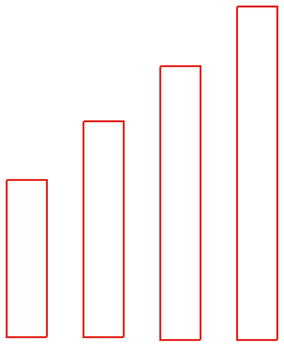
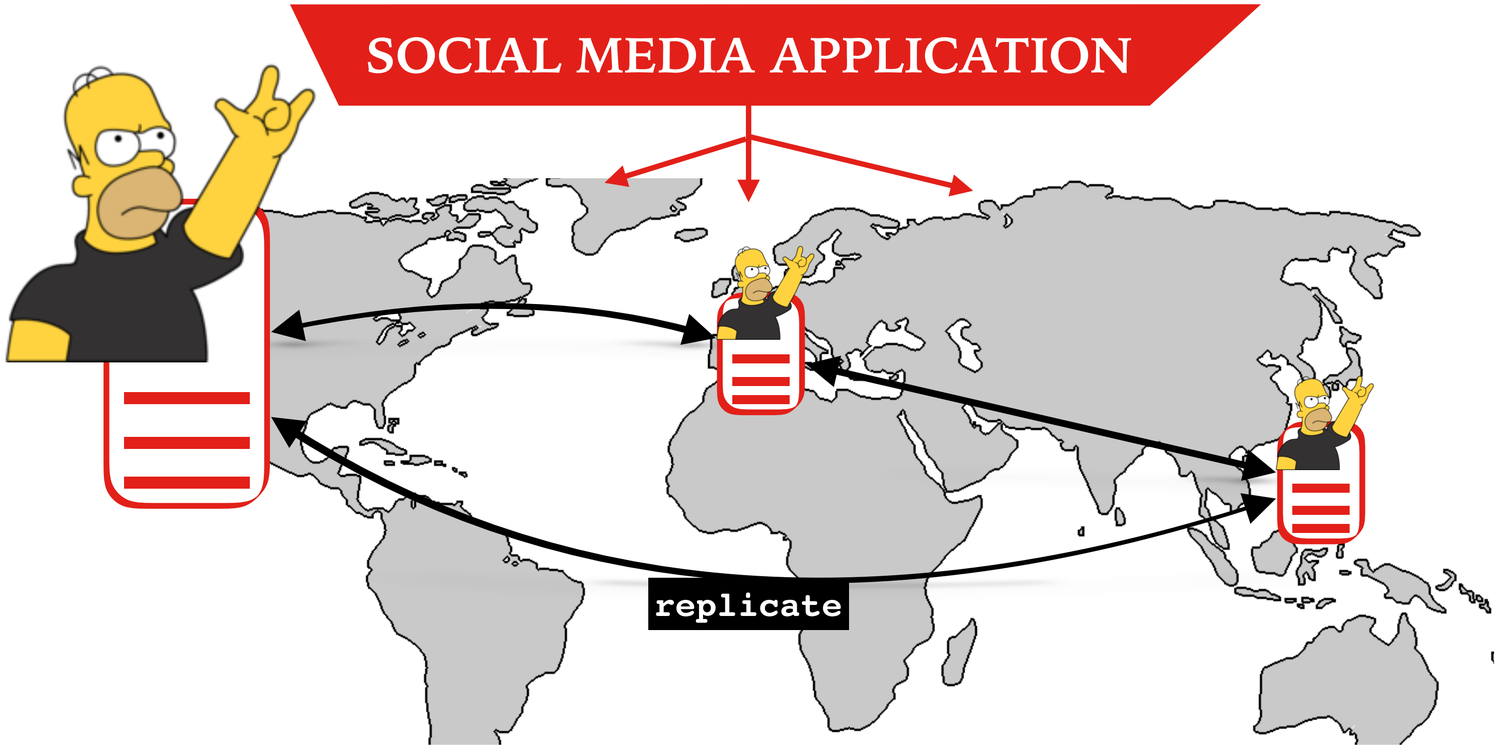


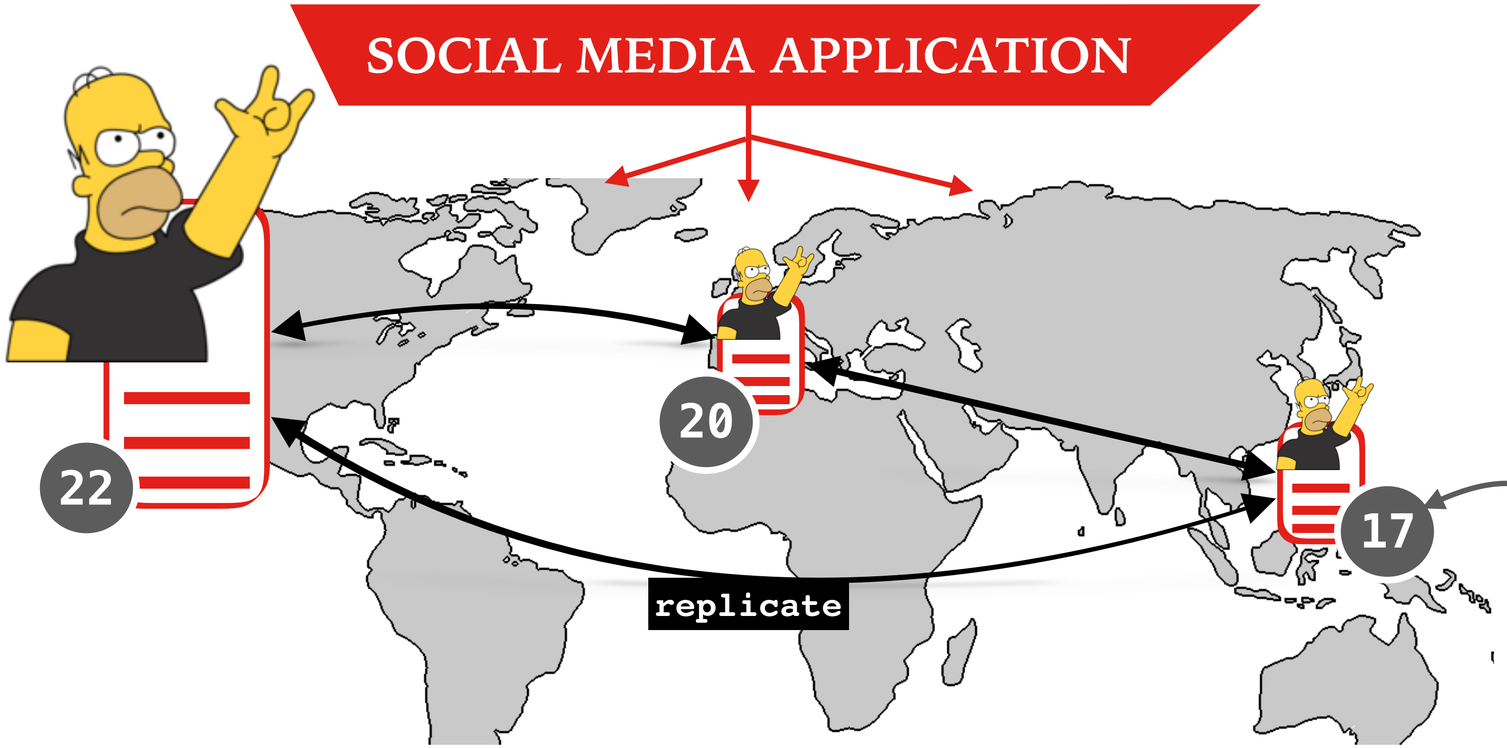
Incremental Consistency Guarantees

For Replicated Objects

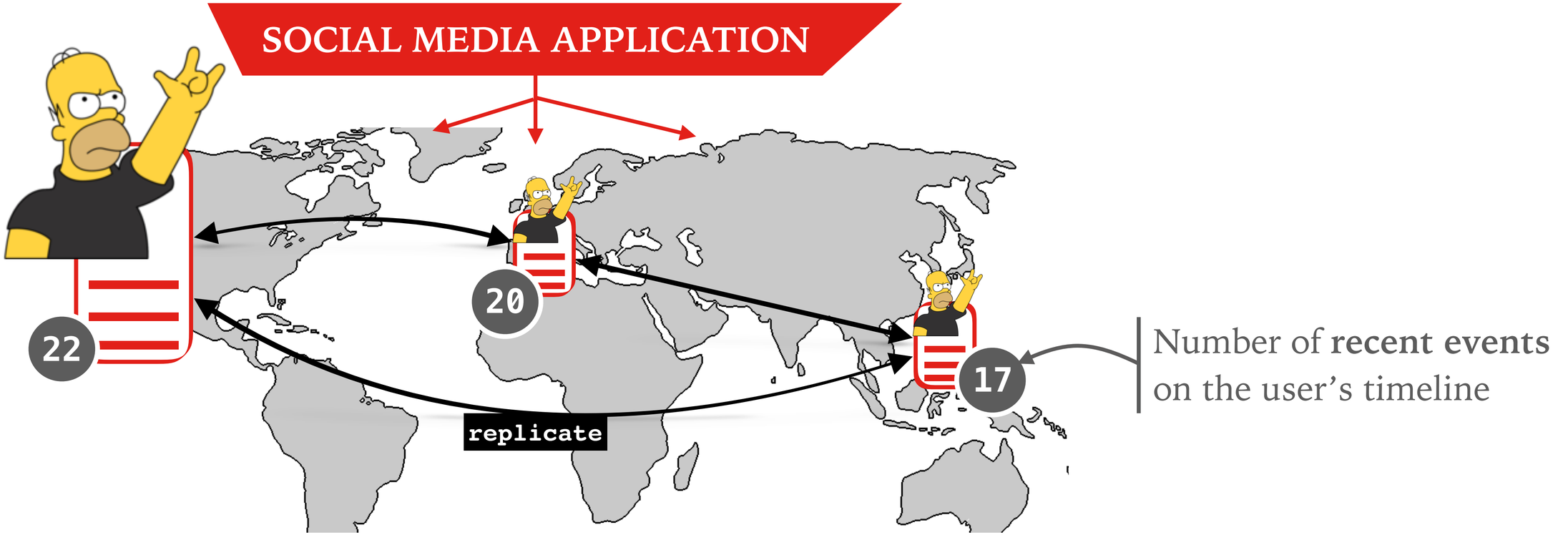
Rachid Guerraoui, Matej Pavlovic, Dragos-Adrian Seredinschi

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE


SOCIAL MEDIA APPLICATION
replicate



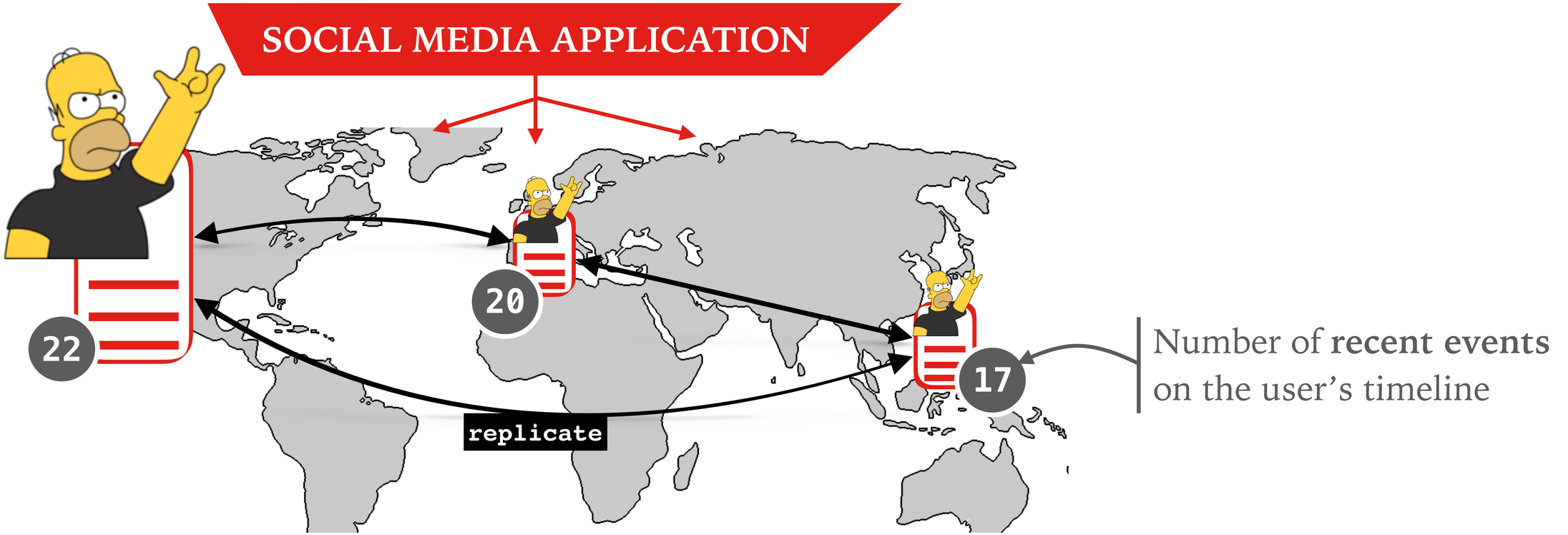
Number of **recent events** on the user's timeline



Strong Consistency

- Returns the **correct** data 22
- Latency: ~200 ms
- Can become **unavailable**

[CAP], [PACELC]



Strong Consistency

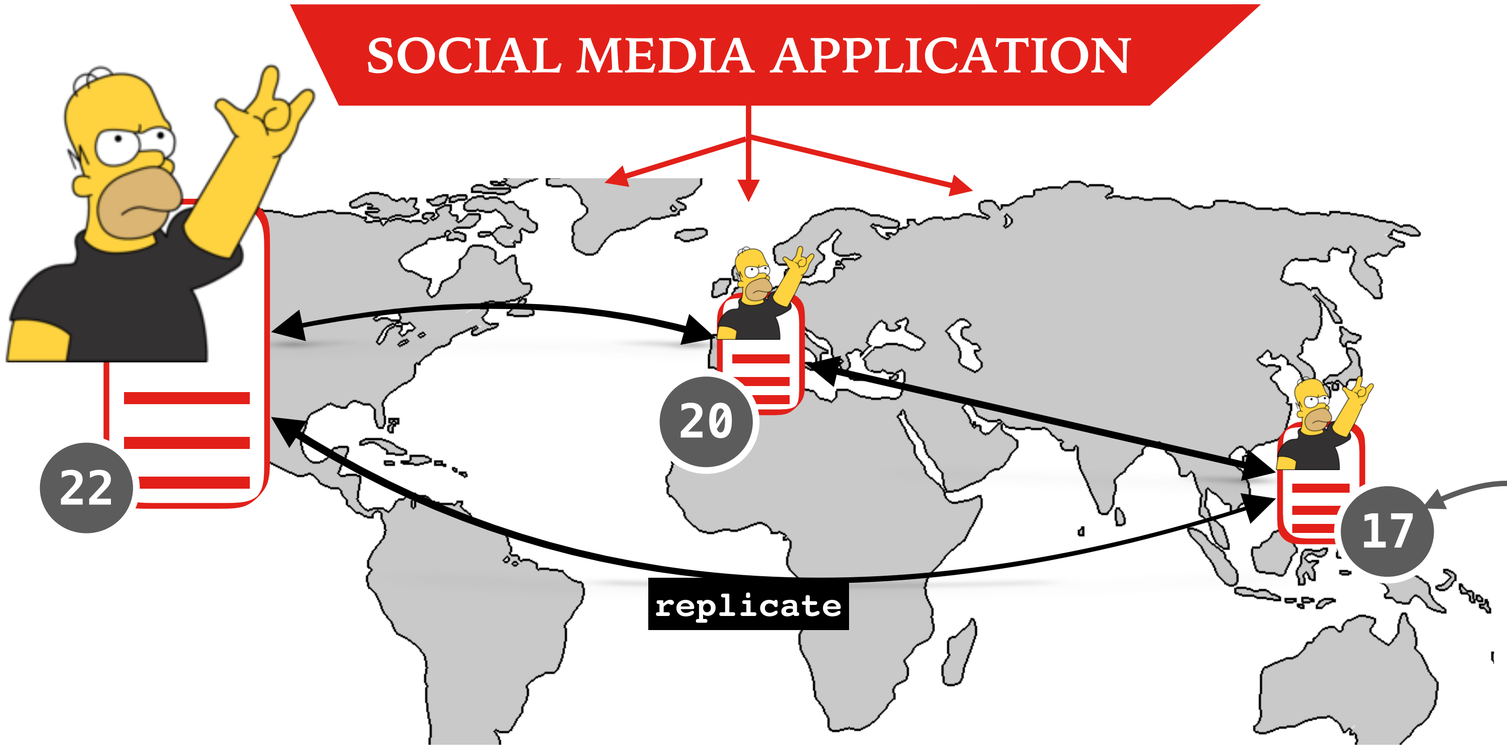
- Returns the **correct** data 22
- Latency: ~200 ms
- Can become **unavailable**

[CAP], [PACELC]

Weak Consistency

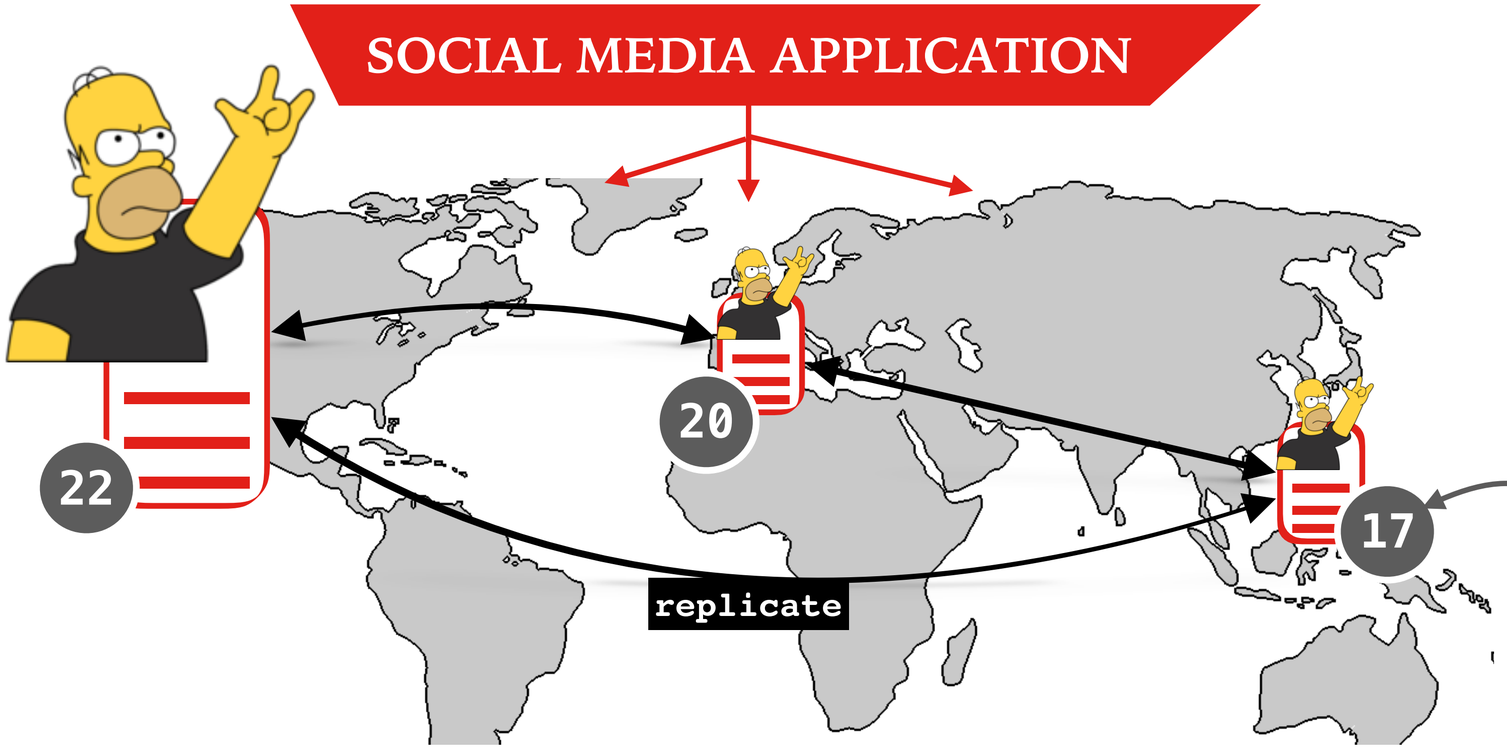
- Latency: ~100 ms
- **High availability**
- Allows inconsistencies: can return

22 *or* 20 *or* 17



Strong Consistency **Weak Consistency**

Neither model is ideal!



Strong Consistency **Weak Consistency**

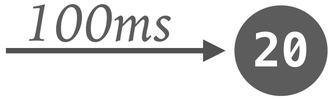
Neither model is ideal!

↓

We use both models.

Multiple models

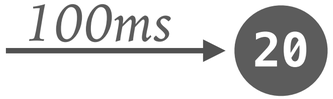
1. **Weak consistency**



2. **Strong consistency**

Multiple models

1. **Weak consistency**



2. **Strong consistency**

Increasingly many systems expose multiple consistency models:

App Engine

cassandra

Dynamo [SOSP'07]

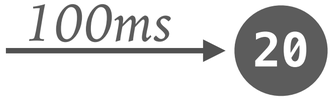
SimpleDB

riakKV

Pileus [SOSP'13]

Multiple models

1. **Weak consistency**



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Issues

1. *Send multiple requests?*
2. *How to leverage individual responses?*
3. *Semantics?*
4. *…*

Multiple models

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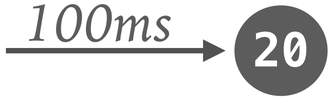

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Issues

1. *Send multiple requests?*
2. *How to leverage individual responses?*
3. *Semantics?*
4. *…*

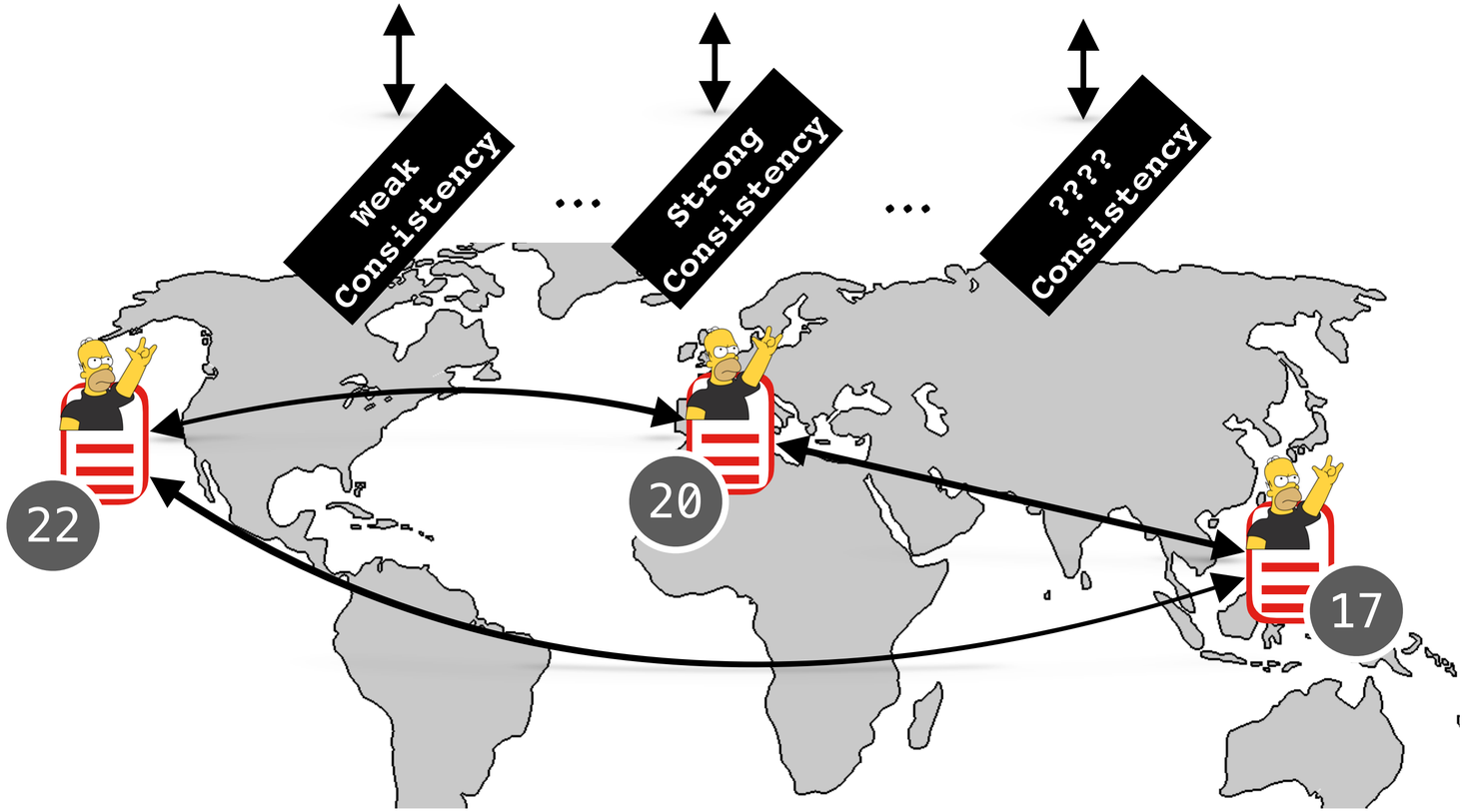
Problem

How do you program with

- ★ **inconsistencies?**
- ★ **multiple values?**

SOCIAL MEDIA APPLICATION

ABSTRACTION
FOR REPLICATED OBJECTS



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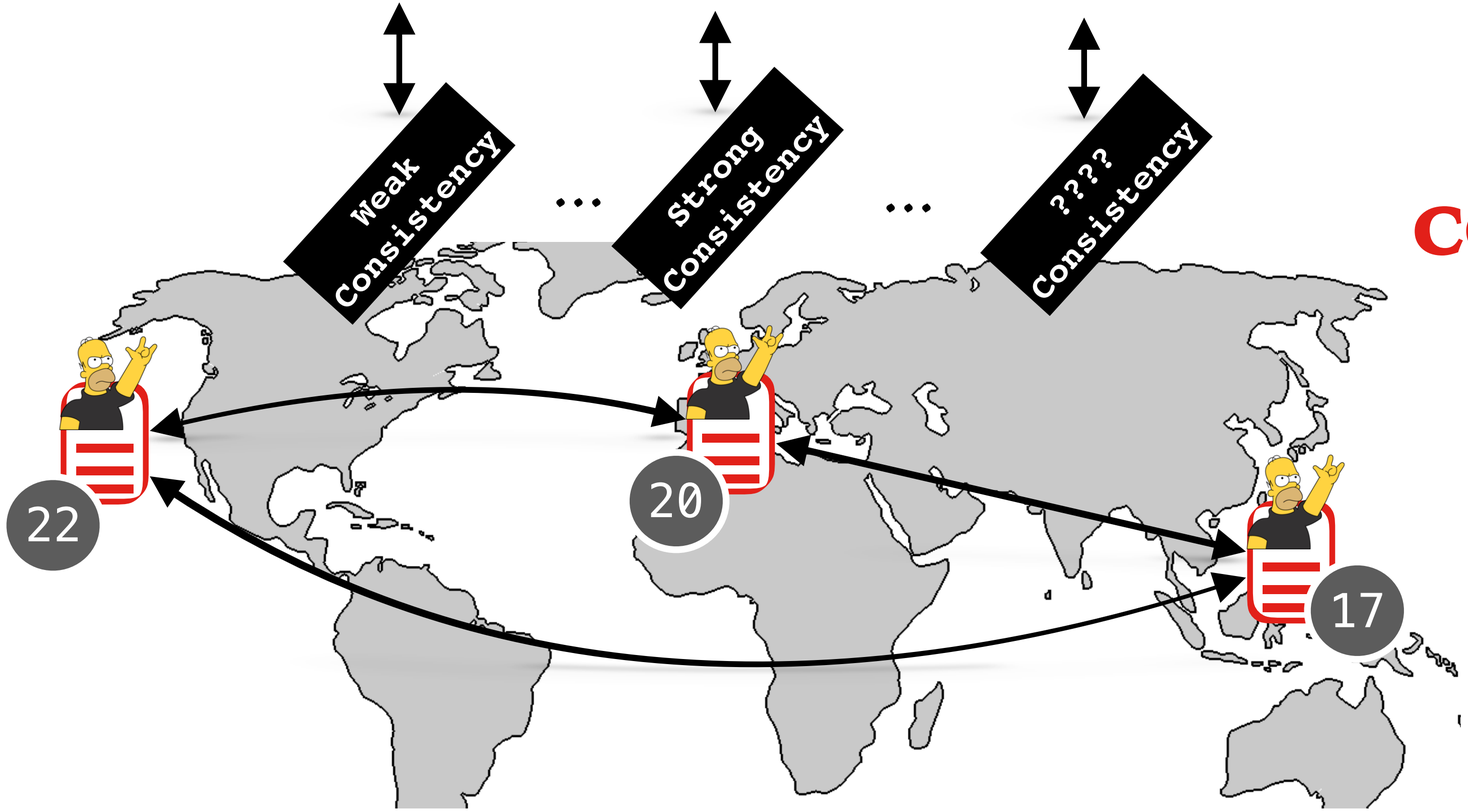

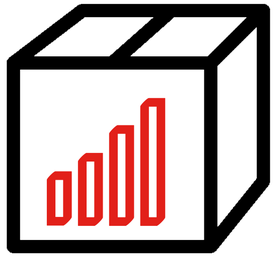

CORRECTABLE

SOCIAL MEDIA APPLICATION

ABSTRACTION
FOR REPLICATED OBJECTS

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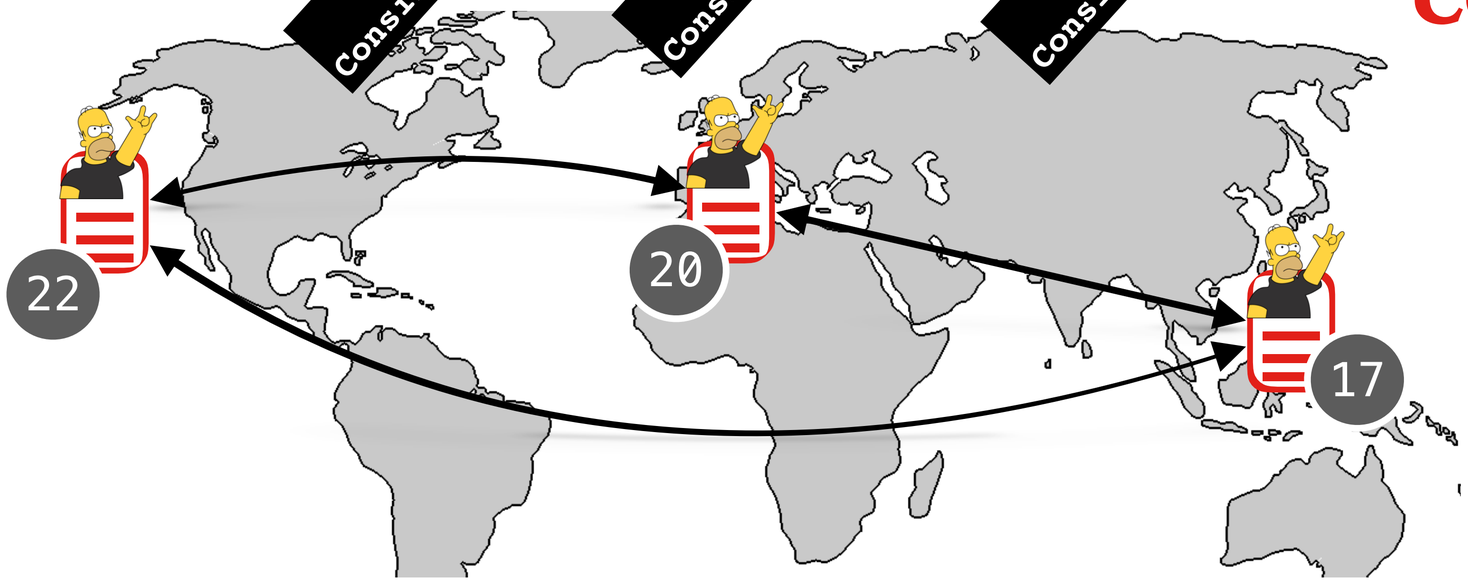
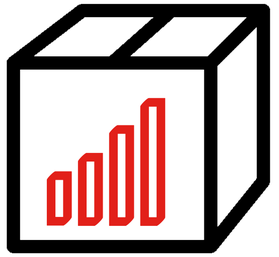
Strong Consistency

???? Consistency



Incremental Consistency Guarantees (ICG)

provides



CORRECTABLE

Correctables / **Design**

- Starting point: **Promises**
  - Placeholders for values
  - Becoming mainstream

Futures and Promises

Scala

finagle

JS

then Promises/A+

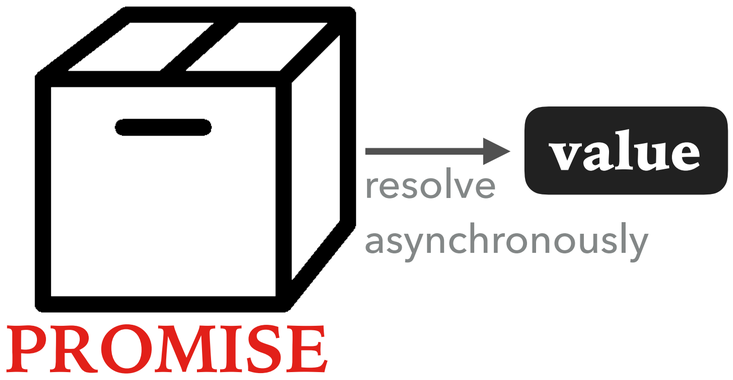
June 19, 2015 BACKEND

Futures for C++11 at Facebook

Hans Fugal

Google Guava

Core libraries for Java & Android



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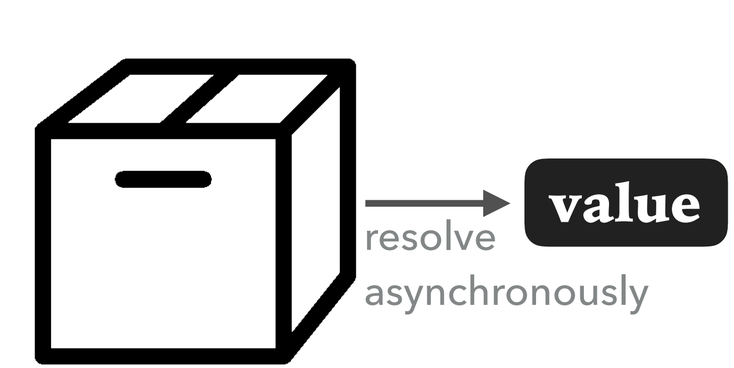
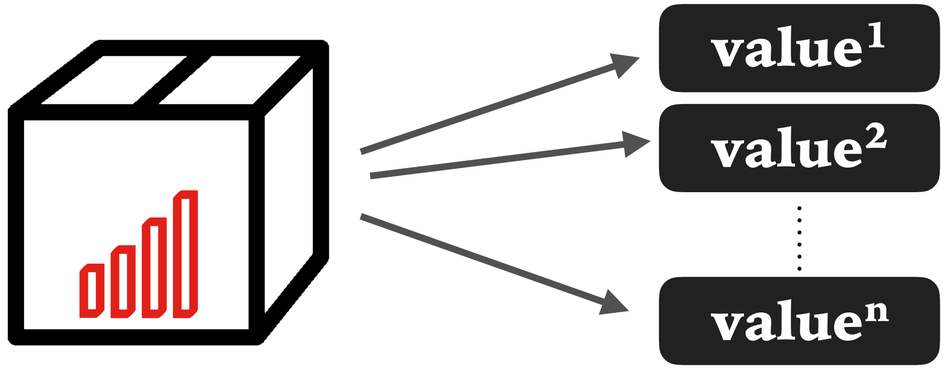


PROMISE



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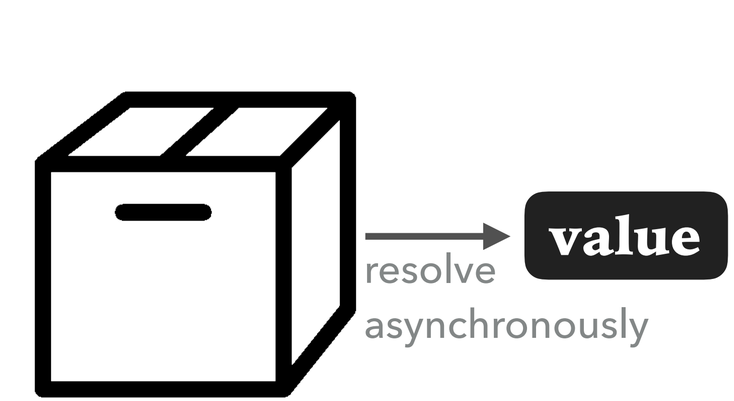
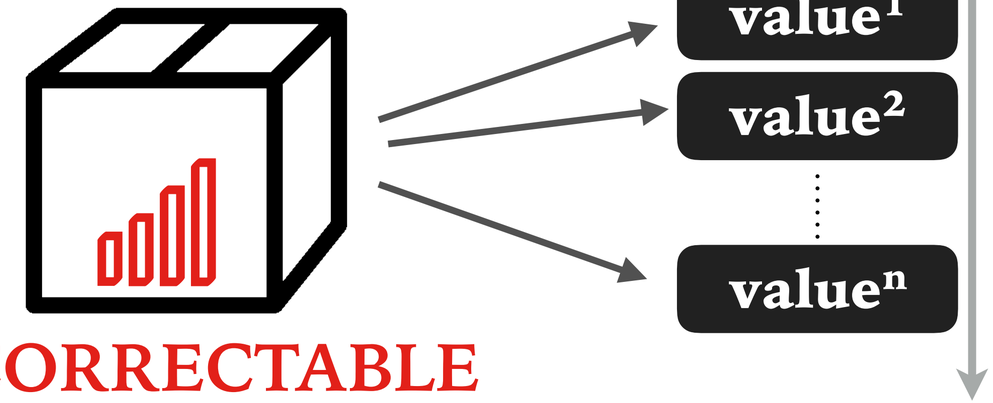


PROMISE

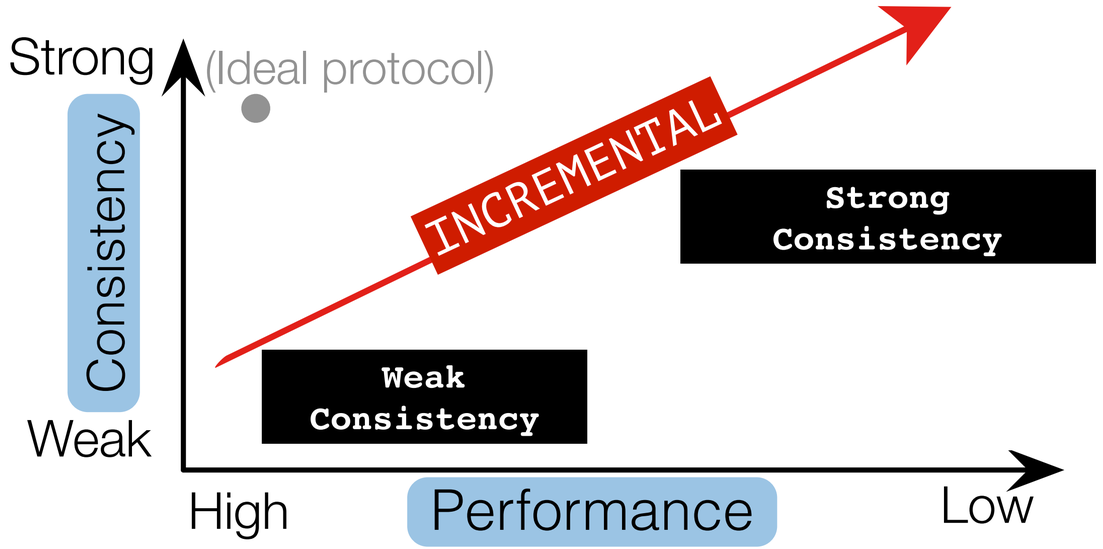


CORRECTABLE

PROGRESSIVELY STRONGER CONSISTENCY (INCREMENTAL)

PROGRESSIVELY HIGHER LATENCY

Consistency Models are **Complementary**



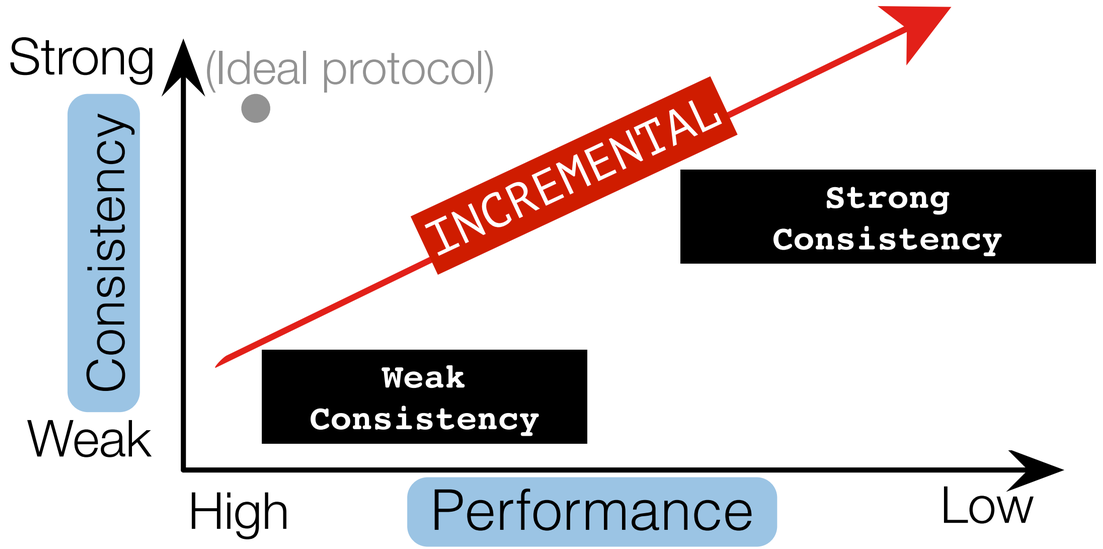
Weak consistency:

- ★ Fast
- ★ (Often correct)

Strong consistency:

- ★ Slower
- ★ (Correct with certainty)

Consistency Models are **Complementary**



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So what?

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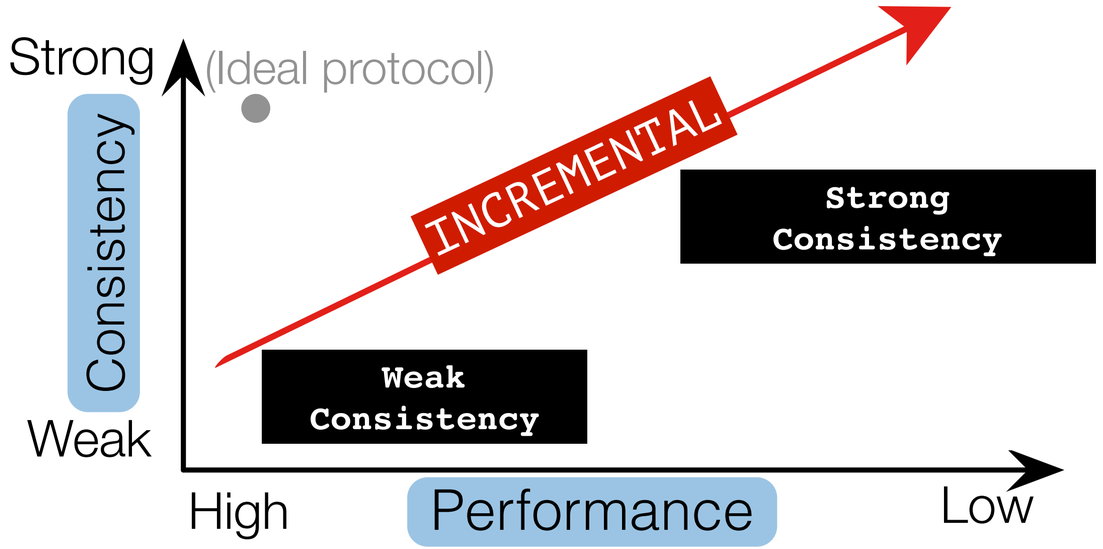

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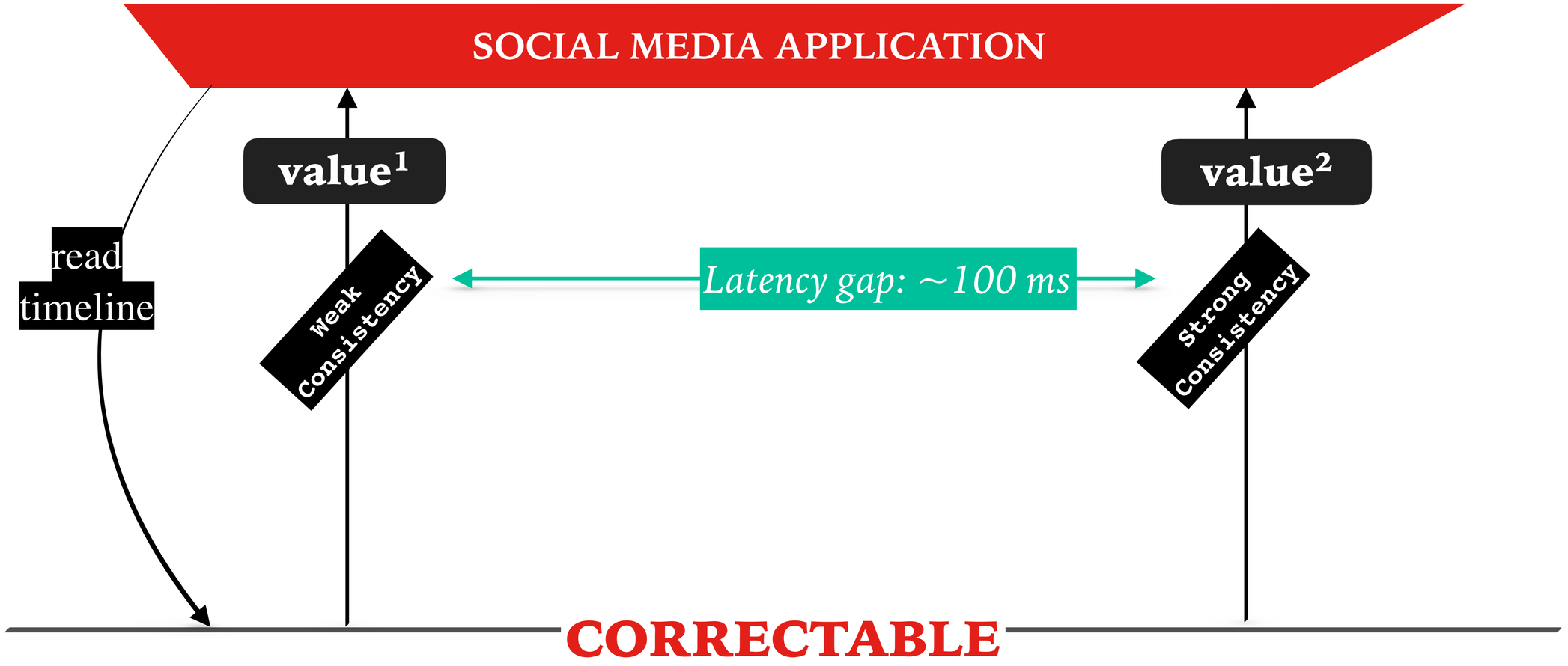
So what?

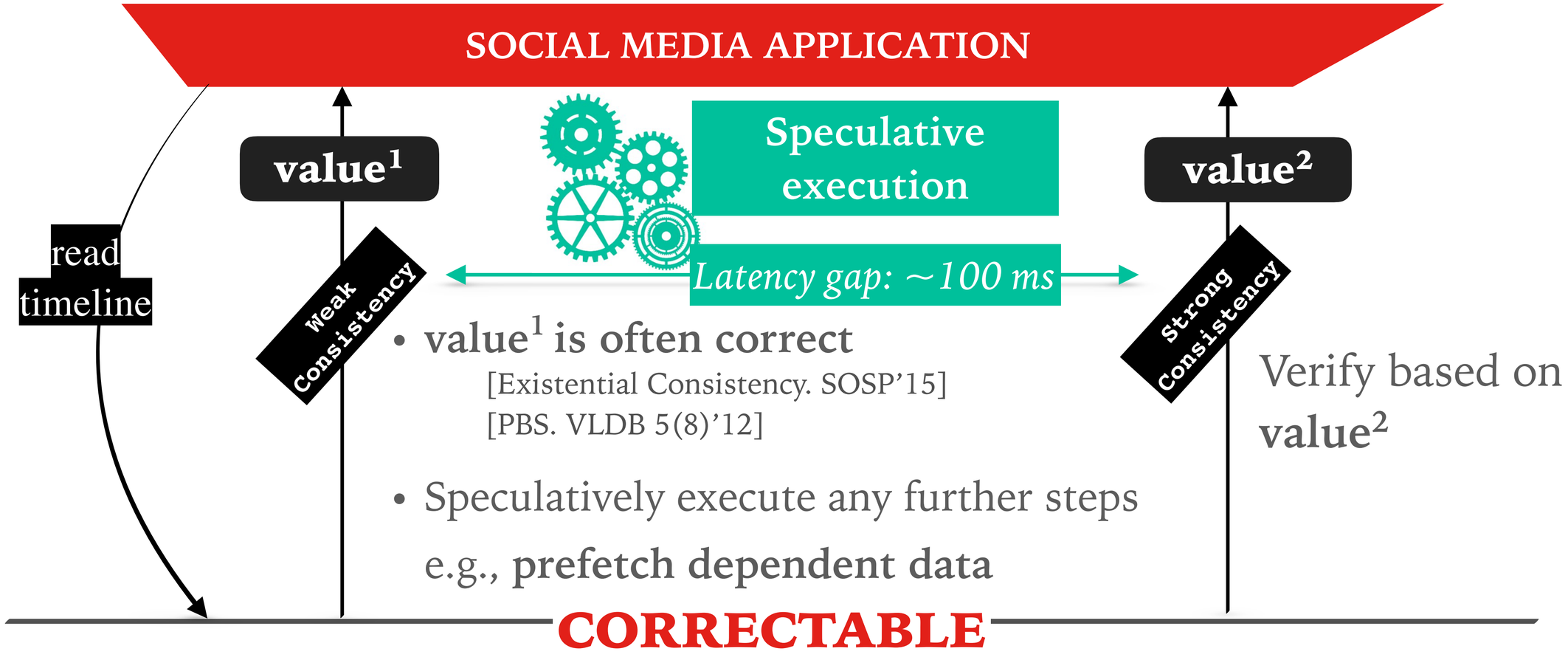
Latency optimizations

Speculating with Correctables

Speculating with Correctables



Speculating with Correctables



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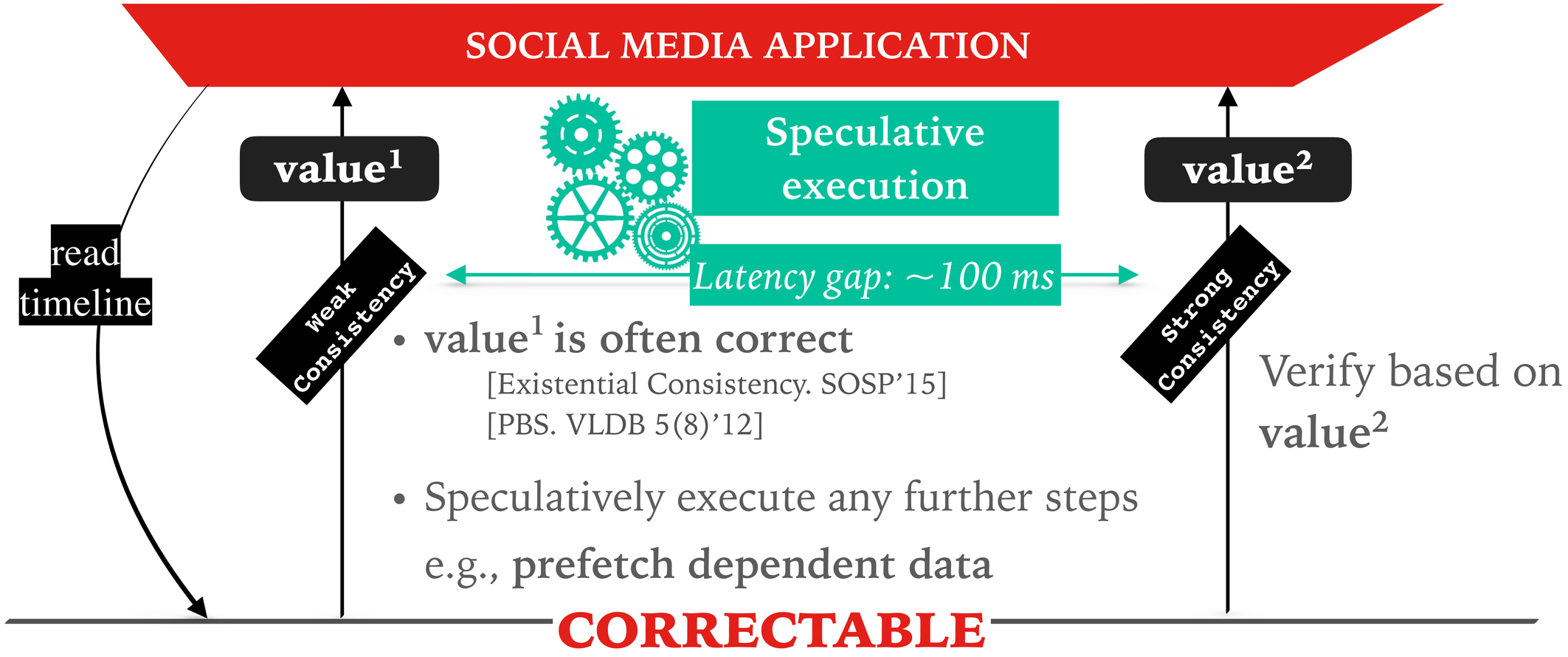
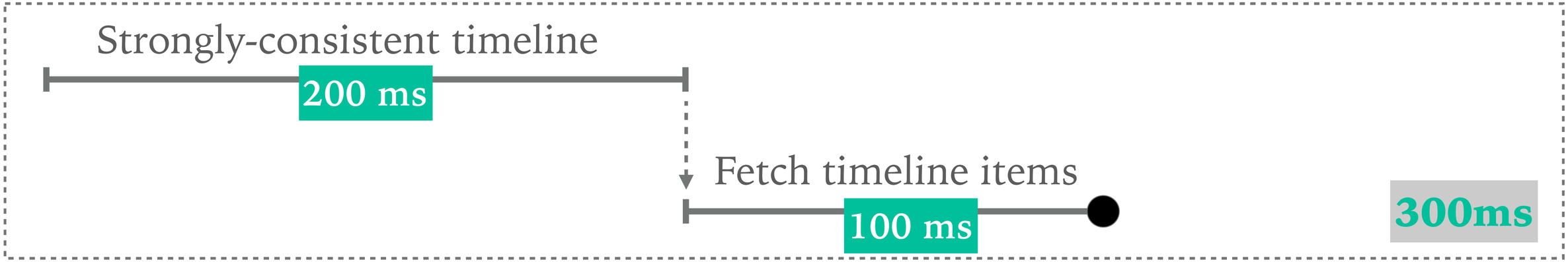


Lower latency of strong consistency

Traditional operation:



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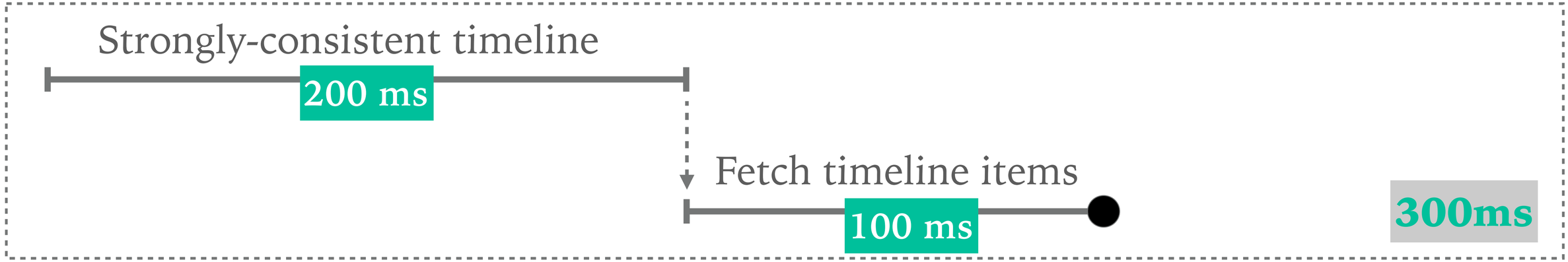
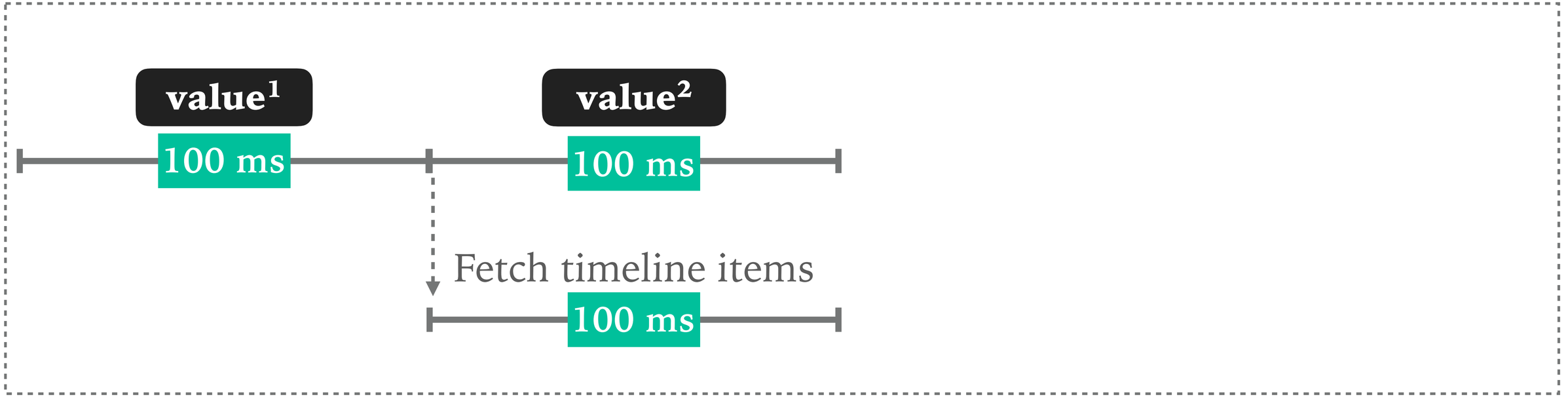


Speculative operation with ICG:



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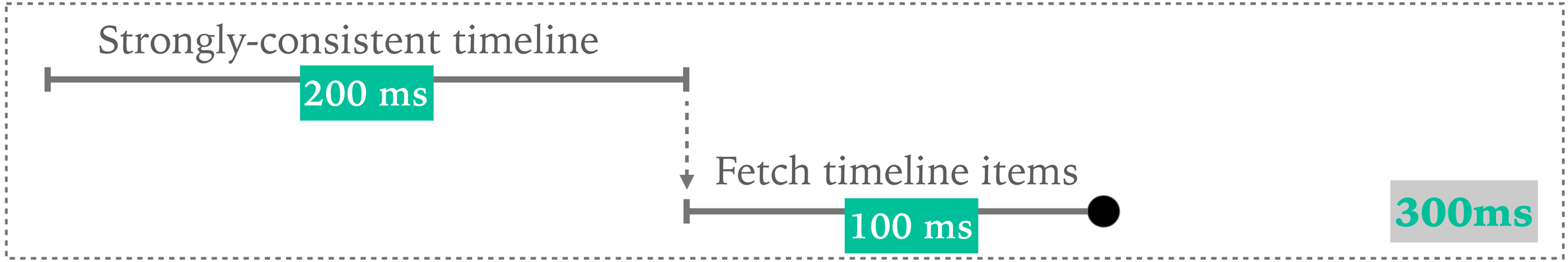

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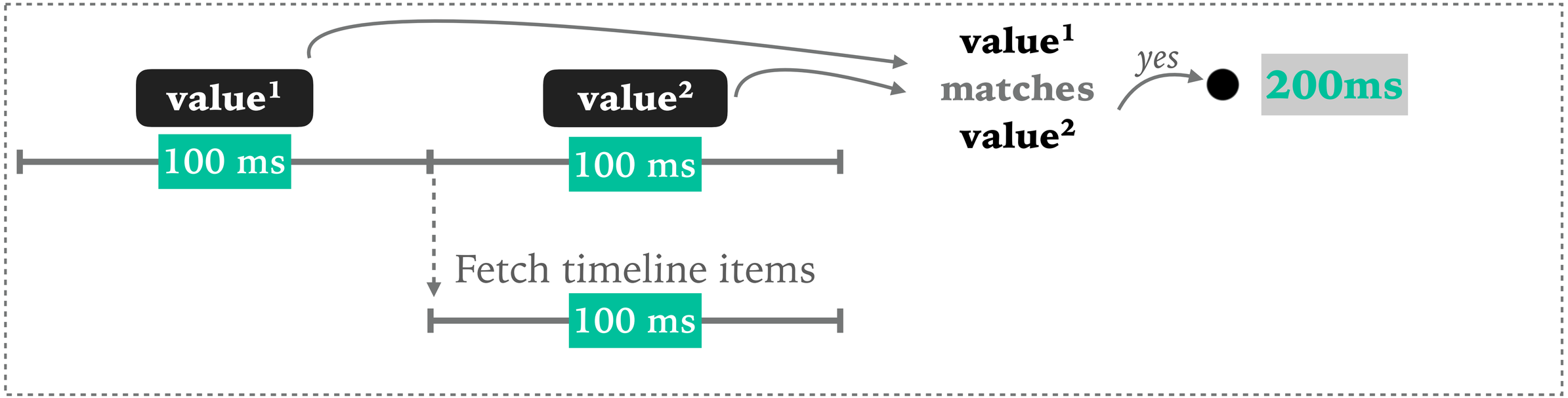

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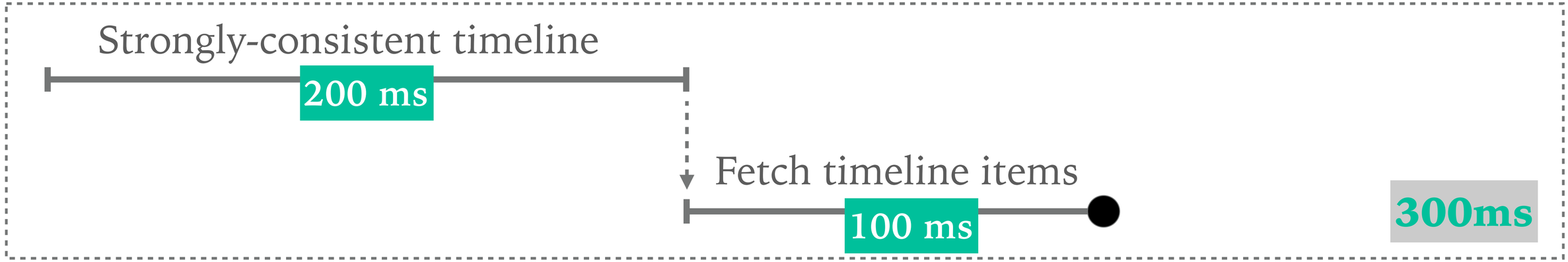

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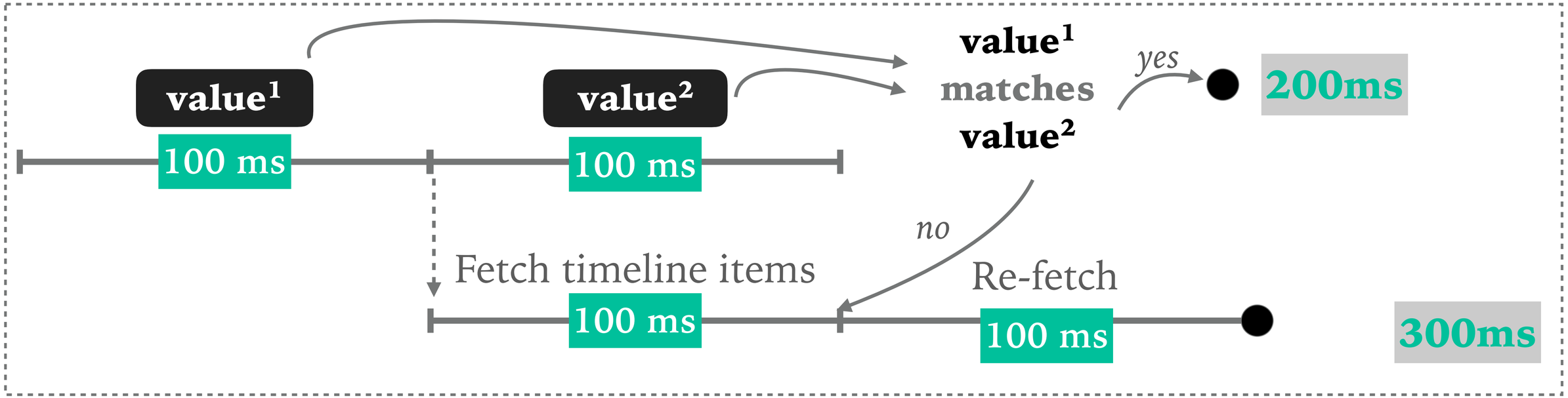

Speculation case-study

- Application: **Twissandra**
- Workload generated via YCSB
- Clients in Ireland
- Geo-replication on Amazon's EC2

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{rachid.guerraoui, matej.pavlovic, dragos-adrian.seredinschi}@epfl.ch

check the paper

★ Advertising System
— Speculation case-study

★ Ticket-selling System
— Exploiting application semantics

★ Overheads evaluation
& Optimizations

★ Latency gaps between consistency models

Decreasing latency of strong consistency

What is the
latency of the **fetch_timeline()** operation?

Decreasing latency of strong consistency

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latency of the **fetch_timeline()** operation?

Baseline

Read using a quorum of 2/3 replicas

vs.

ICG

1. *Weak:* Read with 1/3 replicas
2. *"Strong:"* Read with quorum of 2/3 replicas

Decreasing latency of strong consistency

What is the
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Workload A (50:50 read/write) **Workload B (95:5 read/write)** **Workload C (read-only)**

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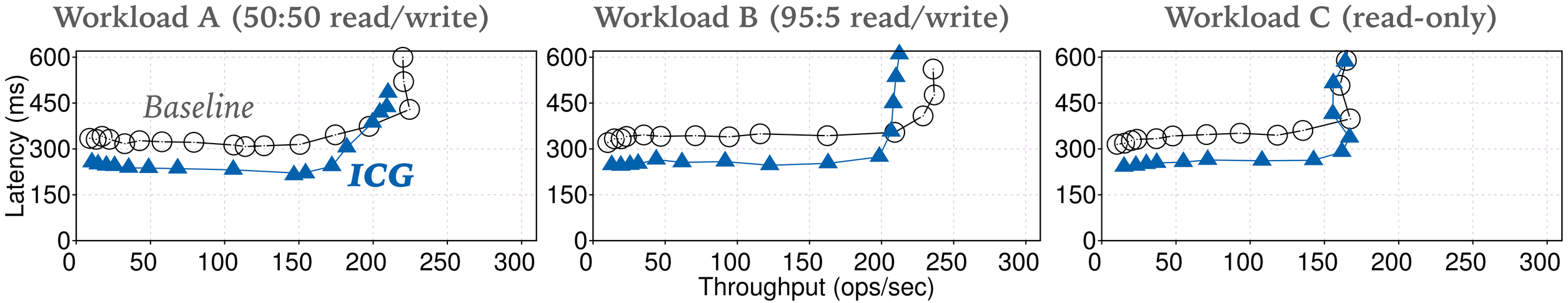

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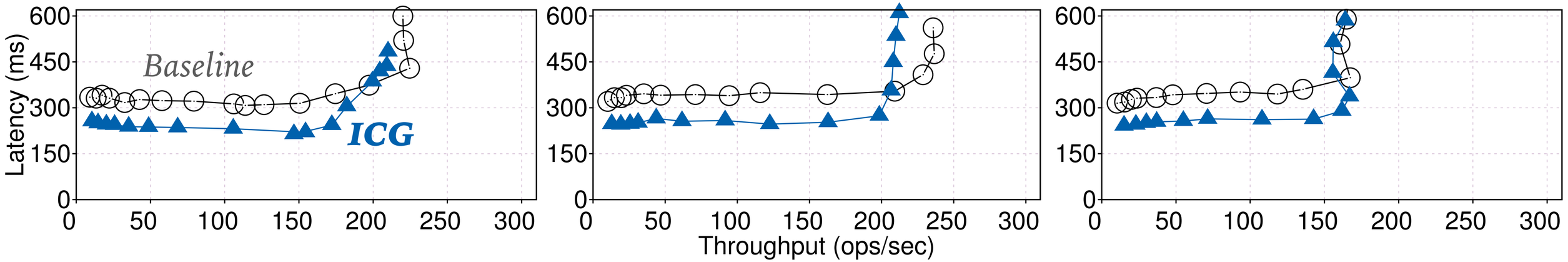
Decreasing latency of strong consistency

What is the
latency of the **fetch_timeline()** operation?

- ★ ***Latency decrease by 40%***
- ★ *Throughput drop by 6%*
- ★ *Same consistency model (2/3 replicas)*

Workload A (50:50 read/write) | **Workload B (95:5 read/write)** | **Workload C (read-only)**



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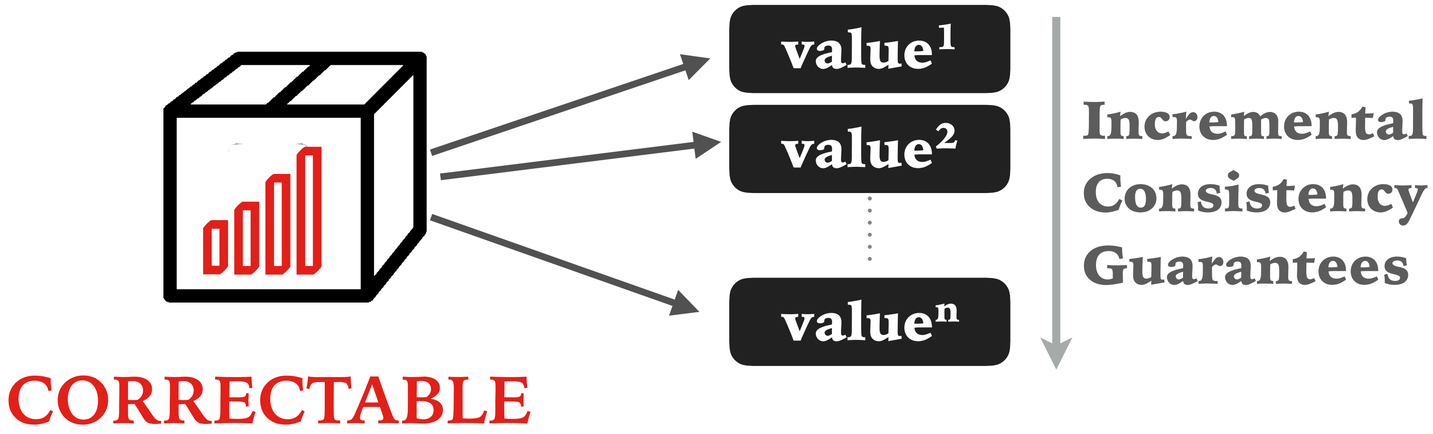
Conclusion

The Correctables abstraction enables you to:

1. **Leverage consistency models incrementally**
2. **Lower latency of strong consistency**



@adizere

backup slides

Speculation // Syntactic sugar

```
1 invoke(read(...))
2   .speculate(speculationFunc[, abortFunc])
3   .setCallbacks(onFinal = (res) => deliver(res))
```

Listing 3: Generic speculation with Correctables. The square brackets indicate that `abortFunc` is optional.

Legacy code vs. Correctables

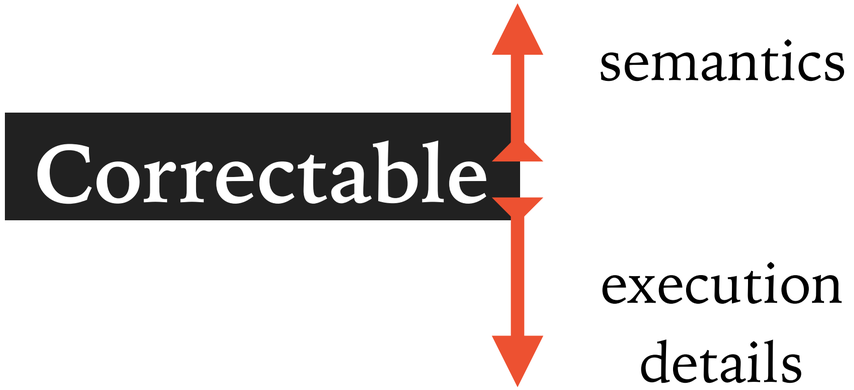
```
1  from pylons import app_globals as g # cache access
2  from r2.lib.db import queries       # backend access

4  def user_messages(user, update = False):
5    key = messages_key(user._id)
6    trees = g.permacache.get(key)
7    if not trees or update:
8        trees = user_messages_nocache(user)
9        g.permacache.set(key, trees) # cache coherence
10   return trees
11 def user_messages_nocache(user):
12   # Just like user_messages , but avoiding the cache...
```

Listing 1: Different consistency guarantees in Reddit [13], as an example of tight coupling between applications and storage. Developers must manually handle the cache and the backend.

```
1 def user_messages(user, strong = False):
2   key = messages_key(user._id)
3   # coherence handled by invoke* functions in bindings
4   if strong: return invokeStrong(get(key))
5        else: return invokeWeak(get(key))
```

Listing 2: Reddit code rewritten using Correctables.



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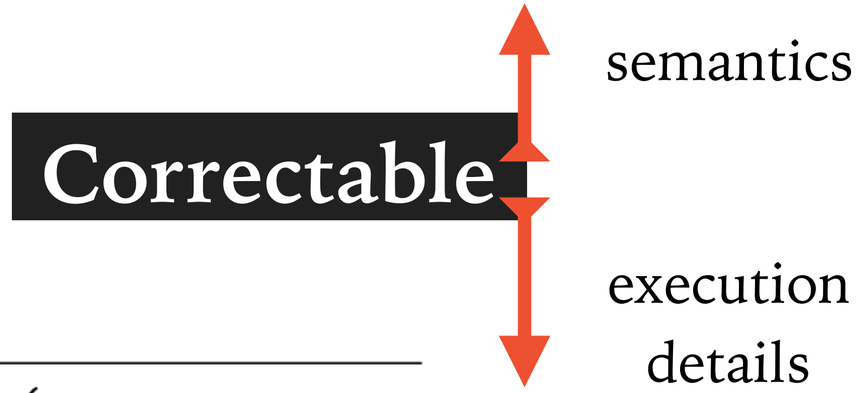
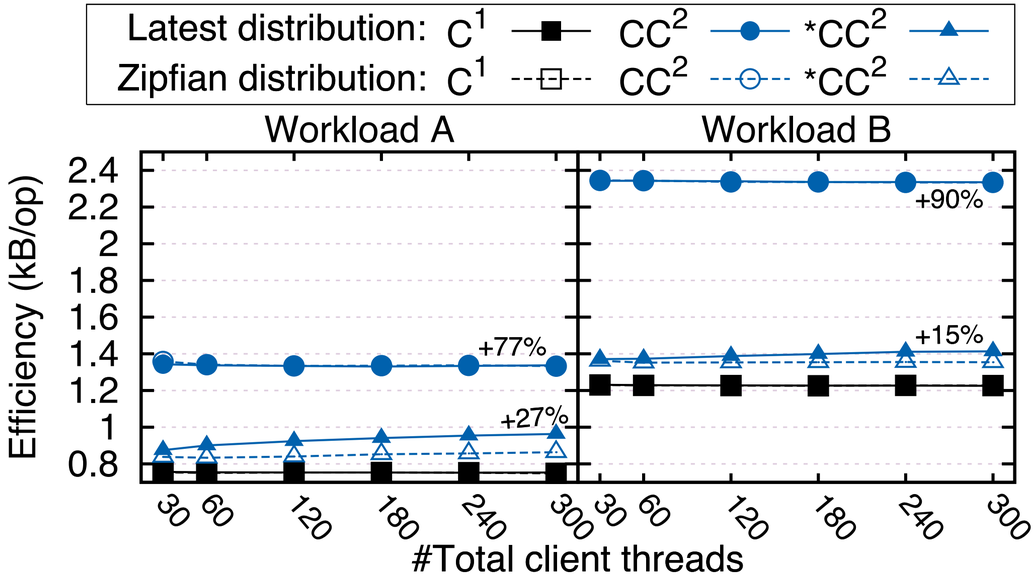



```
1 invoke(getLatestNews()).setCallbacks(
2     onUpdate = (items) => refreshDisplay(items))
```

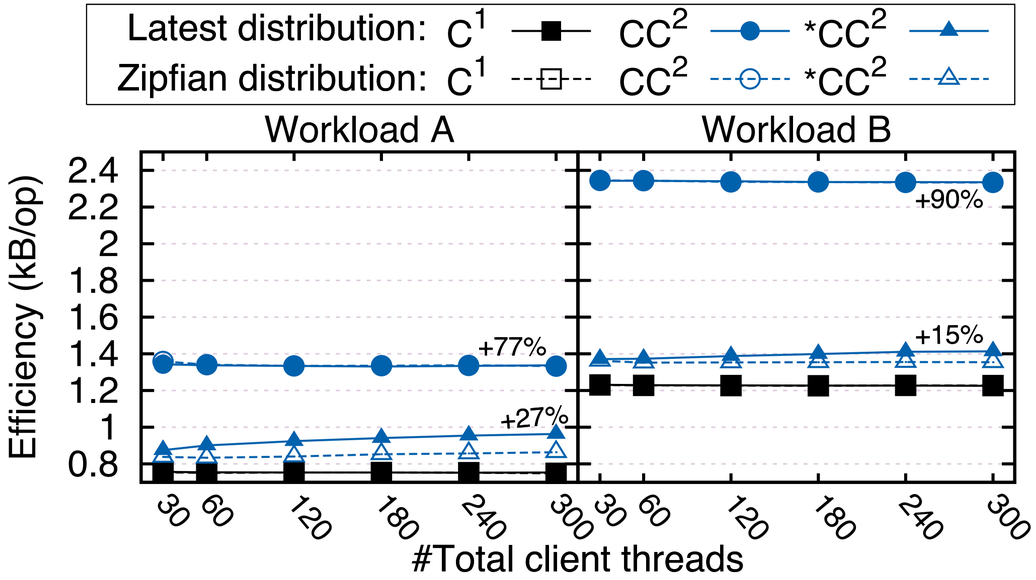
Listing 6: Progressive display of news items using Correctables. The `refreshDisplay` function triggers with every update on the news items.

Overheads



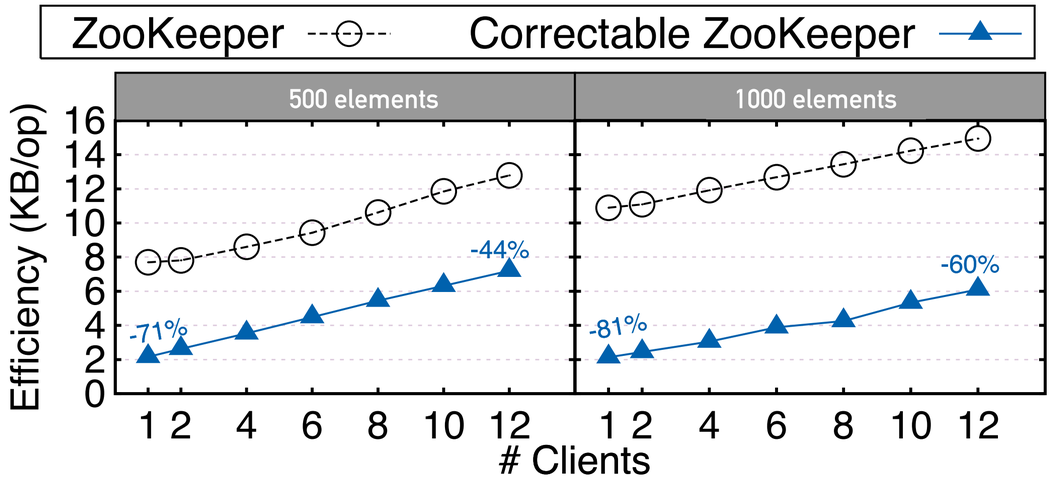
- Cassandra
- YCSB workload, various configurations
- Client in Ireland
- Replicas in Virginia, Frankfurt, and Ireland

Overheads



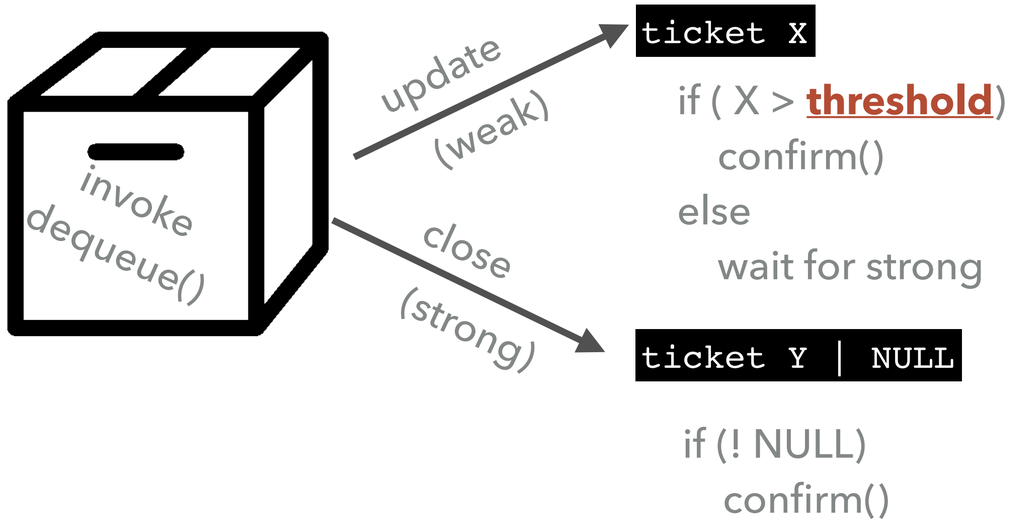
- Cassandra
- YCSB workload, various configurations
- Client in Ireland
- Replicas in Virginia, Frankfurt, and Ireland

- ZooKeeper queue implementation
- Wasteful implementation (by default)
- We were able to improve
  — negative overhead



Exploiting application semantics

- Ticket selling application
  - Implemented through a ZooKeeper queue
  - Buy ticket = dequeue operation



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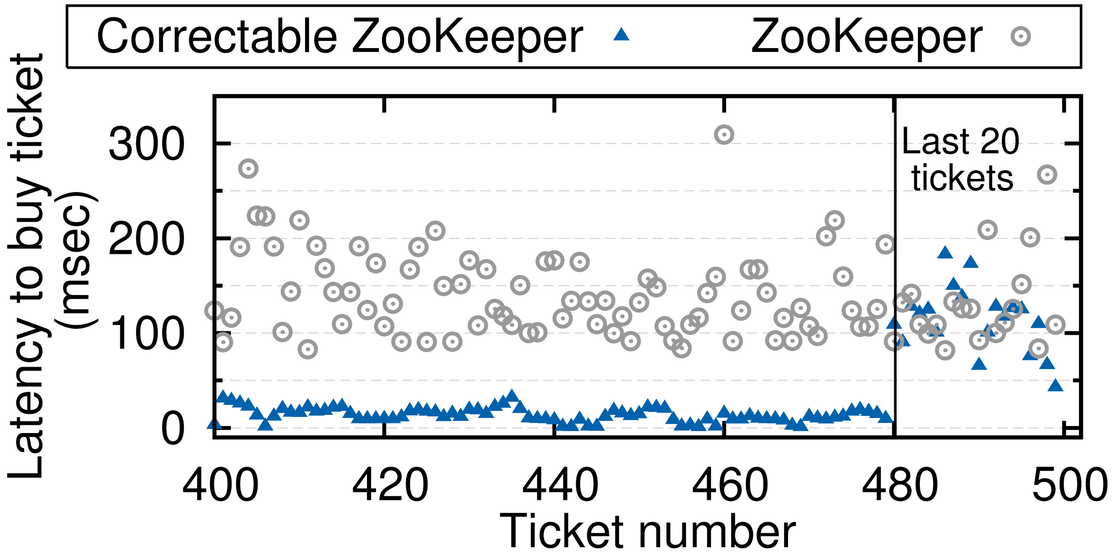
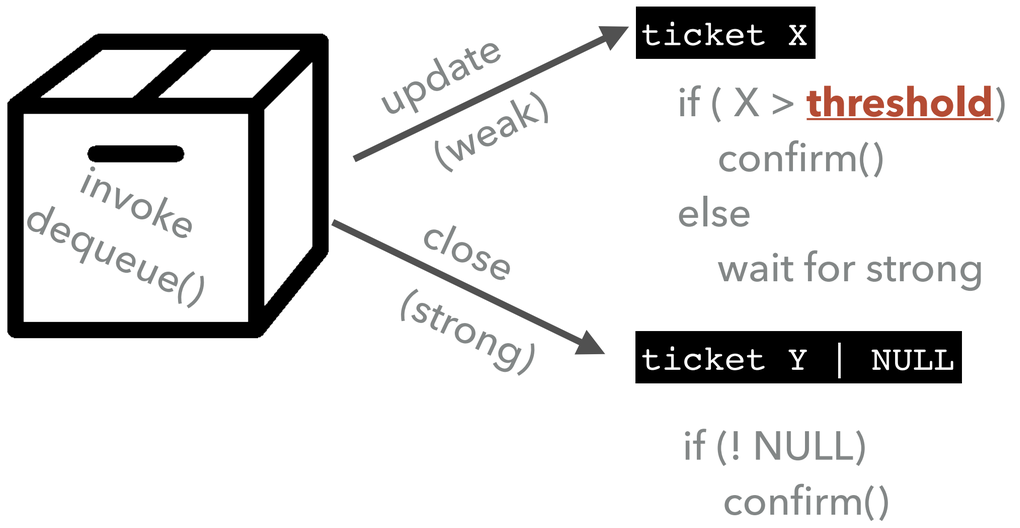
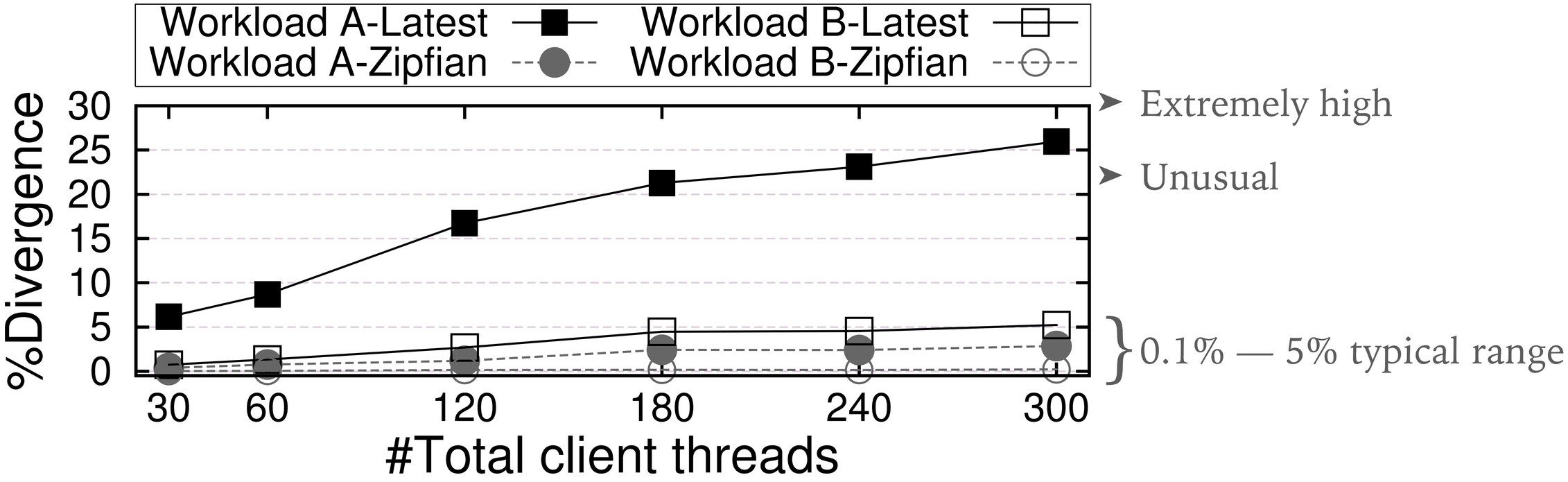
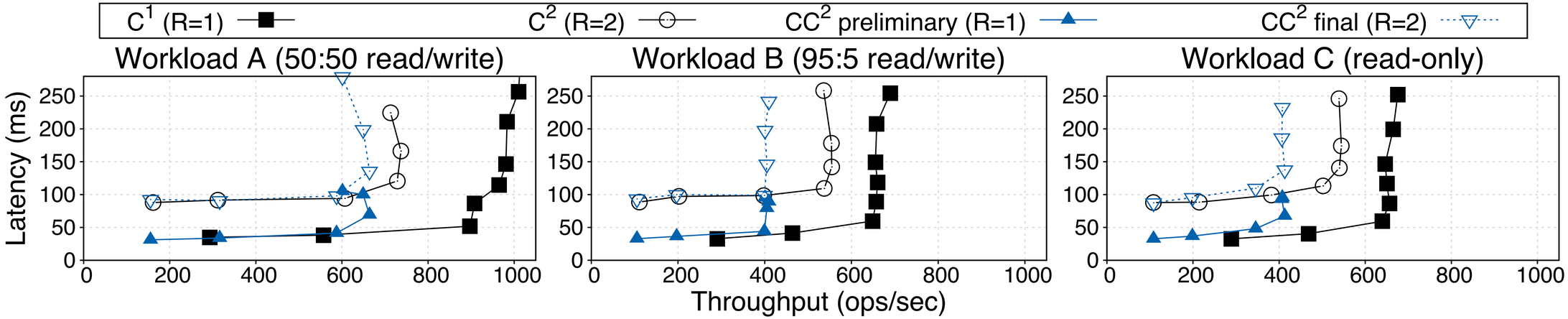


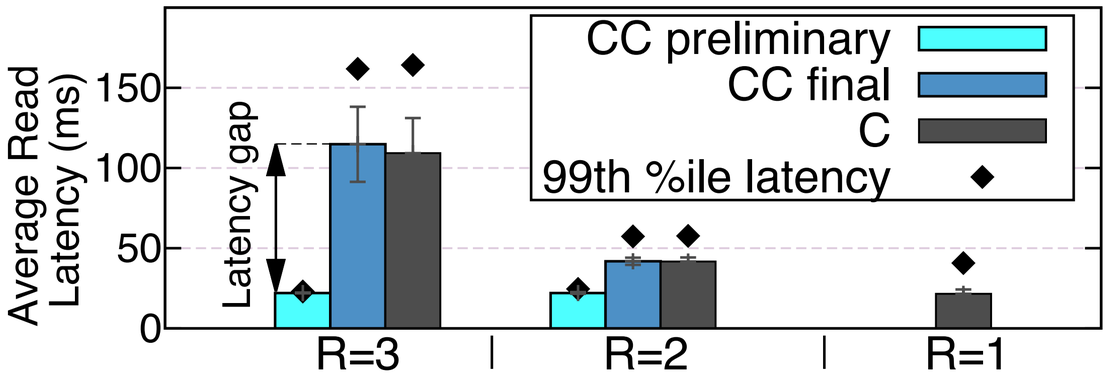


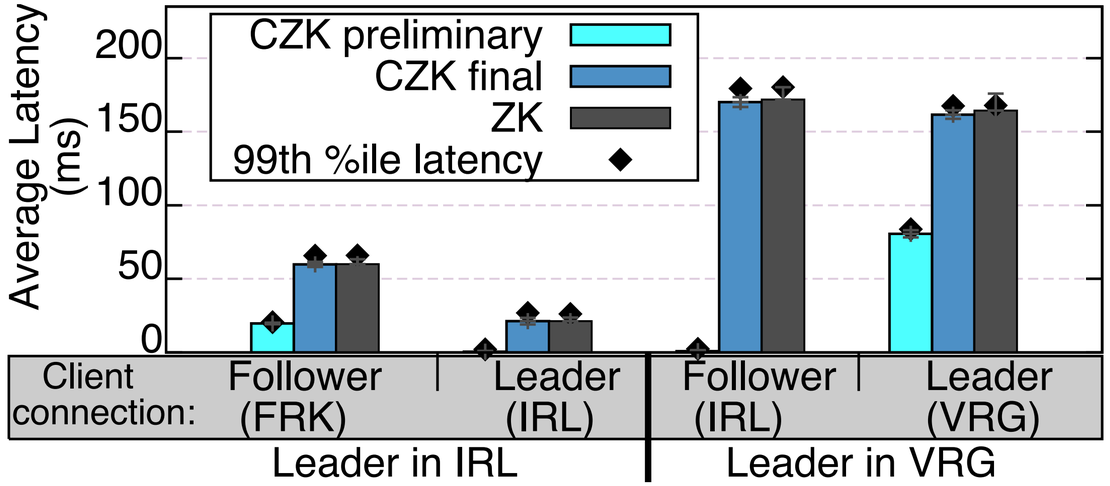
Divergence between weak and strong consistency



Latency gaps between consistency models







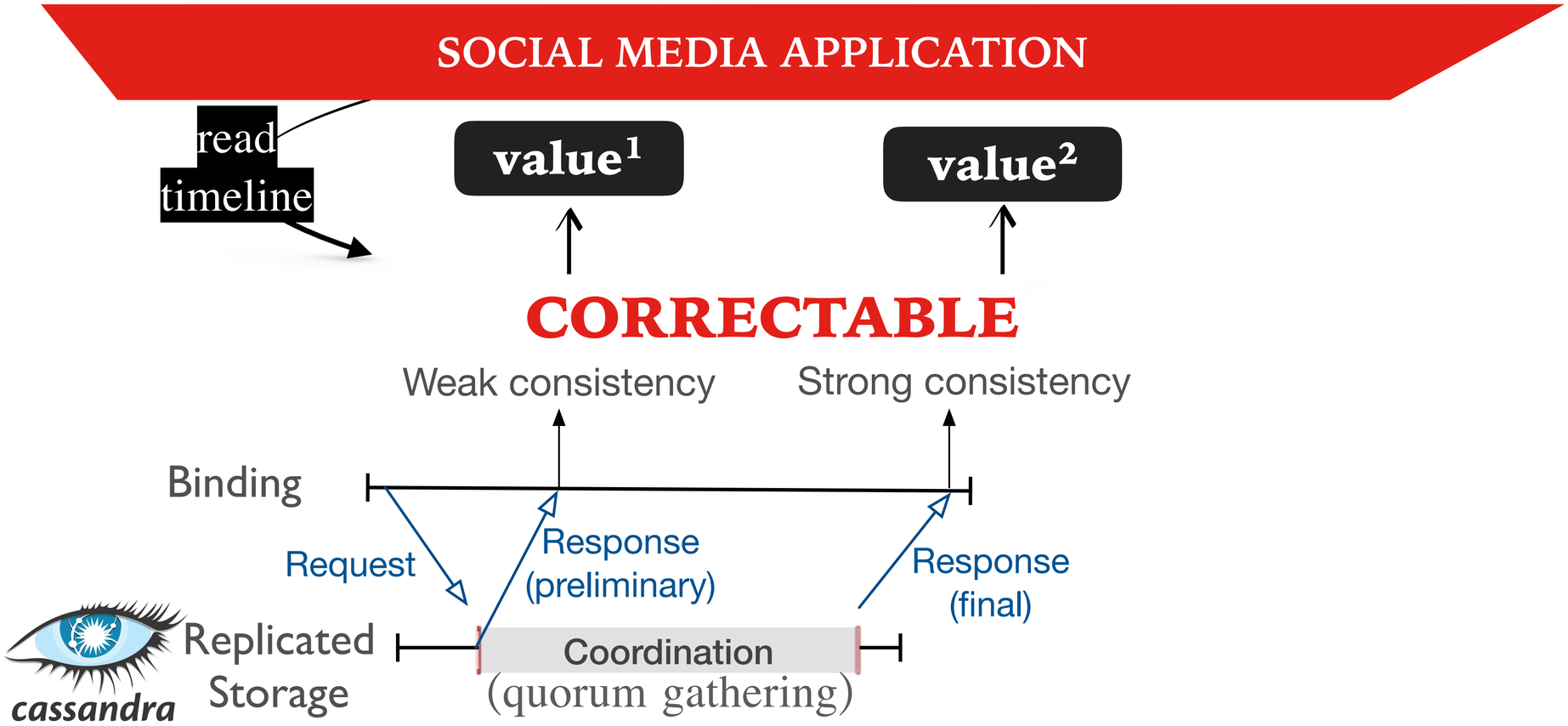
Efficiency of Multiple Responses

Efficiency of Multiple Responses

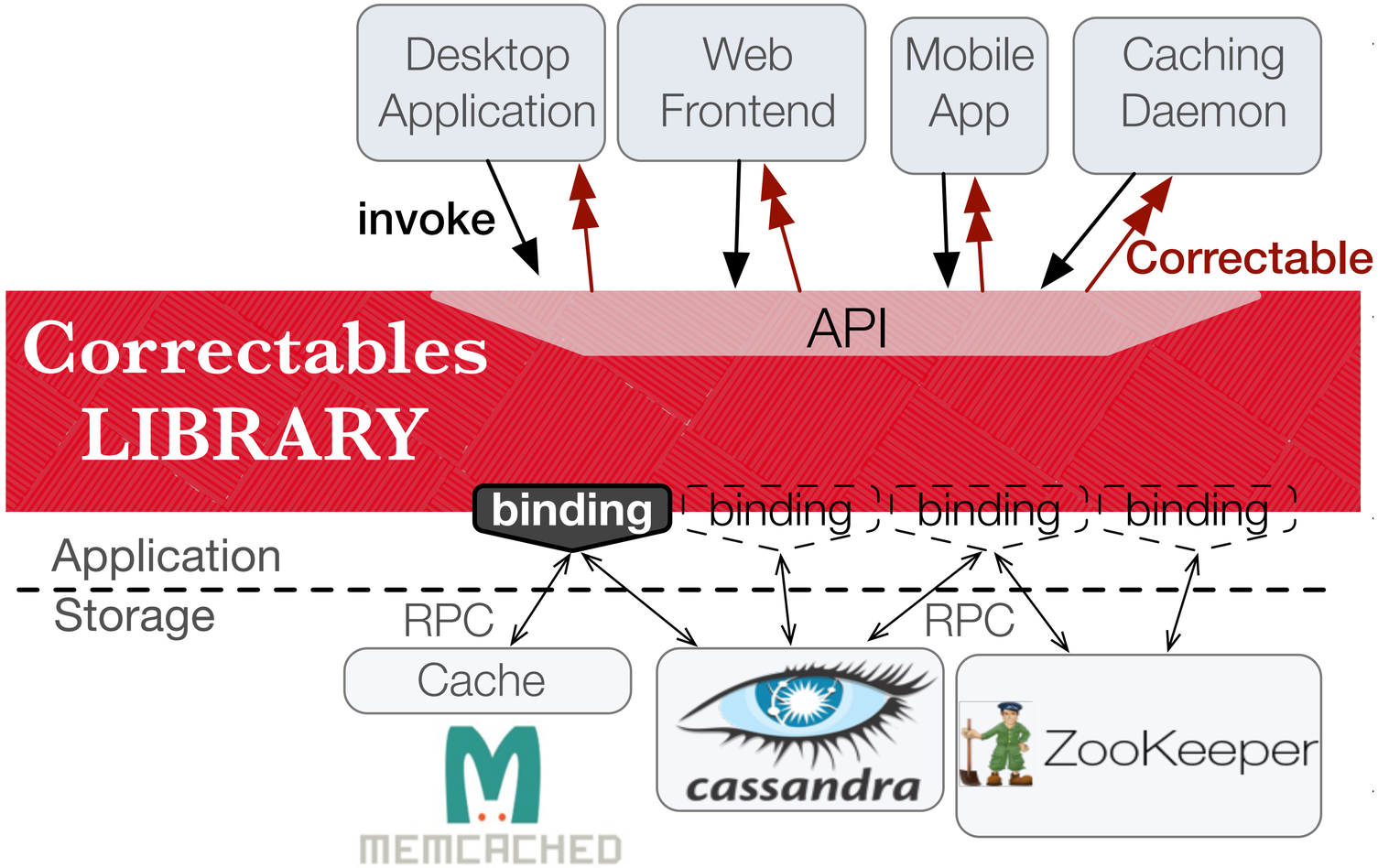
Binding

Replicated Storage

Efficiency of Multiple Responses



Correctables / **Library**



SimpleDB

MySQL