2110446 - Data Science and Data Engineering

Data Storages

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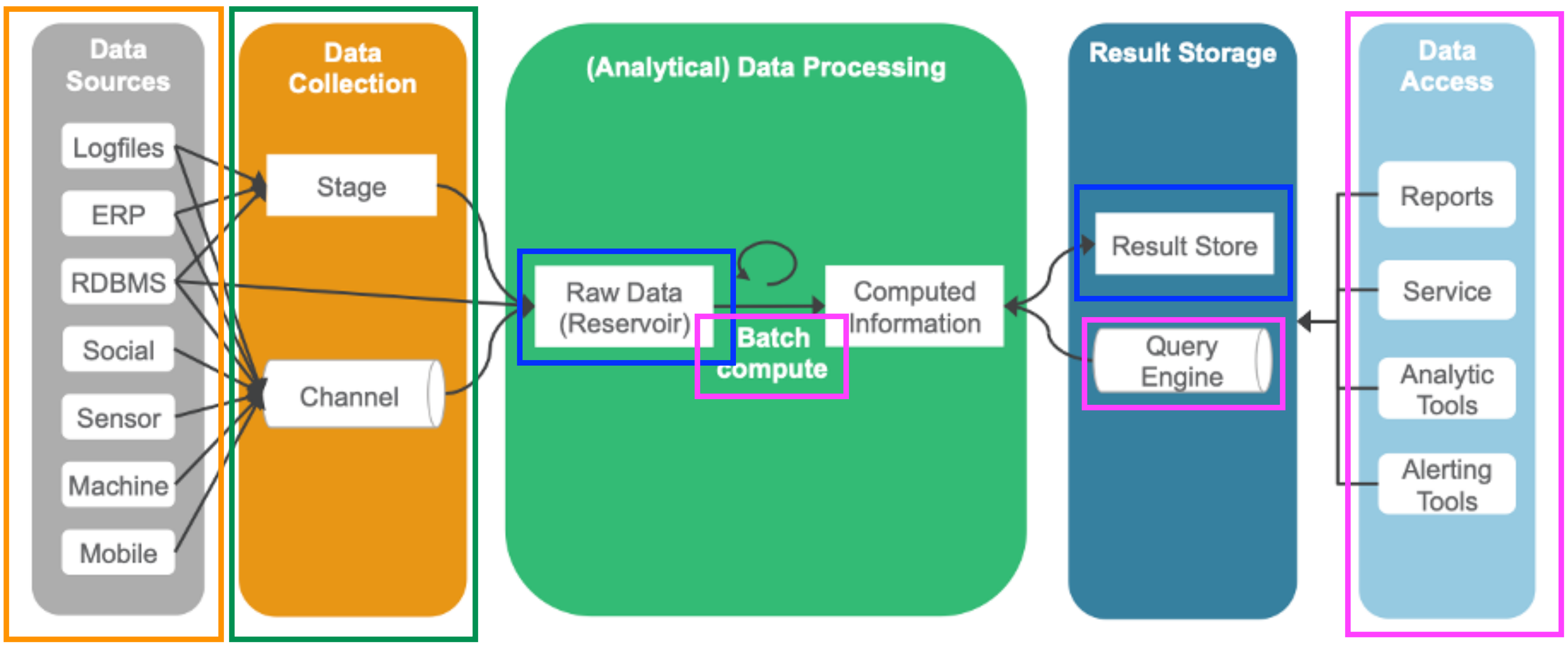
Simple Big Data Analytic Architecture

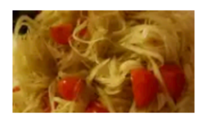


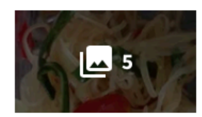
Data Generation   Data Ingestion   Data Storage   Data Analytics

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

Add Photo





Prep Time:
20 mins

Total Time:
20 mins

Servings:
6

Jump to Nutrition Facts

Ingredients

- 3 cloves garlic, peeled
- 3 Thai green chiles
- 6 green beans, cut into 1-inch pieces
- 1 large unripe papaya, peeled and cut into

Local Offers

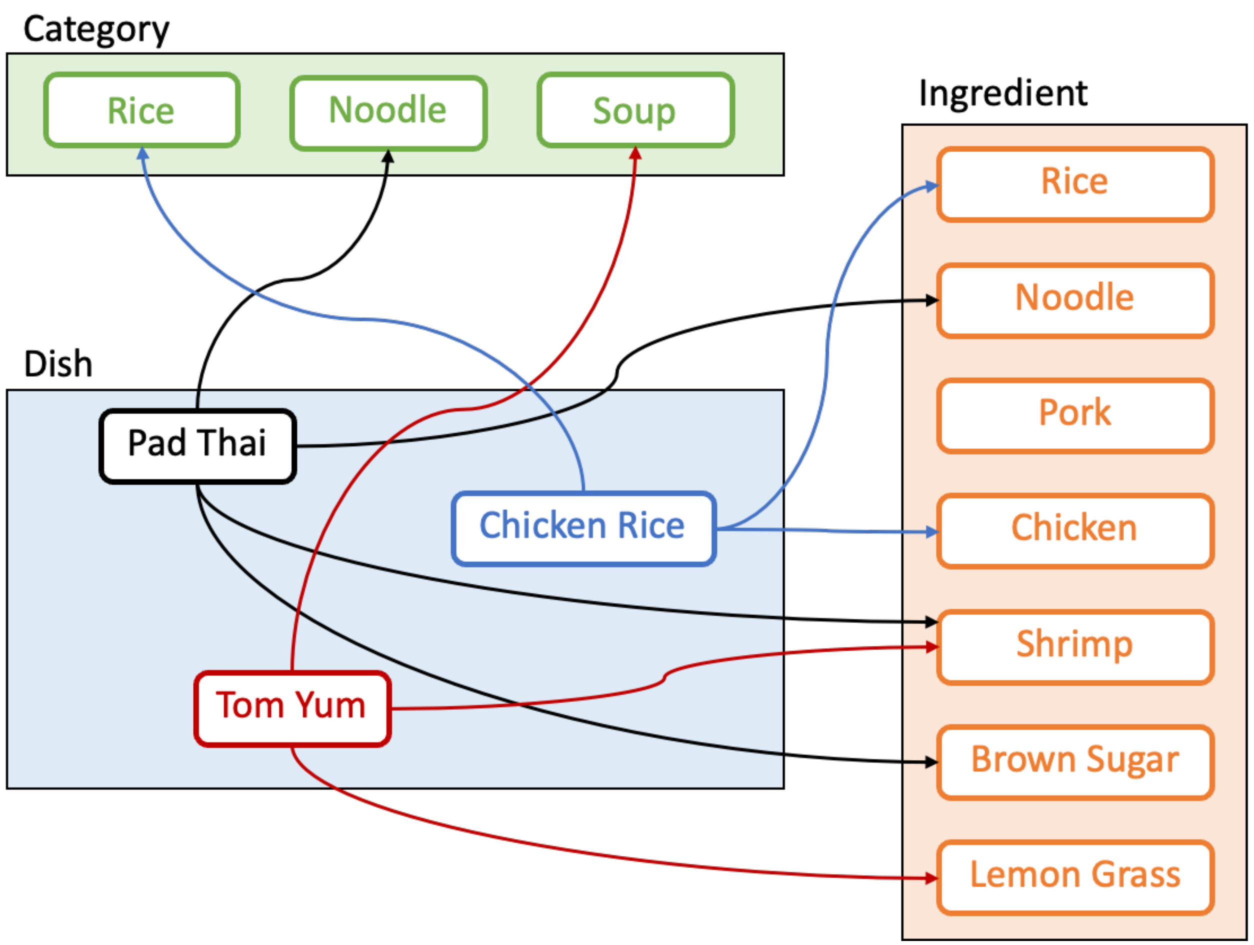
00000 Change

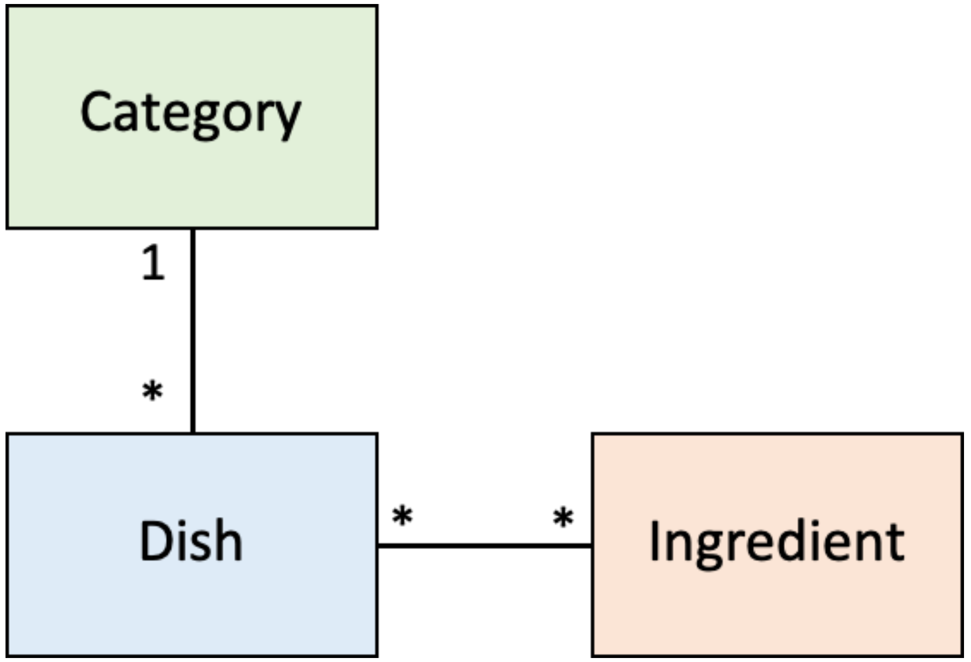
Oops! We cannot find any ingredients on sale near you. Do we have the correct zip code?

Recipe Data is Hierarchical

- A dish has the following data:
  - belong to a category
  - consists of one or more main ingredients
  - Ingredients are different in portions and units
- For example:
  - Padthai belongs to a noodle category with 3 main ingredients noodle, shrimp, brown sugar
  - Tomyum belongs to a soup category; shrimp and lemon grass are main ingredients

Relational Database: Focus on Relation of Tables

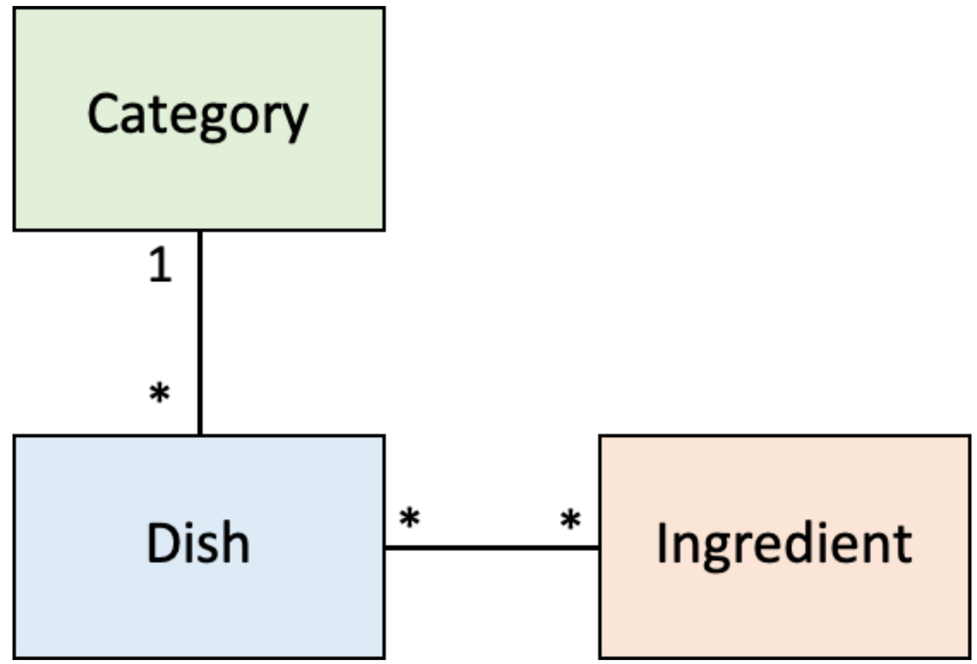




Example RDBMS: Recipe

Category

id	category
1	Soup
2	Noodle
3	Rice



Dish

id	name	category	…
1203	Pad Thai	2	
1288	Chicken Rice	3	

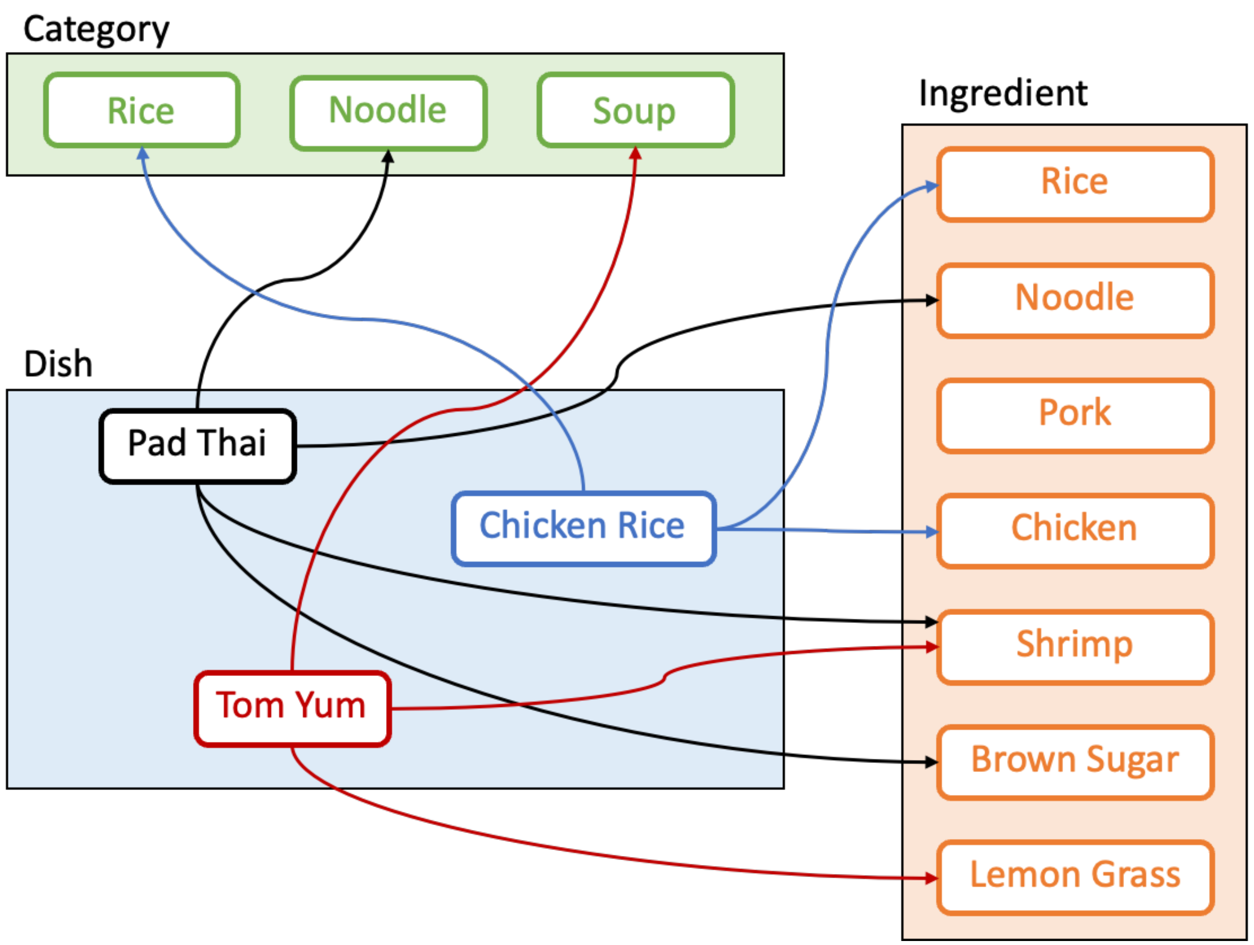
DI_link

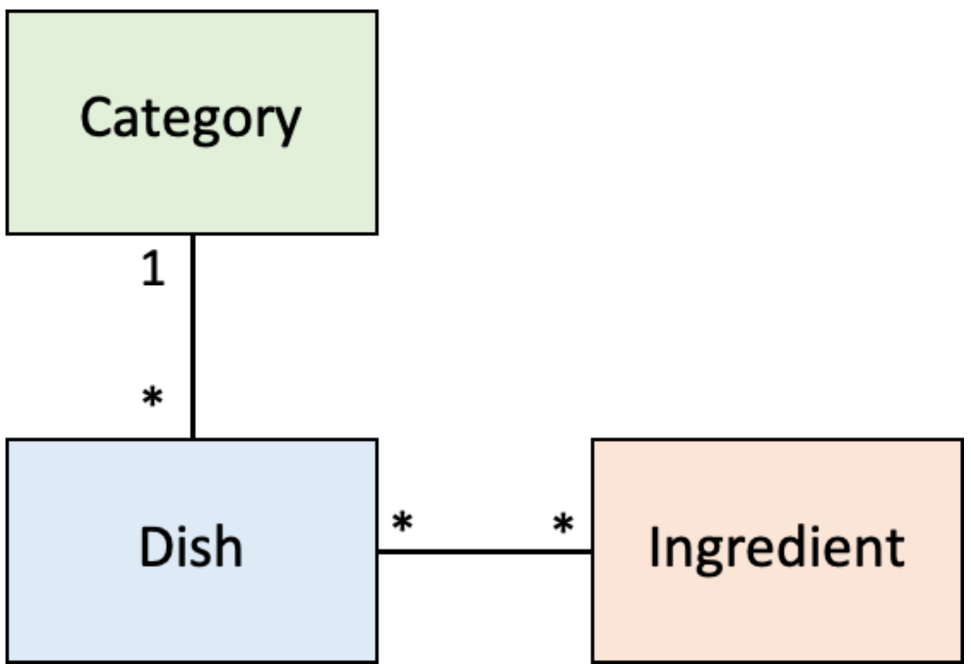
d_id	i_id	quantity	unit
1203	45	125	g
1203	48	150	g
1203	52	3	tbsp

Ingredient

id	item
45	noodle
46	rice
48	chicken
52	brown sugar

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

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

availability

CAP Theorem (Brewer's Theorem)

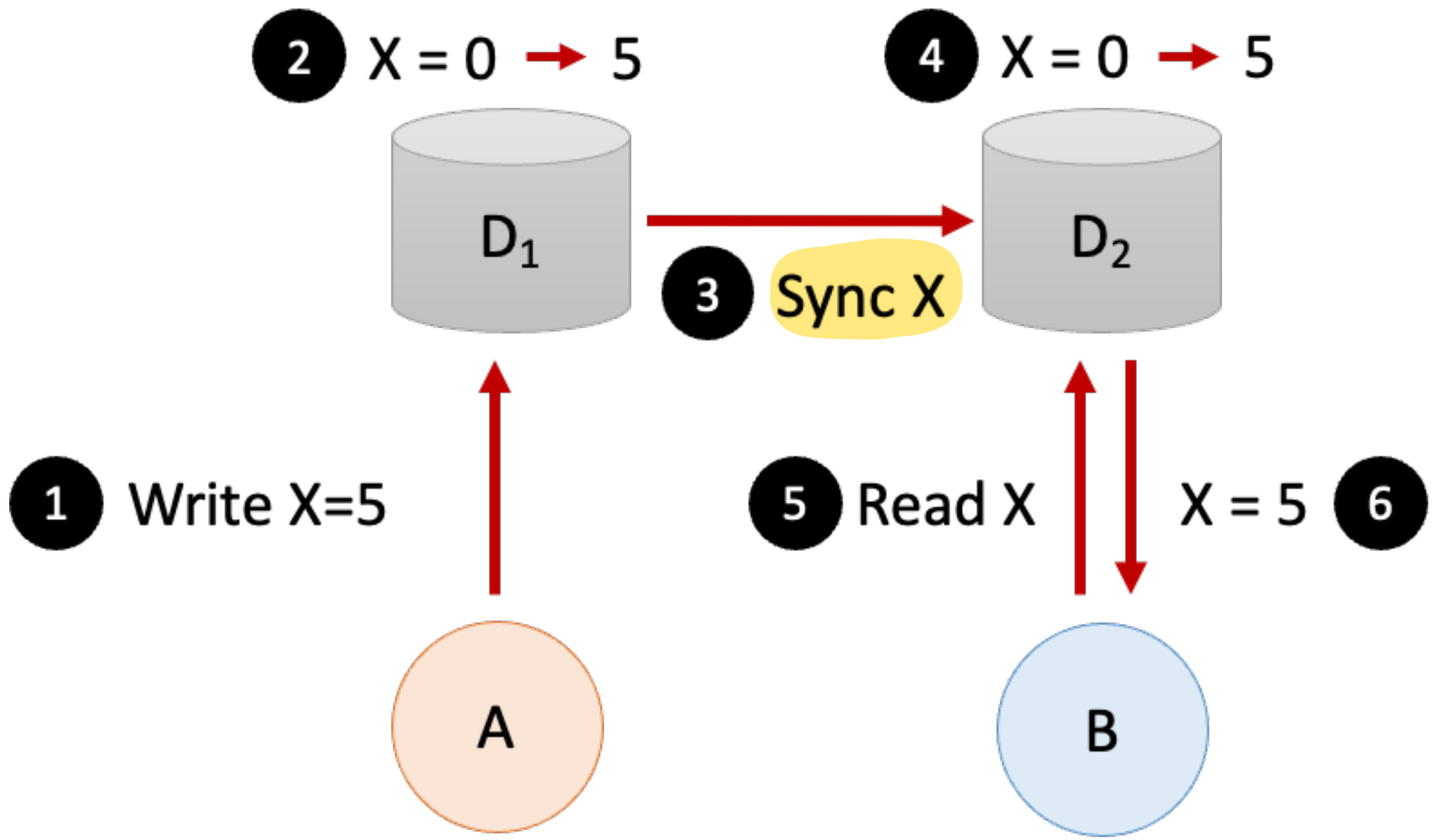
consistency partition-tolerant

- 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

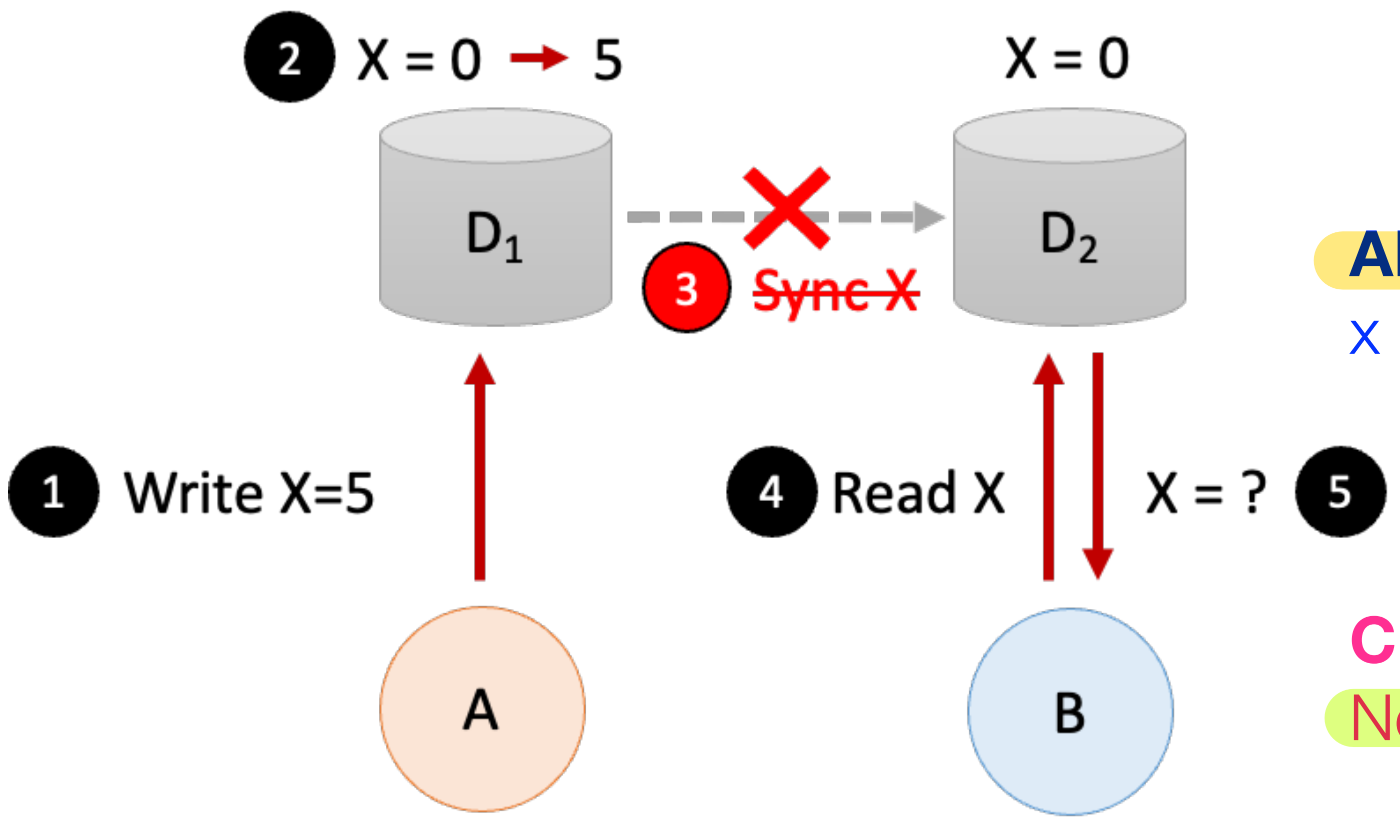
CAP Guarantees only 2 out of 3

- 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)

old version

CP Data Store

No response (Not available)

PACELC Theorem

- An extension to the CAP theorem by Prof. Daniel J. Abadi from Yale University in 2010

- In case of network partitioning (P) in a distributed computer system, one has to choose between availability (A) and consistency (C), but else (E), even when the system is running normally in the absence of partitions, one has to choose between latency (L) and consistency (C)

- Reading assignment

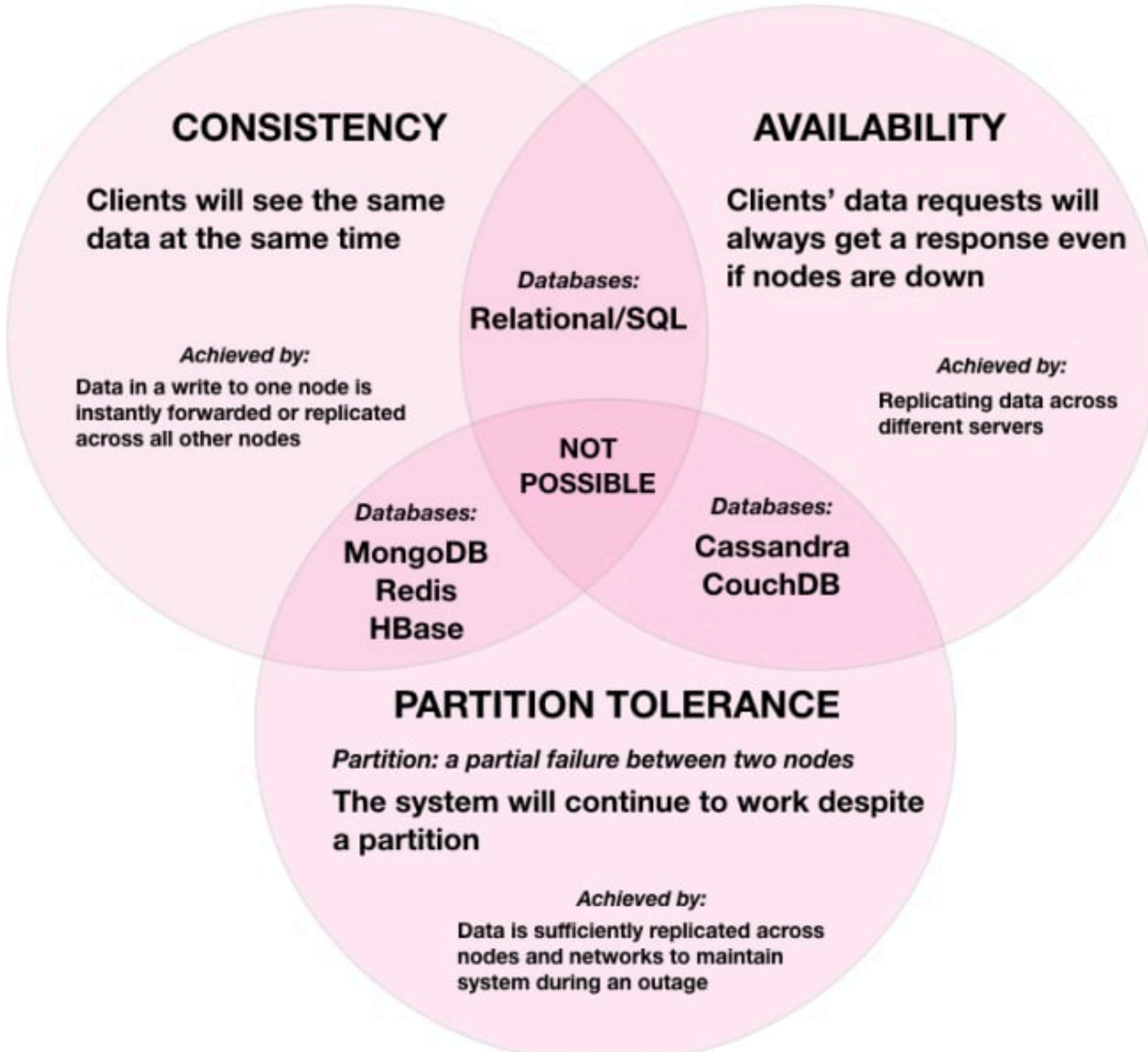
The Landscape of NoSQL

- 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

คล้ายๆกัน
แค่มี search

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

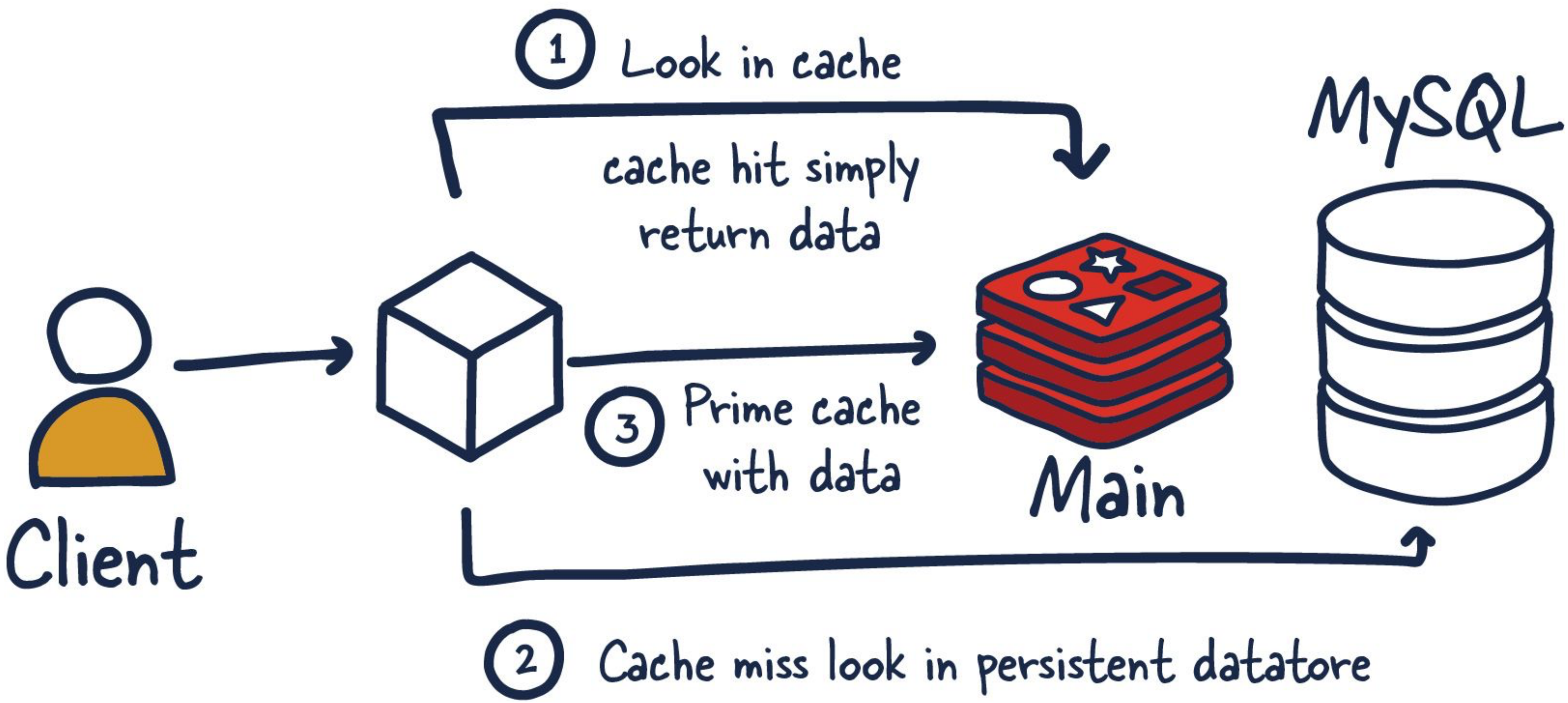
Key-Value Stores

- A data store designed for storing, retrieving, and managing associative arrays (aka. dictionary or hash table)
- Main concept is to store data as a collection of key-value pairs in which a key serves as a unique identifier
- Simple and fast, often use in-memory architecture, ability to scale-out
- Use cases: session store, shopping cart, SQL/API caching, etc.

Redis (Remote Dictionary Server)

- In-memory data structure store with clustering, transactional, time-to-live limiting, and auto-failover capabilities
- Support wide-range of data structure with lots of related operations for each structure
- Being used for database cache, message broker, streaming engine, feature store engine, etc.
- Provide CLI and support many programming languages
- Many useful modules are available to extend the functionality of Redis core e.g. RedisJSON, RedisSearch, RedisTimeSeries, Redis OM, etc.

How is redis traditionally used



Source: https://architecturenotes.co/redis/

Running Redis

- 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

- You can also use docker-compose.yml and other example files in redis folder in datasci_architecture repo

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

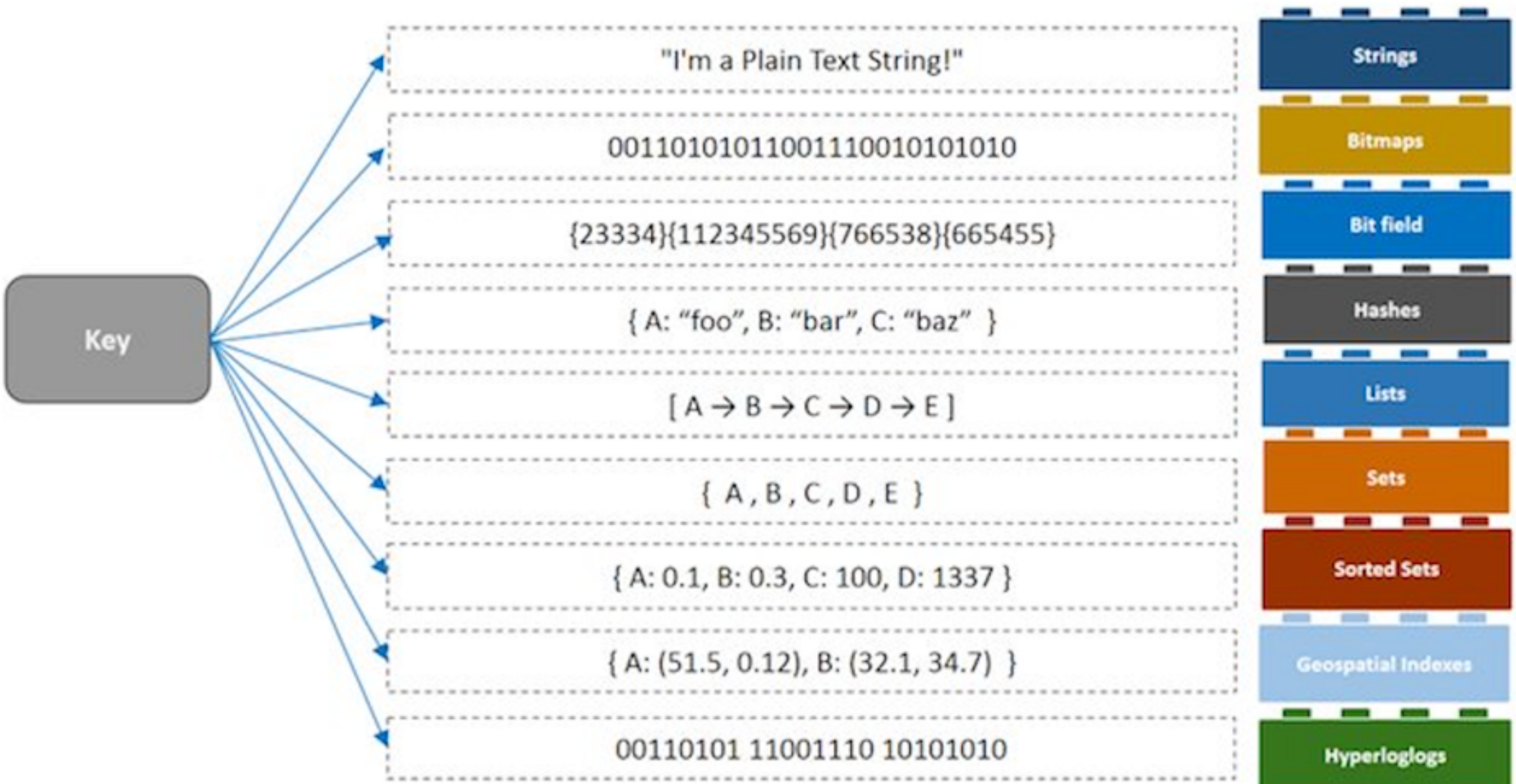
```
pip install redis
```

- Example

```
import redis

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

Redis Data Types



ID ของของที่
ผ่านไป?

แปลง ID → binary

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
HINCRBY profile: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

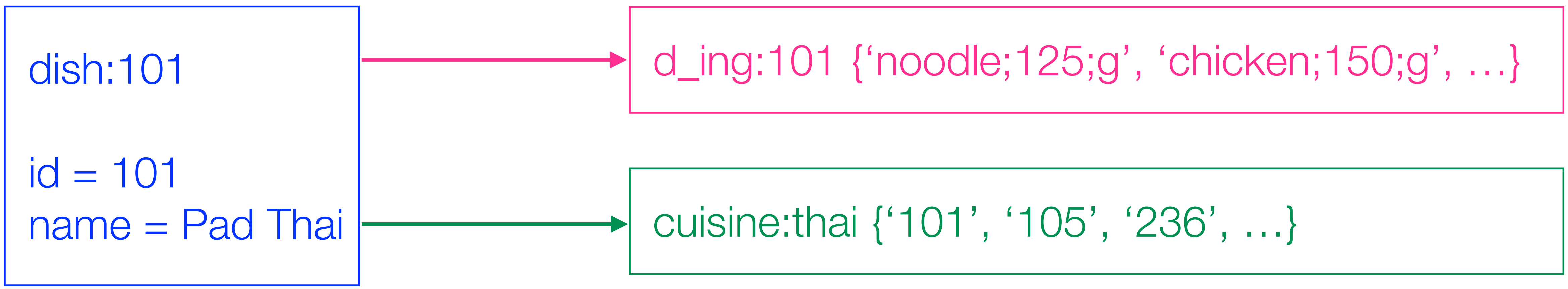
HSTRLEN

HVALS

Example: Recipes in Redis

- Create data model for recipe
- Data items
  - Main data
    - Dish - hash - key = dish:dish_id, value = dish_id, name, category, cuisine
    - Dish Ingredients - set - key = d_ing:dish_id, value = string(name; size; unit)
  - For query
    - Cuisine - set - key = cuisine:cuisine_value, value = string(dish_id)
- Relationship
  - 1 dish can have multiple ingredients
  - Cuisine, as a helper data item, points back to dishes belong in the cuisine
- This is only one example of model design

Example: Recipes in Redis



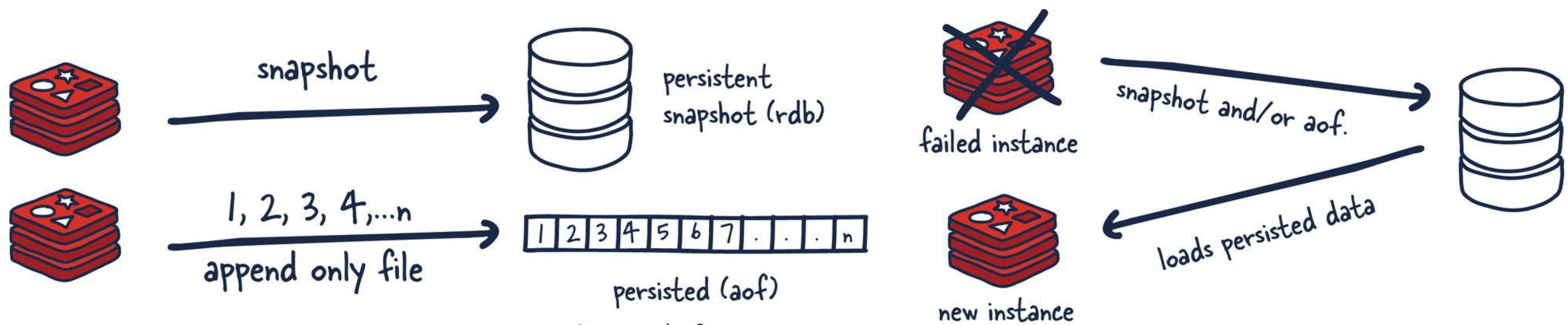

```
HMSET dish:1 id 101 name “Pad Thai” cuisine “thai” category “noodle”

SADD d_ing:101 “noodle;125;g”
SADD d_ing:101 “shrimp;150;g”
SADD d_ing:101 “brown sugar;3;tbsp”

SADD cuisine:thai “101”
```

Redis Persistence

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

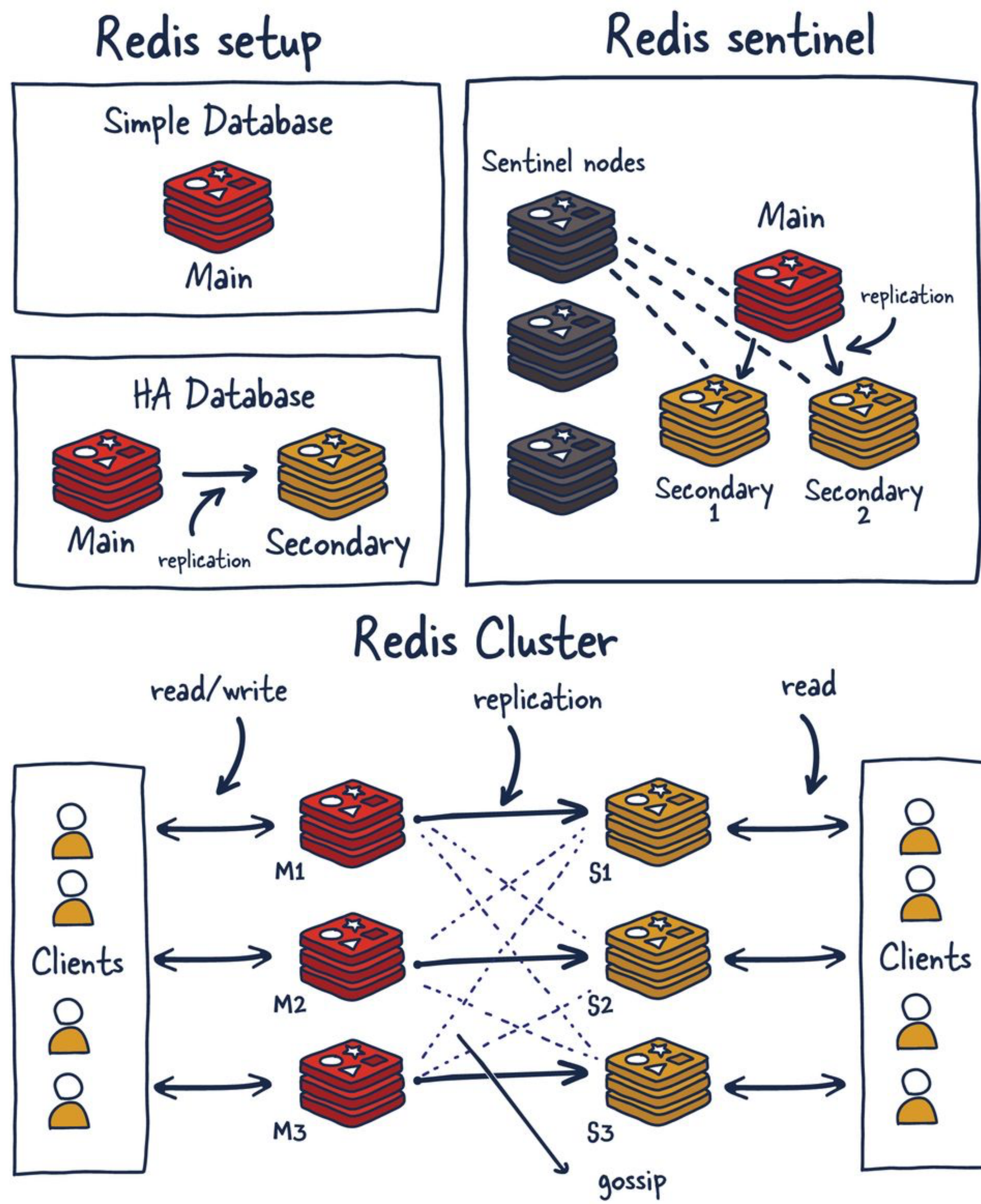


เร็วในการบันทึก

แต่ตอน recovery ต้อง playback

Redis Architecture

- Redis supports flexible architecture
  - Single instance
  - High Availability
  - Sentinel
  - Cluster



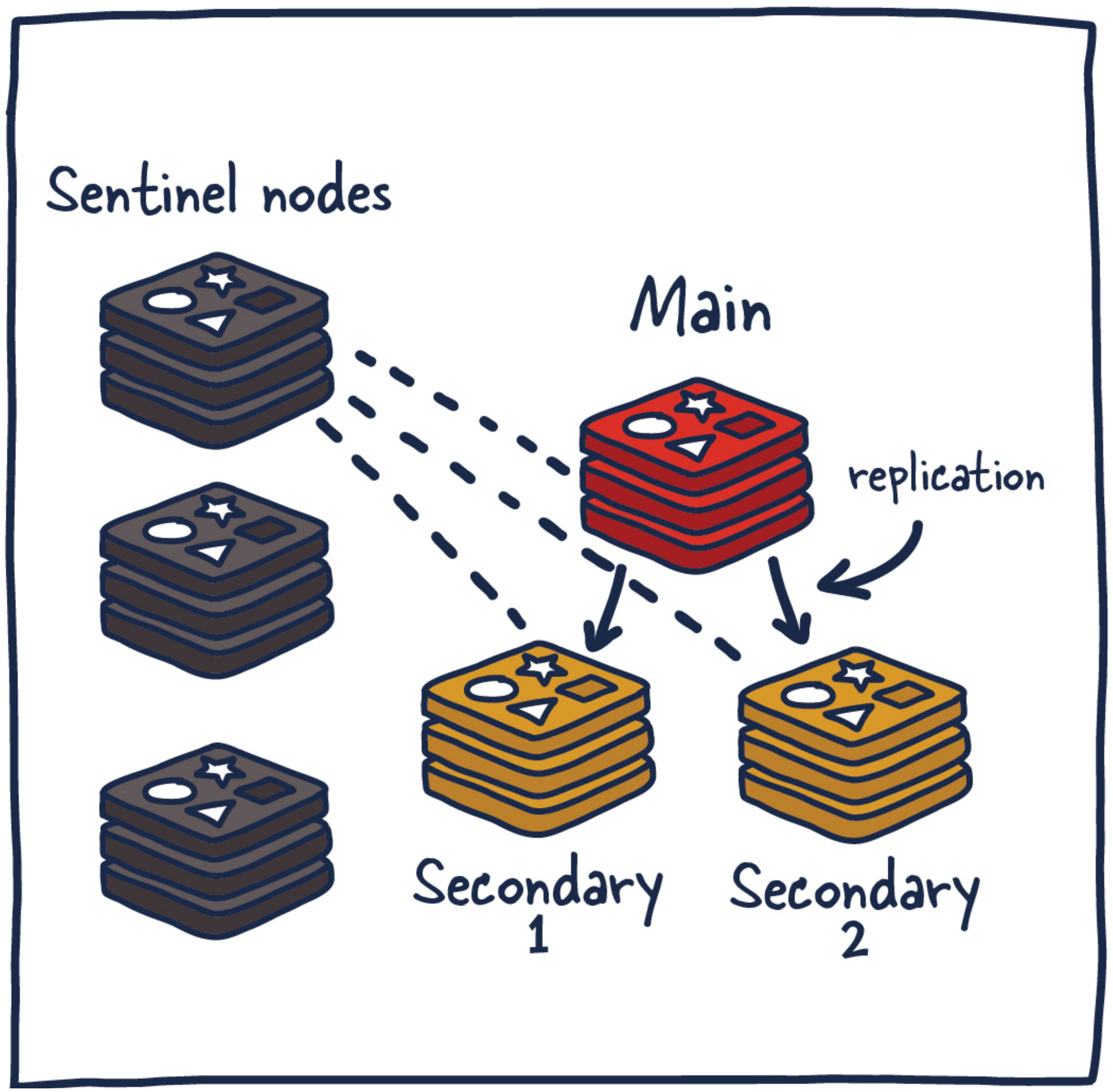
Source: https://architecturenotes.co/redis/

Redis High Availability

- When setup for HA, Redis consists of a master and one or more replicas and follows the following rules
    - Master performs all commands (read/write/etc.), replica performs only read commands
    - When a master and a replica instances are well-connected, the master keeps the replica updated by sending a stream of commands to the replica to replicate the effects on the dataset
    - When the link between the master and the replica breaks, for network issues or because a timeout is sensed in the master or the replica, the replica reconnects and attempts to proceed with a partial resynchronization
    - When a partial resynchronization is not possible, the replica will ask for a full resynchronization
    - Redis uses asynchronous replication, with asynchronous replica-to-master acknowledges of the amount of data processed

Redis High Availability

- To ensure data synchronization, all servers keep data version (replication id, offset); equal data versions mean both servers hold the same data
  - When a server becomes a master, it generates a new replication ID; replica server inherits replication ID from its master once connected
  - When master updates its data, it increments offset by one
- When replicas connect to masters, they use the PSYNC command to send their old master replication ID and the offsets they processed so far
  - If the differences of offsets are not too far behind, partial synchronization is performed
  - If too far or mismatched replication ID, a full resynchronization happens: in this case the replica will get a full copy of the dataset, from scratch



Source: https://architecturenotes.co/redis/

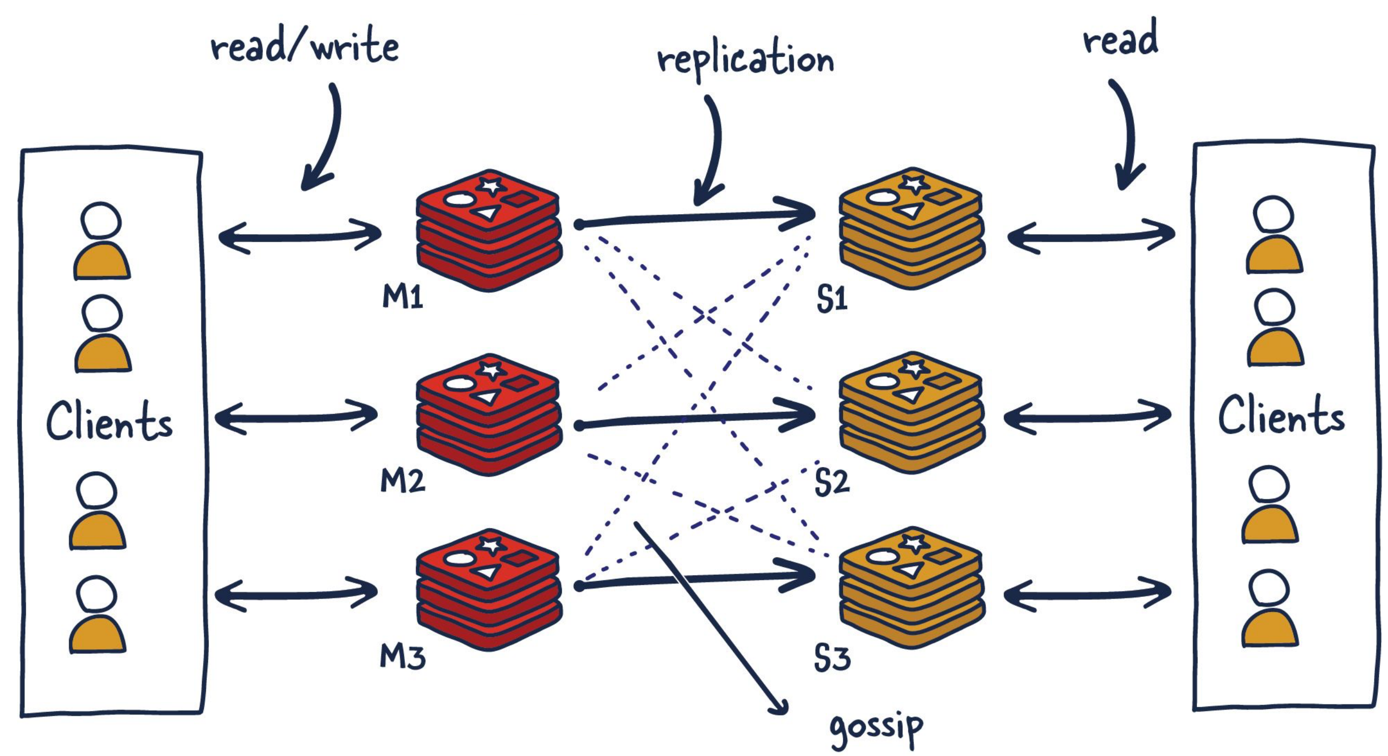
Redis Sentinel

- A cluster of sentinel processes working together to coordinate states of Redis master (main) and replicas (secondaries)
- Focus on HA aspects with minimum number of nodes
- Support single master with multiple replicas with monitoring, notification, auto-failover, configuration providing
- Need at least three Sentinel instances for a robust deployment (quorum or agreement protocol)
- Can be deployed in Redis and client nodes

monitor ว่า replication สมบูรณ์มั้ย

Redis Cluster

- Support algorithmic sharding for horizontal scaling
  - Incoming data is hashed into a hash slot using deterministic hash function and mod with number of nodes
  - Data with a given key always maps to the same shard
  - Perform resharding when adding new nodes
- There are 16k hashslot; all data in the same hashslot always moves to the new node when resharding
- Nodes communicate with one another using gossiping protocol to determine the entire cluster's health
- Redis Cluster does not guarantee strong consistency

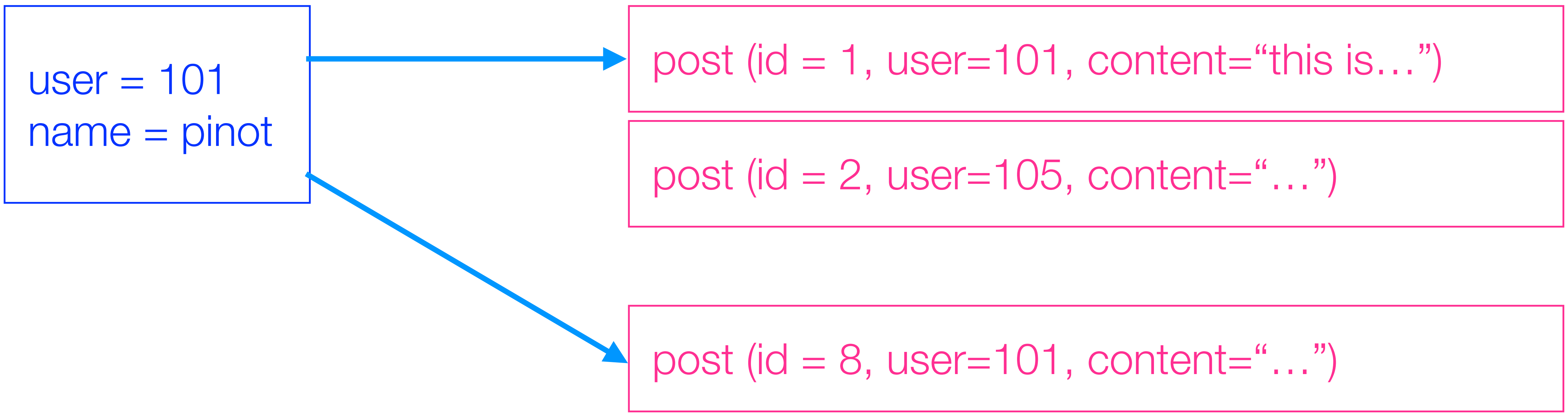


Source: https://architecturenotes.co/redis/

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

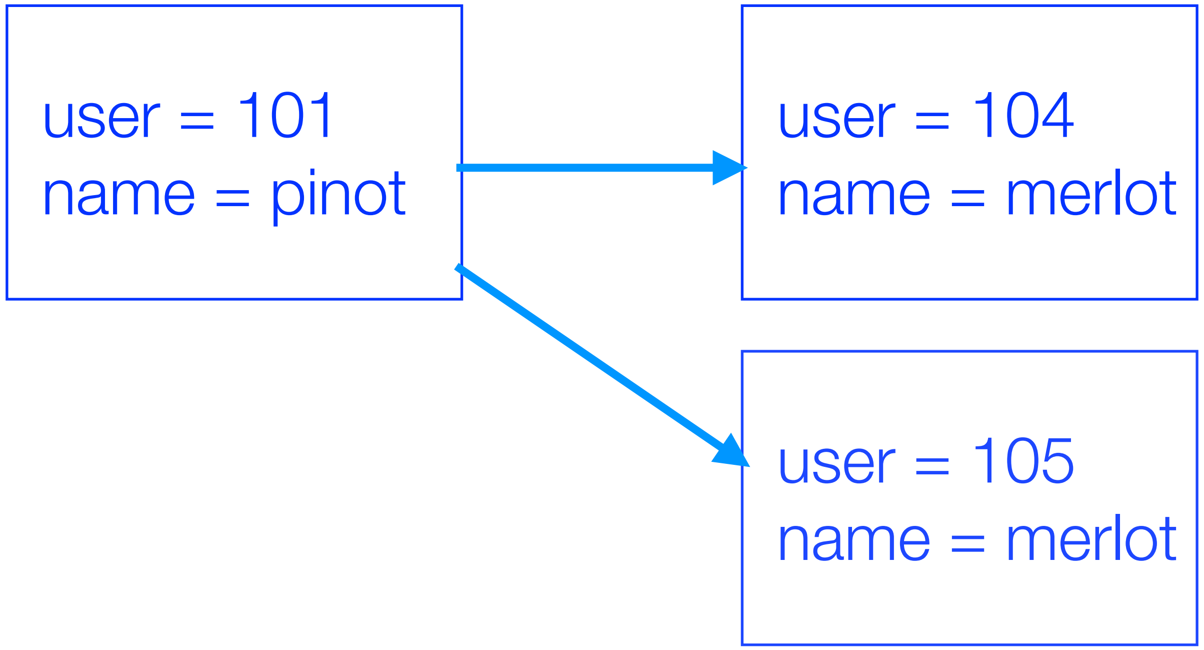



```
SET user:101:name pinot        # user id 101 with name "pinot"
SET username:pinot 101         # refer back to user-id

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

For your local redis only

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]:
```python
rd.lrange('user:101:post', 0, -1)
```
Out[9]:
```
['1', '8']
```

In [10]:
```python
rd.sadd('user:101:follows', 104)
rd.sadd('user:101:follows', 105)
```
Out[10]:
```
1
```

In [11]:
```python
rd.scard('user:101:follows')
```
Out[11]:
```
2
```

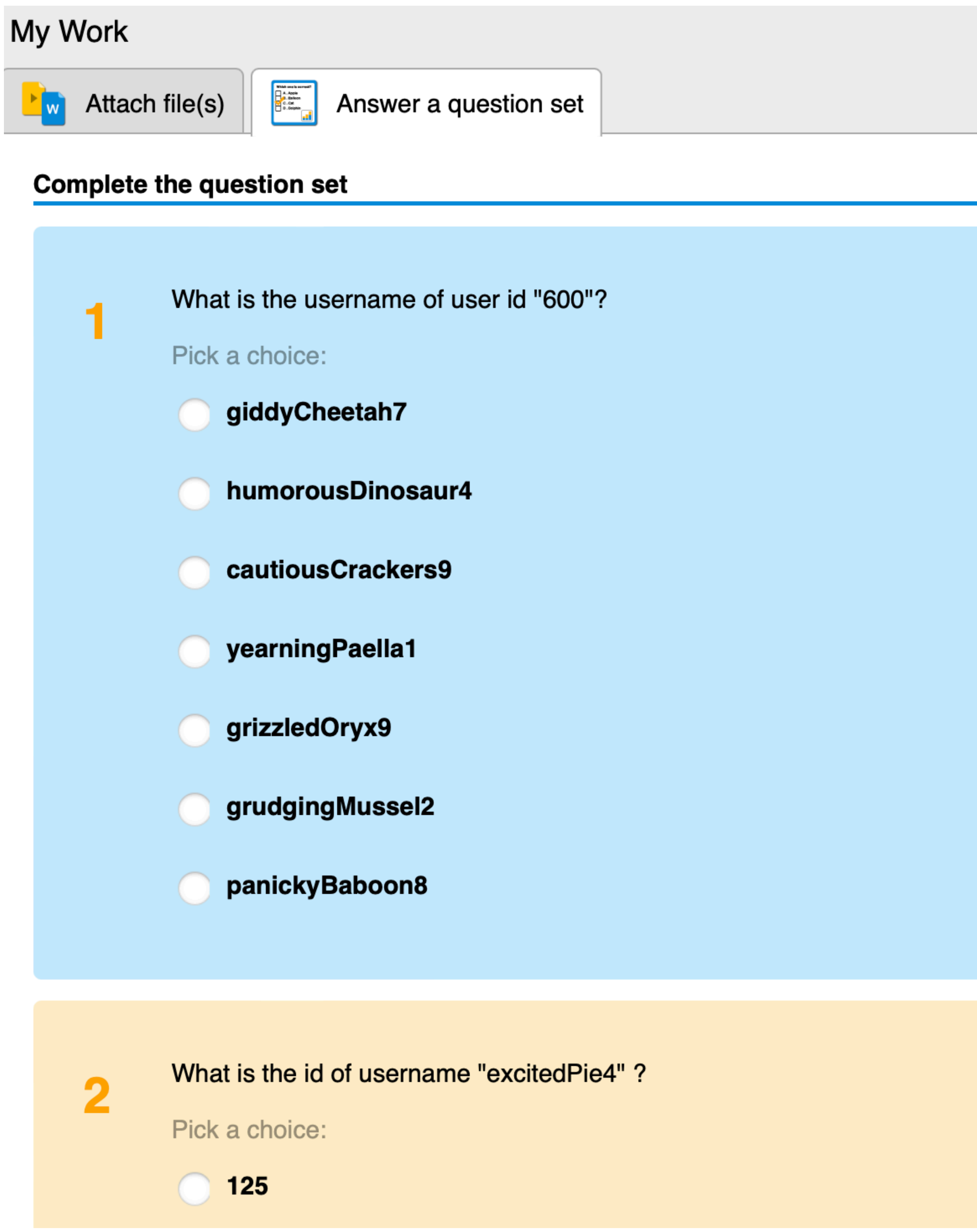
In [12]:
```python
rd.smembers('user:101:follows')
```
Out[12]:
```
{'104', '105'}
```

In [13]:
```python
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
```

Assignment: Simple Social Network

- Use the redis assignment notebook in class git repo and provide the following answers:
  - Answer questions in the question set
  - Save your notebook solution in the PDF format similar to the example in class git repo (used File -> Print Preview and then export as PDF or print to PDF with your browser)



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/

- M. Yusuf, “Redis Explained”, https://architecturenotes.co/redis/