GRAMMATECH

Minimizing Software Containers: Forethought or Hindsight

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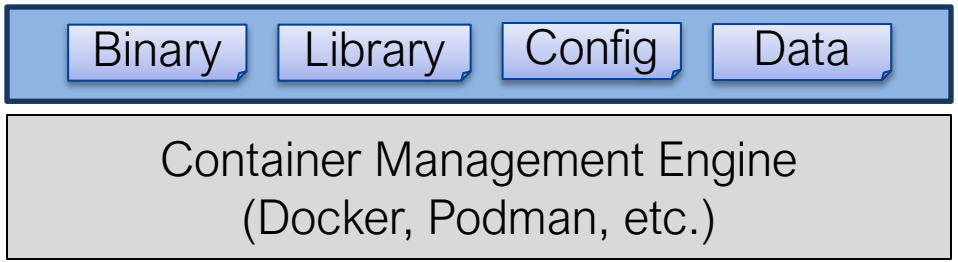
Overview

- Bloat in software containers.
- Hindsight and its limitations.
- Potential for forethought.
- Open questions and directions.
- Discussion.

Container Bloat

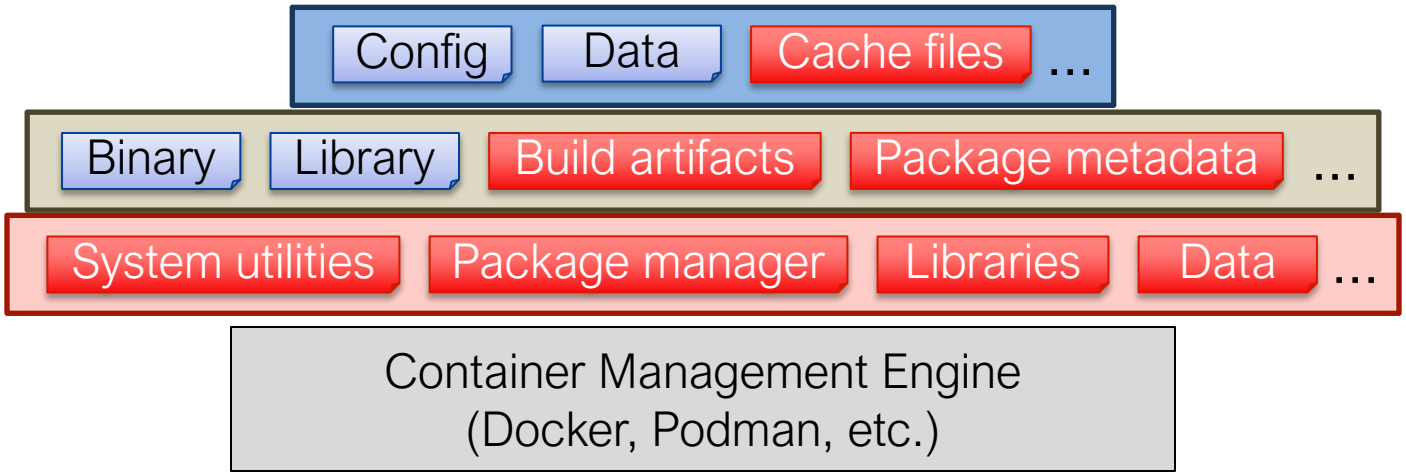
Containers in Theory

- Wrap application in a lightweight, portable environment.

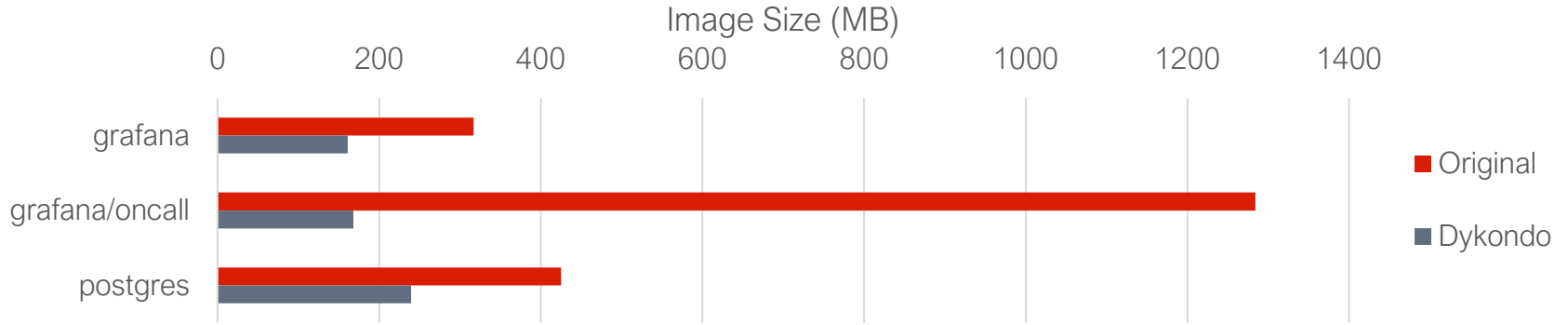


Containers in Reality

- Wrap application in a ~~lightweight~~, portable? environment.

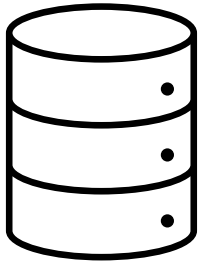


Bloat in Open-Source Containers

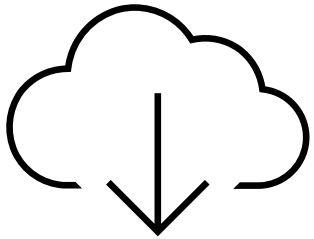


Application	Version	Type	Language	Bloat
Grafana	9.5.3	Web Dashboard	Golang, Javascript	49%
Grafana OnCall	1.3.80	On-call Management	Python	87%
PostgreSQL	16.1	Database	C	44%

Bloat Impacts



Wasted Storage



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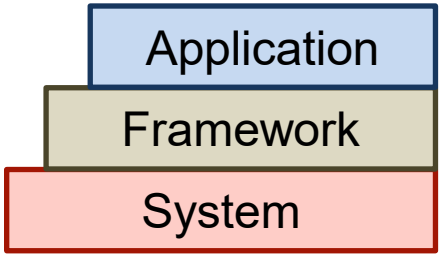
Container Debloating

Typical Scenario

- Simplified REST application.
  1. System layer provides common Linux utilities.
  2. Framework layer provides REST infrastructure.
  3. Application layer implements endpoints.
- Four distinct actors:
  - Three development teams.
  - One end-user.

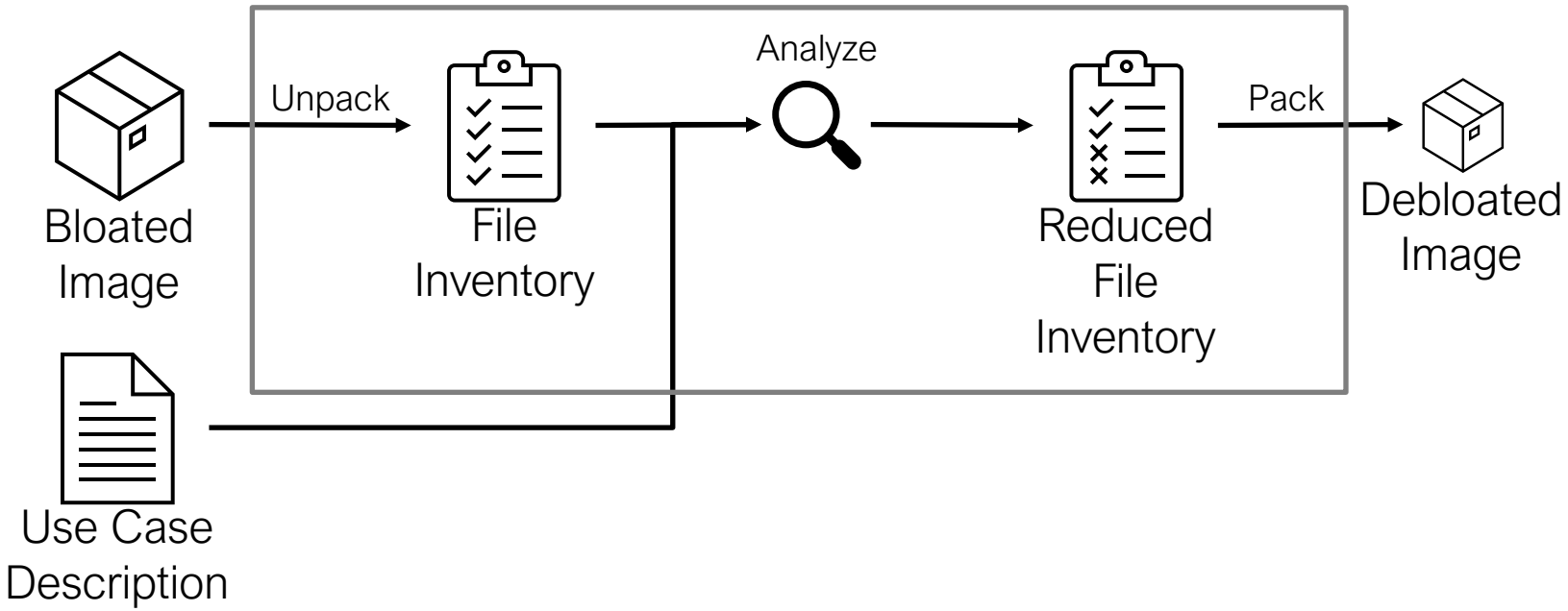


Traditional Bloat Mitigation

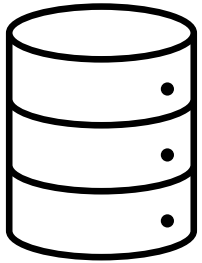
- Dominated by (manual) best practices.[1]
- Mostly containerfile design:
  - Multi-stage builds—exclude bloat in final stage.
  - Explicitly remove caches and build artifacts.
  - Use fine-grained dependencies when possible.
    - Depends on upstream developer effort.

[1] E.g., https://docs.docker.com/build/building/best-practices

Hindsight: Automatic Bloat Repair



Problem Solved?



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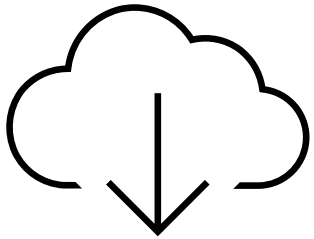

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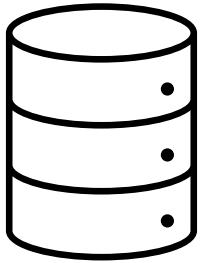
Problem Solved? Yes



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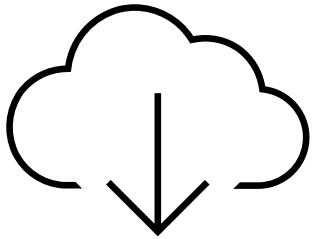

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Problem Solved? Sort Of

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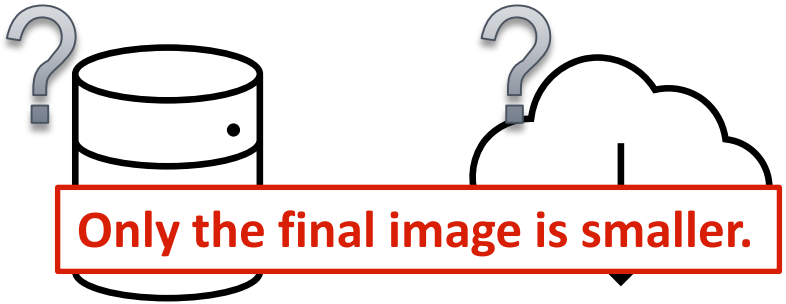
A New Challenge Arises



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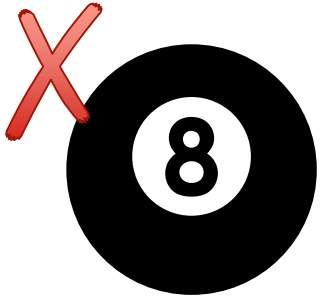


Oracle Problem

The Oracle Problem

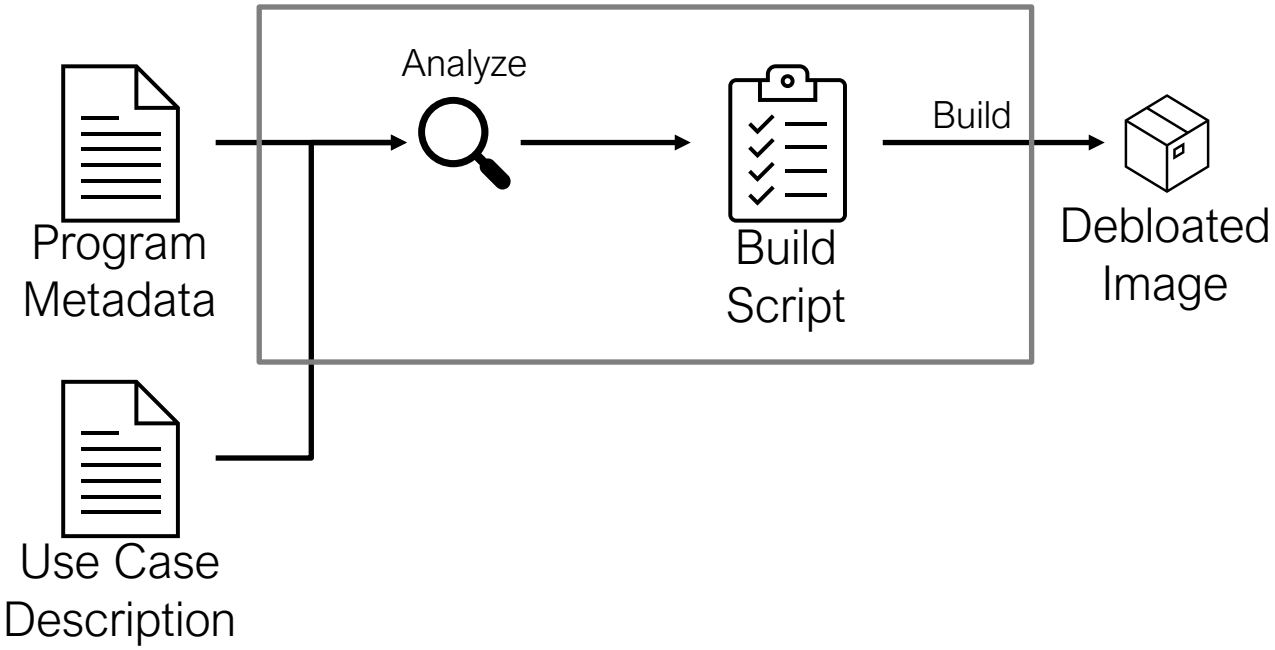
- Software testing:
  - Determine whether program behavior on an arbitrary input is correct.
- Container debloating:
  - Determine whether reduced container is correct.
  - Responsibility for checking is on the debloater: **end-user** or **Application developer**.

Foresight: Bloat-Free Synthesis

Goal

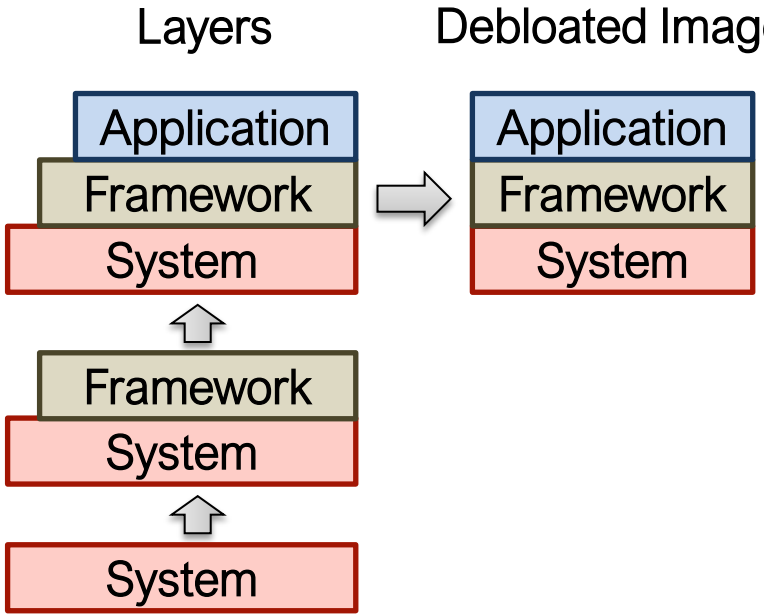
Construct minimal containers in the first place.

Automatic Bloat-Free Synthesis

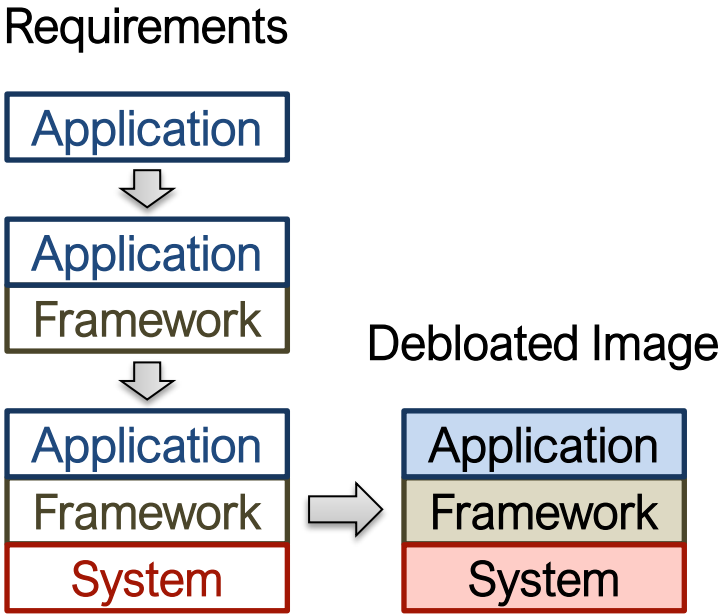


Approach Comparison

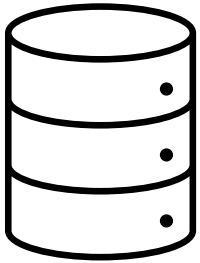
Repair



Synthesis



Problem Solved?



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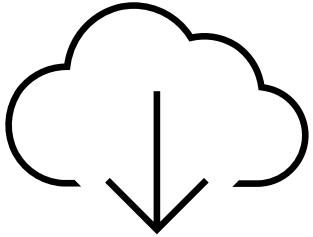

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Oracle Problem

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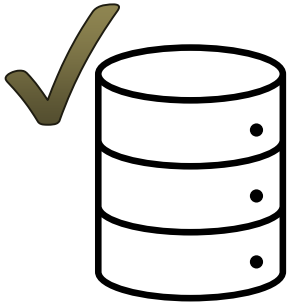

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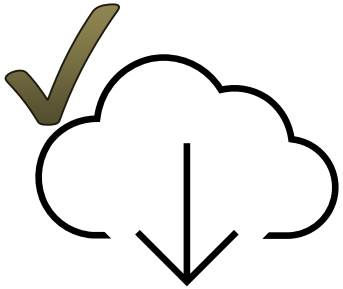

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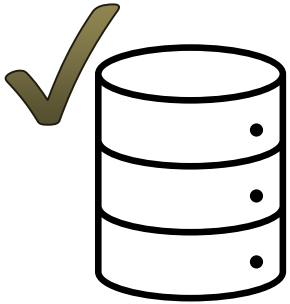
Oracle Problem

Problem Solved?



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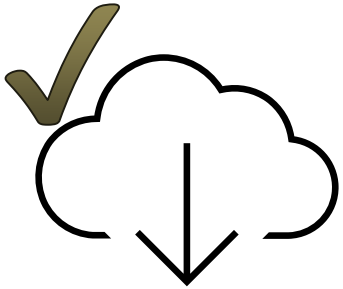

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Oracle Problem

The Specification Problem

- Oracle problem → specification problem.
  - Container will be correct if dependencies and build are correctly specified for each layer.
- Developers, not end-users, create specs.
  - Responsibility distributed across layers.
- Specs used when building debloated image.
  - Compatibility is critical.

Open Questions and Research Directions

- How do we represent specifications?
- Can dev tools help create specifications?
- How can layer developers protect IP?
- Hybrid workflows: synthesize some layers, repair the rest.
- What are the implications for software development and deployment practices?

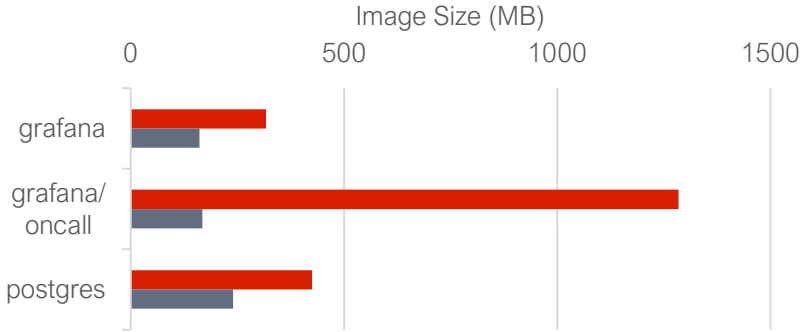
Challenge: Disclosure and Build Costs

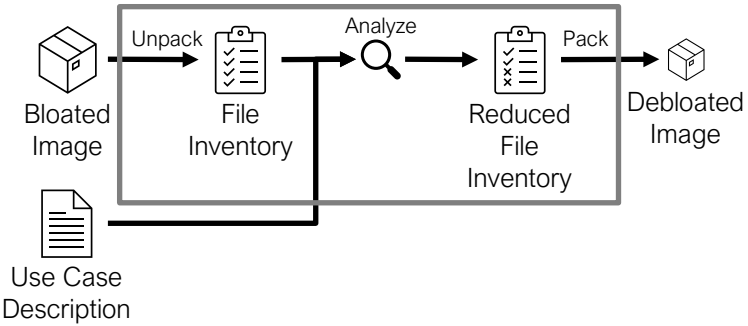
- Layers cannot be built until end-user requirements are known.

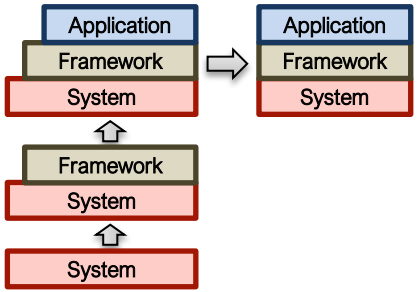
- Option 1: End-user builds all layers.
  - How can layer developers protect their IP?
- Option 2: Layer developer builds their own layer.
  - Significant ongoing resource costs.
  - Significant long-term commitment.

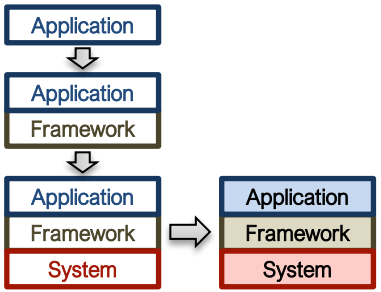
Discussion

Discussion









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