Operating Systems

Signals

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Basic Concepts

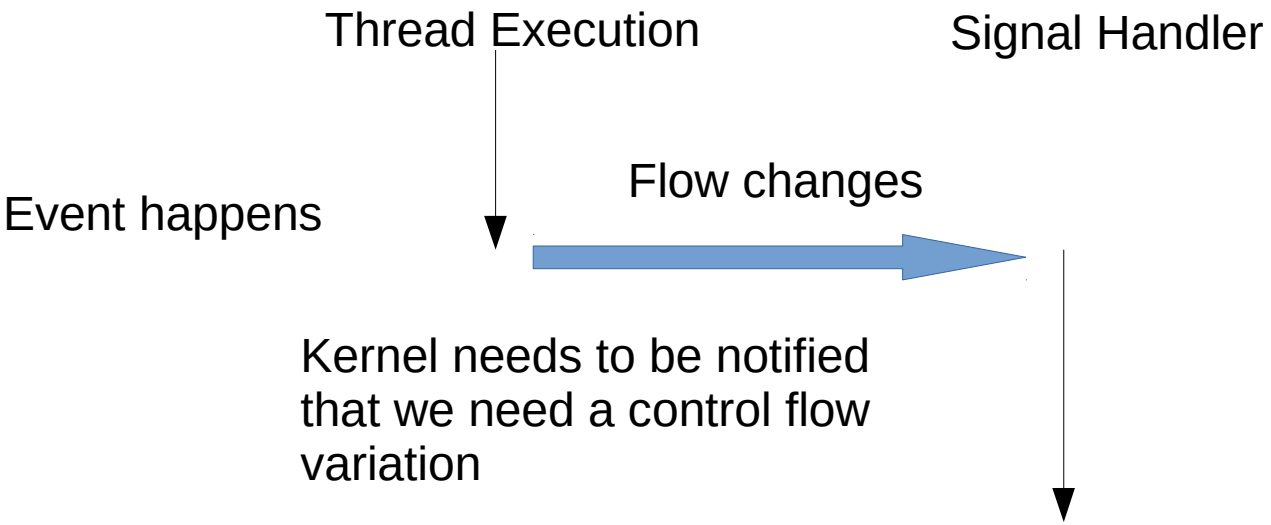
Signals in UNIX are an basic mechanism through which events are notified to a process

- When a process receives such an event, he can perform specific actions to handle the event

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 might not carry information about the sender

Signals in UNIX



There is a predefined set of events.

For a process, each event might be either

- Ignored implicitly
- Ignored explicitly
- Captured

Such a policy is changed through syscall 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 has been closed, or the connection is interrupted
- **`SIGINT`**: received when the user presses 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`**: cannot 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`. It 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 with these
- **`SIGCHLD`**: sent to a process when one of its 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 te 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
  - **`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
- does not know who sent the signal or which signal unlocked the process just from such a syscall
  - How do we tackle this problem?
    - Easy answer:
      - Capture the signal
      - In the implementation one should:
        - 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. Arguments:

- **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
*/
            …
        }
```