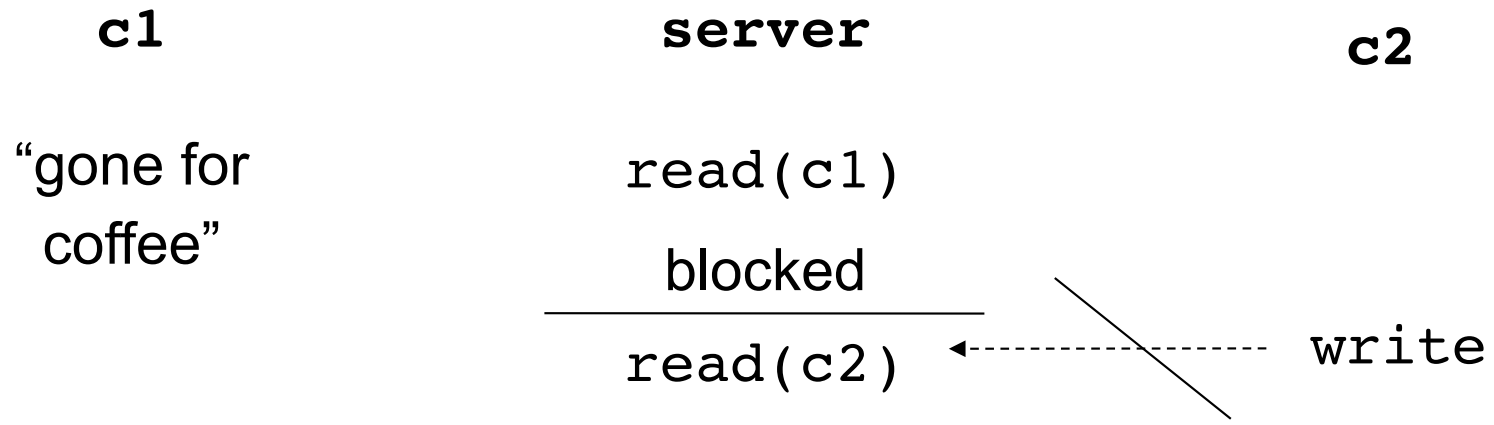
# The problem




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

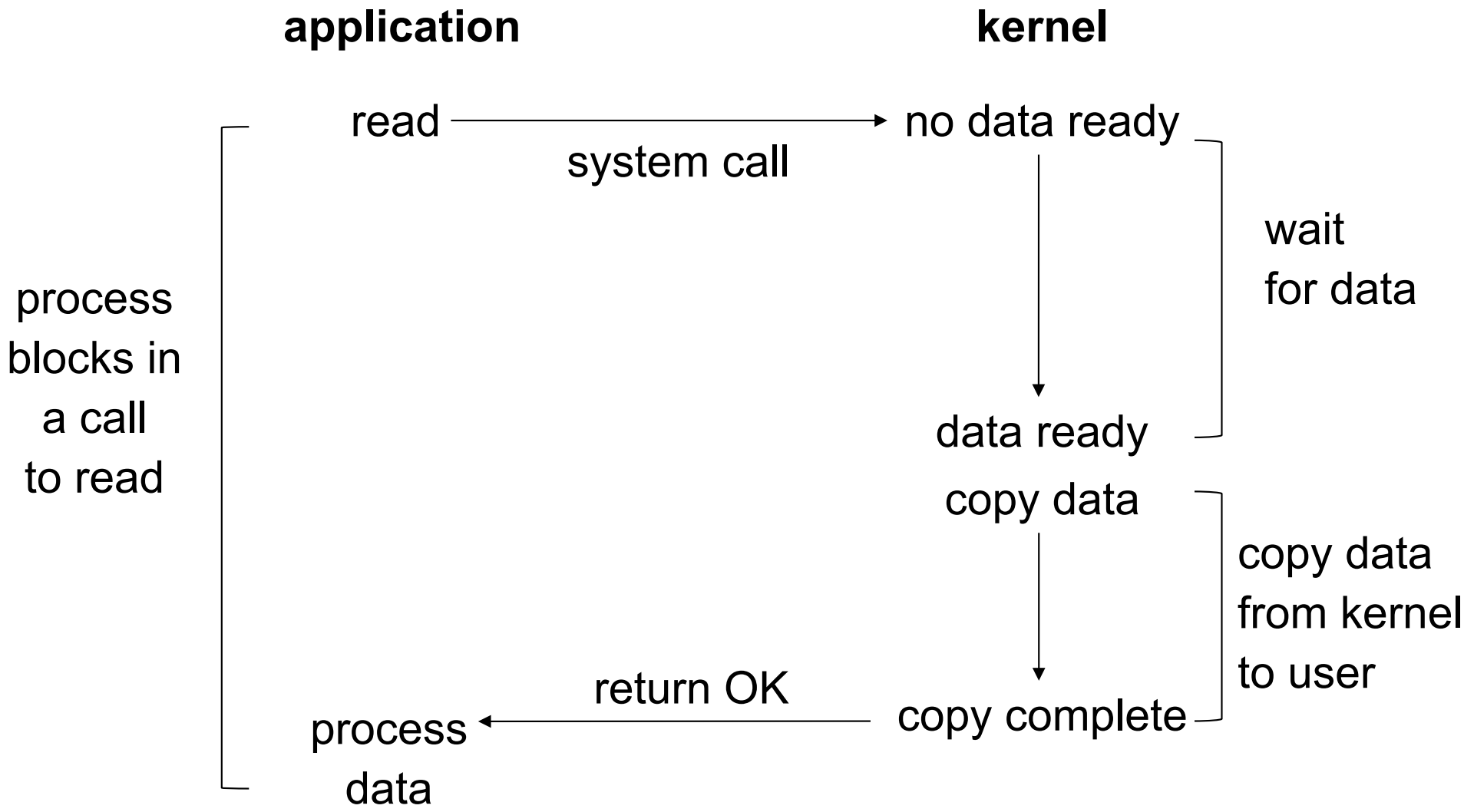
```
Server
while(1)
   accept a new connection
   for each existing connection
     read
     write
```

Which of the system calls might block indefinitely?

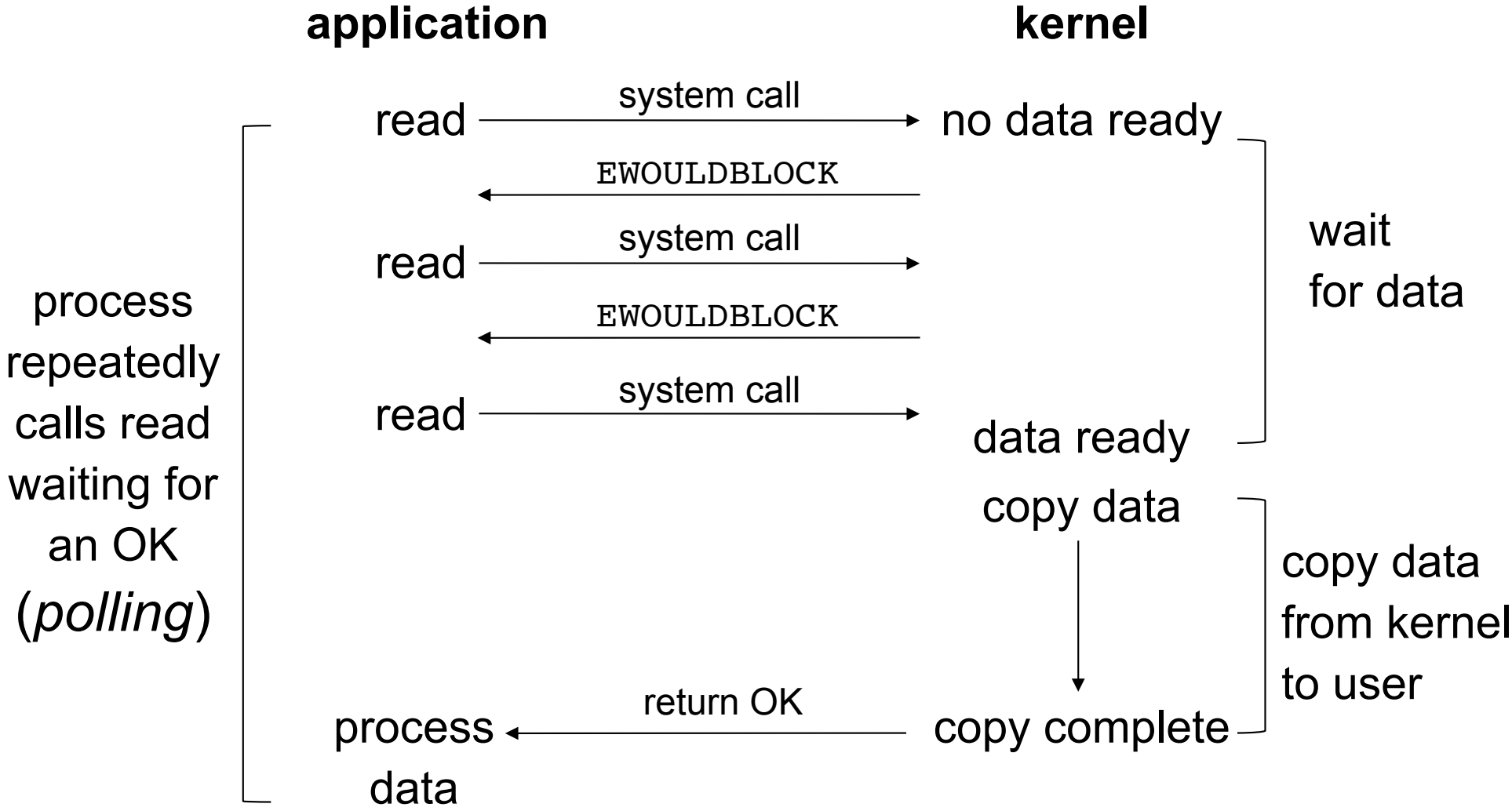
read and accept

So what happens if there is only one connection?

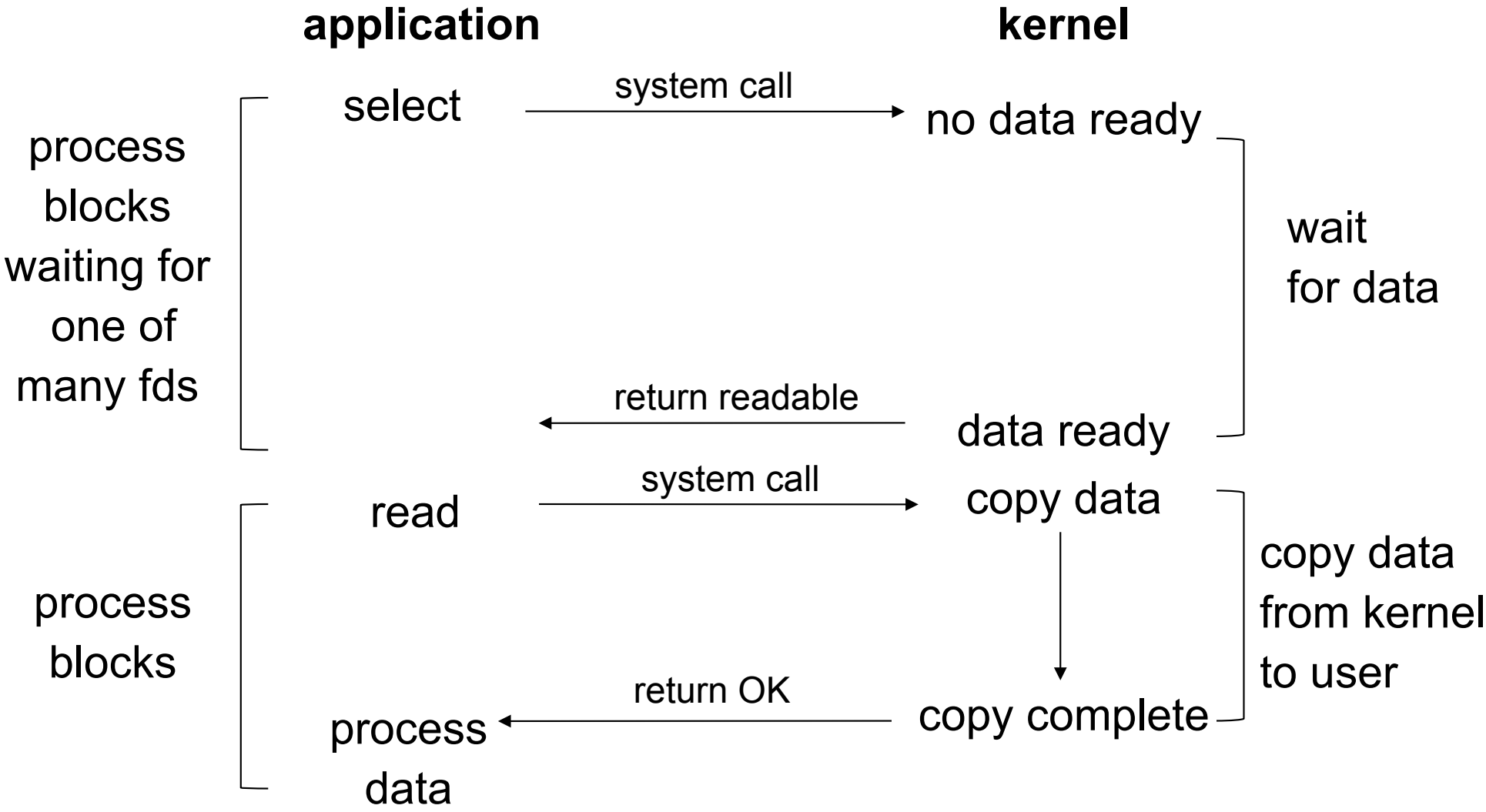
# Blocking I/O Model



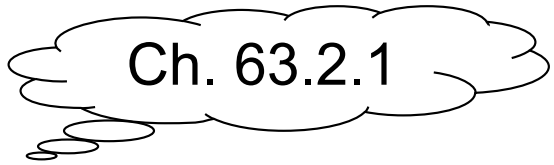
# Nonblocking I/O Model



# I/O Multiplexing Model



# select()




```
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

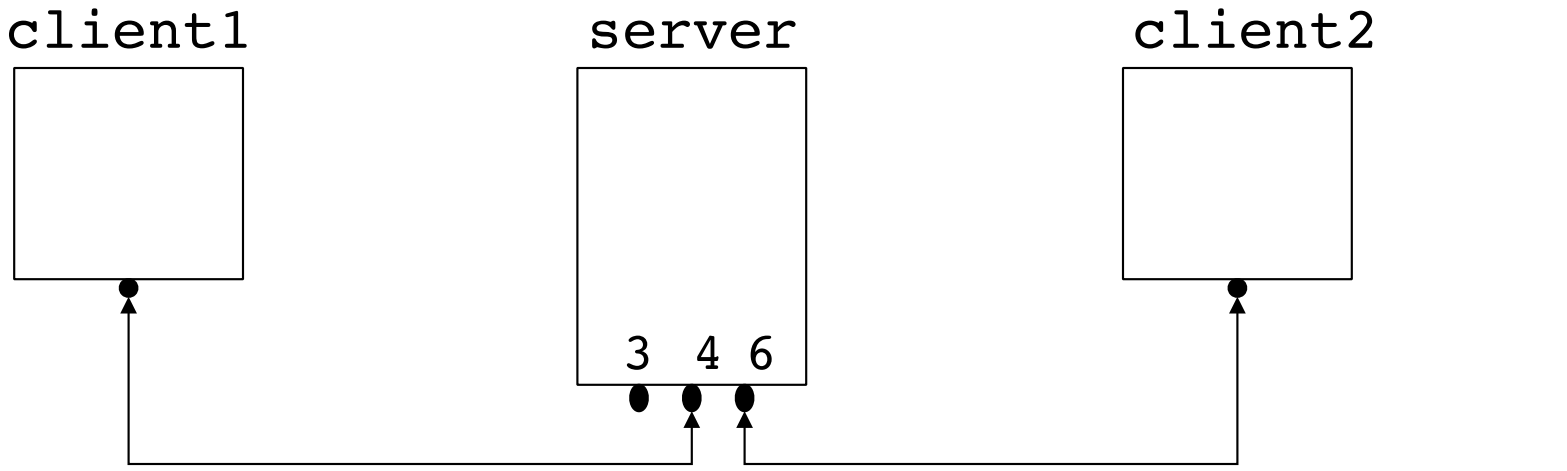
`FD_SETSIZE` is the number of descriptors in the data type

`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




| | fd0 | fd1 | fd2 | fd3 | fd4 | fd5 | fd6 | |
|---|---|---|---|---|---|---|---|---|
| allset | 0 | 0 | 0 | 1 | 1 | 0 | 1 | |

maxfd + 1 = 7

After select:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| rset | 0 | 0 | 0 | 1 | 0 | 0 | 0 | |

# 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);
      }
   }
}
```

```
for( ; ; ) {
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   }
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           }
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      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);
      }
   }
}
```

# 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

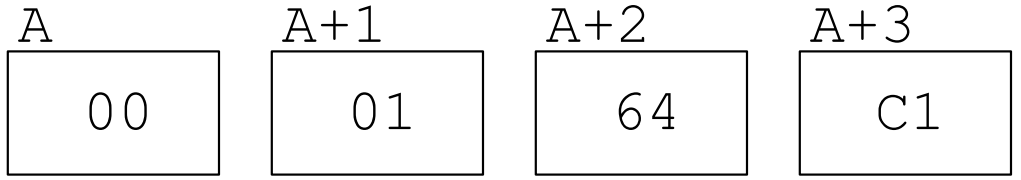
# Network Line Ending

- 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.)

# Byte order

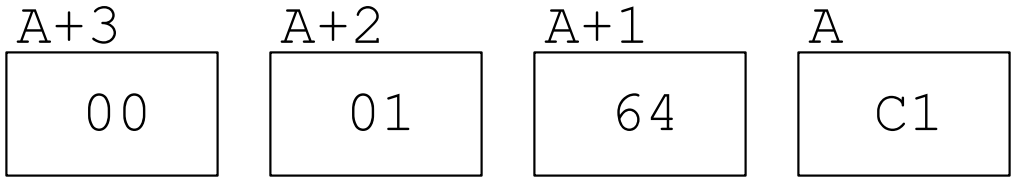
- Big-endian

91,329 =




- Little-endian

91,329 =




- Intel is little-endian, and Sparc is big-endian

# Network byte order

- To communicate between machines with unknown or different “endian-ness” we convert numbers to network byte order (big-endian) before we send them.
- There are functions provided to do this:
  - `unsigned long htonl(unsigned long)`
  - `unsigned short htons(unsigned short)`
  - `unsigned long ntohl(unsigned long)`
  - `unsigned short ntohs(unsigned short)`

# Arrays of bit strings

- FD_SETSIZE is bigger than 32.

```
struct bits {
  unsigned int field[N];
}
typedef struct bits Bitstring;
Bitstring a, b;
setzero(&a);
b = a;
a.field[0] = ~0;
```

# Setting and unsetting

```
int set(unsigned int bit, Bitstring *b) {
  int index = bit / 32;
  b->field[index] |= 1 << (bit % 32);
  return 1;
}

int unset(unsigned int bit, Bitstring *b) {
  int index = bit / 32;
  b->field[index] &= ~(1 << (bit % 32));
}
```

# Testing and emptying

```
int ifset(unsigned int bit, Bitstring *b) {
  int index = bit / 32;
  return ( (1 << (bit % 32))
           & b->field[index]);
}

int setzero(Bitstring *b){
  if(memset(b,0, sizeof(Bitstring)) == NULL)
    return 0;
  else
    return 1;
}
```

# Printing

```
char *intToBinary(unsigned int number) {
  char *binaryString = malloc(32+1);
  int i;
  binaryString[32] = '\0';
  for (i = 31; i >= 0; i--) {
    binaryString[i] = ((number & 1) + '0');
    number = number >> 1;
  }
  return binaryString;
}
```