Secure Virtual Machines on Power

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Agenda.

- Problem Statement
- Protected execution facility
- Secure Virtual Machines
  - Image
  - Runtime
- Ultravisor
- Hypervisor
What is the problem?

Security is a major obstacle for cloud adoption, especially in security sensitive sectors such as healthcare, banking, government …

VM can be attacked by

- Rogue/vulnerable hypervisor
- Rogue/vulnerable “other” VMs launching privilege escalation attacks.
- Applications launching privilege escalation attacks.
- Malicious, curious or careless cloud administrator.
Solution: Secure Virtual Machines (SVM)

**SVM**

- Virtual machines backed by secure memory.
- Hardware and *Protected Execution Ultrvisor* firmware (Ultrvisor) prevents Hypervisor from accessing secure memory.
- No entity can access the contents of SVM except the SVM and the Ultrvisor.

**Ultrvisor firmware**

- Light weight firmware responsible for protecting SVM.
Protected Execution Facility (PEF) on Power9

- **Secure Memory**
  - Entirely different range of physical addresses.
  - Accessible only if CPU in secure mode.

- **Secure CPU mode**: MSR(S) = 0b1
  - Can access secure memory.

- **Ultravisor CPU mode**: MSR(H,S) = 0b11
  - Highest privileged CPU mode.
  - Access to all resources.

- **Hypervisor CPU mode**: MSR(H, S) = 0b10
  - Loses access to many key resources including secure memory.
  - Can access the resources through Ultracalls.

- **Ultracalls**
  - Access to Ultravisor services.
Introduction to SVM

- **SVM Image**
  - SVM image = Normal VM image + lock boxes + encrypted secrets
    - All secrets in the image encrypted.
    - The encryption key put in the lock box.
    - One lock box per authorized platform, locked using platform's public key.
    - A tool to convert a normal VM image to Secure VM image.
Introduction to SVM (cont..)

- **SVM Runtime**
  - All SVM images start as Normal VM, backed with normal pages.
  - VM invokes a ultracall to switch to secure mode (SVM).
  - On successful transition, UV transitions all SVM pages into secure memory.
Introduction to SVM (cont...)

- SVM Runtime (cont..)
  - Explicitly request UV to share address ranges with the Hypervisor. (Shared pages).
  - Needed for
    - VPA(Virtual Processor Area)
    - Virtual I/O
      - https://lkml.org/lkml/2018/7/20/30
Ultravisor

- Firmware Code, Opensource GPL
- Loads and executes in secure memory.

Responsibility

- Authorize/validate VM before transitioning it to Secure mode.
- Manage secure memory.
- Back SVM with secure pages.
- Handle Ucalls from Hypervisor and from SVM/VM
- Provide services to SVM
  - Marshall and reflect select Hcalls and Exceptions to Hypervisor.
  - Handle other hcalls and exceptions.
- Offload non-security related services to Hypervisor.
  - Scheduling
  - I/O
Hypervisor

- **Aware of secure pages**
  - Secure pages are mapped into qemu's address space.

- **Treats secure memory as heterogeneous memory.**

- **UV_HMM module orchestrates secure-data movement**
  - From normal memory to secure memory and vice-versa
  - HV or UV can initiate the movement.
  - But UV always moves the content.
    - Encrypted when moved to HV.
    - Decrypted when moved from HV.

- [https://www.mail-archive.com/linuxppc-dev@lists.ozlabs.org/msg140597.html](https://www.mail-archive.com/linuxppc-dev@lists.ozlabs.org/msg140597.html)
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Backup
Ultracalls (an incomplete list. Under development)

Ultracalls made by Virtual Machines:

- UV_ESM : *Execute in Secure Mode.*

- UV_SHARE_PAGE: *Share the page at the provide address with the Hypervisor.*

- UV_UNSHARE_PAGE: *Unshare the page at the specified address.*

- UV_UNSHARE_ALL: *Unshare all shared pages.*
Ultracalls (an incomplete list. Under development)

Ultracalls made by Hypervisor:

- **UV_PAGE_OUT**: Move the contents of a secure page into normal page.

- **UV_PAGE_IN**: Move the contents of a normal page into secure page.
  Or, use the normal page for sharing.

- **UV_PAGE_INVAL**: Invalidate a shared page.

- **UV_REGISTER_MEM_SLOT**: register a memory slot for a given SVM.

- **UV_REGISTER_MEM_SLOT**: unregister a memory slot of a given SVM.

- .....
Steps to deploy a secure virtual machine

1. Get the public keys of all the Power platforms you trust to deploy your VM image.
2. Convert your VM image into Secure VM image using a new open source tool.
   - This step must be done in your private setup.
   - Feed all the public keys to the tool.
   - Feed any other secrets that you choose to store in the image.
     - Crash dump key
     - File-system encryption pass-phrase
     - Etc.
   - The secrets in the VM image gets encrypted with a dynamically created symmetric key.
   - The tool also outputs the symmetric key. Save the symmetric key securely.
Steps to deploy a secure virtual machine cont..

3. Upload the Secure VM image to your Cloud Service Provider.

4. Deploy the Secure VM image on the POWER platform in the cloud.
   - The ultravisor will only be able to read and deploy the SVM image if the image was created using the machine's public key.
   - Otherwise it will fail.
Steps for switching a VM to a SVM (UV_ESM ucall)

- Allocate secure pages to the VM
- Move the contents of VM's normal page into the secure page.
- Locate the lock-box
- Procure the symmetric key from the lock box with the help of TPM.
- Using the symmetric key, unlock the contents of the secrets-box.
- Match the kernel-hash, initrd-ram hash, kernel command line parameters hash against the hashes located in the secrets-box.
  - If match fail, return failure.
- Commit all the secure pages to the VM's page table.
- Enable the secure-page access capability for the VM.
- Return Success.