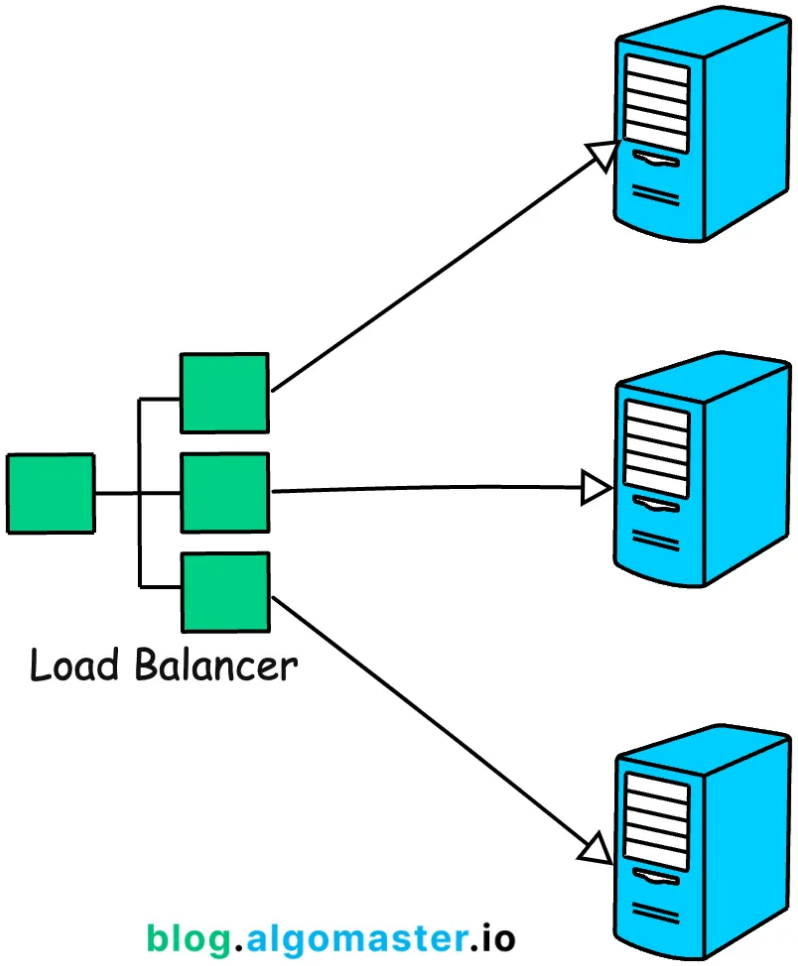
Load Balancing Algorithms Explained with Code

#14 System Design - Load Balancing Algorithms

ASHISH PRATAP SINGH

JUN 02, 2024

Load balancing is the process of **distributing incoming network traffic** across multiple servers to ensure that no single server is overwhelmed.

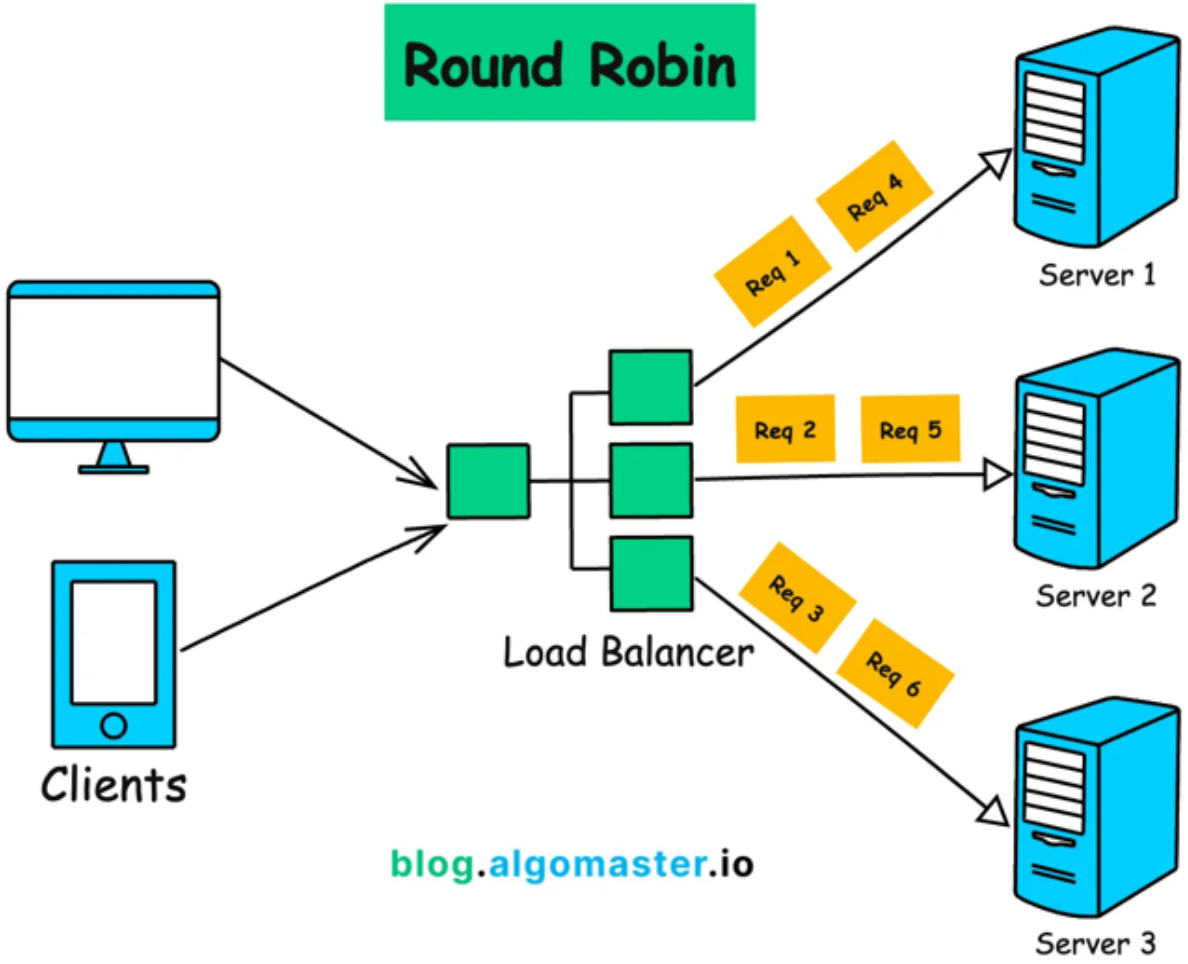


By evenly spreading the workload, load balancing aims to **prevent overload** on a single server, **enhance performance** by reducing response times and **improve availability** by rerouting traffic in case of server failures.

There are several algorithms to achieve load balancing, each with its pros and cons.

In this article, we will dive into the most commonly used load balancing algorithms, how they work, when to use them, their benefits/drawbacks and how to implement them in code.

Algorithm 1: Round Robin



How it Works:

1. A request is sent to the first server in the list.
2. The next request is sent to the second server, and so on.

3. After the last server in the list, the algorithm loops back to the first server.

When to Use:

- When all servers have similar processing capabilities and are equally capable of handling requests.
- When simplicity and even distribution of load is more critical.

Benefits:

- Simple to implement and understand.
- Ensures even distribution of traffic.

Drawbacks:

- Does not consider server load or response time.
- Can lead to inefficiencies if servers have different processing capabilities.

Implementation:

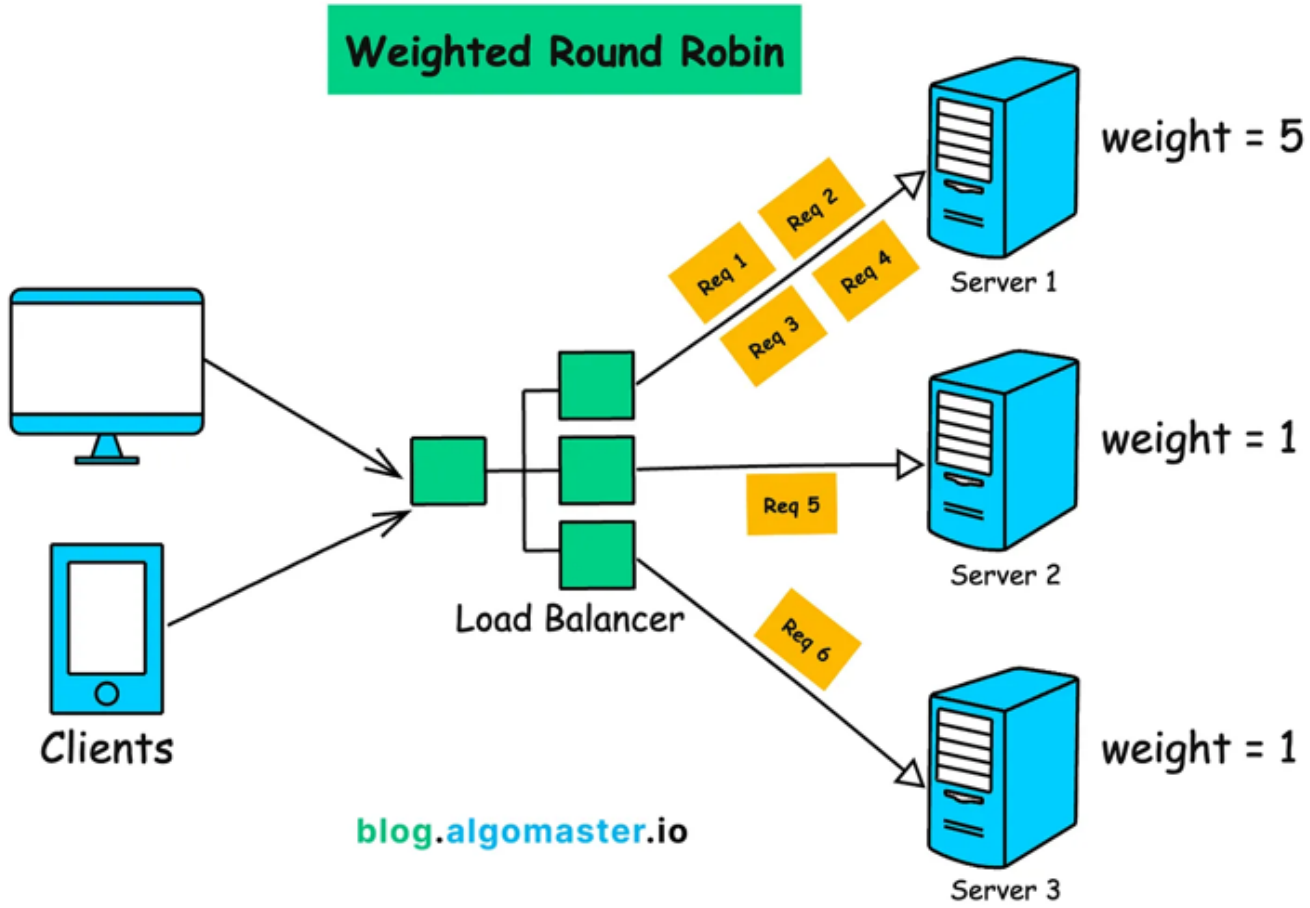
```python
class RoundRobin:
    def __init__(self, servers):
        self.servers = servers
        self.current_index = -1

    def get_next_server(self):
        self.current_index = (self.current_index + 1) % len(self.servers)
        return self.servers[self.current_index]

# Example usage
servers = ["Server1", "Server2", "Server3"]
load_balancer = RoundRobin(servers)

for i in range(6):
    server = load_balancer.get_next_server()
    print(f"Request {i + 1} -> {server}")
```

[Code Link]

In this implementation, the `RoundRobin` class maintains a **list of servers** and keeps track of the **current index**.

The `get_next_server()` updates the index and returns the next server in the cycle.

Algorithm 2: Weighted Round Robin



How it Works:

1. Each server is assigned a **weight** based on their processing power or available

resources.

2. Servers with higher weights receive a proportionally larger share of incoming requests.

When to use:

- When servers have different processing capabilities or available resources.
- When you want to distribute the load based on the capacity of each server.

Benefits:

- Balances load according to server capacity.
- More efficient use of server resources.

Drawbacks:

- Slightly more complex to implement than simple Round Robin.
- Does not consider current server load or response time.

Implementation:

```python
class WeightedRoundRobin:
    def __init__(self, servers, weights):
        self.servers = servers
        self.weights = weights
        self.current_index = -1
        self.current_weight = 0

    def get_next_server(self):
        while True:
            self.current_index = (self.current_index + 1) % len(self.servers)
            if self.current_index == 0:
                self.current_weight -= 1
                if self.current_weight <= 0:
                    self.current_weight = max(self.weights)
            if self.weights[self.current_index] >= self.current_weight:
                return self.servers[self.current_index]

# Example usage
servers = ["Server1", "Server2", "Server3"]
weights = [5, 1, 1]
load_balancer = WeightedRoundRobin(servers, weights)

for i in range(7):
    server = load_balancer.get_next_server()
    print(f"Request {i + 1} -> {server}")
```

[Code Link]

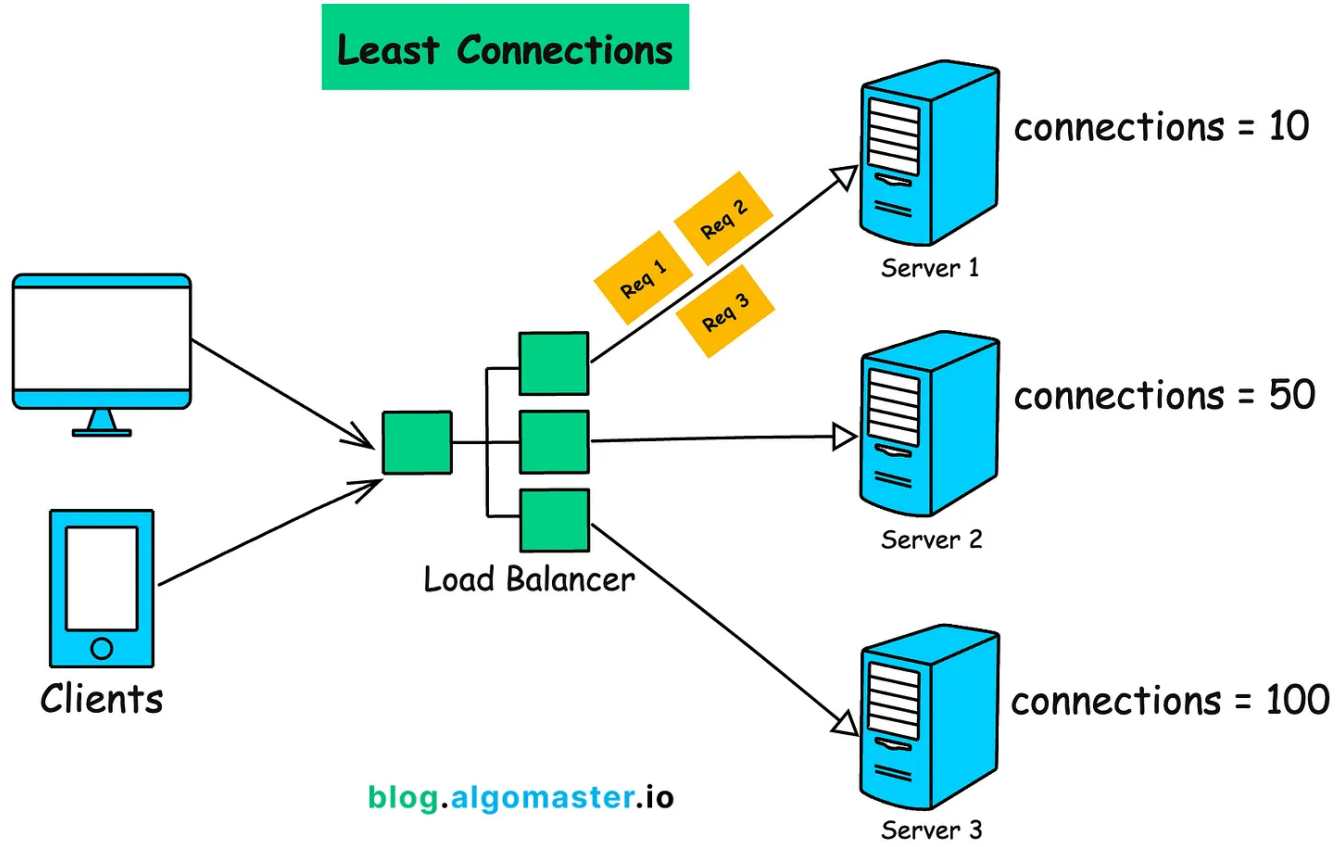
In this implementation, the `WeightedRoundRobin` class takes a list of servers and their corresponding weights.

The `get_next_server()` method runs an infinite loop to find a suitable server based on the weights, ensuring that servers with higher weights receive more requests.

The algorithm keeps track of the current weight and adjusts it in each iteration to maintain the desired distribution ratio.

Example: if the weights are `[5, 1, 1]`, Server 1 will be selected 5 times more often than Server 2 or Server 3.

Algorithm 3: Least Connections



How it Works:

1. Monitor the **number of active connections** on each server.
2. Assigns incoming requests to the server with the least number of active connections.

When to use:

- When you want to distribute the load based on the current number of active connections.
- When servers have similar processing capabilities but may have different levels of concurrent connections.

Benefits:

- Balances load more dynamically based on current server load.
- Helps prevent any server from becoming overloaded with a high number of active connections.

Drawbacks:

- May not be optimal if servers have different processing capabilities.
- Requires tracking active connections for each server.

Implementation:

```python
import random

class LeastConnections:
    def __init__(self, servers):
        self.servers = {server: 0 for server in servers}

    def get_next_server(self):
        # Find the minimum number of connections
        min_connections = min(self.servers.values())
        # Get all servers with the minimum number of connections
        least_loaded_servers = [server for server, connections in self.servers.items() if
connections == min_connections]
        # Select a random server from the least loaded servers
        selected_server = random.choice(least_loaded_servers)
        self.servers[selected_server] += 1
        return selected_server

    def release_connection(self, server):
        if self.servers[server] > 0:
            self.servers[server] -= 1

# Example usage
servers = ["Server1", "Server2", "Server3"]
load_balancer = LeastConnections(servers)

for i in range(6):
    server = load_balancer.get_next_server()
    print(f"Request {i + 1} -> {server}")
    load_balancer.release_connection(server)
```

Code Link

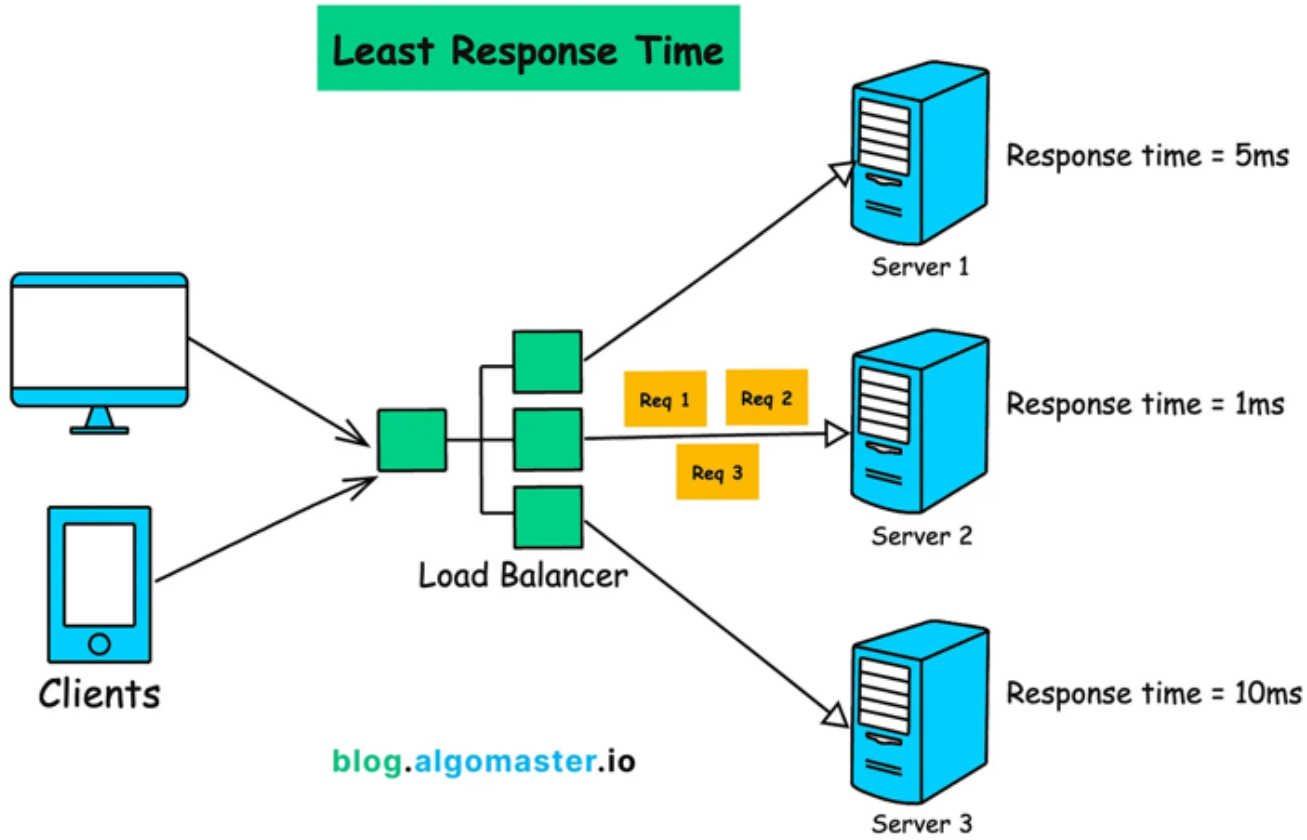
In this example, the `LeastConnections` class maintains a map of servers and the

number of active connections for each server.

The `get_next_server()` method selects a random server with the least number of connections and increments the connection count for that server.

The `release_connection()` method is called when a connection is closed, decrementing the connection count for the corresponding server.

Algorithm 4: Least Response Time



How It Works:

- Monitors the response time of each server
- Assigns incoming requests to the server with the fastest response time.

When to Use:

- When you have servers with varying response times and want to route requests to the fastest server.

Benefits:

- Minimizes overall latency by selecting the server with the fastest response time.
- Can adapt dynamically to changes in server response times.
- Helps improve the user experience by providing quick responses.

Drawbacks:

- Requires accurate measurement of server response times, which can be challenging in distributed systems.
- May not consider other factors such as server load or connection count.

Implementation:

```
import time
import random

class LeastResponseTime:
    def __init__(self, servers):
        self.servers = servers
```

Search

```
        self.response_times = [0] * len(servers)

    def get_next_server(self):
        min_response_time = min(self.response_times)
        min_index = self.response_times.index(min_response_time)
        return self.servers[min_index]

    def update_response_time(self, server, response_time):
        index = self.servers.index(server)
        self.response_times[index] = response_time

# Simulated server response time function
def simulate_response_time():
    # Simulating response time with random delay
    delay = random.uniform(0.1, 1.0)
    time.sleep(delay)
    return delay

# Example usage
servers = ["Server1", "Server2", "Server3"]
load_balancer = LeastResponseTime(servers)

for i in range(6):
    server = load_balancer.get_next_server()
    print(f"Request {i + 1} -> {server}")
    response_time = simulate_response_time()
```

```
load_balancer.update_response_time(server, response_time)
print(f"Response Time: {response_time:.2f}s")
```

[Code Link]

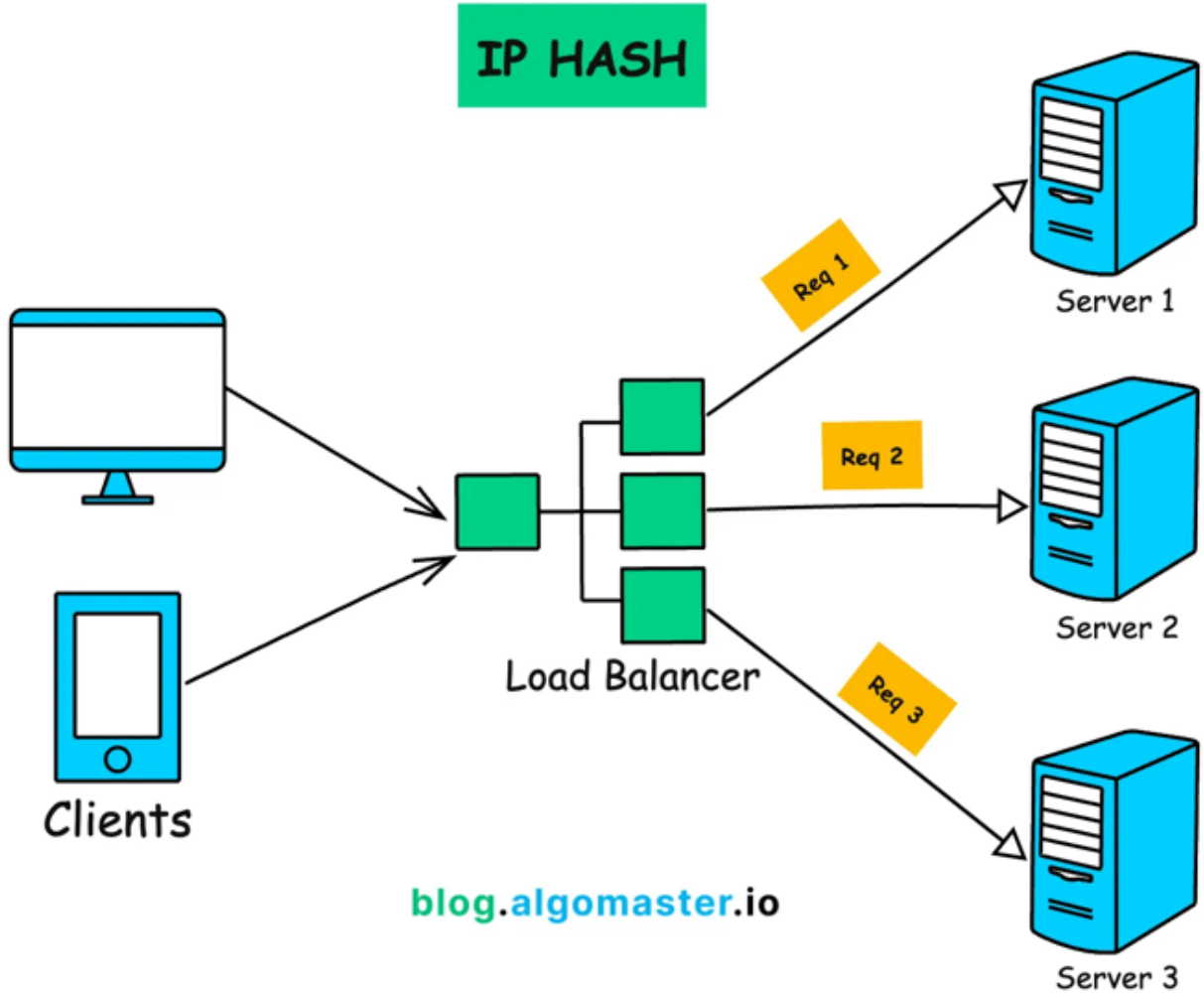
In this example, the `LeastResponseTime` class maintains a list of servers and keeps track of the response time for each server.

The `get_next_server()` method selects the server with the least response time. The `update_response_time()` method is called after each request to update the response time for the corresponding server.

To simulate the response time, we use a `simulate_response_time()` function that introduces a random delay to mimic the server's response time.

In a real-world scenario, you would measure the actual response time of each server.

Algorithm 5: IP Hash



How It Works:

- Calculates a hash value from the client's IP address and uses it to determine the server to route the request.

When to Use:

- When you need session persistence, as requests from the same client are always directed to the same server.

Benefits:

- Simple to implement.
- Useful for applications that require sticky sessions.

Drawbacks:

- Can lead to uneven load distribution if certain IP addresses generate more traffic than others.
- Lacks flexibility if a server goes down, as the hash mapping may need to be reconfigured.

Implementation:

```python
import hashlib

class IPHash():
    def __init__(self, servers):
        self.servers = servers

    def get_next_server(self, client_ip):
        hash_value = hashlib.md5(client_ip.encode()).hexdigest()
        index = int(hash_value, 16) % len(self.servers)
        return self.servers[index]

# Example usage
servers = ["Server1", "Server2", "Server3"]
load_balancer = IPHash(servers)

client_ips = ["192.168.0.1", "192.168.0.2", "192.168.0.3", "192.168.0.4"]
for ip in client_ips:
    server = load_balancer.get_next_server(ip)
    print(f"Client {ip} -> {server}")
```

[Code Link]

In this implementation, the `IPHash` class takes a list of servers.

The `get_next_server()` method calculates the MD5 hash of the client's IP address and uses the modulo operator to determine the index of the server to which the

request should be routed.

This ensures that **requests from the same IP address are always directed to the same server.**

Summary:

- **Round Robin**: Simple and even distribution, best for homogeneous servers.
- **Weighted Round Robin**: Distributes based on server capacity, good for heterogeneous environments.
- **Least Connections**: Dynamically balances based on load, ideal for varying workloads.
- **Least Response Time**: Optimizes for fastest response, best for environments with varying server performance.
- **IP Hash**: Ensures session persistence, useful for stateful applications.

Choosing the right load balancing algorithm depends on the specific needs and characteristics of your system, including server capabilities, workload distribution, and performance requirements.

Thank you for reading!

If you found it valuable, hit a like ❤️ and consider subscribing for more such content every week.

If you have any questions or suggestions, leave a comment.

This post is public so feel free to share it.

P.S. If you're enjoying this newsletter and want to get even more value, consider becoming a paid subscriber.

As a paid subscriber, you'll unlock all **premium articles** and gain full access to all premium courses on algomaster.io.

There are group discounts, gift options, and referral bonuses available.

Checkout my Youtube channel for more in-depth content.

Follow me on LinkedIn, X and Medium to stay updated.

Checkout my [GitHub repositories] for free interview preparation resources.

I hope you have a lovely day!

See you soon,
Ashish

146 Likes • 9 Restacks

← Previous

Next →

Discussion about this post

Comments Restacks

Write a comment...

Mohammed Nooh 9 Jun 2024

Liked by Ashish Pratap Singh

nice article 👍

LIKE (1) REPLY SHARE

civics101 5 Jun 2024

Liked by Ashish Pratap Singh

Thank you for sharing the salient features of each method. I've heard of load balancing being equated with air traffic control so these methods make sense in that respect.

LIKE (1) REPLY SHARE

3 more comments...