## 1. Introduction to Service Discovery

### Definition of Service Discovery

Service discovery refers to the process through which microservices within a distributed system dynamically identify and communicate with each other. Since microservices architectures often involve multiple instances of services, distributed across various nodes, these services need a reliable way to locate one another without hardcoding network addresses. Service discovery solves this problem by providing a registry where services register themselves and discover other services.

### Importance of Service Discovery in Microservices

In a microservices architecture, services are often dynamic, scaling up or down based on load, or moving across environments like containers or cloud instances. Manually managing the location and health of services becomes difficult and prone to errors. Service discovery automates this process, ensuring that:

- Services can be dynamically located.
- Services can scale horizontally without issues.
- Load balancers and service consumers know which instances are healthy and available.

This ensures resilience, scalability, and ease of maintenance in the microservices architecture.

### Differences Between Client-Side and Server-Side Discovery

- **Client-Side Discovery**: In client-side discovery, the client is responsible for determining the location of service instances. The client queries the service registry, retrieves the list of available services, and applies load balancing before making a request to the selected instance. Examples include tools like Netflix Ribbon and Spring Cloud LoadBalancer.
- **Server-Side Discovery**: In server-side discovery, the client sends a request to a load balancer or API Gateway. The server then queries the service registry, chooses an available service instance, and forwards the client's request. Tools like AWS Elastic Load Balancer (ELB) or API Gateway typically handle server-side discovery.

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## 2. Eureka Overview

### What is Eureka?

Eureka is a service registry developed by Netflix as part of their open-source project, Netflix OSS. It acts as a **registry** where microservices can register themselves and discover other services. It's particularly popular in Spring Cloud microservices environments due to its integration with Spring Boot.

**Purpose of Eureka in Microservices Architecture**

In microservices, the Eureka server acts as a **centralized service discovery system**. It registers all the microservices and keeps track of their availability, health, and metadata. By using Eureka, services can:

- Register themselves when they start up.
- Continuously send heartbeats to indicate that they're still active.
- Discover other services without hardcoding their addresses.

**Key Features of Eureka**

- **Registry**: A central directory where services register themselves and are discoverable by other services.
- **Health Checks**: Services send periodic heartbeats to indicate their availability. If a service fails to send heartbeats, it's considered down, and Eureka deregisters it.
- **Instance Metadata**: Eureka stores additional metadata like instance IDs, ports, IP addresses, and other useful information about each registered instance.
- **Self-Preservation Mode**: To maintain resilience in case of network issues, Eureka switches to a self-preservation mode that prevents aggressive deregistration of instances when the server doesn't receive timely heartbeats.

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**Demonstration of Eureka Dashboard**:

- Once the Eureka Server is up and running, you can navigate to http://localhost:8761 to access the Eureka dashboard. The dashboard displays registered services, their status, and metadata.

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**Dependencies Required (Spring Cloud Dependencies)**:

- Both the Eureka Server and Client require Spring Cloud Netflix dependencies. These dependencies integrate the Netflix OSS libraries, allowing the Eureka client and server to interact smoothly.

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**Common Configuration Properties:**

1. **eureka.client.register-with-eureka**:

    - This property specifies whether the application should register itself with the Eureka server.
    - For Eureka Server itself, this is typically set to false to avoid self-registration.
2. **eureka.client.fetch-registry**:
    - Determines whether the application should fetch the registry from Eureka. This is useful for clients, but the server should not fetch the registry from itself, hence set to false in the Eureka server configuration.
3. **eureka.instance.lease-renewal-interval-in-seconds**:
    - This controls the interval (in seconds) at which the client will send heartbeats to the Eureka server to renew its lease. If the Eureka server does not receive a heartbeat within the leaseExpirationDurationInSeconds period, it marks the instance as unavailable.

**4. Practical Demonstration of Registration and Discovery Process**

**Service Registration**

- **How a Microservice Registers with Eureka Server**: Each microservice that starts up automatically registers with the Eureka server by sending a registration request, along with metadata such as instance ID, IP address, port, and health check information.
- **Visual Demo of Services Appearing in the Eureka Dashboard**: Once a service is registered, you can navigate to the Eureka dashboard (http://localhost:8761) and observe the newly registered service in the list of instances. Each instance shows detailed metadata, health status, and instance ID.

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**Service Discovery**

- **How Services Discover Each Other via Eureka**: When a service needs to communicate with another, it sends a request to Eureka to get the address of the target service. Eureka responds with the list of available service instances. This eliminates the need for hardcoded URLs.
- **Usage of Ribbon/Feign for Service Discovery and Load Balancing**:
    - **Ribbon**: Client-side load balancing tool that works with Eureka to automatically distribute requests across multiple instances of a service.
    - **Feign**: A declarative REST client that integrates with Eureka and Ribbon to simplify HTTP calls between services. It abstracts away the manual process of discovery and load balancing.

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**Monitoring Eureka Dashboard**

- **Walkthrough of Eureka Server Dashboard**: The dashboard provides an overview of all registered services, their status (UP/DOWN), and metadata such as instance count, health status, and lease expiration.
- **Service Instance Visibility**: Each microservice instance appears in the dashboard with its unique ID and status. You can monitor real-time changes when instances go up or down.

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**5. Handling Service Instance Changes**

**Service Instance Registration**

- **How Eureka Handles Registration of Multiple Instances**: When multiple instances of the same service are deployed (due to auto-scaling or manual scaling), each instance registers itself with the Eureka server. Eureka maintains all instances in its registry and distributes traffic across them using load balancing.
- **Auto-scaling and Its Effect on Service Registration**: As new instances are scaled up, they automatically register with Eureka, and the registry is updated dynamically. This allows for seamless scaling without reconfiguring services manually.

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**Health Checks and Instance Monitoring**

- **Eureka's Heartbeat Mechanism**: Eureka relies on a heartbeat mechanism where each service instance periodically sends a heartbeat to the Eureka server. If a heartbeat is not received within the configured lease time, Eureka marks the service as DOWN.
- **How Eureka Performs Health Checks and Detects Unhealthy Services**: In addition to heartbeats, Eureka can be configured to perform health checks using HTTP endpoints provided by the services. If a service fails the health check, it is marked as DOWN.

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**Handling Service Failures**

- **Demonstration of What Happens When a Service Instance Fails**: When an instance fails to send heartbeats or fails a health check, Eureka deregisters the service after a configurable number of missed heartbeats. The service is marked as DOWN in the registry.

- **How Eureka Deregisters a Service After a Failure**: After repeated heartbeat failures, Eureka removes the instance from its registry and updates the dashboard accordingly. Other services will no longer discover the failed instance during service discovery.

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**Service Recovery**

- **Eureka's Behavior During Service Instance Recovery**: When a failed service instance recovers and begins sending heartbeats again, Eureka re-registers the instance. The Eureka dashboard reflects the updated status, and other services can once again discover the instance.
- **How Eureka Handles Retries and Reconnections**: Eureka continuously retries connections to failed instances. Once an instance recovers, Eureka automatically re-adds it to the registry without manual intervention.

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**6. Behavior During Scaling and Failover**

**Scaling Up/Down**

- **Impact of Scaling on Eureka's Registry**: When services scale up, new instances are automatically registered with Eureka, and when they scale down, Eureka deregisters the terminated instances. The registry always reflects the current state of available service instances.
- **Eureka's Ability to Handle Dynamic Service Instances**: Eureka is designed to handle dynamic microservices environments, where instances are constantly being added or removed. Its registry and load balancers adjust in real-time to reflect these changes.

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**Failover and Redundancy**

- **How Eureka Manages Failover When Instances Become Unavailable**: Eureka provides automatic failover management by monitoring the health of instances. If an instance becomes unavailable, Eureka reroutes traffic to other healthy instances.
- **Handling of Replication Across Multiple Eureka Servers**: In production environments, multiple Eureka servers can be set up for redundancy. When an instance registers with one server, the registration information is replicated across all Eureka servers, ensuring high availability and fault tolerance. This allows the system to remain operational even if one Eureka server fails.