Fast key-value stores:

An idea whose time has come and gone

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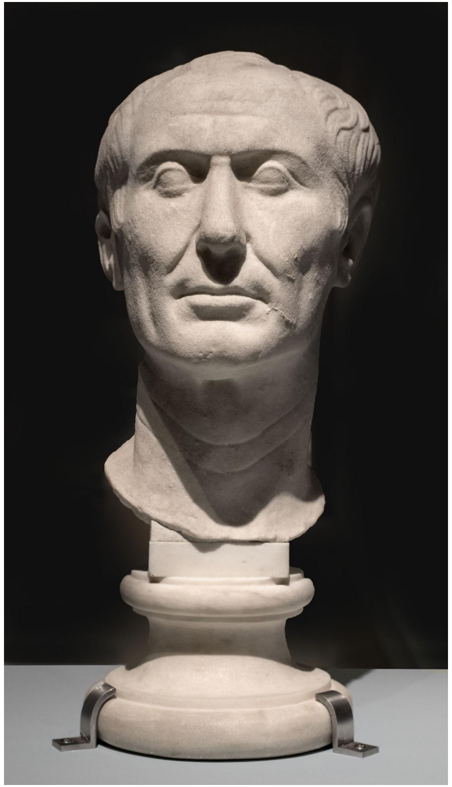
Since we're in Italy...

"I come to bury key/value stores, not to praise them."

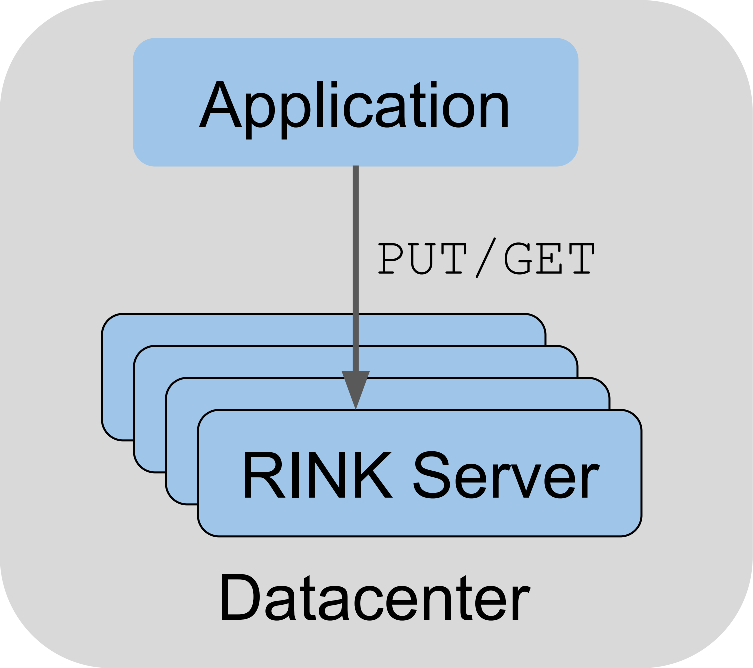


Take-home message

- **Remote, in-memory** key/value stores are a performance dead-end
- We need to look at end-to-end application performance
- Better performance requires better abstractions

Prelude: What is a key/value store?

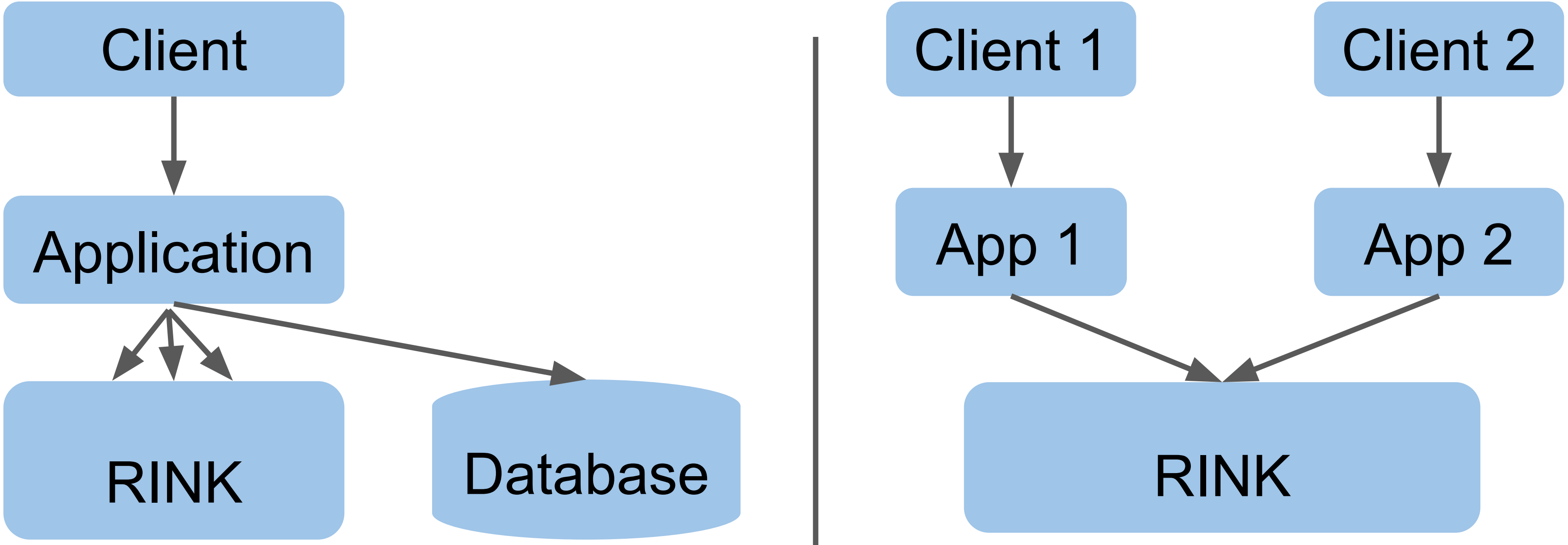
- Remote, In-Memory, Key/Value store (RINK)
- Domain-independent API
- Think Memcache or Redis, not Bigtable or HBase



Key/value stores are a thing

- **Academia**: FLOEM (OSDI ‘18), NetCache, KV-Direct (SOSP ‘17), Mega-KV (VLDB ‘15), MemcachedGPU (SoCC ‘15), MemC3 (NSDI ‘13), FaRM, MICA (NSDI ‘14), ...
- **Industry:** Redis / Memcacheg on all Clouds
  - 44M / 18.7M hits on Google
  - 17.8M for HotOS ;)

How are they used?



Stateless Servers

Cross-app coordination

Goals of this talk: #1

Goal: Convince you that key/value stores have outlived their usefulness

- Key/value stores make applications slow
- Industry: please stop using them
- Academia: please stop improving them

Goals of this talk: #2

Goal: Convince you that we can do better

- Idea 1: Better performance by better abstractions
  - Stateful servers or domain-specific in-memory stores
- Idea 2: Build infrastructure to enable Idea 1

Disagree? Find a better solution; we'll use it.

How can key/value stores be slow?

- **NetCache (2017):** 2+ billion queries/sec/switch
- **KV-Direct (2017):** 1.22 billion queries/sec/server
- **Mega-KV (2015):** 110M queries/sec

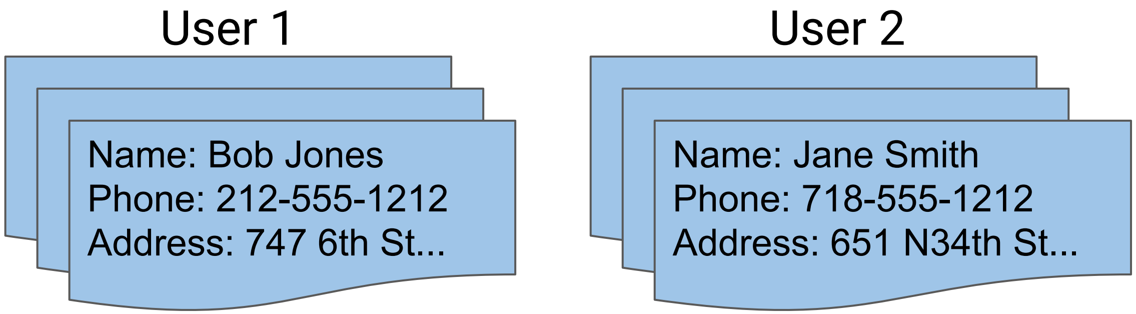
All are objectively fast and did interesting work

End-to-end view of performance

- No developer wants a fast key/value store per se
- Developers want to build fast *applications*
- RINK abstraction pushes costs to applications
  - (Un)marshalling
  - Overreads
  - Network latency

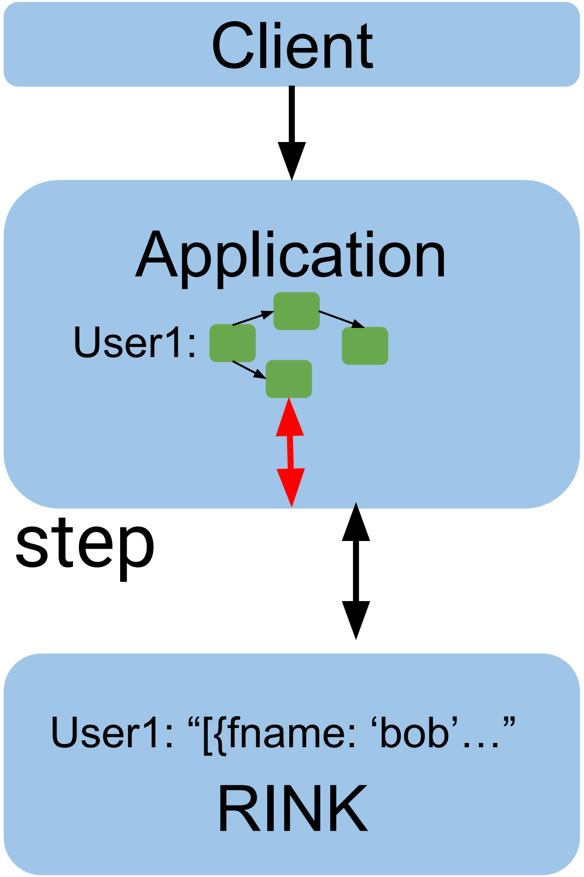
Example: address book service

- Simplified real application ("ProtoCache" in paper)
- Maintains an address book per user
- Imagine implementing using a RINK store



(Un)marshalling

- (Mostly) can't compute on strings
  - `jsnstr.find("fname: bob")`?
- Need a string ←→ data structure step
- Our experiments: 40% of CPU

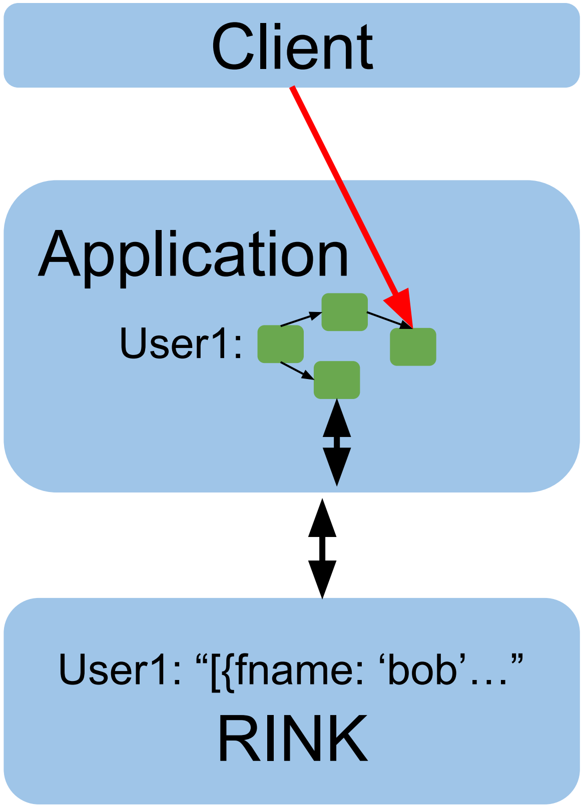


But wait!

- Is (un)marshalling really fundamental?
  - Can't I just `memcpy(&rink, &myobj)`?
- Yes (it is); no (you can't)
  - Object graphs / pointers
  - Cross-language interoperability
  - **Software upgrades, schema evolution**

Overreads

- Key/value API forces whole record read
- ProtoCache: 4% of value needed (mean)
- Another system: 7/70 fields, 37% of bytes (mean)

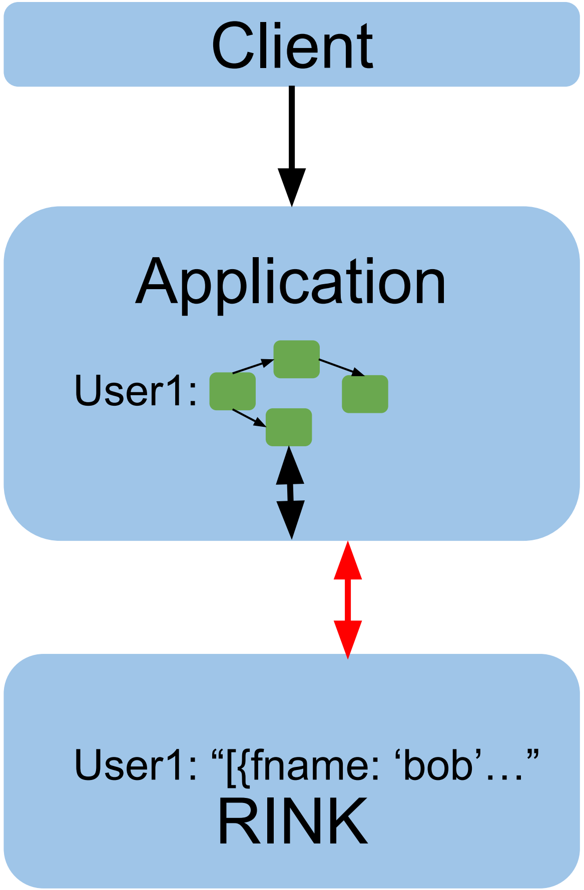


But wait!

- Isn't this a strawman data model? **No.**
- Non-workable alternatives:
  - Multiple key/value pairs
  - Lists / sets / sparse columns
  - ...
- In general: danger in tying application too closely to "storage" system

Network Latency

- Even with fast networks, large value transfer takes time
- 10MB address book?
  - 80 ms at 1 Gbps
  - 8 ms at 10 Gbps

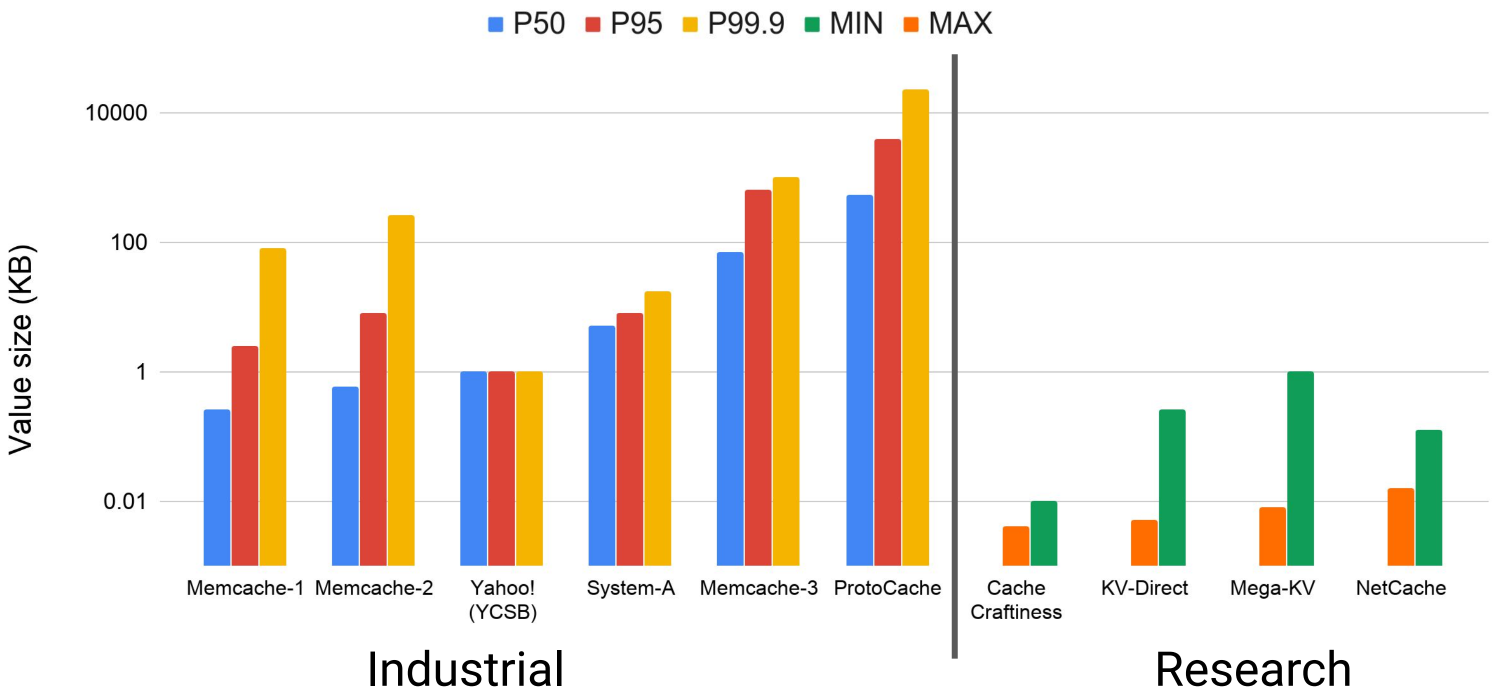


Remember these?

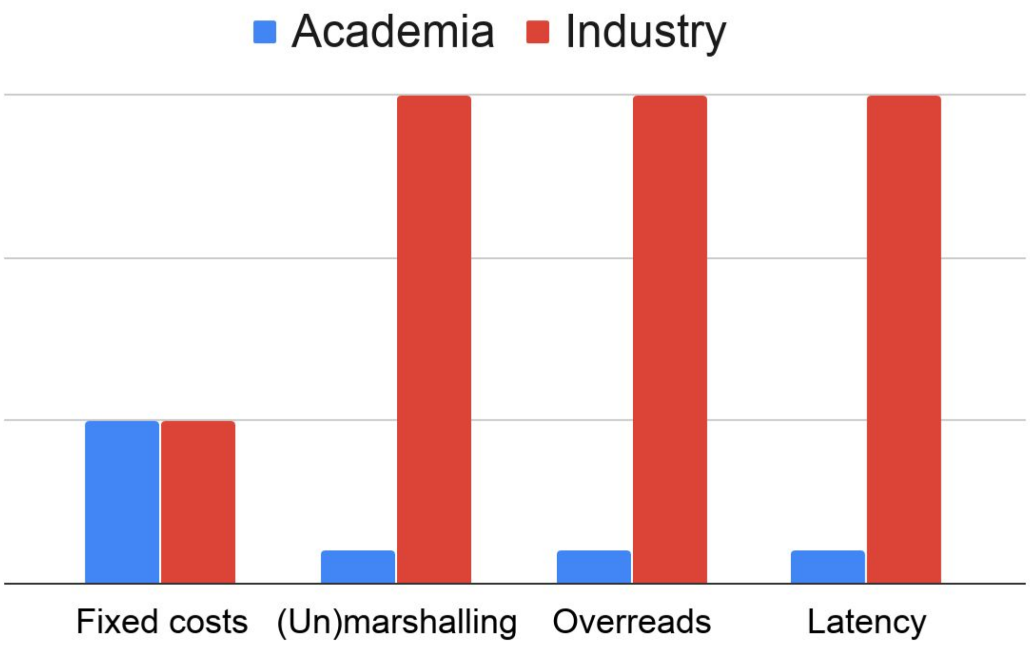
But wait!

- Isn’t 10MB an absurdly huge value?
- No.
- Research systems often focus on small values
  - Production workloads can have large values
  - **Large values exacerbate (un)marshalling, overread, and network latency costs**

Industrial vs Research Workloads



Amdahl's Law



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Our Proposal

- Better abstractions
- New infrastructure

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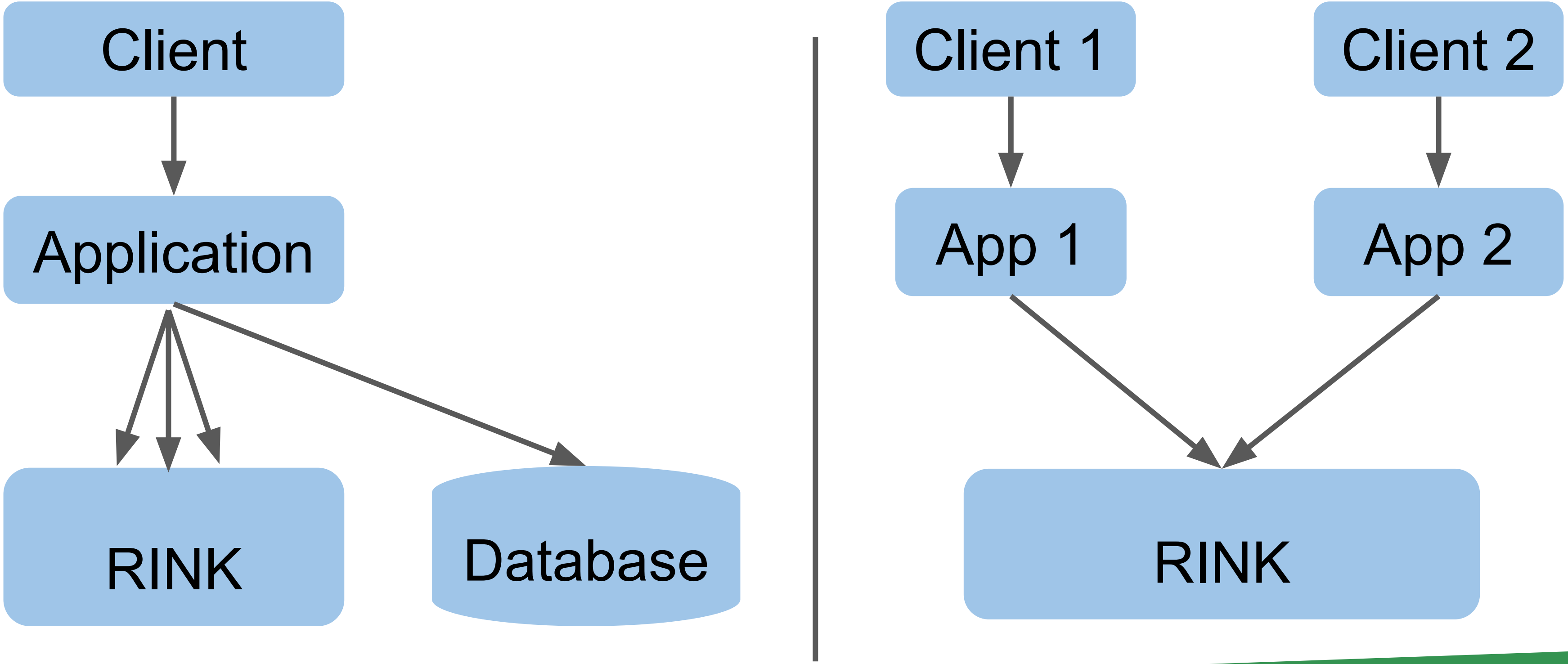
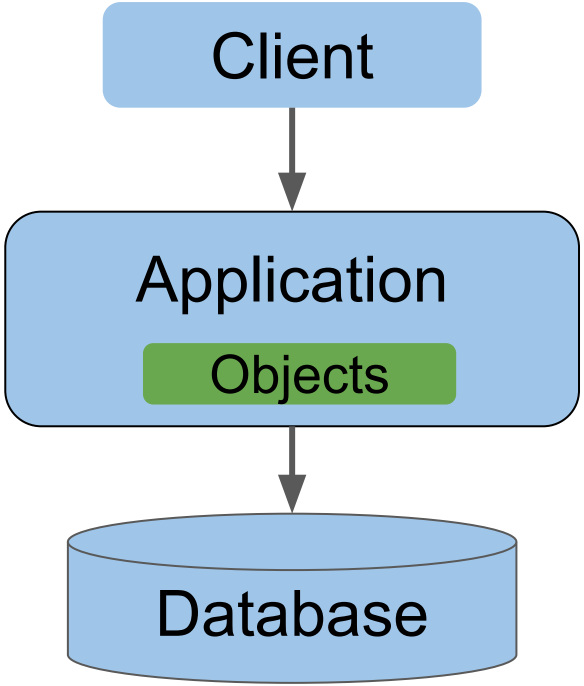
Change the abstraction

- Costs exist regardless of RINK performance
- To reduce / eliminate, change the abstraction
- Store domain-specific application objects, not strings or simple data structures

Original Architectures

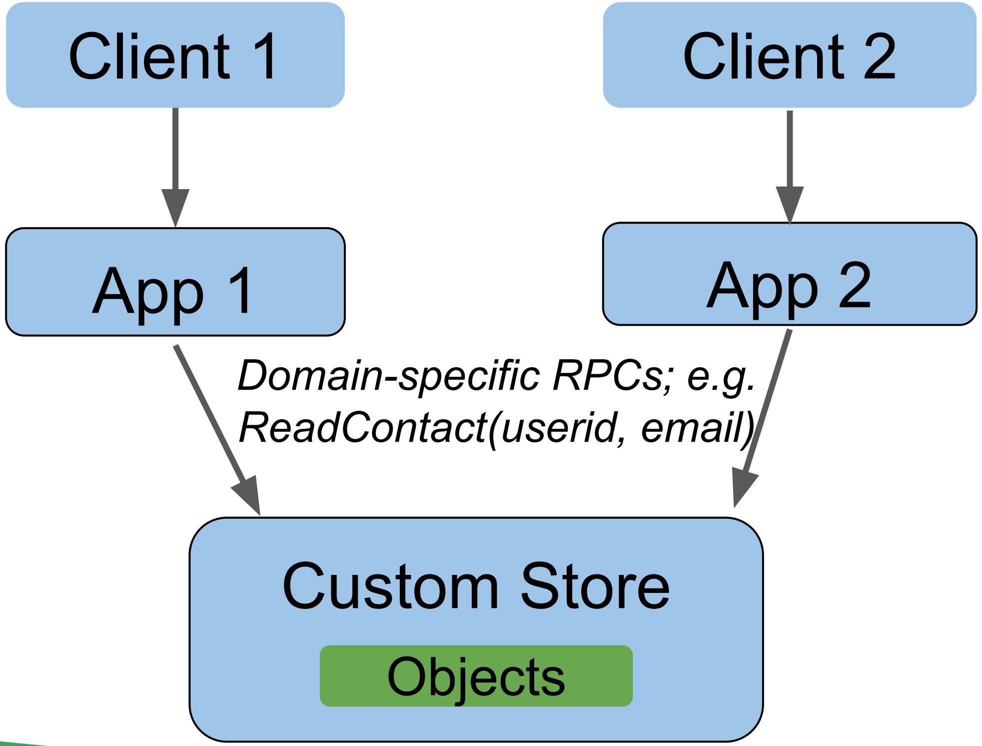


Revised Architecture: Best Case



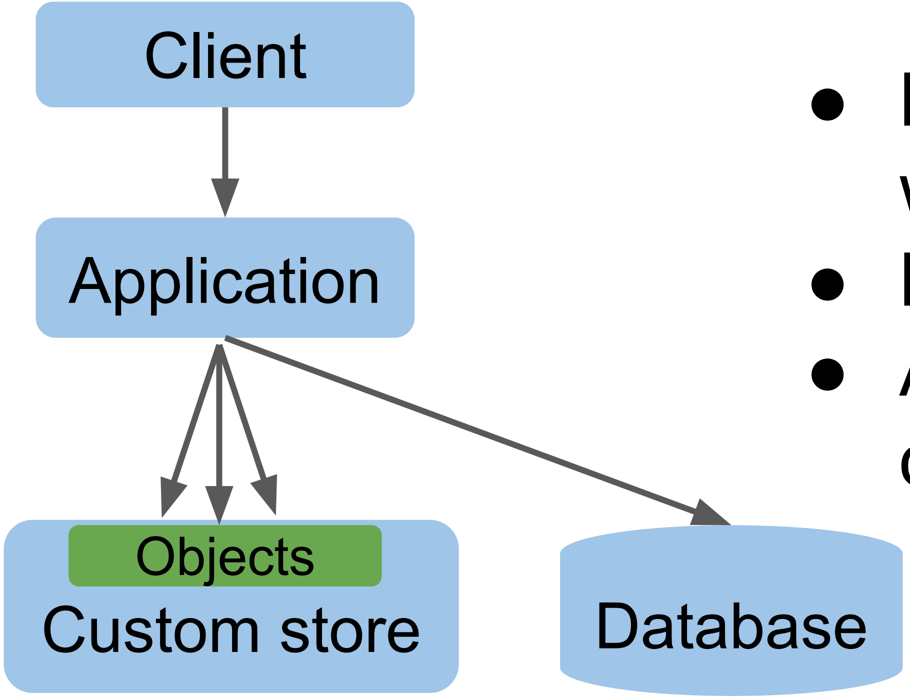
- Embed sharded cache directly into application
- One cache access per application operation
- Eliminates (un)marshalling, overreads, network latency
- Relatively common

Revised Architecture: Coordination



- Replace RINK with new server
- Can reduce (un)marshalling, overreads, network latency

Revised Architecture: Fanout



- For non-partitionable workloads, request fanout
- Hybrid of first two models
- Application serves as custom store

Wouldn't it be nice...

...to have efficient partial reads, RMW?

```
class Objects<V> {
  // Retrieve object from store.
  V* Get(string key);

  // Return object to store.
  bool Commit(string key, V* value);
};

void HandleAddressLookupRpc(String userId, String contactEmail, Writer out)
{
  AddressBook contacts = objects.Get(userId);
  out.write(contacts.lookupByEmail(contactEmail));
  contact.recordAccess();  // Bump hit count.
  objects.Commit(userId, contacts);
}
```

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Why can’t we write code this way?

- Systems are constantly perturbed
- Replication for load, availability
- Fine; let’s make it possible

New Abstraction: LINK Store

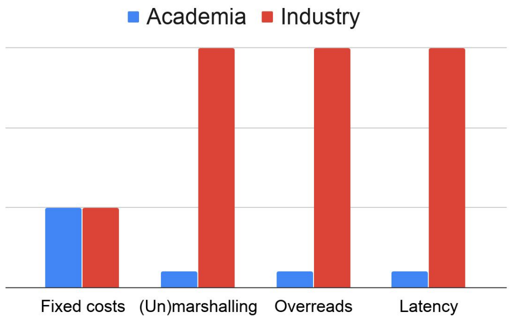
- Linked, In-Memory Key/Value Store
- Stores application objects
- Data migration on reconfiguration

```
class Link<V> {
  interface Marshaller {
    string marshal(V v);
    V unmarshal(string s);
  }
  V* Get(string key);
  bool Commit(string k, V* v);
};
```

Deployment Experience at Google

- Built a LINK prototype with load balancing (Slicer, OSDI 2016) and state migration
- ProtoCache rewritten using a subset of prototype
  - Reduced 99.9% latency by 40% (~750 ms to ~450 ms)
- Events processing system being built
  - No numbers yet, but developers like the abstraction

Summary



- RINK costs are under-appreciated
- Reduce costs by changing architectures
  - Stateful services or domain-specific stores
- LINK to make new architectures easy

Not a LINK fan? Find a better solution; we'll use it.

Call to the Community

- Please think about end-to-end performance
- Many technical problems to solve, including:
  - Replication for load and availability
  - Freshness
  - Partitioning code between servers and store
- Please help!