L8: Memory Models

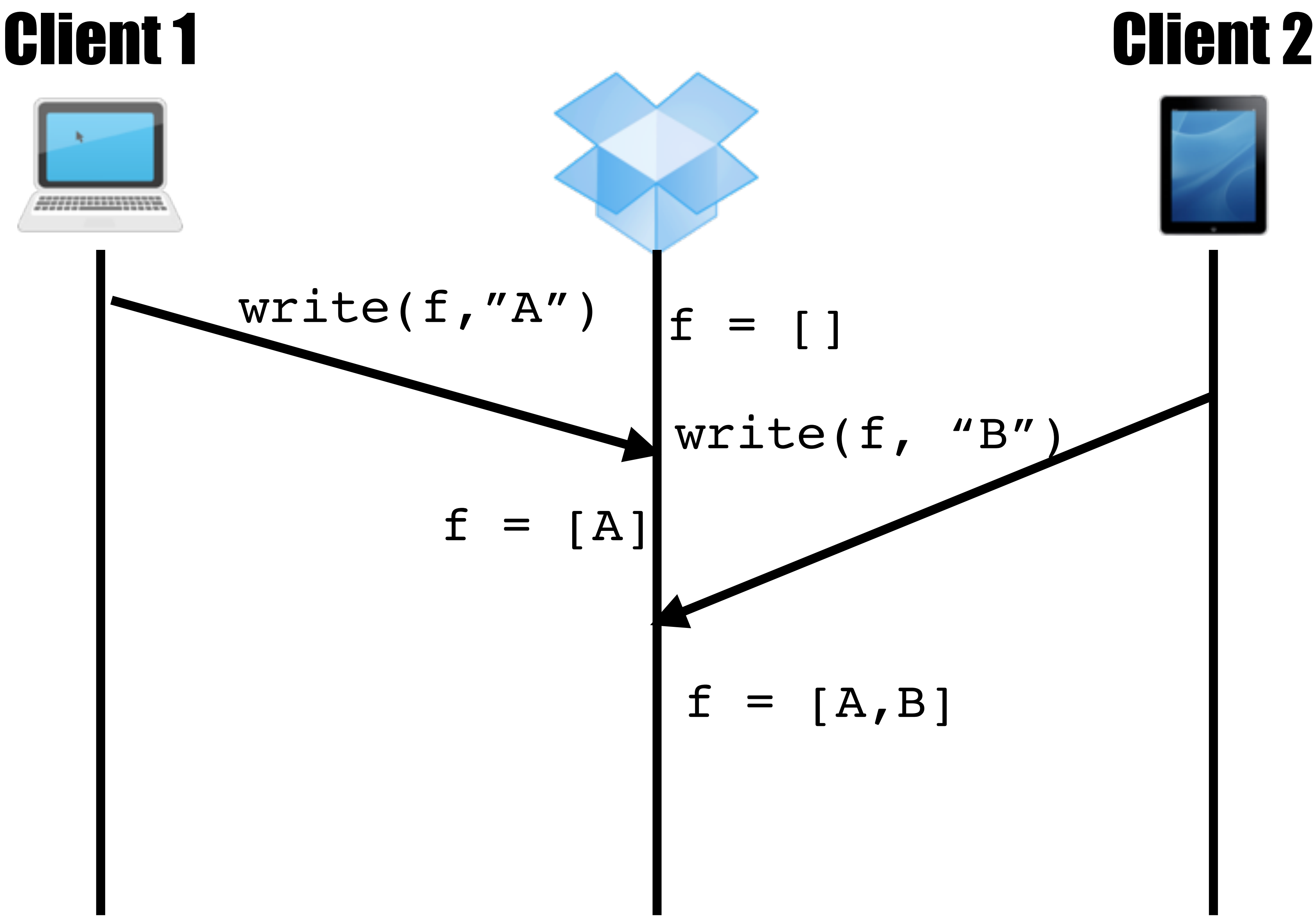
CSE 452 Winter 2016

“There are only two hard things in computer science: cache invalidation and naming things.”
- Phil Karlton

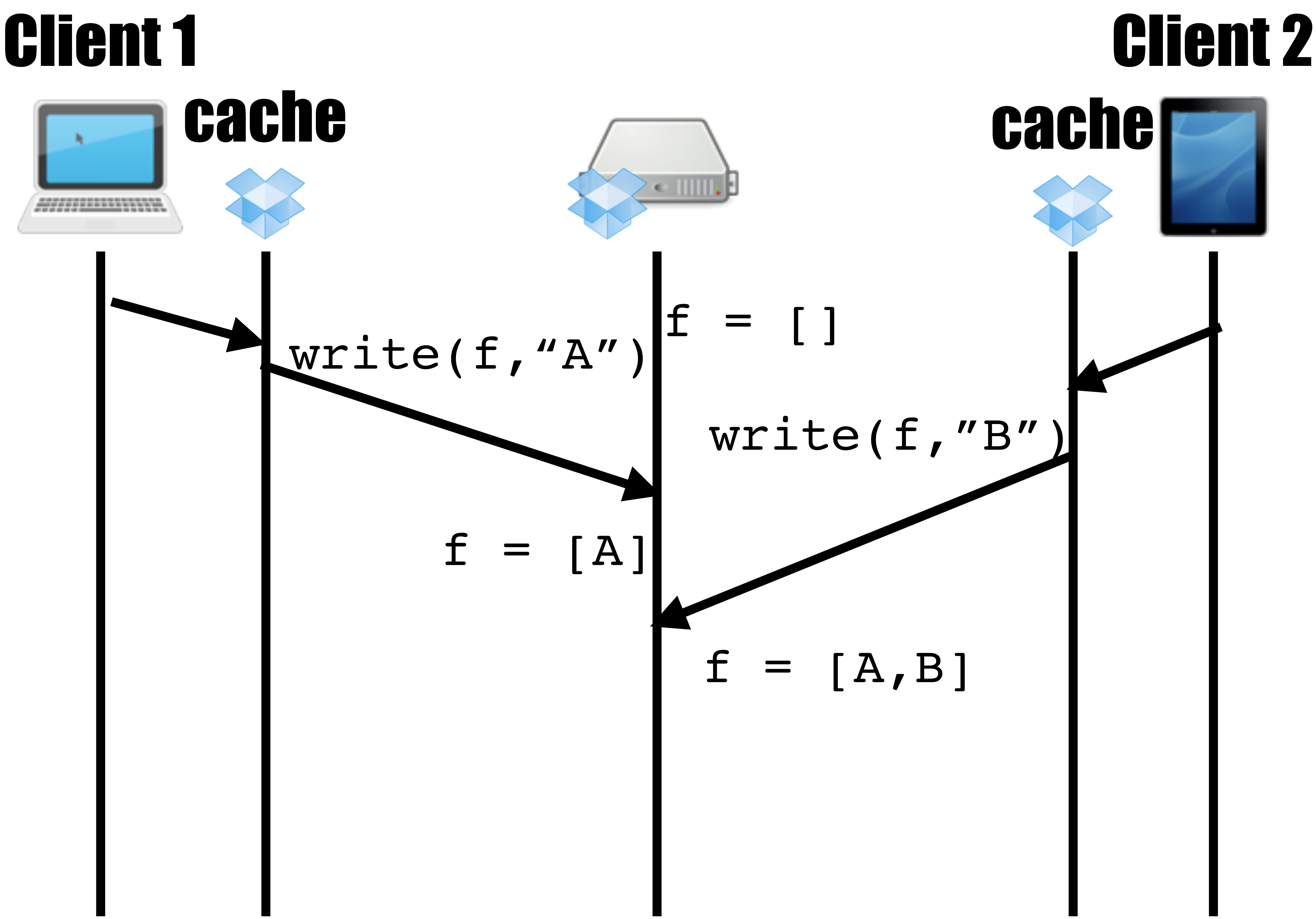
Caching is the other half of distributed systems

- Option #1: Go to the data (RPC)
  - Problems: server has to process all operations, latency from going to server on every operation, can't run operations if the server isn't available
- Option #2: Bring the data to you (caching)
  - Problems: how to keep the data synchronized with the server, what if there is more than one cache

Example: Dropbox, ideally



Example: Dropbox, real-life

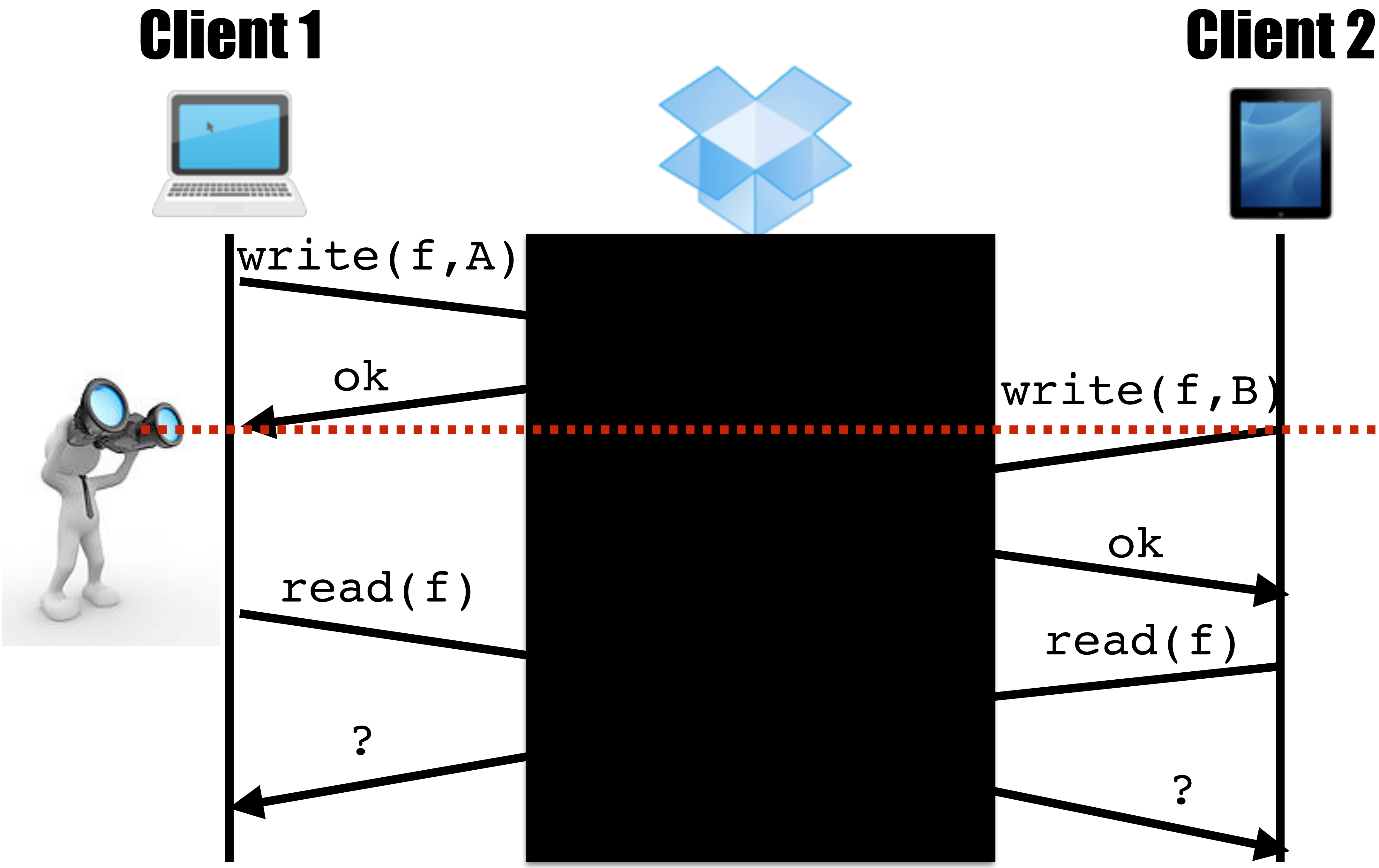


Some definitions

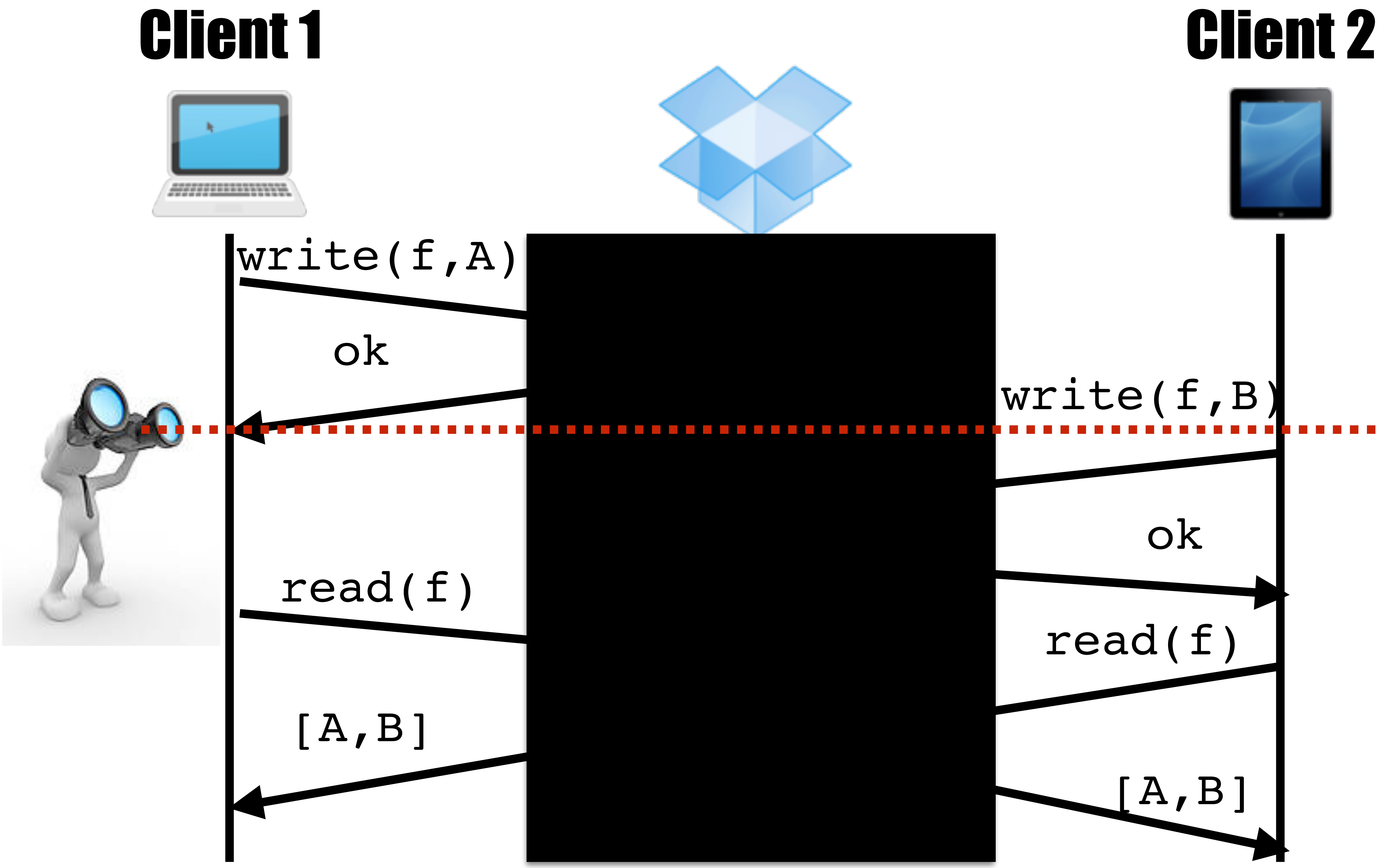
- Coherence/consistency models: Does the reality match the ideal?
  - Coherence = guarantee for single object
  - Consistency = guarantee for multiple objects across the system
  - Caveat: literature is not consistent about this terminology! Naming is hard!
- Anomaly: a sequence of operations leading to a state that cannot occur in the ideal system
- Some models:
  - weak consistency: doesn't match the ideal system, could have anomalies
  - eventual consistency: temporary anomalies, but over time (if no further modifications are made), the system will converge
  - sequential consistency/serializable: behaves like the idea system for applications but might not matching external user expectations
  - linearizable: behaves like a single system to users

Consistency Models

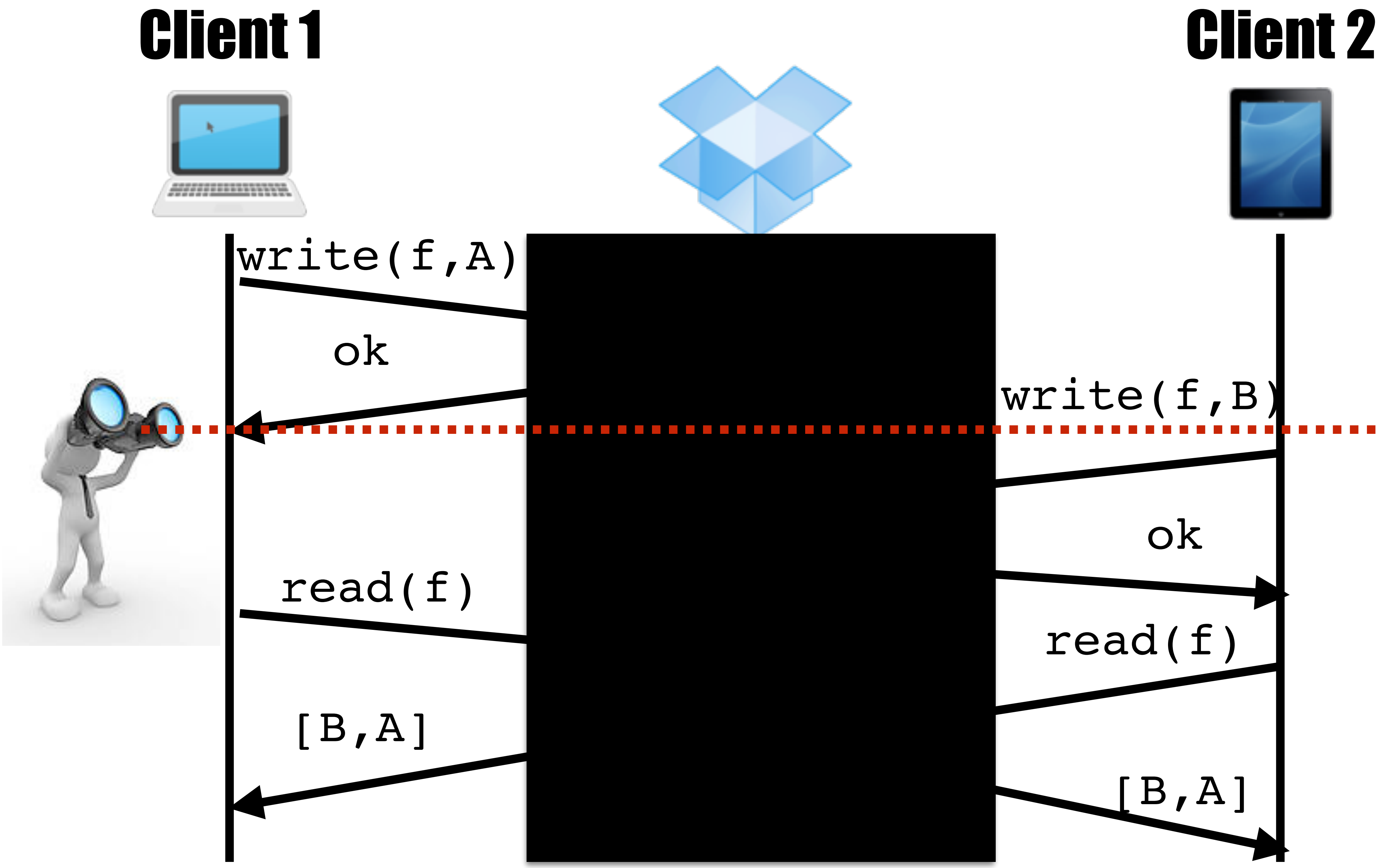
Defining Consistency Models



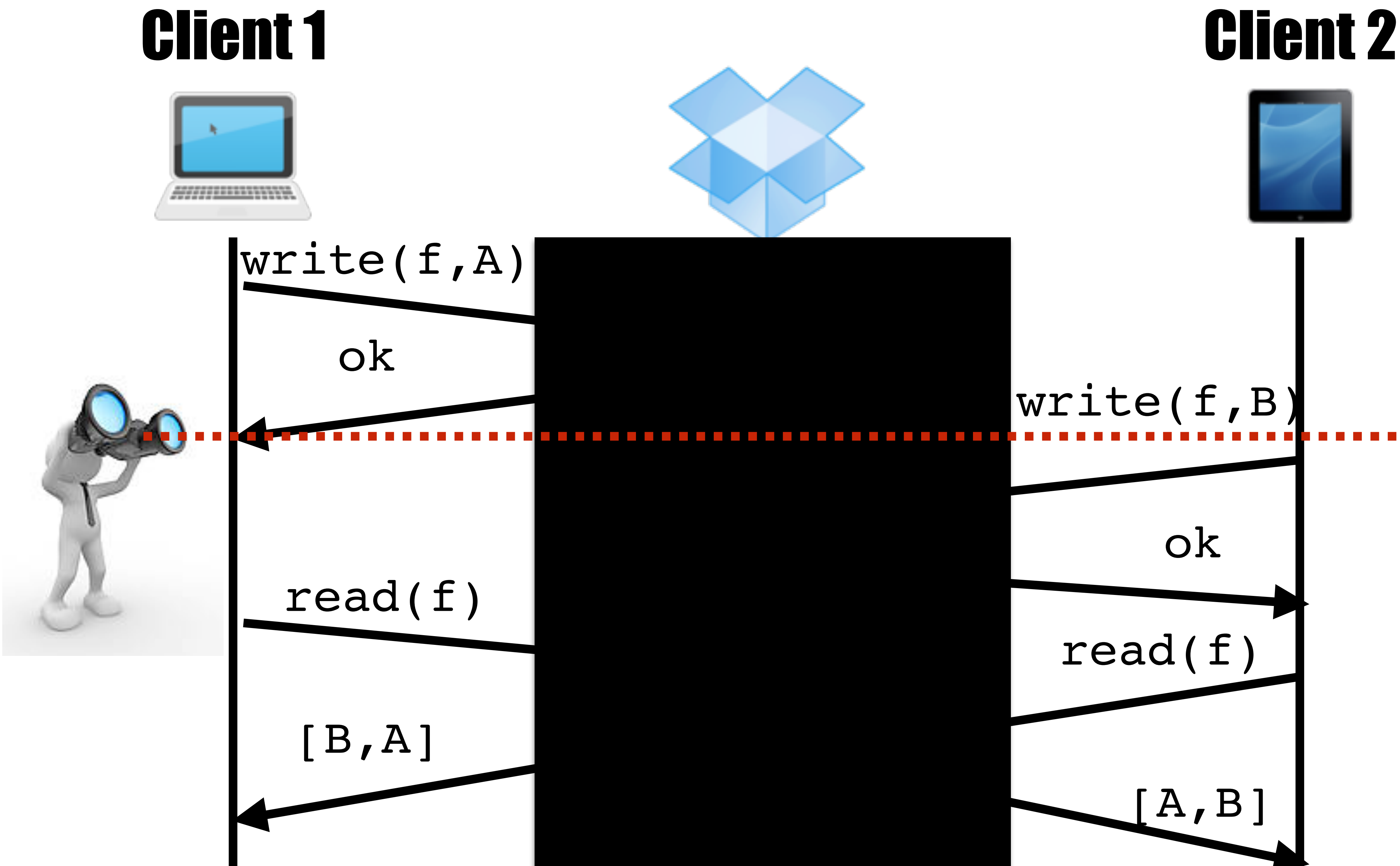
Linearizability



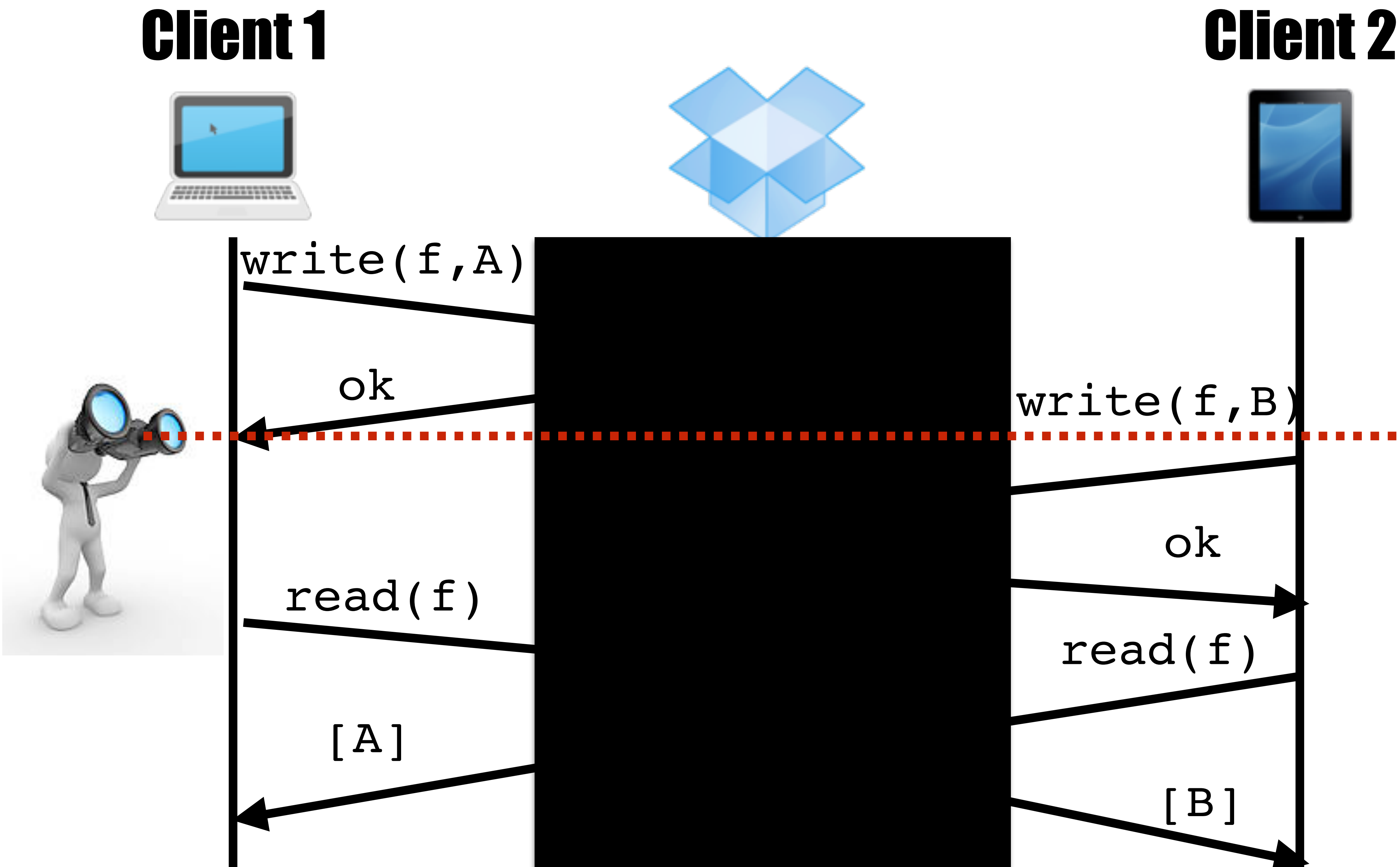
Serializability



Weak Consistency

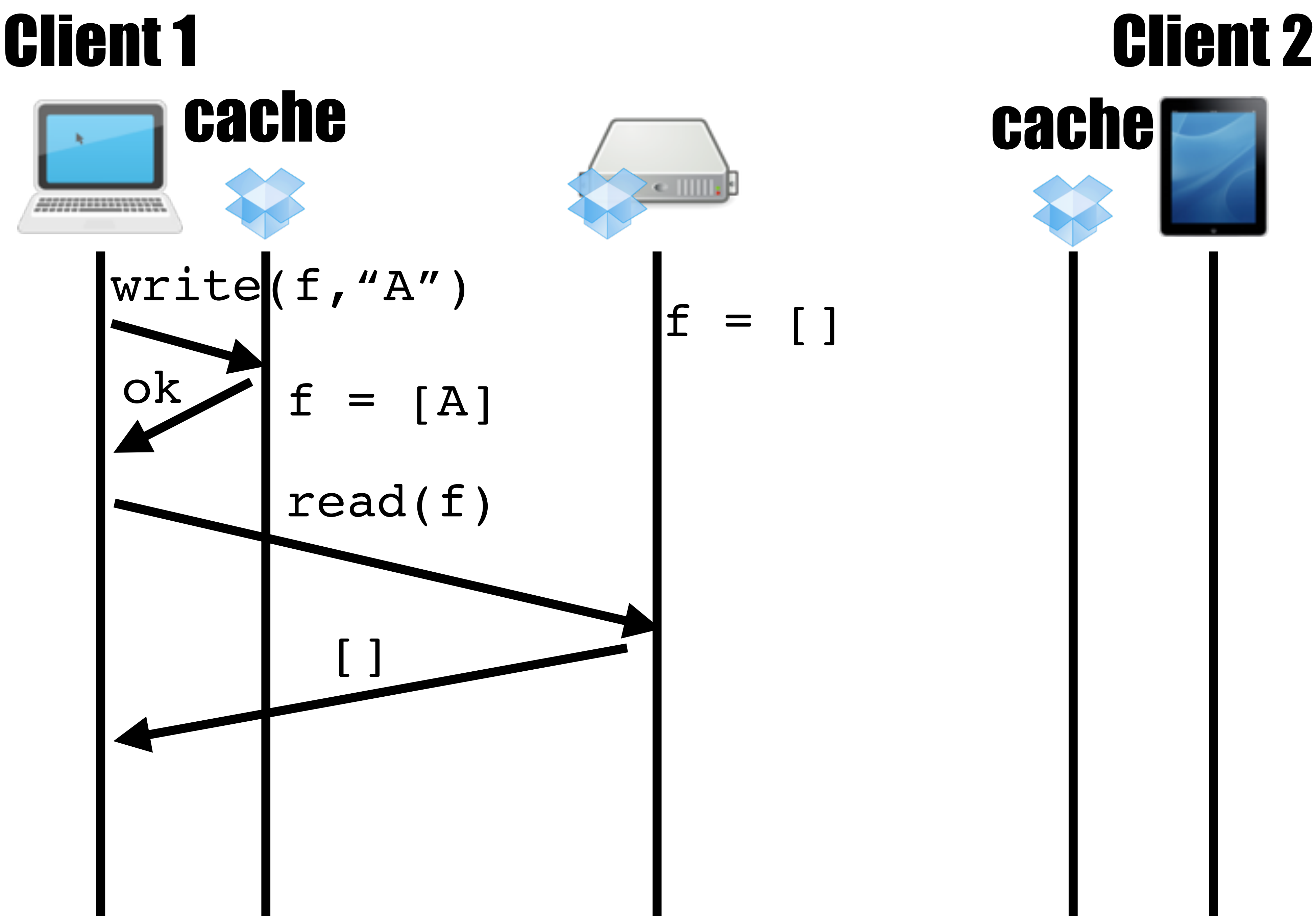


Eventual Consistency

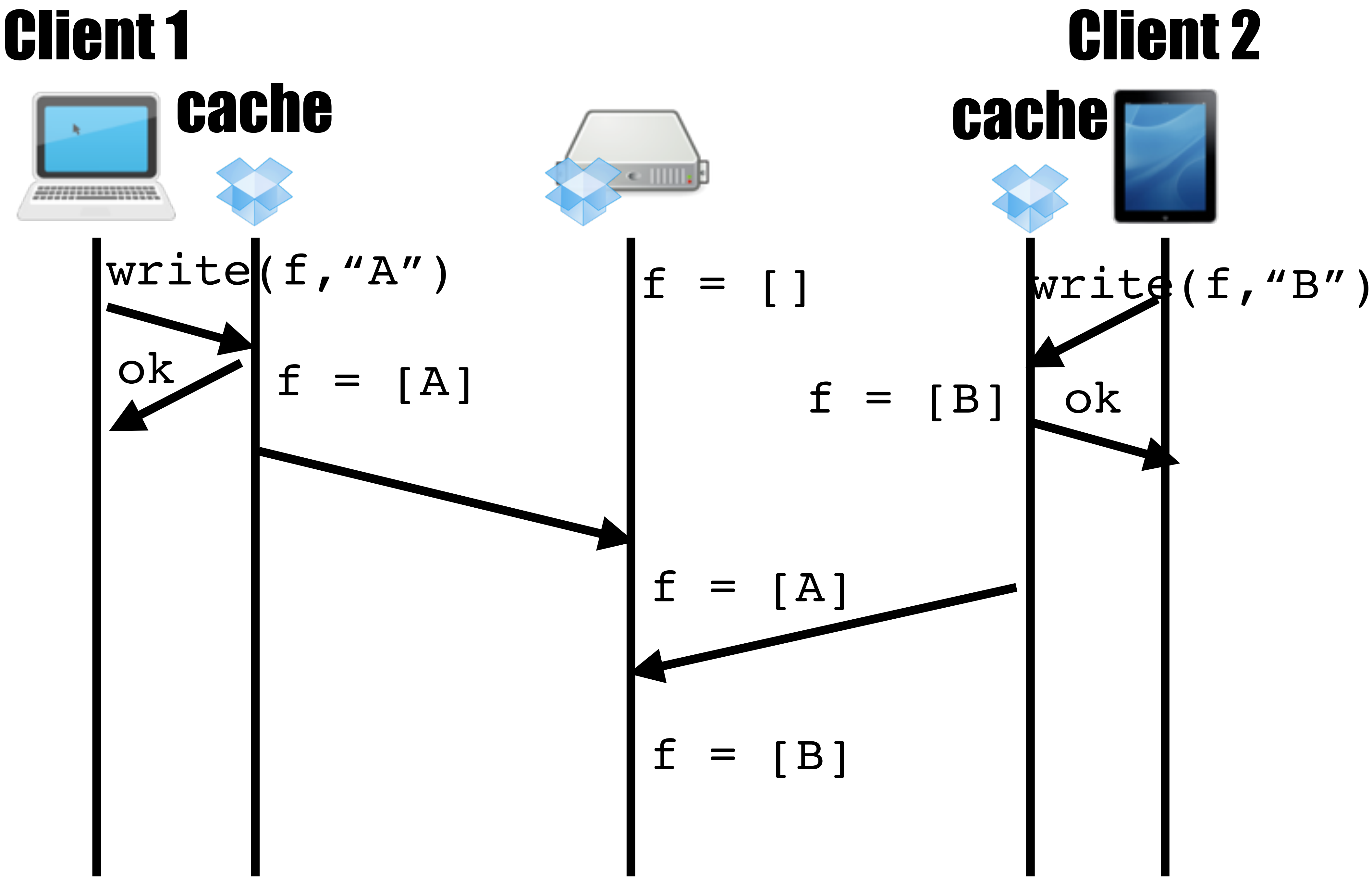


Maintaining Consistency

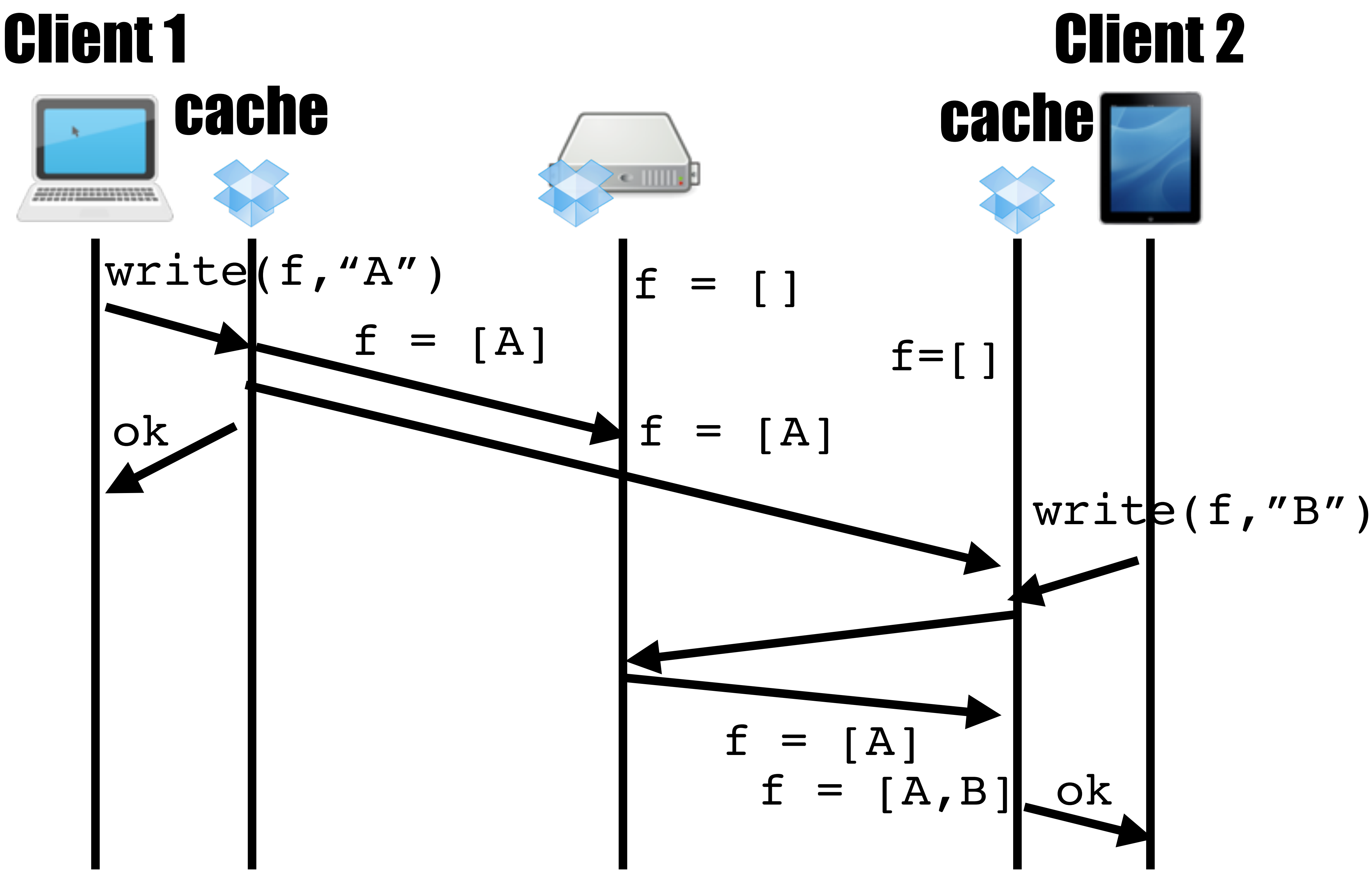
Example: Single client



Example: Multiple clients



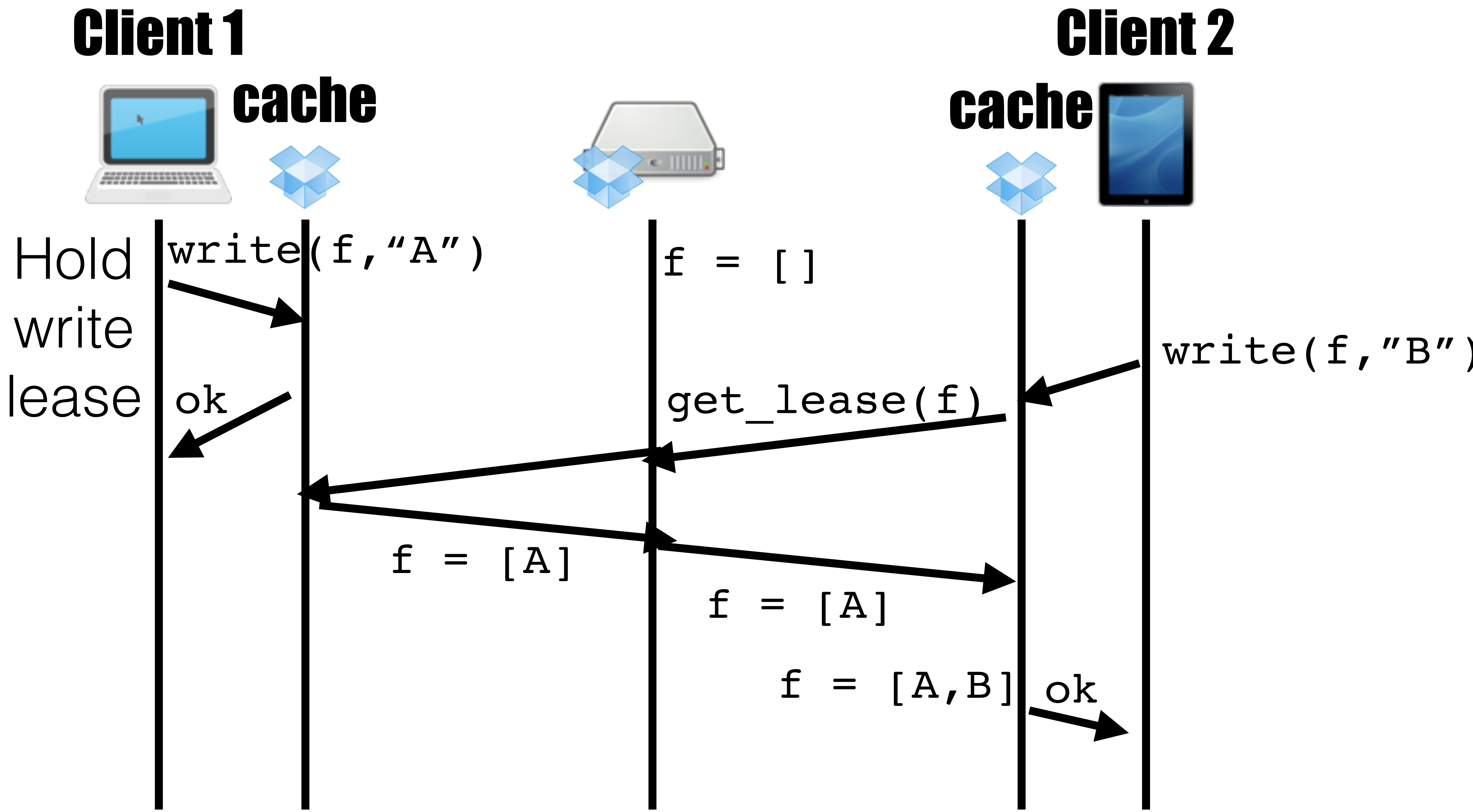
Idea: Cache Invalidations



Cache invalidations

- Need to lock the store and not allow any updates before invalidation to ensure strong consistency
- Slow, especially in a distributed system
- Sometimes practical on processors where caches share a bus, but even modern processors do not provide strong consistency

Idea: Leases



Client 1
cache
Client 2
cache
Hold
write
lease
write(f,“A”)
ok
f = []
write(f,”B”)
get_lease(f)
f = [A]
f = [A]
f = [A,B]
ok

Cache invalidations

- Need to revoke all read leases before acquiring a write lease
- Requires all to all communication
- Again can be practical on processors where caches can snoop on a bus, but even modern processors do not provide strong consistency

Strong vs. Weak consistency

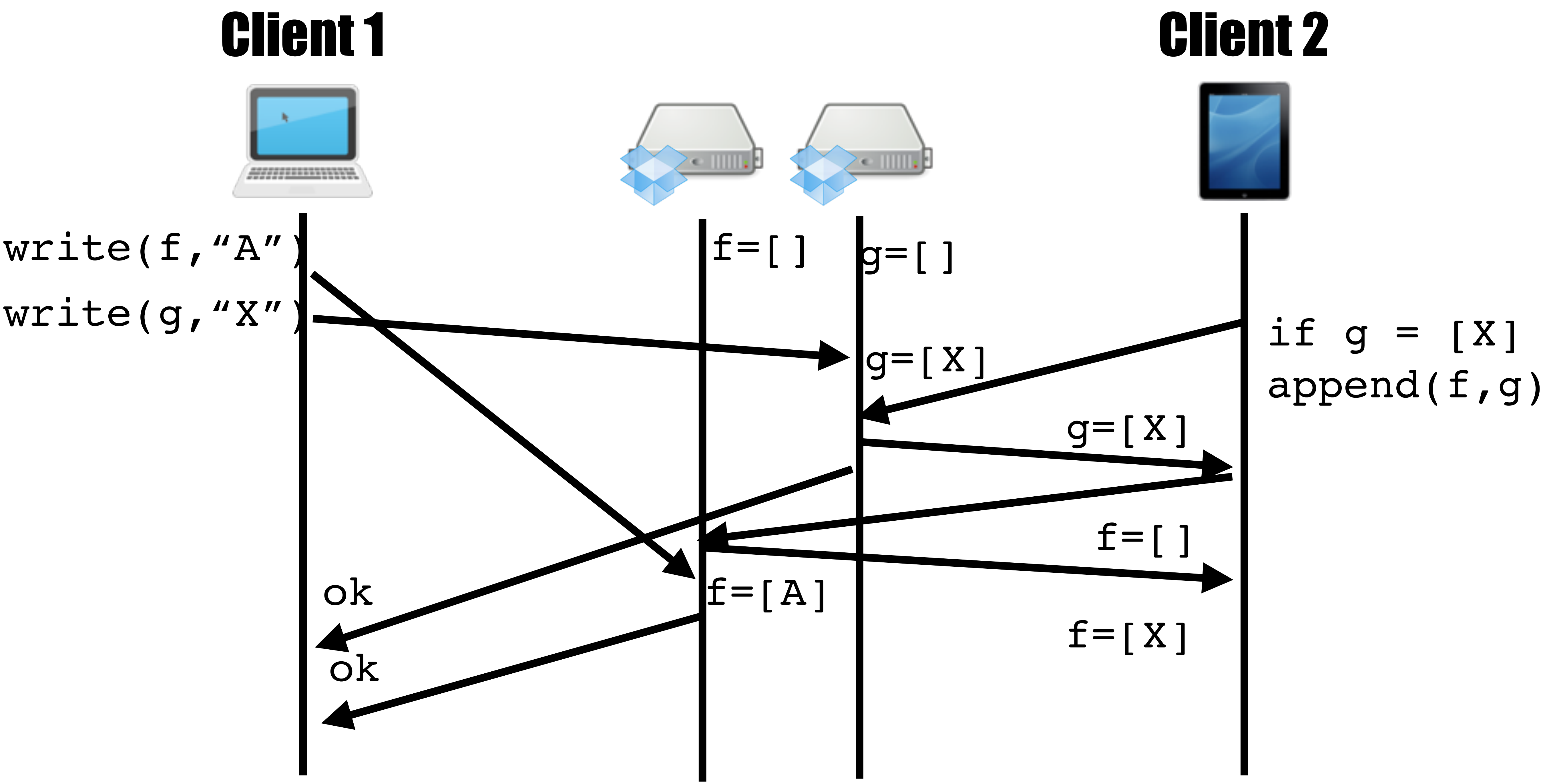
- Strong is obviously easier for programmers to use but performance can be bad

- What about when you can't reach some clients for invalidation or to revoke leases? Do you wait for them?

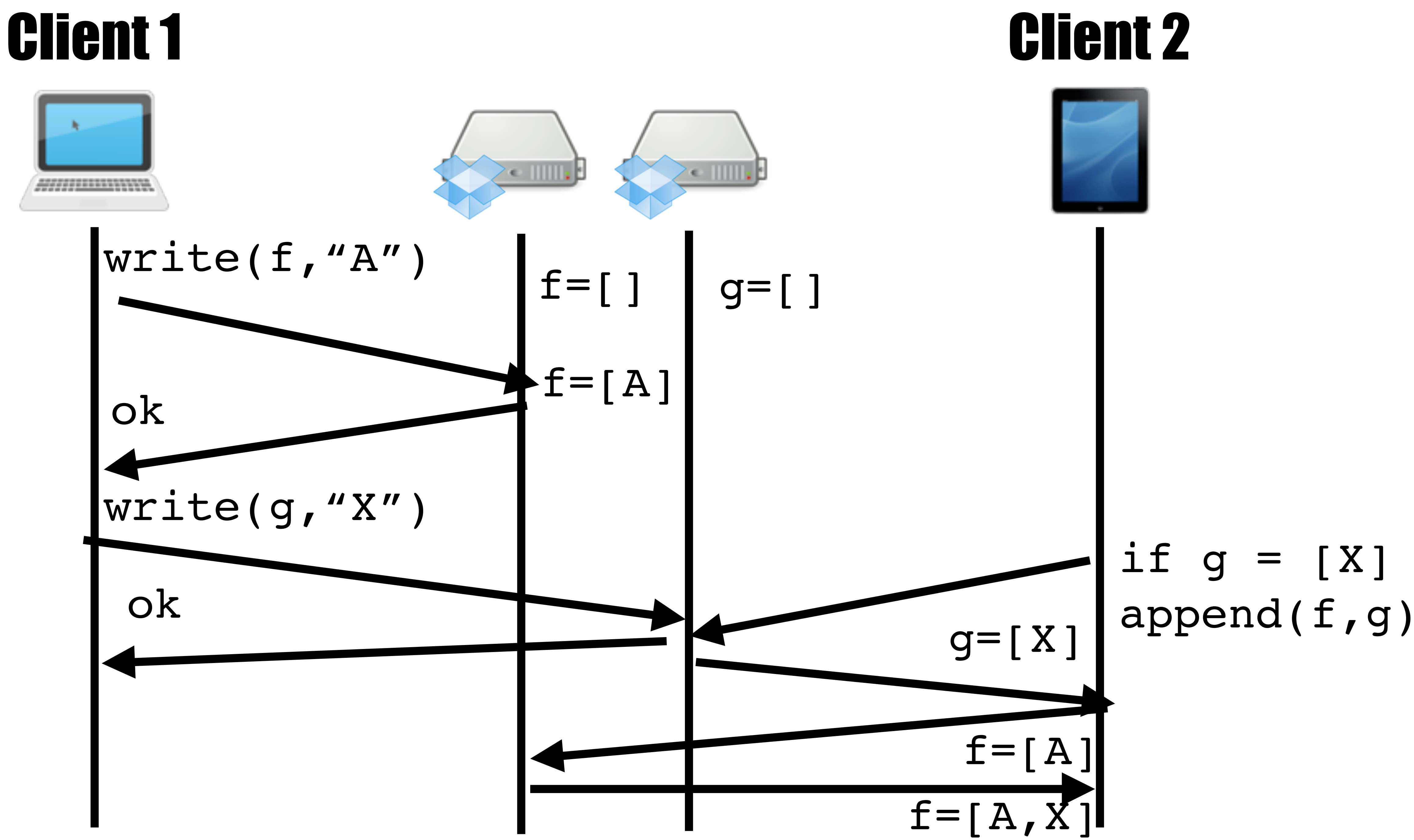
- CAP theorem deals with exactly the case where some clients are unreachable: The system can either give up (A)vailability by blocking or (C)onsistency by going ahead without reaching some of the clients

Maintaining Consistency in systems with sharding

Example: Sharding



Idea: Blocking writes



Processor Ordering

- Linearizability and sequential consistency guarantee processor ordering (operations at one client execute in the order they are issued).
- Re-ordering can happen for many reasons: out-of-order execution, network re-ordering
- Again, it is easier to reason about but more expensive
- Another option for this example in a distributed system is transactions to guarantee atomicity: if the write(g) is visible then so is the write(f), otherwise neither