Status

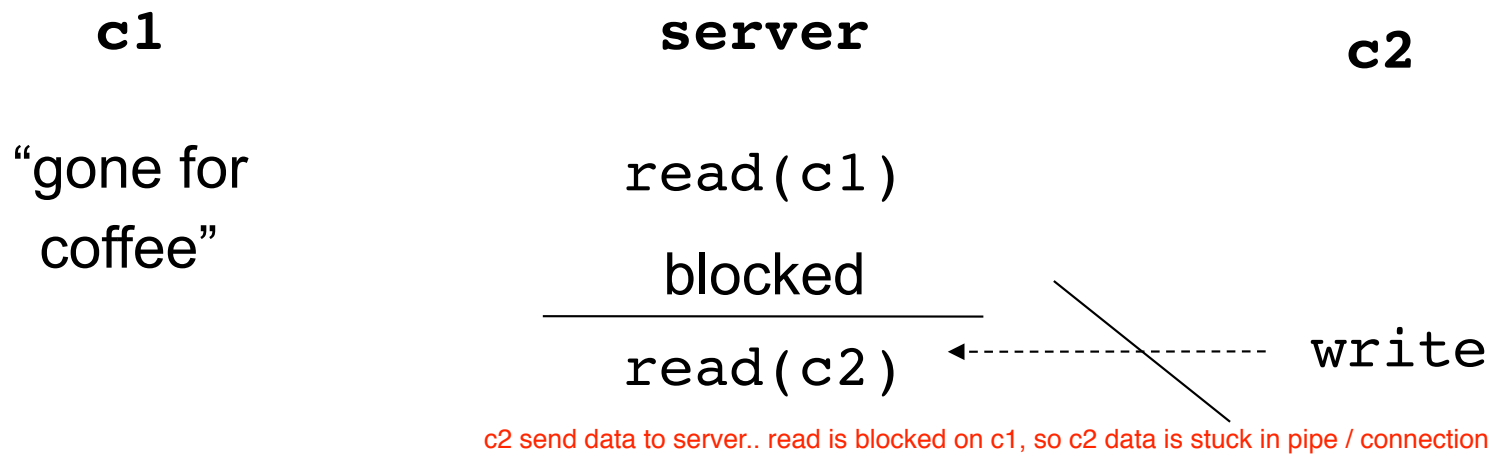
- A4 will be out later today
  - No extensions are possible
  - You may use late penalties

- Exercises 10 and 11 are posted
  - We will take the best 9 out of 10 marks for labs.
  - Exercise 7 was not for credit.
  - This sort of makes exercise 11 optional

I/O Multiplexing

Kerrisk Ch 63

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?

1.accept call generate socket ,
2.incoming connection is being forked and accept data in a separate process
3. may be problematic
   a. too many child process
   b. shared data between child processes

Another way to look at the problem

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

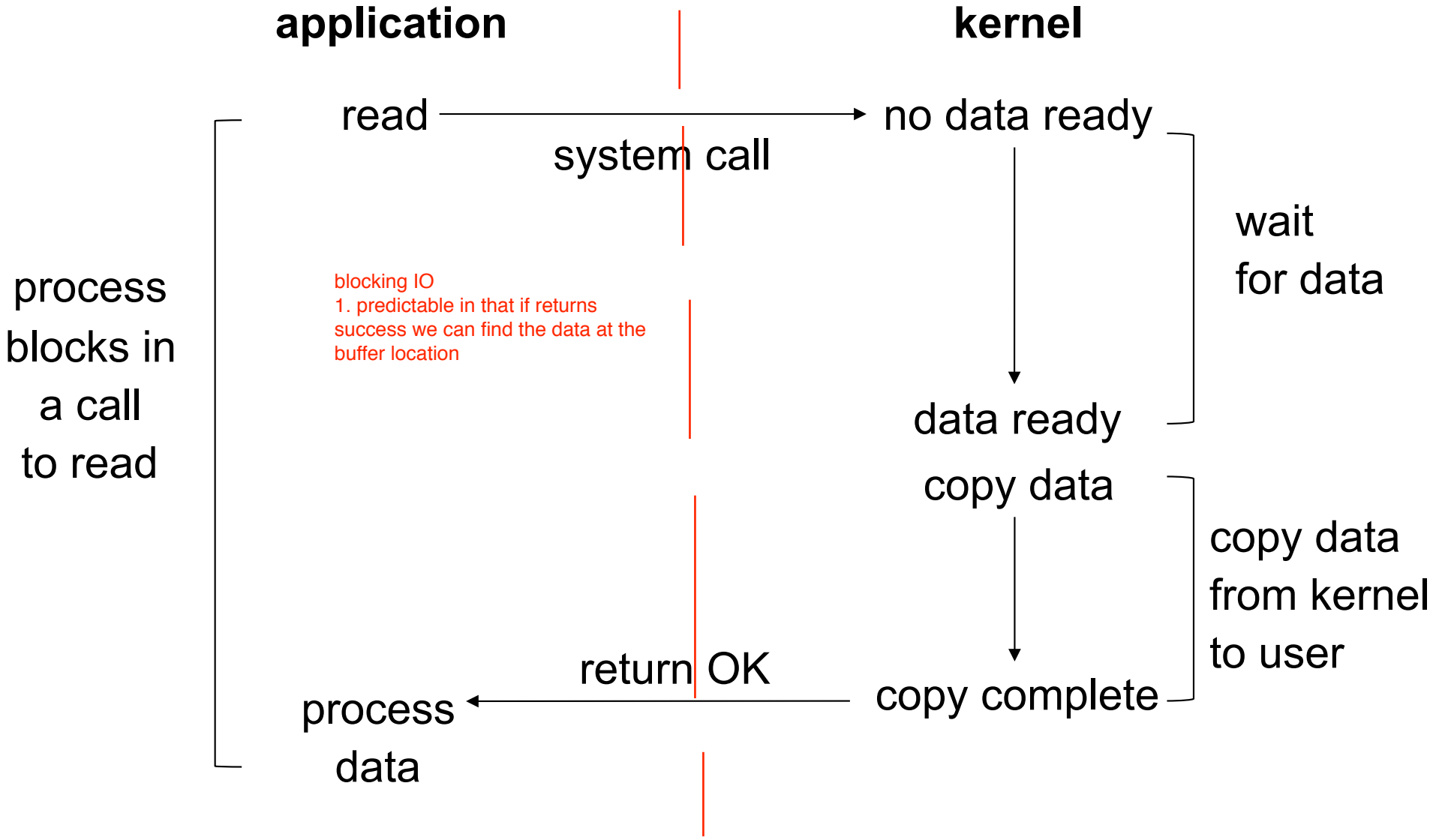
Which of the system calls might block indefinitely?

read and accept

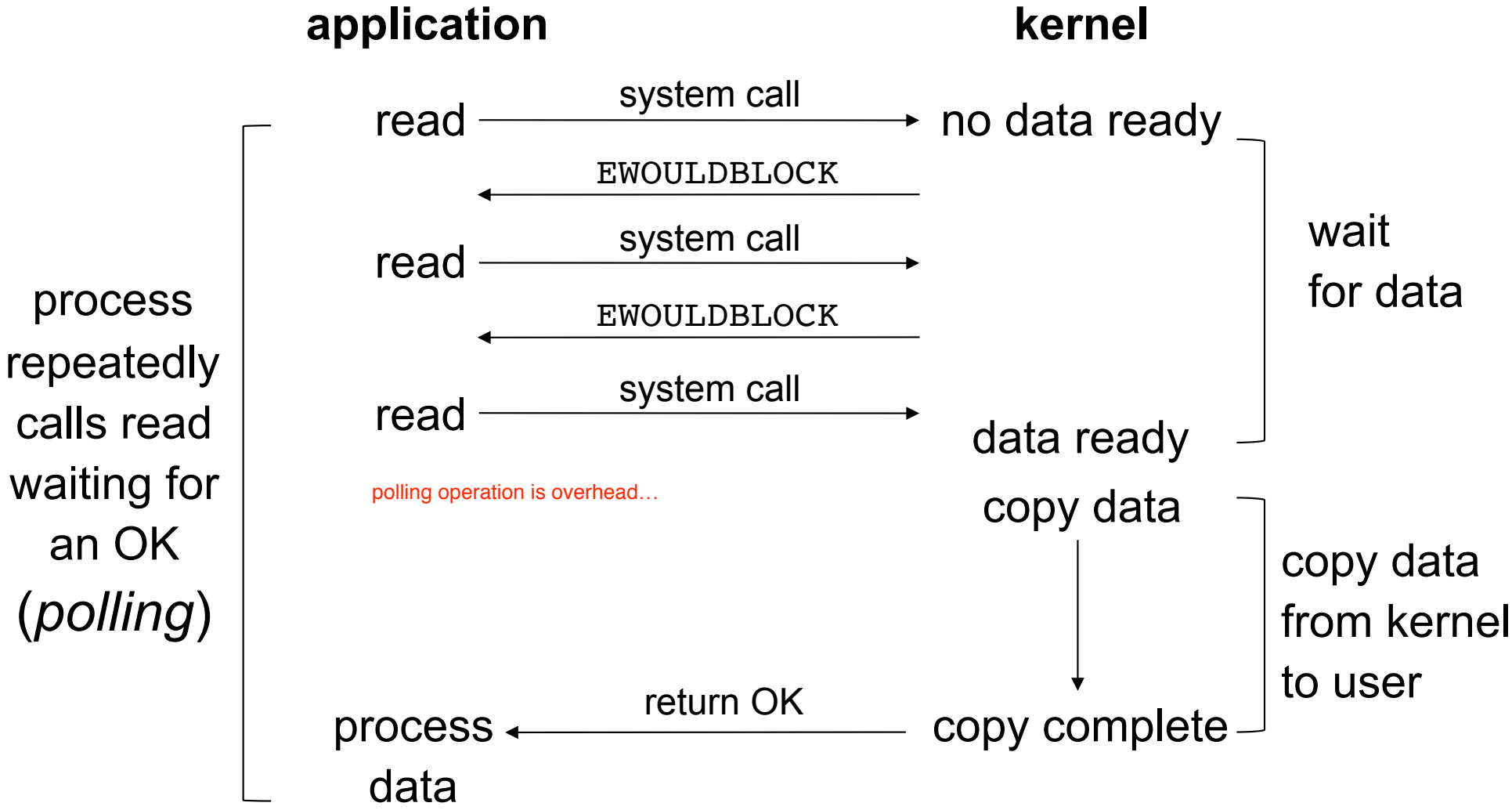
So what happens if there is only one connection?

blocked in accept call …

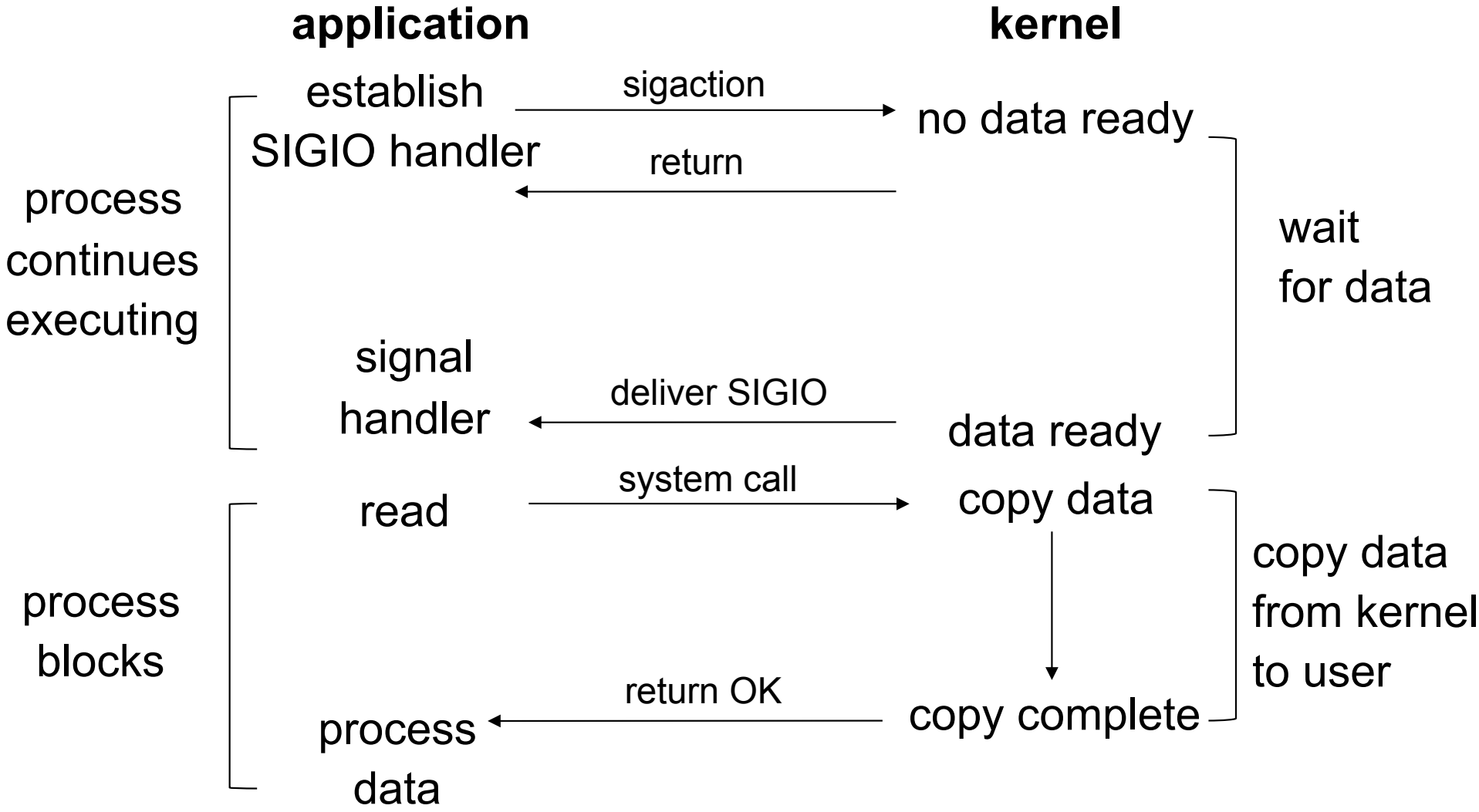
Blocking I/O Model



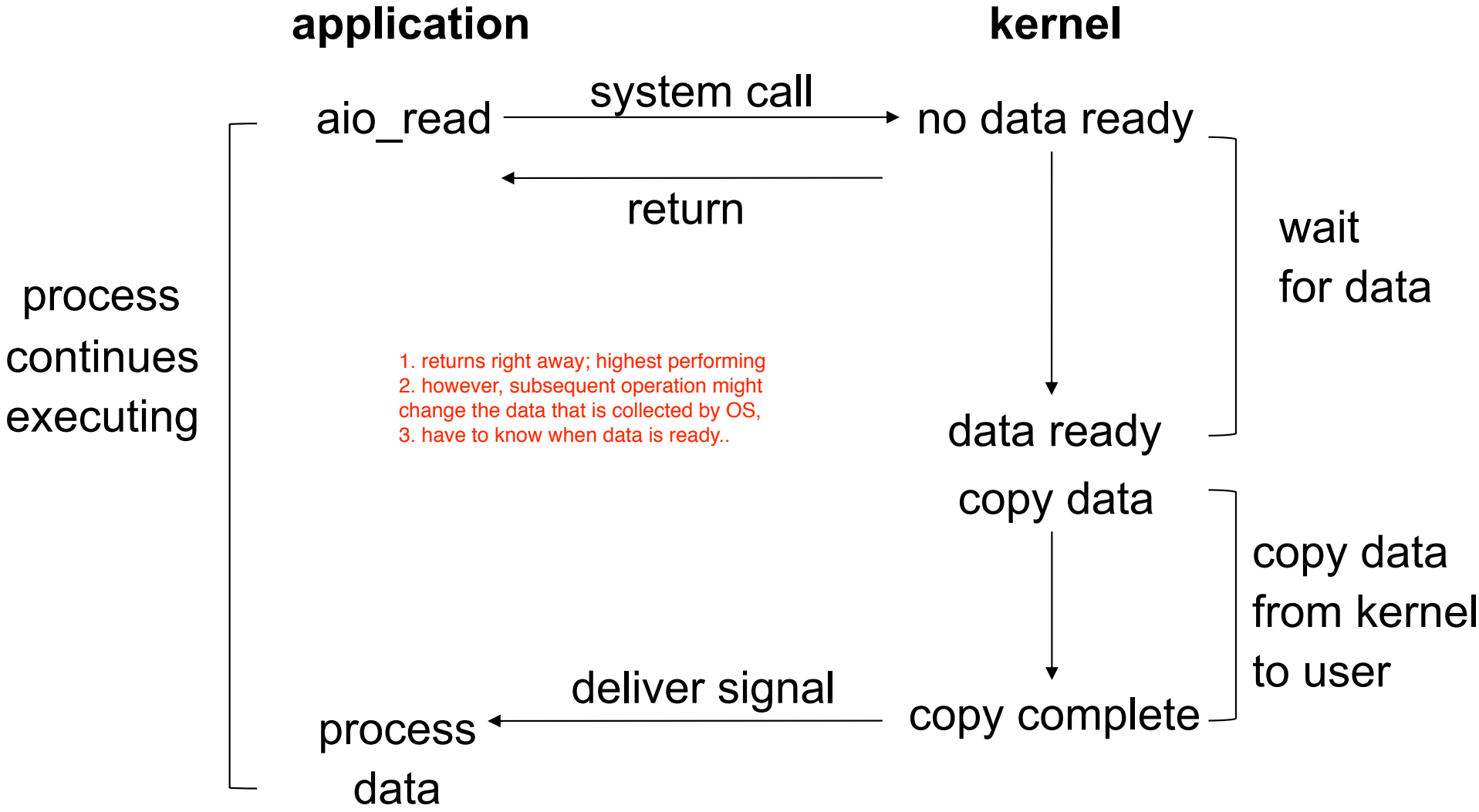
Nonblocking I/O Model



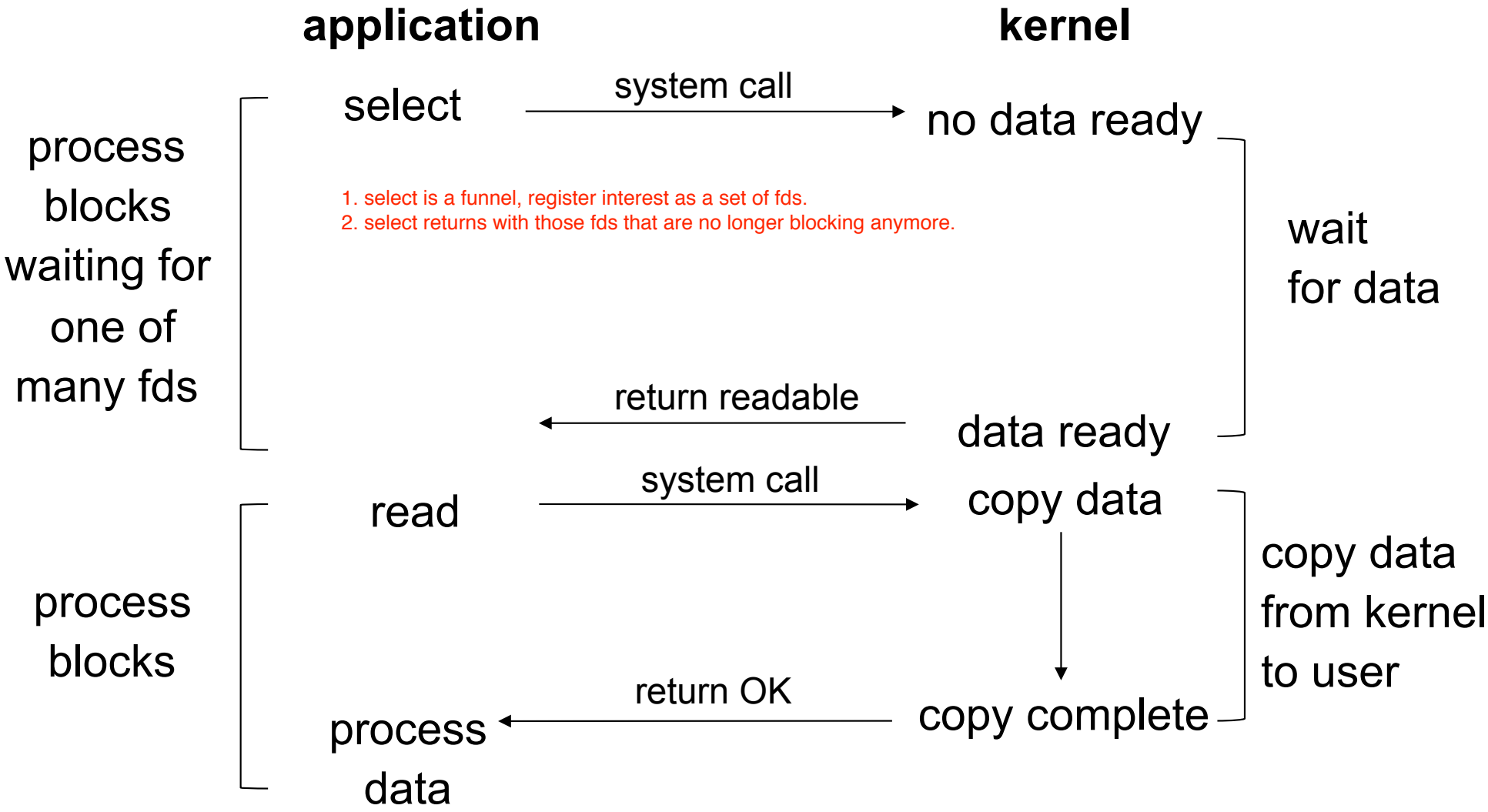
Signal Driven I/O Model



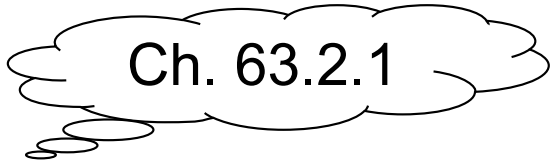
Asynchronous I/O Model



I/O Multiplexing Model



write does usually block for period to write data. unusual to wait indefinitely



select()

how far into set we have to search

```
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

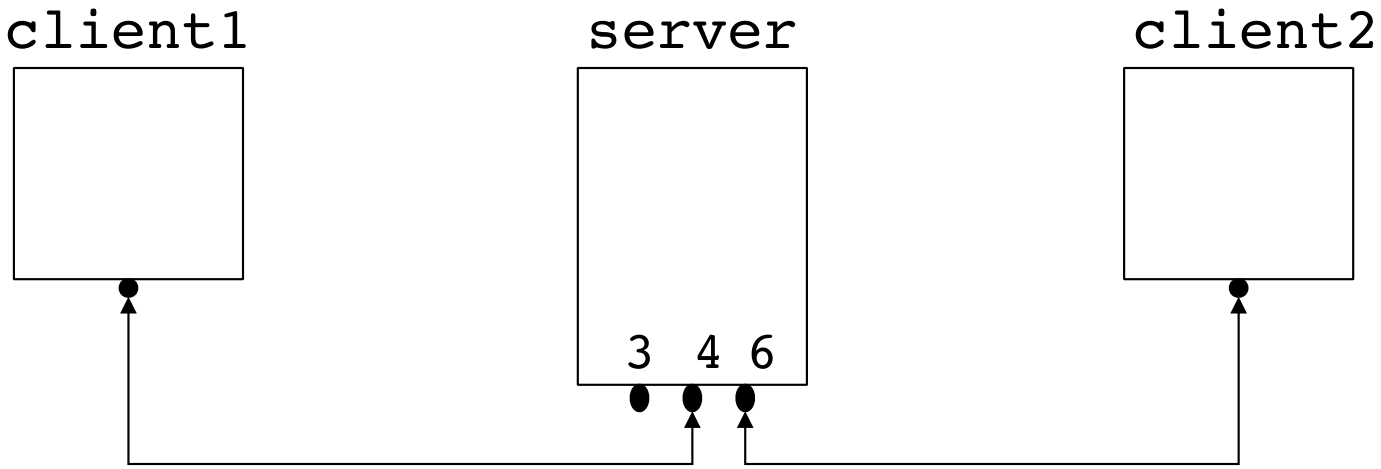
`FD_SETSIZE` is the number of descriptors in the data type

`maxfdp1` specifies the number of descriptors to test

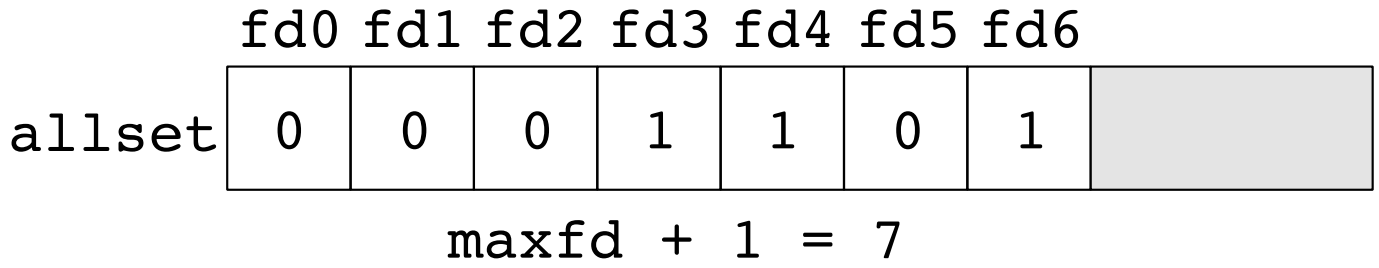
Macros:

```
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);
```

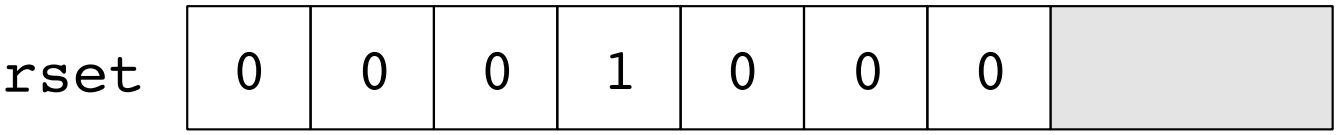
Descriptor sets



select search linearly, so efficient to tell select where to stop



After select:



select modify set, only fds that has something to read is in the set

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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   }
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      if(sockfd = client[i]) < 0) continue;
      if(FD_ISSET(sockfd, &rset))
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      }
   }
}
```

End of Line

- There are two characters that determine end-of-line
  - Carriage return (CR, \r, ^M)
  - Line feed (LF, \n)
- Early operating systems defined their own conventions using one or both of CR and LF.
  - Unix: LF,
  - DOS/Windows: CR LF
  - Mac classic: CR

Network Line Ending

- Transferring data between machines with different operating systems, means deciding on a common line ending.
- CR LF is the standard
- (Of course it is possible with regular expression matching to mostly ignore this issue, but still better to conform.)