2110446 - Data Science and Data Engineering

Data Storages

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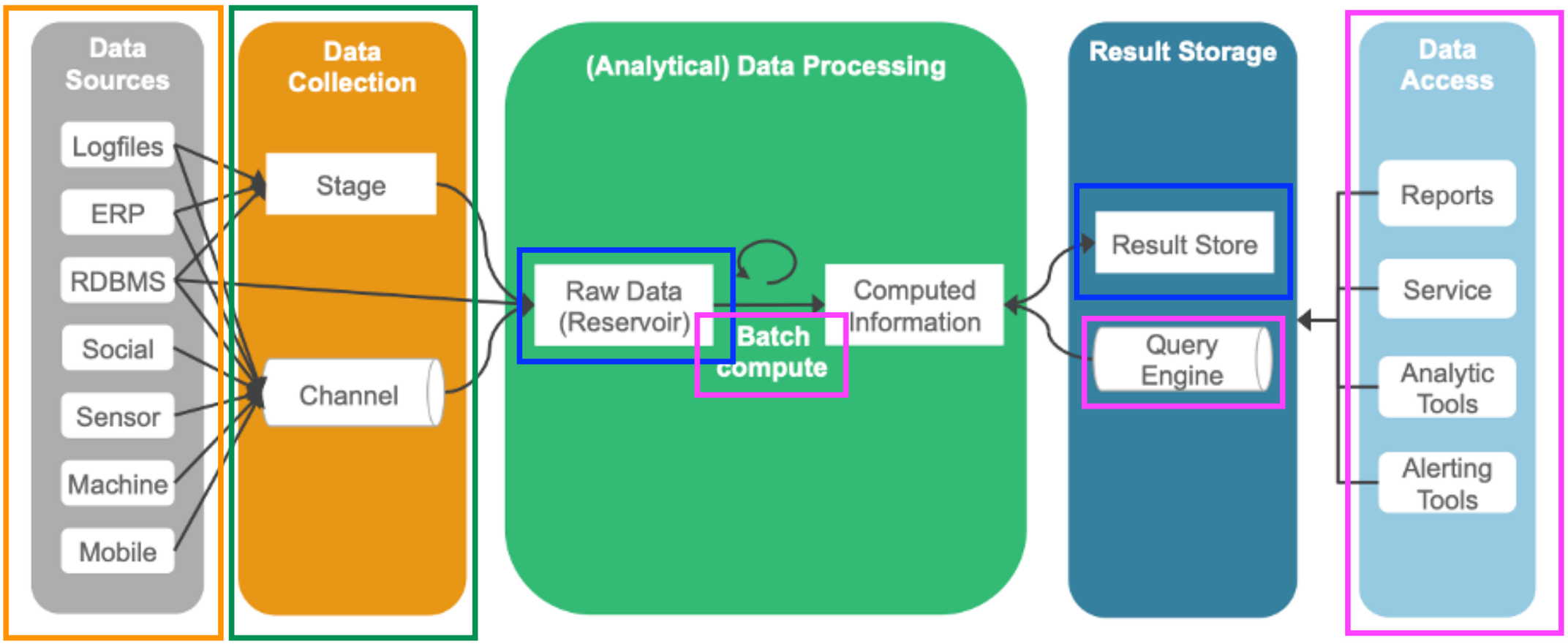
Simple Big Data Analytic Architecture



Data Generation Data Ingestion Data Storage Data Analytics

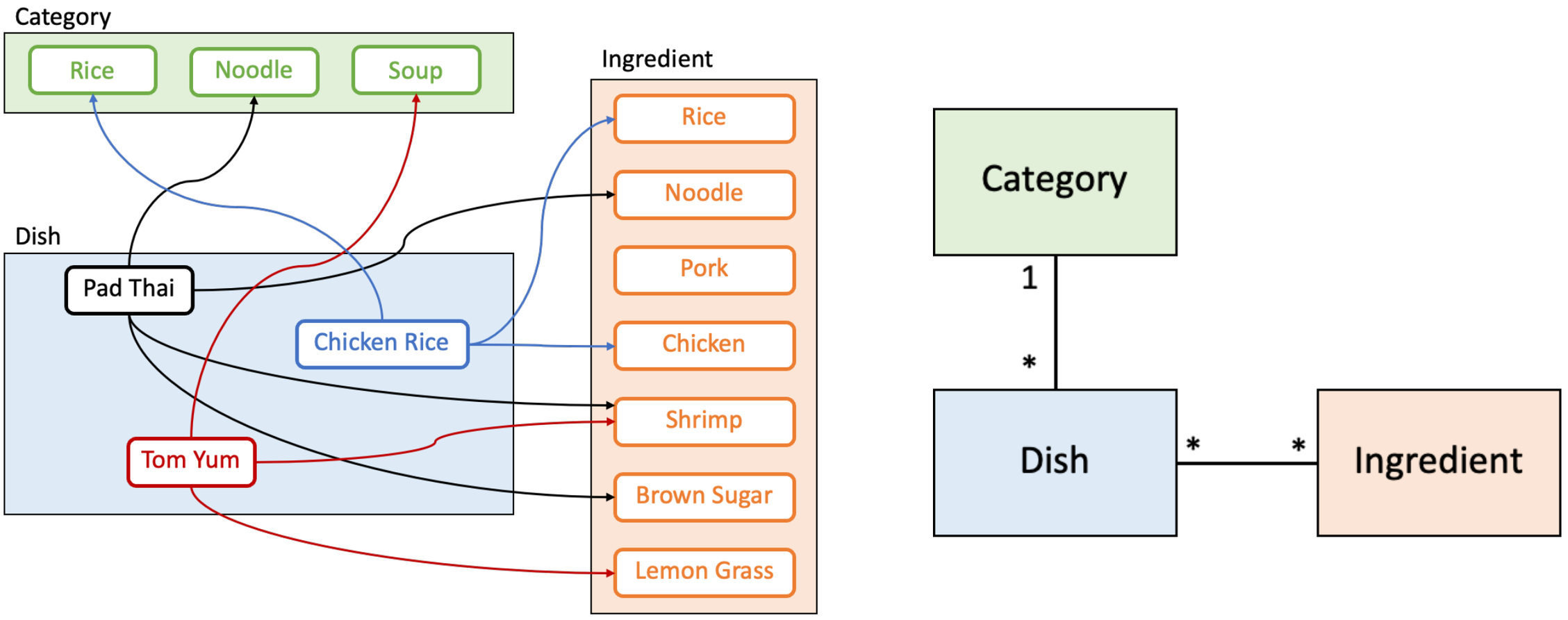
Traditional Database

- Based on ”relational model”
  - Data is split and stored into tables
  - Tables can be processed together using set-like operations
  - Data model is usually normalized to remove duplication
- Very suitable for OLTP or transaction systems
  - Provide lots of complicated SQL operations
  - Lots of inserts and updates

Problems of Data Science Storage

- There are several needs for data analytics purposes e.g. traditional data store, caching, feature store
- Data is historical data and its volume can be huge
- Scalability is extremely important and “Relational + Consistency” can limit scalability
- SQL command can be very complex and time-consuming
  - It requires the synchronization of data accessing between multiple tables
  - It will be poor when using on more than a few servers in the same cluster

Relational Database: Normalized Data Model

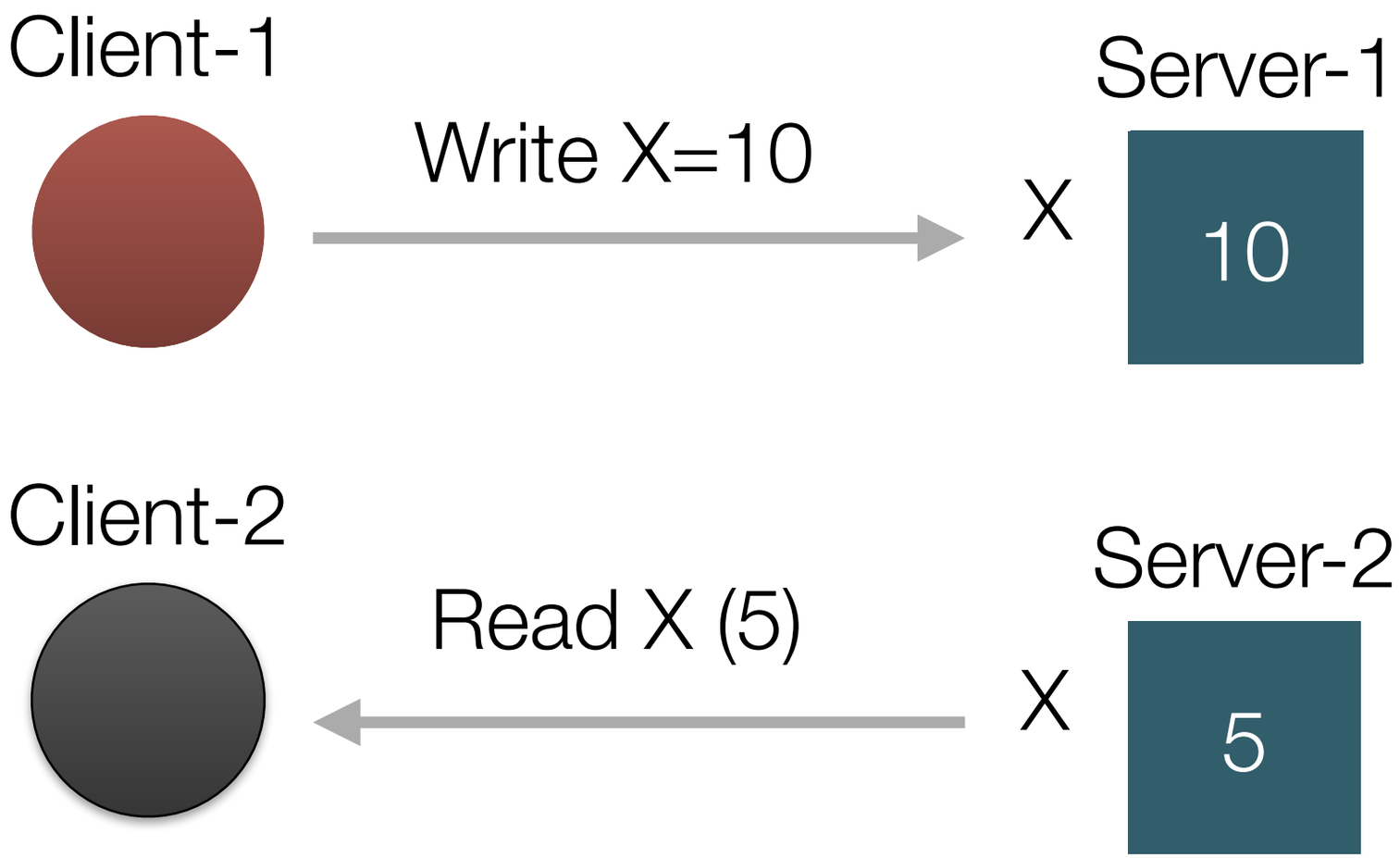


How can we split these tables to lots of machines?

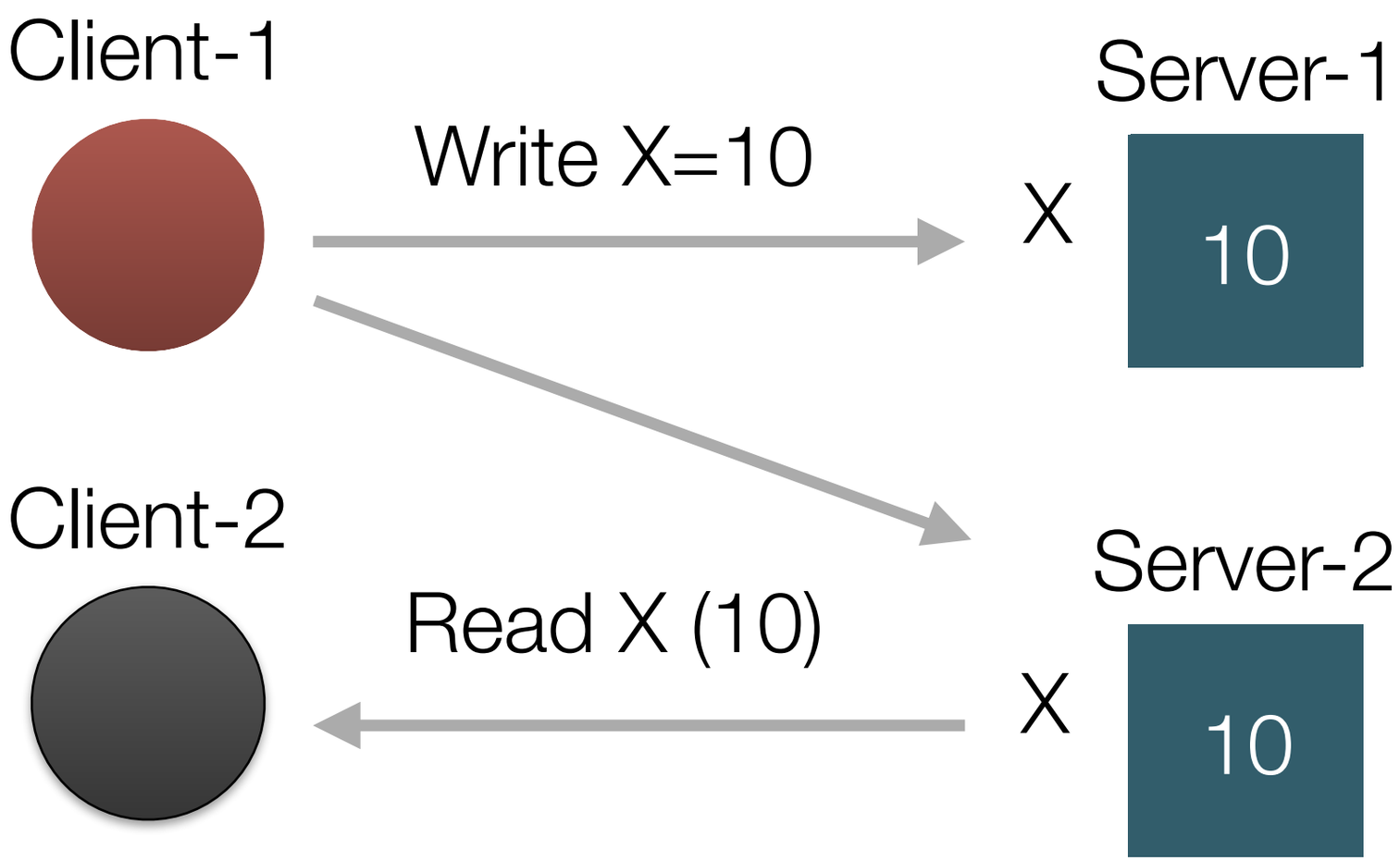
- Dishes of the same category in the same machine
- How about dishes and ingredients?

Or we can replicate data — lead to data consistency problems

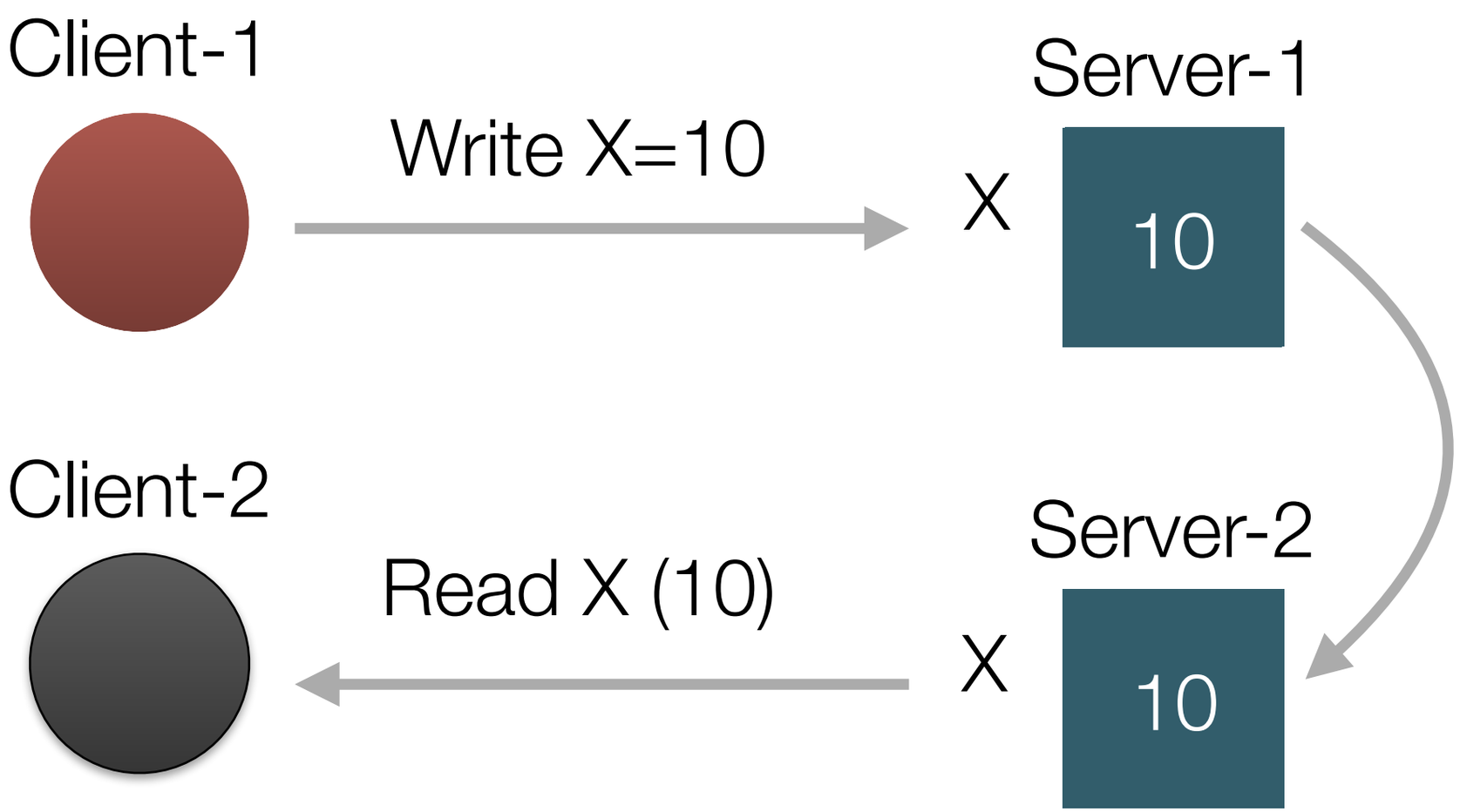
Replication and Data Consistency Problem



Solution to Data Consistency - Active Replication



Solution to Data Consistency - Passive Replication



Data Consistency Models

- Strong consistency
  - After update completes, any access will return the updated value
  - High costs for large scale system
- Weak consistency
  - Certain conditions must be met before the consistency is guaranteed
  - Time between update completion and guaranteed consistency is called inconsistency window

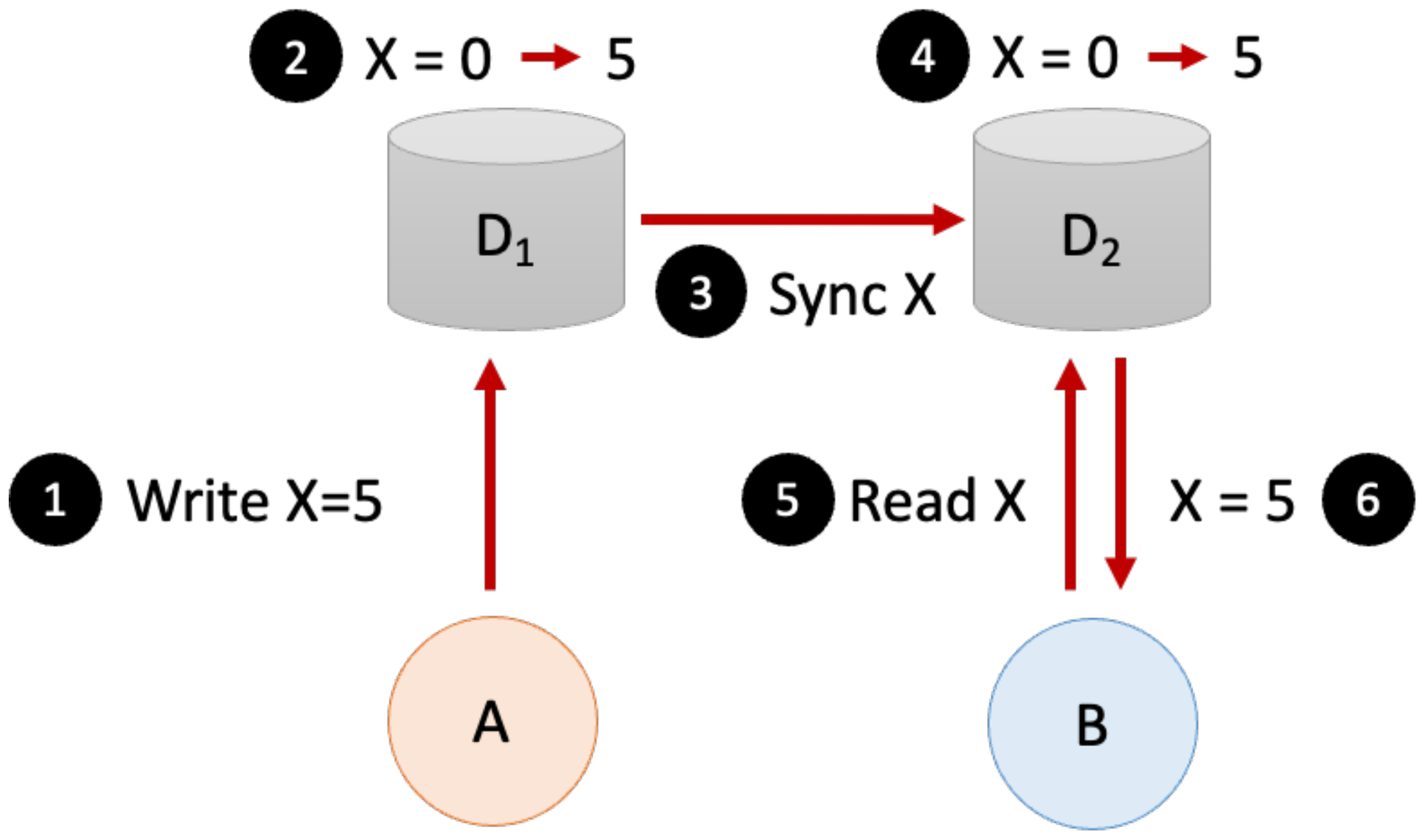
CAP Theorem (Brewer's Theorem)

- By Eric Brewer (University of California, Berkeley)
- It is impossible for a distributed computer system to simultaneously provide all three of the following guarantees: Consistency, Availability, Partition tolerance
- Scenario
  - Distributed system (clients and servers)
  - Multiple servers working together
  - Multiple clients may read or write on the same data at the same time

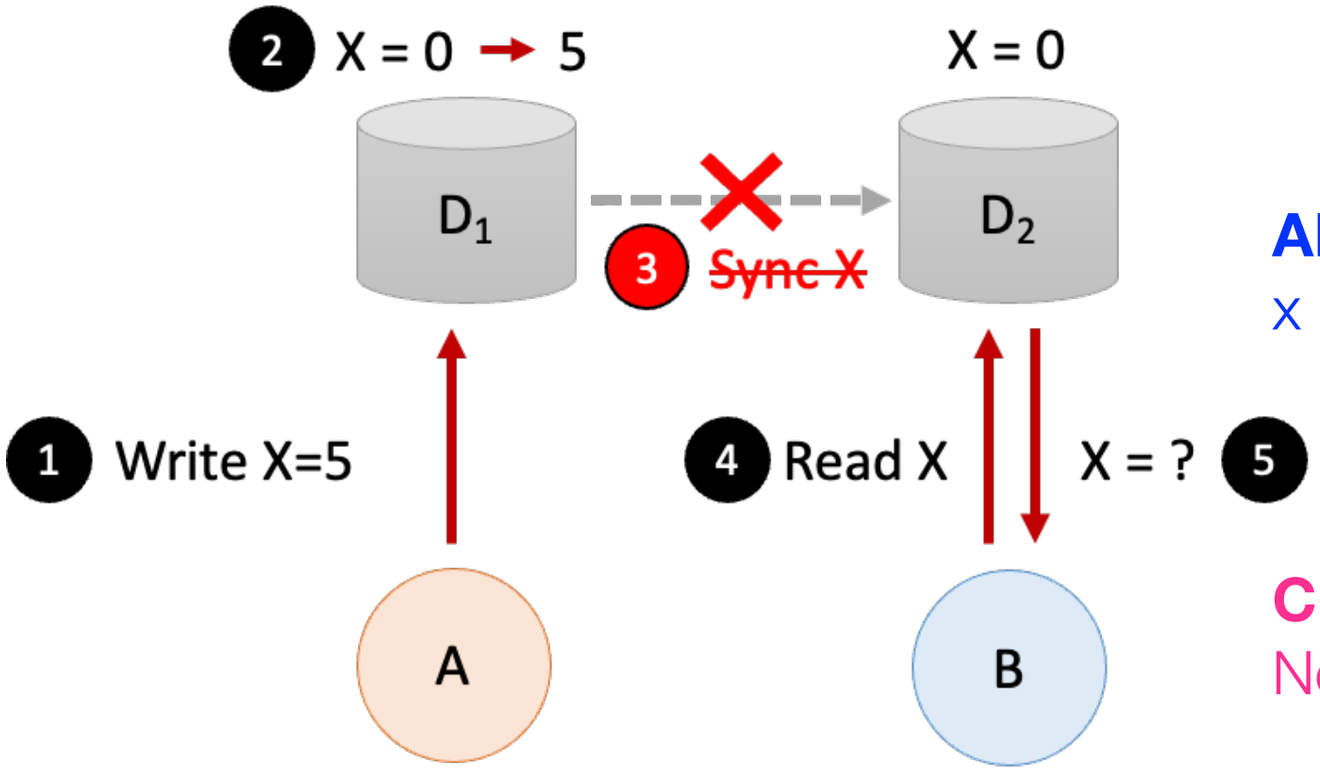
CAP Guarantees only 2 out of 3

- Consistency
  - Every read receives the most recent write or an error
- Availability
  - Every request receives a (non-error) response – without guarantee that it contains the most recent write
  - Response from any server is good
- Partition tolerance
  - The system continues to operate despite arbitrary message loss or failure of part of the system
  - Lots of servers require long synchronization time causing servers to not be able to communicate among one another within reasonable time

CA Data Store



Given P, Choosing between C and A (at step 5)



AP Data Store

x = 0 (not consistent, but available)

CP Data Store

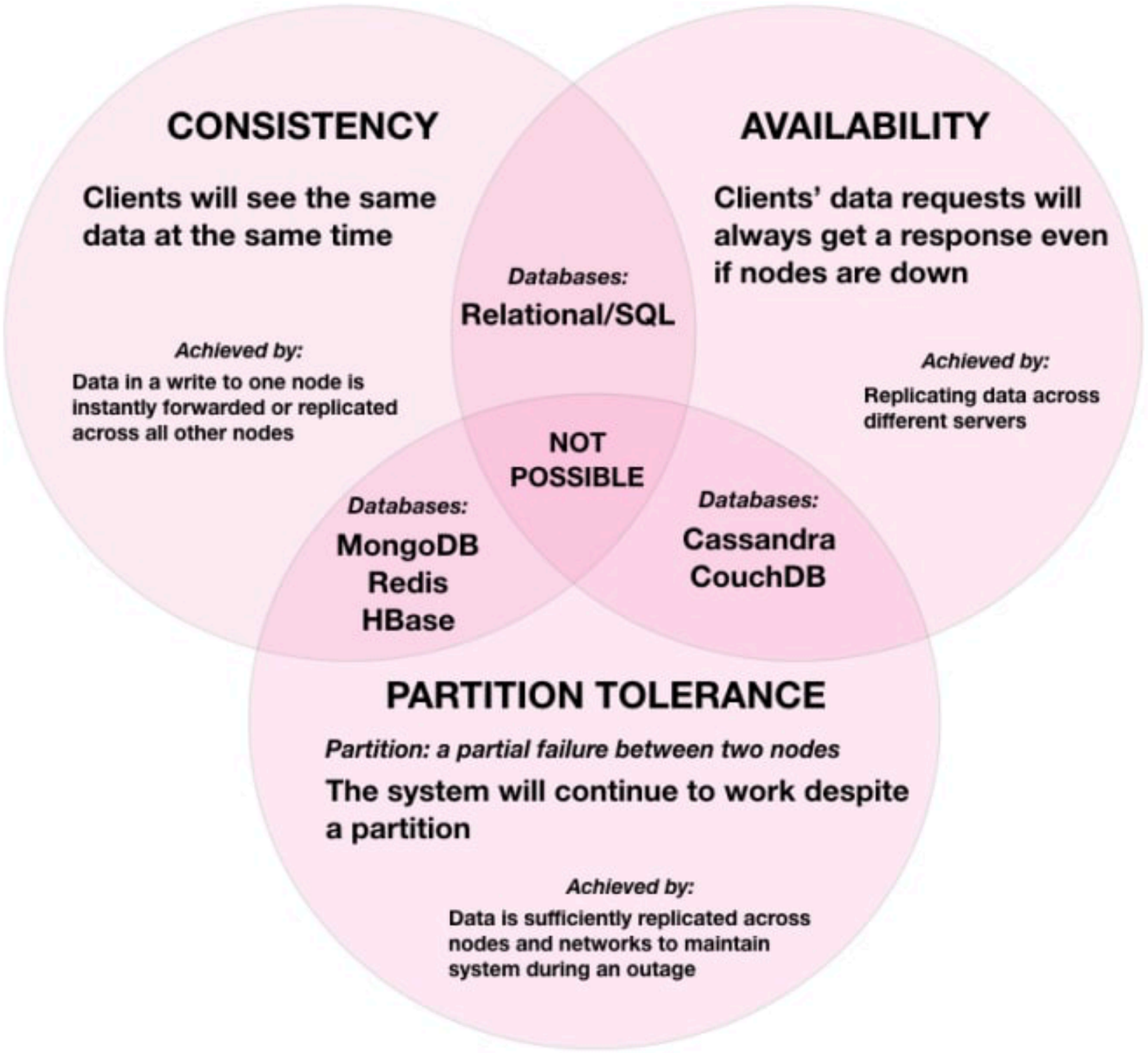
No response

The Landscape of NoSQL

- Alternatives to SQL database - non-relational, distributed, and horizontally scalable
- Data is shared and distributed across multiple servers
- Typically use weak consistency model (but not always)
- Examples
  - Document: MongoDB, DynamoDB, CosmosDB, Couchbase, Firebase
  - Column: Cassandra, HBase, CosmosDB, Accumulo
  - Key-value: Redis, DynamoDB, CosmosDB, MemcacheDB
  - Graph: Neo4J, CosmosDB, ArrangoDB, OrientDB
  - Search Engine: Elasticsearch, Splunk, Solr

How NoSQL can “Scale”

- Principle ideas
  - Split data into chunks or shards
  - Distribute data across multiple servers
  - Must require minimum synchronization
- Have to give up some traditional features
  - No complex relational model
  - Relax consistency
  - Duplicated information (not space optimized)
  - Fast to insert new record, but not so fast to update the existing one



Source: https://dev.to/katkelly/cap-theorem-why-you-can-t-have-it-all-ga1

Redis
Key-Value Store

Data Storage

Redis

- Remote Dictionary Server
- In-memory data structure store with clustering, transactional, time-to-live limiting, and auto-failover capabilities
- Being used for database cache, message broker, streaming engine, feature store engine, etc.
- Support wide-range of data structure with lots of related operations for each structure
- Provide CLI and support many programming languages

Working with Redis

- Redis CLI
  - Standard client program to connect to any redis server
  - Come with any redis installation (see: https://redis.io/docs/getting-started/)

```
redis-cli

redis-cli -h 34.143.227.66
```

  - You can type in redis command in the CLI input

Working with Redis

- Redis-Py
  - Standard python package for redis client

```
pip install redis
```

- Example

```
import redis

r = redis.Redis(host='hostname', port=port)
```

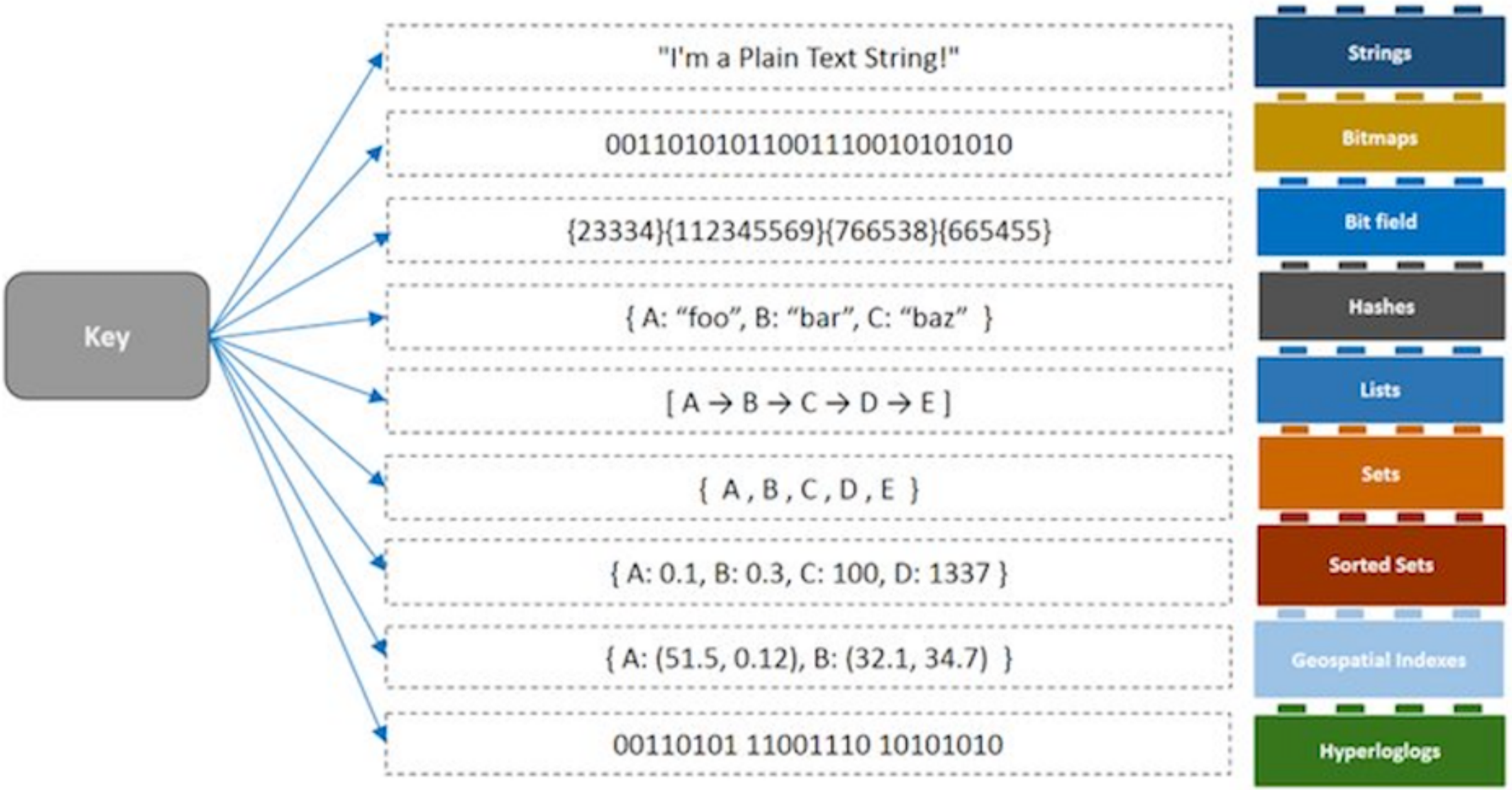
Running Redis Locally

- The simplest way to run a redis instance is to use docker

```
docker pull redis
docker run -d --rm --name redis -p 6379:6379 redis
```

- This will start redis in your docker at port 6379 and map the port to your localhost

Redis Data Types



String

- Similar to Python or Java Strings, maximum length of 512MB

```
SET “user” “Natawut Nupairoj”
GET “user”
DEL “user”
```

- Use cases
  - Server-side object cache e.g. HTML fragments, shopping cart, user profile
  - Queues
  - Activity tracking

Other String Commands

APPEND

DECR

DECRBY

GET

GETDEL

GETEX

GETRANGE

GETSET

INCR

INCRBY

INCRBYFLOAT

LCS

MGET

MSET

MSETNX

PSETEX

SET

SETEX

SETNX

SETRANGE

STRLEN

SUBSTR

Useful Commands

- Any item in Redis can be made to expire after or at a certain time

```
EXPIRE user 60.  # in seconds
TTL user
```

- You can scan all index with scan command

```
SCAN 0
```

- You can delete item or test its existence

```
DEL mykey
EXISTS mykey
```

List

- List of strings, sorted by insertion order
- Can be used as list, queue, stack

```
LPUSH mylist abc  # mylist contains “abc”
LPUSH  mylist xyz # mylist contains “xyz”, “abc”
RPUSH  mylist 123 # mylist contains “xyz”, “abc”, “123”
```

- Use cases
  - Queue
  - Timelines

List Commands

BLMOVE

BLMPOP

BLPOP

BRPOP

BRPOPLPUSH

LINDEX

LINSERT

LLEN

LMOVE

LMPOP

LPOP

LPOS

LPUSH

LPUSHX

LRANGE

LREM

LSET

LTRIM

RPOP

RPOPLPUSH

RPUSH

RPUSHNX

Set

- Powerful data types for unordered non-duplicated keys
- Support many set operations e.g. intersection, union, etc.

```
SADD user_set natawut
SCARD user_set
SMEMBERS user_set
```

- Use cases
  - Set of user profiles
  - Set of inappropriate words for inappropriate content filtering

Set Commands

SADD

SCARD

SDIFF

SDIFFSTORE

SINTER

SINTERCARD

SINTERSTORE

SISMEMBER

SMEMBERS

SMISMEMBER

SMOVE

SPOP

SRANDMEMBER

SREM

SSCAN

SUNION

SUNIONSTORE

Sorted Set

- Set of sorted items based on the score associated to each member

```
ZADD my_sortedset 5 data1
ZADD my_sortedset 1 data2 10 data3
ZRANGEBYSCORE my_sortedset 5. +inf WITHSCORES
```

- Use
  - Leader scoreboard
  - Priority queue

Sorted Set Commands

BZMPOP

BZPOPMAX

BZPOPMIN

ZADD

ZCARD

ZCOUNT

ZDIFF

ZDIFFSTORE

ZINCRBY

ZINTER

ZINTERCARD

ZINTERSTORE

ZLEXCOUNT

ZMPOP

ZMSCORE

ZPOPMAX

ZPOPMIN

ZRANDMEMBER

ZRANGE

ZRANGEBYLEX

ZRANGEBYSCORE

Hash

- A container of unique fields and their values

```
HMSET profile:12345 user nnp id 12345  name “Natawut Nupairoj” balance 10
HGETALL profile:12345
HINCRBYprofile:12345 balance 5
```

- Use
  - User profile information
  - Post. Information

Hash Commands

HDEL

HEXISTS

HGET

HGETALL

HINCRBY

HINCRBYFLOAT

HKEYS

HLEN

HMGET

HMSET

HRANDFIELD

HSCAN

HSET

HSETNX

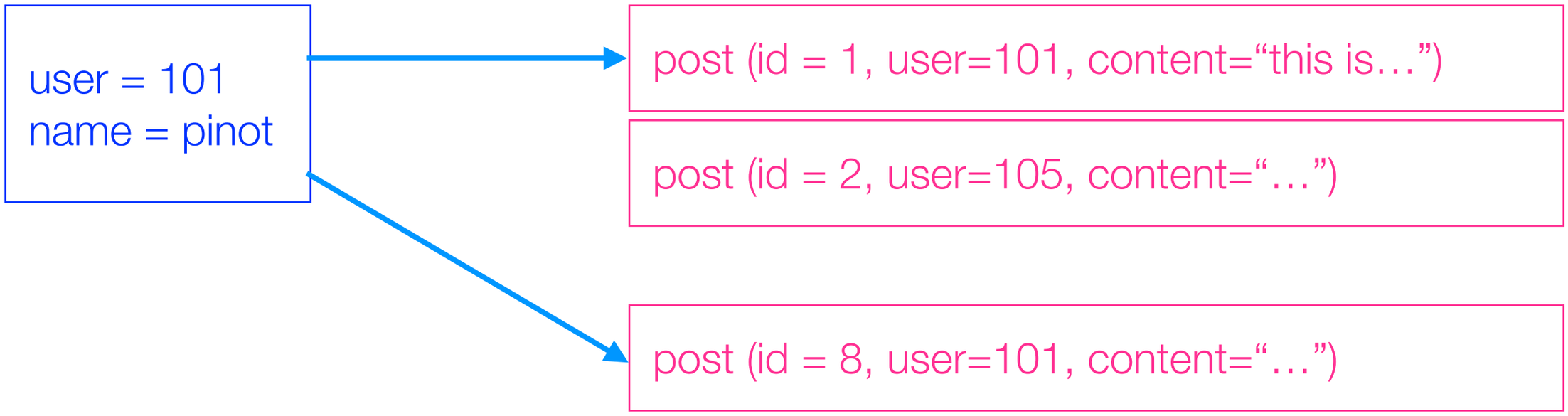
HSTRLEN

HVALS

Example: Redis in Action

- Create data model for simple social network
- Data items
  - Users - id, name, can follow others, can be followed
  - Posts - id, content
- Relationship
  - 1 user can have many posts, each post can associate to only one user
  - User can follow one another

Users and Posts

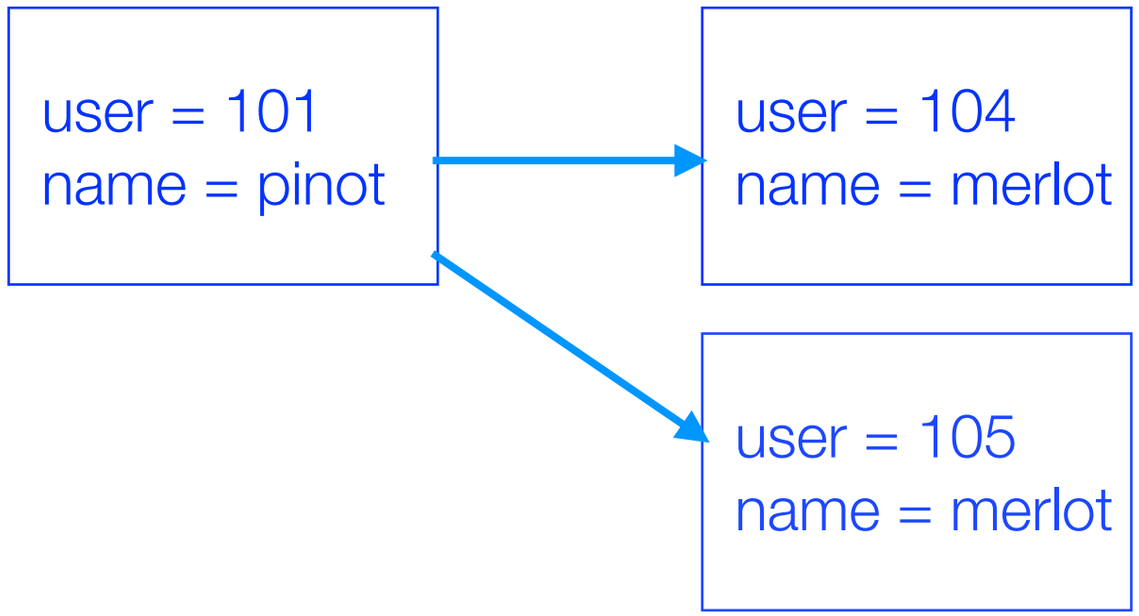



```
SET user:101:name pinot          # user id 101 with name "pinot"
SET username:pinot 101           # refer back to user-id

HMSET post:1 user 101 content "this is the first post"

RPUSH user:101:post 1
RPUSH user:101:post 8
```

Users and Followers




```
SADD user:101:follows 104
SADD user:101:follows 105

SADD user:104:followed_by 101
SADD user:105:followed_by 101
```

Simple Redis-Py Example

This notebook contains simple redis python commands.

In [1]:
```
import redis
```

Connect to local server -- no hostname or ip is needed

In [2]:
```
rd = redis.Redis(charset="utf-8", decode_responses=True)
```

In [3]:
```
rd.set('user:101:name', 'pinot')
```

Out[3]:
```
True
```

In [4]:
```
rd.get('user:101:name')
```

Out[4]:
```
'pinot'
```

In [5]:
```
rd.hset('post:1', 'user', 101)
rd.hset('post:1', 'content', 'this is the first post')
```

Out[5]:
```
1
```

In [6]:
```
rd.hgetall('post:1')
```

Out[6]:
```
{'user': '101', 'content': 'this is the first post'}
```

In [7]:
```
rd.rpush('user:101:post', 1)
rd.rpush('user:101:post', 8)
```

Out[7]:
```
2
```

In [8]:
```
rd.llen('user:101:post')
```

Out[8]:
```
2
```

In [9]:
```
rd.lrange('user:101:post', 0, -1)
```

Out[9]:
```
['1', '8']
```

In [10]:
```
rd.sadd('user:101:follows', 104)
rd.sadd('user:101:follows', 105)
```

Out[10]:
```
1
```

In [11]:
```
rd.scard('user:101:follows')
```

Out[11]:
```
2
```

In [12]:
```
rd.smembers('user:101:follows')
```

Out[12]:
```
{'104', '105'}
```

In [13]:
```
cursor = 0
cursor, keys = rd.scan(cursor=cursor, match='user:*')
while cursor > 0:
    for key in keys:
        print('found: ', key)
    cursor, keys = rd.scan(cursor=cursor, match='username:*')

for key in keys:
    print('found: ', key)
```

```
found:  user:101:follows
found:  user:101:name
found:  user:101:post
```

Additional Information - see redis.io

- Redis supports many level of persistence: no persistence, RDB(point-in-time snapshot), AOF (log every write), RDB+AOF

- Redis can be setup as a cluster of multiple Redis servers for horizontally scaling and weak consistency replication

- Many useful modules are available to extend the functionality of Redis core e.g. RedisJSON, RedisSearch, RedisTimeSeries, Redis OM, etc.

References

- ScaleGrid, “Top Redis Use Cases by. Core Data Structure Types”, https://scalegrid.io/blog/top-redis-use-cases-by-core-data-structure-types/

- Jerry An, “The most important Redis data structures you must understand”, https://medium.com/analytics-vidhya/the-most-important-redis-data-structures-you-must-understand-2e95b5cf2bce

- Brad Solomon, “How to use Redis with python”, https://realpython.com/python-redis/