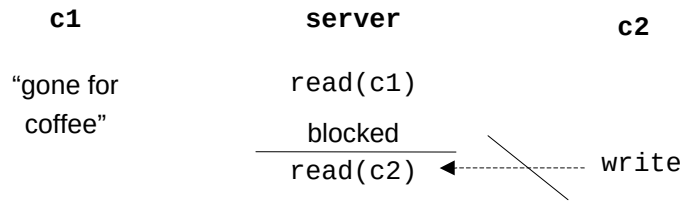
I/O Multiplexing

Haviland 7.1.6

The problem



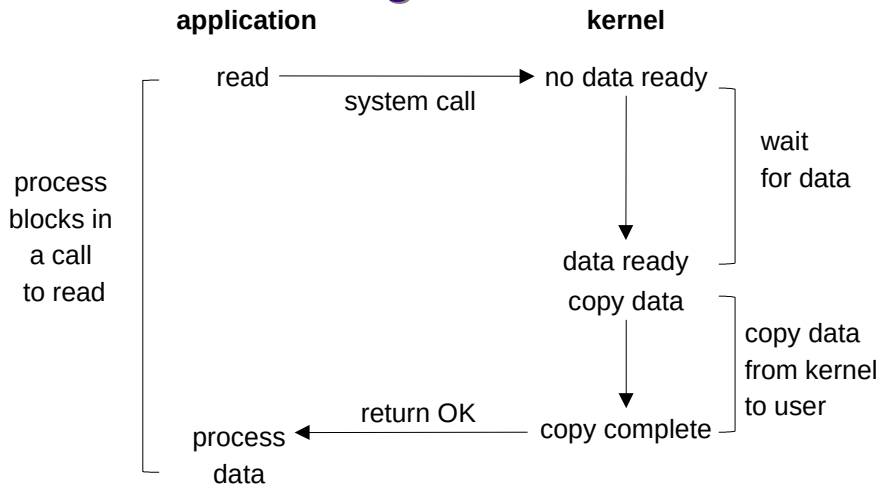
- When reading from multiple sources, blocking on one of the sources could be bad.
  - An example of denial of service.
- One solution: one process for every client. What are the pros and cons of this solution?

Another way to look at the problem

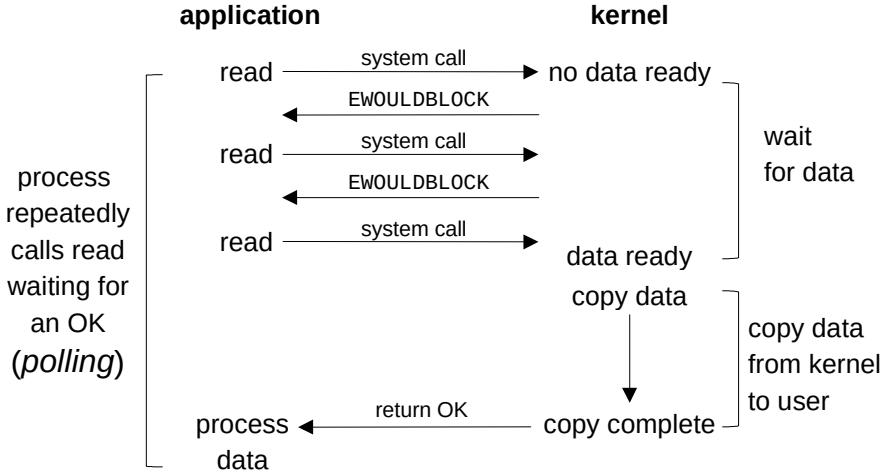
```
Server
while(1)
   accept a new connection
   for each existing connection
         read
         write
```

- Which of the system calls might block indefinitely?
  - read and accept
- So what happens if there is only one connection?

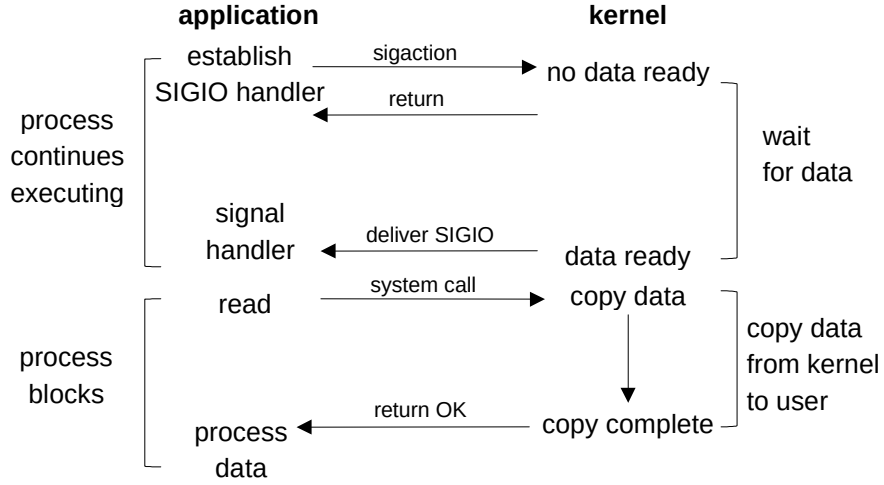
Blocking I/O Model



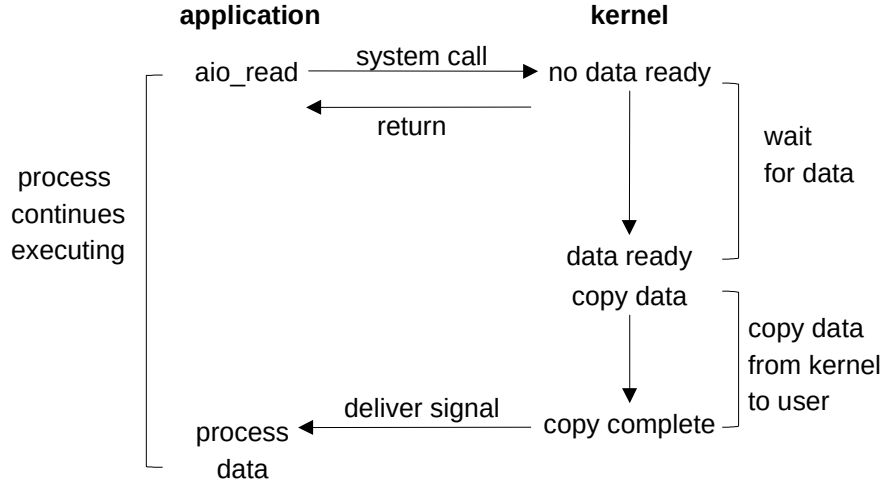
Nonblocking I/O Model



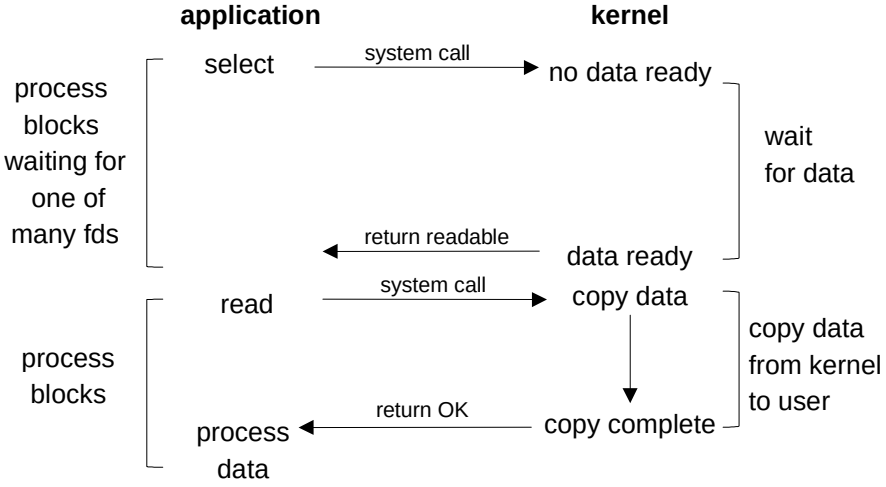
Signal Driven I/O Model



Asynchronous I/O Model



I/O Multiplexing Model



select()

Ch. 7.1.6

```
int select(int maxfdp1,
           fd_set *readset,
           fd_set *writeset,
           fd_set *exceptset,
           const struct timeval *timeout);
```

- A call to select returns when one of the file descriptors in one of the sets is ready for I/O.
- If timeout is not NULL, then select returns when a descriptor is ready or timeout time has passed.
- If timeout is 0, select returns immediately after checking descriptors.

Readiness

- Ready to read when
  - there is data in the receive buffer to be read
  - end-of-file state on file descriptor
  - the socket is a listening socket and there is a connection pending
  - a socket error is pending
- Ready to write when
  - there is space available in the write buffer
  - a socket error is pending
- Exception condition pending when
  - TCP out-of-band data
- We are typically interested in when bytes are available to be read, but sometimes we use select on write or exception sets

select timeout

- The timeout specifies how long we're willing to wait for a fd to become ready

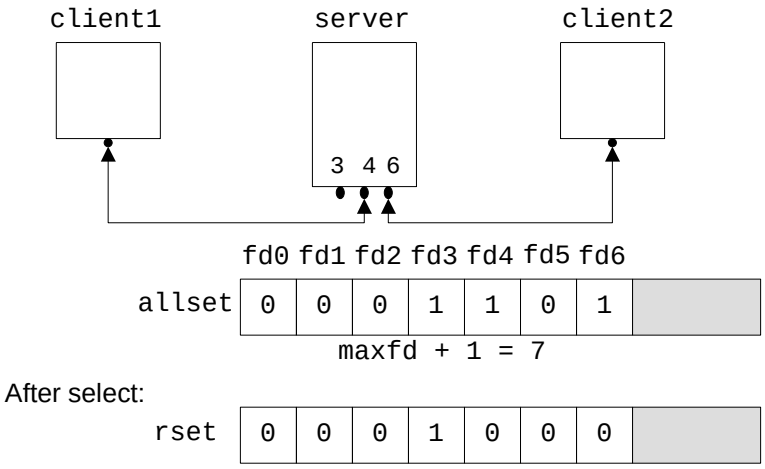
```
struct timeval {
    long  tv_sec;     /* seconds */
    long  tv_usec;    /* microseconds */
};
```

  - If timeout is NULL, wait forever (or until we catch a signal)
  - If timeout is zero, test and return immediately
  - Otherwise wait up to specified timeout
- `select` returns when a fd ready or we timeout

Descriptor sets

- Typically implemented as an array of integers where each bit corresponds to a descriptor (except in Windows).
- Implementation is hidden in the `fd_set` data type
- `FD_SETSIZE` is the number of descriptors in the data type
- `maxfdp1` specifies the number of descriptors to test
- Macros:
  - `void FD_ZERO(fd_set *fdset);`
  - `void FD_SET(int fd, fd_set *fdset);`
  - `void FD_CLR(int fd, fd_set *fdset);`
  - `int  FD_ISSET(int fd, fd_set *fdset);`

Descriptor sets



`select` example

```
fd_set rfds;
struct timeval tv;
int retval;

FD_ZERO(&rfds);  /* Watch stdin (fd 0) for input */
FD_SET(STDIN_FILENO, &rfds);
tv.tv_sec = 5;   /* Wait up to five seconds. */
tv.tv_usec = 0;
retval = select(1, &rfds, NULL, NULL, &tv);
if (retval == -1)
  perror("select()");
else if (retval > 0)
  printf("Data is available now.\n");
  /* FD_ISSET(0, &rfds) will be true, can use read() */
else
  printf("No data within five seconds.\n");
```



```
for( ; ; ) {
  rset = allset;
  nready = Select(maxfd+1, &rset ,NULL,NULL,NULL);
  if(FD_ISSET(listenfd, &rset)) {
     connfd = Accept(listenfd, &caddr, &clen);
     for(i = 0; i < FD_SETSIZE; i++)
          if(client[i] < 0) {
               client[i] = connfd; break;
          }
     FD_SET(connfd, &allset);
     if(connfd > maxfd) maxfd = connfd;
  }
  for(i = 0; i <= maxi; i++) {
     if(sockfd = client[i]) < 0) continue;
     if(FD_ISSET(sockfd, &rset))
          Read(sockfd, line, MAXLINE);
     }
  }
}
```



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