Concurrent Programming

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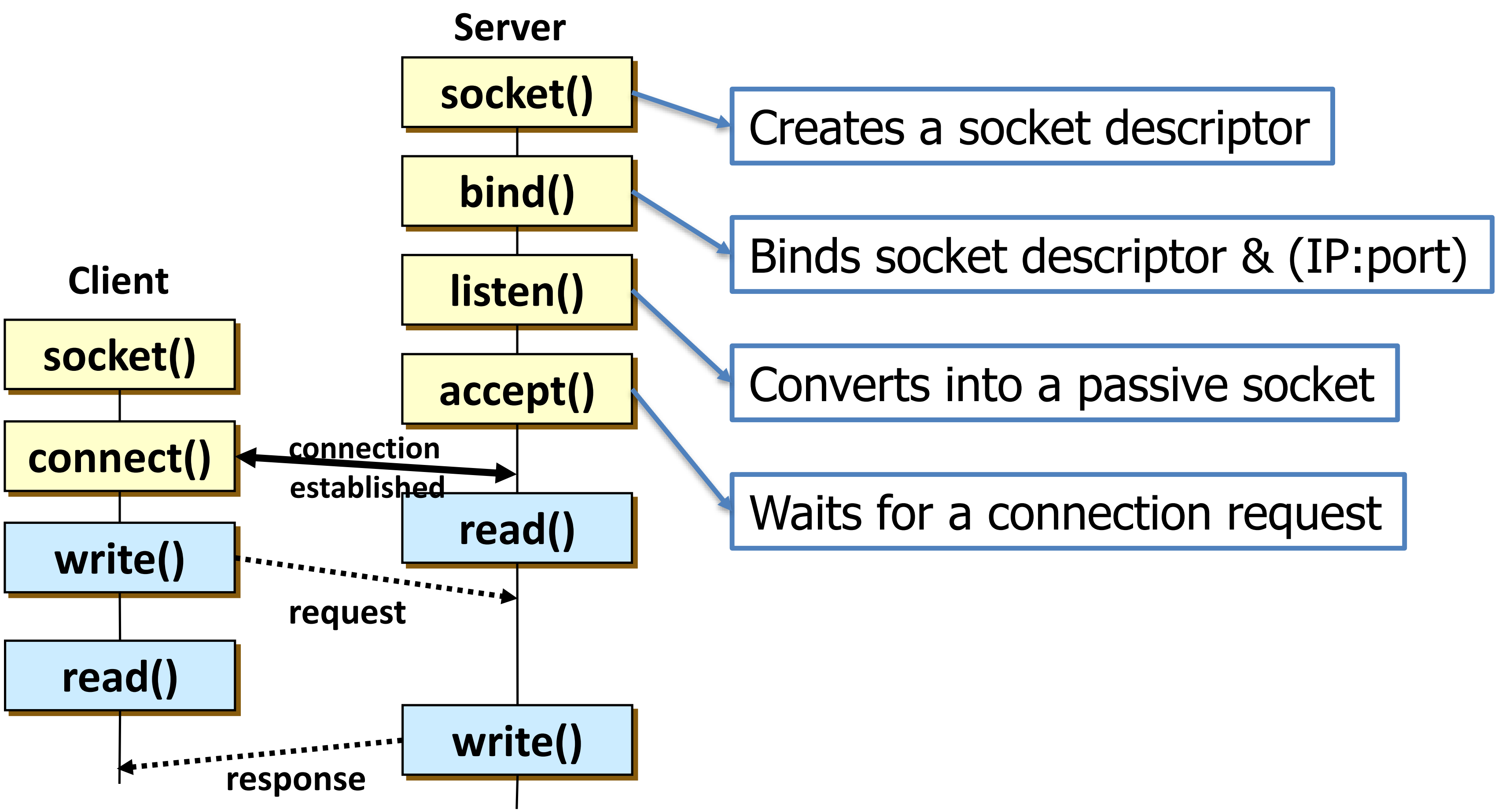
Server

Connection-oriented service



Echo Server Revisited

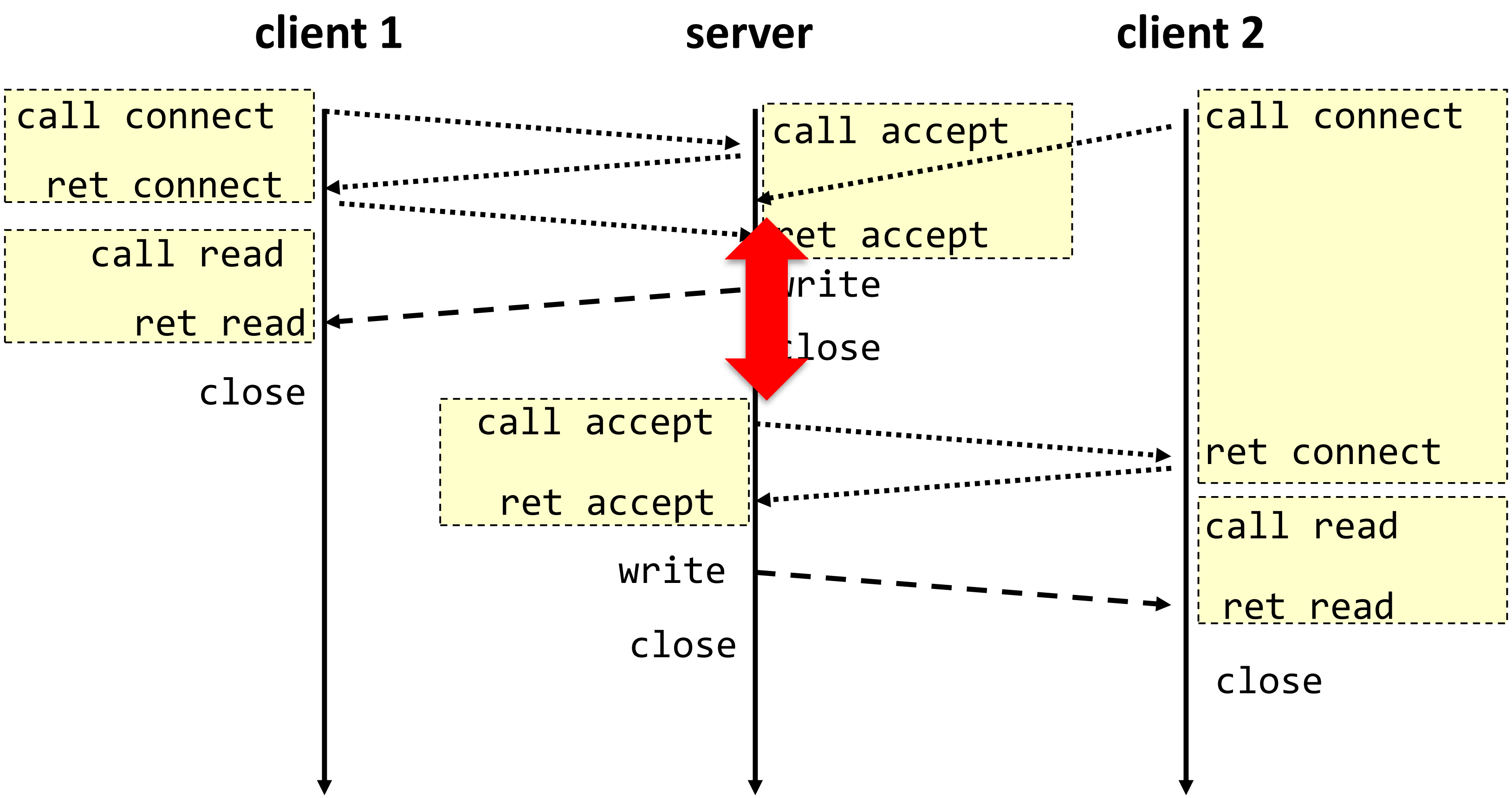
```
int main (int argc, char *argv[]) {
   ...
   listenfd = socket(AF_INET, SOCK_STREAM, 0);

   bzero((char *)&saddr, sizeof(saddr));
   saddr.sin_family = AF_INET;
   saddr.sin_addr.s_addr = htonl(INADDR_ANY);
   saddr.sin_port = htons(port);
   bind(listenfd, (struct sockaddr *)&saddr, sizeof(saddr));

   listen(listenfd, 5);
   while (1) {
      connfd = accept(listenfd, (struct sockaddr *)&caddr, &clen);
      while ((n = read(connfd, buf, MAXLINE)) > 0) {
         printf ("got %d bytes from client.\n", n);
         write(connfd, buf, n);
      }
      close(connfd);
   }
}
```

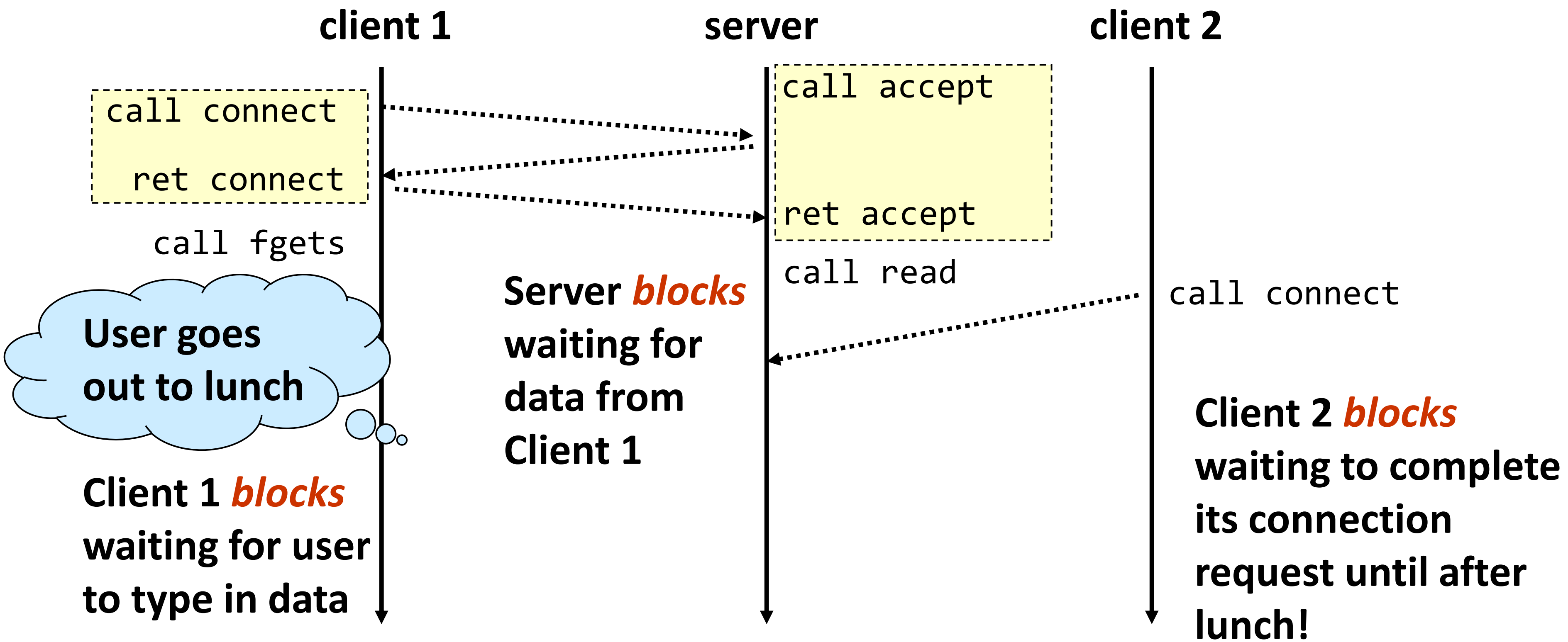
Iterative Servers (1)

- One request at a time



Iterative Servers (2)

- **Fundamental flaw**



- **Solution: use concurrent servers instead**
  - Use multiple concurrent flows to serve multiple clients at the same time.

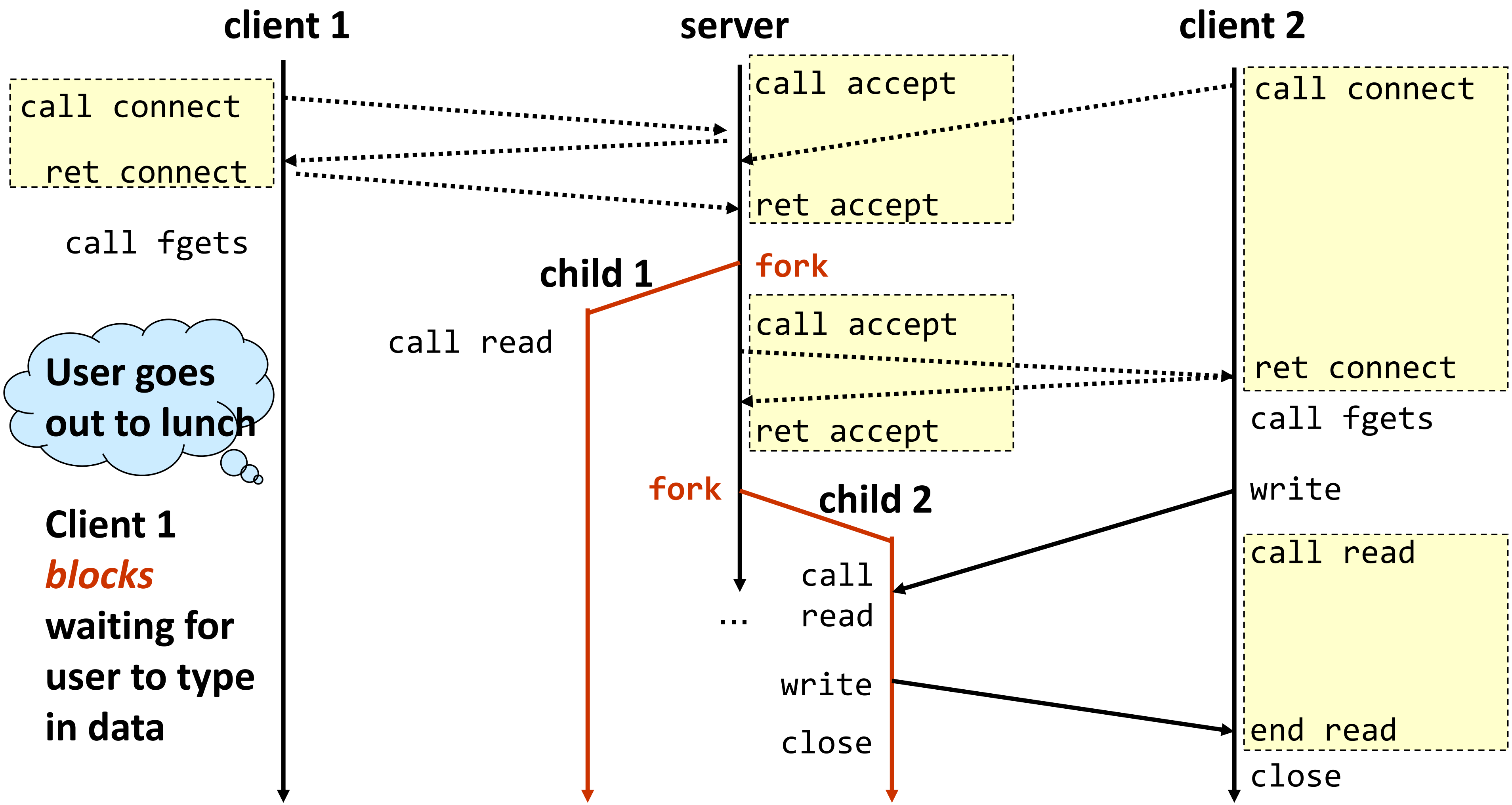
Creating Concurrent Flows

- **Processes**
  - Kernel automatically interleaves multiple logical flows.
  - Each flow has its own private address space.
- **Threads**
  - Kernel automatically interleaves multiple logical flows.
  - Each flow shares the same address space.
  - Hybrid of processes and I/O multiplexing
- **I/O multiplexing with select()**
  - User manually interleaves multiple logical flows
  - Each flow shares the same address space
  - Popular for high-performance server designs.

Concurrent Programming

Process-based

Process-based Servers



Implementation Issues

- **Servers should restart accept() if it is interrupted by a transfer of control to the SIGCHLD handler**
  - Not necessary for systems with POSIX signal handling.
  - Required for portability on some older Unix systems.
- **Server must reap zombie children**
  - to avoid fatal memory leak
- **Server must close its copy of connfd.**
  - Kernel keeps reference for each socket.
  - After **fork(), refcnt(connfd) = 2**
  - Connection will not be closed until **refcnt(connfd) = 0**

Process-based Designs

- **Pros**
  - Handles multiple connections concurrently.
  - Clean sharing model.
    - Descriptors (no), file tables (yes), global variables (no)
  - Simple and straightforward.
- **Cons**
  - Additional overhead for process control.
    - Process creation and termination
    - Process switching
  - Nontrivial to share data between processes.
    - Requires IPC (InterProcess Communication) mechanisms: FIFO's, System V shared memory and semaphores

Exercise

- "Guess the Number"
  - At the same time, multiple client can be served by echo server
- **There should be no memory leakage**
  - How about closing files?

```
./server [port]
```

```
./client 127.0.0.1 [port]
Guess? 32
Up
Guess? 74
Down
Guess? 34
Correct!
$
```

```
./client 127.0.0.1 [port]
Guess? 34
Up
Guess? 40
Down
Guess? 35
Correct!
$
```

```
./client 127.0.0.1 [port]
Guess? 35
Down
Guess? 10
Up
Guess? 14
Correct!
$
```