Operating Systems

Signals

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Basic Concepts

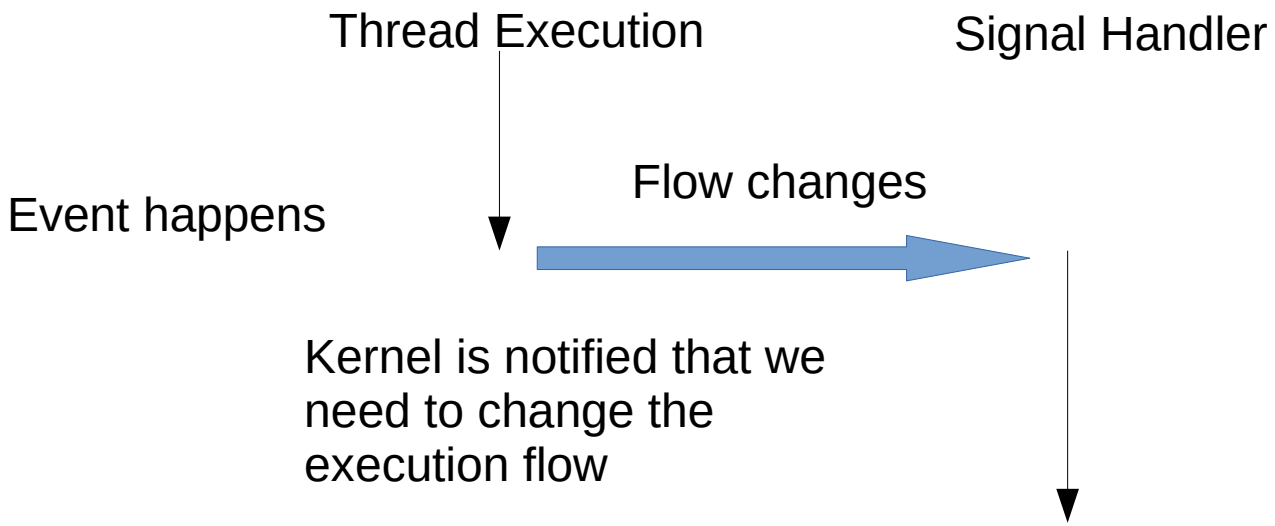
Signals in UNIX are an basic mechanism through which events are notified to a process

- When a process receives such an event, it can perform specific handling actions

Signals are **NOT** messages since

- Signals are sent
  - occasionally by another process,
  - very often by the OS as a result of a system event (SIGSEGV/SIGINT/SIGFPE)
- A signal (in its original form) does not carry information about the emitter

Signals in UNIX



There is a predefined set of events.

For a process, each event might be either

- Ignored implicitly (if received they typically terminate the process)
- Ignored explicitly (if received, they are ignored)
- Capture

Such a policy is changed by syscalls and can vary during the process execution

The OS sends a signal anyway to a process, if a process chooses of not explicitly ignore or not capture some events, it might be terminated when receiving them.

Common UNIX signals

- **SIGHUP**: received when the terminal to which it was associated is closed, or the connection is interrupted
- **SIGINT**: received when the user presses c key combination (typically ctrl-c)
- **SIGQUIT**: same as SIGINT, but the OS generates a “core dump”
- **SIGILL**: sent by the OS when a process attempt to execute an illegal instruction
- **SIGKILL**: can’t be captured and brutally terminates the receiving process
- **SIGSEGV**: sent by the os when an attempt to preform an operation on a memory address would cause a violation
- **SIGTERM**: something in between SIGINT and SIGKILL. Can be captured.
- **SIGALRM**: sent by the process alarm (if set) when a certain time interval elapsed.
- **SIGUSR1/2**: User defined you can do what you like
- **SIGCHLD**: send to a process when one of it’s children terminates

Sending Signals

```
int kill(int pid, int signal)// sends a signal to a pid

int raise(int signal) // sends a signal to self

uint alarm(uint time) // sends sigalarm after time seconds
```

- All signals but SIGKILL are implicitly ignored
- SIGCHLD, albeit implicitly ignored by default does not terminate the process
- The alarm settings are not completely preserved through a fork

Capturing Signals

```
#include <signal.h>
typedef void (*sighandler_t)(int);
sighandler_t signal(int signum, sighandler_t handler);
```

- **`signum`**: the signal we want to capture
- **`handler`**: the function pointer
- Two specific values are defined for the handler
  - SIG_DFL: default behavior
  - SIG_IGN: explicitly ignore the signal

Inheritance behavior of signal handlers

- Signal handlers are inherited through fork()
- exec*(...) only preserves SIG_IGN/SIG_DFL (why?)

How kernel manages signals

Overall:

- A signal is generated by some means (another process, the OS, kill, raise or alarm). Receiving a signal alters a bit in the **signal mask** within the PCB
- When this happens the receiving process is moved in ready (even if it was not in ready)
- If a bit was set in the signal mask, when the CPU is assigned to the process, the context is the one of the signal handles

Caveats:

- Multiple deliveries of the same signal might be lost
- If the computation was interrupted at a generic instruction, the flow continues from that point when the handler is done
- If a process was in a syscall, two things can happen:
  - blocking syscalls (e.g. a read from disk), are aborted and **errno** is set to **EINTR**. Such a syscalls are not resumed
  - Non blocking syscalls are not interrupted by any signal

Note to self: errno is now thread safe, and is a macro

Safe bloking syscall

Bad

```
if (syscall()==-1) {
    Do stuff..
}
```

Good

```
while (syscall()==-1) {
  if (errno!=EINTR){
    Do stuff..
  }
}
```

Waiting for Signals

```
#include <unistd.h>

int pause(void);
```

- blocks a process until any signal arrives
- can’t know who sent the signal or which signal unlocked the process just from such a syscall
  - how would you do
    - Easy answer:
      - capture the signal
      - in the implementation
        - save the signal number.
        - roll back to the original handler (IF ANY)

Two simple examples

```
#include <stdio.h>
#include <fcntl.h>
#include <signal.h>
char c;

void sh() {
   printf("I'm alive!\n");
    //reinstall the handler

    signal(SIGALRM, sh);
    alarm(5)

}


int main(int argc, char *argv[]) {
   alarm(5);
   signal(SIGALRM,sh);
   while(1) read(0, &c, 1);
}
```

```
#include <stdio.h>
#include <fcntl.h>
#include <signal.h>
int x,y,i;

void sh() {
   //race conditon x and y might
be
   //different
   printf("I'm alive! %d-%d-\n",
            x,y);
   signal(SIGALRM, sh);
   alarm(5)

}


int main(int argc, char *argv[])
{
   alarm(5);
   signal(SIGALRM,sh);
   while(1)    x = y = i++ %
1000;
}
```

Unreliability of the Signals

```
char c;

void sh() {
   printf("caught sigint!\n");
   // receiving another sigint
   // in this time terminates
   // the process
   signal(SIGINT, sh)
}


int main(int argc, char *argv[]) {
   signal(SIGINT,sh);
   while(1) read(0, &c, 1);
}
```

Signal Sets

`sigset_t:` represents a set of signals

Functions to manage a sigset

```
int sigemptyset(sigset_t *set);

int sigfillset(sigset_t *set);

int sigaddset(sigset_t *set, int signum);

int sigdelset(sigset_t *set, int signum);

int sigismember(const sigset_t *set, int signum);
```

Masking Signals

```
int sigprocmask(int how,
                const sigset_t *set,
                sigset_t *oldset);
```

Examines and changes blocked signals, setting the management of the signal mask

- **how**: **SIG_BLOCK**, **SIG_UNBLOCK**, **SIG_SETMASK**
- **set**: the set in the pool is the one to which the change will be applied
- **oldset**: if not null, stores a backup prior the operation

```
int sigpending(const sigset_t *set);
```

Returns the signals that were masked while blocked

Sigaction: safe signals

```
#include <signal.h>
int sigaction(int signum, const struct sigaction *act,
                          struct sigaction *oldact);
```

Allows to inspect or modify the action performed when a signal is received

signum: the signal

act: the new struct encoding all fields for the handler

oldact: the old struct returned as backup

```
struct sigaction {
  // old style handler
  void     (*sa_handler)(int);
  // new style handler // use either one or the other. Not both!!!
  void     (*sa_sigaction)(int, siginfo_t *, void *);

  sigset_t   sa_mask;   //signals blocked while handling this one
  int        sa_flags;  //behavior (ignore, reinstall..etc)
  void     (*sa_restorer)(void); // obsolete
};
```

Siginfo: gets even more info

```
siginfo_t {
               int      si_signo;     /* Signal number */
               int      si_errno;     /* An errno value */
               int      si_code;      /* Signal code */
               int      si_trapno;    /* Trap number that caused
                                         hardware-generated signal
                                         (unused on most
architectures) */
               pid_t    si_pid;       /* Sending process ID */
               uid_t    si_uid;       /* Real user ID of sending
process */
               int      si_status;    /* Exit value or signal */
               clock_t  si_utime;     /* User time consumed */
               clock_t  si_stime;     /* System time consumed */
               sigval_t si_value;     /* Signal value */
               int      si_int;       /* POSIX.1b signal */
               void    *si_ptr;       /* POSIX.1b signal */
               int      si_overrun;   /* Timer overrun count;
                                         POSIX.1b timers */
               int      si_timerid;   /* Timer ID; POSIX.1b timers
*/
               void    *si_addr;      /* Memory location which
caused fault */
               …
           }
```