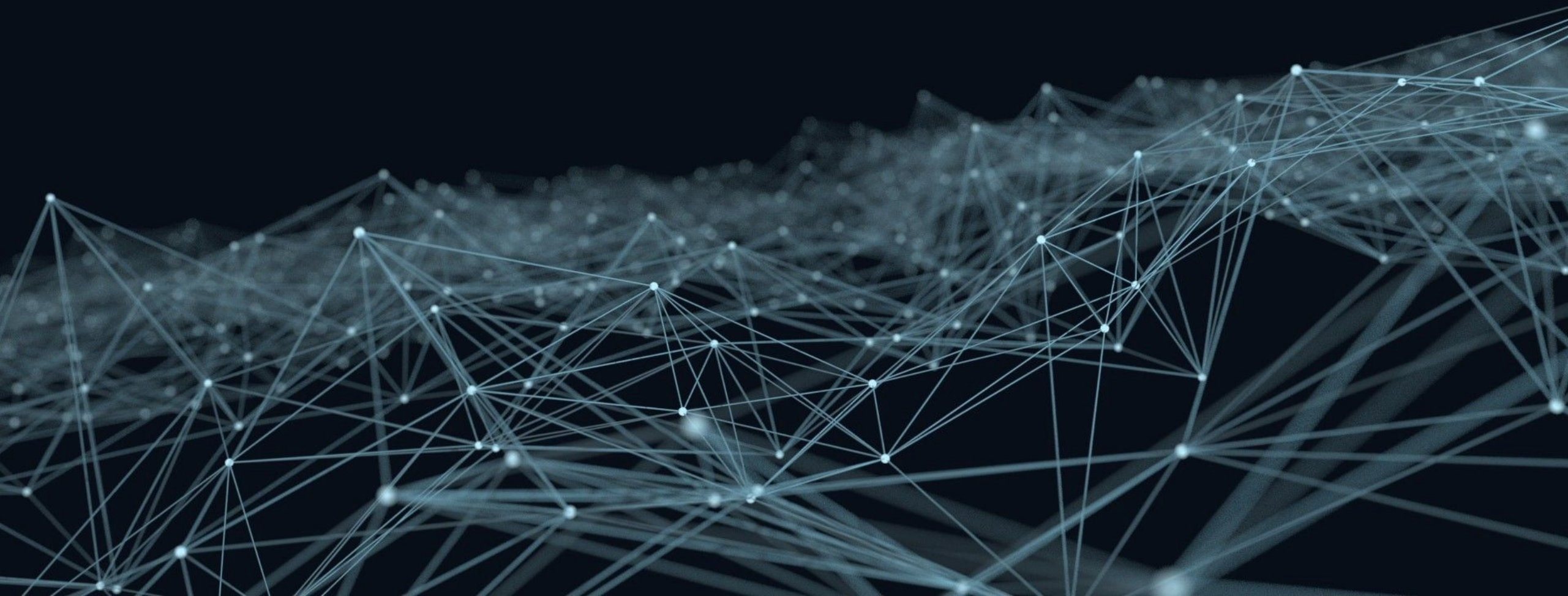
Microservices Architecture

Introduction to Microservices

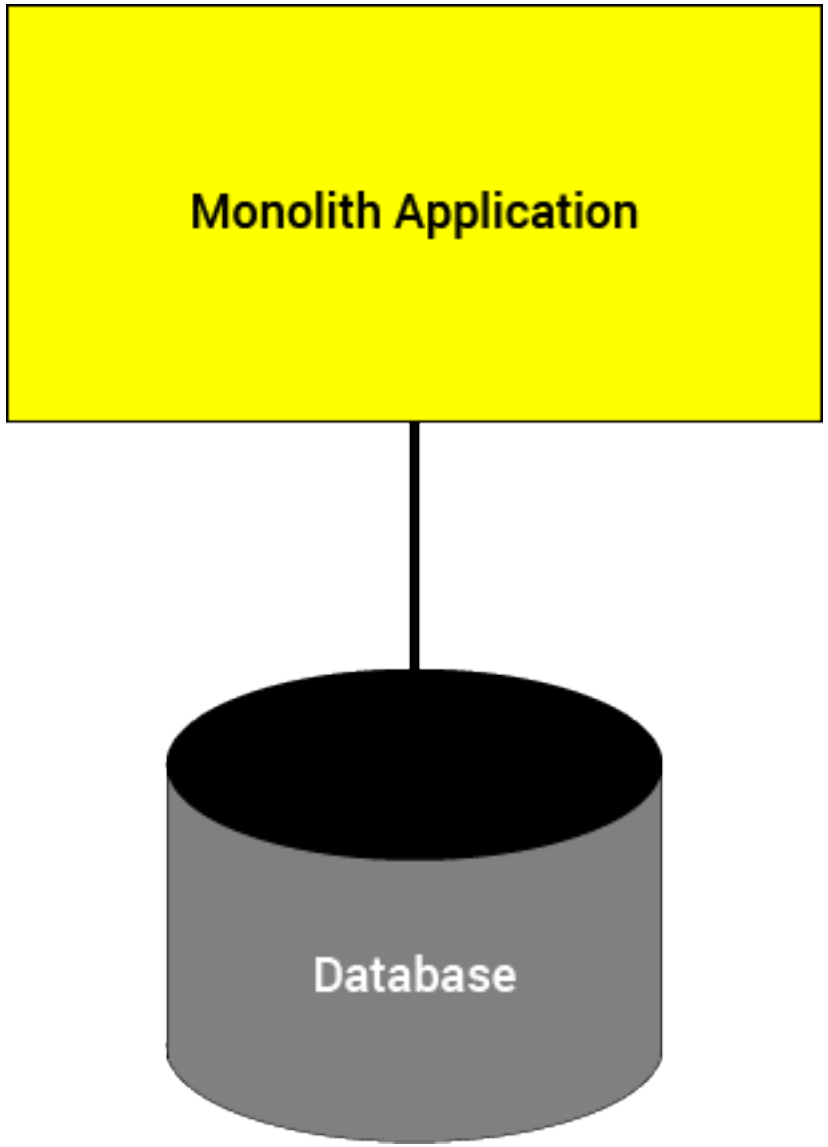


Introduction

- Microservices are a software architectural pattern
- There are specific challenges that they solve effectively
  - These are generally issues around scaling in both the development and operations
  - Microservices are not a “magic” bullet, sometime they are the wrong choice
- Deploying microservices requires
  - Supporting technologies in operations – for example: Kubernetes, Kafka, Docker
  - Analysis and design techniques for building a component based software architecture
  - Code and application design techniques to make code “microservices ready”
  - Production techniques to support the successful deployment of a microservice
- This first module will cover a number of foundational ideas that will be used in the following modules

Monolith Application

- Characterized by a single code base
  - May be modular at the programming language level
- Integrated with a single database
  - All code uses a common schema
- “Monolith” means
  - If a change to the code base or to the data schema
  - Then the entire application needs to be redeployed

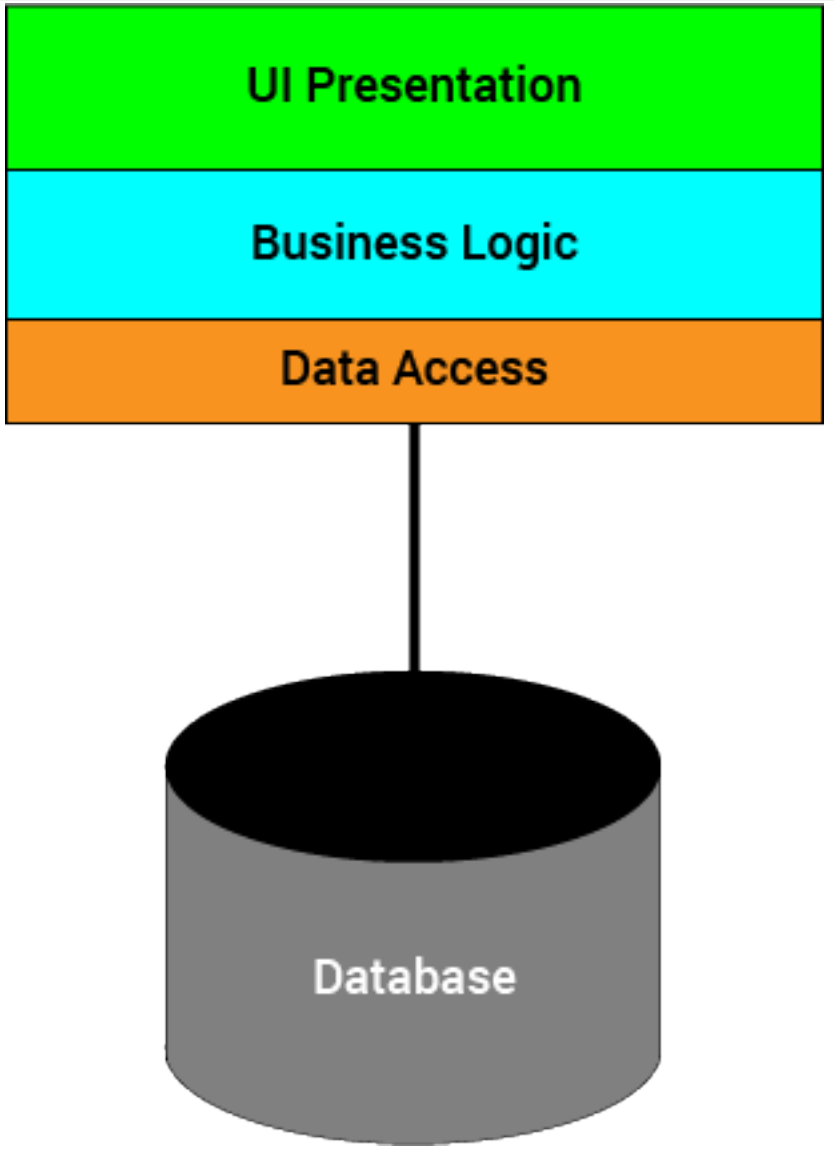


Business Analogy

- Start-up businesses are monoliths
- There are a few people who do everything
- The enterprise is small enough that this model works
  - It’s actually counterproductive to have a highly structured departmental organization with just a few employees
- Early versions of applications are similar
  - Simple enough that all of the code is manageable
  - Single code base for the whole app
  - Flat or minimal architectural structure

Modular Monolith Application

- Code is modularized
- Organized along job descriptions
  - Front end dev has their modules
  - Programmers have their modules
  - Data engineers have their modules
- Shows up historically as a n-tier architecture

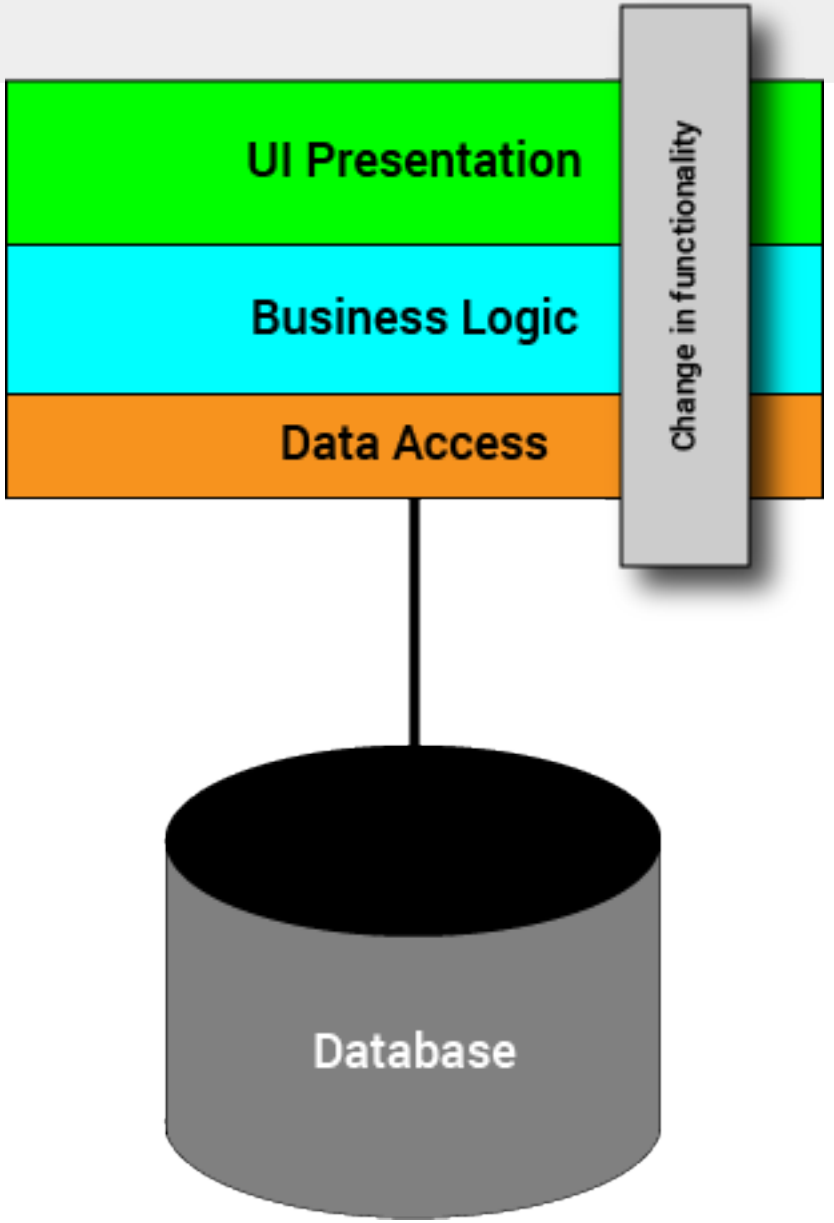


Business Analogy

- As start-up grows, it adds more people
- The original organization starts to become ineffective
  - The entrepreneurial “all hands-on deck” model doesn’t scale well
  - Processes become chaotic
  - Difficult to manage
  - Productivity stalls
- At some point the business must modularize
  - Usually by creating specialized departments
  - Accounting, sales, HR, etc.

Modular Monolith Application

- The application is still a monolith
- A change in functionality
  - Affects each layer because related changes have to be made in each layer
- Interacts with the data model
  - The data model may constrain what changes can be made
  - Changing the data model might break other parts of the app
- The modules and the database often show high coupling
  - Due to how the modules are defined



Pros and Cons of Monoliths

Pros

- Simple to develop
- Simple to test
- Simple to deploy
- Simple to scale horizontally
  - Run multiple copies behind a load balancer
- Although persistence is problematic when using horizontal scaling

Cons

- The size of the application can slow down the start-up time
- The entire application must be redeployed on each update
- Monolithic applications can also be challenging to scale vertically
- Reliability – easy to crash the whole application
- Difficult to migrate to new technologies

Legacy Monolithic Issues

- Codebase is enormous
  - Little or no documentation
  - Coupled to legacy technology
- Eg. Internal Revenue Service
  - Running 1960s vintage code
  - Application highly complex
  - Attempts to replace it have failed
  - Over $15 billion so far
- The IRS is not unique
  - Migrating legacy monolith to a modern monolith is not an option

Scaling in Systems

- Scaling is an increase in size or quantity along some dimension
- Can take place in the development or operations space
- Development scaling
  - Increase in complexity, functionality or volume of code
  - These dimensions are often related
  - Business analogy is a company increasing the range of services and products they offer or expanding into different markets (like a Canadian company expanding into Europe)
- Operational scaling
  - Increase in the amount of activity of a system
  - Throughput, load, transaction time, simultaneous users, etc
- Traditional monoliths tend to be scalable only to a limited degree
  - There is a certain level of complexity after which they become unmaintainable

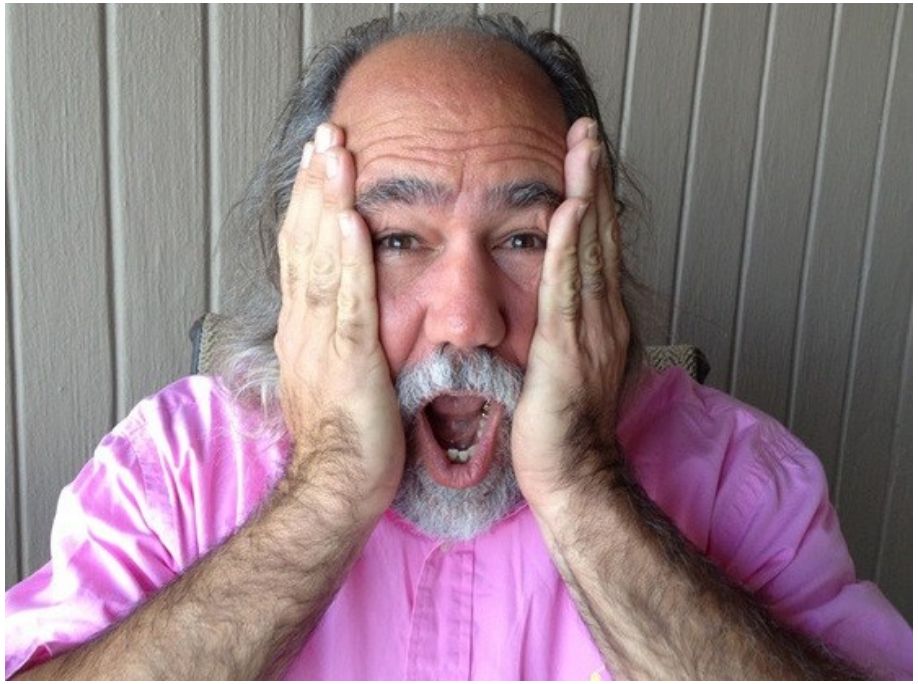
Mission Critical Industrial Strength Software

Mission critical software tends to have a long lifespan, and over time, many users come to depend on their proper functioning. In fact, the organization becomes so dependent on the software that it can no longer function in its absence. At this point, we can say the software has become industrial-strength.

The distinguishing characteristic of industrial strength software is that it is intensely difficult, if not impossible, for the individual developer to comprehend all of the subtleties of its design.

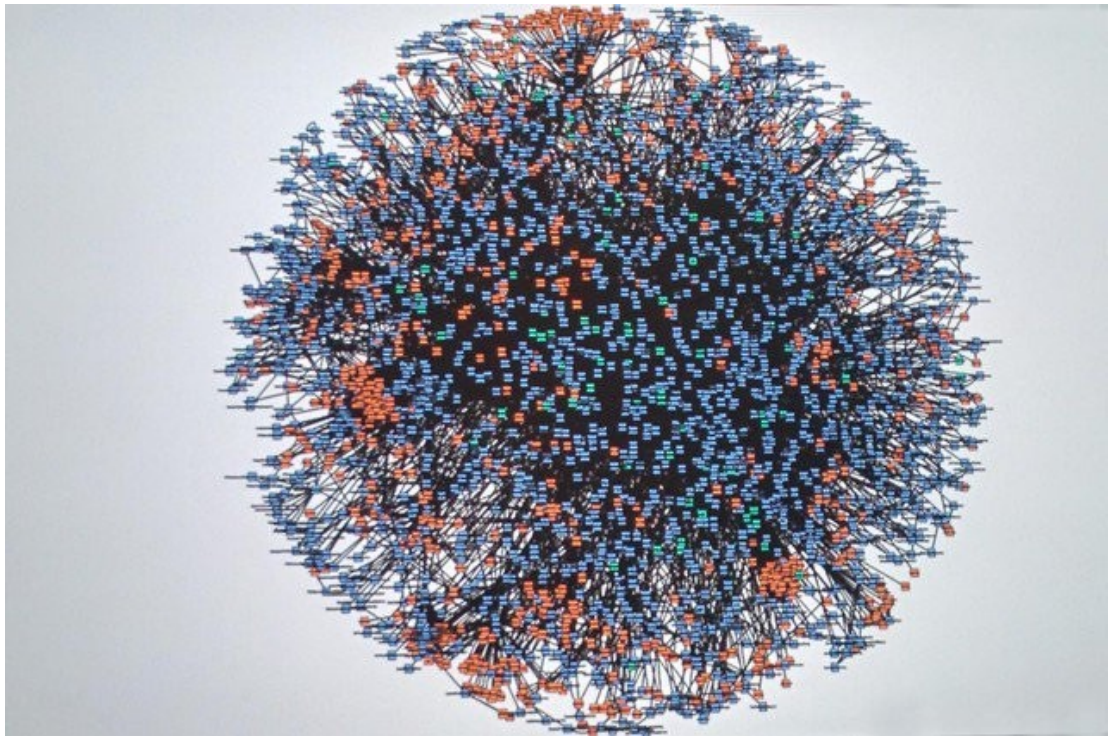
Stated in blunt terms, the complexity of such systems exceeds the human intellectual capacity. Alas, this complexity we speak of seems to be an essential property of all large software systems. By 'essential' we mean that we may master this complex ity, but we can never make it go away.

Grady Booch



Operational Complexity

- Modern applications have to deal with
  - Petabytes of streaming data
  - Billions of transaction
  - Mission critical fault tolerance
- Non-functional requirements
  - Throughput, response time, loading, stress
  - Disaster recovery, transaction time
- Results in a “death star” architecture
  - Image: Amazon in 2008
  - The complexity of the operational architecture is now industrial strength



IT Failures and Complexity

The United States is losing almost as much money per year to IT failure as it did to the [2008] financial meltdown. However the financial meltdown was presumably a onetime affair. The cost of IT failure is paid year after year, with no end in sight. These numbers are bad enough, but the news gets worse. According to the 2009 US Budget [02], the failure rate is increasing at the rate of around 15% per year.

Is there a primary cause of these IT failures? If so, what is it?.... The almost certain culprit is complexity.... Complexity seems to track nicely to system failure.

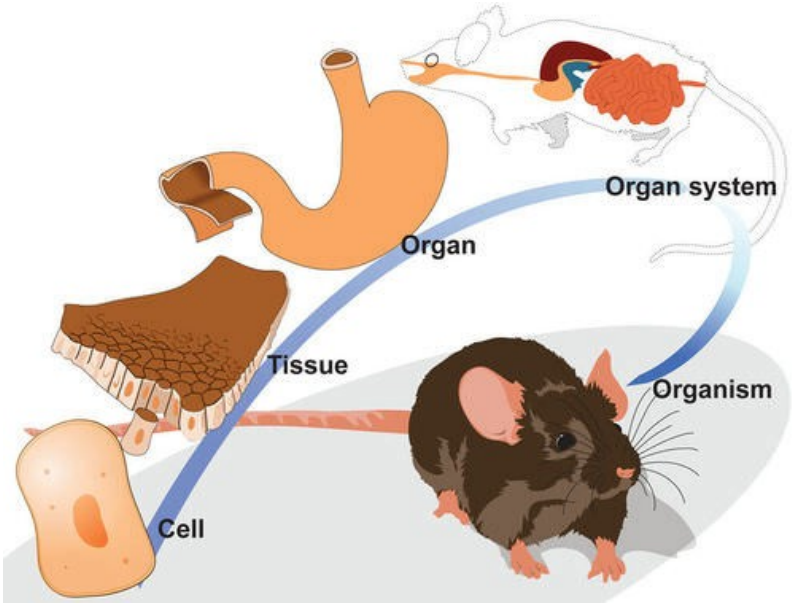
Once we understand how complex some of our systems are, we understand why they have such high failure rates.

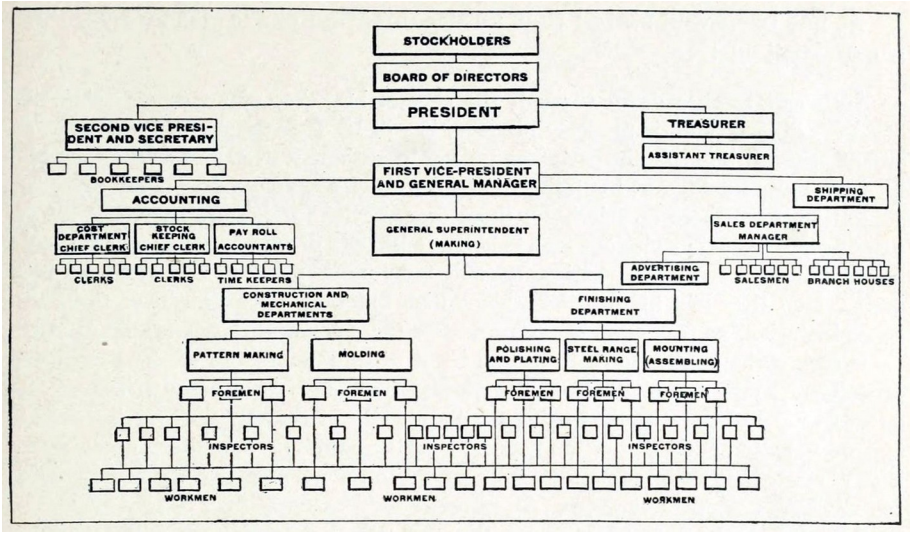
We are not good at designing highly complex systems. That is the bad news. But we are very good at architecting simple systems. So all we need is a process for making the systems simple in the first place.

Roger Sessions

Natural Systems Organization

- Naturally occurring systems scale successfully
  - Biological processes, social organization etc.
  - They all show similarities in organization regardless of domain
- Natural occurring systems tend to be
  - Recursive in structure
  - Hierarchical or layered
  - Modular at each layer
  - Loosely coupled and highly cohesive





Operational Complexity in Practice

- In production, systems have to scale operationally
- Consider a diner
  - During the lunch and dinner hour rush, the number of servers and cooks have to scale up
  - There has to be clear boundaries on what each role does
  - During non-peak hours, the amount of staff can be scaled down

Operational Complexity in Practice

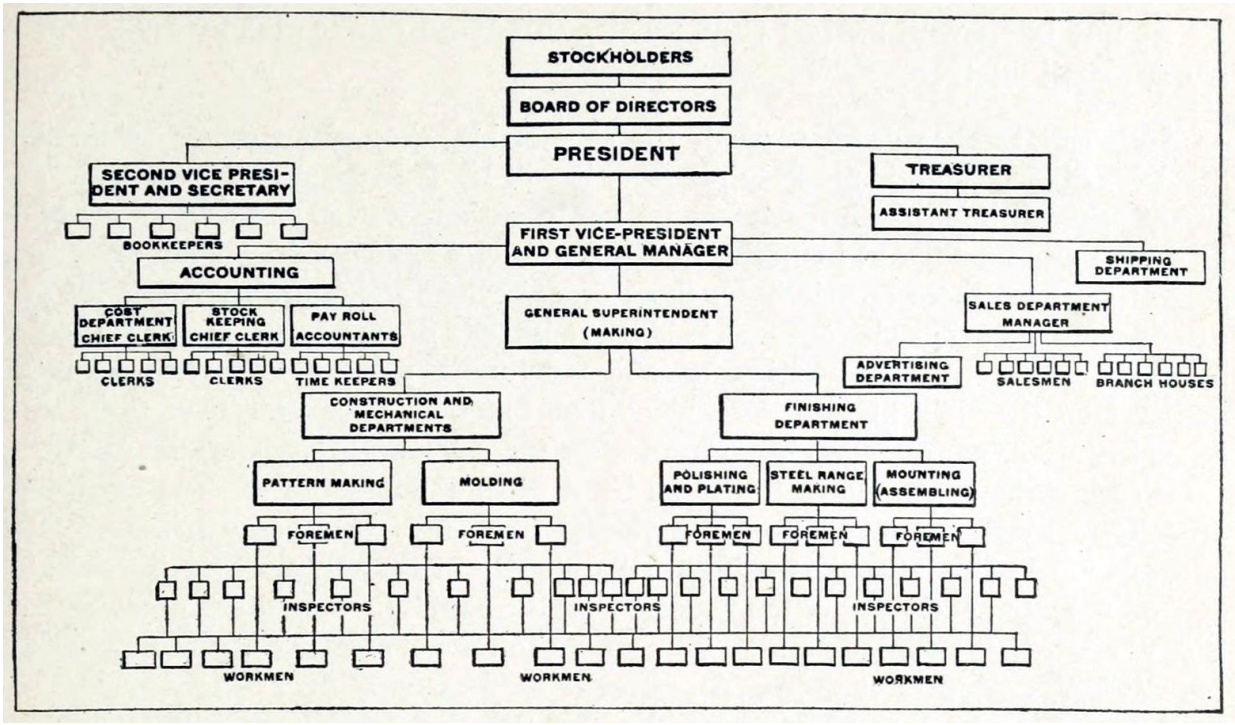
- Operations are specialized
- Tasks are broken down into sub-tasks, and sub-tasks broken down into sub-sub-tasks, and so on
- At some point
  - Specialized systems or agents perform an individual sub-task
  - These are all coordinated
- For example, the specialized positions on a sports team

Complex Systems

Frequently, complexity takes the form of a hierarchy, whereby a complex system is composed of interrelated subsystems that have in turn their own subsystems, and so on, until some lowest level of elementary components is reached

Courtois

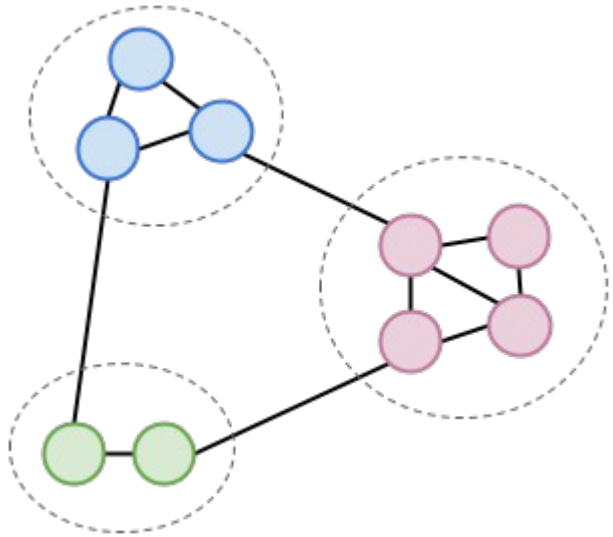
On Time and Space Decomposition of Complex Structures
Communications of the ACM, 1985, 28(6)



Complex Systems

Intra-component linkages are generally stronger than inter-component linkages. This fact has the effect of separating the high frequency dynamics of the components – involving the the internal structure of the components – from the low frequency dynamics – involving the interaction among components

Simeon



Complex Systems

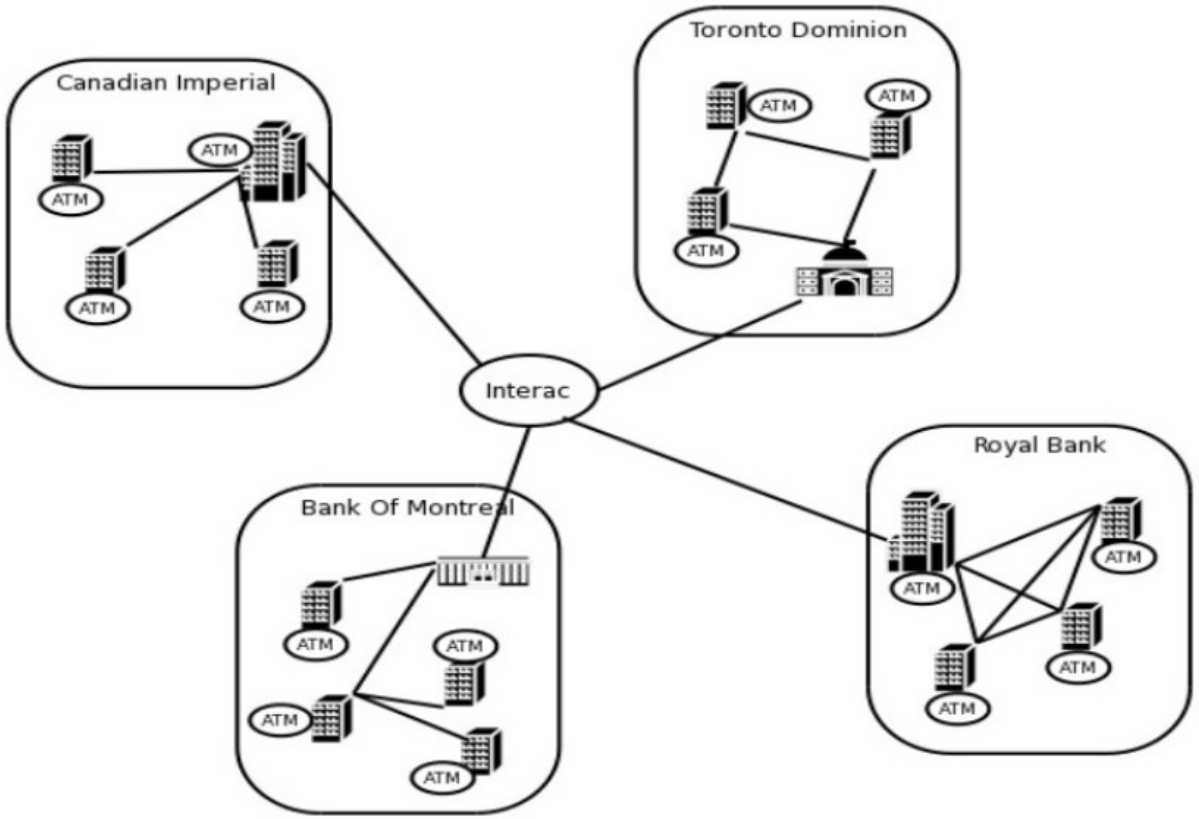
Hierarchical systems are usually composed of only a few different kinds of sub-systems in various combinations and arrangements

Simeon

A complex system that works is invariably found to have evolved from a simple system that worked. A complex system designed from scratch never works and can never be patched up to make it work. You have to start over, beginning with a simple working system.

John Gall

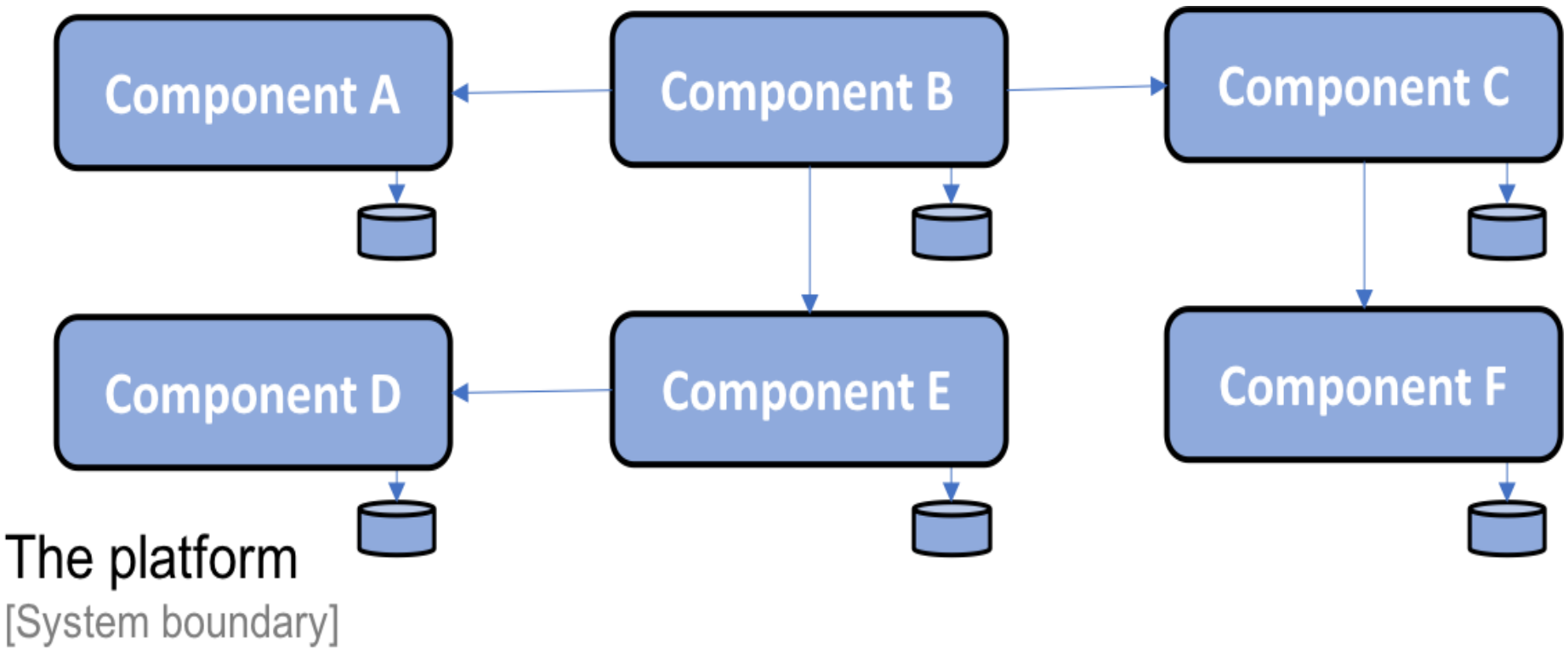
Systemantics: How Sytems Really Work an How They Fail
1975



Microservices

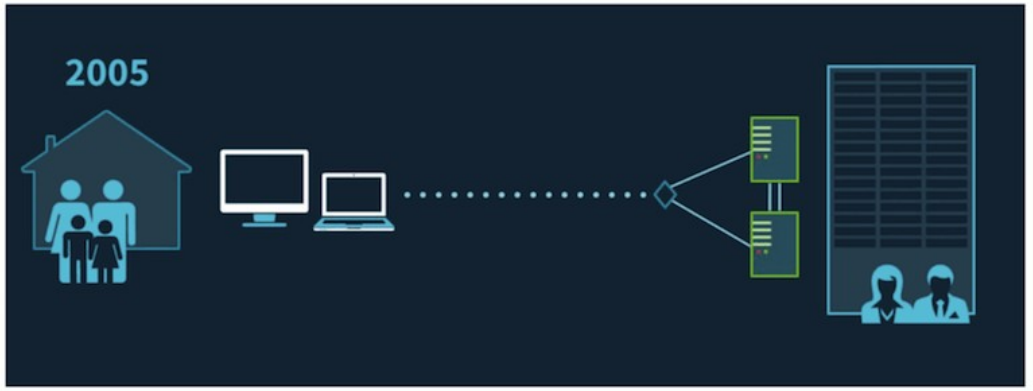
“The Microservice architectural style is an approach to developing a single application as a suite of small services, each running in its own process and communicating with lightweight mechanisms, often an HTTP resource API.”

Microservices

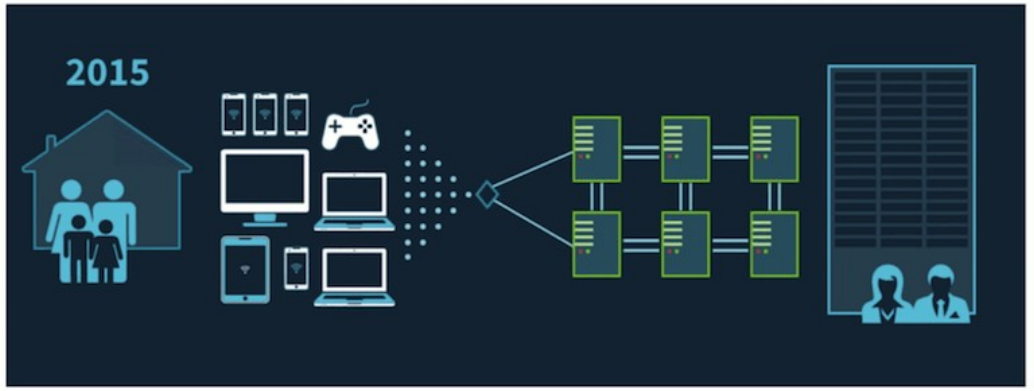


Microservices

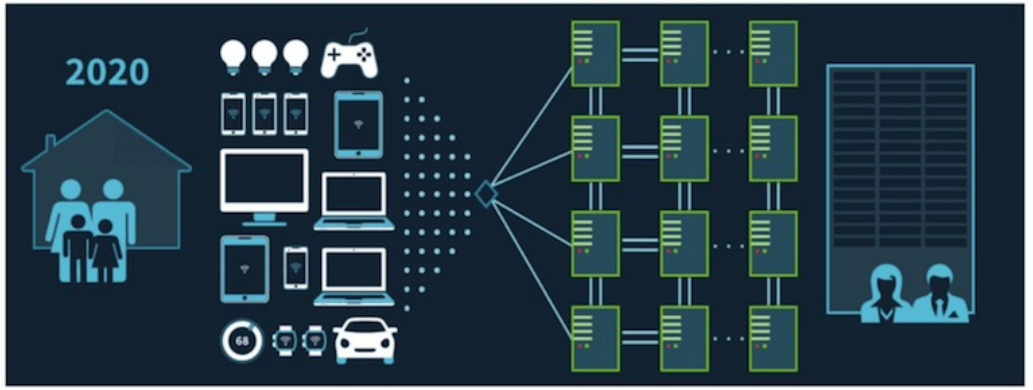
2005 ARCHITECTURE



2015 ARCHITECTURE



2020 ARCHITECTURE



THE WORLD BY 2020

» 4 billion connected people

» 25+ million apps

» 25+ billion embedded systems

» 40 zettabytes (40 trillion gigabytes)

» 5,200 GB of data for every person on Earth

Microservices Drivers

Microservices Essential Principles

- Single Responsibility
- Discrete
- Carries its own data
- Transportable
- Ephemeral

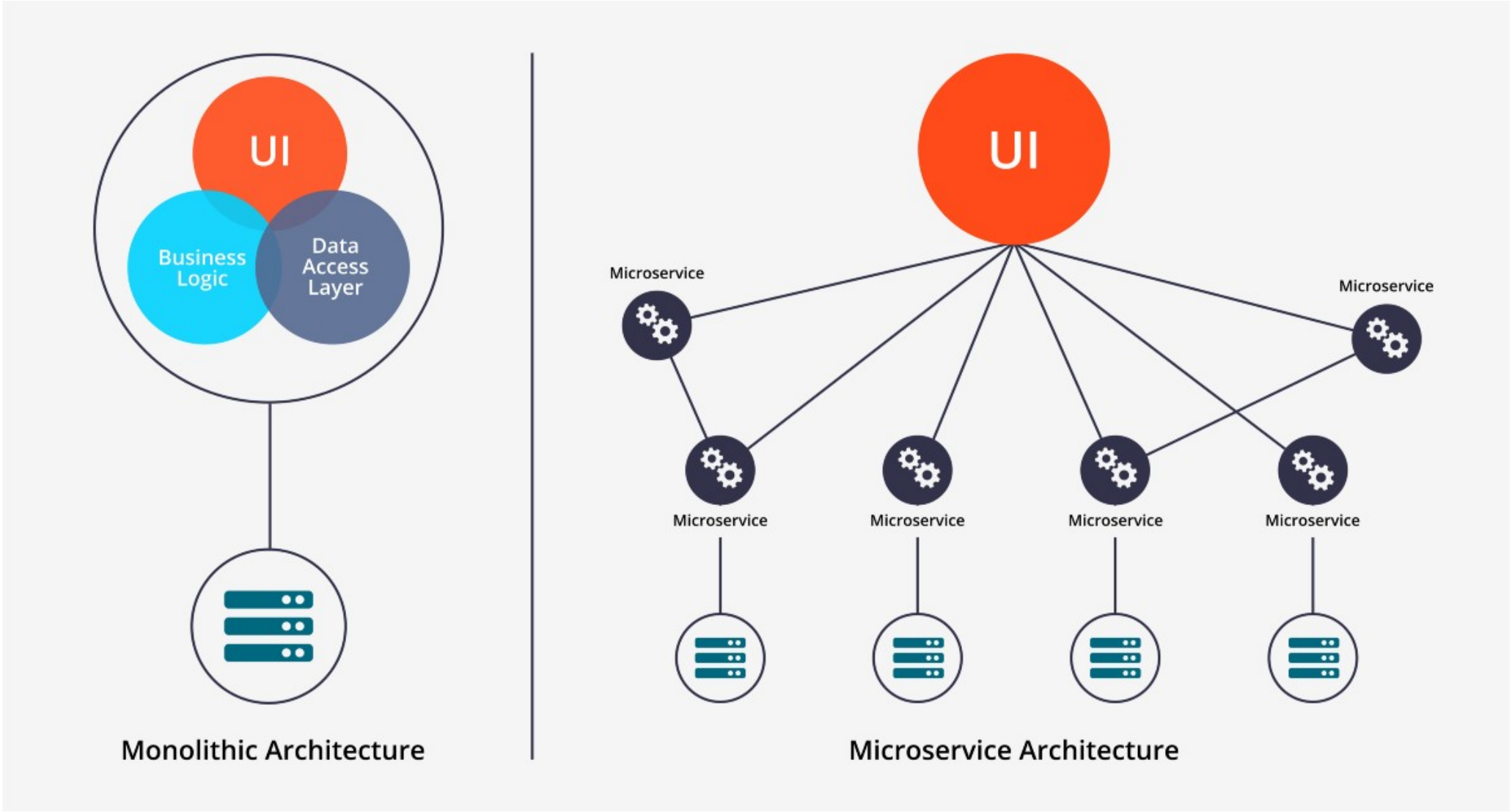
Microservices Core Concepts

- Microservices are small, independent, composable services
- Each service can be accessed by way of a well-known API format
  - Like REST, GraphQL, gRPC or in response to some event notifications
- Breaks large business processes into basic cohesive components
  - These basic process actions are implemented as microservices
  - The business process is executed by making calls to these microservices
- Each microservice provides one cohesive service
  - Microservices do not exist in isolation
  - They are part of a larger organization framework

Microservices Core Concepts

- Microservices coordinate with other microservices to accomplish the tasks normally handled by a monolithic application
- Microservices communicate with each other synchronously or asynchronously
- Microservices make applications easier to develop and maintain
- BUT A LOT HARDER TO MANAGE

Monolith to Microservice



Characteristics of Microservice Deployments

- Light-weight, independent, and loosely-coupled
- Each has its own codebase
- Responsible for a single unit of business functionality
- Uses the best technology stack for its use cases
- Has its own DevOps plan for test, release, deploy, scale, integrate, and maintain independent of other services
- Deployed in a self-contained environment
- Communicates with other services by using well-defined APIs and simple protocols like REST over HTTP
- Responsible for persisting its own data and keeping external state

Business Drivers

- Business Agility
  - Speed of change is faster with a more modular architecture
  - React quicker to feature and enhancement requirements
  - Easy integration with new technology, processes (Mobile, Cloud, Continuous DevOps)
- Composability
  - Allows for reuse of capability and functionality
  - Allows for integration with other internal and external services
  - Reduces technical debt and replication
- Robustness and Migration
  - A single microservice failures does not bring down an application
  - The business functionality is always available
  - Updated functionality can be rolled out in a controlled and safe manner
  - Smaller components reduces risk exposure

Business Drivers

- Scalability
  - Services can scale up to handle peak loads, or down to save costs
- Enable Polyglot Development
  - Different technologies can be used for different services
  - No lock-in to a single technology across the whole business

Pros and Cons of Microservices

Pros

- Easy to develop
- Easy to understand
- Easy to deploy
- Easy to monitor each service
- Flexible Release Schedule
- Use standard APIs (JSON, XML)

Cons

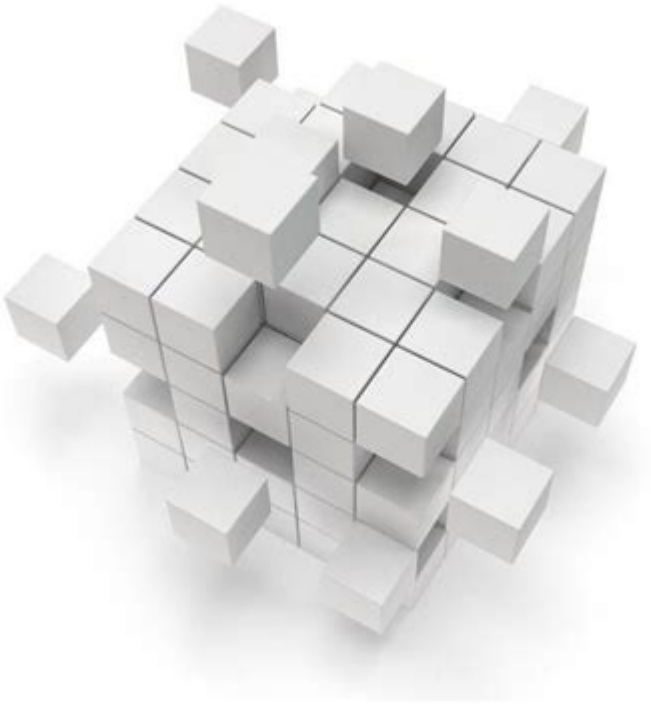
- Requires retooling
- Requires more deployments
- Requires translation (JSON, XML)
- Requires more monitoring
- Operations configuration can be very complex
- System can be very complex

Design Concepts

- Modularity
- Coupling
- Cohesion
- Suppleness
- Dependency Injection (DI)
- Dependency Inversion Principle (DIP)
- Inversion of Control (IoC)

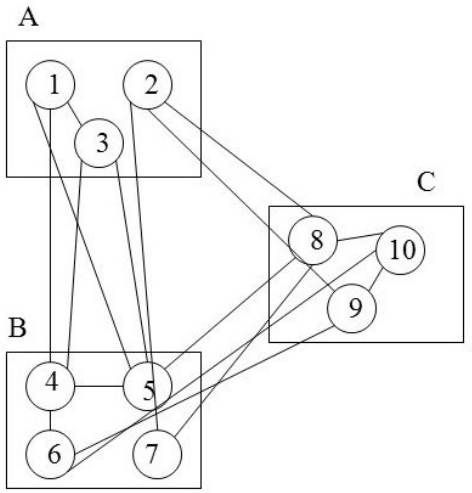
Modularity

- Closely tied to abstraction
  - Allows the use of independent model implementation
  - Internal implementation is hidden
  - Communication is through stable interfaces
- Modules allow for reuse of components
  - Supports higher level architectural structuring of programs
- Enhances design clarity, simplifies implementation
  - Reduces cost and effort of testing, debugging and maintenance
- Modularity is not arbitrary
  - The choice of components is based on the domain

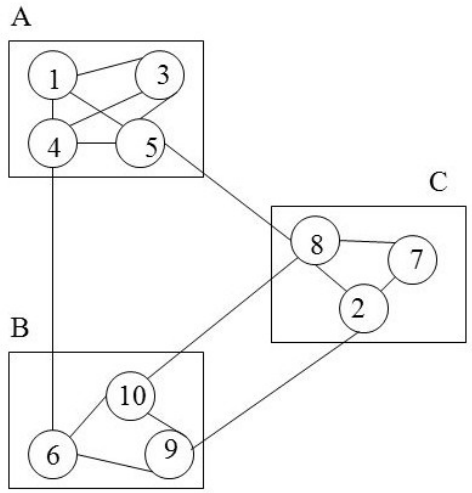


Coupling and Cohesion

Cohesion	Coupling
Cohesion is the indication of the relationship within **module**.	**Coupling** is the indication of the relationships between modules.
Cohesion shows the module's relative **functional** strength.	Coupling shows the relative **independence** among the modules.
Cohesion is a degree (quality) to which a component / module focuses on the **single** thing	Coupling is a degree to which a component / module is connected to the **other** modules.



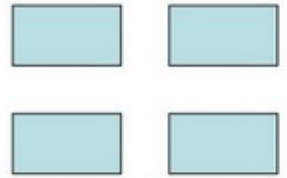
Bad modularization:
low cohesion, high coupling



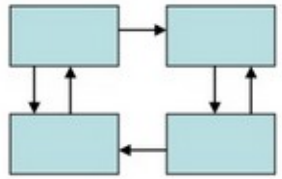
Good modularization:
high cohesion, low coupling

Coupling

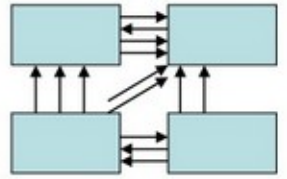
- Degree of dependence among components
  - High coupling makes modifying different parts of the system difficult
  - Modifying a highly coupled component affects all the other connected components
- Often results in brittle and unusable systems



No dependencies



Loosely coupled-some dependencies



Highly coupled-many dependencies

Cohesion

- The degree to which:
  - All elements of a component are directed towards a single task; and,
  - When all elements directed towards a specific task are contained in a single component
  - High cohesion is good
  - Highly cohesive components tend to have low coupling
- Often expressed as the single responsibility principle
  - Highly cohesive components specialize in implementing a single responsibility
  - There is only one component that implements that responsibility
- Achieving cohesiveness depends on how we modularize an architecture

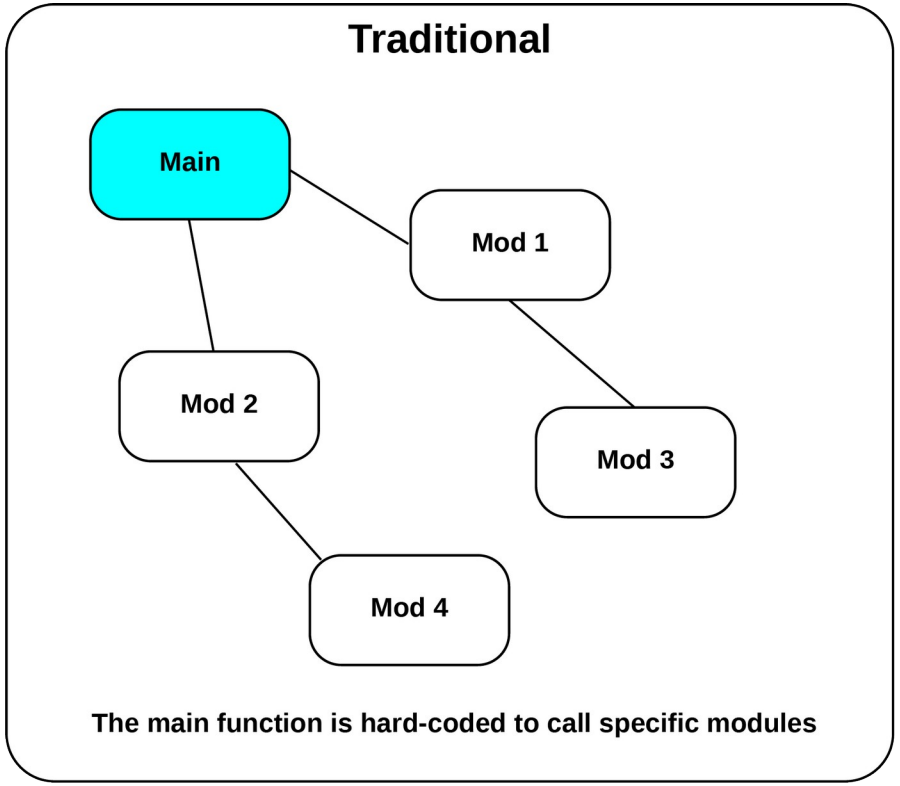
Suppleness

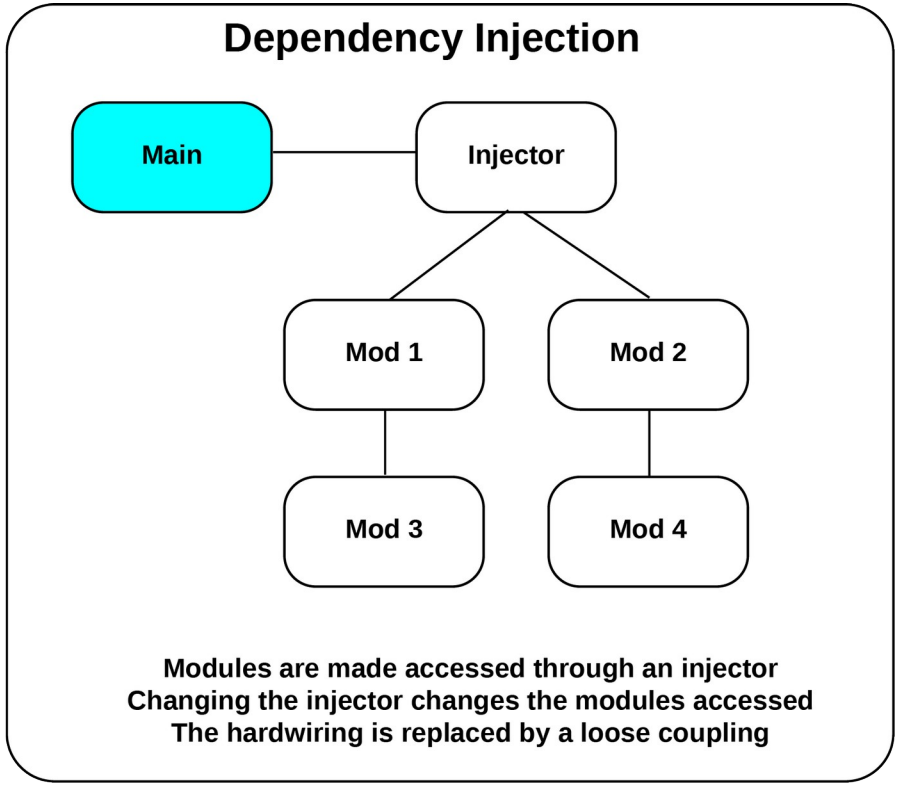
- Modular systems interact through interfaces
- Suppleness refers to the design of the interfaces
  - Follow good interface design rules, e.g., Open-Close principle
- Suppleness allows for future expansion of the architecture
  - Without breaking existing inter-module communications
- For example, anti-corruption layer
  - Links two modules with different internal representations with a “translation” from one representation to the other of some shared data item
  - E.g. Data seamlessly shared between databases that use different units (pounds versus kilograms for example)

Dependency Injection

- Used when a client module depends on a service module
  - E.g., an invoicing module depends on a catalog module for pricing
- The service module provides an interface
  - Describes how to access the services of the service module
  - This interface is independent of the actual implementation of the service
  - The interface is “injected” or provided to the client module dynamically
  - At build time, the appropriate implementation of the service interface is used
- Requires that
  - The injected interface remain stable even if the implementation changes
  - The injected interface can be easily swapped out in the client code for a different interface

Dependency Injection

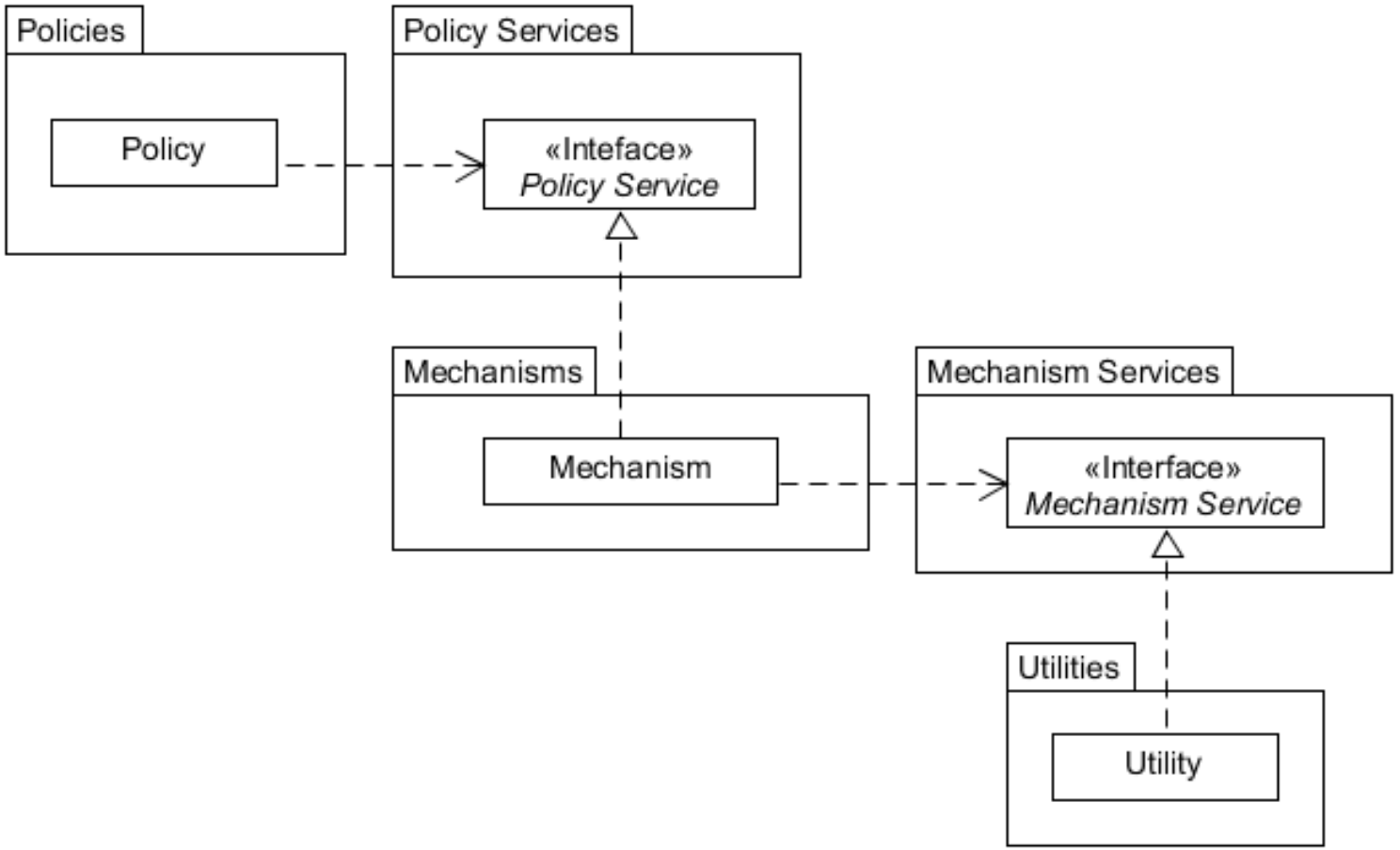




Dependency Inversion Principle

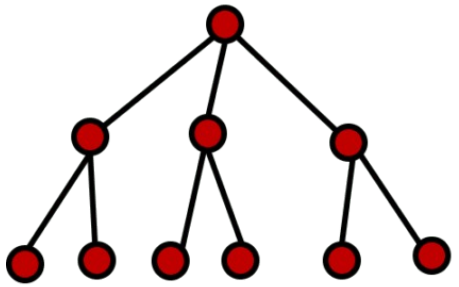
- Abstraction should be used in place of concrete implementations
  - High-level modules should not depend on low-level modules, and both types of modules should depend on abstraction (interface)
  - A concrete implementation should depend on a defined abstraction rather than an abstraction that is derived from a concrete implementation
- The purpose of the DIP is to manage the dependency between high and low-level modules abstractly
  - High and low-level modules are designed independently
  - The bindings between modules are done through abstractions implemented as interfaces (suppleness)
- Interfaces are defined before the code is written

Dependency Inversion Principle

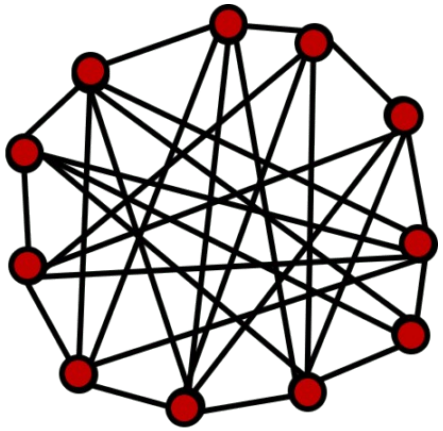


Inversion of Control

- Traditional top-down flow of control
  - Starts at a code entry point (e.g., the main() method)
  - Flow of control passes from calling modules to called modules
  - Then control returns to the calling module
- Ideal for execution of algorithms
  - Not so much for event driven applications



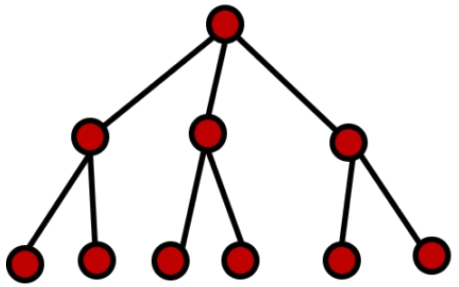
"Top-down"



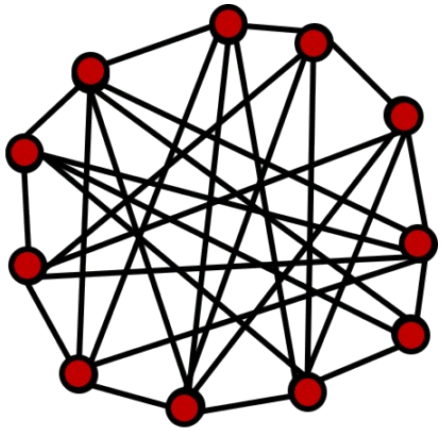
"Bottom-up"

Inversion of Control

- In IoC, control starts with an “event” or client request
  - Different flows of control depending on the event
- Assumes a framework of some type (module graph)
- When a module needs a service
  - A service is located
  - The service is bound to the module
  - Often bound using DiP and DI



“Top-down”

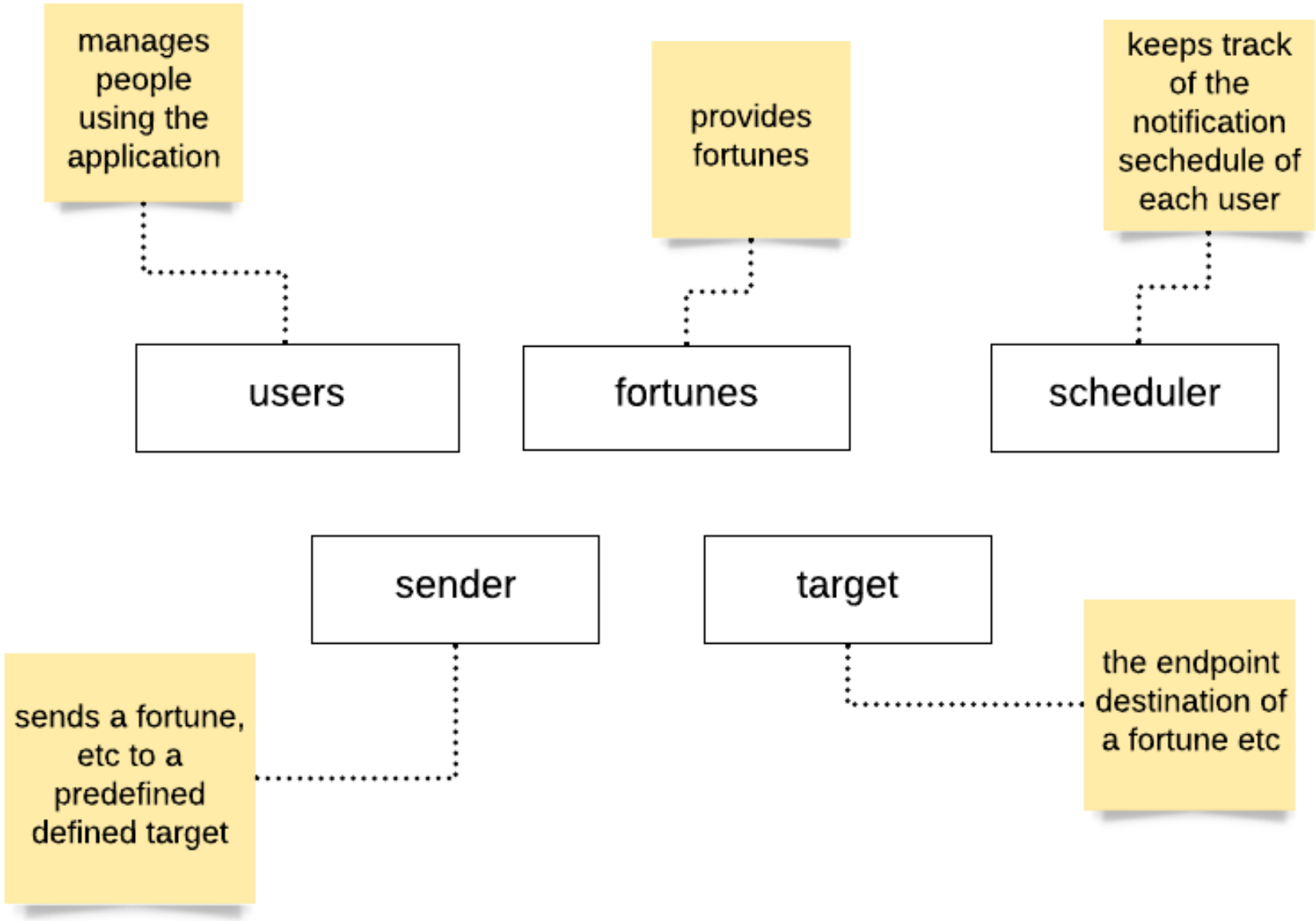


“Bottom-up”

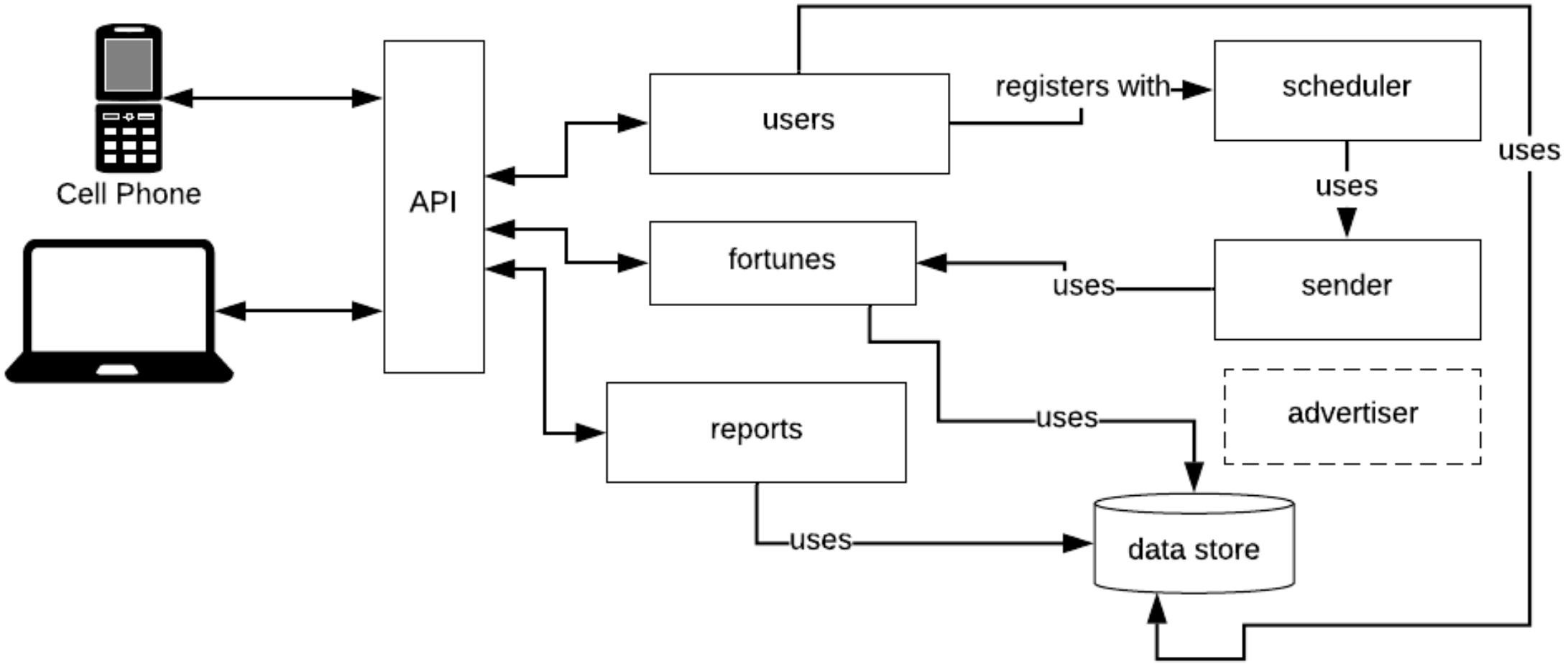
Microservice Styles

- Synchronous
- Asynchronous
- Hybrid
- Serverless
- API Gateway

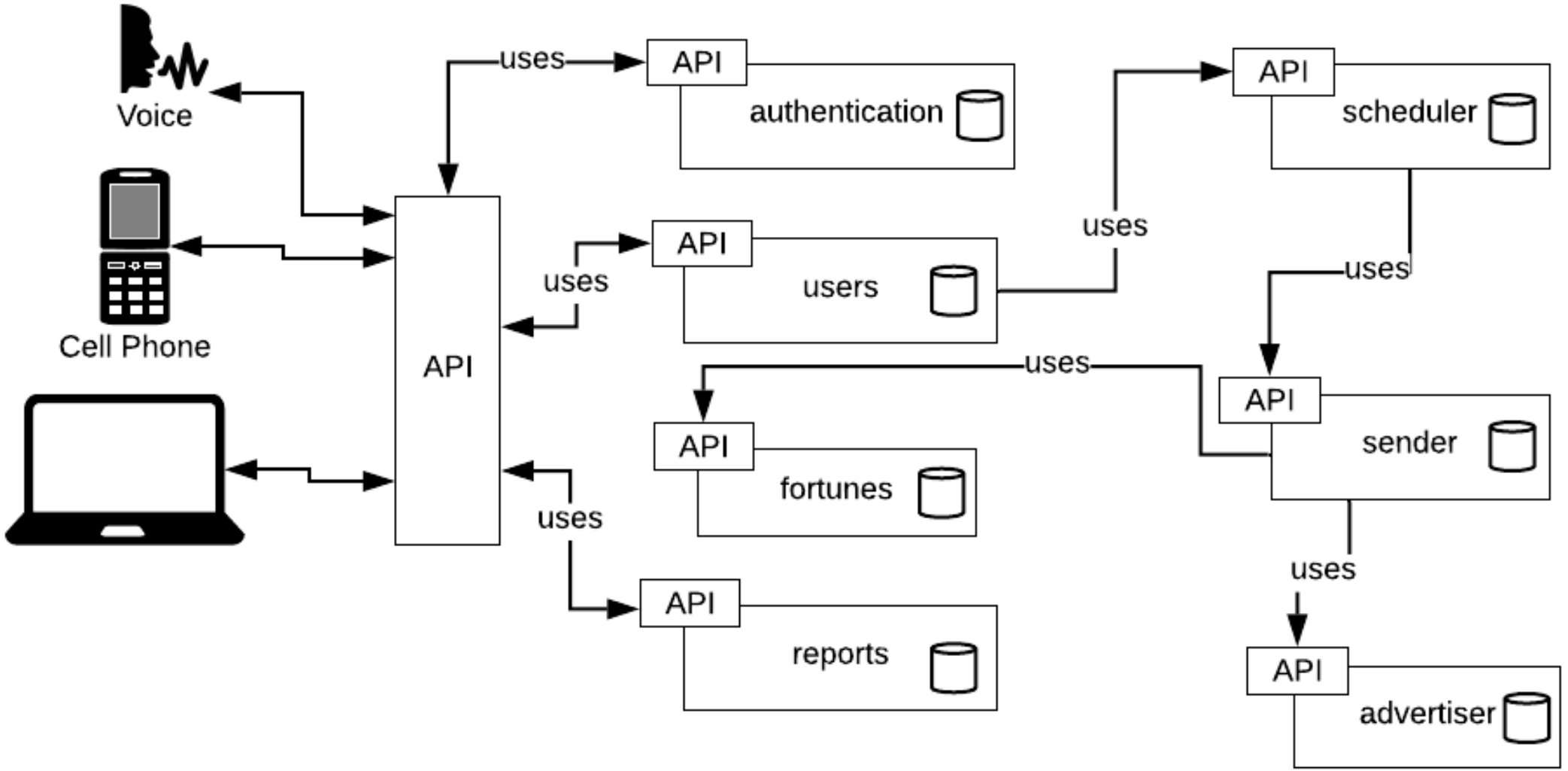
Understanding the Application Components



Monolithic Application



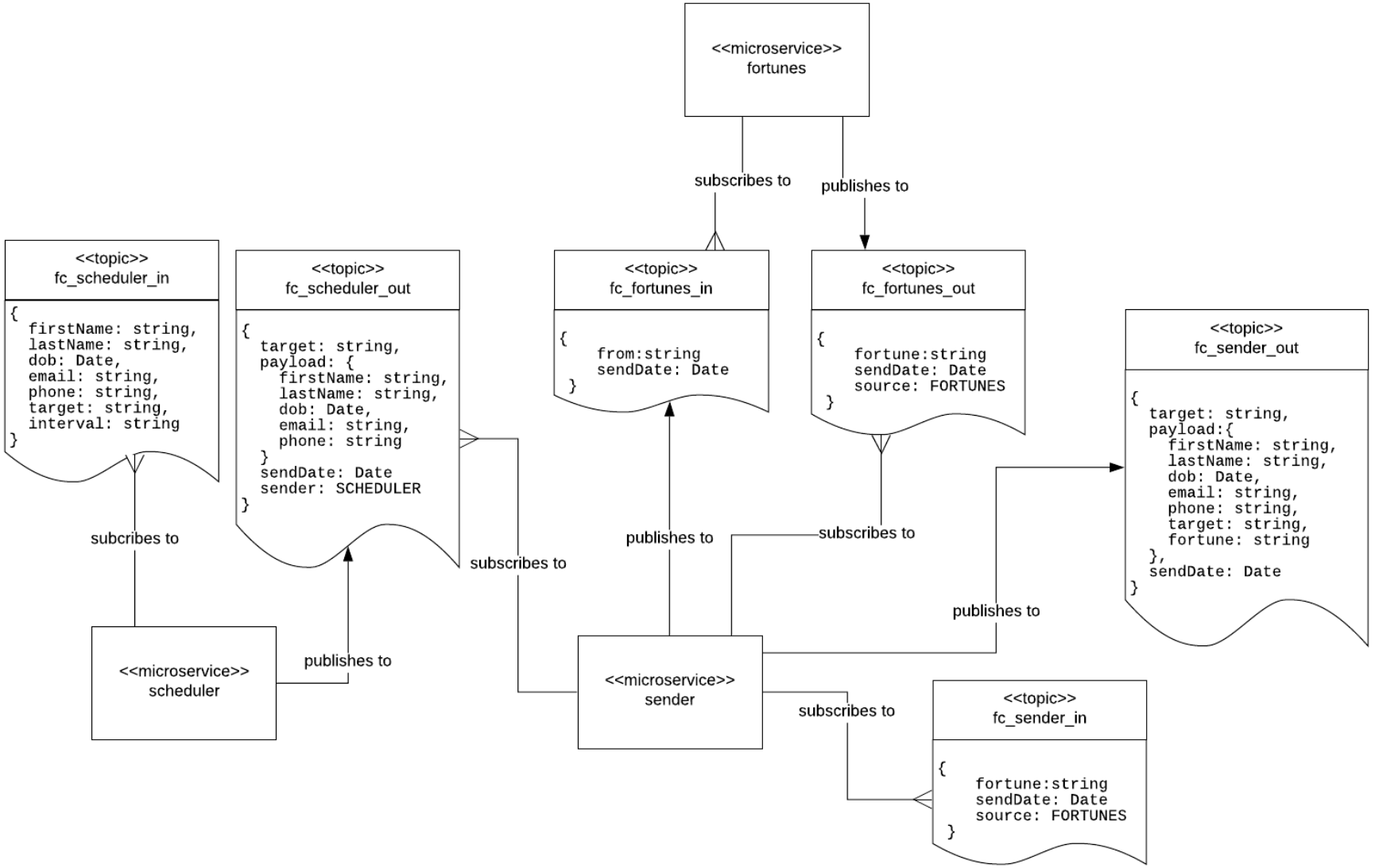
Microservices: Synchronous



Microservices: Synchronous

- Advantages:
  - Service is stateless (relative to caller)
  - Allows many active instances
  - Lower management overhead since no message server
  - Immediate and direct feedback (success or failure)
- Disadvantages:
  - Caller must wait, potentially limiting caller scalability
  - Can add hard dependencies between services if chained

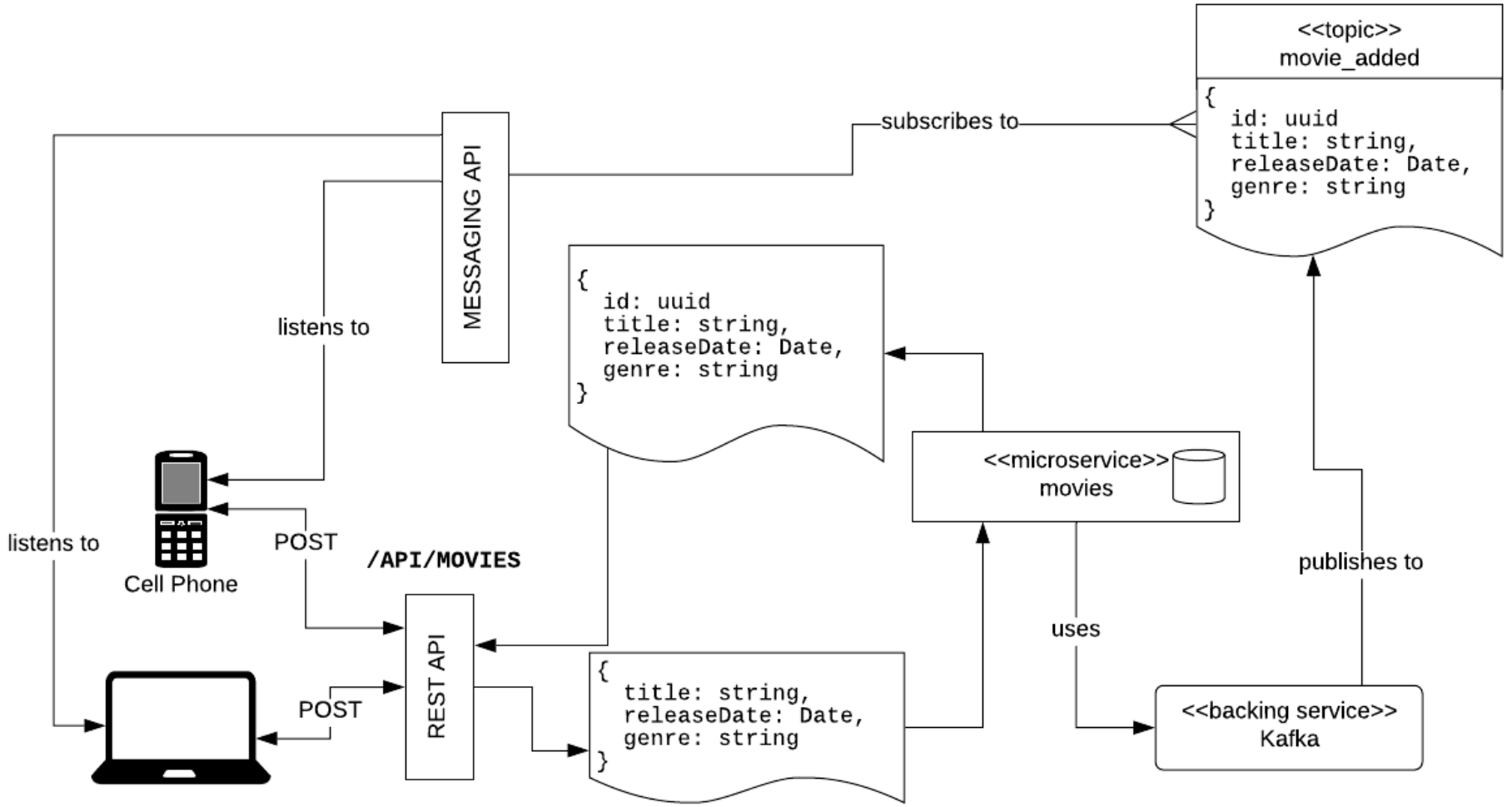
Microservices: Asynchronous



Microservices: Asynchronous

- Advantages:
  - Improves scalability since no coupling between caller and service instance
  - Queueing allows for degree of inherent load balancing
- Disadvantages:
  - Dependent on external message server
  - Additional tuning and monitoring is required

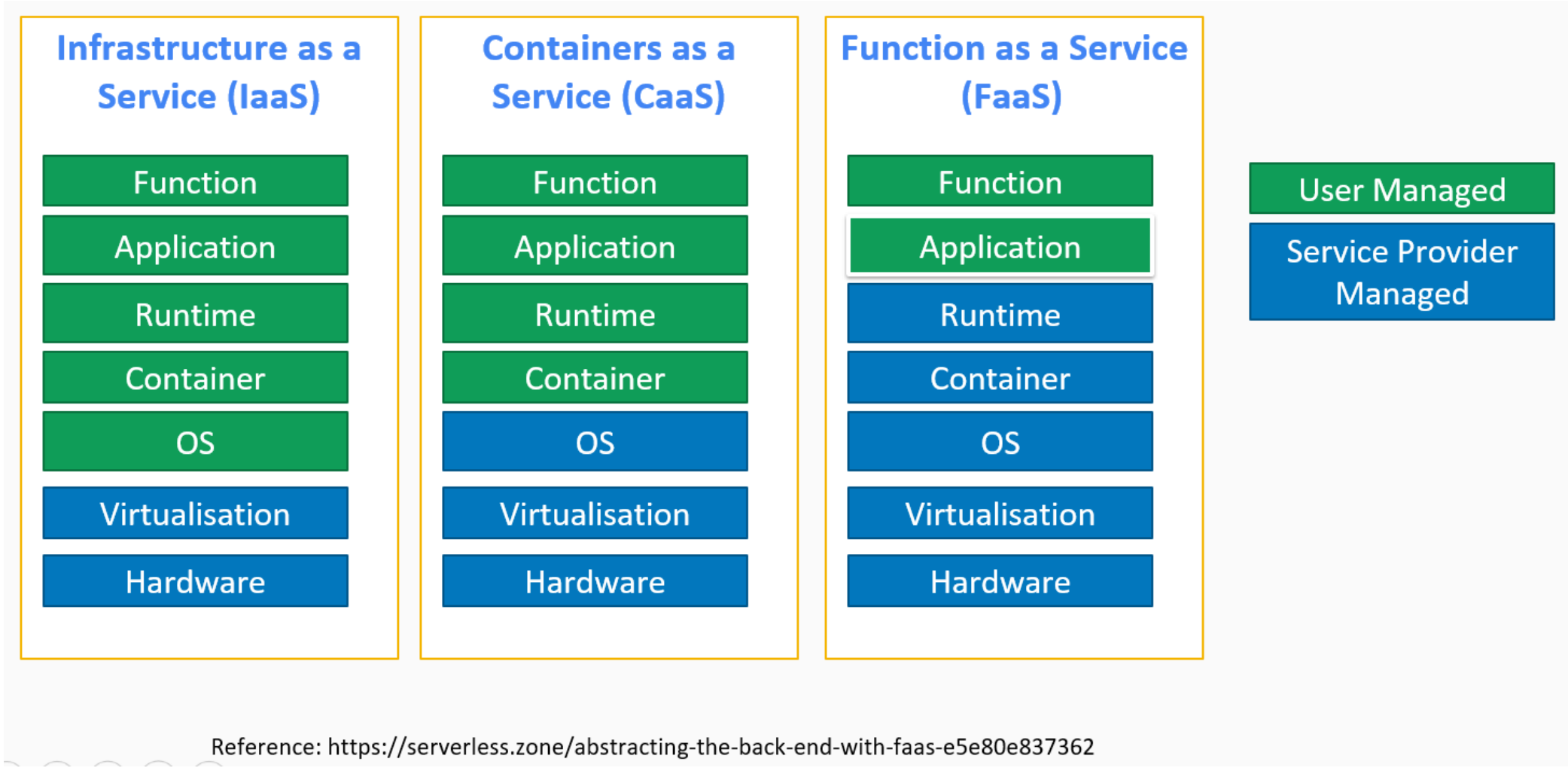
Microservices: Hybrid



Microservices: Hybrid

- Advantages:
  - Best of both worlds
  - Flexibility in terms of developer experience
  - Easy to implement as an API
- Disadvantages:
  - Hard to implement as a microservices
  - There’s no free lunch, you must contend with more latency issues

Serverless Microservices

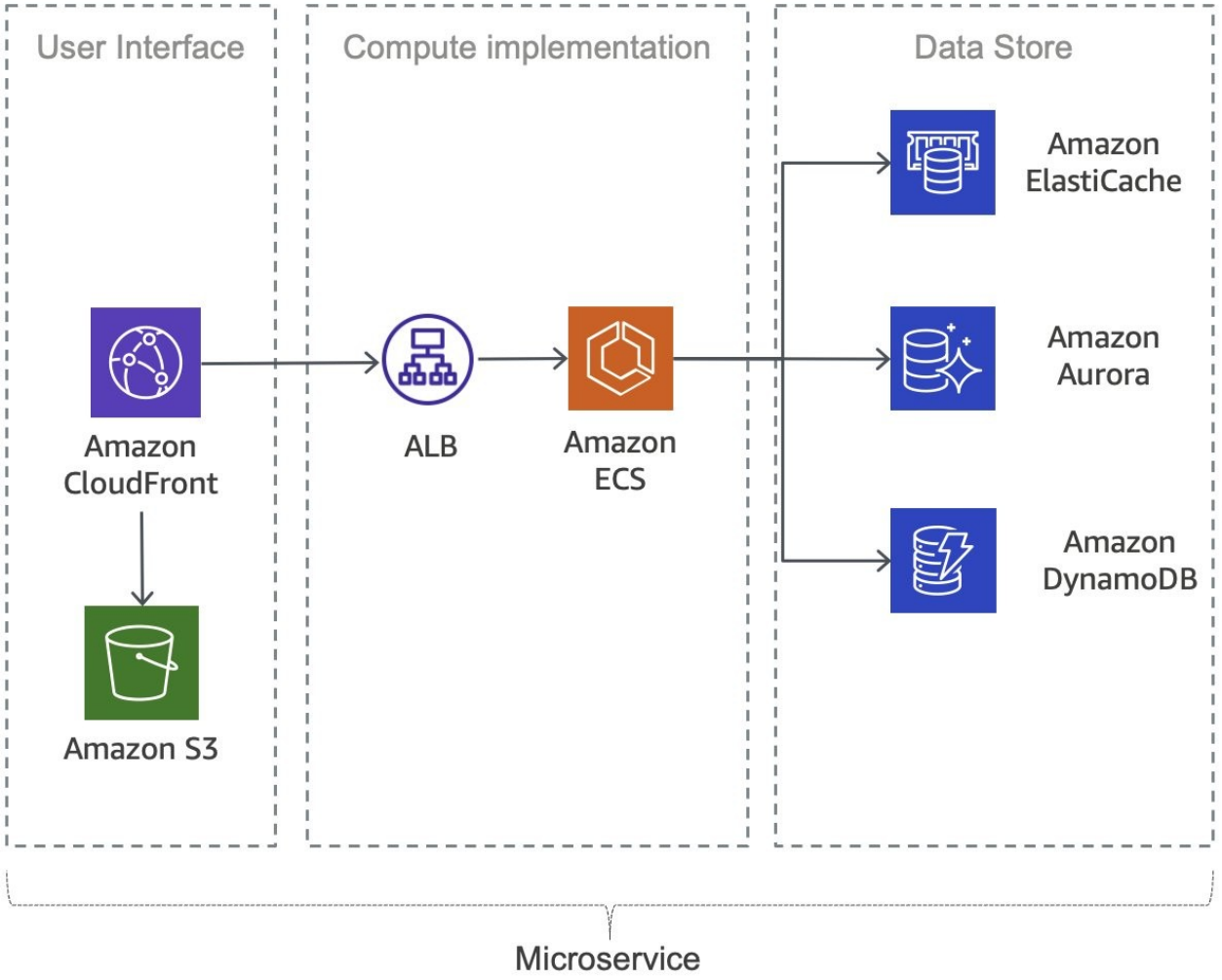


Reference: https://serverless.zone/abstracting-the-back-end-with-faas-e5e80e837362

Serverless Microservices

- Serverless microservices are cloud based FaaS applications
  - Containerization, deployment and scaling are all handled by the cloud infrastructer
  - The services are provided with cloud units of execution
  - AWS Lambda for example
- Serverless is characterized by the following principles: (from AWS)
  - No infrastructure to provision or manage
  - Automatically scaling by unit of consumption
  - "Pay for value" billing model
  - Built-in availability and fault tolerance
  - Event Driven Architecture (EDA)

Serverless Microservices



API Gateway

- An API gateway is a single point of entry to a microservices application
  - Accepts API requests from a client
  - Processes them based on defined policies
  - Directs them to the appropriate services
  - Combines the responses for a simplified user experience
- Typically handles a request by invoking multiple microservices and aggregating the results
  - It can also translate between protocols in legacy deployments
- Often found in the application layer of the layered architecture (discussed later)

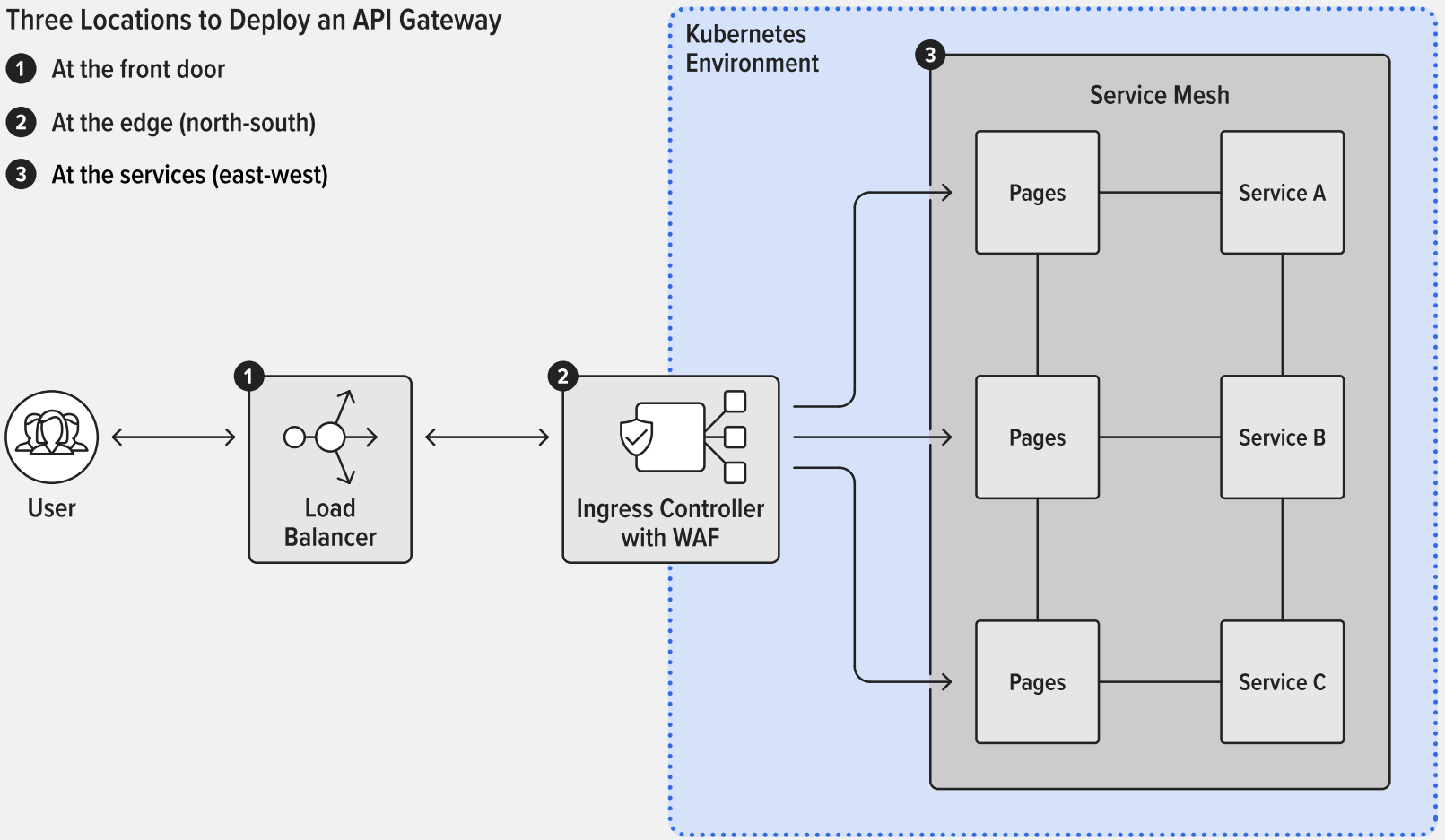
https://www.nginx.com/learn/api-gateway/

API Gateway

- API gateways commonly implement capabilities that include:
  - Security policy – Authentication, authorization, access control, and encryption
  - Routing policy – Routing, rate limiting, request/response manipulation, circuit breaker, blue-green and canary deployments, A/B testing, load balancing, health checks, and custom error handling
  - Observability policy – Real-time and historical metrics, logging, and tracing
- For additional app- and API-level security, API gateways can be augmented with web application firewall (WAF) and denial of service (DoS) protection.

https://www.nginx.com/learn/api-gateway/

API Gateway



https://www.nginx.com/learn/api-gateway/

End of Module