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Secure Virtual Machines on Power

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Agenda.

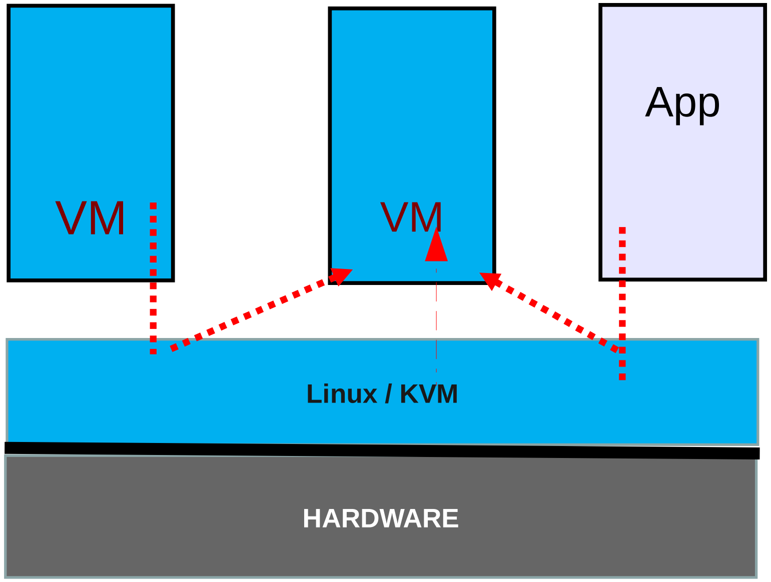
- Problem Statement
- Protected execution facility
- Secure Virtual Machines
    - Image
    - Runtime
- Ultravisor
- Hypervisor

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

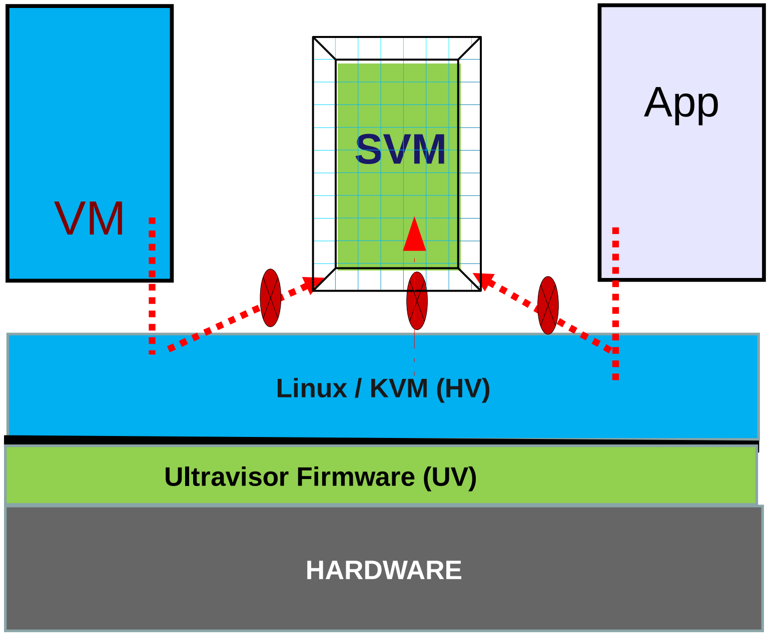
- Rogue/vulnerable hypervisor
- Rogue/vulnerable “other” VMs launching privilege escalation attacks.
- Applications launching privilege escalation attacks.
- Malicious, curious or careless cloud administrator.



Solution: Secure Virtual Machines (SVM)

SVM

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

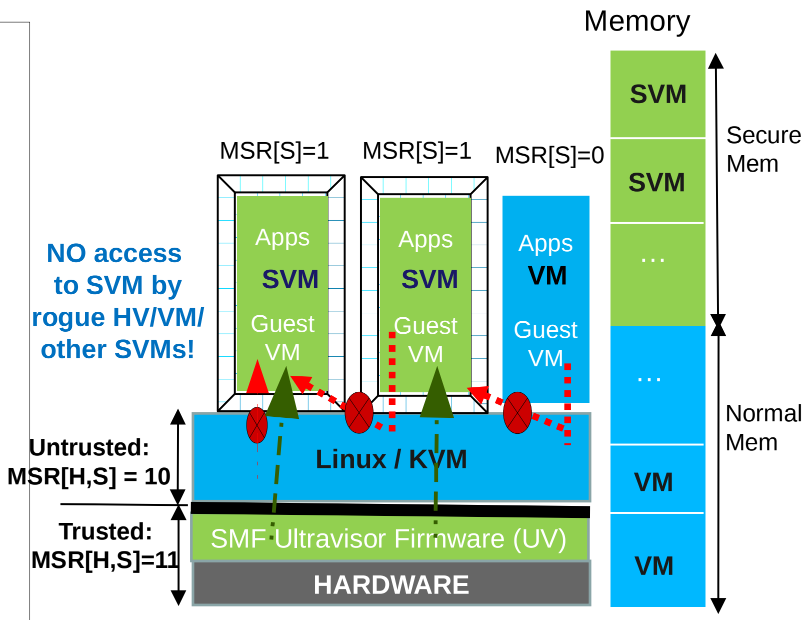


Ultravisor firmware

- Light weight firmware responsible for protecting SVM.

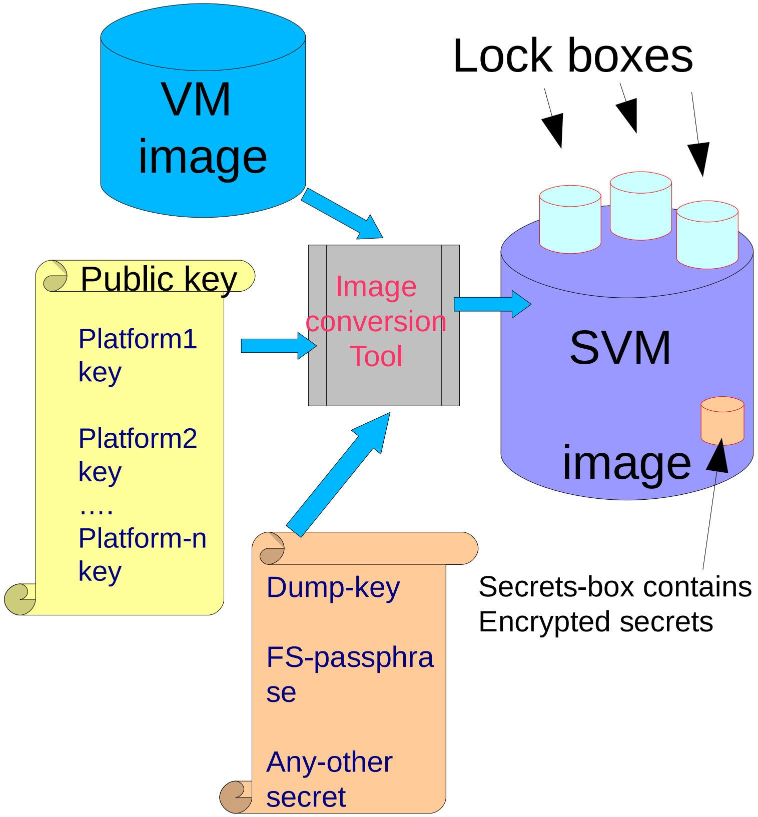
Protected Execution Facility(PEF) on Power9

- 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

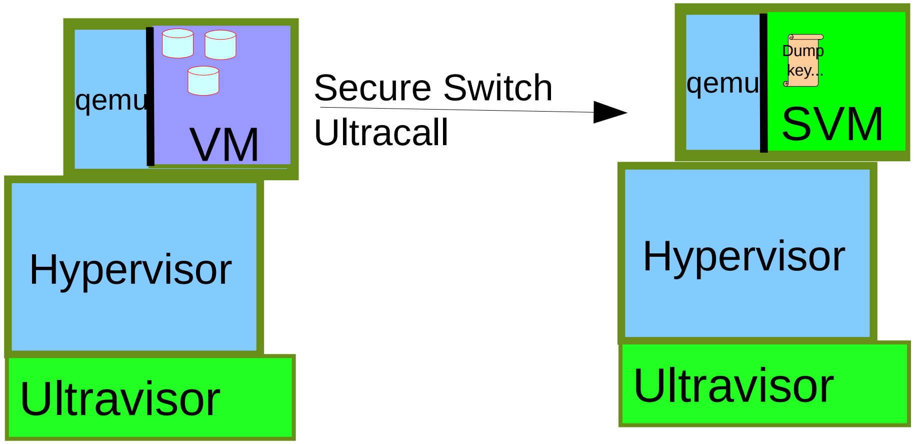
- SVM Image
  - **SVM image = Normal VM image +**
    lock boxes +
    encrypted secrets
  - All secrets in the image encrypted.
  - The encryption key put in the lock box.
  - One lock box per authorized platform, locked using platform's public key
  - A tool to convert a normal VM image to Secure VM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

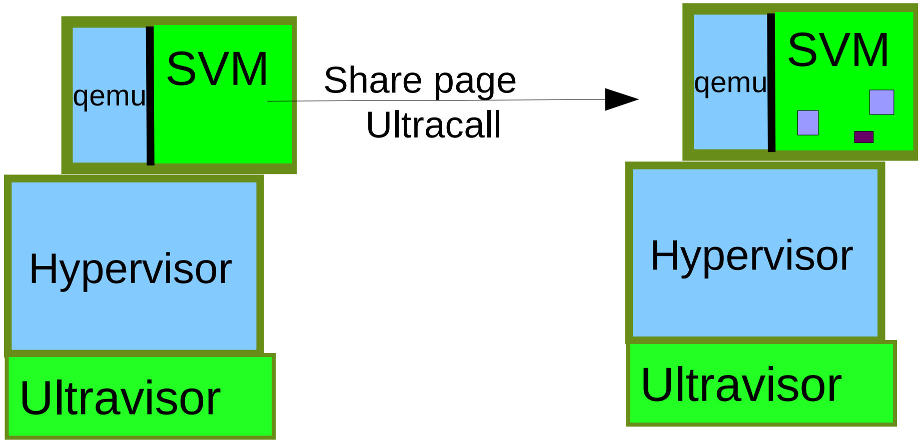
🟩 Secure memory
🟪 Normal memory



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)
      - *https://lists.ozlabs.org/pipermail/linuxppc-dev/2018-August/177334.html*
    - Virtual I/O
      - *https://lkml.org/lkml/2018/7/20/30*

🟩 Secure memory
🟪 Normal memory

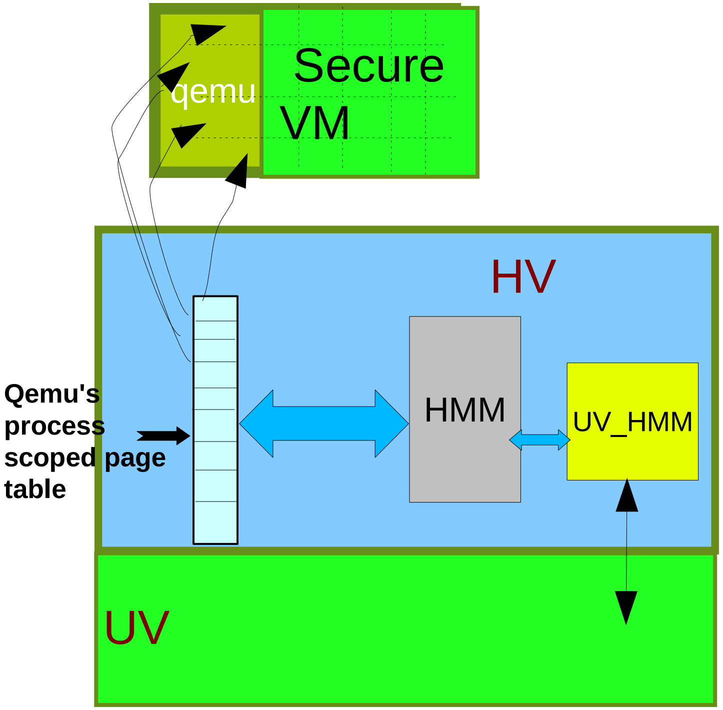


Ultravisor

- **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*



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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)

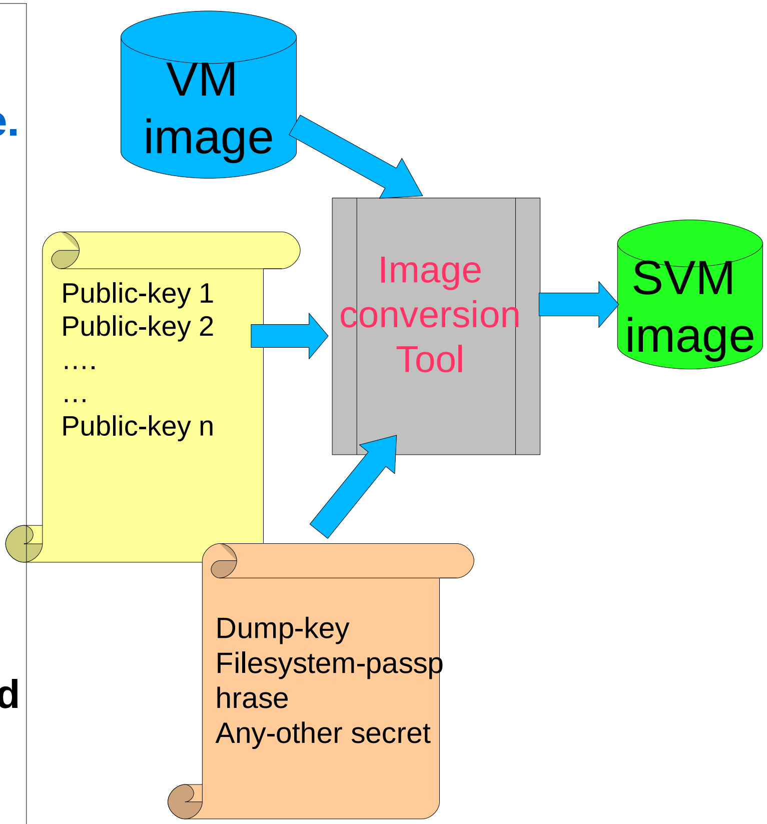
Ultracalls made by Hypervisor:

- 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.**

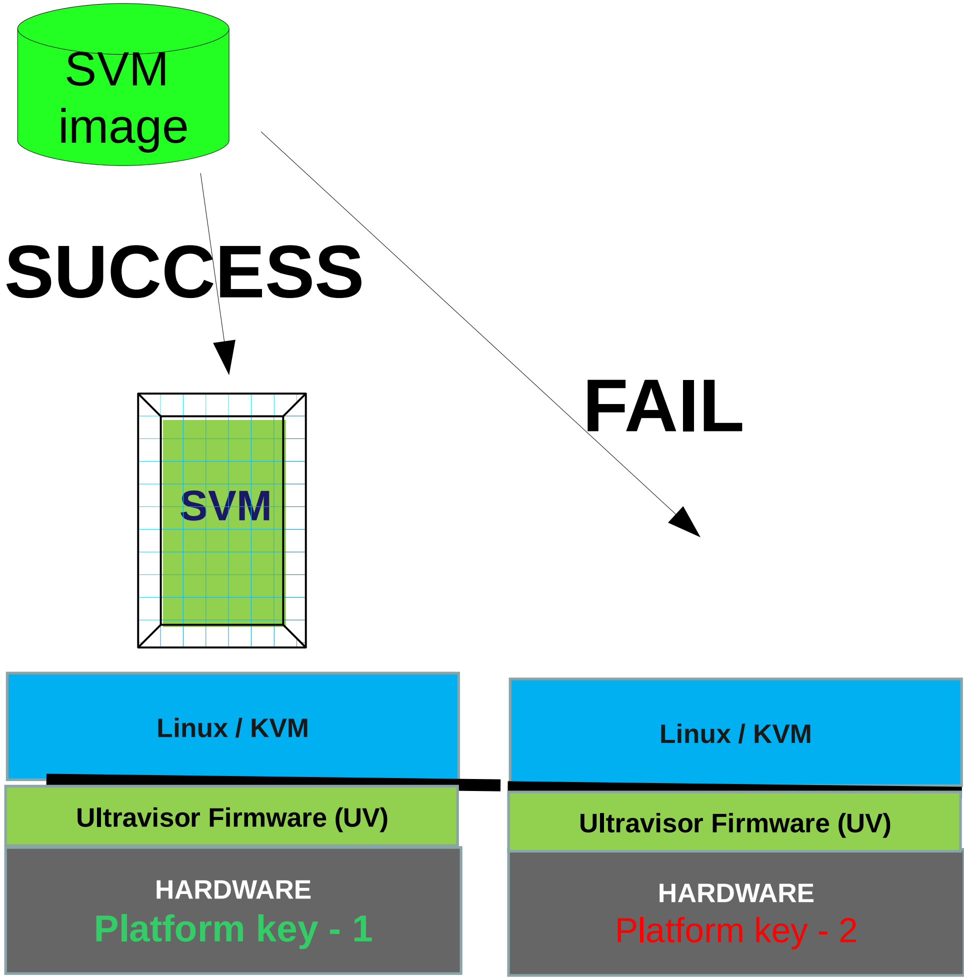


Steps to deploy a secure virtual machine cont..

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.