Fundamentals of Computer Security

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Isolation
Virtual Machines
Covert Channels

Overview

- The confinement problem
- Isolating entities
  - Virtual machines
  - Sandboxes
- Covert channels
  - Detecting them
  - Analyzing them
  - Mitigating them

“Isolation”

- Process cannot communicate with any other process
- Process cannot be observed

Impossible for this process to leak information

- Not practical as process uses observable resources such as CPU, secondary storage, networks, etc.

Rule of Transitive Confinement

- If *p* is confined to prevent leaking, and it invokes *q*, then *q* must be similarly confined to prevent leaking
- Rule: if a confined process invokes a second process, the second process must be as confined as the first

Lipner’s Observation (1975)

- All processes can obtain rough idea of time
  - Read system clock or wall clock time
  - Determine number of instructions executed
- All processes can manipulate time
  - Wait some interval of wall clock time
  - Execute a set number of instructions, then block

Kocher's Attack

- This computes $x = a^z \bmod n$, where $z = z_0 \ldots z_{k-1}$

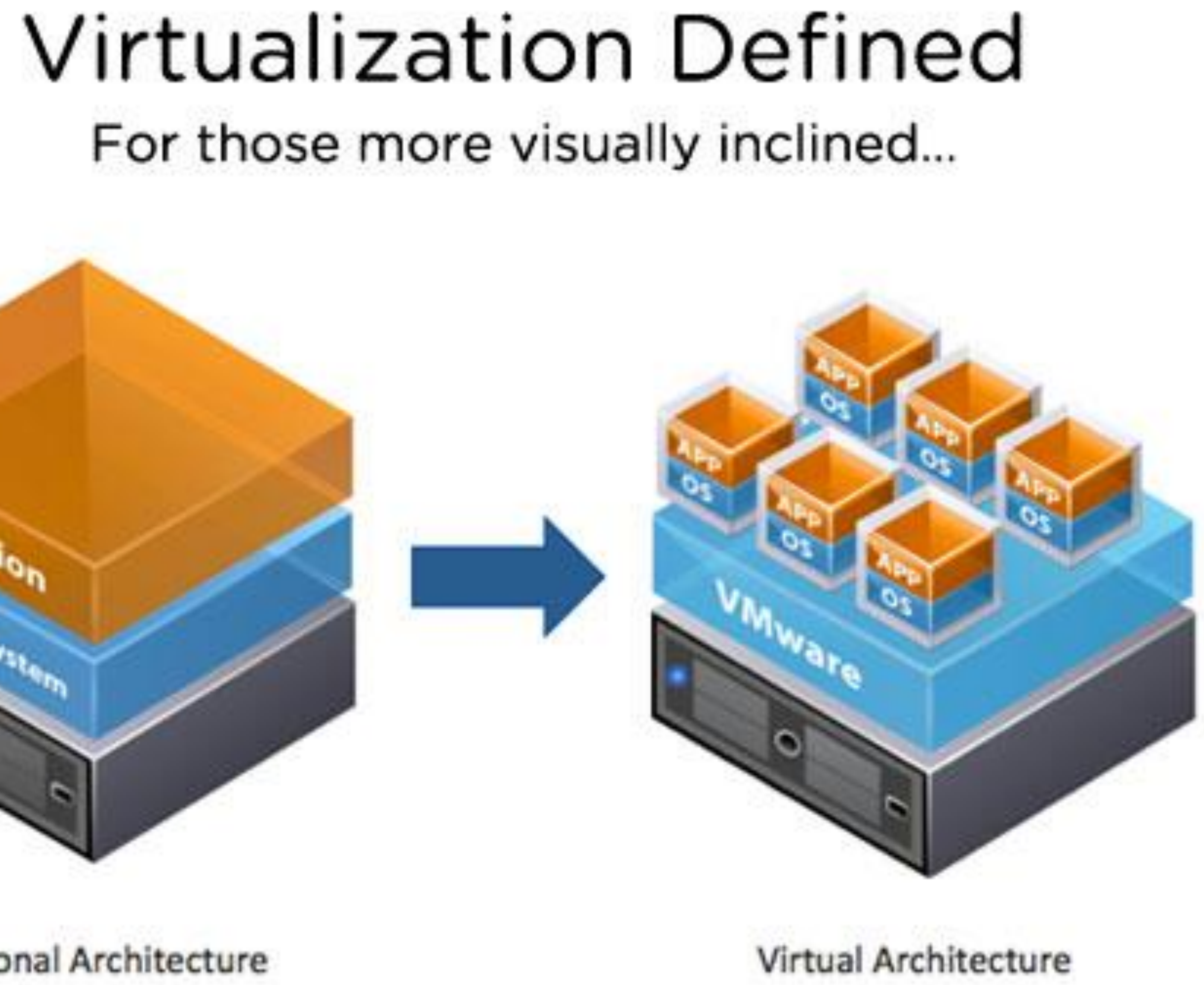
```
x := 1; atmp := a;
for i := 0 to k-1 do begin
  if z_i = 1 then
      x := (x * atmp) mod n;
  atmp := (atmp * atmp) mod n;
end
result := x;
```

- Length of run time related to number of 1 bits in z

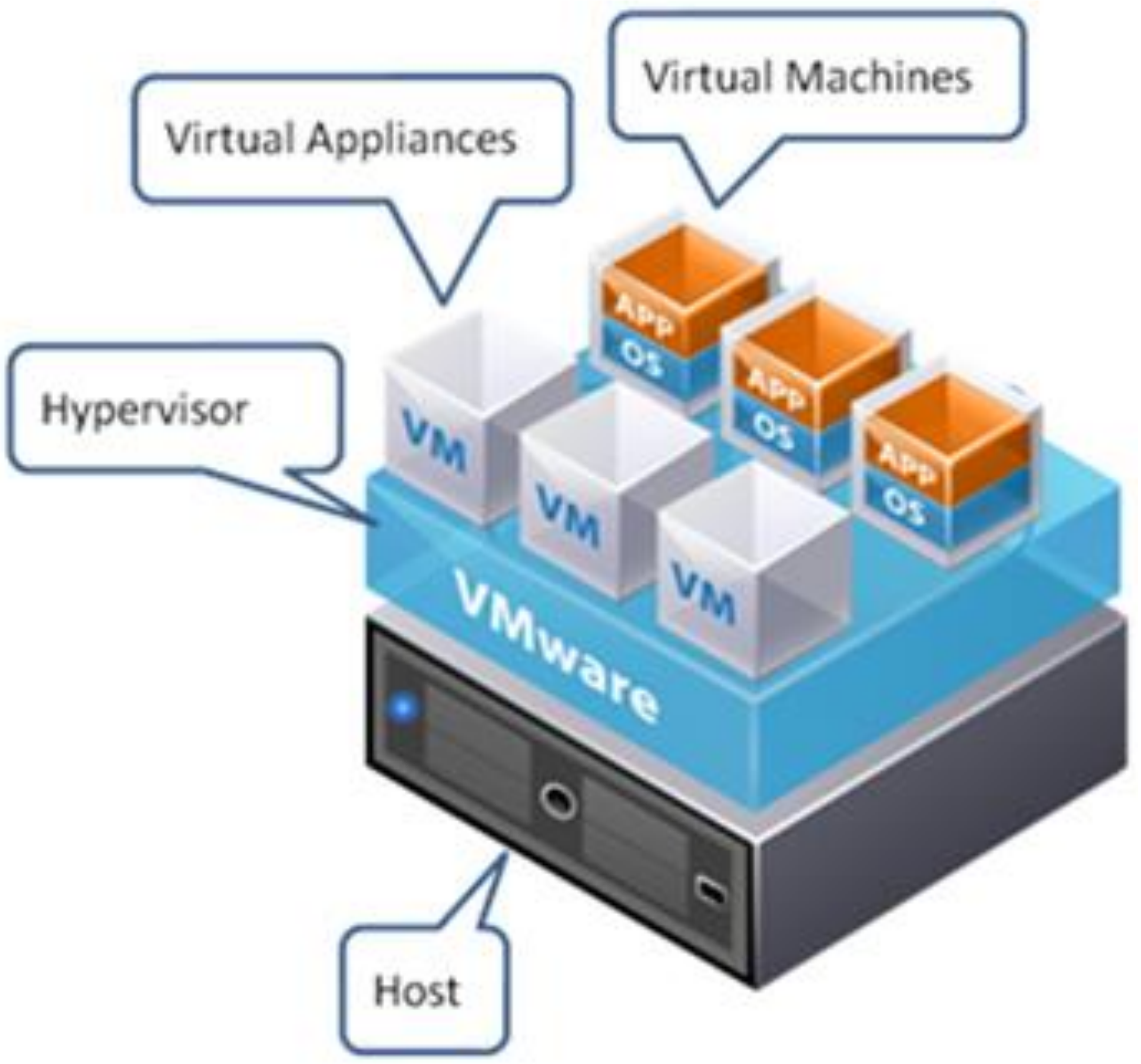
Isolation

- Virtual machines
  - Emulate computer
  - “Guest” entity cannot access underlying computer system
- Sandboxing
  - Does not emulate computer
  - Alters interface between computer, process

Virtualization



Virtualization



Virtual Machine (VM)

- A program that simulates hardware of computer system
- *Virtual machine monitor* (VMM, "hypervisor") provides VM on which conventional OS can run
  - Each VM is one subject; VMM doesn't worry about processes running inside each VM
  - VMM mediates all interactions of VM with resources, other VMS
  - Satisfies rule of transitive closure

KVM/370

- Security-enhanced version of IBM VM/370 VMM
- Goals
  - Provide virtual machines for users
  - Prevent VMs of different security classes from communicating
- Provides minidisks; some VMs could share some areas of disk
  - Security policy controlled access to shared areas to limit communications to those allowed by policy

DEC VAX VMM

- VMM is security kernel
  - Can run Ultrix or VMS
- Invoked on trap to execute privileged instruction
  - Only VMM can access hardware directly
  - VM kernel, executive levels both mapped into physical executive level
- VMM subjects: users, VMs
  - Each VM has own disk areas, file systems
  - Each subject, object has multilevel security, integrity labels

Oracle VirtualBox

You are seeing these slides inside a VirtualBox VM ☺

Here’s a demo …

Sandbox

- Environment in which actions of process are restricted according to security policy
  - Can add extra security-checking mechanisms to libraries, kernel
    - Program to be executed is not altered
  - Can modify program or process to be executed
    - Similar to debuggers, profilers that add breakpoints
    - Add code to do extra checks (memory access, etc.) as program runs (*software fault isolation*)

Example: Limiting Execution

- Sidewinder
  - Uses type enforcement to confine processes
  - Sandbox built into kernel; site cannot alter it
- Java VM
  - Restricts set of files that applet can access and hosts to which applet can connect
- DTE, type enforcement mechanism for DTEL
  - Kernel modifications enable system administrators to configure sandboxes

Example: Trapping System Calls

- Sandboxie (! download and use it !)
  - File system sandbox

Here’s a demo …

Example: Trapping System Calls

- Janus: execution environment
  - Users restrict objects, modes of access
  - Two components
    - *Framework* does run-time checking
    - *Modules* determine which accesses allowed
  - Configuration file controls modules loaded, constraints to be enforced

Janus Configuration File


```
# basic module
basic
    – Load basic module
# define subprocess environment variables
putenv IFS="\t\n" PATH=/sbin:/bin:/usr/bin TZ=PST8PDT
    – Define environmental variables for process
# deny access to everything except files under /usr
path deny read,write *
path allow read,write /usr/*
    – Deny all file accesses except to those under /usr
# allow subprocess to read files in library directories
# needed for dynamic loading
path allow read /lib/* /usr/lib/* /usr/local/lib/*
    – Allow reading of files in these directories (all dynamic load libraries are here)
# needed so child can execute programs
path allow read,exec /sbin/* /bin/* /usr/bin/*
    – Allow reading, execution of subprograms in these directories
```

Janus Implementation

- System calls to be monitored defined in modules
- On system call, Janus framework invoked
  - Validates system call *with those specific parameters* are allowed
  - If not, sets process environment to indicate call failed
  - If okay, framework gives control back to process; on return, framework invoked to update state
- Example: reading MIME mail
  - Embed "delete file" in Postscript attachment
  - Set Janus to disallow Postscript engine access to files

Covert Channel

- Channel using *shared* resources as a communication path
- *Covert storage channel* uses attribute of shared resource
- *Covert timing channel* uses temporal or ordering relationship among accesses to shared resource

Example: File Manipulation

- Communications protocol:
  - *p* sends a bit by creating a file called *0* or *1*, then a second file called *send*
    - *p* waits until *send* is deleted before repeating to send another bit
  - *q* waits until file *send* exists, then looks for file *0* or *1*; whichever exists is the bit
    - *q* then deletes *0*, *1*, and *send* and waits until *send* is recreated before repeating to read another bit
- Covert storage channel: resource is directory, names of files in directory

Example: Using Real Time Clock

- KVM/370 had covert timing channel
  - VM1 wants to send 1 bit to VM2
  - To send 0 bit: VM1 relinquishes CPU as soon as it gets CPU
  - To send 1 bit: VM1 uses CPU for full quantum
  - VM2 determines which bit is sent by seeing how quickly it gets CPU
  - Shared resource is CPU, timing because real-time clock used to measure intervaps between accesses

Example: Ordering of Events

- Two VMs
  - Share cylinders 100–200 on a disk
  - One is *High*, one is *Low*; process on *High* VM wants to send to process on *Low* VM
- Disk scheduler uses SCAN algorithm
- *Low* process seeks to cylinder 150 and relinquishes CPU
  - Now we know where the disk head is

Example: Ordering (continued)

- *High* wants to send a bit
  - To send 1 bit, *High* seeks to cylinder 140 and relinquish CPU
  - To send 0 bit, *High* seeks to cylinder 160 and relinquish CPU
- *Low* issues requests for tracks 139 and 161
  - Seek to 139 first indicates a 1 bit
  - Seek to 161 first indicates a 0 bit
- Covert timing channel: uses ordering relationship among accesses to transmit information

Noise

- *Noiseless covert channel* uses shared resource available *exclusively* to sender and receiver
- *Noisy covert channel* uses shared resource available to sender, receive, and others
  - Need to minimize interference enough so that message can be read in spite of others' use of channel

Key Properties

- Existence
  - Determining whether the covert channel exists
- Bandwidth
  - Determining how much information can be sent over the channel

How do we detect them?

- Covert channels require sharing
- Manner of sharing controls which subjects can send, which subjects can receive information using that shared resource
- Porras, Kemmerer: model flow of information through shared resources with a tree
  - Called *covert flow trees* (*study them in more advanced class*)

Mitigation

- Goal: obscure amount of resources a process uses
  - Receiver cannot determine what part sender is using and what part is obfuscated
- How to do this?
  - Devote uniform, fixed amount of resources to each process
  - Inject randomness into allocation, use of resources

Key Points

- Confinement problem: prevent leakage of information
  - Solution: separation and/or isolation
- Shared resources offer paths along which information can be transferred
- Covert channels difficult if not impossible to eliminate
  - Bandwidth can be greatly reduced, however!