Concurrent TCP Servers

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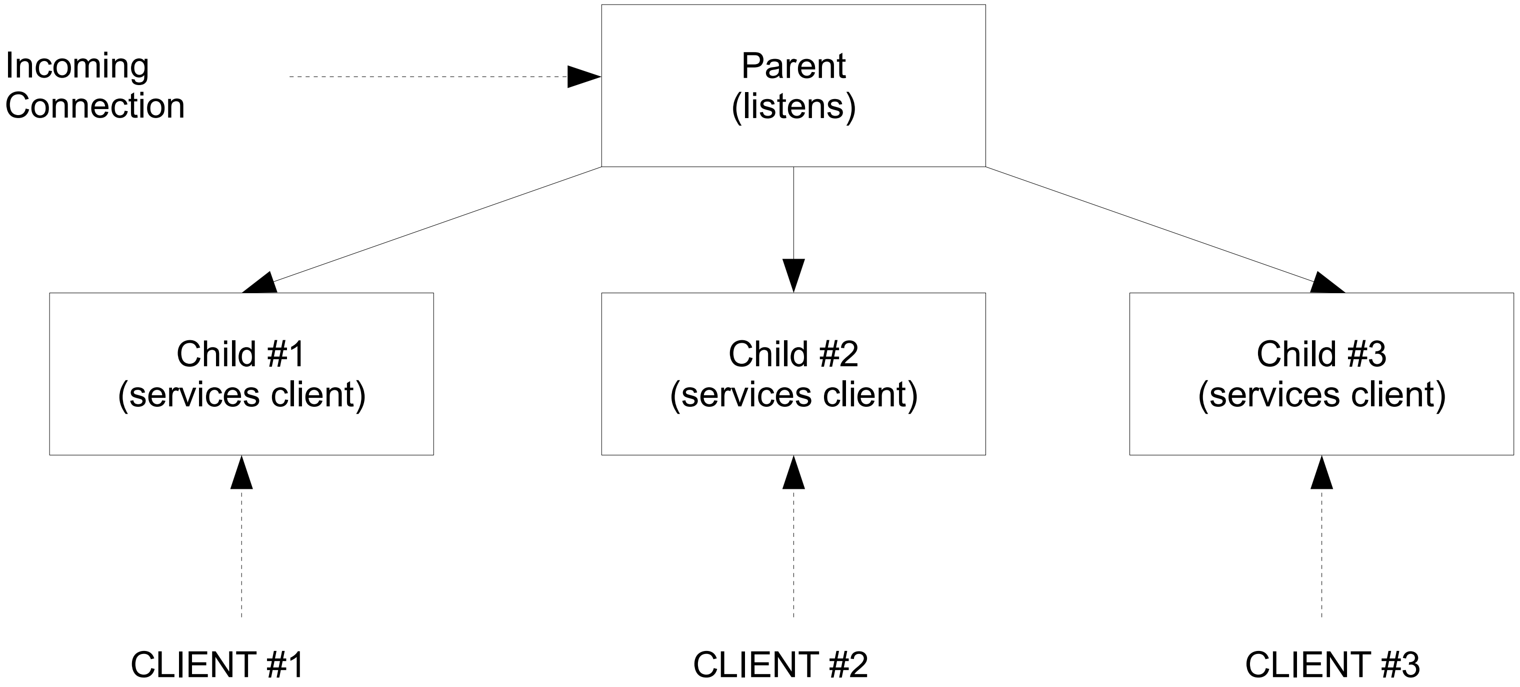
Concurrency Necessary

- Most services require concurrent servers.
  - Clients may require a “long time” to service.
    - Long downloads requested by the client
    - Multiple commands issued by the client
  - Clients might connect and do nothing.
    - Because they are broken
    - Because they are malicious
    - Because they are waiting for human users
  - Network might be slow
- Can't afford to block other clients!

Process Tree



Incoming Connection

Parent (listens)

Child #1 (services client)

Child #2 (services client)

Child #3 (services client)

CLIENT #1

CLIENT #2

CLIENT #3

Multi-Thread Alternative

- Create a thread for each client instead.
  - This is good because...
    - Thread creation is faster than process creation
    - Easy for threads to share resources
  - BUT...
    - Less isolation between threads than processes
    - Multi-threaded programming is tricky.
- We will focus on process level concurrency here.

Unix `fork` Function

- Once a connection has been accepted...

  -
    ```
    if ((child_ID = fork()) == -1) {
      perror(“Unable to fork”);
      return error_code;          // Is this right?
    }
    else if (child_ID == 0) {     // We are the child.
      close(listen_handle);       // Don't need to listen.
      // Service connection...
      close(connection_handle);   // Close connection.
      exit(0);                    // Child terminates!
    }
    ```
  - `fork` creates an identical copy of the parent. Both parent and child run the same code. Returns child PID to parent. Returns 0 to child.

Parent's Main Loop

- The parent accepts connections and forks a child for each...

  -
    ```
    while (1) {
      if ((connection_handle = accept(...)) == -1) {
        perror(“Accept failed”);
      }
      // Create child to service client (previous slide)
      // Parent doesn't need this handle.
      close(connection_handle);
    }
    ```
  - Parent calls accept again “as soon as possible”
    - Next client doesn't have to wait.
    - NOTE: *Child inherits parent's handles!*

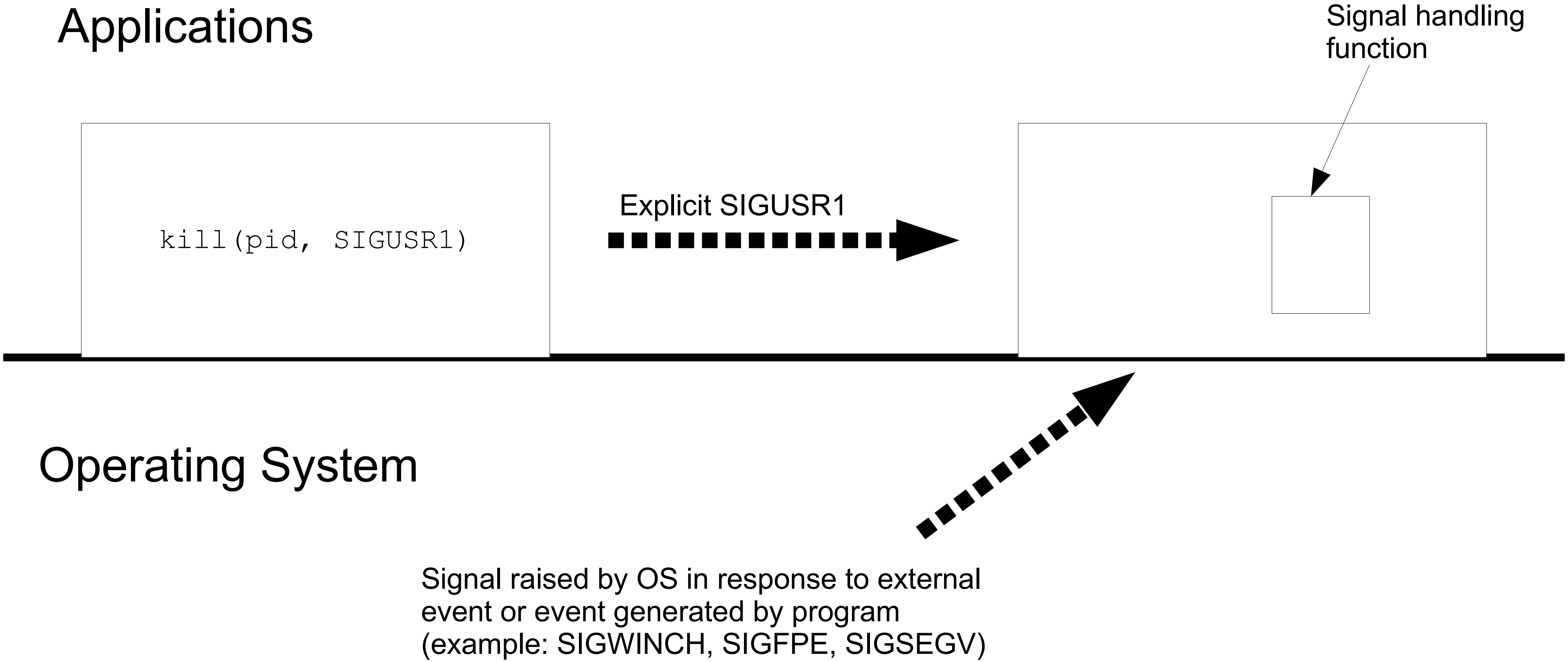
Zombies

- Each process produces an “exit status” to return to its parent.
    - Can be used to signal success/failure.
    - When a process terminates it becomes a *zombie* until parent reads its exit status.
    - Unless the parent server handles this, zombies will accumulate.
    - Zombies are also called “defunct” processes.
- Previous code did not deal with zombies.

Signals

- A “signal” is a software interrupt.
    - Unix-specific concept (Windows does things differently).
    - Generated by the operating system.
    - Many different system signals are defined.
- When a signal is received...
    - The process might be killed.
    - The signal might be ignored.
    - A special “signal handling function” might be called.
    - *Action depends on signal and on program.*

General Structure



Applications

Signal handling function

```
kill(pid, SIGUSR1)
```

Explicit SIGUSR1

Operating System

Signal raised by OS in response to external
event or event generated by program
(example: SIGWINCH, SIGFPE, SIGSEGV)

SIGCHLD

- The `SIGCHLD` signal indicates child termination.
  - Unix sends the parent `SIGCHLD` when one of its children dies.
  - Normally `SIGCHLD` is ignored.
  - We must...
    - Install a signal handling function for `SIGCHLD` that:
    - Collects the exit status of the child to eliminate the zombie.

Set Up Signal Handling

- During the program's initialization...

  -
    ```
    struct sigaction action, old_action;

    action.sa_handler = SIGCHLD_handler;
    sigemptyset(&action.sa_mask);
    action.sa_flags = 0;
    sigaction(SIGCHLD, &action, &old_action);
    ```
  - `SIGCHLD_hander` is a pointer to the signal handling function (defined elsewhere in your program).
  - `sigaction` installs the new handler and returns the old handler information.
  - See the man page for more details.

SIGCHLD Handler

- Also need a function for handling the `SIGCHLD` signal...

  -
    ```
    void SIGCHLD_handler(int signal_number)
    {
      int status;

      while (waitpid(-1, &status, WNOHANG) > 0) ;
    }
    ```
  - Called whenever `SIGCHLD` received.
    - Uses `waitpid` to retrieve the exit status of a child.
    - Loops to handle all dead children. Multiple children might have terminated “at the same time.”

Slight Complication

- Blocking system calls (like `accept`) return “spuriously” after a signal has been handled.
  - This gives your application control again.
    - You might want to do something different.
  - In our case, we just want to call accept again.
    - When a child dies we just want to go back to what we were doing (waiting for a new connection).

Call accept In a Loop

- Instead of a simple conditional statement...

  -
    ```
    while ((connection_handle = accept(...)) == -1) {
      if (errno != EINTR) {
        perror(“Accept failed!”);
        return error_code;
      }
    }
    ```
  - `accept` returns with `errno` set to `EINTR` if it is “interrupted” by a signal.
    - This is not really an error!
    - Code above just ignores that case and calls `accept` again.

Other Possibilities

- Some Unixes allow you to...
  - Set a flag in the `sigaction` structure so that system calls are automatically “restarting”
    - No `EINTR` return.
  - Set a flag in the `sigaction` structure so that dead children don't create zombies in the first place.
  - Features are optional according to POSIX.
- Does Linux allow either of this options?