# Remote Procedure Call

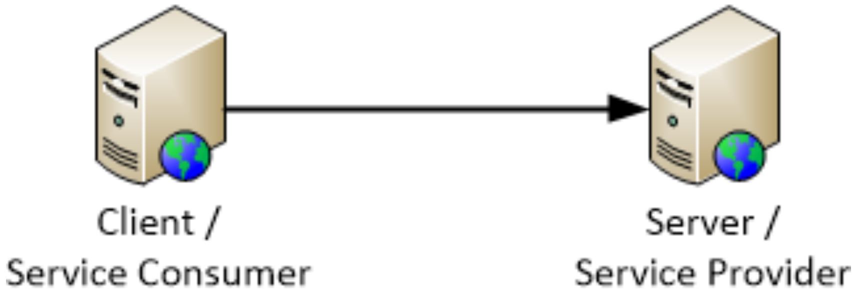
# Agenda

- The need of communication
- Message transport and format
- Synchronous and asynchronous communication patterns
- Traditional load balancers
- Service Registry and Discovery
- Service meshes
- Idempotent service design

# Communication in Distributed System

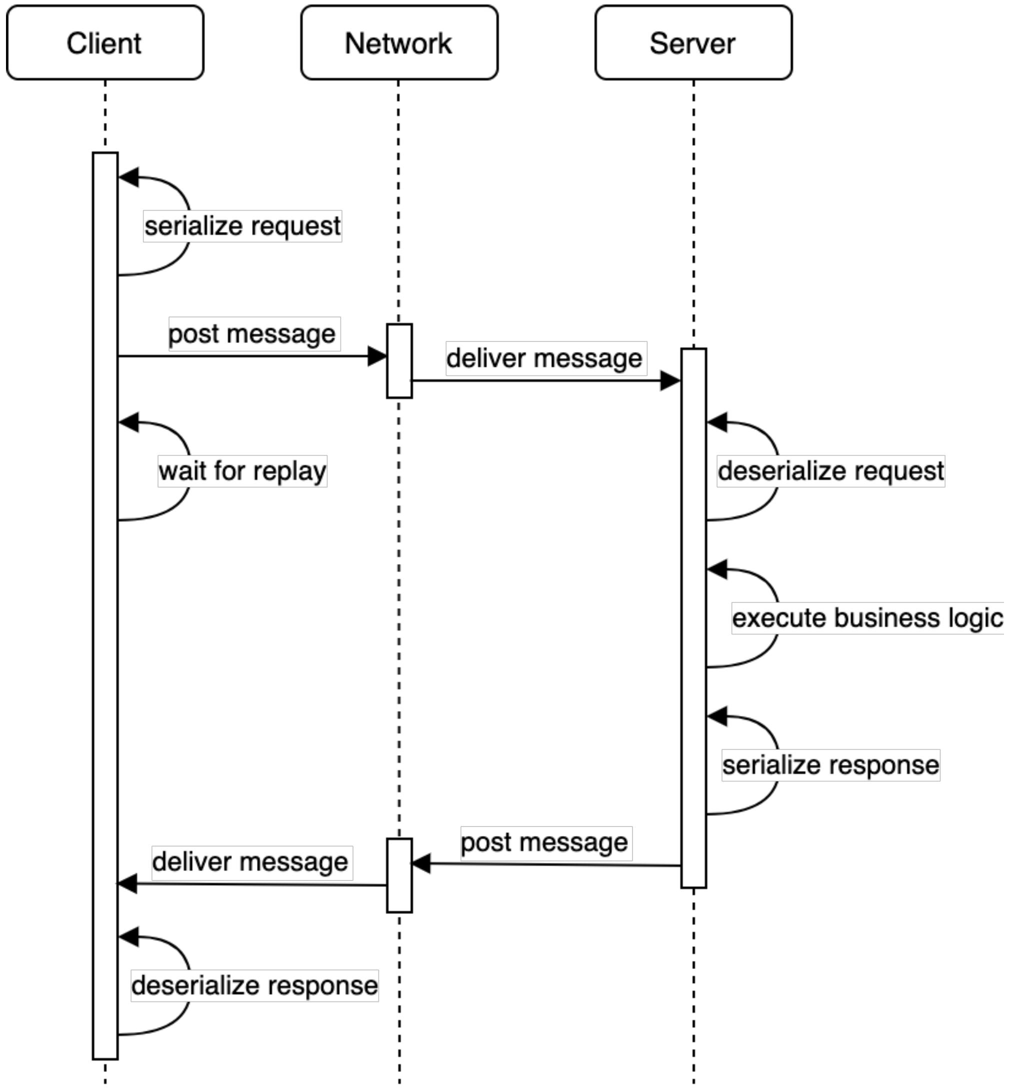
## Definition

Distributed system is a computing environment, where multiple processes running on different machines, communicate through the network and coordinate actions in order to appear to the end-user as a single coherent system.



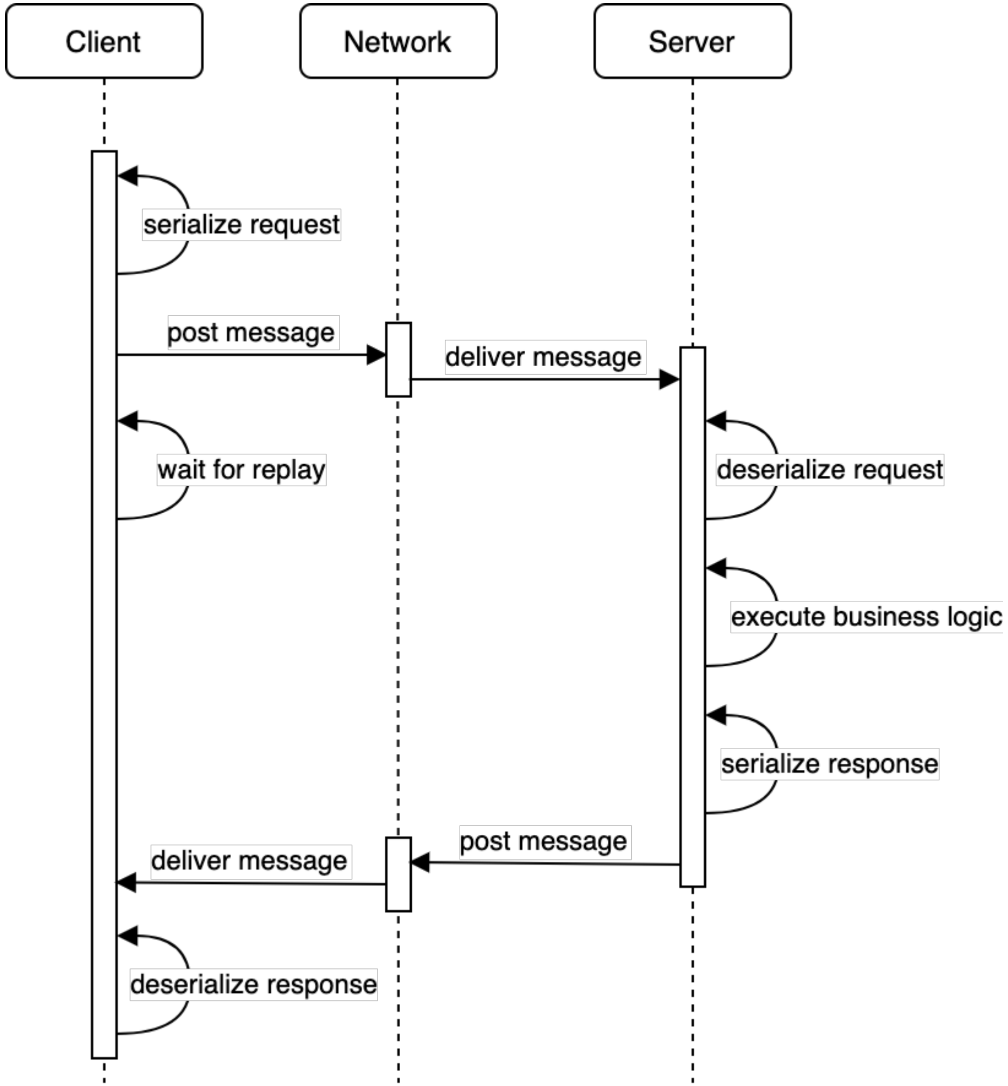
```
sayHello("Lukasz");

private String sayHello(String name) {
    return String.format(
        "Greetings %s!", name
    );
}
```

# Steps in RPC


Client
Network
Server
serialize request
post message
deliver message
wait for replay
deserialize request
execute business logic
serialize response
post message
deliver message
deserialize response

# Faults in RPC

- What are the consequences of?
  - Client fails to serialize request or send message to the network
  - Server fails to deserialize request e.g., invalid format of the message
  - Server raises error during execution of business logic
  - Network fails to deliver reply to the client or server takes too long to respond (timeout)



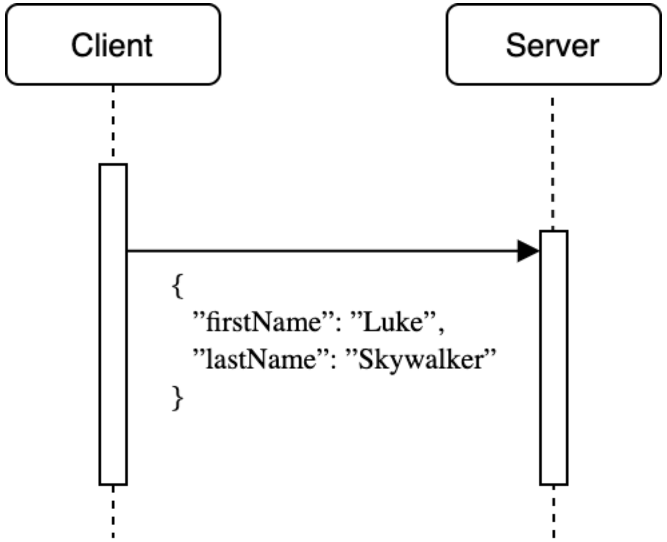
# RPC Error Handling

```
(error, reply) = network.send(remote, actionData)
switch error
  case POST_FAILED:
    // handle case where you know server didn't get it
  case RETRYABLE:
    // handle case where server got it but reported transient failure
  case FATAL:
    // handle case where server got it and definitely doesn't like it
  case UNKNOWN: // i.e., time out
    // handle case where the *only* thing you know is that the server received
    // the message; it may have been trying to report SUCCESS, FATAL, or RETRYABLE
  case SUCCESS:
    if validate(reply)
      // do something with reply object
    else
      // handle case where reply is corrupt/incompatible
```

Source: [https://aws.amazon.com/builders-library/challenges-with-distributed-systems](https://aws.amazon.com/builders-library/challenges-with-distributed-systems)

# Message Transport and Format

- Message transport defines a protocol used to exchange data between client and a remote server. Examples:
  - TCP or UDP sockets
  - FTP file exchange
  - HTTP
  - Messaging (e.g. JMS, Kafka, MQTT, RabbitMQ)



```
{
  ”firstName”: ”Luke”,
  ”lastName”: ”Skywalker”
}
```

- Message format specifies how data is being represented. Examples:
  - XML
  - JSON
  - Google Protocol Buffers
  - Apache Avro

```
<customer>
   <firstName>Luke</firstName>
   <lastName>Skywalker</lastName>
</customer>
```

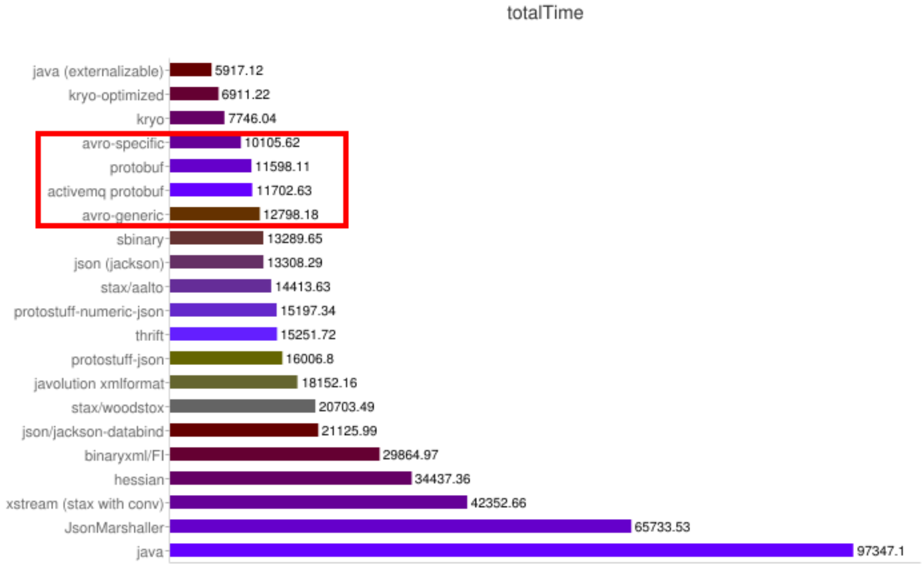
```
{
   "firstName": "Luke",
   "lastName": "Skywalker"
}
```

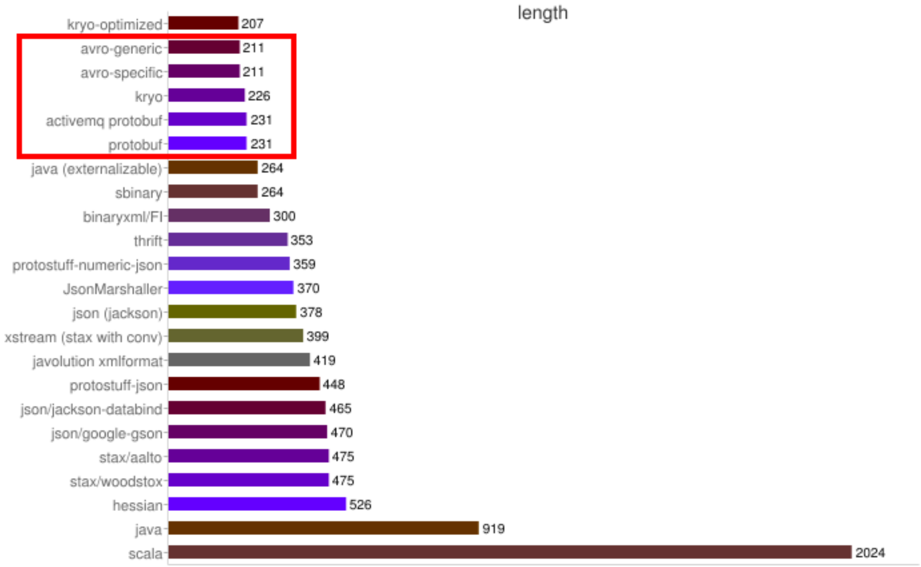
protobuf
Protocol Buffers

AVRO™

# Message Transport and Format

- Performance of modern binary serializers – Avro and ProtoBuf

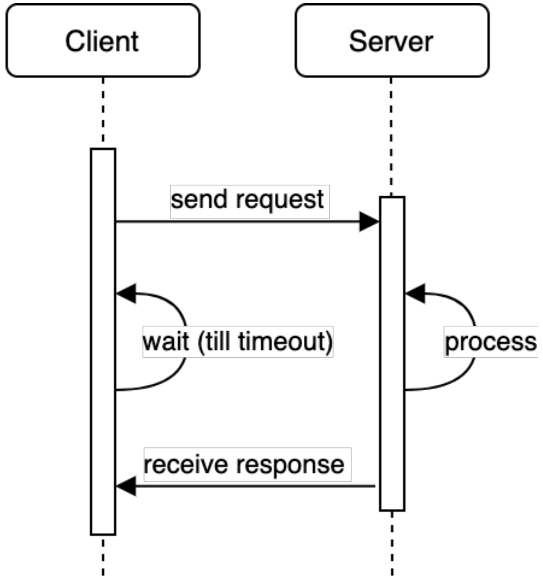




Source: https://blog.softwaremill.com/the-best-serialization-strategy-for-event-sourcing-9321c299632b

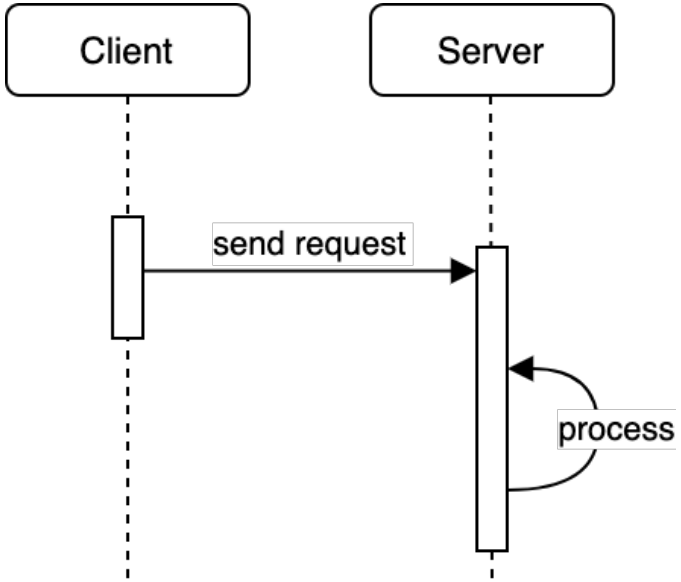
# Communication Patterns

## Synchronous (Request-Replay)



- Use for short running processes, without human intervention
- Always define timeout at client side
- Implement idempotent services for safe retry upon timeout

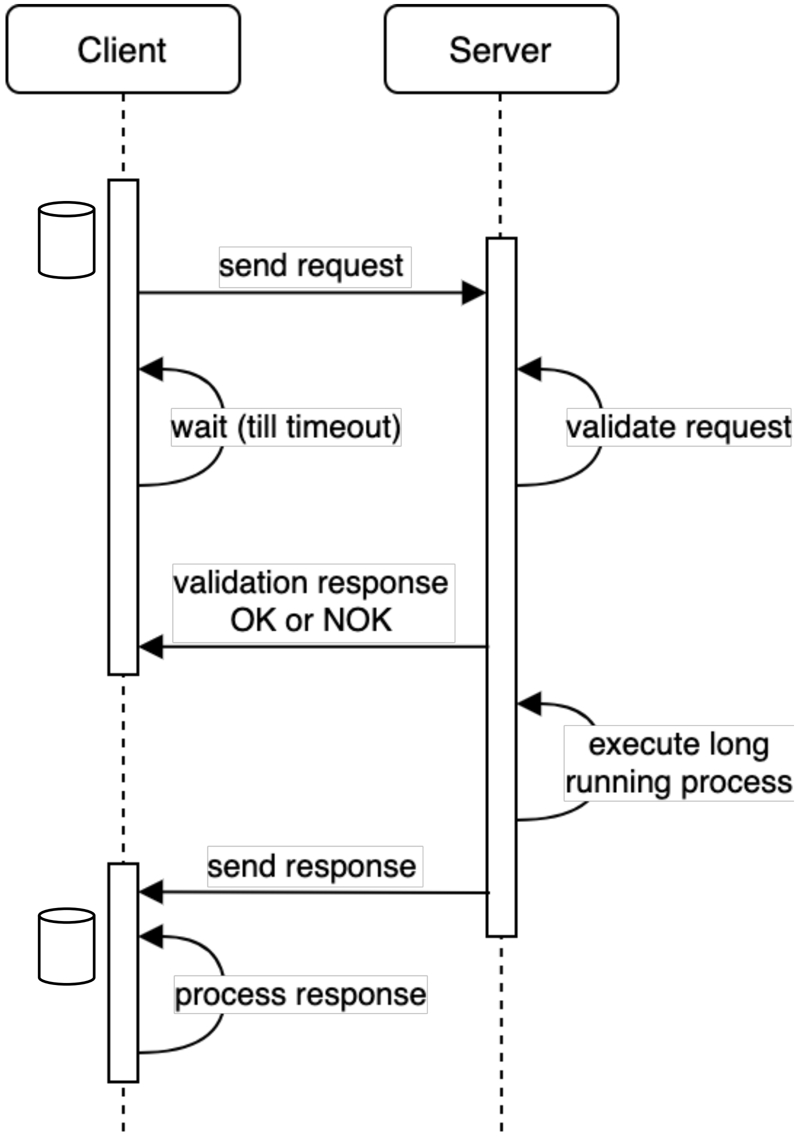
## Asynchronous (Fire-and-Forget)



- Use for long running processes or when human intervention required
- Usually requires messaging solution to decouple service consumer from service provider

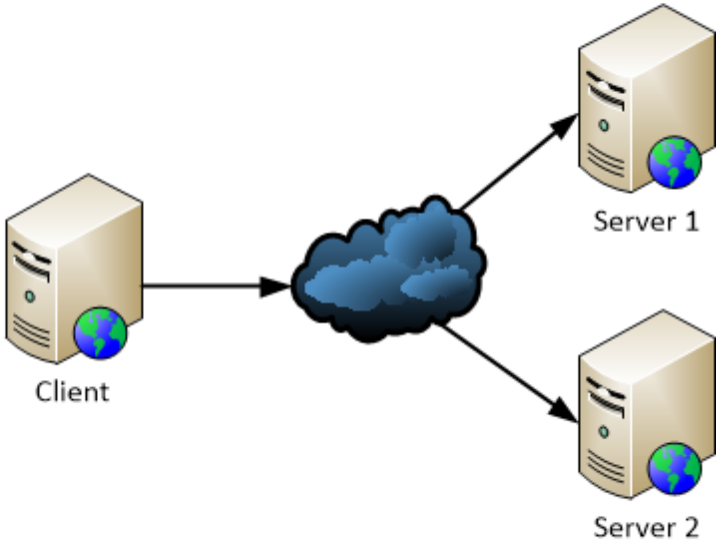
# Communication Patterns

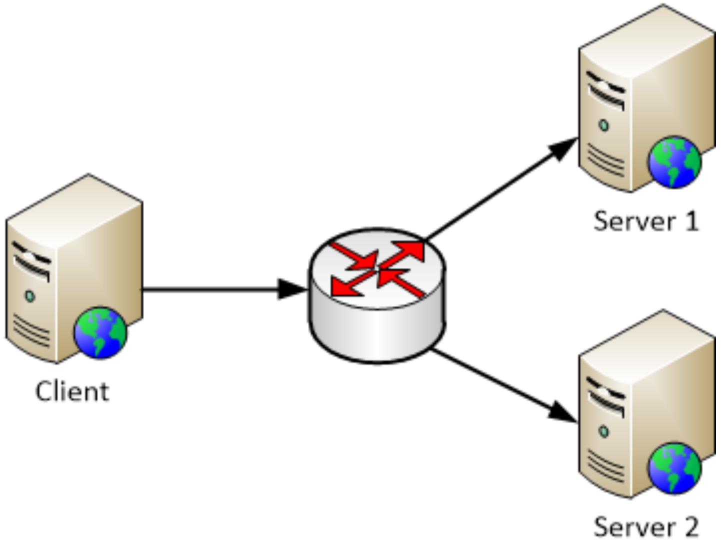
- Asynchronous with Confirmation
  - Server provides synchronous response only after quick validation of client's request
  - Final feedback is sent after completing long running process
- Use correlation ID in asynchronous communication
  - Client generates unique correlation ID and includes it in request message
  - Client stores request context and correlation ID in the database
  - Server provides response with given correlation ID
  - Client looks up request context by correlation ID in the database



# Traditional Load Balancers

- Hardware (or software) load balancers distribute traffic between configured number of backend servers
- If the backend server is unavailable, requests are forwarded to other servers from the pool
- Backend servers should expose “health-check” endpoints that will be invoked by load balancer every N seconds to confirm their availability
  - Verify availability of dependent components in health-check implementation

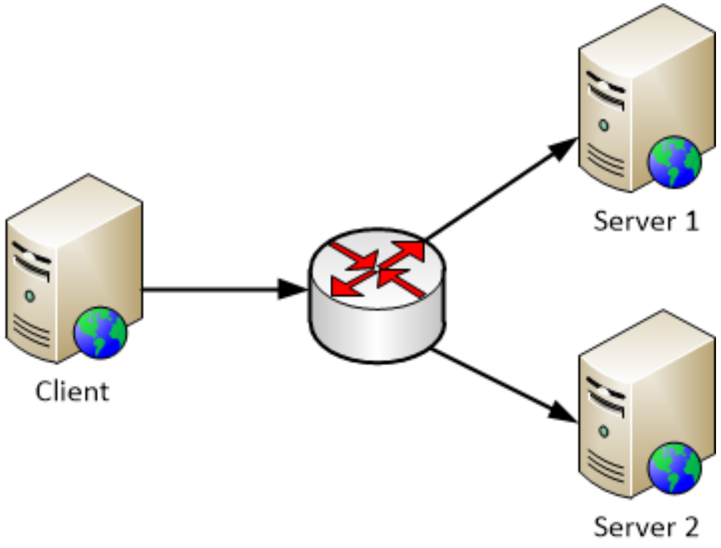




# Traditional Load Balancers

Apache Web Server or NGINX can be easily configured as software load balancer

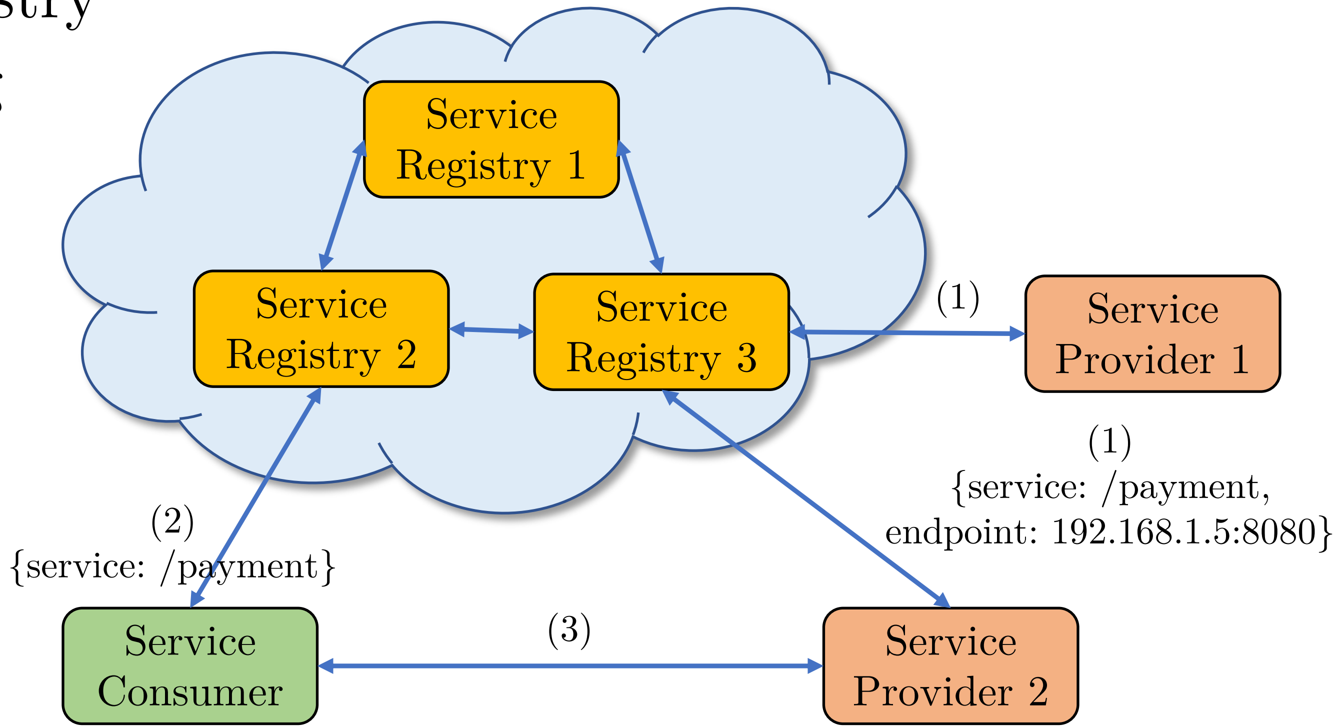
```
http {
  upstream myApp1 {
    server srv1.example.com;
    server srv2.example.com;
    server srv3.example.com;
  }
  server {
    listen 80;
    location / {
      proxy_pass http://myApp1;
      health_check interval=3 fails=3 passes=2 uri=/health;
    }
  }
}
```



Single Point of Failure!

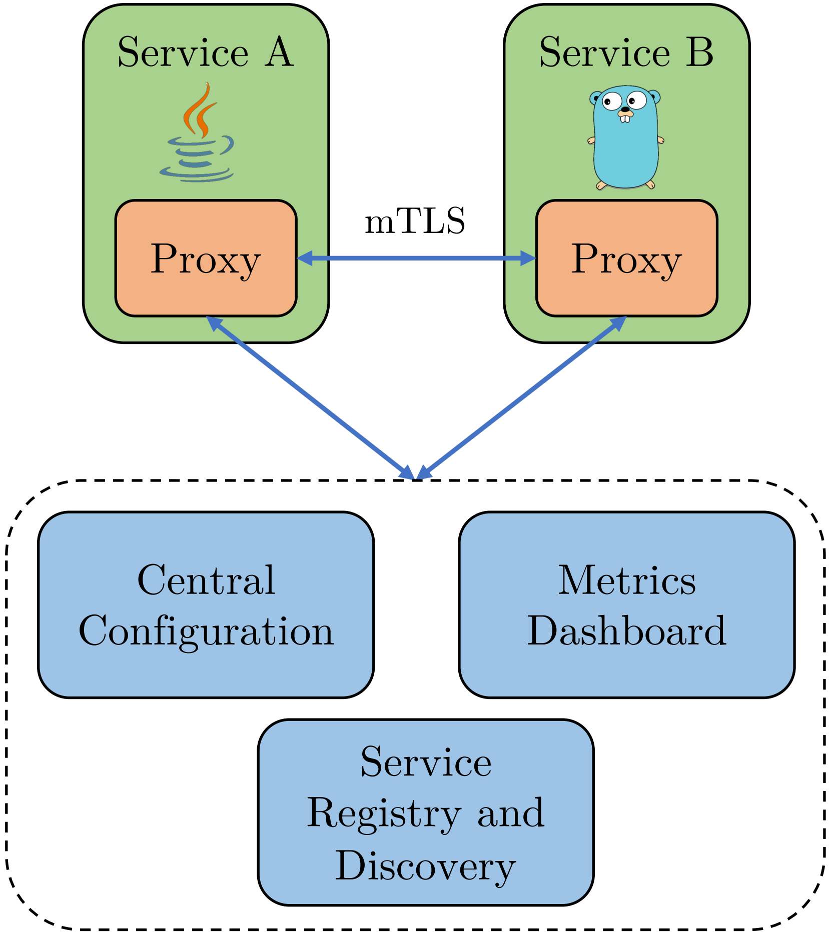
# Service Registry and Discovery

- Service producers register in distributed Service Registry (1)
  - Service Registry keeps track of all alive instances of given service
  - Each instance of service provider periodically heartbeats with registry
  - Easy dynamic scaling (up and down) of service producers
- Clients query any of Service Registry nodes to get all endpoints hosting given service (2)
- Clients contact service providers directly (3)
  - Client-side load balancing based on various metrics
  - No extra hops between client and a service



# Service Mesh

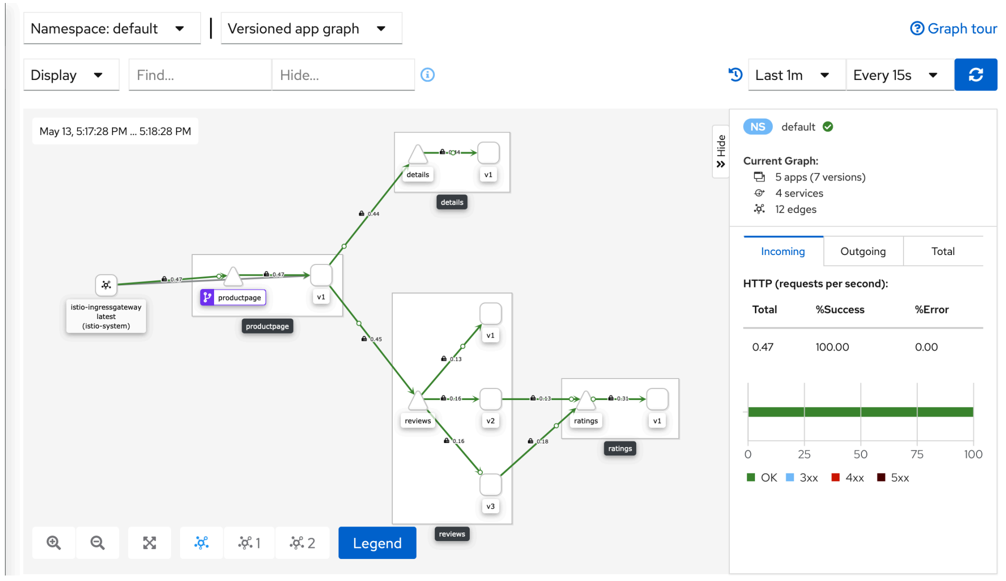
- Leverage Proxy Sidecar pattern to abstract inter-service communication
- Service Mesh features:
  - Service discovery and registry
  - Request load balancing and routing
  - Retry logic, rate limiting and Circuit Breaker pattern
  - Transport-level security (mTLS) and ACLs
  - Performance metrics
  - Distributed track and trace
  - Traffic splitting and Canary Deployments pattern
- Programming language independent inter-communication
- Example frameworks:
  - Linkerd 1.x (standalone) and 2.x (Kubernetes)
  - Istio



# Service Mesh

```
apiVersion: security.istio.io/v1beta1
kind: AuthorizationPolicy
metadata:
  name: jwt-per-host
  namespace: istio-system
spec:
  selector:
    matchLabels:
      istio: ingressgateway
  action: ALLOW
  rules:
  - from:
    - source:
        requestPrincipals: ["*@example.com"]
    to:
    - operation:
        hosts: ["example.com", "*.example.com"]
```

Source: Istio Documentation



Namespace: default | Versioned app graph

Last 1m · Every 15s

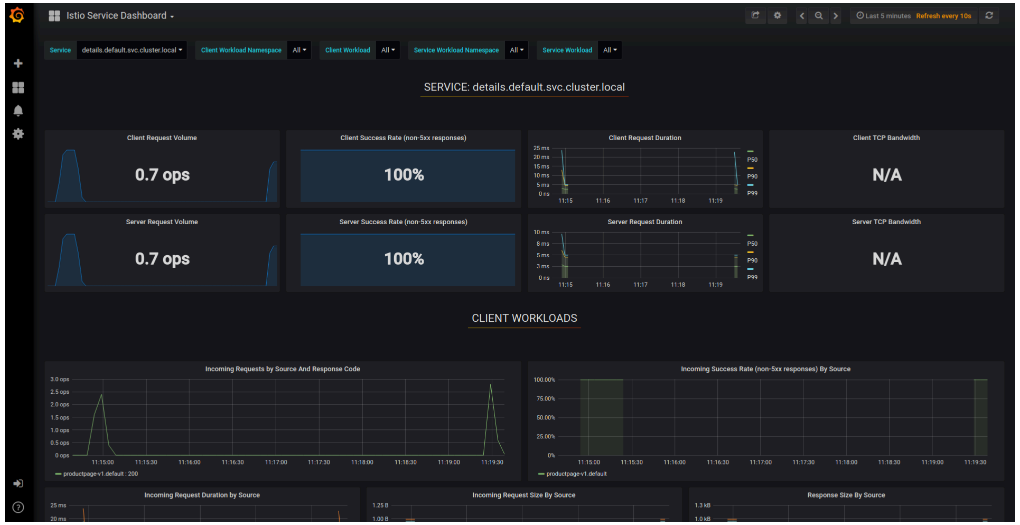
May 13, 5:17:28 PM ... 5:18:28 PM

NS default

Current Graph:
5 apps (7 versions)
4 services
12 edges

HTTP (requests per second):

| Total | %Success | %Error |
|---|---|---|
| 0.47 | 100.00 | 0.00 |



Istio Service Dashboard

Service: details.default.svc.cluster.local · Client Workload Namespace: All · Client Workload: All · Service Workload Namespace: All · Service Workload: All

Last 5 minutes · Refresh every 10s

SERVICE: details.default.svc.cluster.local

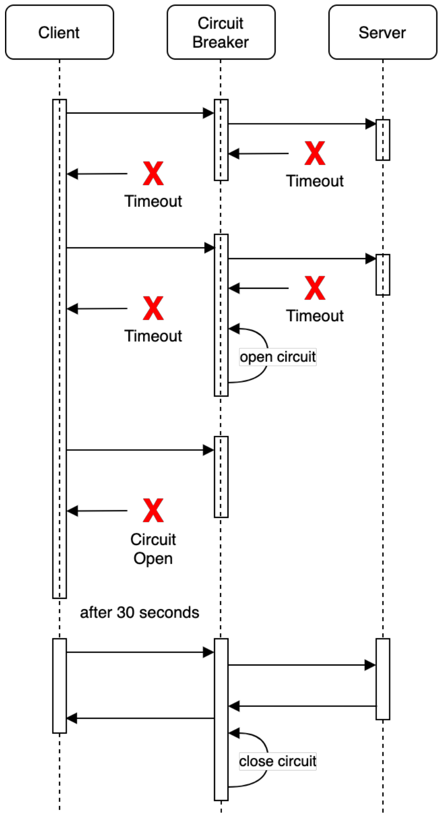
| Client Request Volume | Client Success Rate (non-5xx responses) | Client Request Duration | Client TCP Bandwidth |
|---|---|---|---|
| 0.7 ops | 100% | | N/A |

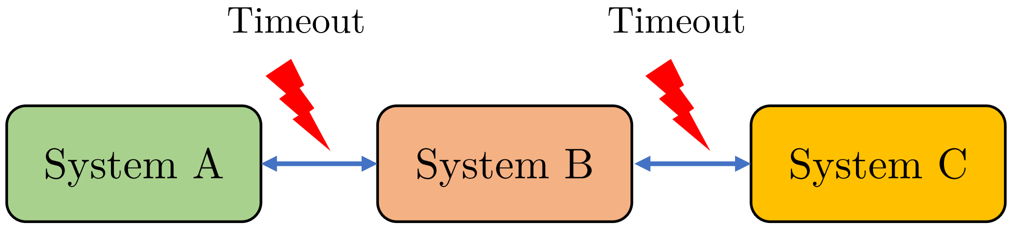
| Server Request Volume | Server Success Rate (non-5xx responses) | Server Request Duration | Server TCP Bandwidth |
|---|---|---|---|
| 0.7 ops | 100% | | N/A |

CLIENT WORKLOADS

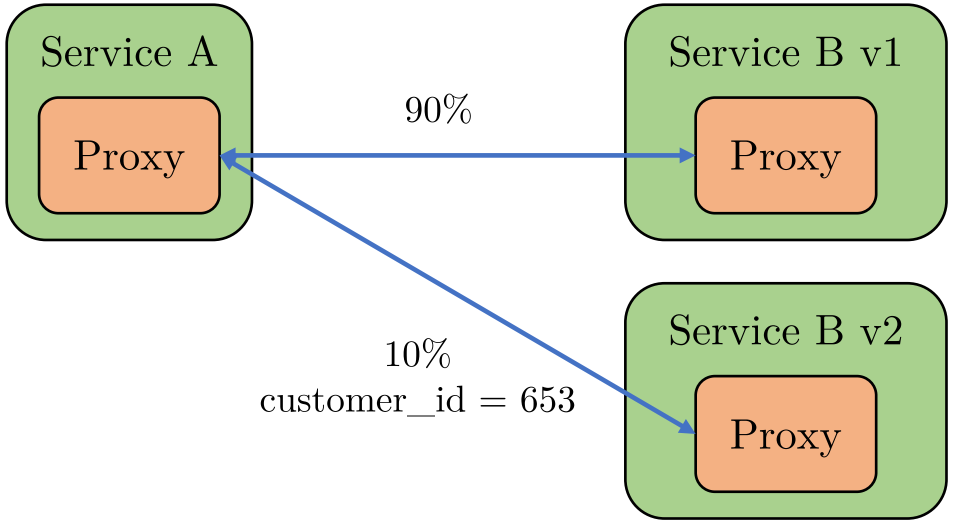
# Service Mesh

- Circuit Breaker

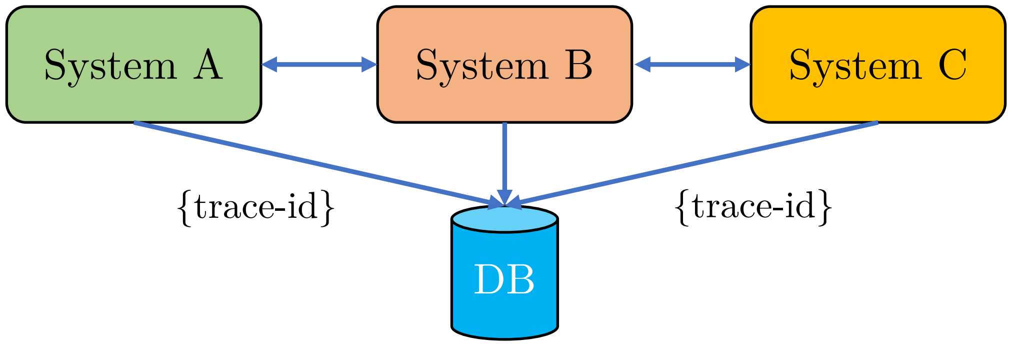




- Canary Deployment



- Distributed Tracing

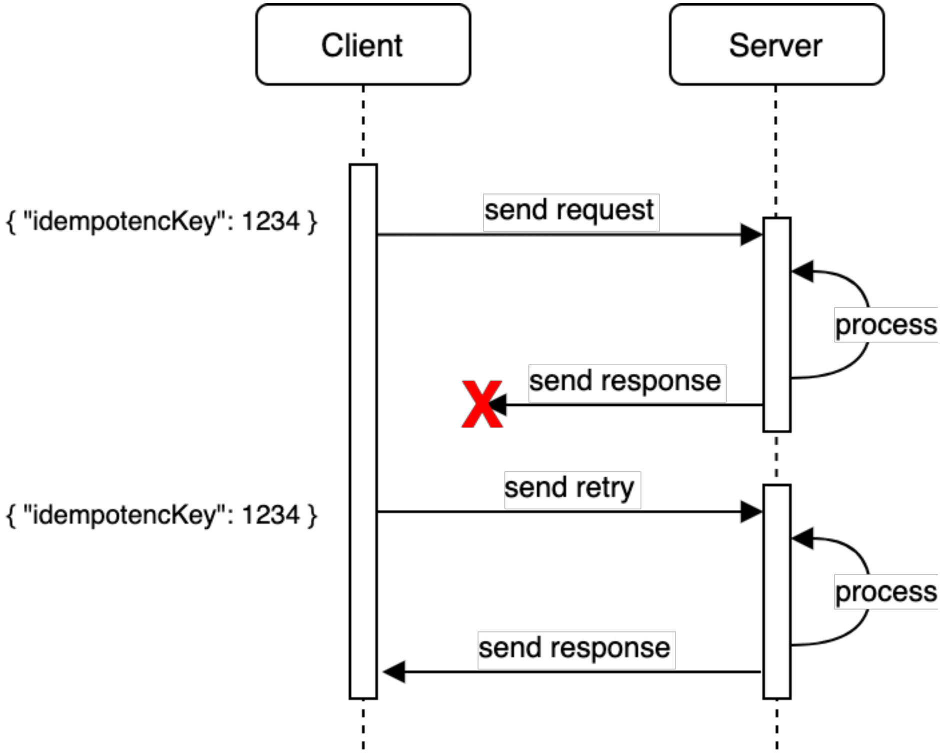


# Idempotent Service Design

## Definition

An idempotent service can be called many times without different outcomes, provided all requests share the same, unique idempotency key (generated by service consumer).

- Benefits:
  - Handling of duplicate requests
  - Clients have the possibility to retry timed out requests safely



# Idempotent Service Design

- Verification scenarios:
  - Any operation within service implementation fails, customer retries
  - Complete service invocation succeeds, but consumer times out and retries
  - Two identical requests picked up at the same time by the system

```
public String shortenUrl(String longUrl) {
    long id = generateNextId();
    String shortUrl = String.format(
        "http://tiny.com:8080/%s",
        Long.toString(id, 36));
    insertMapping(shortUrl, longUrl);
    return shortUrl;
}
```

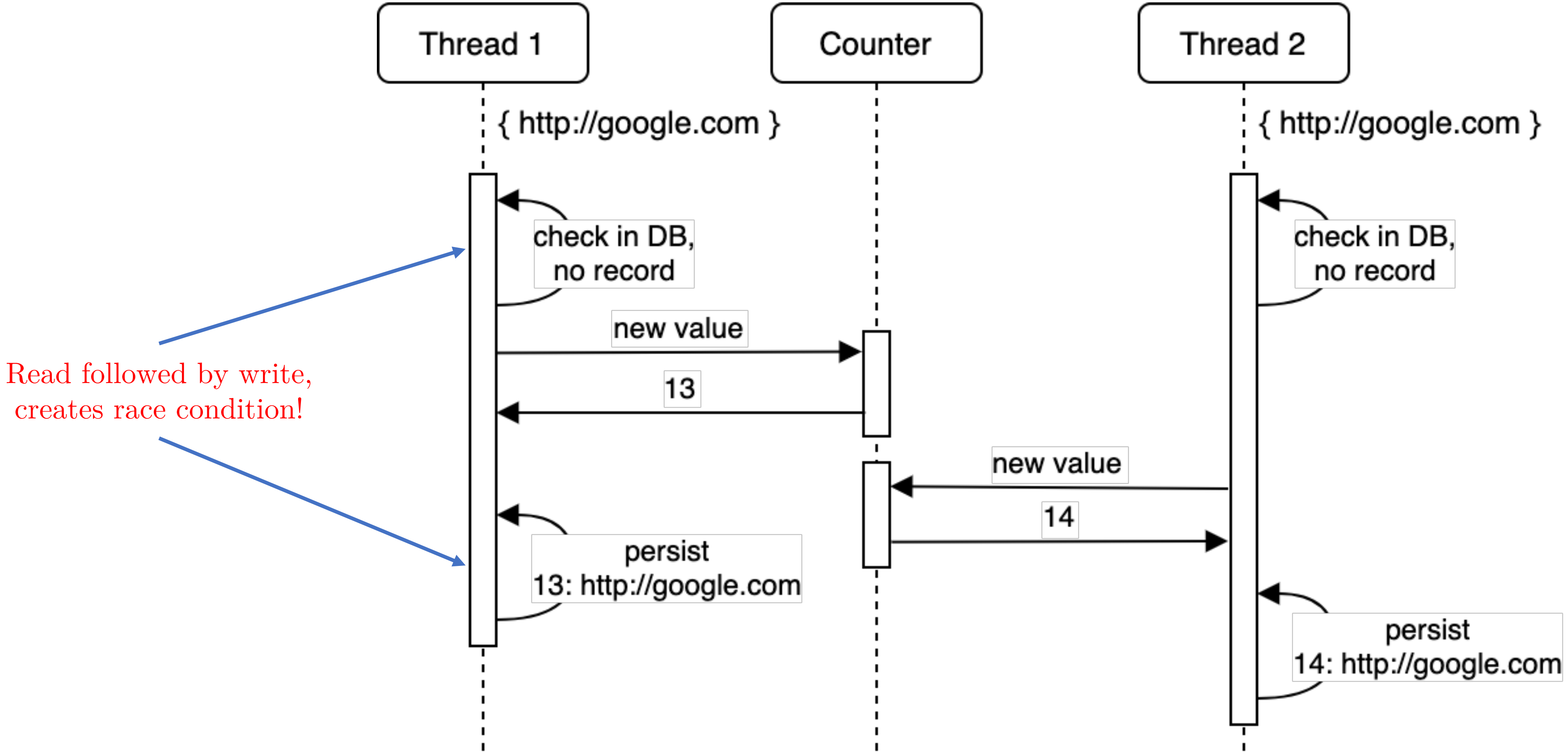
Loose one ID number

Nothing happens, local operations only

Orphaned mapping inserted
Client will retry the request

# Idempotent Service Design

- Two identical requests picked up at the same time by the system



Read followed by write, creates race condition!

# Idempotent Service Design

- Invoking non-idempotent services
  - Keep track whether we tried to invoke given service with idempotency key
  - We cannot retry the service invocation for the second time
  - Raise alert for operations team if we have called the service before

```
if (! didInvokeBefore("serviceA", idempotencyKey)) {
    persistStatus("serviceA", TPC_INVOKE, idempotencyKey);
    response = invokeServiceA(idempotencyKey, request);
    updateStatus("serviceA", INVOKED, idempotencyKey);
}
public boolean didInvokeBefore(String serviceName, String key) {
    Status status = queryStatus(serviceName, key);
    if (TPC_INVOKE.equals(status)) throw new UnsupportedRetryException(serviceName, key);
    return INVOKED.equals(status);
}
```

# Summary

- Client and server communicate over the network
- Message transport and format
- Request-replay and Fire-and-forget communication patterns
- Service Registry and Discovery
- Service Meshes
- Idempotent service design