CHAPTER 6: DISTRIBUTED FILE SYSTEMS

Chapter outline

- DFS design and implementation issues: system structure, file access, and sharing semantics
- Transaction and concurrency control: serializability and concurrency control protocols
- Replicated data management: one-copy serializability and coherency control protocols

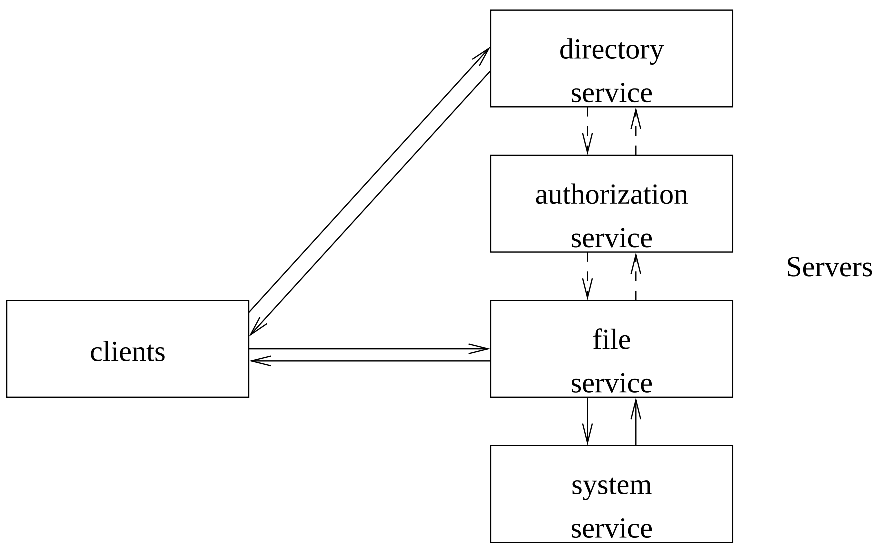
Why is DFS important and interesting?

- It is one of the two important components (process and file) in any distributed computation.
- It is a good example for illustrating the concept of transparency and client/server model.
- File sharing and data replication present many interesting research problems.

Structure of and access to a file system

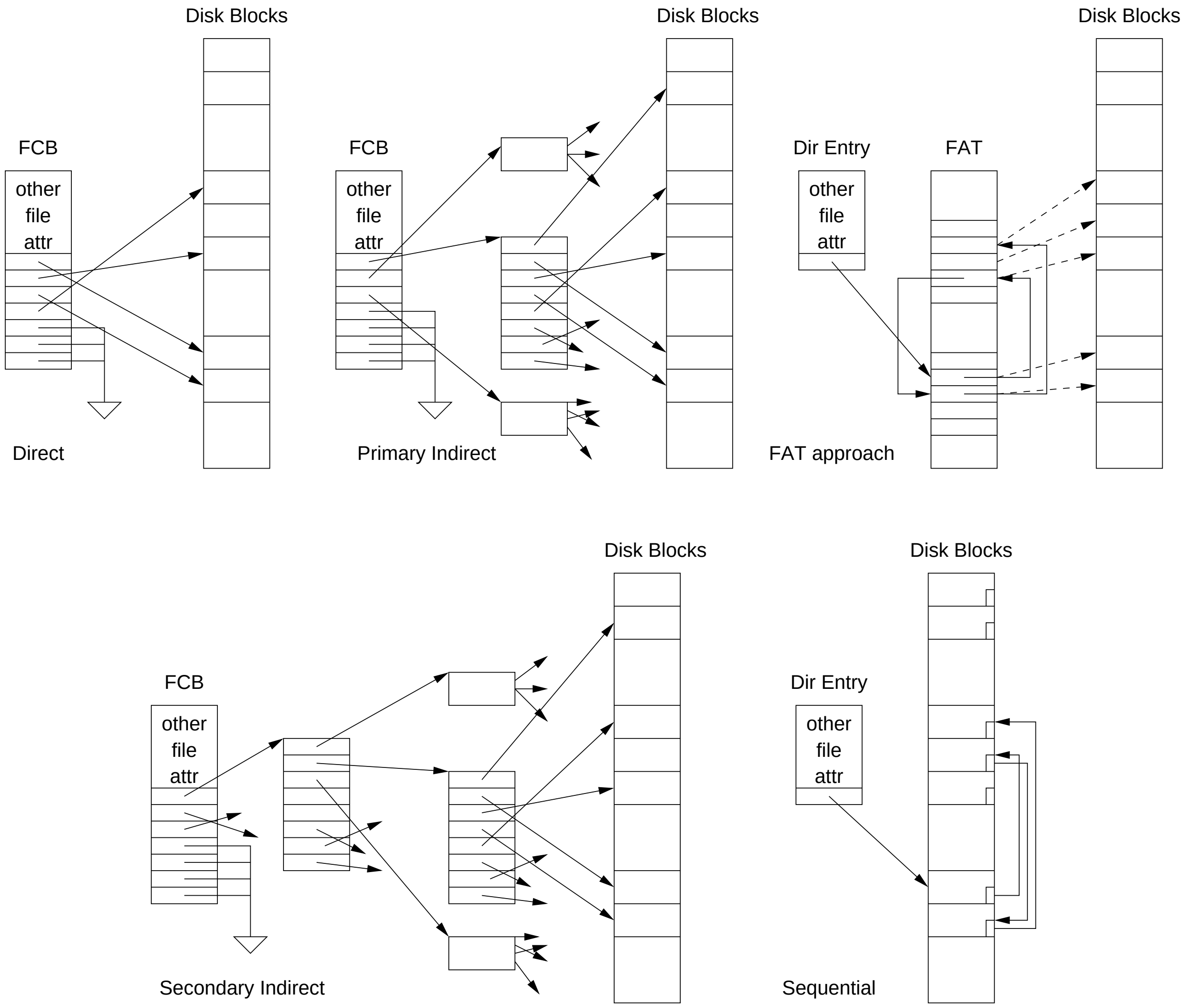
directory service		name resolution, add and deletion of files
authorization service		capability and / or access control list
file service	transaction	concurrency and replication management
	basic	read / write files and get / set attributes
system service		device, cache, and block management

File Service Interactions



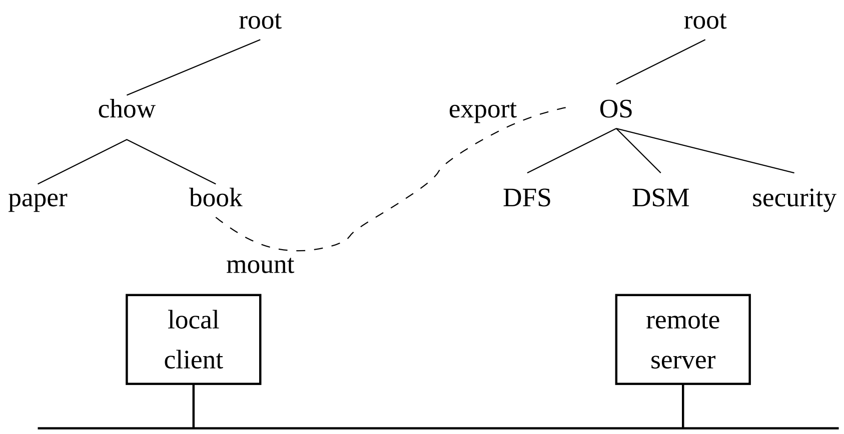
- File: sequential, direct, indexed, indexed-sequential
- File System: flat, hierarchical

File Structures



Mounting protocols and NFS

- Explicit mounting
- Boot mounting
- Auto mounting



Stateful and stateless file servers

- Opened files and their clients
- File descriptors and file handles
- Current file position pointers
- Mounting information
- Lock status
- Session keys
- Cache or buffer

Semantics of sharing in DFS

space / time	remote access	cache access	down/up load access
simple RW	no true sharing	coherency control	coherency control
transaction	concurrency control	coherency and concurrency	coherency and concurrency
session	not applicable	not applicable	ignore sharing

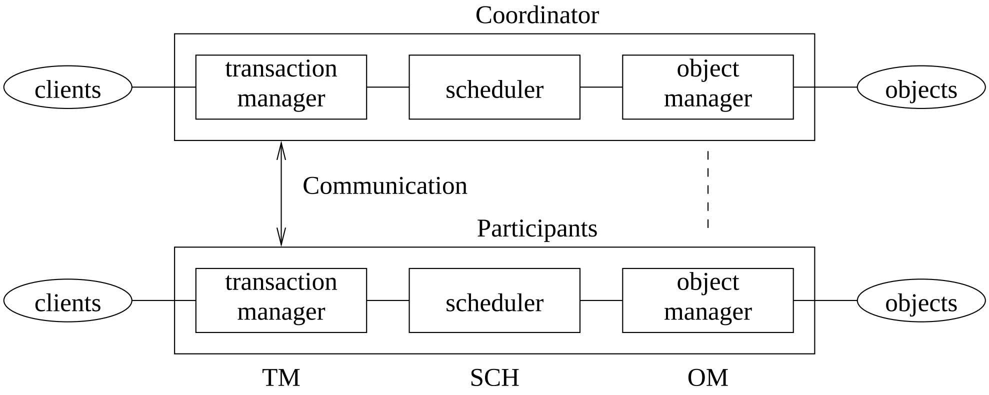
sharing

- Unix semantics - currentness
- Transaction semantics - consistency
- Session semantics - efficiency

replication

- Write policies: write-through and write back
- cache coherence control: write-invalidate and write-update
- Version control (immutable files): ignore conflict, resolve version conflict, resolve serializability conflict

Transaction and concurrency control



transaction processing system (TPS)

- Transaction manager (TM)
- Scheduler (SCH)
- Object manager (OM)

atomicity

- All or none: TM, two-phase commit
- Indivisible (serializable): SCH, concurrency control protocols
- Atomic update: OM, replica management

Serializability

IF the interleaved execution of transactions is to be equivalent to a serial execution in some order, then all conflicting operations in the interleaved serializable schedule must also be executed in the same order at all object sites.

t_0 : **bt** Write A=100, Write B=20 **et**
t_1 : **bt** Read A, Read B, 1: Write sum in C, 2: Write diff in D **et**
t_2 : **bt** Read A, Read B, 3: Write diff in C, 4: Write sum in D **et**

Sched	*Interleave*	*Log in* C	*Log in* D	*Result* (C,D)	*2PL*	*Timestamp*
1	$1,2,3,4$	$W_1 = 120$ $W_2 = 80$	$W_1 = 80$ $W_2 = 120$	$(80,120)$ consistent	feasible	feasible
2	$3,4,1,2$	$W_2 = 80$ $W_1 = 120$	$W_2 = 120$ $W_1 = 80$	$(120,80)$ consistent	feasible	t_1 aborts and restarts
3	$1,3,2,4$	$W_1 = 120$ $W_2 = 80$	$W_1 = 80$ $W_2 = 120$	$(80,120)$ consistent	not feasible	feasible
4	$3,1,4,2$	$W_2 = 80$ $W_1 = 120$	$W_2 = 120$ $W_1 = 80$	$(120,80)$ consistent	not feasible	t_1 aborts and restarts
5	$1,3,4,2$	$W_1 = 120$ $W_2 = 80$	$W_2 = 120$ $W_1 = 80$	$(80,80)$ inconsistent	not feasible	cascade aborts
6	$3,1,2,4$	$W_2 = 80$ $W_1 = 120$	$W_1 = 80$ $W_2 = 120$	$(120,120)$ inconsistent	not feasible	t_1 aborts and restarts

Banzai Timestamp Protocol

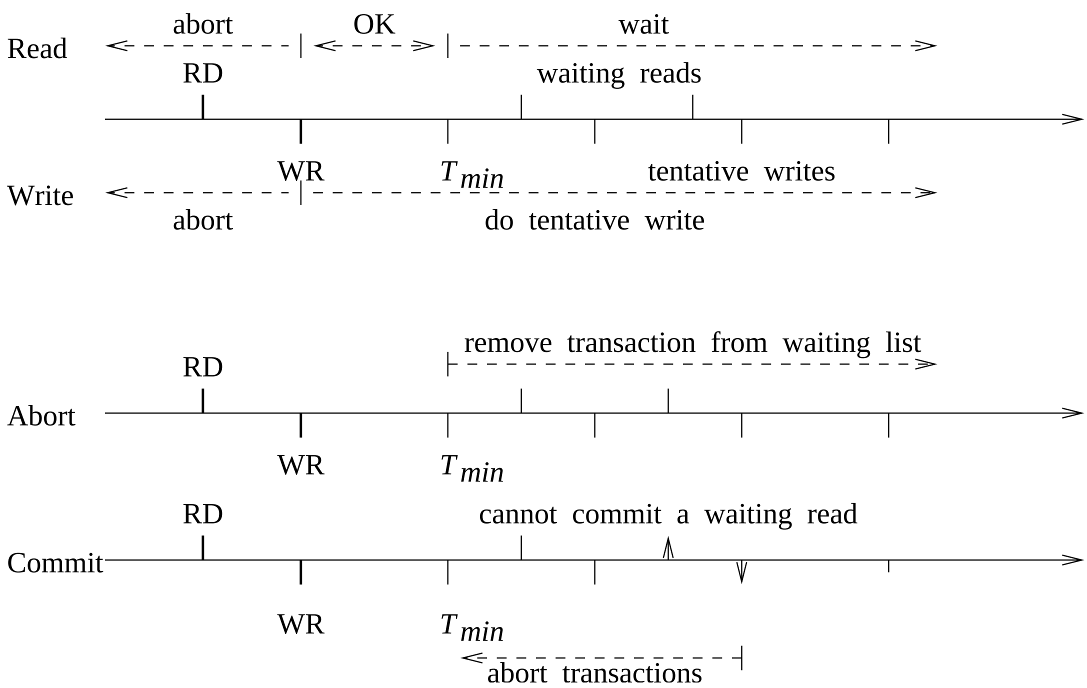
1. Get timestamp TS from TM at **bt**
2. When performing an operation on object O,
   if (read and $WR(O) < TS$) {do read; $RD(O) = max(RS(O), TS)$}
   if (write and $max(RD(O), WR(O) < TS$) {do write; $WR(O) = TS$}
   else abort
3. if any writes were performed before aborting, any other transactions that read the value written by that write must also be aborted

Concurrency control protocols

Two-phase locking

- locking and shrinking phases of requesting and releasing objeccts
- concurrency versus serializability
- rolling abort, strict two-phase locking

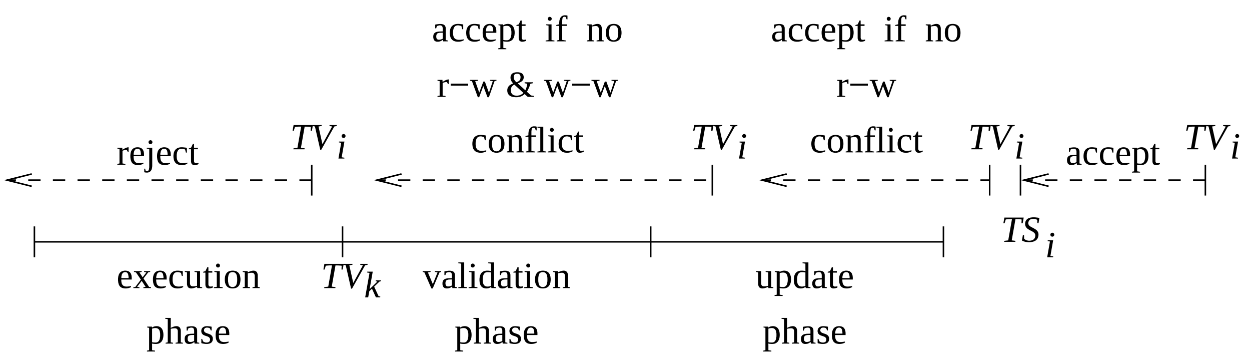
Timestamp ordering



- May delay transaction completion (waiting reads)
- Prevents cascading abort (reads wait until tentative write resolved)

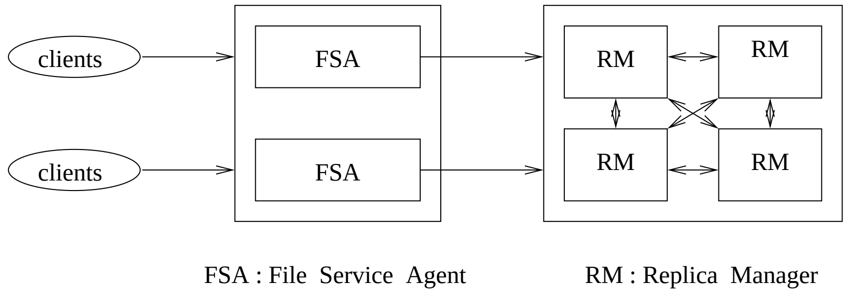
Optimistic concurrency control

- Execution phase
- Validation phase:
  1. Validation of transaction t_i is rejected if $TV_i < TV_k$. All transactions must be serialized with respect to TV.
  2. Validation of transaction t_i is accepted if it does not overlap with any t_k. t_i is already serialized with respect to t_k.
  3. The execution phase of t_i overlaps with the update phase of t_k, and t_k completes its update phase before TV_i. Validation of t_i is accepted if $R_i \cap W_k = \phi$.
  4. The execution phase of t_i overlaps with the validation and update phases of t_k, and t_k completes its execution phase before TS_i. Validation of t_i is accepted if $R_i \cap W_k = \phi$ and $W_i \cap W_k = \phi$.
- Update phase



Data and file replication

Architecture of a replica manager



read operations

- Read-one-primary
- Read-one
- Read-quorum

write operation

- Write-one-primary
- Write-all
- Write-all-available
- Write-quorum
- Write-gossip

One-copy serializability

The execution of transactions on replicated objects is equivalent to the execution of the same transactions on nonreplicated objects. Some approaches:

- read-one-primary/write-one-primary
- read-one/write-all
- read-one/write-all-available

failures

Failures can cause problems with one-copy serializability. For example:

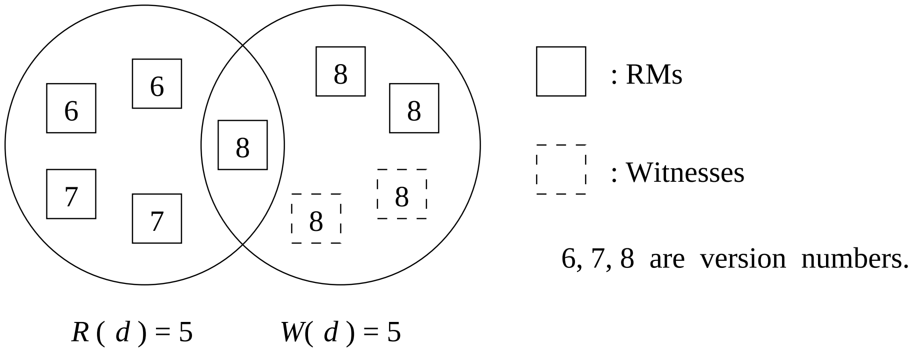
t_0 : **bt** $W(X)$ $W(Y)$ **et**
t_1 : **bt** $R(X)$ $W(Y)$ **et**
t_2 : **bt** $R(Y)$ $W(X)$ **et**

t_1 : **bt** $R(X_a)$ (Y_d fails) $W(Y_c)$ **et**
t_2 : **bt** $R(Y_d)$ (X_a fails) $W(X_b)$ **et**

Quorum voting

From read-one/write-all-available to read-quorum/write quorum:

1. **Write-write conflict**: $2 * W(d) > V(d)$.
2. **Read-write conflict** : $R(d) + W(d) > V(d)$.



Question: What happens if the read contacts a witness (dashed box) instead of the RM with the actual version 8 copy of the object?

Gossip update propagation

Lazy update propagation: read-one/write-gossip

- Basic gossip protocol: read/overwrite
- Causal order gossip protocol: read/modify-update