

System-Level I/O:

Short Counts & The Robust I/O package

On Short Counts

- **Short counts can occur in these situations:**
 - Encountering (end-of-file) EOF on reads
 - Reading text lines from a terminal
 - Reading and writing network sockets

- **Short counts never occur in these situations:**
 - Reading from disk files (except for EOF)
 - Writing to disk files

- **Best practice is to always allow for short counts**

The RIO Package

- RIO is a set of wrappers that provide efficient and robust I/O in apps, such as network programs that are subject to short counts
- RIO provides two different kinds of functions
 - *Unbuffered* input and output of binary data
 - `rio_readn` and `rio_writen`
 - *Buffered* input of text lines and binary data
 - `rio_readlineb` and `rio_readnb`
 - Buffered RIO routines are thread-safe and can be interleaved arbitrarily on the same descriptor
- Download from <http://csapp.cs.cmu.edu/3e/code.html>
→ `src/csapp.c` and `include/csapp.h`

Unbuffered RIO Input and Output

- Same interface as Unix `read` and `write`
- Especially useful for transferring data on network sockets

```
#include "csapp.h"
```

```
ssize_t rio_readn(int fd, void *usrbuf, size_t n);  
ssize_t rio_writen(int fd, void *usrbuf, size_t n);
```

Return: num. bytes transferred if OK, 0 on EOF (`rio_readn` only), -1 on error

- `rio_readn` returns short count only if it encounters EOF
 - Only use it when you know how many bytes to read
- `rio_writen` never returns a short count
- Calls to `rio_readn` and `rio_writen` can be interleaved arbitrarily on the same descriptor

Implementation of `rio_readn`

```
/*
 * rio_readn - Robustly read n bytes (unbuffered)
 */
ssize_t rio_readn(int fd, void *usrbuf, size_t n)
{
    size_t nleft = n;
    ssize_t nread;
    char *bufp = usrbuf;

    while (nleft > 0) {
        if ((nread = read(fd, bufp, nleft)) < 0) {
            if (errno == EINTR) /* Interrupted by sig handler return */
                nread = 0;      /* and call read() again */
            else
                return -1;      /* errno set by read() */
        }
        else if (nread == 0)
            break;              /* EOF */
        nleft -= nread;
        bufp += nread;
    }
    return (n - nleft);        /* Return >= 0 */
}
```

csapp.c

Buffered RIO Input Functions

- Efficiently read text lines and binary data from a file partially cached in an internal memory buffer

```
#include "csapp.h"

void rio_readinitb(rio_t *rp, int fd);

ssize_t rio_readlineb(rio_t *rp, void *usrbuf, size_t maxlen);
ssize_t rio_readnb(rio_t *rp, void *usrbuf, size_t n);
```

Return: num. bytes read if OK, 0 on EOF, -1 on error

- **rio_readlineb** reads a text line of up to **maxlen** bytes from file **fd** and stores the line in **usrbuf**
 - Especially useful for reading text lines from network sockets
- Stopping conditions
 - **maxlen** bytes read
 - EOF encountered
 - Newline ('\n') encountered

Buffered RIO Input Functions (cont)

```
#include "csapp.h"
```

```
void rio_readinitb(rio_t *rp, int fd);
```

```
ssize_t rio_readlineb(rio_t *rp, void *usrbuf, size_t maxlen);
```

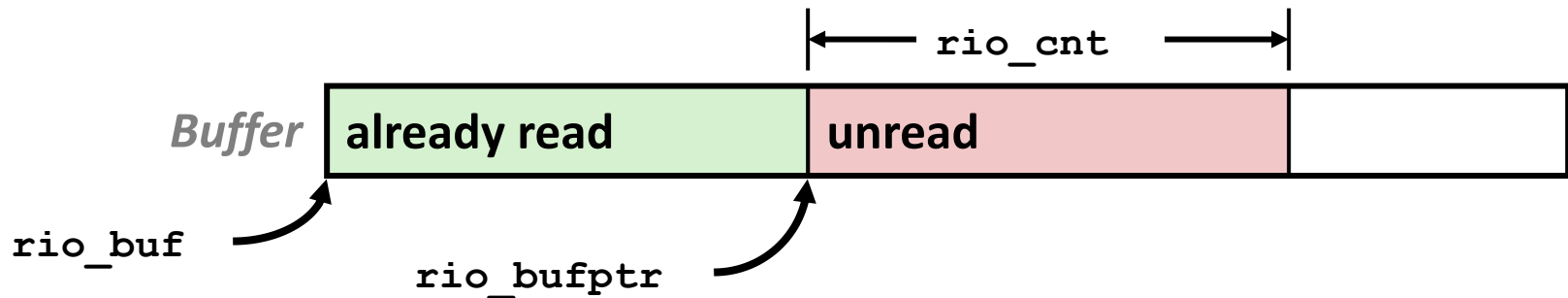
```
ssize_t rio_readnb(rio_t *rp, void *usrbuf, size_t n);
```

Return: num. bytes read if OK, 0 on EOF, -1 on error

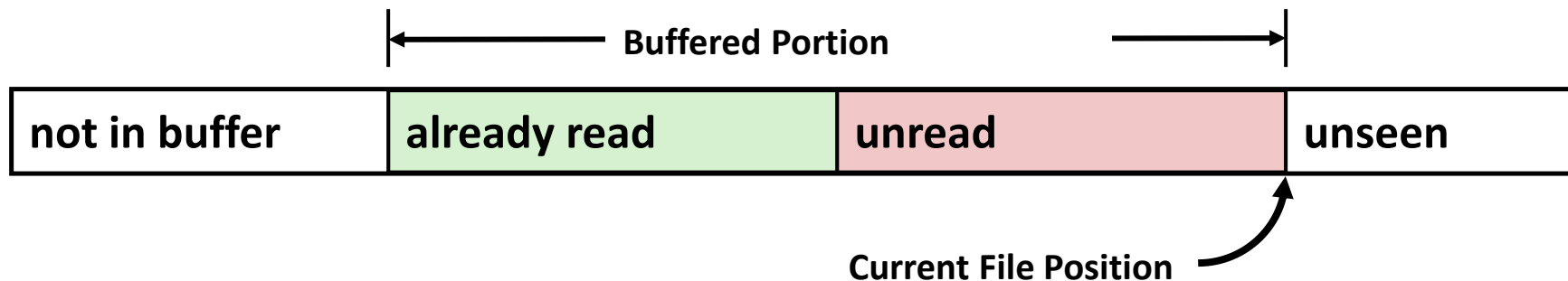
- **rio_readnb** reads up to **n** bytes from file **fd**
- Stopping conditions
 - **maxlen** bytes read
 - EOF encountered
- Calls to **rio_readlineb** and **rio_readnb** can be interleaved arbitrarily on the same descriptor
 - Warning: Don't interleave with calls to **rio_readn**

Buffered I/O: Implementation

- For reading from file
- File has associated buffer to hold bytes that have been read from file but not yet read by user code

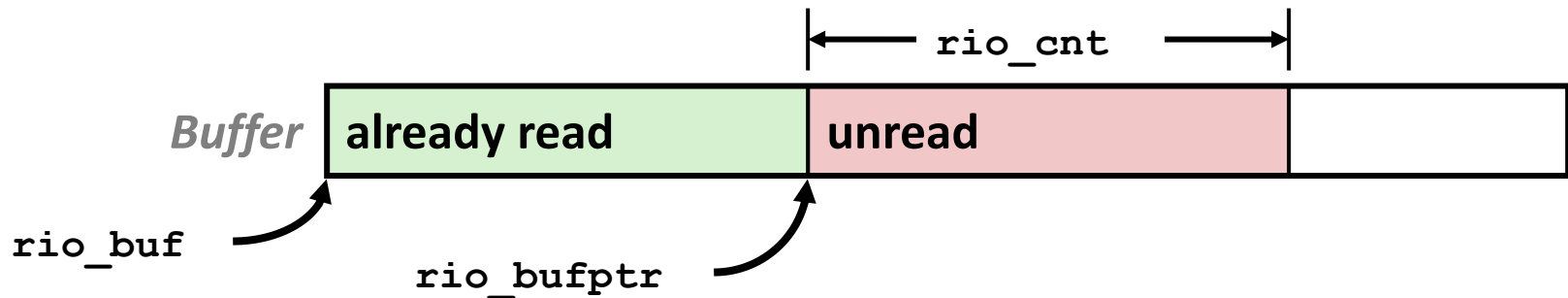


- Layered on Unix file:



Buffered I/O: Declaration

- All information contained in struct



```
typedef struct {  
    int rio_fd;           /* descriptor for this internal buf */  
    int rio_cnt;          /* unread bytes in internal buf */  
    char *rio_bufptr;     /* next unread byte in internal buf */  
    char rio_buf[RIO_BUFSIZE]; /* internal buffer */  
} rio_t;
```

RIO Example

- Copying the lines of a text file from standard input to standard output

```
#include "csapp.h"

int main(int argc, char **argv)
{
    int n;
    rio_t rio;
    char buf[MAXLINE];

    Rio_readinitb(&rio, STDIN_FILENO);
    while((n = Rio_readlineb(&rio, buf, MAXLINE)) != 0)
        Rio_writen(STDOUT_FILENO, buf, n);
    exit(0);
}
```

cpfile.c