535. Encode and Decode TinyURL

Medium Design Hash Table String Hash Function

Leetcode Link

Problem Description

The problem asks us to design a system that can encode a long URL into a short URL and decode it back to the original URL. This is similar to services like TinyURL that make long URLs more manageable and easier to share. The problem specifically requires implementing a class with two methods: one to encode a URL and one to decode a previously encoded URL.

Intuition

To solve this problem, we need to establish a system that can map a long URL to a unique short identifier and be able to retrieve the original URL using that identifier. The core idea behind the solution is to use a hash map (or dictionary in Python) to keep track of the association between the encoded short URLs and the original long URLs.

Here's the step-by-step reasoning for arriving at the solution:

1. **Encoding:**
   - Each time we want to encode a new URL, we increment an index that acts as a unique identifier for each URL.
   - Then, we add an entry to our hash map where the key is the string representation of the current index and the value is the long URL.
   - The encoded tiny URL is generated by concatenating a predefined domain (e.g., "https://tinyurl.com/") with the index.
2. **Decoding:**
   - To decode, we can extract the index from the end of the short URL. This index is the key to our hash map.
   - We then use this key to look up the associated long URL in our hash map and return it.

This approach efficiently encodes and decodes URLs using the methods `encode` and `decode`, assuming no two URLs will be encoded at the same index.

Solution Approach

The implementation uses a simple yet effective approach, based on a hash map and an incremental counter to correlate long URLs with their tiny counterparts.

Data Structures:

- **Hash Map (`defaultdict` in Python)**: A hash map is used to store and quickly retrieve the association between the unique identifier (`idx`) and the original long URL.

Algorithm:

The codec class is implemented in Python with the following methods:

1. **Initialization (`__init__`):**
   - A hash map `self.m` is initialized to store the mapping between a short URL suffix (a unique index) and the original long URL.
   - `self.idx` is initialized to `0` which is used as a counter to create unique identifiers for each URL.
2. **Encode Method (`encode`):**
   - Increment the `self.idx` counter to generate a new unique identifier for a new long URL.
   - Store the long URL in the hash map with the string representation of the incremental index as the key.
   - Generate the tiny URL by concatenating the predefined domain `self.domain` with the current index.
   - Return the full tiny URL.

   The encode function can be articulated with a small formula where `longUrl` is mapped to `"https://tinyurl.com/" + str(self.idx)`.

```python
self.idx += 1
self.m[str(self.idx)] = longUrl
return f'{self.domain}{self.idx}'
```

3. **Decode Method (`decode`):**
   - Extract the unique identifier from the short URL by splitting it at the '/' and taking the last segment.
   - The identifier is then used to find the original long URL from the hash map.
   - Return the long URL.

   This process can be described as retrieving `self.m[idx]`, where `idx` is the last part of `shortUrl`.

```python
idx = shortUrl.split('/')[-1]
return self.m[idx]
```

Patterns:

- **Unique Identifier**: By using a simple counter, each URL gets a unique identifier which essentially works as a key, preventing collisions between different long URLs. DbSetti does not rely on hashing functions or complex encoding schemes, reducing overhead and complexity.
- **Direct Mapping**: The system relies on direct mappings from unique identifiers to original URLs, allowing O(1) time complexity for both encoding and decoding functions.

This straightforward approach is easy to understand and implement, requiring only basic data manipulation. It does not involve any complex hash functions, avoids collisions, and ensures consistent O(1) performance for basic operations.

Example Walkthrough

Let's demonstrate the encoding and decoding process with a simple example:

Imagine we have the following URL to encode: `https://www.example.com/a-very-long-url-with-multiple-sections`.

After we initiate our codec class, it might look something like this:

```python
class Codec:
    def __init__(self):
        self.m = {}
        self.idx = 0
        self.domain = "https://tinyurl.com/"

    def encode(self, longUrl):
        # Increment the index to create a new identifier
        self.idx += 1
        # Map the current index to the long URL
        self.m[str(self.idx)] = longUrl
        # Generate and return the shortened URL
        return f'{self.domain}{self.idx}'

    def decode(self, shortUrl):
        # Extract the identifier from the URL
        idx = shortUrl.split('/')[-1]
        # Retrieve the original long URL
        return self.m[idx]
```

Let's go through the actual encoding and decoding steps with our example URL:

1. **Encoding the URL:**
   - We take the long URL `https://www.example.com/a-very-long-url-with-multiple-sections`.
   - Since `self.idx` starts at `0`, after encoding our first URL, it will become `1`.
   - We add the long URL to the hash map with the key `'1'`.
   - The method `encode` returns a tiny URL, which will be `"https://tinyurl.com/1"`.
2. **Decoding the URL:**
   - Now, when we want to access the original URL, we take the tiny URL `"https://tinyurl.com/1"`.
   - The method `decode` will extract the identifier `'1'` which is the last segment after splitting the URL by `'/'`.
   - It will then look up this index in our hash map to find the original URL, which is `https://www.example.com/a-very-long-url-with-multiple-sections`.
   - The `decode` method will return this long URL.

By following this simple example, we've seen how the unique identifier helps in associating a long URL with a shortened version, and how easy it becomes to retrieve the original URL when needed. Each encode operation generates a new, unique tiny URL, and each decode operation precisely retrieves the corresponding original URL using this mechanism.

Python Solution

```python
from collections import defaultdict

class Codec:
    def __init__(self):
        # Initialize a dictionary to store the long URL against unique indexes
        self.url_mapping = defaultdict()
        self.index = 0  # A counter to create unique keys for URL
        self.domain = 'https://tinyurl.com/'  # The domain prefix for the short URL

    def encode(self, longUrl: str) -> str:
        """Encodes a URL to a shortened URL."""
        # Increment the index to get a unique key for a new URL
        self.index += 1
        # Store the long URL in the dictionary with the new index as key
        self.url_mapping[str(self.index)] = longUrl
        # Return the domain concatenated with the unique index
        return f'{self.domain}{self.index}'

    def decode(self, shortUrl: str) -> str:
        """Decodes a shortened URL to its original URL."""
        # Extract the index from the short URL by splitting on '/'
        index = shortUrl.split('/')[-1]
        # Use the index to retrieve the corresponding long URL from the dictionary
        return self.url_mapping[index]


# Example of Usage:
# codec = Codec()
# short_url = codec.encode("https://www.example.com")
# print(codec.decode(short_url))

```

Java Solution

```java
import java.util.HashMap;
import java.util.Map;

public class Codec {
    // Map to store the index-to-URL mappings
    private Map<String, String> indexToUrlMap = new HashMap<>();

    // Counter to generate unique keys for shortened URLs
    private int indexCounter = 0;

    // Domain to prepend to the unique identifier creating the shortened URL
    private String domain = "https://tinyurl.com/";

    /**
     * Encodes a URL to a shortened URL.
     * @param longUrl The original long URL to be encoded
     * @return The encoded short URL
     */
    public String encode(String longUrl) {
        // Increment the indexCounter to get a unique key for this URL
        String key = String.valueOf(++indexCounter);
        // Store the long URL with the generated key in the map
        indexToUrlMap.put(key, longUrl);
        // Return the complete shortened URL by appending the key to the domain
        return domain + key;
    }

    /**
     * Decodes a shortened URL to its original URL.
     * @param shortUrl The shortened URL to be decoded
     * @return The original long URL
     */
    public String decode(String shortUrl) {
        // Find the position just after the last '/' character in the shortened URL
        int index = shortUrl.lastIndexOf('/') + 1;
        // Extract the key from the short URL and look it up in the map to retrieve the original URL
        String key = shortUrl.substring(index);
        return indexToUrlMap.get(key);
    }
}

// The Codec class may be used as follows:
// Codec codec = new Codec();
// String shortUrl = codec.encode("https://www.example.com");
// String longUrl = codec.decode(shortUrl);

```

C++ Solution

```cpp
#include <string>
#include <unordered_map>

class Solution {
public:
    // Encodes a URL to a shortened URL.
    std::string encode(std::string longUrl) {
        // Convert the current counter value to a string to create a unique key
        std::string key = std::to_string(++counter);

        // Associate the key with the original long URL in the hashmap
        urlMap[key] = longUrl;

        // Construct the short URL by appending the key to the predefined domain
        return domain + key;
    }

    // Decodes a shortened URL to its original URL.
    std::string decode(std::string shortUrl) {
        // Find the position of the last '/' in the short URL
        std::size_t lastSlashPos = shortUrl.rfind('/') + 1;

        // Extract the key from the short URL based on the position of the last '/'
        // and use it to retrieve the original long URL from the hashmap
        return urlMap[shortUrl.substr(lastSlashPos, shortUrl.size() - lastSlashPos)];
    }

private:
    // Hashmap to store the association between the unique key and the original long URL
    std::unordered_map<std::string, std::string> urlMap;

    // Counter to generate unique keys for each URL encoded
    int counter = 0;

    // The base domain for the shortened URL
    std::string domain = "https://tinyurl.com/";
};

// Usage example:
// Solution solution;
// std::string shortUrl = solution.encode("https://example.com");
// std::string longUrl = solution.decode(shortUrl);

```

Typescript Solution

```typescript
// Import necessary components for working with maps
import { URL } from "url";

// Create a Map to store the association between the unique key and the original long URL
const urlMap = new Map<string, string>();

// Declare a counter to generate unique keys for each URL encoded
let counter: number = 0;

// Define the base domain for the shortened URL
const domain: string = "https://tinyurl.com/";

// Encodes a URL to a shortened URL.
function encode(longUrl: string): string {
    // Convert the current counter value to a string to create a unique key
    counter++;
    const key: string = counter.toString();

    // Associate the key with the original long URL in the map
    urlMap.set(key, longUrl);

    // Construct the short URL by appending the key to the predefined domain
    return domain + key;
}

// Decodes a shortened URL to its original URL.
function decode(shortUrl: string): string {
    // Find the position of the last '/' in the short URL using URL class
    const shortUrlObj = new URL(shortUrl);
    const key: string = shortUrlObj.pathname.substring(1); // Remove the leading '/'

    // Use the key to retrieve the original long URL from the map
    const longUrl: string | undefined = urlMap.get(key);
    if (longUrl) {
        return longUrl;
    } else {
        throw new Error("Short URL does not correspond to a known long URL");
    }
}

// Note: Usage example is not included as we are defining things in the global scope

```

Time and Space Complexity

Time Complexity

- `encode`: The `encode` method has a time complexity of `O(1)` because it only performs simple arithmetic incrementation and one assignment operation, neither of which depend on the size of the input.
- `decode`: The `decode` method has a time complexity of `O(1)` because it performs a split operation on a URL which is a constant time operation since the URL length is fixed ("https://tinyurl.com/" part), and a dictionary lookup, which is generally considered constant time given a good hash function and well-distributed keys.

Space Complexity

- The space complexity of the overall Codec class is `O(N)` where `N` is the number of URLs encoded. This is because each newly encoded URL adds one additional entry to the dictionary (`self.m`), which grows linearly with the number of unique long URLs processed.