# Tango

Emmett Witchel

CS380L

# Faux Quiz Questions

- Compare/contrast Tango against LFS
- Compare/contrast Tango against TxOS
- Compare/contrast Tango against Spark/DryadLINQ
- How are streams used in Tango?
- Why do holes arise in a tango log? How does the system deal with them?
- How do streams complicate cross-object transactions in Tango?
- How does Tango's commit protocol differ from a traditional protocol like 2PC?
- Compare/contrast fault-tolerance techniques in Tango and Spark

# Tango: distributed data structures over a shared log

*Mahesh Balakrishnan*, Dahlia Malkhi, Ted Wobber, Ming Wu, Vijayan Prabhakaran
Michael Wei, John D. Davis, Sriram Rao, Tao Zou, Aviad Zuck

Microsoft Research

# big **meta**data

- design pattern: distribute data, *centralize metadata*
- schedulers, allocators, coordinators, namespaces, indices (e.g. HDFS namenode, SDN controller…)

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- … but hardening is difficult!

# the abstraction gap for metadata

centralized metadata services are built using in-memory data structures (e.g. Java / C# Collections)

- state resides in maps, trees, queues, counters, graphs…
- transactional access to data structures
    - example: a scheduler atomically moves a node from a free list to an allocation map

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adding high availability requires different abstractions

- move state to external service like ZooKeeper
- restructure code to use state machine replication
- implement custom replication protocols

# the Tango abstraction

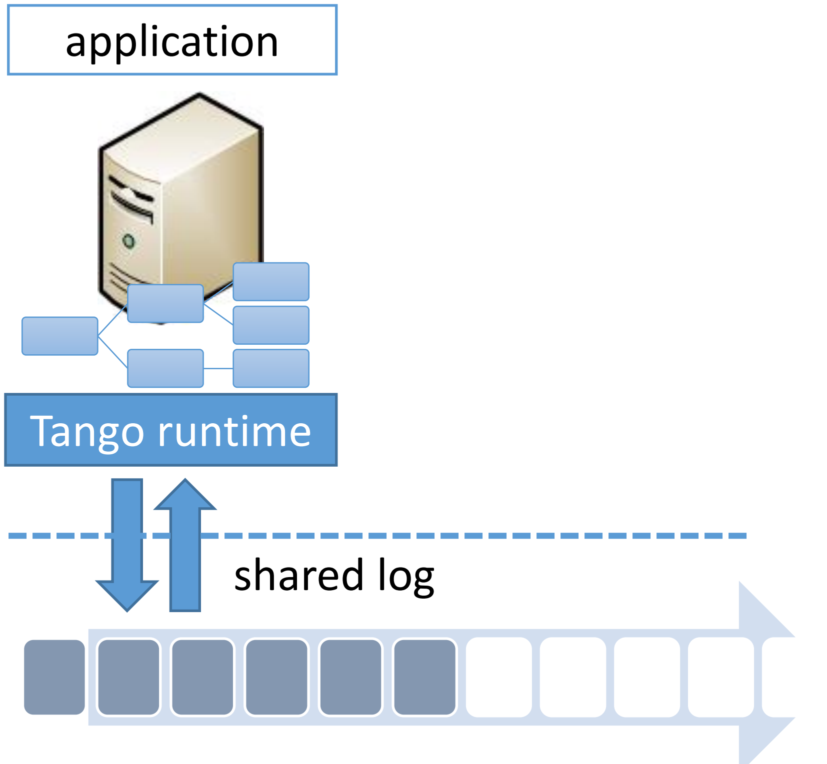
a Tango object

**=**

**view**
in-memory
data structure

**+**

**history**
ordered
updates in
shared log



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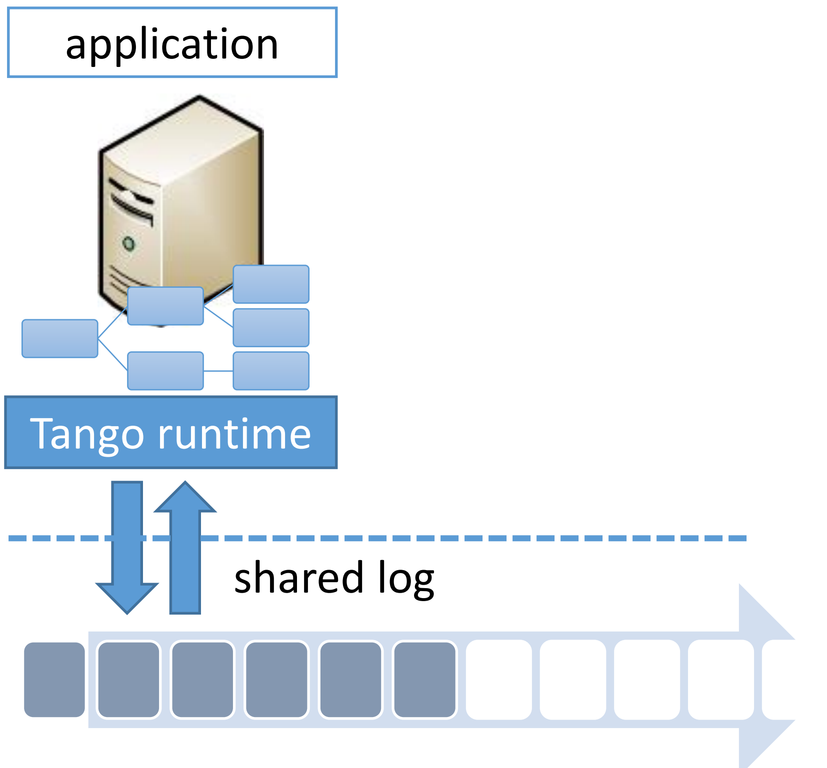


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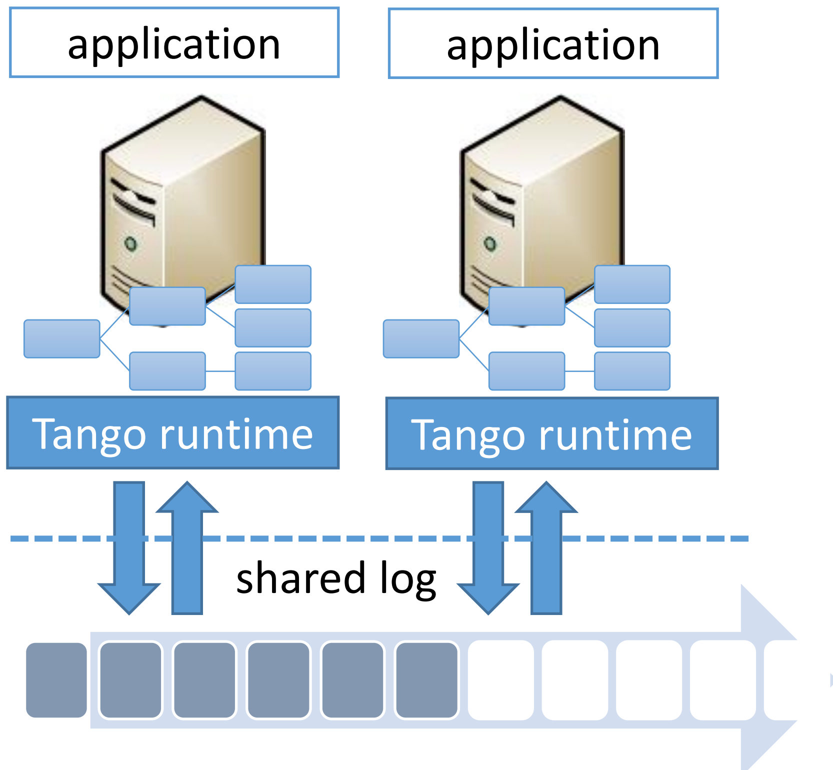


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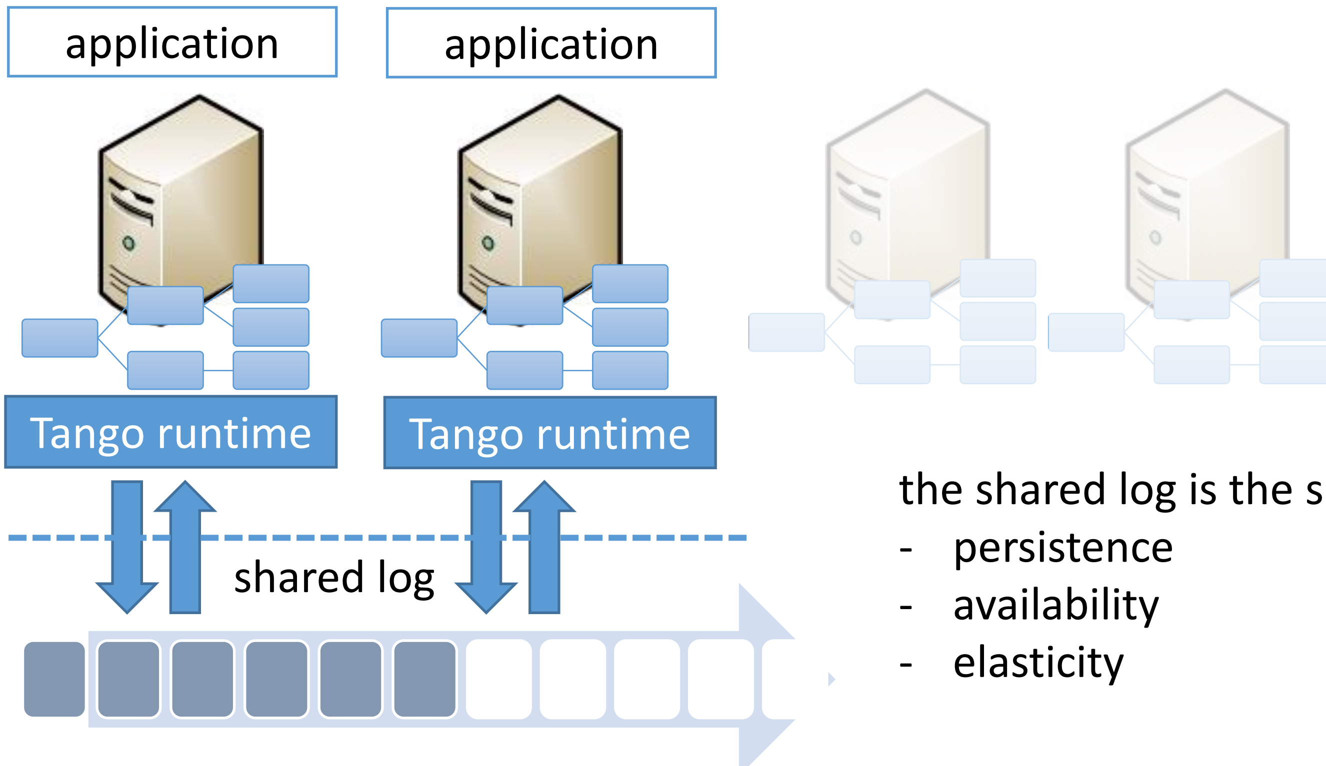


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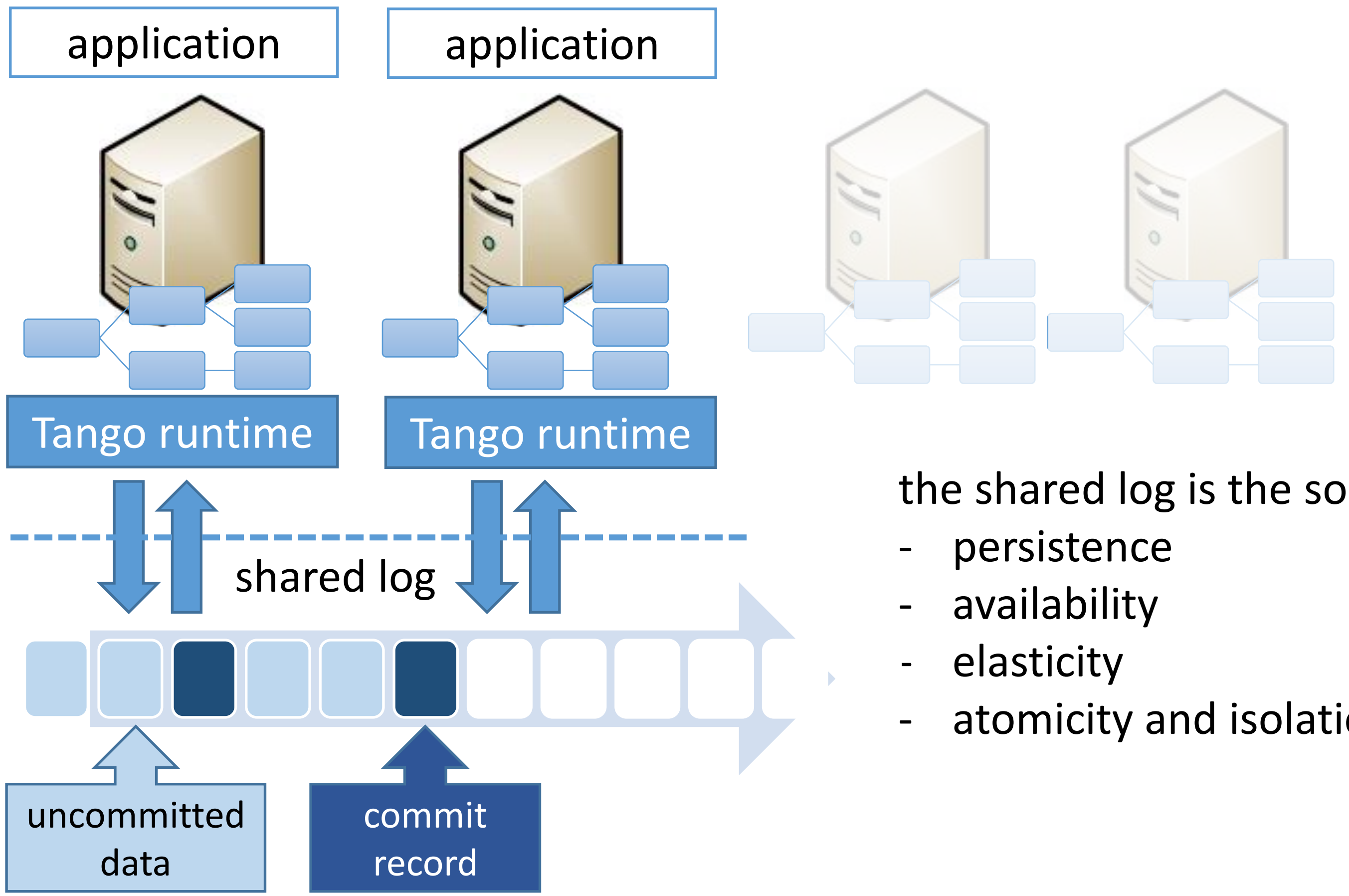


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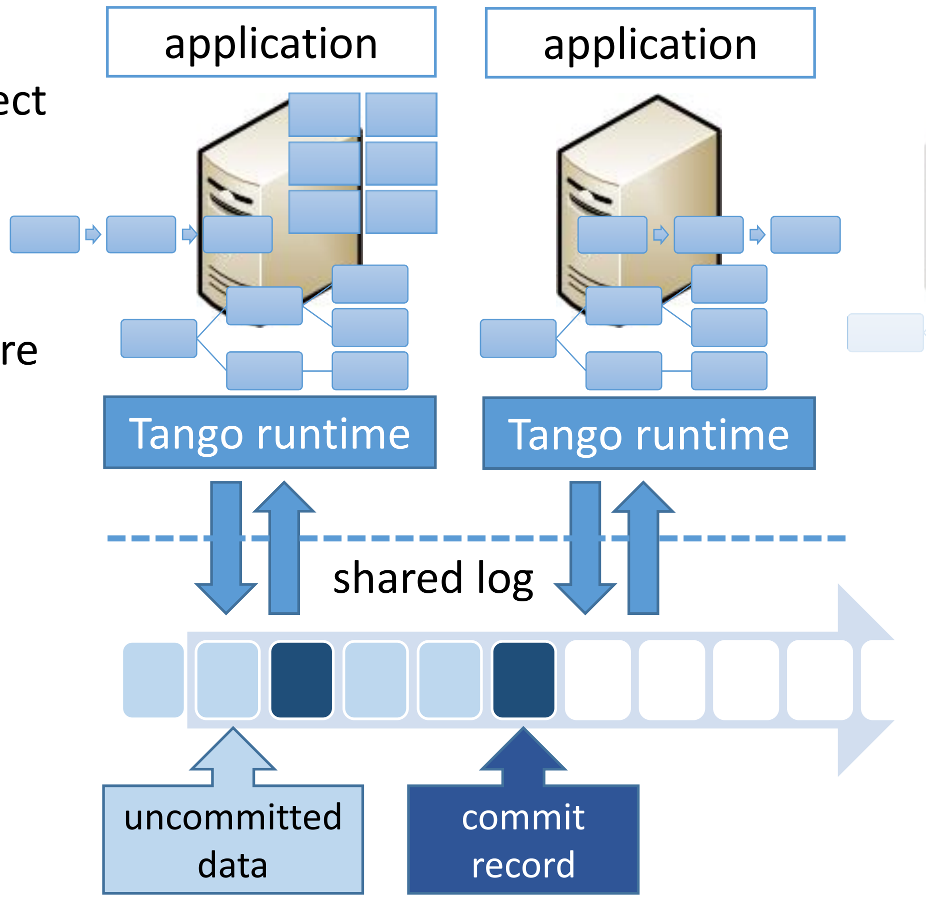


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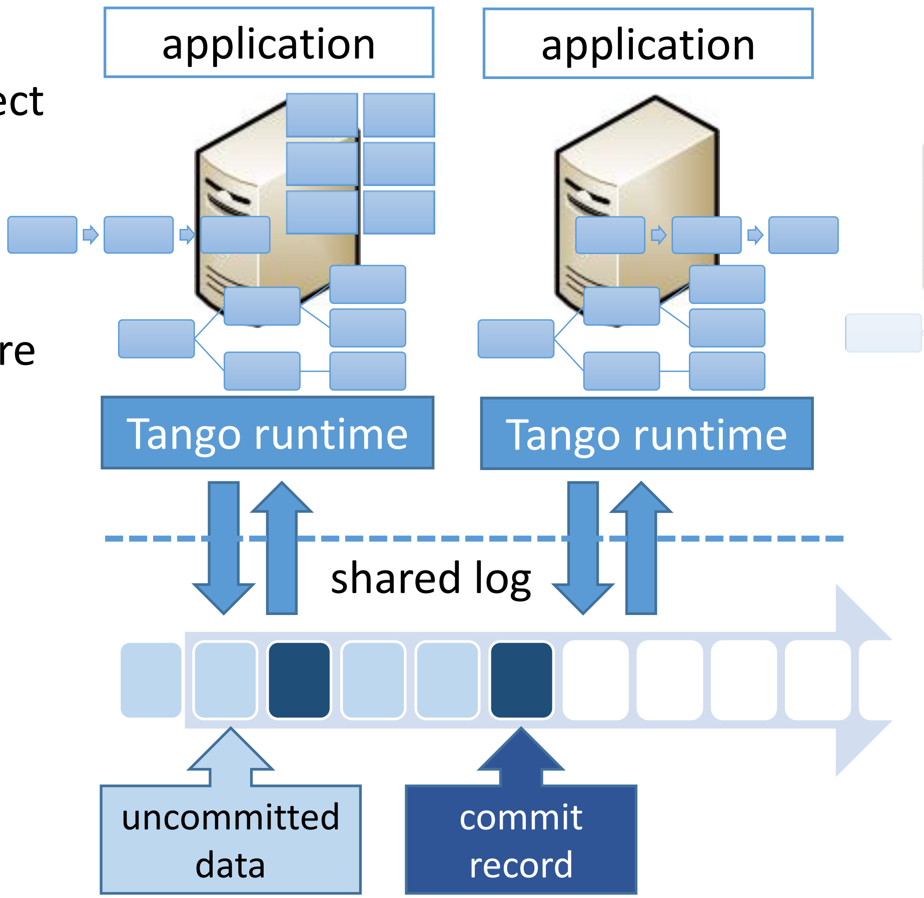


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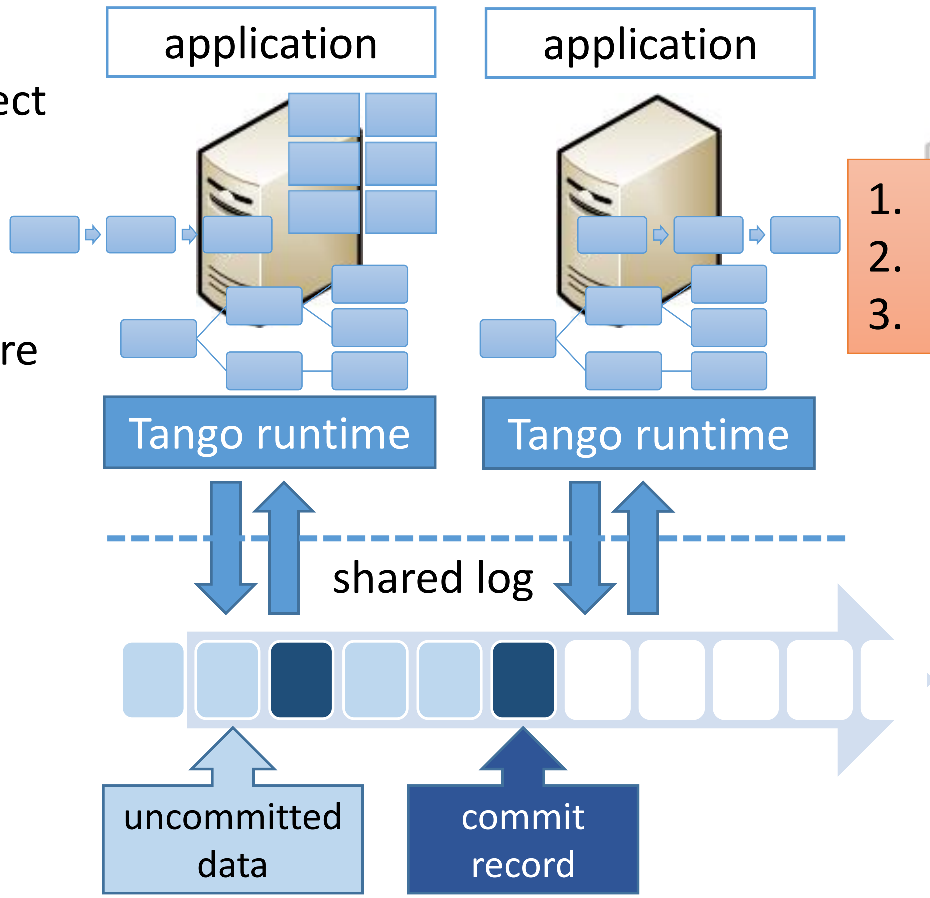


1. Tango objects are **easy to use**
2. Tango objects are **easy to build**
3. Tango objects are **fast and scalable**

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# Tango objects are easy to use

- implement standard interfaces (Java/C# Collections)
- linearizability for single operations

**example:**

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curowner = ownermap.get("ledger");
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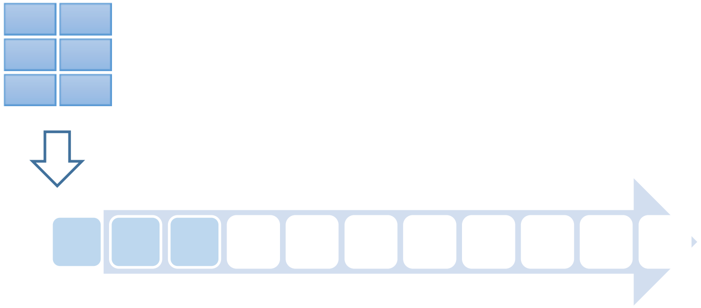

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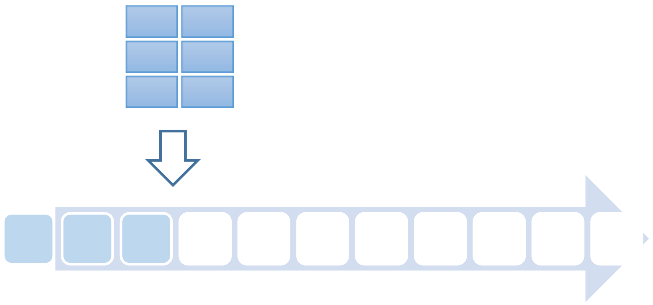

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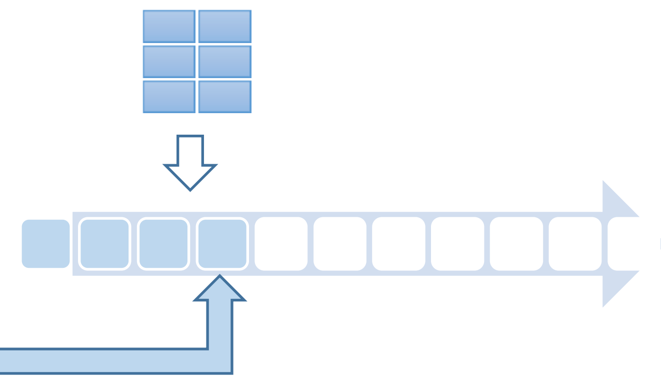

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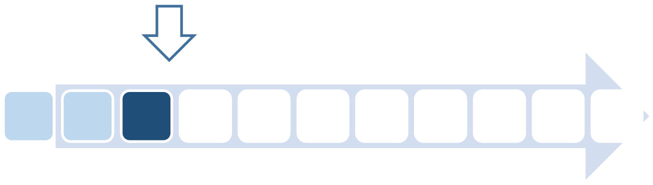

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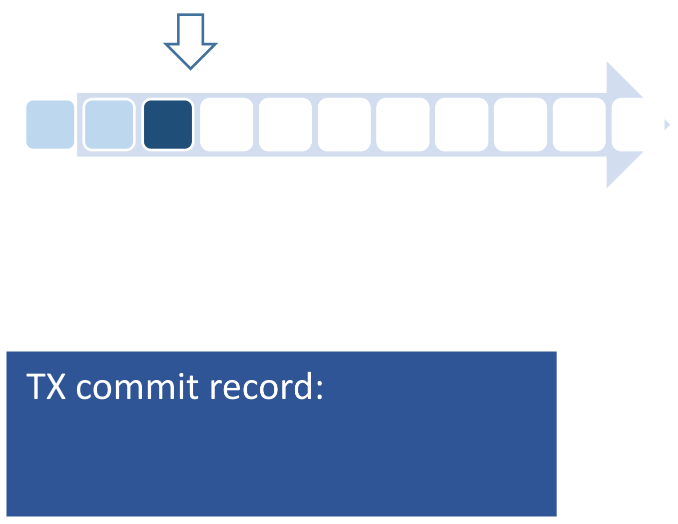

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**example:**

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TR.BeginTX();
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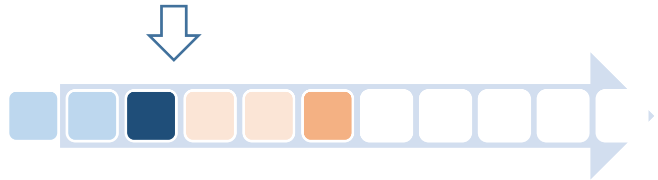

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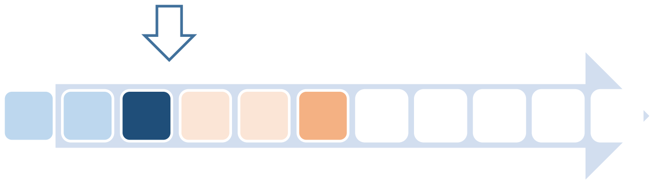

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read-set: (ownermap, ver:2)

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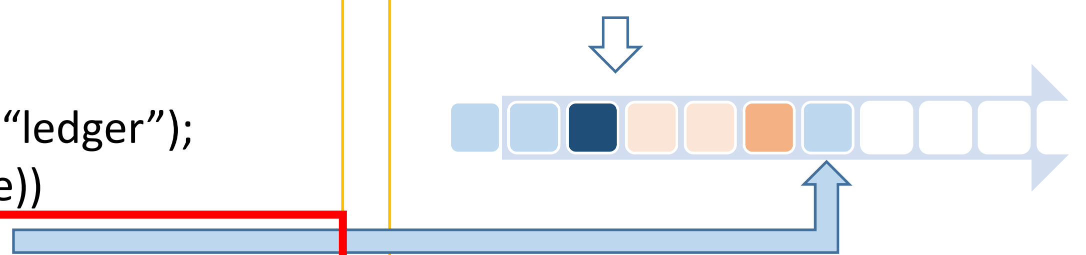

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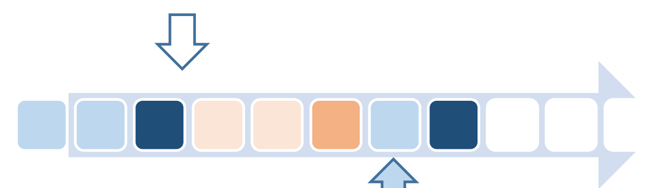

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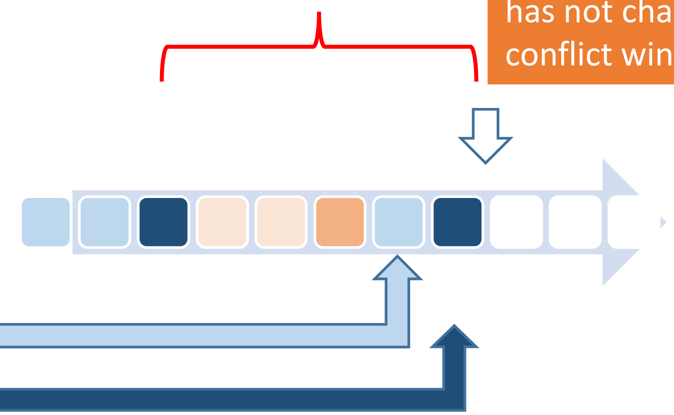
TX commits if read-set (*ownermap*) has not changed in conflict window



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speculative commit records: each client decides if the TX commits or aborts **independently but deterministically**
[similar to Hyder (Bernstein et al., CIDR 2011)]

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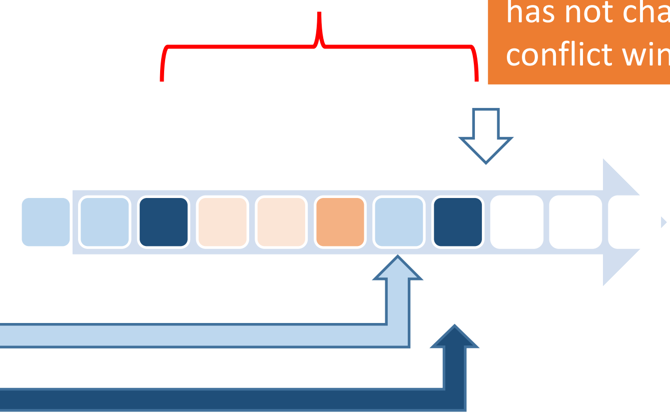

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# Tango objects are easy to build

15 LOC == persistent, highly available, transactional register

```
class TangoRegister {
        int oid;
        TangoRuntime *T;
        int state;
        void apply(void *X) {
                state = *(int *)X;
        }
        void writeRegister (int newstate) {
                T->update_helper(&newstate , sizeof (int) , oid);
        }
        int readRegister () {
                T->query_helper(oid);
                return state;
        }
}
```

simple API exposed by runtime to object: 1 upcall + two helper methods
arbitrary API exposed by object to application: mutators and accessors

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object-specific state

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invoked by Tango runtime on EndTX to change state

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mutator: updates TX write-set, appends to shared log

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accessor: updates TX read-set, returns local state

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Other examples:
Java ConcurrentMap: 350 LOC
Apache ZooKeeper: 1000 LOC
Apache BookKeeper: 300 LOC

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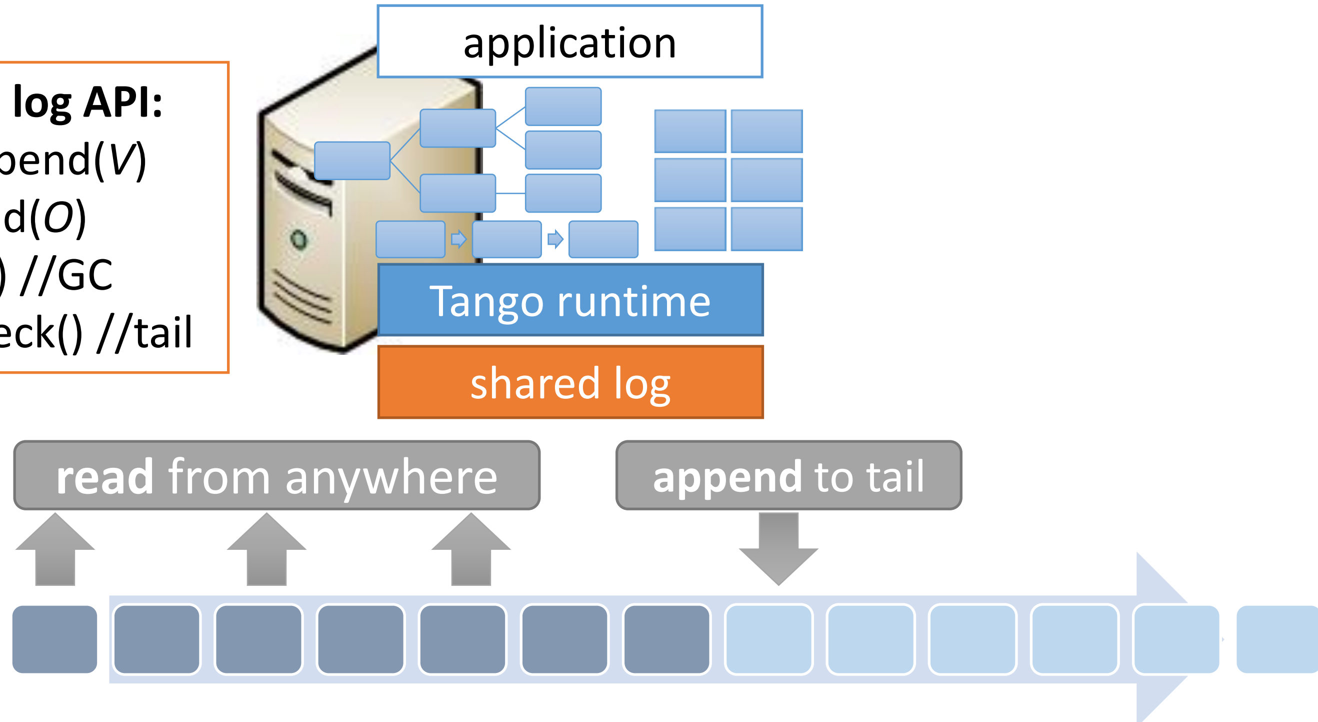
# the secret sauce: a fast shared log

**shared log API:**
O = append(*V*)
V = read(*O*)
trim(*O*) //GC
O = check() //tail



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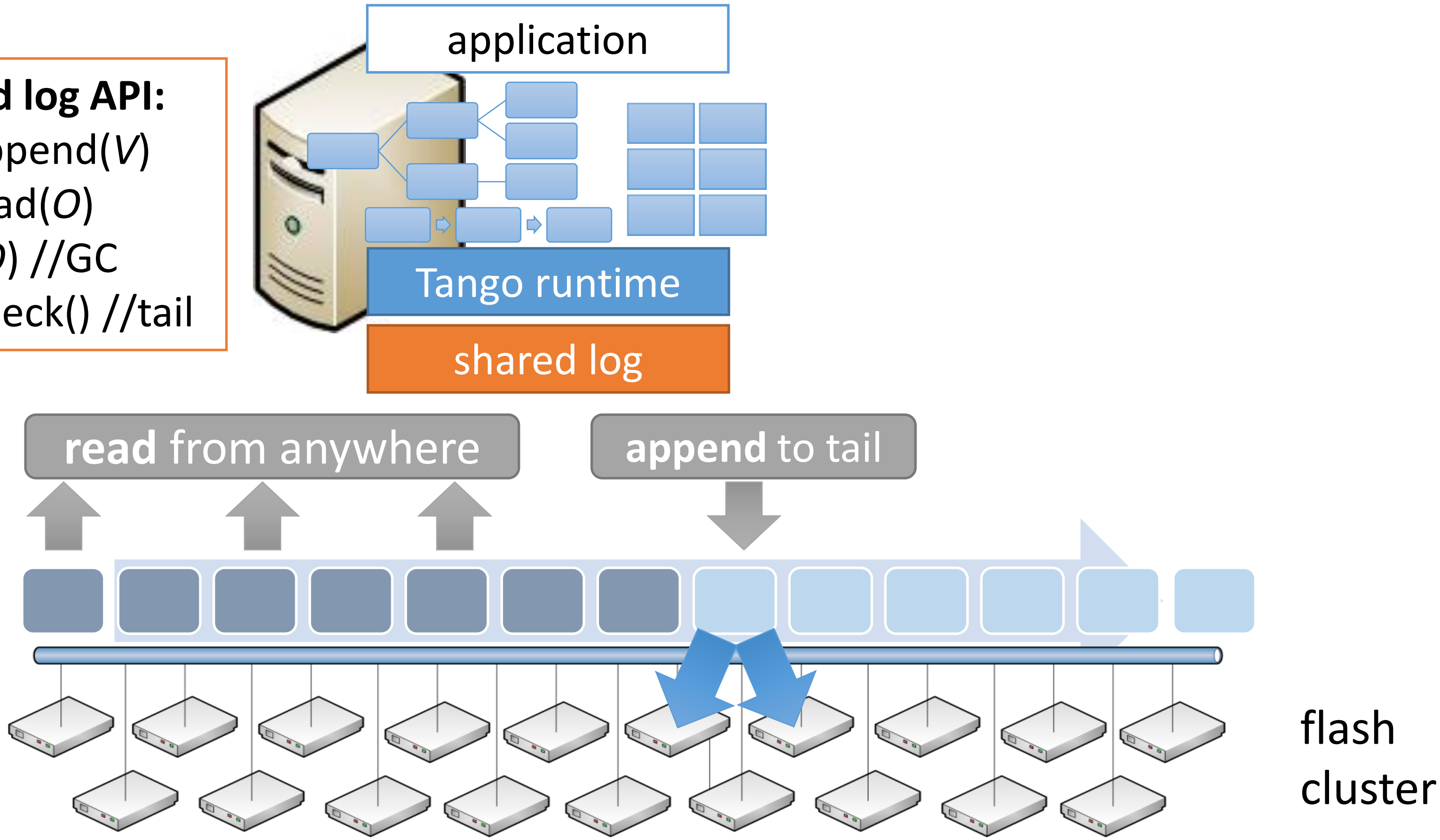


the CORFU decentralized shared log [NSDI 2012]:
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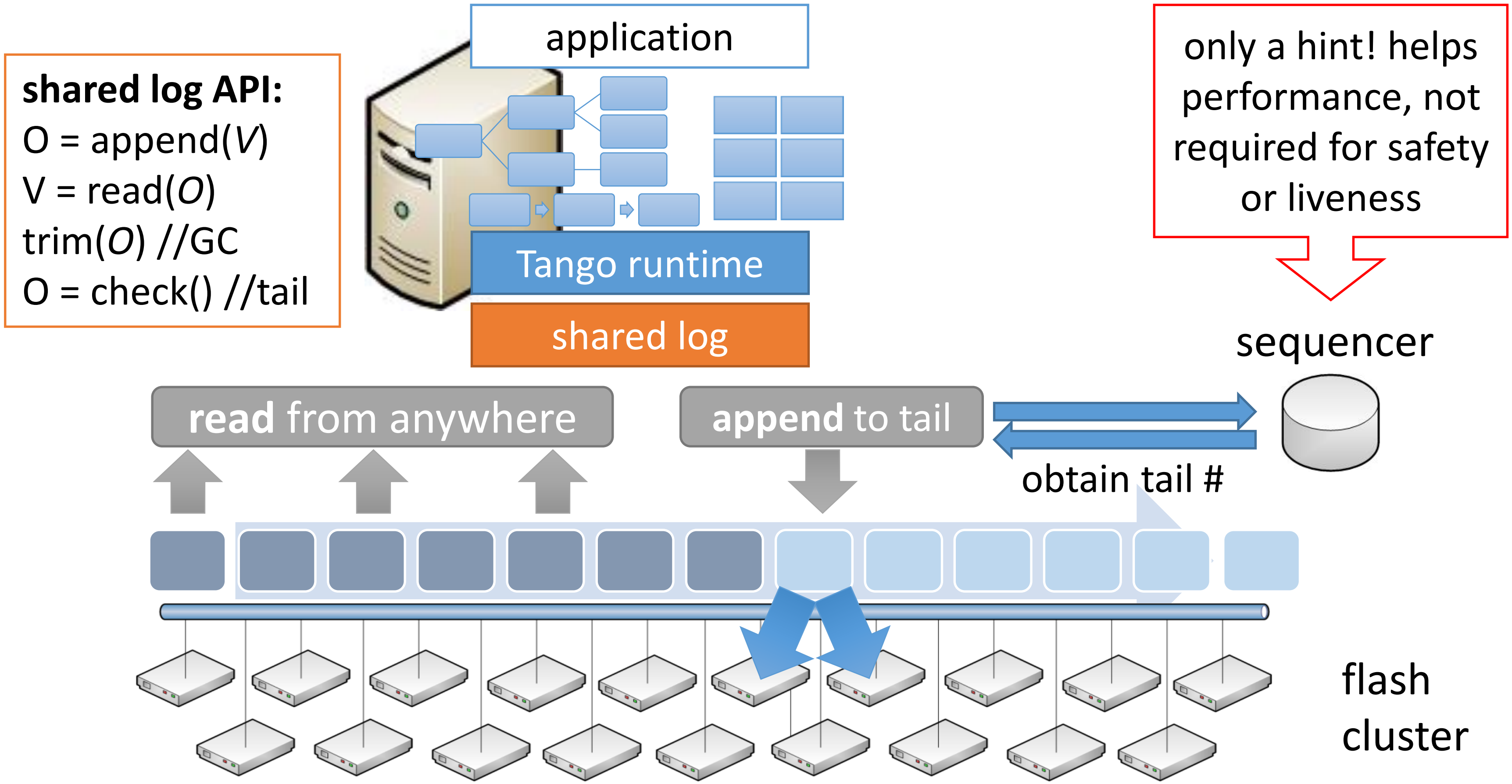
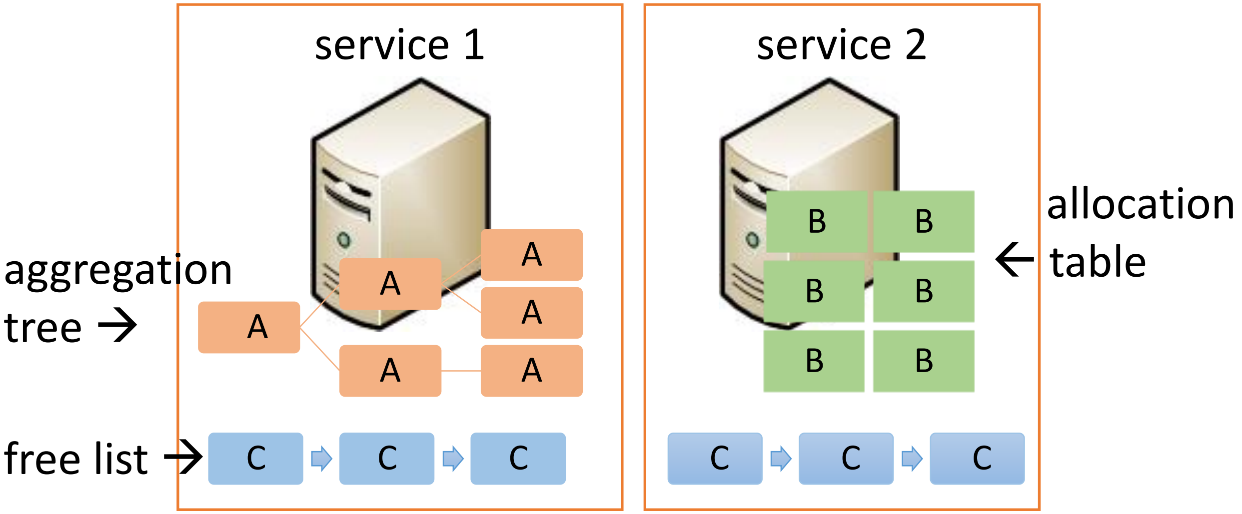



the CORFU decentralized shared log [NSDI 2012]:
- reads scale linearly with number of flash drives
- 600K/s appends (limited by sequencer speed)

# a fast shared log isn't enough…



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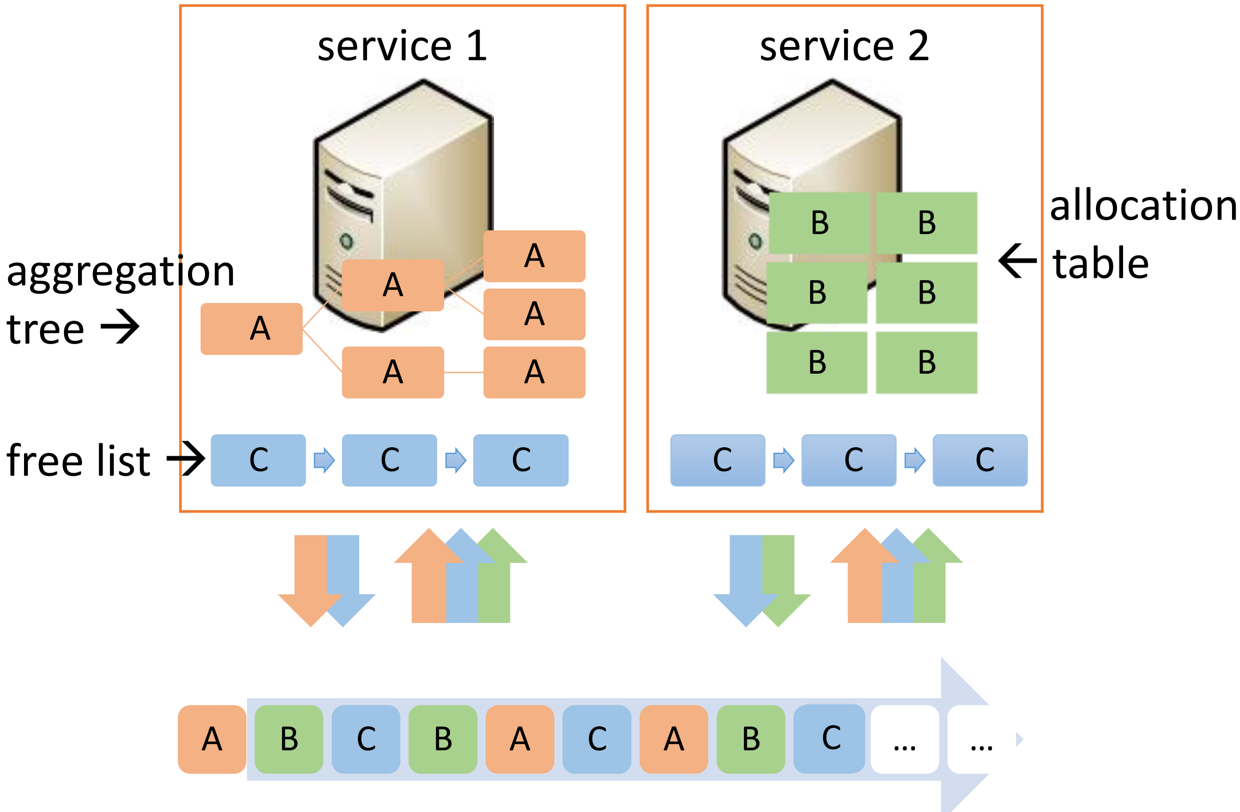

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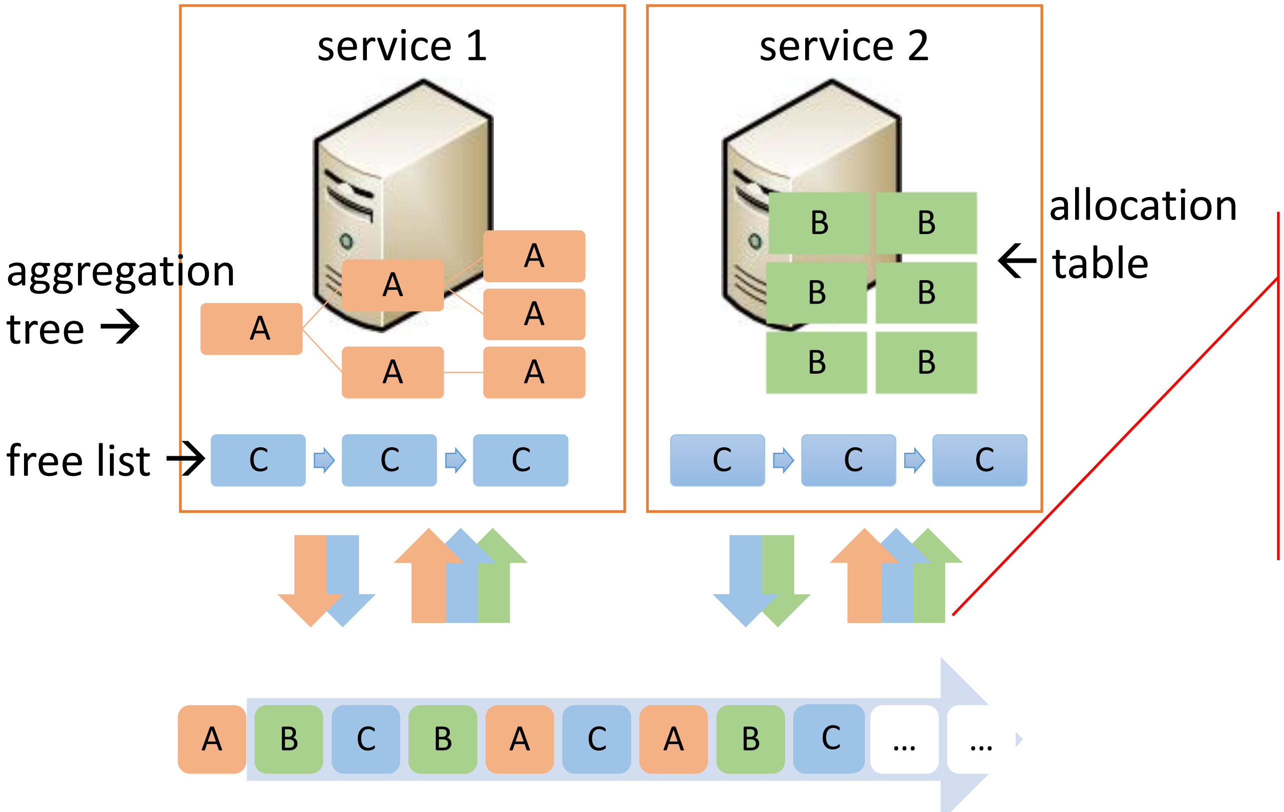


**the playback bottleneck**: clients must read all entries → inbound NIC is a bottleneck

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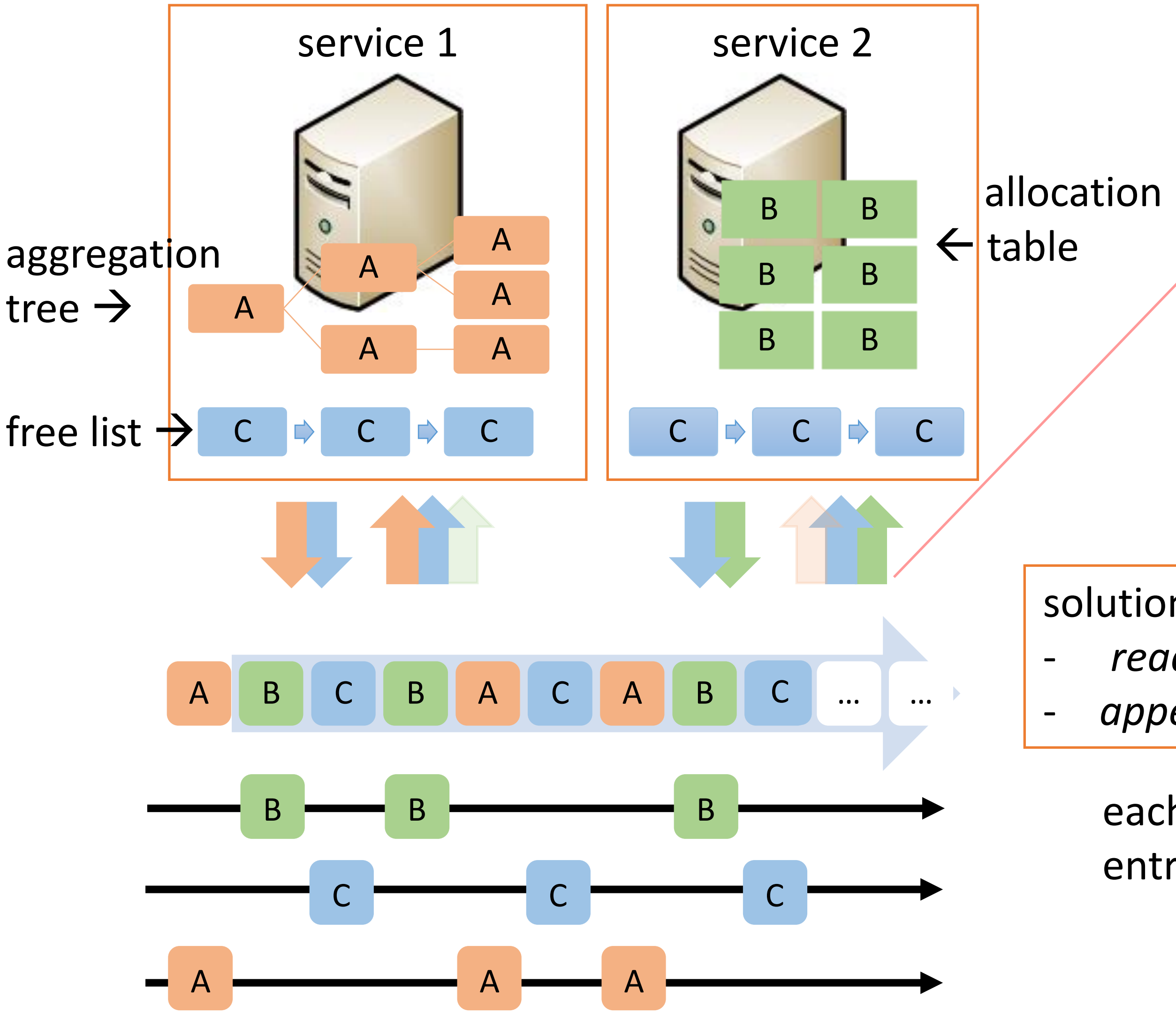


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solution: **stream** abstraction
- *readnext(streamid)*
- *append(value, streamid1, … )*

each client only plays entries of interest to it

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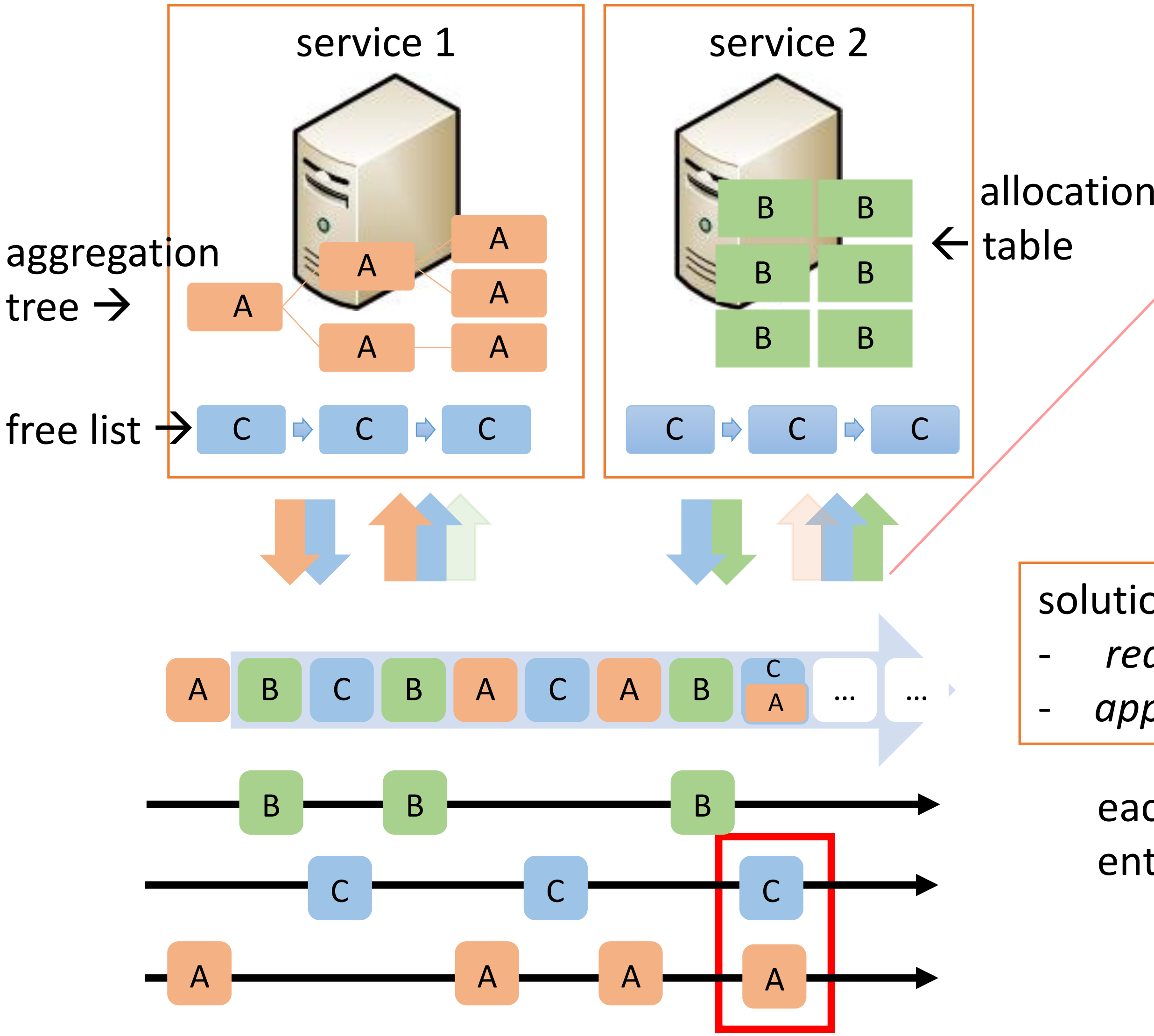


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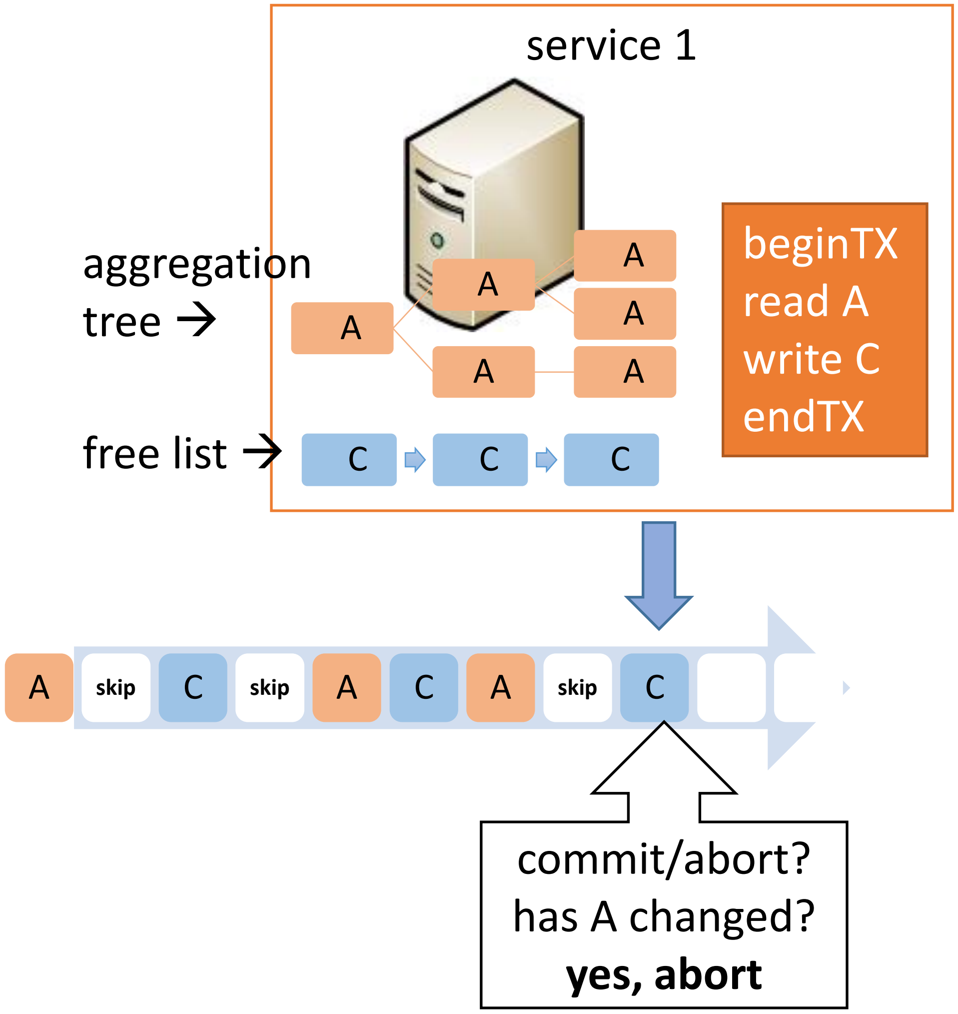
# transactions over streams



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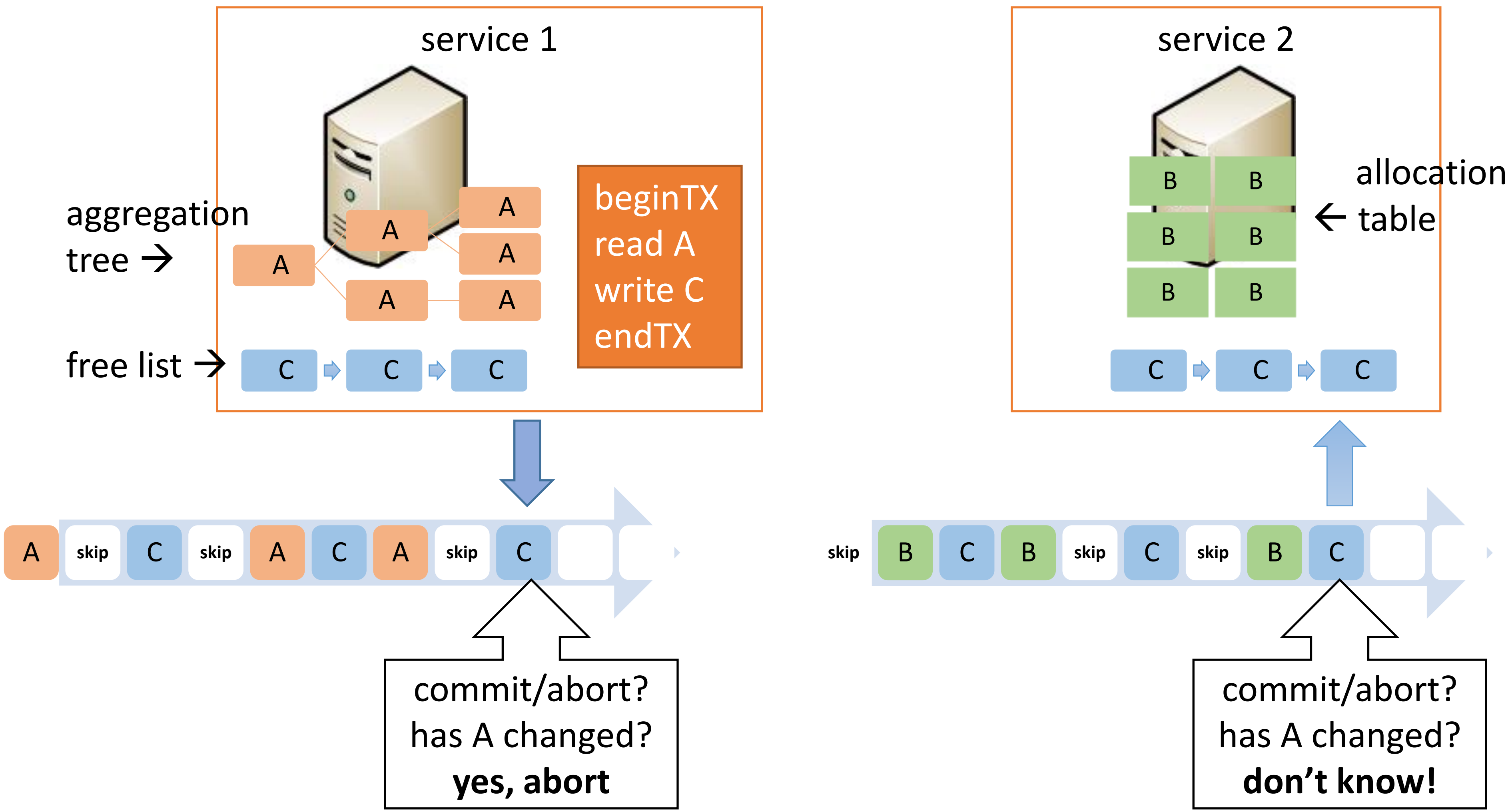

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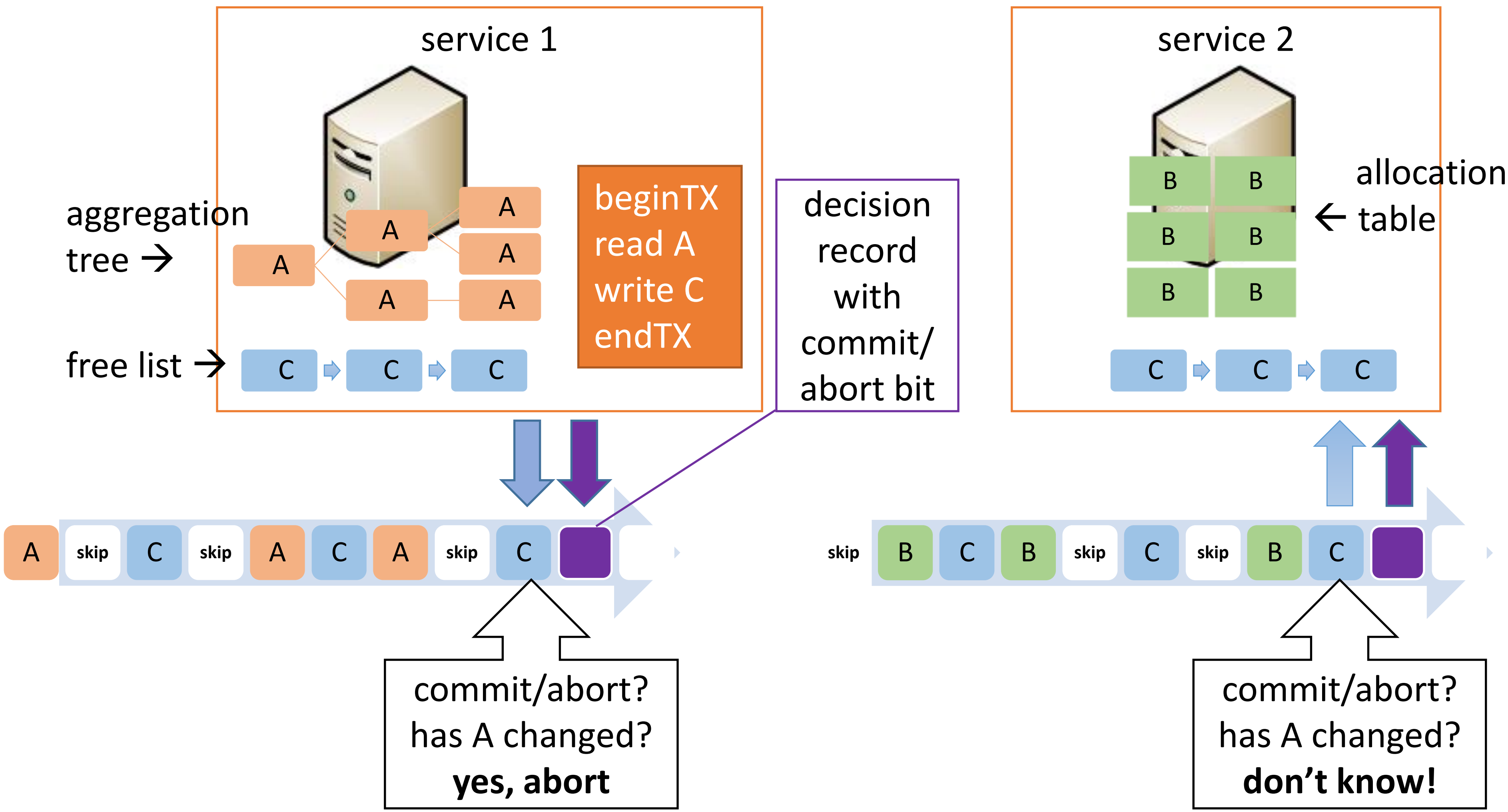
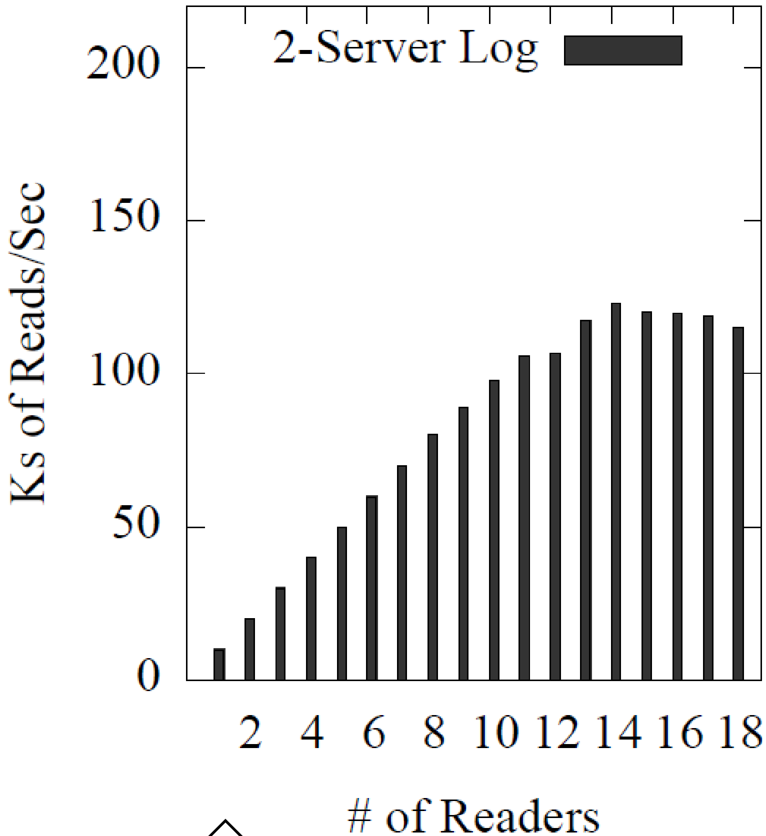


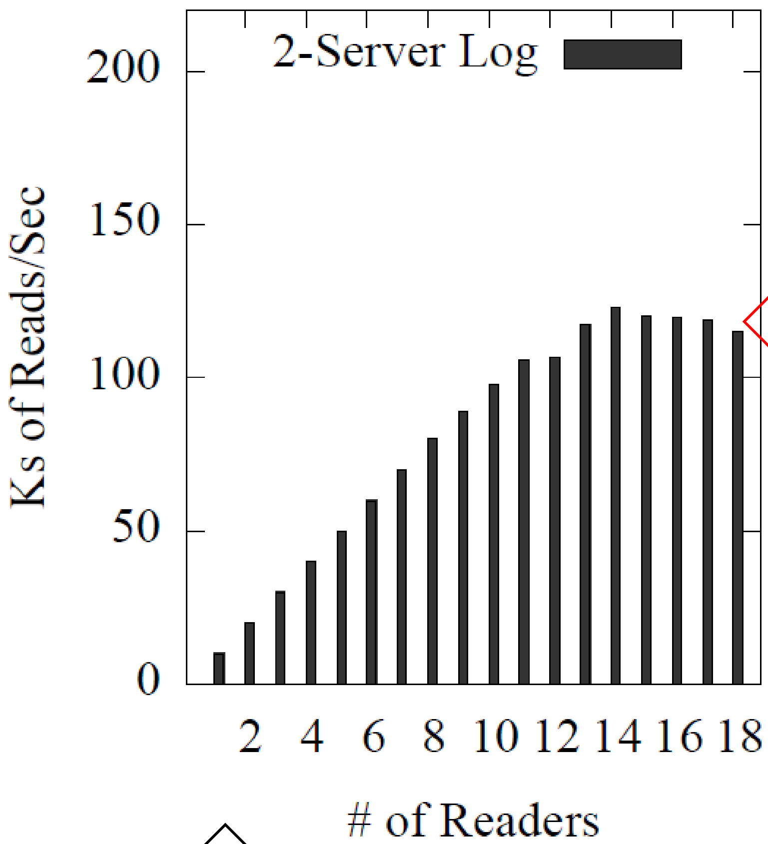
# evaluation: linearizable operations




constant write load (10K writes/sec), each client adds 10K reads/sec

a Tango object provides elasticity for strongly consistent reads

# evaluation: linearizable operations

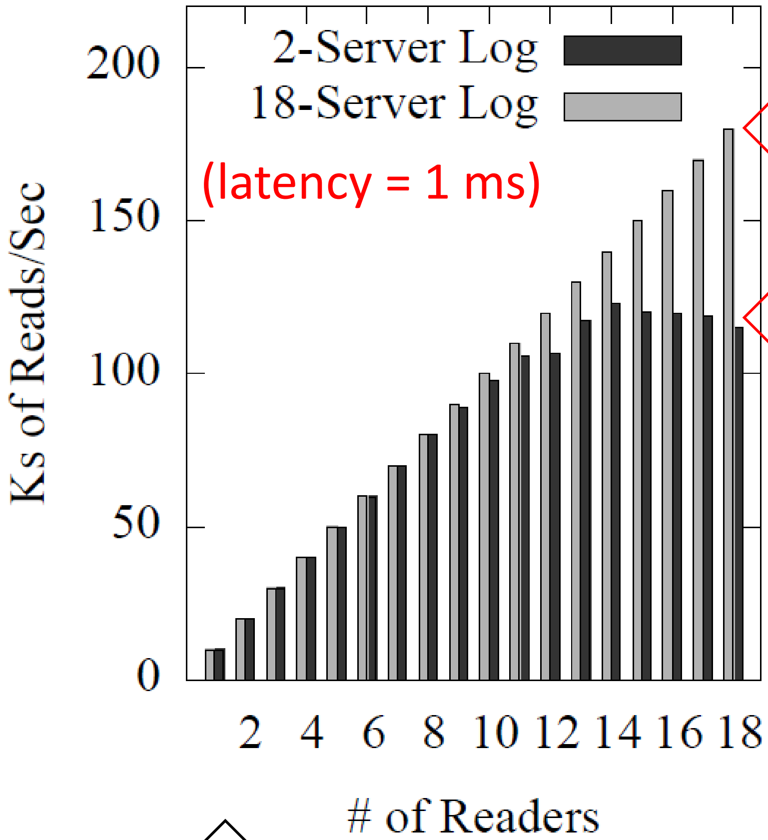



adding more clients → more reads/sec
… until shared log is saturated

a Tango object provides elasticity for strongly consistent reads

constant write load (10K writes/sec), each client adds 10K reads/sec

# evaluation: linearizable operations




beefier shared log → scaling continues…
ultimate bottleneck: sequencer

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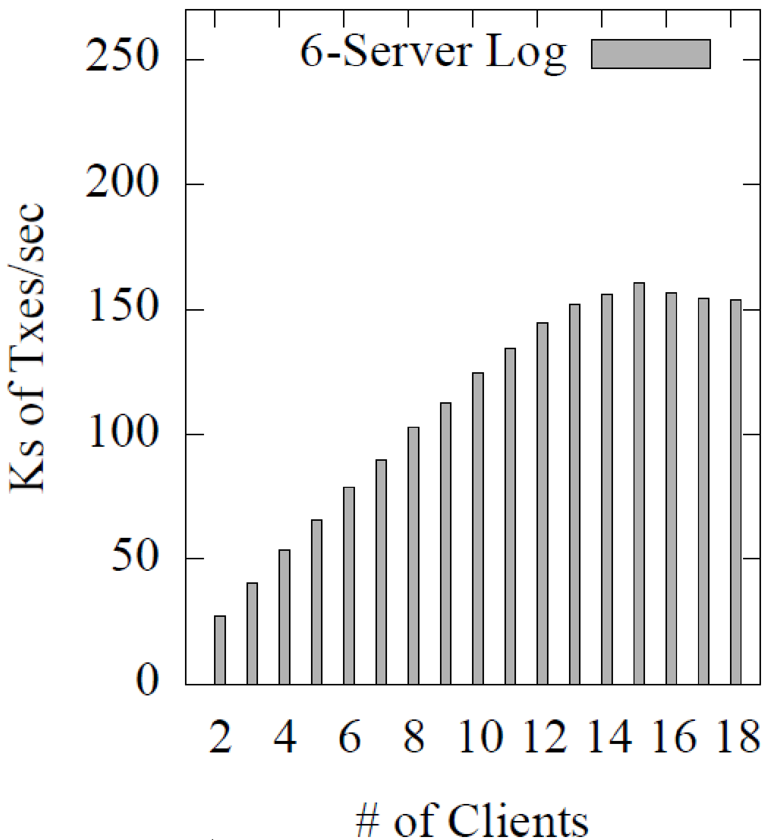


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but there's a cap on aggregate throughput

each client does transactions over its own TangoMap

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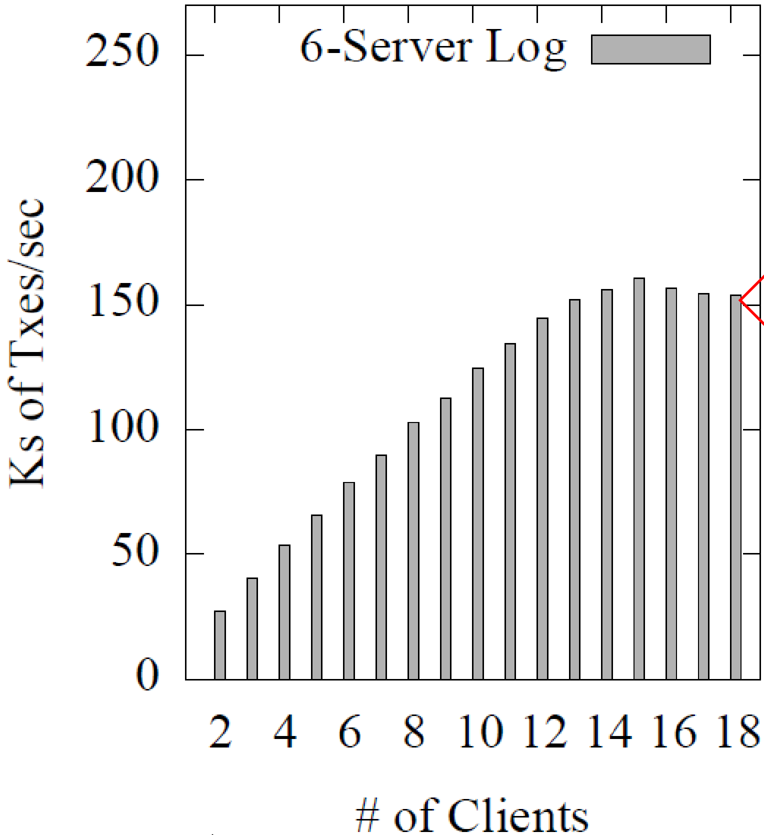


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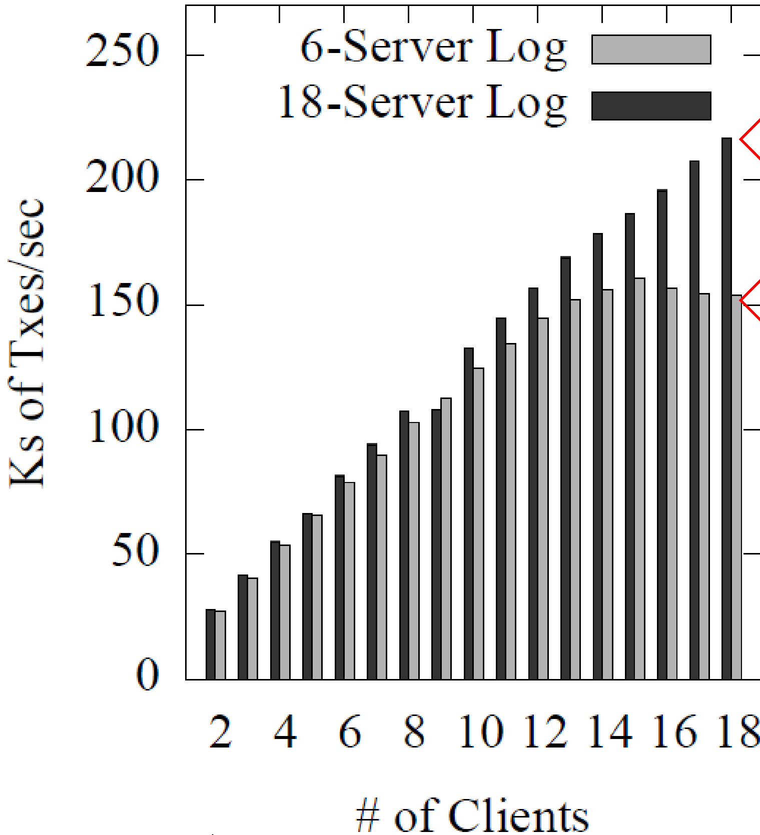


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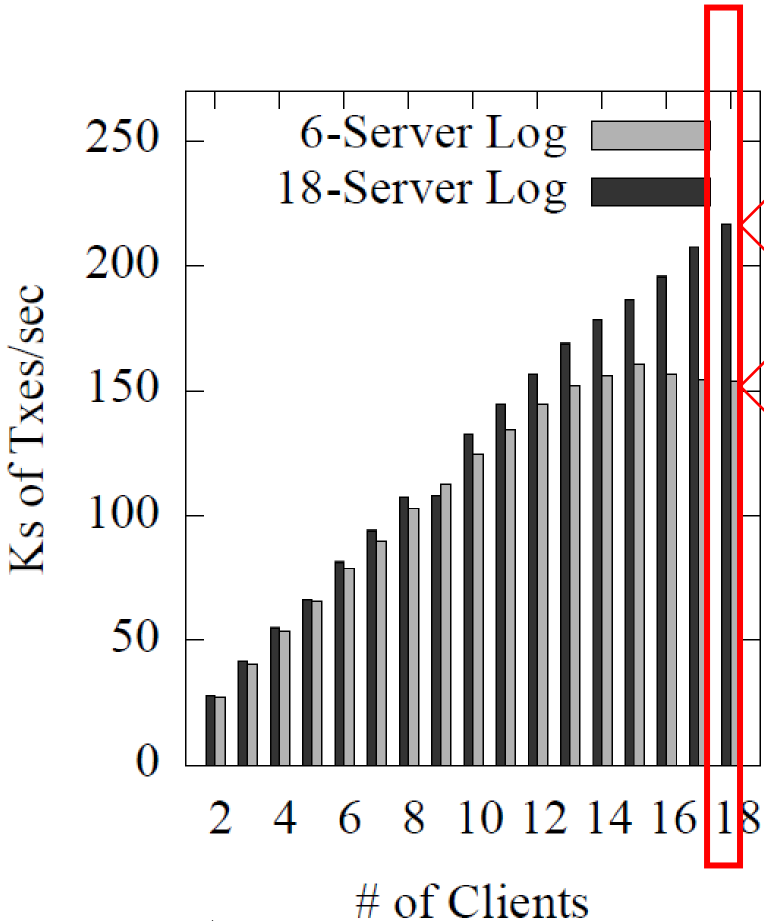


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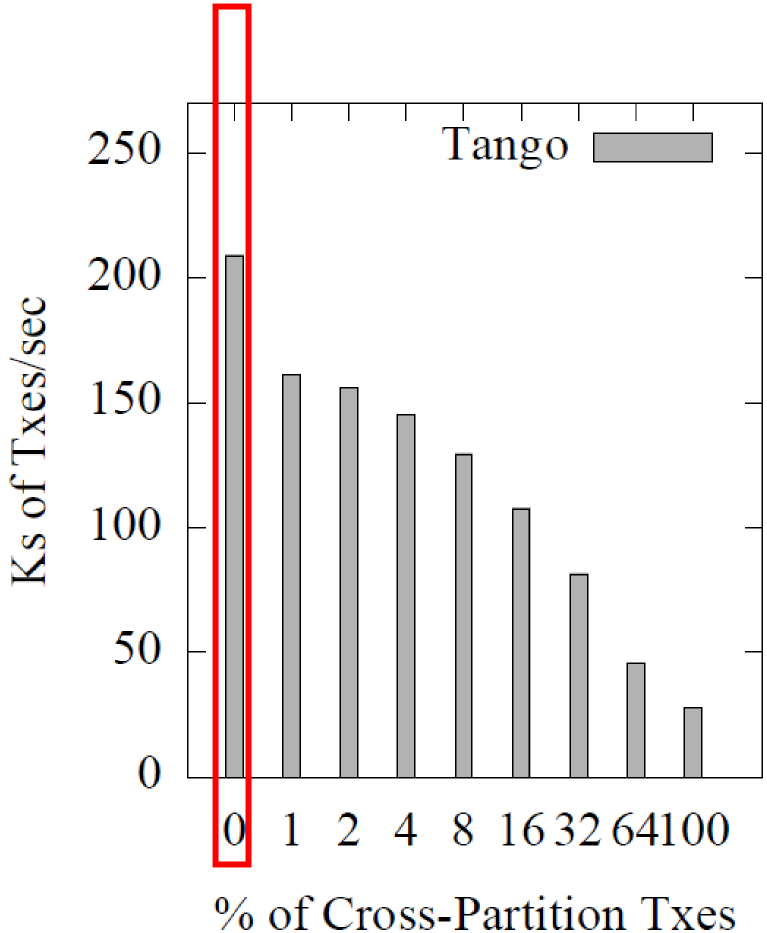


Tango enables fast, distributed transactions across multiple objects

18 clients, each client hosts its own TangoMap
cross-partition tx: client moves element from its own TangoMap to some other client's TangoMap

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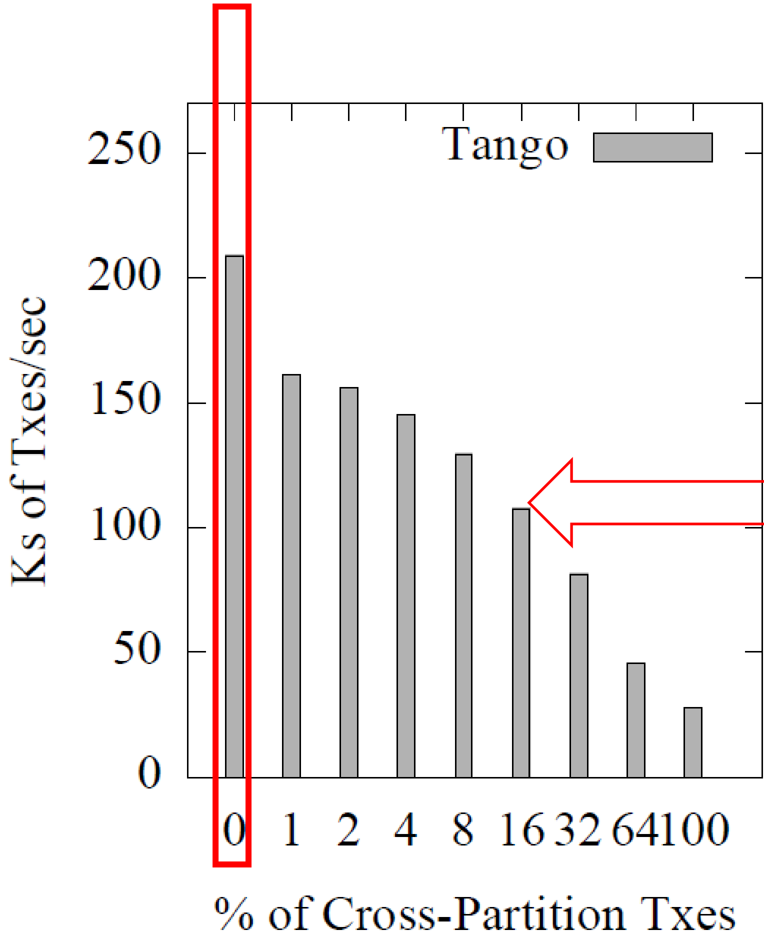


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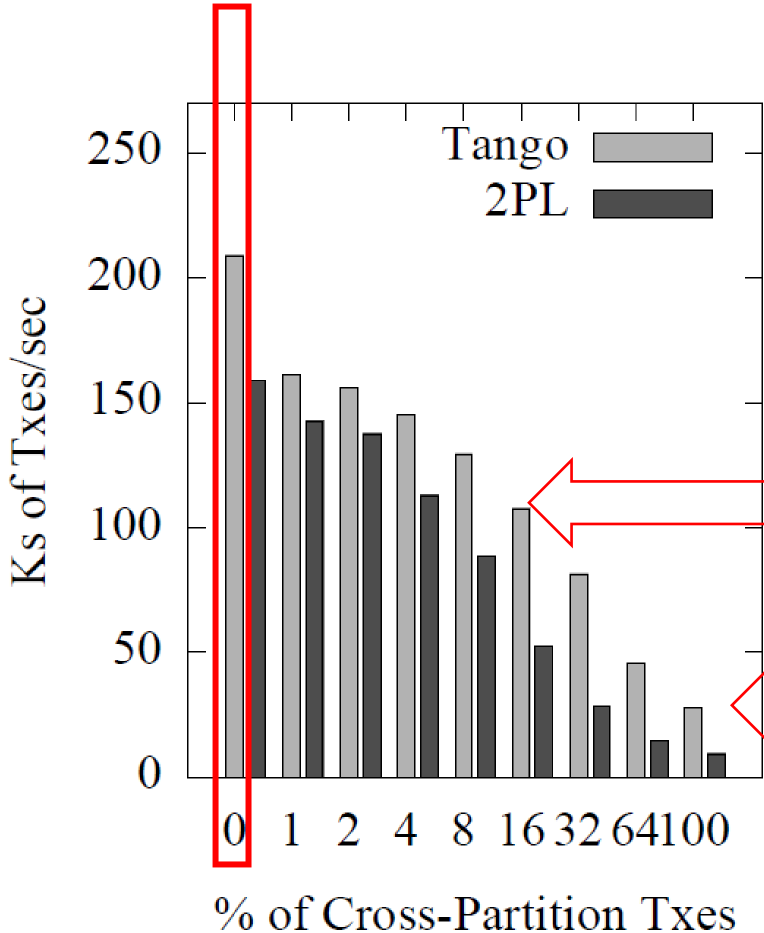


Tango enables fast, distributed transactions across multiple objects

over 100K txes/sec when 16% of txes are cross-partition

similar scaling to 2PL…
without a complex distributed protocol

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# conclusion

Tango objects: data structures backed by a shared log

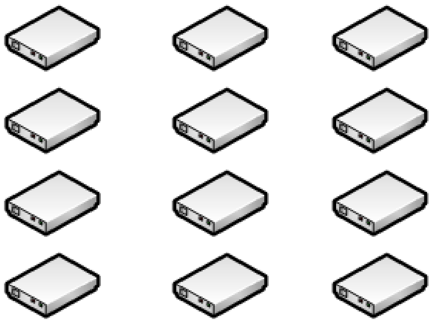
key idea: the shared log does all the heavy lifting

(persistence, consistency, atomicity, isolation, history, elasticity…)

Tango objects are easy to use, easy to build, and fast!

Tango democratizes the construction of highly available metadata services thank you!

# the CORFU protocol: (chain) replication



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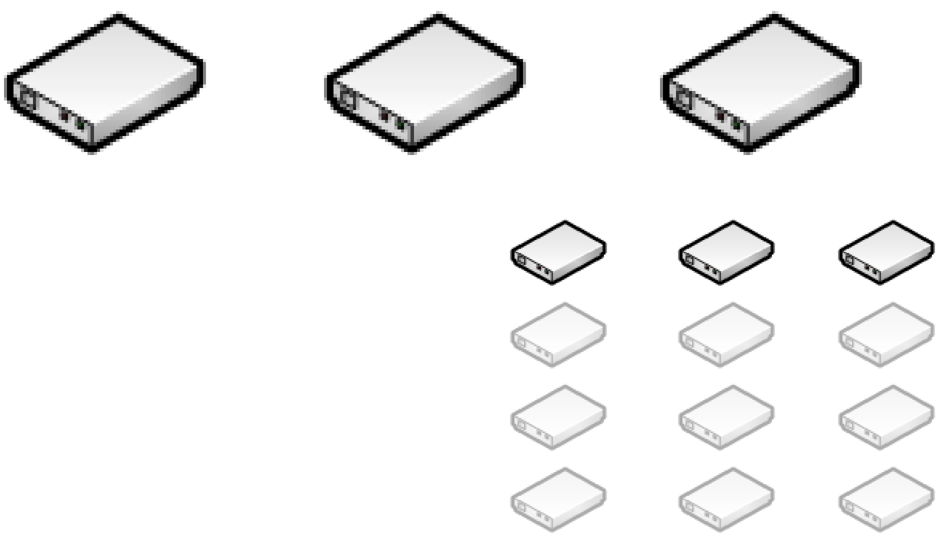

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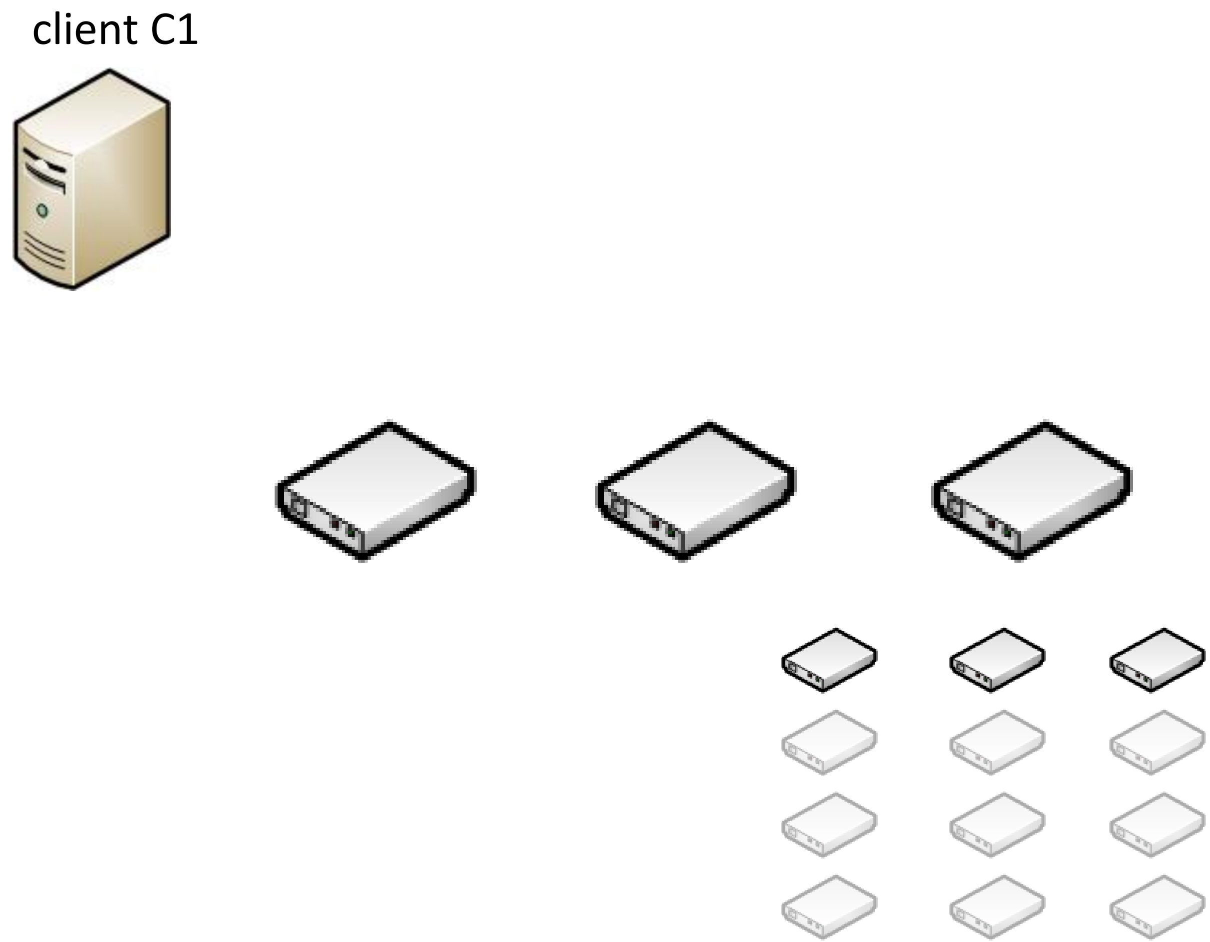

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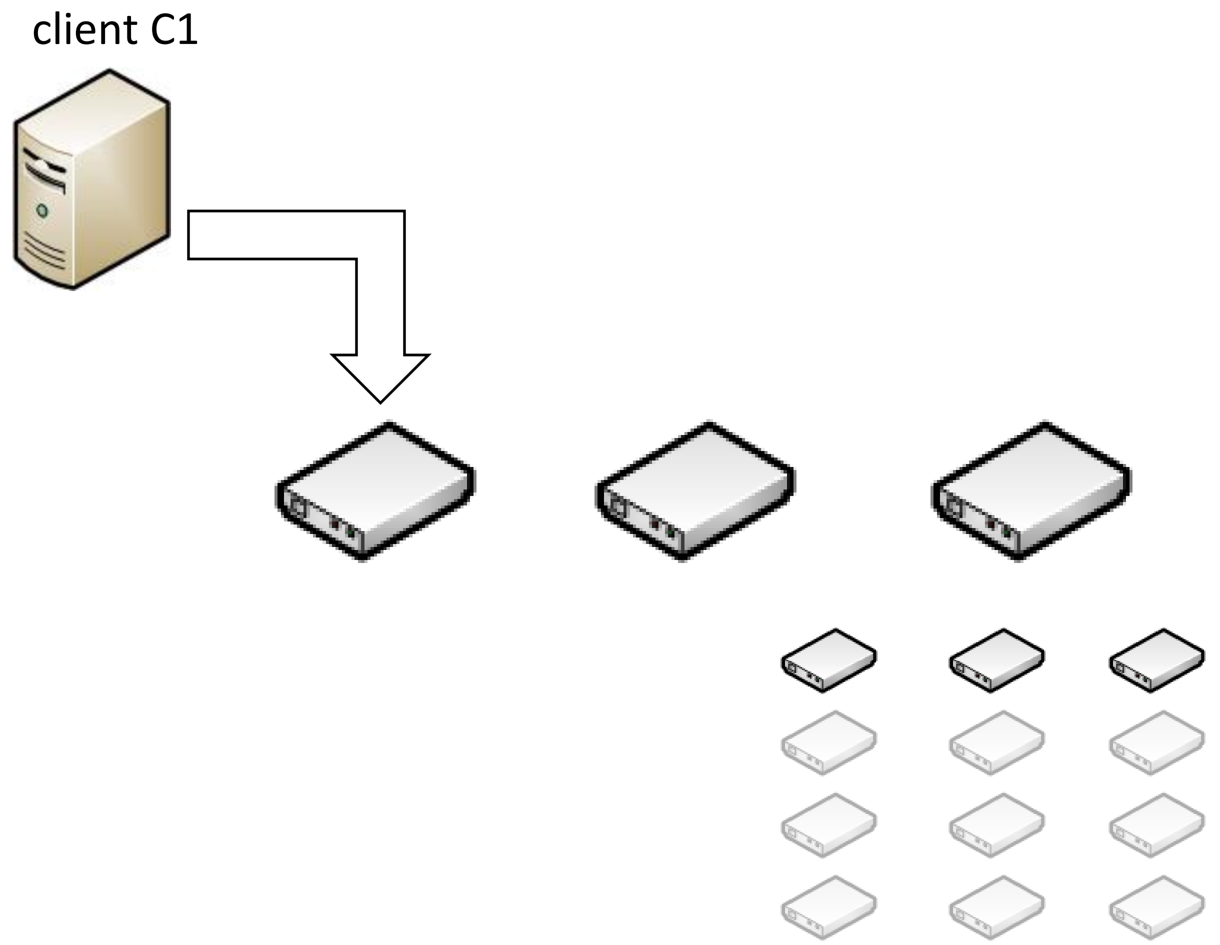

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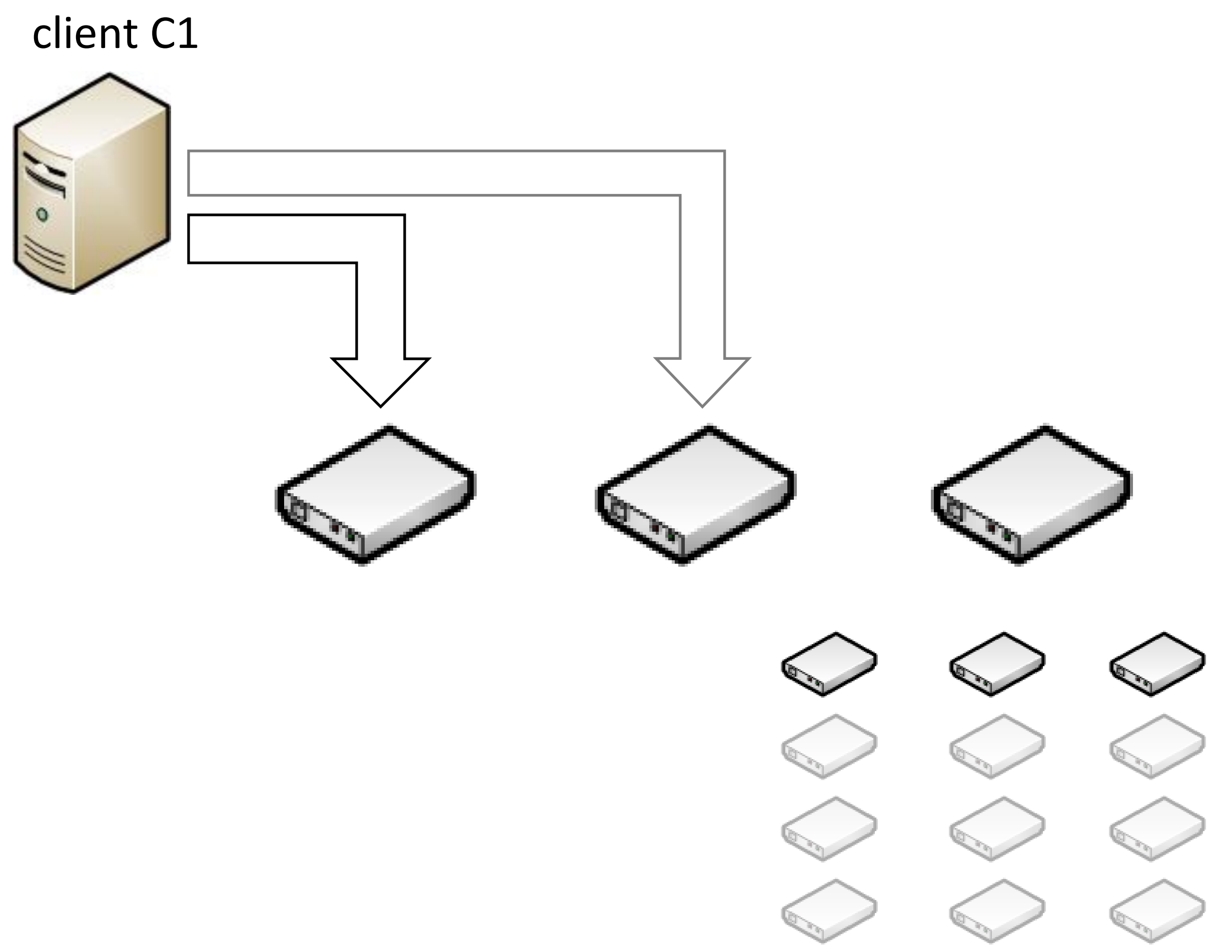

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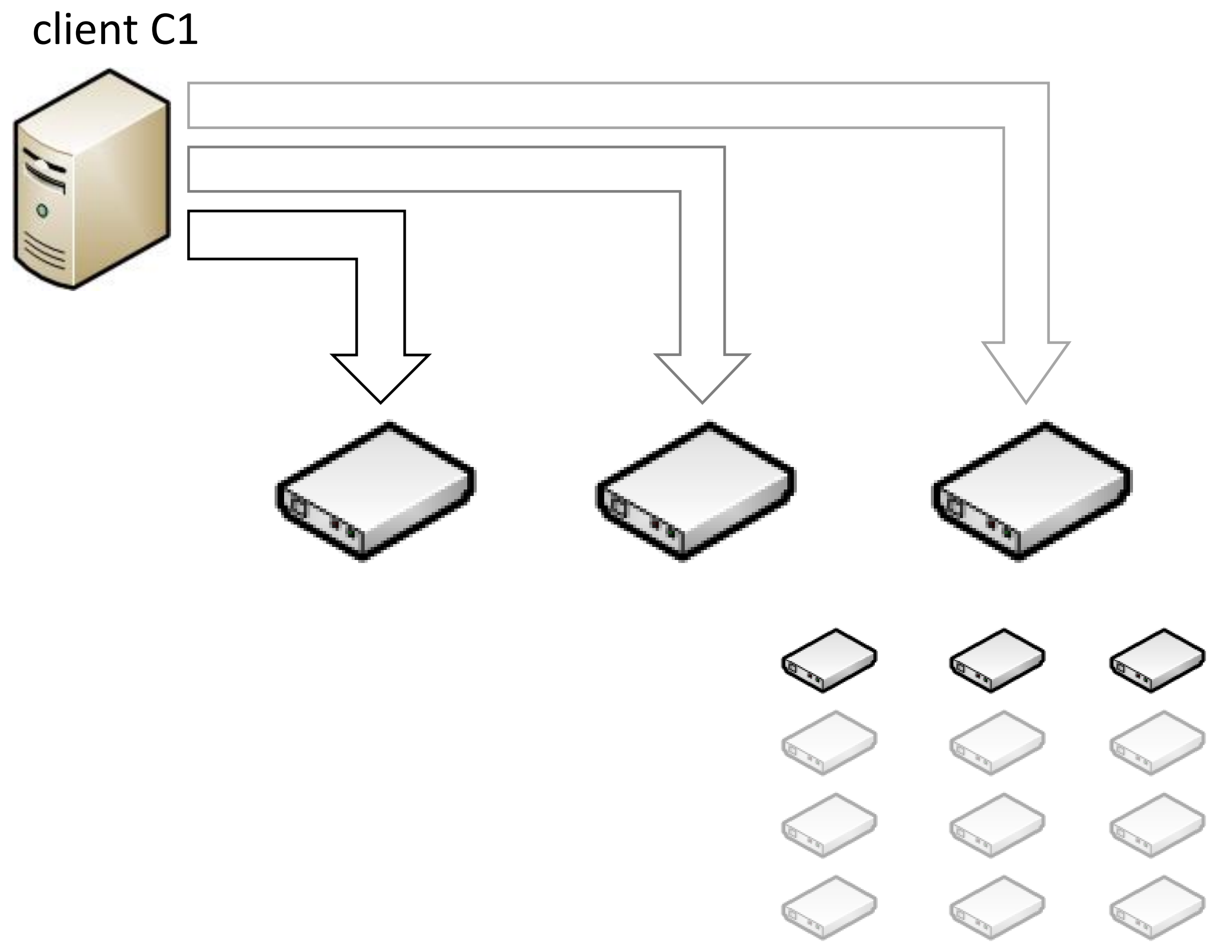

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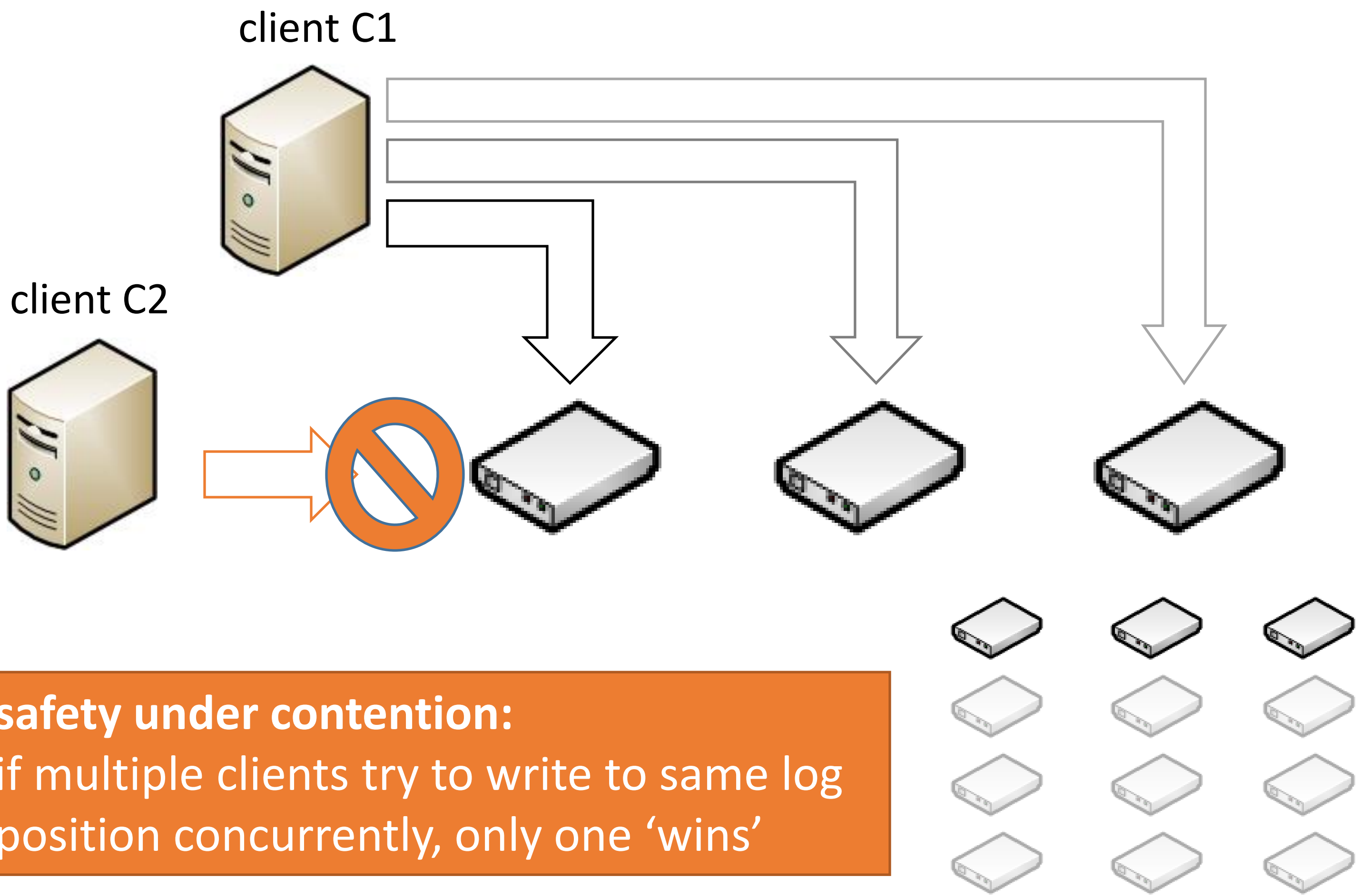


**safety under contention:**
if multiple clients try to write to same log position concurrently, only one 'wins'

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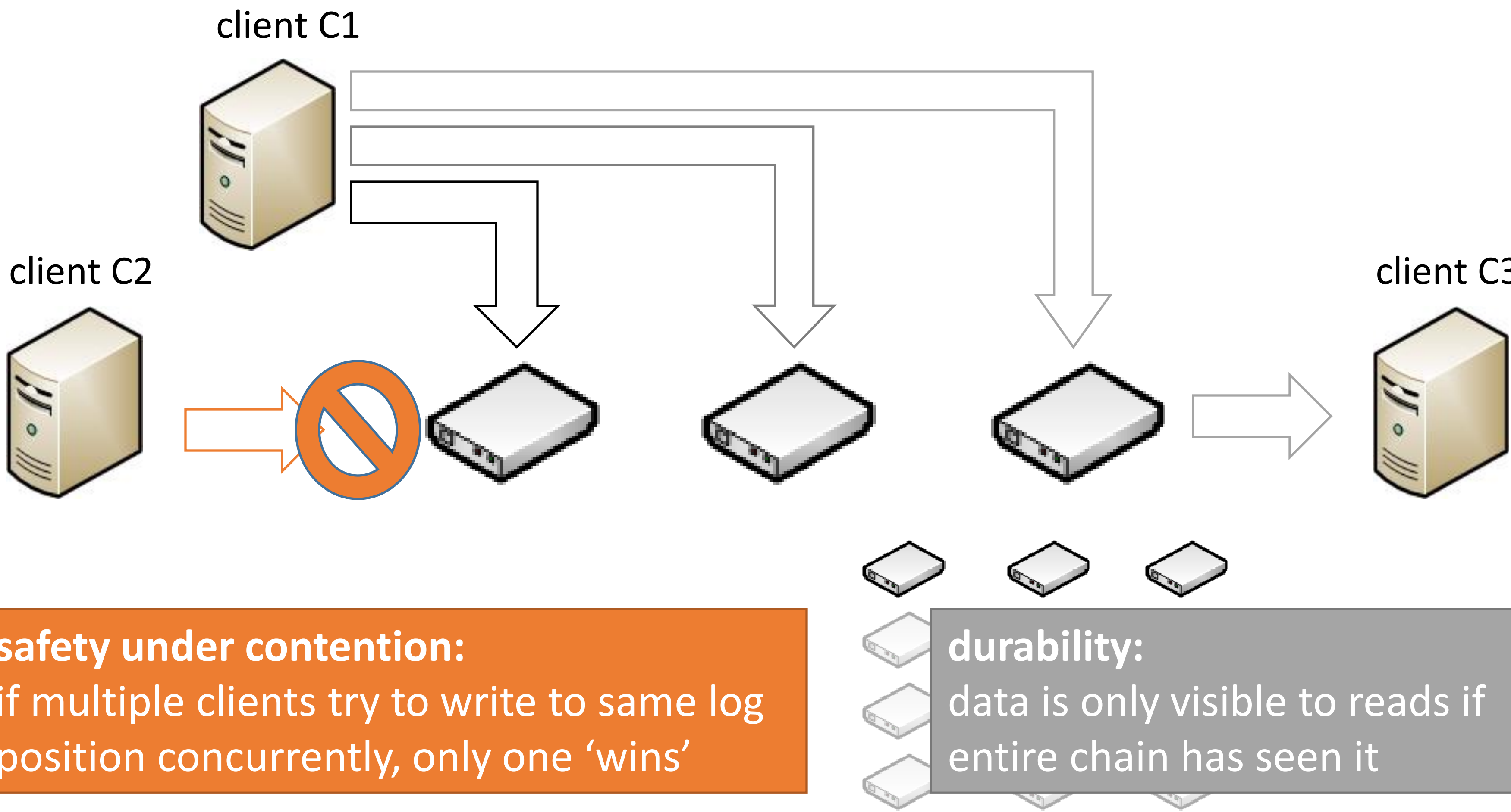


**safety under contention:**
if multiple clients try to write to same log position concurrently, only one 'wins'

**durability:**
data is only visible to reads if entire chain has seen it