Kata Containers: Challenges and State of the Art

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Journées Cloud 2019, IRIT
Short Curriculum

PhD Computer Science -- HPC, Distributed Systems & Cloud - INRIA/LIG/Grenoble University (2012)
  → Heavy Grid’5000 practitioner (deployment challenge, 2011)

Various software engineering positions since 2006
  → Currently Cloud Software Architect, Continental

Links
  → github.com/rchakode
  → medium.com/@rodrigue.chakode
  → slideshare.net/RodriqueChakode
  → www.linkedin.com/in/rodriguechakode/
How to run multitenant, i.e. untrustworthy and potentially malicious, container workloads on today’s microservices based architectures so to guaranteeing high performance and strong security isolation.
What’ll be discussed

Trends on computing technologies
→ Bare metals
→ Virtual machines, cloud computing
→ Containers, cloud native computing

Multitenancy, a challenge for cloud native platforms
→ Kata Containers, or the emerging of virtual machines as “containers”
→ Leverage the strong isolation of virtual machines with the speed of containers
→ Research perspectives
Computing technologies: Before 2000

On-premises data centers
→ Mainframes, bare metal servers
→ Clusters
→ Grids
→ ...

Source

Virtualization and Cloud Computing

→ Virtual machines
  ○ VMware, Xen, KVM...

→ On-demand virtual resources
  ○ Public clouds
  ○ Private and hybrid clouds
Review basics on virtual machines

Virtual machine (VM)

- Emulated HW
- Dedicated host/guest OSes
## Pros & cons of virtual machines

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
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<tbody>
<tr>
<td><strong>Virtual machine</strong></td>
<td><strong>Slow startup time</strong></td>
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<tr>
<td>• Emulated HW</td>
<td>• High performance overhead</td>
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Computing technologies: 2015 onwards

Containers
→ Docker on production
→ Tools to orchestrate containers at scale
   (Mesos, Swarm, Rancher, ...)

Source
Review basics: Container

**Virtual machine (VM)**
- Emulated HW
- Dedicated host/guest OSes

**Container**
- No HW emulation
- Linux namespaces/cgroups
- Shared host OS

Source
# Pros & cons: Container

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<td><strong>Container</strong></td>
<td>● Fast startup time ● High performance (near native) ● High workload density/host</td>
<td>● Shared host OS ● Low isolation, security threats ● No live migration</td>
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Anecdotal facts

In many organizations containers are actually executed inside VMs

→ Hosted on public clouds
→ Few, yet expensive, bare metal instances on public clouds
Rise of cloud native computing

→ Driven by open governance initiatives
  ○ Open Containers Initiative
  ○ Cloud Native Computing Foundation

→ Kubernetes, the “mascot”
Cloud Native is the new way to go

**Kubernetes** to automate the deployment, the orchestration, and the scaling of containerized workloads

→ Created by Google and donated to CNCF/Linux Foundation (2015)
→ Increasingly huge ecosystem
→ "Kubernetes is Linux of cloud", everything should be run in Kubernetes?

35K 148K 83K 1.1M 2,000+

contributors code commits pull requests contributions contributing companies

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Review of basics: Kubernetes

Resource sharing is at its core design

→ Control plane (1+ masters)
→ 1+ worker nodes
→ Workload (Pod) = 1+ containers
Kubernetes multitenancy attack surfaces

Control plane shared among users

→ DoS attacks on API service

Node OS shared among containers

→ OS is a SPOF on each node
→ Risks on privileged containers
→ Trade-offs on app compatibility
Current multitenancy with Kubernetes is soft

Restrictive containers

→ Restricted Linux capabilities, no privileges escalation
  ○ E.g. Docker containers with blocked syscalls
    ■ settimeofday
    ■ swapon/off
    ■ (u)mount
    ■ More: https://docs.docker.com/engine/security/seccomp/

→ Security hardening through Seccomp, AppAmore, SELinux, ...

→ Trade-offs on application compatibility and capabilities, no protection on control plane
Each technology solves and brings problems

Kubernetes solves the problem of highly scalable containerized applications

→ Stateless applications at first
→ All workloads assume a trustworthy execution environment (multitenancy is not built-in)

New usages, not always carefully analyzed (e.g. risk of misuse or no actual added values)

→ Running (untrusted) multitenant workloads on a single cluster
→ Anti-patterns? (e.g. deploy any stateful applications on Kubernetes)
Refocus and fix up problems

Facts

→ Containers become a kind of “de-facto standard” to run enterprise applications
→ Containers orchestrated at scale, Kubernetes being driving the transformation at fast pace
→ Multitenant workloads executed as containers on virtual machines

Problems

→ Handle hard multitenancy with untrustworthy and potential malicious workloads
Hard multitenancy with Kubernetes platforms?

Separated resources per tenant

→ Resource sprawl, with impacts on costs

Native platform-wide mechanism

→ Requires means to handle hard segregation regarding the orchestrator and workloads

→ Active topic in Kubernetes community (e.g. Kubernetes Multitenancy Working Group)

→ **Hardened sandboxed workloads** (restrictive containers, *virtual machines as “containers”*)
A vision of **hard** multitenancy in Kubernetes

By **Jessie Frazelle**

→ Deeply inspired from Linux (namespaces/cgroups)
→ Hard isolation through virtual machines as containers
Virtual machines as “containers”

Hardening container workloads by leveraging the strong isolation of VMs and the speed of containers

→ Strong isolation of virtual machines
→ Performant as containers
→ Compliant with existing OCI-compliant container engines
→ Active area of innovation with projects such as Kata Containers and Firecracker
Kata Containers

Secure container runtime with lightweight virtual machines

- Launched in 2017
- Driven by an open source community
- Hypervisor + microVM
- OCI-compliant
Kata Containers brings seamless integration

OCI runtime implementation

→ Containerd, CRI-O
→ Multi-architectures: x86_64, AMD64, ARM, IBM p/z-series
Firecracker

Multitenancy with efficient resource use

→ Initially designed for AWS, open sourced in nov. 2018
→ Improved security and reduced startup time
→ Not OCI-compliant, but planned to work as runtime for Kata Containers
Firecracker

Hypervisor and runtime for lightweight multitenant workloads

→ KVM, with restricted devices and functionality
→ microVM in user space
→ Only Intel CPUs currently
Kata Containers Demo

My Setup

→ Ubuntu 16.04
→ Docker 18.09.5
→ Kata Container 1.9.0-alpha0
→ Officiation Installation Guide
Add Kata Runtime on Docker

$ vi /etc/docker/daemon.json

```json
{
    "kata-runtime": {
        "path": "/usr/bin/kata-runtime",
        "runtimeArgs": [
            "--kata-config",
            "/opt/kata/share/defaults/kata-containers/configuration-fc.toml"
        ]
    }
}
```
Run a Kata Container on Docker

```bash
$ uname -a
$ docker run \
   -it \
   --runtime=kata \
   --cpus=1 \
   --memory=512MB \n   busybox \n   sh

$ free -m
$ cat /proc/cpuinfo
$ uname -a
Kata Containers base configuration

$ cat /etc/kata-containers/configuration.toml
Kata Containers Limitations (vs containers)

→ Pre-allocated computing resources (CPU, memory, network bridges)
→ Minimum resource footprint can be significant (default_cpus, default_memory) [1]
→ Need to keep default_cpus=1 for fast boot time and small memory footprint [2]
→ Young technologies, still needing to be improved [3]
  ○ Join an existing VM network (similar to $ docker run --net=containers)
  ○ Docker host network support (docker --net=host)
  ○ More
Other research perspectives

Performance on HPC/computing intensive applications

→ Raw performances compared against bare metals, VMs and containers (e.g. [1])
→ Performances with nested virtualization (microVM in VM, [2])

Distributed systems and clouds

→ Need to optimize placement and consolidation of microVMs to avoid wasting resources [3]

High performance storage drivers

→ Current drivers [4] (virtio-9p, virtio-fs) have poor performances [1] or are still young
Q/A

Thanks