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Generating single mermaid chart 🎨 Rendered Mermaid diagram 1 Generating single mermaid chart 🎨 Rendered Mermaid diagram 2 Generating single mermaid chart 🎨 Rendered Mermaid diagram 3 Generating single mermaid chart 🎨 Rendered Mermaid diagram 4 Generating single mermaid chart 🎨 Rendered Mermaid diagram 5 Generating single mermaid chart 🎨 Rendered Mermaid diagram 6 Generating single mermaid chart 🎨 Rendered Mermaid diagram 7 Generating single mermaid chart 🎨 Rendered Mermaid diagram 8 Generating single mermaid chart 🎨 Rendered Mermaid diagram 9 Generating single mermaid chart 🎨 Rendered Mermaid diagram 10

Caching - 1 Hour Session

Duration: 60 minutes **Level:** Intermediate

📋 Session Agenda

- [ ] Introduction to Caching (10 min)
- [ ] Cache Types & Layers (10 min)
- [ ] Caching Strategies & Patterns (15 min)
- [ ] Cache Eviction Policies (10 min)
- [ ] Implementation & Best Practices (15 min)

🎯 Learning Objectives

By the end of this session, you will understand: - What caching is and when to use it - Different types and layers of caching - Common caching patterns and strategies - Cache eviction policies and their trade-offs - How to implement and manage caching effectively - Common pitfalls and how to avoid them

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1. Introduction to Caching (10 min)

What is Caching?

Caching is the process of storing copies of data in a temporary storage location (cache) for faster access.

> 💬 **Quote** "There are only two hard things in Computer Science: cache invalidation and naming things." - Phil Karlton

Why Cache?

Performance Improvements: - 🚀 **Speed:** RAM access ~100ns vs Database ~10ms (100,000x faster) - 💰 **Cost:** Reduce database load and infrastructure costs - 📊 **Scalability:** Handle more requests with same resources - 🌐 **User Experience:** Faster response times = happier users

The Cache Hit/Miss Concept

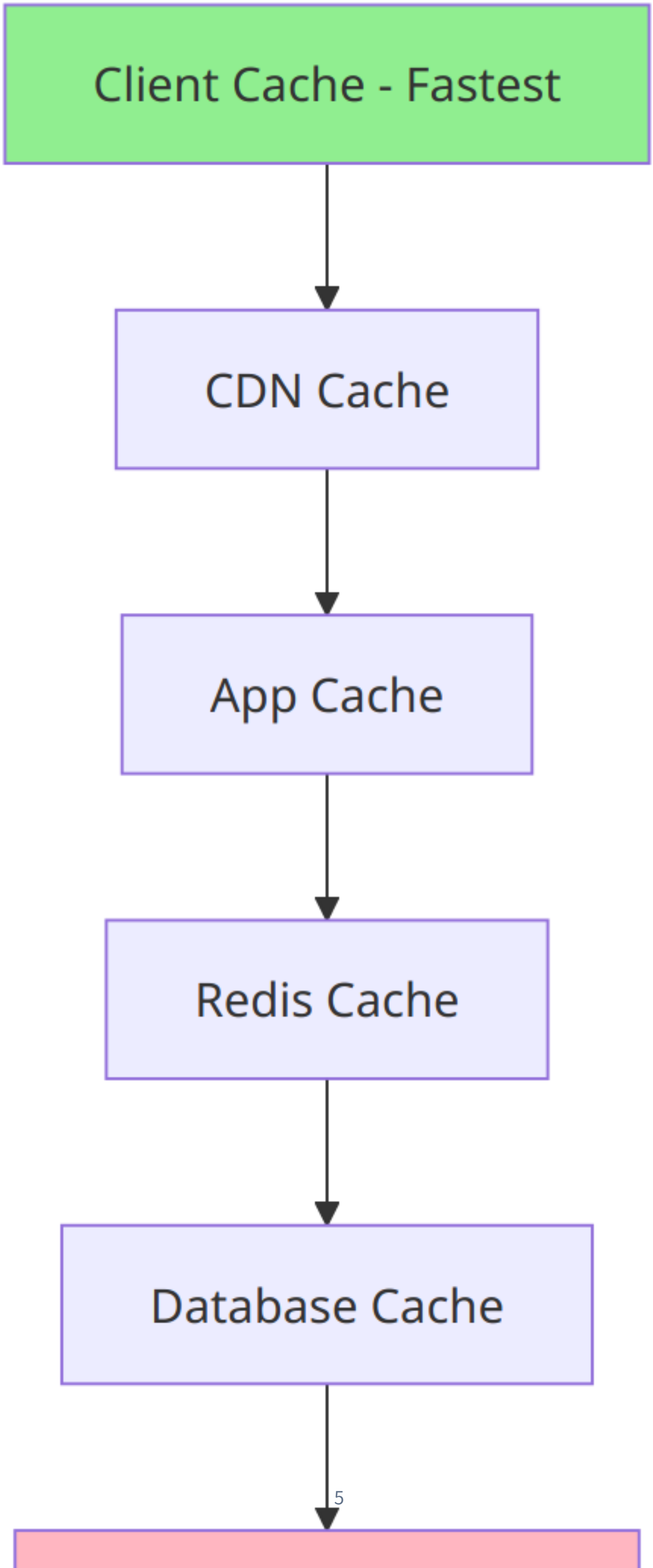
```
Request Flow:

1. Check Cache
   ├─ HIT: Return cached data (fast!) √
   └─ MISS:
       ├─ Query database/API (slow)
       ├─ Store in cache
       └─ Return data

Cache Hit Ratio = (Cache Hits / Total Requests) × 100%
Target: 80-95% for most applications
```

Key Metrics

METRIC	DESCRIPTION	GOOD TARGET
Hit Ratio	Percentage of requests served from cache	> 80%
Latency	Time to retrieve from cache	< 10ms
TTL	Time data stays in cache	Depends on use case
Memory Usage	Cache size vs available memory	< 80% of allocated

2. Cache Types & Layers (10 min)

Caching Layers (Closest to Farthest from User)


Client Cache - Fastest
CDN Cache
App Cache
Redis Cache
Database Cache

Diagram

1. Client-Side Cache

Browser Cache: - Stores static assets (images, CSS, JS) - Controlled via HTTP headers

```
HTTP Headers:

Cache-Control: max-age=3600, public
ETag: "33a64df551425fcc55e4d42a148795d9f25f89d4"
Last-Modified: Wed, 21 Oct 2023 07:28:00 GMT
Expires: Thu, 01 Dec 2024 16:00:00 GMT
```

LocalStorage/SessionStorage: - JavaScript-accessible storage - 5-10MB limit per domain

```
        // LocalStorage example
        localStorage.setItem('user_preferences', JSON.stringify(data));
        const prefs = JSON.parse(localStorage.getItem('user_preferences'));
```

> ❓ **Question** How to update a data? ### 2. CDN Cache

Content Delivery Network caches at edge locations worldwide.

```
User in Tokyo → Tokyo Edge Server (cached) ✓ (50ms)
              vs
User in Tokyo → US Origin Server (not cached) ✗ (250ms)
```

Use Cases: - Static assets (images, videos, CSS, JS) - API responses (with proper headers) - Entire pages (for static sites)

3. Application-Level Cache

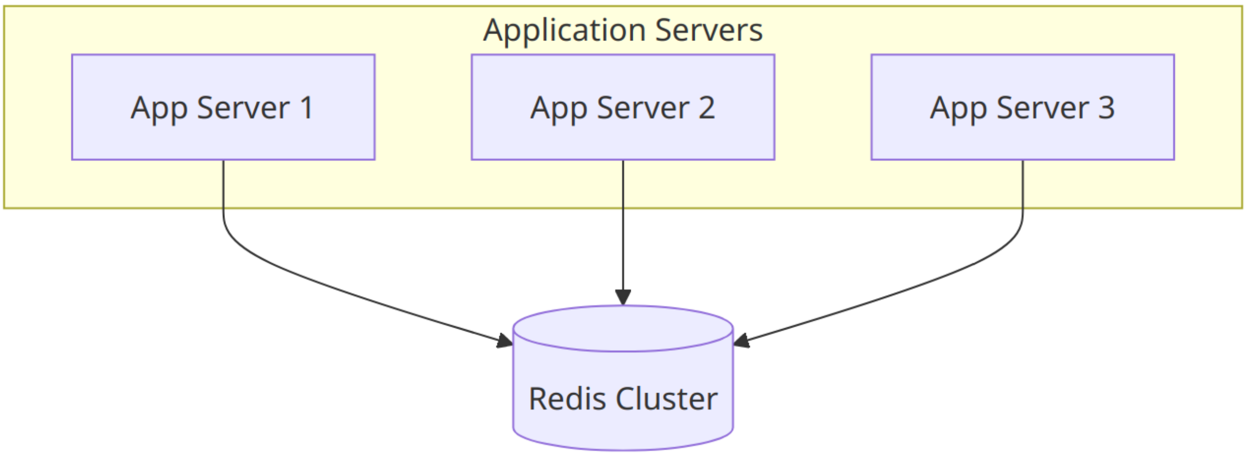
In-Process Cache: - Stored in application memory - Fastest but not shared across instances

```python
# Python simple in-memory cache
from functools import lru_cache

@lru_cache(maxsize=1000)
def get_user(user_id):
    # This result will be cached
    return database.query(f"SELECT * FROM users WHERE id={user_id}")
```

4. Distributed Cache

Shared cache across multiple application instances.

Popular Solutions: - **Redis** - Feature-rich, supports data structures - **Memcached** - Simple, fast, key-value only - **Hazelcast** - Distributed in-memory data grid



Diagram

5. Database Cache

Query Result Cache: - MySQL Query Cache (deprecated in 8.0) - PostgreSQL shared buffers - MongoDB WiredTiger cache

ORM-Level Cache: - Hibernate second-level cache - Django cache framework - Entity Framework caching

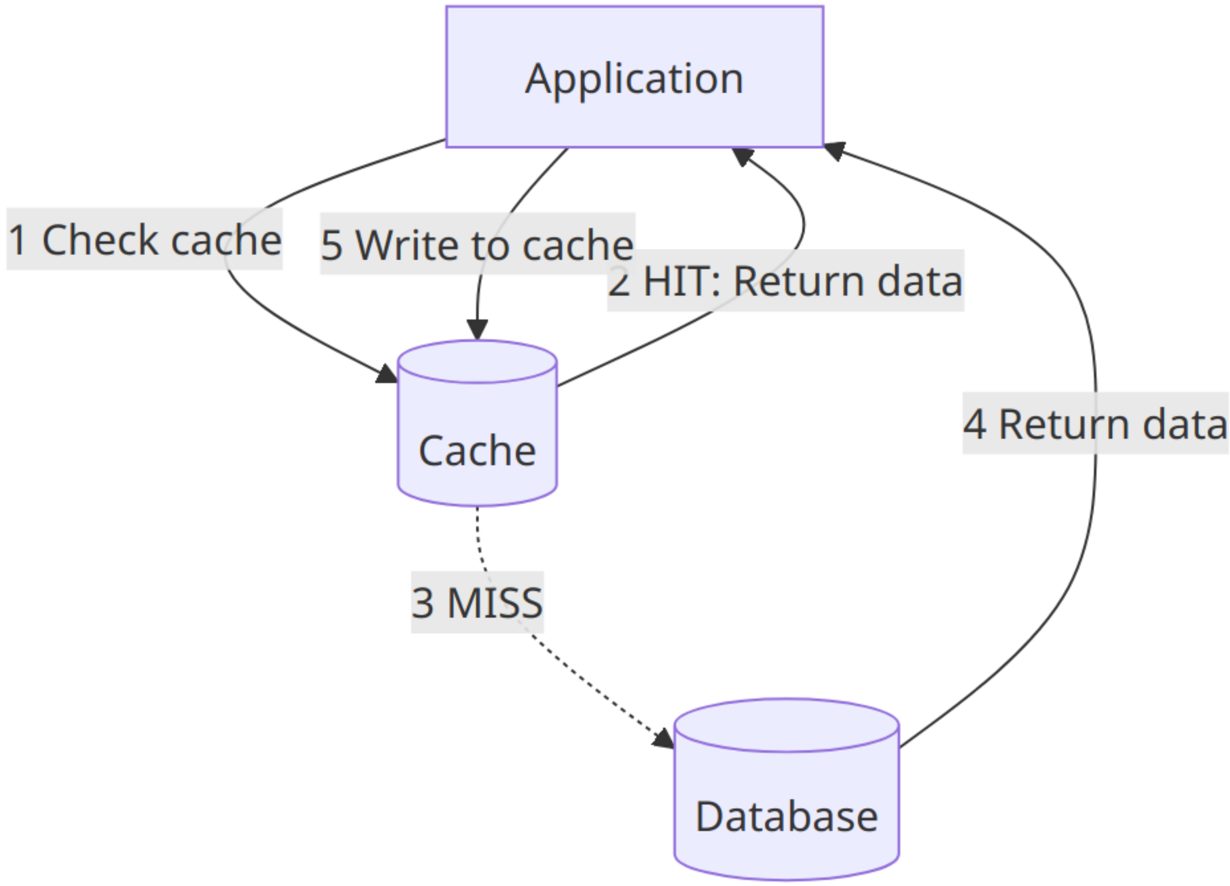
Cache Type Comparison

TYPE	SPEED	SHARED	COMPLEXITY	PERSISTENCE
Browser	Fastest	No	Low	Session-based
CDN	Very Fast	Yes	Medium	Configurable
In-Memory	Fast	No	Low	No
Redis	Fast	Yes	Medium	Optional
Database	Medium	Yes	Low	Yes

3. Caching Strategies & Patterns (15 min)

1. Cache-Aside (Lazy Loading)

Most common pattern. Application manages cache explicitly.



Diagram

Implementation:

```python
def get_user(user_id):
    # 1. Try cache first
    cache_key = f"user:{user_id}"
    user = cache.get(cache_key)

    if user is not None:
        return user  # Cache HIT

    # 2. Cache MISS - query database
    user = database.query(f"SELECT * FROM users WHERE id={user_id}")

    # 3. Store in cache
    cache.set(cache_key, user, ttl=3600)  # 1 hour

    return user
```

Pros: - Only requested data is cached - Cache failure doesn't break the app

Cons: - Cache miss penalty (extra latency) - Data can become stale

Question: Update data

2. Read-Through Cache

Cache sits between app and database. Cache manages data loading.

```
Application → Cache → Database
              (auto-loads on miss)
```

```
        # Pseudo-code (handled by cache library)
        user = cache.get(user_id)  # Cache automatically queries DB on miss
```

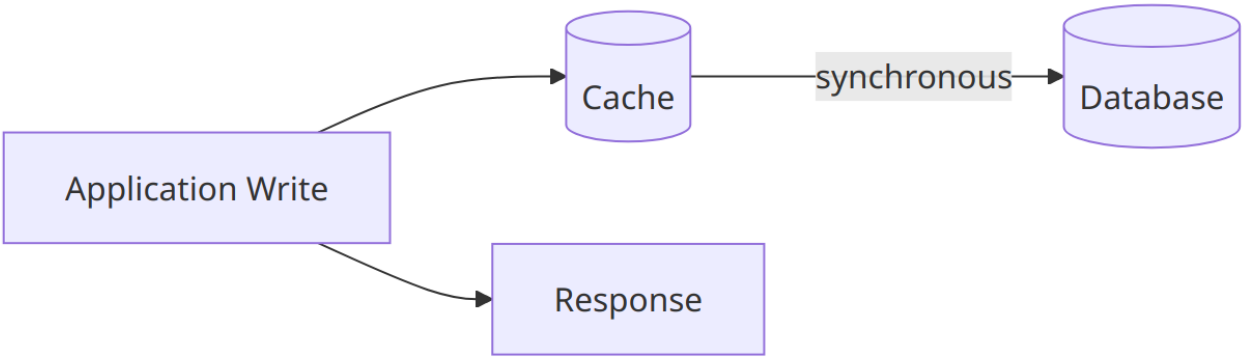
Pros: - Simplified application code - Consistent pattern

Cons: - Tight coupling to cache - First request still slow

3. Write-Through Cache

Write to cache and database simultaneously.

```
        def update_user(user_id, data):
            # 1. Update database
            database.update(user_id, data)

            # 2. Update cache
            cache_key = f"user:{user_id}"
            cache.set(cache_key, data, ttl=3600)

            return data
```



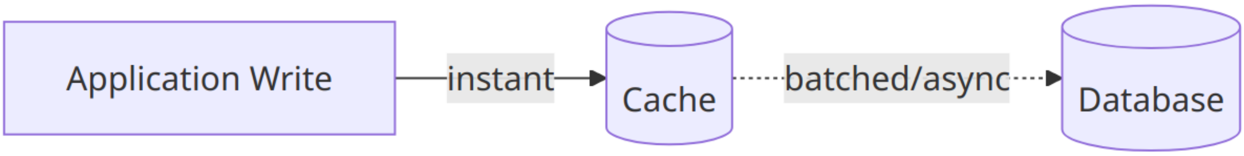
Diagram

Pros: - Cache always consistent with DB - No stale data

Cons: - Write latency (two operations) - Wasted writes for unread data

4. Write-Behind (Write-Back) Cache

Write to cache immediately, database asynchronously.



Diagram

```python
def update_user(user_id, data):
    # 1. Update cache immediately
    cache_key = f"user:{user_id}"
    cache.set(cache_key, data, ttl=3600)

    # 2. Queue database update (async)
    queue.enqueue('db_update', user_id, data)

    return data  # Fast response!
```

Pros: - Very fast writes - Can batch database operations

Cons: - Risk of data loss if cache fails - Complex to implement correctly

5. Refresh-Ahead

Proactively refresh cache before expiration.

```python
import time
from threading import Thread

def get_user_with_refresh(user_id):
    cache_key = f"user:{user_id}"
    user, expiry = cache.get_with_expiry(cache_key)

    if user is None:
        # Cache miss - load from DB
        user = database.query(user_id)
        cache.set(cache_key, user, ttl=3600)
    elif time.time() > (expiry - 300):  # 5 min before expiry
        # Refresh in background
        Thread(target=refresh_cache, args=(user_id,)).start()

    return user

def refresh_cache(user_id):
    user = database.query(user_id)
    cache.set(f"user:{user_id}", user, ttl=3600)
```

Pros: - Reduced latency (no cache miss delays) - Predictable performance

Cons: - Additional complexity - May refresh unused data

Strategy Comparison

PATTERN	READ PERF	WRITE PERF	COMPLEXITY	DATA FRESHNESS
Cache-Aside	Good	Good	Low	Can be stale
Read-Through	Good	Good	Medium	Can be stale
Write-Through	Good	Slower	Medium	Always fresh
Write-Behind	Good	Fastest	High	Eventually consistent
Refresh-Ahead	Best	Good	High	Very fresh

4. Cache Eviction Policies (10 min)

Why Eviction?

> ⚠️ **Warning** Caches have finite memory. When full, old data must be removed to make room for new data.

Common Eviction Algorithms

1. LRU (Least Recently Used)

Removes the least recently accessed item.

```
Cache: [A, B, C, D] (max size: 4)

Access B → [A, C, D, B]
Access C → [A, D, B, C]
Add E   → [D, B, C, E]  (A evicted - oldest access)
```

Best for: General purpose, temporal locality

```python
from collections import OrderedDict

class LRUCache:
    def __init__(self, capacity):
        self.cache = OrderedDict()
        self.capacity = capacity

    def get(self, key):
        if key not in self.cache:
            return None
        # Move to end (most recently used)
        self.cache.move_to_end(key)
        return self.cache[key]

    def put(self, key, value):
        if key in self.cache:
            self.cache.move_to_end(key)
        self.cache[key] = value
        if len(self.cache) > self.capacity:
            # Remove first item (least recently used)
            self.cache.popitem(last=False)
```

2. LFU (Least Frequently Used)

Removes the least frequently accessed item.

```
Item A: accessed 10 times
Item B: accessed 5 times
Item C: accessed 2 times  ← Evicted first
Item D: accessed 8 times
```

Best for: Items with consistent popularity

3. FIFO (First In, First Out)

Removes oldest item regardless of access.

```
Cache: [A(1st), B(2nd), C(3rd), D(4th)]

Add E → [B(2nd), C(3rd), D(4th), E(5th)]  (A evicted)
```

Best for: Simple use cases, streaming data

4. TTL (Time To Live)

Items expire after a set time.

```python
import time

cache = {}

def set_with_ttl(key, value, ttl_seconds):
    expiry = time.time() + ttl_seconds
    cache[key] = {'value': value, 'expiry': expiry}

def get_with_ttl(key):
    if key not in cache:
        return None

    item = cache[key]
    if time.time() > item['expiry']:
        del cache[key]  # Expired
        return None

    return item['value']
```

Best for: Time-sensitive data (sessions, tokens)

5. Random Replacement

Randomly selects item to evict.

Best for: When access patterns are unpredictable

Eviction Policy Comparison

POLICY	COMPLEXITY	HIT RATIO	USE CASE
LRU	Medium	High	General purpose, recency matters
LFU	High	High	Popularity-based content
FIFO	Low	Low	Simple queues
TTL	Low	Medium	Time-sensitive data
Random	Low	Low	Unpredictable patterns

Redis Eviction Policies

Redis supports multiple policies:

```
# redis.conf
maxmemory 2gb
maxmemory-policy allkeys-lru

# Options:
# noeviction        - Return errors when memory limit reached
# allkeys-lru       - Remove any key, LRU algorithm
# volatile-lru      - Remove keys with TTL, LRU
# allkeys-lfu       - Remove any key, LFU algorithm
# volatile-lfu      - Remove keys with TTL, LFU
# allkeys-random    - Remove random key
# volatile-random   - Remove random key with TTL
# volatile-ttl      - Remove key with nearest expiration
```

5. Implementation & Best Practices (15 min)

Redis Implementation Examples

Basic Operations

```python
import redis
import json

# Connect to Redis
r = redis.Redis(host='localhost', port=6379, db=0, decode_responses=True)

# SET with TTL
def cache_user(user_id, user_data):
    key = f"user:{user_id}"
    r.setex(key, 3600, json.dumps(user_data))  # 1 hour TTL

# GET
def get_cached_user(user_id):
    key = f"user:{user_id}"
    data = r.get(key)
    return json.loads(data) if data else None

# DELETE
def invalidate_user_cache(user_id):
    key = f"user:{user_id}"
    r.delete(key)

# CHECK EXISTS
def is_cached(user_id):
    key = f"user:{user_id}"
    return r.exists(key) > 0
```

Advanced Patterns

1. Cache Warming:

```python
def warm_cache():
    """Pre-load frequently accessed data"""
    popular_users = database.query("SELECT * FROM users ORDER BY views DESC LIMIT 100")

    pipeline = r.pipeline()
    for user in popular_users:
        key = f"user:{user['id']}"
        pipeline.setex(key, 3600, json.dumps(user))

    pipeline.execute()  # Batch operation
```

2. Cache Stampede Prevention:

```python
import time
import random

def get_with_stampede_protection(key, fetch_func, ttl=3600):
    """Prevent multiple threads from fetching same data simultaneously"""

    data = r.get(key)
    if data:
        return json.loads(data)

    # Try to acquire lock
    lock_key = f"lock:{key}"
    lock_acquired = r.set(lock_key, "1", nx=True, ex=10)  # 10 sec lock

    if lock_acquired:
        try:
            # Fetch data
            data = fetch_func()
            r.setex(key, ttl, json.dumps(data))
            return data
        finally:
            r.delete(lock_key)
    else:
        # Wait and retry
        time.sleep(random.uniform(0.1, 0.5))
        return get_with_stampede_protection(key, fetch_func, ttl)
```

3. Multi-Level Cache:

```
class MultiLevelCache:
    def __init__(self):
        self.l1_cache = {}  # In-memory (fast)
        self.l2_cache = redis.Redis()  # Redis (shared)

    def get(self, key):
        # Try L1 first
        if key in self.l1_cache:
            return self.l1_cache[key]

        # Try L2
        data = self.l2_cache.get(key)
        if data:
            # Promote to L1
            self.l1_cache[key] = data
            return data

        return None

    def set(self, key, value, ttl=3600):
        # Write to both levels
        self.l1_cache[key] = value
        self.l2_cache.setex(key, ttl, value)
```

Memcached Implementation

```python
import memcache

mc = memcache.Client(['127.0.0.1:11211'], debug=0)

# SET
mc.set("user:123", user_data, time=3600)

# GET
user = mc.get("user:123")

# DELETE
mc.delete("user:123")

# GET MULTIPLE
users = mc.get_multi(["user:123", "user:456", "user:789"])
```

Application-Level Caching (Node.js)

```javascript
const NodeCache = require('node-cache');
const cache = new NodeCache({ stdTTL: 3600 });

// Middleware for Express
function cacheMiddleware(duration) {
  return (req, res, next) => {
    const key = req.originalUrl;
    const cachedResponse = cache.get(key);

    if (cachedResponse) {
      return res.send(cachedResponse);
    }

    // Override res.send to cache response
    const originalSend = res.send;
    res.send = function(data) {
      cache.set(key, data, duration);
      originalSend.call(this, data);
    };

    next();
  };
}

// Usage
app.get('/api/users', cacheMiddleware(300), (req, res) => {
  // This response will be cached for 5 minutes
  const users = database.getUsers();
  res.json(users);
});
```

Best Practices

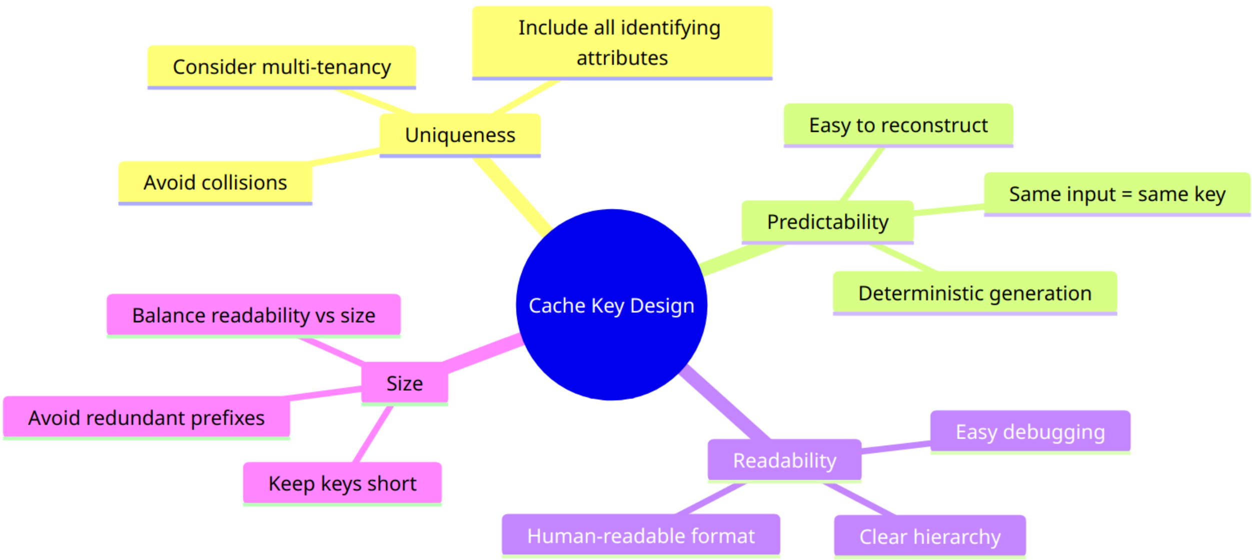
1. Cache Key Naming Convention

```
Pattern: {resource}:{identifier}:{attribute}

Examples:
user:123                    - User object
user:123:profile            - User profile
user:123:posts              - User's posts
session:abc123              - Session data
product:456:inventory       - Product inventory
api:v1:users:list:page:1    - API response
```

2. Cache Key Design Considerations

Choosing the right cache key is critical for cache effectiveness. Poor key design leads to low hit rates, memory waste, and debugging nightmares.

Key Design Principles:



Diagram

Common Pitfalls & Solutions:

PITFALL	PROBLEM	SOLUTION
Missing context	`user:123` cached differently per tenant	Include tenant: `tenant:abc:user:123`
Query parameter order	`?a=1&b=2` vs `?b=2&a=1` different keys	Sort parameters before hashing
Case sensitivity	`User:123` vs `user:123` collision	Normalize to lowercase
Locale/timezone	Same data, different representations	Include locale: `user:123:en-US`
Version mismatch	Old cached data after schema change	Include version: `v2:user:123`

Key Generation Strategies:

```python
import hashlib
import json

# Strategy 1: Hierarchical Keys (Recommended for simple cases)
def simple_key(resource, identifier, *attributes):
    """
    user:123:profile
    product:456:reviews:page:1
    """
    parts = [resource, str(identifier)] + list(attributes)
    return ":".join(parts)

# Strategy 2: Hash-based Keys (For complex queries)
def query_key(endpoint, params):
    """
    For API responses with many parameters
    Produces: api:users:a1b2c3d4e5f6
    """
    # Sort params for consistency
    sorted_params = json.dumps(params, sort_keys=True)
    hash_value = hashlib.md5(sorted_params.encode()).hexdigest()[:12]
    return f"api:{endpoint}:{hash_value}"

# Strategy 3: Composite Keys (For multi-dimensional lookups)
def composite_key(tenant_id, user_id, resource, **filters):
    """
    tenant:abc:user:123:orders:status:pending:page:1
    """
    base = f"tenant:{tenant_id}:user:{user_id}:{resource}"
    filter_parts = [f"{k}:{v}" for k, v in sorted(filters.items())]
    return ":".join([base] + filter_parts)

# Usage examples
key1 = simple_key("user", 123, "profile")
# → "user:123:profile"

key2 = query_key("search", {"q": "redis", "page": 1, "sort": "date"})
# → "api:search:a1b2c3d4e5f6"

key3 = composite_key("acme", 123, "orders", status="pending", page=1)
# → "tenant:acme:user:123:orders:page:1:status:pending"
```

Multi-Tenancy Considerations:

```
class TenantAwareCache:
    def __init__(self, redis_client):
        self.redis = redis_client

    def _build_key(self, tenant_id, key):
        """Always prefix with tenant to prevent data leakage"""
        return f"tenant:{tenant_id}:{key}"

    def get(self, tenant_id, key):
        full_key = self._build_key(tenant_id, key)
        return self.redis.get(full_key)

    def set(self, tenant_id, key, value, ttl=3600):
        full_key = self._build_key(tenant_id, key)
        self.redis.setex(full_key, ttl, value)

    def invalidate_tenant(self, tenant_id):
        """Invalidate all cache for a tenant"""
        pattern = f"tenant:{tenant_id}:*"
        keys = self.redis.keys(pattern)
        if keys:
            self.redis.delete(*keys)
```

Key Size Optimization:

```
# ❌ Bad: Verbose keys waste memory
"application:production:service:user-service:cache:user:profile:id:
123:version:2"

# ✅ Good: Concise but readable
"prod:usr:123:profile:v2"

# Key size impact calculation
key_size = 50  # bytes average
num_keys = 10_000_000  # 10M keys
overhead = key_size * num_keys / (1024**3)  # ~0.47 GB just for keys!
```

Debugging-Friendly Keys:

```python
# Include metadata for debugging (development only)
def debug_key(resource, identifier, **metadata):
    """
    Creates keys with debug info in development
    Production: user:123
    Development: user:123#created:1704067200#source:api
    """
    base_key = f"{resource}:{identifier}"

    if settings.DEBUG:
        meta_parts = [f"{k}:{v}" for k, v in metadata.items()]
        return f"{base_key}#{'#'.join(meta_parts)}"

    return base_key
```

2. TTL Strategy

```python
# Different TTL for different data types
CACHE_TTL = {
    'static_content': 86400,    # 24 hours
    'user_profile': 3600,       # 1 hour
    'user_session': 1800,       # 30 minutes
    'api_response': 300,        # 5 minutes
    'real_time_data': 60,       # 1 minute
}
```

3. Cache Invalidation Strategies

Time-based (TTL): ~~python cache.setex('user:123' , 3600, user_data) # Auto-expires~~

Event-based: ~~python def update_user(user_id, new_data): database.update(user_id, new_data) cache.delete(f' user:{user_id}') # Invalidate on update~~

Tag-based: ~~python # Invalidate all user-related caches tags = cache.smembers(f' tags:user:{user_id}') for tag in tags: cache.delete(tag)~~

4. Monitoring & Alerting

```python
# Track cache metrics
def cache_get_with_metrics(key):
    start_time = time.time()
    data = cache.get(key)
    latency = time.time() - start_time

    # Log metrics
    if data:
        metrics.increment('cache.hit')
    else:
        metrics.increment('cache.miss')

    metrics.histogram('cache.latency', latency)

    return data
```

Key Metrics to Monitor: - Hit/Miss ratio - Cache memory usage - Eviction rate - Average latency - Connection pool usage

5. Cache Size Calculation

```python
import sys

def calculate_cache_size(data_size_bytes, num_items, overhead=1.2):
    """
    data_size_bytes: Average size of each cached item
    num_items: Number of items to cache
    overhead: Redis overhead factor (keys, metadata)
    """
    total_size = data_size_bytes * num_items * overhead

    # Convert to GB
    size_gb = total_size / (1024 ** 3)

    return size_gb

# Example: Cache 1M user profiles, avg 2KB each
cache_size = calculate_cache_size(2048, 1_000_000)
print(f"Required cache size: {cache_size:.2f} GB")
```

🚨 Common Pitfalls & Solutions

1. Cache Stampede

Problem: Multiple requests for expired key hit database simultaneously.

```
Cache expires → 1000 concurrent requests → 1000 DB queries! 💥
```

Solution: Use locks or probabilistic early expiration

```python
def get_with_early_expiration(key, ttl=3600, beta=1.0):
    data, expiry, delta = cache.get_with_metadata(key)

    if data is None:
        # Cache miss - fetch and store
        data = fetch_from_db(key)
        cache.set(key, data, ttl)
        return data

    # Probabilistic early refresh
    time_to_expiry = expiry - time.time()
    if time_to_expiry < 0:
        return data

    # XFetch algorithm
    if time.time() - delta * beta * math.log(random.random()) >= expiry:
        # Refresh in background
        refresh_async(key)

    return data
```

2. Stale Data

Problem: Cache returns outdated information.

Solutions: - Shorter TTL for frequently changing data - Event-driven invalidation - Write-through caching - Cache versioning

```python
# Cache versioning
CACHE_VERSION = "v2"

def versioned_key(key):
    return f"{CACHE_VERSION}:{key}"

# When data structure changes, increment version
# Old cached data automatically becomes inaccessible
```

3. Cache Penetration

Problem: Requests for non-existent keys always hit database.

```
Request for user:99999 (doesn't exist)
→ Cache miss
→ Database query (returns null)
→ No caching (null not cached)
→ Repeat 1000 times 💥
```

Solution: Cache null results with short TTL

```python
    def get_user(user_id):
        key = f"user:{user_id}"
        user = cache.get(key)

        if user == "NULL":  # Cached null result
            return None

        if user:
            return user

        user = database.query(user_id)

        if user is None:
            cache.setex(key, 60, "NULL")  # Cache null for 1 min
        else:
            cache.setex(key, 3600, user)

        return user
```

4. Memory Overflow

Problem: Cache grows too large, OOM errors.

Solutions: - Set maxmemory limit - Configure eviction policy - Monitor memory usage - Use TTL aggressively

```
# redis.conf
maxmemory 2gb
maxmemory-policy allkeys-lru
```

5. Cache Inconsistency

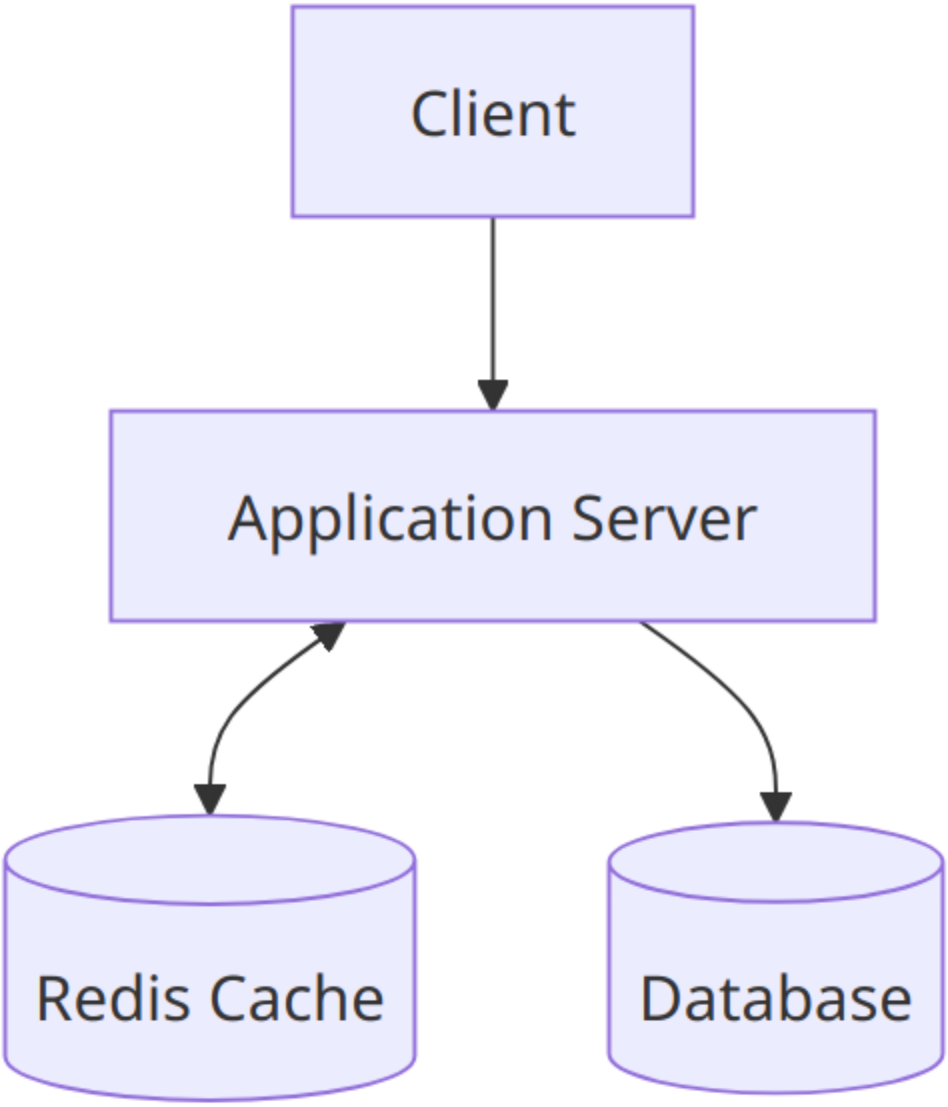
Problem: Cache and database out of sync.

Solutions:

```python
# Use database transactions with cache updates
def update_user_transactional(user_id, data):
    try:
        # Start transaction
        db.begin()
        db.update('users', user_id, data)
        db.commit()

        # Only update cache after successful DB update
        cache.set(f'user:{user_id}', data, ttl=3600)

    except Exception as e:
        db.rollback()
        # Don't update cache if DB update failed
        raise e
```

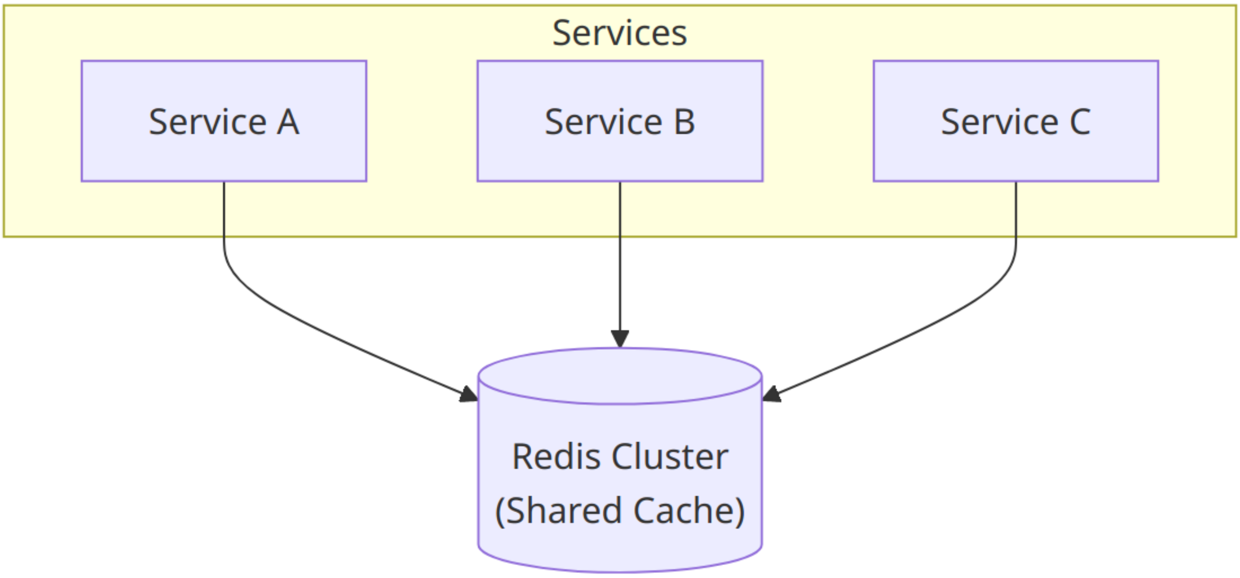
📊 Cache Architecture Patterns

Pattern 1: Simple Web Application



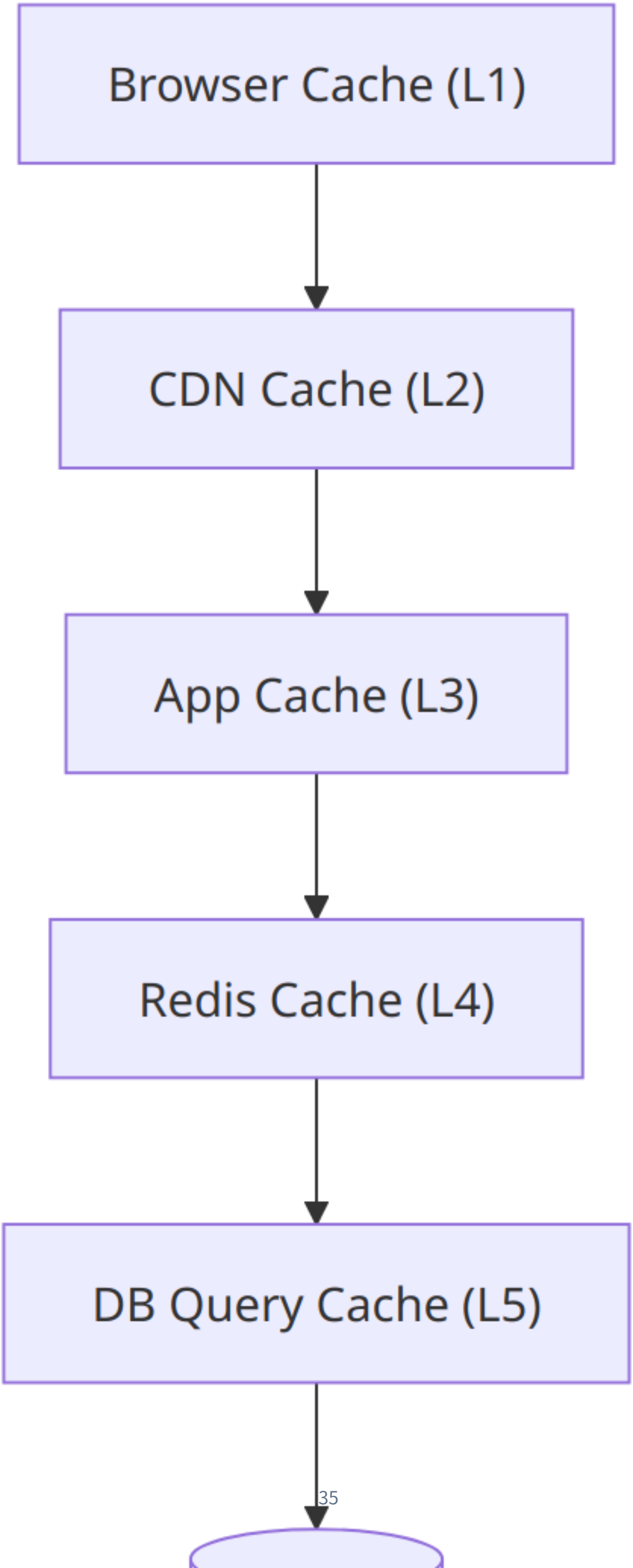
Diagram

Pattern 2: Microservices with Shared Cache



Diagram

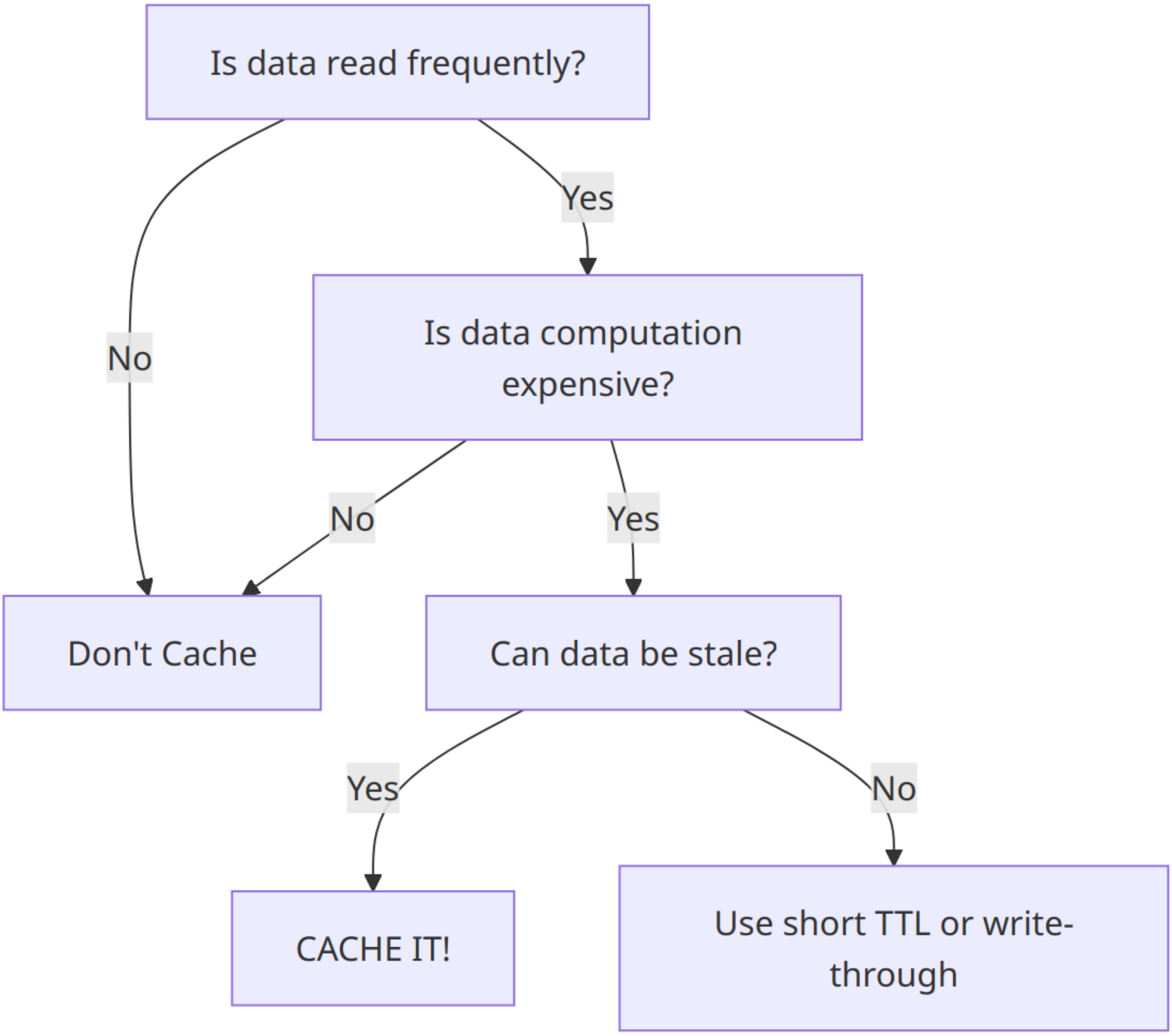
Pattern 3: Multi-Tier Caching


Browser Cache (L1)
CDN Cache (L2)
App Cache (L3)
Redis Cache (L4)
DB Query Cache (L5)

Diagram

🔍 Decision Framework

When to Cache?



Diagram

Cache if: - ✅ Read frequency >> Write frequency - ✅ Expensive to compute/fetch - ✅ Can tolerate some staleness - ✅ Limited data size

Don' t cache if: - ❌ Write-heavy workload - ❌ Must be real-time accurate - ❌ Data is already fast to fetch - ❌ Unlimited data size

Choosing Cache Type

REQUIREMENT	RECOMMENDED SOLUTION
Static assets	CDN (CloudFront, Cloudflare)
Session data	Redis with TTL
Database query results	Application cache + Redis
API responses	CDN + Redis
Computed values	Redis with refresh-ahead
User preferences	Browser localStorage + Redis
Real-time data	Redis with short TTL (30-60s)

✅ Key Takeaways

1. **Caching dramatically improves performance** but adds complexity
2. **Choose the right cache layer** based on data access patterns
3. **Cache invalidation is hard** - use TTL, event-based, or hybrid approaches
4. **Monitor your cache** - hit ratio, memory, latency
5. **Handle edge cases** - stampede, penetration, inconsistency
6. **Different data needs different strategies** - one size doesn' t fit all
7. **Start simple** - add complexity only when needed

💡 Practical Exercise

Scenario: You' re building a social media feed application.

Requirements: - User posts (10k posts/day) - User profiles (1M users) - Feed generation (complex algorithm, 2s to compute) - Real-time likes/comments

Questions: 1. What should you cache? 2. What TTL for each cache? 3. Which caching strategy for each? 4. How to handle real-time updates?

Suggested Solution:

```
Cache Strategy:

User Profiles:
  - Strategy: Cache-Aside
  - TTL: 1 hour
  - Invalidation: On profile update

Feed (Personalized):
  - Strategy: Cache-Aside with refresh-ahead
  - TTL: 5 minutes
  - Invalidation: Time-based + new post event

Feed (Public):
  - Strategy: Write-through
  - TTL: 1 minute
  - Invalidation: On new post

Posts:
  - Strategy: Write-through
  - TTL: 1 hour
  - Invalidation: On edit/delete

Likes/Comments Count:
  - Strategy: Write-behind (async update)
  - TTL: 30 seconds
  - Invalidation: Eventual consistency OK
```

📝 Quick Reference

Redis Commands Cheatsheet

```
# String operations
SET key value EX 3600          # Set with TTL
GET key                         # Get value
DEL key                         # Delete
EXISTS key                      # Check exists
TTL key                         # Check remaining TTL
EXPIRE key 3600                 # Set TTL on existing key

# Hash operations (for objects)
HSET user:123 name "John"
HGET user:123 name
HGETALL user:123
HDEL user:123 name

# List operations
LPUSH list value                # Add to front
RPUSH list value                # Add to end
LRANGE list 0 10                # Get range

# Set operations
SADD tags "redis" "cache"
SMEMBERS tags
SISMEMBER tags "redis"

# Sorted Set (for leaderboards)
ZADD leaderboard 100 "user1"
ZRANGE leaderboard 0 10 WITHSCORES

# Cache patterns
SETEX key 3600 value           # Set with expiry
SETNX key value                # Set if not exists (lock)
GETEX key EX 3600              # Get and refresh TTL
```

Q&A Session

Time remaining for questions and discussion

Common Questions:

1. **Redis vs Memcached?**
    - Redis: Feature-rich, persistent, data structures
    - Memcached: Simpler, pure cache, slightly faster
2. **How to size cache?**
    - Calculate: items × size × overhead
    - Start with 20% of hot data
    - Monitor and adjust
3. **Cache in serverless (AWS Lambda)?**
    - Use external cache (ElastiCache)
    - Or global variables (limited)
    - Or DAX for DynamoDB
4. **Handling cache cluster failures?**
    - Graceful degradation (fall back to DB)
    - Cache replication
    - Circuit breaker pattern

Session End - Thank You! 🎉

#caching #performance #redis #architecture #session-notes