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# Distributed Systems

Winter Term 2025/26

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## 10 Distributed File Systems



### Contents

- ➔ General
- ➔ Case study: NFS

### Literature

- ➔ Tanenbaum, van Steen: Ch. 10
- ➔ Colouris, Dollimore, Kindberg: Ch. 8



### 10.1 General

[Colouris, 8.1-8.3]

- ➔ Objective: support the sharing of information (files) in an **intranet**
  - ➔ in the Internet: WWW
- ➔ Allows applications to access remote files in the same way as local files
  - ➔ similar (or even better) performance and reliability
- ➔ Allows operation of diskless nodes
- ➔ Examples:
  - ➔ NFS (standard in the UNIX area)
  - ➔ AFS (goal: scalability), CIFS (Windows), CODA, xFS, ...

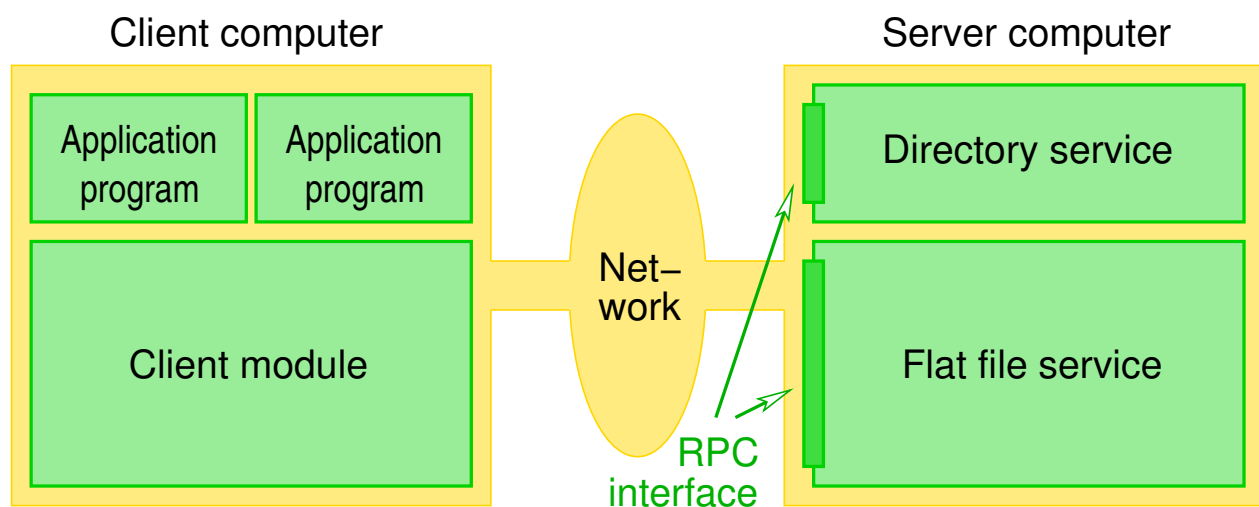


## Requirements

- ➔ Transparency: access, location, mobility, performance and scaling transparency
- ➔ Concurrent file updates (e.g., locks)
- ➔ File replication (often: local caching)
- ➔ Heterogeneity of hardware and operating system
- ➔ Fault tolerance (especially in case of server failure)
  - often: at-least-once semantics + idempotent operations
  - advantageous: stateless server (easy reboot)
- ➔ Consistency (👉 9)
- ➔ Security (access control, authentication, encryption)
- ➔ Efficiency



## Model Architecture of a Distributed File System



- ➔ Tasks of the client module:
  - emulation of the file interface of the local OS
  - if necessary, caching of files or file sections



### Model Architecture of a Distributed File System ...

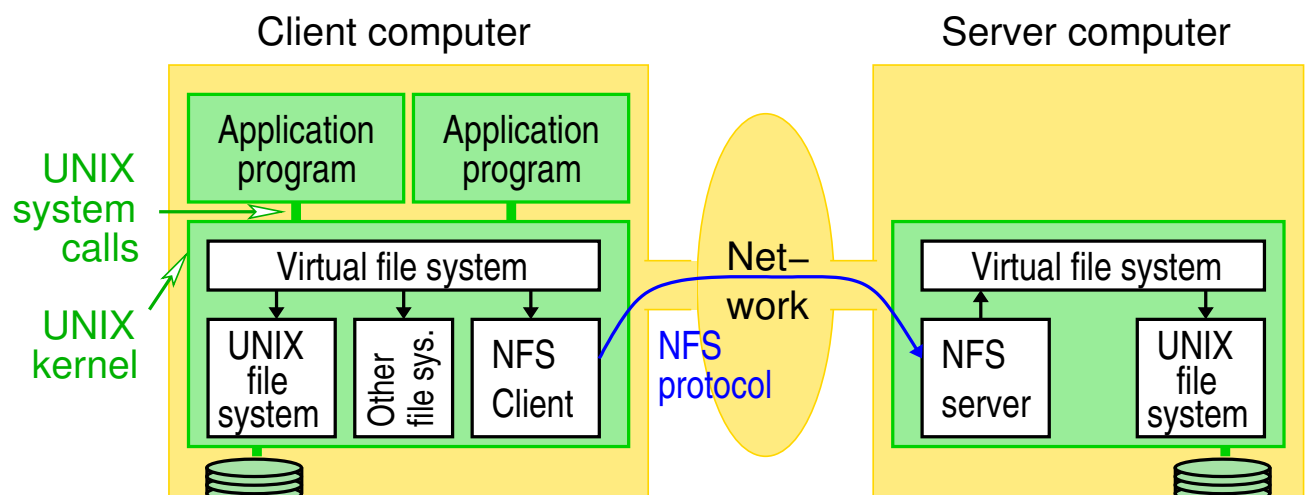
- ➔ Flat file service:
  - provides idempotent access operations to files
    - e.g., *read*, *write*, *create*, *remove*, *getAttributes*, *setAttributes*
    - no *open* / *close*, no implicit file pointer
  - files are identified by UFIDs (Unique File IDs)
    - (long) integer IDs, can serve as capabilities
- ➔ Directory service:
  - maps file or path names to UFIDs
    - if necessary first authenticates the client and verifies its access rights
  - services for creating, deleting and modifying directories

## 10 Distributed File Systems ...



### 10.2 Case Study: NFS

- ➔ Introduced in 1984 by Sun
- ➔ Open, OS independent protocol
- ➔ Architecture:





### Access Control and Authentication

- ➔ NFS server is stateless (up to and including NFS3)
- ➔ UFID (file handle): essentially just the file system ID and i-node
  - ➔ not a capability
- ➔ Thus, access rights are checked with each request
  - ➔ by the RPC protocol
- ➔ Authentication usually only via user and group ID
  - ➔ extremely insecure!
- ➔ More possibilities in NFS3:
  - ➔ Diffie-Hellman key exchange (insecure)
  - ➔ Kerberos
- ➔ NFS4: secure RPC (RPCSEC\_GSS)



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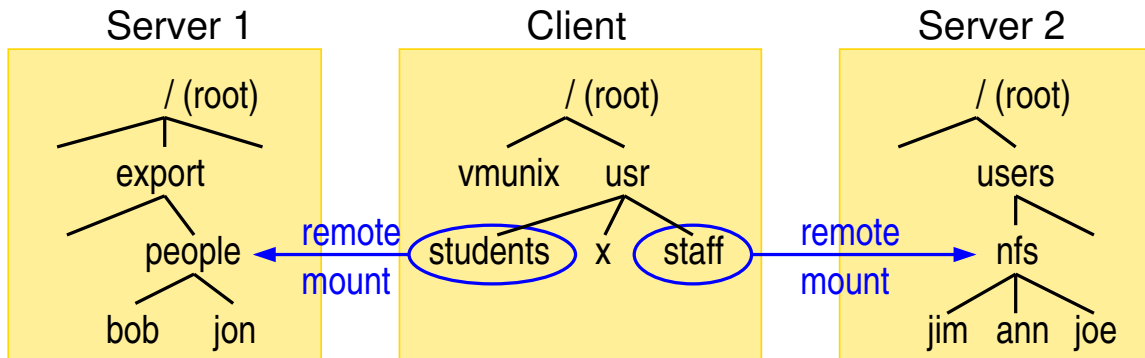
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### Mount Service

- ➔ An NFS file system can be mounted in the local directory tree



- ➔ Collaboration of `mount` command in the client with the mount service of the NFS server
  - ➔ on request, the mount service provides file handles of the exported directories (for name resolution)

#### Notes for slide 302:

A directory exported from an NFS server *A* may contain a subdirectory that this server imports from another NFS server *B*. However, *A* is not allowed to export this subdirectory to its clients. A client importing the directory from *A* must therefore also import the subdirectory from *B*.



### Translation of Pathnames

- ➔ Iteratively (NFS3): for each directory one request to NFS server
  - necessary because path can cross mount points
  - inefficiency is mitigated by client caching

### Automounter

- ➔ Goal: set up an NFS mount only when it is accessed
  - better fault tolerance, load balancing is possible
- ➔ Automounter is local NFS server
  - thereby it sees the *lookup()*-requests of the client
- ➔ On request: set up the NFS mount and create a symbolic link to the mount point
- ➔ After prolonged inactivity: release the mount



### Server Caching

- ➔ Traditional file caching in UNIX:
  - buffer in main memory for most recently used disk blocks
  - *read ahead*: sequential blocks are loaded into cache beforehand
  - *delayed write*: modified blocks only written back when space is needed; additionally every 30s by `sync`
- ➔ Server caching in NFS: two modes
  - *write through*: write requests are executed in the server cache and immediately also on disk
    - advantage: no data loss in case of server crash
  - *delayed write*: modified data will remain in the cache until a *commit* operation is executed (i.e. file is closed)
    - advantage: better performance if many write operations



### Client Caching

- ➔ NFS client buffers the results of (among other things) *read* / *write* and *lookup* operations in a local cache
  - leads to consistency issues, since now multiple copies
- ➔ Client is responsible for maintaining consistency
- ➔ Timeliness of the cache entry is checked with each access
  - for that: compare whether the modification timestamp in the cache matches the modification timestamp on the server
  - in case of negative validation: cache entry is deleted
  - if validation is successful: cache entry is considered current for a certain time (3 - 30 s) without further checks
    - i.e. changes only become visible after a few seconds
    - compromise between consistency and efficiency



### Client Caching ...

- ➔ Treatment of write operations:
  - file block is marked as *dirty* in the cache
  - marked blocks are sent asynchronously to the server:
    - when closing the file
    - at a `sync` operation on client machine
    - possibly more often by block-input/output-demons
- ➔ Demons also realize asynchronous operations for *read ahead* and *delayed write*
  - for performance optimization
- ➔ NFS does not guarantee real consistency of client caches