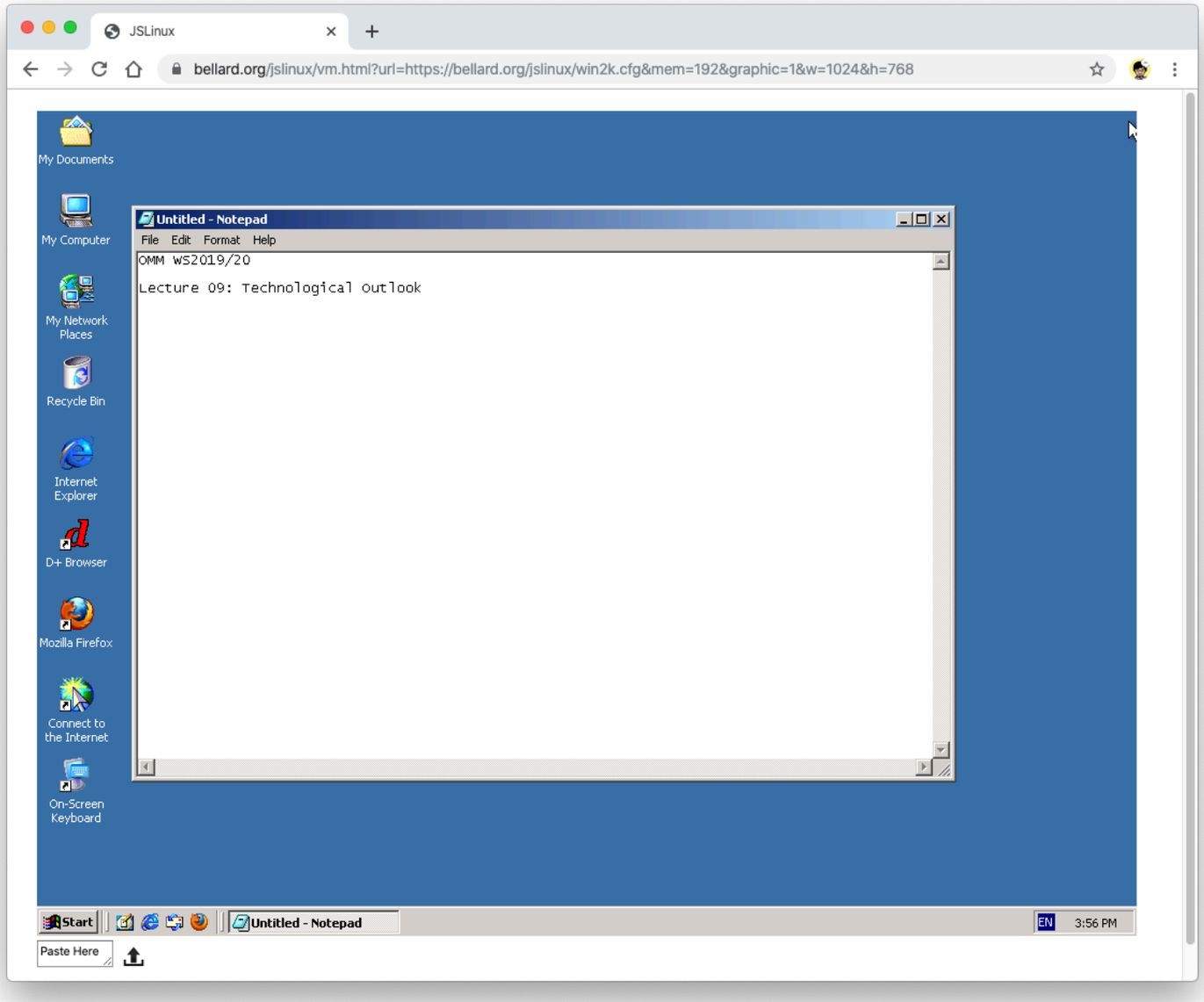
9 Technological Outlook

Literature:

https://webassembly.org

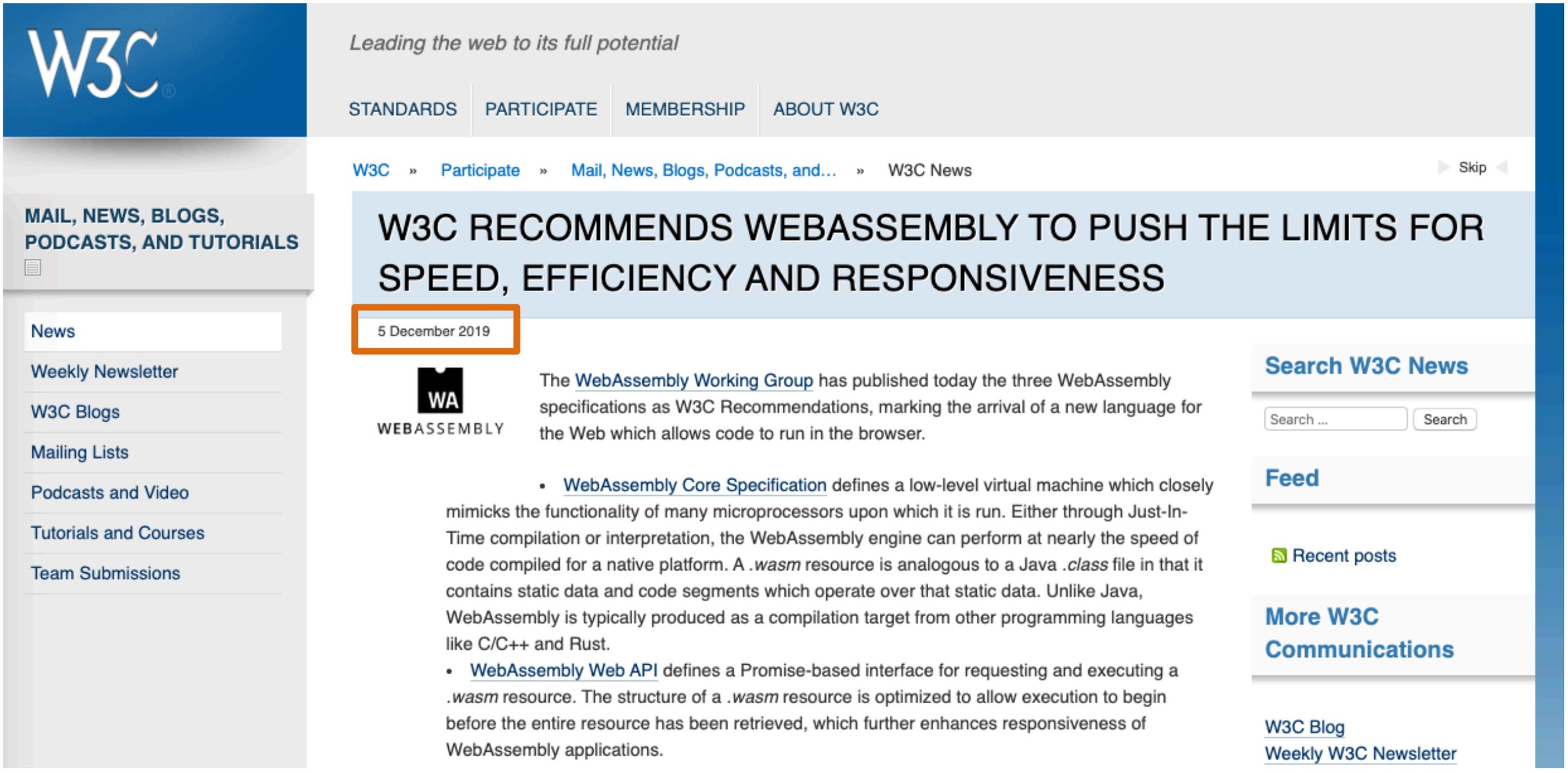
Example: Windows 2000 in a Browser

- Can you imaging how the OS is running in a browser?



Windows 2000 runs in a browser, https://bellard.org/jslinux/

WebAssembly (WASM)



https://www.w3.org/blog/news/archives/8123

Evolution of Front-end Engineering

- ECMAScript evolves a lot
  - The first formal draft submitted to ECMA (ECMAScript 1.1, 1997)
  - “Strict mode” is introduced (ECMAScript 5, 2009)
  - Massive changes to the language (ECMAScript 6, 2015)
  - Latest version: ECMAScript 2019 (version 10)
- Business is becoming much more complex
  - HTML/CSS/JS in the beginning
  - jQuery addresses pain points better manipulating DOMs and AJAX
  - Frameworks (Phase 1): Knockout / Backbone / AngularJS
  - Tooling: NodeJS/NPM/Babel/Webpack …
  - Frameworks (Phase 2): React/Angular/Vue
- JavaScript, as a dynamic typed language, is the only language for front-end web development

JavaScript: The Good Parts

https://www.reddit.com/r/ProgrammerHumor/comments/621qrt/javascript_the_good_parts/

Early Attempts: ASM.js and NaCl

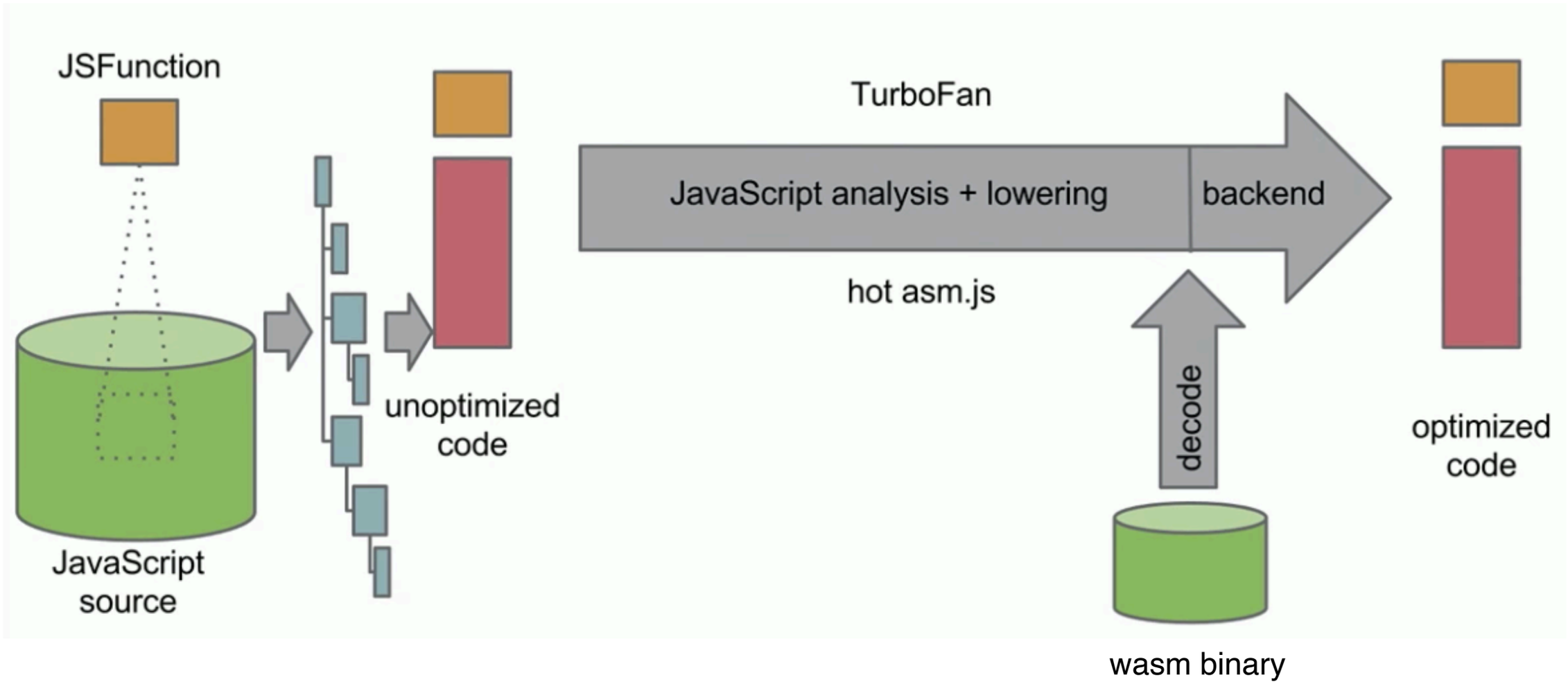
- JavaScript deduces types in runtime

- ASM.js by Mozilla
  - A subset of JavaScript to avoid type inconsistency and garbage collection
  - Proved that languages can be transpired to JavaScript and run in the browser

```
function f(i) {
  i = i|0;
  return (i + 1)|0;
}
```

- NativeClient (NaCl) by Google
  - but never implemented except Chrome
  - Dropped in 2017

V8 Pipeline Design + WASM



Source: Compiling for the Web with WebAssembly (Google I/O '17)

WebAssembly (WASM)

- Binary instruction format
  - a low-level virtual machine standard for web application
  - Memory safe execution environment sandbox
- W3C WebAssembly Working Group, Community Group
- The “fourth” language for web development
- Benefits
  - Speed: (Near) native
  - Portability: Extreme Low-level
  - Flexibility: Get rid of JavaScript only

https://caniuse.com/#search=wasm

Discussion

- What makes asm.js and NaCl failed?
- Do you think JavaScript will die in the near future?

https://www.destroyallsoftware.com/talks/the-birth-and-death-of-javascript

9 Technological Outlook

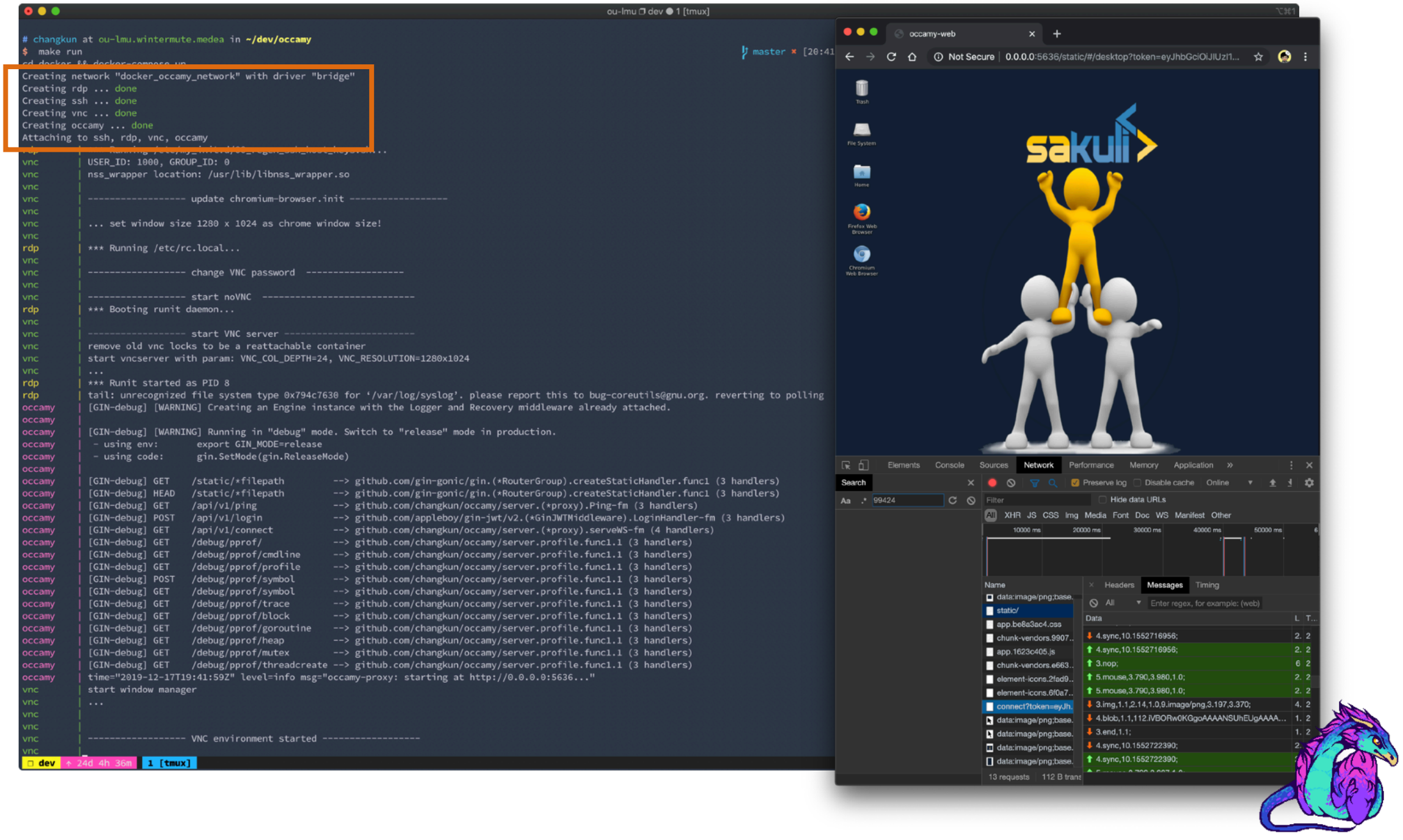
Literature:

Newman S. Building microservices: designing fine-grained systems. O'Reilly Media, Inc. 2015 Feb 2.

https://kubernetes.io

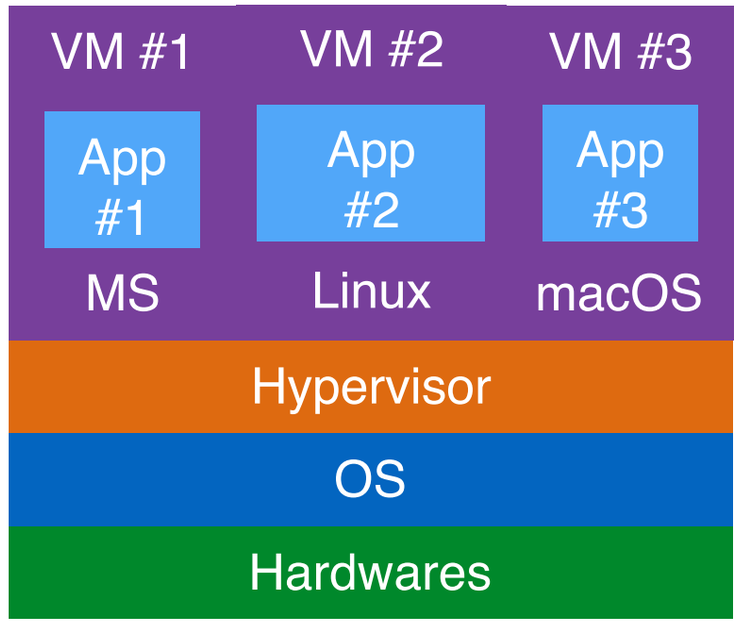
https://cncf.io

Example: Occamy Remote Desktop Streaming



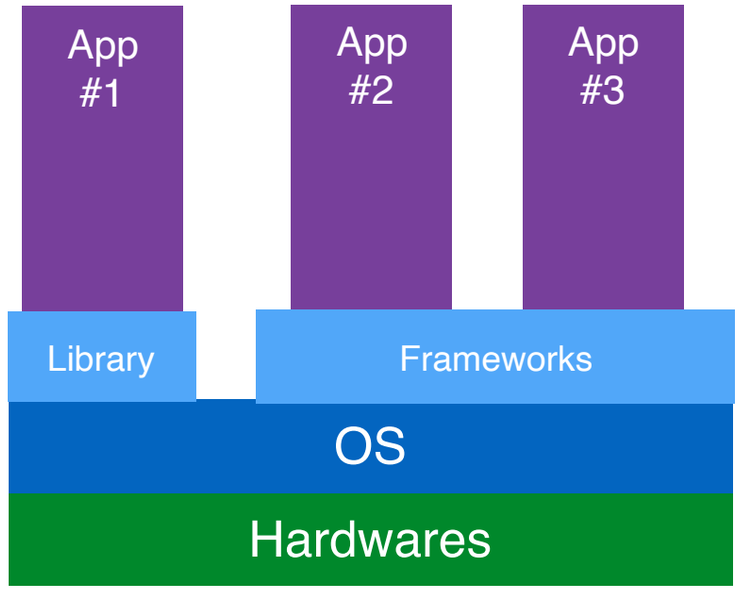
https://github.com/changkun/occamy

Virtualization (2000-2010)



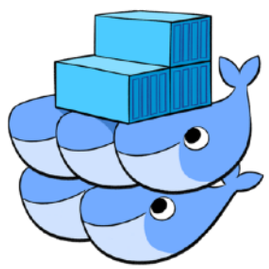
- Windows 2000 (NT) Server introduce “Active Directory”
  - All servers centralized in a single domain
- Virtualization & OS-level resources isolation
  - Virtual machines (VMs) over the operating system
  - Debugging different platforms
  - Enables programmable hardware resource management automation
- Related tech.: VMware Workstation, vSphere, Hyper-V, QEMU, Xen, KVM…
- Products offer the ability of virtualization requires better managements
  - Infrastructure-as-a-Service (IaaS)
  - AWS by Amazon (2006)
  - Azure by Microsoft (2008)
  - OpenStack (2010)
- But VMs are expensive for lightweight applications

Containerization (2010-2015)

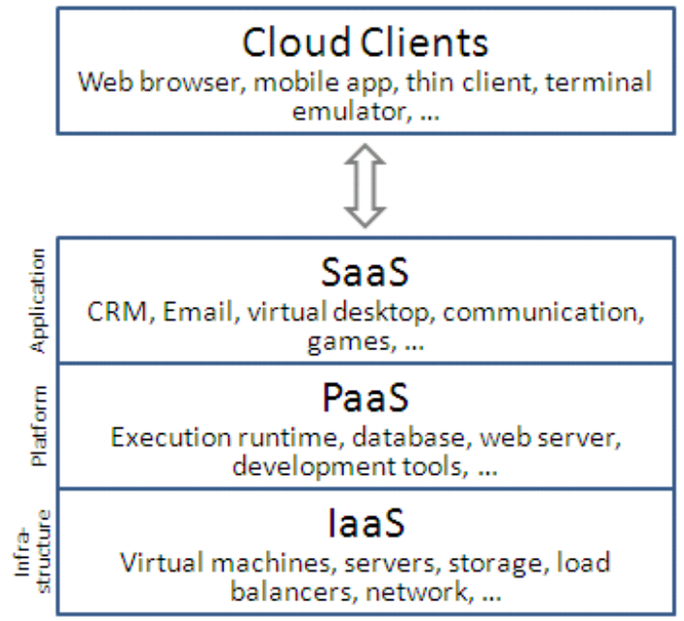


- Platform-as-a-Service (PaaS)
  - Cloud Foundry (2010) Foundation (2014)
  - OpenShift (2011)
- Docker (2013):
  - Encapsulate simple, friendly, and easy to use
  - **Resolve issues of packaging and delivery**
  - Based on LXC, Cgroups, and Namespace
  - Process-level hardware resources isolation

- Operations eventually require platform-level orchestration utilities
  - Apache Mesos: Marathon (2013) offers large-scale cluster management
  - Docker Swarm (2014) uses Docker APIs for container orchestration
  - Kubernetes initiated by Google in 2014 and releases in 2015 rescues CoreOS (a major competitor of Docker) and RedHat (early contributor of Docker) in the container market



Serverless (2015-today)



Source: Wikipedia

- Open Container Initiative (OCI)
  - Container image spec and runtime spec
- Cloud Native Computing Foundation (CNCF)
  - Cloud native standardizing incubating applications and best practices of creating cloud native applications

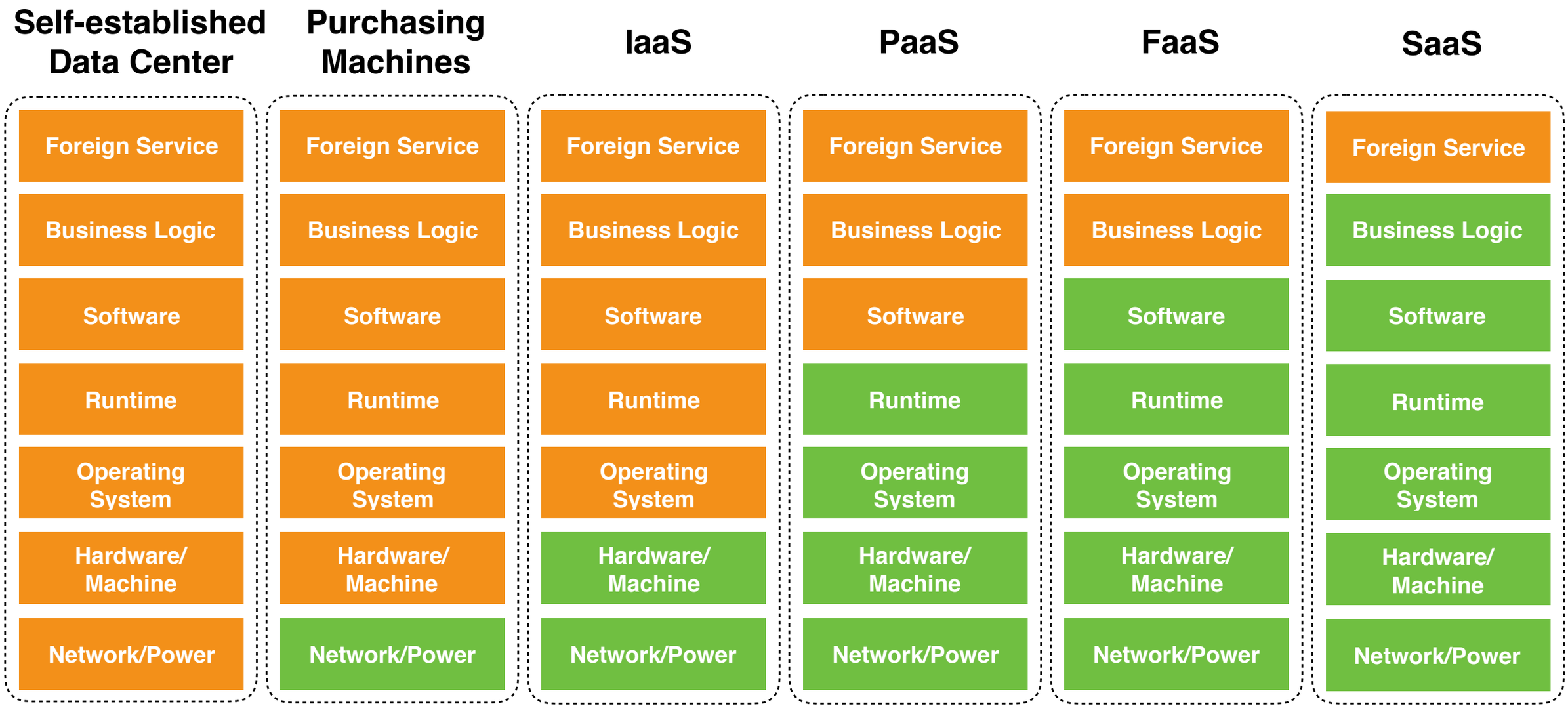
- Serverless != No server
  - is an ideology for eliminating hardware and operation details
  - Cloud Native is a set of standards and infrastructures to achieve serverless
  - Today: Serverless ≈ Container Runtime (e.g., Docker) + Kubernetes

Cloud Computing Terminologies

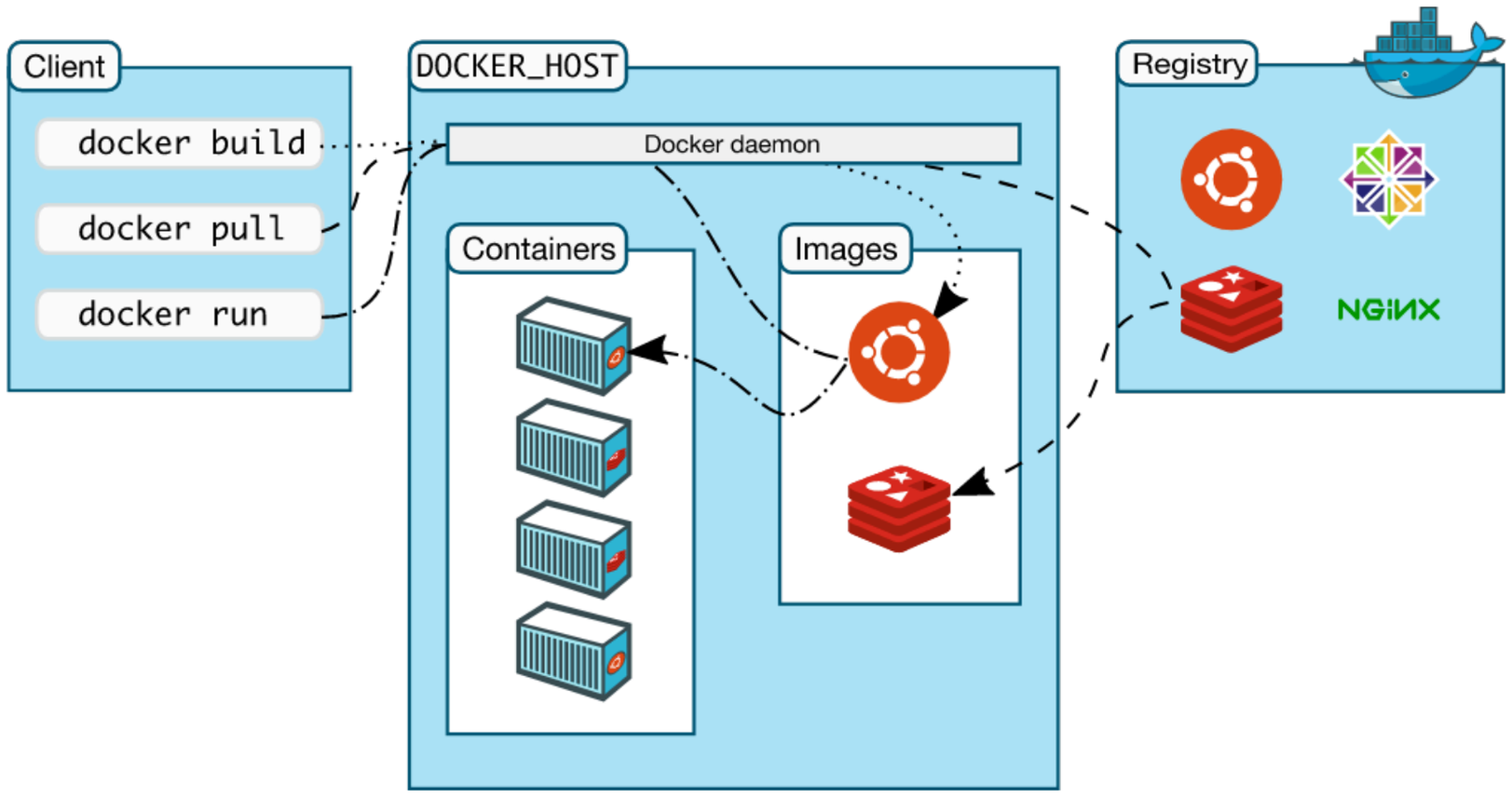
Self-Managed

Provider-supplied

- Building a data center is prohibitively expensive
- Computing resource business is feasible



Docker (now Moby) Core Concept and Architecture



docker

moby project

Source: https://docs.docker.com/engine/docker-overview/

The Rise and Fall of Docker, Inc. (former dotCloud)

- 2013 - A PaaS startup *dotCloud* open sourced their product *Docker*
  - Gathering developers and building community shapes its early success
  - Changed the company to Docker and branded the name of Docker
- 06/2014 - Google announced the Kubernetes project
- 12/2014 - Docker announced Docker Swarm project
  - 250 Million investments from Goldman Sachs, Greylock Partners, Sequoia Capital, etc.
- 06/2015 - Docker, CoreOS, Google, and RedHat initiated OCI
  - Docker donated *libcontainer* as *RunC* for container standardization
- 07/2015 - Kubernetes 1.0 release, Google & Linux Foundation launched CNCF
- 2016 - Docker, Inc. accounted for the abandonment of Docker Swarm
- 2017 - Rename *Docker* project to *Moby* at *Dockercon17*
  - Docker announce Kubernetes support
- 2018 - Solomon Hykes (the CTO of Docker) announces his resignation

Discussion

- What did you learn from the rise and fall of Docker Inc.?
  - Think about the balance of building a successful product and make profits
  - Think about the developer community

- Where should Container-as-a-Service (CaaS) be placed in:
  - IaaS > PaaS > FaaS > SaaS

Kubernetes

- *Kubernetes* (greek for governor, helmsman, captain)
  - Open-source container orchestration system
  - Originally designed by Google, maintained by CNCF since 1.0 release
  - Aim to provide “platform for automating deployment, scaling and operations of application containers across clusters of hosts
- Declarative YAML-based configuration

```
- kubectl apply -f deployment.yaml
```

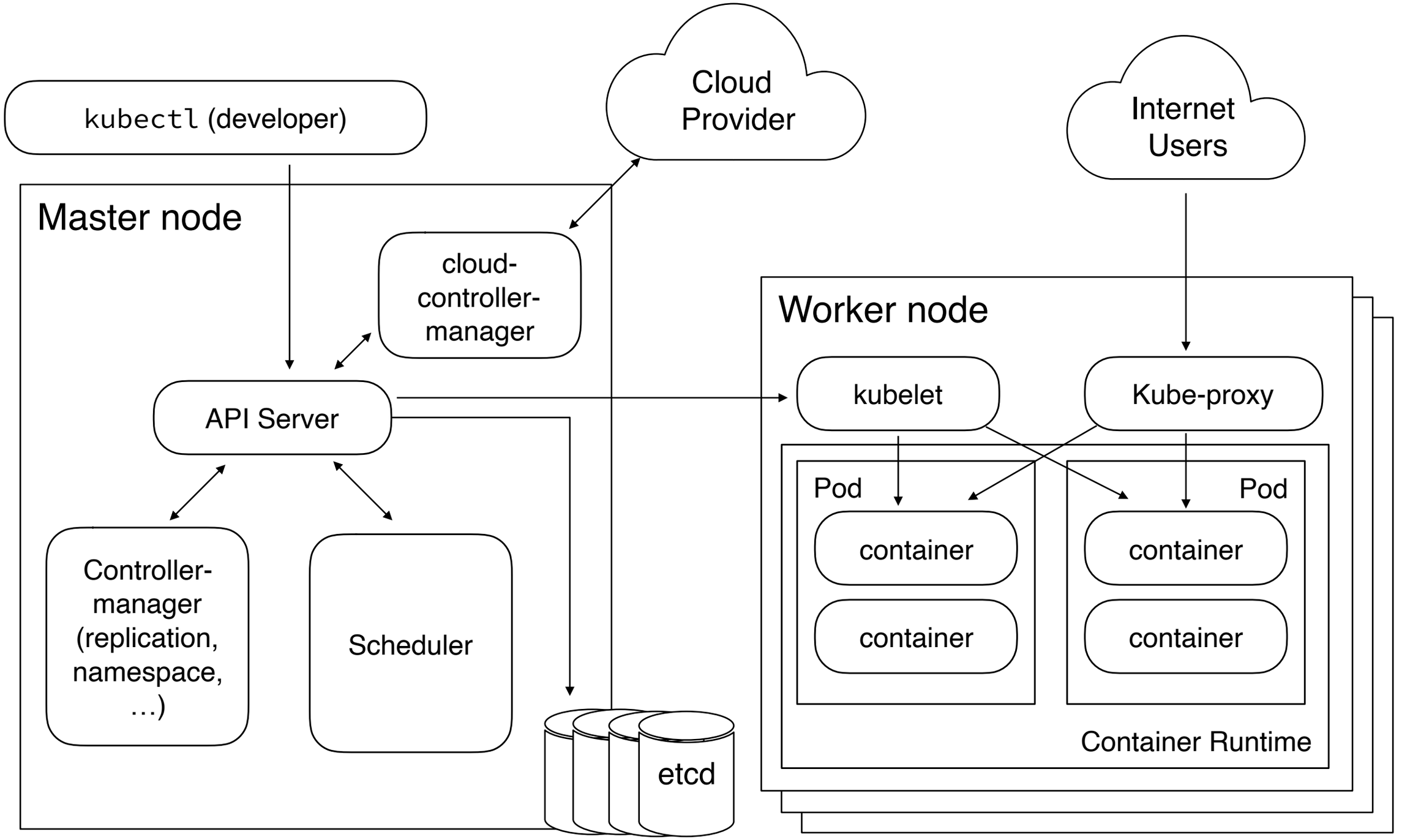
Kubernetes Core Concepts

- Pod
  - The smallest deployable object in Kubernetes
  - Encapsulates multiple application's containers, storage resources, a unique network IP, and options that govern how the containers should run
- Controllers
  - Control loop
    - » `for { if actual state != desired state then do orchestrate }`
    - » The desired state is defined in a YAML configuration file
  - Kind: Deployments
    - » horizontal scaling (e.g., rolling update)

deployment.yaml

```yaml
apiVersion: apps/v1
kind: Deployment
metadata:
  name: myapp-deployment
spec:
  selector:
    matchLabels:
      app: myapp
  replicas: 2
  template:
    metadata:
      labels:
        app: myapp
    spec:
      containers:
      - name: myapp
        image: myapp:latest
        ports:
          - containerPort: 80
```

Kubernetes Architecture



https://github.com/kubernetes/community/blob/master/contributors/design-proposals/architecture/architecture.md

Cloud Native Computing Foundation (CNCF)

> Cloud native technologies *empower* organizations to *build and run scalable applications* in modern, dynamic environments such as public, private, and hybrid clouds. **Containers, service meshes, microservices, immutable infrastructure, and declarative APIs exemplify this approach.**
>
> CNCF Cloud Native Definition v1.0 https://github.com/cncf/toc/blob/master/DEFINITION.md

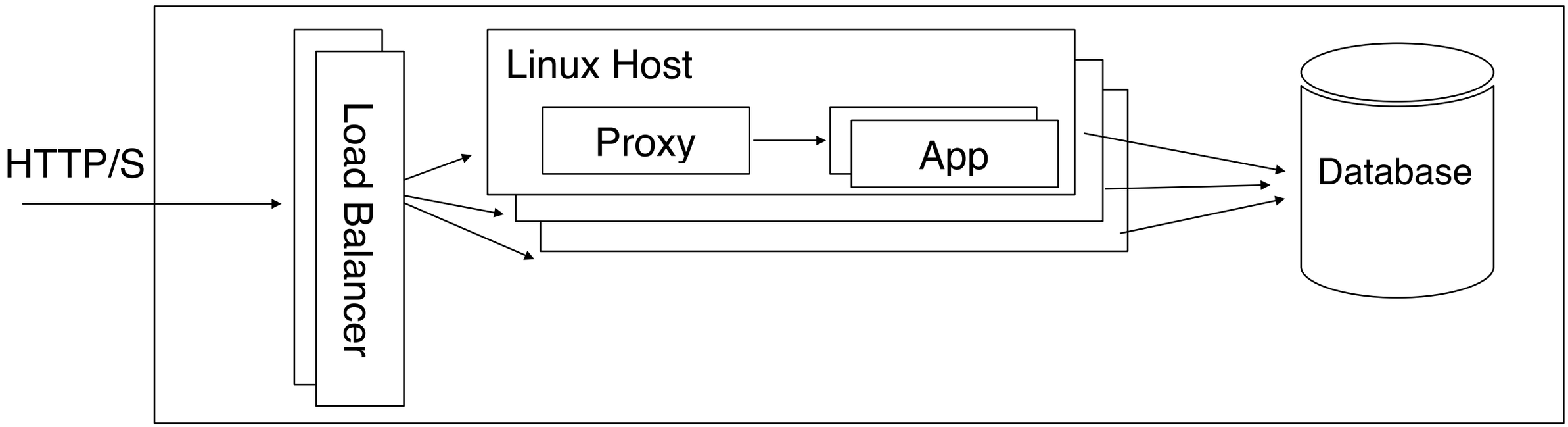
- Is a Linux Foundation project
  - Linux Foundation was founded by non-profit Open Source Development Labs (OSDL) and Free Standards Group (FSG)
- Announced with Kubernetes 1.0 in 2015
  - Operational control handed over to the community in 2018

- Hosts critical components of the global technology infrastructure
  - Microservices architecture!

CLOUD NATIVE COMPUTING FOUNDATION

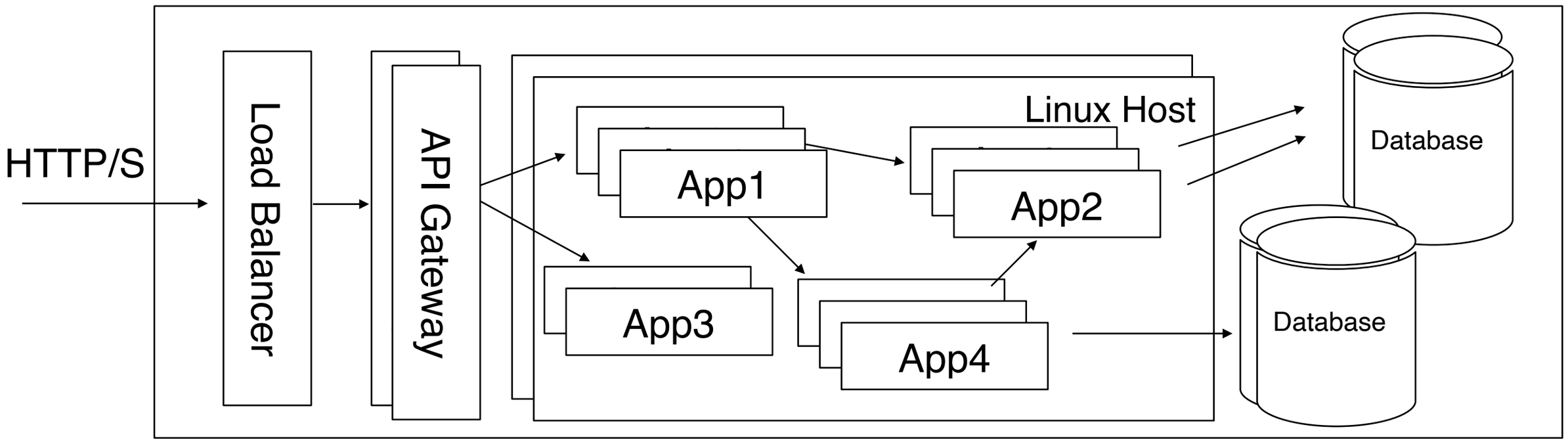
Monolith Architecture

- Monolithic code base: contributes to a single big codebase
- Monolithic database and everything tightly coupled architecture
  - Massive conflicts
  - Crash at once
  - Sticky connections



Microservice Architecture

- "…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." — Martin Fowler
- Separation of concerns: Modularity, encapsulation
- Scalability: Horizontally scaling, workload partitioning
- Virtualization & elasticity: Automated operations, on demand provisioning



Microservice Metaphors

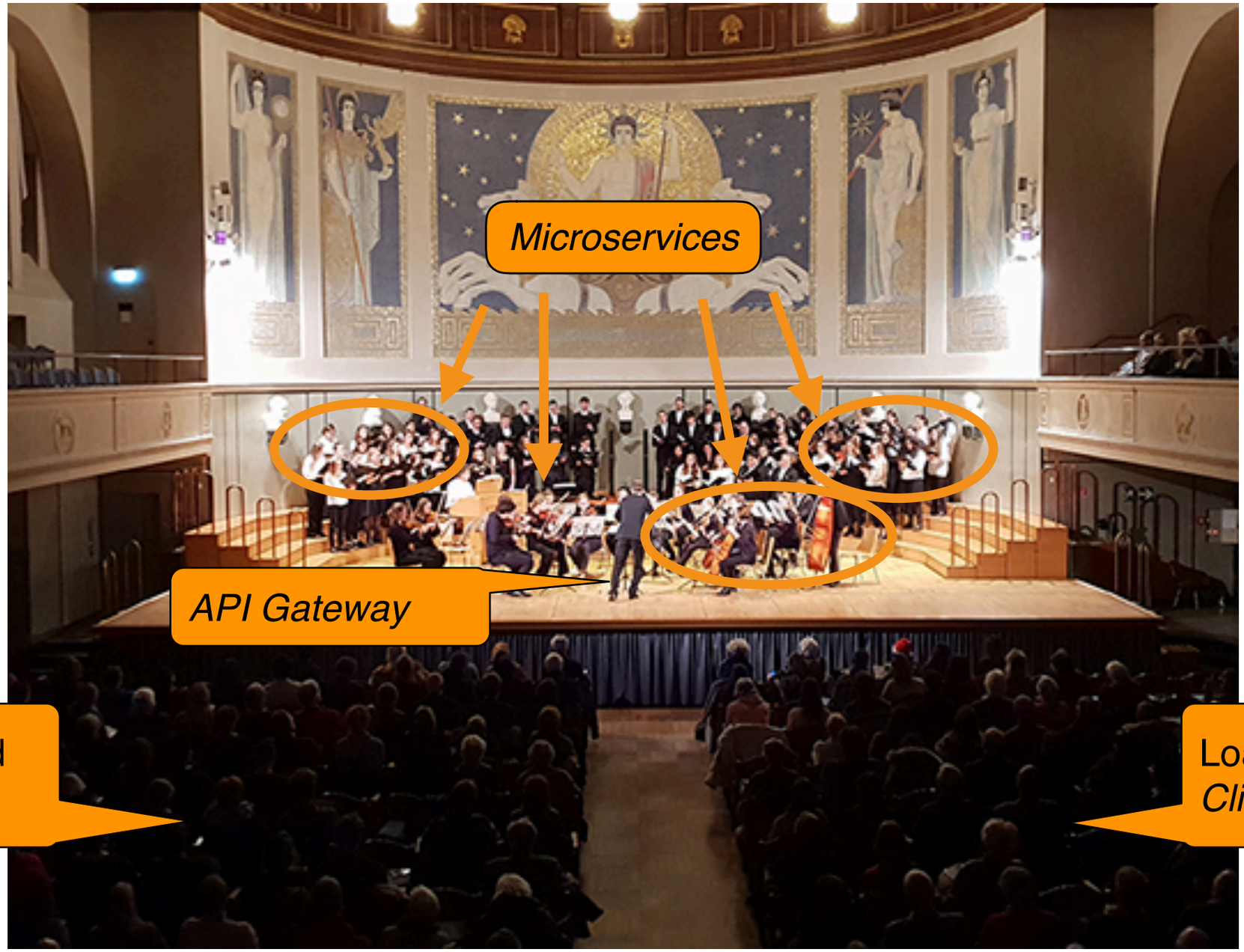


Image taken from https://www.musikwissenschaft.uni-muenchen.de/musikpraxis/collegium/eindruecke/index.html

Technologies in Microservices

Access

Load Balancer

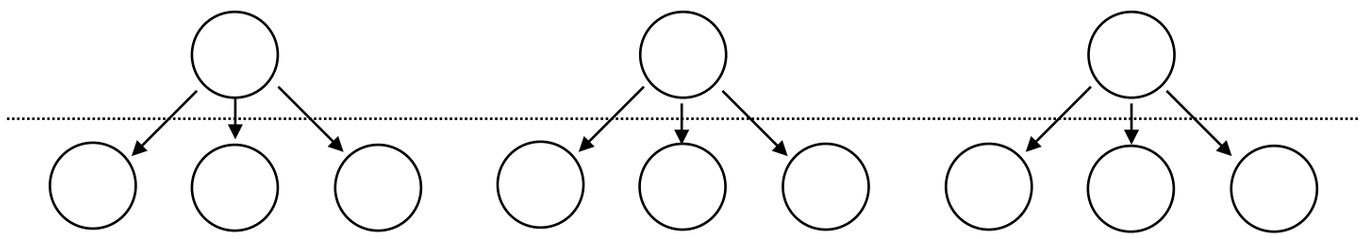
Gateway

Internal GW / Third-party GW

Business Service

Integration

Foundation



Supporting Service

Service Discovery | Configuration Center | Fault Tolerance Rate Limit | Authentication | Log Tracing | Monitoring

PaaS

Delivery System | Cluster Scheduling | Image Orchestration | Resource Orchestration | IAM

IaaS

Computation | Network | Storage | Security

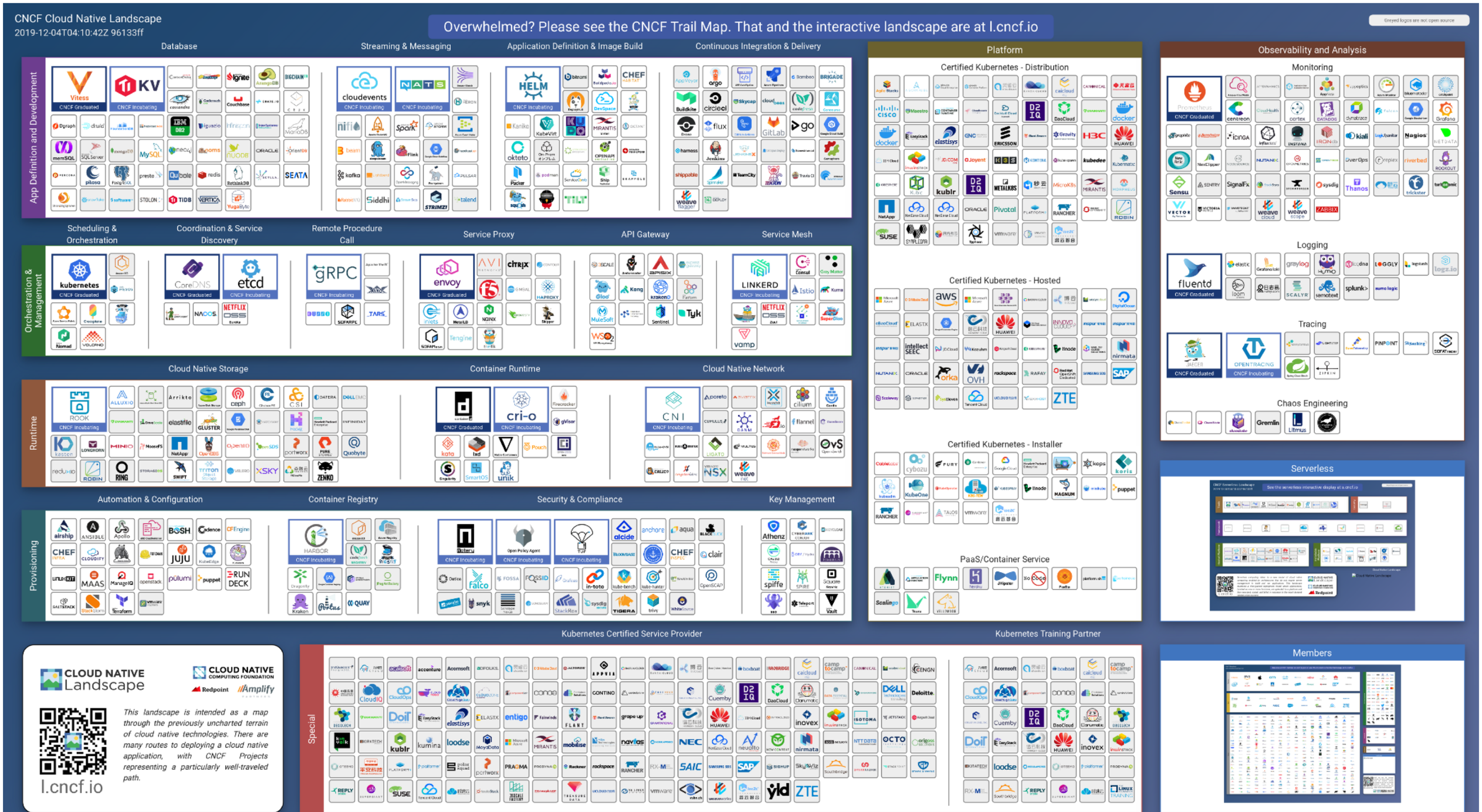
Microservices Governance and Technologies

- Providers   
- Provisioning 
  - Automation & Configuration
  - Container Registry 
  - Security & Compliance 
  - Key Management 
- Runtime 
  - Storage 
  - Container runtime 
  - Network 
- Observability and Analysis
  - Monitoring 
  - Logging 
  - Tracing 

Microservices Governance and Technologies

- Orchestration
  - Scheduling
  - Coordination & service discovery
  - PRC
  - Service proxy
  - API gateway
  - Service mesh
- Developments
  - Database
  - Streaming
  - Image build
  - continues integration & delivery
- Front-end

CNCF Cloud Native Landscape



Discussion

- Does microservice always better than monolithic?
  - Think about building your personal website with microservice architecture

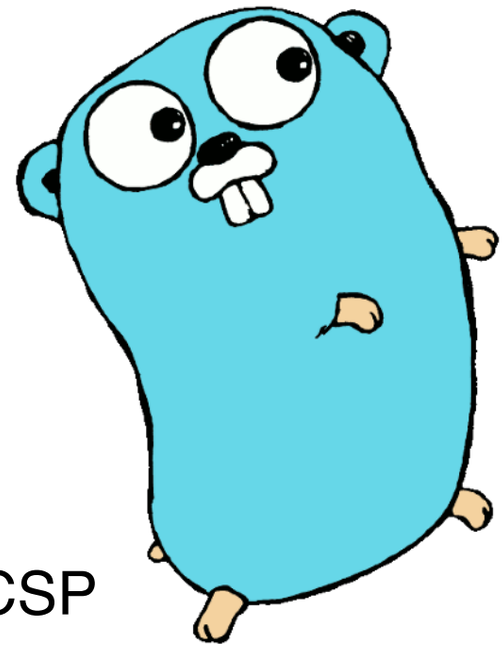
- When do you want to choose microservices architecture?

9 Technological Outlook

Literature:

https://golang.org
https://quicwg.org/base-drafts/draft-ietf-quic-http.html

Go



- Open source programming language
  - Creators: Rob Pike, Ken Thompson, Robert Griesemer
  - Started almost simultaneously with V8
  - Start from C, inspired by Pascal family and Tony Hoare's CSP
- Key features: Simple, stable, fast compilation, built-in concurrency
  - 25 keywords, stable for 10 years since Go 1 releases
  - No cycle import, no function override
  - *Goroutines* as lightweight threads
  - *Channel* philosophy "Do not communicate by sharing memory, share memory by communicating"
- Support cross compilation and package modularization
- Must be formatted to pass compilation, only one style of coding
- Is de facto the language of cloud computing at present:
  - Kubernetes, etcd, Prometheus, Docker… are implemented by Go

Why Go? An Oversimplified Version

- Before Go
  - C and Unix became dominant in research
  - The desire for a higher-level language led to C++, e.g.
    ```
    for(map<string, pair<string,string> >::const_iterator
    iter = p.begin(); iter != p.end(); ++p)
    ```
  - C++ became the language of choice in parts of industry and in many research universities.
  - Java arose as a clearer stripped-down C++
  - By the late 1990s, a teaching language was needed that seemed relevant, and Java was chosen.
  - C++03 brings more complex features, e.g.
    ```
    for(const auto&& val: p)
    ```

https://spf13.com/presentation/the-legacy-of-go/

Why Go? Sophistication or Level of Abstraction

"Any given function template specialization F1 is eliminated if the set contains a second function template specialization whose function template is more specialized than the function template of F1 according to the partial ordering rules of 17.6.6.2. After such eliminations, if any, there shall remain exactly one selected function." — *Working Draft, Standard for Programming Language C++ 16.4 Address of overloaded function*

- *"The reason I was enthusiastic about Go is because, at the same time we were starting on Go, I tried to read the C++ 0x proposed standard, that was the convincer for me." — Ken Thompson*
- *"The code is harder to understand simply because it is using a more complex language" — Rob Pike*
- *"In Go (compare to C++), we're trying to do a completely different approach, to take things out as much as we can, to reduce them to the bare bones, the absolute minimum that you need to build everything up." — Robert Griesemer*

Go Design: Concurrency

- Concurrency is the ability to write your program as independently executing pieces. In Go, concurrency has three elements:
  - Grouting (execution): light-weight threads
    - » `go function(args)`
  - Channels (communication): Message passing and synchronization
    - » Send message: `ch <- value`
    - » Receive message: `dst := <- ch`
  - Select (coordination): managing channels concurrently
    - »
```
select {
 case value := <- ch1: …
 case ch2 <- value: …
 }
```

Example: A High Performance HTTP Server

main.go

```go
package main

import (
    "fmt"
    "log"
    "net/http"
)

func こんにちは_Gophers(w http.ResponseWriter, req *http.Request) {
    fmt.Fprintf(w, "こんにちは  Gophers!\n")
}

func main() {
    http.HandleFunc("/", こんにちは_Gophers)
    err := http.ListenAndServe("localhost:12345", nil)
    if err != nil {
        log.Fatal("ListenAndServe: ", err)
    }
}
```

Packages

UTF8 by default

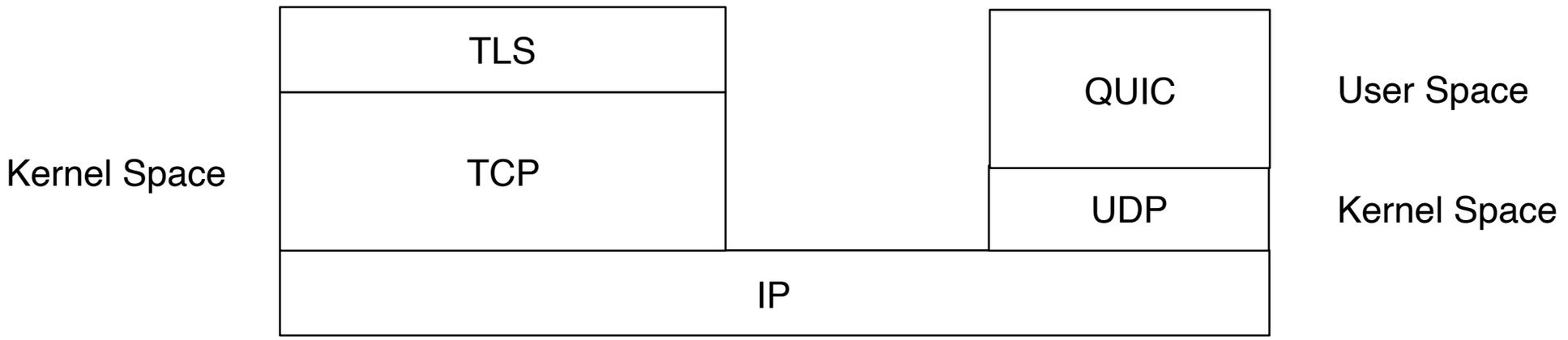
Fprintf direct to network connection

Truly concurrent and production ready

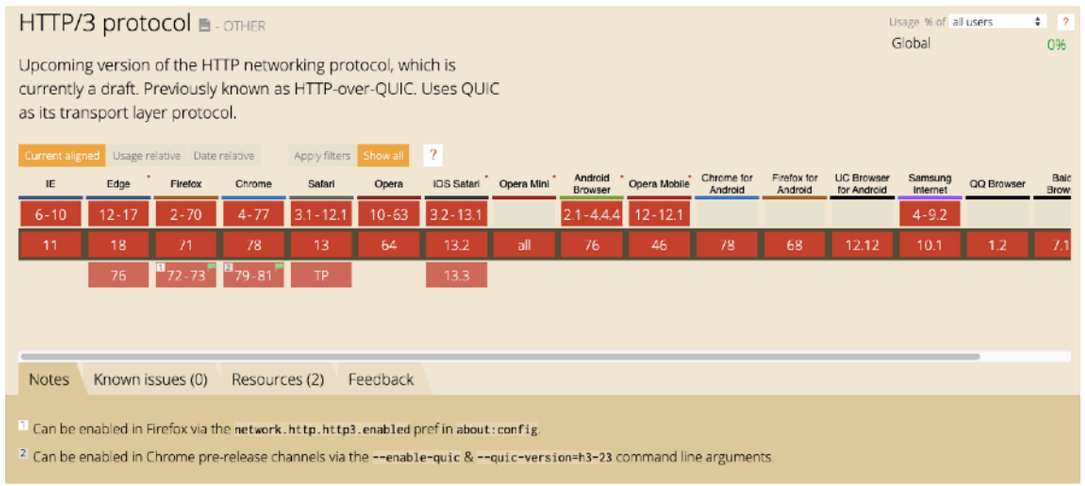
Error handling

HTTP/3

- Is the upcoming third major version of Hypertext Transfer Protocol
- Draft based on Request on Comments (RFC) draft, named “HTTP over QUIC, user space congestion control is used over UDP



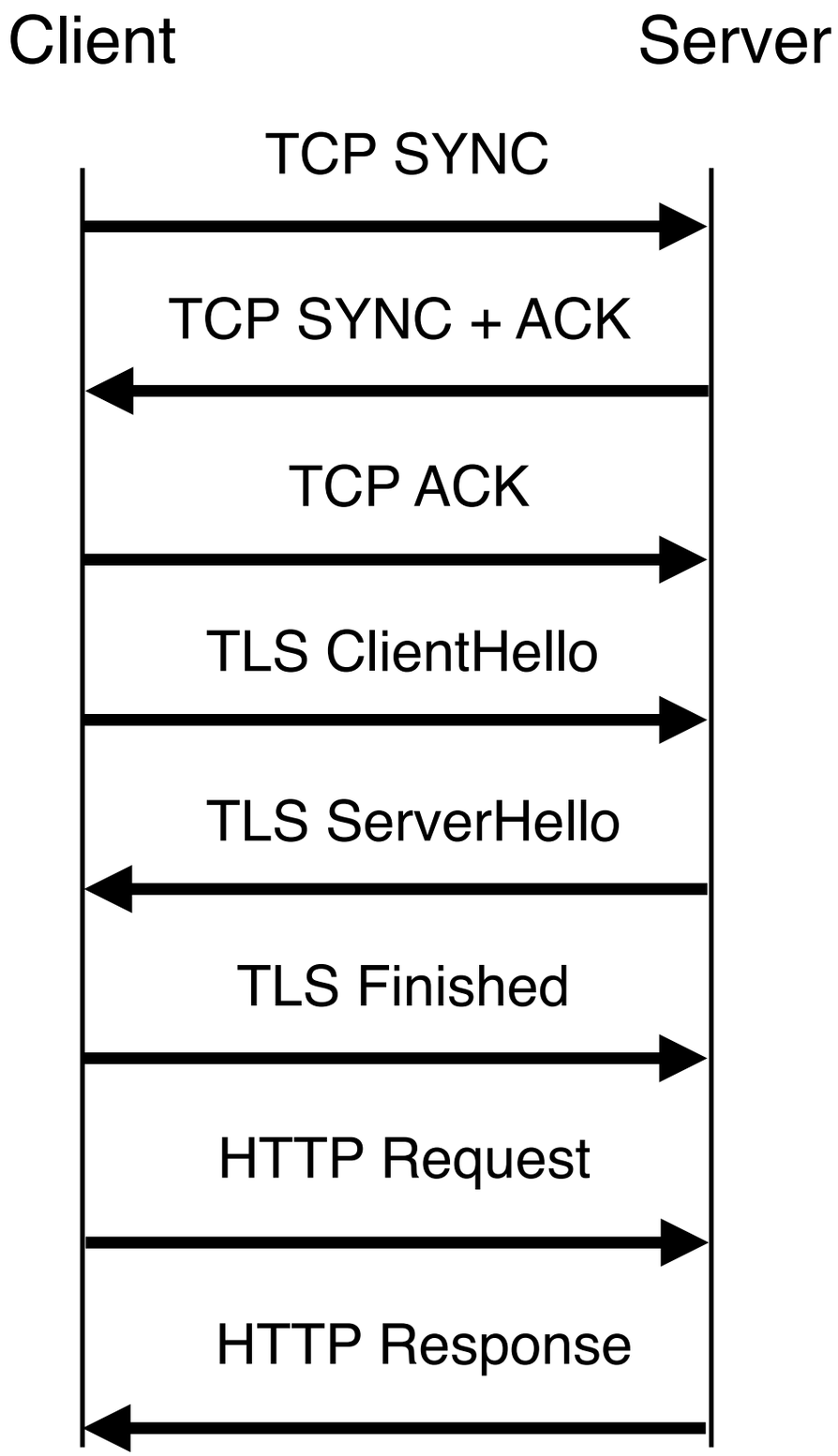
- No public supports yet
  - Available on Chrome and Firefox latest beta



https://caniuse.com/#feat=http3

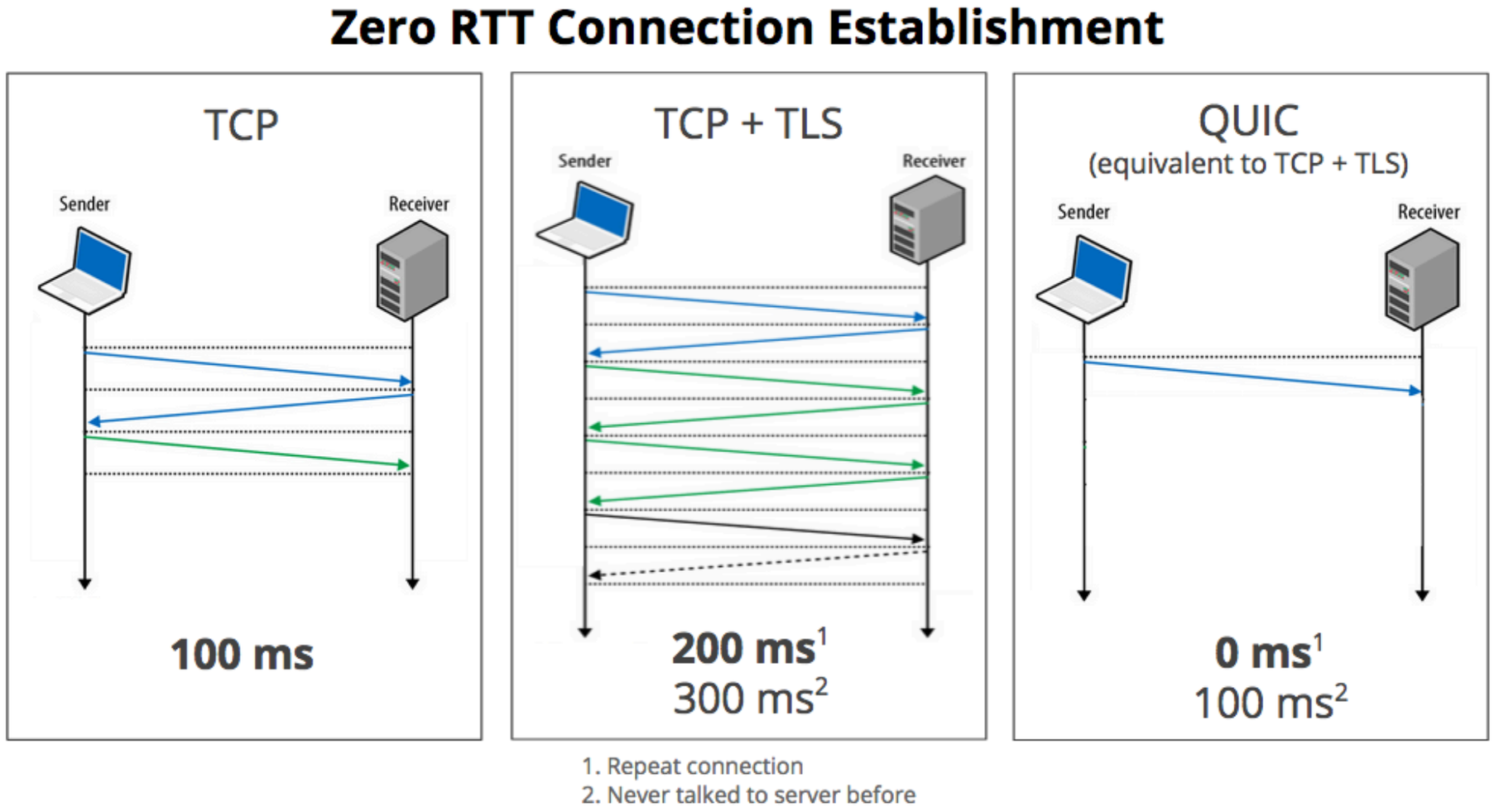
Evolution of HTTP

- HTTP/0.9 (1991)
- HTTP/1.0 (1996)
  - TCP connection is created for each request/response exchange between clients
  - All requests incur a latency penalty
- HTTP/1.1 (1997)
  - “keep-alive” connections that allow clients to reuse TCP connections
- HTTP/2.0 (2015)
  - Allow concurrently multiplex different HTTP exchanges onto the same TCP connection
- HTTP/3.0 (2018)



HTTP/3.0

- How communication is processed between two persons?



https://blog.chromium.org/2015/04/a-quic-update-on-googles-experimental.html

9 Technological Outlook

Literature:

Conway ME. How Do Committees Invent? Datamation magazine. 14(4), pp.28-31.

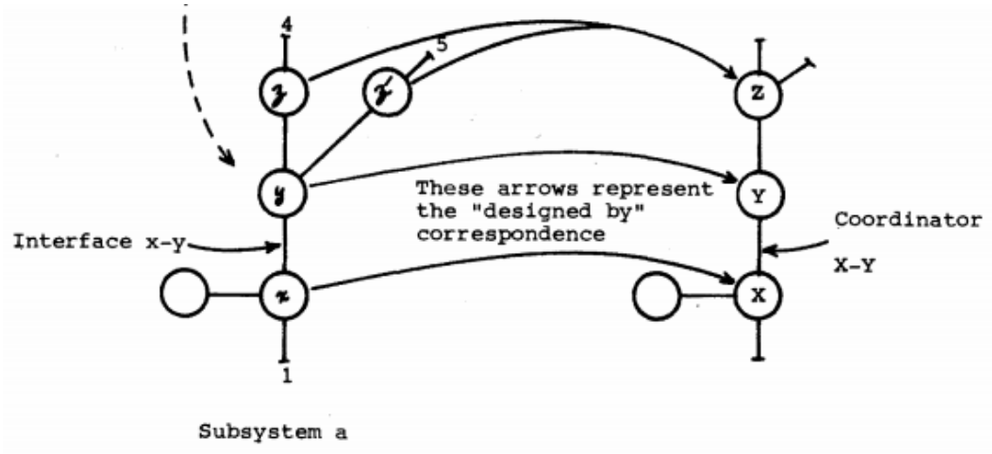
Brooks FP, No Silver Bullet. IEEE computer. 1987 Apr;20(4):10-9.

Brooks FP. The Mythical Man-Month, Anniversary ed. p. cm. 1995.

Micah Beck. 2019. On the hourglass model. Commun. ACM 62, 7 (June 2019), 48-57.

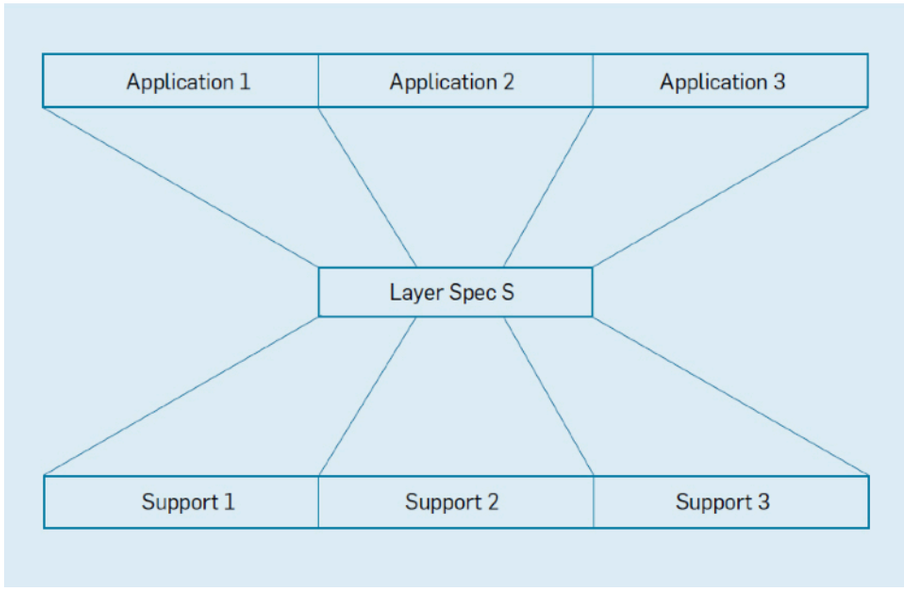
Architecture and Organizations

- Maintainability, reliability, and security are the most important (at scale)
- Monolith vs. Microservice
  - Web applications support any style
  - Stateless is the key to introduce redundancy (reliability)
  - Premature optimization is the root of all evil



Conway ME. How do committees invent. Datamation. 1968 Apr;14(4):28-31.

- Conway's Law and Hourglass Model
  - The Conway's Law: *Organizations which design systems … are constrained to produce designs which are copies of the communication structure of these organizations*
  - The Hourglass Model: *Logical weakness is critical to the development scalability*



Micah Beck. 2019. On the hourglass model. Commun. ACM 62, 7 (June 2019), 48-57.

Take Away

- Open-source and developer community matters and are eating the world
- Future outlook:
  - Is hard to say, popularity != future
    - » But many experiences and lessons can help us make the prediction
  - Virtualization, containerization, and orchestration are hard
    - » See WebAssembly and CNCF landscape
  - Simplicity is complicated, but the clarity is worth the fight
    - » Compare JavaScript, TypeScript, C++, Rust, and also Go

Discussion (Time Permitting)

- When does a technical problem become an “organization” problem?
  - What is the general process of resolving the issue?
  - What is the root cause that technologies been revolutionized?

- How do you imaging WebAssembly changes the way of front-end developments?
  - Think about virtualization and containerization

- What could change if content distribution achieve (nearly) zero delay time?