# Distributed Caching

# Introduction

- Caching is essential in a distributed system.
- Makes the results of expensive queries and computations available for reuse.
- Caches exist in many places in an application.
- Two types of caching will be covered:
  - Application caching
  - Web caching

# Application Caching

- Application caching is designed to improve request responsiveness by storing the results of queries and computations in memory so they can be subsequently served by later requests.
  - Newspapers articles (how?)
  - Concert seating map
  - Hourly weather forecast.

# Application Caching

- Caching benefits?
  - Heavy read traffic reduction
  - Computation costs reduction
- Caching requires additional resources, and hence cost, to store cached results.
- Well designed caching schemes are low-cost compared to upgrading database and service nodes to cope with higher request loads.
- 3% of infrastructure at Twitter is dedicated to application-level caches.

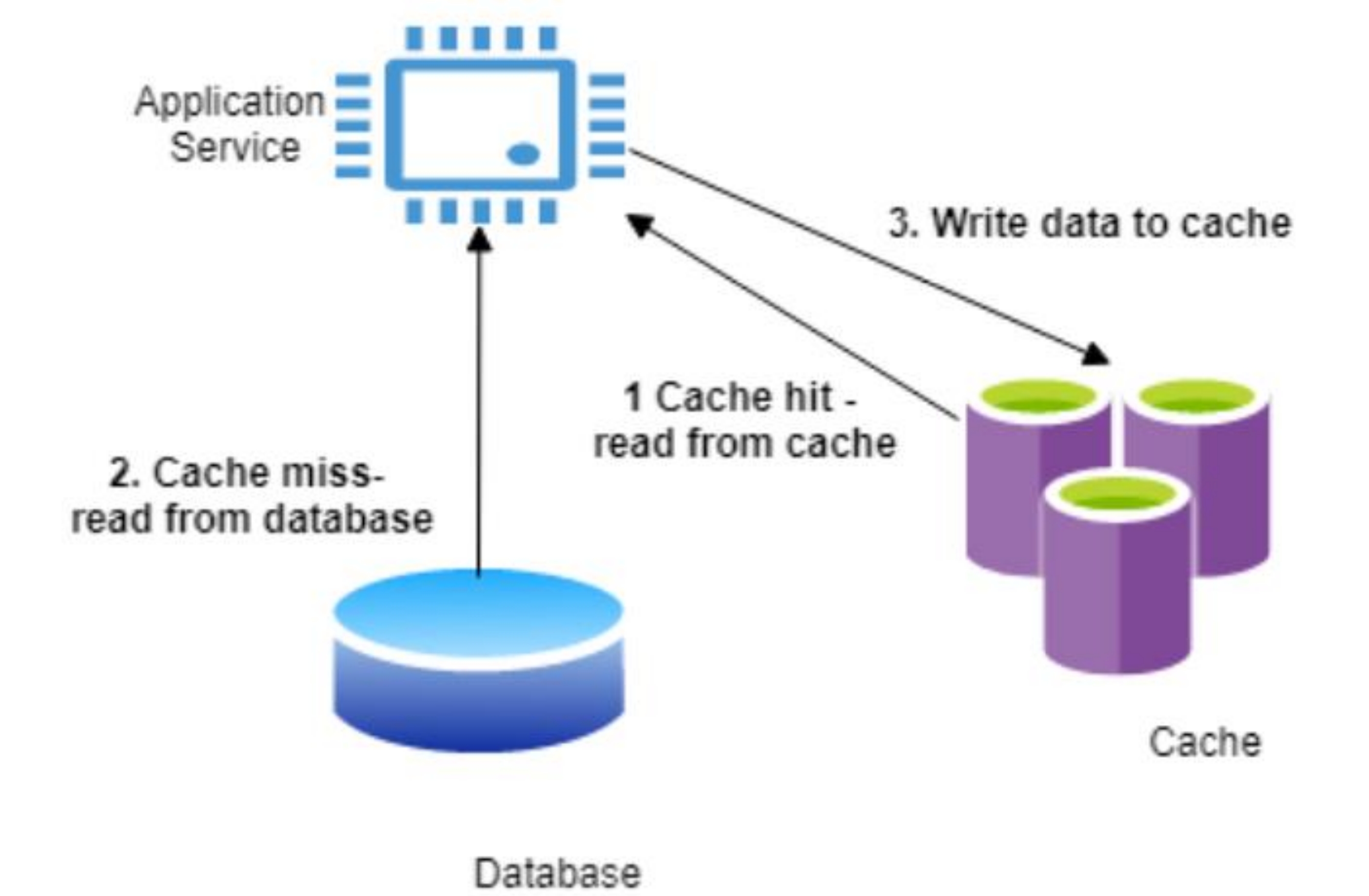
# Application Caching

- Utilize cache engines. The two predominant technologies in this area are:
  - Memcached (Supported by Netflix)
  - Redis
- Such cache engines are distributed in-memory hash tables designed for arbitrary data (strings, objects) representing the results of database queries or downstream service API calls.
- Possible storage?
  - User session data, database queries

# Application Caching

- The cache appears to application services as a single store, and objects are allocated to individual cache servers using a hash function on the object key

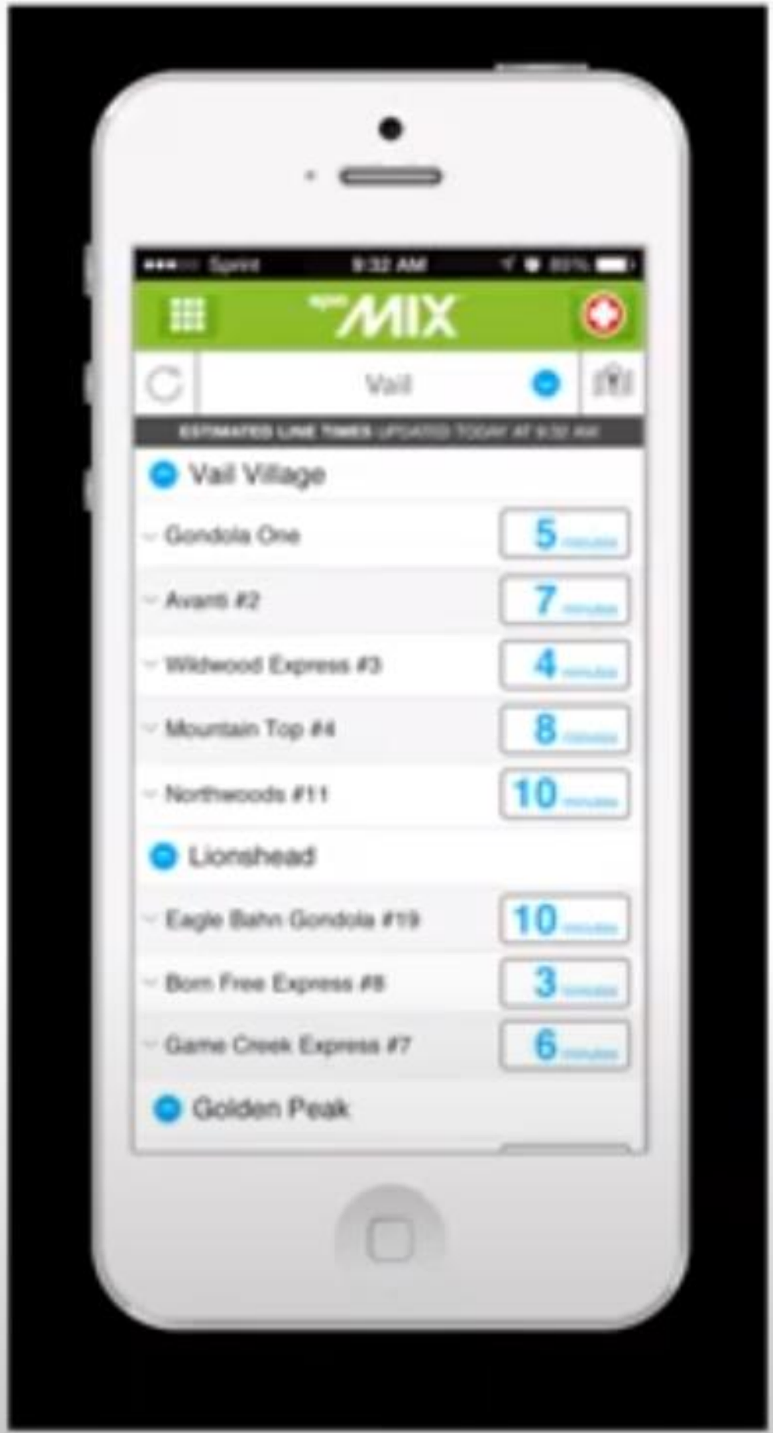
# Application Caching


Application Service
3. Write data to cache
1 Cache hit - read from cache
2. Cache miss- read from database
Cache
Database

# Application Caching - **Example**

- At a busy winter resort, skiers and boarders can use their mobile app to get an estimate of the lift wait times across the resort.
- This enables them to plan and avoid congested areas where they will have to wait to ride a lift for say 15 minutes (or sometimes more!).
- How would the company calculate the estimated wait time to get a lift?
- Is such calculation expensive? Why?
- What needs to be cached?

# Appli mple



Sprint 9:32 AM 89%

MIX

Vail

ESTIMATED LINE TIMES UPDATED TODAY AT 9:32 AM

**Vail Village**

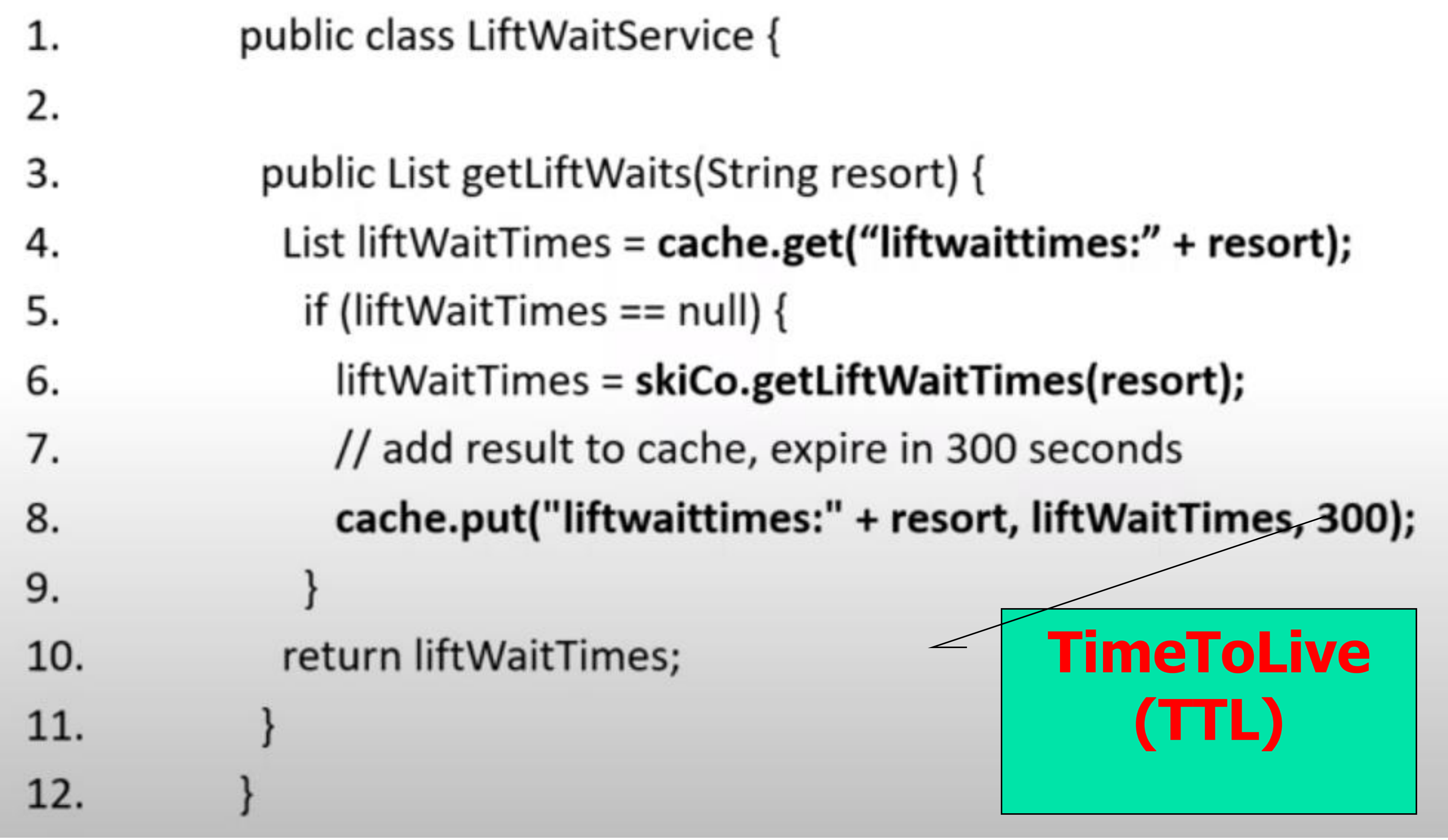
| | |
|---|---|
| Gondola One | 5 minutes |
| Avanti #2 | 7 minutes |
| Wildwood Express #3 | 4 minutes |
| Mountain Top #4 | 8 minutes |
| Northwoods #11 | 10 minutes |

**Lionshead**

| | |
|---|---|
| Eagle Bahn Gondola #19 | 10 minutes |
| Born Free Express #8 | 3 minutes |
| Game Creek Express #7 | 6 minutes |

**Golden Peak**

# Application Caching - Example



```
public class LiftWaitService {

  public List getLiftWaits(String resort) {
    List liftWaitTimes = cache.get(“liftwaittimes:” + resort);
      if (liftWaitTimes == null) {
        liftWaitTimes = skiCo.getLiftWaitTimes(resort);
        // add result to cache, expire in 300 seconds
        cache.put("liftwaittimes:" + resort, liftWaitTimes, 300);
      }
    return liftWaitTimes;
  }
}
```

**TimeToLive (TTL)**

# Application Caching - **Example**

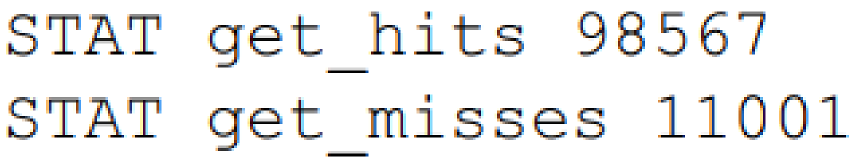
- A cache hit on a fast network will take maybe a millisecond – much faster than the lift wait times calculation.
- Hence if we get N requests in a 5 minute period, N-1 requests are served from the cache. Imagine if N is 10000?
- This is a lot of expensive calculations saved, and CPU cycles that your database can use to process other queries.

# Application Caching Design

- Application caching can provide significant throughput boosts, reduced latencies, and increased client application responsiveness.
- The key to achieving these desirable qualities is to satisfy as many requests as possible from the cache.
- The general design principle is to maximize the cache hit rate and minimize the cache miss rate.
- When items are updated regularly, the cost of cache misses can negate the benefits of the cache

# Application Caching Design

- It is needed to monitor the cache usage once a service is in production to ensure the hit and miss rates are in line with design expectations.
- Caches will provide both management utilities and APIs to enable monitoring of the cache usage characteristics.
- For example, memcached makes a large number of statistics available, including the hit and miss counts



```
STAT get_hits 98567
STAT get_misses 11001
```

# Caching Patterns

- Application level caching known as cache-aside pattern (**Why?**)
- Alternatives exist, commonly supported by databases
  - Read-through
  - Write-through
  - Write-behind

# Caching Patterns

- Read-through: The application satisfies all requests by accessing the cache. If the data required is not available in the cache, a loader is invoked to access the data systems and load the results in the cache for the application to utilize
- Write-through: The application always writes updates to the cache. When the cache is updated, a writer is invoked to write the new cache values to the database. **When the database is updated**, the application can complete the request.
- Write-behind: Like write-through, except the application does not wait for the value to be written to the database from the cache. (**Pros/Cons**)

# Cache-aside versus (Read-through, Write-through, Write-behind)?

- Read/Write-through/behind simplify application logic (how?)
  - Require a cache augmented with an application specific handler to perform database reads/writes (e.g., Amazon's DynamoDB Accelerator (DAX))
- DAX: AWS launched Amazon DynamoDB Accelerator (**DAX**), a highly available, in-memory cache for Amazon DynamoDB.

# Cache-aside versus (Read-through, Write-through, Write-behind)?

- How does DAX work?
  - The application developer points their application at the DAX endpoint instead of at the DynamoDB endpoint
  - DAX seamlessly intercepts the API calls that an application normally makes to DynamoDB so that both read and write activity are reflected in the DAX cache.
  - Cache failure?

# Caching Patterns

- For cache-aside:
  - More complex programming model
  - Resilient to cache failure

# Web Caching

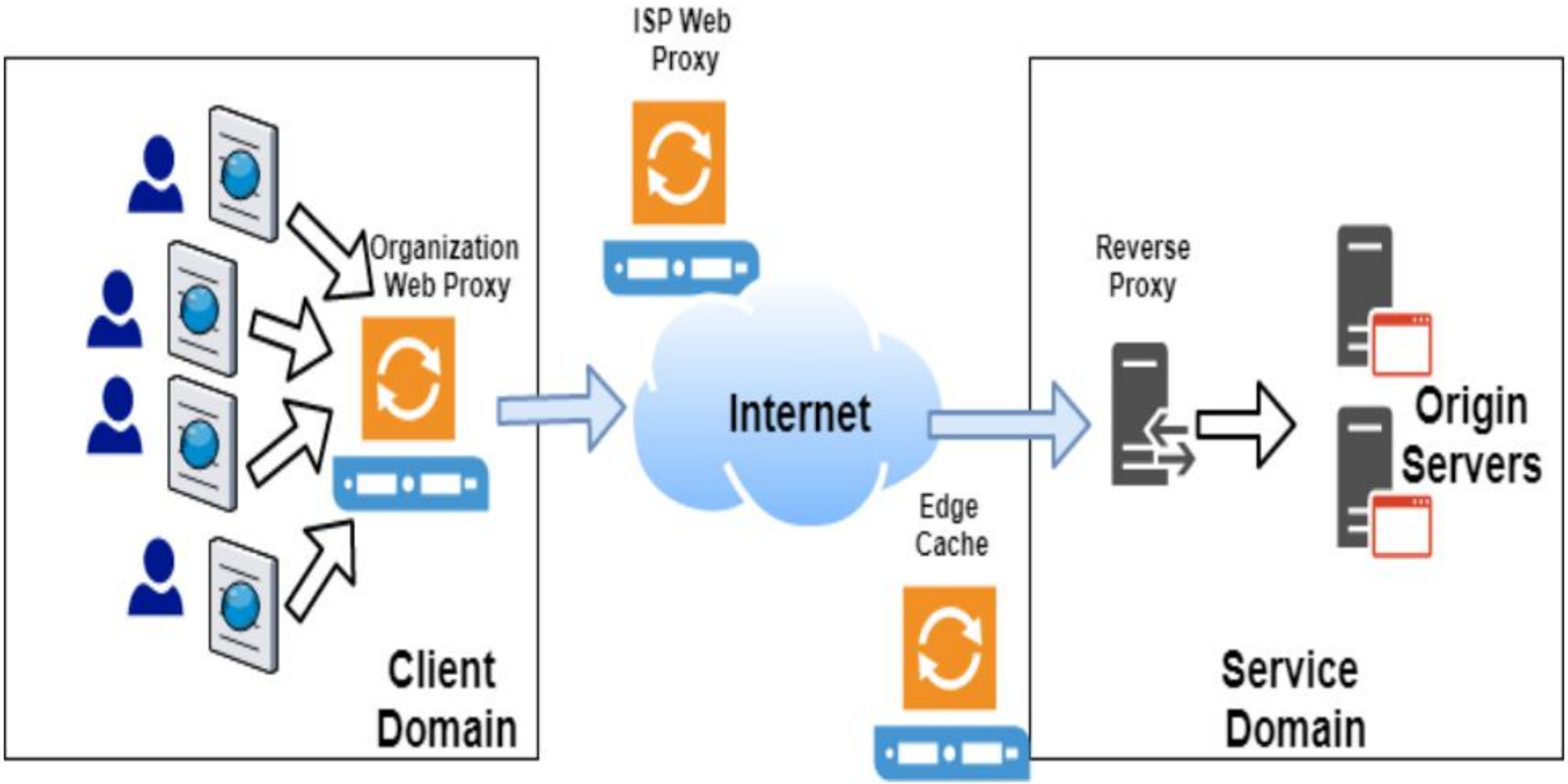


*Figure 6-2. Web Caches in the Internet*

# Web Caching

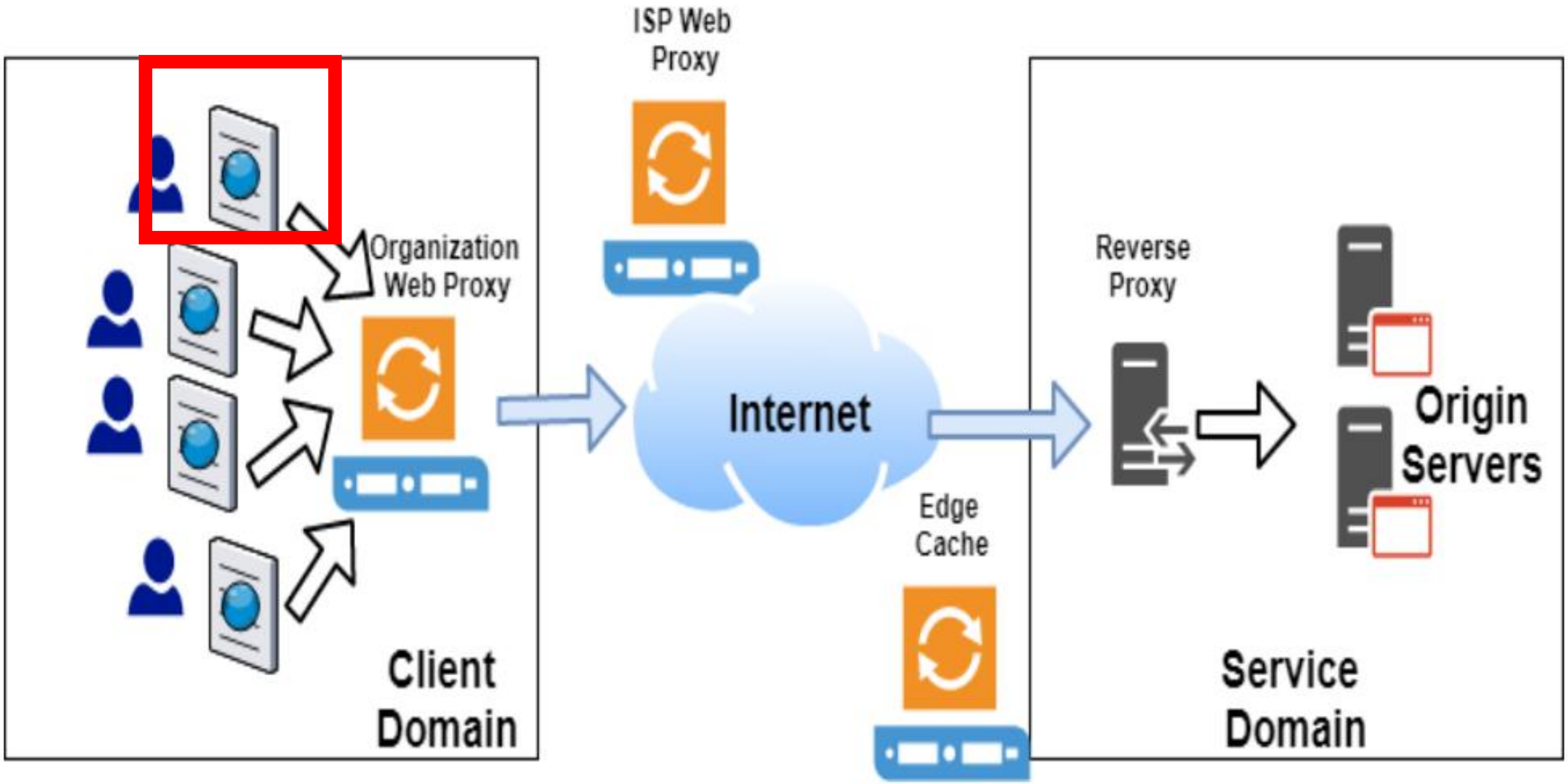


*Figure 6-2. Web Caches in the Internet*

# Web Caching

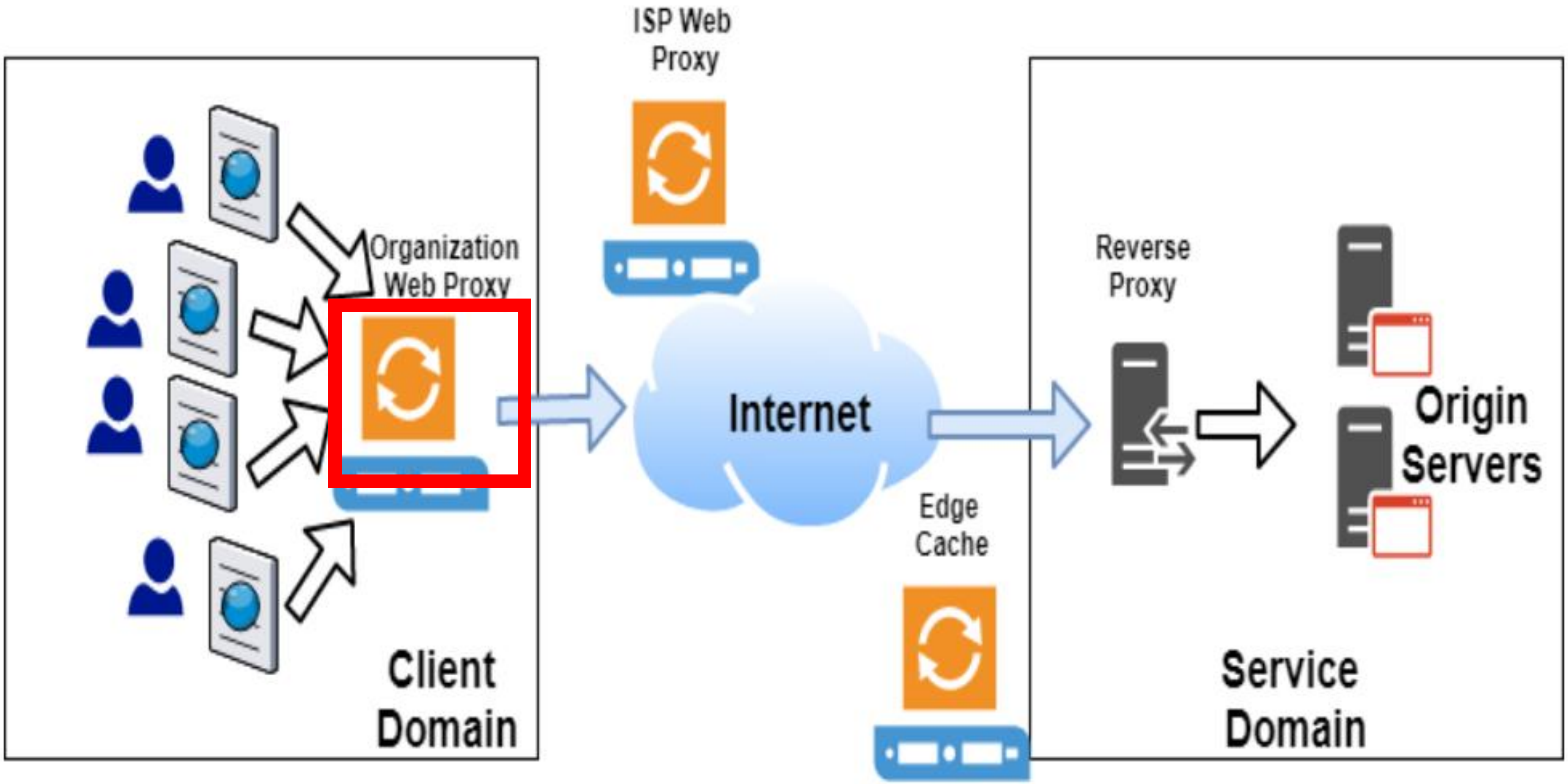


*Figure 6-2. Web Caches in the Internet*

# Web Caching

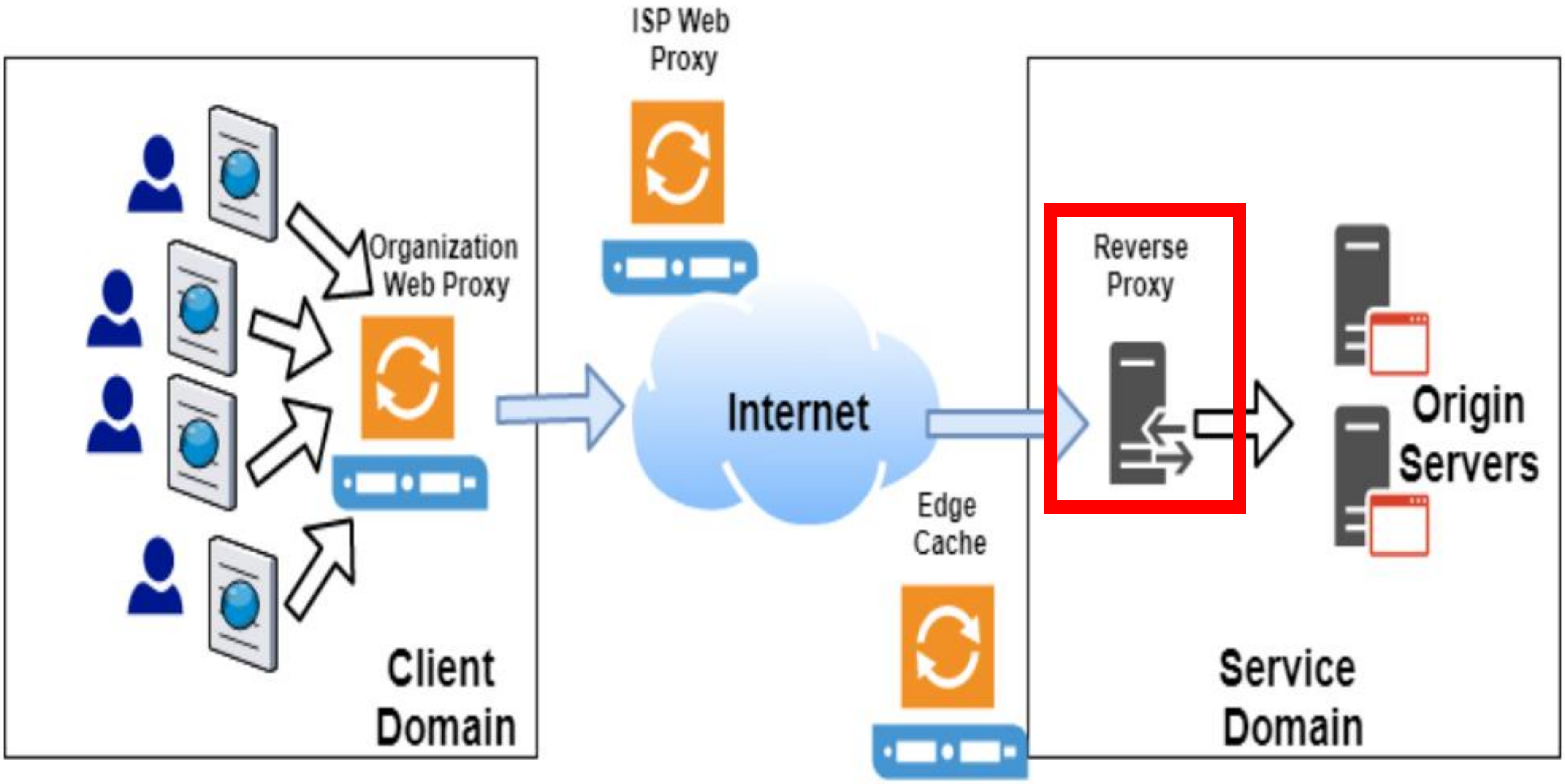


*Figure 6-2. Web Caches in the Internet*

# Web Caching

- Web browser caches are also known as private caches (for a single user).
- Organizational and ISP proxy caches are shared caches that support requests from multiple users.
- Edge caches: live at various strategic geographical locations globally, so that they cache frequently accessed data close to clients. (Example?)
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# Required Readings

- Chapter 6: Distributed Caching, from the textbook: “Foundations of Scalable Systems”, Ian Gorton, O’reilly Media Inc., 2022.