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Problem 1 – System Calls, Error Checking and Reporting

Source Code (121 Lines)

```
#include <fcntl.h>
#include <stdio.h>
#include <errno.h>
#include <unistd.h>
#include <stdlib.h>
#include <string.h>
//manages error display
int printError(char *msg, char *file, char *detail)
{
   if(!detail)
   {
      fprintf(stderr,"Error: %s\n", msg);
   }
   fprintf(stderr,"Error: %s [%s] - %s \n", msg, file, detail);
   return -1;
}
//manages read/write operations
void doRDWR(int inFD, int outFD, char *input, char *output, char* buffer, int buffersize)
{
   int wrSize, wrBytes;
   while((wrSize = read(inFD, buffer, buffersize)) > 0)
   {
      if(wrSize == -1)
      {
         printError("Failed to read following file to buffer", input, strerror(errno));
      }else{
         while(1)
         {
            if((wrBytes = write(outFD, buffer, wrSize)) <=0)
            {
               printError("Failed to write following file to output", output, strerror(errno));
            }else if(wrBytes != wrSize){
```

```
                buffer += wrBytes;
                wrSize -= wrBytes;
            }else{
                break;
            }
        }
    }
}

int main(int argc, char **argv)
{
    int outFD, option;
    int inFD = -1, bflag = 0, oflag = 0, bufsize = 0;
    char *outputName = 0;
//gather option arguments from stdin
    while( (option=getopt(argc, argv, "b:o:")) != -1)
    {
        switch (option)
        {
            case 'b':
                if(++bflag > 1 || !strcmp("-b",optarg))
                {
                    printError("Multiple '-b' flags", 0, 0);
                }else if((bufsize = strtol(optarg, NULL, 0)) <= 0){
                    printError("Not a valid buffer size", 0, 0);
                }else if(!strcmp("-o",optarg) || !strcmp("-", optarg)){
                    printError("No size of buffer mentioned", 0, 0);
                }
                break;
            case 'o':
                if(++oflag > 1 || !strcmp("-o", optarg))
                {
                    printError("Multiple '-o' flags", 0, 0);
                }else if(!strcmp("-b",optarg)){
                    printError("No output file specified", 0 ,0);
                }else if(!strcmp("-",optarg)){
                    printError("- reserved for stdin", 0, 0);
                }
                outputName = optarg;
```

```
            break;
        default:
            exit(EXIT_FAILURE);
    }
}
//set default size of buffer and initialize a buffer as bufsize
if(bufsize <= 0)
{
    bufsize = 8192;
}
char buf[bufsize];
//if there is outputName = 0, set it to stdout. otherwise, open file with the given name
if(!outputName)
{
    outputName = "stdout";
}else if((outFD = open(outputName, O_WRONLY | O_CREAT | O_TRUNC, 0666)) == -1){
    printError("Failed to open following file for writing", outputName, strerror(errno));
}
//if input files were specified go thorugh loop and RD/WR/Close
for(; optind < argc; ++optind)
{
    if(!strcmp(argv[optind],"-"))
    {
        argv[optind] = "stdin";
        inFD = STDIN_FILENO;
    }else if((inFD = open(argv[optind], O_RDONLY)) == -1){
        printError("Failed to open following file for reading", argv[optind], strerror(errno));
    }

    doRDWR(inFD, outFD, argv[optind], outputName, buf, bufsize);

    if(close(inFD) == -1 && inFD != STDIN_FILENO)
    {
        printError("Failed to close following input file", argv[optind], strerror(errno));
    }
}
//if no input files were specified then optind = argc so it skips the for loop and reads from stdin
if(inFD == -1)
{
    doRDWR(STDIN_FILENO, outFD, "stdin", outputName, buf, bufsize);
```

```
    }
    //close output file and error check
    if(close(outFD) == -1 && outFD != STDOUT_FILENO)
    {
        printError("Failed to close following output file", outputName, strerror(errno));
    }
    //there were no errors and program ran successfully
    return 0;
}
```

Sample Run and Error Handling

Run on ArchLinux VirtualBox, includes initial run and then error handling including all system calls. Not all error handling situations such as partial write errors could be tested due to their difficulty in artificially generating them.

```
[danpark@archserver OS-HW]$ gcc -o minicat minicat.c
[danpark@archserver OS-HW]$ cat test1.txt test2.txt test3.txt
hello
world
day
[danpark@archserver OS-HW]$ ./minicat -b 2048 -o output test1.txt test2.txt - te
st3.txt
sunny
[danpark@archserver OS-HW]$ ./minicat output
hello
world
sunny
day
[danpark@archserver OS-HW]$ ./minicat
takes in from stdin and prints to stdout
takes in from stdin and prints to stdout
[danpark@archserver OS-HW]$ ./minicat -b
./minicat: option requires an argument -- 'b'
[danpark@archserver OS-HW]$ ./minicat -b -b
Error: Multiple '-b' flags
Error: Multiple '-b' flags  [(null)] - (null)
[danpark@archserver OS-HW]$ ./minicat -b randomvar
Error: Not a valid buffer size
Error: Not a valid buffer size [(null)] - (null)
[danpark@archserver OS-HW]$ ./minicat -o
./minicat: option requires an argument -- 'o'
[danpark@archserver OS-HW]$ ./ minicat -o -o
-bash: ./: Is a directory
[danpark@archserver OS-HW]$ ./minicat -o -o
Error: Multiple '-o' flags
Error: Multiple '-o' flags  [(null)] - (null)
[danpark@archserver OS-HW]$ ./minicat nofile
Error: Failed to open follwing file for reading [nofile] - No such file or direc
tory
Error: Failed to close following input file [nofile] - Bad file descriptor
[danpark@archserver OS-HW]$
```

Experimental Raw Data (Run Times vs Buffer Sizes)

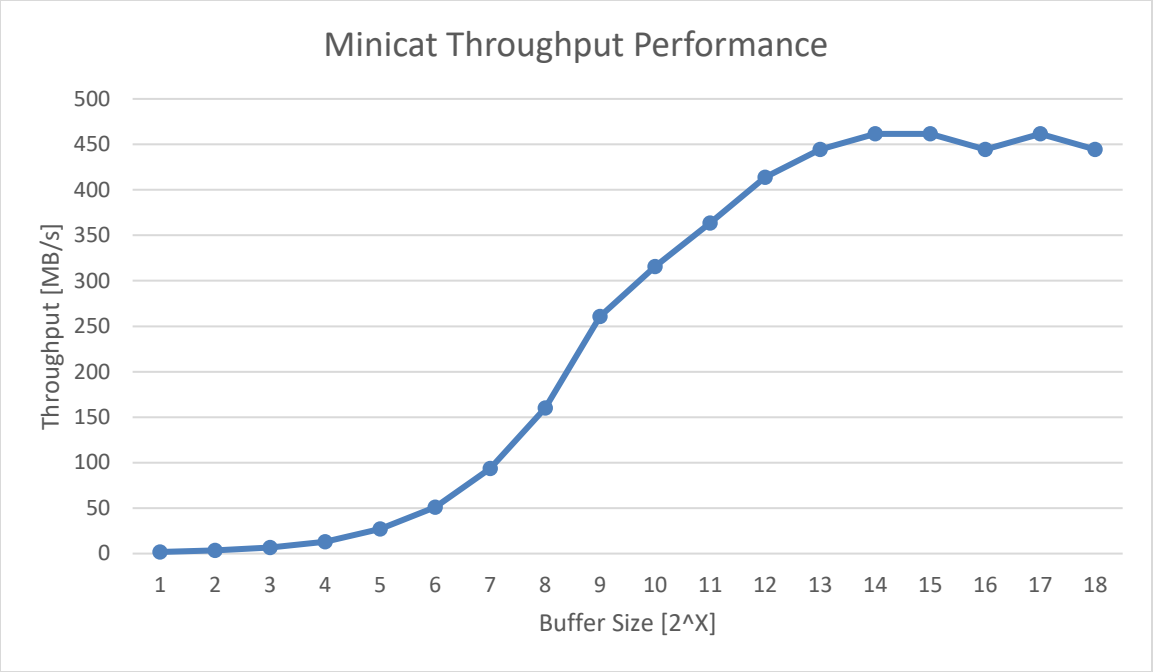
For large files and smaller-than-file buffer sizes, it is logical to see that the program would need to cycle through multiple read and write system call loops to be able write the same amount of data that a larger buffer size would be able to in a single loop. By using a sufficiently large buffer, time performance would increase but after a certain point, having a greatly larger buffer not give improved performance due to the hardware limitations. The program was run on a MSI GS60 2PC Ghost, which has Intel i7-4710HQ @ 2.50 GHz, NVIDIA GeForce GTX 860M, 12GB DDR3, Kingston 128 GB SSD. A 12 MB file was generated using:

```
cat -> file.txt
for i in {1..20}; do cat file.txt file.txt > file2.txt && mv file2.txt file.txt; done
```

This generated a file with 2^{21} lines in it, duplicating the original two lines of 'hello' and world'. The buffer sizes were sampled between 1 byte up to 256K (2^{18} = 262,144 bytes) in powers of 2, which means 18 measurements. Time was measured using the following command, where test.txt was the 12 MB file:

```
time ./minicat -b [buffer size] -o output.txt test.txt
```

2^X	Buffer Size [bytes]	Real Time Elapsed [s]	Throughput [MB/s]
1	2	6.765	1.774
2	4	3.398	3.531
3	8	1.756	6.834
4	16	0.922	13.015
5	32	0.445	26.966
6	64	0.235	51.064
7	128	0.128	93.750
8	256	0.075	160.000
9	512	0.046	260.870
10	1024	0.038	315.789
11	2048	0.033	363.636
12	4096	0.028	413.793
13	8192	0.027	444.444
14	16384	0.026	461.538
15	32768	0.026	461.538
16	65536	0.027	444.444
17	131072	0.026	461.538
18	262144	0.027	444.444



From the table and chart above, one can tell that after the buffer size of 2^{13} bytes, the throughput plateaus off, showing that the limit of the hardware has been reached and any further increase in the buffer will not give better results.