Big Data
WITHOUT A BIG DATABASE

Kate Matsudaira
popforms
@katemats

TWO KINDS OF DATA

nicknames	"user", "transactional"	"reference", "non-transactional"
examples:	• ***user accounts*** • ***shopping cart/orders*** • ***user messages*** • ***...***	• ***product/offer catalogs*** • ***service catalogs*** • ***static geolocation data*** • ***dictionaries*** • ***...***
created/modified by:	users	business (you)
sensitivity to staleness:	***high***	***low***
plan for growth:	hard	easy
access optimization:	***read/write***	***mostly read***

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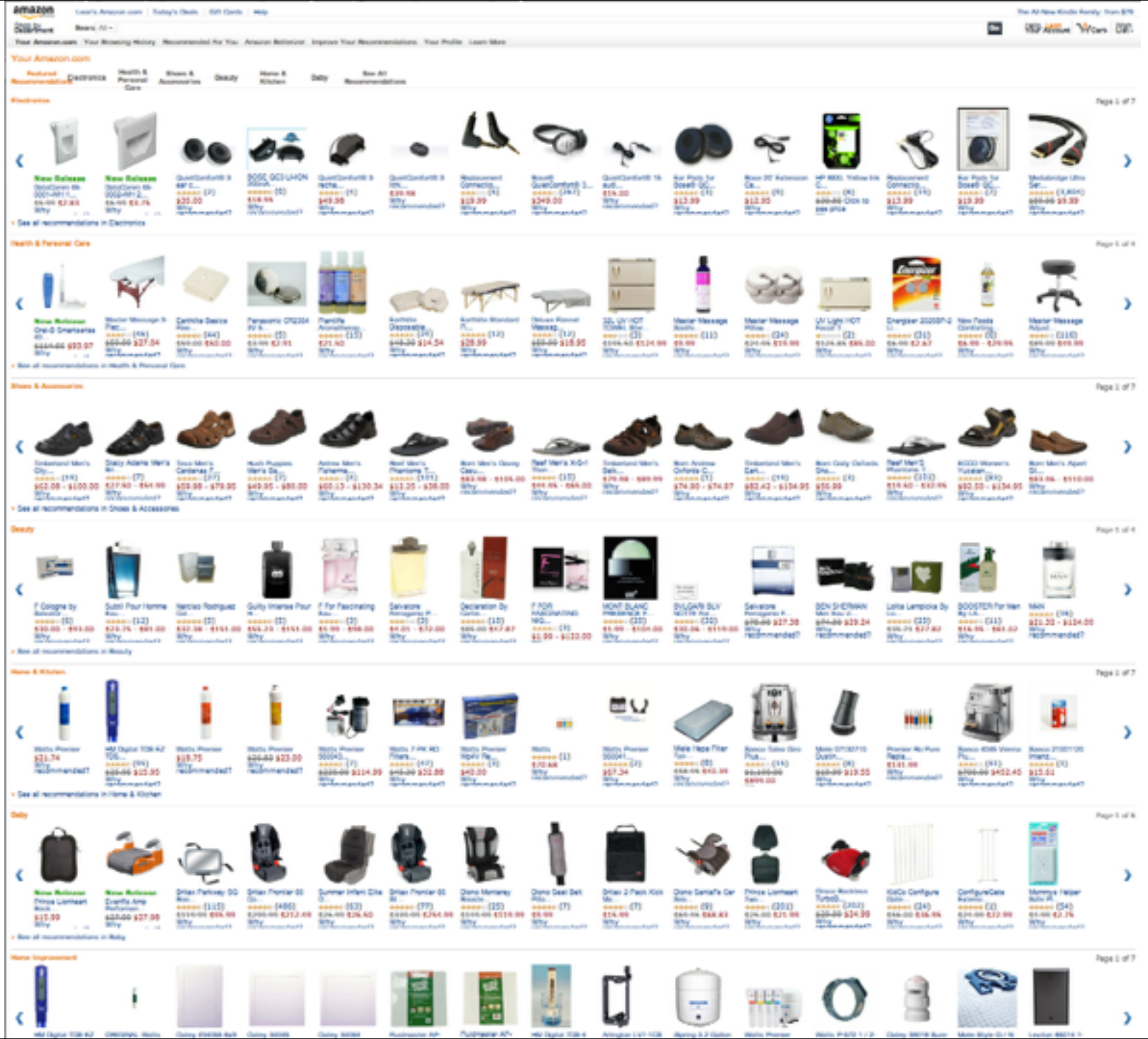
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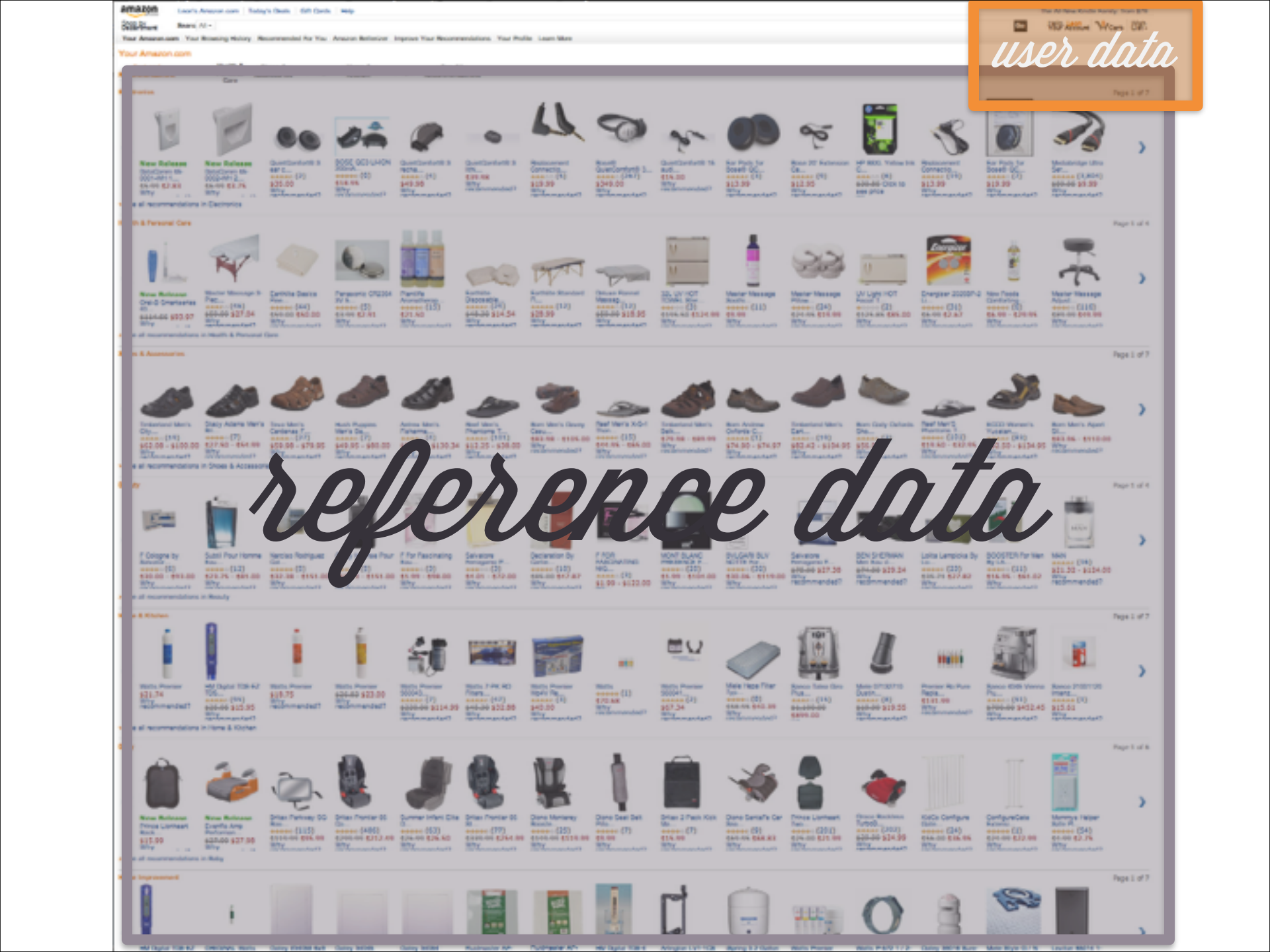
See all recommendations in Baby


reference data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reference data

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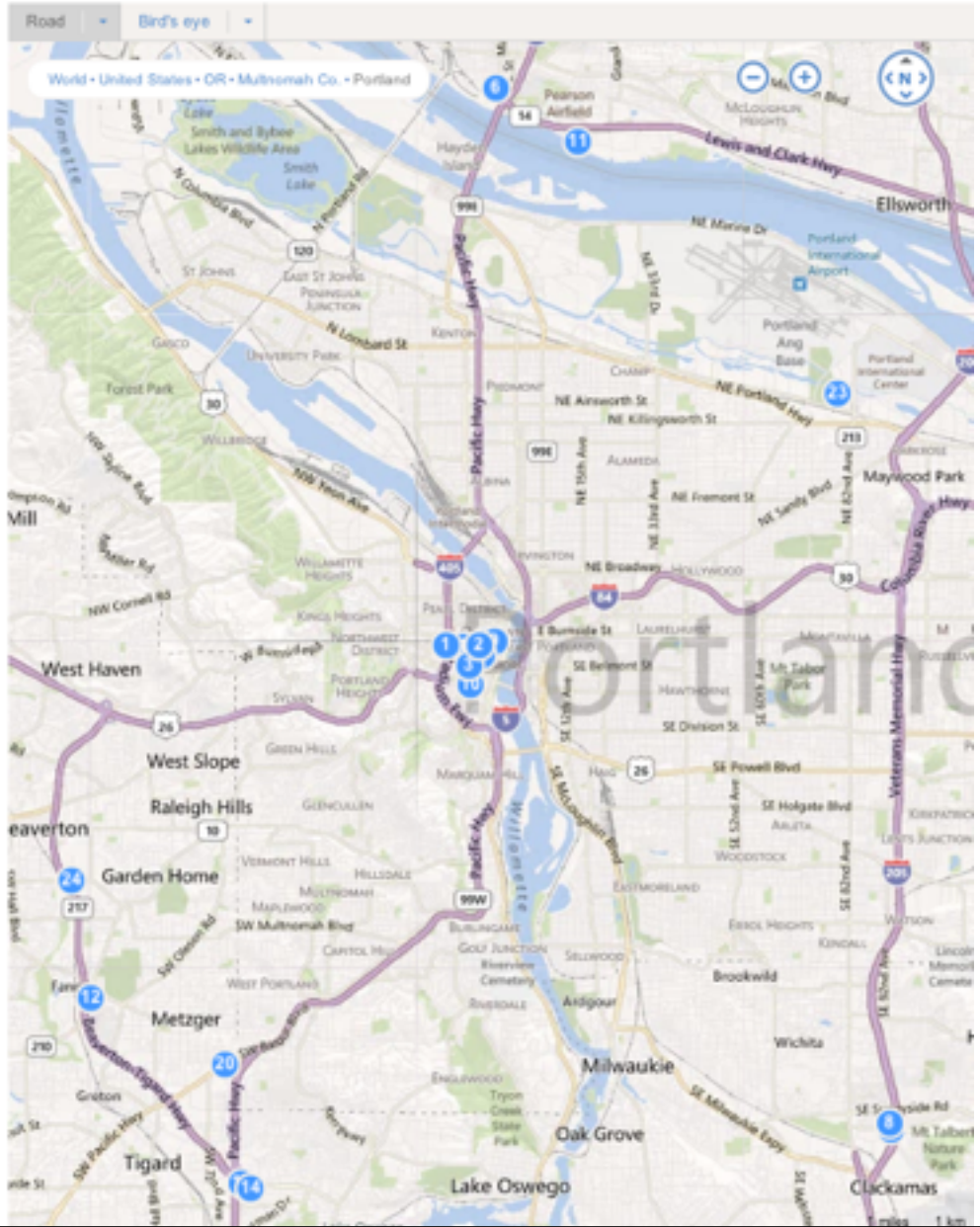

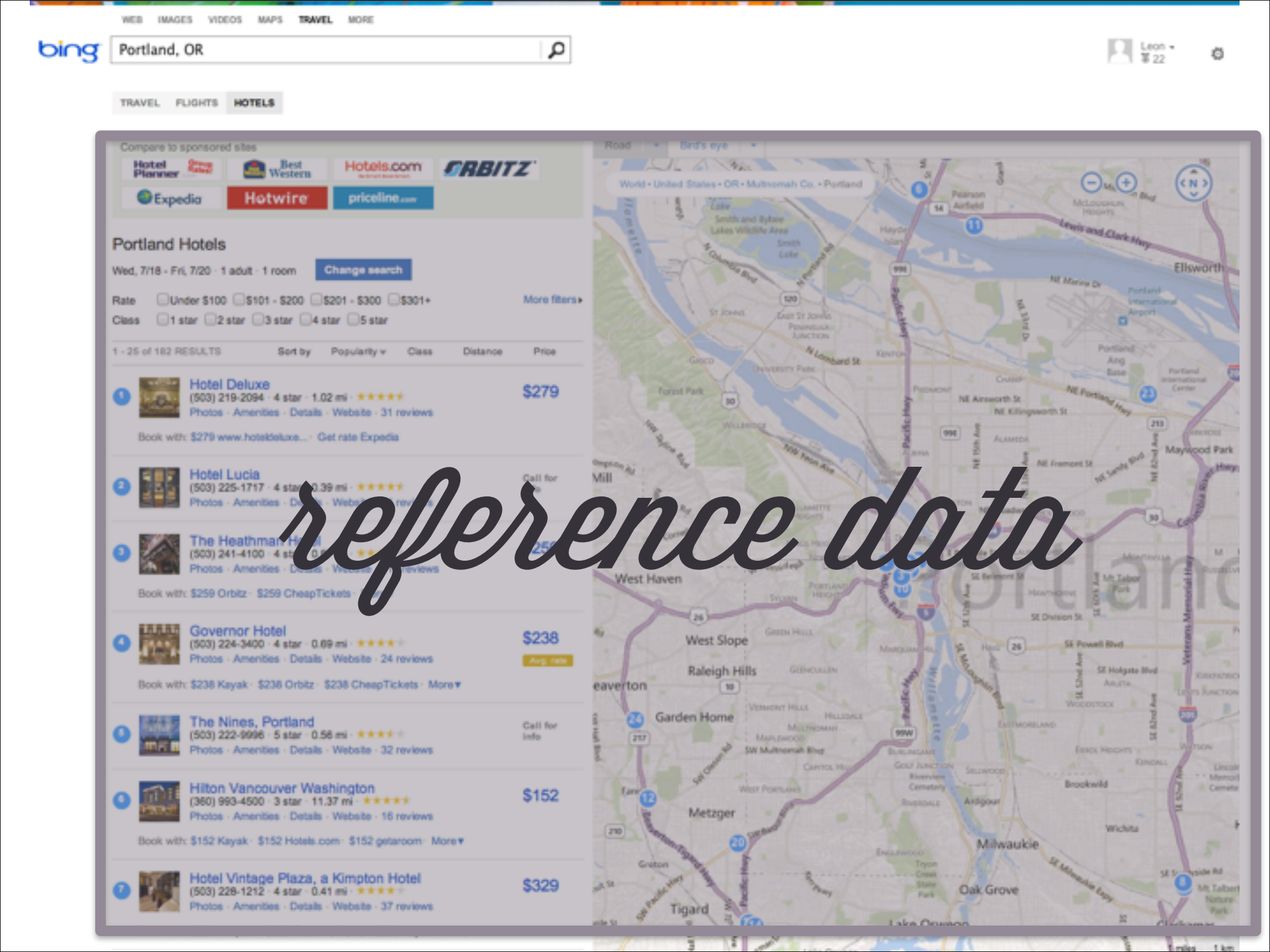
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Garden Home
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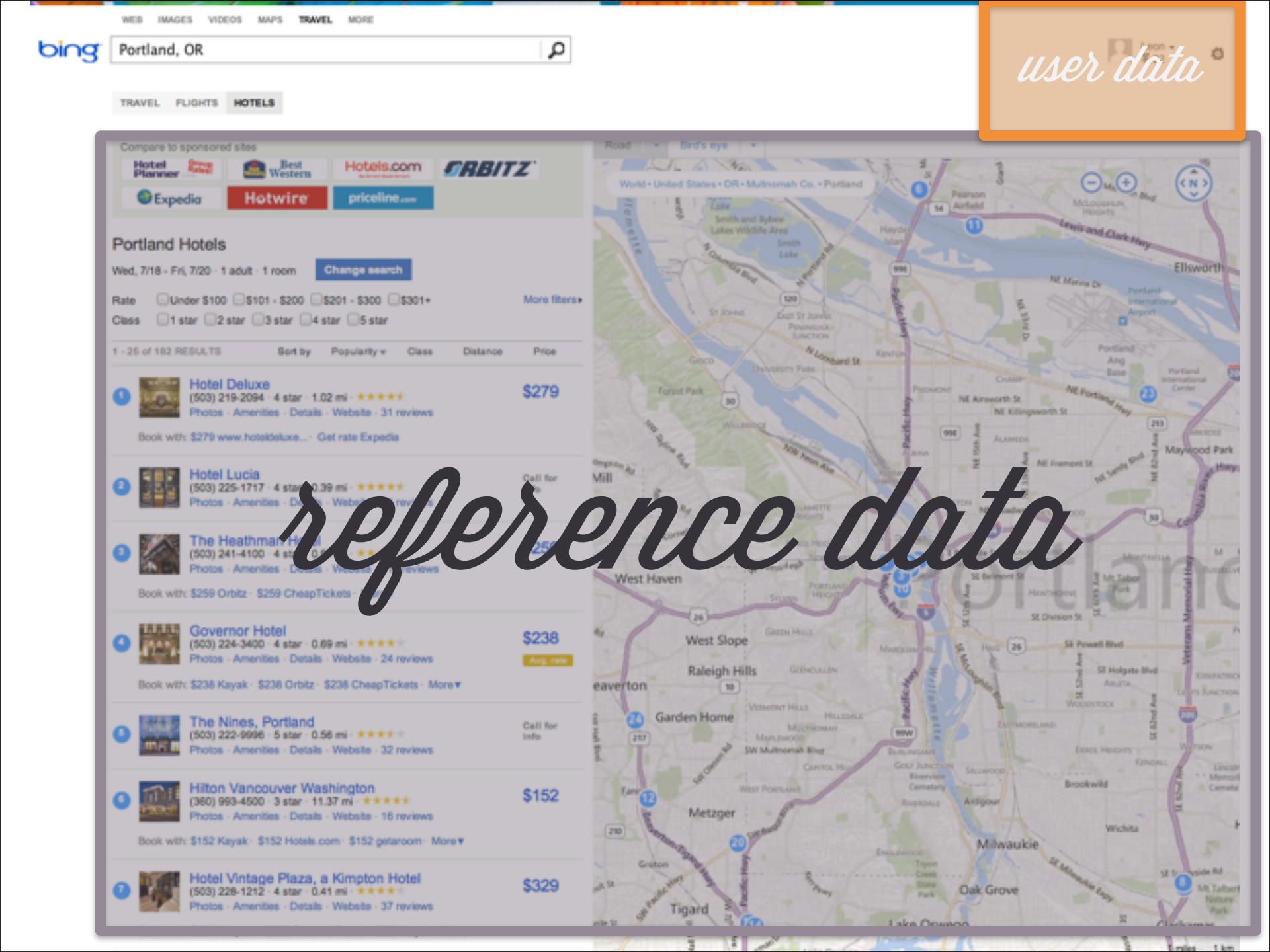
Milwaukie
Oak Grove
Tigard
Maywood Park
Brookwild
Wichita
reference data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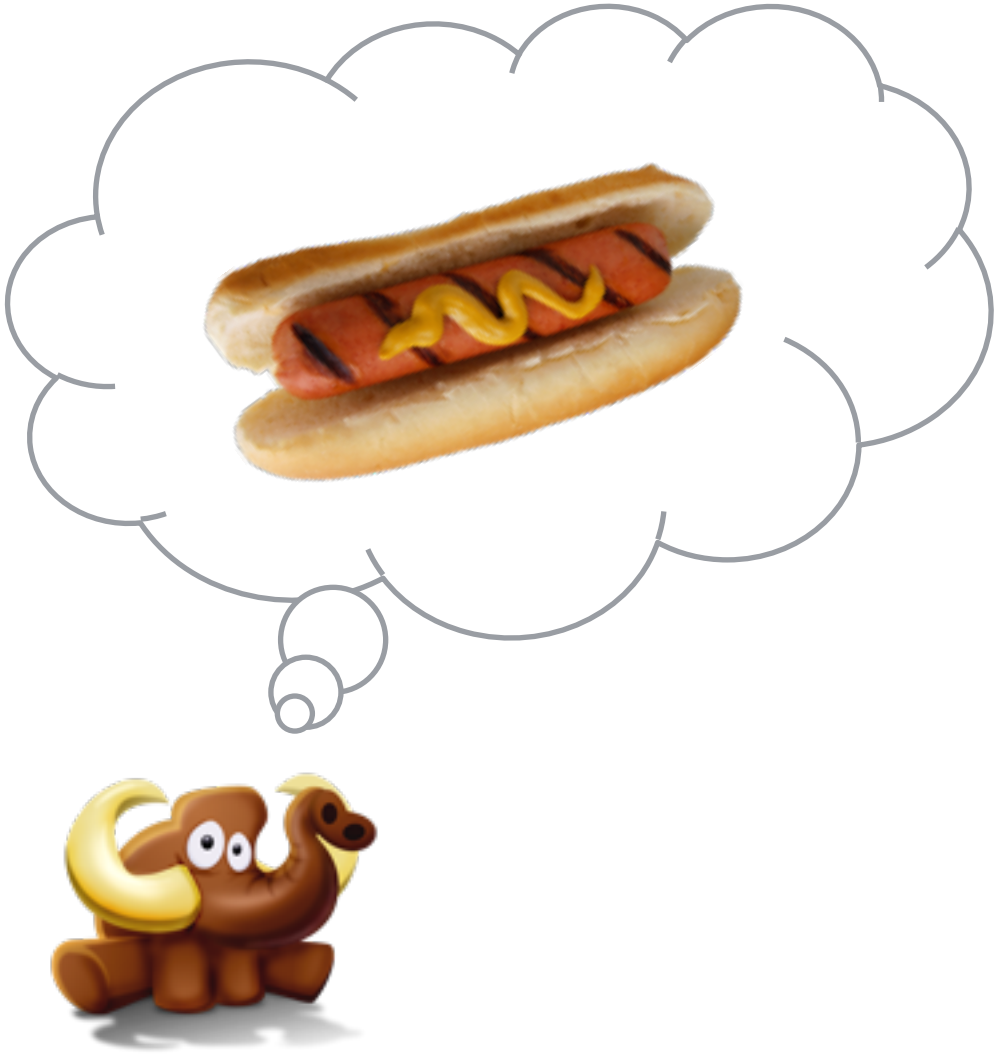
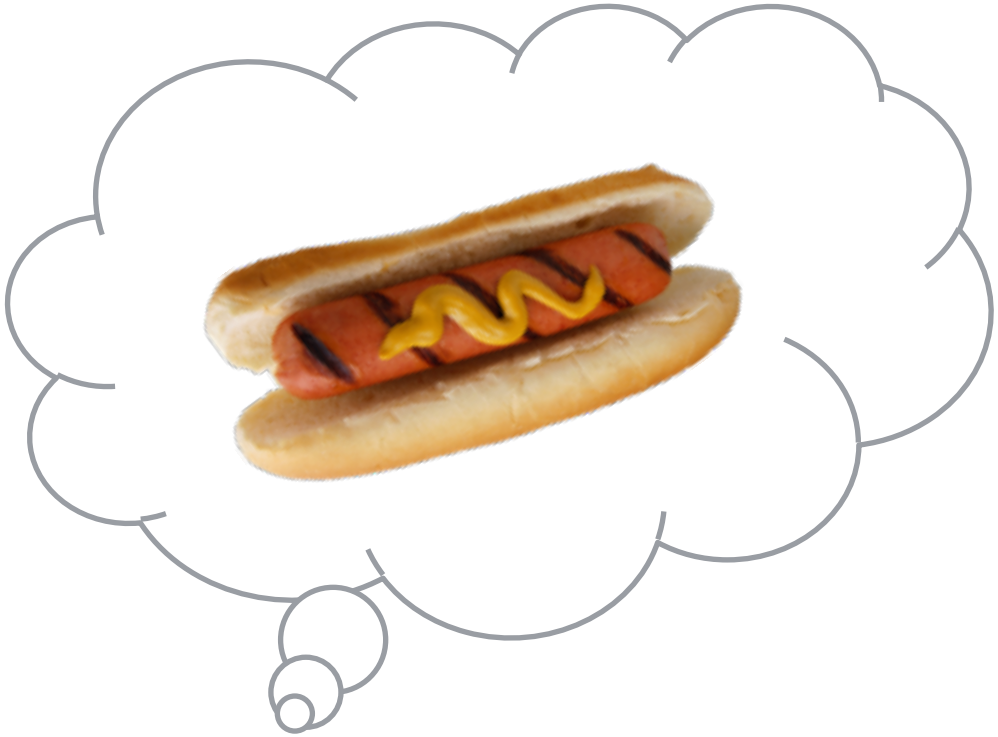
Maywood Park
Mill
West Haven
West Slope
Raleigh Hills
Garden Home
Metzger
Milwaukie
Oak Grove
Tigard
Brookwild
Wichita
reference data

PERFORMANCE REMINDER

main memory read	0.0001 ms (100 ns)
network round trip	***0.5 ms (500,000 ns)***
disk seek	10 ms (10,000,000 ns)

source: http://www.cs.cornell.edu/projects/ladis2009/talks/dean-keynote-ladis2009.pdf



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Pennsylvania
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Nevada
Utah
Colorado
United States
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West Virginia
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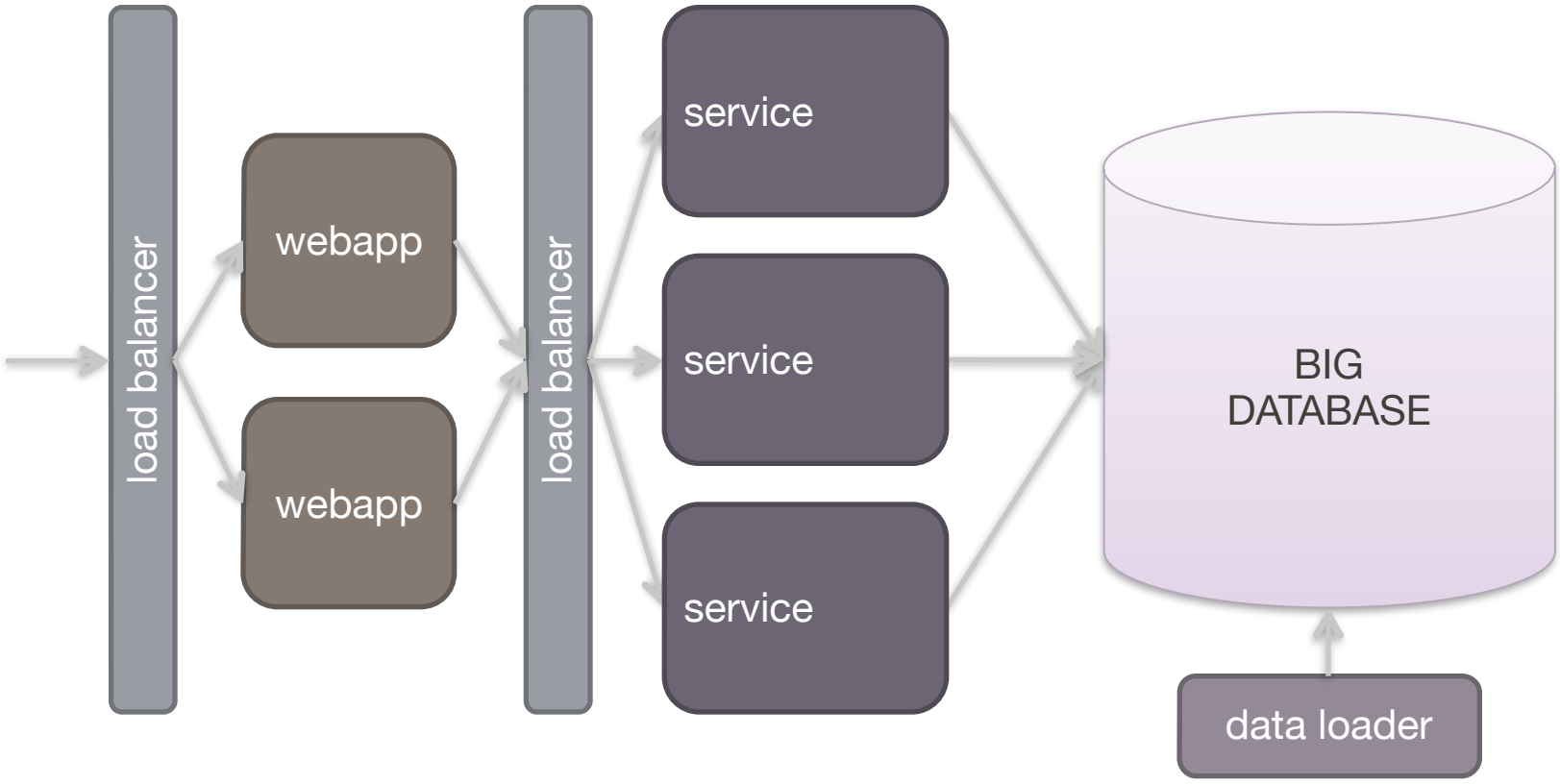
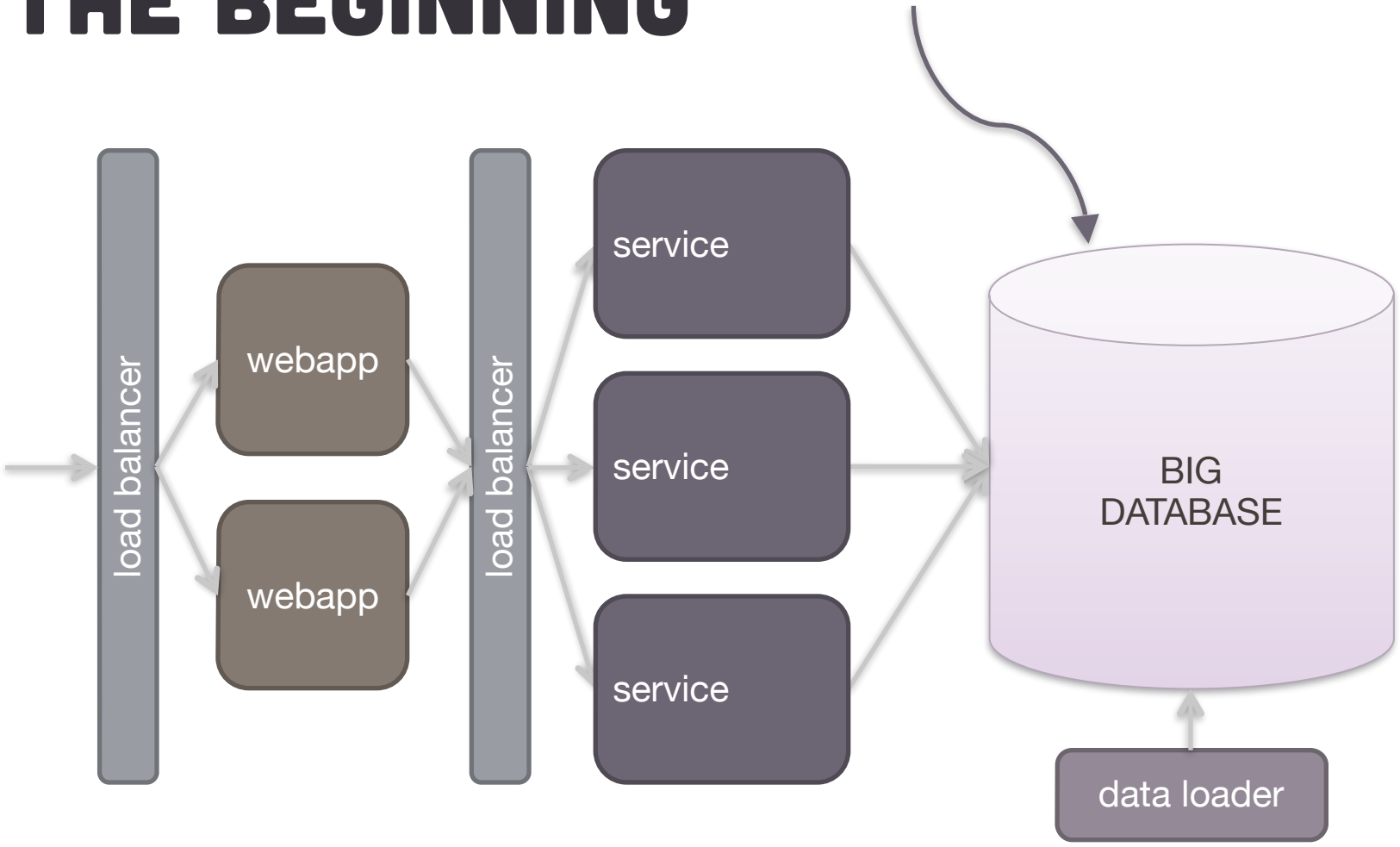


availability problems

THE BEGINNING



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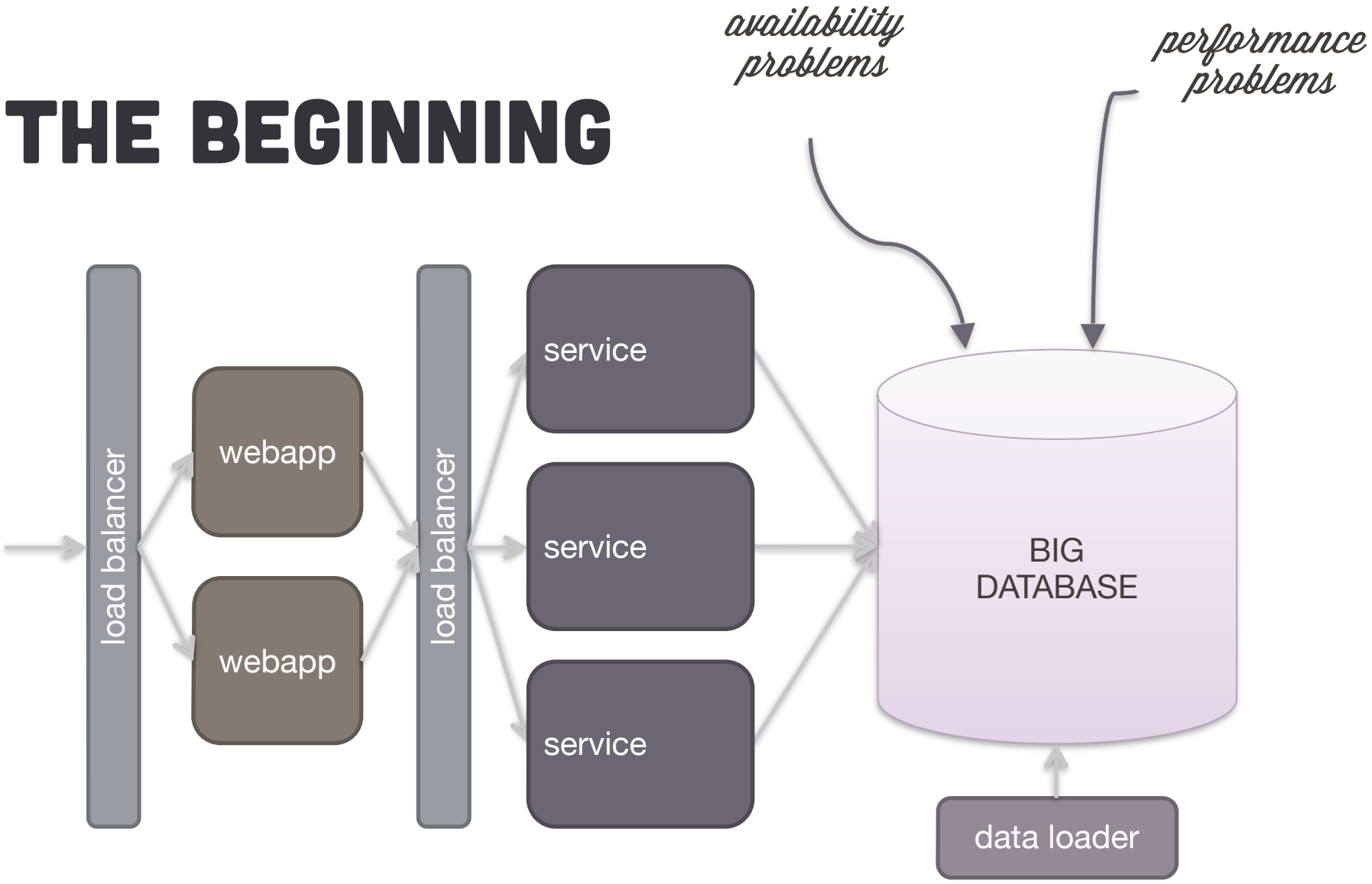

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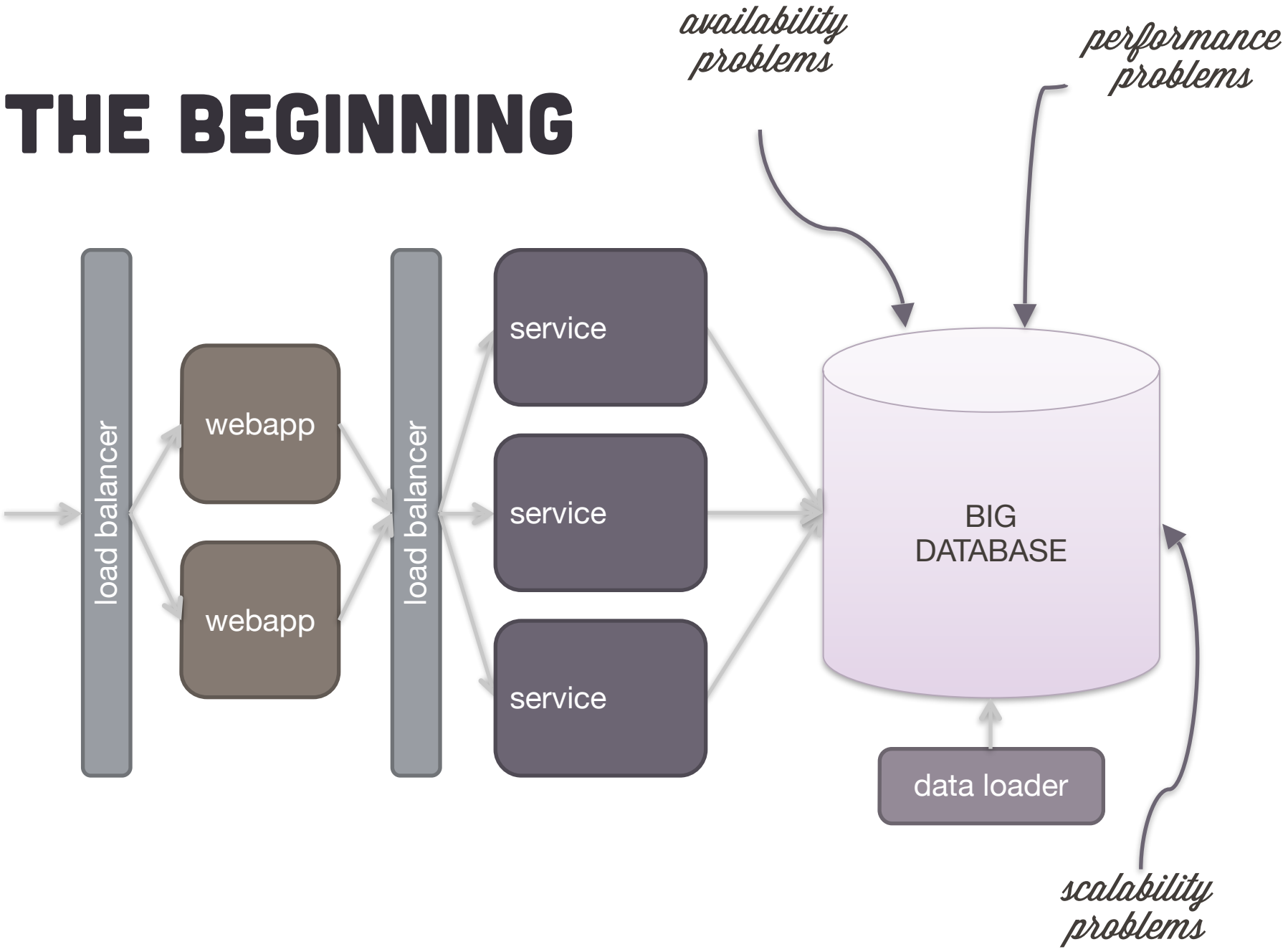

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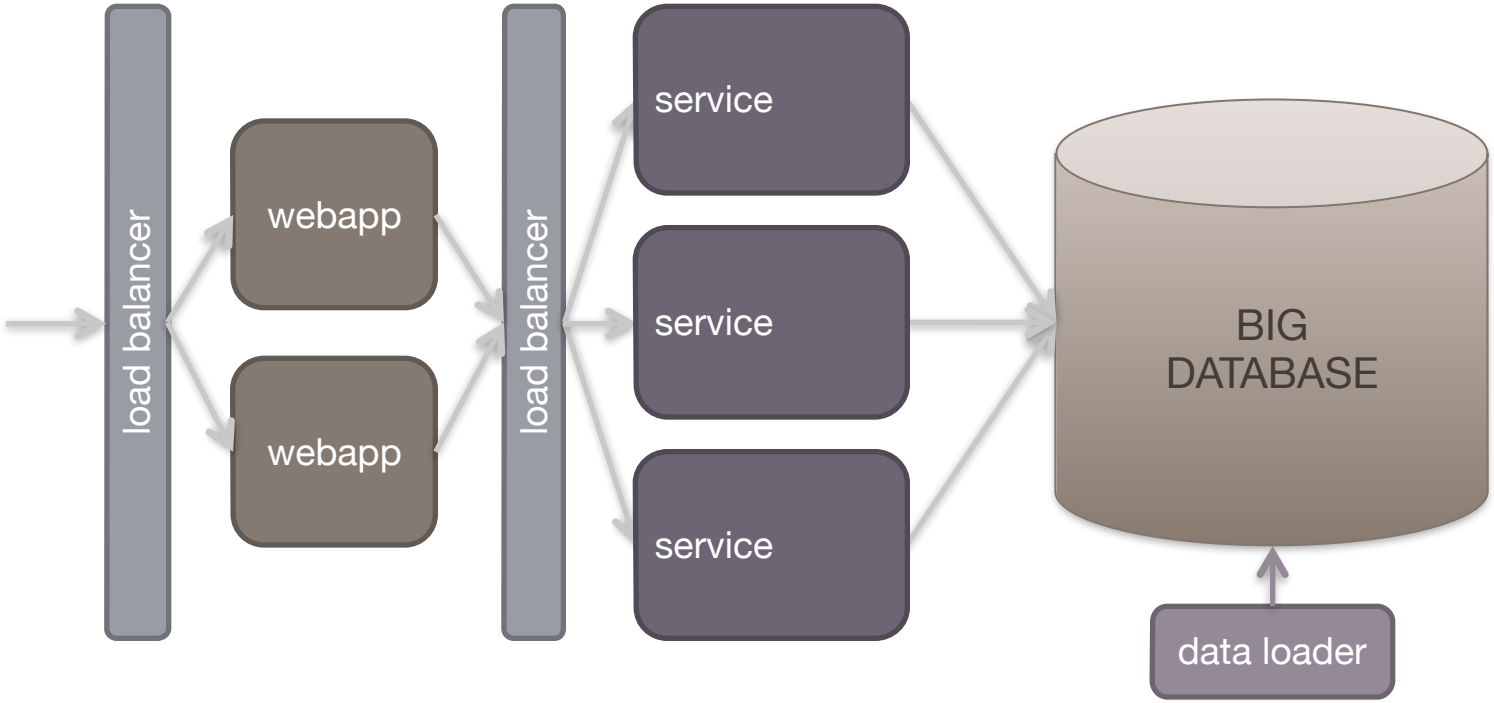

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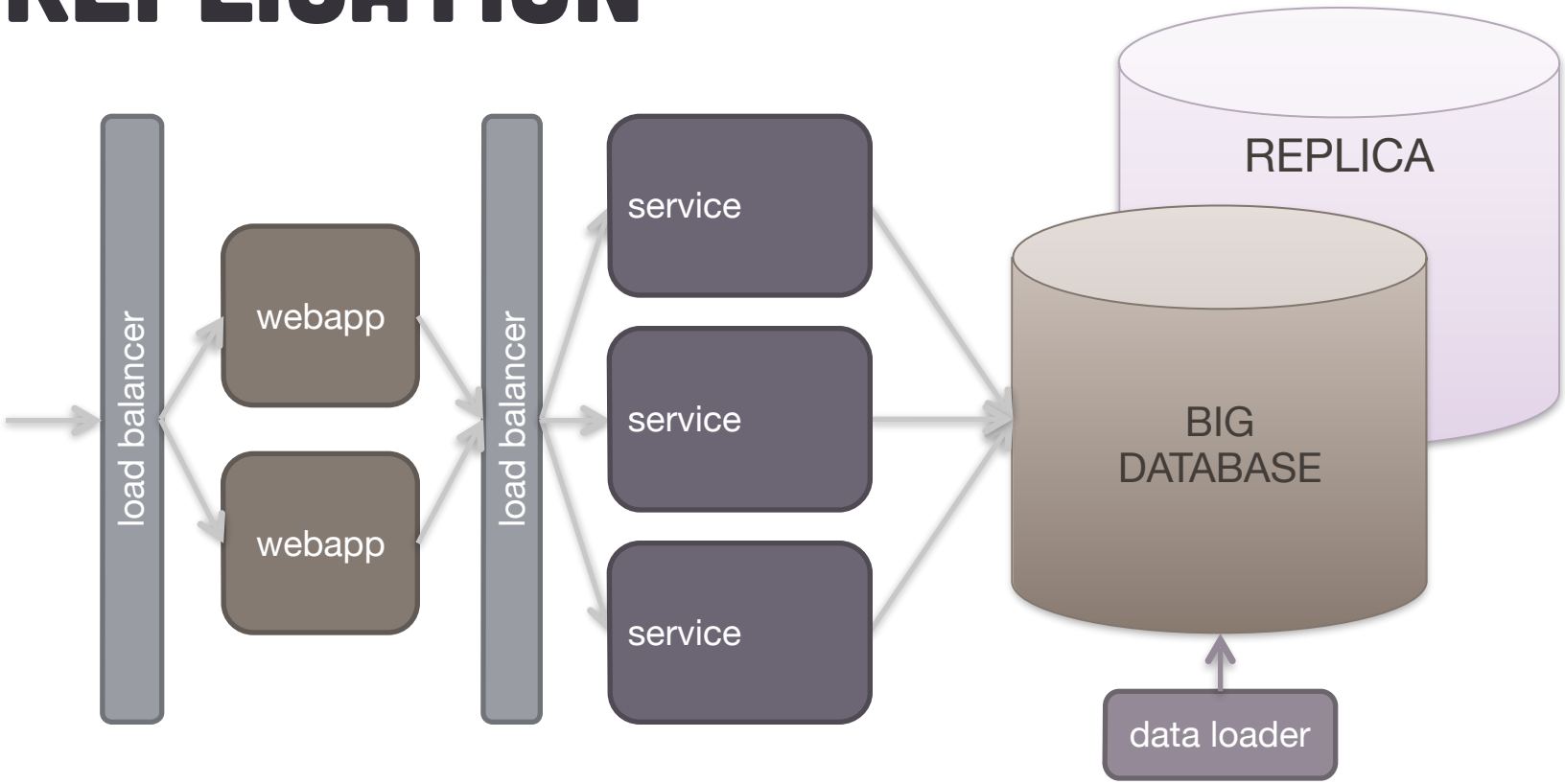

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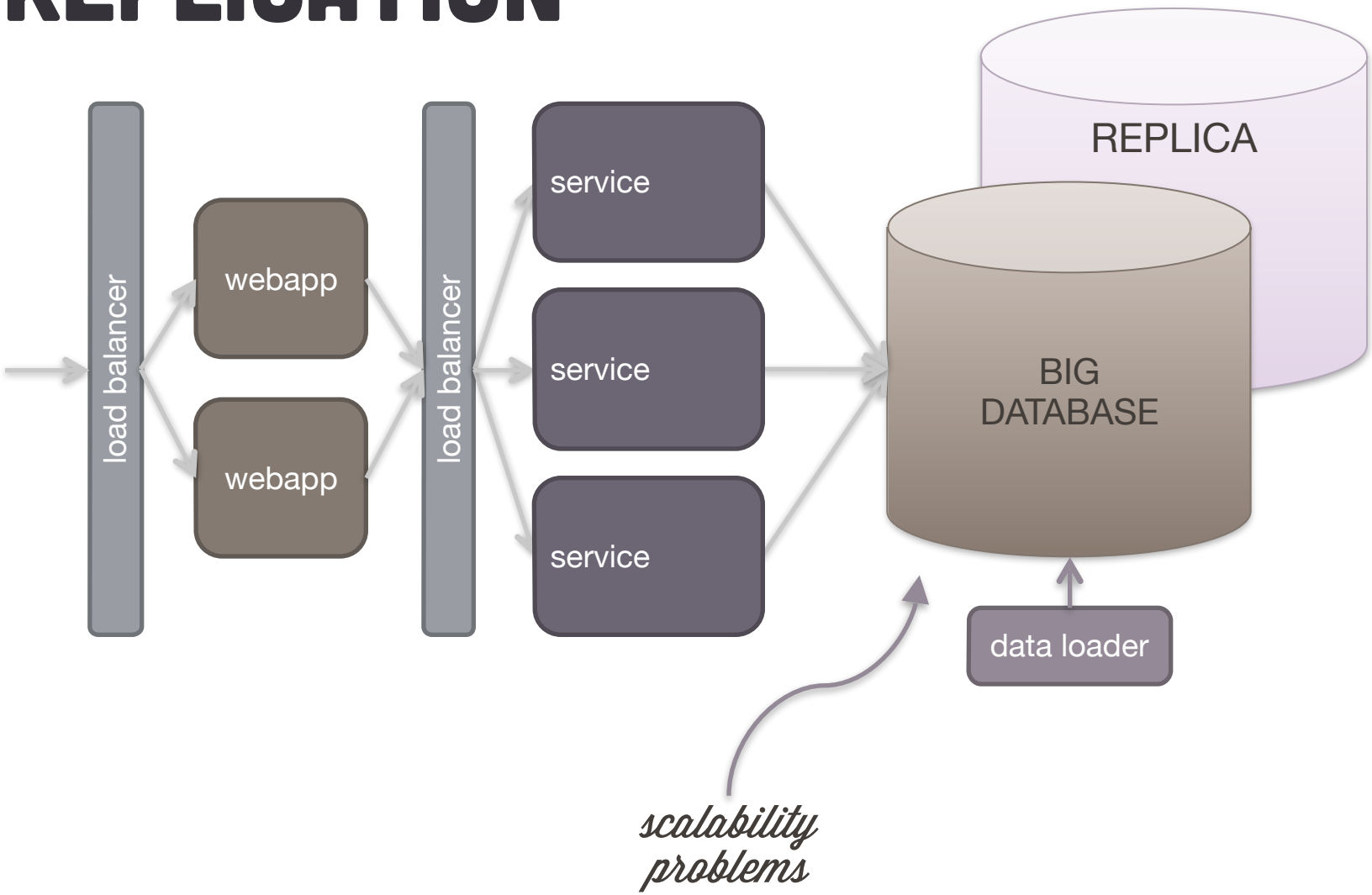

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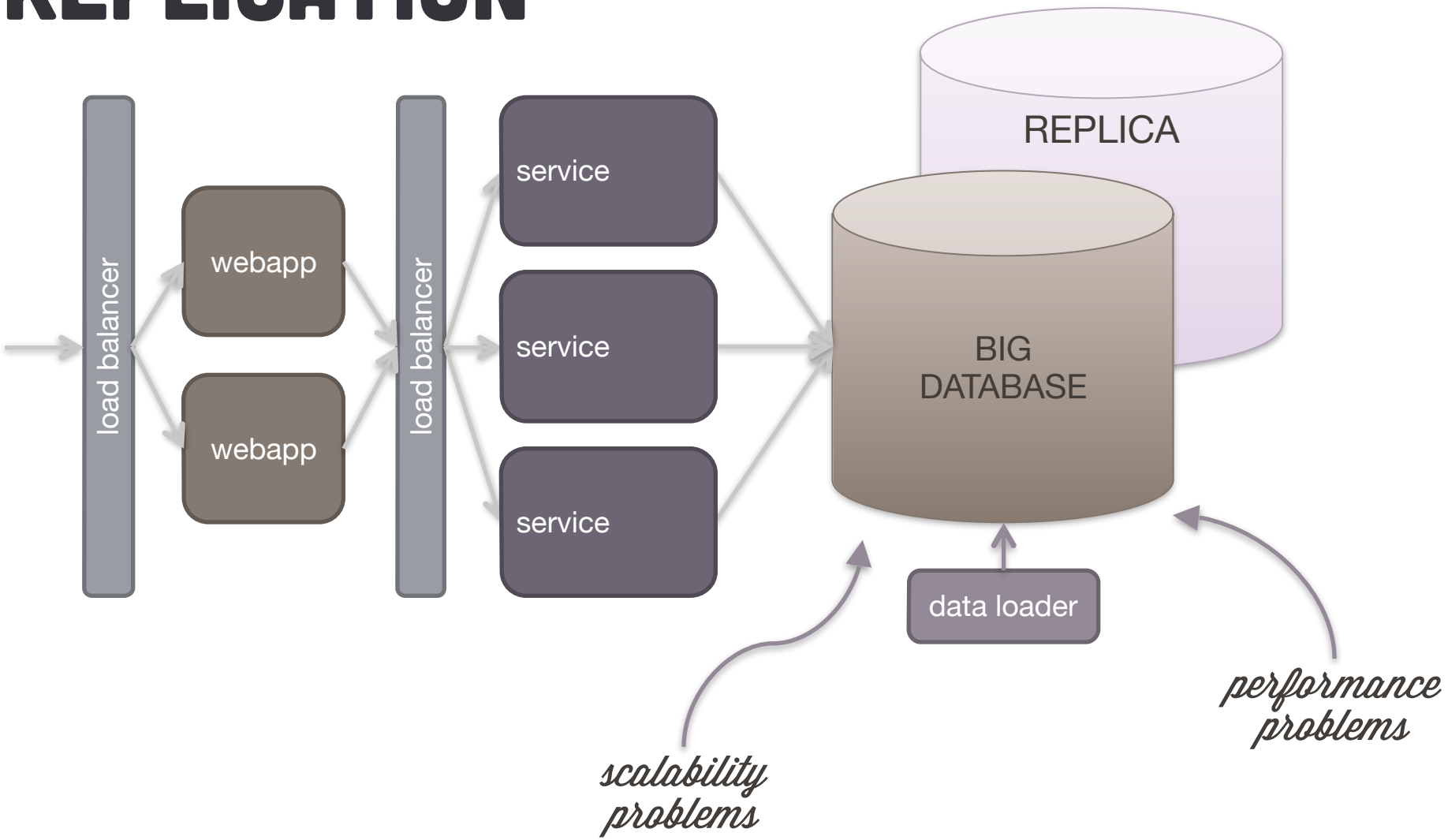

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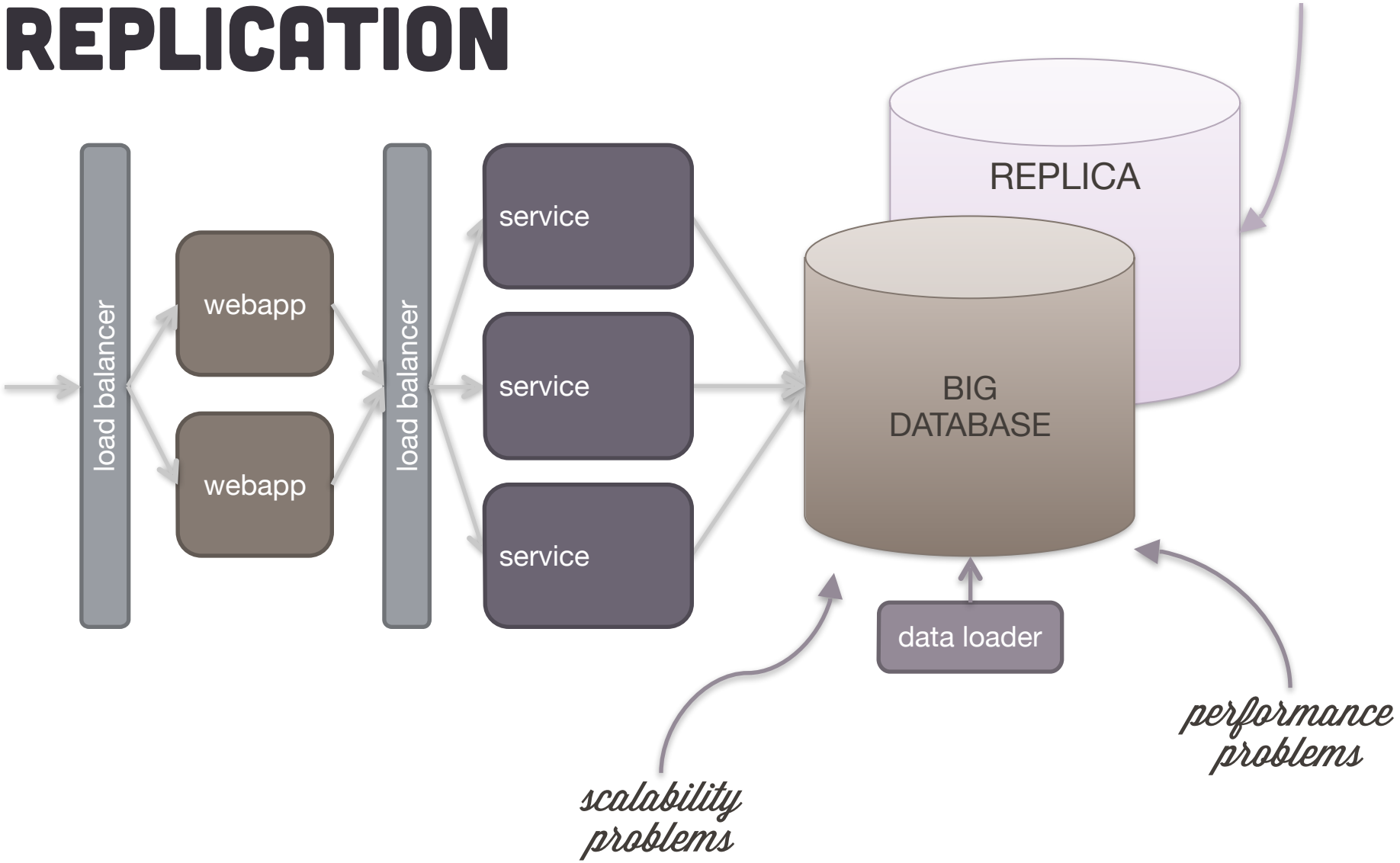

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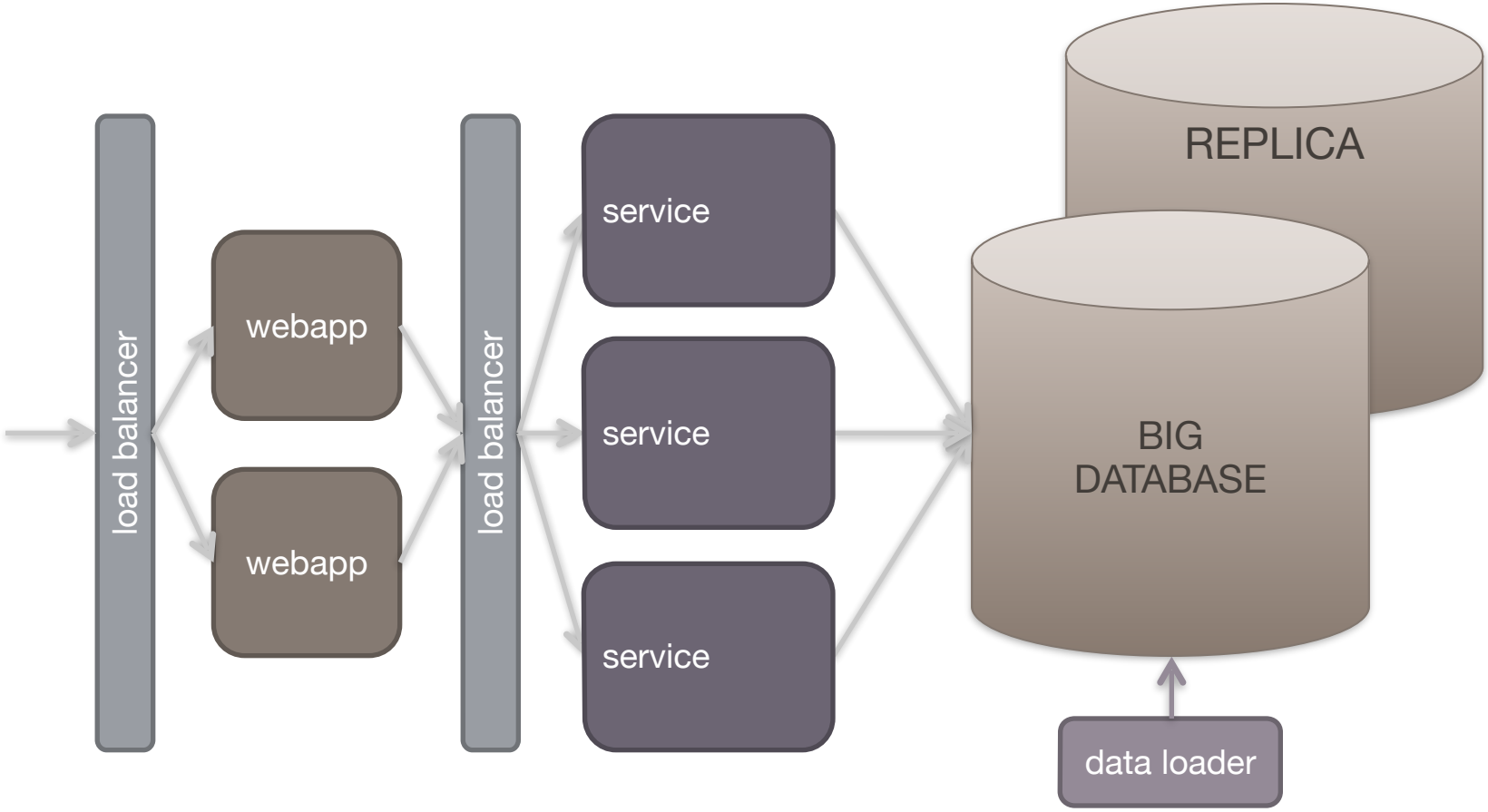

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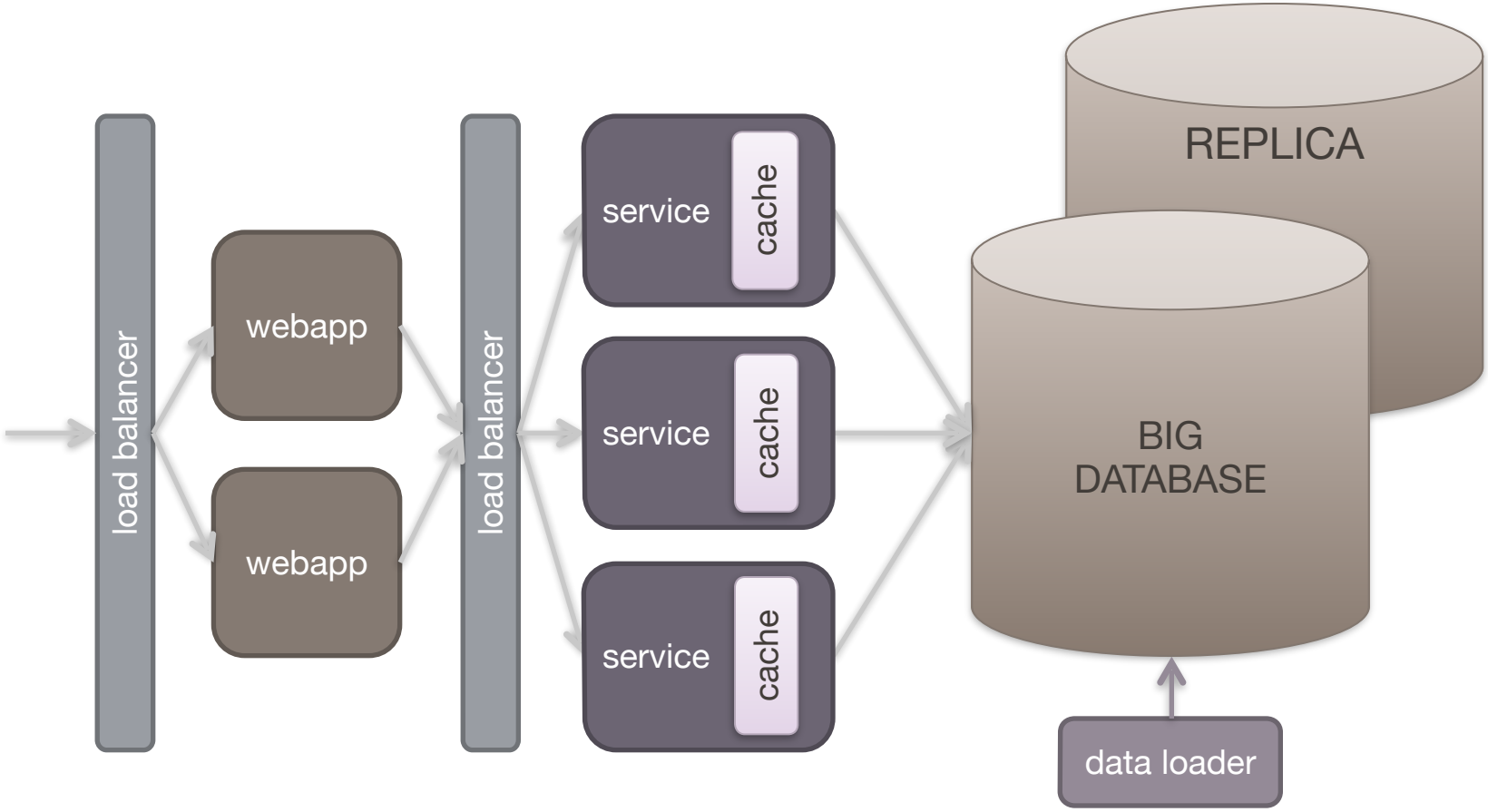
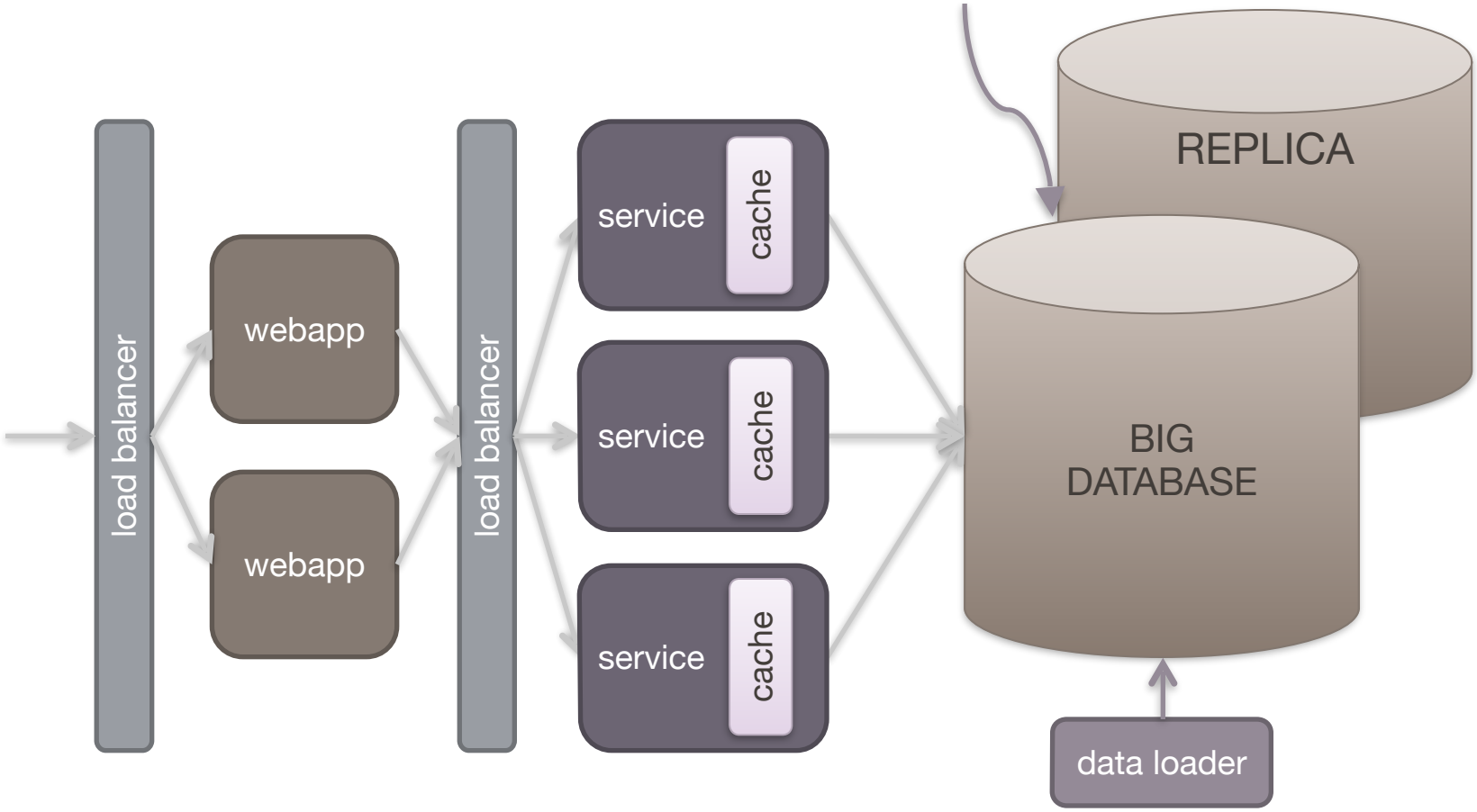


LOCAL CACHING

scalability problems



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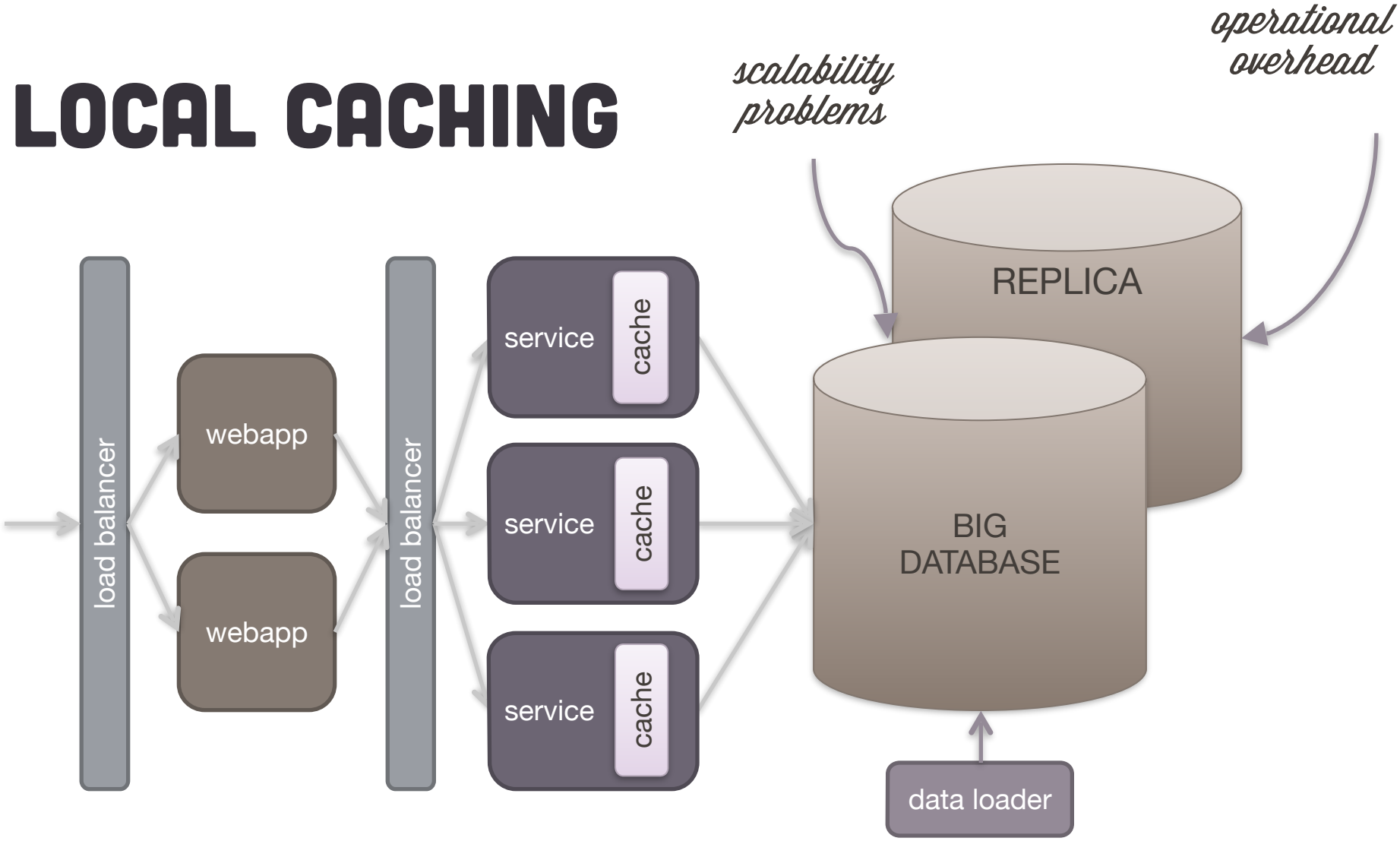

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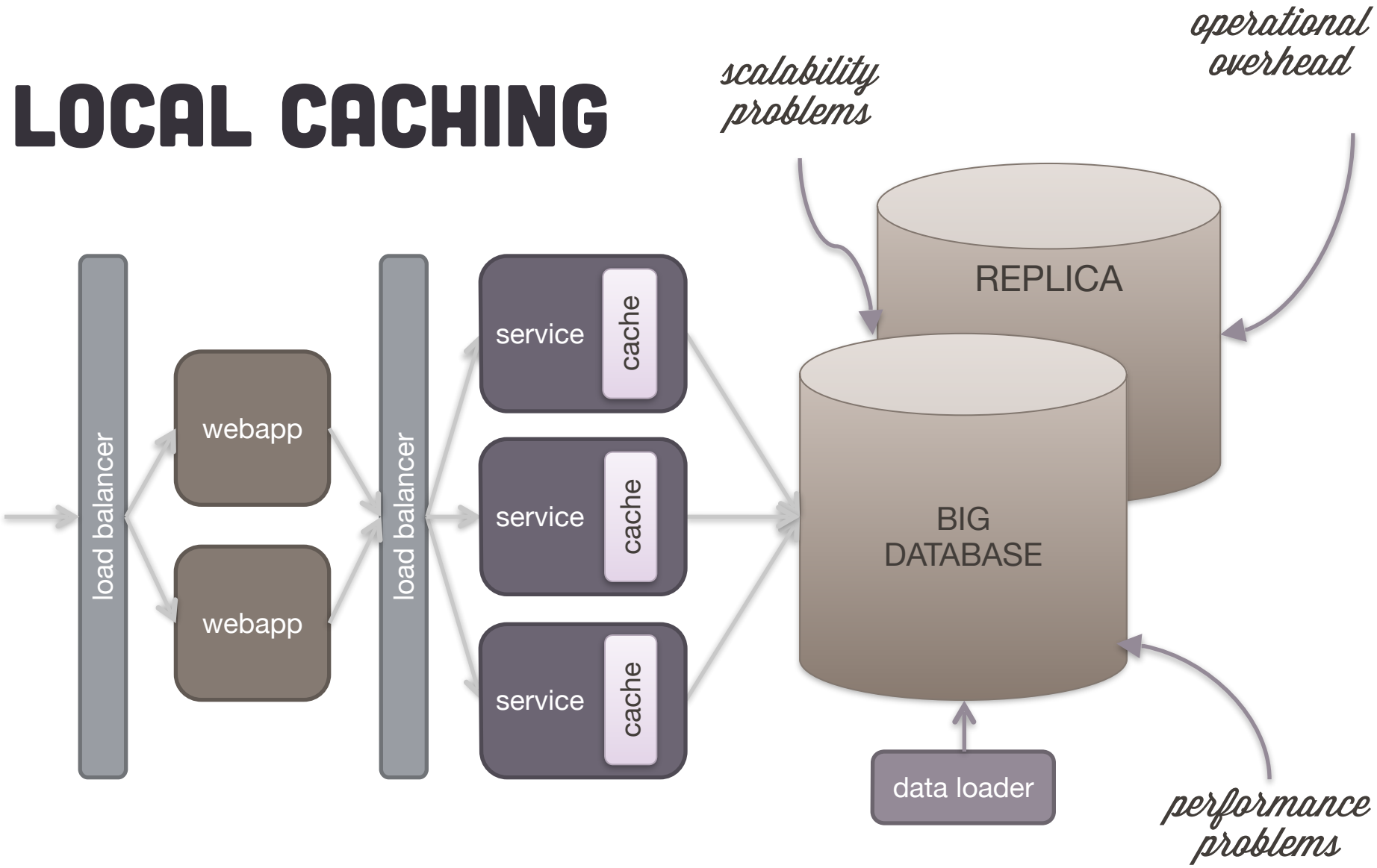

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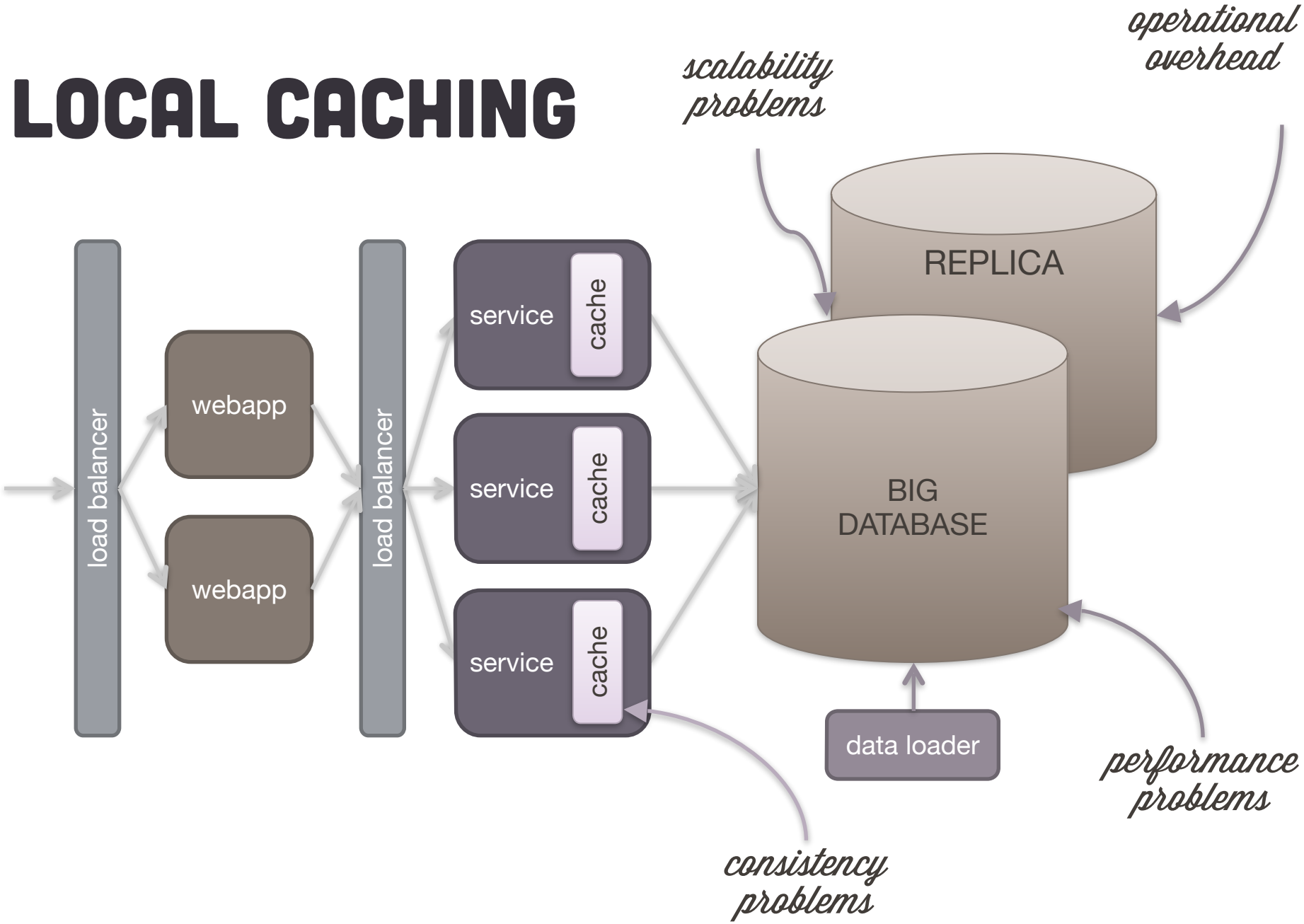

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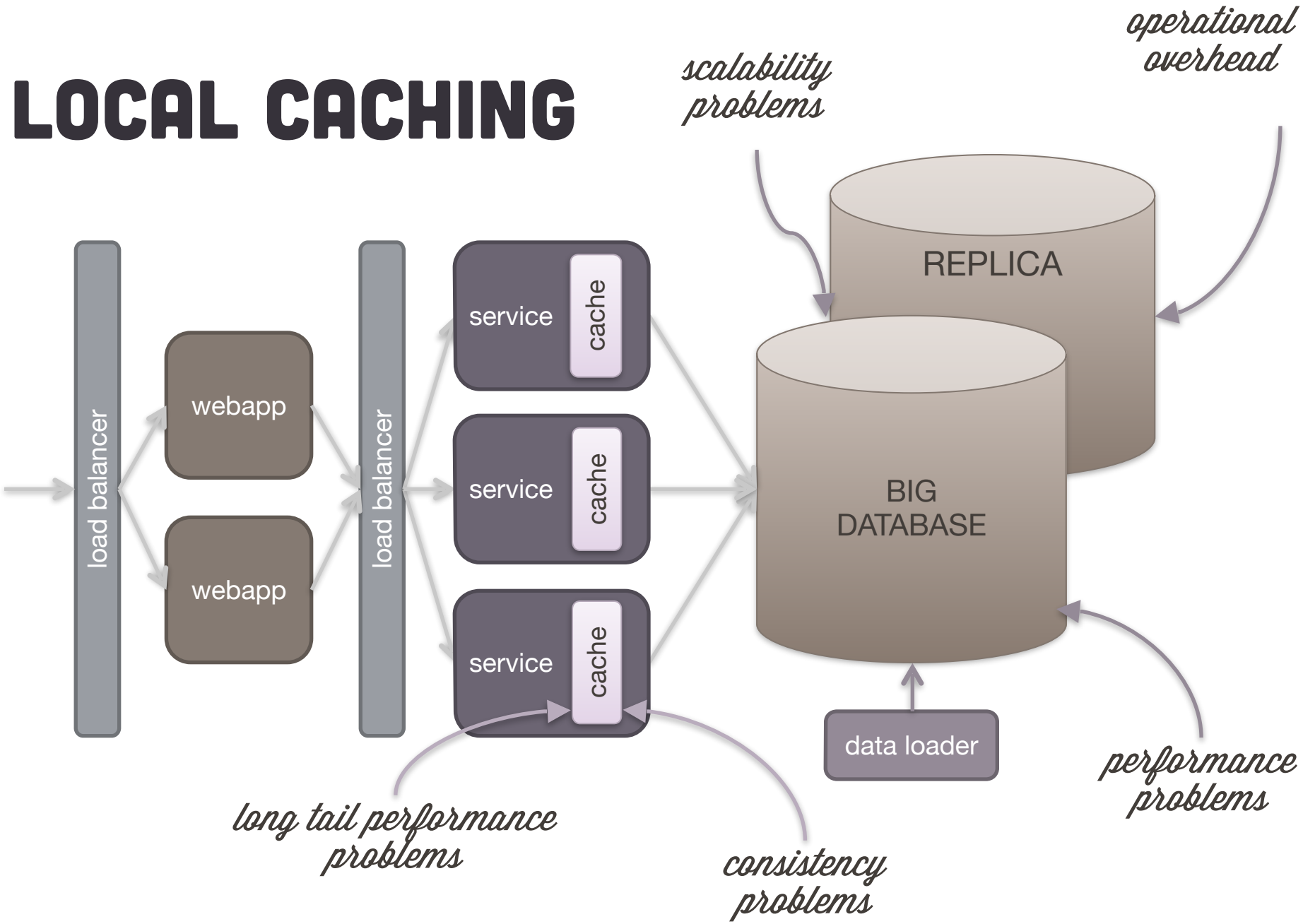

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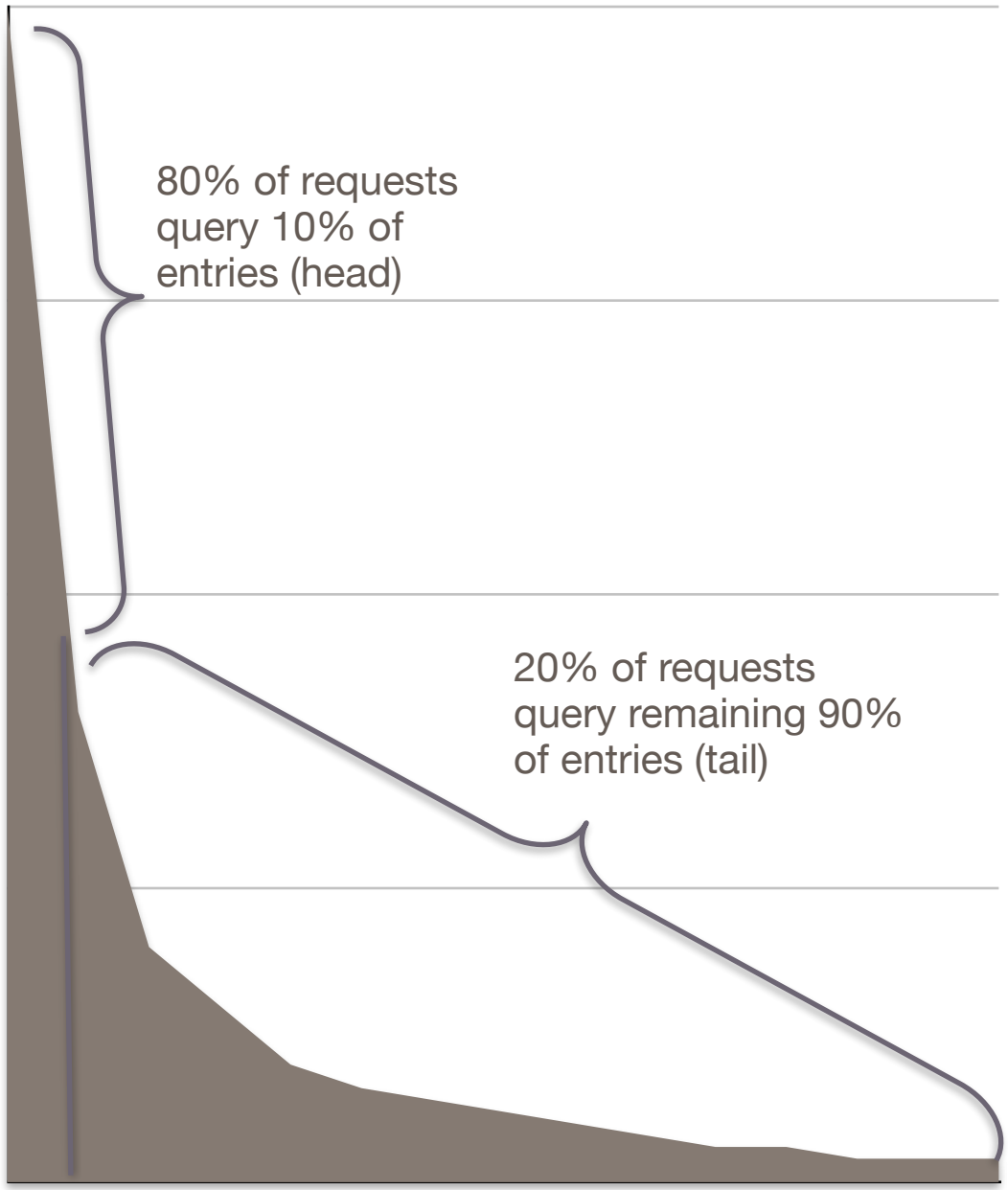

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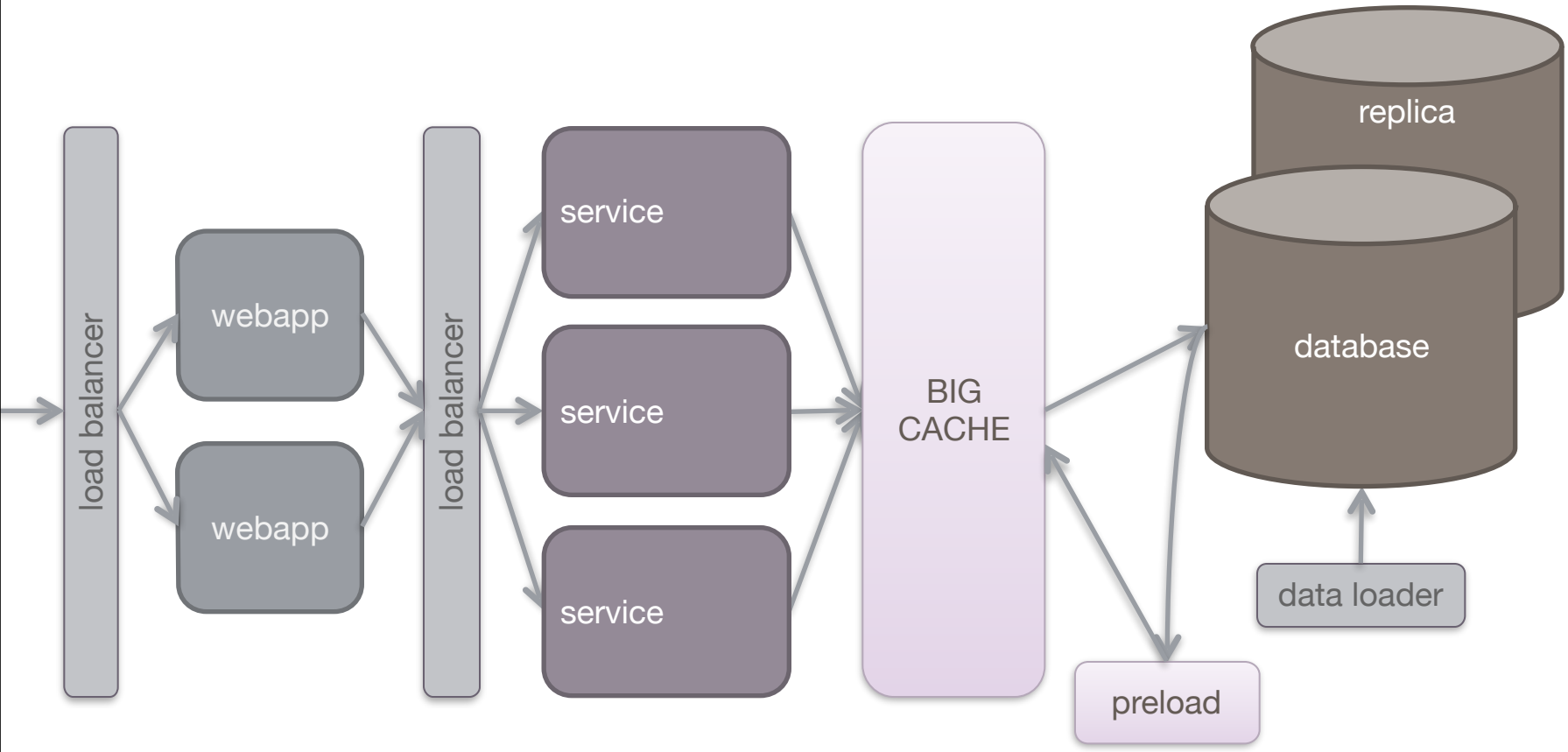
load balancer
webapp
webapp
load balancer
service
service
service
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replica
database
data loader
preload

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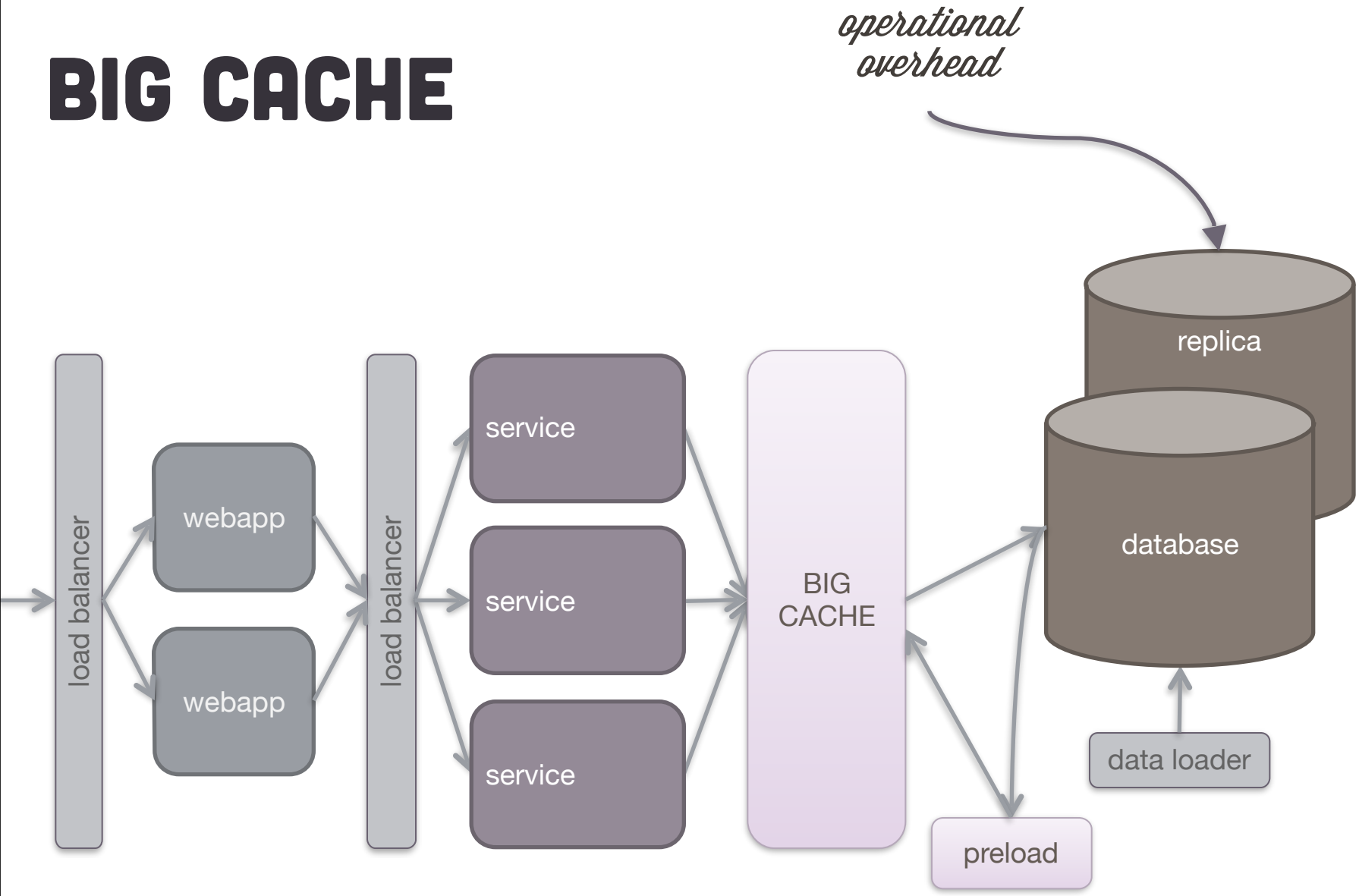
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webapp
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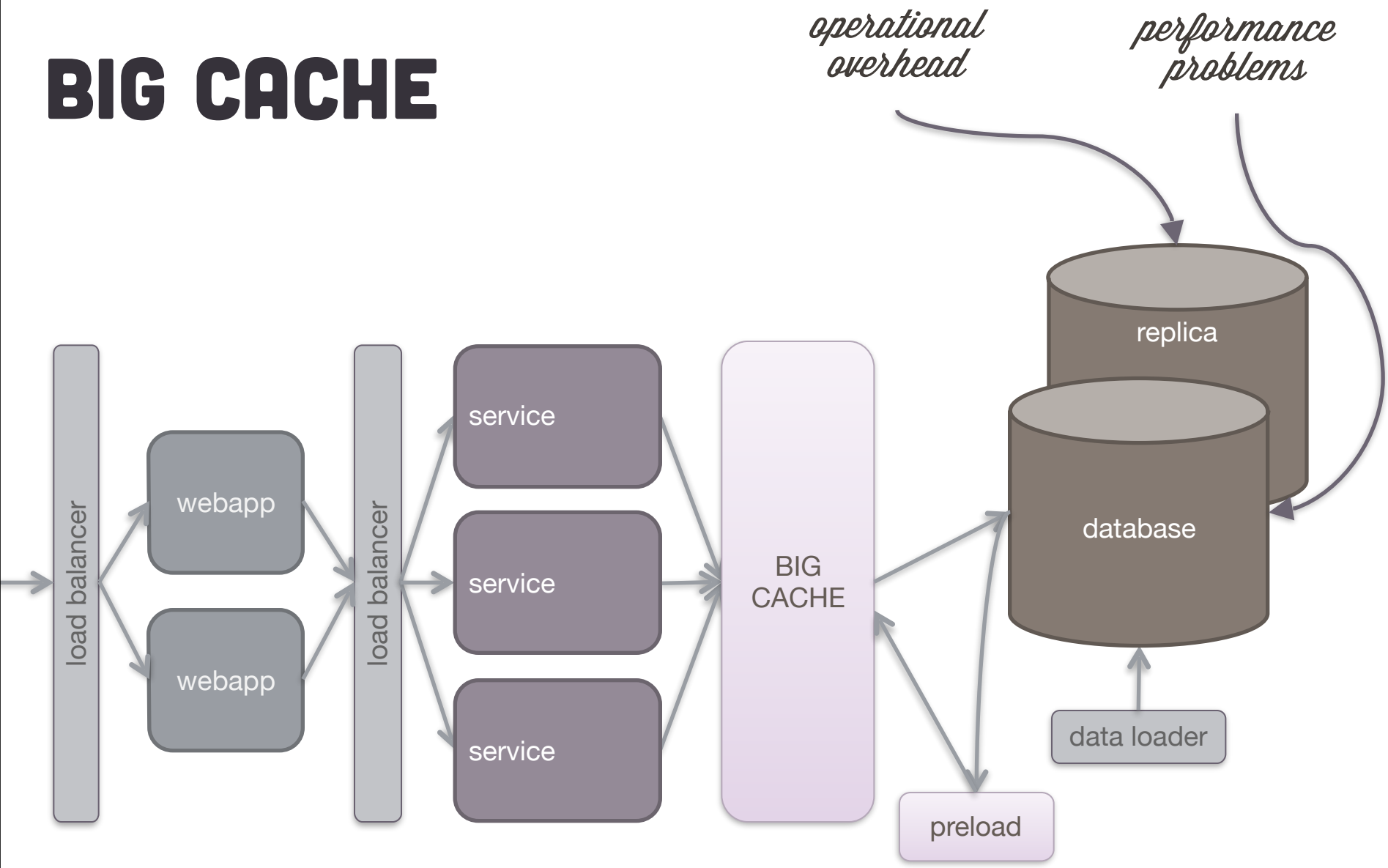
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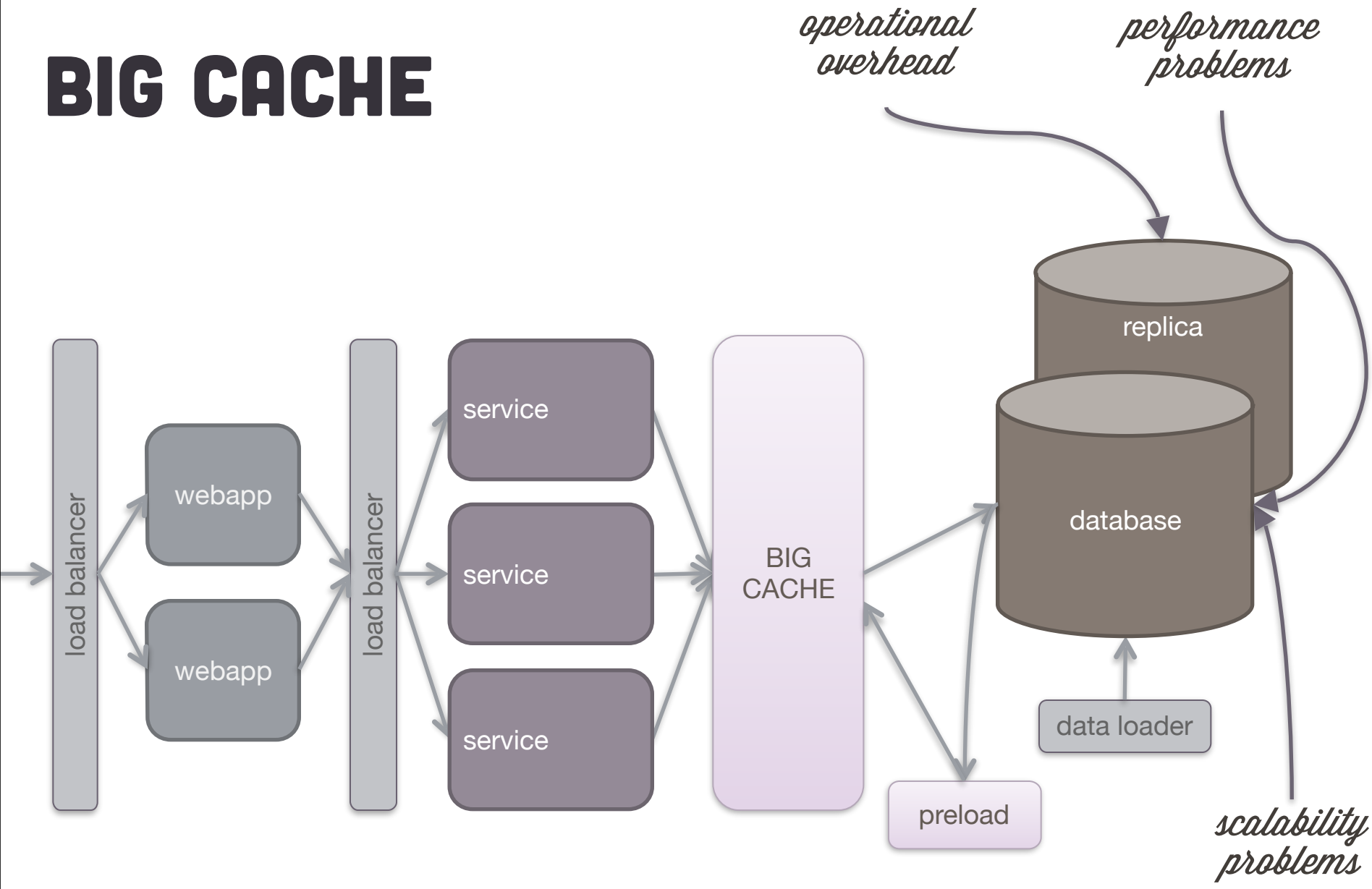
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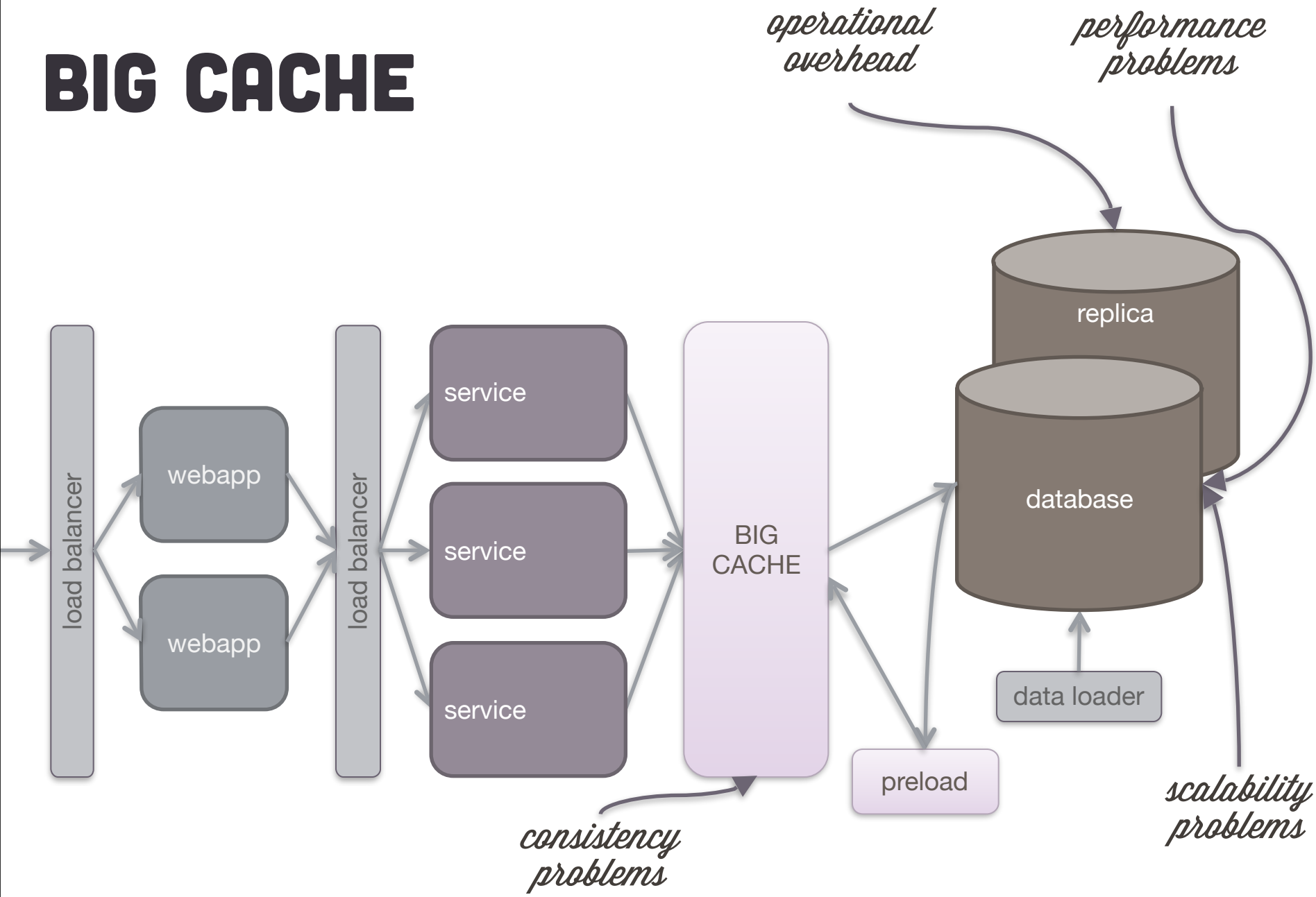
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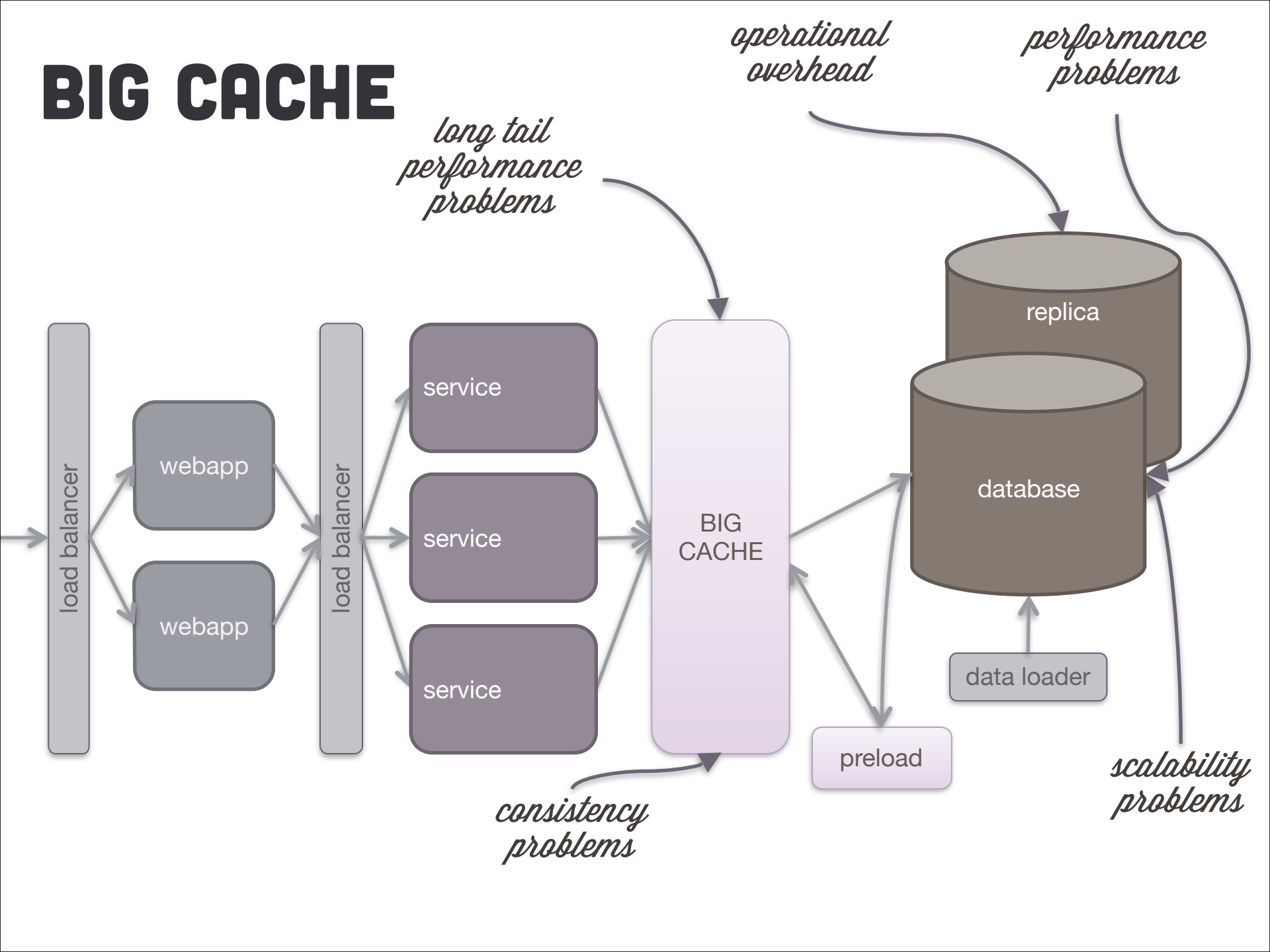
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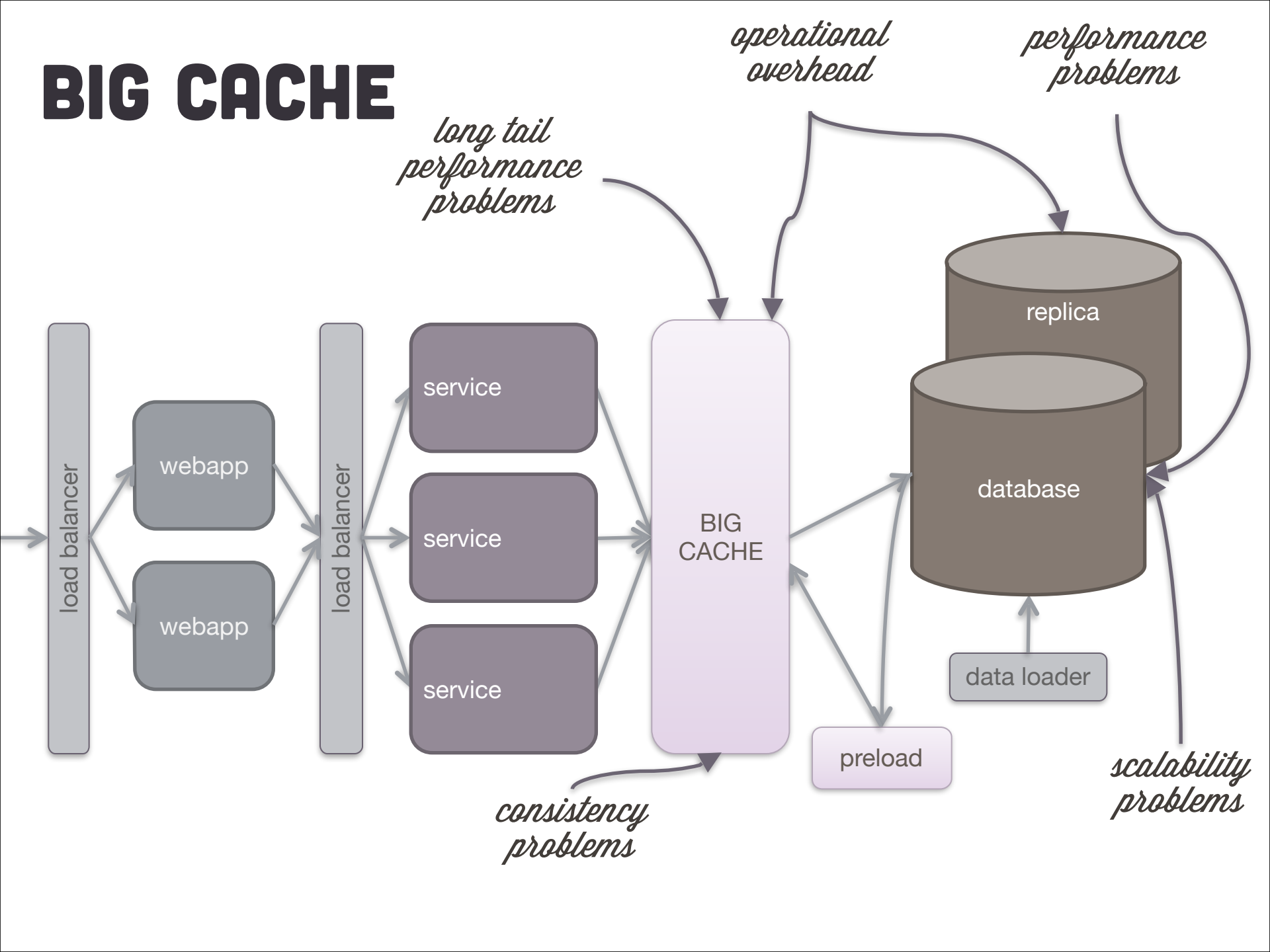
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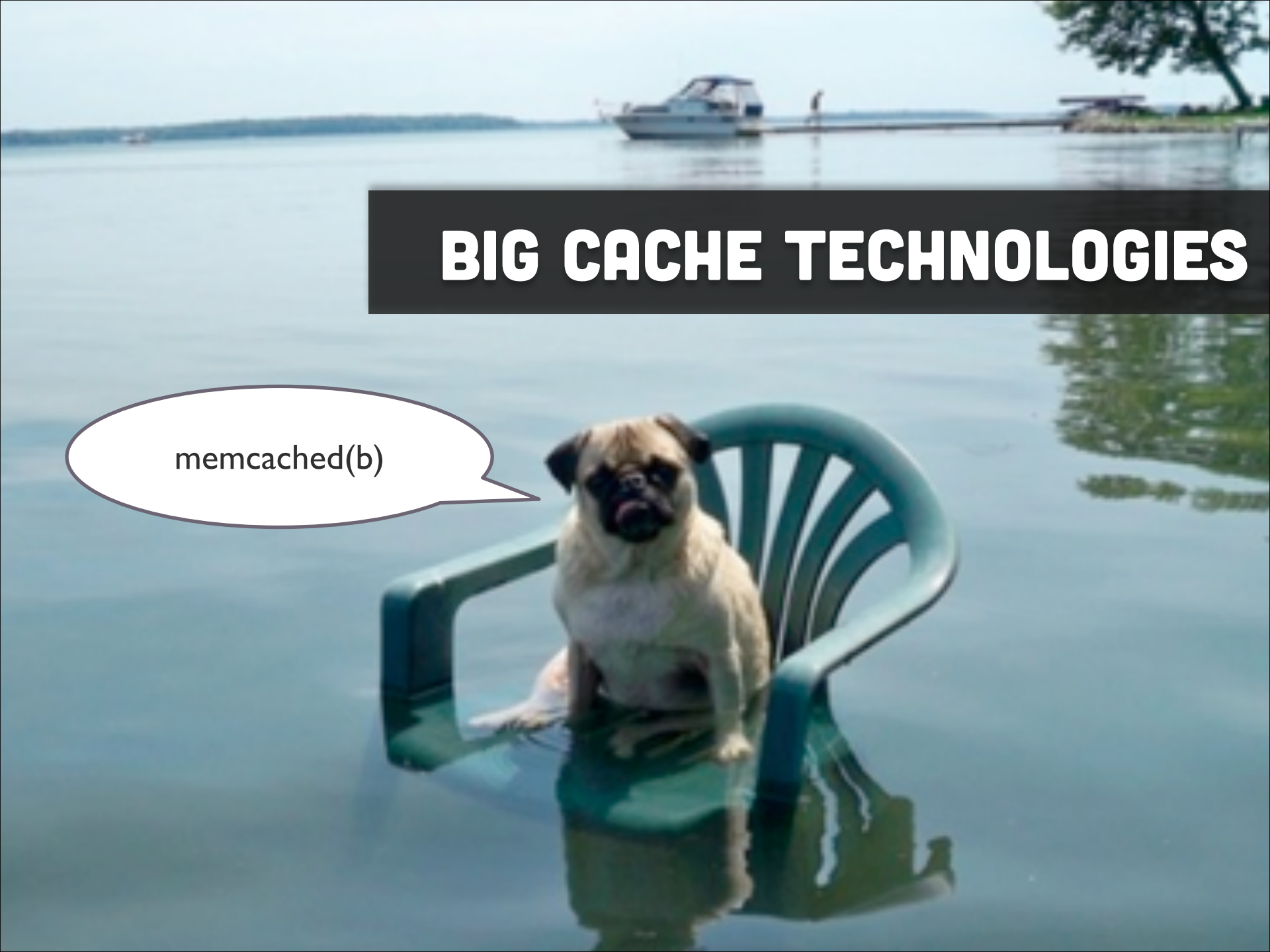

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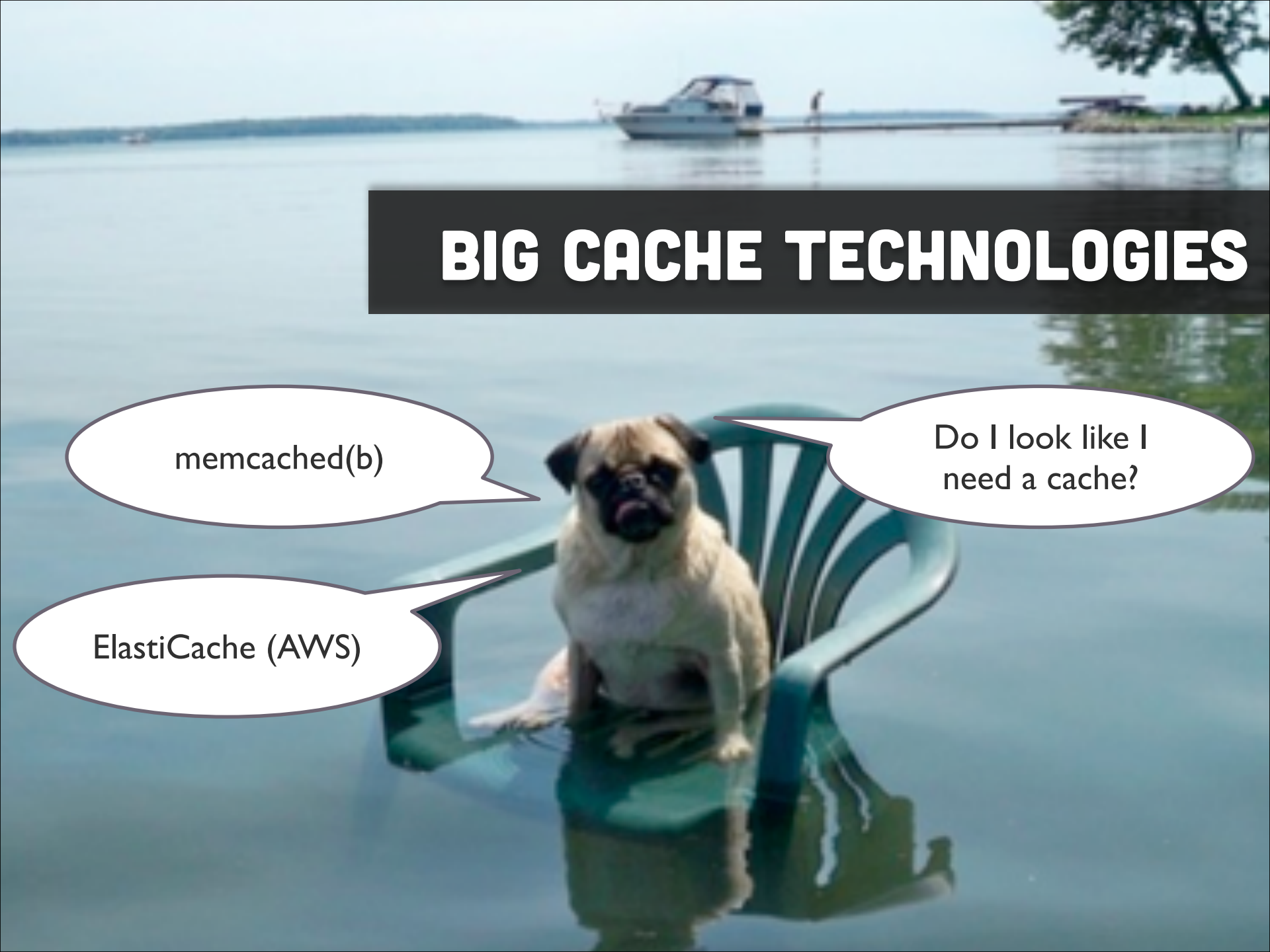

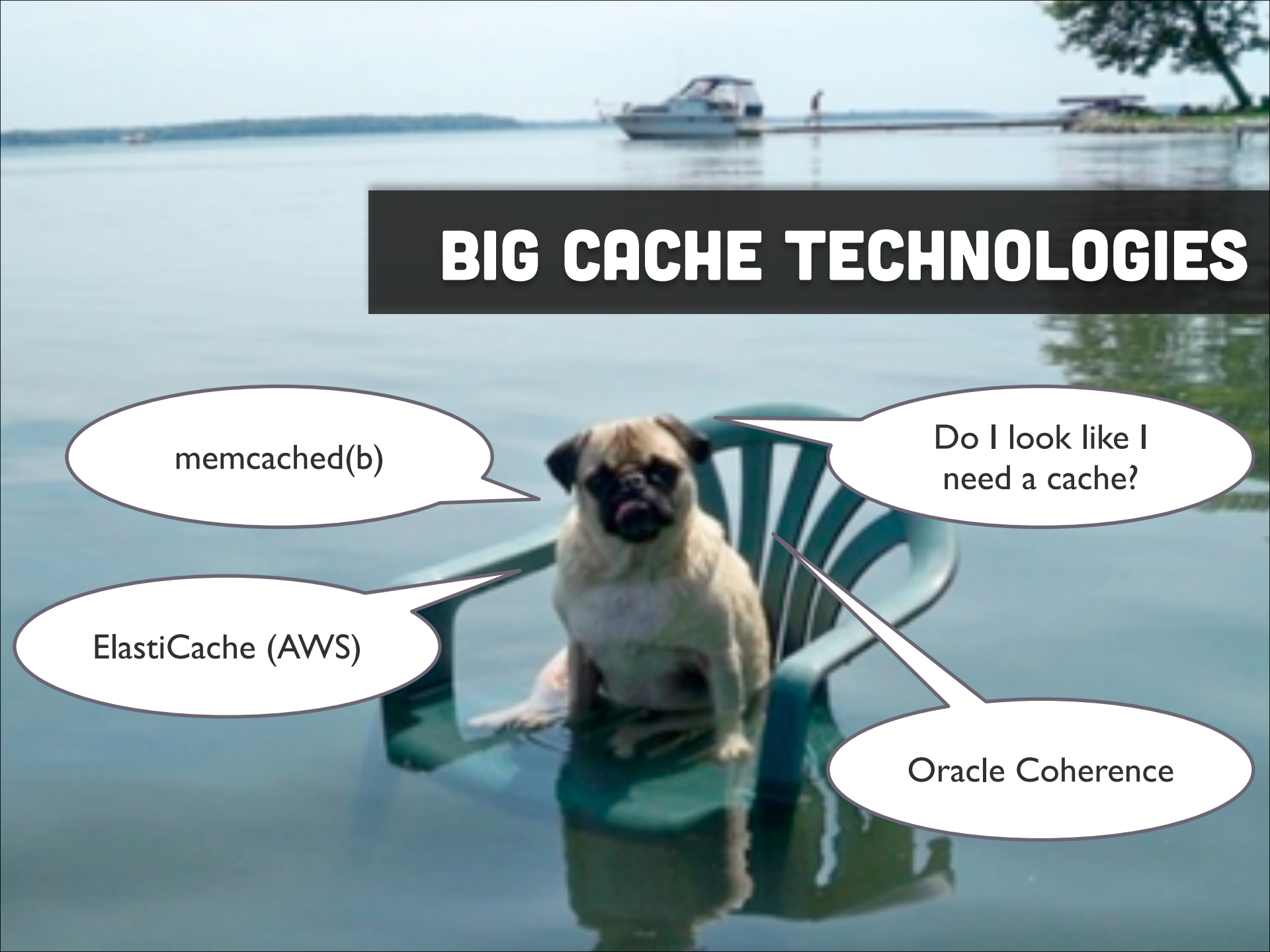
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Targeted generic data/ use cases.
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Scales horizontally
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Dynamically assign keys to the "nodes"
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Dynamically rebalances data
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Dynamically assign keys to the "nodes"
Targeted generic data/ use cases.
Scales horizontally
Dynamically rebalances data
Poor performance on cold starts
New
Ikea Kitteh Storage Solutions
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Dynamically assign keys to the "nodes"
Targeted generic data/ use cases.
Scales horizontally
Dynamically rebalances data
No assumptions about loading/ updating data
Poor performance on cold starts
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BIG CACHE TECHNOLOGIES

- Additional hardware
- Additional configuration
- Additional monitoring

- Extra network hop
- Slow scanning
- Additional deserialization

BIG CACHE TECHNOLOGIES

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} *operational overhead*

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BIG CACHE TECHNOLOGIES

- Additional hardware
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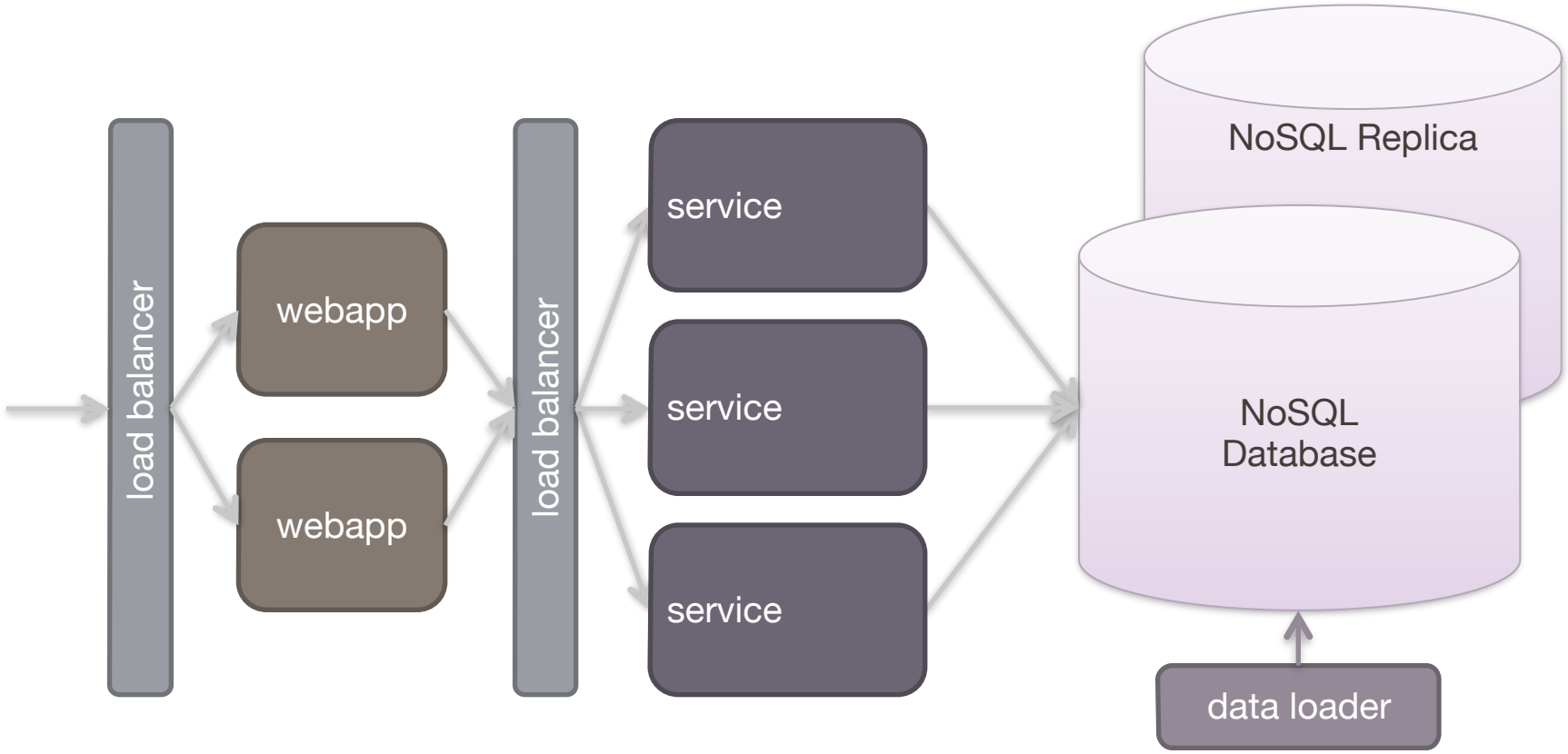
- Additional monitoring

} *operational overhead*

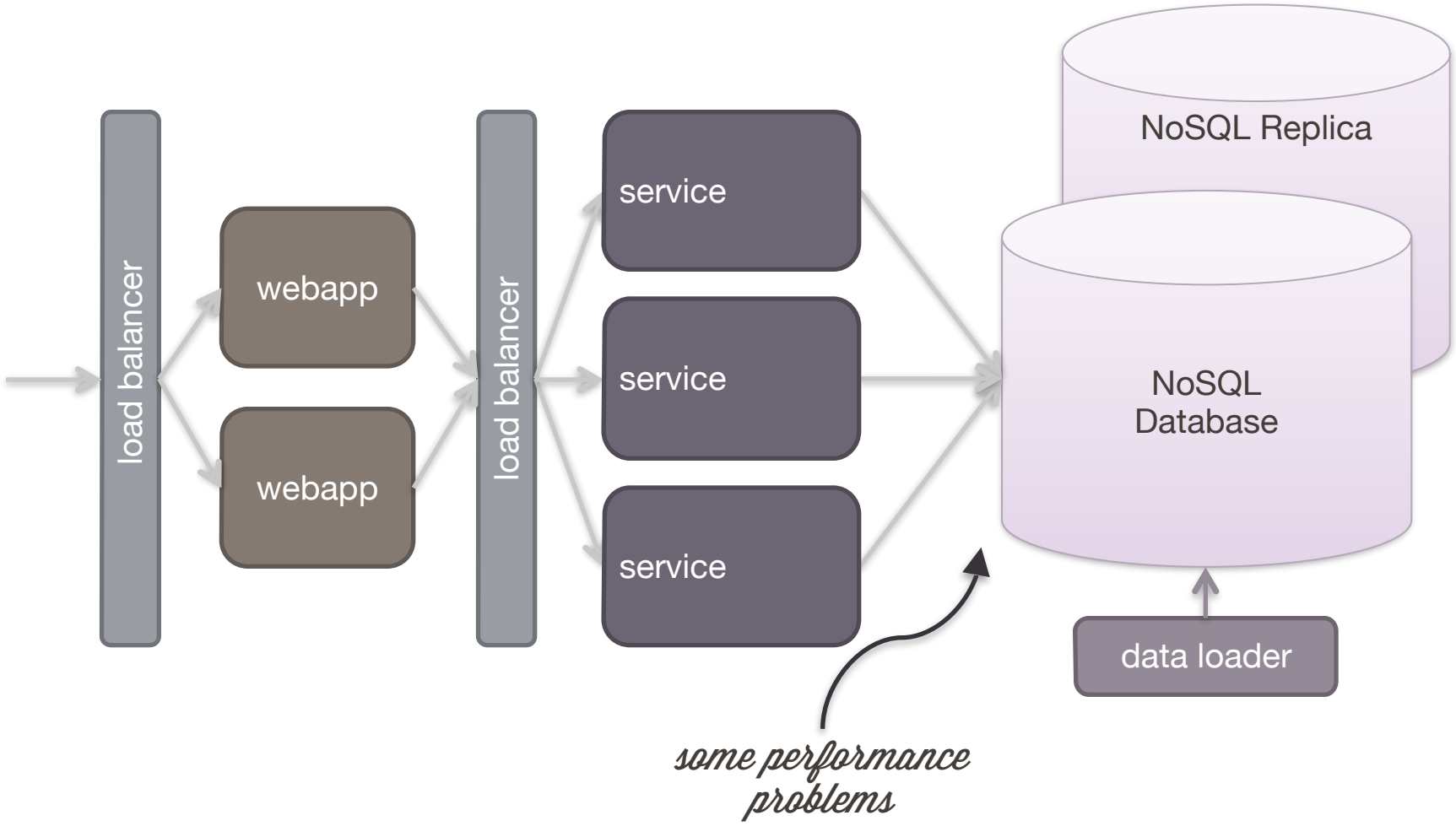
- Extra network hop
- Slow scanning
- Additional deserialization

} *performance*

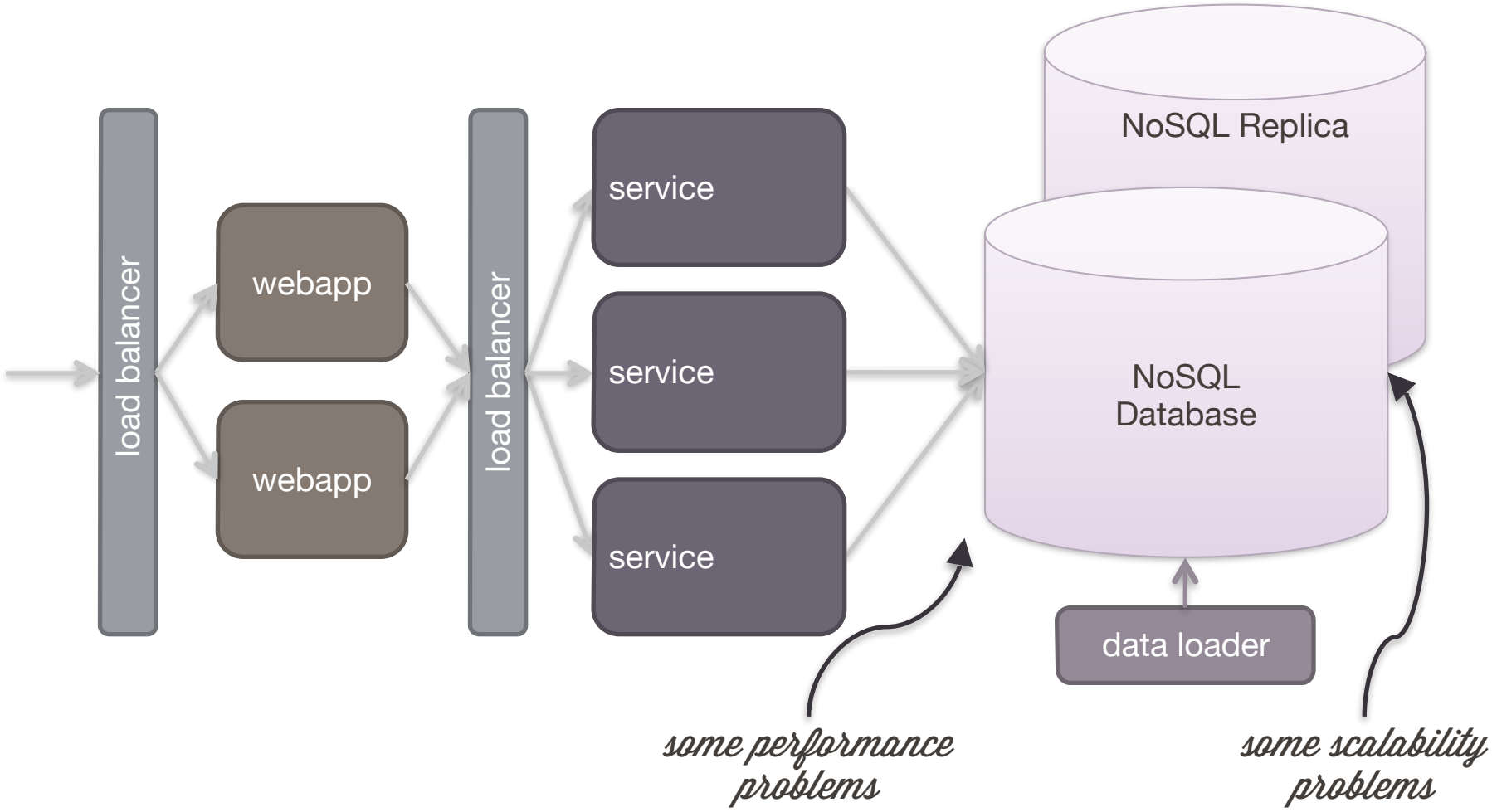
NOSQL TO THE RESCUE?



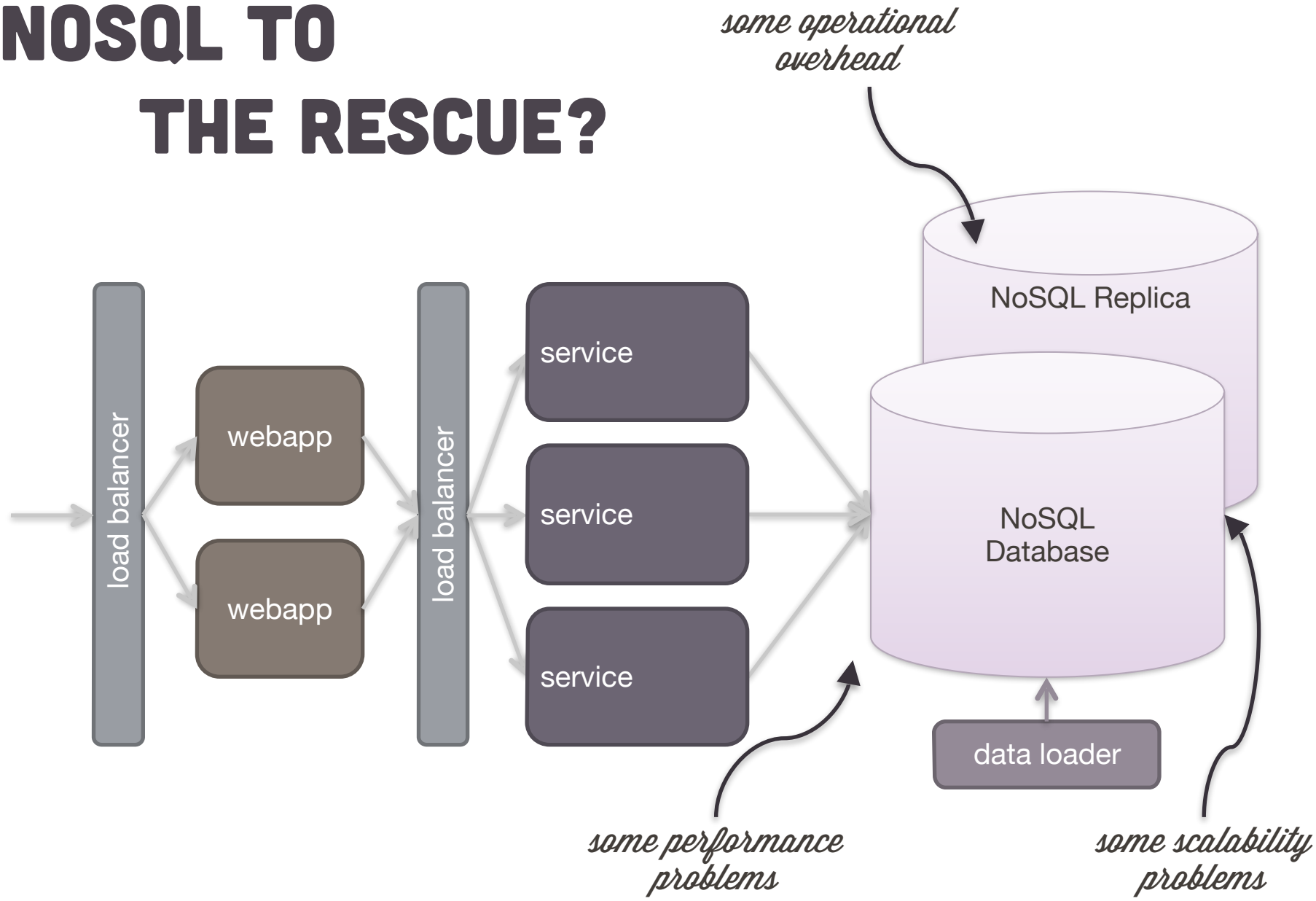
NOSQL TO THE RESCUE?



NOSQL TO THE RESCUE?



NOSQL TO THE RESCUE?



REMOTE STORE RETRIEVAL LATENCY

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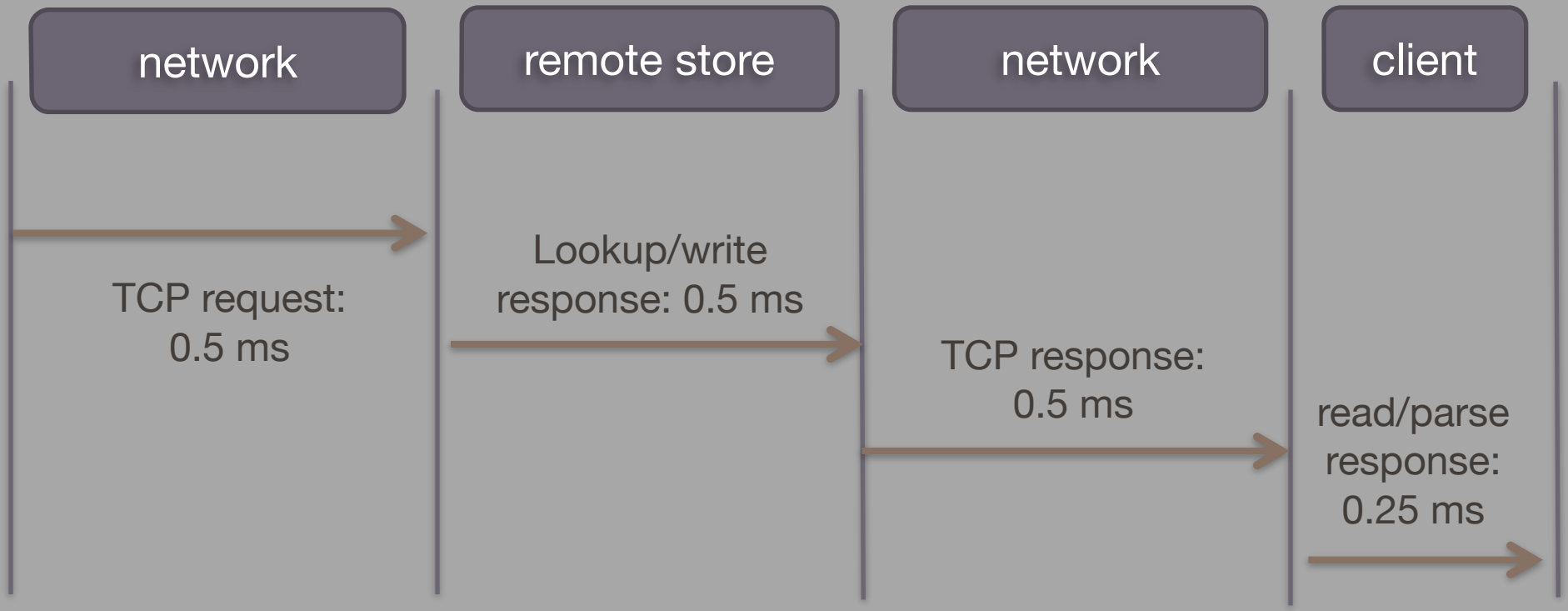
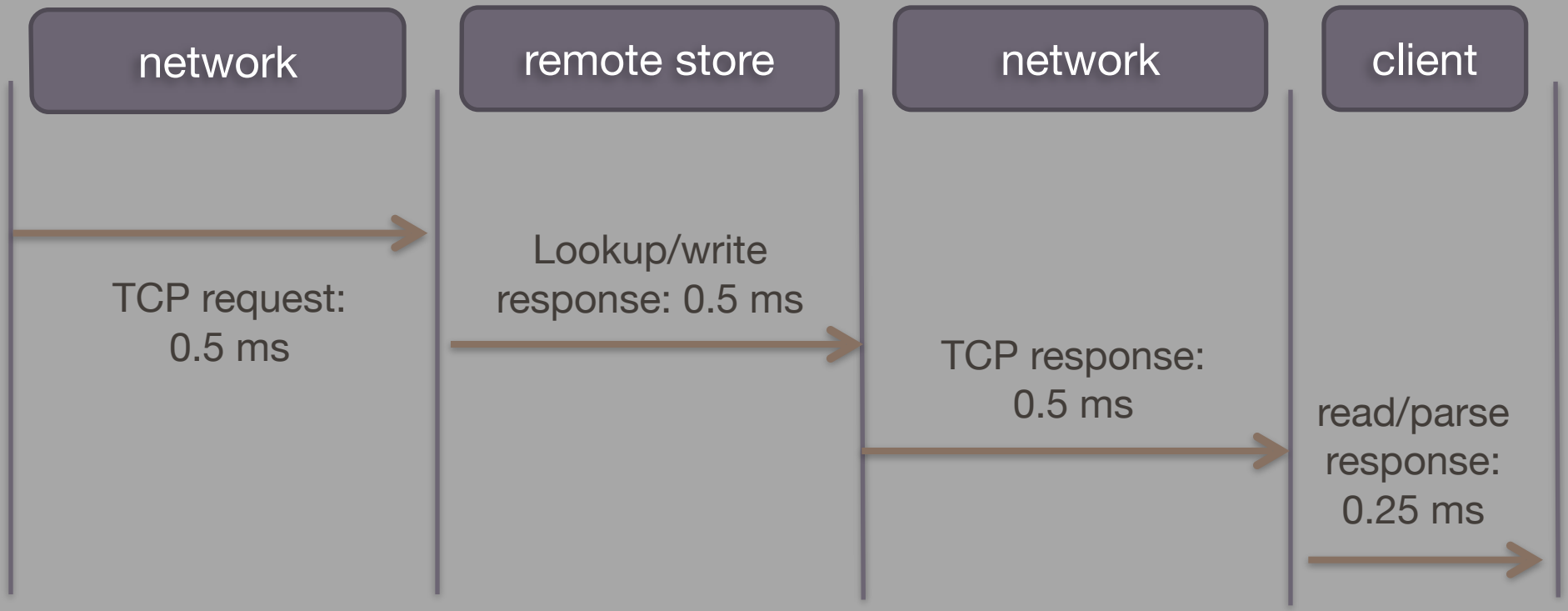


REMOTE STORE RETRIEVAL LATENCY



Total time to retrieve single value:

1.75 MS

TOTAL TIME TO RETRIEVE A SINGLE VALUE

from remote store: 1.75 ms
from memory: 0.001 ms
(10 main memory reads)

TOTAL TIME TO RETRIEVE A SINGLE VALUE

from remote store: 1.75 ms
from memory: 0.001 ms
(10 main memory reads)

SEQUENTIAL ACCESS OF 1 MILLION RANDOM KEYS

from remote store: 30 minutes
from memory: 1 second

THE TRUTH ABOUT DATABASES

“What I'm going to call as the *hot data cliff*: As the size of your hot data set (data frequently read at sustained rates above disk I/O capacity) approaches available memory, write operation bursts that exceeds disk write I/O capacity can create a *trashing death spiral* where hot disk pages that MongoDB desperately needs are evicted from disk cache by the OS as it consumes more buffer space to hold the writes in memory.”

MONGODB

Source: http://www.quora.com/Is-MongoDB-a-good-replacement-for-Memcached

“Redis is an in-memory but persistent on disk database, so it represents a different trade off where very high write and read speed is achieved with the limitation of data sets that can't be larger than memory.”

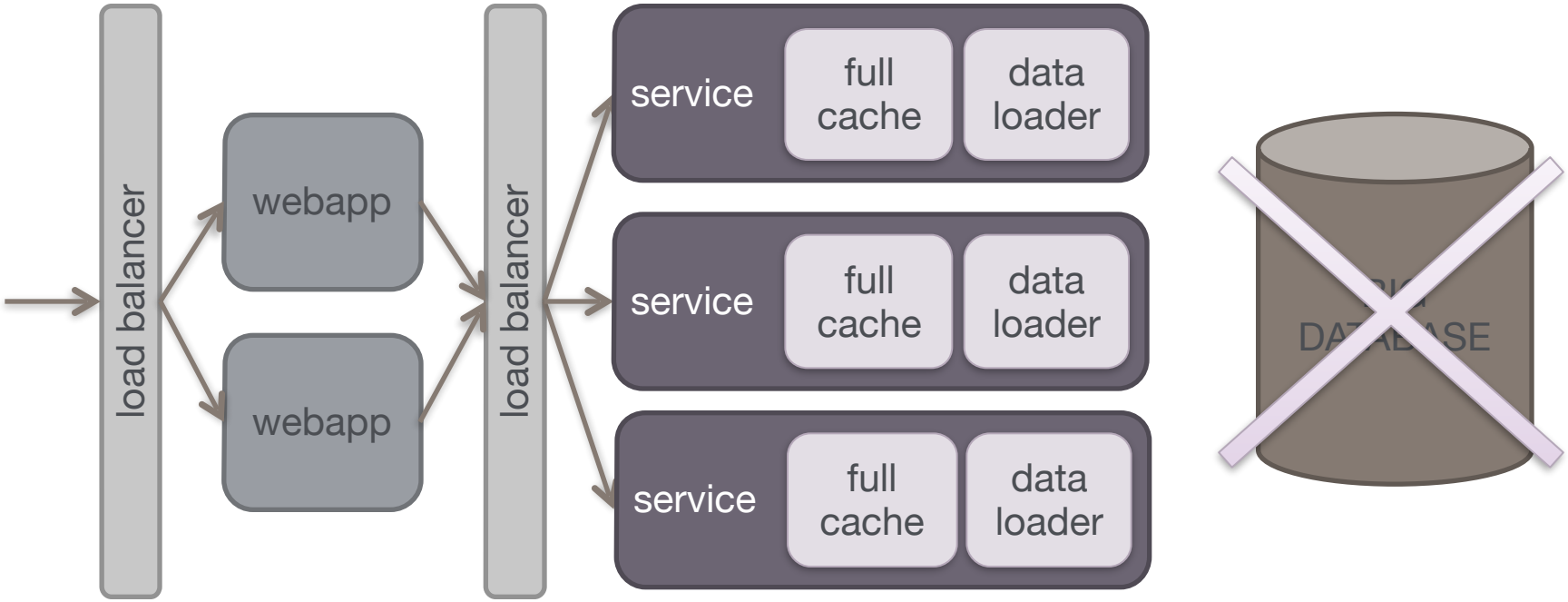
REDIS

source: http://redis.io/topics/faq

THEY ARE FAST IF EVERYTHING FITS INTO MEMORY.


Ur computr needs
More rams
ICANHASCHEEZBURGER.COM

CAN YOU KEEP IT IN MEMORY YOURSELF?



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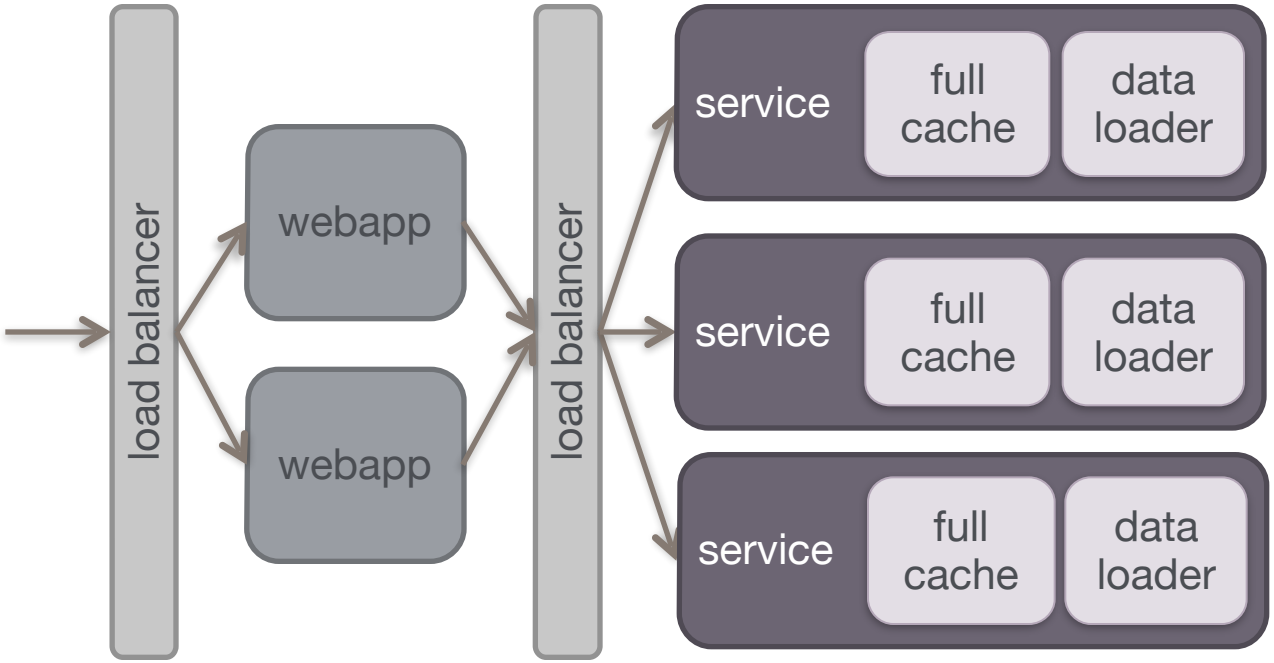

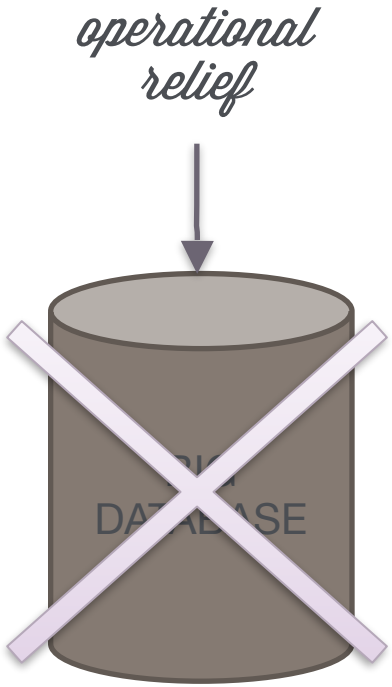

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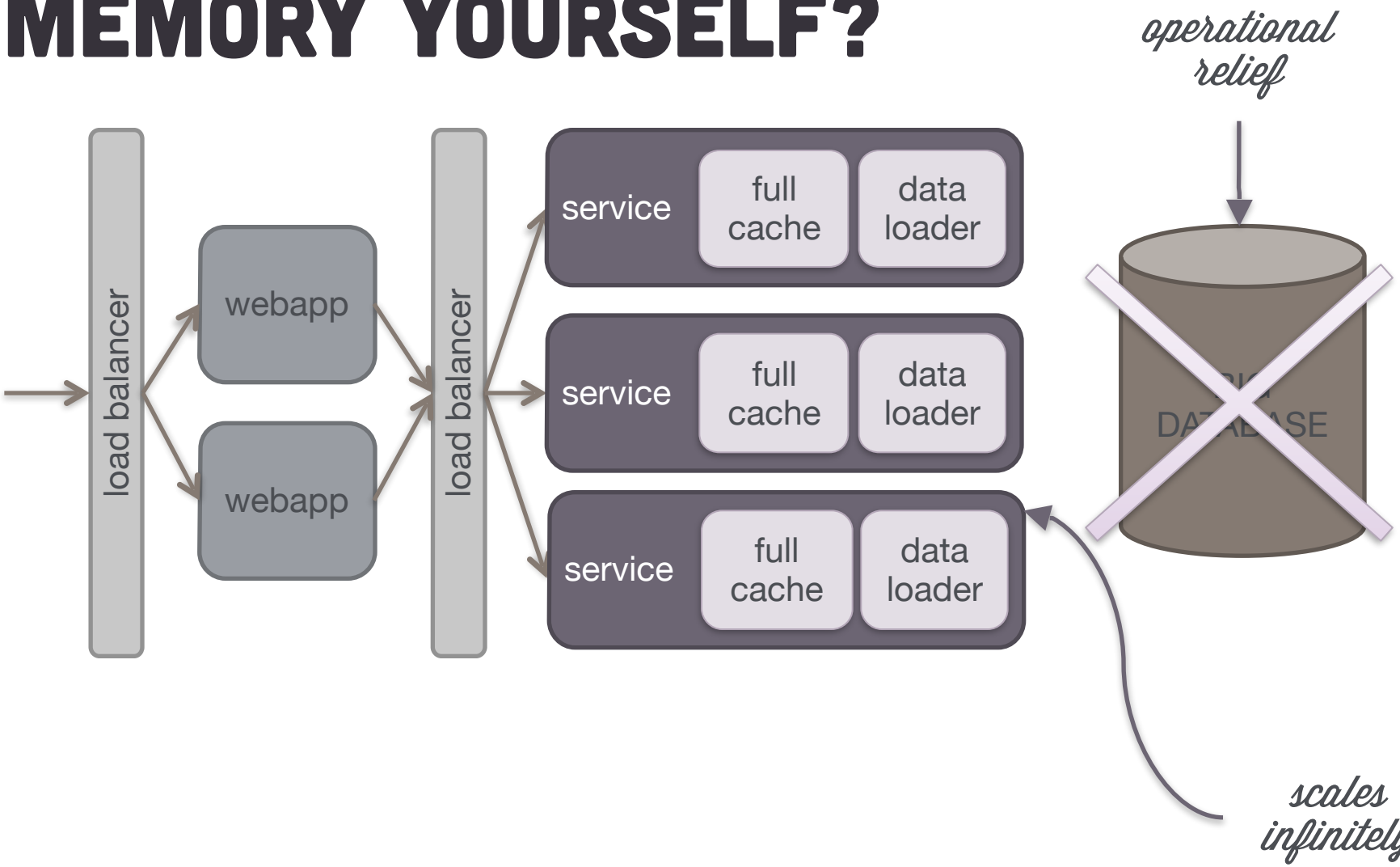

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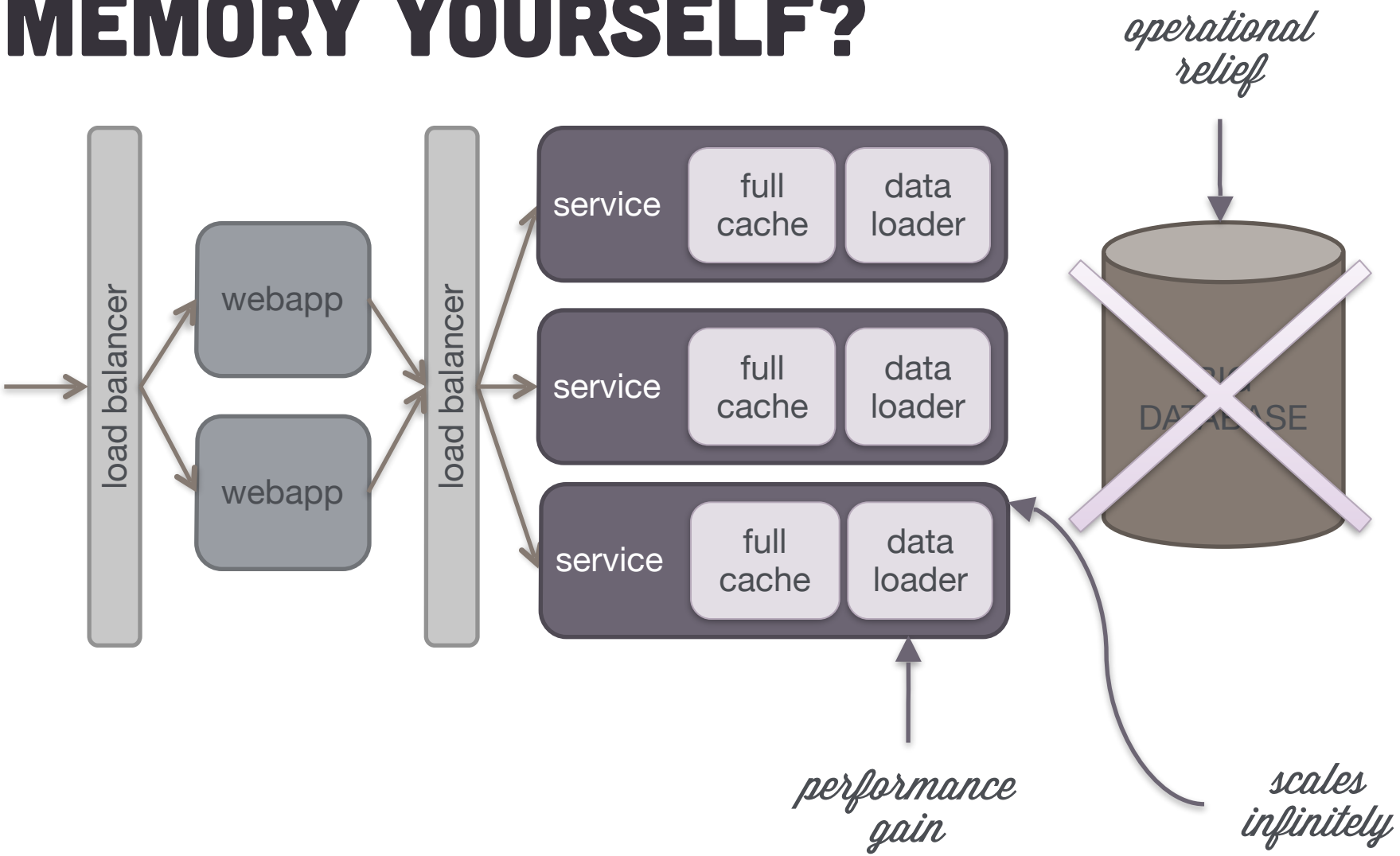

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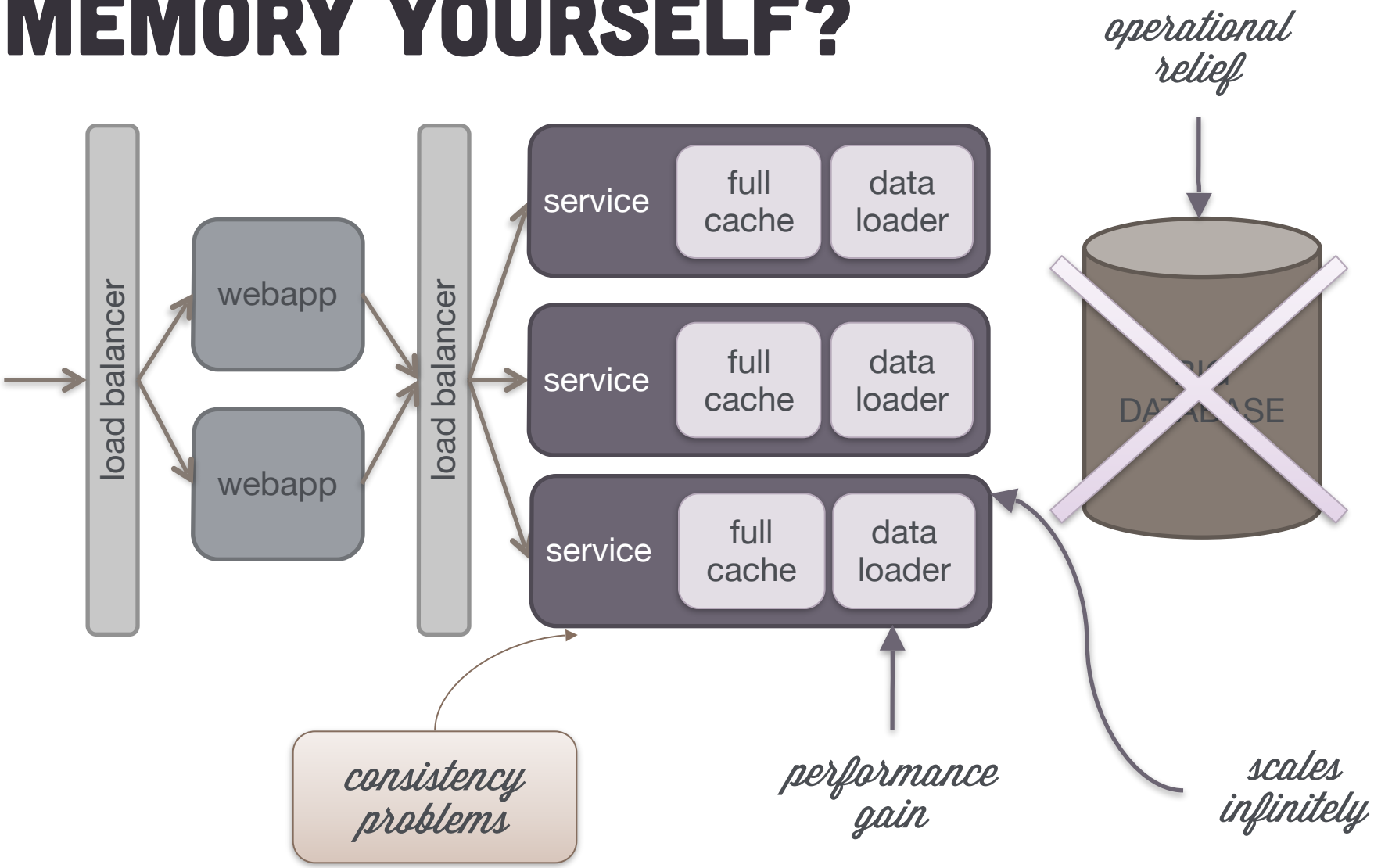
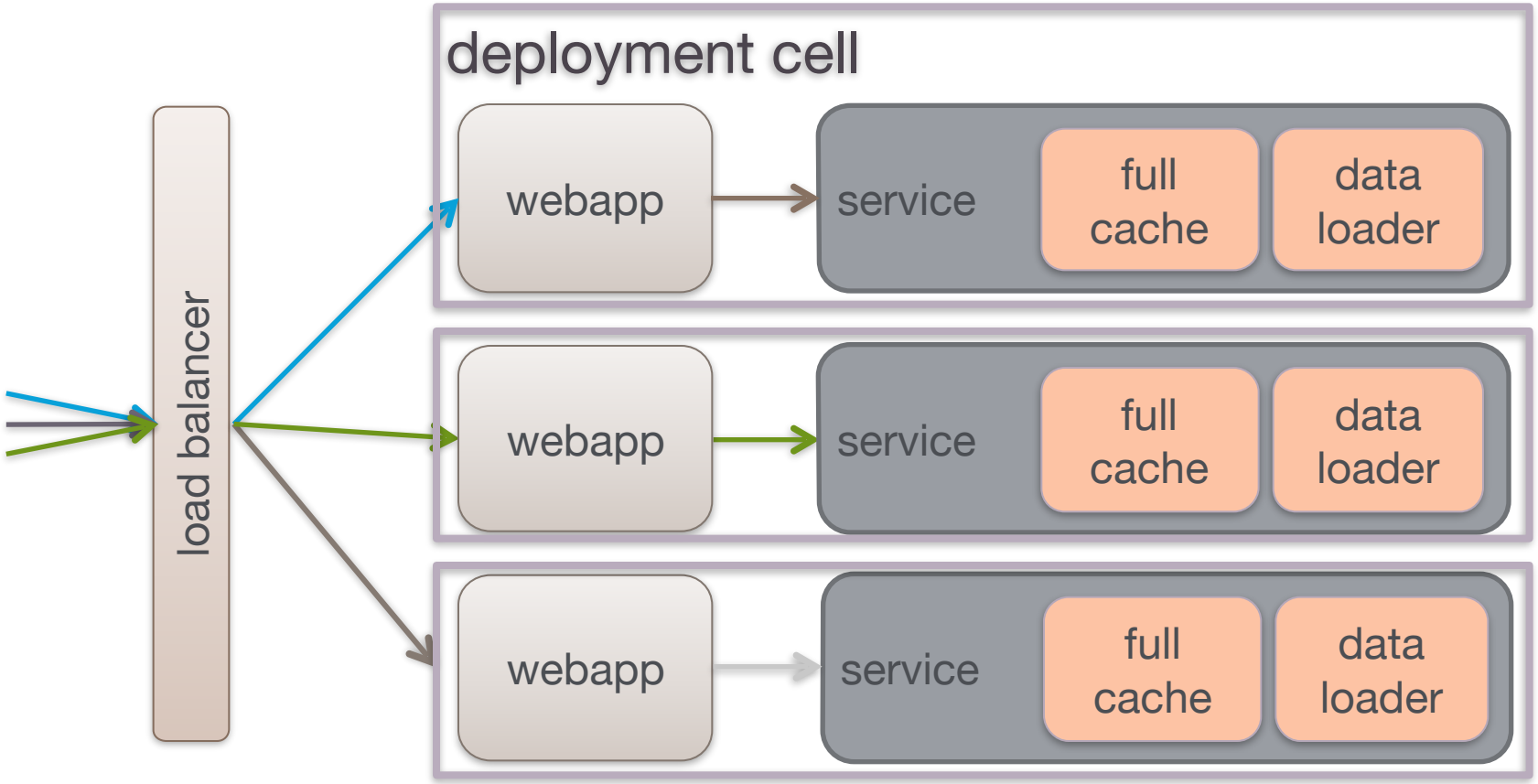
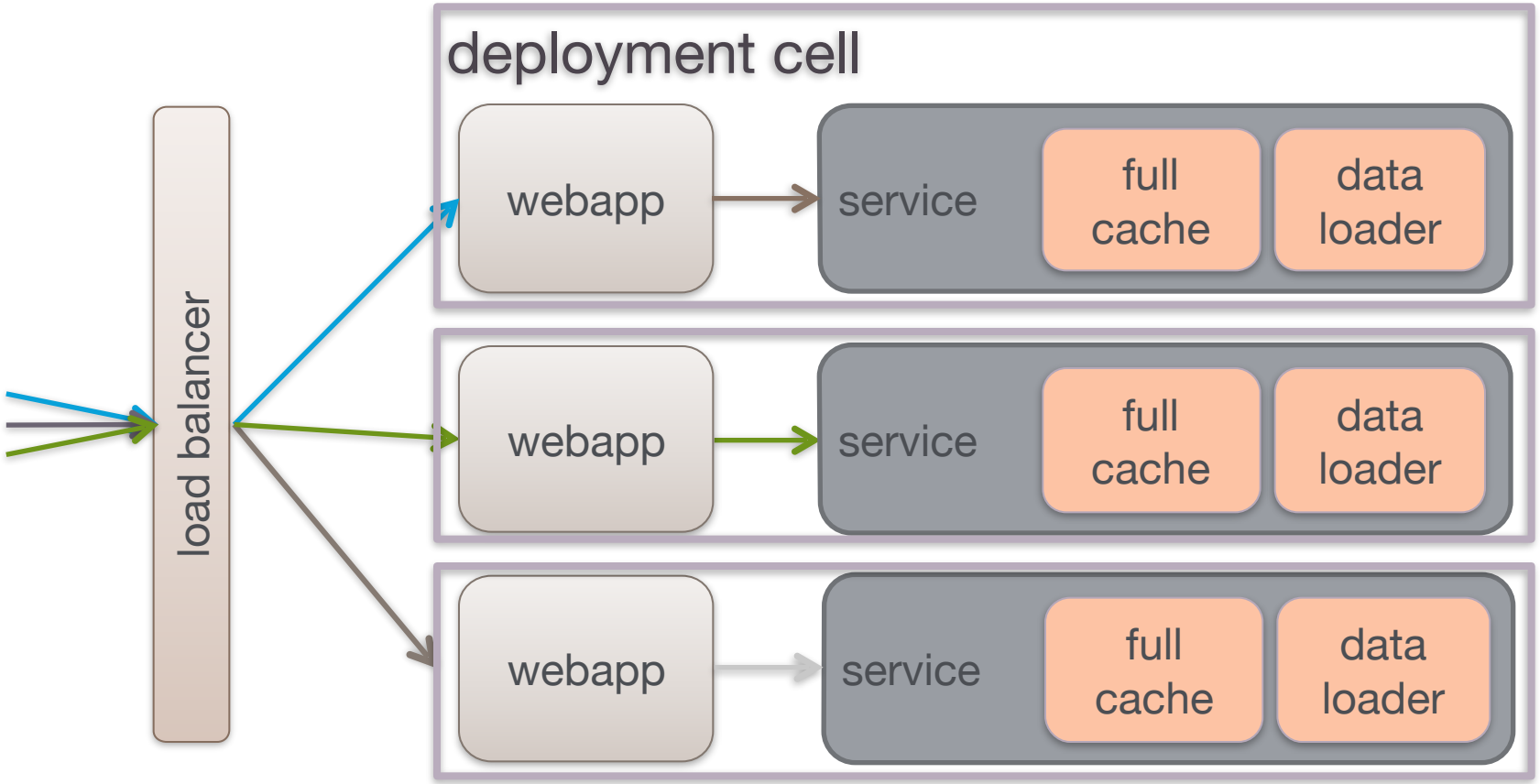


FIXING CONSISTENCY



FIXING CONSISTENCY

1. Deployment “Cells”
2. Sticky user sessions




HOW DO YOU FIT ALL OF THAT DATA INTO MEMORY?
AZ 23-BD-179
credit: http://www.fruitshare.ca/wp-content/uploads/2011/08/car-full-of-apples.jpeg

"Programmers waste enormous amounts of time thinking about, or worrying about, the speed of noncritical parts of their programs, and these attempts at efficiency actually have a strong negative impact when debugging and maintenance are considered.

We *should* forget about small efficiencies, say about 97% of the time: **premature optimization is the root of all evil.** *Yet we should not pass up our opportunities in that critical 3%.*”

Donald Knuth

HOW DO YOU FIT ALL THAT DATA IN MEMORY?

THE ANSWER

1 2 3 4 5

DOMAIN MODEL DESIGN

"Domain Layer (or Model Layer):

Responsible for representing concepts of the business, information about the business situation, and business rules. State that reflects the business situation is controlled and used here, even though the technical details of storing it are delegated to the infrastructure. This layer is the heart of business software."

Eric Evans, Domain-Driven Design, 2003

DOMAIN MODEL DESIGN GUIDELINES

http://alloveralbany.com/images/bumper_gawking_dbgeek.jpg

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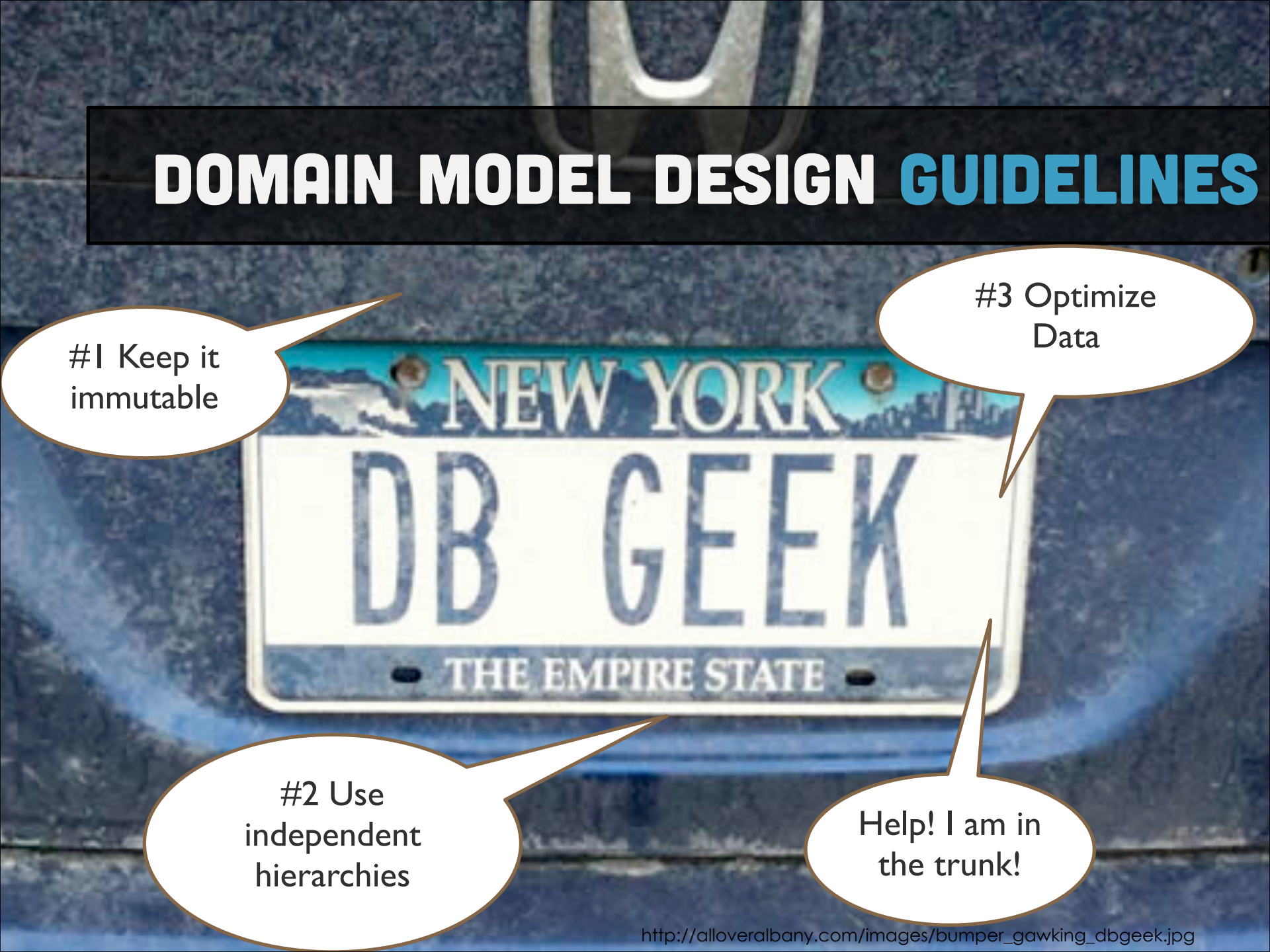
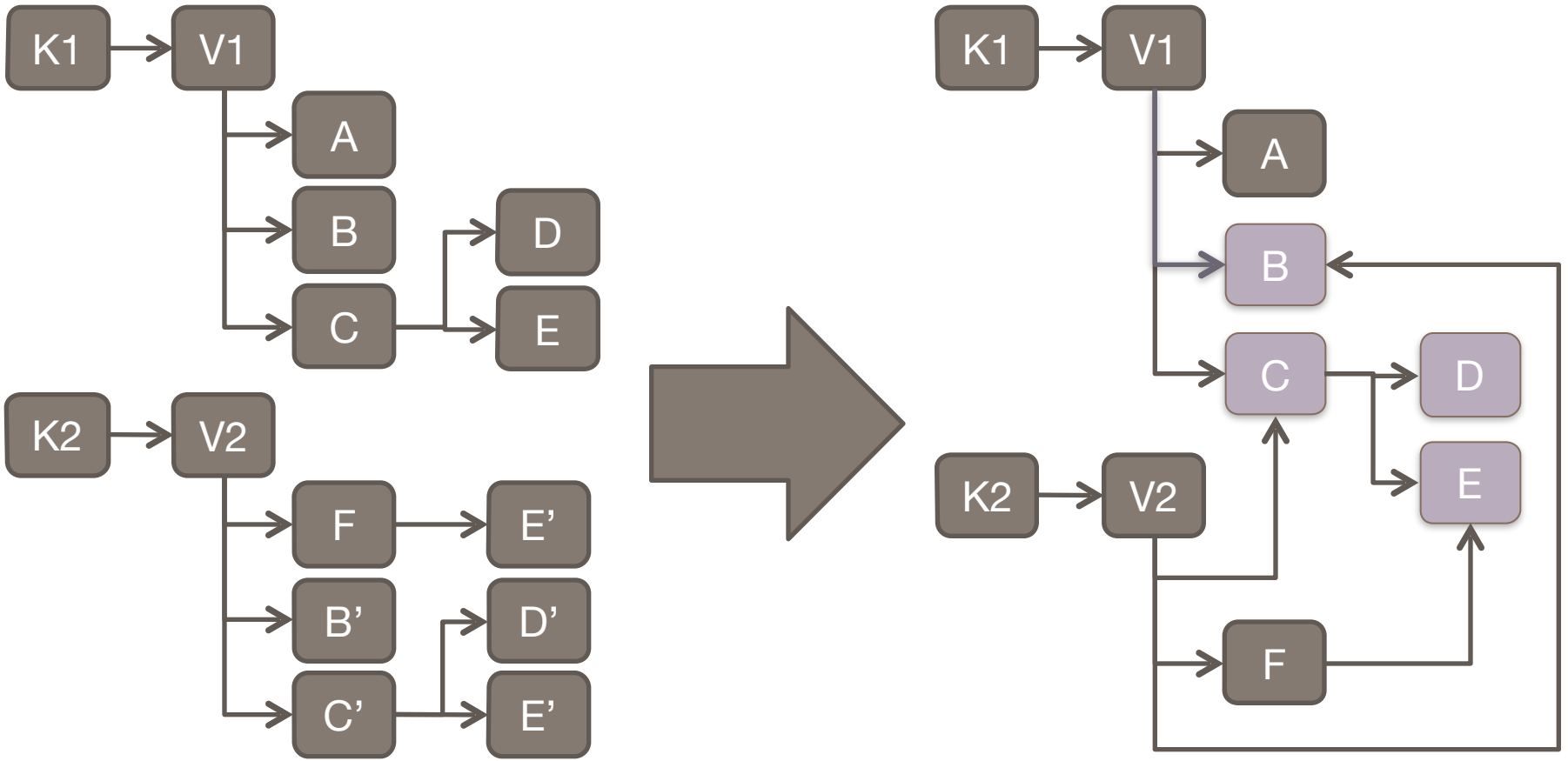
DOMAIN MODEL DESIGN GUIDELINES



http://alloveralbany.com/images/bumper_gawking_dbgeek.jpg

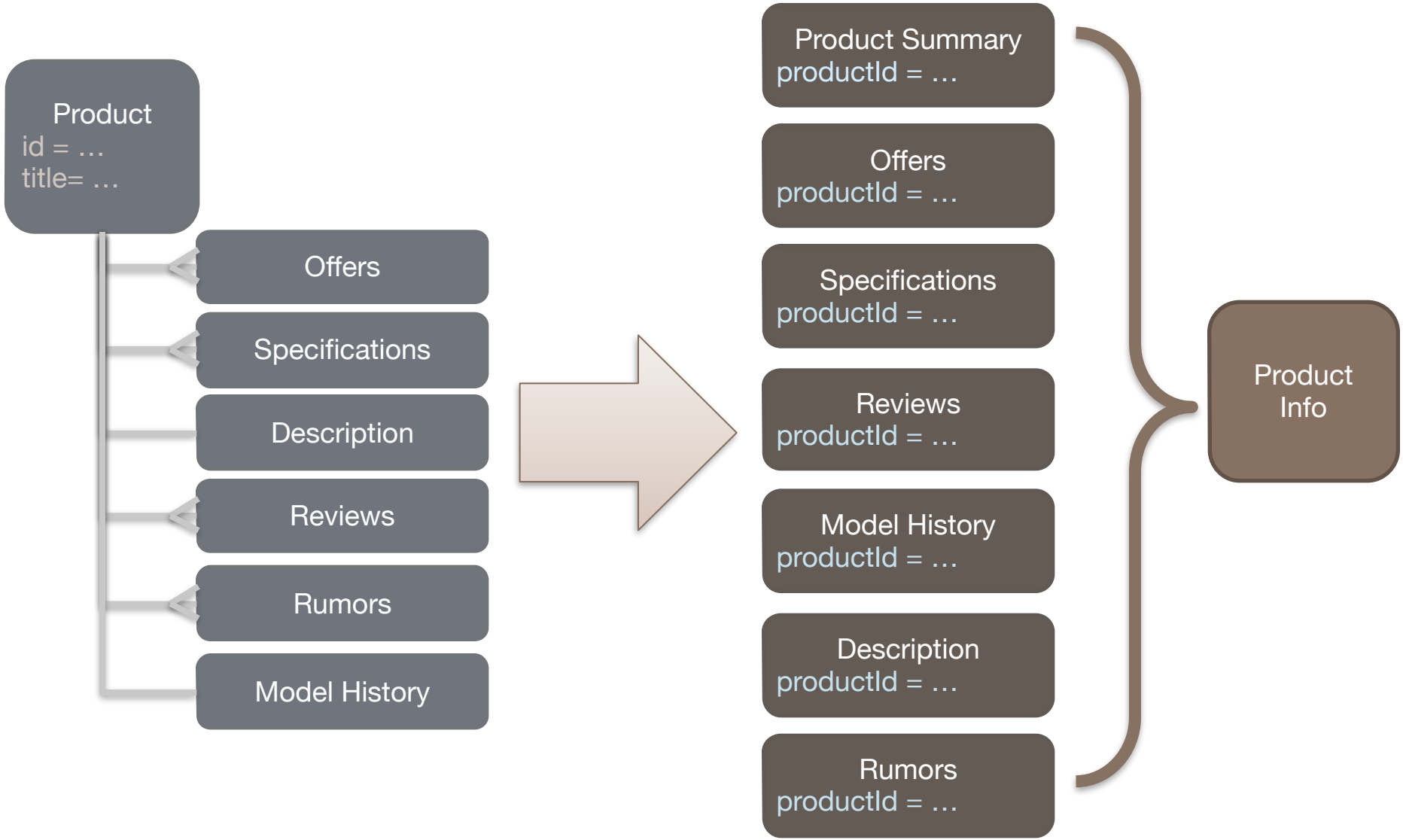
intern() YOUR IMMUTABLES



```
private final Map<Class<?>, Map<Object, WeakReference<Object>>> cache =
                    new ConcurrentHashMap<Class<?>, Map<Object,
WeakReference<Object>>>();

public <T> T intern(T o) {
    if (o == null)
        return null;
    Class<?> c = o.getClass();
    Map<Object, WeakReference<Object>> m = cache.get(c);
    if (m == null)
        cache.put(c, m = synchronizedMap(new WeakHashMap<Object,
WeakReference<Object>>()));
    WeakReference<Object> r = m.get(o);
    @SuppressWarnings("unchecked")
    T v = (r == null) ? null : (T) r.get();
    if (v == null) {
        v = o;
        m.put(v, new WeakReference<Object>(v));
    }
    return v;
}
```

USE INDEPENDENT HIERARCHIES



COLLECTION OPTIMIZATION

Leverage
PRIMITIVE KEYS/VALUES

collection with 10,000 elements [0 .. 9,999]	size in memory
java.util.ArrayList<Integer>	***200K***
java.util.HashSet<Integer>	546K
gnu.trove.list.array.TIntArrayList	***40K***
gnu.trove.set.hash.TIntHashSet	**102K**

Trove ("High Performance Collections for Java")

Optimize
SMALL IMMUTABLE COLLECTIONS

Collections with small number of entries (up to ~20):

```
class ImmutableMap<K, V> implements Map<K,V>, Serializable {
... }

class MapN<K, V> extends ImmutableMap<K, V> {
    final K k1, k2, ..., kN;
    final V v1, v2, ..., vN;
    @Override public boolean containsKey(Object key) {
            if (eq(key, k1)) return true;
            if (eq(key, k2)) return true;
            ...
            return false;
    }
    ...
```

SPACE SAVINGS

`java.util.HashMap`:

128 bytes + 32 bytes per entry

compact immutable map:

24 bytes + 8 bytes per entry

NUMERIC DATA OPTIMIZATION

PRICE HISTORY EXAMPLE

EXAMPLE: PRICE HISTORY

Problem:

- Store daily prices for 1M products, 2 offers per product
- Average price history length per product ~2 years

Total price points:

(1M + 2M) * 730 = ~2 billion

PRICE HISTORY FIRST ATTEMPT

`TreeMap<Date, Double>`

88 bytes per entry * 2 billion =

~180 GB

TYPICAL SHOPPING PRICE HISTORY

$1

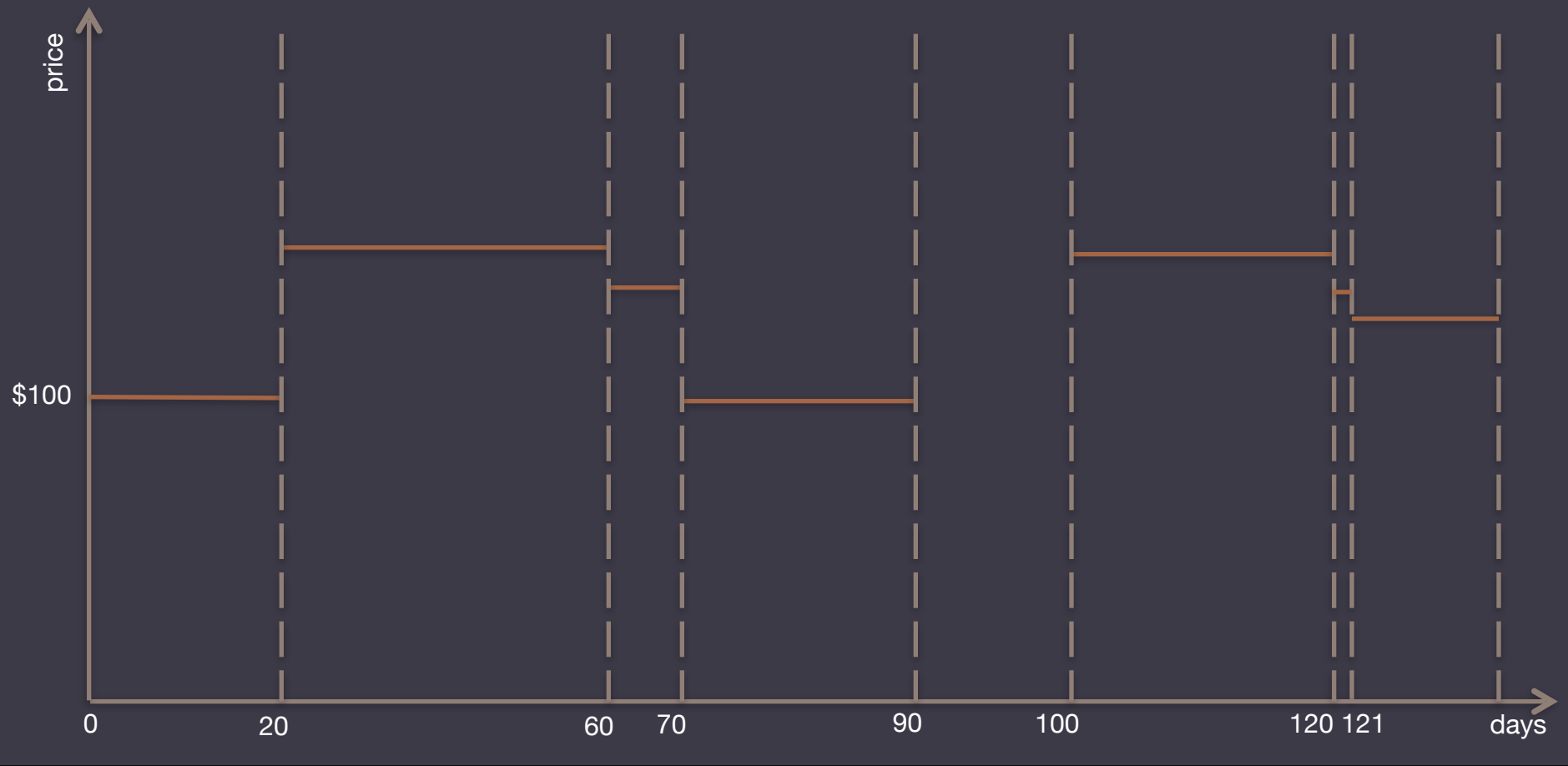
0 20 60 70 90 100 120 121 days

TYPICAL SHOPPING PRICE HISTORY

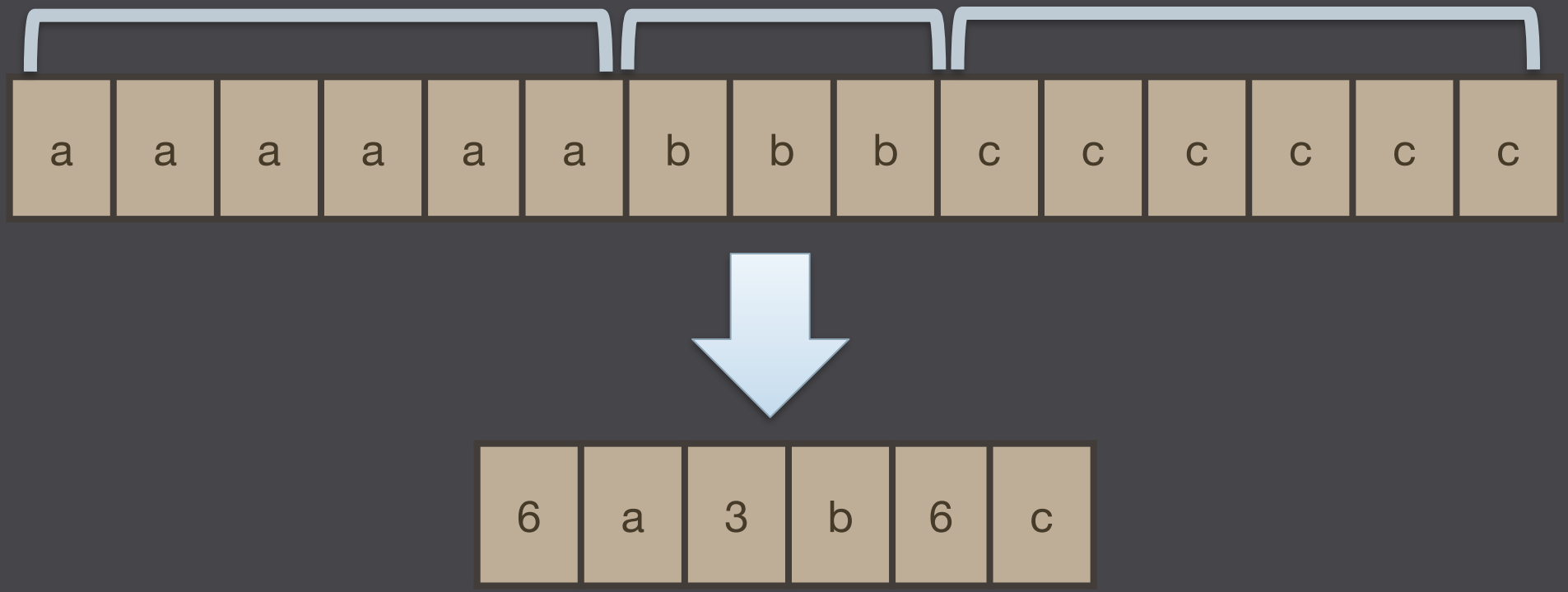
$1

0 20 60 70 90 100 120 121 days

TYPICAL SHOPPING PRICE HISTORY



RUN LENGTH ENCODING



PRICE HISTORY OPTIMIZATION

- **positive:** price (adjusted to scale)
- **negative:** run length (precedes price)
- **zero:** unavailable

-20	100	-40	150	-10	140	-20	100	-10	0	-20	100	90	-9	80

- Drop pennies
- Store prices in primitive short (use scale factor to represent prices greater than `Short.MAX_VALUE`)

Memory:
15 * 2 + 16 (array) + 24 (start date) + 4 (scale factor) = **74 bytes**

SPACE SAVINGS

Reduction compared to `TreeMap<Date, Double>`:

155 times

Estimated memory for 2 billion price points:

1.2 GB

SPACE SAVINGS

Reduction compared to `TreeMap<Date, Double>`:

155 times

Estimated memory for 2 billion price points:

1.2 GB **<< 180 GB**

PRICE HISTORY MODEL

```
public class PriceHistory {

        private final Date startDate; // or use org.joda.time.LocalDate
        private final short[] encoded;
        private final int scaleFactor;

        public PriceHistory(SortedMap<Date, Double> prices) { … } // encode
        public SortedMap<Date, Double> getPricesByDate() { … } // decode
        public Date getStartDate() { return startDate; }

        // Below computations implemented directly against encoded data
        public Date getEndDate() { … }
        public Double getMinPrice() { … }
        public int getNumChanges(double minChangeAmt, double minChangePct,
boolean abs) { … }
        public PriceHistory trim(Date startDate, Date endDate) { … }
        public PriceHistory interpolate() { … }
```

KNOW YOUR DATA

COMPRESS TEXT

STRING COMPRESSION: BYTE ARRAYS

- Use the minimum character set encoding

```
static Charset UTF8 = Charset.forName("UTF-8");

String s = "The quick brown fox jumps over the lazy dog”; // 42 chars, 136
bytes
byte[] b a= "The quick brown fox jumps over the lazy dog”.getBytes(UTF8); //
64 bytes
String s1 = “Hello”; // 5 chars, 64 bytes
byte[] b1 = “Hello”.getBytes(UTF8); // 24 bytes

byte[] toBytes(String s) { return s == null ? null : s.getBytes(UTF8); }
String toString(byte[] b) { return b == null ? null : new String(b, UTF8); }
```

STRING COMPRESSION: SHARED PREFIX

- Great for URLs

```
public class PrefixedString {
    private PrefixedString prefix;
    private byte[] suffix;

    . . .

    @Override public int hashCode() { … }
    @Override public boolean equals(Object o) { … }
}
```

STRING COMPRESSION:
SHORT ALPHANUMERIC CASE-INSENSITIVE STRINGS

```
public abstract class AlphaNumericString {
    public static AlphaNumericString make(String s) {
     try { return new Numeric(Long.parseLong(s, Character.MAX_RADIX));
      } catch (NumberFormatException e) { return new Alpha(s.getBytes(UTF8)); }
    }
    protected abstract String value();
    @Override public String toString() {return value(); }
    private static class Numeric extends AlphaNumericString {
      long value;
      Numeric(long value) { this.value = value; }
      @Override protected String value() { return Long.toString(value, Character.MAX_RADIX); }
      @Override public int hashCode() { … }
      @Override public boolean equals(Object o) { … }
    }
    private static class Alpha extends AlphaNumericString {
      byte[] value;
      Alpha(byte[] value) {this.value = value; }
      @Override protected String value() { return new String(value, UTF8); }
      @Override public int hashCode() { … }
      @Override public boolean equals(Object o) { … }
    }
}
```

STRING COMPRESSION: LARGE STRINGS

Image source:https://www.facebook.com/note.php?note_id=80105080079image

STRING COMPRESSION: LARGE STRINGS

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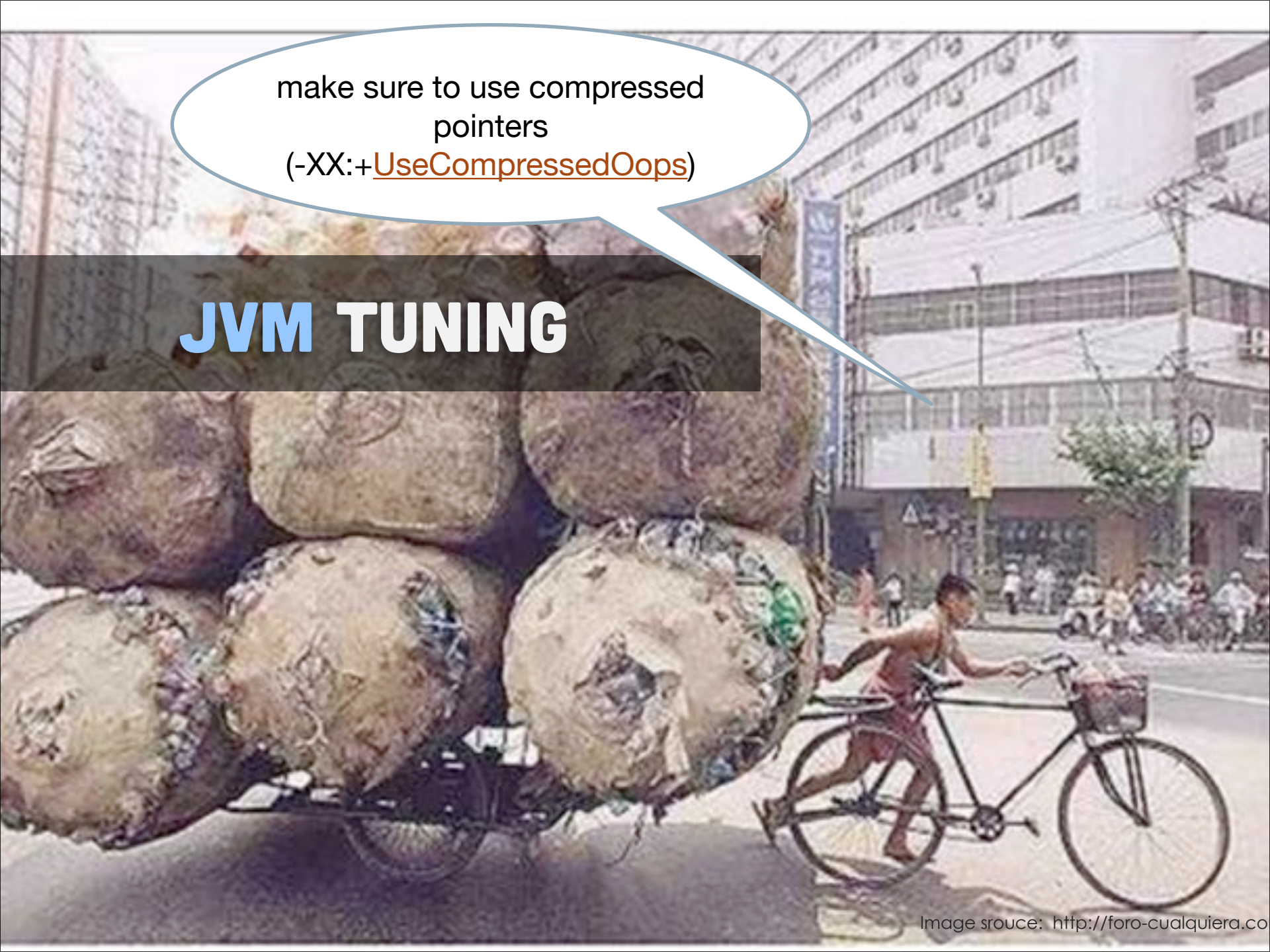
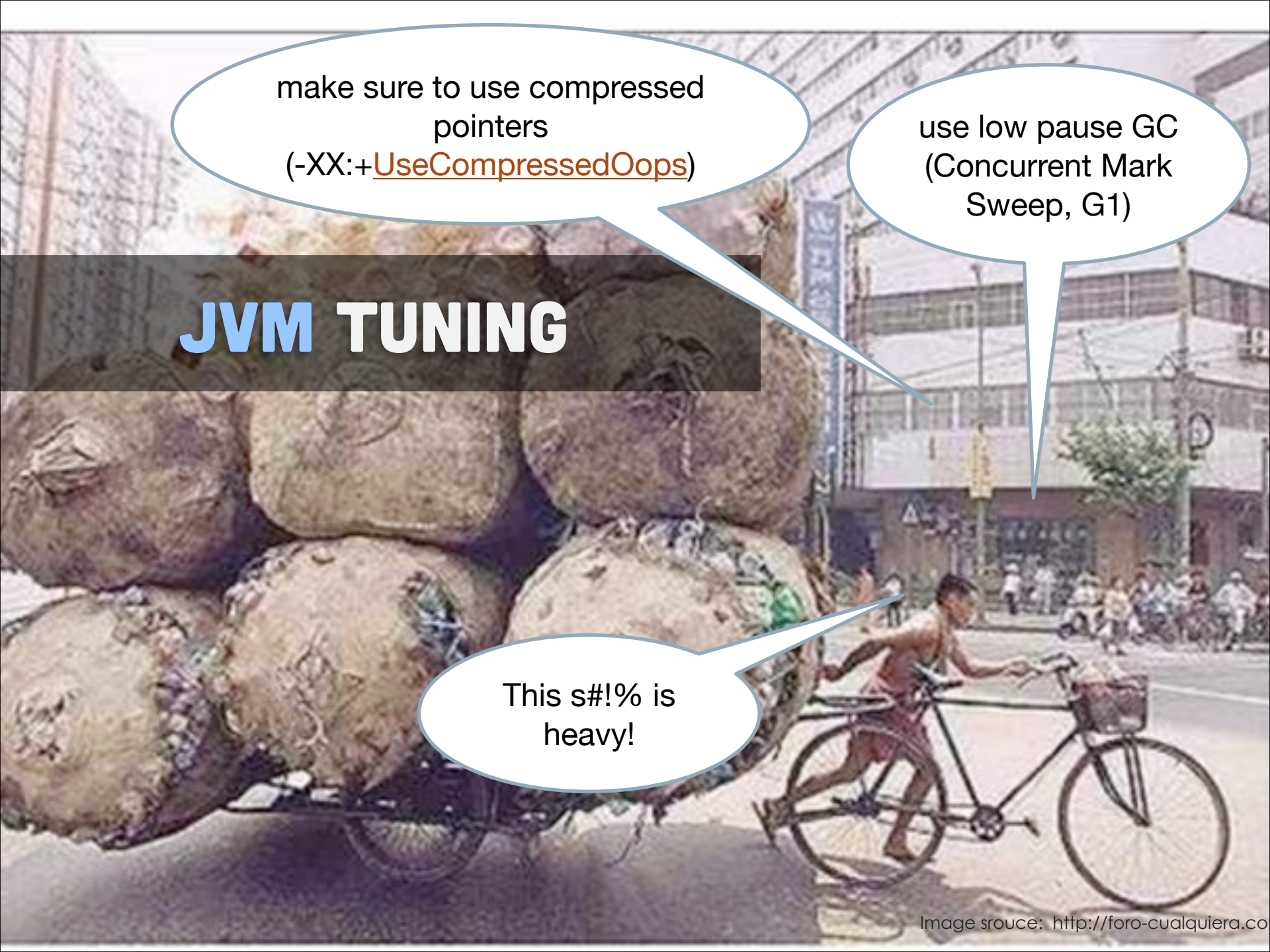
JVM TUNING

JVM TUNING

Image srouce: http://foro-cualquiera.co


make sure to use compressed pointers (-XX:+UseCompressedOops)
JVM TUNING
Image srouce: http://foro-cualquiera.co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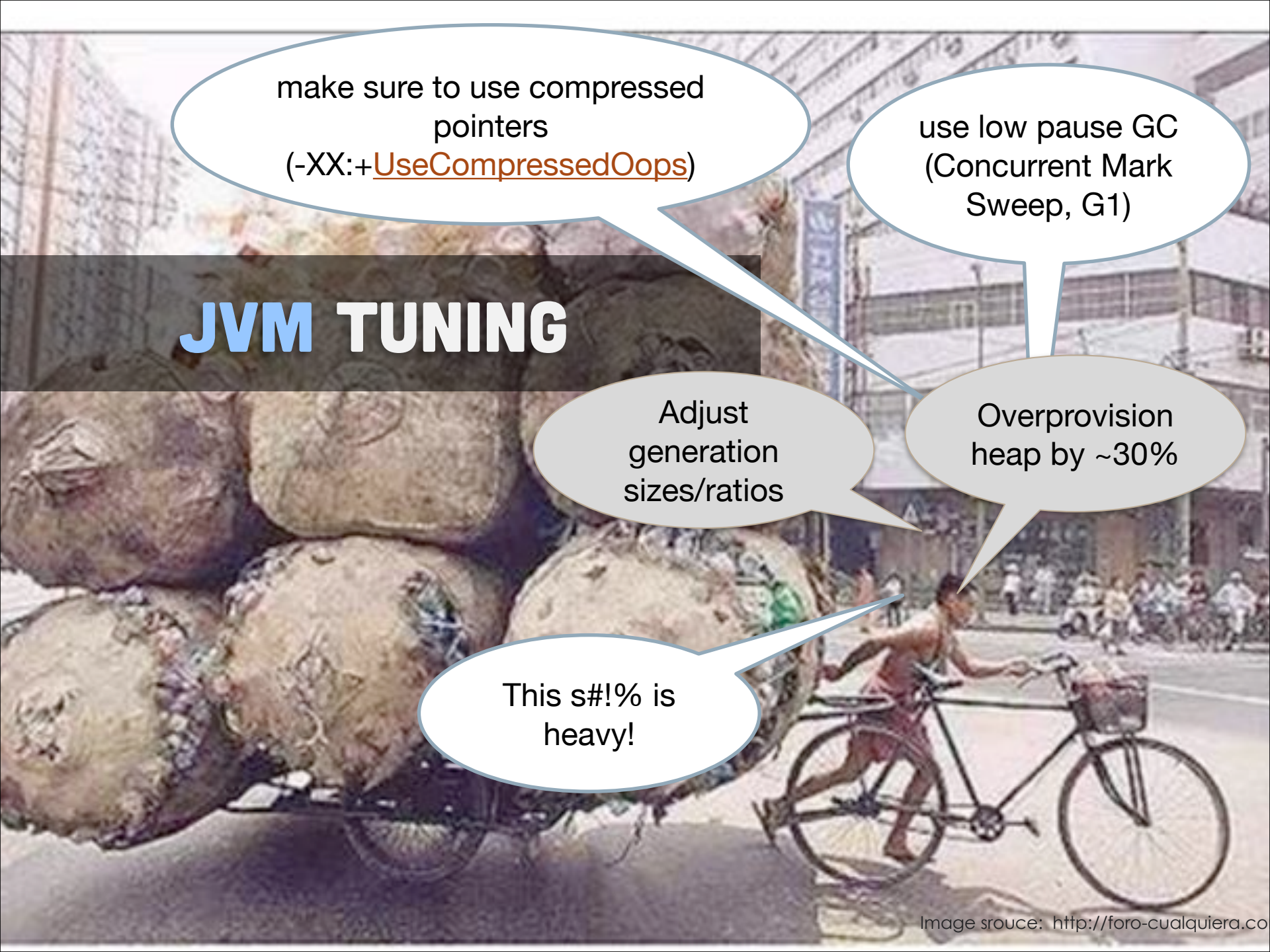
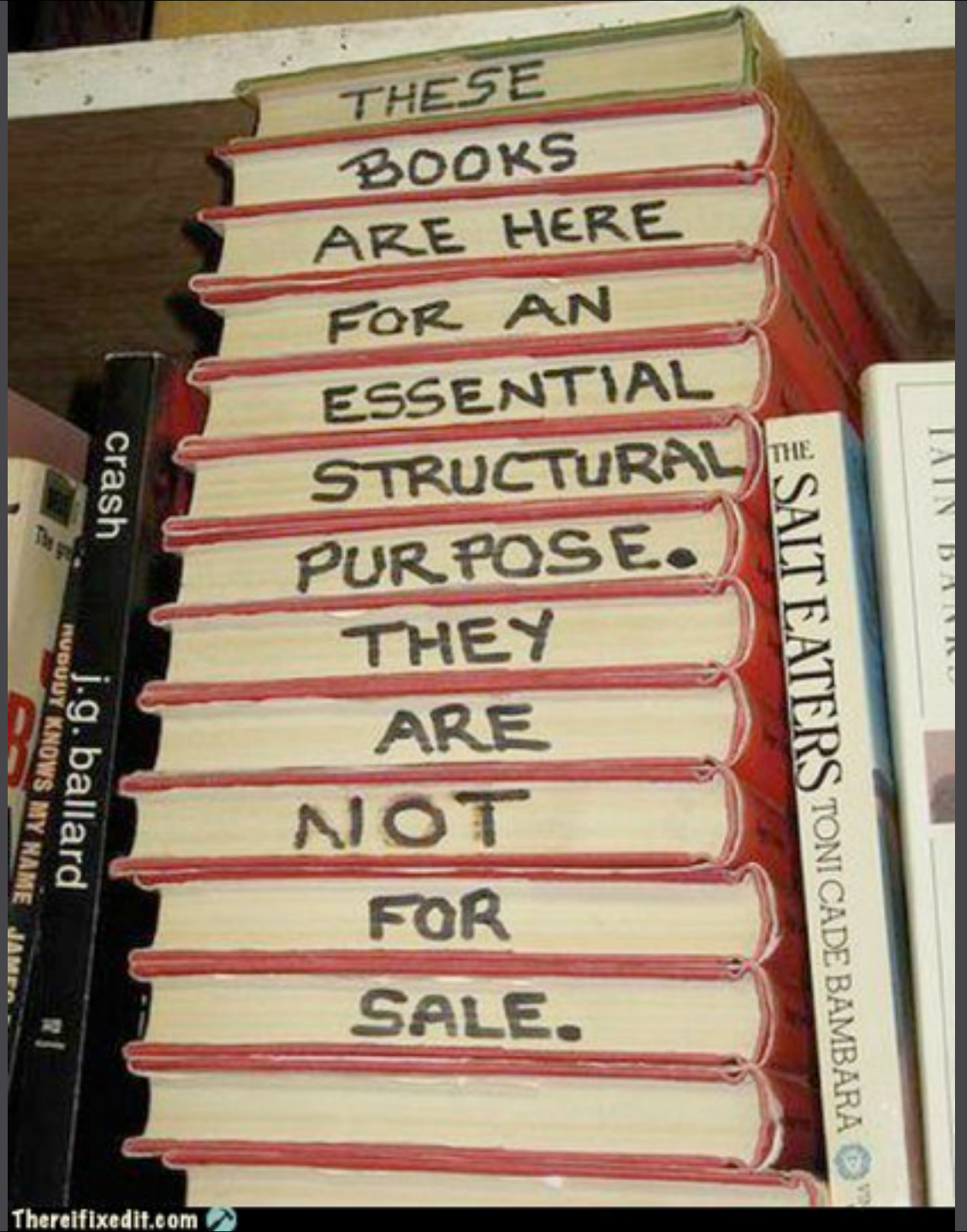
use low pause GC (Concurrent Mark Sweep, G1)
JVM TUNING
This s#!% is heavy!
Image srouce: http://foro-cualquiera.co


make sure to use compressed pointers (-XX:+UseCompressedOops)
use low pause GC (Concurrent Mark Sweep, G1)
JVM TUNING
Adjust generation sizes/ratios
Overprovision heap by ~30%
This s#!% is heavy!
Image srouce: http://foro-cualquiera.co

JVM TUNING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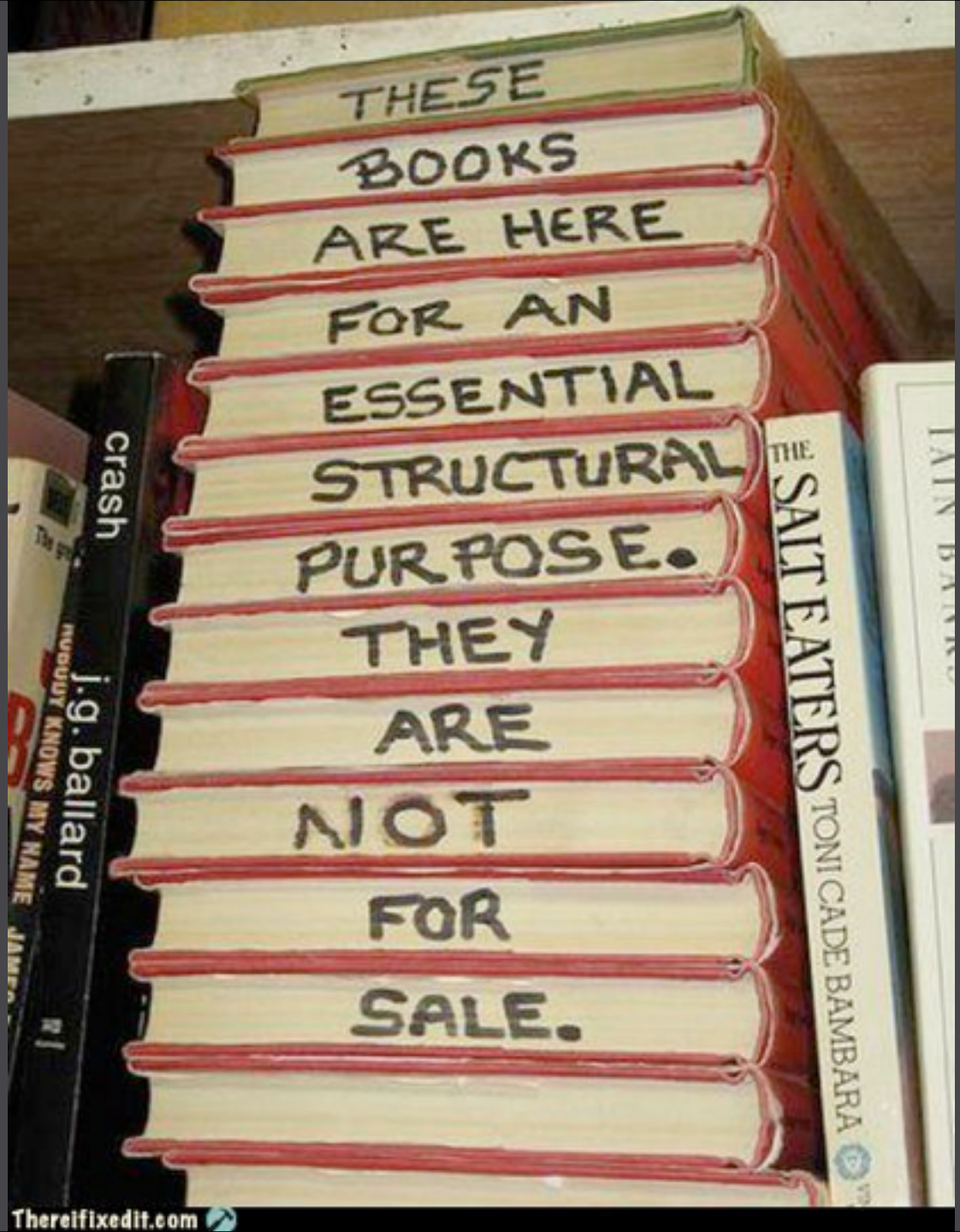
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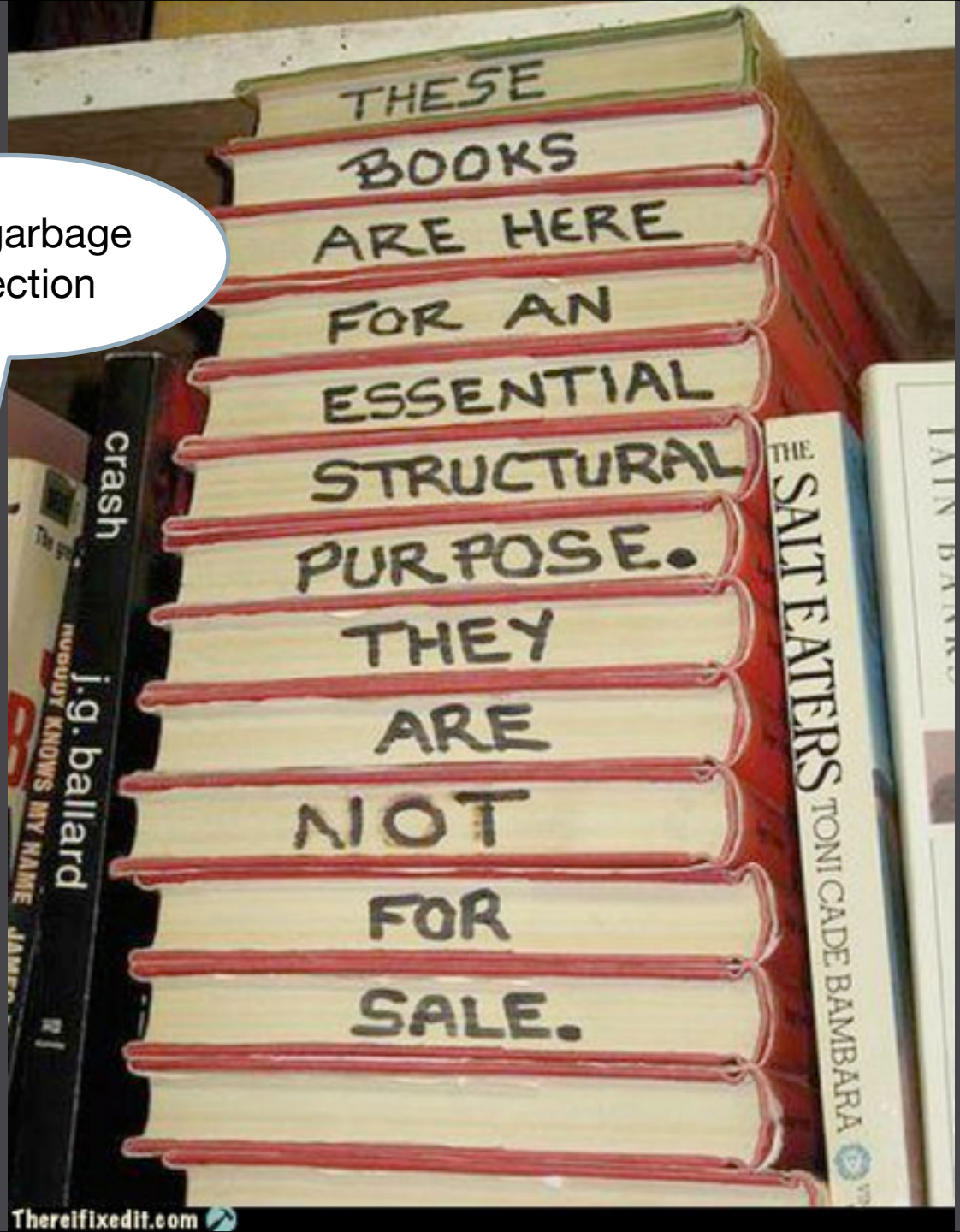
THE SALT EATERS TONI CADE BAMBARA
Thereifixedit.com

JVM TUNING

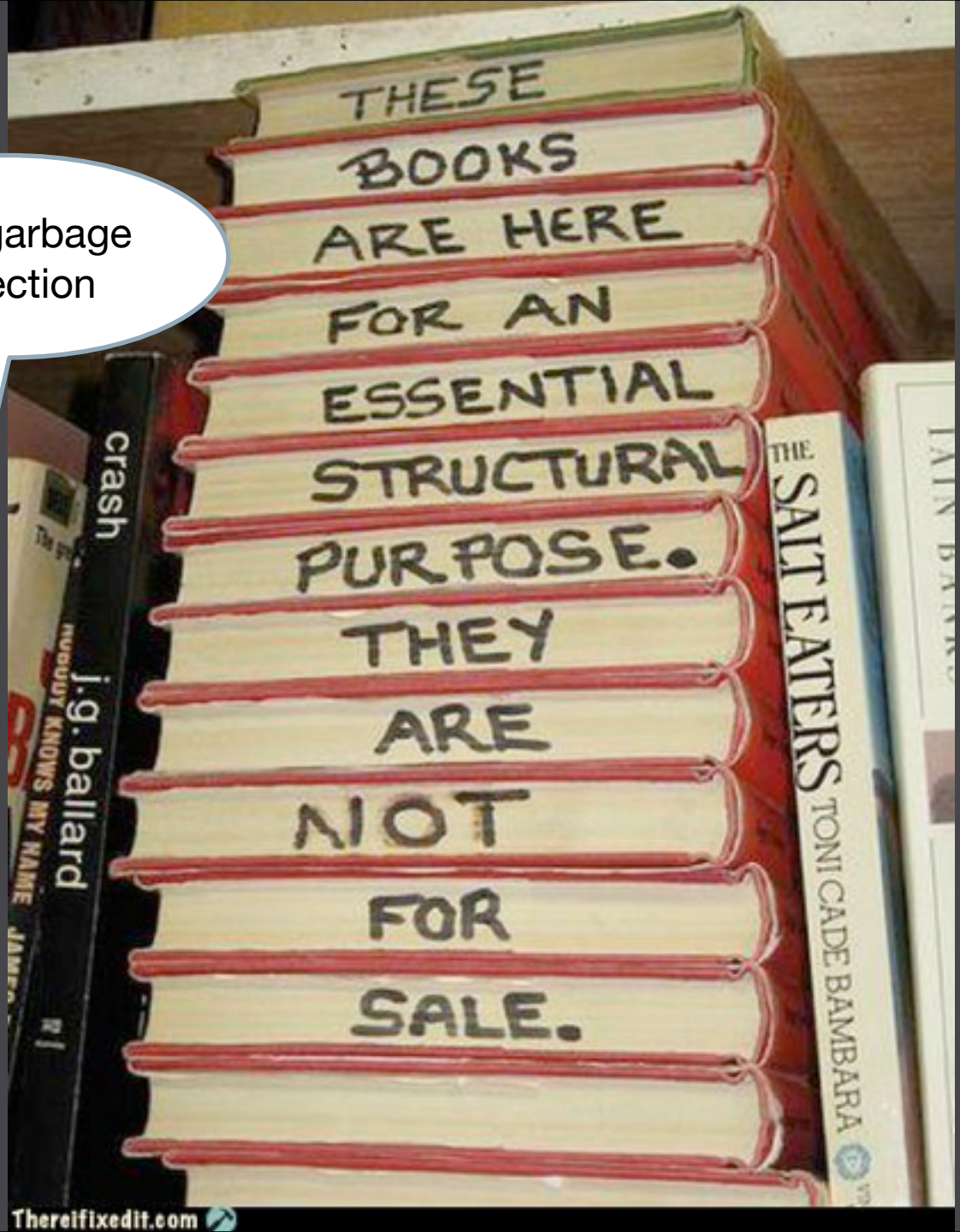
Print garbage collection



JVM TUNING

Print garbage collection

If GC pauses still prohibitive then consider partitioning



IN SUMMARY

KNOW YOUR BUSINESS

KNOW YOUR DATA

KNOW WHEN TO OPTIMIZE

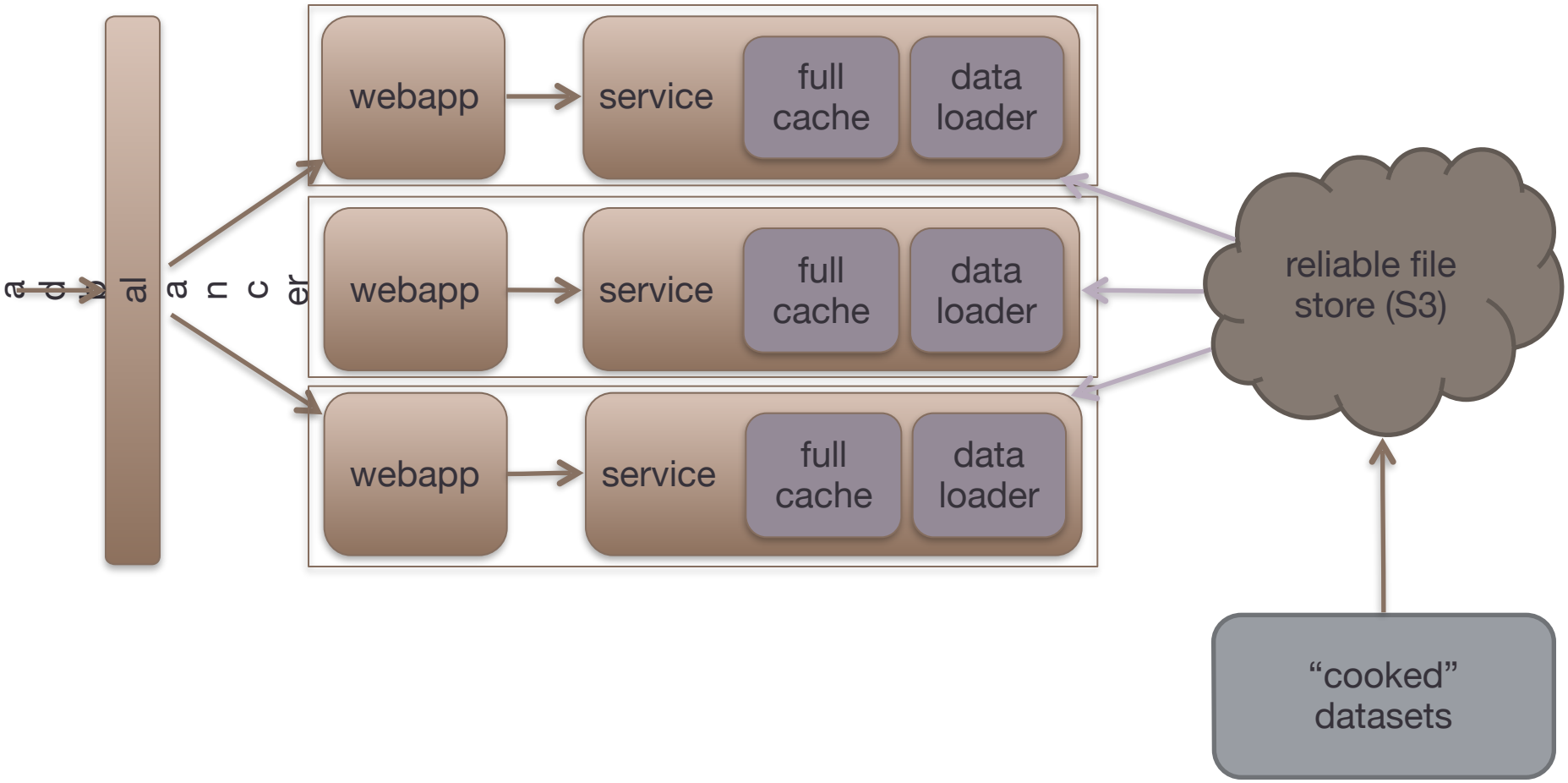
THE END

My company: https://popforms.com
My website: http://katemats.com

And much of the credit for this talk goes to Leon Stein for developing the technology. **Thank you, Leon.**


HOW DO YOU LOAD THE DATA?
PEPSI
FAIL
epicfail.com

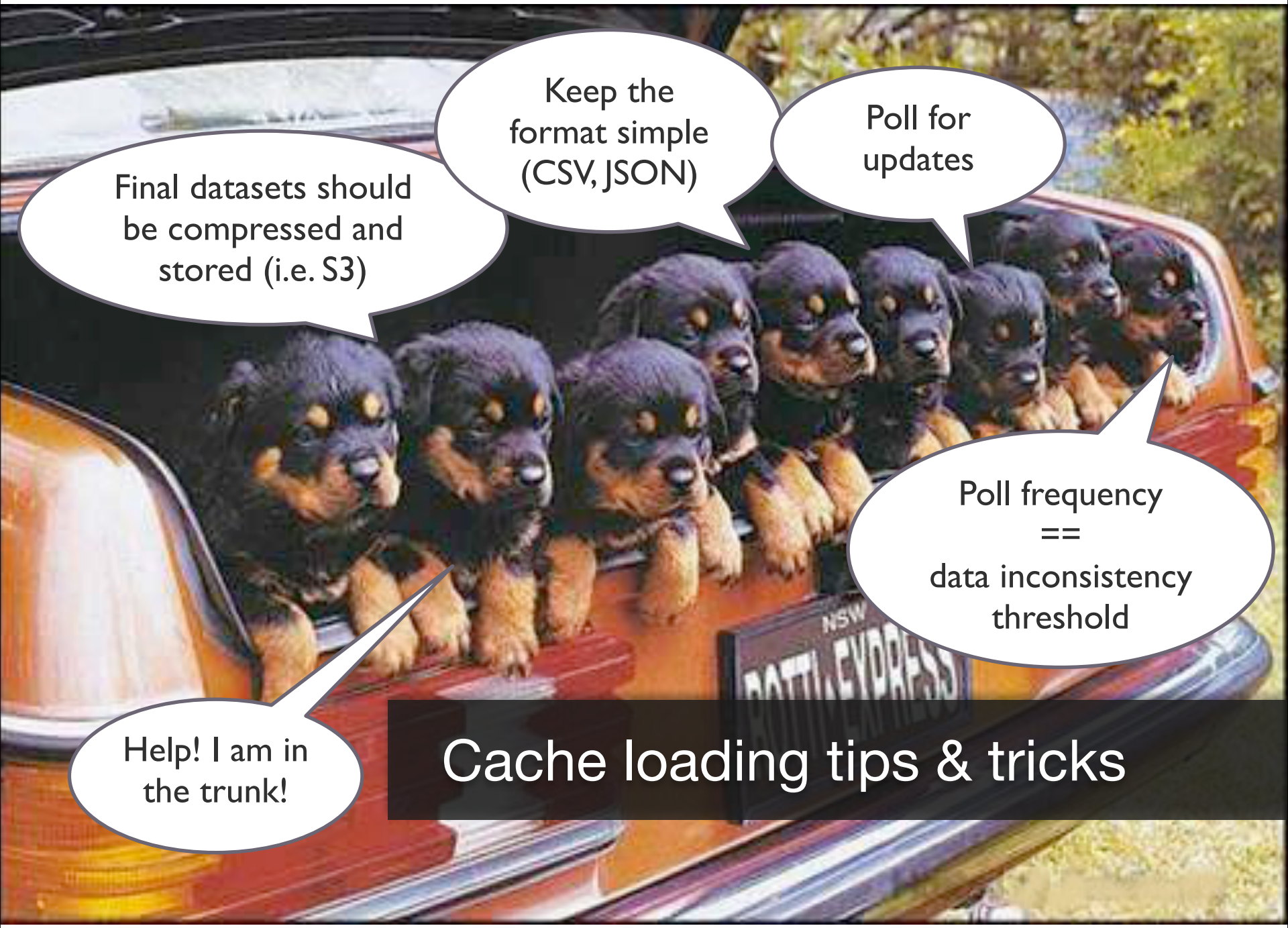
CACHE LOADING



Cache loading tips & tricks

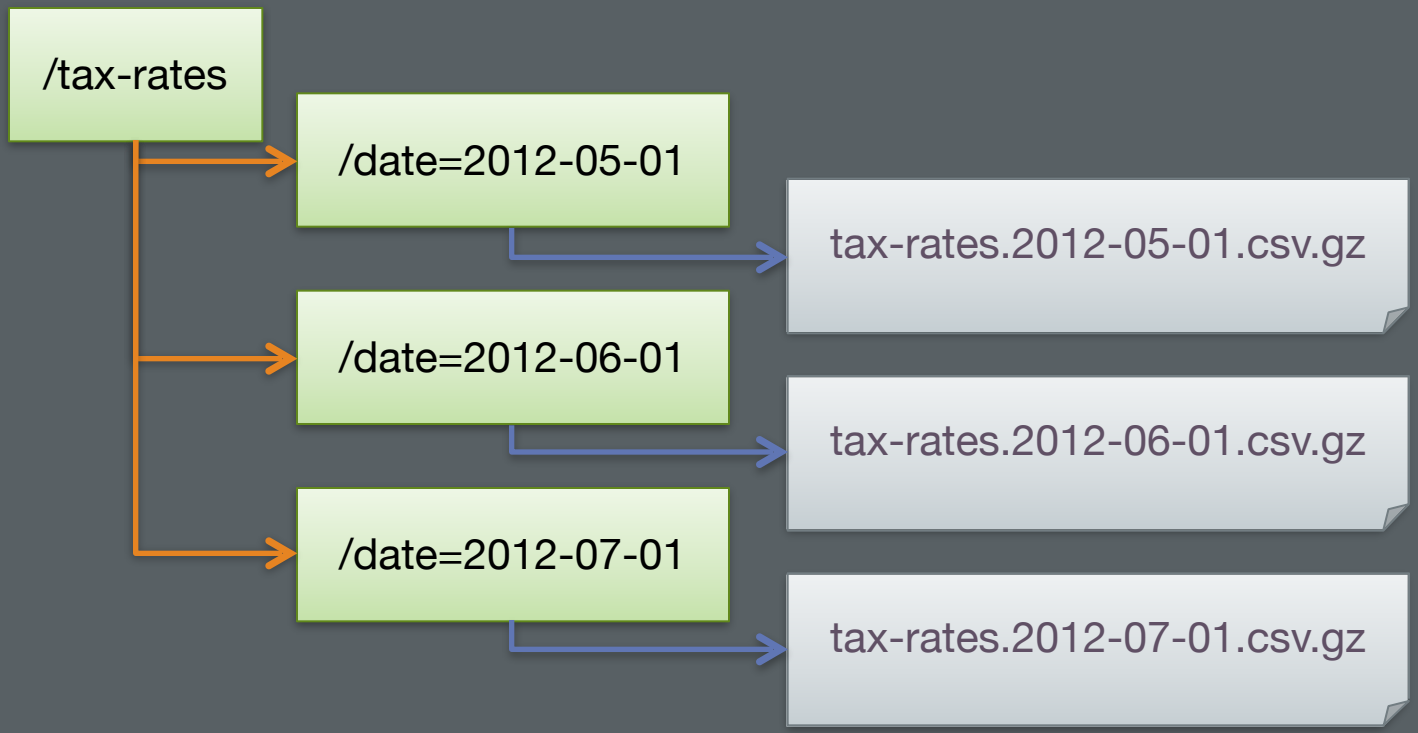
Cache loading tips & tricks


Keep the format simple (CSV, JSON)
Final datasets should be compressed and stored (i.e. S3)
Help! I am in the trunk!
Cache loading tips & tricks

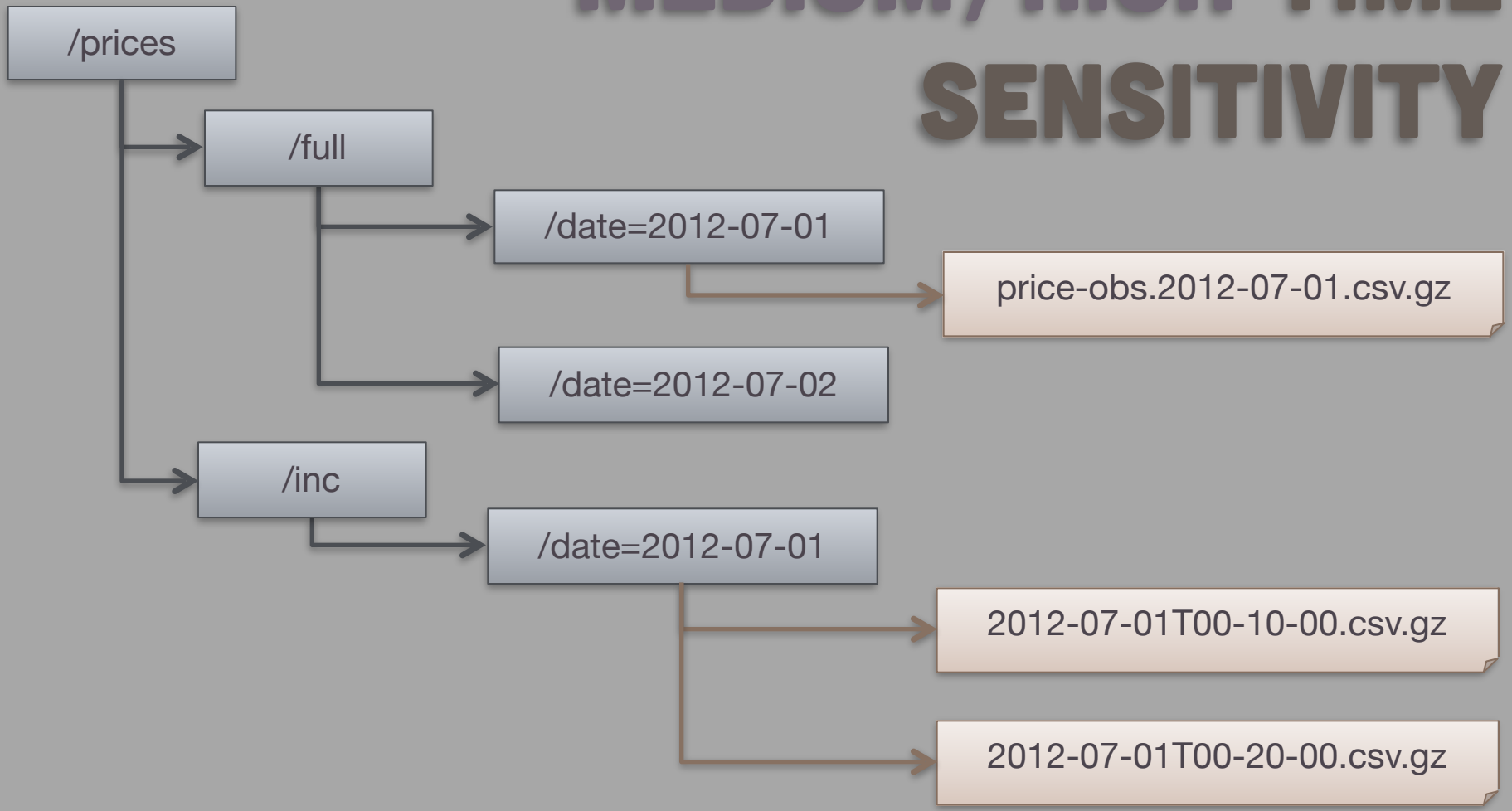

Keep the format simple (CSV, JSON)
Poll for updates
Final datasets should be compressed and stored (i.e. S3)
Poll frequency == data inconsistency threshold
Help! I am in the trunk!
Cache loading tips & tricks

CACHE LOADING TIME SENSITIVITY

CACHE LOADING:
LOW TIME SENSITIVITY DATA



CACHE LOADING: MEDIUM/HIGH TIME SENSITIVITY



CACHE LOADING STRATEGY

SWAP

Image src:http://static.fjcdn.com/pictures/funny_22d73a_372351.jpg

CACHE LOADING STRATEGY SWAP

Cache is immutable, so no locking is required

Image src:http://static.fjcdn.com/pictures/funny_22d73a_372351.jpg

CACHE LOADING STRATEGY SWAP

Cache is immutable, so no locking is required

meow

Works well for infrequently updated data sets

And for datasets that need to be refreshed each update

Image src:http://static.fjcdn.com/pictures/funny_22d73a_372351.jpg

CACHE LOADING STRATEGY: CRUD

http://www.lostwackys.com/wacky-packages/WackyAds/capn-crud.htm

CACHE LOADING STRATEGY: CRUD

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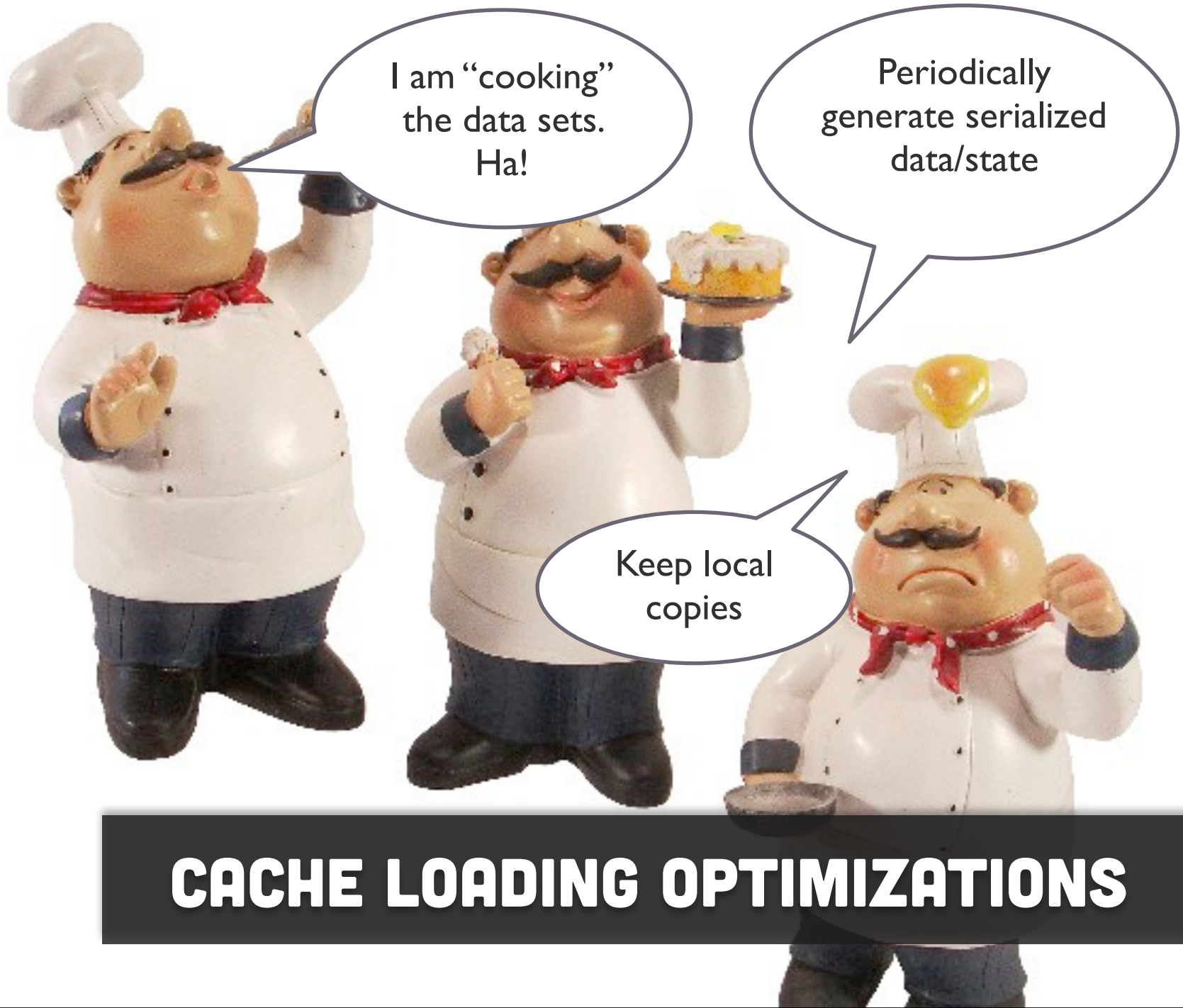
CACHE LOADING STRATEGY: CRUD

http://www.lostwackys.com/wacky-packages/WackyAds/capn-crud.htm

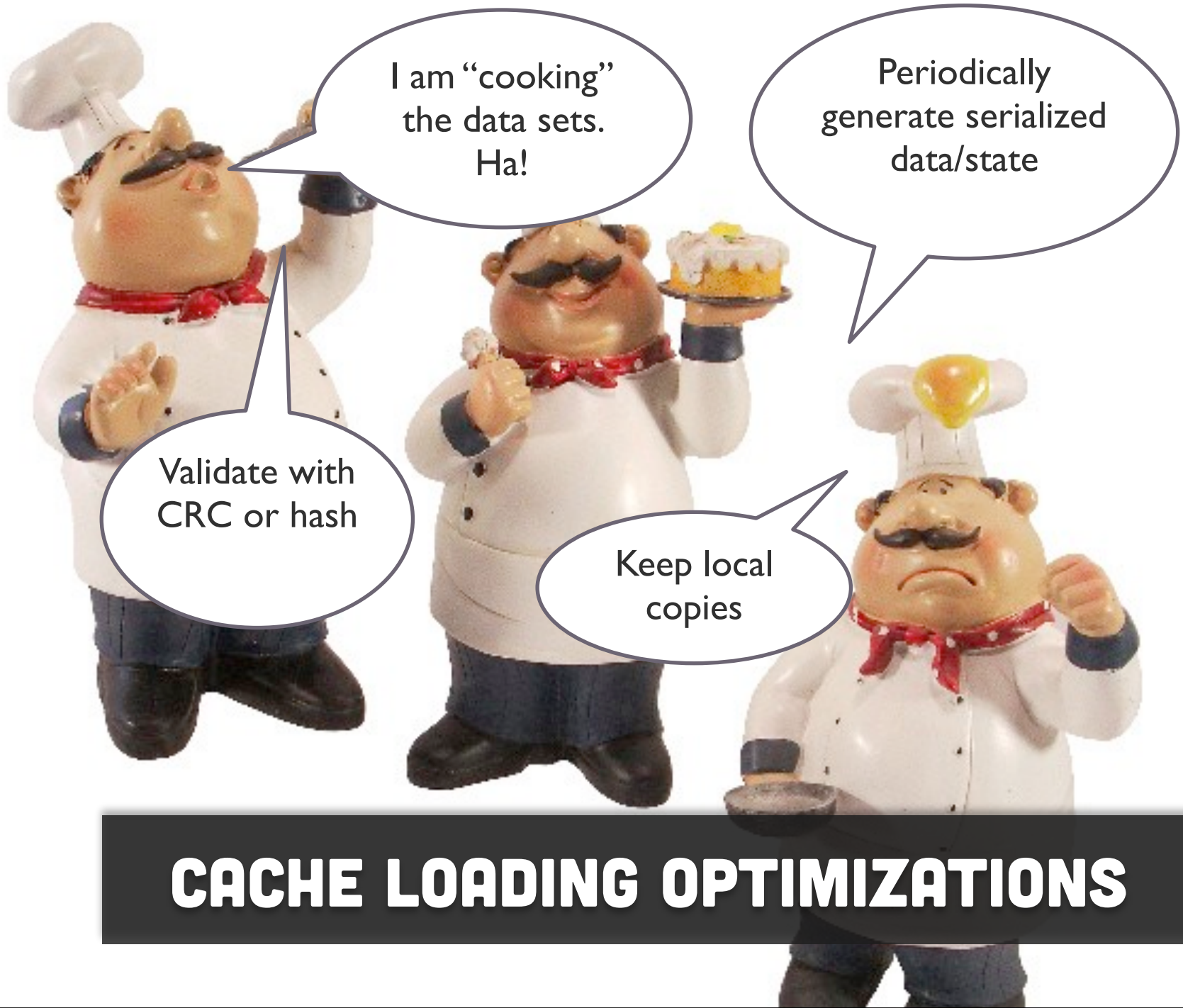
CONCURRENT LOCKING WITH *Trove Map*

```
public class LongCache<V> {
    private TLongObjectMap<V> map = new TLongObjectHashMap<V>();
    private ReentrantReadWriteLock lock = new ReentrantReadWriteLock();
    private Lock r = lock.readLock(), w = lock.writeLock();
    public V get(long k) {
        r.lock();
        try { return map.get(k); } finally { r.unlock(); }
    }
    public V update(long k, V v) {
        w.lock();
        try { return map.put(k, v); } finally { w.unlock(); }
    }
    public V remove(long k) {
        w.lock();
        try { return map.remove(k); } finally { w.unlock(); }
    }
}
```

CACHE LOADING OPTIMIZATIONS

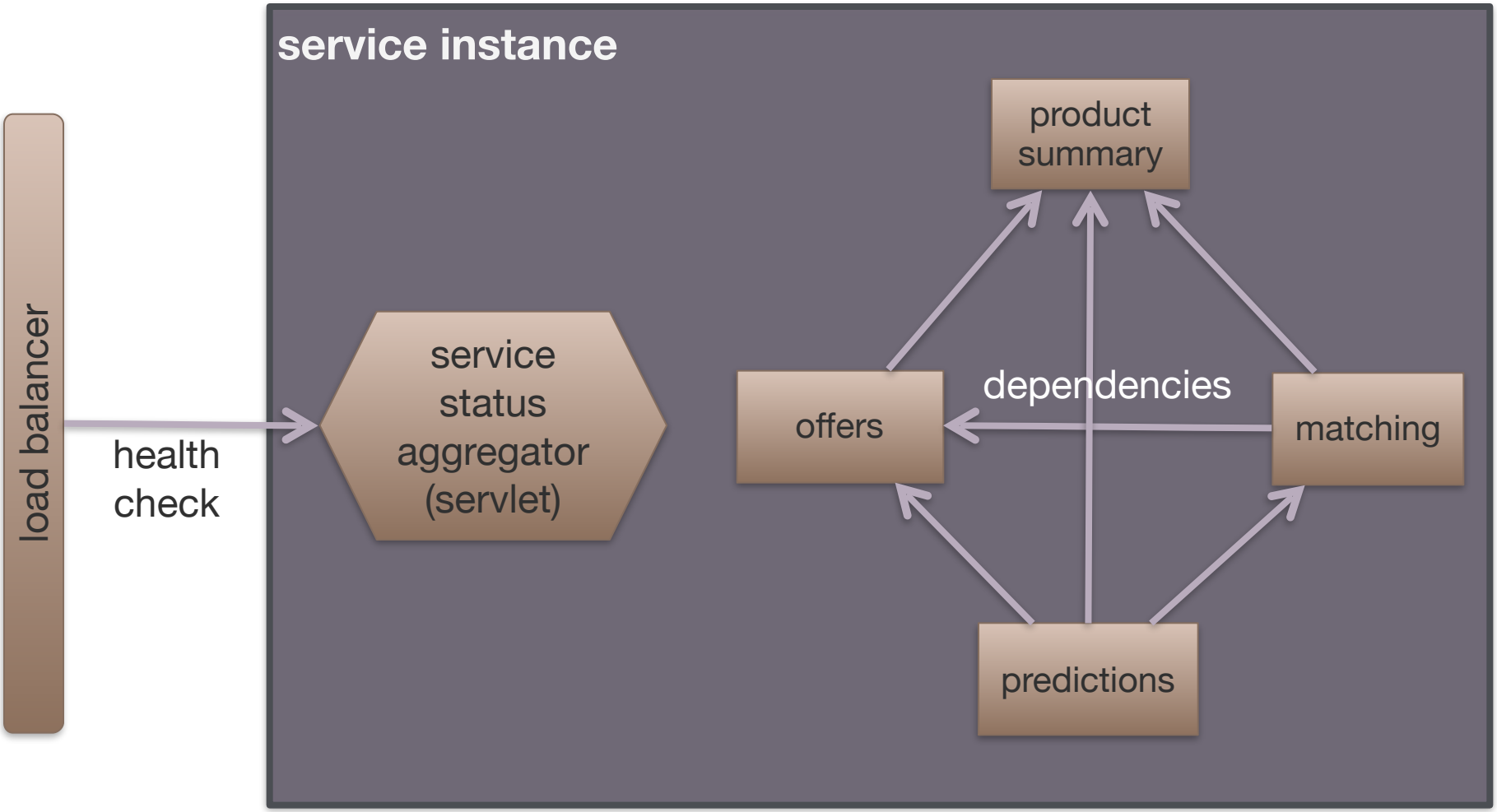


CACHE LOADING OPTIMIZATIONS

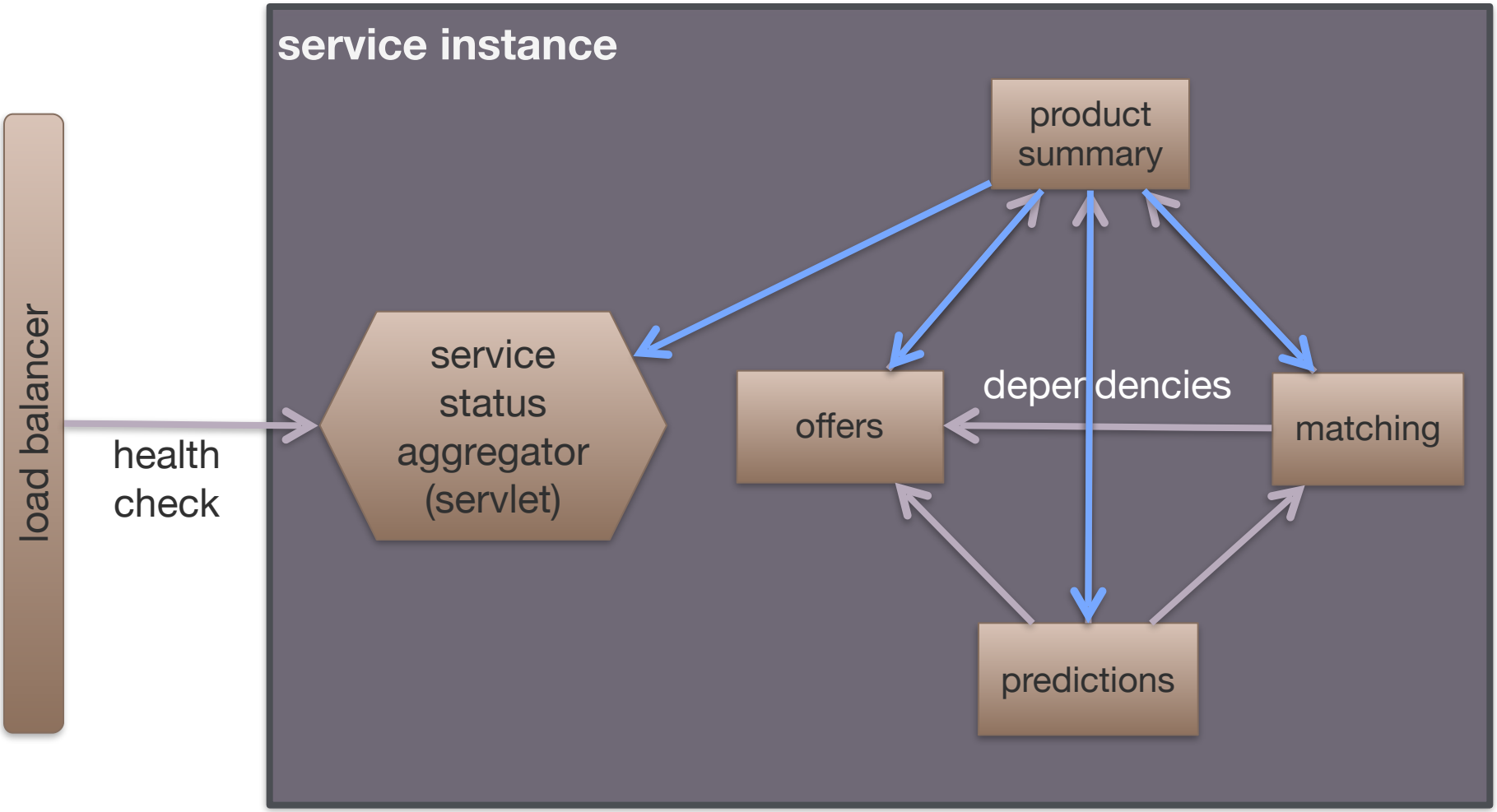


CACHE LOADING OPTIMIZATIONS

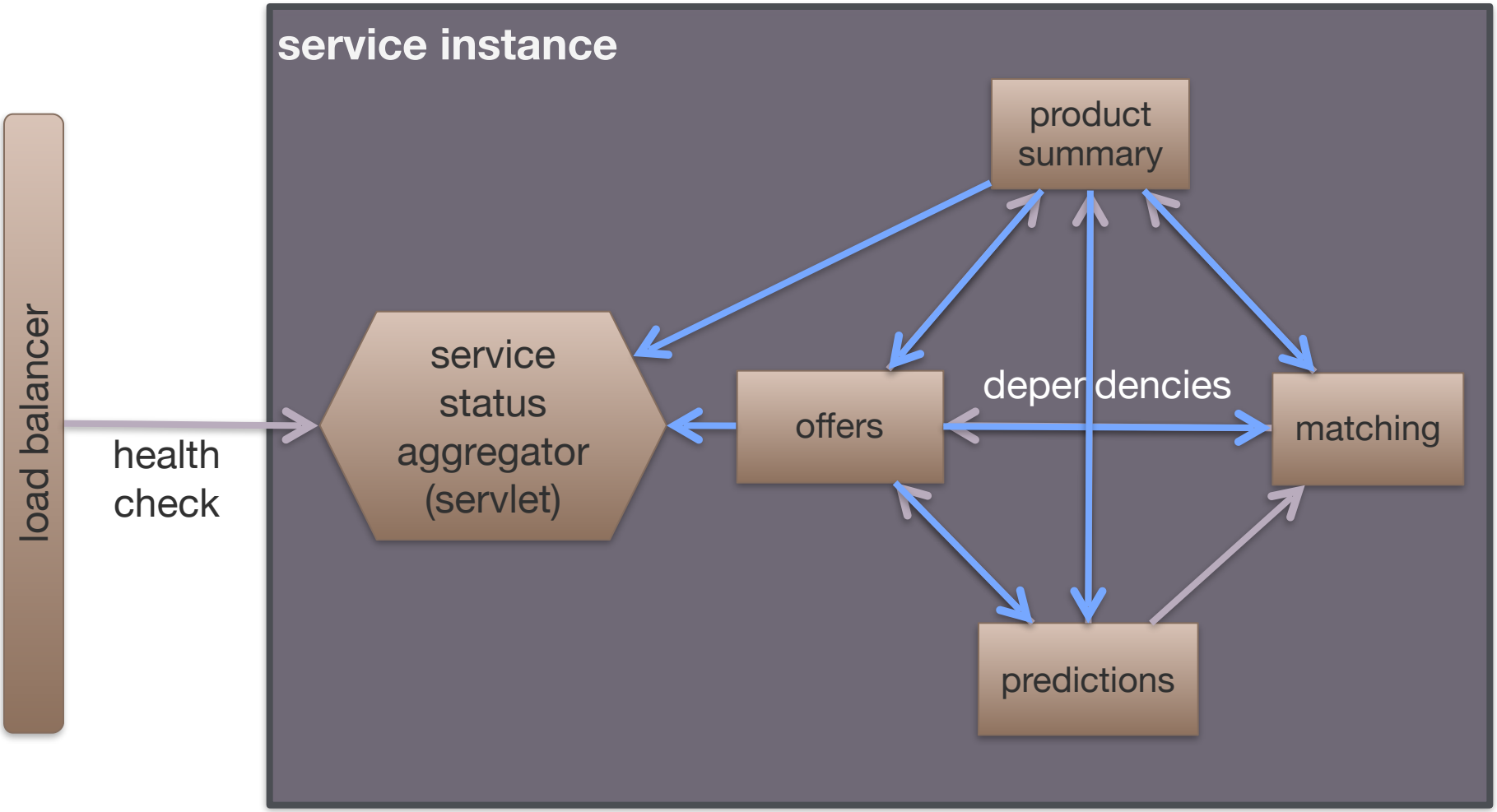
DEPENDENT CACHES



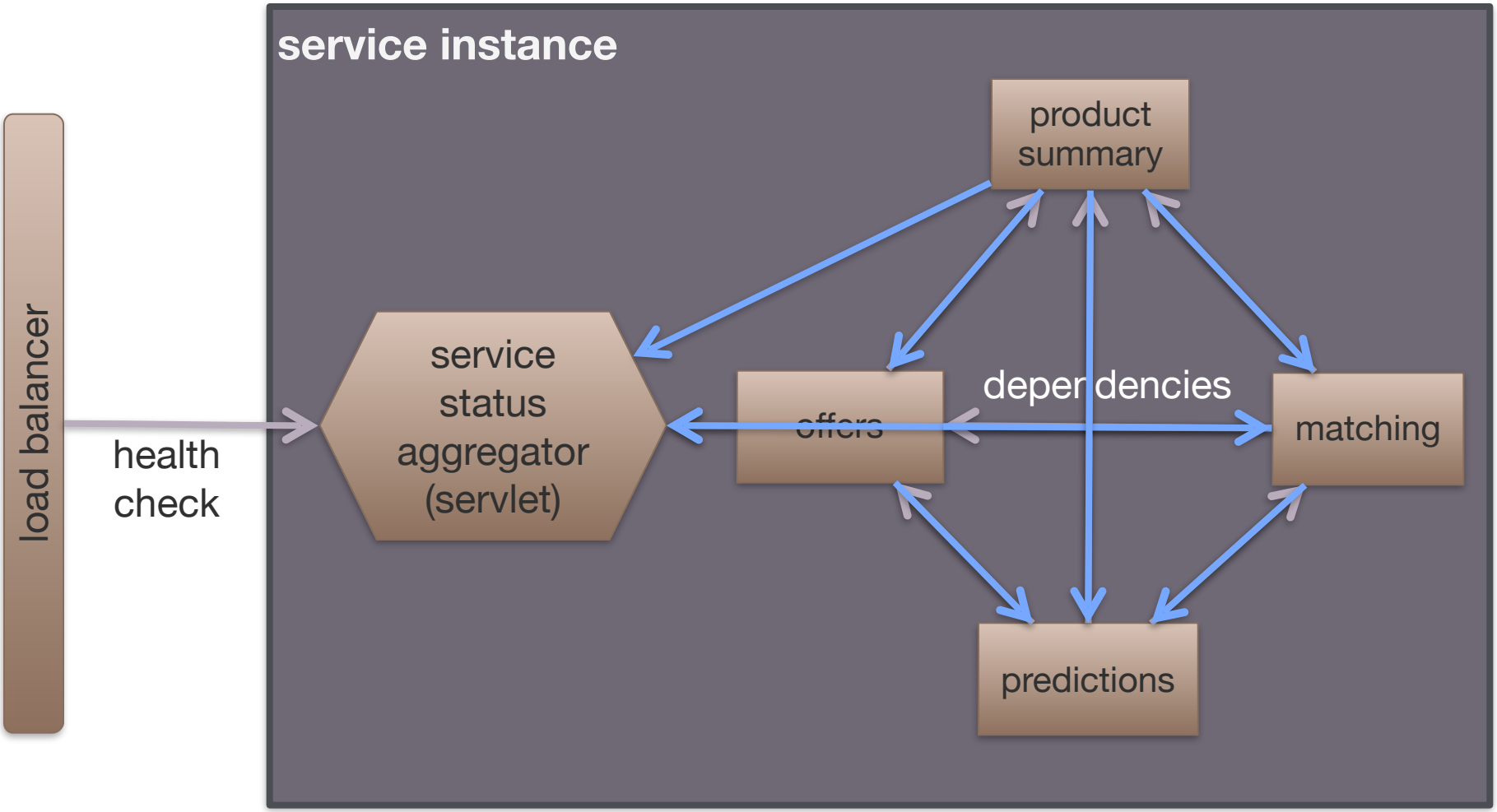
DEPENDENT CACHES



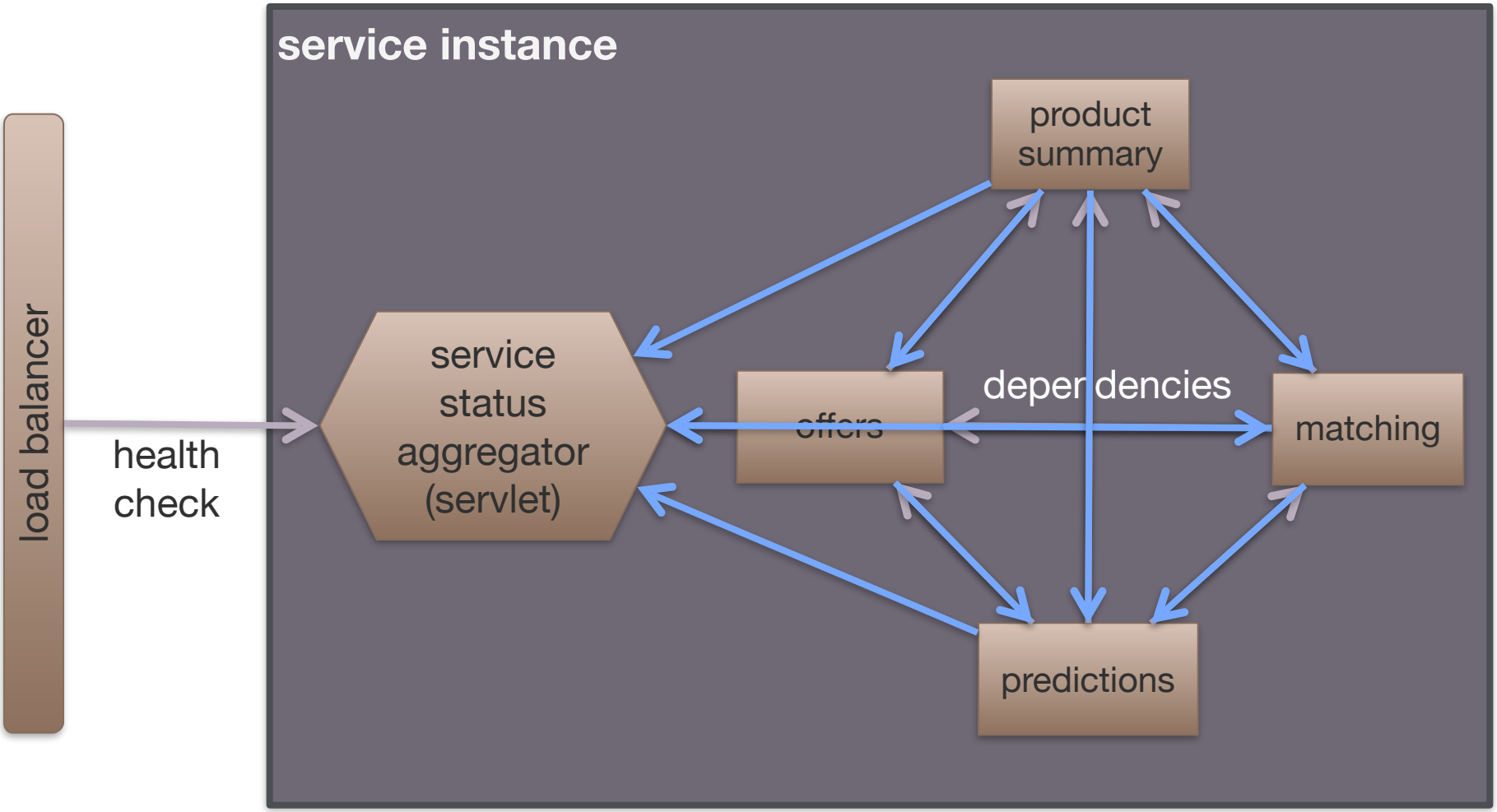
DEPENDENT CACHES



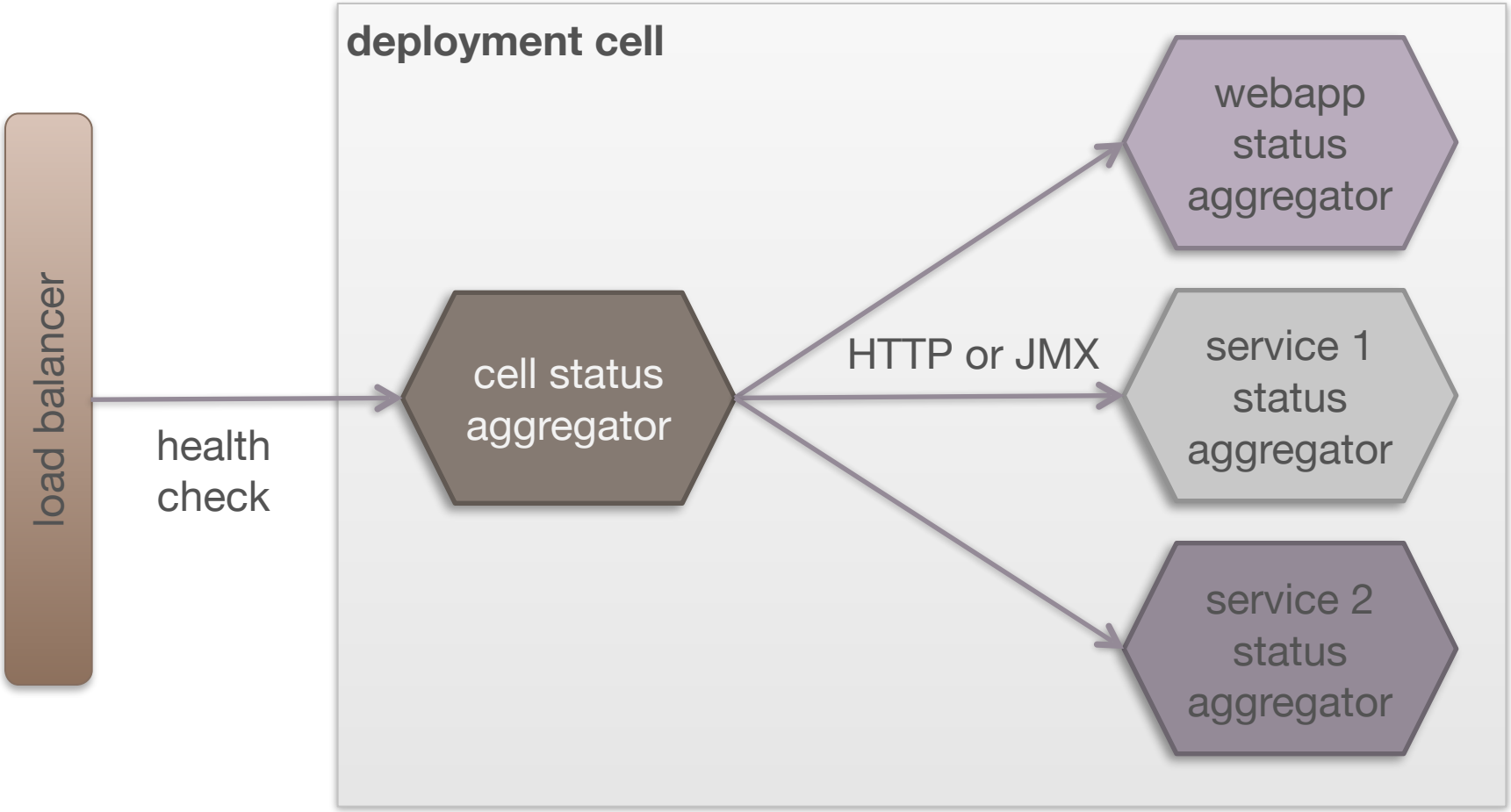
DEPENDENT CACHES



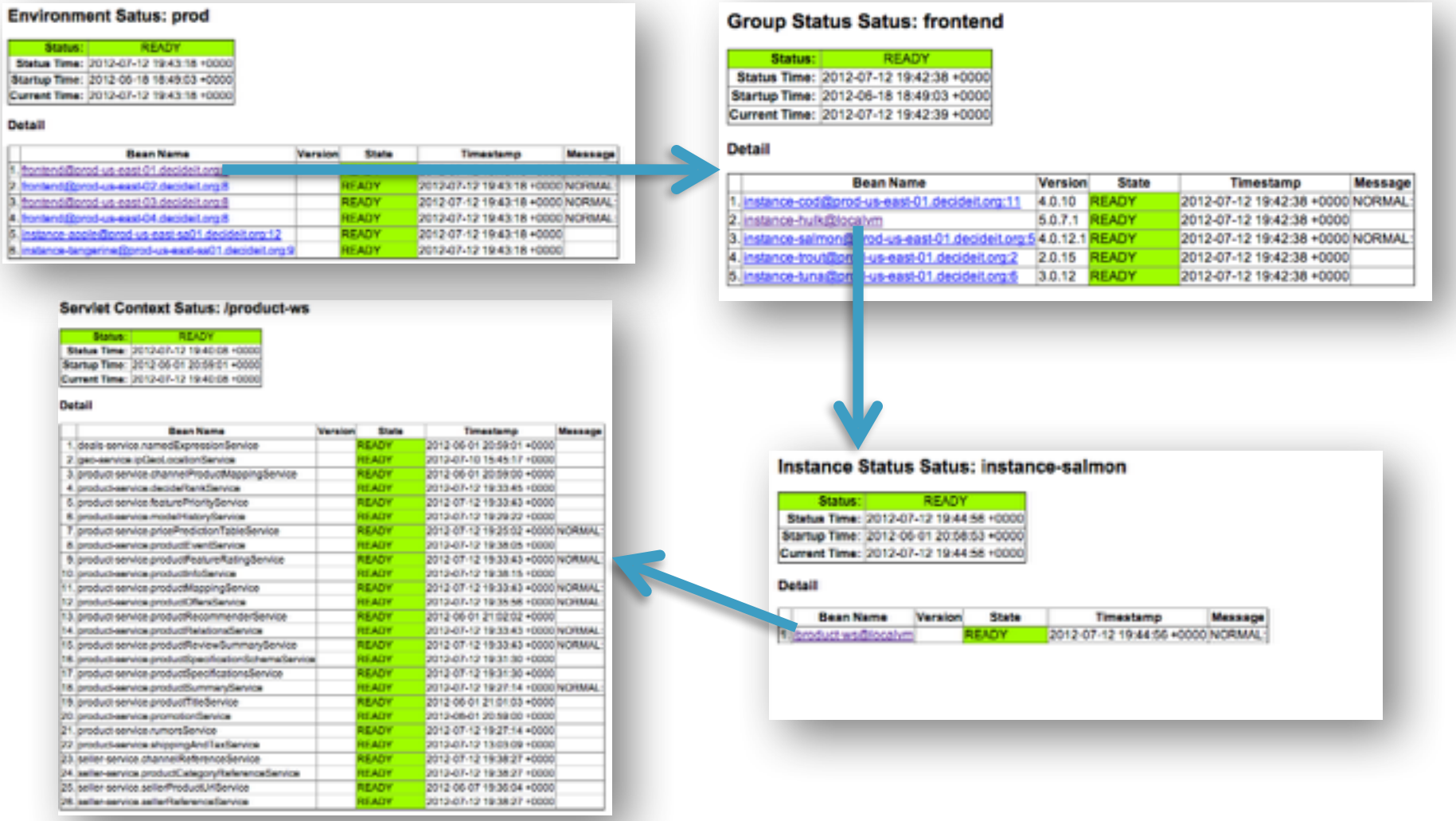
DEPENDENT CACHES



DEPLOYMENT CELL STATUS



HIERARCHICAL STATUS AGGREGATION



Environment Satus: prod

Status:	READY
Status Time:	2012-07-12 19:43:18 +0000
Startup Time:	2012-06-18 18:49:03 +0000
Current Time:	2012-07-12 19:43:18 +0000

Detail

	Bean Name	Version	State	Timestamp	Message
1.	frontend@prod-us-east-01.decideit.org:7				
2.	frontend@prod-us-east-02.decideit.org:8		READY	2012-07-12 19:43:18 +0000	NORMAL:
3.	frontend@prod-us-east-03.decideit.org:8		READY	2012-07-12 19:43:18 +0000	NORMAL:
4.	frontend@prod-us-east-04.decideit.org:8		READY	2012-07-12 19:43:18 +0000	NORMAL:
5.	instance-apple@prod-us-east-sa01.decideit.org:12		READY	2012-07-12 19:43:18 +0000	
6.	instance-tangerine@prod-us-east-sa01.decideit.org:9		READY	2012-07-12 19:43:18 +0000	

Group Status Satus: frontend

Status:	READY
Status Time:	2012-07-12 19:42:38 +0000
Startup Time:	2012-06-18 18:49:03 +0000
Current Time:	2012-07-12 19:42:39 +0000

Detail

	Bean Name	Version	State	Timestamp	Message
1.	instance-cod@prod-us-east-01.decideit.org:11	4.0.10	READY	2012-07-12 19:42:38 +0000	NORMAL:
2.	instance-hulk@localvm	5.0.7.1	READY	2012-07-12 19:42:38 +0000	
3.	instance-salmon@prod-us-east-01.decideit.org:5	4.0.12.1	READY	2012-07-12 19:42:38 +0000	NORMAL:
4.	instance-trout@prod-us-east-01.decideit.org:2	2.0.15	READY	2012-07-12 19:42:38 +0000	
5.	instance-tuna@prod-us-east-01.decideit.org:6	3.0.12	READY	2012-07-12 19:42:38 +0000	

Servlet Context Satus: /product-ws

Status:	READY
Status Time:	2012-07-12 19:40:08 +0000
Startup Time:	2012-06-01 20:59:01 +0000
Current Time:	2012-07-12 19:40:08 +0000

Detail

	Bean Name	Version	State	Timestamp	Message
1.	deals-service.namedExpressionService		READY	2012-06-01 20:59:01 +0000	
2.	geo-service.ipGeoLocationService		READY	2012-07-10 15:45:17 +0000	
3.	product-service.channelProductMappingService		READY	2012-06-01 20:59:00 +0000	
4.	product-service.decideRankService		READY	2012-07-12 19:33:45 +0000	
5.	product-service.featurePriorityService		READY	2012-07-12 19:33:43 +0000	
6.	product-service.modelHistoryService		READY	2012-07-12 19:29:22 +0000	
7.	product-service.pricePredictionTableService		READY	2012-07-12 19:25:02 +0000	NORMAL:
8.	product-service.productEventService		READY	2012-07-12 19:38:05 +0000	
9.	product-service.productFeatureRatingService		READY	2012-07-12 19:33:43 +0000	NORMAL:
10.	product-service.productInfoService		READY	2012-07-12 19:38:15 +0000	
11.	product-service.productMappingService		READY	2012-07-12 19:33:43 +0000	NORMAL:
12.	product-service.productOffersService		READY	2012-07-12 19:35:56 +0000	NORMAL:
13.	product-service.productRecommenderService		READY	2012-06-01 21:02:02 +0000	
14.	product-service.productRelationsService		READY	2012-07-12 19:33:43 +0000	NORMAL:
15.	product-service.productReviewSummaryService		READY	2012-07-12 19:33:43 +0000	NORMAL:
16.	product-service.productSpecificationSchemaService		READY	2012-07-12 19:31:30 +0000	
17.	product-service.productSpecificationsService		READY	2012-07-12 19:31:30 +0000	
18.	product-service.productSummaryService		READY	2012-07-12 19:27:14 +0000	NORMAL:
19.	product-service.productTitleService		READY	2012-06-01 21:01:03 +0000	
20.	product-service.promotionService		READY	2012-06-01 20:59:00 +0000	
21.	product-service.rumorsService		READY	2012-07-12 19:27:14 +0000	
22.	product-service.shippingAndTaxService		READY	2012-07-12 13:03:09 +0000	
23.	seller-service.channelReferenceService		READY	2012-07-12 19:38:27 +0000	
24.	seller-service.productCategoryReferenceService		READY	2012-07-12 19:38:27 +0000	
25.	seller-service.sellerProductUIService		READY	2012-06-07 19:36:04 +0000	
26.	seller-service.sellerReferenceService		READY	2012-07-12 19:38:27 +0000	

Instance Status Satus: instance-salmon

Status:	READY
Status Time:	2012-07-12 19:44:56 +0000
Startup Time:	2012-06-01 20:58:53 +0000
Current Time:	2012-07-12 19:44:56 +0000

Detail

	Bean Name	Version	State	Timestamp	Message
1.	product-ws@localvm		READY	2012-07-12 19:44:56 +0000	NORMAL: