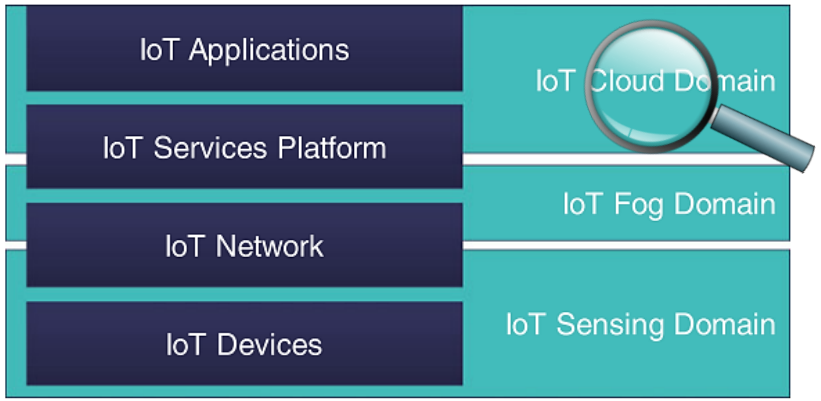
Ch. 14 - IoT Security and Privacy

Sec 2 – Cloud Domain

COMPSCI 147

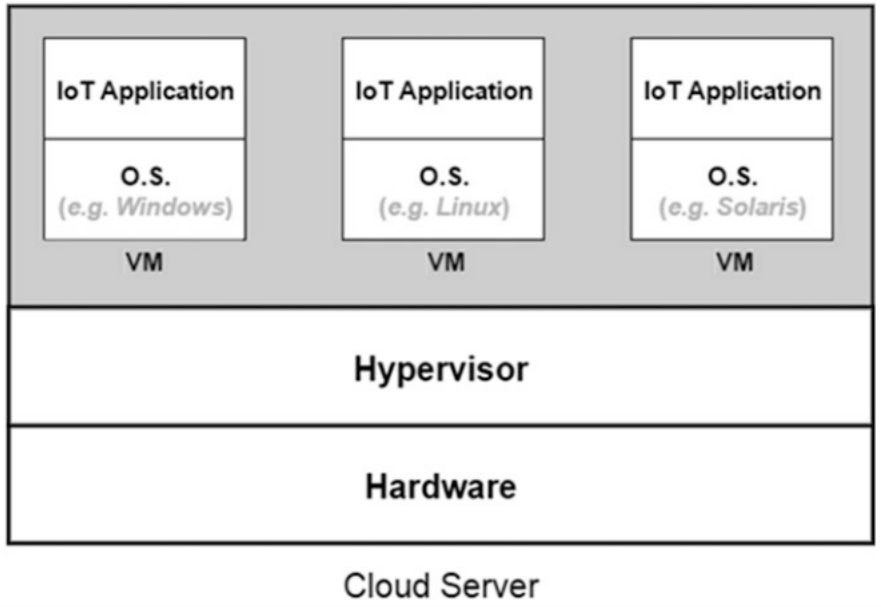
Internet-of-Things; Software and Systems



Cloud Domain – Hypervisor based structure

- IoT application can have one or multiple dedicated virtual machines (VMs)
  - Cloud data center is made up of thousands of servers
  - Certain amount of CPU and memory resources are allocated
  - One server can accommodate several VMs

- Hypervisor
  - Manages how VMs share the server' s hardware
  - Provides the logical separation among VMs
  - Migrates VMs on the server to another server



vmware ESXi

Microsoft Hyper-V

Xen Server™

RED HAT ENTERPRISE VIRTUALIZATION

KVM

Cloud Domain – Attacks

Five categories of cloud domain attacks:

1. Hidden-Channel Attacks
2. VM Migration Attacks
3. Theft-of-Service Attack
4. VM Escape Attack
5. Insider Attacks

Cloud Domain – 1. Hidden-Channel Attacks

- Some hardware components are shared among VMs.
  - E.g. Cache, on-chip communication, etc.
- Opportunities for **data leakage** across the VMs on the **same** server.
- The steps for attack are as follows:
  - Step1: Mapping Target VM
  - Step2: Malicious VM Placement
  - Step3: Cross-VM Data Leakage

Cloud Domain – 1. Hidden-Channel Attacks
Step 1: Mapping Target VM

- **Gaol: To locate where the target VM resides**
- Cloud data center is divided into multiple clusters
  - Each cluster is in a certain **geographical location** and is made up of **thousands** of **servers**
- To know where a target VM resides, the attacker needs only to know the **external IP** address of that VM
  - External IP address **=>** geographical location
- To identify in what zone within the cluster the target VM resides the target VM's **internal IP** address is needed
  - VMs within the same zone have the same network prefix
  - The attacker rents a VM in the same cluster
  - Query the DNS server of the cloud cluster from the rented VM **=>** fetch internal IP address of the target VM

Cloud Domain – 1. Hidden-Channel Attacks
Step 2: Malicious VM Placement

- **Goal: To place a malicious VM on the same server where the target VM resides**

- The following process is needed:
  - The attacker rents a VM in the same cluster as the target VM
  - The scheduling algorithm places the rented VM on one of the servers within one of the cluster's zones
  - The attacker performs a **traceroute** from the rented VM to the target VM
  - **Multiple hops** from the target VM to the rented VM **=>** the rented VM and target VM are **NOT** in the same server
  - The attacker **releases** the rented VM and requests a **new** one
  - Do it repeatedly to succeed

Cloud Domain – 1. Hidden-Channel Attacks
Step 3: Cross-VM Data Leakage

- **Goal: To learn some information about the target VM by exploiting the shared server's hardware**

- For example, learn what lines of cache (data or instruction) the target VM has **accessed** recently
  - The attacker **fills** the whole shared cache by **dummy** data
  - Observing the time it takes to access each chunk of the dummy data after the target VM changes some chunks
    - Short time => cache access
    - Long time => memory access
  - Extracting addresses the target VM has accessed recently
  - Access pattern partially recovers the security keys

Cloud Domain – 1. Hidden-Channel Countermeasures

- Hard Isolation
  - To separate the cache dedicated for each VM
  - To assign only one VM to each server
    - Both facing cloud underutilization problem!
  - Cloud client specify a list of trusted cloud users (**white list**), and sharing the server with only the VMs in the white list
    - New scheduling algorithms are needed.
    - VM must have a list of identified untrusted VMs (**black list**)
- Cache Flushing
  - To flush the shared cache every time the allocation of the cache is switched from a VM to another
    - Performance degradation!

Cloud Domain – 1. Hidden-Channel Countermeasures II

- Noisy Data Access Time
  - Adding **random noise** to the amount of **time** needed to fetch data
    - Fetched data gets delayed due to the noise
- Limiting Cache Switching Rate
  - Limiting how often the cache is switched from a VM to another
    - i.e., the cache is not switched too soon

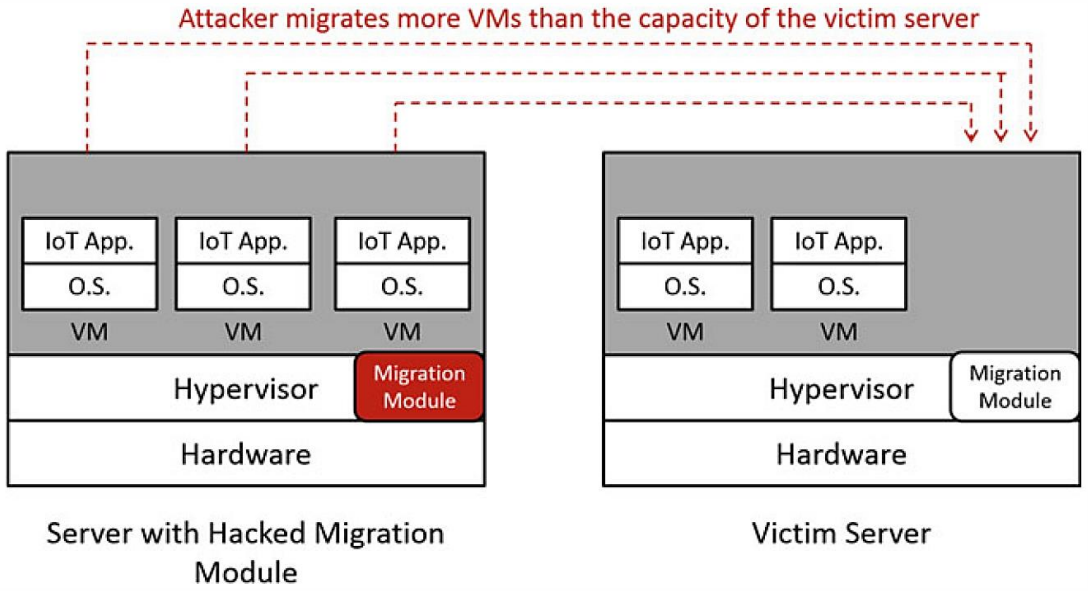
Cloud Domain - 2. VM Migration Attacks

- ***Live*** VM migration allows moving a VM transparently from a server to another
  - live => only hundreds of milliseconds disruption
  - Useful for maintenance, patch installation, or load balancing

1. Copying the VM' s memory content
2. If the destination server is the same local network, VM will keep the same IP address
3. An ARP (Address Resolution Protocol) reply packet is sent to the routing devices within the cloud to inform about the VM ' s new physical address

Cloud Domain - 2. VM Migration Attacks II

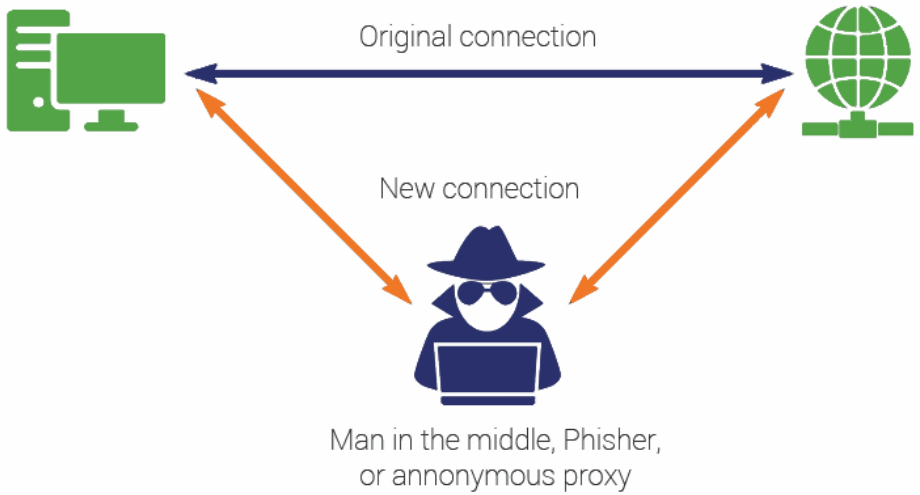
- **Control Plane Attacks** (taking control over the migration module):
  - Migration Flooding:
    - Overloading the victim server to cause a DoS
  - False Resource Advertising:
    - Claiming that it has a large resource slack
    - Some VMs are off-loaded to the hacked server



Migration flooding attack

Cloud Domain - 2. VM Migration Attacks III

- **Data Plane Attacks** (targeting the network links over which the VMs are moved)**:**
  - Sniffing Attack:
    - Reads migrated memory pages via sniffing the exchanged packets
  - Man-In-The-Middle Attack:
    - Fabricating an ARP Reply packet to receive the victims VM data by the attacker's malicious VM
    - The attacker continues to forward the packets to the victim VM to hide the attack

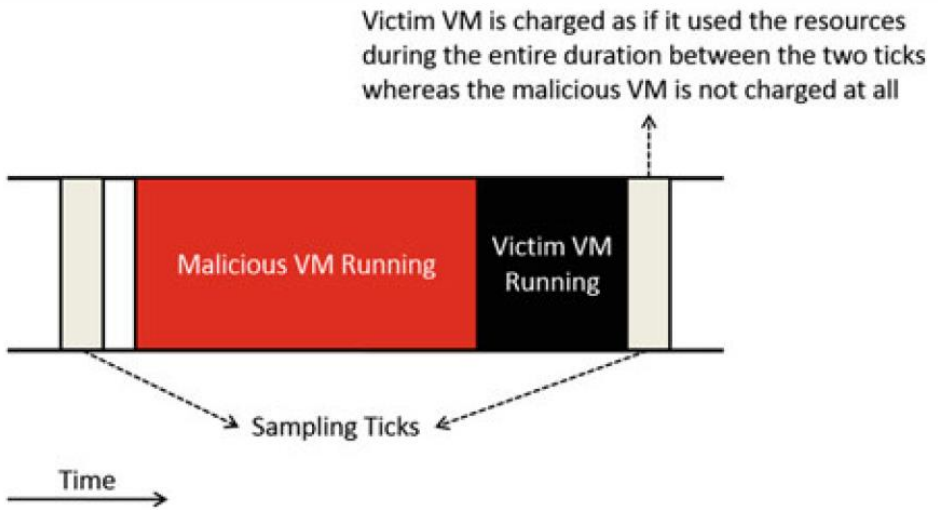


Cloud Domain - 2. VM Migration COUNTERMEASURES

- ✓ **Mutual authentication** between the source and destination servers prior to migration.
- ✓ Control messages should be encrypted and signed by the respective entity
  - ✓ Avoids fabricating fake control messages
- ✓ Sequence numbers for control messages
  - ✓ Prevent a malicious entity from **replaying** an **old** control message
- ✓ ARP reply packets should be accepted only after authentication

Cloud Domain - 3. Theft-of-Service Attack

- **A malicious VM misbehaves to obtain more resources than its share from the hypervisor**
  - Victim VMs get allocated less share of resources than what they should obtain.
  - **Xen** is a well-known hypervisor that is susceptible to this attack
  - Xen samples every 10 ms VMs core utilization
  - It assumes the VM has had the core during the entire 10 ms



Cloud Domain - 3. Theft-of-Service Countermeasures

1. To **log more accurately** the start and end time when each VM was utilizing the cores
   - Using accurate clocks

2. To randomize the sampling times

Cloud Domain - 4. VM Escape Attack and Countermeasures

- **Attack: Software bugs can be exploited to break the isolation and escape the hypervisor layer and reaches the server's hardware**
  - VM can **gain root access** to the whole server where it resides

- **Countermeasure: CloudVisor** adds an extra isolation layer between the hardware and the hypervisor through **nested virtualization**
  - Prevents obtaining the root privileges even if hypervisor is bypasses

Cloud Domain - 5. Insider Attacks and Countermeasures

- **Attack**: Someone with access to the cloud server can perform the attack
  - Data center **administrators** might be the risk!
  - **Sensitive applications** may have serious concerns about hosting their information on the cloud.

- **Countermeasures**:
  - Homomorphic encryption: Allows cloud servers to perform certain computing operations on **encrypted input** data to generate **an encrypted result.**
    - Only the **smart objects** and the **user** running the IoT application can **interpret** these data.
  - Data storage: Data is broken down into multiple chunks and sorted with permutations defined by a secret key. Data is uninterpretable for the administrators.

Cloud Domain - Summary of the security attacks

Attack	Vulnerability Reason	Security Violation	Countermeasures
Hidden-Channel Attack	Shared hardware components (e.g. cache) among the server's VMs	Confidentiality	- Hard Isolation - Cache Flushing - Noisy Data Access Time - Limiting Cache Switching Rate
VM Migration attacks	- VM Migration software bugs - VM Migration is performed without authentication - Memory pages copied in clear	Confidentiality Integrity Availability	- Server authentication - Encrypting migrated memory pages
Theft-of-Service Attack	Periodic sampling of VMs' used resources	Availability Non-Repudiation	-Fine-grain sampling using high precision clocks - Random sampling
VM Escape Attack	Hypervisor software bugs	Confidentiality Availability Integrity	- Add an isolation domain between the hypervisor and hardware
Insider Attacks	Lack of trust in cloud administrators	Confidentiality Integrity	- Homomorphic Encryption - Secret storage through data chopping and permutation based on a secret key