44. URL Shortening System

Requirements clarification

Functional requirements

- URL Shortening (Write): Given an original URL, our service should generate a shorter and unique URL of it.
- URL Redirection (Read): When users access a short URL, our service should redirect them to the original URL.

Optional function requirements

- URL Customization: Users should optionally be able to pick a custom short URL for their original URL.
- URL Expiration: Shorter URL will expire after a standard default timespan. Users should be able to specify the expiration time.

Non-functional requirements

- The system should be highly available (If our service is down, all the URL redirections will start failing).
- URL redirection should happen in real-time with minimal latency.
- Shortened links should not be guessable (not predictable).

Estimation

Traffic estimation

Our system will be read-heavy (Lots of redirection requests compared to new URL shortenings).

- Read-write ratio is 100 : 1 (Assumed)
- Number of read actions and write actions per month

- Number of writes (URL Shortening) per month = 500 millions (Assumed)
- Number of reads (URL Redirection) per month= 500 millions x 100 = 50 billion
- Frequency of read actions and write actions per second (QPS)
- Frequency of writes per second = 500 millions / (30 days x 24 hours x 3600 seconds) = 200 times/s
- Frequency of reads per second = 200 times/s x 100 = 20000 times/s

Storage estimation

Types

Data: Yes

File: No

Capacity

- Time length of storing a record = 5 years (Assumed)
- Number of records created in 5 years = Number of writes per month x Number of months = 500 million x 5 years x 12 months = 30 billion
- Size of one record = 500 bytes (Assumed)
- Total capacity needed in 5 years = 30 billion * 500 bytes = 15 TB

Bandwidth estimation

- Write bandwidth = Frequency of writes per second x Size of one record = 200 times/s x 500 bytes = 100 KB/s
- Read bandwidth = Frequency of reads per second x Size of one record = 20000 times/s x 500 bytes = 10 MB/s

System interface definition

Interface 1

- **createURL(original_url)**
  - Function
    - Create a new shorter URL.
  - Parameters
    - original_url (string): Original URL to be shortened.
  - Return
    - The short URL.

Interface 2

- **getURL(api_key, short_url)**
  - Function
    - Get the original long URL of a short URL.
  - Parameters
    - short_url (string): The short URL to be redirected.
  - Return
    - The original long URL.

Data model definition

Schema

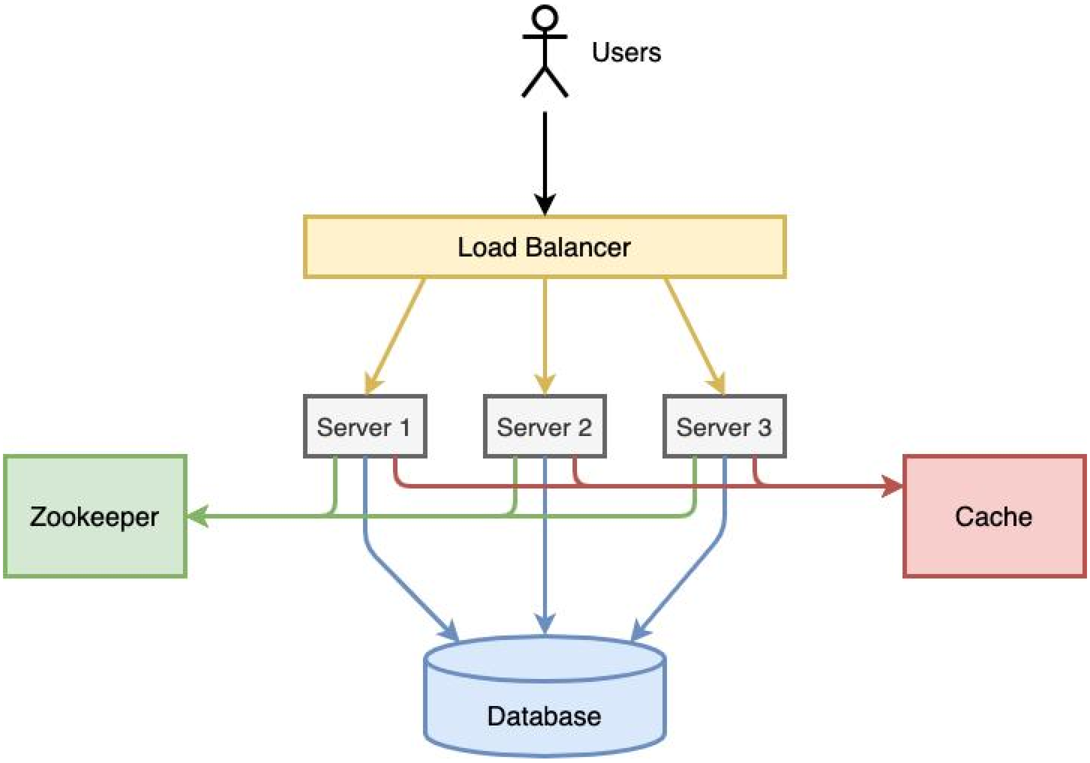
- Table 1: URL
  - Description
    - Store URL mappings.
      - Columns

Column Name	Column Type	PK	Description
ID	int	PK	
ShortUrl	string		The short URL.
LongUrl	string		The original long URL.

Database

- NoSQL
  - Reason
    - No relation need to look up.
    - NoSQL is good at scaling.

High-level design



Zookeeper

- Distributed coordinator to give each server a unique unused range of keys.

Cache

- Stores the top 20% most used URLs.
- When a server receives a URL query request, it can search the cache first. It the target URL is in in the cache, it can query the database.

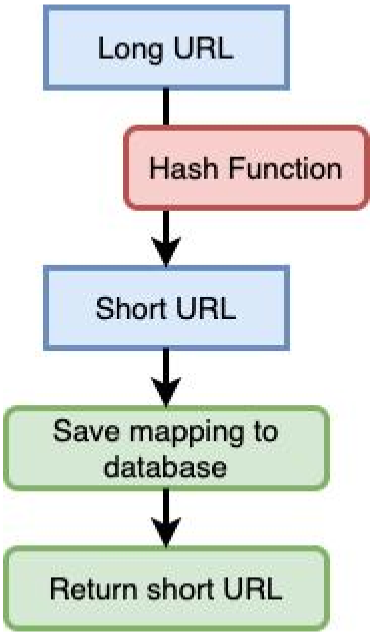
Database

- Stores URLs and users.

Detailed design

URL shortening

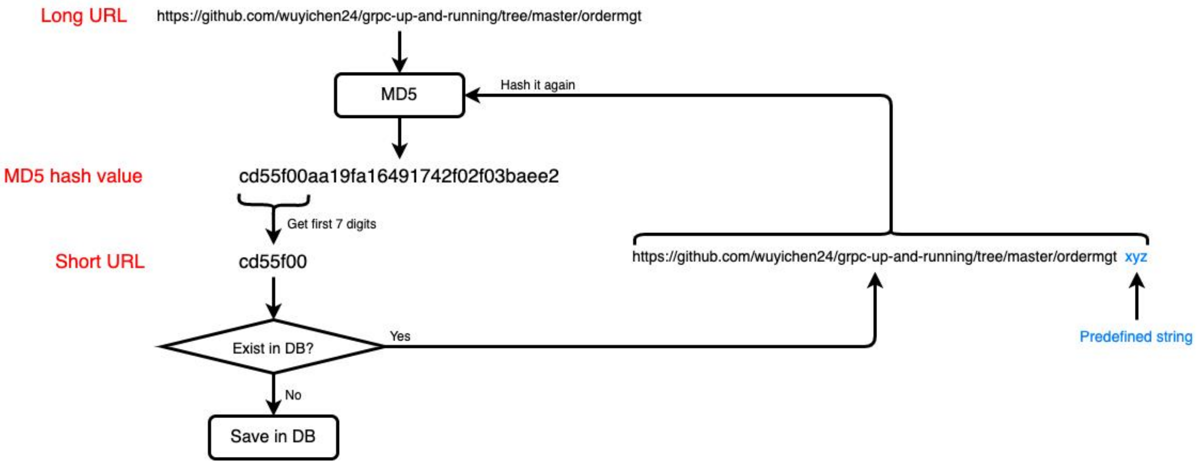
Process



Choices of hash function

Use existing hashing algorithm with collision resolution

- A hash value from an existing hashing algorithm (CRC32, MD5, SHA-1, SHA-2, etc.) is too long, so we cannot use it directly. Our solution is to only use the first 7 characters of a hash value from an existing hashing algorithm.
- Using the first 7 characters can result in a hash collision more easily.
- If the first 7 characters has a hash collision, recursively append a new predefined string to the long URL and hash the new long URL again, until no hash collision.

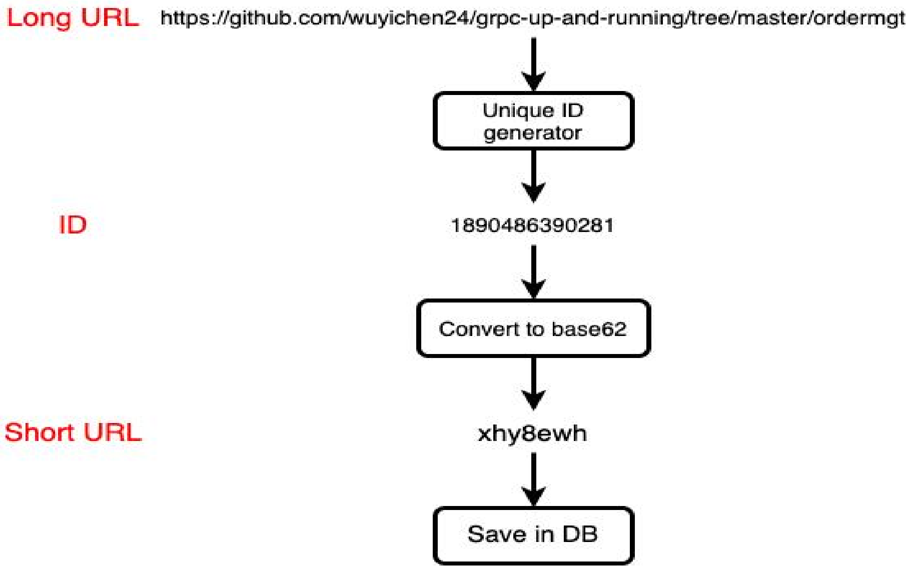

Long URL
https://github.com/wuyichen24/grpc-up-and-running/tree/master/ordermgt
MD5
Hash it again
MD5 hash value
cd55f00aa19fa16491742f02f03baee2
Get first 7 digits
Short URL
cd55f00
https://github.com/wuyichen24/grpc-up-and-running/tree/master/ordermgt xyz
Exist in DB?
Yes
Predefined string
No
Save in DB

Use base62 conversion

- Convert the unique ID (numeric value) of the new row for the URL mapping table from base 10 to base 62.

Example

- The long URL is https://github.com/wuyichen24/grpc-up-and-running/tree/master/ordermgt.
- The new ID for the new row is 1890486390281.
- Convert the ID from base 10 to base 62: xhy8ewh.
- The short URL will be https://abc.com/xhy8ewh.



Uniqueness of short URLs

- **Factors**
  - Number of all possible characters in one digit.
  - The length of a short URL (Number of digits).
- **Calculation**: Number of unique URLs = Number of all possible characters in one digitNumber of digits
- **Evaluation tradeoffs**
  - Keep short URL as short as possible.
  - Don't let unique short URLs run out easily (Maximal number of URLs > Total number of short URLs created in 5 years).

Solutions

Number of all possible characters in one digit	Length of URLs	Maximal number of URLs
Only numbers (0-9) = 10	7	107 = 10 million
Base36 ([0-9, a-z]) = 36	7	367 = 78 billion
Base62 ([0-9, a-z, A-Z]) = 62	7	627 = 3.5 trillion

Key points

Use Zookeeper as the distributed coordinator to solve the key conflict problem among multiple servers.