Hardware accelerated applications on unikernels for Serverless Computing

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Overview

- Serverless computing
- Unikernels as the basis for lightweight function execution
- Current state & missing pieces
    - "echo" demo on OpenFaaS with solo5
- ML workloads, hardware acceleration & unikernels
    - image classification demo on OpenFaaS with unikraft & vAccel

Serverless Computing

- Managed infrastructure orchestration by the service provider
- Effortless scaling (scale-out)
- Focus on Business logic
- Deploy code without provisioning the infrastructure

Serverless Computing

- Code deployed as a function with its dependencies
- Event-driven execution
- billing model: actual resource usage vs idle
- Stateless execution oriented to:
  - microservices
  - triggered actions

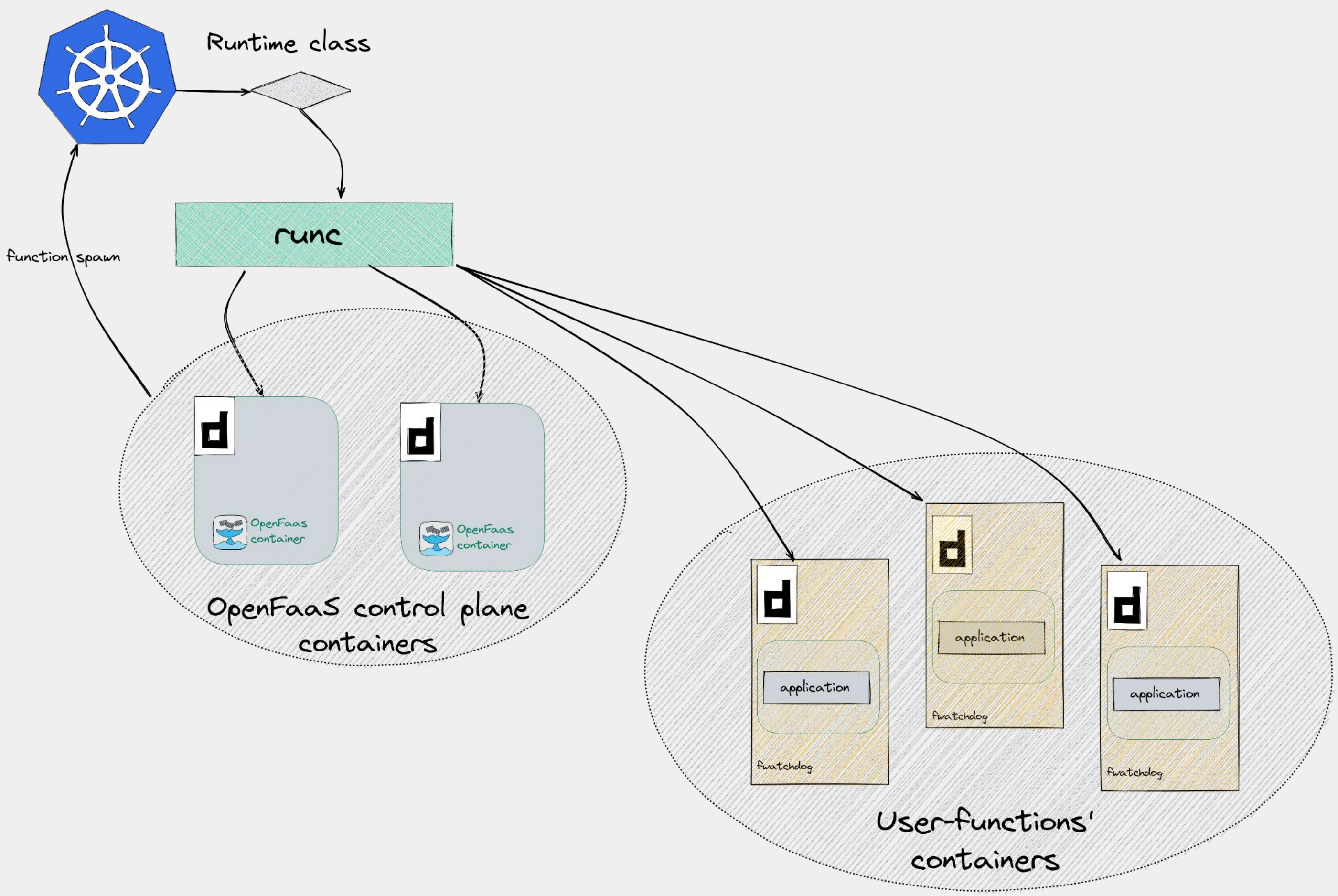
Serverless Computing

- mostly deployed on Cloud infrastructure
- mode of execution seems useful for Edge workloads as well
    - e.g. ML inference for fast decision making
- currently backed by containers

Serverless Computing - common workflow

- control plane:
  - API gateway/scheduler/queue worker
- functions:
  - main init function / endpoint (*provider*)
    - setup environment (interface/endpoint init)
    - setup handler (to trigger user code)
  - handler function (*user*)
    - spawned on invocation (via endpoint trigger)
    - actual code execution
- bundled in container images:
    - spawned (sandboxed or plain)
    - listen to events via the endpoint/gateway

Serverless Computing - OpenFaaS in k8s



Serverless Computing - containers

- currently backed by containers: multi-tenancy issues (security/data leaks)
- current solution: sandbox containers using VMs (hardware extensions to isolate workloads).
- But, VMs:
    - exhibit non-negligible overhead (mem/mgt footprint)
    - do not facilitate hardware access / device sharing

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Serverless Computing - sandboxed containers

- overhead associated with VM sandboxing:
    - boot time (cold boot) vs warm boot / invocation (checkpointing)
    - memory footprint (Edge devices)
    - VM lifecycle / state (VMM, dependencies)
- complicated stack:
    - VMM, kernel/ramdisk/rootfs/libcontainerd etc.

Serverless Computing - unikernels

- how about we try something more elegant as the basis for serverless execution: **unikernels**!

- unikernels offer:
    - fast boot (inherently, serverless functions have no state)
    - low mem/mgt footprint
    - increased security (sandbox with hardware extensions + minimal attack surface)

- but unikernels lack:
    - function/code compatibility (interoperability)
    - runtime support (orchestration/process spawning)

Serverless Computing - unikernels

- Serverless frameworks are designed for containers:
  - based on container runtimes/operators
- Unikernels are not containers:
  - their management interface (+ I/O) resembles the one of VMs
  - the application is bundled in a single bootable binary
  - there is limited orchestration support

Serverless Computing - unikernels

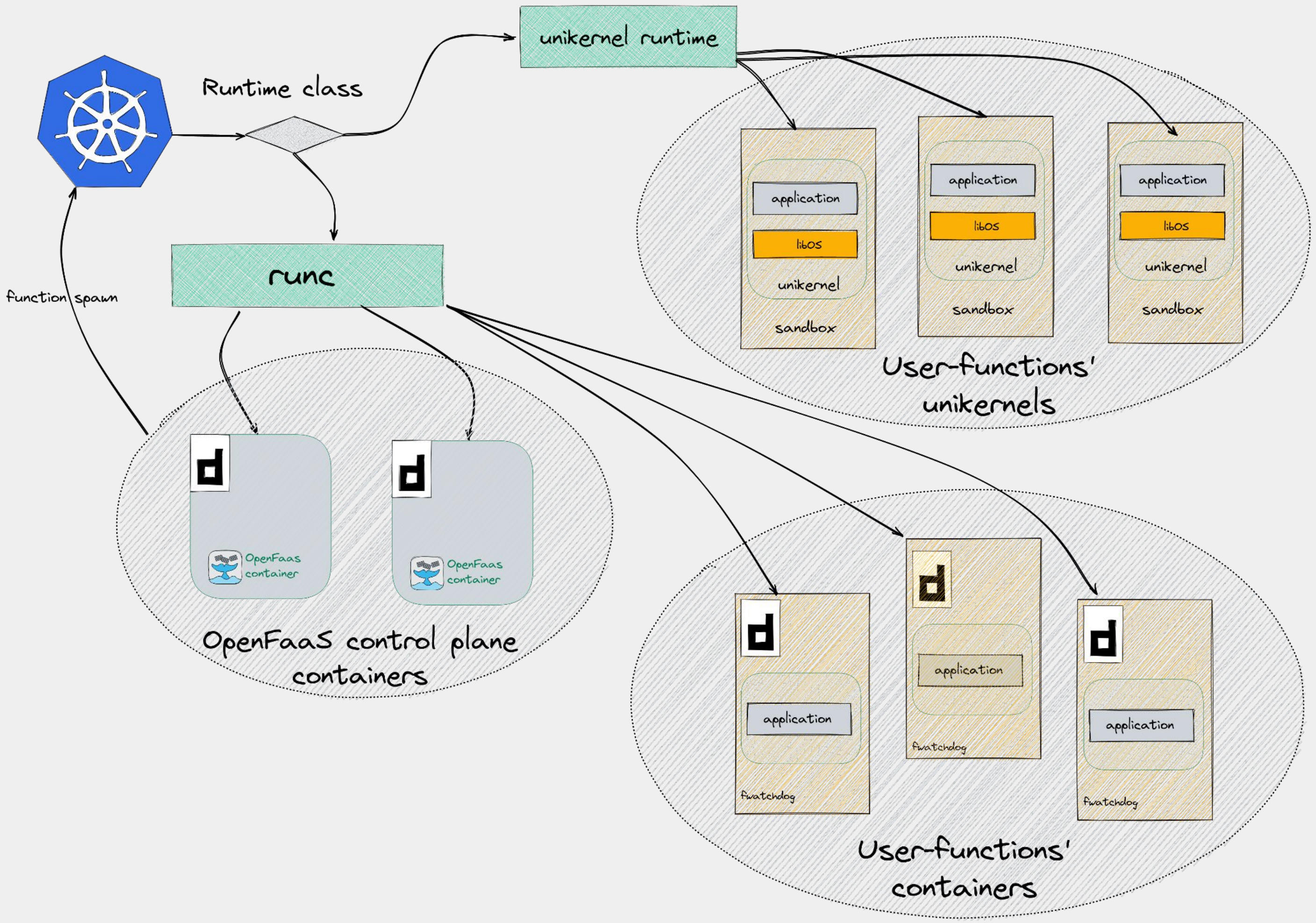
unikernels for Serverless:

- container image & runtime flows:
  - bundle the unikernel binary & dependencies in a container image
  - tweak a container runtime to spawn a unikernel along with its monitor/sandbox
- invocation triggers
  - endpoint setup
  - interface with the serverless gateway

Serverless Computing - unikernels

- integrate unikernels in modern orchestrators:
  - build a compatible runtime able to spawn a unikernel (WiP)
- using the above runtime on a Serverless Framework is straightforward:
  - instead of spawning a container on function invocation, the system will spawn a unikernel -> no change needed on the serverless workflow.

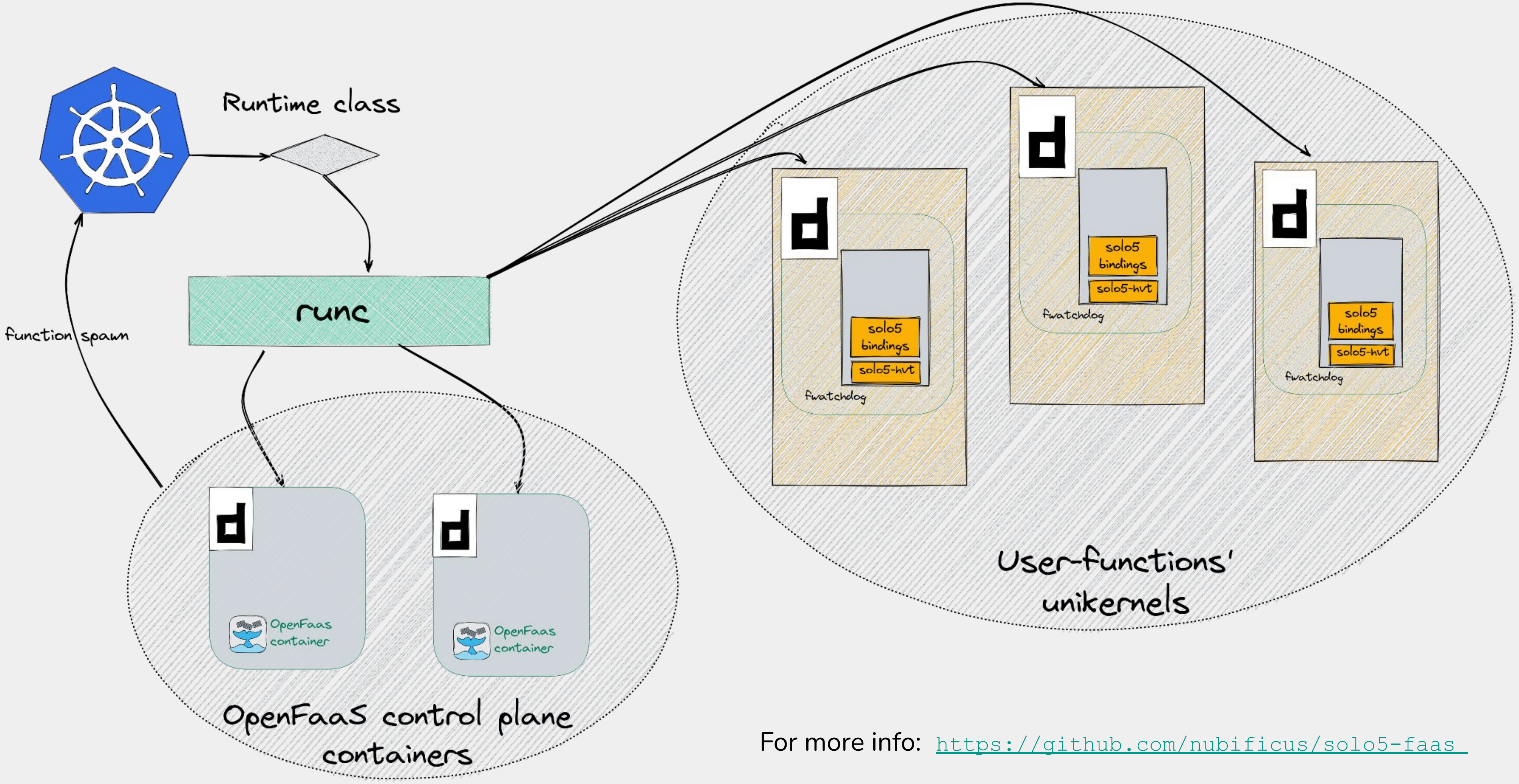
Serverless Computing - OpenFaaS & unikernels



Serverless Computing - unikernels

- as a first step, we take a hybrid approach where:
  - we keep the container for the interface & the endpoint setup and
  - spawn the unikernel for the actual code execution
- we use OpenFaaS as the serverless framework, on a generic k8s cluster:
  - `faas-netes` & gateway (control plane)
  - function pods -> generic containers with `fwatchdog` to exec user function
- we use solo5 as the unikernel example

Deploy an echo function with solo5 & OpenFaaS



For more info: https://github.com/nubificus/solo5-faas

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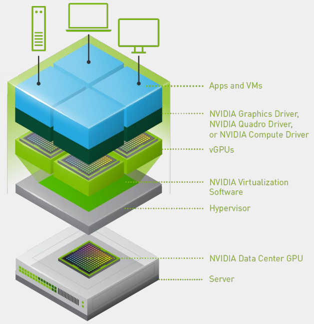
Serverless Computing - ML/AI

- workloads that need device access in serverless execution are ML/AI applications
  - Edge instant decision making based on sensor data
  - Image processing, information extraction based on specific models
- how do we combine unikernel execution with hardware device access ?

Unikernels for ML/AI

Unikernels are not a good fit for ML/AI workloads (at least not yet..)

- ML frameworks come in contrast with Unikernel architecture
  - ML frameworks dynamically link dependent libraries
  - ML frameworks have a lot of dependencies
  - Porting such a framework on a unikernel requires huge engineering effort
- No support for accelerated devices
  - hardware passthrough requires porting device drivers – not a good idea
  - the generic paravirtualization solution is almost non-existent



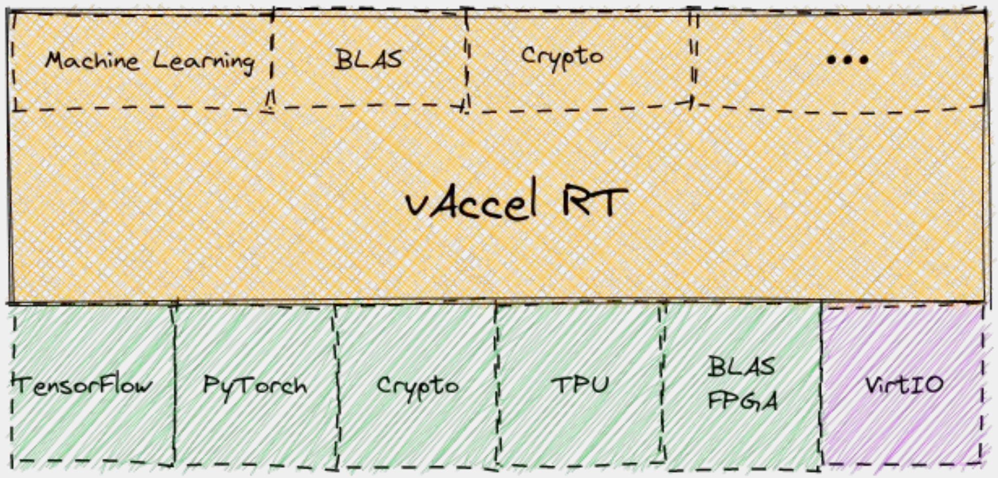
Proposed solution: vAccel

Components:

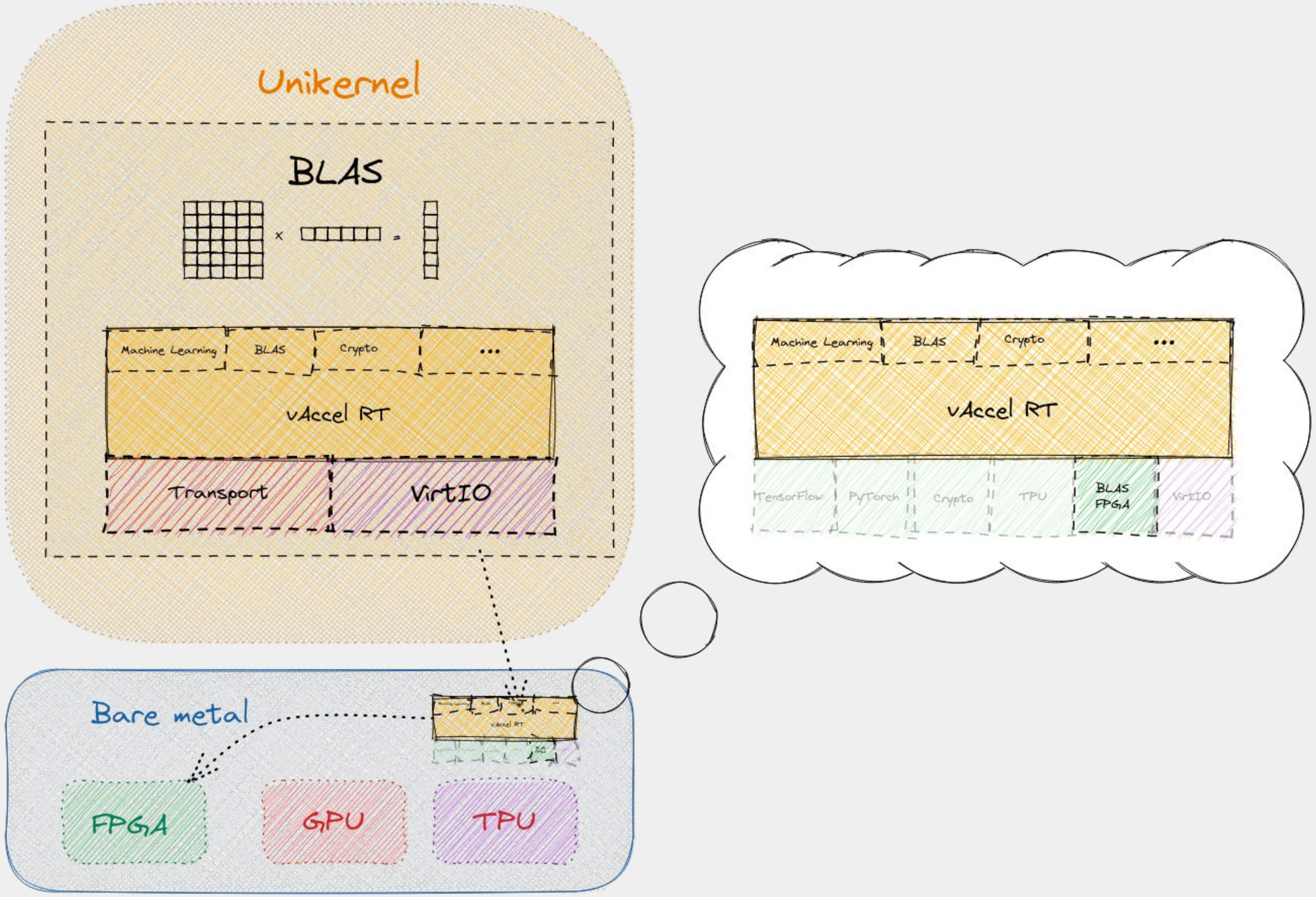
- user-facing API (accelerate-able functions)
- vAccelRT (dispatch)
- plugins (hardware, acceleration frameworks & transport)

Features:

- Hardware-agnostic API
  - Generic API at function granularity
  - Hardware-specific logic in vAccel, not in unikernel
- Portability
  - binary compatibility for functions
  - integration with high-level frameworks (Tensorflow, PyTorch, etc)
  - multiple execution environments (host/container, VMs, unikernels)
- Security:
  - User code does not access directly the (shared) accelerator
  - Support for execution in virtualized guests



vAccel on Unikernels



Unikernel

- One Transport (VirtIO) plugin
- Offload acceleration requests to host

Host

- vAccelRT linked with VMM or standalone handler (virtio-pci or vsock)
- Receives acceleration requests
- Hardware execution

vAccel: Current state

Unikernel frameworks

- Unikraft
- Rumprun

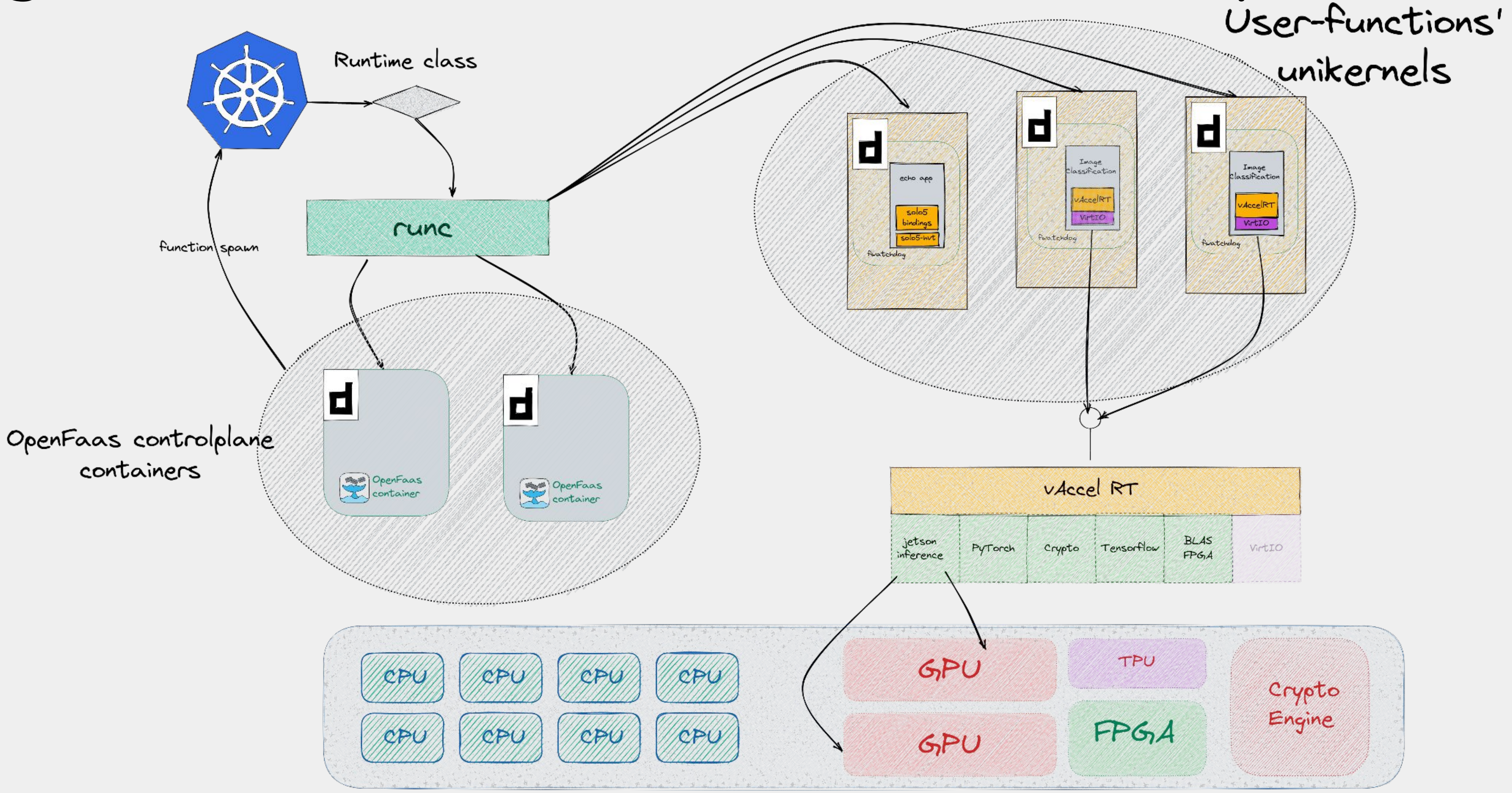
Programming interface

- C/C++ API
- Rust & Python

Framework integration

- Initial integration with TensorFlow
- Support for BLAS operations

Image classification with Unikraft & OpenFaaS



Summary

- Serverless execution based on unikernels
  - reduce cold boot times
  - reduce attack surface
- we use vAccel to expose hardware acceleration semantics to unikernels
  - function-based hardware acceleration
  - multi-framework support
- next step: develop a pure unikernel runtime for upper-layer orchestrators

SERRANO

5GComplete

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HORIZON 2020

Source Code & Demo info:

- vAccel: https://vaccel.org & https://docs.vaccel.org
- vAccelRT: https://github.com/cloudkernels/vaccelrt
- vAccel unikraft: https://github.com/nubificus/unikraft-vaccel
- openfaas-solo5: https://github.com/nubificus/solo5-faas
- openfaas-vaccel: https://github.com/nubificus/unikraft-vaccel-faas

Thanks!

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