timer_t timer_hdr);
int timer_delete(timer_t timer_hdr);
```

POSIX.1B TIMERS

- *timer_create* API – used to dynamically create a timer and return its handler.
- *clock* argument – specifies which system clock the new timer should be based on.
- *clock* value may be CLOCK_REALTIME for creating a real-time clock timer.
- *spec* argument – defines what action to take when the timer expires.

```
struct sigevent{
        int sigev_notify;
        int sigev_signo;
        union sigval sigev_value;
};
```

```
union sigval{
        int sival_int;
        void *sival_ptr;
};
```

POSIX.1B TIMERS

- *timer_settime* API – used to start or stop a running timer.
- *timer_gettime* API – used to query the current values of a timer.

```
struct itimerspec{
        struct timespec it_interval;
        struct timespec it_value;
};
```

```
struct timespec{
        time_t tv_sec;
        long tv_nsec;
};
```

- *timer_getoverrun* API – returns the number of signals generated by a timer but was lost / overrun.
- *timer_delete* API – used to destroy a timer created by *timer_create* API.

DAEMONS

- Processes that live for a long time.
- Often started when system is bootstrapped and terminate only when the system is shut down.
- No controlling terminal – daemons run in the background.
- Perform day-to-day activities in the UNIX system.
- Process names of a daemon usually end with "*d*".
- Examples: *syslogd* – a daemon that implements system logging facility, *sshd* – a daemon that serves incoming SSH connections.

DAEMONS

- Respond to network requests, hardware activity, or other programs by performing some task.
- *cron* daemon performs defined tasks at scheduled times.
- Alternative terms – service (Windows and later versions of Linux), started task (IBM z/OS), ghost job (XDS UTS).
- Network services – daemons that connect to a computer network.

DAEMON CHARACTERISTICS

- *ps* command – prints the status of various processes in the system.
- Options:
  -a: displays the status of process owned by others
  -x: displays the processes that do not have a controlling terminal
  -j: displays the job-related information – session ID, process group ID, controlling terminal and terminal process group ID.
- Typical output will contain – parent process ID, process ID, process group ID, session ID, terminal name, terminal process group ID, user ID and command string.

DAEMON CHARACTERISTICS

- Kernel processes – any process whose parent process ID is 0.
- Special and generally exist for the entire lifetime of the system.
- Run with superuser privileges and have no controlling terminal and no command line.
- Process 1 – *init* process.
- System daemon responsible for starting system services specific to various run levels.
- These services are usually implemented with the help of their own daemons.

DAEMON CHARACTERISTICS

- *keventd* daemon – provides process context for running scheduled functions in the kernel.
- *kapmd* daemon – provides support for the advanced power management features available with various computer systems.
- *kswapd* daemon – supports the virtual memory subsystem by writing dirty pages to disk slowly over time, so the pages can be reclaimed. (a.k.a pageout daemon)
- *bdflush* daemon – flushes dirty buffers from the buffer cache back to disk when available memory reaches a low-water mark.
- *kupdated* daemon – flushes dirty pages back to disk at regular intervals to decrease data loss in the event of a system failure.

DAEMON CHARACTERISTICS

- *portmap* daemon – portmapper daemon which provides the service of mapping RPC (Remote Procedure Call) program numbers to network port numbers.
- *syslogd* daemon – available to any program to log system messages for an operator. The messages may be printed on a console device and written to a file.
- *inetd* daemon – listens on the system's network interfaces for incoming requests for various network servers.
- *nfsd, lockd, rpciod* daemons – provide support for the Network File System (NFS).
- *cron* daemon – executes commands at specified dates and times. Numerous system administration tasks are handled by having programs executed regularly by *cron*.

DAEMON CHARACTERISTICS

- *cupsd* daemon – handles print requests on the system (print spooler).
- Most of the daemons run with superuser privilege (a user ID of 0).
- None of the daemons has a controlling terminal: the terminal name is set to a question mark, and the terminal foreground process group is 1.
- All the user-level daemons are process group leaders and session leaders and are the only processes in their process group and session.
- The parent of most of these daemons is the *init* process.

CODING RULES

- Rules to code a daemon – prevent unwanted interactions from happening.
- Rule 1 – Call *umask* to set the file mode creation mask to 0.
- Inherited file mode creation mask – set to deny certain permissions.
- If the daemon process is going to create files – may want to set specific permissions.
- Example: specifically creates files with group-read and group-write permissions enabled – file mode creation mask should be set accordingly.

CODING RULES

- Rule 2 – Call *fork* and make the parent *exit*.
- If the daemon was started as a simple shell command – having the parent terminate makes the shell think that the command is done.
- The child inherits the process group ID of the parent but gets a new process ID – implies that the child is not a process group leader.
- A prerequisite for the call to *setsid* that is done next.

CODING RULES

- Rule 3 – Call *setsid* to create a new session.
- The process becomes a session leader of a new session.
- The process becomes the process group leader of a new process group.
- The process has no controlling terminal.

CODING RULES

- Rule 4 – Change the current working directory to the root directory.
- Current working directory inherited from parent could be on a mounted file system.
- Daemons normally exist until the system is rebooted – if it stays on a mounted file system, that file system cannot be unmounted.
- Alternate – some daemons might change the current working directory to some specific location, where they will do all their work.
- Example: line printer spooling daemons often change to their spool directory.

CODING RULES

- Rule 5 – Unneeded file descriptors should be closed.
- Prevents the daemon from holding open any descriptors that it may have inherited from its parent, which could be a shell or some other process.
- *open_max* function or *getrlimit* function – determine the highest descriptor and close all descriptors up to that value.

CODING RULES

- Rule 6 – Open file descriptors 0, 1, and 2 to /dev/null so that any library routines that try to read from standard input or write to standard output or standard error will have no effect.
- Daemon is not associated with a terminal device – there is nowhere for output to be displayed; nor is there anywhere to receive input from an interactive user.
- Even if the daemon was started from an interactive session, the daemon runs in the background, and the login session can terminate without affecting the daemon.
- Other users log in on the same terminal device – output from the daemon should not show up on the terminal, and input from users should not be read by daemon.

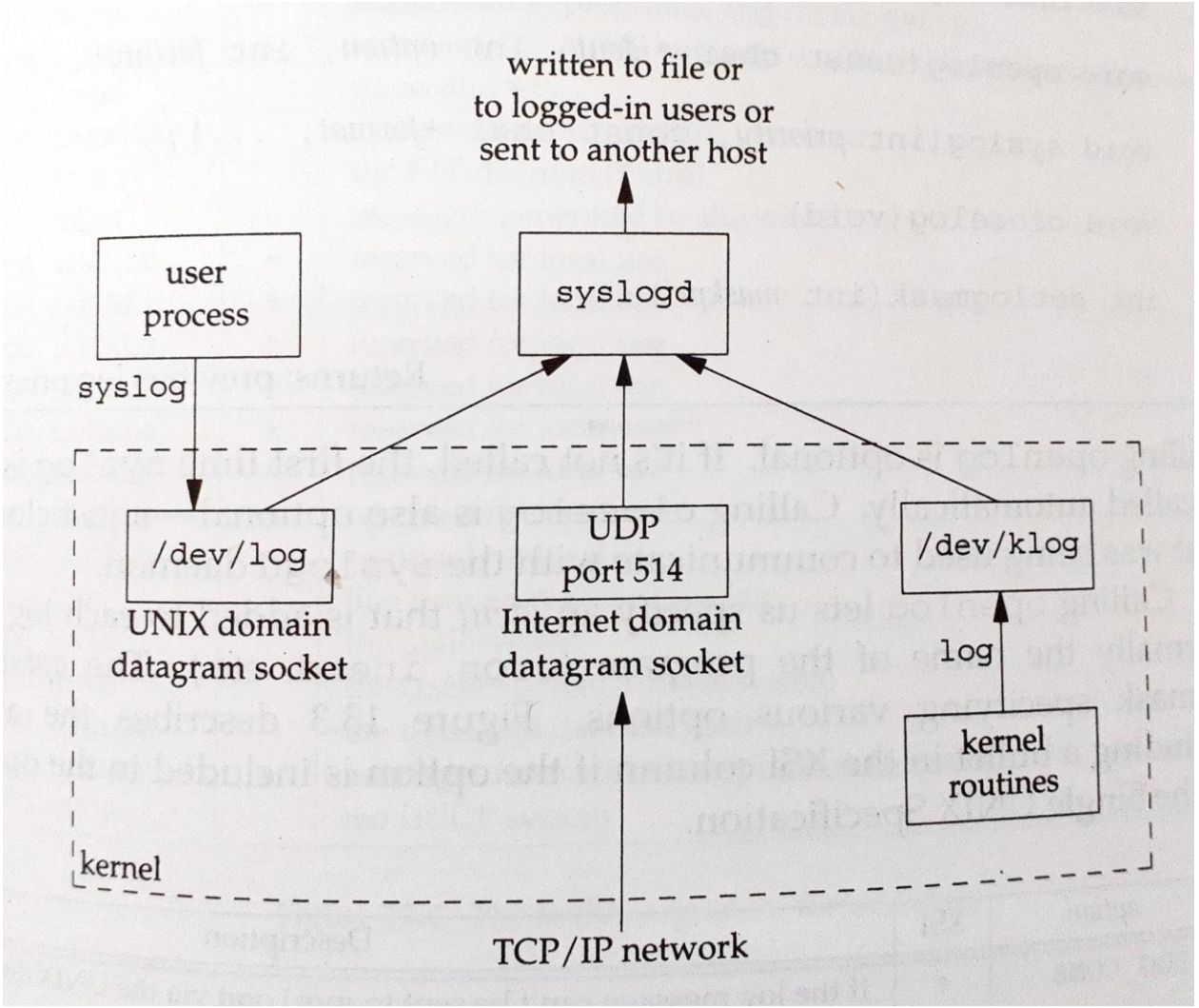
ERROR LOGGING

- Problem faced by daemon – handling of error messages.
- Cannot write to standard error, as it should not have a controlling terminal.
- Daemons should not write to console device – many workstations have windowing system running on console device.
- Daemons should not write error messages into a separate file – impossible for admin to keep up with which daemon writes to which log file, and to check these logs on a regular basis.
- Central daemon error-logging facility is required.

ERROR LOGGING

- *syslog* facility developed at Berkeley, for the BSD 4.2.
- Most systems derived from BSD support *syslog*.
- Included as an XSI extension in Single UNIX Specification.
- Most daemons use *syslog* to log their error messages.

ERROR LOGGING



Structure of *syslog* facility

ERROR LOGGING

- Three ways to generate log messages:
  - Kernel routines can call the *log* function. These messages can be read by any user process that opens and reads the /dev/klog device.
  - Most user processes (daemons) call the *syslog* function to generate log messages. This causes the message to be sent to the UNIX domain datagram socket /dev/log.
  - A user process on this host, or on some other host that is connected to this host by a TCP/IP network, can send log messages to UDP port 514.
    syslog never generates these UDP datagrams: they require explicit network programming by the process generating the log message.

ERROR LOGGING

- *syslogd* daemon reads all three forms of log messages.
- On start-up – *syslogd* reads a configuration file, usually */etc/syslog.conf*, which determines where different classes of messages are to be sent.
- Example: urgent messages can be sent to the system administrator (if logged in) and printed on the console, whereas warnings may be logged to a file.

ERROR LOGGING

- Interface to the logging facility is through these functions:

```
#include<syslog.h>

void openlog(const char *ident, int option, int facility);
void syslog(int priority, const char *format, ...);
void closelog(void);
int setlogmask(int maskpri);
```

- Returns: previous log priority mask value

ERROR LOGGING

- Calling *openlog* is optional.
  If it is not called, when *syslog* is called for the first time, *openlog* is called automatically.
- Calling *closelog* is also optional.
  It just closes the descriptor that was being used to communicate with the *syslogd* daemon.
- *ident* – added to each log message.
  This is normally the name of the program (*cron*, *inetd*, etc.)
- *option* – bit mask specifying various options.

ERROR LOGGING

option	Description
LOG_CONS	If the log message cannot be sent to *syslogd* via the UNIX domain datagram, the message is written to the console instead.
LOG_NDELAY	Open the UNIX domain datagram socket to the *syslogd* daemon immediately; do not wait until the first message is logged.
LOG_NOWAIT	Do not wait for child processes that might have been created in the process of logging the message.
LOG_ODELAY	Delay the open of the connection to the *syslogd* daemon until the first message is logged.
LOG_PERROR	Write the log message to standard error in addition to sending it to *syslogd*.
LOG_PID	Log the process ID with each message. This is intended for daemons that fork a child process to handle different requests.

ERROR LOGGING

- *facility* – lets the configuration file specify that messages from different facilities are to be handled differently.
- If we do not call *openlog*, or if we call it with a *facility* of 0, we can still specify the facility as part of the *priority* argument to *syslog*.
- Single UNIX Specification – defines only a subset of the facility codes typically available on a given platform.

ERROR LOGGING

facility	Description
LOG_AUTH	Authorization programs such as *login, su, getty*
LOG_AUTHPRIV	Same as LOG_AUTH, but logged to file with restricted permissions
LOG_CRON	*cron* and *at*
LOG_DAEMON	System daemons such as *inetd, routed*
LOG_FTP	FTP daemon *ftpd*
LOG_KERN	Messages generated by the kernel
LOG_LOCAL0 to LOG_LOCAL7	Reserved for local use

ERROR LOGGING

facility	Description
LOG_LPR	Line printer system functions such as *lpd*, *lpc*
LOG_MAIL	Mail system
LOG_NEWS	Usenet network news system
LOG_SYSLOG	*syslogd* daemon itself
LOG_USER	Messages from other user processes
LOG_UUCP	UUCP system

ERROR LOGGING

- *level* – ordered by priority, from highest to lowest.

level	Description
LOG_DEBUG	Debug message (lowest priority)
LOG_INFO	Informational message
LOG_NOTICE	Normal, but significant condition
LOG_WARNING	Warning condition
LOG_ERR	Error condition
LOG_CRIT	Critical condition (such as hard device error)
LOG_ALERT	Condition that must be fixed immediately
LOG_EMERG	Emergency – system is unusable (highest priority)

ERROR LOGGING

- *priority* – combination of *facility* and *level*
- The *format* argument and any remaining arguments are passed to the *vsprintf* function for formatting.
- Any occurrence of the two characters *%m* in the *format* are first replaced with the error message string (*strerror*) corresponding to the value of *errno*.
- The *setlogmask* function can be used to set the log priority mask for the process.
- This function returns the previous mask.

ERROR LOGGING

- When the log priority mask is set, messages are not logged unless their priority is set in the log priority mask.
- Attempts to set the log priority mask to 0 will have no effect.
- *logger* program – provided by many systems to send log messages to the *syslog* facility.
- Optional arguments – specifies the *facility*, *level*, and *ident*.
- Single UNIX Specification does not define any options.
- Intended for a shell script running non-interactively that needs to generate log messages.

ERROR LOGGING

- *vsyslog* – a variant of *syslog* that handles variable argument lists.

```
#include<syslog.h>
#include<stdarg.h>

void vsyslog(int priority, const char *format, va_list arg);
```

- Not included in the Single UNIX Specification.

ERROR LOGGING

- Most *syslogd* implementations will queue messages for a short time.
- If a duplicate message arrives during this time – the *syslog* daemon will not write it to the log.
- Instead, the daemon will print out a message similar to "last message repeated N times."

CLIENT-SERVER MODEL

- Common use for a daemon process – a server process.
- *syslogd* process – a server that has messages sent to it by user processes (clients) using a UNIX domain datagram socket.
- Server – a process that waits for a client to contact it, requesting some type of service.
- The service being provided by the *syslogd* server is the logging of an error message.
- Communication between the client and the server is one-way.
  The client sends its service request to the server; the server sends nothing back to the client.


THANK YOU