CS202 (003): Operating Systems
File System IV

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Most of the materials covered in this slide come from the lecture notes of Mike Walfish's CS202

Last Time

RPC (Remote Procedure Call)

A mechanism that allow programs to call procedures on other computers across a network

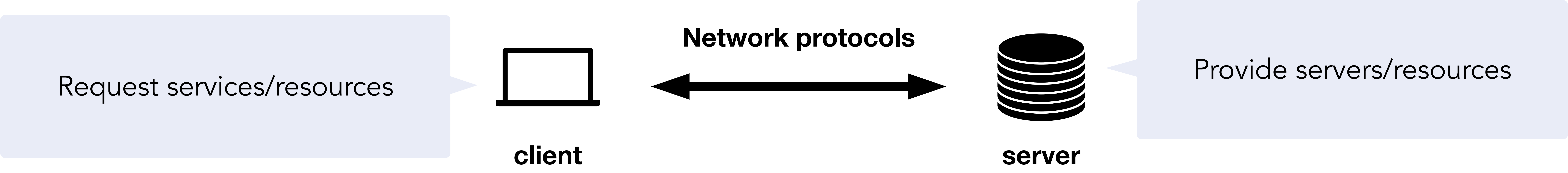
Make remote function calls **appear similar** to local ones

Access remote services/resources
without worrying about distributed/network issues
But, more things might go wrong
(failures, network latency, distributed transactions)

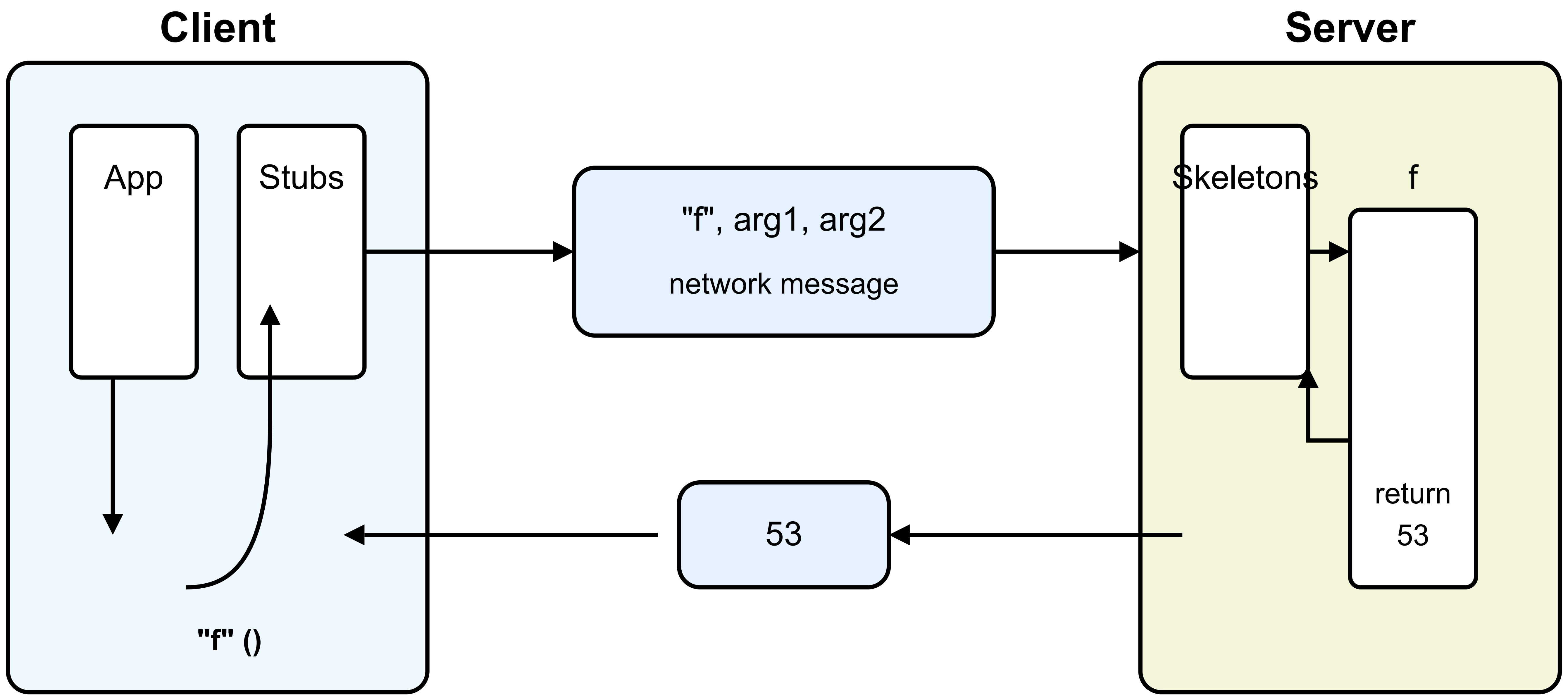
Direct memory access (fast!)
Predictable performance
But, only works w/ local resources

One of the building blocks for client/server systems

Client/server system



Example: web browser/servers, database client/servers, …



Networked file systems

Look like a file system to the application,
but the data potentially stored on another machine
Reads/writes must go over the network

Benefits

Easy to share if files available on multiple machines
Easier to administer servers than clients
Access way more data than fits on your local disk
Network + remote buffer cache faster than local disk (in certain cases)

Disadvantages

Network + remote disk slower than local disk
Network or server fail even when client is still running
Complexity and security issues

NFS: Network File System

Design and Implementation of the Sun Network Filesystem

Russel Sandberg
David Goldberg
Steve Kleiman
Dan Walsh
Bob Lyon

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Introduction

The Sun Network Filesystem (NFS) provides transparent, remote access to filesystems. Unlike many other remote filesystem implementations under UNIX†, the NFS is designed to be easily portable to other operating systems and machine architectures. It uses an External Data Representation (XDR) specification to describe protocols in a machine and system independent way. The NFS is implemented on top of a Remote Procedure Call package (RPC) to help simplify protocol definition, implementation, and maintenance.

https://web.stanford.edu/class/cs240/readings/nfs.pdf

NFS: Network File System

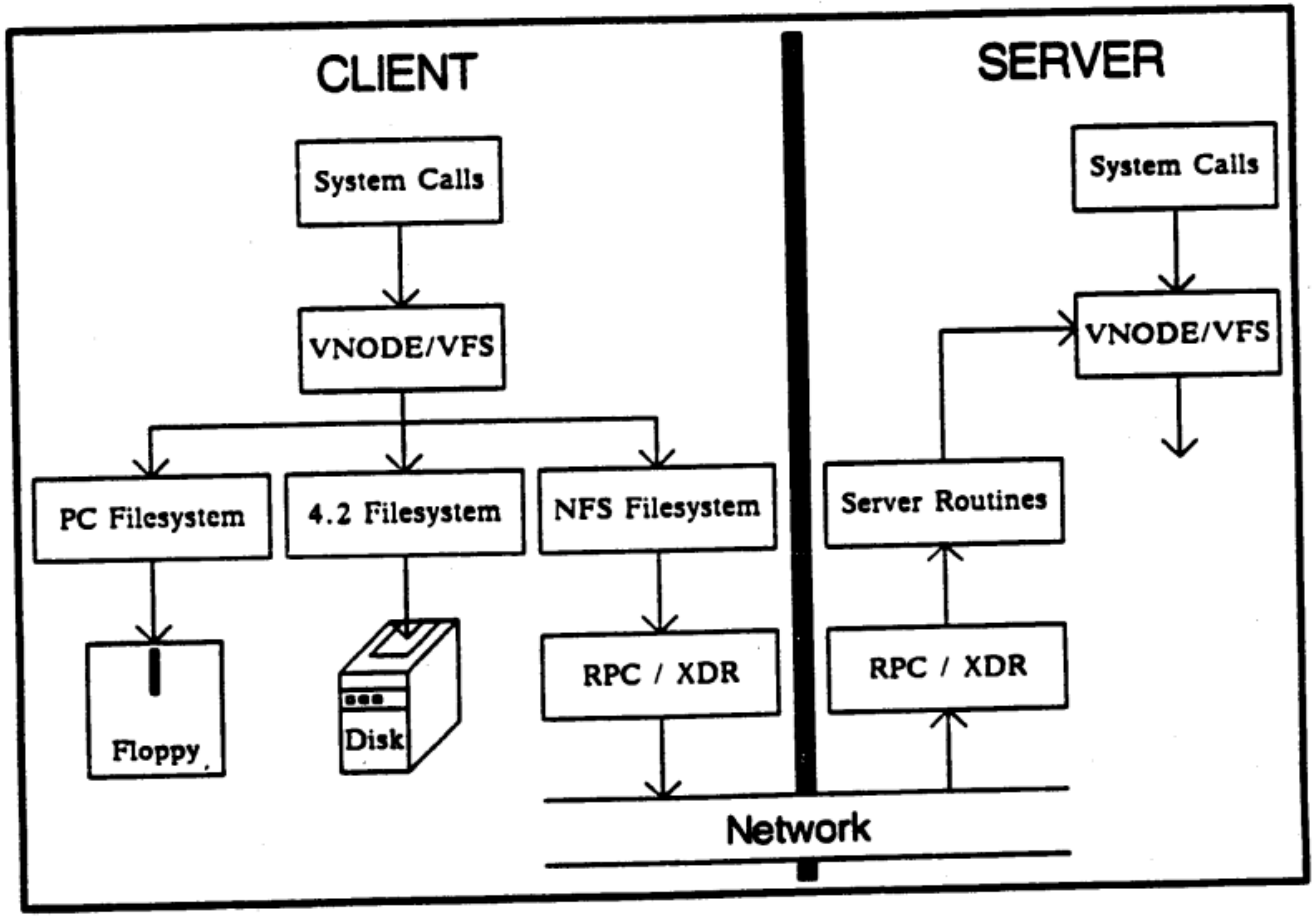

Figure 1

https://web.stanford.edu/class/cs240/readings/nfs.pdf

NFS implements vnode operations through RPC

```
open("/usr/jo/lab1.c", …)

                    Lookup("/usr")

                  fh1 = (FS id, i#, gen#)

                   Lookup(fh1, "jo")

                  fh2 = (FS id, i#, gen#)

                 Lookup(fh2, "lab1.c")

                  fh3 = (FS id, i#, gen#)

  write(fd, buf, sz);

              Write(fh3, offset, data, size)

                      return code
```

Why not embed file name in file handle?

(file names can change; would mess everything up. client needs to use an identifier that's invariant across such renames.)

How does client know what file handle to send?

(stored with vnode)

Statelessness of NFS

Every network protocol request contains all of the information needed to carry out that request, without relying on anything remembered from previous protocol requests.

Are all NFS operations idempotent?
(i.e., performing the op multiple times has the same effect as performing it once)

Benefits — simplifies implementation, failure recovery

Disadvantages — mess up w/ traditional unix semantics

Transparency

Transparency requires that the system calls **mean** the same things

Gen #

What if client A deletes a file and it (or another client) creates a new one that uses the same i-node?

The server maintains a generation number in each i-node on disk
Every time an i-node is reallocated (used for a new file), its generation number is incremented
When a client gets a file handle (FH) through operations like LOOKUP, the current generation number is included in that file handle

For every client request, the server compares two numbers:
1. The generation number in the client's file handle
2. The current generation number stored in the i-node on disk
If they match: The request is valid and proceeds normally
If they don't match: The client gets a "stale FH" error when trying to READ() or WRITE()

Non-traditional Unix Semantics

Error returns on successful operations

Non-traditional Unix Semantics

Close-to-open consistency

When client A writes and close a file, Client B will only see those changes after opening the file

Non-traditional Unix Semantics

Close-to-open consistency

Server must flush to the disk before returning

The server has to make sure, before returning:

1. Inode with new block # and new length safe on disk
2. Indirect block safe on disk

Writes have to be synchronous

Would this case performance issue?

Non-traditional Unix Semantics

Would this case performance issue?

No, because there are caching (at the client; not all RPCs go to server. although write go to the server in NFSv3, they don’t cause disk accesses necessarily)

Read-caching
(useful when re-reading files)

Write-caching
(improve performance)

Caching of file attributes
(helps with command such as `ls -l`)

Caching of name->fh mapping
(Caches path prefixes (e.g., /home/jo))

But, now you have to worry about coherence and semantics!

Close-to-open consistency

When client A writes and close a file, Client B will only see those changes after opening the file

Non-traditional Unix Semantics

Close-to-open consistency

When client A writes and close a file, Client B will only see those changes after opening the file

1. writing client forces dirty blocks during a close()
2. reading client checks with server during open(): “is this data current?”

Hmmm, why not a stronger guarantee?

Trading stronger guarantee for better performance!

Obviously, this might cause issues, for example:

1. Errors might occur on close() rather than write()
2. Legacy applications that don't check close() return values might fail
3. Certain usage patterns don't work well, such as using "tail -f" on one client while another client writes to the file

Non-traditional Unix Semantics

Server failure

Previously: open(“some_file”, RD_ONLY) failed if “some_file” does not exist
Now: app might hang while trying to access the file

Deletion or permission change of open files

What if Client A deletes a file that Client B has “open”?

Previously: Client B reads still work (file exists until all clients close() it)
Now: Client B reads fail

What if Client A make the file inaccessible to others while Client B has the file open()?

Previously: Nothing happens
Now: Client B reads fail

……

Security

NFS's only security measure is IP address verification (which is quite weak)

Previously: Unix enforces read/write protections — cannot read my files w/o passwords
Now: Server believes whatever UID appears in NFS request (and anyone can put whatever in the request)

Not extremely vulnerable because of how FH works

```
Example structure (simplified):
struct file_handle {
    uint32_t filesystem_id;     // Random unique identifier
    uint32_t inode_number;      // File system location
    uint32_t generation_number; // Changes when inode is reused
    uint8_t  extra_data[20];    // Additional metadata
}
```

It does not solve all types of attack though!

Vulnerabilities are technically fixable (strong auth, secure protocols, …), but hard to reconcile with the stateless design

Quiz Time!