Cloud Security: The Malicious Insider Threat

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Outline

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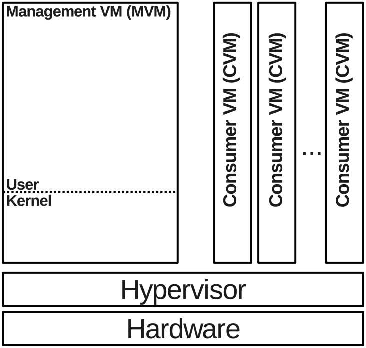
Terminology

- Consumer – cloud user, e.g., VM owner or cloud application developer.
- Hypervisor – virtualization layer, e.g., Xen Hypervisor.
- Management Virtual Machine (MVM) – administration tools (launch/destroy VMs), e.g., Xen's Dom0.
- Consumer Virtual Machine (CVM) – cloud consumer owned VM.



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Malicious Insider Threat (1/2)

- **#3** in the Cloud Security Alliance (CSA) top threats list.
- Current studies focus on **consumer-side** and **co-residency** attacks.
- Biggest shift is having data processing/storage **entrusted** to a cloud provider.
- Companies holding **critical data** (e.g., medical data) want to use the cloud for data processing.
- What is the security impact of a malicious insider?

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Malicious Insider Threat (2/2)

- Data processed in a cloud infrastructure is **not protected**, e.g., malicious insider can **compromise private keys**. (Rocha and Correia)
- Other attacks can be performed using virtual machine introspection. (Rocha, Gross, Van Moorsel)
- Cryptography on its own **is not enough**.
- Applicability of Fully Homomorphic Encryption (FHE).

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Methodology

- Work environment using Xen 4.2 unstable source code and two consumer virtual machines.
- Verify if a VM's memory dump contains security sensitive data.
- Explore virtual machine introspection (VMI) (e.g., *libVMI* library).
- Use VMI as a malicious insider's attack tool against virtual machines' memory areas.
- Attack Xen's inter-virtual machine communication library (*libvchan*).
- Develop prevention techniques against known attacks.
- Verify if known attacks are no longer feasible.

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Access to Security Sensitive Data

- Recall *coldboot* attack (Princeton University).
- Plaintext passwords in memory (can be used in dictionary attacks).
- Compromised private keys in memory dump.
- It is as simply as running **two commands**.
- Used key search mechanism from *coldboot* attack.
- Obtained all the data stored in virtual disks.

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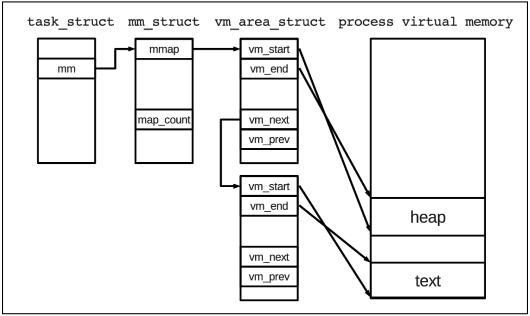
VMI as an Attack Tool

- Two consumer VMs (VMServer and VMClient) exchanging messages over an inter-VM channel.
- As root in the MVM, attack VMServer's memory to pinpoint *libvchan*'s data structure.
- Extract and monitor the shared memory location addresses.
- Result: compromised data confidentiality.



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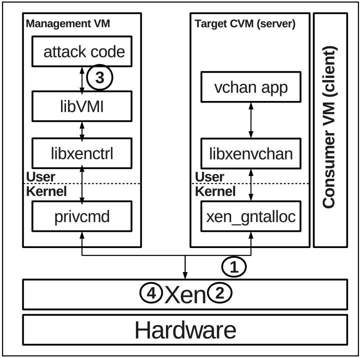
Secure Inter-VM Communication

- Proof of concept for a more generic solution.
- (1) Change the kernel to send to Xen the used memory page.
- (2) Flag the memory page as inaccessible to MVM.
- (3) and (4) The attack code previously used receives a permission denied response from Xen.



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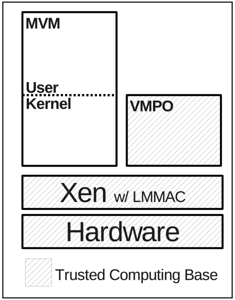
LMMAC: Lightweight Mandatory Memory Access Control

- Generalize the secure inter-VM approach.
- Combines trusted computing base reduction with MAC.
- Access to a VM's special purpose pages required (e.g., load virtual firmware for HVM guests).
- Use the reference count in the memory pages to identify the special purpose pages.
- Flag all memory pages free for VM's usage as inaccessible to MVM.



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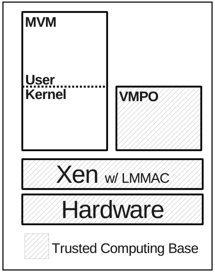
Discussion – LMMAC (1/2)

- Guarantees data **confidentiality** and **integrity** for consumer VM's memory.
- Uses two layers of protection TCB reduction and LMMAC.
- No need to load extra modules that might originate multiple executable files for Xen (FLASK/sHype).
- No mutable executable file, beneficial for use with trustworthy computing.
- No key management issues or overhead from encrypting memory pages before passing them to MVM (Chunxiao Li et al).

Discussion – LMMAC (2/2)

- Using special purpose VM to execute privileged operations.
- Reduced TCB when compared with previous work (Murray et al).
- Why? Xen is used as the policy decision and enforcement point.
- It will need a "micro TPM" similar to the one used by TrustVisor (McCune et al).
- vTPM (IBM) is vulnerable to TOCTOU attacks and it bloats the TCB.



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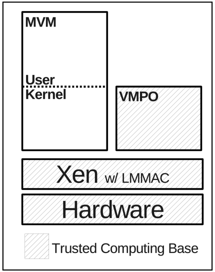
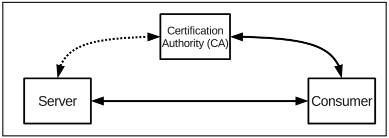
Secure Cloud Architecture (1/2)

- The architecture in the figure represents a single cloud server.
- Goals:
  - have all the servers with trustworthy computing support using the suggested architecture.
  - use remote attestation to verify a server's software integrity.
  - improve the granularity of components that can be measured.



Secure Cloud Architecture (1/2)



- 1. Server's TPM generates a AIK key pair and registers a certificate for the public AIK with a CA.
- 2. The consumer requests certificate from CA.
- 3. The consumer initiates remote attestation. Server's TPM signs a vector of PCRs with the private AIK and sends it to the consumer.
- 4. The consumer verifies if the signature is valid, and if the values in the PCRs match a trusted configurantion.

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Conclusions

- Guarantees data **confidentiality** and **integrity** for a VM's memory space.
- Transparency for the consumer, i.e., attest remote operations.
- Brings the risk level closer to what is acceptable today for commodity systems.
- The consumer is left with trusting that the TCB is as free of vulnerabilities as it can be.

Thank you!

Questions?