

> What is a process's umask and how is it used?

What is the default value?

When is it used?

> Case study: Use mount to explore an iso image

Example : Use curl -O to download a file

What is an .iso file?

> Starting a virtual machine using an iso file image

What is qemu?

```
qemu-system-x86_64 -k en-us -cdrom dsl-4.4.10.iso
```

```
int main() {
    int fd = open("file", O_RD);
    fstat(fd, &s);
    char *ptr = mmap(NULL, s.st_size,
        PROT_READ,
        MAP_FILE | MAP_SHARED, fd, 0);

    for(int i=0; i< s.st_size;i++)
        if(ptr[i] >31) printf("%x %c\n",i, ptr[i]);
}
```

> Welcome to the mmap diner. What would you like?

```
void *
mmap(
    void *addr,
    size_t len,
    int prot,
    int flags,
    int fd,
    off_t off);    returns (void*)-1 if failed
```

Ask yourself -

1. What kind of memory protection would you like?

2. Will the contents of your RAM (random access memory) be backed by a file or will be it anonymous?

3. What happens if you change your RAM contents? Will anyone know?

PROT_EXEC ?

MAP_SHARED or MAP_PRIVATE. Choose one.

Got no file but still want to mmap? MAP_ANONYMOUS!

```
>mmap and fork
    fd = open("alice.txt", O_RDWR);

    char *ptr = mmap(NULL, 4096,
        PROT_READ|PROT_WRITE,
        MAP_FILE|MAP_SHARED, fd, 0);

    if( (fork() ) ==0)
        strcpy(ptr, "The child wrote to the memory");
    else {
        sleep(1); puts( ptr );
    }
```

> What is RAID? Why is it necessary?

Making filesystems resilient:

RAID : "Redundant Array of Inexpensive Disks"

RAID Motivation

Mean Time to Failure (MTTF) ?

$MTTF(\text{disk array}) = MTTF(\text{single disk}) / \# \text{ disks}$

Adding more disks means that failures happen more frequently!

Simplest form: Mirroring "RAID 1"

All data is mirrored across two disks

Advantages:

Reads are faster, since both disks can be read in parallel

Higher reliability (of course)

Disadvantages:

Writes are slightly slower, since wait for both disks to do write

Doubles the cost of the storage system

RAID 3

Rather than mirroring, use parity codes

Given N bits {b1, b2, ..., bN}, the parity bit P is the bit {0,1} that yields an even number of "1" bits in the set {b1, b2, ..., bN, P}

Idea: If any bit in {b1, b2, ..., bN} is lost, can use the remaining bits (plus P) to recover it.

Where to store the parity codes? Add an extra "check disk" that stores parity bits

RAID 3 example

1. Read back data from other disks
2. Recalculate lost data from parity code
3. Rebuild data on lost disk

RAID 3 issues: performance

Terminology:

MTTF = mean time to failure

MTTR = mean time to repair

What is the MTTF of RAID?

Both RAID 1 and RAID 3 tolerate the failure of a single disk

RAID 5

Another approach: Interleaved check blocks ("RAID 5")

Rotate the assignment of data blocks and check blocks across disks

Avoids the bottleneck of a single disk for storing check data

Allows multiple reads/writes to occur in parallel (since different disks affected)

> A Planetary-sized Filesystem Case Study

Problem: Build a file system for Google

How do you make it resilient?

Reliable distributed storage

Issues

Failure is the common case

Google reports 2-10% of disks fail per year

Now multiply that by 60,000+ disks in a single warehouse...

Must survive failure of not just a disk, but failure of a rack of servers or even... a whole data center

How:

GFS 2001: Simple redundancy (2 or 3 copies of each file)

GFS 2010:

More efficient redundancy (analogous to RAID 3++)

Reed-Solomon codes with 1.5x redundancy

RS codes found in CDs, Space communication protocols