CompSci 401: Cloud Computing

Monolithic Applications

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How should a program be structured?

- Much software engineering research
    - Several trade-offs to consider
    - No clear answer

Monolithic applications

- Tight coupling between components
  - Higher performance (e.g., shared memory, function calls)
- One piece of software to install, configure, use, and update

Monolithic applications

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    - Higher performance (e.g., shared memory, function calls)
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- Examples
    - Games
    - Acrobat Reader
    - Word (desktop version)
    - Photoshop

Monolithic applications

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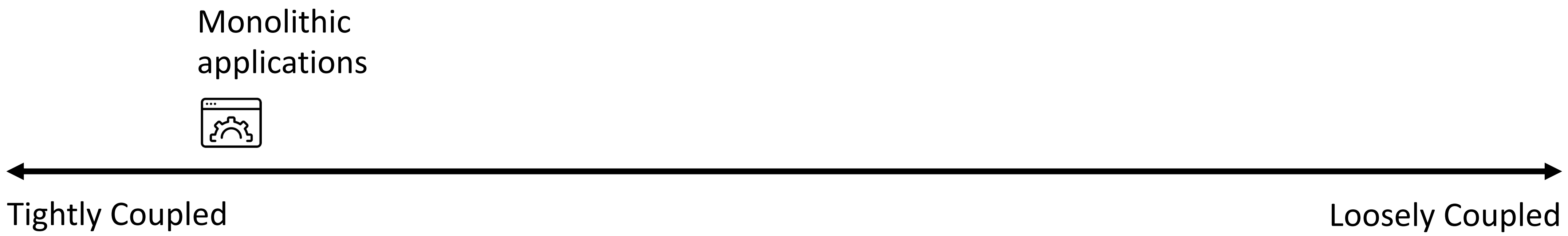
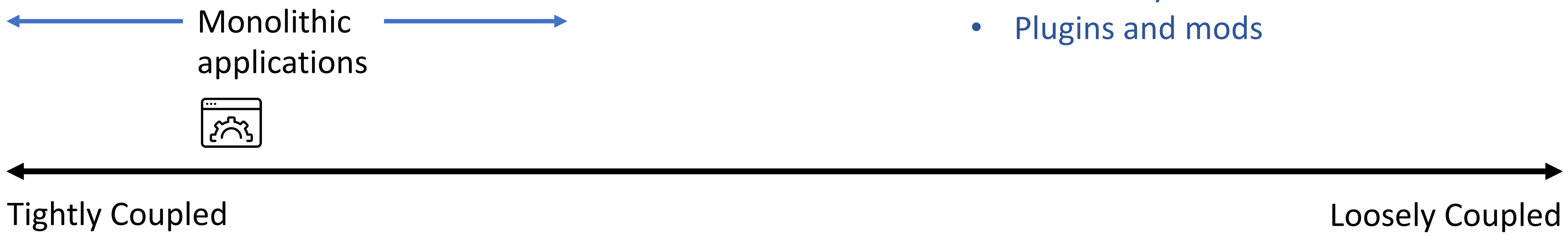


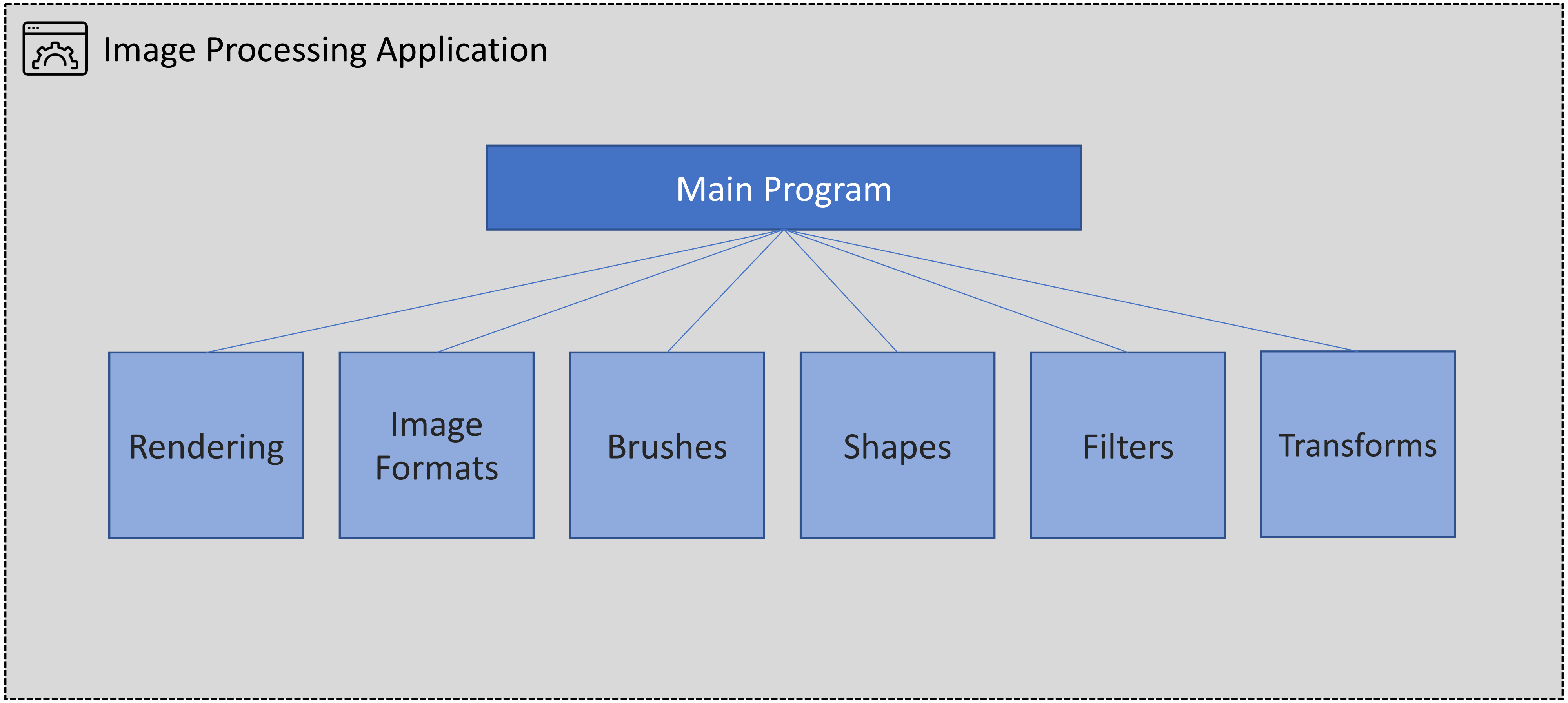
Monolithic applications

- Tight coupling between components
  - Higher performance (e.g., shared memory, function calls)
- One piece of software to install, configure, use, and update

Different degrees of coupling.
Monolithic applications can be modular:
- Install only some features
- Plugins and mods



Example image processing monolithic app



Monolithic applications in a data center

- We *can* run monolithic applications in a data center
  - Tenants can rent VMs, install the application in the virtual machine, and use it
- Not the best match for cloud computing
  - Containers are more lightweight
  - Containers can be started and stopped faster than a VM

Monolithic applications in a data center

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- Not the best match for cloud computing
  - Containers are more lightweight
  - Containers can be started and stopped faster than a VM
- Loading the whole application will waste resources
  - Most users will only use a fraction of the functionalities:
    - User A may be rotating images
    - User B may be removing red eyes
    - User C may be recalibrating colors
    - User D may be converting file formats

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Microservices

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Microservice approach

- Split an application’s functionality across different programs
    - Each program is small and handles a single or a few related functions
- A monolithic application can be *disaggregated* into microservices

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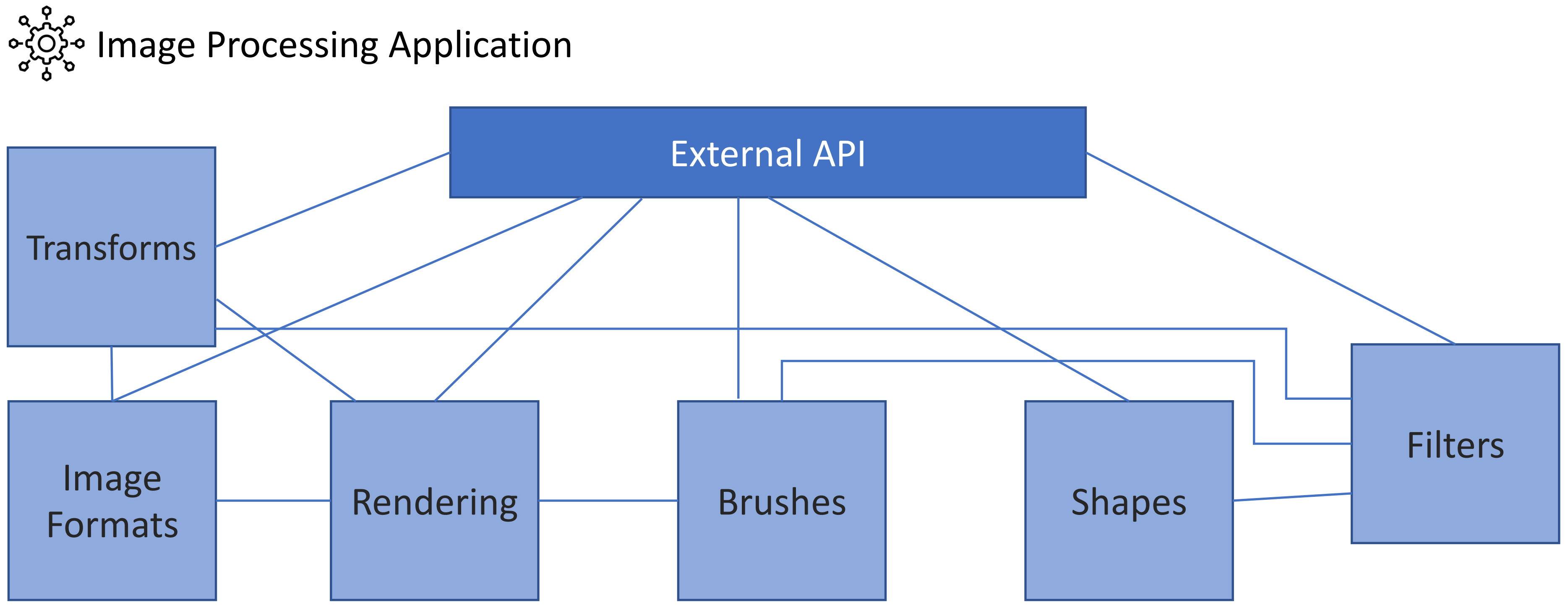

Microservice approach

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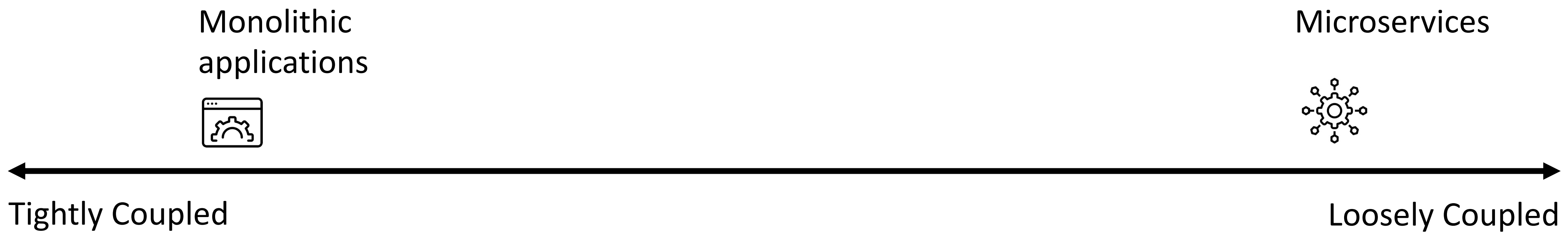

Advantages of microservices for development

- Smaller scope
  - Do one task and to it well
  - Requires decomposition of problem into parts
- Smaller teams
- Better modularity
- Less complexity
- Choice of programming language
- Extensive testing

Advantages of microservices for development

- Smaller scope
- Smaller teams
  - Engineers can understand the microservice in its entirety
  - More uniform code and better manageability
  - Less effort in coordinating large teams
- Better modularity
- Less complexity
- Choice of programming language
- Extensive testing

Advantages of microservices for development

- Smaller scope
- Smaller teams
- Better modularity
  - Define clean interfaces for interaction between microservices
  - Interface only over the network
  - One team cannot change another microservice
- Less complexity
- Choice of programming language
- Extensive testing

Advantages of microservices for development

- Smaller scope
- Smaller teams
- Better modularity
- Less complexity
  - Complexity may still exist in a microservice, but it’s well contained and isolated
- Choice of programming language
- Extensive testing

Advantages of microservices for development

- Smaller scope
- Smaller teams
- Better modularity
- Less complexity
- Choice of programming language
  - Microservices are independent and can be implemented in any language
- Extensive testing

Advantages of microservices for development

- Smaller scope
- Smaller teams
- Better modularity
- Less complexity
- Choice of programming language
- Extensive testing
    - Microservices are small, easier to get high coverage in tests
    - Well-defined interfaces (over the network) implies less interactions to check

Advantages of microservices for operations

- Rapid deployment
  - Small size implies implementation, test, and deployment are quicker
- Improve fault isolation
  - Failures likely confined to one microservice
  - Easier to identify and troubleshoot
- Better control of scaling
  - Finer granularity than monolithic applications
  - Each microservice can be scaled separately
- Compatibility with containers and orchestration systems
- Independent upgrade of each service
  - Update rollout independent of other services
  - Other services can keep running unchanged during upgrade

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Possible Disadvantages of Microservices

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Possible disadvantages of microservices

- Cascading errors
  - One failing microservices may induce failures in other microservices
    - For example, excessive requests
  - One failed microservice may be used by many others
    - May induce failures in other microservices
- Management complexity
- Duplication of functionality and overlap
- Replication of data and transmission overhead
- Increased attack surface
- Workforce training

https://sre.google/books/

Possible disadvantages of microservices

- Cascading errors
- Management complexity
    - Interactions between hundreds of microservices get complex
    - Management also becomes more complex and costly
- Duplication of functionality and overlap
- Replication of data and transmission overhead
- Increased attack surface
- Workforce training

Possible disadvantages of microservices

- Cascading errors
- Management complexity
- Duplication of functionality and overlap
  - Teams might not be aware that functionality exist
  - Duplication increases complexity
- Replication of data and transmission overhead
- Increased attack surface
- Workforce training

Possible disadvantages of microservices

- Cascading errors
- Management complexity
- Duplication of functionality and overlap
- Replication of data and transmission overhead
  - No shared memory or global variables
  - Requests, responses, and data is transmitted over the network
- Increased attack surface
- Workforce training

Possible disadvantages of microservices

- Cascading errors
- Management complexity
- Duplication of functionality and overlap
- Replication of data and transmission overhead
- Increased attack surface
    - Microservices are easier to secure, but each microservice is a possible point of attack
- Workforce training

Possible disadvantages of microservices

- Cascading errors
- Management complexity
- Duplication of functionality and overlap
- Replication of data and transmission overhead
- Increased attack surface
- Workforce training
  - Developing and operating microservices requires complementary skills

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Microservice Granularity

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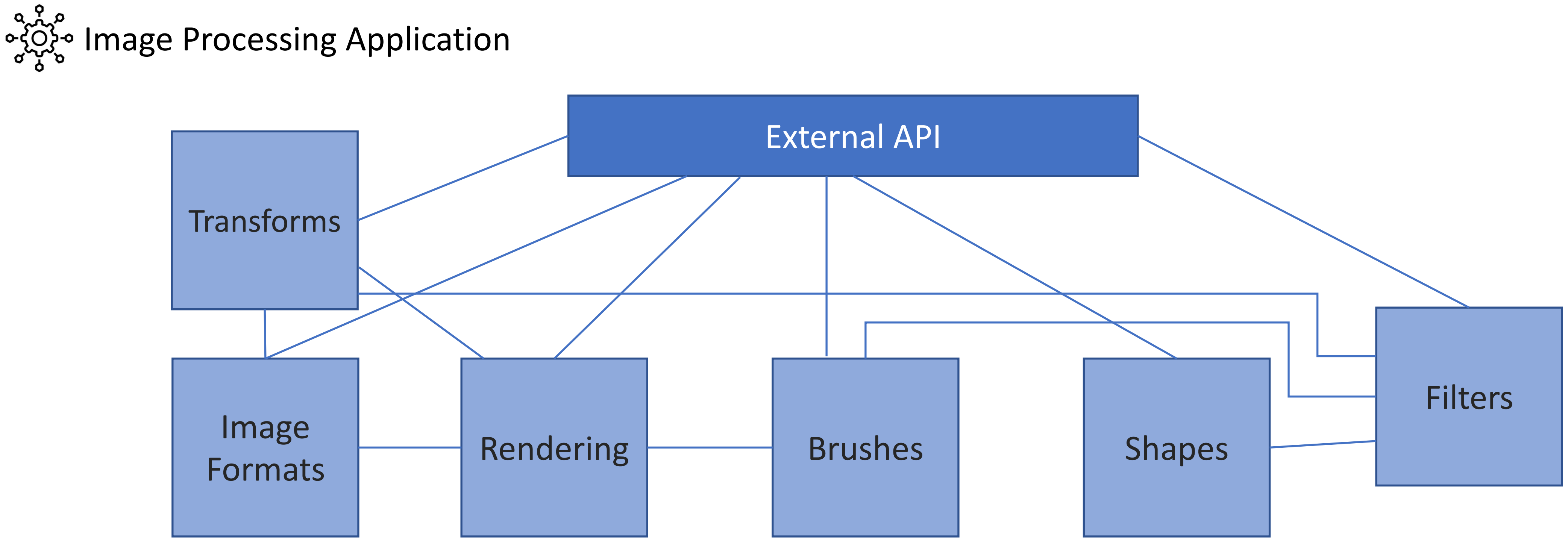
How much functionality in a microservice?

- A functionality may be broken down into different components
- Multiple implementation decisions are possible

How to implement the transforms service



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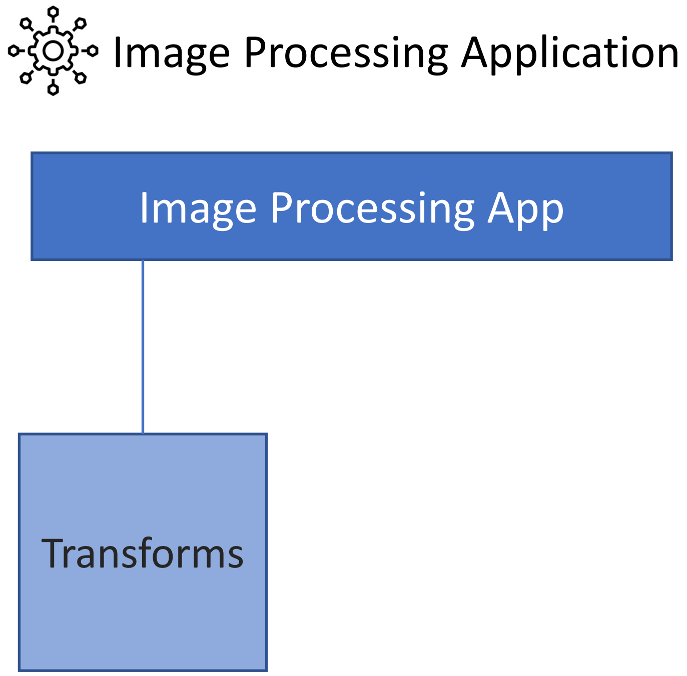

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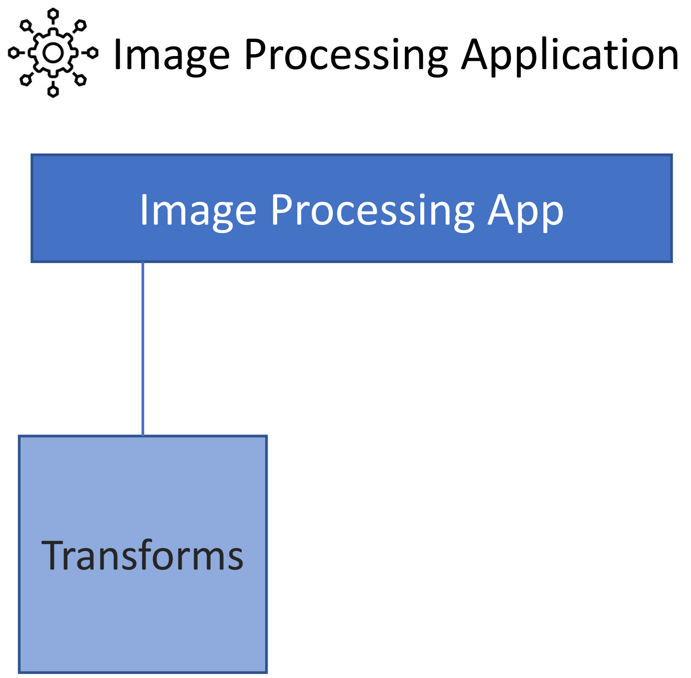

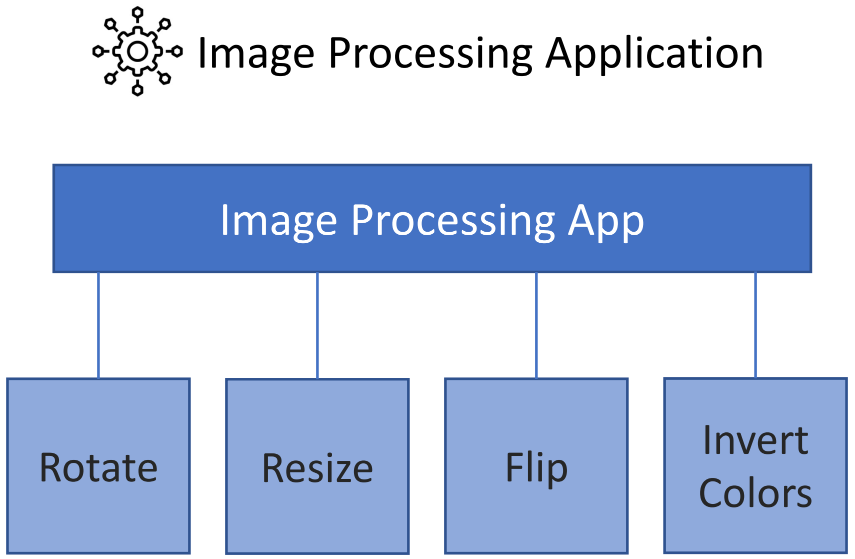

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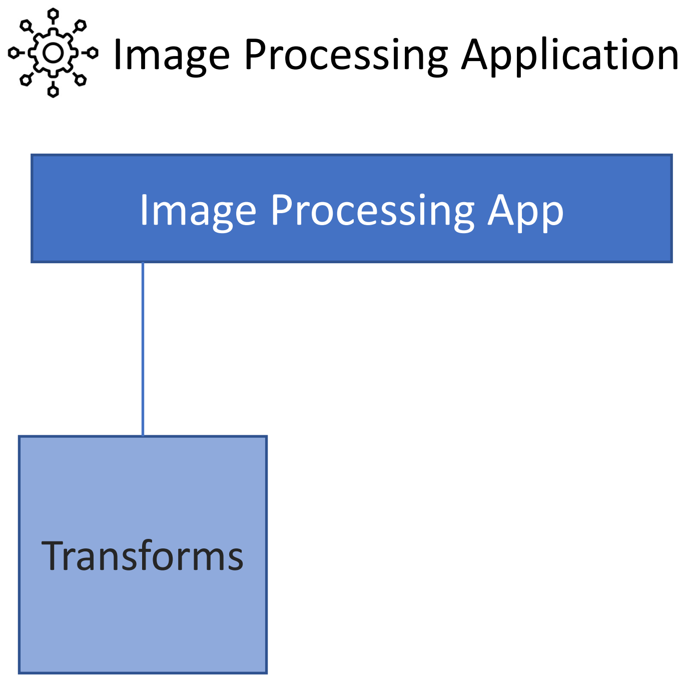
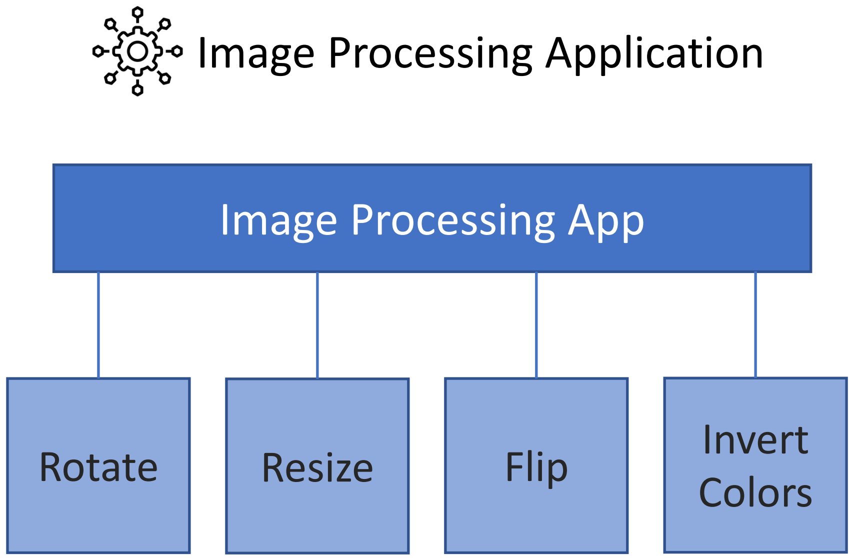
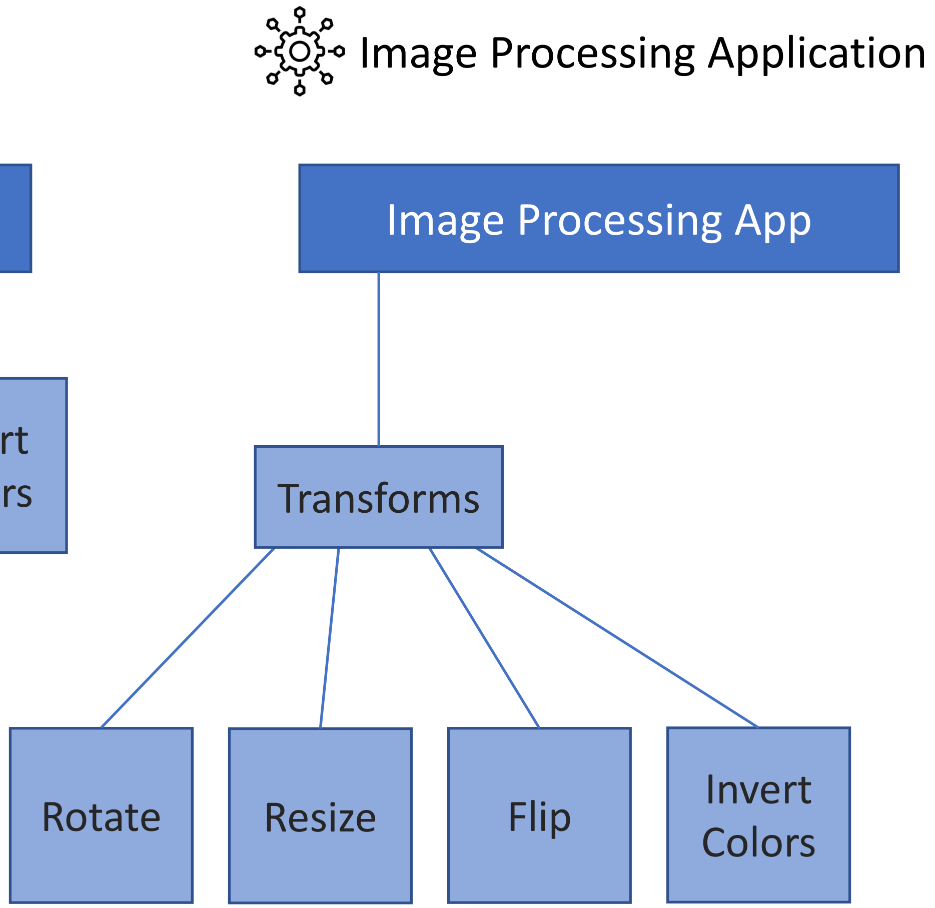
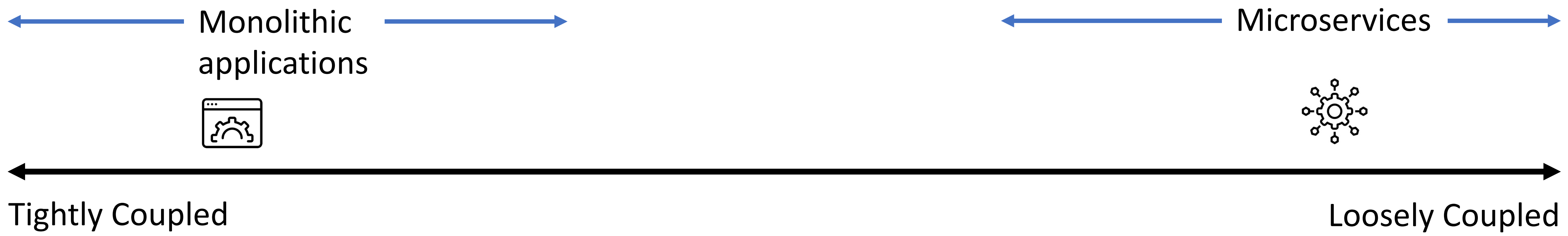




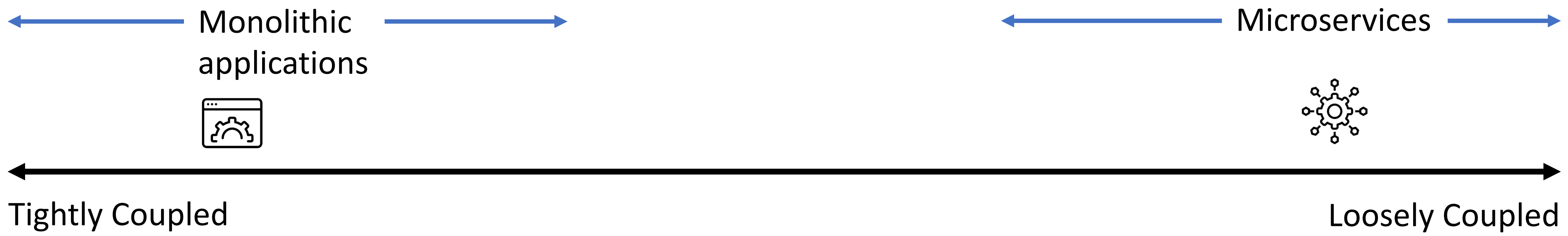


Microservices can have different granularities



Microservices can have different granularities

Trade-off between microservice granularity and management complexity



Heuristics for sizing microservices

- Business process modeling
  - Identify how applications are used and steps in the workflow
  - Try to make one microservice per step
- Identification of common functionality
  - Try to make general microservices that can be used broadly
  - Design interface that supports many different use cases
- Adaptative refactoring
  - Microservices are small, so easier to iterate
  - Can refactor to split or join microservices, as well as add functionalities

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Microservice Communications

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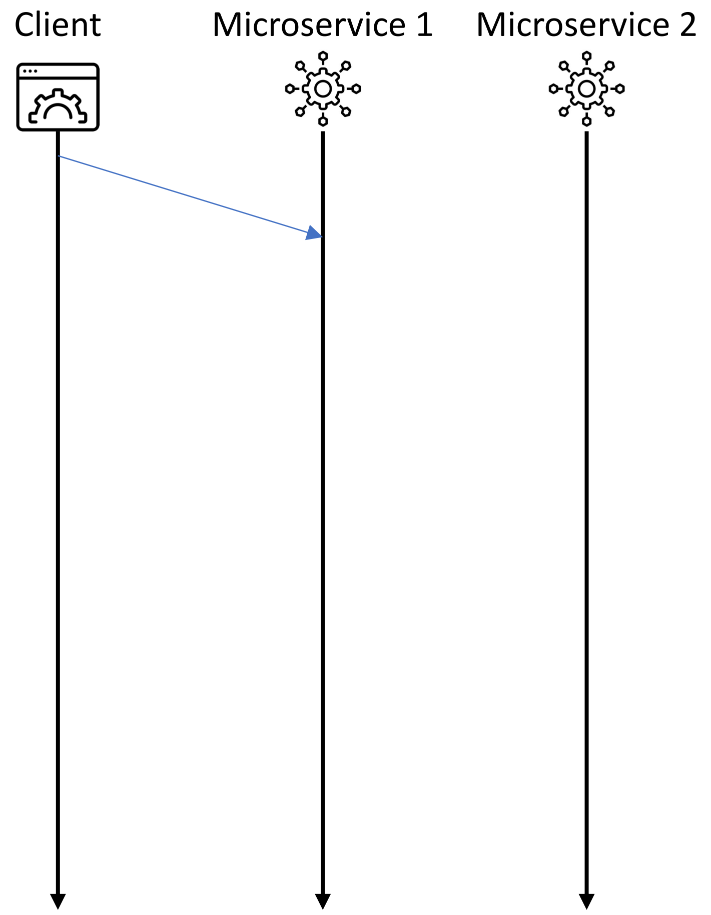
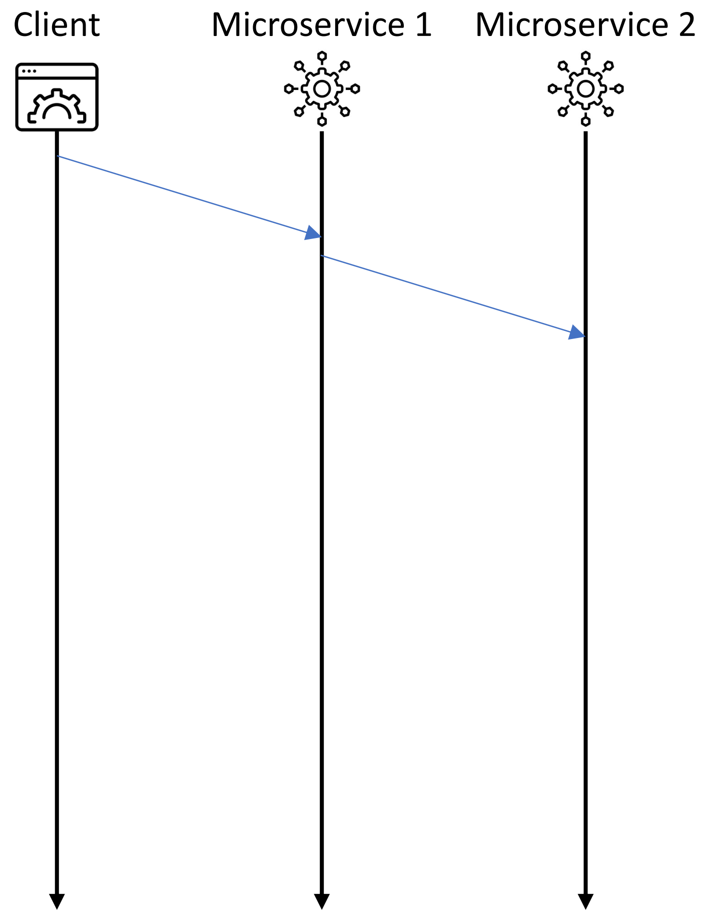
Synchronous vs asynchronous protocols

Synchronous



Synchronous vs asynchronous protocols

Synchronous



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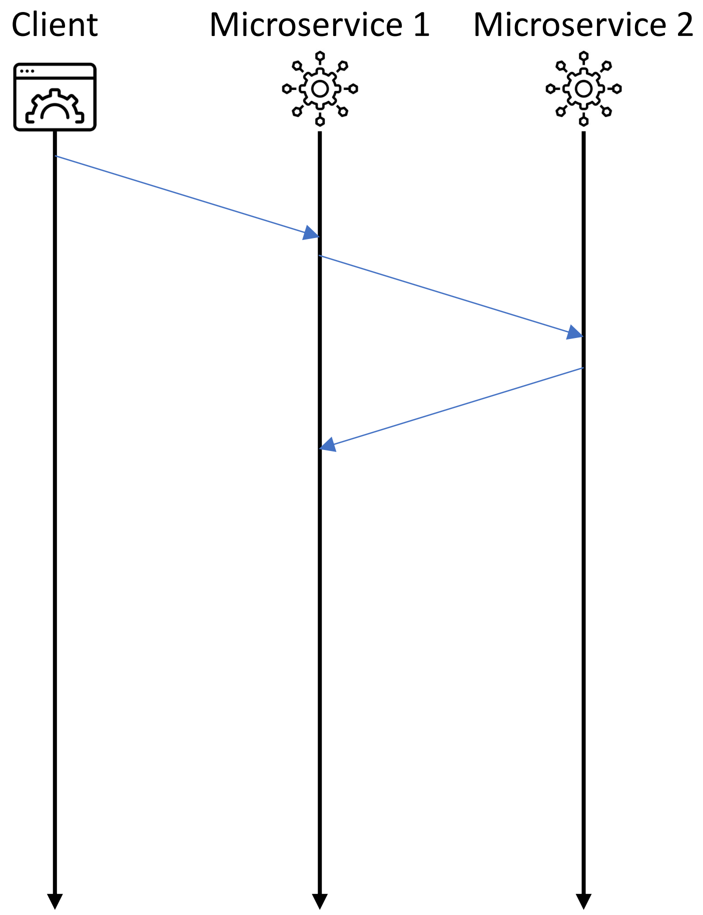

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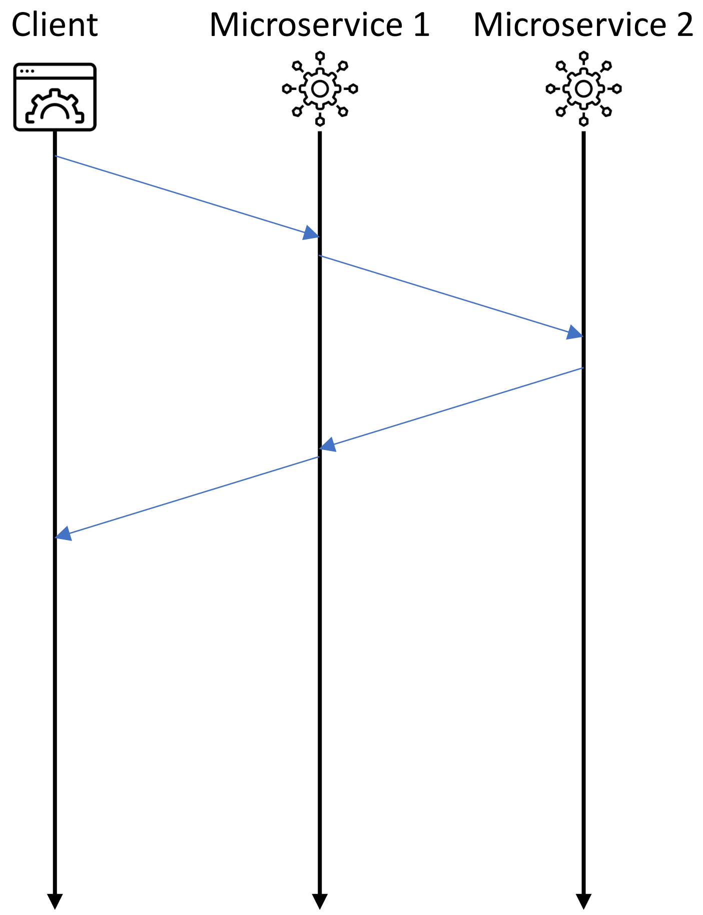

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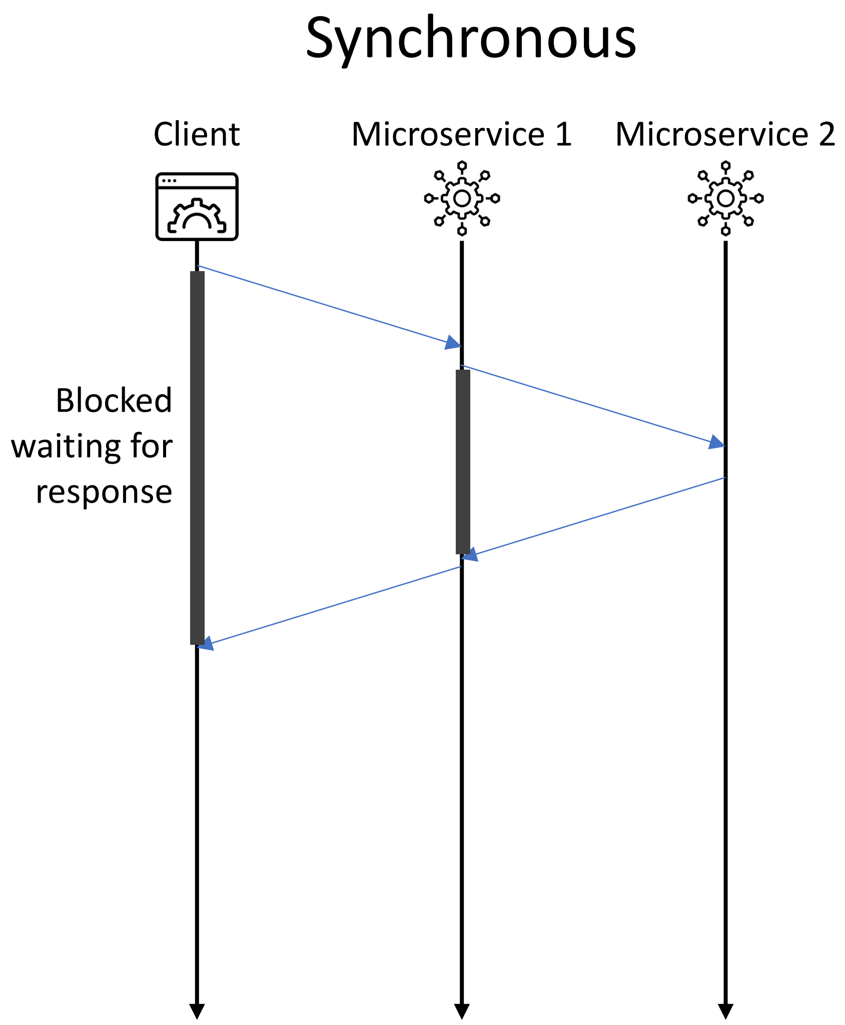

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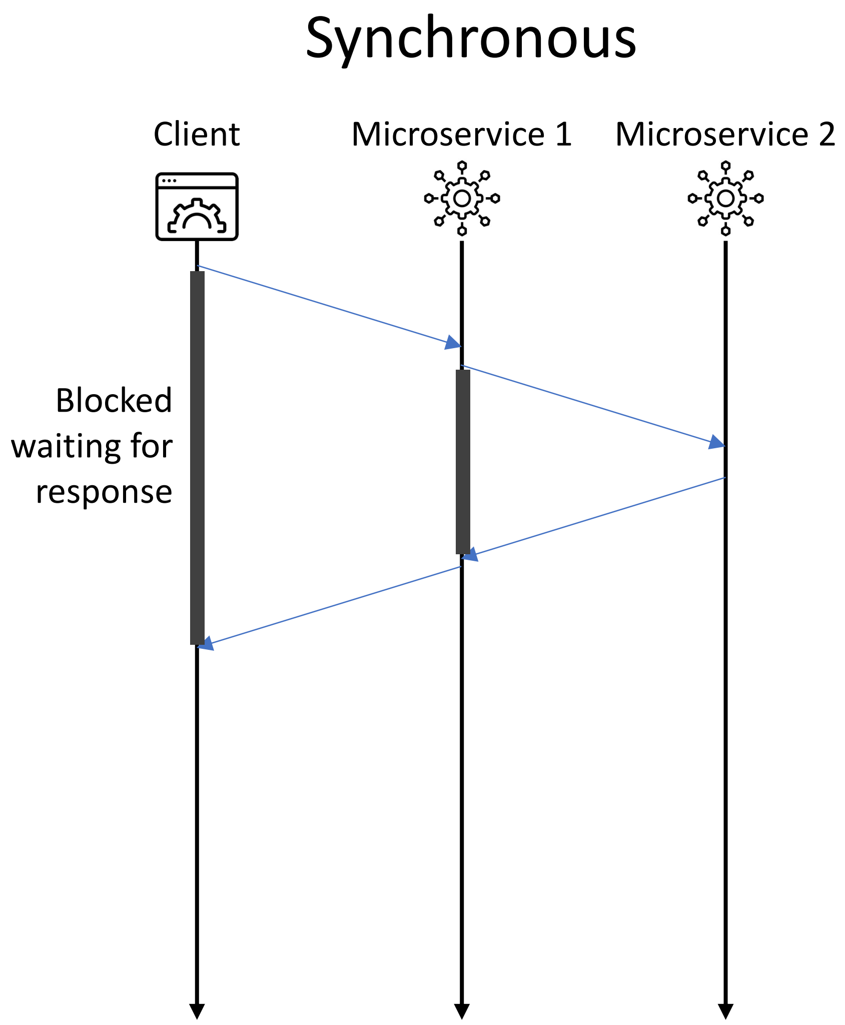

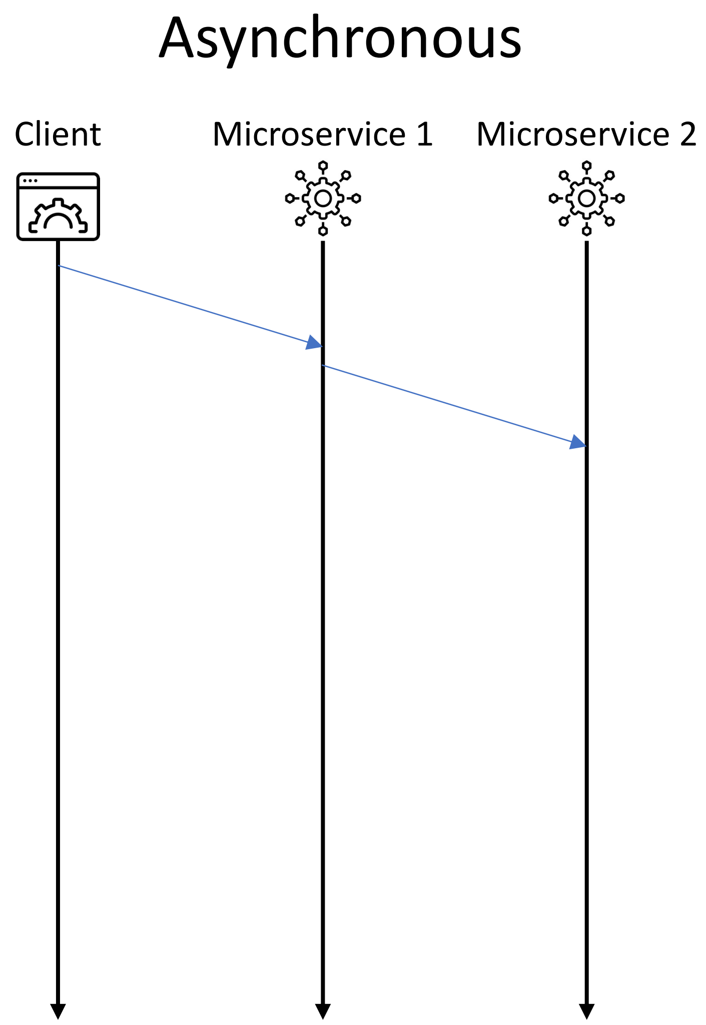

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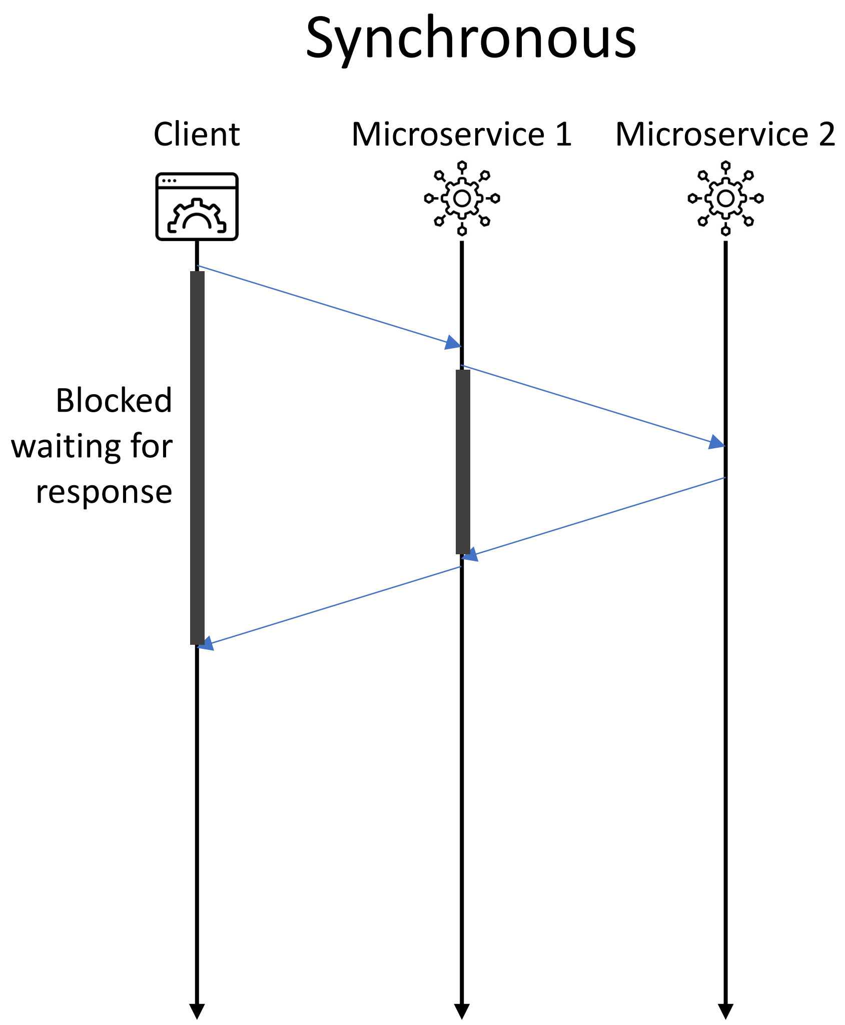

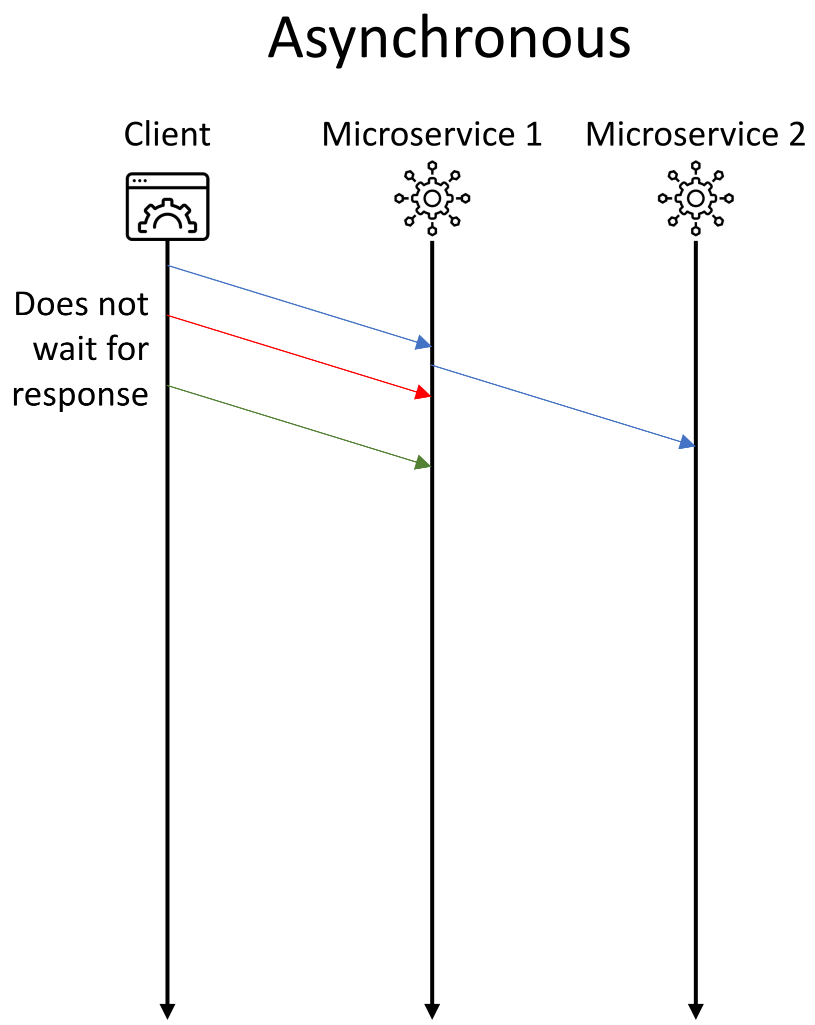

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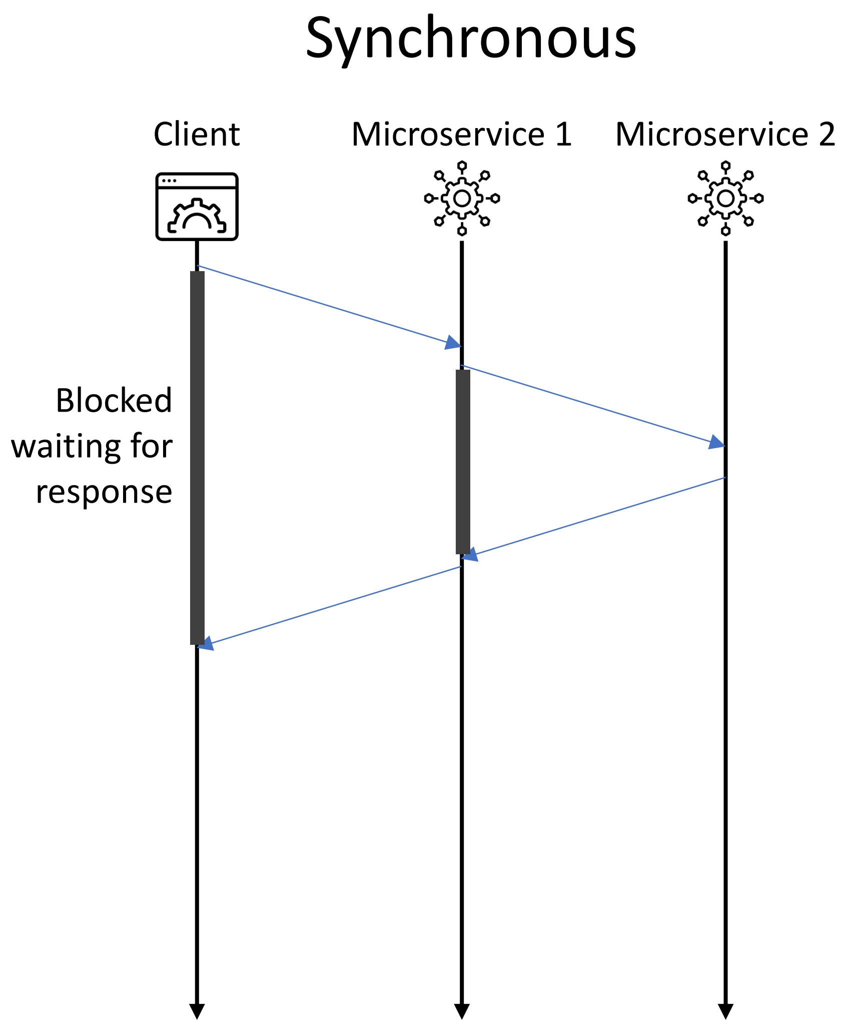

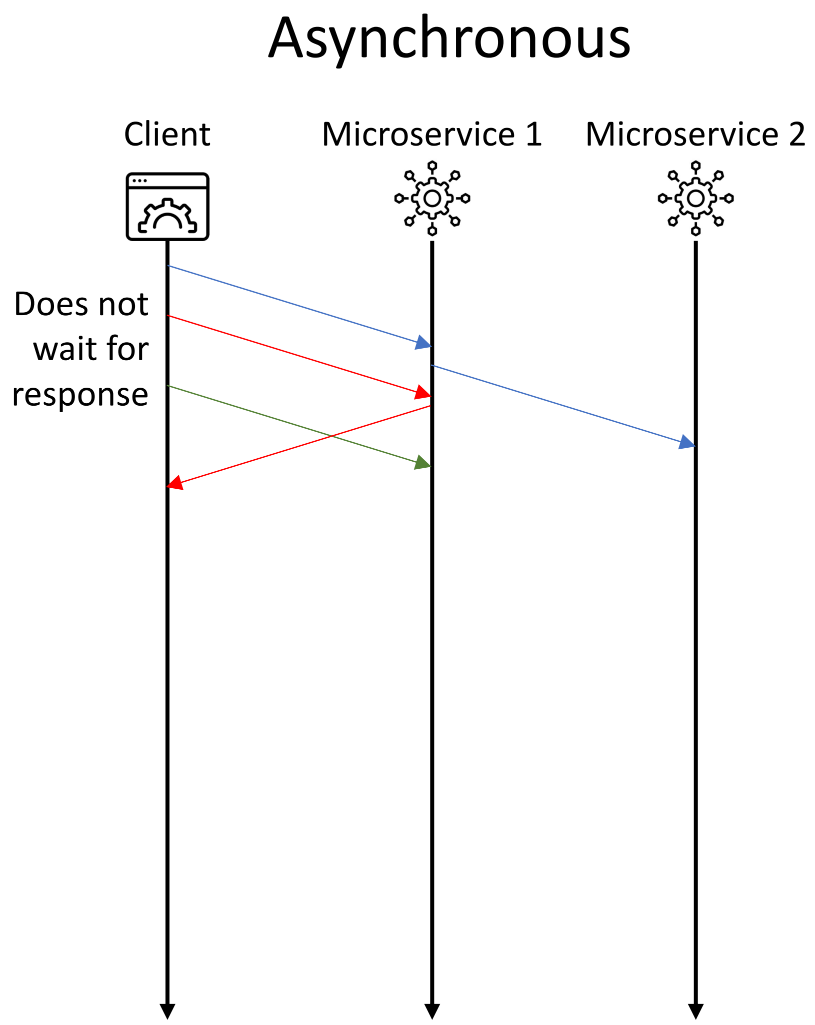

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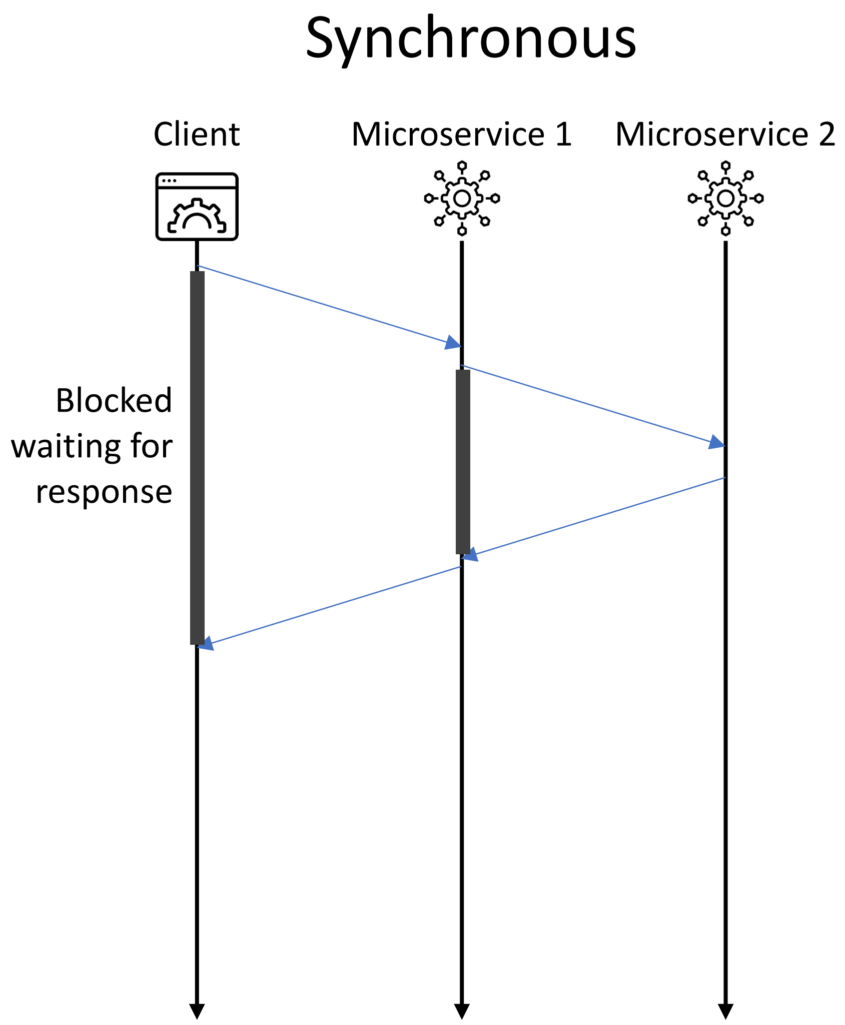

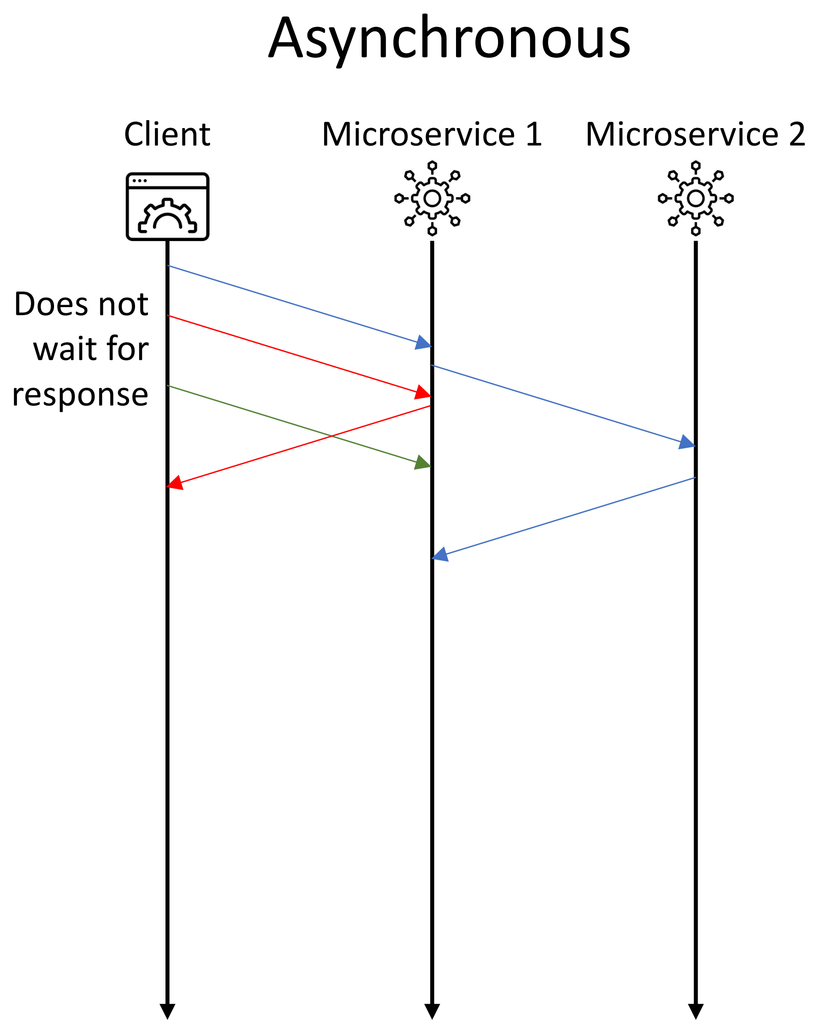

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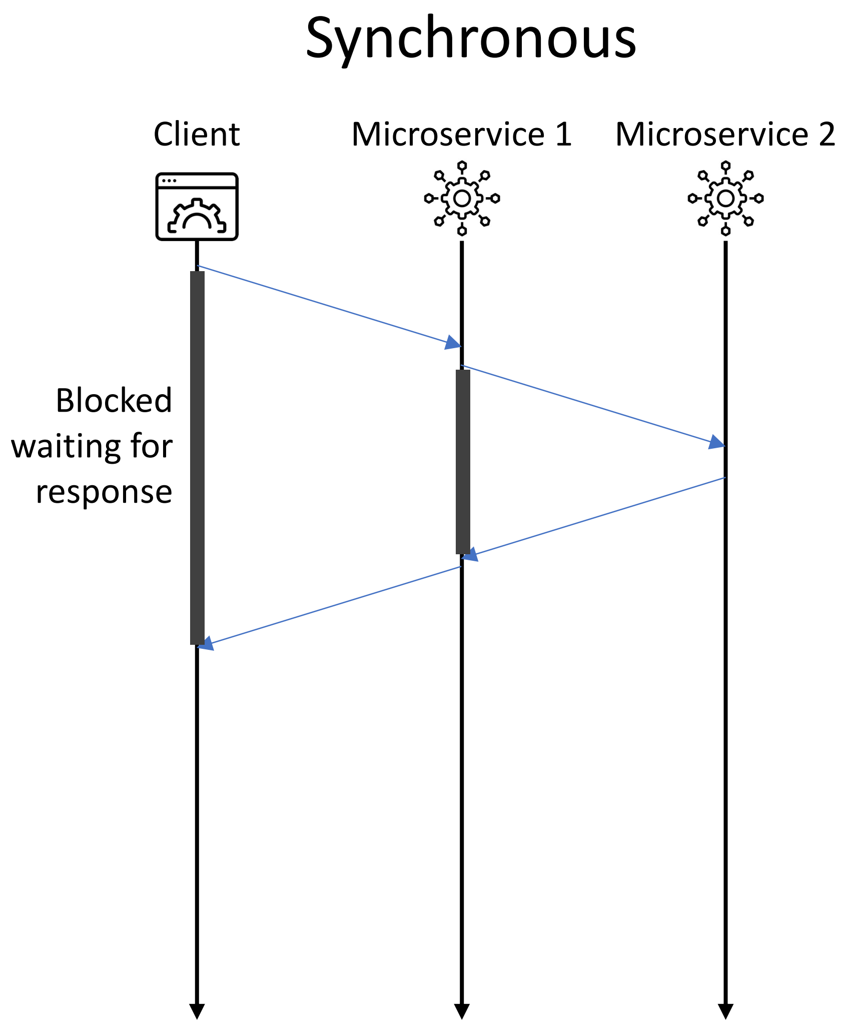

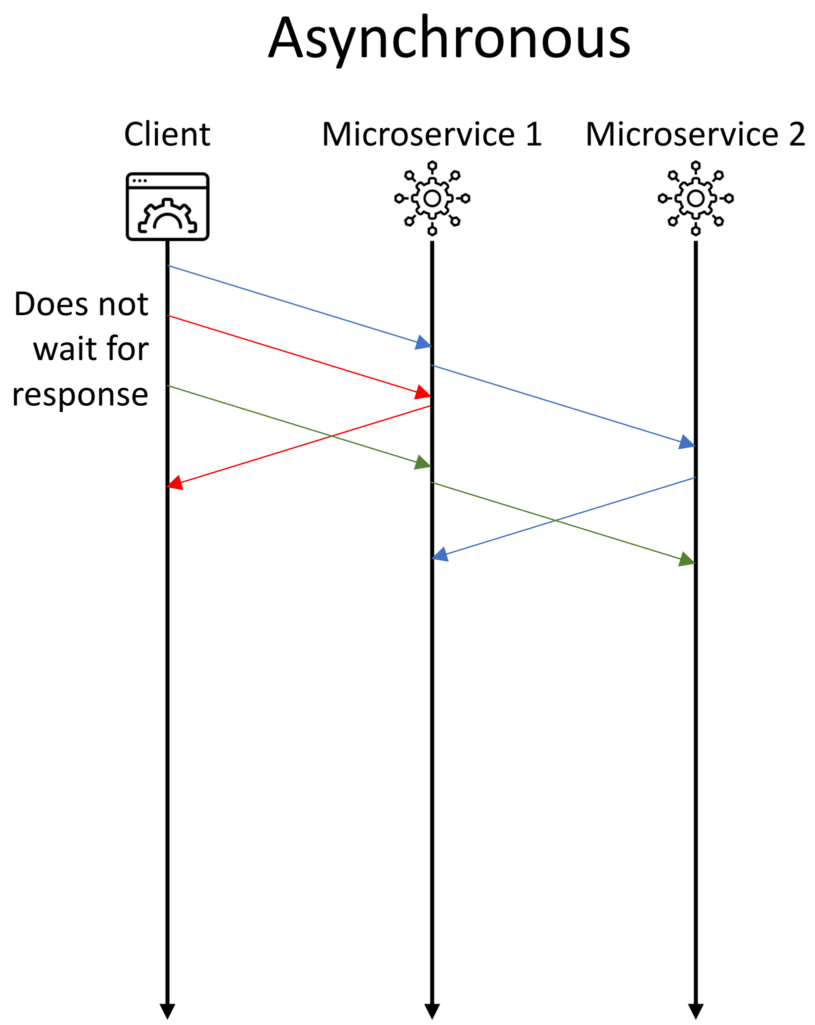

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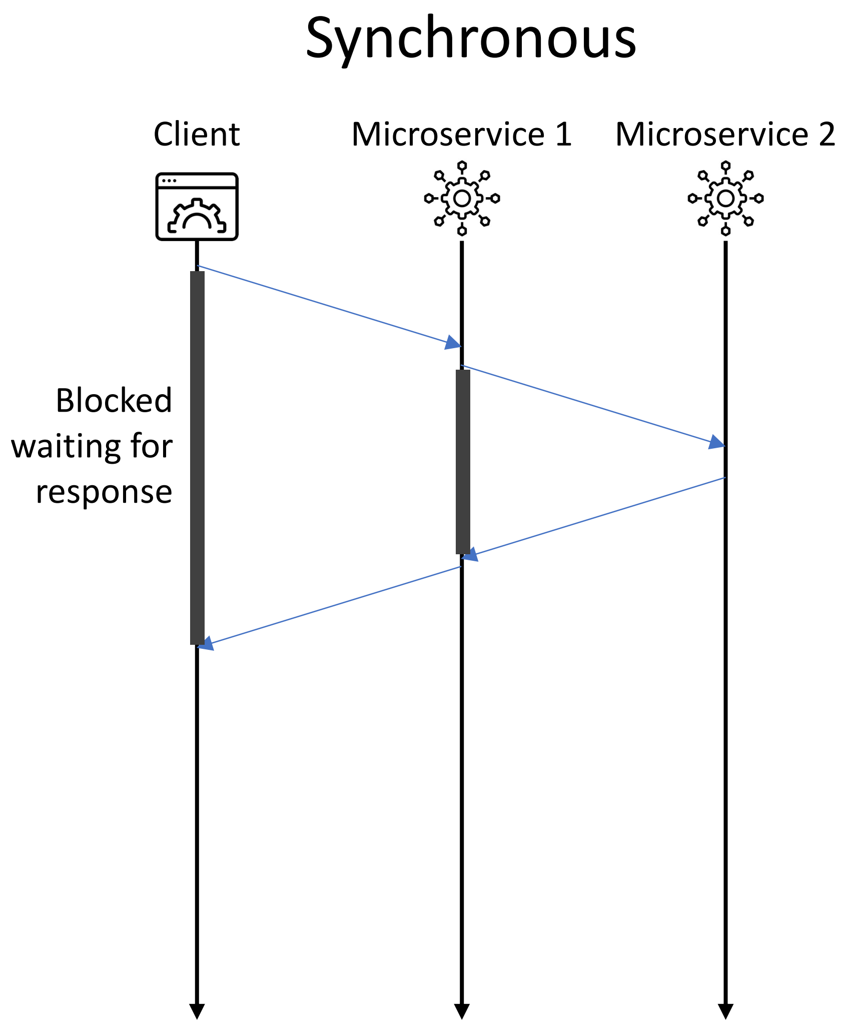

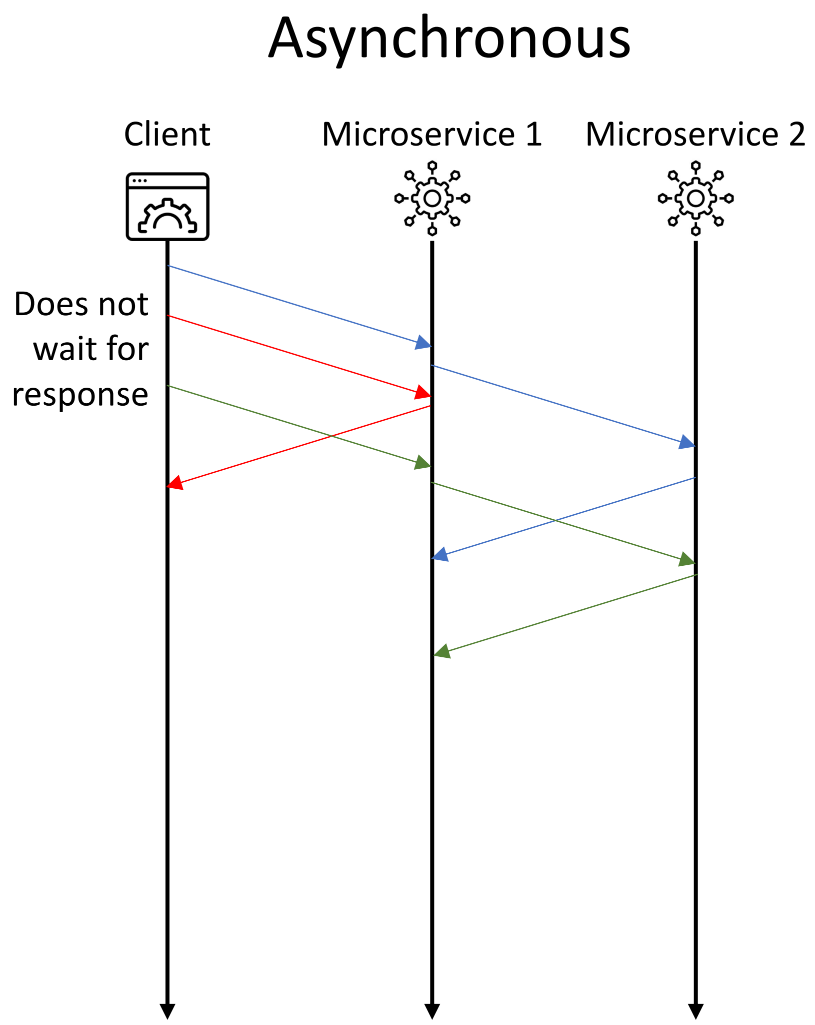

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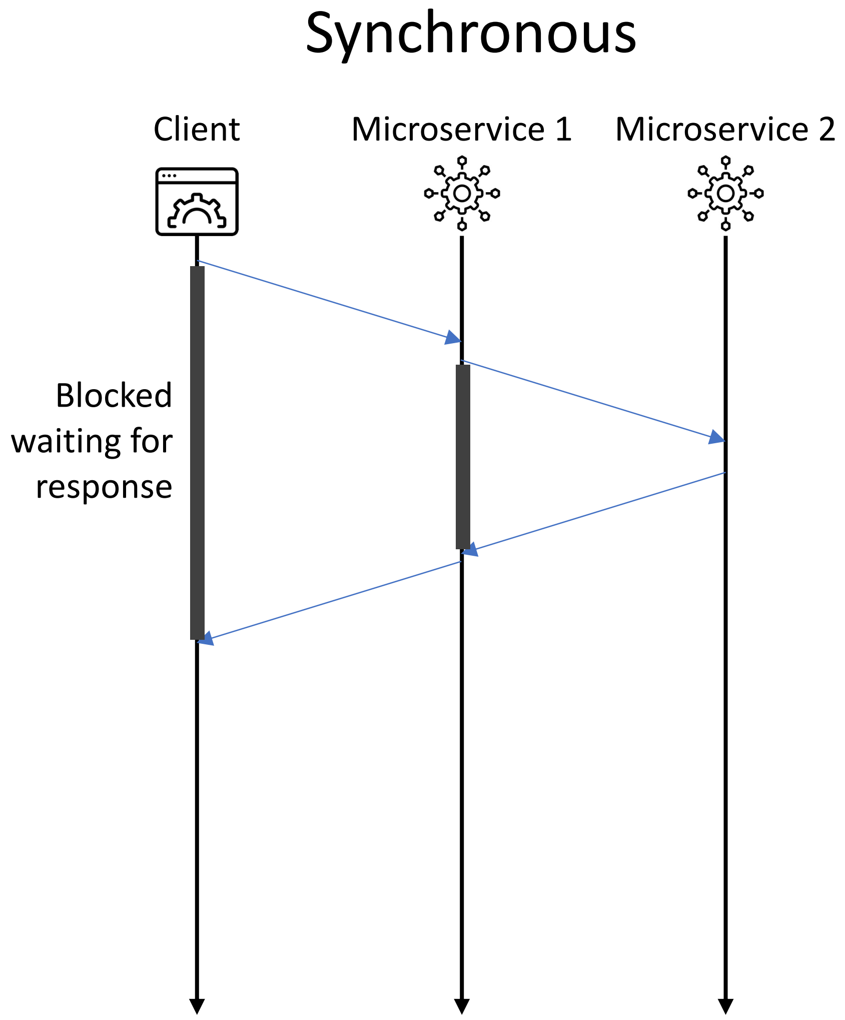

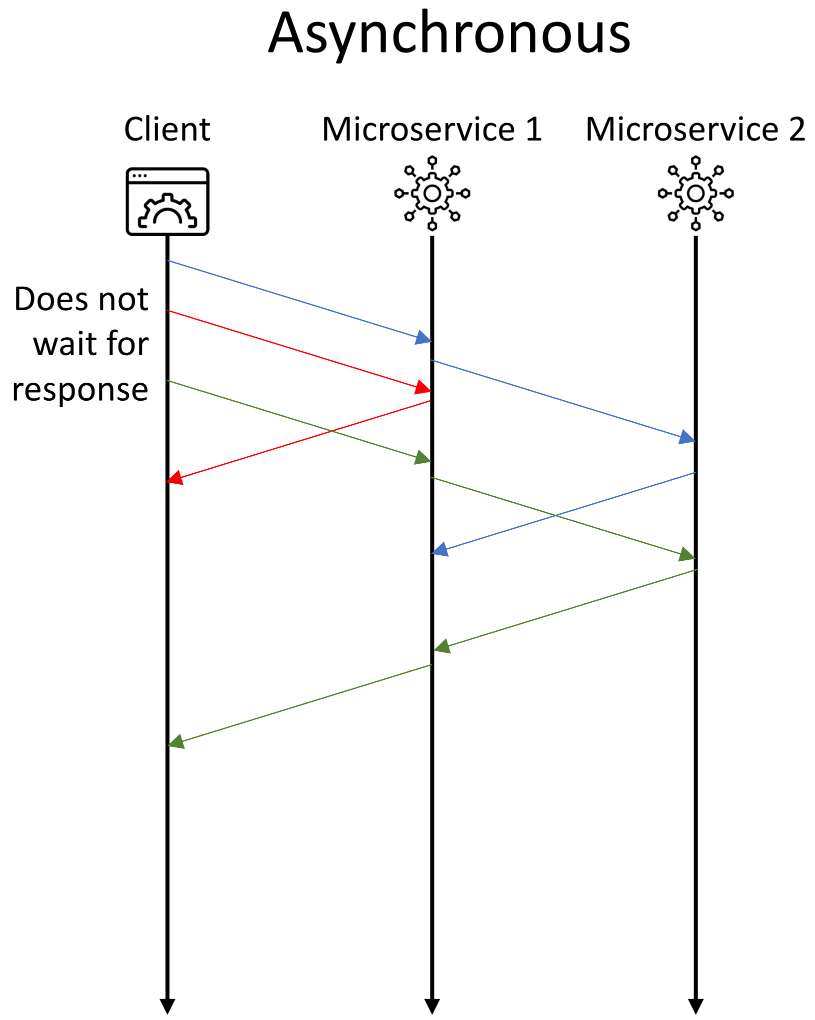

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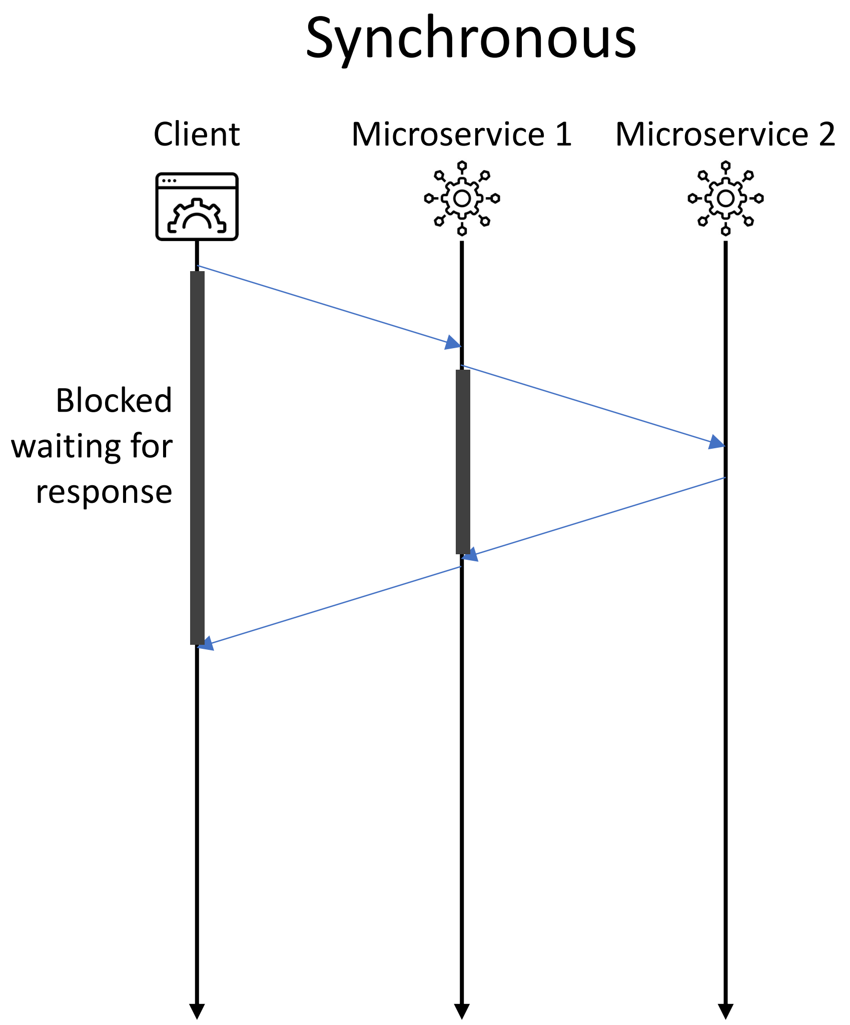
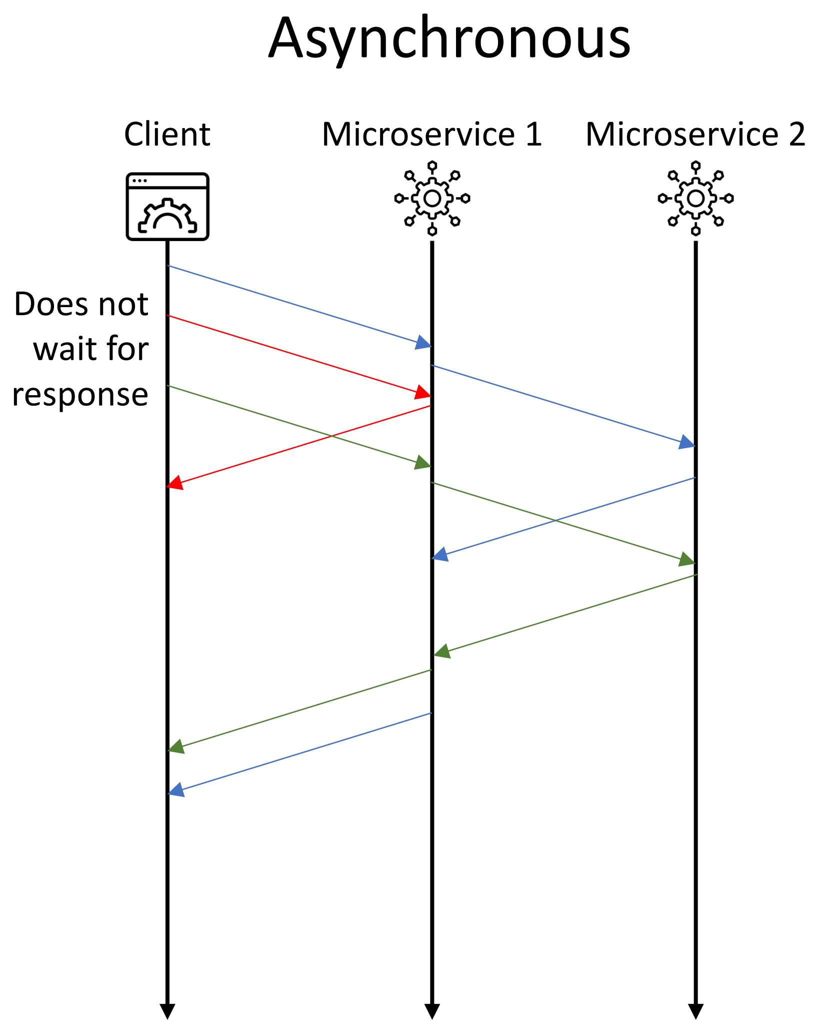
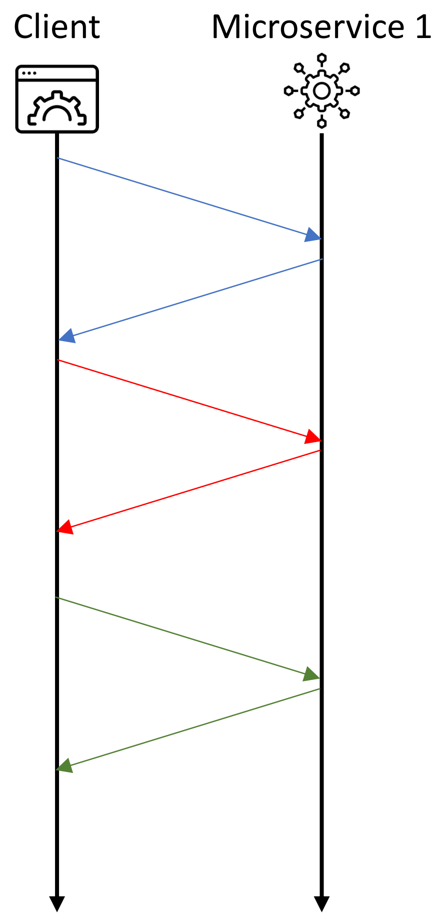




Communication patterns

Request/Response



Communication patterns

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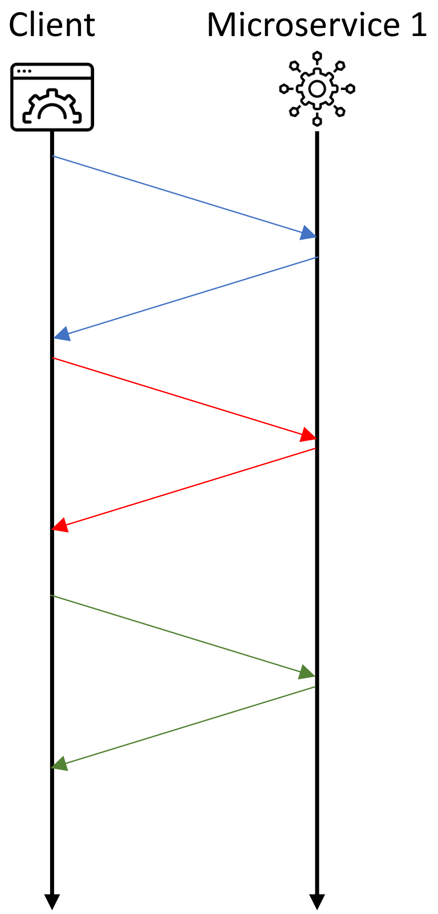
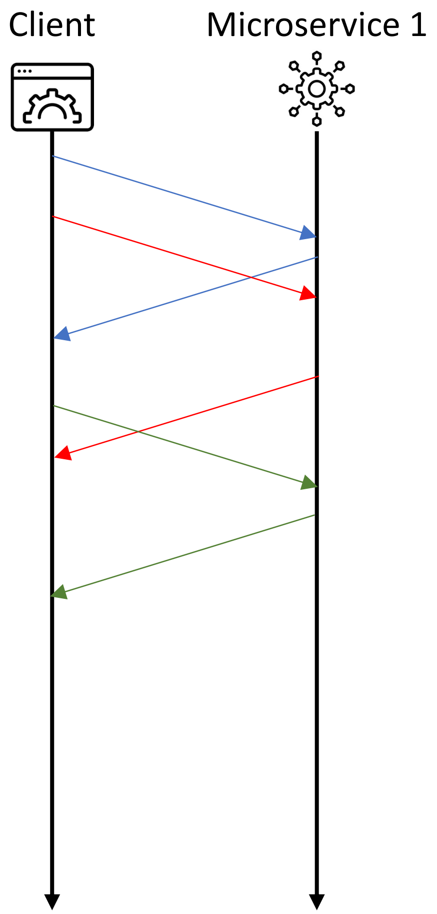


Request/Response (async)



Communication patterns

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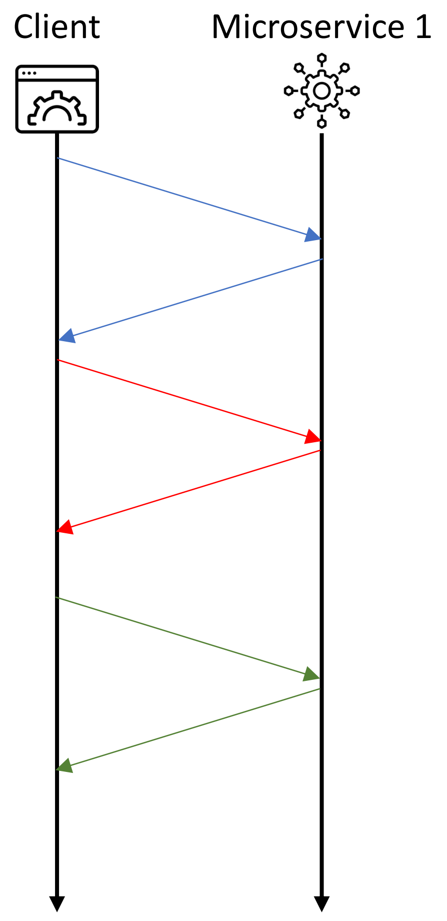
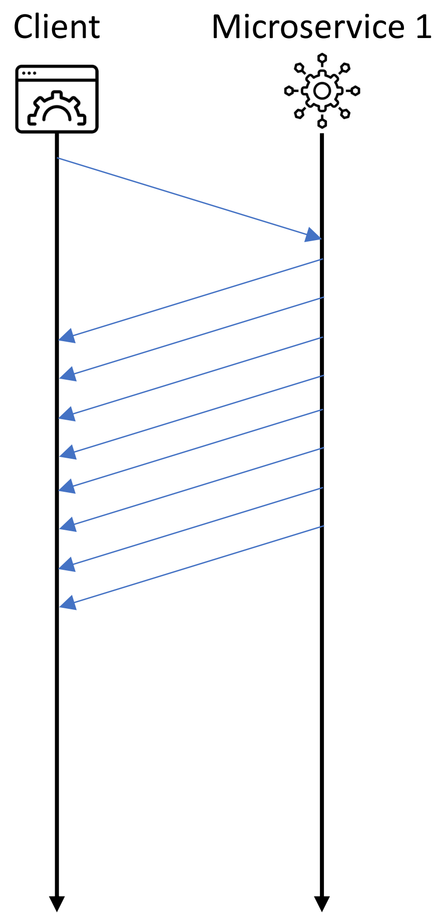


Streaming



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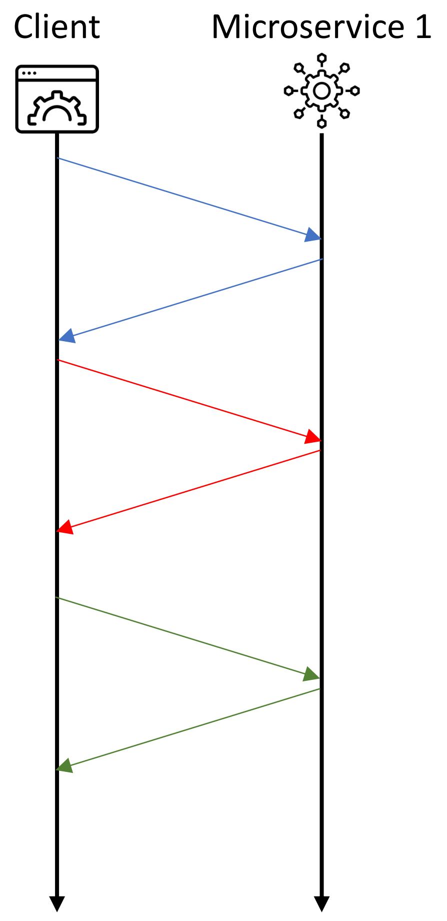

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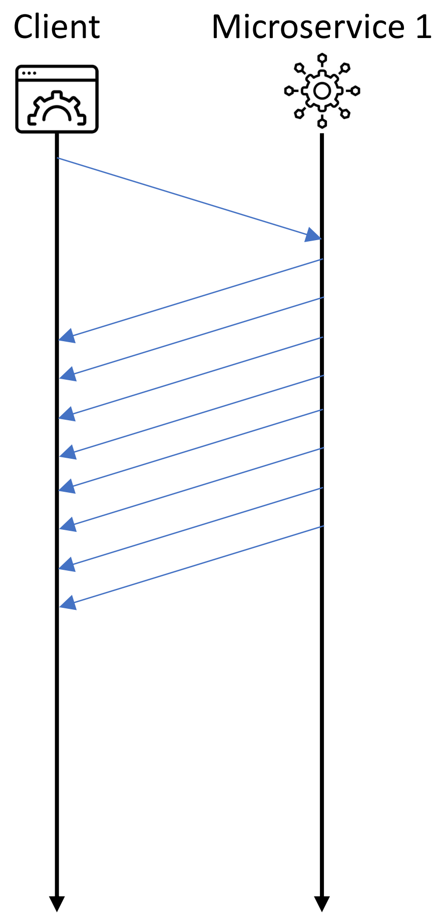
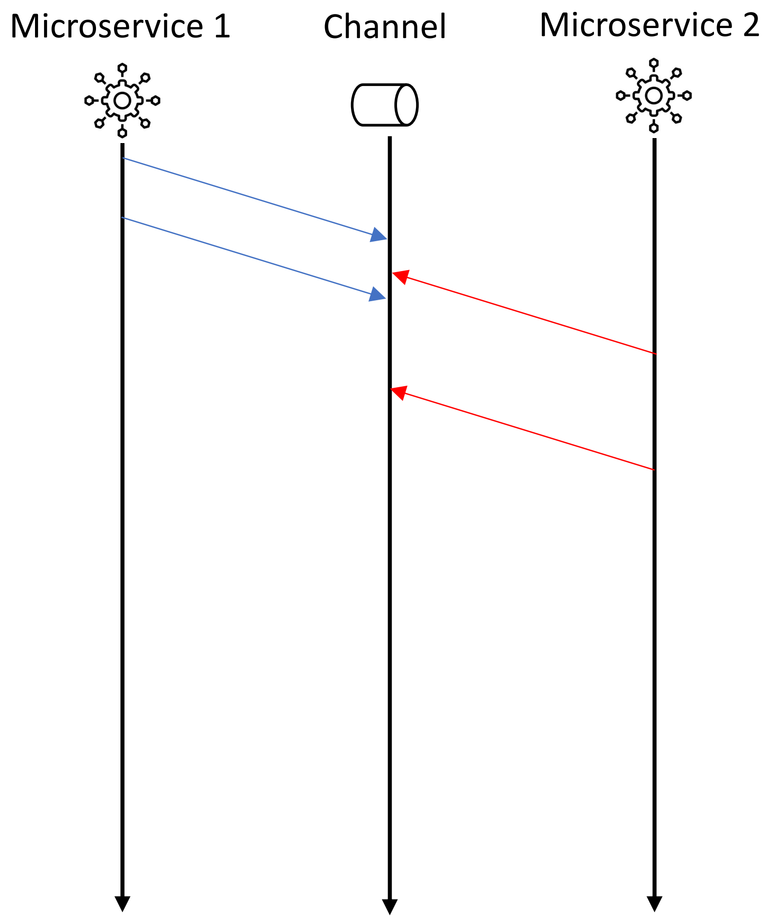


Message Passing



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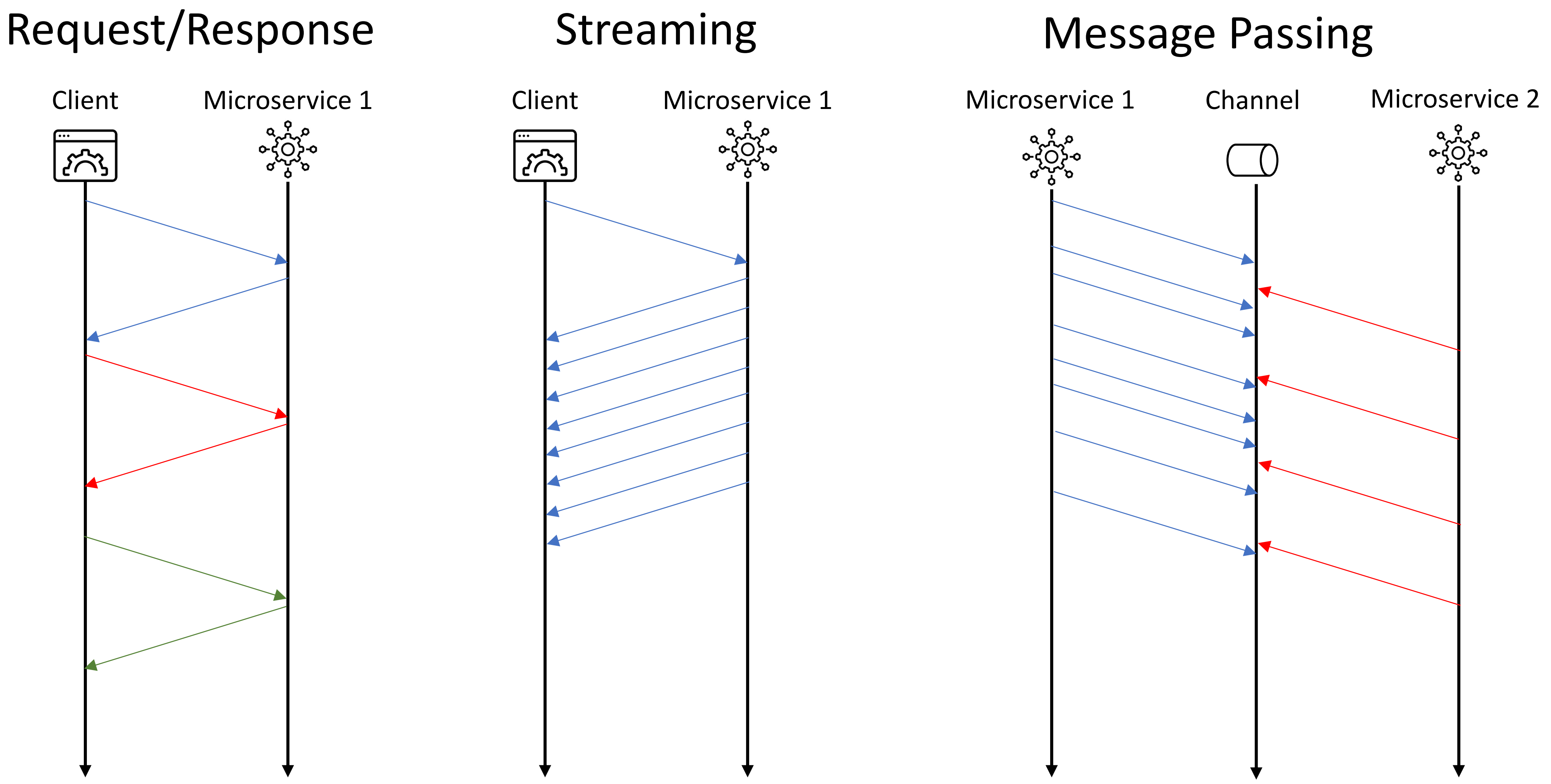
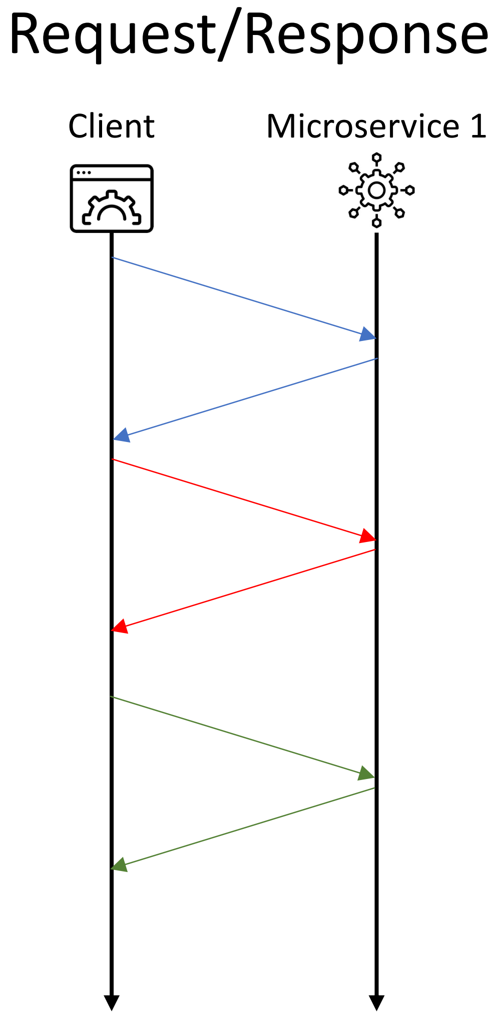
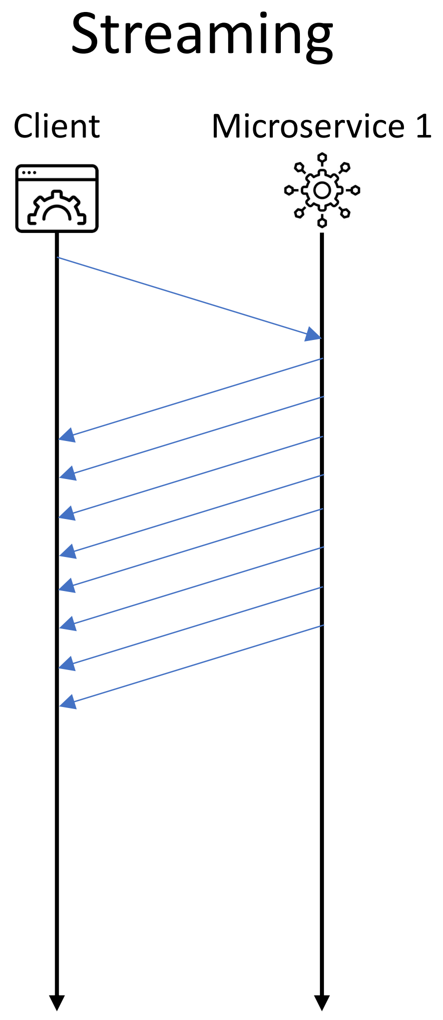
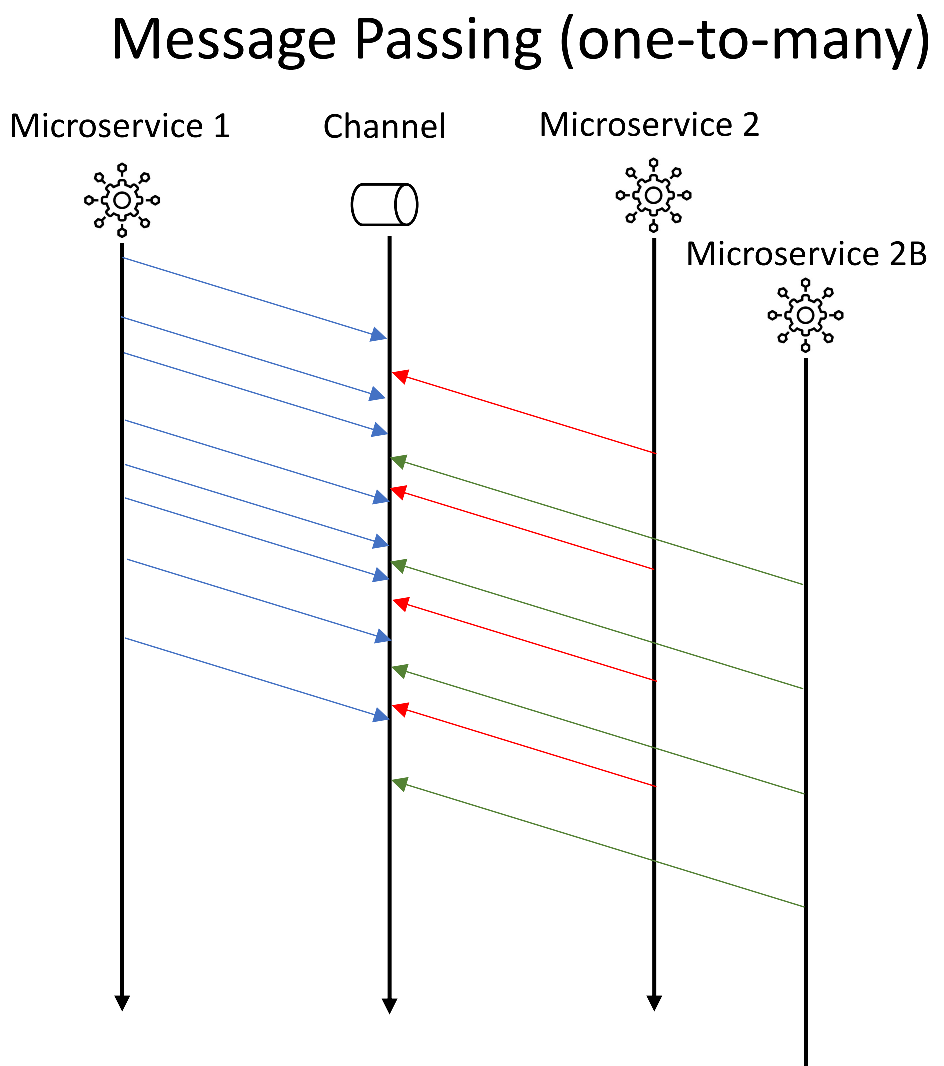


Communication patterns







Communication technologies

	Request/Response	Streaming	Message Passing
Synchronous	{REST} gRPC	🚫	🚫
Asynchronous	gRPC	RabbitMQ gRPC APACHE kafka	RabbitMQ APACHE kafka

Message and data encoding

- Text
  - JSON
  - XML
  - YAML
  - CSV
  - …
- Binary
  - Pickle
  - ProtoBuf
  - Cap’n Proto
  - …

Message and data encoding

- Text
  - JSON
  - XML
  - YAML
  - CSV
  - …
- Binary
  - Pickle
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  - Cap’n Proto
  - …

Editable, easily viewable

Smaller size, faster encoding and decoding

Message and data encoding

- Text
  - JSON
  - XML
  - YAML
  - CSV
  - …
- Binary
  - Pickle → Language specific (Python)
  - ProtoBuf → Language agnostic
  - Cap'n Proto
  - …

```
@0xdbb9ad1f14bf0b36;  # unique file ID

struct Person {
  name @0 :Text;
  birthdate @3 :Date;

  email @1 :Text;
  phones @2 :List(PhoneNumber);

  struct PhoneNumber {
    number @0 :Text;
    type @1 :Type;

    enum Type {
      mobile @0;
      home @1;
      work @2;
    }
  }
}

struct Date {
  year @0 :Int16;
  month @1 :UInt8;
  day @2 :UInt8;
}
```

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Service Meshes

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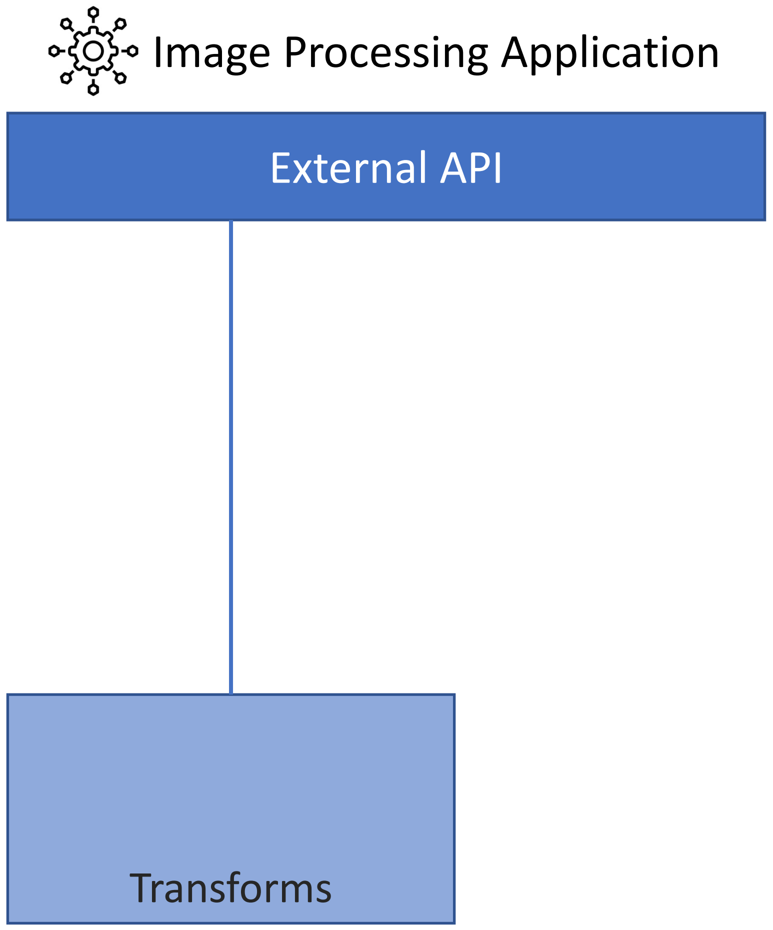
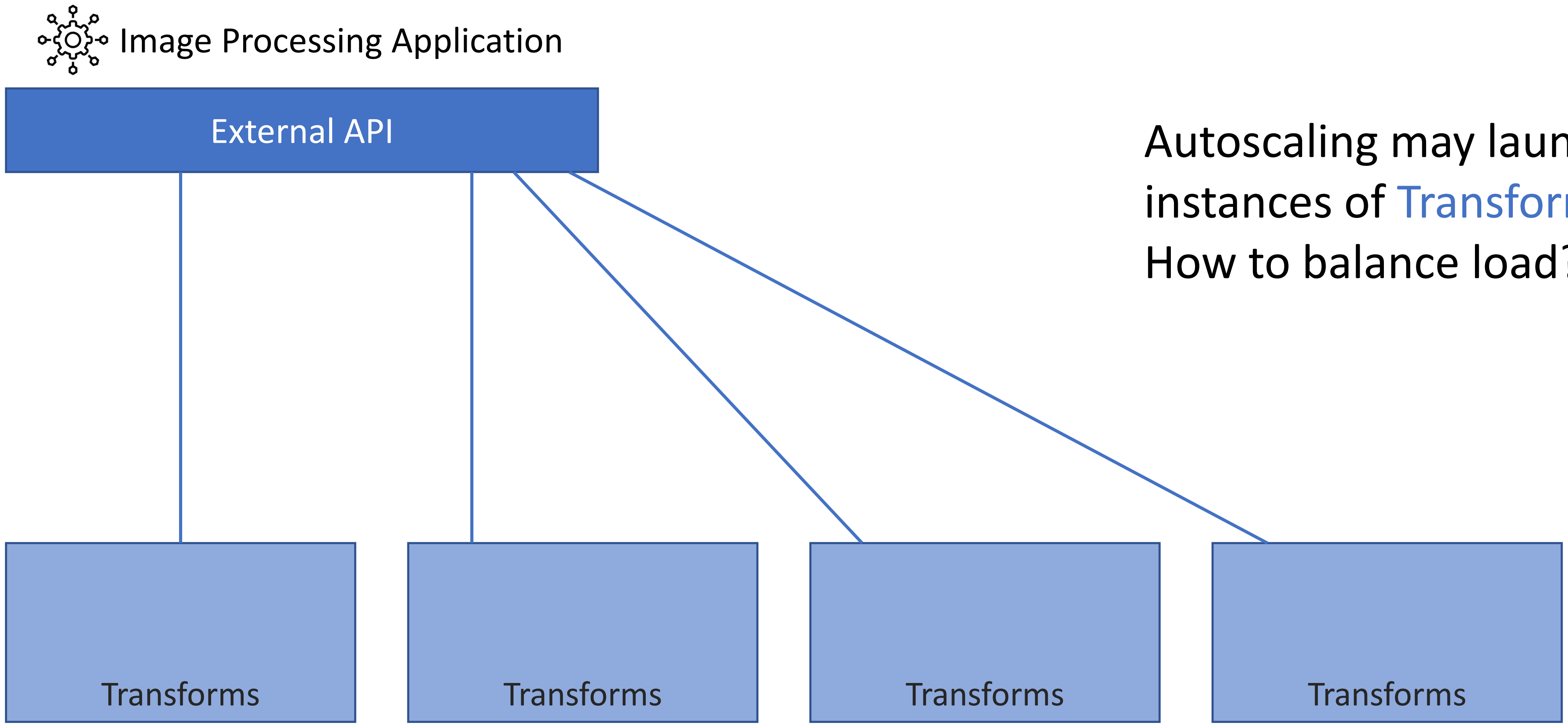
Service mesh

- Orchestration for microservice communications
  - Load balancing
  - Discovery (compatible with autoscaling)
  - Security
  - Monitoring
- Service-to-service (internal communication)
- Client-to-service (external communication)

Service mesh

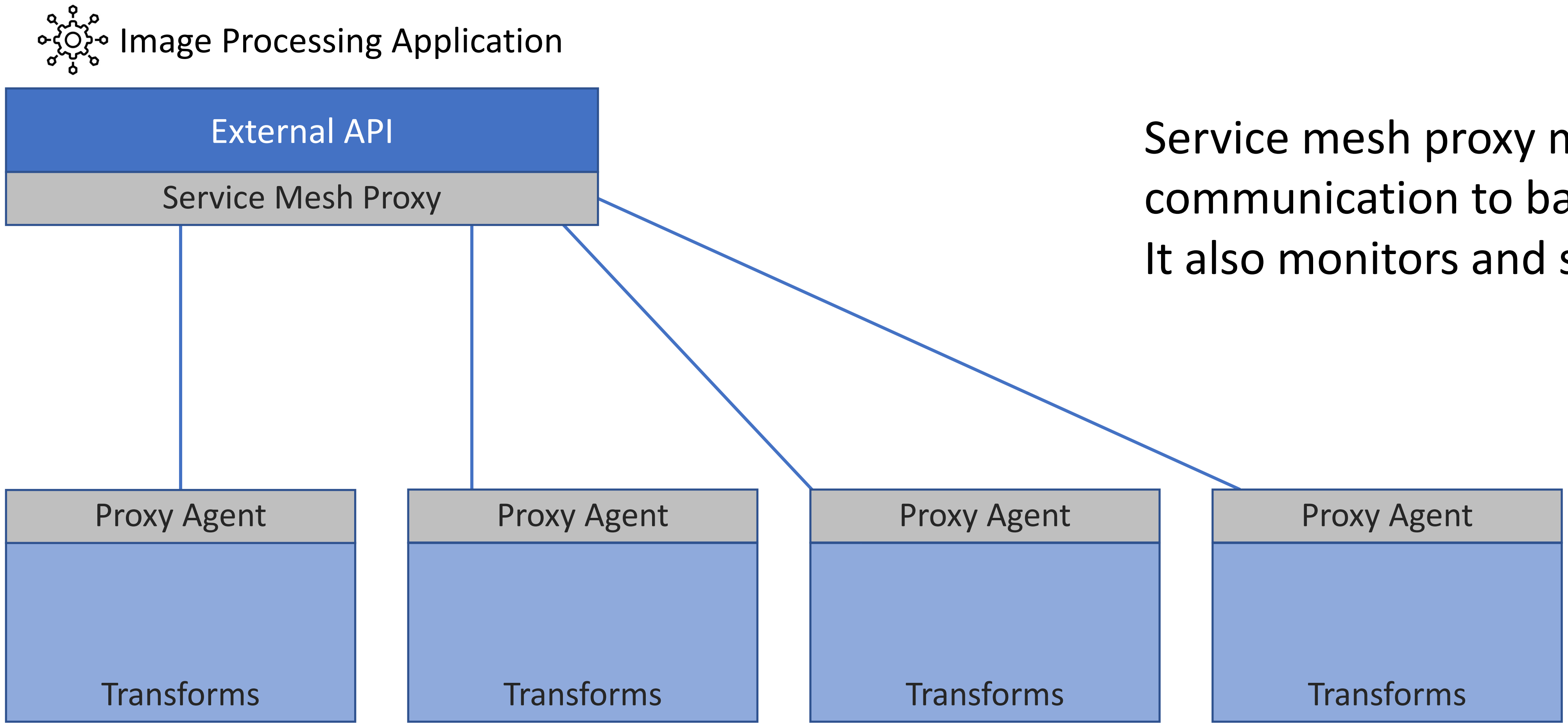


Service mesh



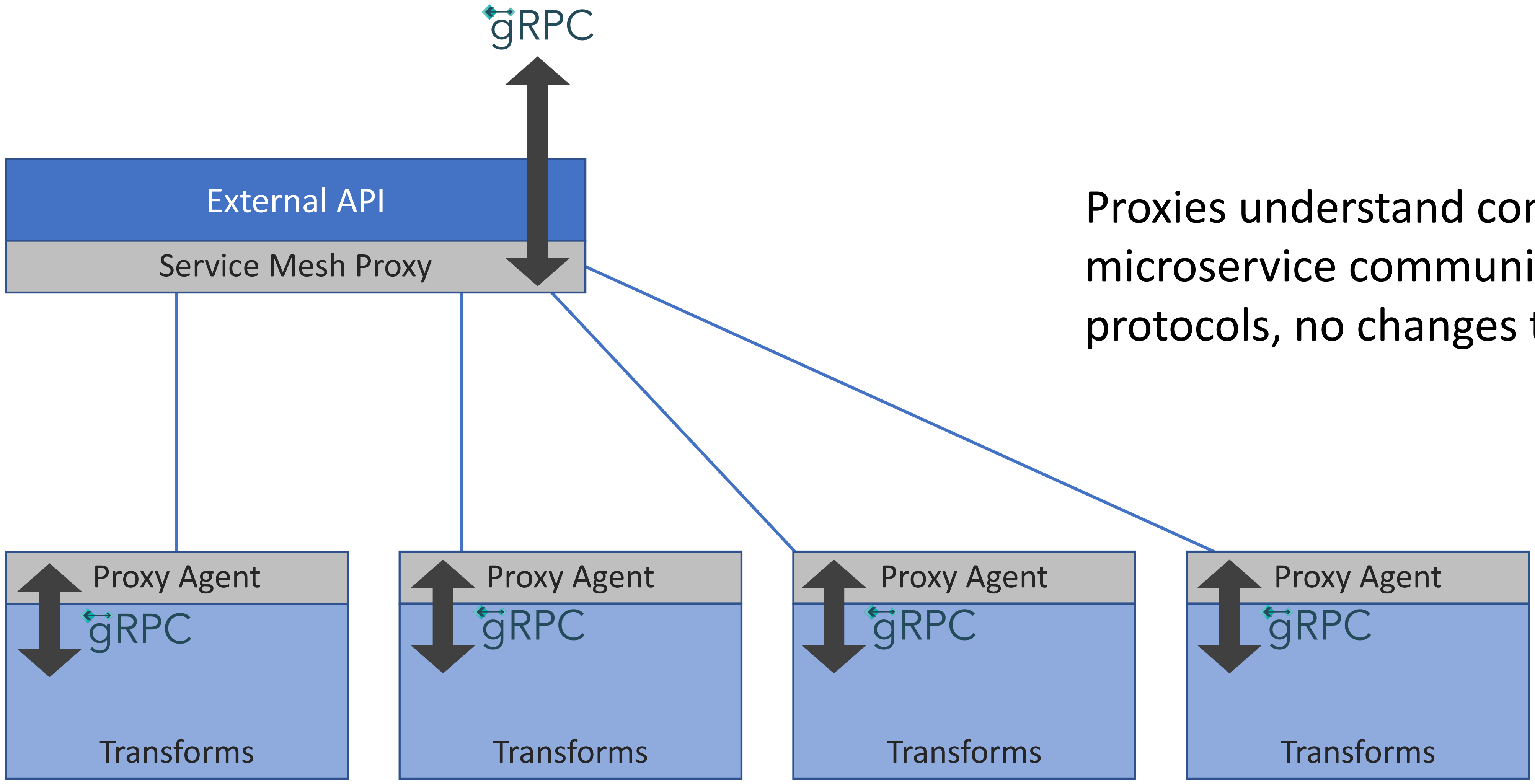
Autoscaling may launch more instances of Transform.
How to balance load?

Service mesh proxy



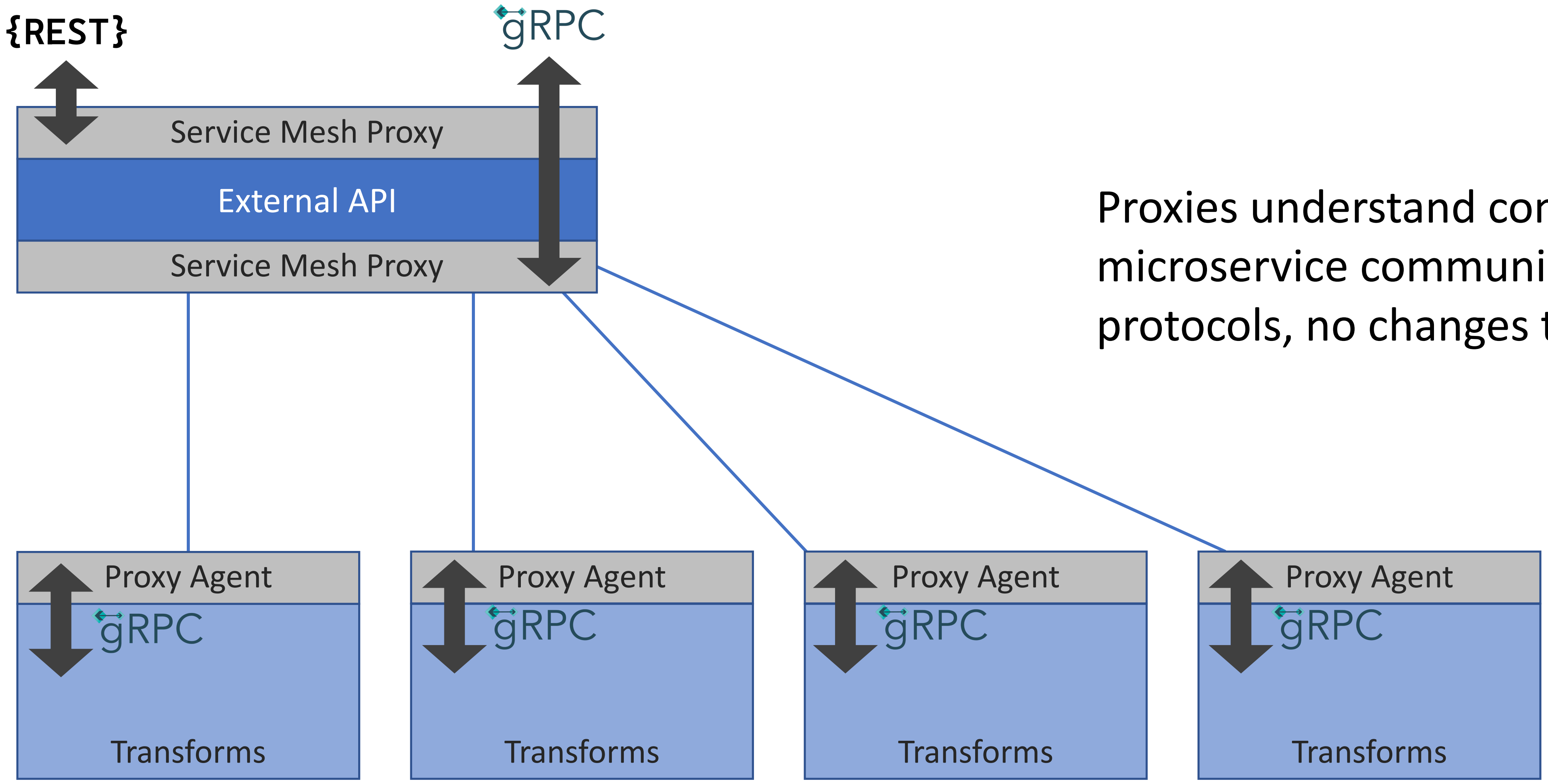
Service mesh proxy mediates all communication to balance load.
It also monitors and secures traffic.

Service mesh proxy



Proxies understand common microservice communication protocols, no changes to code.

Service mesh proxy



Proxies understand common microservice communication protocols, no changes to code.