Grand Theater

Showings

Star Wars	7pm
Star Wars	9pm
Spectre	6:30pm

List[Event]

latency(page load) ≤ 20ms

STAR WARS

7pm Remaining: **5**

Purchase

Counter

invariant: *error tolerance:*
tickets ≥ 0   tickets ± 5%

⊤ := Consistent[T]   Datastore-specific
                            consistency levels

Interval[T]   Rushed[T]   LocalQuorum[T]...

⊥ := Inconsistent[T]

T

×

×
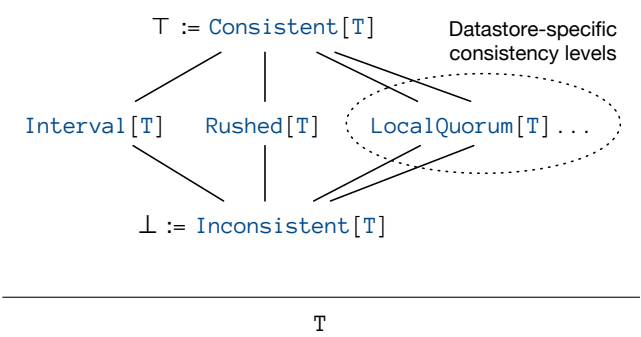
Counter

SetTSet[T] with Consistency(Strong)SetSet[T] with LatencyB

LatencyBound(x)
ErrorTolerance(x%)sizeSet

Setsizecontains
ErrorTolerance(5%)List

TInconsistent[T]Consistent[T]T≺

BoundedCounter

$$\frac{\tau \tau'}{\tau'[T] \prec \tau[T]}$$

Consistent[T]T
   Inconsistent[T]Inconsistent[T]Consistent(x)Consistent[T]

Set[T]

$$\frac{\Gamma \vdash e_1 : \tau[T]T \prec \tau[T]}{\Gamma \vdash \mathrm{Consistent}(e_1) : T}$$
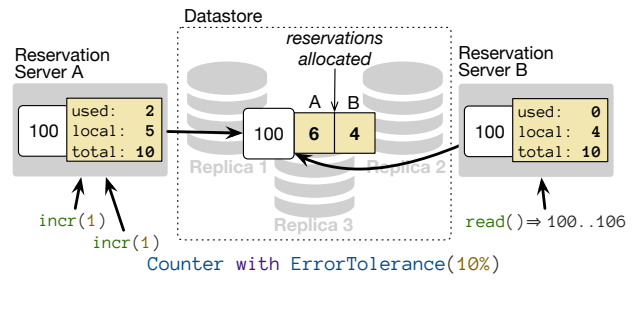
Inconsistent[T]

Rushed[T]LatencyBound(x)Rushed[T]LatencyBoundRushed[T]
Rushed[T]
   Rushed[T]Consistent[T]LocalQuorum[T]Inconsistent[T]

```
set.contains() match {
  case Consistent(x) => print(x)
  case LocalQuorum(x) => print(x + ", locally")
  case Inconsistent(_) => print("unknown")
}
```

Inconsistent(_)

Interval[T]ErrorTolerance(x%)Interval[T]
   Interval[T]Setsizeaddsizesize$[95, 105]$$[100, 107]$add

   Interval[Int]

Datastore
reservations allocated
Reservation Server A
Reservation Server B

Counter with ErrorTolerance(10%)

Setaddremovesize

```
Interval(min = v - removePool.delta()
         max = v + addPool.delta())
```

vdelta

```
delta(): pool.total - (pool.local - pool.used)
```

$$W + R > N \quad (N+1)/2 \text{QUORUM} N \text{ALLONELOCAL\_QUORUM}$$

LatencyBound

   Counter
   Setaddremovecontainssizesize
   BoundedCounter
   UUIDPoolBoundedCounter
   List

QUORUMQUORUM

tc netemnetem

incr(1)read

   Counter
   ALL
   $[100, 106]$

```scala
trait LatencyBound {
  // execute readOp with strongest consistency possible
  // within the latency bound
  def rush[T](bound: Duration,
              readOp: ConsistencyLevel => T): Rushed[T]
}

/* Generic reservaton pool, conceptually one per
 * ADT instance. `max` recomputed as needed
 * (e.g. for percent error) */
abstract class ReservationPool(max: () => Int) {
  def take(n: Int): Boolean // try to take tokens
  def sync(): Unit        // sync to regain used tokens
  def delta(): Int        // # possible ops outstanding
}

/* Counter with ErrorBound (simplified) */
class Counter(key: UUID) with ErrorBound {
  def error: Float // error bound
  def computeMax(): Int = (cass.read(key) * error).toInt

  val incrPool = ReservationPool(computeMax)
  val decrPool = ReservationPool(computeMax)

  def value(): Interval[Int] = {
    val v = cass.read(key)
    Interval(v - decrPool.delta,
             v + incrPool.delta)
  }

  def incr(n: Int): Unit = {
    waitFor(incrPool.take(n)) {
      cass.incr(key, n)
    }
  }
}
```
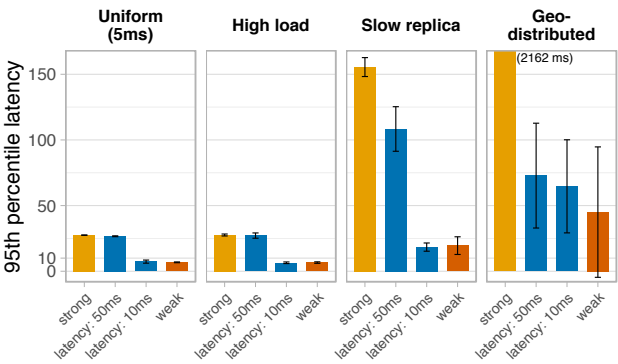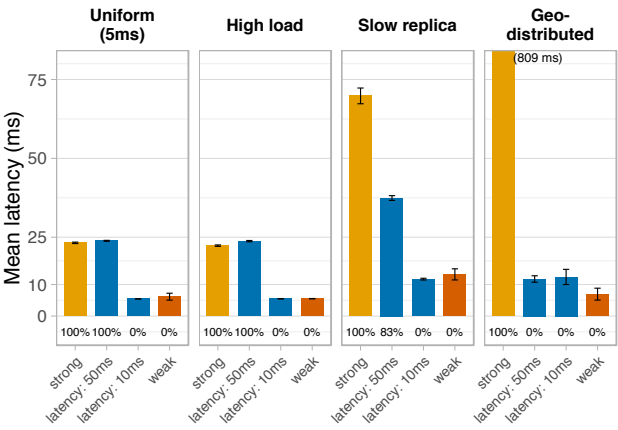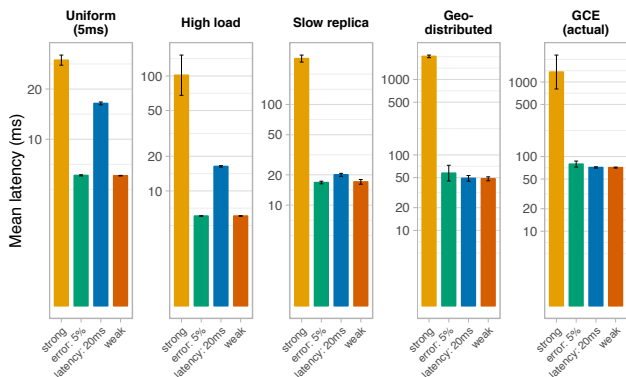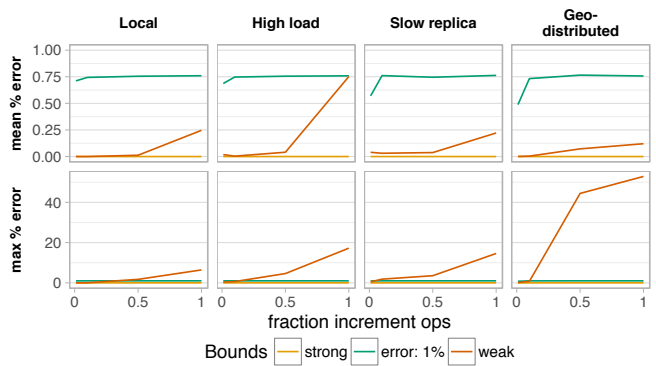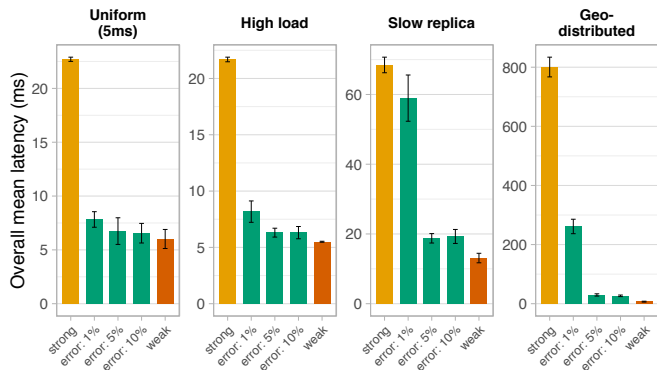

QUORUM

weakALLQUORUM

ALL

us–eastus–centraleurope–westasia–east

browse
viewEvent
purchase
addEvent

ListUUIDPoolBoundedCounter
BoundedCounter
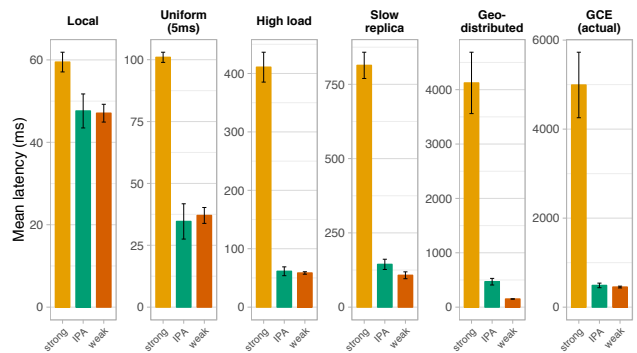
Uniform (5ms) **High load** **Slow replica** **Geo-distributed**

Overall mean latency (ms)

strong error: 1% error: 5% error: 10% weak

Local **High load** **Slow replica** **Geo-distributed**

mean % error
max % error

fraction increment ops

Bounds strong   error: 1%   weak

Uniform (5ms) **High load** **Slow replica** **Geo-distributed** **GCE (actual)**

Mean latency (ms)

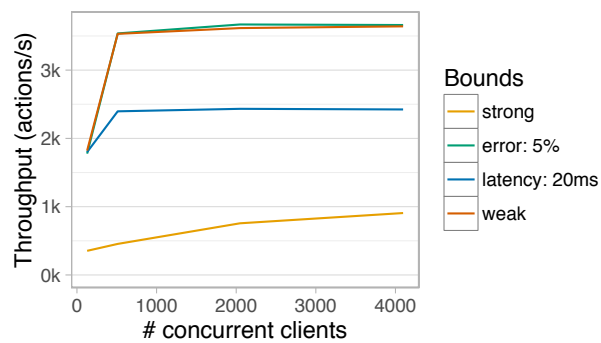strong error: 5% latency: 20ms weak

×Pool

```
User(id: UserID,
  name: String,
  followers: Set[UserID] with LatencyBound(20 ms),
  timeline: List[TweetID] with LatencyBound(20 ms)
)

Tweet(id: TweetID,
  user: UserID,
  text: String,
  posted: DateTime,
  retweets: Set[UserID] with Size(ErrorTolerance(5%))
)
```

size

Throughput (actions/s)

concurrent clients

Bounds
strong
error: 5%
latency: 20ms
weak

tweet

Local **Uniform (5ms)** **High load** **Slow replica** **Geo-distributed** **GCE (actual)**

Mean latency (ms)

strong IPA weak

×

Interval
timeline tweet retweet follow newUser

viewEvent browse purchase addEvent ×purchase BoundedCounter
× ×
viewEvent browse

PoolCounter

SetSetListListSet

Rushed[T]

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