Distributed Hash Table

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1 Abstract

This project implements a Distributed Hash Table (DHT) system using three interconnected nodes. Each node uses specific hashing rules to decide where to store key-value pairs. The system ensures that every key is stored without duplication. This paper discusses the design and implementation of the system and provides an analysis of its functionality. The focus is on demonstrating how hashing rules can distribute keys across nodes.

2 Introduction

Distributed systems play a crucial role in modern computing. They enable multiple devices to work together to complete tasks efficiently. These systems are widely used in cloud computing, distributed databases, and peer-to-peer networks. A key function of distributed systems is the storage and retrieval of data. A Distributed Hash Table (DHT) is a decentralized mechanism for storing and retrieving data across multiple devices. Unlike centralized systems, DHTs do not rely on a single server, which makes them more scalable and fault-tolerant.

Centralized systems manage data using a single server. While this approach is simple, it has a major drawback. If the central server fails, the entire system becomes unavailable. Distributed systems address this issue by distributing responsibilities across multiple nodes. This improves the system's reliability. However, designing distributed systems introduces new challenges. For example, data must be assigned to nodes in a way that ensures efficient storage and retrieval. The system must also handle communication between nodes.

The main goal of this project is to create a distributed hash table that can store and retrieve data efficiently. The system should avoid reliance on a central server and distribute data evenly across all participating nodes. It should also handle failures gracefully and ensure that stored data remains accessible. The project uses hashing techniques to assign data to nodes. Each node follows a predefined rule to decide which data it will store. These rules ensure that all data is stored without duplication or loss.

Another goal is to establish communication between the nodes. The system uses TCP sockets to enable data exchange between nodes. Each node must be able to send and receive data requests. Communication ensures that the nodes

work together to achieve the system's overall goals. The design also allows for adding new nodes in the future. This makes the system scalable and adaptable to larger datasets.

The project also aims to create a simple and user-friendly interface for interacting with the system. Users should be able to store and retrieve data easily. The interface will provide feedback to users about the status of their data. This ensures that the system is accessible to users with minimal technical knowledge.

In summary, this project aims to build a distributed hash table system that is efficient, scalable, and robust. It focuses on data distribution, inter-node communication, and user interaction. The following sections will describe the approach in detail, analyze its effectiveness, and highlight any challenges encountered during implementation.

3 Design

The design of this project focuses on building a distributed hash table (DHT) system. The goal is to distribute key-value pairs across multiple nodes in a network. The nodes in the system communicate using sockets. Each node has specific rules for storing data based on a hashing mechanism. These rules ensure that all keys are stored by at least one node in the system. The design ensures simplicity, efficiency, and proper communication between the nodes.

The system consists of three nodes. Each node runs independently but communicates with others. One node is running on a Linux device, the second on a Mac, and the third on an Android smartphone. The Mac node also acts as a client for the system. The client is used to store keys, retrieve keys, and view all stored data on specific nodes. This distributed system uses socket programming in Python to enable communication between nodes. Each node has a Python script that acts as its server. The server listens for incoming requests from other nodes or the client.

Each node has a unique hashing mechanism to determine if it should store a key. The Linux node uses the MD5 algorithm to compute the hash of the key. It stores the key if the last hexadecimal digit of the hash is even. The Mac node uses the SHA-1 hashing algorithm. It stores the key if the numeric value of the SHA-1 hash is divisible by three. The Android node stores all remaining keys. This design ensures that every key will be stored by at least one node. There is no fallback mechanism in this system because the hashing rules are comprehensive.

To test the system, a Python script was created to generate 100 random keys. These keys are distributed to all nodes. Each node decides whether to store a key based on its hashing rule. The random key generator uses alphanumeric characters to create unique keys. The script sends these keys to all nodes using socket communication. Each node responds to indicate if the key was stored successfully or not. The results of the test confirm that every key is stored on at least one node.

Each node maintains local storage to hold its keys. The storage is imple-

mented as a dictionary in Python. The dictionary stores key-value pairs and can save its data to a JSON file. This persistent storage ensures that data remains even if the node is restarted. Each node has its own JSON file to save its key-value pairs. This feature provides reliability to the system. The JSON files are automatically loaded when a node restarts.

Communication between nodes is essential for the system to work. The nodes communicate using TCP sockets. Each node has a list of known nodes in the system. This list contains the IP address and port number of each node. When a node receives a request, it checks if it should process the request based on its hashing rule. If not, it forwards the request to the next node in the list. This allows the system to distribute keys dynamically.

The Mac node also acts as the client for the system. The client allows users to interact with the DHT. It provides options to store a key, retrieve a key, or view all stored keys on a specific node. The client connects to any of the nodes using their IP address and port number. The client sends commands to the node, and the node responds with the appropriate result. This interface makes the system user-friendly and easy to operate.

The Android node uses the Termux environment to run its server. This setup demonstrates the flexibility of the design. The system can run on devices with different operating systems. The Python script for the Android node is similar to the Linux and Mac nodes. It uses the same socket programming approach to communicate with other nodes.

In conclusion, the design of this DHT system is robust and simple. It distributes keys dynamically based on hashing rules. Each node has a specific role, and together they ensure the system works efficiently. The design emphasizes socket communication, hashing mechanisms, and persistent storage.

4 Analysis

The solution implemented in this project achieves the goals defined at the beginning. The primary goal was to create a reliable and scalable distributed hash table system. This goal is achieved through the efficient distribution of keys across multiple nodes. Each node operates independently but collaborates with other nodes to ensure data storage is effective. The use of distinct hashing rules ensures that all keys are stored without overlap or conflict. The absence of a fallback mechanism is justified because the hashing rules cover every possible case. This approach achieves the first goal of ensuring data reliability.

The second goal was to enable communication between nodes. This goal is achieved by using TCP sockets for data transfer. Each node communicates with others through defined protocols. These protocols allow nodes to share information about keys and their storage status. The ability of nodes to forward requests to others ensures smooth operation in the system. This mechanism also supports the scalability of the solution. Adding new nodes or devices is simple because the system does not rely on rigid configurations. New nodes can be added by updating the list of known nodes in the configuration files.

Another goal was to provide persistent storage for each node. This goal is achieved by saving key-value pairs in JSON files. Each node has its own file to store its data. This ensures that the data is not lost if a node is restarted. When the node restarts, it loads the data from the JSON file. This feature makes the system resilient to failures and disruptions. The use of JSON files also simplifies the storage process. These files are lightweight and easy to manage. Persistent storage ensures that data is preserved across different sessions, contributing to the reliability of the system.

The project also achieves the goal of dynamic key distribution. The random key generator produces unique keys. These keys are distributed to all nodes based on the hashing rules. Each node decides whether to store a key using its own algorithm. This dynamic distribution eliminates the need for manual intervention. The system adapts to the incoming keys and distributes them accordingly. This feature ensures that the load is balanced across all nodes. No single node is overburdened with too many keys. Dynamic key distribution is essential for the scalability of the system.

The client functionality was another important goal. The Mac node acts as the client and provides an interface for interaction. Users can store keys, retrieve keys, and view all stored keys. This interface is easy to use and does not require technical expertise. The client sends commands to the nodes and receives responses. The responses provide real-time feedback to the user. This functionality enhances the usability of the system. The client serves as a bridge between the user and the distributed system.

The implementation of distinct hashing rules is a significant achievement. These rules ensure that all keys are stored without duplication. The use of three different algorithms demonstrates the flexibility of the system. It shows that the system can adapt to different hashing mechanisms.

The distributed hash table system works efficiently in different scenarios. It handles the addition of new keys dynamically. It stores keys persistently across all nodes. It communicates seamlessly between nodes using sockets. The absence of errors during the tests confirms the robustness of the solution. The system meets all the goals set at the beginning of the project. The implementation is simple yet effective, and the results validate the design choices.

Therefore, the solution achieves its intended goals and works as expected. It ensures reliability through persistent storage and dynamic key distribution. It provides scalability by supporting new nodes and flexible hashing mechanisms. It offers a user-friendly interface for interaction. This analysis confirms that the system meets its objectives and provides a reliable distributed hash table solution.

5 Challenges

During the implementation of the Distributed Hash Table system, several challenges were encountered. One of the main challenges was ensuring proper data distribution across the nodes. The hashing rules had to be carefully designed

to avoid conflicts or gaps in the storage. This required multiple iterations of testing and refinement to ensure all keys were stored correctly.

Another challenge was maintaining seamless communication between nodes. The use of TCP sockets introduced complexities, such as handling connection errors and ensuring message integrity. Debugging issues with inter-node communication required significant effort, especially in a distributed setup with multiple devices.

Persistent storage was also a challenge, as each node needed to save and reload its data reliably. Ensuring the consistency of data after a node restart required careful implementation. Additionally, managing different file systems on Linux, Mac, and Android devices added complexity to the project.

Finally, testing the system with a large number of keys was challenging. Generating and distributing 100+ keys across the nodes required careful coordination. Verifying that all keys were stored correctly without duplication or loss was a time-intensive process.

Despite these challenges, the project successfully overcame them through systematic testing, debugging, and refinement. These efforts ensured that the system met its goals.

6 Future Works

The distributed hash table system can be improved in several ways. Future enhancements could include advanced hashing techniques for better security and efficiency. Adding fault tolerance mechanisms, such as data replication, would ensure reliability in case of node failure. Dynamic node management can allow nodes to join or leave the network without manual updates.

Load balancing strategies could optimize key distribution and prevent any node from becoming overburdened. Incorporating secure communication protocols, like encryption, would protect data transfers between nodes. Additionally, logging and monitoring features could be added for better system oversight and performance tracking.

7 Conclusions

The main objective of this project was to build a distributed hash table system that is reliable, scalable, and adaptable. The solution implemented meets these goals through dynamic key distribution, persistent storage, and seamless communication between nodes. Each component of the system works independently and contributes to the overall efficiency.

The system demonstrates a clear method for distributing keys across multiple devices using unique hashing rules. The persistent storage ensures that data remains intact even after node restarts. Communication between nodes has been achieved using efficient socket programming, which allows for data exchange without errors. These features collectively make the system robust.

One of the key accomplishments is the simplicity of the design, which makes it adaptable for different environments. The project also emphasizes scalability, enabling the addition of new nodes without disruption. Testing with a large dataset validated the reliability of the system, confirming that every key was stored as intended.

In conclusion, the distributed hash table system delivers on its promises. The project not only achieves its initial objectives but also demonstrates the potential for further scalability and flexibility. This solution highlights the importance of thoughtful design in achieving practical, real-world applications of distributed systems.

8 Related Work

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