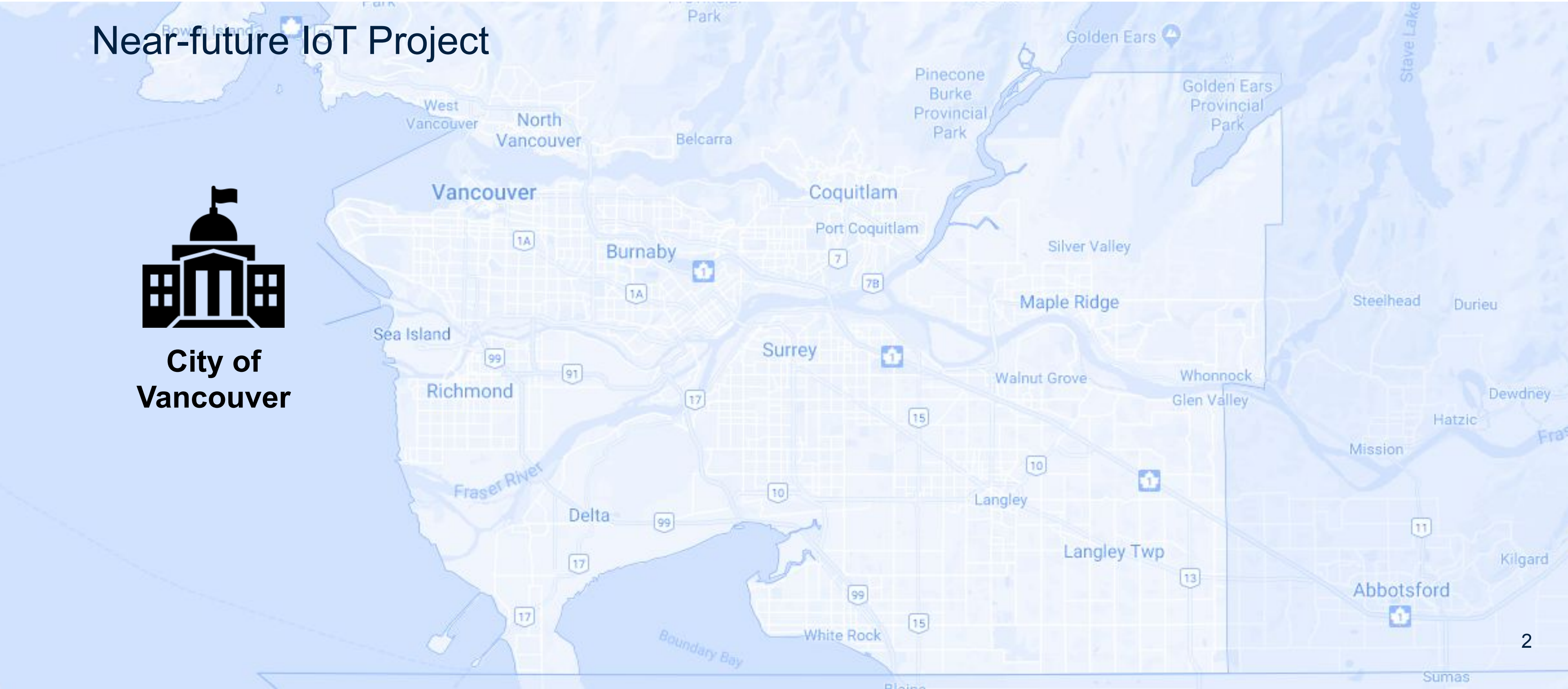
OneOS: IoT Platform based on POSIX and Actors

🎤 Kumseok Jung, UBC
Julien Gascon-Samson, ÉTS Montréal
Karthik Pattabiraman, UBC

Motivation

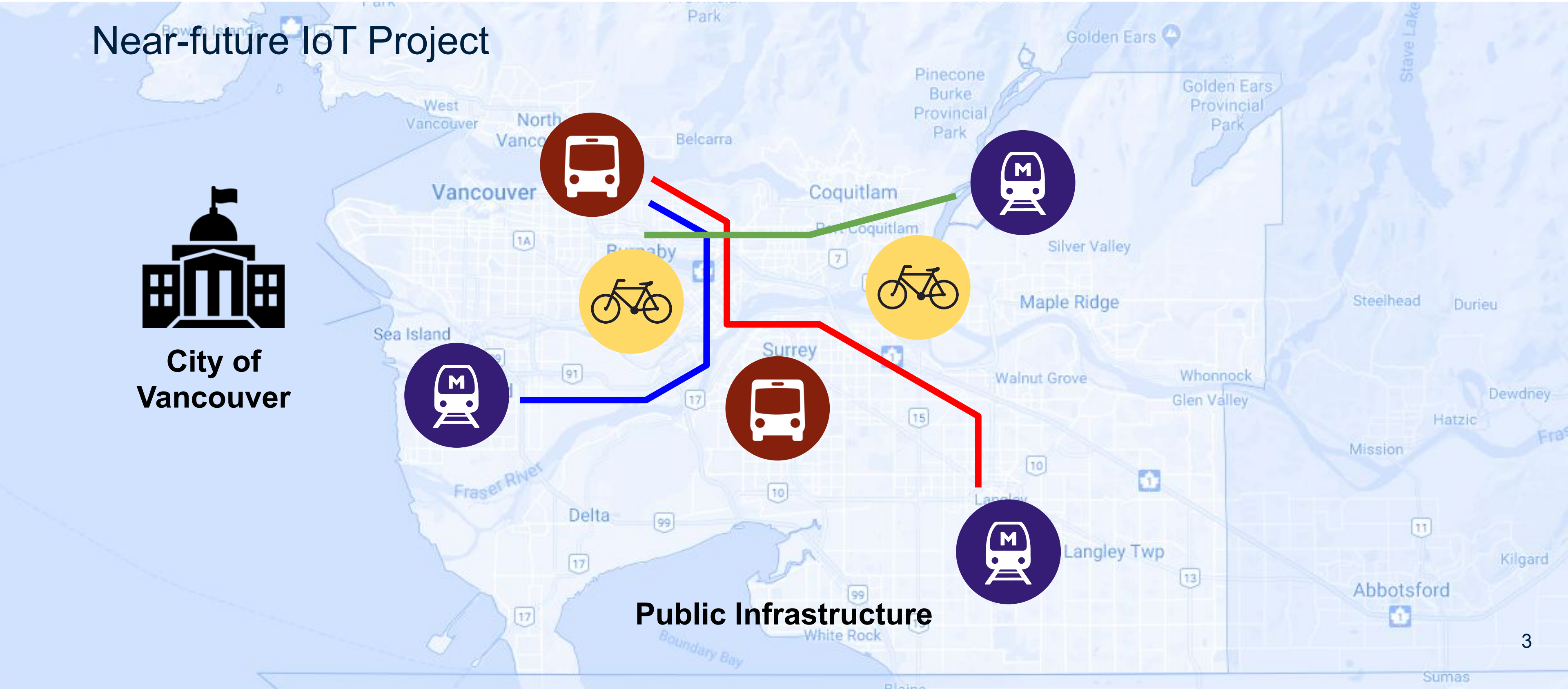
Near-future IoT Project



City of Vancouver

Motivation

Near-future IoT Project

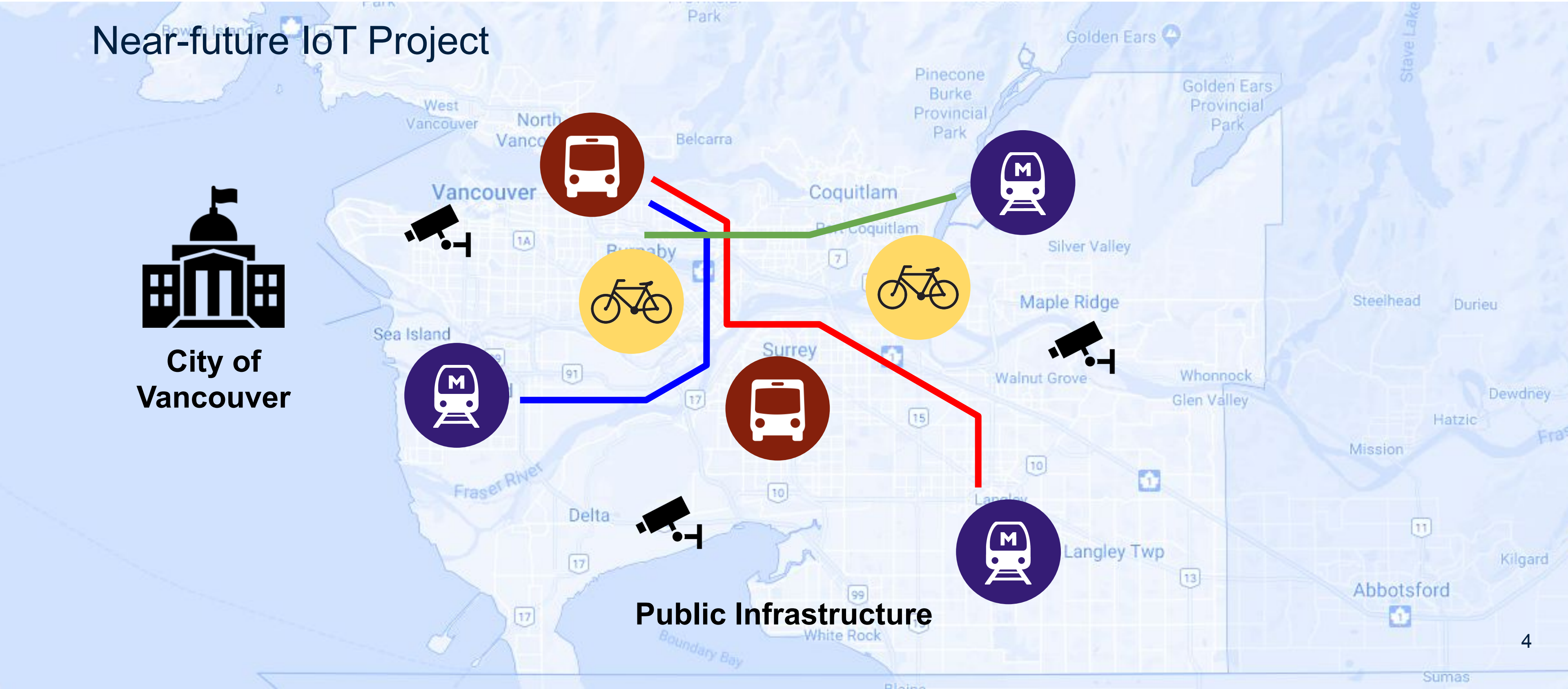


City of Vancouver

Public Infrastructure

Motivation

Near-future IoT Project



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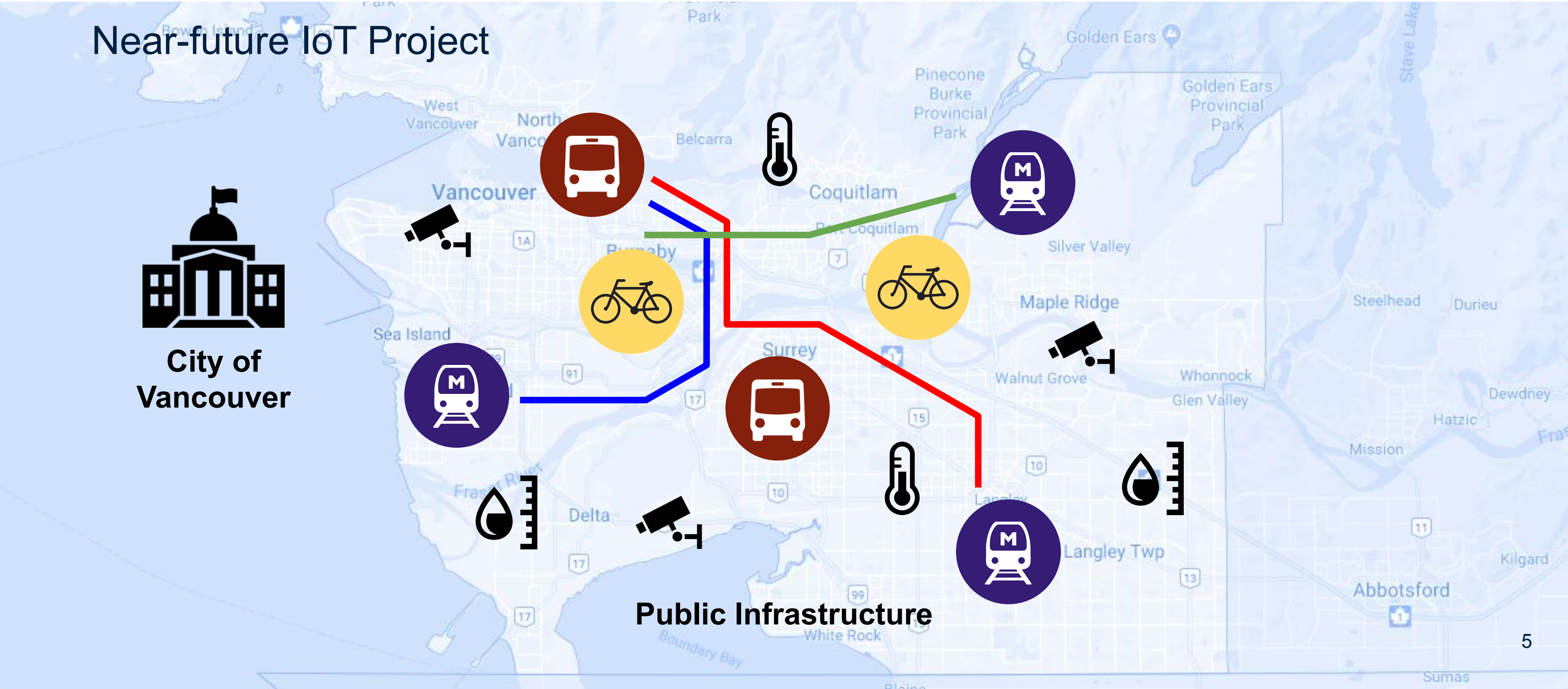
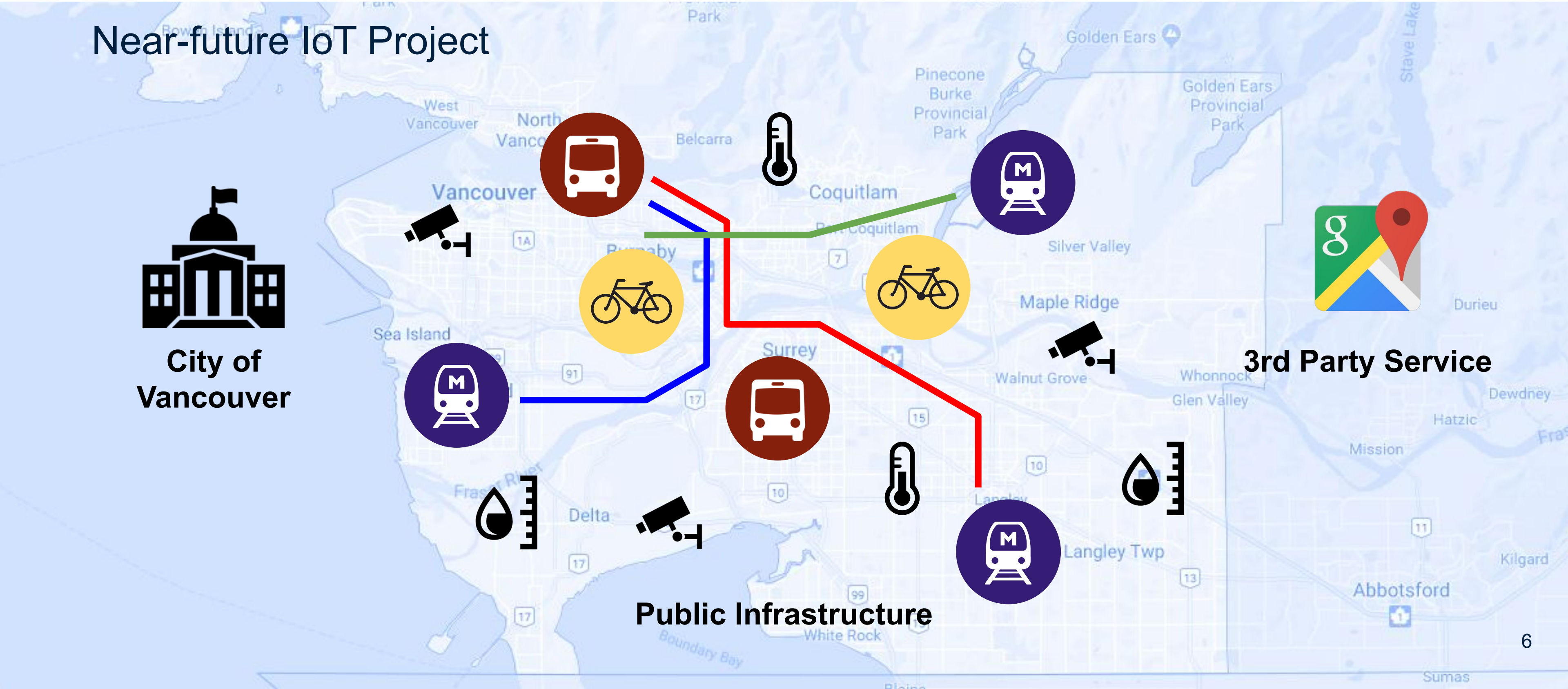


City of Vancouver

Public Infrastructure

Motivation

Near-future IoT Project



City of Vancouver

3rd Party Service

Public Infrastructure

Motivation

City of Vancouver

Alice
Engineer

Motivation

City of Vancouver

Alice
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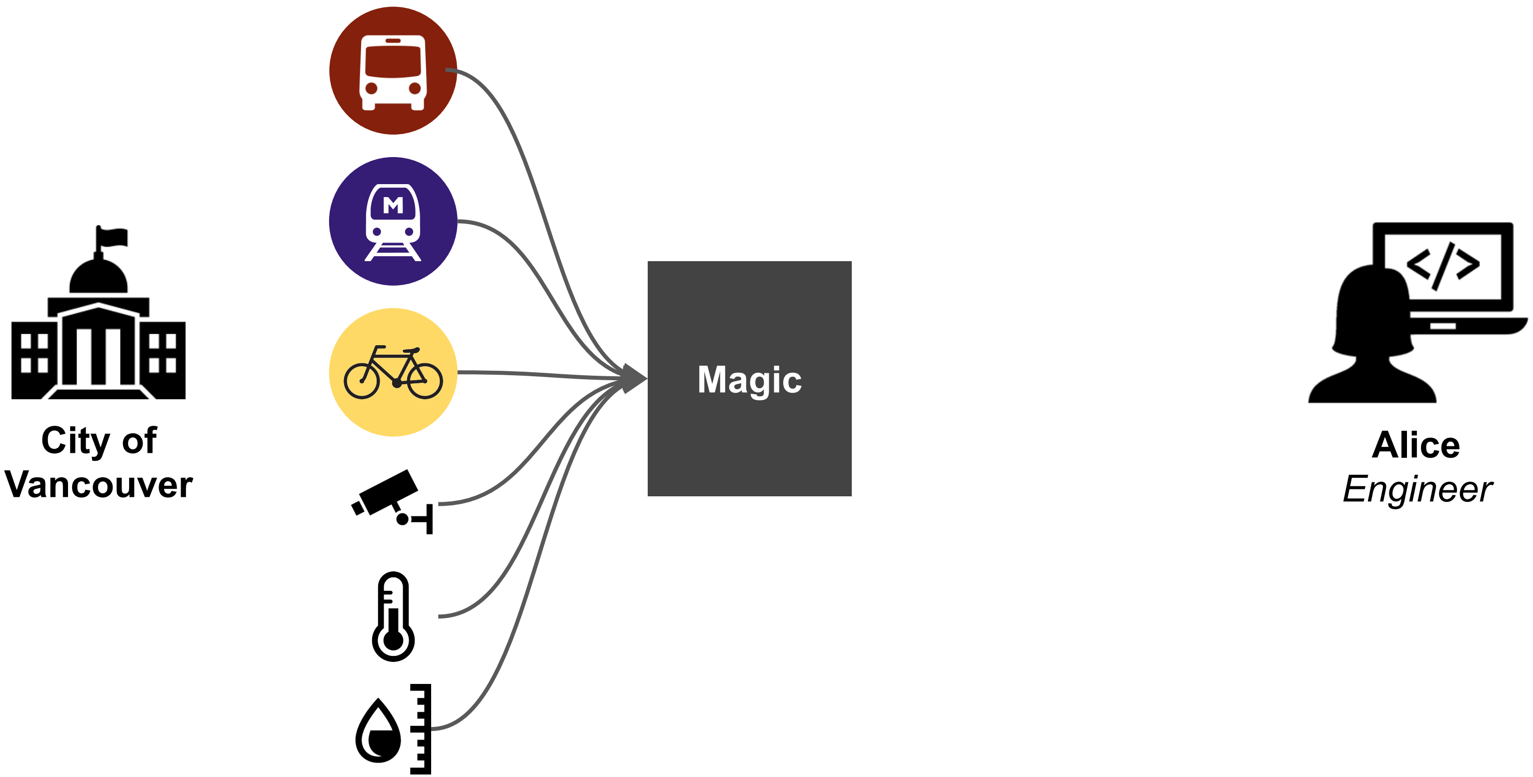
Motivation

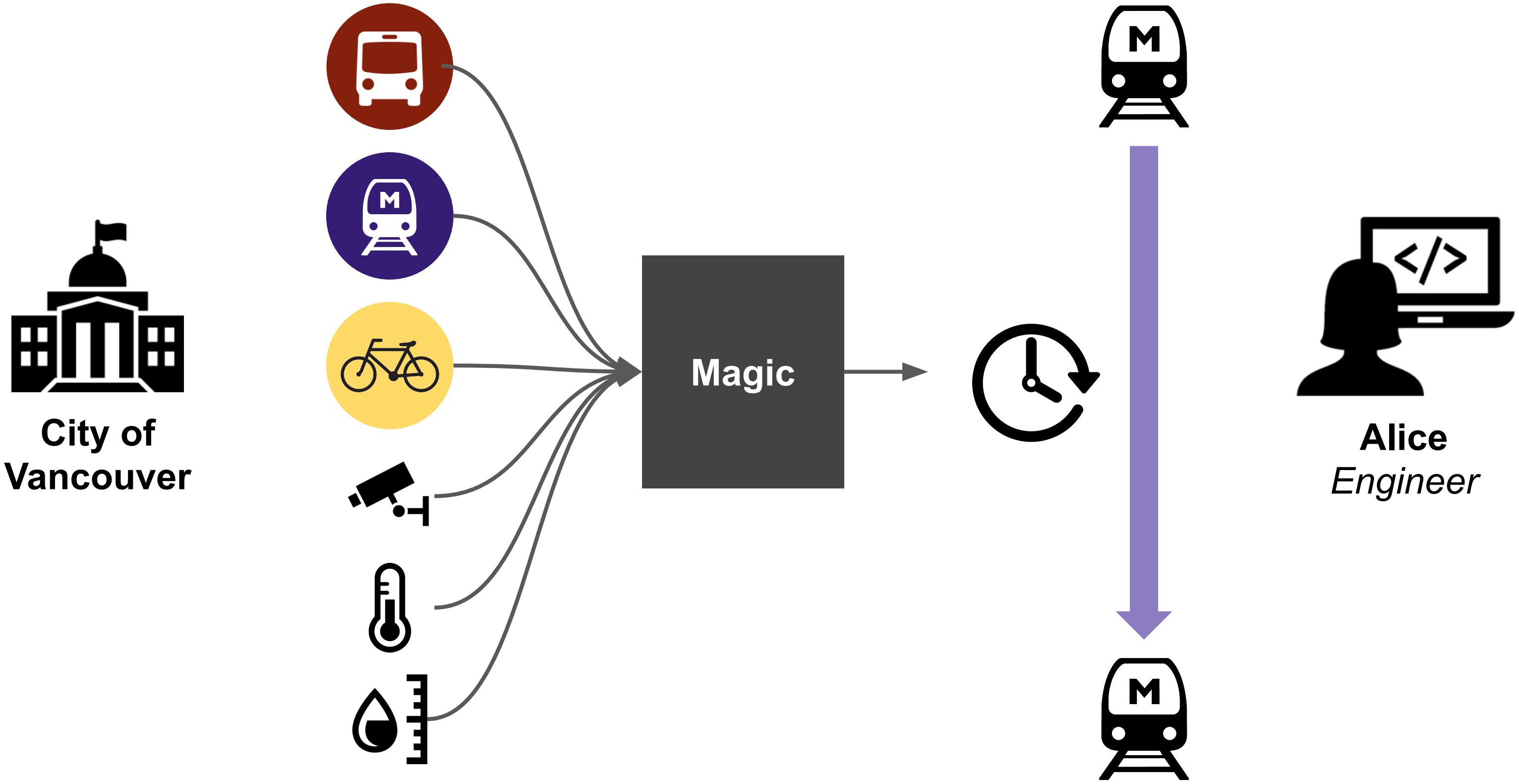


City of Vancouver

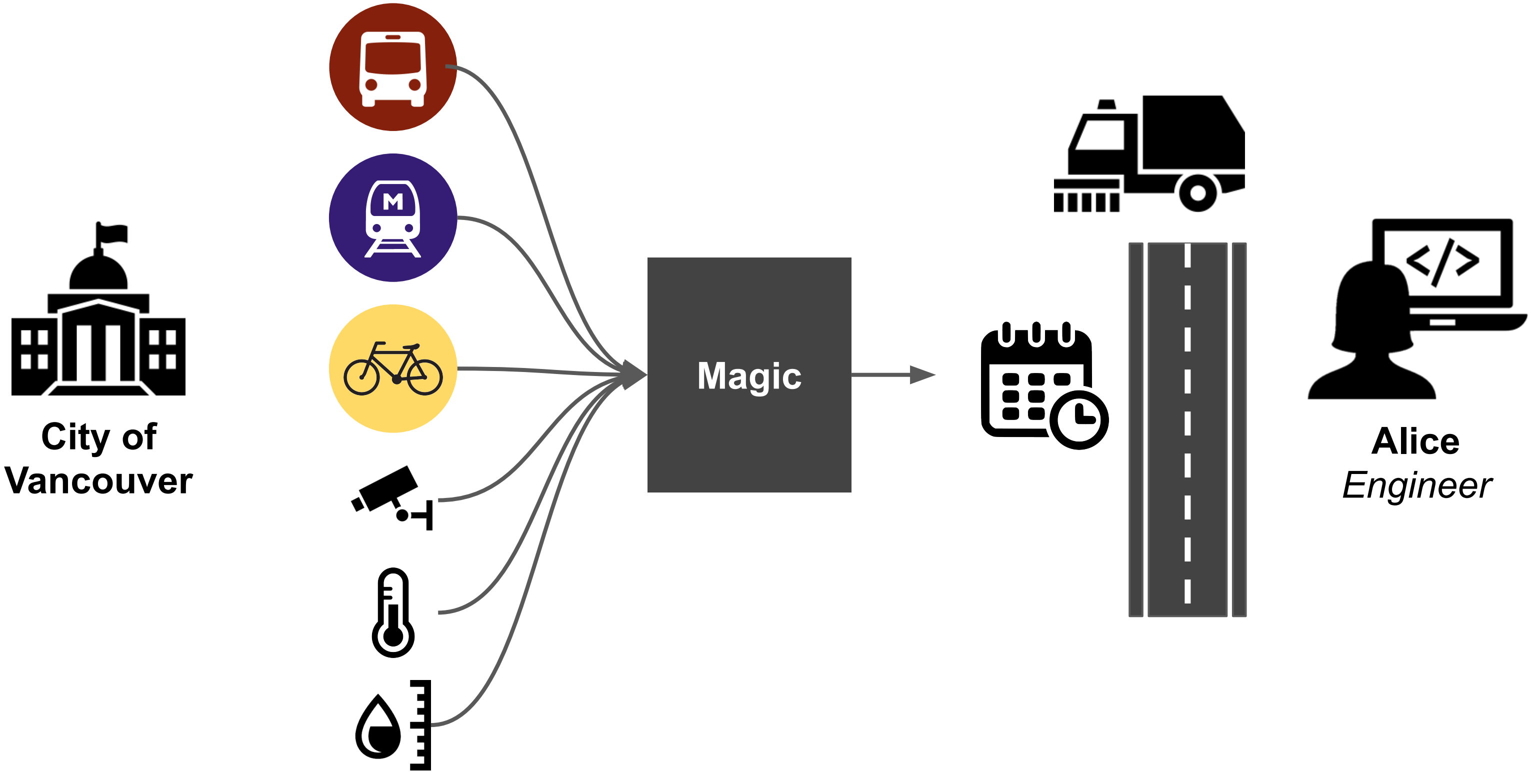
Magic

Alice
Engineer

Motivation



Motivation



City of Vancouver

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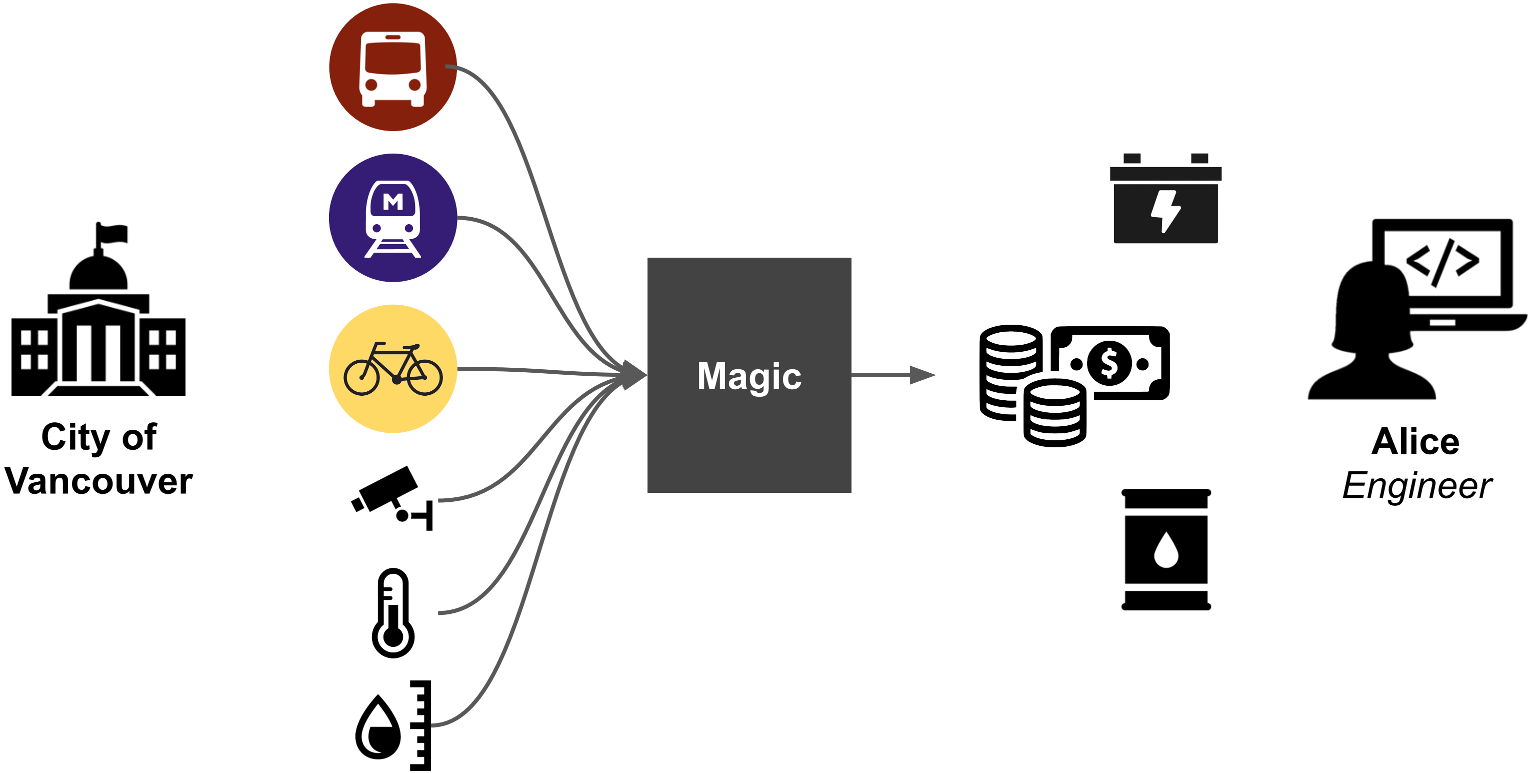
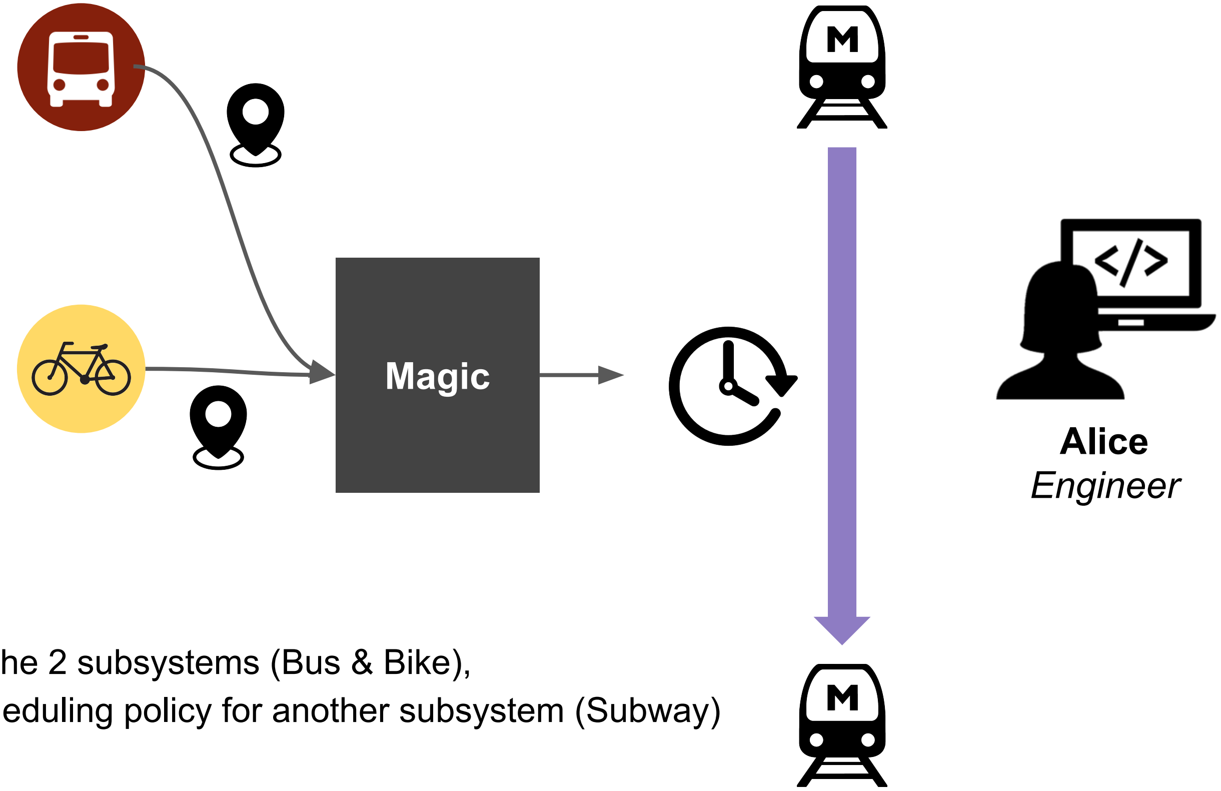
Motivation



Challenges



Example Problem:

Collect GPS data from the 2 subsystems (Bus & Bike),
compute an optimal scheduling policy for another subsystem (Subway)

Challenges: Heterogeneity

Company A 🚌

Company B 🚲

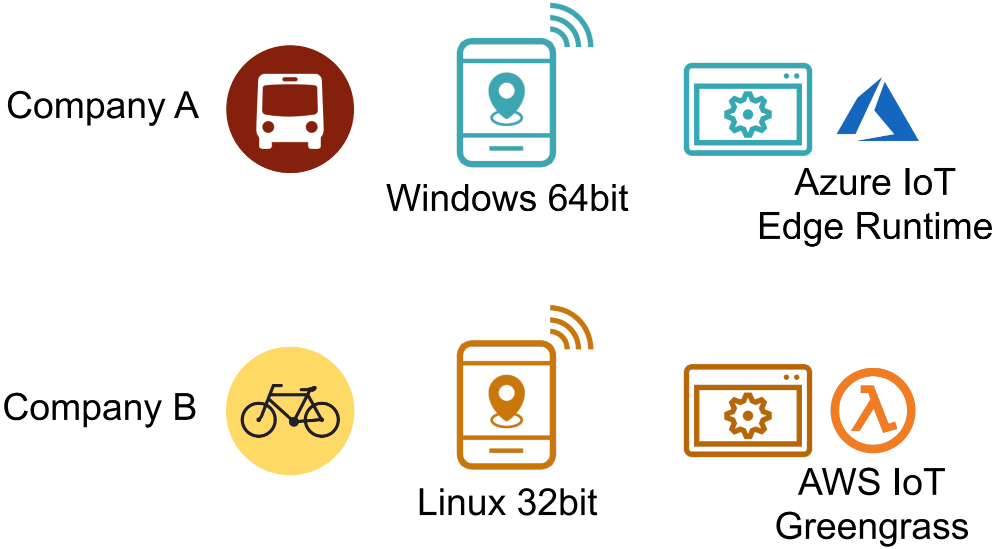
Challenges: Heterogeneity

Company A 🚌 📱 Windows 64bit

Company B 🚲 📱 Linux 32bit

Heterogeneity in Hardware and Operating Systems

Challenges: Heterogeneity



Company A

Windows 64bit

Azure IoT
Edge Runtime

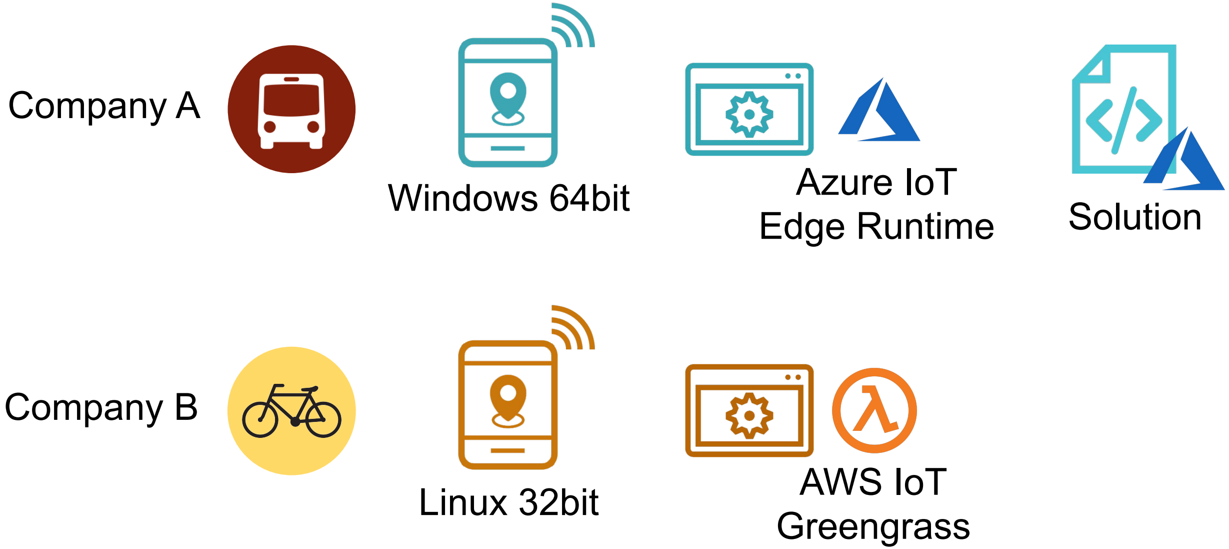
Company B

Linux 32bit

AWS IoT
Greengrass

Heterogeneity in Languages and Frameworks

Challenges: Heterogeneity



Company A

Windows 64bit

Azure IoT Edge Runtime

Solution

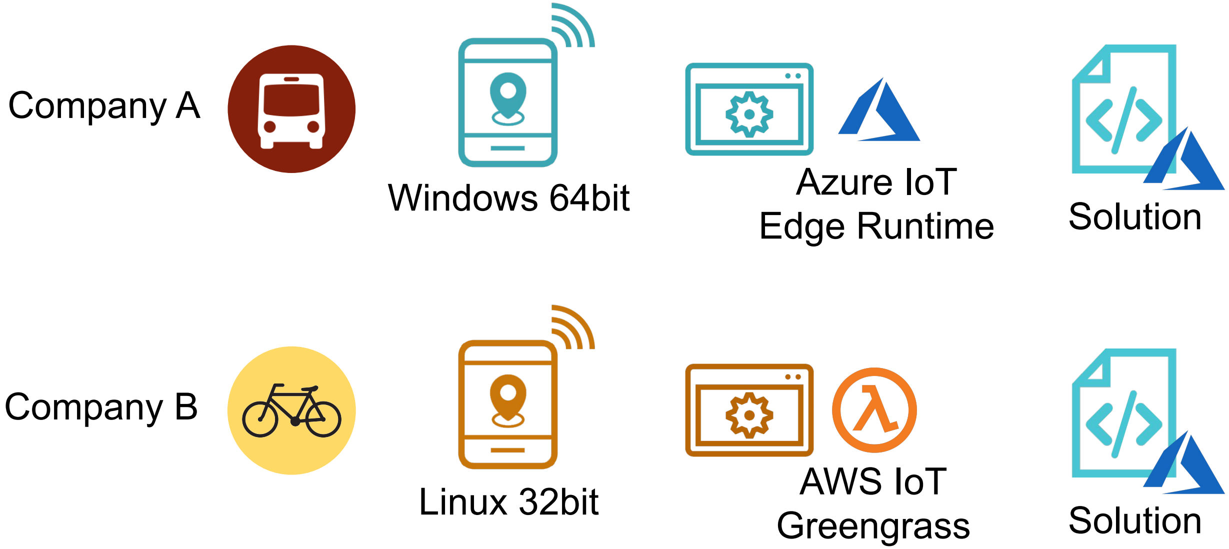
Company B

Linux 32bit

AWS IoT Greengrass

Software within a **specific framework** is **not portable** across different frameworks

Challenges: Heterogeneity



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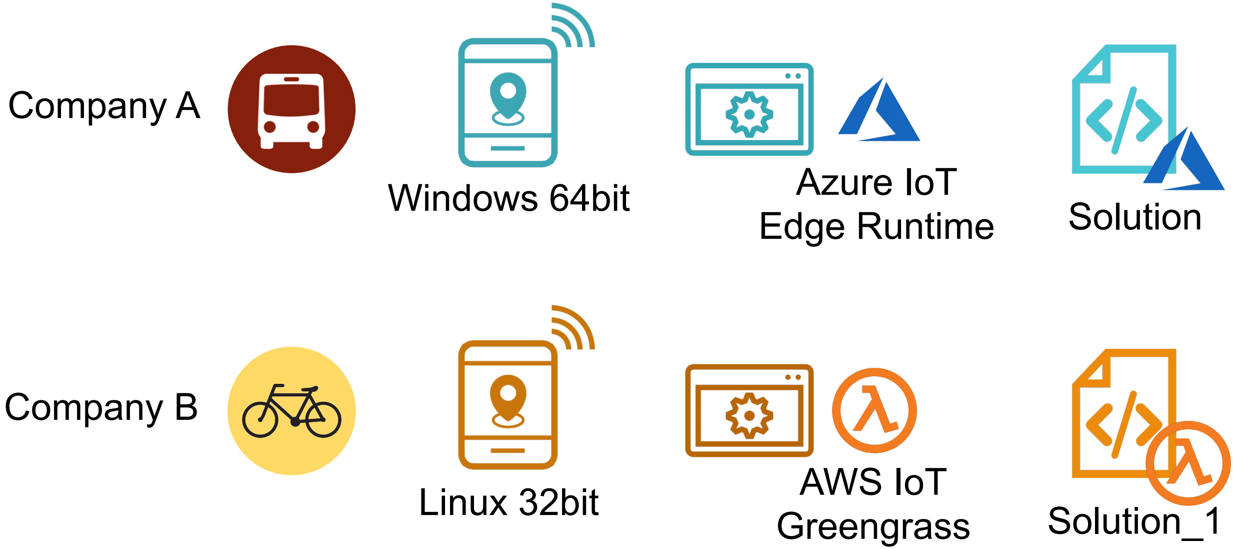

Company A

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Azure IoT
Edge Runtime

Solution

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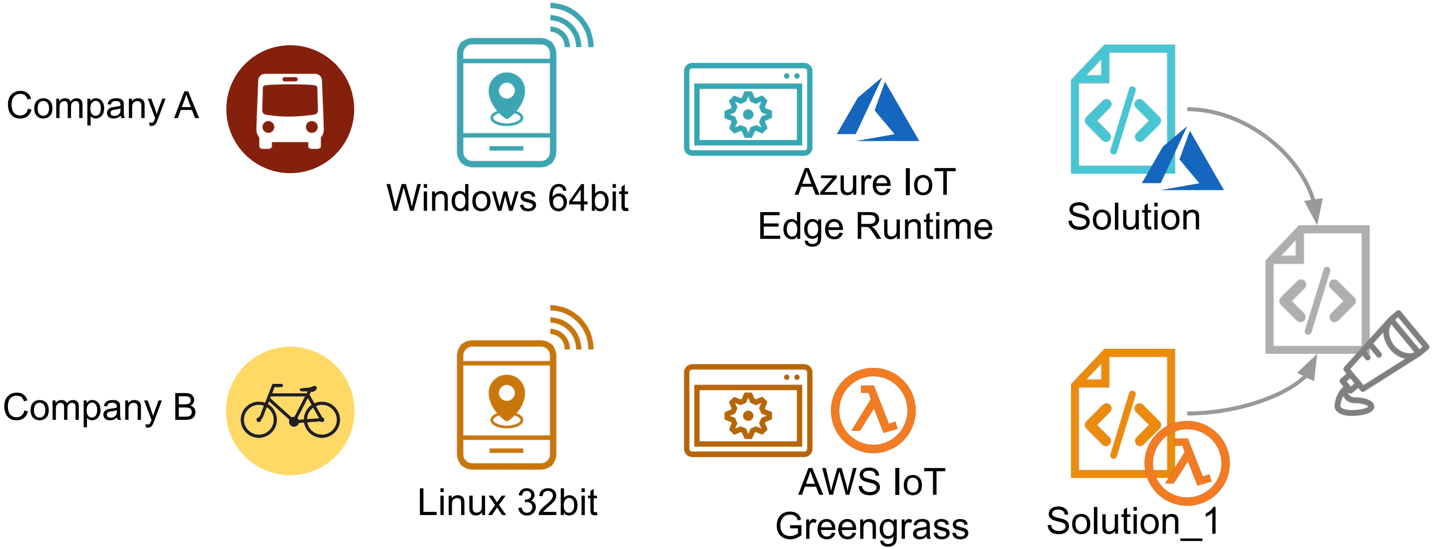
Linux 32bit

AWS IoT
Greengrass

Solution_1

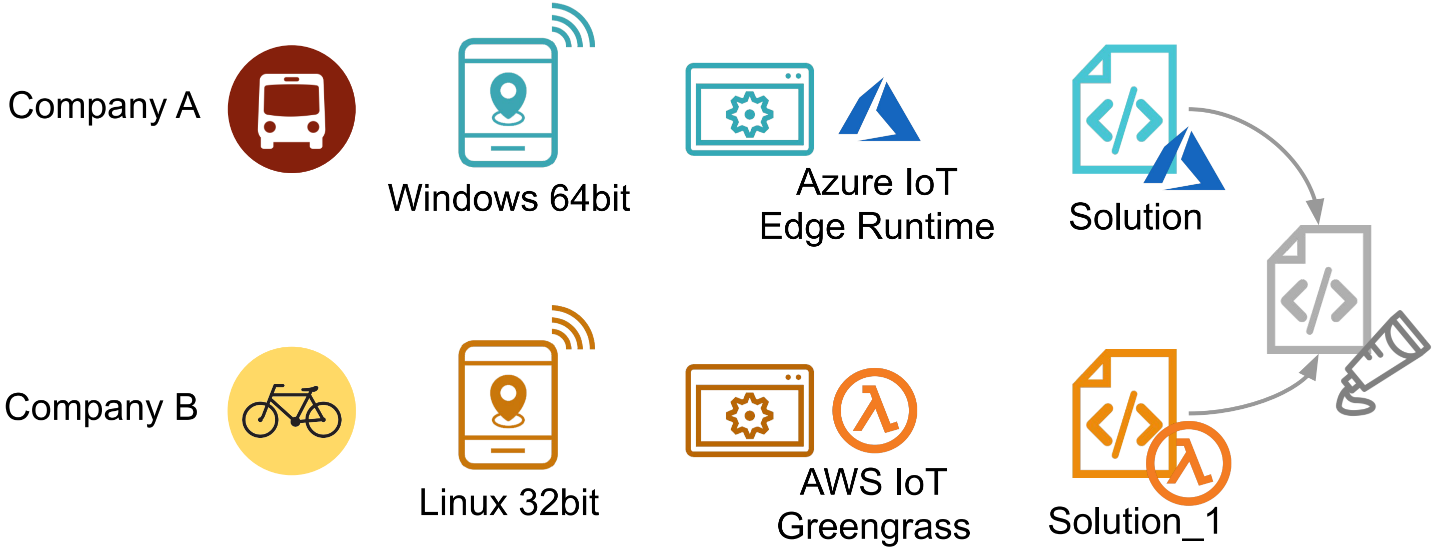
Need to rewrite the **same application logic**
for **different frameworks**

Challenges: Heterogeneity



Difference in application semantics
resolved by **more glue software**

Challenges: Heterogeneity



Company A

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Azure IoT Edge Runtime

Solution

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Linux 32bit

AWS IoT Greengrass

Solution_1

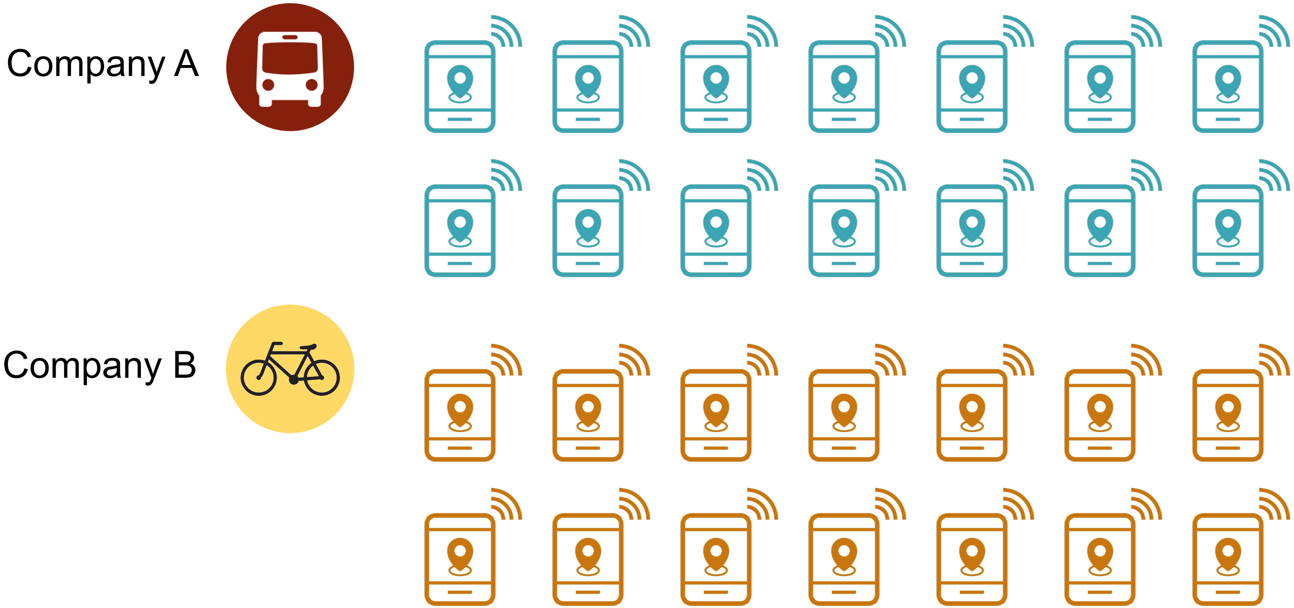
We end up with: **Heterogeneity** in Application Software

Challenges: Scale & Dynamicity

Company A

Company B

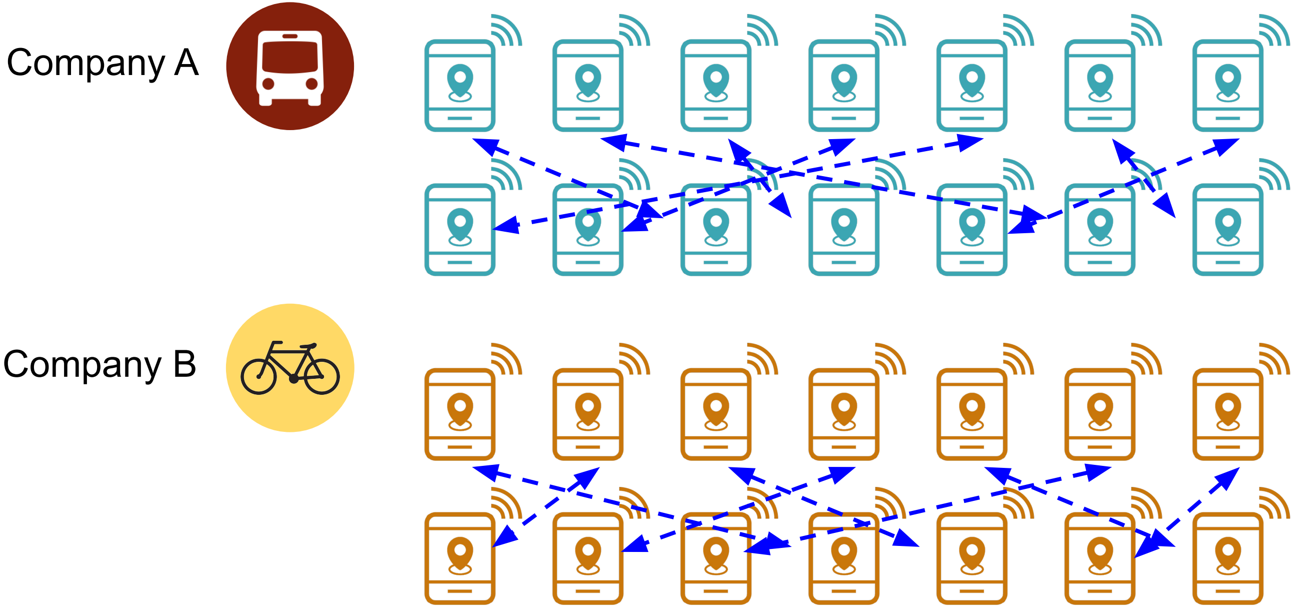
Challenges: Scale & Dynamicity



Company A

Company B

Challenges: Scale & Dynamicity



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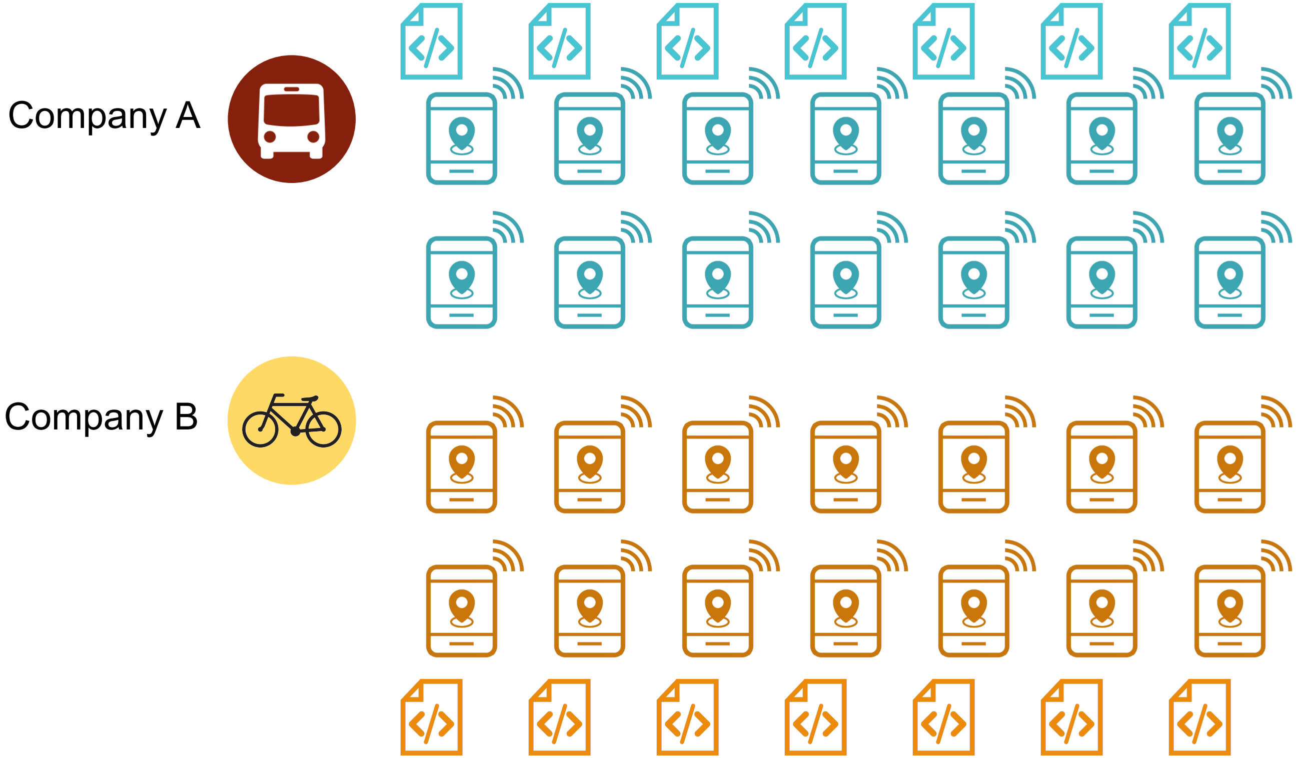
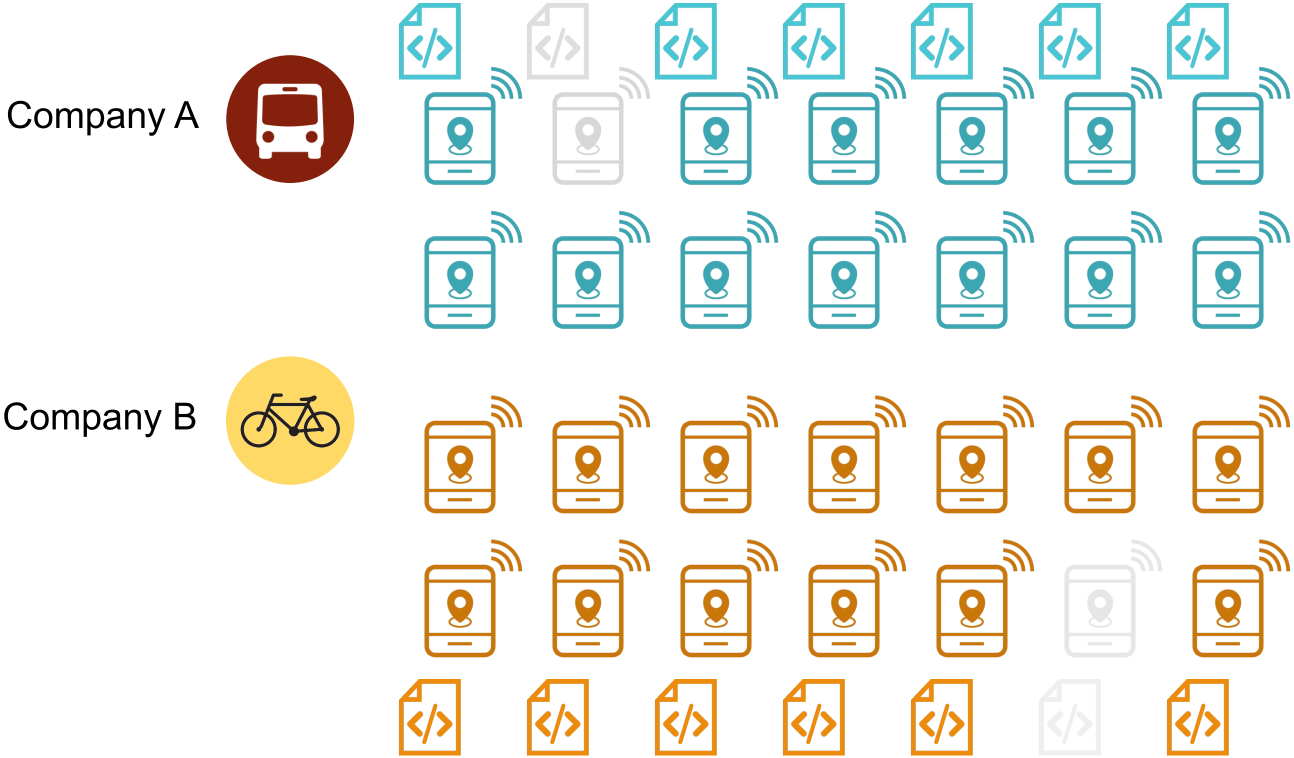


Company A

Company B

Challenges: Scale & Dynamicity



Company A

Company B

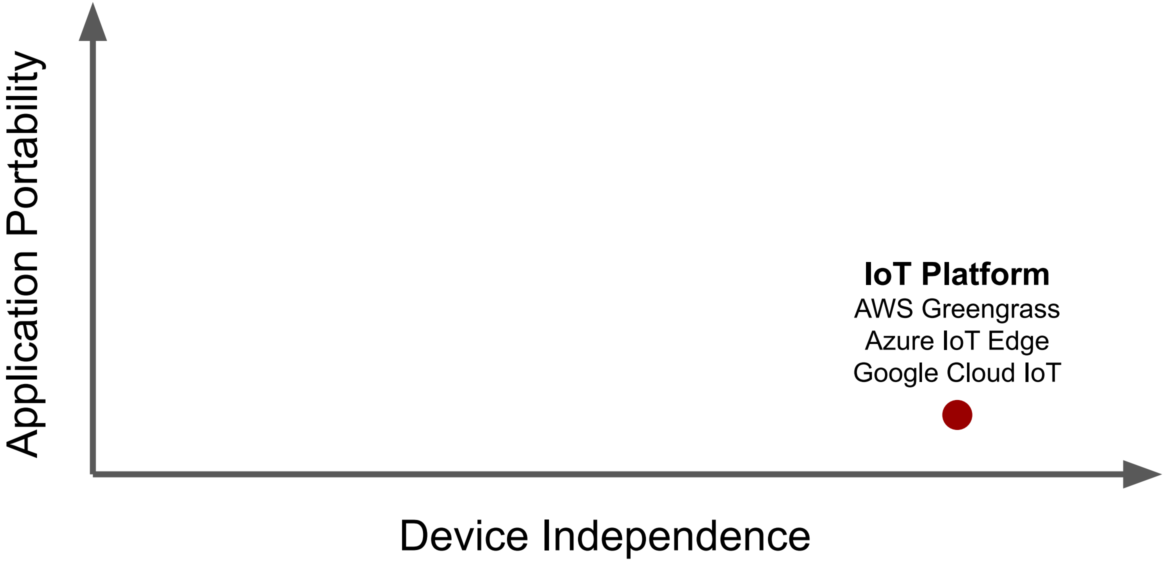
Challenges: Scale & Dynamicity

Company A

Company B

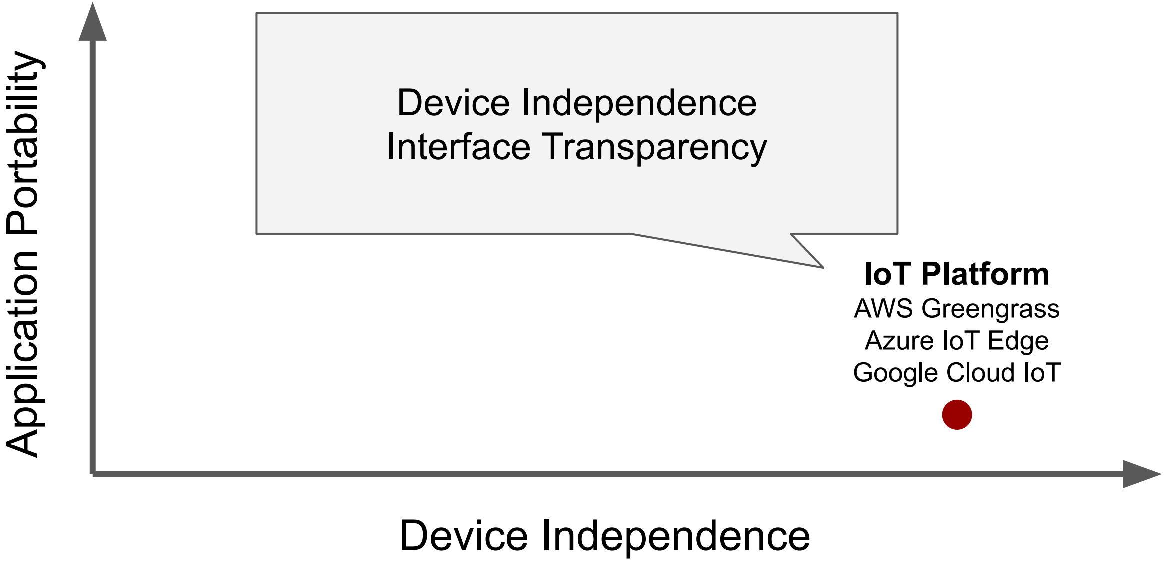
Related Work

Distributed Computing Platforms



Related Work

Distributed Computing Platforms



Related Work

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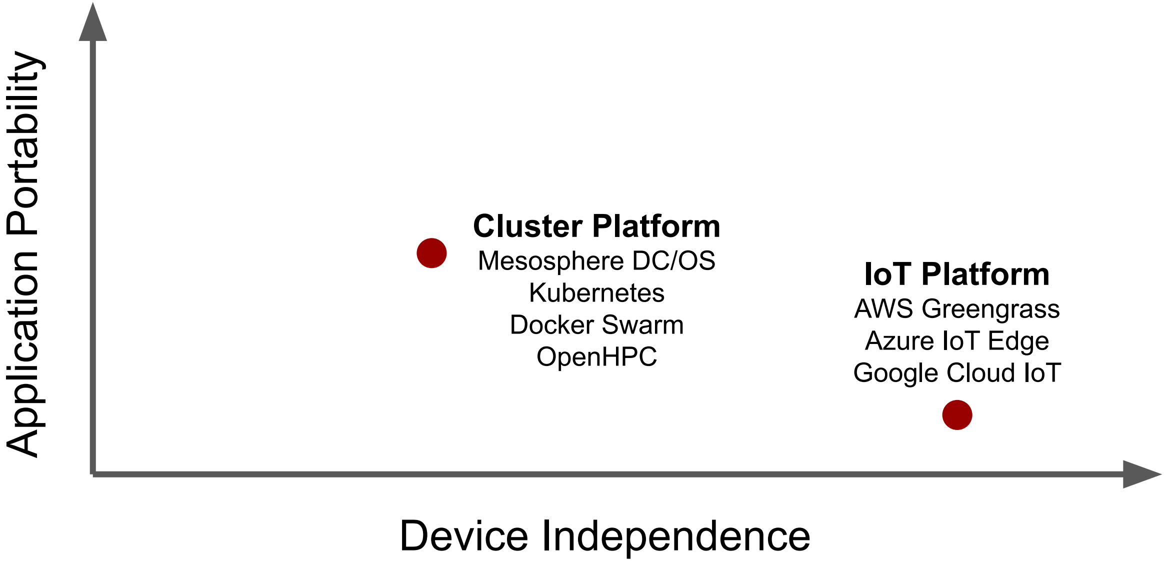

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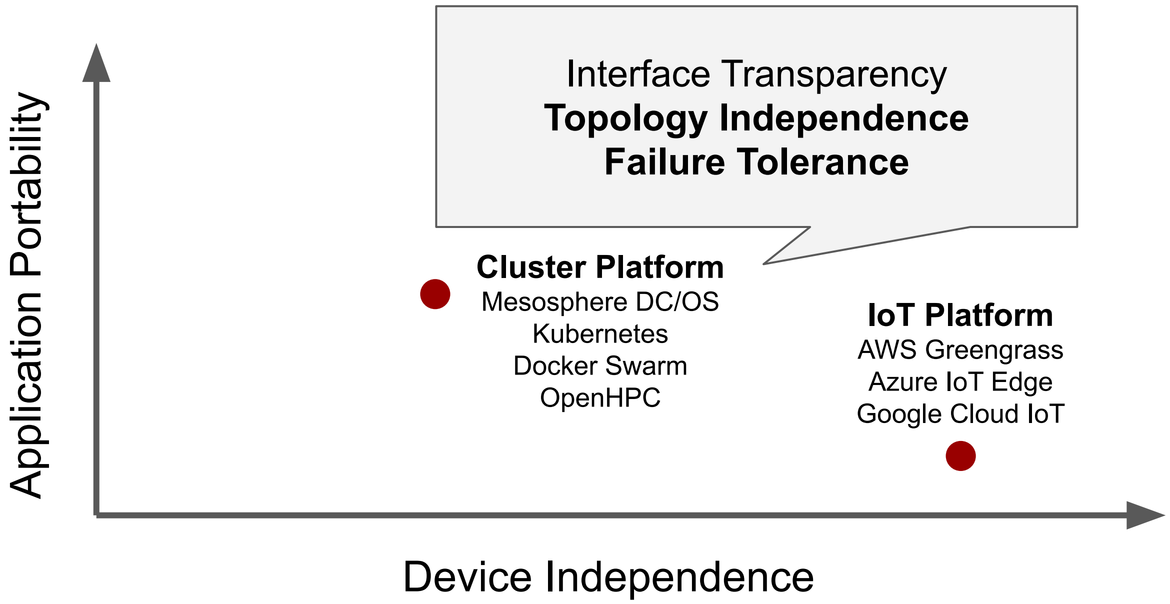


Interface Transparency
Topology Independence
Failure Tolerance

Cluster Platform
Mesosphere DC/OS
Kubernetes
Docker Swarm
OpenHPC

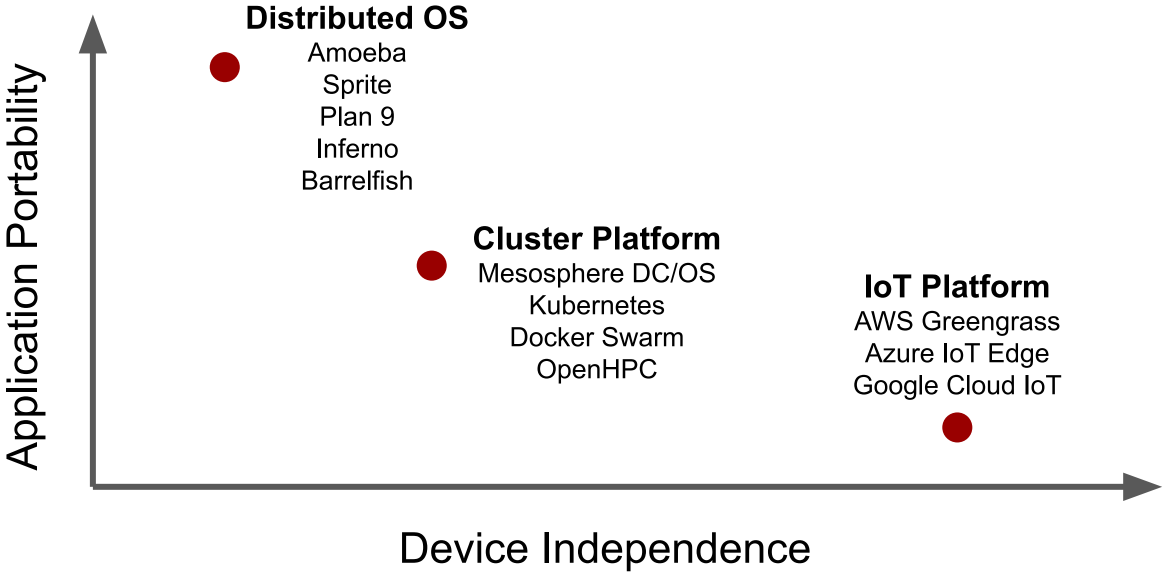
IoT Platform
AWS Greengrass
Azure IoT Edge
Google Cloud IoT

Application Portability

Device Independence

Related Work

Distributed Computing Platforms



Distributed OS
Amoeba
Sprite
Plan 9
Inferno
Barrelfish

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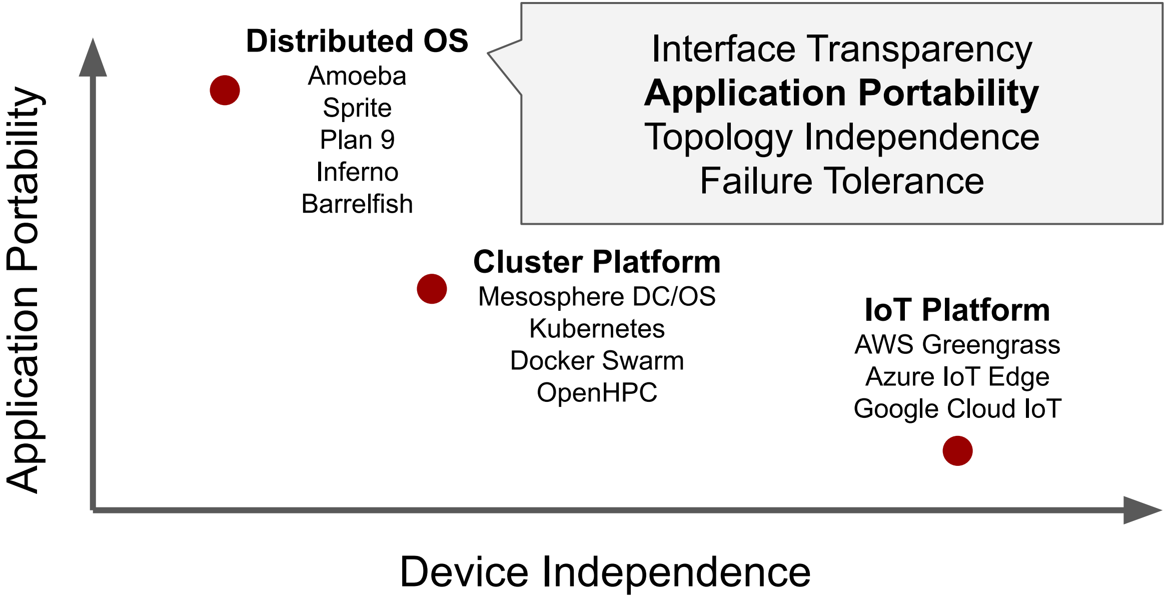
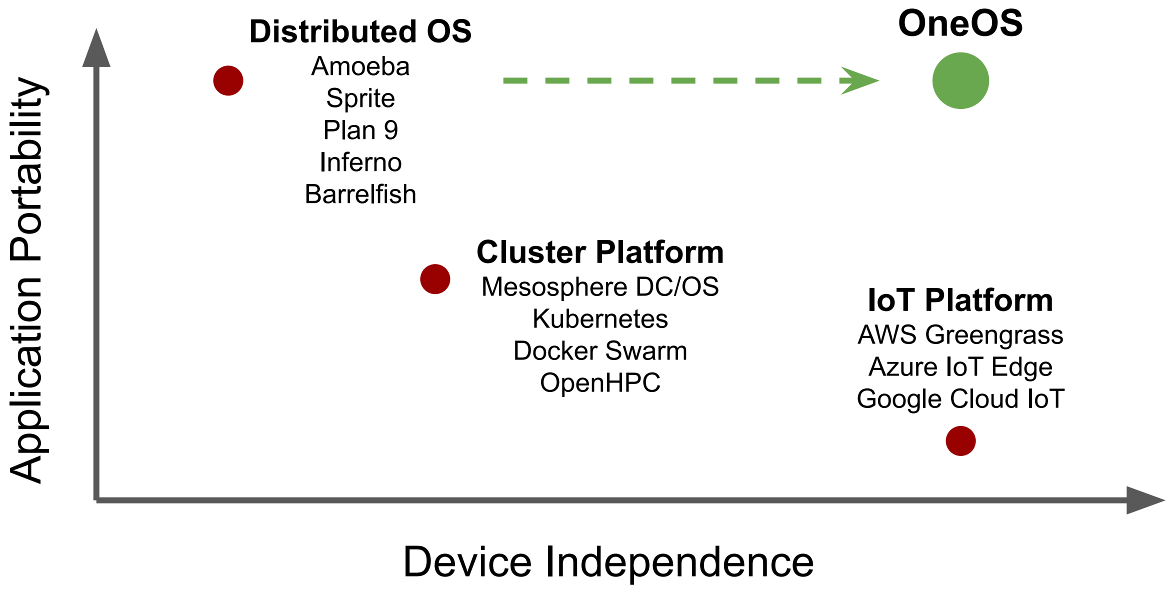


Our Goal: OneOS

Distributed Computing Platforms



Distributed OS
Amoeba
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OneOS

Cluster Platform
Mesosphere DC/OS
Kubernetes
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OpenHPC

IoT Platform
AWS Greengrass
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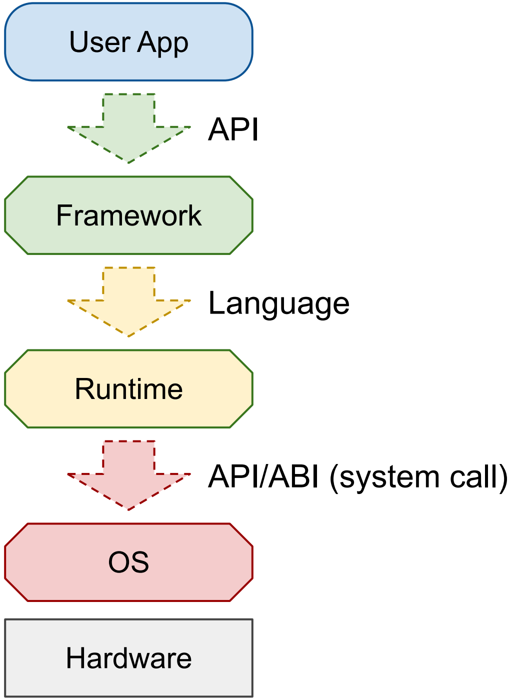
Google Cloud IoT

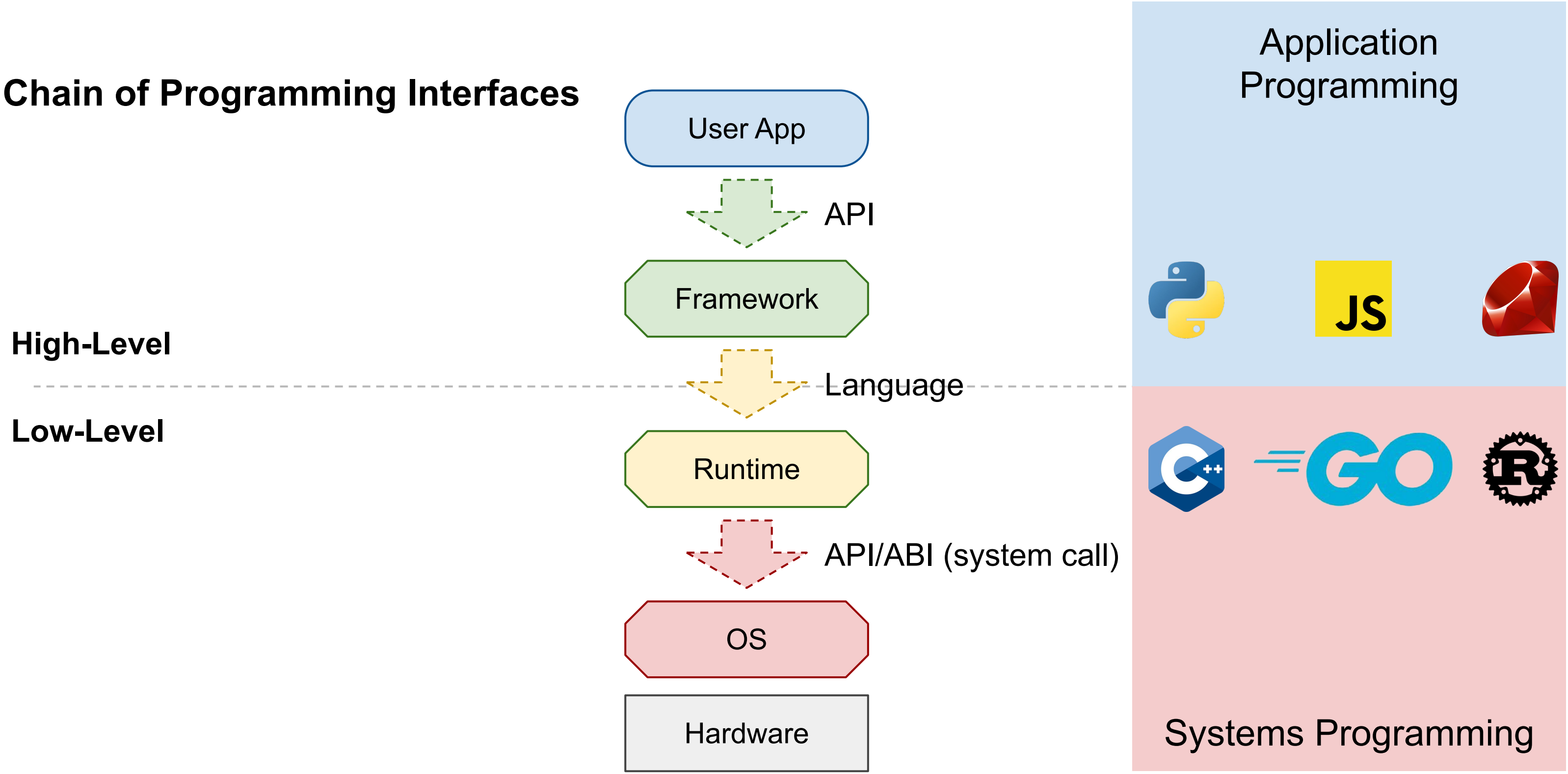
OneOS: Approach

Chain of Programming Interfaces



OneOS: Approach

Chain of Programming Interfaces



High-Level

Low-Level

User App

API

Framework

Language

Runtime

API/ABI (system call)

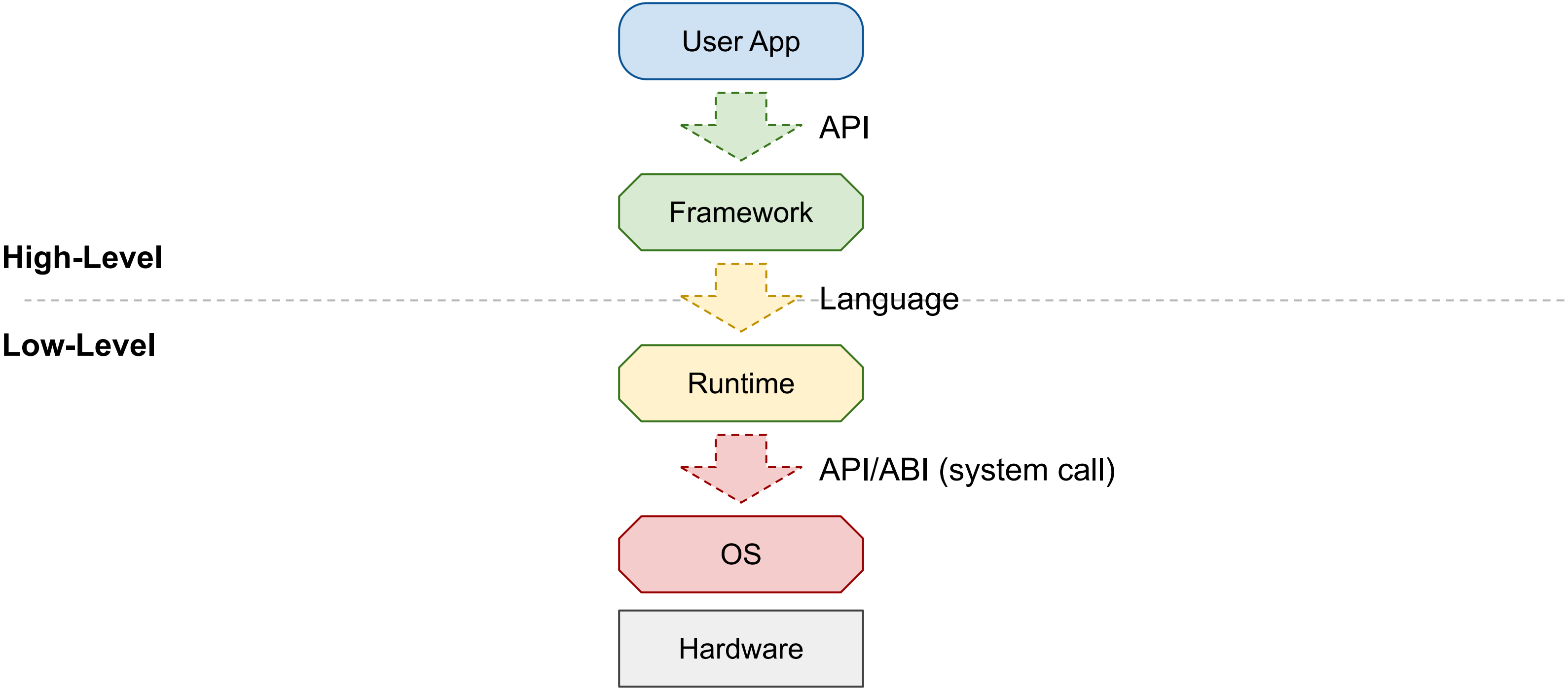
OS

Hardware

Application Programming

Systems Programming

OneOS: Approach



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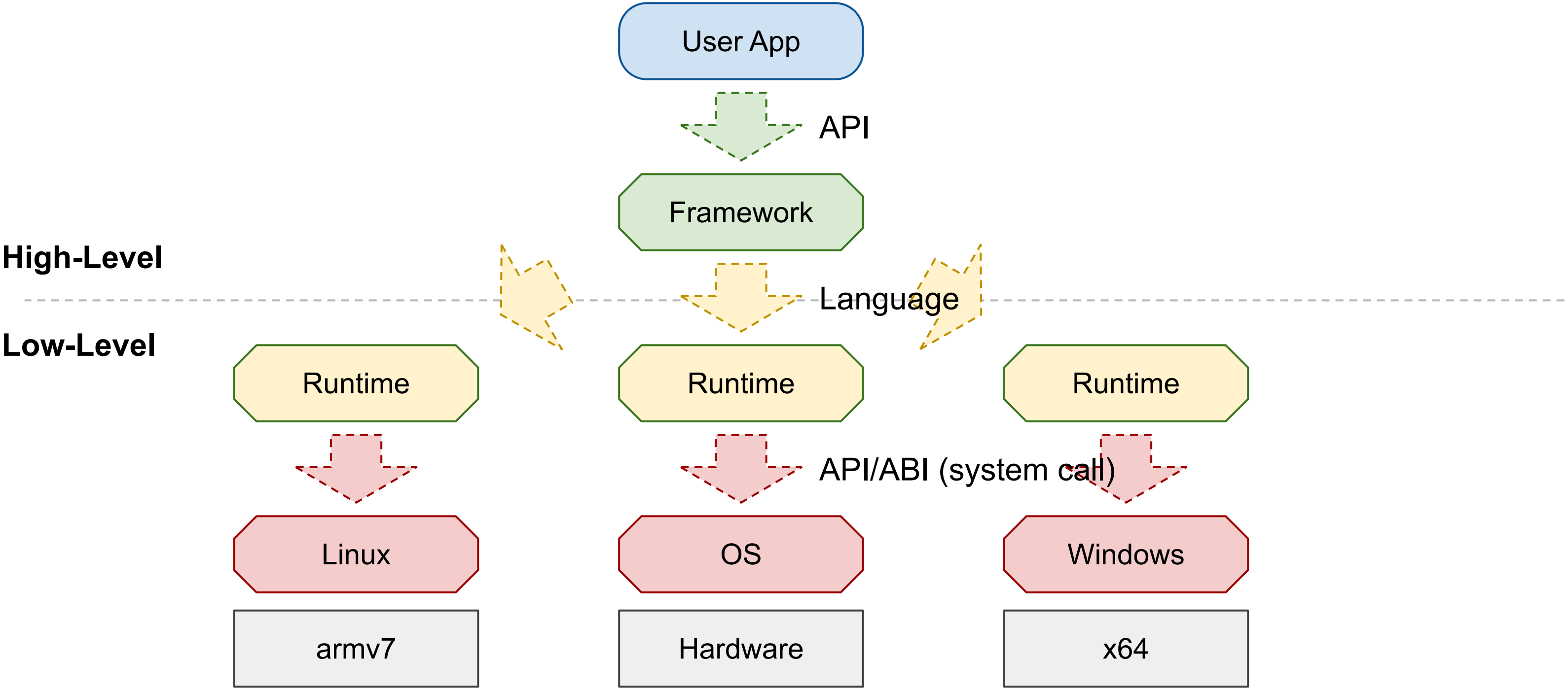
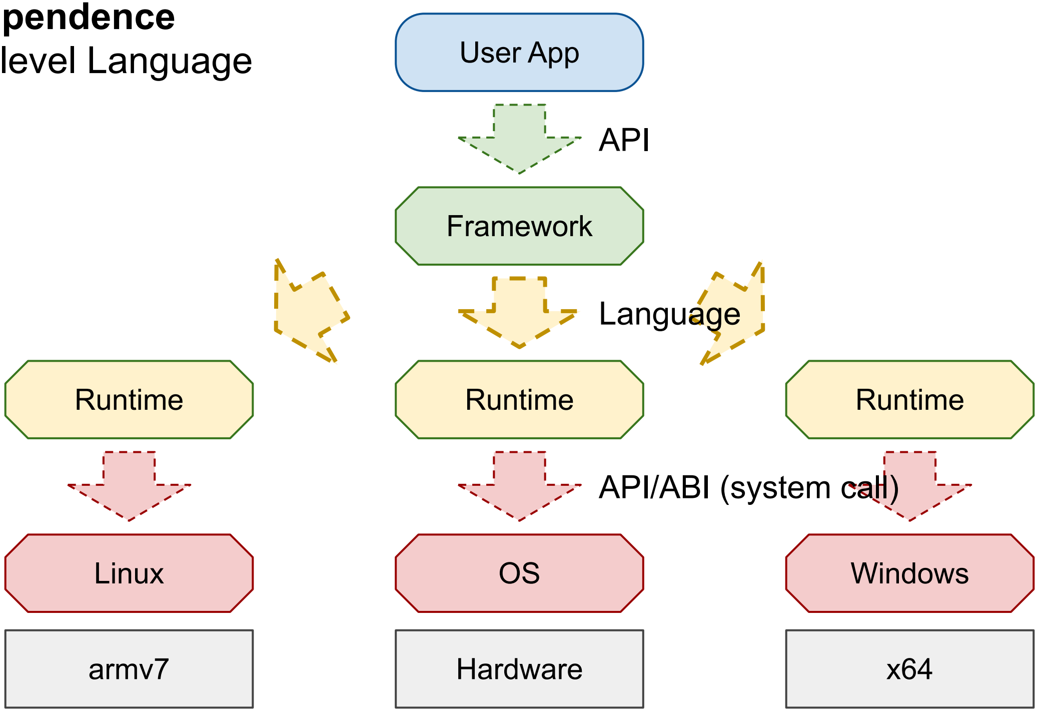


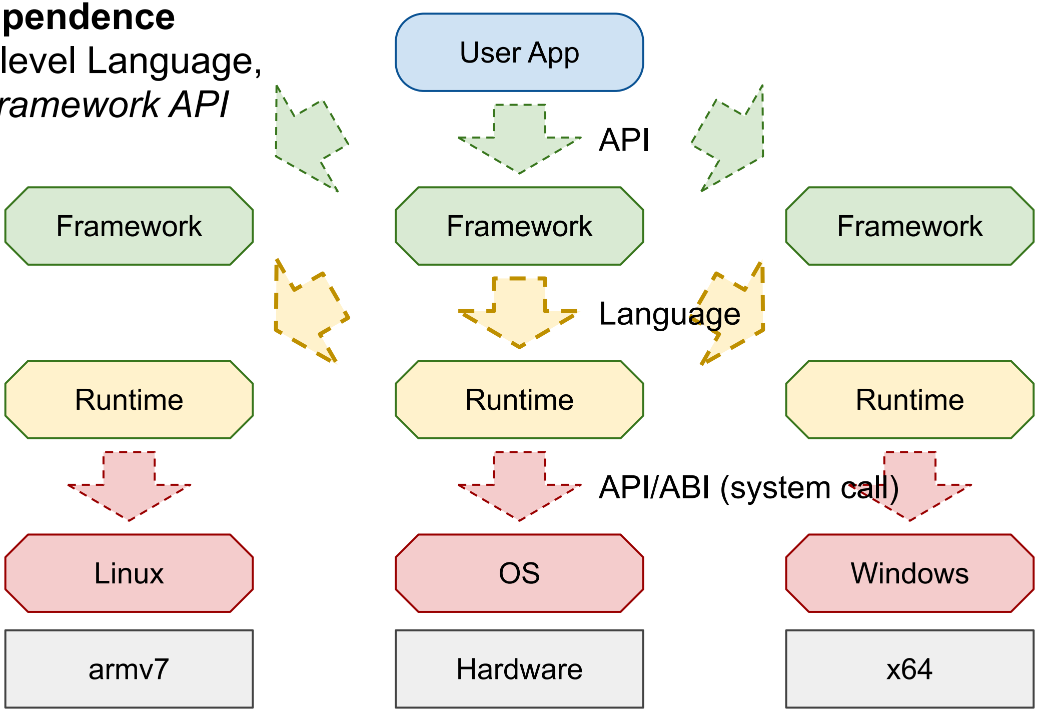
OneOS: Approach

Platform-Independence
by using High-level Language



OneOS: Approach

Platform-Independence
by using High-level Language,
not by using Framework API



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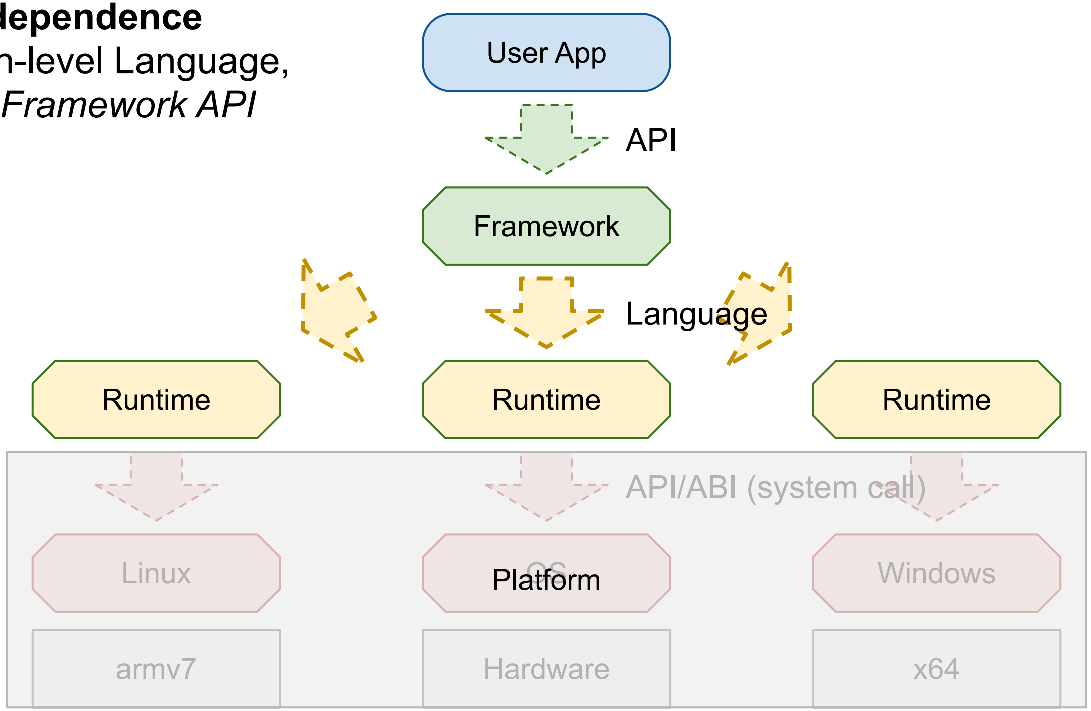

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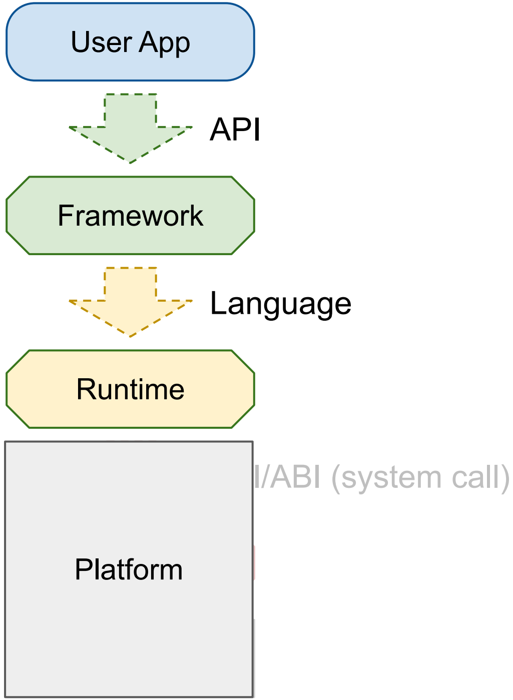

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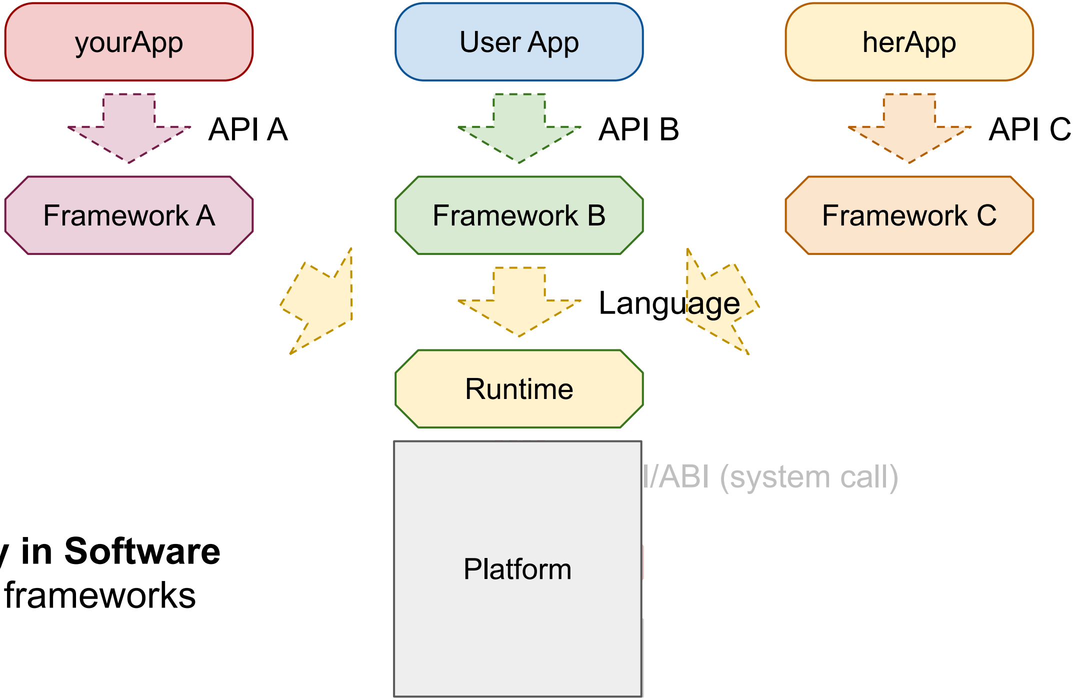
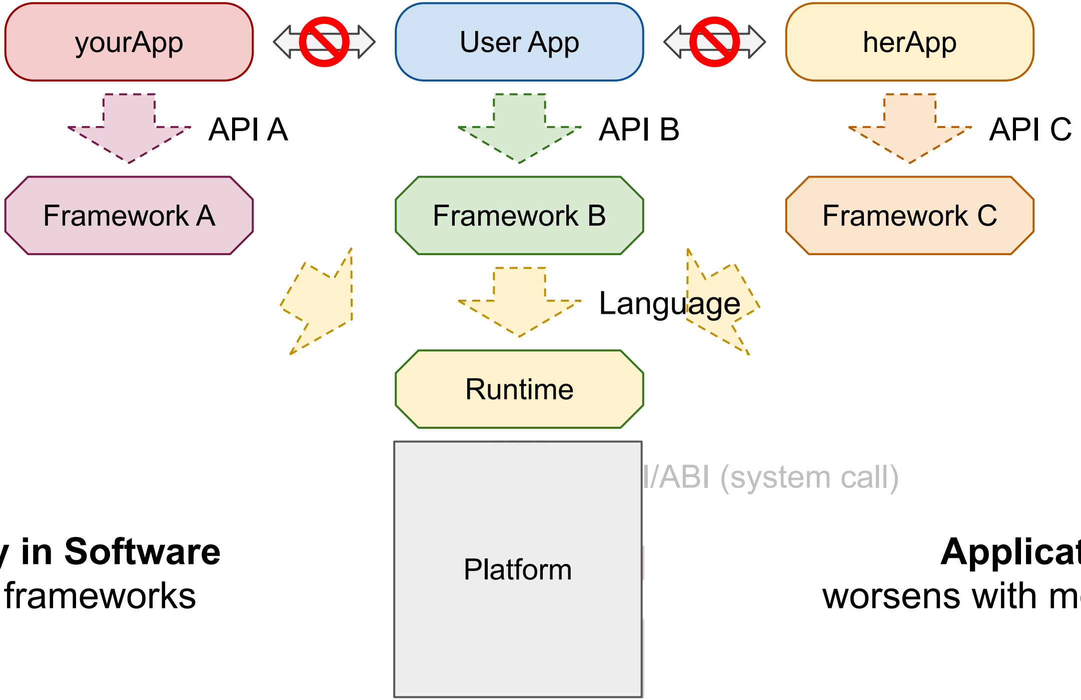


Heterogeneity in Software
unresolved by frameworks

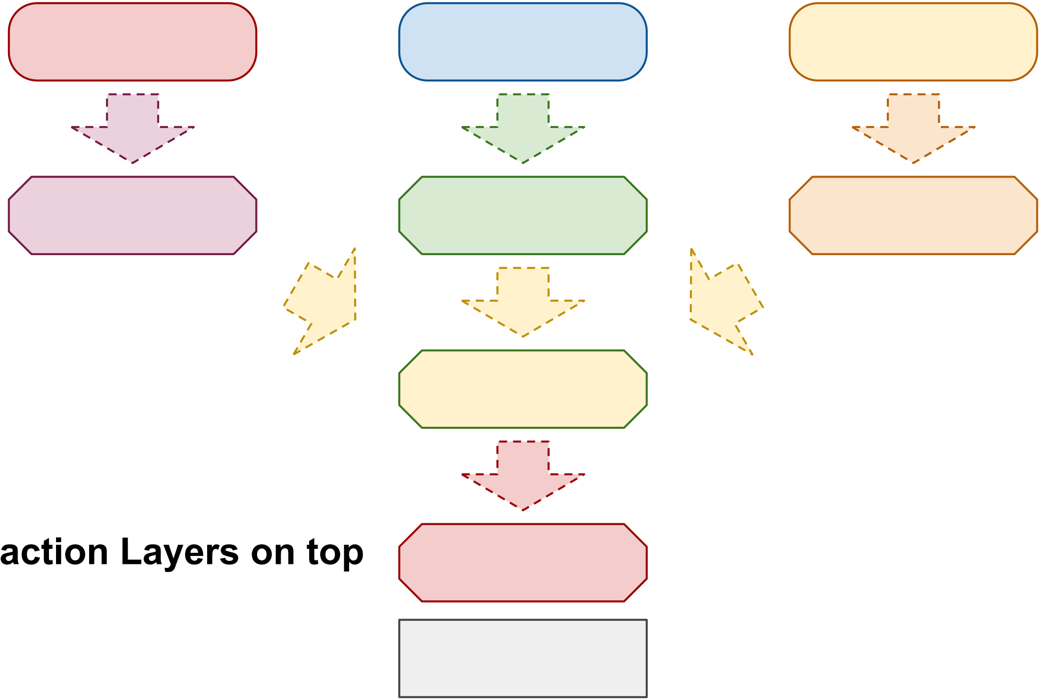
OneOS: Approach



Heterogeneity in Software
unresolved by frameworks

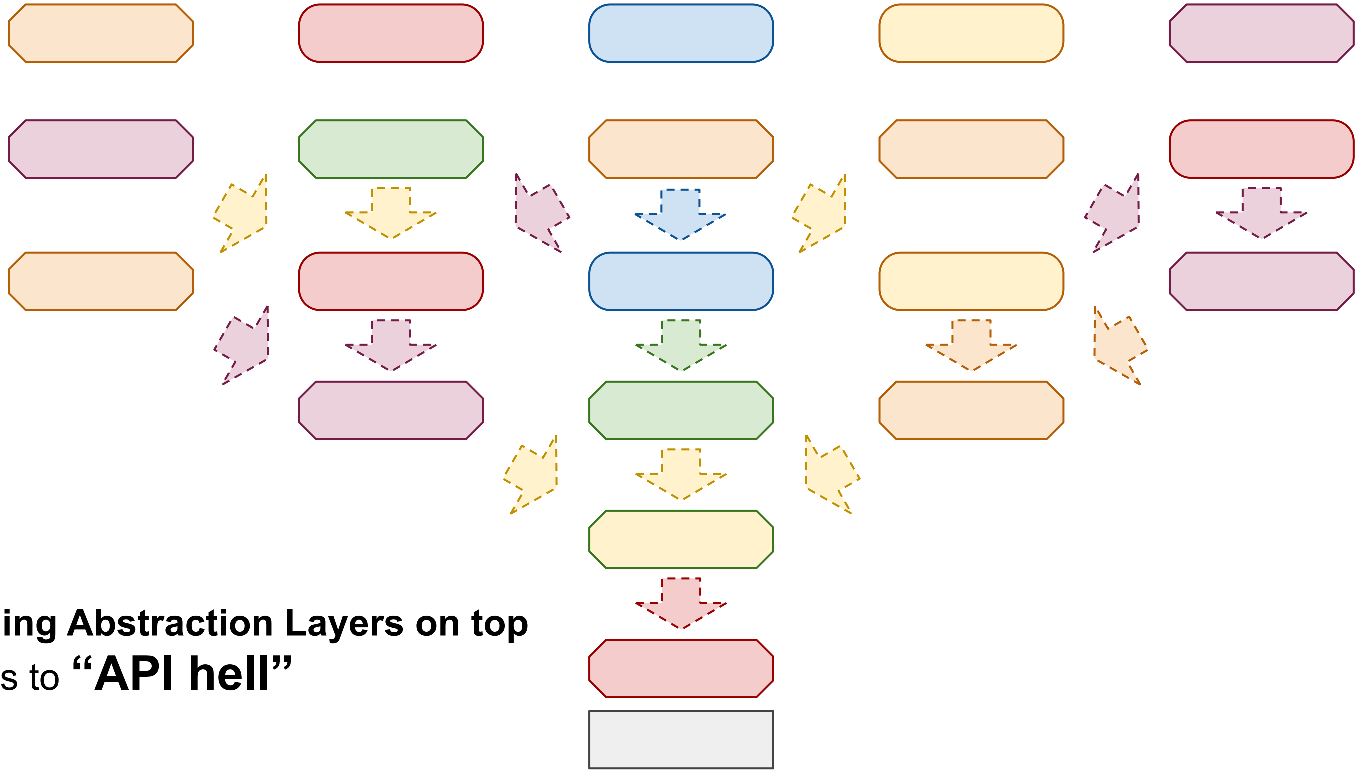
Application Portability
worsens with more frameworks

OneOS: Approach



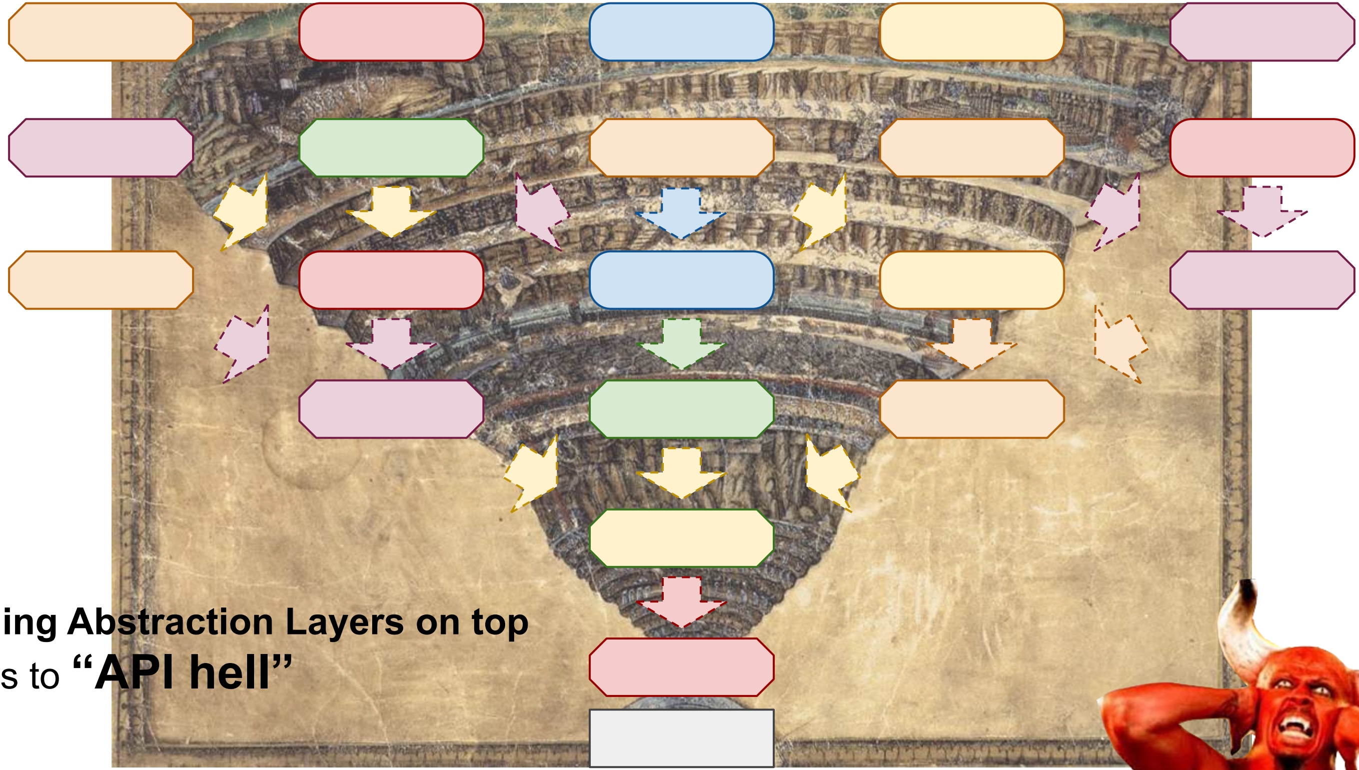
Adding Abstraction Layers on top

OneOS: Approach



Adding Abstraction Layers on top leads to **“API hell”**

OneOS: Approach



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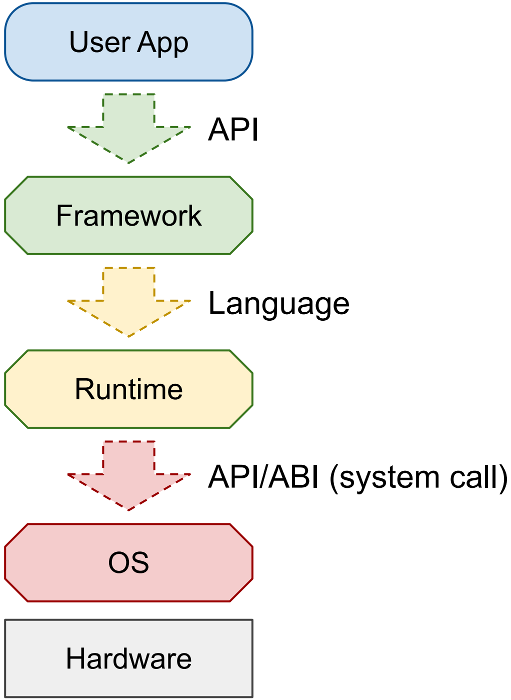
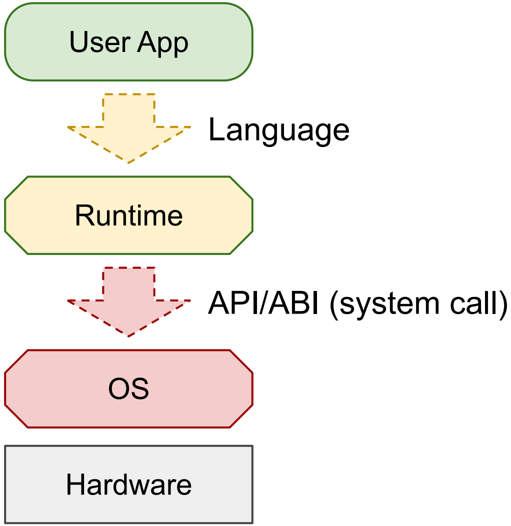


Our approach:
Not a high-level framework

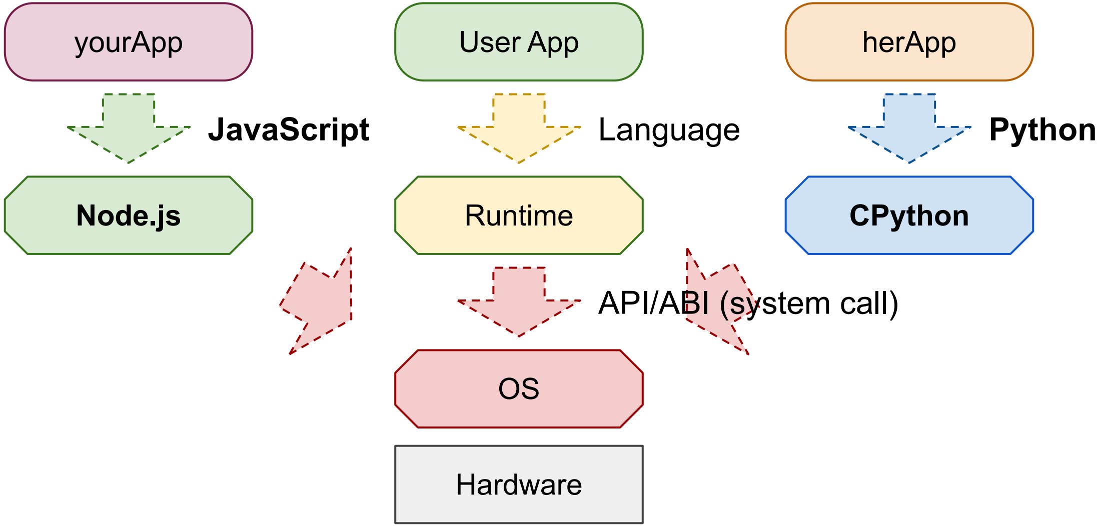
OneOS: Approach



Our approach:
Not a high-level framework

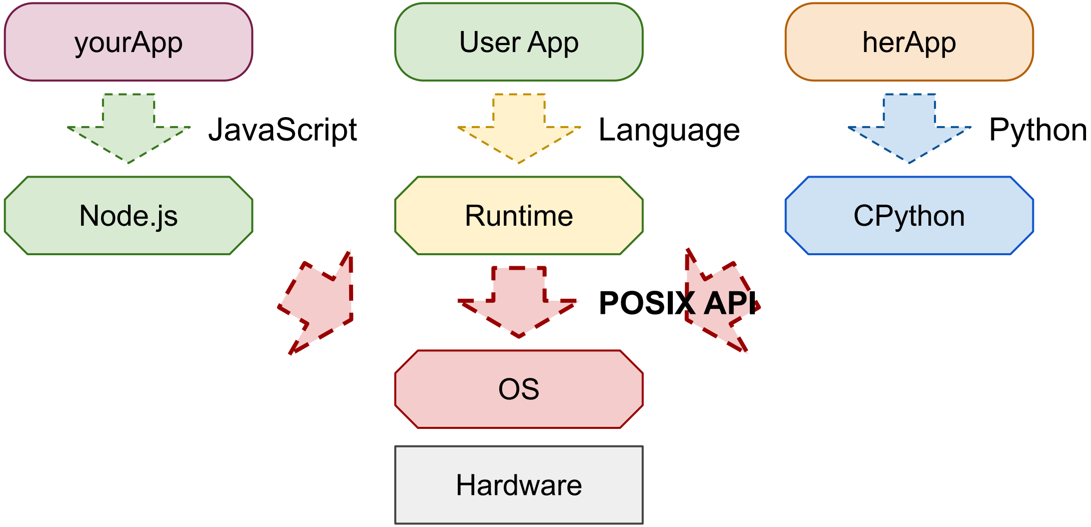
OneOS: Approach

Embrace heterogeneity in software
allow existing technology to work together



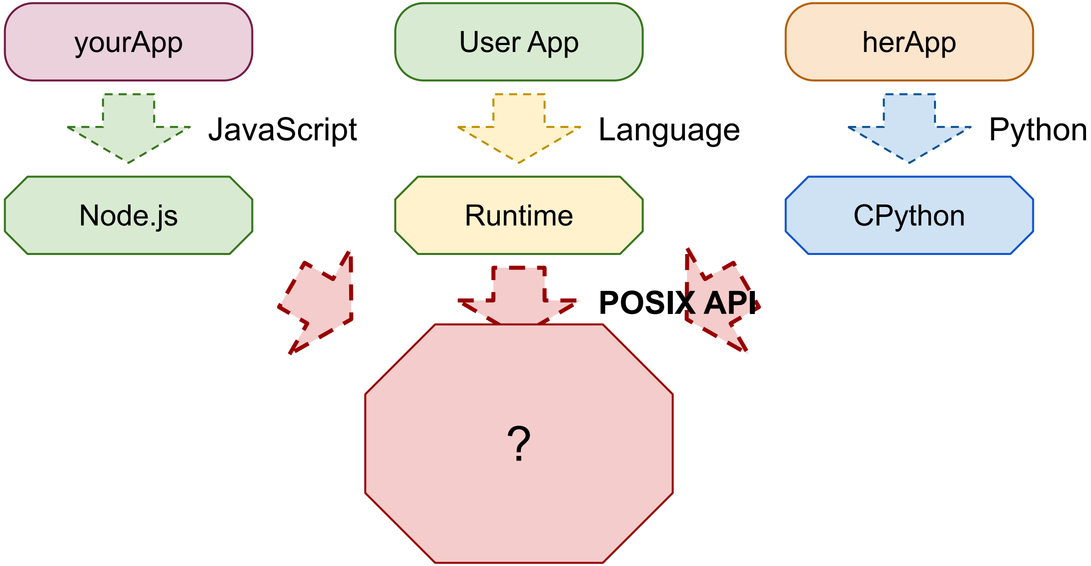
OneOS: Approach

High-level Language VMs share a **common interface**
to the underlying **abstract machine**



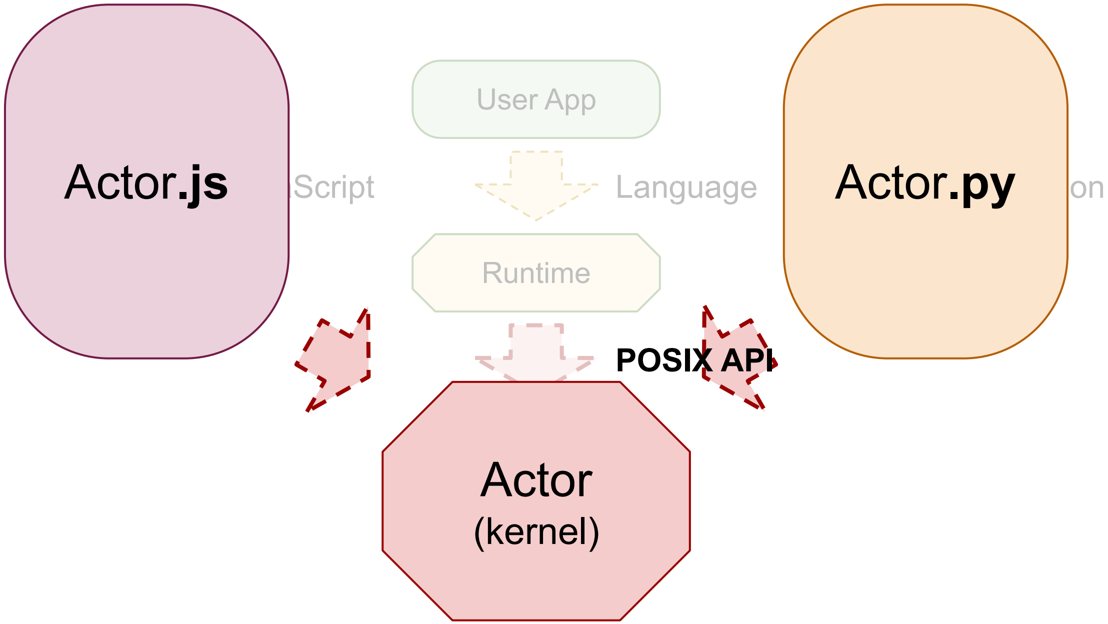
OneOS: Approach

High-level Applications are **agnostic** about the underlying **abstract machine**



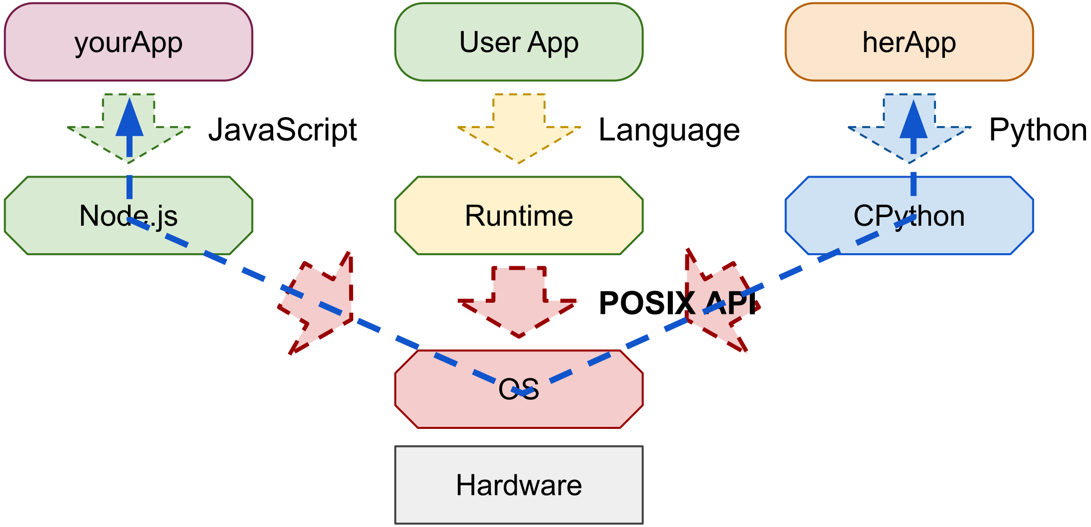
OneOS: Approach

High-level Applications are **agnostic** about the underlying **abstract machine**
System call modeled as **message between Actors**

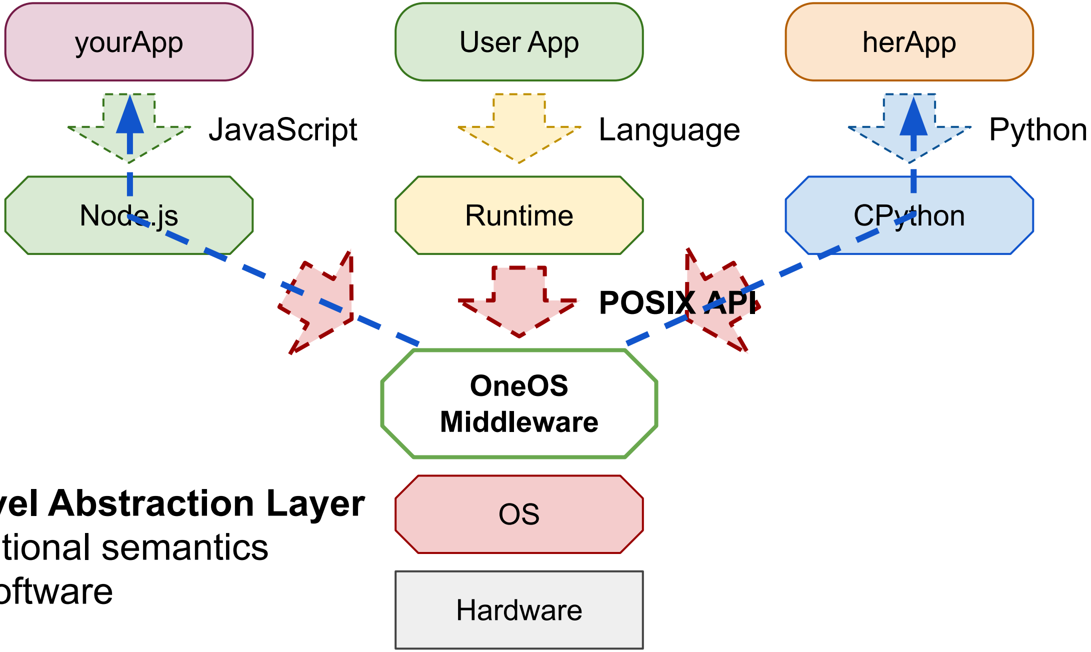


OneOS: Approach

Applications make system calls
to interact with other agents

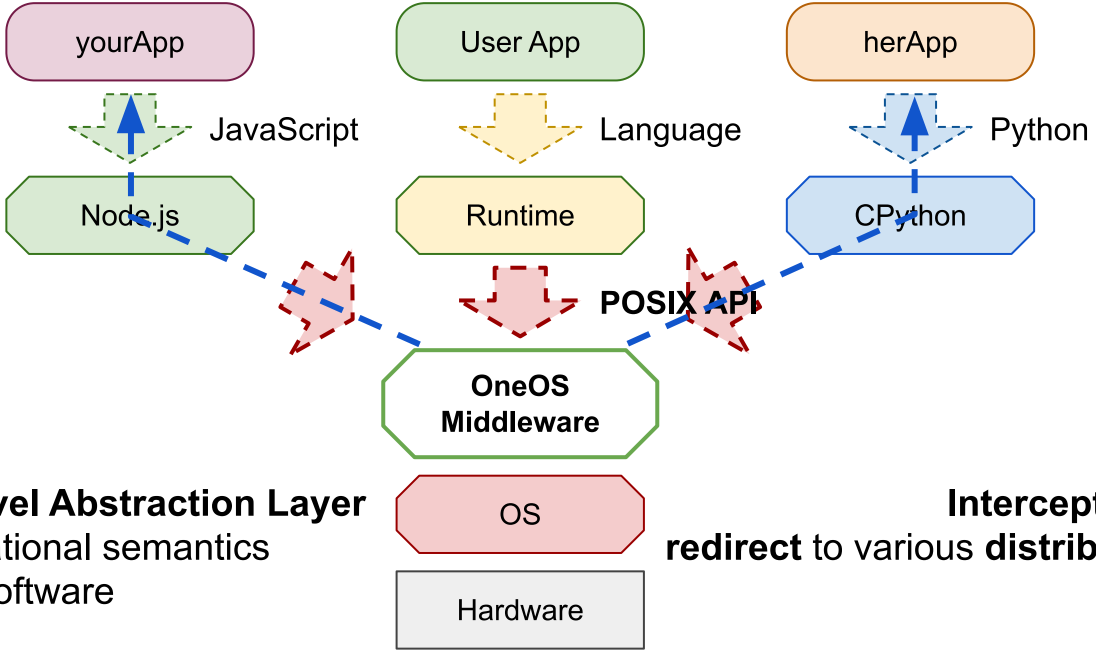


OneOS: Approach



Hijack low-level Abstraction Layer
alter the operational semantics
of high-level software

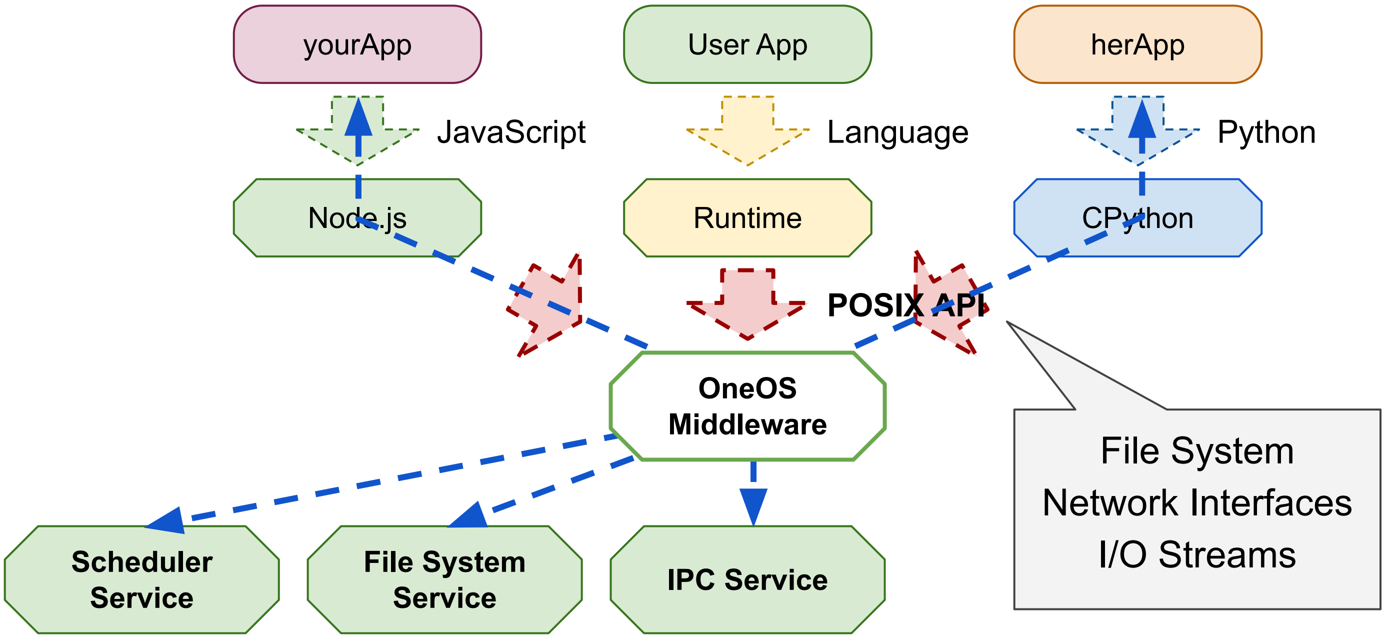
OneOS: Approach



Hijack low-level Abstraction Layer
alter the operational semantics
of high-level software

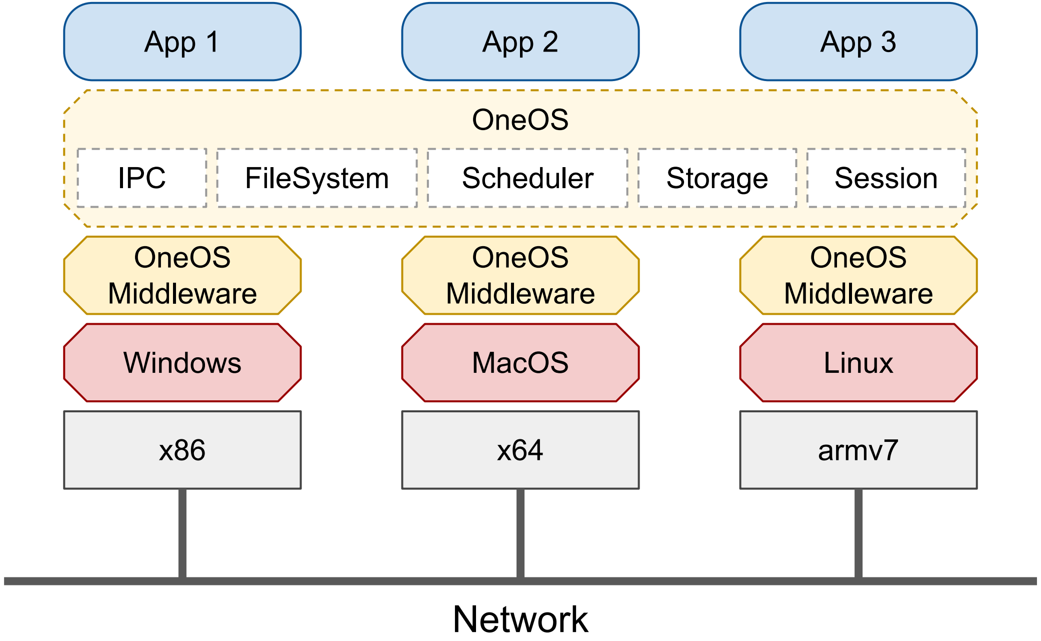
Intercept system calls
redirect to various **distributed services**

OneOS: Approach



File System
Network Interfaces
I/O Streams

OneOS: Design



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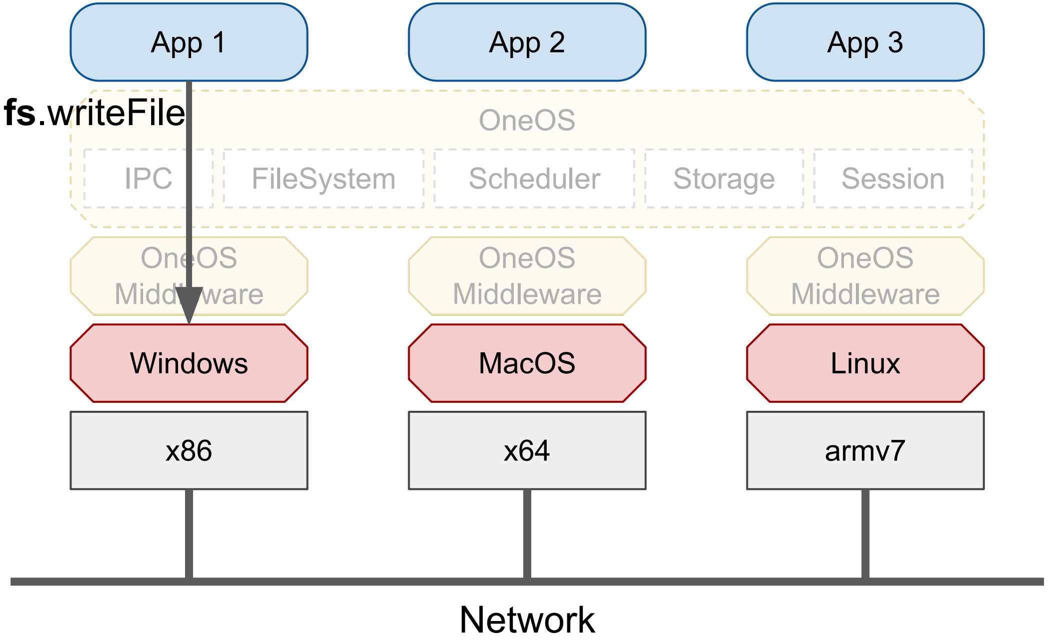

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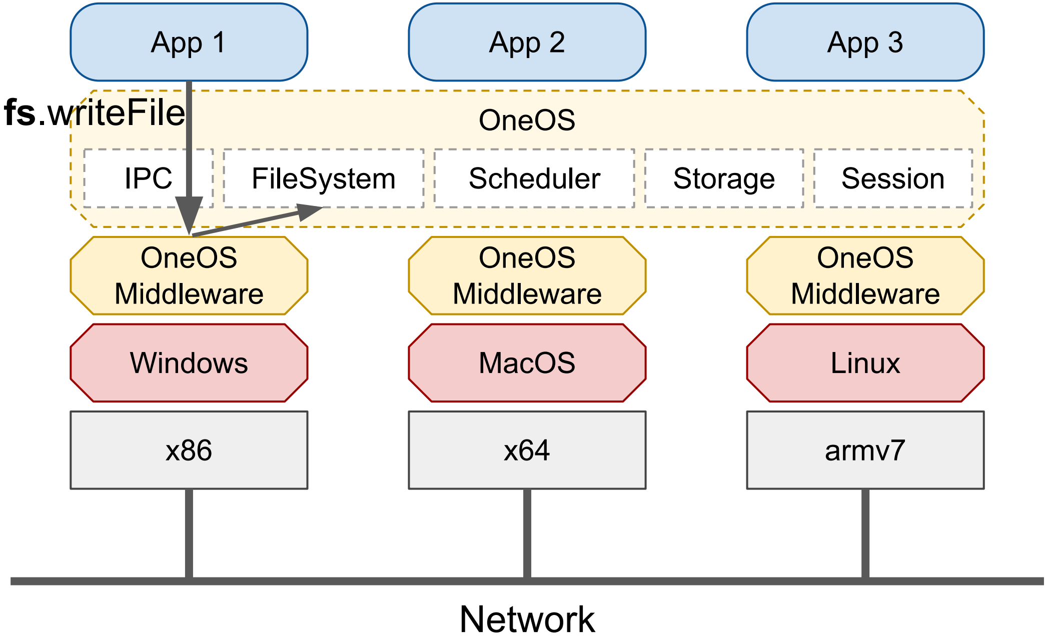

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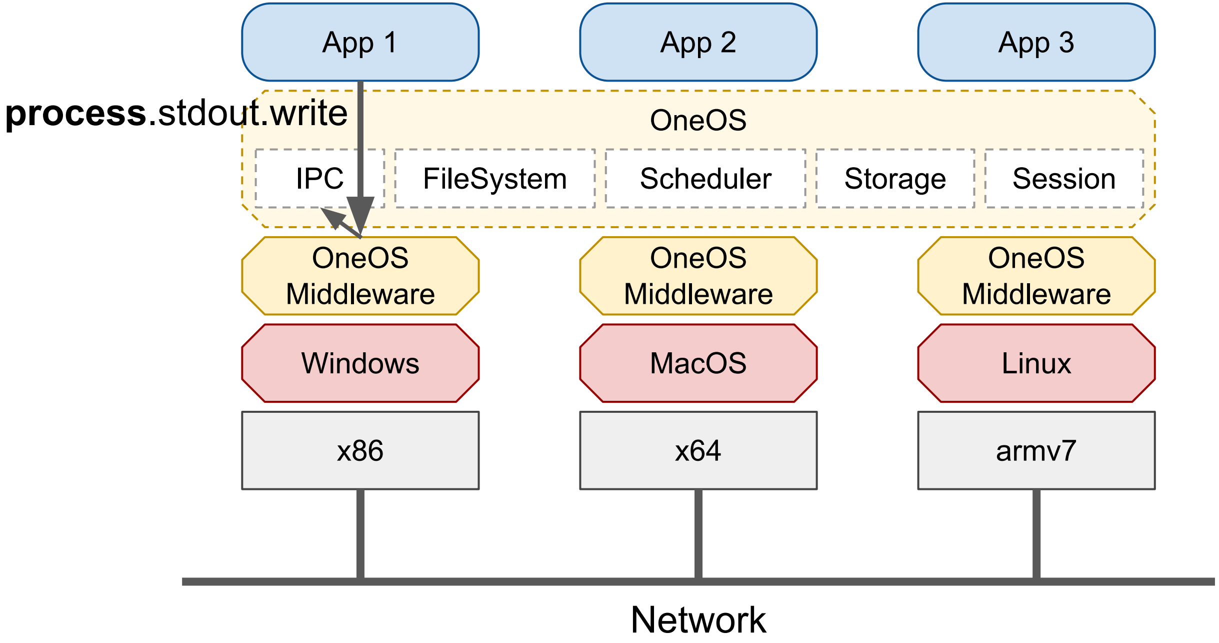

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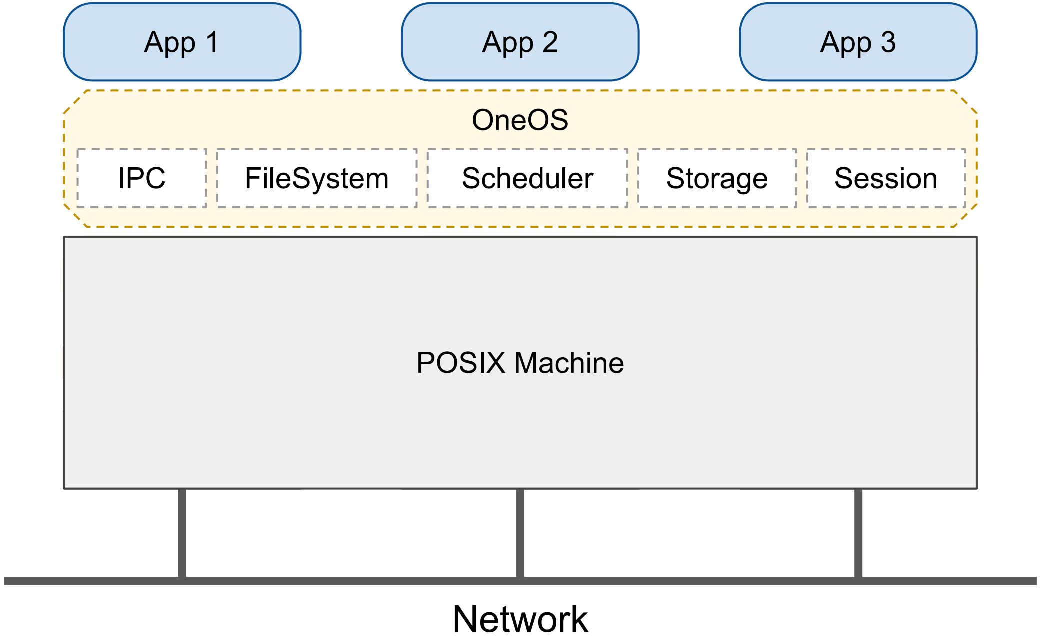
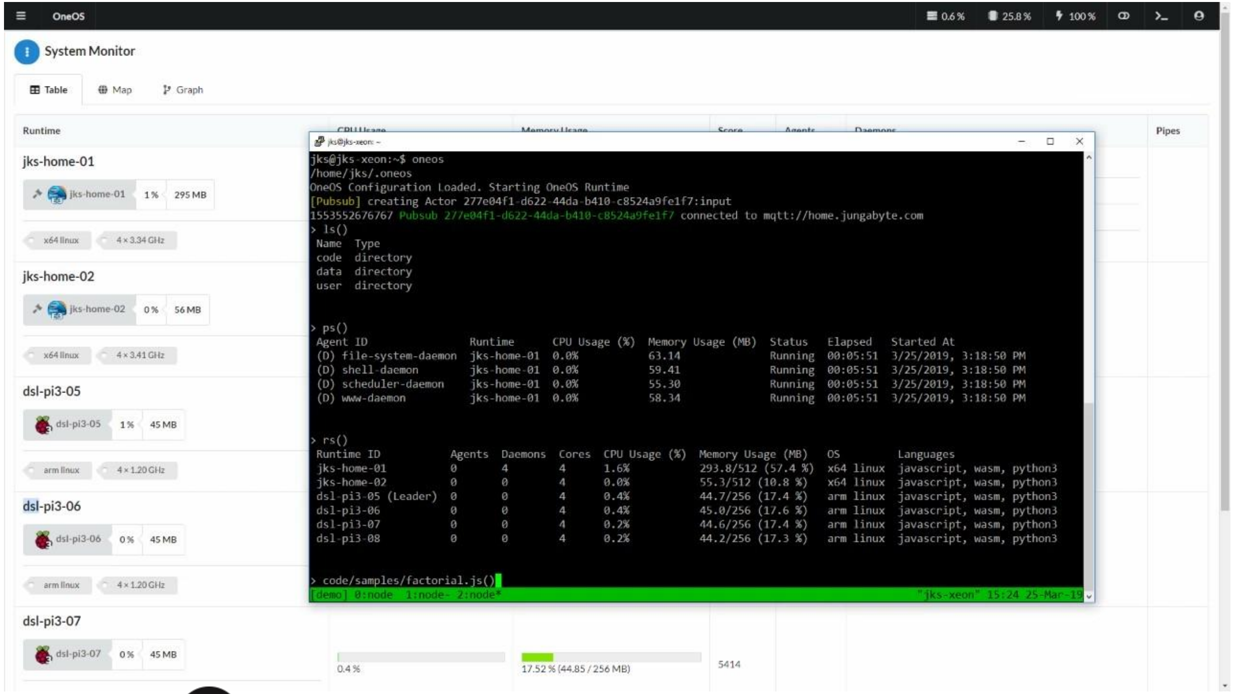


OneOS: Proof-of-Concept Demo



```
jks@jks-xeon:~$ oneos
/home/jks/.oneos
OneOS Configuration Loaded. Starting OneOS Runtime
[Pubsub] creating Actor 277e04f1-d622-44da-b410-c8524a9fe1f7:input
1553552676767 Pubsub 277e04f1-d622-44da-b410-c8524a9fe1f7 connected to mqtt://home.jungabyte.com
> ls()
 Name  Type
 code  directory
 data  directory
 user  directory


> ps()
 Agent ID                Runtime      CPU Usage (%)  Memory Usage (MB)  Status   Elapsed   Started At
 (D) file-system-daemon  jks-home-01  0.0%           63.14              Running  00:05:51  3/25/2019, 3:18:50 PM
 (D) shell-daemon        jks-home-01  0.0%           59.41              Running  00:05:51  3/25/2019, 3:18:50 PM
 (D) scheduler-daemon    jks-home-01  0.0%           55.30              Running  00:05:51  3/25/2019, 3:18:50 PM
 (D) www-daemon          jks-home-01  0.0%           58.34              Running  00:05:51  3/25/2019, 3:18:50 PM


> rs()
 Runtime ID            Agents  Daemons  Cores  CPU Usage (%)  Memory Usage (MB)    OS         Languages
 jks-home-01           0       4        4      1.6%           293.8/512 (57.4 %)  x64 linux  javascript, wasm, python3
 jks-home-02           0       0        4      0.0%           55.3/512 (10.8 %)   x64 linux  javascript, wasm, python3
 dsl-pi3-05 (Leader)   0       0        4      0.4%           44.7/256 (17.4 %)   arm linux  javascript, wasm, python3
 dsl-pi3-06            0       0        4      0.4%           45.0/256 (17.6 %)   arm linux  javascript, wasm, python3
 dsl-pi3-07            0       0        4      0.2%           44.6/256 (17.4 %)   arm linux  javascript, wasm, python3
 dsl-pi3-08            0       0        4      0.2%           44.2/256 (17.3 %)   arm linux  javascript, wasm, python3


> code/samples/factorial.js()
[demo] 0:node  1:node- 2:node*                                                    "jks-xeon" 15:24 25-Mar-19
```

DependableSystemsLab/OneOS

OneOS: Discussion

Feedback Wanted:

- Evaluation strategies
- Practicality of Actor-based micro-kernel
- Suitability of high-level language for systems programming

Controversial Points:

- *Single system image* appropriate for a *geographically distributed grid*?
- Mapping *POSIX interface* over an *inherently distributed and concurrent* architecture?
- *Limiting application space* to *high-level languages*?

Open Issues & Future Work:

- Security and Privacy model
- Failure handling
- Semantics of cyber-physical resources

Potential Drawbacks:

- Fundamental tension between cyber-physical resources and their abstract representations
- Reasoning about security concerns within high-level programming space
- Inability to make low-level optimizations

✉ kumseok@ece.ubc.ca DependableSystemsLab/OneOS