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## Experiment 1

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### Aim

To study and design a scalable URL Shortener system by analyzing its functional requirements, non-functional requirements, API design, database schema, and low-level design approaches including counter-based short URL generation for distributed systems.

### Objective

1. To understand the working of a URL shortening service.
2. To design REST APIs for URL creation and redirection.
3. To identify suitable database and server choices.
4. To analyze different short URL generation techniques.
5. To understand scalability challenges and their solutions.

### Problem Statement

Design a URL Shortener system that converts long URLs into short URLs and redirects users from short URLs to original long URLs with **low latency, high availability, and scalability**.

### Requirements

#### A. Functional Requirements

1. Generate a short URL from a long URL.
2. Support custom URLs (optional).
3. Support URL expiration (default and custom).



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4. Redirect short URL to the original long URL.
5. User registration and login using REST APIs.

## B. Non-Functional Requirements

1. **Low Latency:** URL creation and redirection < 200 ms.

2. **Scalability:**

- o 100M daily active

- users o 1B shortened URLs

3. **Availability:** System should be available 24x7.

4. **Uniqueness:** Each short URL must be unique.

5. **CAP Theorem:**

- o Availability >

- Consistency o Eventual

Consistency model.

## System Entities

1. **User**
2. **Long URL**
3. **Short URL**

## API Design

**1. Create Short URL Endpoint:** POST /v1/url

**Request Body:**

```
{  
  "longURL": "string",  
  "customURL": "string (optional)",  
  "expirationDate": "date"
```



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}

Response:

```
{  
    "shortURL": "https://short.ly/2bi"  
}
```

## 2. Redirect Short URL

Endpoint: GET /v1/url/{ shortURL }

Action: Redirects to original long URL.

## 3. User APIs

- POST /v1/register
- POST /v1/login

## High Level Design (HLD)

Components:

1. Client (Browser / App)
2. Server (Business Logic)
3. Database (Storage)

Flow:

Client → Server → Database → Server → Client

## Workflow

1. **Short URL Generation** 1. Client sends long URL request.



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2. Server generates short URL.
3. Server stores long URL + short URL in database.
4. Server responds with short URL.

## 2. Redirection

1. Client enters short URL.
2. Server validates short URL from database.
3. Server redirects to original long URL.

## Database Design

**Table T1 – User Metadata**

**Column Description** user\_id Primary Key

name      User Name email      Unique

password Encrypted created\_at Timestamp

**Table T2 – URL Table**

<b>Column</b>	<b>Description</b>
id	Primary Key
shortURL	Unique
longURL	Original URL



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customURL	Optional
expirationDate	Expiry Time
user_id	Foreign Key

## Low Level Design (LLD) Approach

### 01: Hashing (Encryption)

**Method:** shortURL = encrypt(longURL)

**Algorithms:** MD5, SHA-1, Base64

#### Problems

1. Long hash length (not short).
2. High collision probability.
3. Multiple DB lookups.
4. High latency at scale.

Not suitable for large-scale systems

### Approach 02: Counter-Based Approach (Recommended)

#### Logic:

1. Generate a global counter value.
2. Convert counter to Base62.
3. Use Base62 value as short URL.

#### Example:

Counter = 10000

Base62 = 2bi



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Short URL = short.ly/2bi

## Advantages

- No collision
- Fast generation
- Predictable length

## Scaling Challenges & Solutions

### Problem 1: Monolithic Server

- Cannot handle 100M users.

**Solution:** Horizontal Scaling (Multiple Servers)

### Problem 2: Distributed Counter Conflict

- Multiple servers may generate same counter.

**Solution:**

Use **Global Counter in Cache (Redis)** with atomic increment.

## Type of Database Used

### Recommended

- **NoSQL (Key-Value Store)**
  - Redis (Cache)
  - DynamoDB / Cassandra (Persistent)

**Reason:**

- Fast read/write
- High availability
- Easy horizontal scaling

## Type of Server



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- Stateless REST API Server • Deployed behind Load Balancer
- Performs:
  - URL validation ◦ Counter fetch ◦ Base62 conversion
  - DB read/write

## Result

A scalable and highly available **URL Shortener System** was successfully designed using **counter-based Base62 encoding**, REST APIs, NoSQL database, and distributed architecture principles.