WASM meets unikernels: Secure and Efficient Cloud-Native Deployments

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About Us

- Young SME (inc. 2020) doing research in virtualization systems
- Involved in Research/Commercial and Open Source projects
- Focus on systems software
    - Hypervisors and container runtimes
    - Optimize application execution
    - Bring cloud-native concepts to Edge / Far-Edge devices

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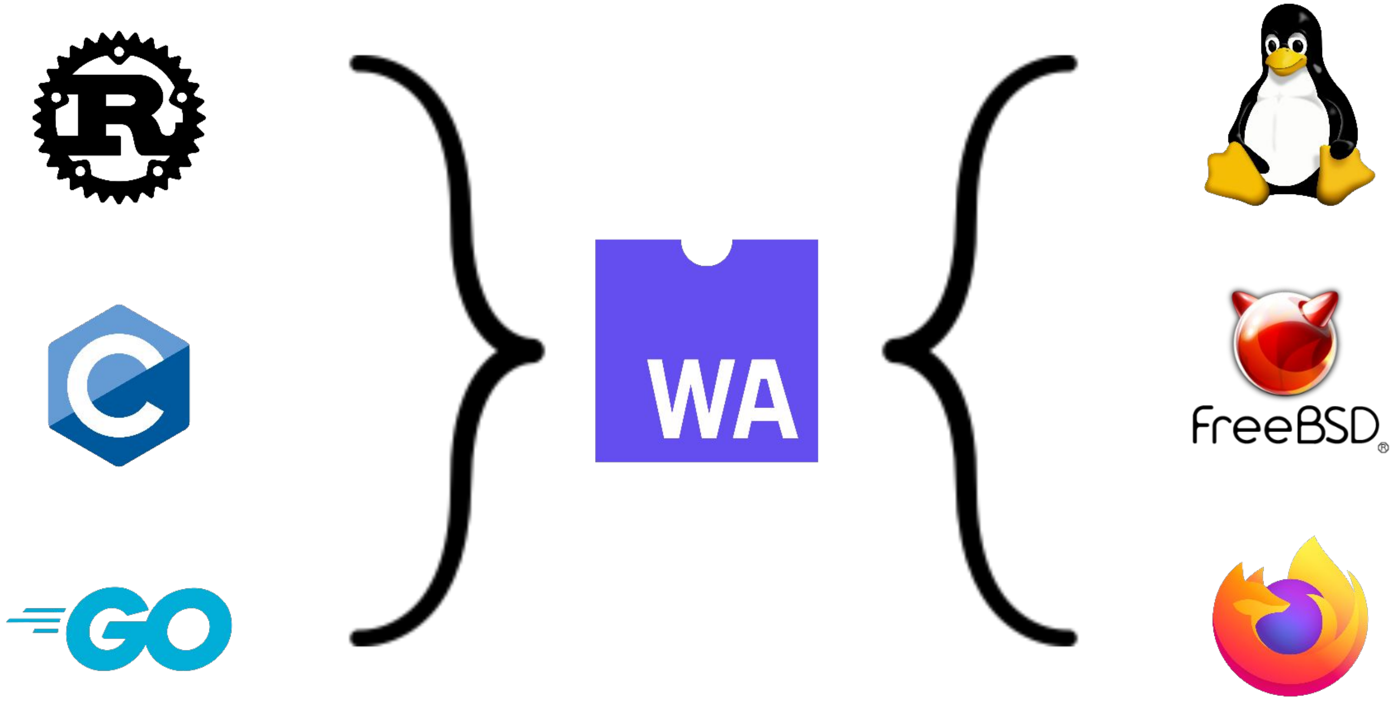
Overview

- WASM
- A closer look on WASM's runtime environment
- The security concerns of WASM
- Providing isolation for WASM
- WASM and unikernels
- Build Wasm unikernels at ease
- Deploy Wasm unikernels at ease

The Art of WebAssembly



The Art of WebAssembly

Portability

Fast spawn

Sandbox

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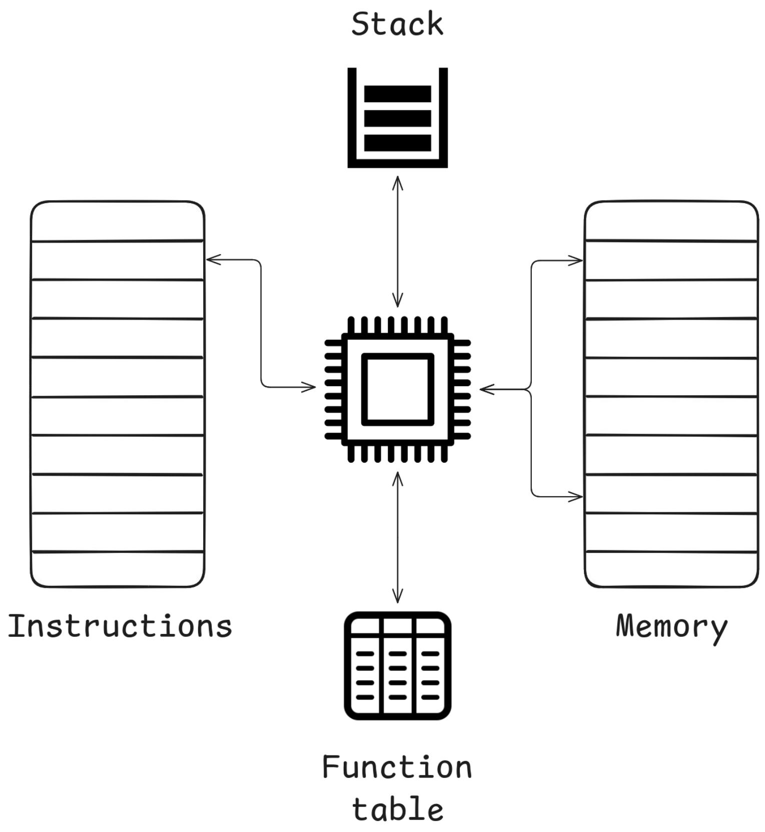
A closer look at WebAssembly

- WebAssembly is a binary instruction format
  - A low-level representation of source code
  - AOT/JIT compilation
- WebAssembly runs on top of a runtime
  - Implementation of WASM's VM
  - Enforcement of WebAssembly semantics



WebAssembly and the outside world

- WASI
  - Standard interface
  - Interact with outside world
  - ABI and Inter-Component communication
- Capability-based system
  - Fine-grained control of system resources
  - Explicit declaration of resources

WebAssembly is not a panacea

- WebAssembly and traditional bugs/attacks [1]
  - Buffer overflow
  - Use after free
  - Double free
- Exploits of the runtime [2,3]
  - Escape sandbox – CVE-2023-26489
  - Data leak between instances– CVE-2022-39393
- User misconfiguration

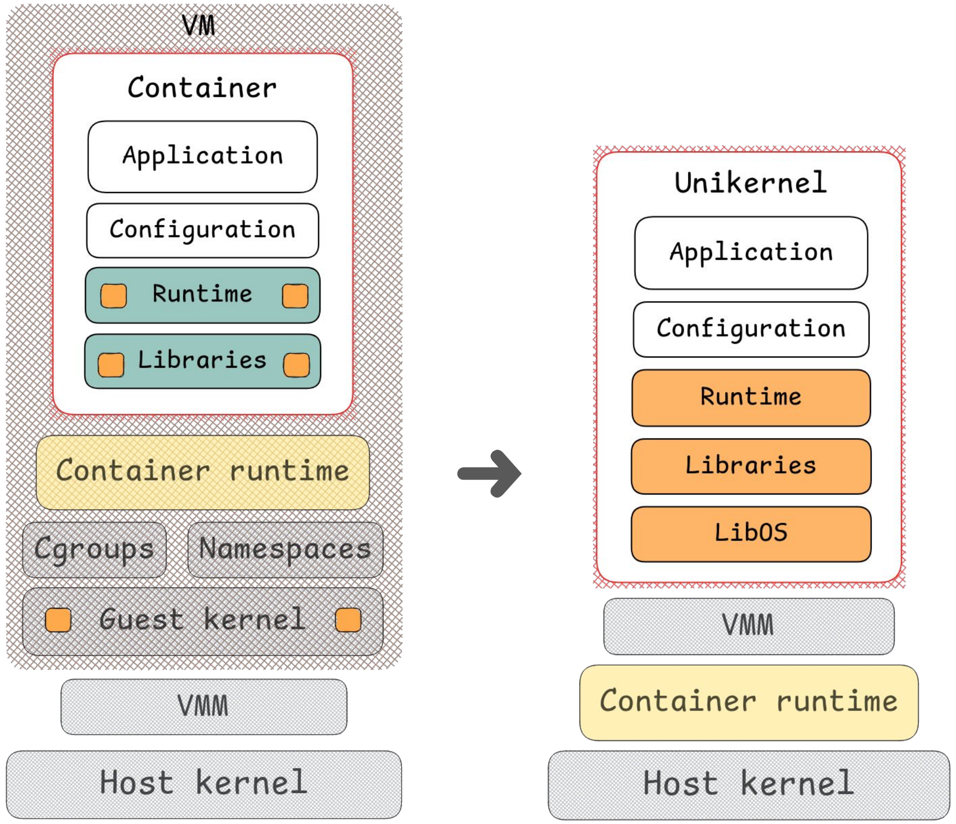
1. https://www.usenix.org/conference/usenixsecurity20/presentation/lehmann
2. https://i.blackhat.com/USA-22/Wednesday/US-22-Hai-Is-WebAssembly-Really-Safe-wp.pdf
3. https://ieeexplore.ieee.org/document/10179357

Sandboxing WebAssembly runtimes

Virtual Machines	Containers
Pros: ● Strong isolation ● Widely-used **Cons:** ● Slow boot time ● Inflexible resource management	**Pros:** ● Faster boot times ● Flexible resource management ● WIdely used **Cons:** ● Not that great isolation

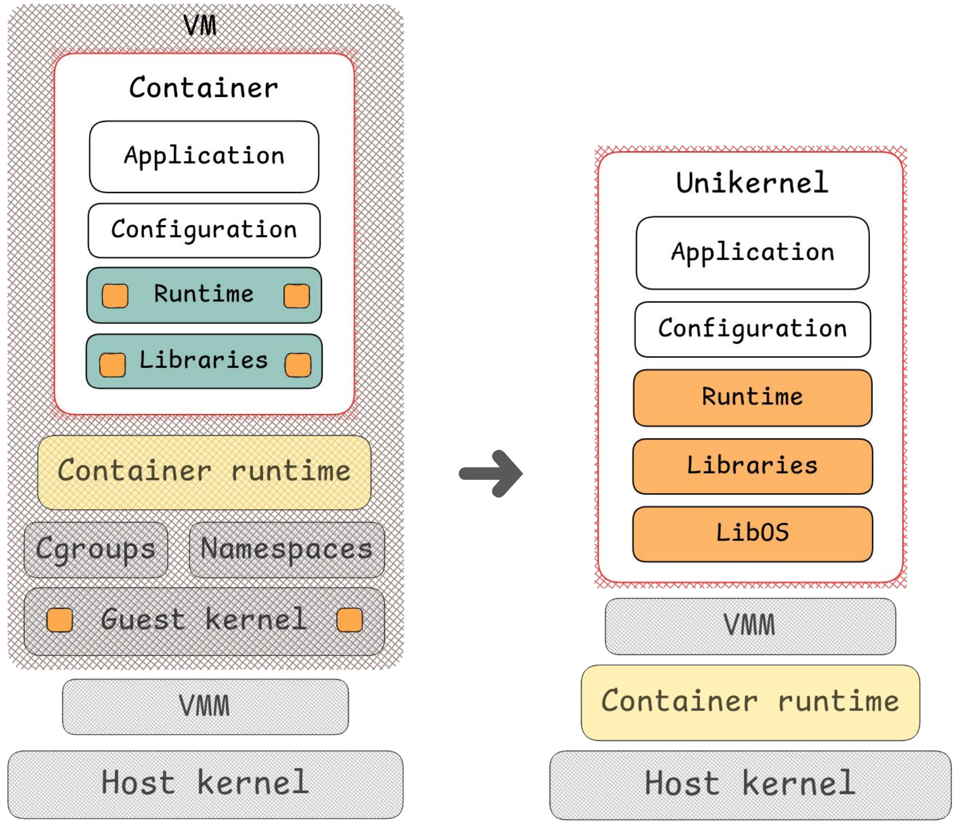
Unikernels

- A unikernel is:
  - specialized
  - single address space
  - constructed using a LibOS



Unikernels

- Benefits:
  - Fast boot times
  - Reduced attack surface
  - Truly isolated
  - Small memory/disk footprint
- Drawbacks:
  - Portability
  - Ease of use and integration with existing tools and practises



A perfect match?

Unikernel

- Low level setup
- Memory management
- I/O
- Strong isolation
- Small overhead/ footprint

A perfect match?

Unikernel
● Low level setup ● Memory management ● I/O ● Strong isolation ● Small overhead/ footprint

WebAssembly
● Process/Thread separation and management ● Standard application Interface ● No dependencies

A perfect match?

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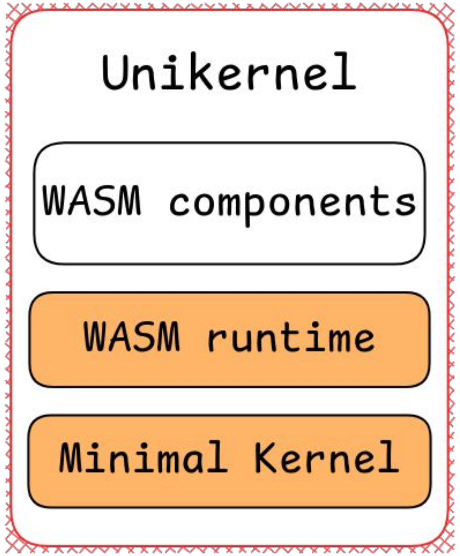


WebAssembly

- Process/Thread separation and management
- Standard application Interface
- No dependencies

WebAssembly in current unikernels

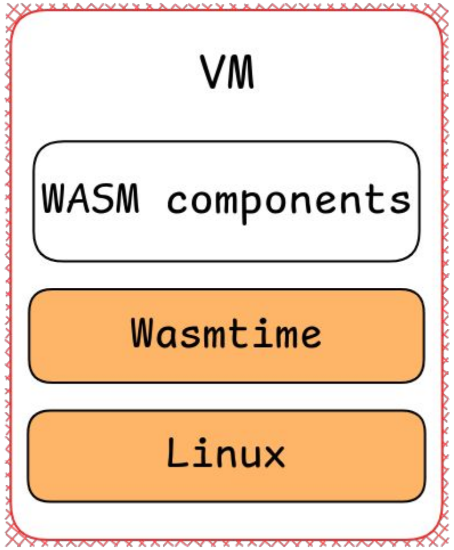
- Mewz
  - Written from scratch in Zig
  - Partial implementation of WASI preview 1 with sockets
- Unikraft:
  - Linux binary compatible unikernel
  - WAMR
- OSv:
  - Linux binary compatible unikernel
  - Wasmer
- Hermit-wasm:
  - Based on RustyHermit
  - Wasmi

More WASM-focused kernels

- k23
  - Microkernel-based
  - https://github.com/JonasKruckenberg/k23
- wasmlinux
  - Linux-based
  - https://github.com/okuoku/wasmlinux-project
- Redshirt
  - Redshirt
  - https://github.com/tomaka/redshirt/tree/main
- wasm-kernel
  - Minimal kernel to run WASM
  - https://github.com/michaelmelanson/wasm-kernel
- kwast
  - Microkernel-based
  - https://github.com/kwast-os/kwast

Cheating: A tiny Linux to run a WebAssembly runtime

- Why Linux:
  - Many WASM runtimes support
  - WIdely used
  - Highly customizable
- We are cheating:
  - Userspace / Kernelspace separation
  - Include unnecessary things
  - Multi-process



But…

- Wasm toolchains are already stiff
  - Unikernels are even more stiff
  - Unikernels are notorious of being user unfriendly
- Wasm can already get deployed as containers
  - Docker support
  - Various runtimes supported by crun
  - Runwasi from containerd
  - SUpport for Kubernetes

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How on earth can I do the same with unikernels?

Building and deploying unikernels such as containers

- Bunny: building WASM unikernels like containers
  - A buildkit frontend able to build code as wasm and build it as unikernel
- Urunc: The unikernel container runtime
  - Manage the execution of unikernels as containers

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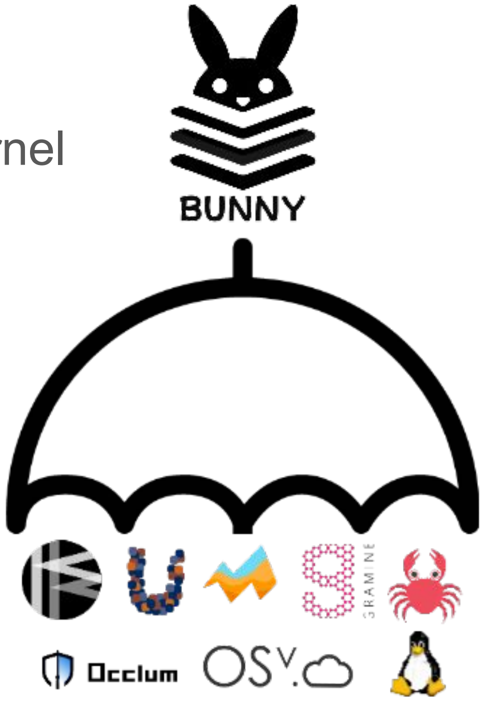
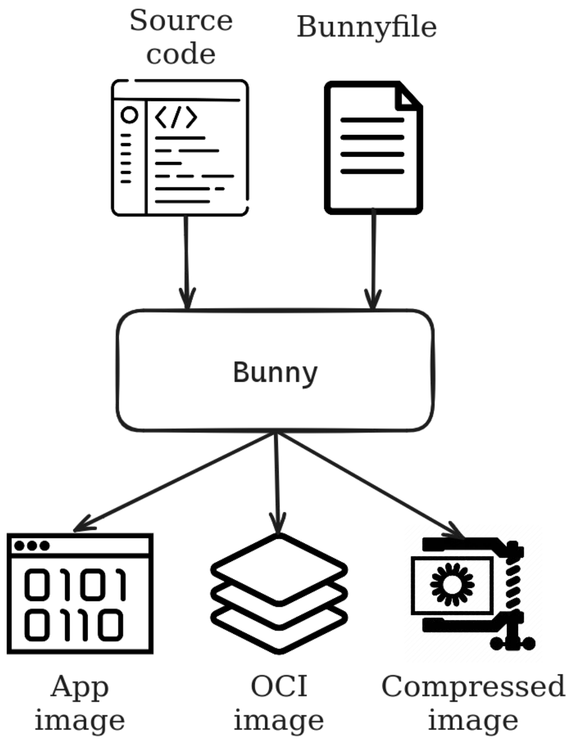
Bunny: build frameworks like containers

- Configure once build against multiple libOSes/kernels
  - Unified interface for libOSes/kernels
- Simplify the process of building an app with a libOS/kernel
  - Abstract away the diversity and complexity of each toolstack
- No dependency hell
  - Bunny takes care of resolving framework dependencies



Bunny: build libOSes/kernels like containers

- A container-like experience
  - Same workflow with containers building
- Generate various outputs
  - VM images, OCI images, or other formats
- A layered building process
  - Reuse previously built components



Bunny: demo

- Building a WASM app as a unikernel targeting:
  - Unikraft
  - Mewz
  - Linux

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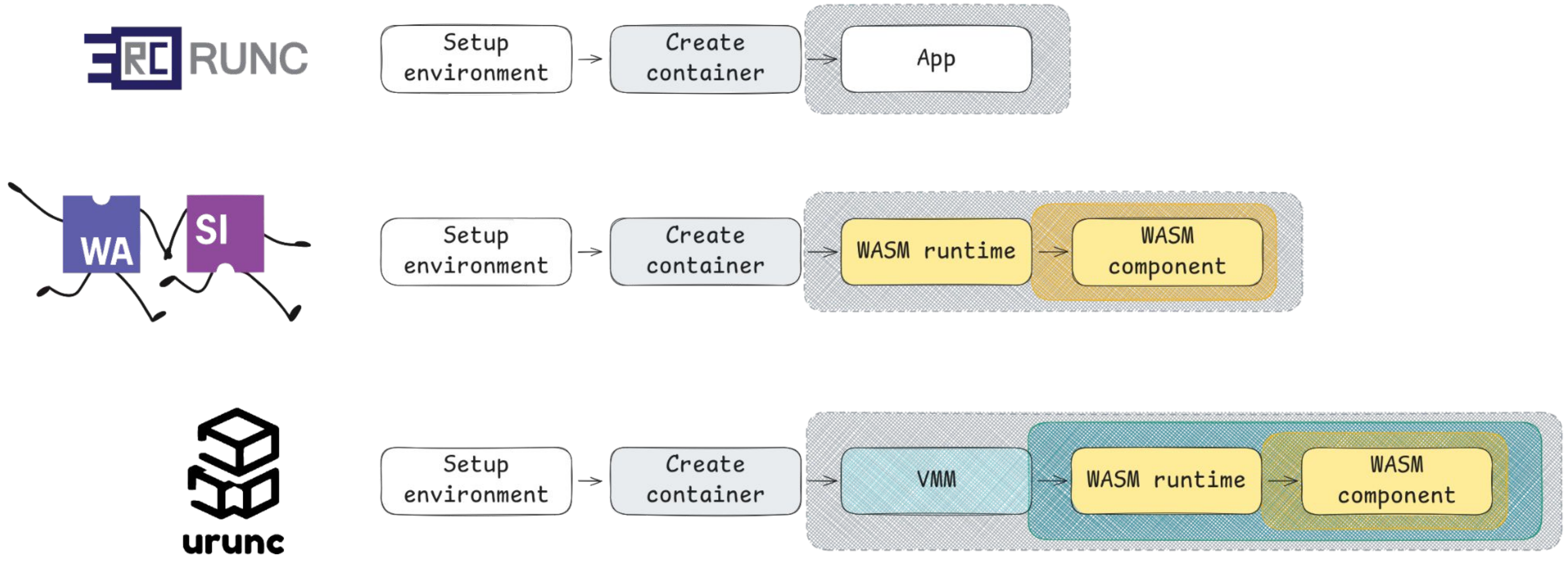
Urunc: The runc of unikernels

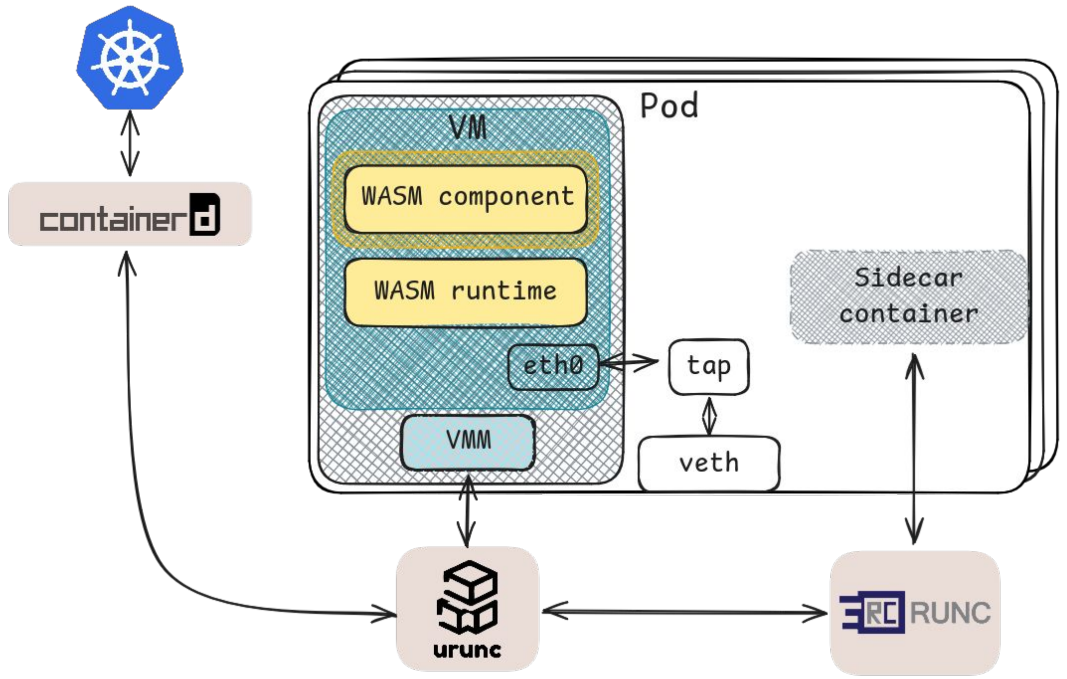
- **CRI-compatible** runtime written in Go
- **Extensible**, **easy** to add support, **without modifications** for unikernel frameworks & hypervisors
- **Hides complexity** of unikernel framework-specific and hypervisor command line options
- Key differences
  - Spawns **app** directly **inside** the **VM**
  - Treats **VMs as processes**
  - One **VM per container**

Urunc: The runc of unikernels



Urunc: Integration with k8s

- Networking
  - TC mirror tap-veth
- Storage
  - Initramfs
  - Block devices
  - Shared-fs
- Sidecar containers
  - Forward to generic container runtime



Urunc: demo

- Running the previously built WASM unikernels with urunc

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Summary

- WASM is an emerging and promising technology
- Security in-depth is necessary
- WASM can benefit from unikernels for isolation and unikernels for portability
- Bunny automates the build process of WASM unikernels
- Urunc enables the deployment and management of WASM unikernels as containers

Summary

- WASM is an emerging and promising technology
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- Bunny automates the build process of WASM unikernels
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Check out the code on github:

- https://github.com/nubificus/urunc
- https://github.com/nubificus/bunny