

# Service Discovery

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## Session Overview

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DURATION	LEVEL	PREREQUISITES
60 min	Intermediate	Basic microservices concepts, networking fundamentals

## Learning Objectives

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By the end of this session, you will be able to: - Understand the need for service discovery in distributed systems - Compare client-side vs server-side discovery patterns - Evaluate different service registry technologies (Consul, etcd, ZooKeeper) - Implement health checking and failure detection - Design DNS-based service discovery solutions

## Agenda

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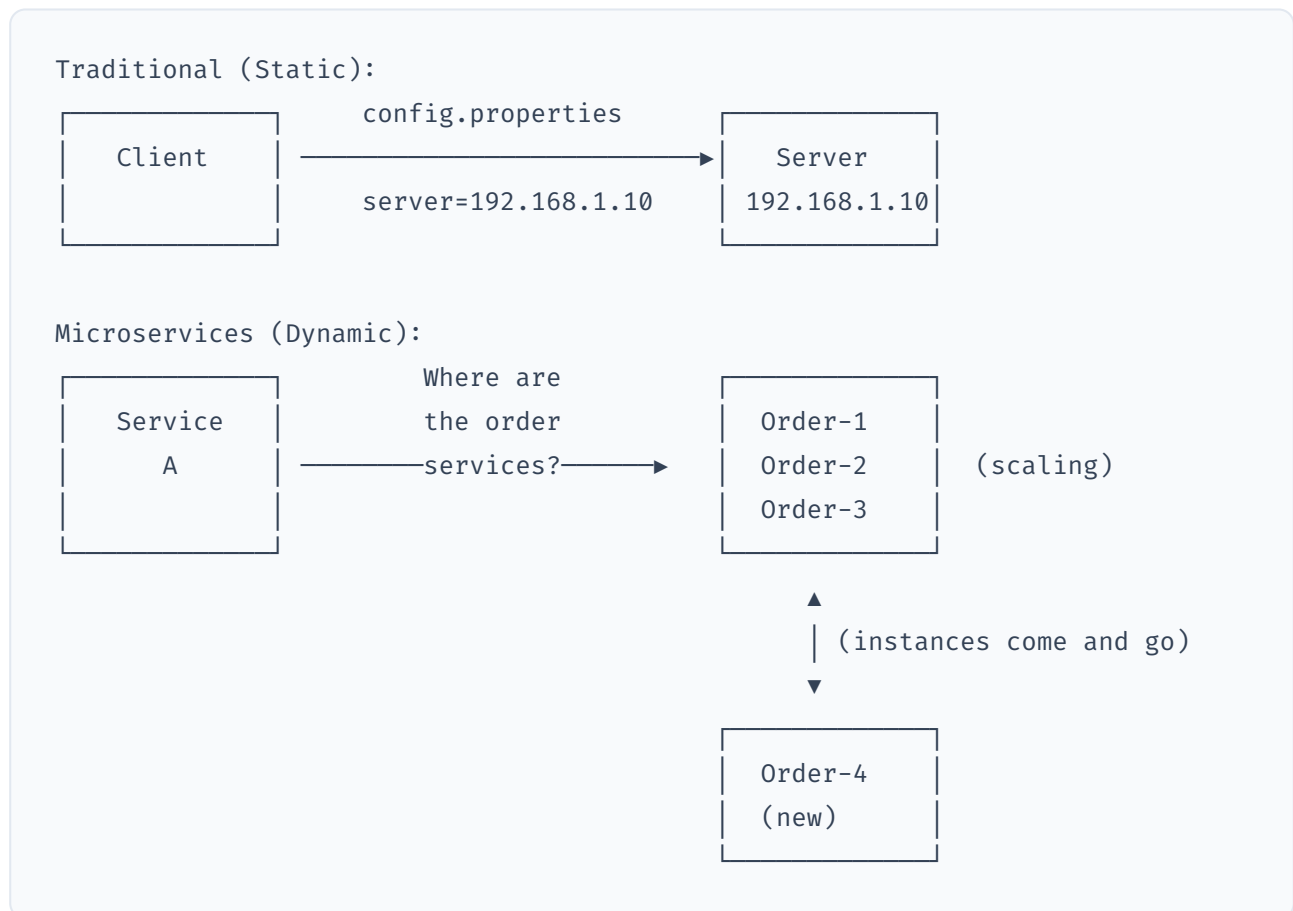
TIME	TOPIC
0-10 min	Why Service Discovery?
10-25 min	Discovery Patterns
25-40 min	Service Registry Technologies
40-50 min	Health Checking & DNS-Based Discovery
50-60 min	Practical Exercise & Q&A

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# 1. Why Service Discovery?

## The Problem

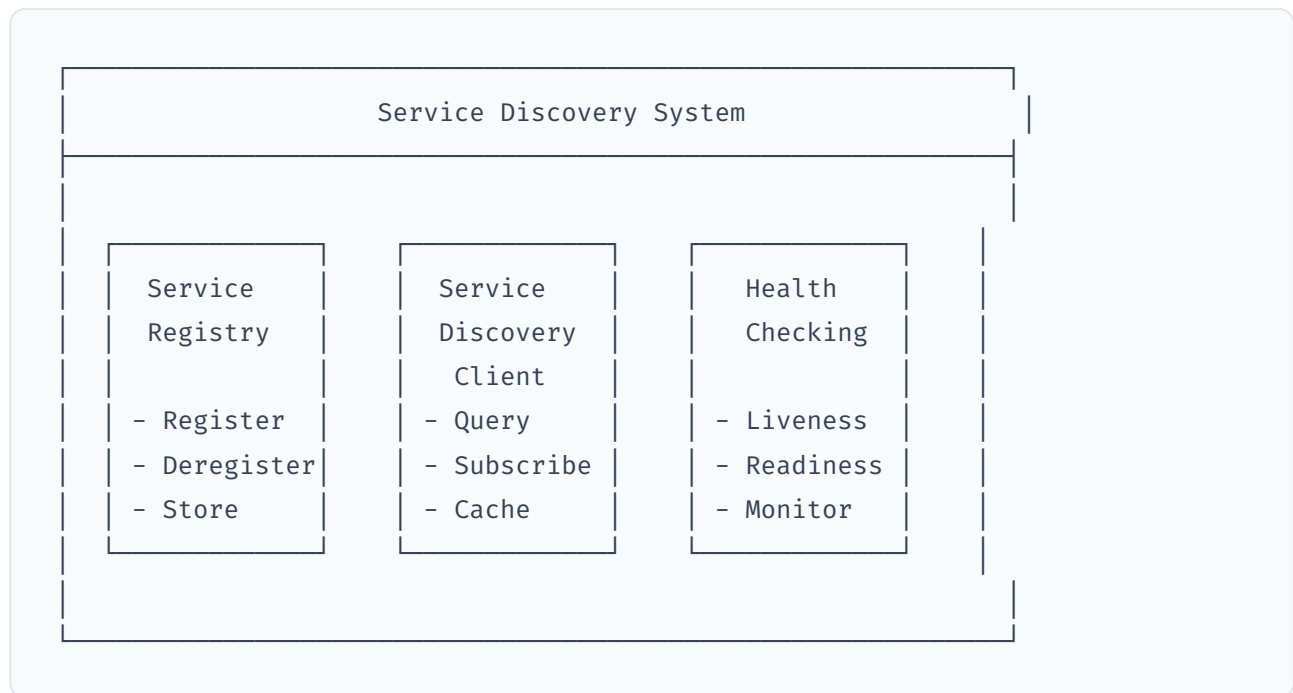
In traditional monolithic applications, service locations are typically static and configured at deployment time. In microservices architectures, this approach breaks down:



## Challenges in Dynamic Environments

1. **Auto-scaling:** Instances are added/removed based on load
2. **Failures:** Instances crash and restart on different hosts
3. **Deployments:** Rolling updates change instance locations
4. **Containerization:** Containers get dynamic IPs

## Service Discovery Components

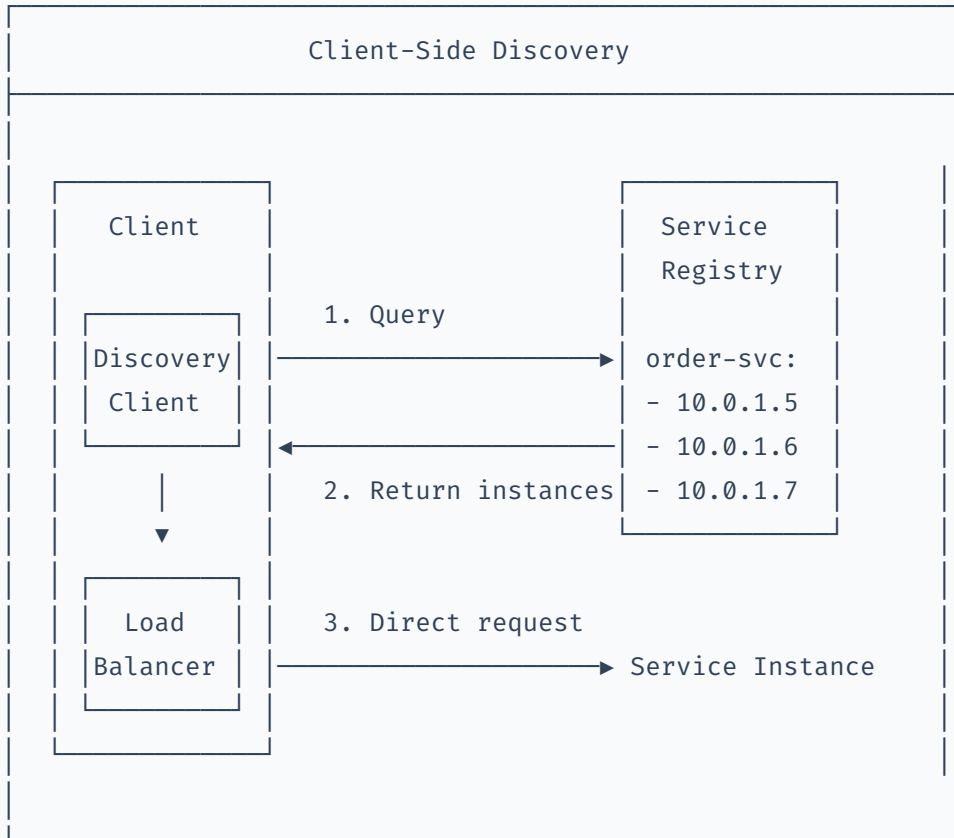


## 2. Discovery Patterns

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### Client-Side Discovery

The client is responsible for determining the network locations of available service instances and load balancing requests across them.



**Implementation Example (Java with Netflix Eureka):**

```

@Configuration
@EnableDiscoveryClient
public class ServiceDiscoveryConfig {

    @Bean
    @LoadBalanced
    public RestTemplate restTemplate() {
        return new RestTemplate();
    }
}

@Service
public class OrderServiceClient {

    @Autowired
    private RestTemplate restTemplate;

    @Autowired
    private DiscoveryClient discoveryClient;

    // Using service name instead of hardcoded URL
    public Order getOrder(String orderId) {
        return restTemplate.getForObject(
            "http://order-service/orders/" + orderId,
            Order.class
        );
    }

    // Manual discovery for more control
    public List<ServiceInstance> getOrderServiceInstances() {
        return discoveryClient.getInstances("order-service");
    }
}

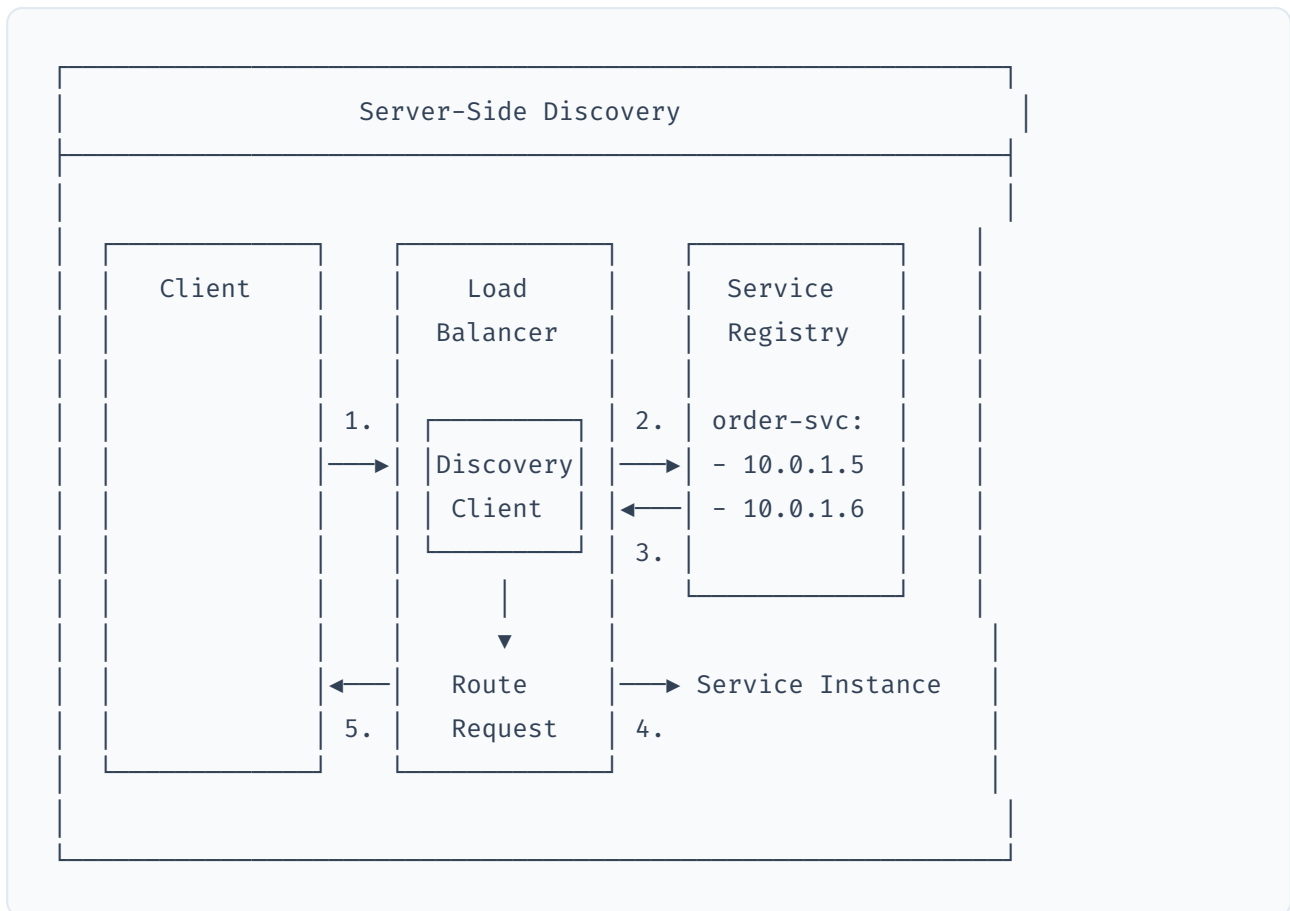
```

**Pros:** - Client has full control over load balancing strategy - No single point of failure in the load balancer - Can implement sophisticated routing (e.g., zone-aware)

**Cons:** - Discovery logic coupled with client code - Must implement for each programming language - Clients must handle registry unavailability

## Server-Side Discovery

A load balancer or router handles service discovery, and clients make requests to the load balancer.



**Implementation Example (Kubernetes Service):**

```

# Kubernetes Service acts as server-side discovery
apiVersion: v1
kind: Service
metadata:
  name: order-service
spec:
  selector:
    app: order
  ports:
    - protocol: TCP
      port: 80
      targetPort: 8080
  type: ClusterIP

—

# Client just uses the service name
apiVersion: apps/v1
kind: Deployment
metadata:
  name: api-gateway
spec:
  template:
    spec:
      containers:
        - name: gateway
          env:
            - name: ORDER_SERVICE_URL
              value: "http://order-service" # DNS resolves to service

```

**Pros:** - Simpler client implementation - Language-agnostic - Centralized load balancing policies

**Cons:** - Load balancer can become a bottleneck - Additional network hop - Must ensure load balancer high availability

## Pattern Comparison

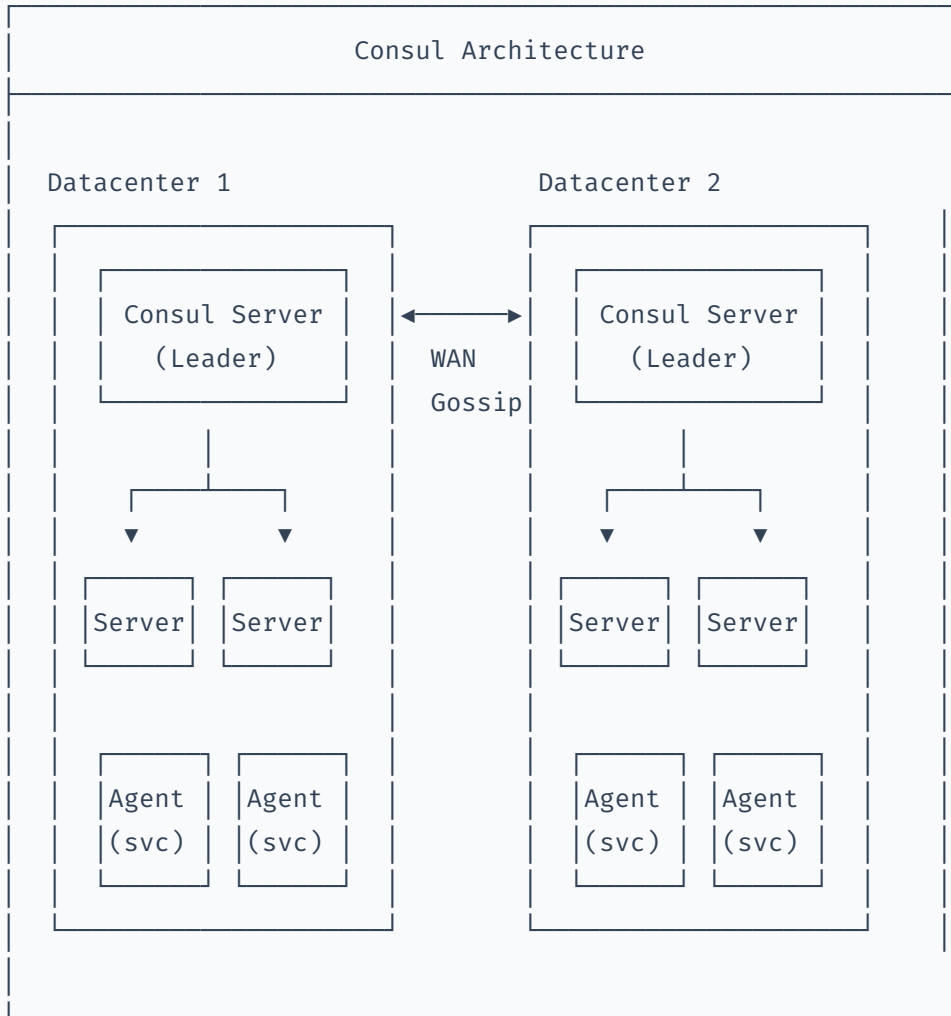
ASPECT	CLIENT-SIDE	SERVER-SIDE
Client Complexity	High	Low
Network Hops	Fewer	More
Load Balancer	Distributed	Centralized
Language Support	Per-language	Universal
Flexibility	High	Medium
Examples	Netflix Ribbon, gRPC	Kubernetes, AWS ALB

## 3. Service Registry Technologies

### Consul

HashiCorp Consul provides service discovery with built-in health checking, KV store, and multi-datacenter support.





### Service Registration:

```
// service.json
{
  "service": {
    "name": "order-service",
    "id": "order-service-1",
    "port": 8080,
    "tags": ["v1", "primary"],
    "check": {
      "http": "http://localhost:8080/health",
      "interval": "10s",
      "timeout": "5s"
    }
  }
}
```

```
# Register service
consul services register service.json

# Query service
consul catalog services
consul catalog nodes -service=order-service

# DNS query
dig @127.0.0.1 -p 8600 order-service.service.consul
```

## Go Client Example:

```

package main

import (
    "fmt"
    "github.com/hashicorp/consul/api"
)

func main() {
    // Create client
    config := api.DefaultConfig()
    client, _ := api.NewClient(config)

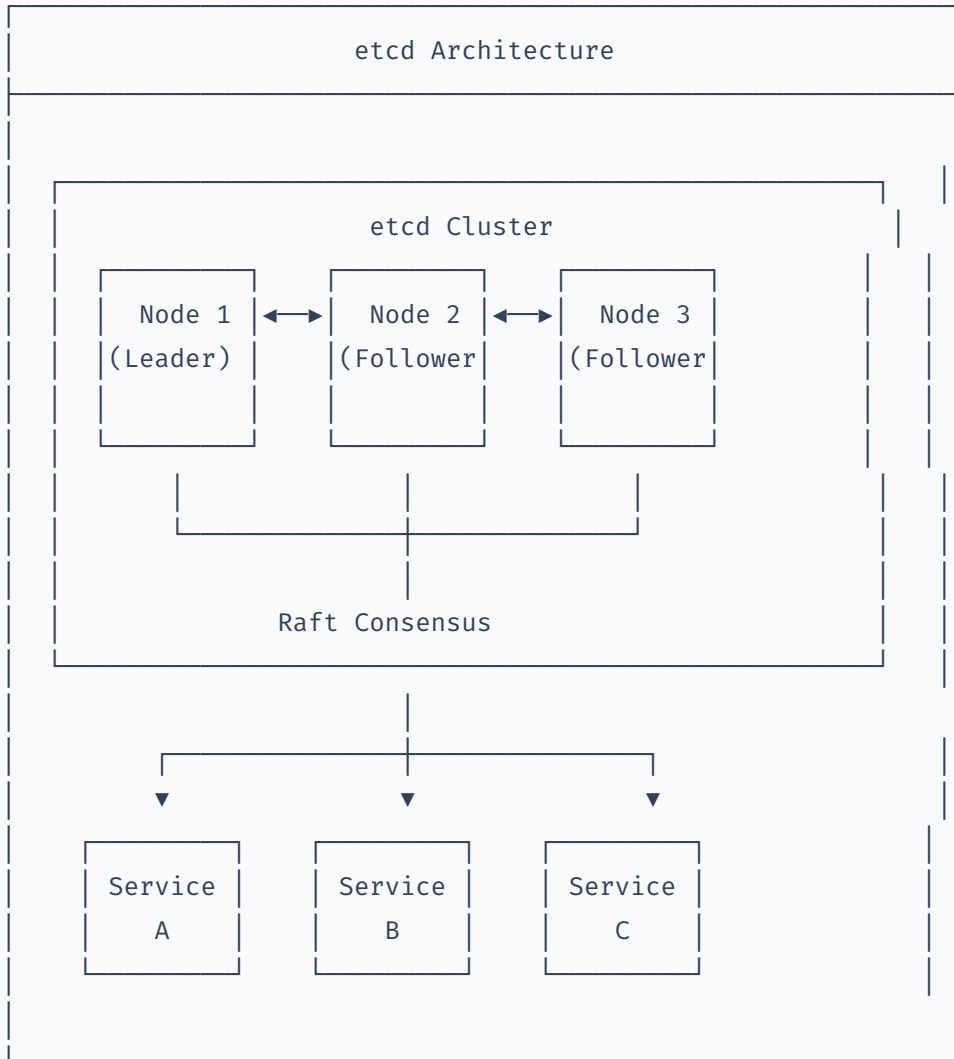
    // Register service
    registration := &api.AgentServiceRegistration{
        ID:      "order-service-1",
        Name:    "order-service",
        Port:    8080,
        Check: &api.AgentServiceCheck{
            HTTP:    "http://localhost:8080/health",
            Interval: "10s",
        },
    }
    client.Agent().ServiceRegister(registration)

    // Discover services
    services, _, _ := client.Health().Service("order-service", "", true, nil)
    for _, svc := range services {
        fmt.Printf("Found: %s:%d\n", svc.Service.Address, svc.Service.Port)
    }
}

```

## etcd

etcd is a distributed key-value store that provides a reliable way to store data across a cluster. It's the backbone of Kubernetes service discovery.



### Service Registration with etcd:

```

import etcd3
import json
import time
from threading import Thread

class ServiceRegistry:
    def __init__(self, etcd_host='localhost', etcd_port=2379):
        self.client = etcd3.client(host=etcd_host, port=etcd_port)
        self.lease = None

    def register(self, service_name, instance_id, host, port, ttl=30):
        """Register service with TTL-based lease"""
        key = f"/services/{service_name}/{instance_id}"
        value = json.dumps({
            "host": host,
            "port": port,
            "registered_at": time.time()
        })

        # Create lease for automatic deregistration
        self.lease = self.client.lease(ttl)
        self.client.put(key, value, lease=self.lease)

        # Start heartbeat thread
        Thread(target=self._heartbeat, daemon=True).start()

    def _heartbeat(self):
        """Keep lease alive"""
        while True:
            self.lease.refresh()
            time.sleep(10)

    def discover(self, service_name):
        """Get all instances of a service"""
        prefix = f"/services/{service_name}/"
        instances = []

        for value, metadata in self.client.get_prefix(prefix):
            instances.append(json.loads(value))

        return instances

```

```
def watch(self, service_name, callback):
    """Watch for service changes"""
    prefix = f"/services/{service_name}/"
    events_iterator, cancel = self.client.watch_prefix(prefix)

    for event in events_iterator:
        callback(event)

# Usage
registry = ServiceRegistry()
registry.register("order-service", "instance-1", "10.0.1.5", 8080)
instances = registry.discover("order-service")
```

## ZooKeeper

Apache ZooKeeper provides distributed coordination and is used by many systems for service discovery.

### ZooKeeper Data Model

```
/
├── /services
│   ├── /order-service
│   │   ├── /instance-001 (ephemeral)
│   │   │   └── {"host":"10.0.1.5","port":8080}
│   │   ├── /instance-002 (ephemeral)
│   │   │   └── {"host":"10.0.1.6","port":8080}
│   │   └── /instance-003 (ephemeral)
│   │       └── {"host":"10.0.1.7","port":8080}
│   └── /user-service
│       ├── /instance-001 (ephemeral)
│       └── /instance-002 (ephemeral)
└── /config
    └── /database
        └── {"url":"jdbc:mysql:// ... "}
```

Note: Ephemeral nodes are automatically deleted  
when the session ends (service crashes)

### Java Implementation with Curator:

```

import org.apache.curator.framework.CuratorFramework;
import org.apache.curator.framework.CuratorFrameworkFactory;
import org.apache.curator.retry.ExponentialBackoffRetry;
import org.apache.curator.x.discovery.*;

public class ZookeeperServiceDiscovery {

    private final ServiceDiscovery<ServiceInstance> serviceDiscovery;
    private final CuratorFramework client;

    public ZookeeperServiceDiscovery(String zkConnection) throws Exception {
        client = CuratorFrameworkFactory.newClient(
            zkConnection,
            new ExponentialBackoffRetry(1000, 3)
        );
        client.start();

        serviceDiscovery =
ServiceDiscoveryBuilder.builder(ServiceInstance.class)
            .client(client)
            .basePath("/services")
            .build();
        serviceDiscovery.start();
    }

    public void register(String serviceName, String host, int port) throws
Exception {
        ServiceInstance<ServiceInstance> instance =
ServiceInstance.<ServiceInstance>builder()
            .name(serviceName)
            .address(host)
            .port(port)
            .build();

        serviceDiscovery.registerService(instance);
    }

    public Collection<ServiceInstance<ServiceInstance>> discover(String
serviceName)

        throws Exception {
        return serviceDiscovery.queryForInstances(serviceName);
    }
}

```



```

        // Watch for changes
        public void watchService(String serviceName, ServiceCacheListener
listener)

            throws Exception {
                ServiceCache<ServiceInstance> cache = serviceDiscovery
                    .serviceCacheBuilder()
                    .name(serviceName)
                    .build();

                cache.addListener(listener);
                cache.start();
            }
    }

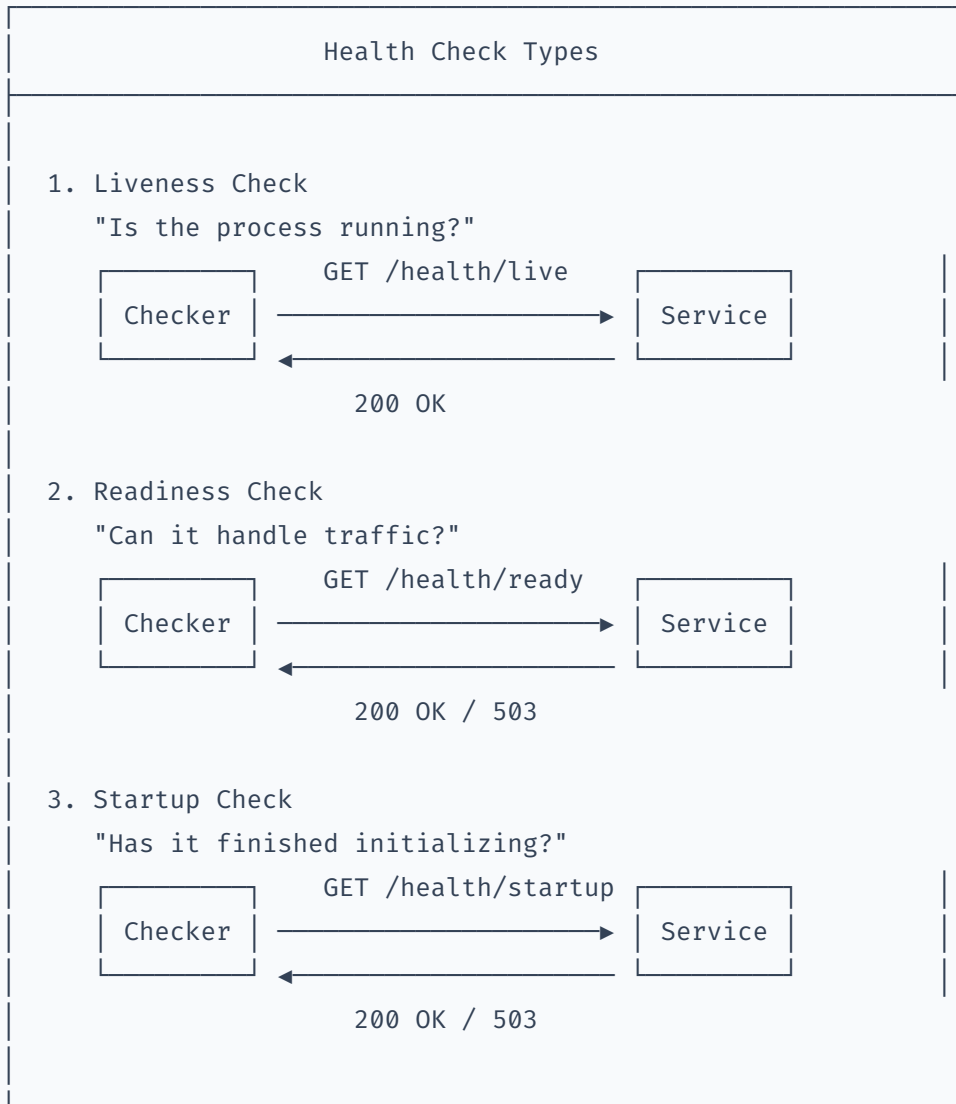
```

## Technology Comparison

FEATURE	CONSUL	ETCD	ZOOKEEPER
Consensus	Raft	Raft	ZAB
Health Checking	Built-in	External	External
Multi-DC	Native	Manual	Manual
DNS Interface	Yes	No	No
KV Store	Yes	Yes	Yes
ACL	Yes	Yes	Yes
Language	Go	Go	Java
Kubernetes	Supported	Native	Supported

## 4. Health Checking & DNS-Based Discovery

### Health Check Types



### Health Check Implementation:

```

@RestController
@RequestMapping("/health")
public class HealthController {

    @Autowired
    private DataSource dataSource;

    @Autowired
    private RedisTemplate<String, String> redisTemplate;

    @GetMapping("/live")
    public ResponseEntity<Map<String, String>> liveness() {
        // Simple check - is the process running?
        return ResponseEntity.ok(Map.of("status", "UP"));
    }

    @GetMapping("/ready")
    public ResponseEntity<Map<String, Object>> readiness() {
        Map<String, Object> health = new HashMap<>();
        boolean ready = true;

        // Check database
        try {
            dataSource.getConnection().isValid(5);
            health.put("database", "UP");
        } catch (Exception e) {
            health.put("database", "DOWN");
            ready = false;
        }

        // Check Redis
        try {
            redisTemplate.getConnectionFactory().getConnection().ping();
            health.put("redis", "UP");
        } catch (Exception e) {
            health.put("redis", "DOWN");
            ready = false;
        }

        health.put("status", ready ? "UP" : "DOWN");

        return ready

```

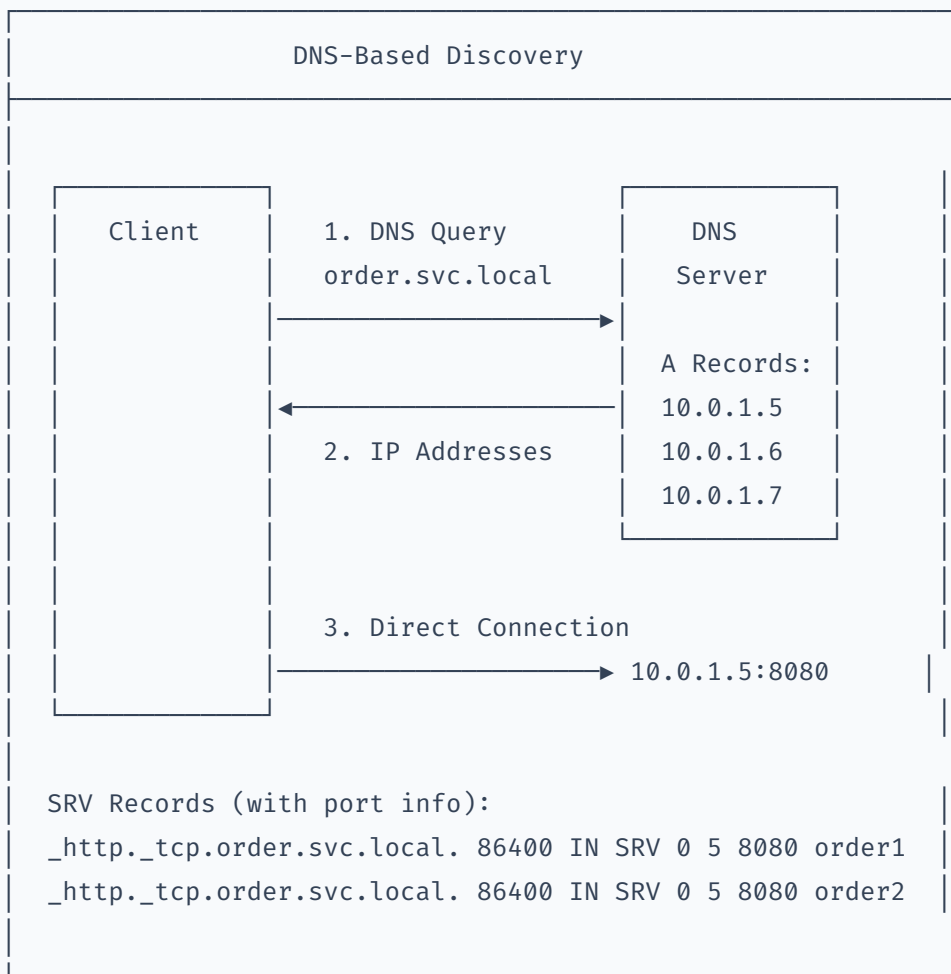
```

        ? ResponseEntity.ok(health)
        : ResponseEntity.status(503).body(health);
    }
}

```

## DNS-Based Service Discovery

DNS-based discovery uses standard DNS protocols to resolve service names to IP addresses.



### Kubernetes DNS Discovery:

```
# Service creates DNS entries automatically
apiVersion: v1
kind: Service
metadata:
  name: order-service
  namespace: production
spec:
  selector:
    app: order
  ports:
    - port: 80
      targetPort: 8080

# DNS names created:
# - order-service.production.svc.cluster.local (full)
# - order-service.production (within cluster)
# - order-service (within same namespace)
```

```

// Go client using DNS
package main

import (
    "net"
    "net/http"
)

func main() {
    // Simple DNS resolution
    ips, _ := net.LookupHost("order-service.production.svc.cluster.local")

    // SRV record lookup for port info
    _, addrs, _ := net.LookupSRV("http", "tcp", "order-
service.production.svc.cluster.local")

    for _, addr := range addrs {
        fmt.Printf("Target: %s, Port: %d\n", addr.Target, addr.Port)
    }

    // HTTP client with DNS
    client := &http.Client{}
    resp, _ := client.Get("http://order-service/api/orders")
}

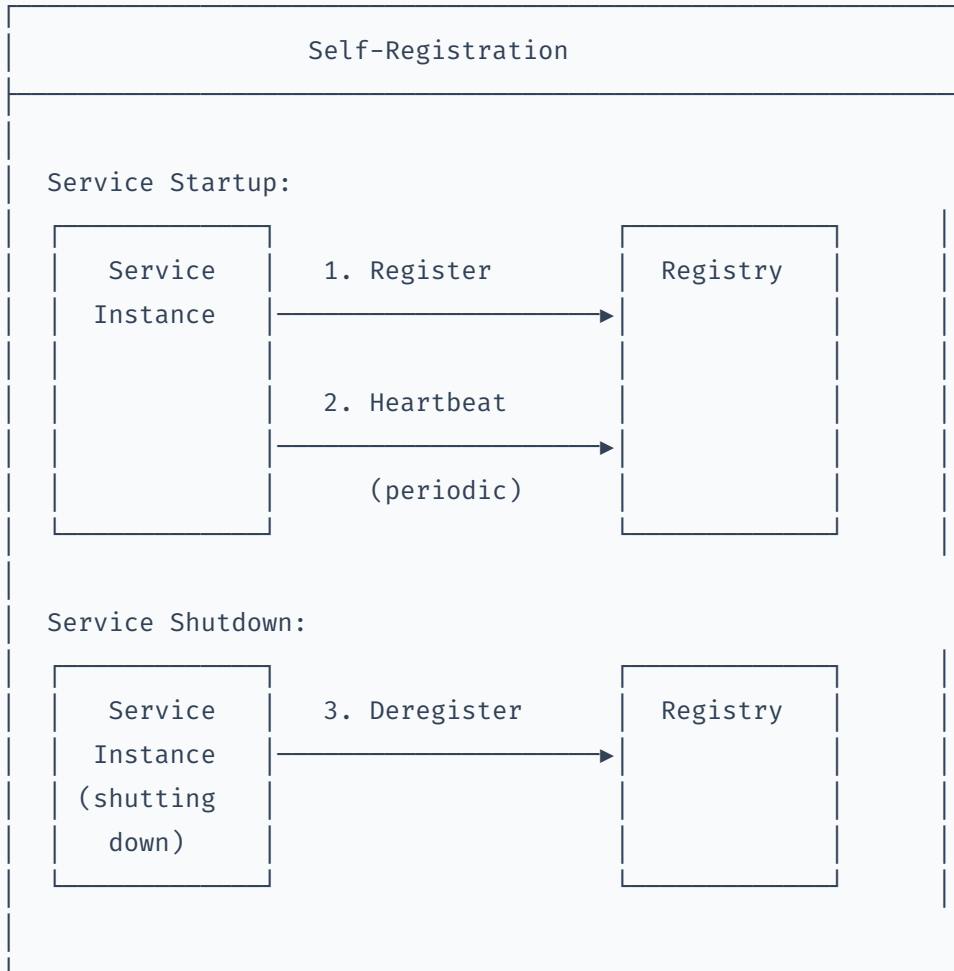
```

## 5. Implementation Patterns

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### Self-Registration Pattern

Services register themselves with the registry on startup.



```

@Component
public class ServiceRegistration implements
ApplicationListener<ApplicationReadyEvent> {

    @Autowired
    private ConsulClient consulClient;

    @Value("${spring.application.name}")
    private String serviceName;

    @Value("${server.port}")
    private int port;

    private String instanceId;

    @Override
    public void onApplicationEvent(ApplicationReadyEvent event) {
        instanceId = serviceName + "-" + UUID.randomUUID().toString();

        NewService service = new NewService();
        service.setId(instanceId);
        service.setName(serviceName);
        service.setPort(port);
        service.setCheck(createHealthCheck());

        consulClient.agentServiceRegister(service);
    }

    @PreDestroy
    public void deregister() {
        consulClient.agentServiceDeregister(instanceId);
    }

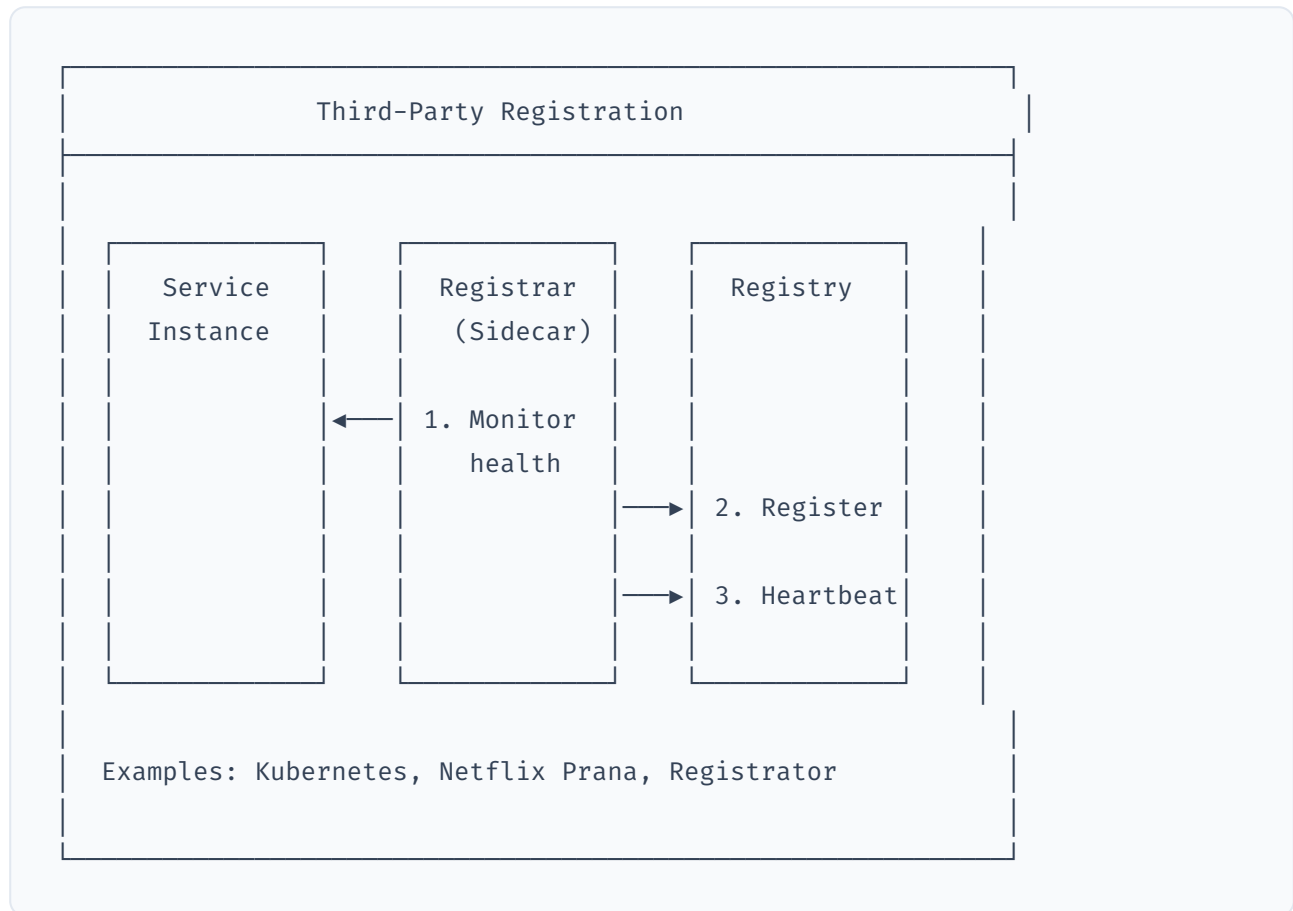
    private NewService.Check createHealthCheck() {
        NewService.Check check = new NewService.Check();
        check.setHttp("http://localhost:" + port + "/health");
        check.setInterval("10s");
        return check;
    }
}

```



## Third-Party Registration Pattern

A separate registrar service handles registration on behalf of services.



## Key Takeaways

1. **Service discovery is essential** for dynamic microservices environments where instances come and go
2. **Two main patterns:** Client-side (more control, more complexity) vs Server-side (simpler clients, centralized)
3. **Choose the right registry:** Consul for multi-DC, etcd for Kubernetes, ZooKeeper for existing Hadoop ecosystems
4. **Health checking is critical:** Implement liveness, readiness, and startup probes appropriately

5. **DNS-based discovery** provides simplicity and language-agnostic access but has caching challenges
  6. **Consider failure modes:** What happens when the registry is unavailable? Cache locally and fail gracefully
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## Practical Exercise

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### Design Challenge: Multi-Region Service Discovery

Design a service discovery solution for a global e-commerce platform with the following requirements:

1. **Services deployed across 3 regions:** US-East, EU-West, Asia-Pacific
2. **Latency-sensitive routing:** Prefer local region, fallback to others
3. **Graceful degradation:** Continue operating if one region's registry fails
4. **Health-aware routing:** Only route to healthy instances

**Consider:** - Which discovery pattern (client-side vs server-side)? - Which registry technology? - How to handle cross-region discovery? - Caching strategy for registry data? - Failover behavior?

**Deliverables:** 1. Architecture diagram showing discovery flow 2. Sequence diagram for service registration 3. Failure scenario analysis

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## Q&A

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Common questions to explore: - How does Kubernetes handle service discovery internally? - What's the difference between service mesh discovery and traditional discovery? - How do you migrate from static configuration to dynamic discovery? - What are the security considerations for service registries?