Don’t Peek Into my Container!

Christophe de Dinechin, Red Hat
Alice Froci, Red Hat
Sergio López Pascual, Red Hat
Today’s Topics

- Confidential computing
- Confidential workloads with k8s and libkrun
- SEV-enabled libkrun
- From Kata Containers to Confidential Containers
“Confidential Computing is the protection of data in use by performing computation in a hardware-based Trusted Execution Environment”

https://confidentialcomputing.io/whitepaper-02-latest/
Confidential workloads are transformed containerized workloads into a special form that can be deployed with libkrun and confidential computing technologies.

Confidential containers are the deployment of a regular containers with an OCI runtime (e.g. Kata Containers) and confidential computing technologies.
Confidential workloads

- Confidentiality at container level
- Single container per encrypted VM
- Deploy a special form of container image with a single layer
- Simpler architecture and reusing the existing k8s infrastructure

Confidential containers

- Confidentiality at pod level
- Multiple containers per encrypted VM
- Use encrypted layered container images
- Part of the infrastructure is moved inside the trusted environment (e.g., image offloading)
Confidential workloads with k8s and libkrun
Receive the pod information
Schedule the workload on a node

Pull the container image on the node
Prepare the bundle with the rootfs of the container
Create the config.json with the container information

Create and run the container

```yaml
apiVersion: v1
kind: Pod
metadata:
  name: pod-krun-sev
  annotations:
    libkrun.attestation: "http-attest"
    run.oci.handler: "krun-sev"
spec:
  containers:
  - image: encrypted/nginx-tls
    name: krun-sev
    command: ["/fake-entrypoint"]
    ports:
    - containerPort: 443
  nodeSelector:
    sev: "true"
```
Attestation

```
config.json

"annotations":
"libkrun.attestation": "http-attest"

libkrun

Inject secret and boot

Kernel cmdline:
LUKs passphrase,
process, env variables, params ...

Encrypted VM

http-attest

session (build+cert chain)

session-uid+crypto params

measurement

Secret
(Kernel cmdline)

corrected workload coordinator

Red Hat
```
Trusted build server

- Encrypted image
  - encrypted.img
  - fake-entrpoynt

Transform in confidential workload

Regular container image

Registry

Encrypted image

Push encrypted image

Untrusted environment

- /var/run/crio/..../merged
  - encrypted.img
  - fake-entrpoynt

libkrun
SEV-enabled libkrun for Confidential Workloads
The need for a Minimal Firmware (I)

- Original functionality
- Guest Memory
  - Initial Page Tables
  - e820
  - MP table
  - Linux Zero Page
  - Kernel Image
  - initramfs

These tables are written by the VMM and become part of the launch measurement!
The need for a Minimal Firmware (II)

These tables are written by the Firmware and are **NOT** part of the launch measurement!
Replacing virtio-fs with virtio-blk (I)

Regular libkrun with virtio-fs

- Guest
  - Kernel
  - crun+libkrun
- Host
  - Image expanded into a directory on the Host

SEV-enabled libkrun with virtio-blk

- Guest
  - Kernel
  - crun+libkrun
- Host
  - Pre-encrypted Image
Replacing virtio-fs with virtio-blk (II)

- libkrun uses virtio-fs because fits nicely with the container isolation use case.
- But, for the Confidential Workloads use case, virtio-fs is not the best solution.
  - Even if we could find an acceptable filesystem-level encryption mechanism, the implementation will leak too much information.
  - The implementation is quite large and complex (is, by far, the largest component in libkrun) compared with virtio-blk, and requires a large number of syscalls, which implies a more permissive seccomp filter.
  - Lines of Code: virtio-fs = 7444, virtio-blk = 1325
Replacing virtio-fs with virtio-blk (III)

- Using virtio-blk allows us to easily rely on LUKS.
  - LUSK2 has the ability to combine dm-crypt and dm-integrity.
  - Provides both confidentiality and integrity protection (Authenticated Encryption with Additional Data, AEAD).
  - Protects against all known attacks, except data replay, which would require specialized hardware storage.
  - Reference: Practical Cryptographic Data Integrity Protection with Full Disk Encryption Extended Version by Milan Brož, Mikuláš Patočka and Vashek Matyáš.
The need for an initramfs

- The binary we use in libkrun to set up the environment inside the guest is bundled in the integrated virtio-fs server.
  - Without virtio-fs, we needed an alternative.
- We’ve incorporated a simple initramfs.
  - Includes a variant of the binary to set up the environment, a static version of cryptsetup, and some support directories and device nodes.
  - For SEV-SNP and TDX cases, it’ll likely include a small attestation client.
  - Opens the LUKS device (using the injected secret) and continues doing the usual environment adjustments before executing the workload entry point.
The Big Picture

**Guest**
- Minimal FW
- Kernel Image
- initramfs
- LUKS-based root filesystem
- Workload entry point and data

**Host**
- crun+libkrun
- CRI-O
- Pre-encrypted image
- kubelet
- Host’s kernel

**Untrusted**

**Trusted**

Part of the launch measurement, attested by the CWC
Pre-encrypted and authenticated (AEAD)
From Kata containers to Confidential containers
Kata Containers overview

- **Run Containers** described the usual way (e.g. same yaml file, images, storage, networking...)
- **... in Virtual Machines** with their own independent kernel and very little user space

The ecosystem of **containers**
The sandboxing of **virtualization**

**CRI**: Container Runtime Interface  
**CNI**: Container Networking Interface  
**CSI**: Container Storage Interface
Problem statement:
Can we trust the host?
Containers run on a host, often managed by a third party, like a cloud provider.

Sandboxing goes only one way, protecting the host from containers, not the other way round.

Resources belong to the host, which owns them and has free access.

Problem Statement: Can we trust your host?

What do you need to do if you start considering the host as hostile?
Problem Statement: Can we trust your host?

- **Data exposure** of information held in the container is possible
- **Multiple tenants** may not want to share the same host because of confidentiality risk
- **Legal concerns** may preclude the use of containers if you cannot guarantee confidentiality

There is a potential for unwanted data leaks

- Data leaving the container
- Leak between containers
- Leak outside of host
Enabling technology: Confidential Computing
Confidential Computing: more than encryption...

- **Memory encryption** prevents the host from getting data out of guest memory
- **Integrity protection** offers guarantees about guest state corruption
- **Attestation** lets the guest owner (tenant) validate what runs in the guest

Enabling technology: Confidential Computing
Many vendor-specific technologies

- **AMD** offers Secure Encrypted Virtualization (SEV)
  - SEV-ES adds Encrypted State (e.g. CPU register file)
  - SEV-SNP adds Secure Nested Pages (integrity protection for memory and more)
- **Intel** offers Trusted Domain Extensions (TDX)
- **IBM S390** offers Secure Execution (SE)
- **Power** offers Protected Execution Facility (PEF)
- **Arm** announced Confidential Computing Architecture (CCA)

- All these technologies are based on **virtualization**
- Each of these technologies works in a slightly\(^1\) different way. There be zombies 🧟‍♂️

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\(^1\) For a slightly understated definition of “slightly”
Separate Trust Realms: Platform, Tenant and Host

**Trusted Platform**: Offers confidentiality guarantees using hardware-level cryptographic enforcement.

**Host**: Offers and manages the resources used to run the container (CPU, memory, I/O, etc)

**Tenancy**: Confidential area carved out of the host, but not visible nor accessible to it.
Enabling Confidential Computing for Kata Pods

**Impacted components:**

- **Kata runtime:** Pass right options to VMM
- **VMM:** Enable encryption, etc, when setting up VM
- **Kernel:** Low-level hardware support, e.g. SEV, TDX
- **Firmware:** Special services, e.g. page validation
- **Hardware:** Encryption in memory controller

The Kata development is done for most platforms
Securing Image Download

- **Pull Image** from *inside* the guest instead of pulling it from the host
- **Store Images** on an encrypted volume, where only guest has decryption keys

The Kubelet delegates the `PullImage` operation to the `ImageService` in the CRI.

Today, that API does not exist between CRI and `kata-shim-v2`, since container images are currently pulled on the host.

This API situation is relatively typical of the sort of issues we run into for this project.

Also, for initial prototyping, the key has to be pulled out of some magic hat.
Attestation: Knowing exactly what runs

Attestation process

kubelet

CRI-O / containerd

kata-shim-v2

Confidential VM

Container Image (Pod Scope)

Image Service

ocicrypt

keyprovider

Kata agent

Guest kernel

Guest firmware

Restricted API over vsock

VMM (e.g. qemu)

Ephemeral Block Device

Relying Party

Container Image Registry

Attestation Service

Key Broker Service (KBS)

Planned for September-November 2021
Hot Plugging is currently used to add memory, CPU or devices to the pod
  - The Pod APIs do not give us the information about container sizes
  - Resources are dynamically added at container creation time
  - This adds a lot of complexity to the runtime, and inefficiency (e.g. fat page tables)

Integrity is hard to guarantee if you can change the configuration at runtime
  - Memory hot-plugging or ballooning mechanisms conflict with encryption / validation
  - Devices, notably pass-through PCI devices with DMA, are also problematic

Immutable Pods are fully defined ahead of time, before booting the virtual machine
  - This requires many changes in the existing Kubernetes APIs
  - Existing APIs may put things “in the wrong place”, e.g. send logs to the host.
  - This will simplify and optimize the non-confidential case, e.g. remove hot-plugging
The need for a shadow control plane

- **Tenants** need their own isolated administrative realm (logs, container metrics, ...)
- **Hosts** manage physical resources (pod creation/destruction, raw disks, H/W metrics...)

Host user with host credentials

- kubelet
- etcd
- CRI0
- containerd
- kata-shim-v3

Create Pod with complete description (not piecewise)

Tenant user with tenant credentials

- kubelet
- etcd
- CRI0
- containerd
- kata-shim-v3

Secure (networked) RPC channel

**No vsock**

All APIs except pod lifetime (create, kill) go through confidential channel

Will take a couple of years at least
Thank you

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