Comprehensive Virtual Appliance Detection

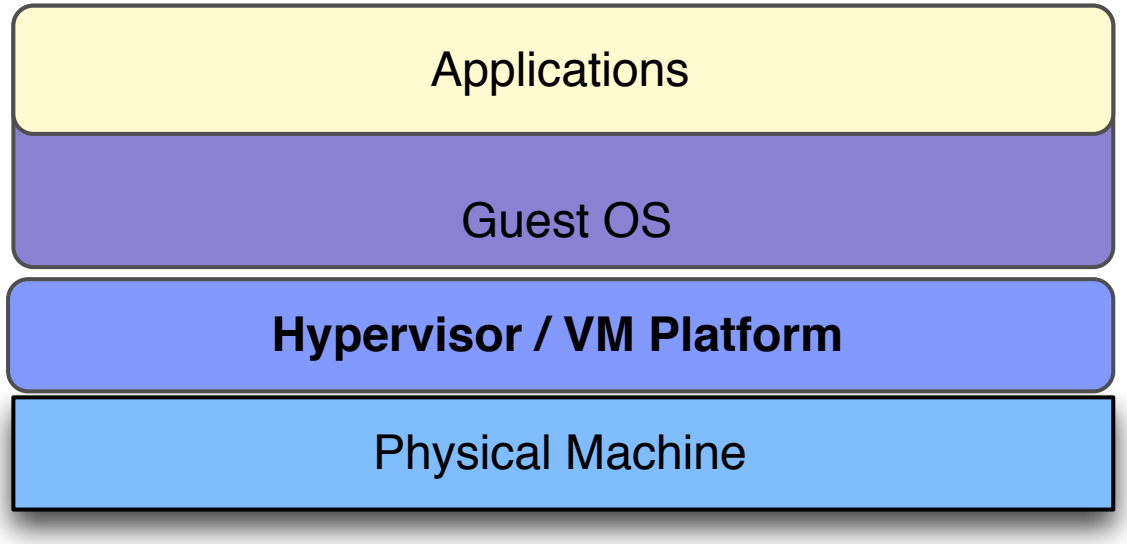
at Web Script, Application, and Kernel Levels

Kang Li **kangli@uga.edu**
Xiaoning Li **ldpatchguard@gmail.com**

About us

- Kang
  - College Educator
- Xiaoning
  - Security Researcher

The Virtualization World

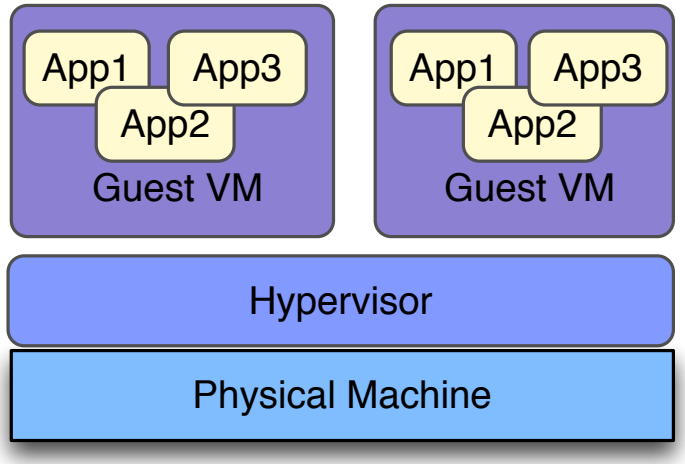


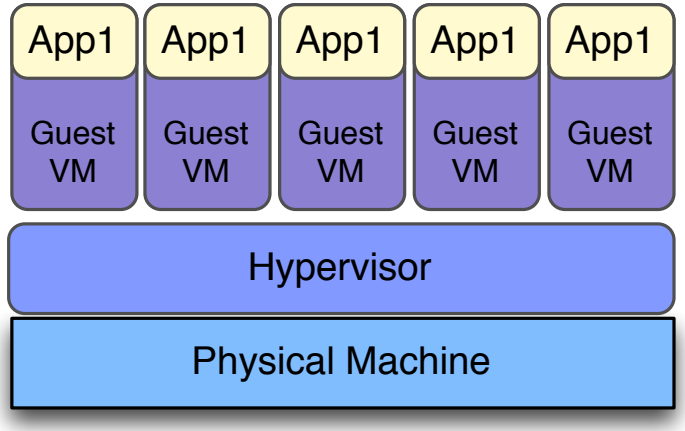
The Virtualization World

- Popular Virtual Machine Platforms

Virtual Machines versus Appliances

- Virtual Machines
  - Generic guests
  - Often run multiple Apps in one guest
- Virtual Appliances
  - Specially built guests
  - Optimized to specific applications
    - Pre-configured OS and App stack
    - Isolations





Why Detecting Virtual Appliances?

In the past

Motivation to detect VMs ...

http://www.cloudlinux.com/blog/clnews/vps-hot-or-not.php

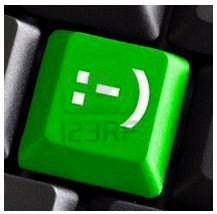
Why Detecting Virtual Appliances?

- Now, the Emerging Needs are:
  - Avoid Malicious VM Emulators
    - Is my program running on hardware or a VM rootkit?
  - Evade Detection
    - Is the program being evaluated in a specific VM environment?

How to Detect Virtual Appliances?

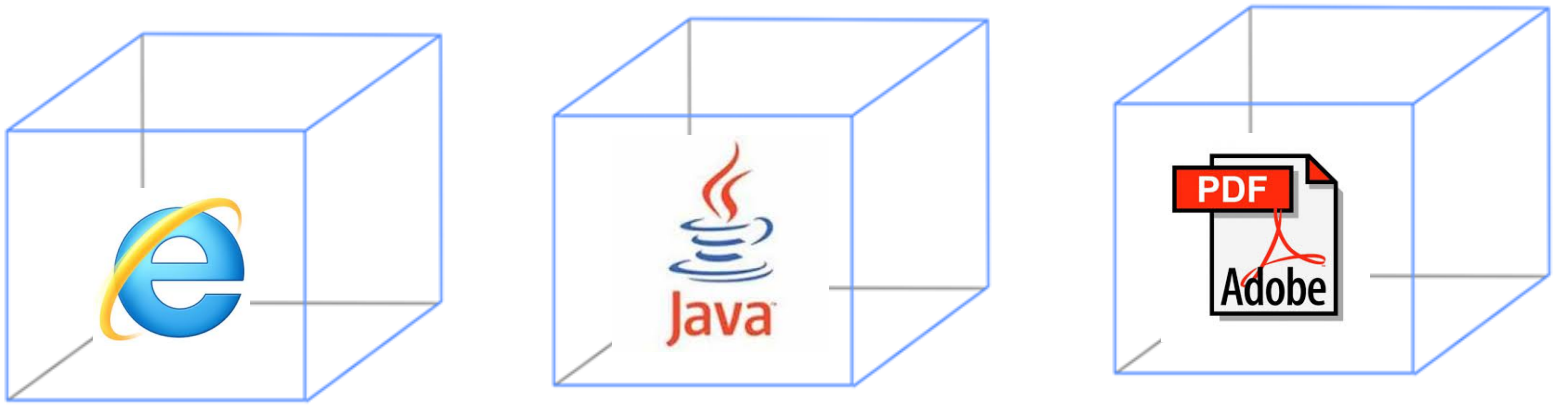
Detection of Virtual Appliances

- For Virtual Appliances that allow to run arbitrary programs
  - Conventional VM detection technique applies
  - A rich set of prior works

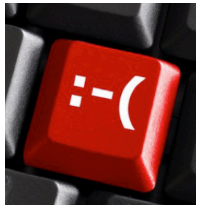


http://strategictrends.ca/
http://comictan.com/

Detection of Virtual Appliances



- But what if the appliance is for a specific application?
  - For example, Browser, PDF, Office …
  - The detection has to be done through application scripts.
  - Most of the prior works on VM detection do not apply.



Solution:

Appliance Detection through Display Properties

webserver.computoredge.com

Why Focusing on Display Properties

- Display needs to be exported to the "sandbox-ed" applications.

- But, lack of hardware support for graphic virtualization
  - Many appliance instances running in one physical box
  - Difficult for PCI Passthrough to multiple VMs

Virtual Appliance Detection Overview

- Goal:
  - Detecting the use of VM by Display Properties
- Sample Approaches:
  - Screen Properties
    - Resolution, color depth, and refresh rate
  - Support of "Advanced" Display Functions
    - HTML5/WebGL
  - Performance Measurement
    - 3D rendering capability

Scenario #1: Detection Using Resolution

- Using Java to obtain list of display properties
  - Screen Size, Refresh Rate, Color depth

- Example: Windows 8 on a Lenovo PC, VMware, and VirtualBox

	Host	VMware Player	VirtualBox
Number of Resolution Supported	38	25	4
Refresh Rate	56, 59, 60, 70, 72,75	64	60
Unique Screen Size		1041x1041	

Scenario #1: Detection Using Resolution

- How to Get Screen Properties

Example: the Monitors methods in Adobe Javascript API

- **Monitors Method**
  - **Primary**
  - Secondary
  - Tallest
  - Widest
  - …
- **Monitor properties**
  - colorDepth
  - isPrimary
  - **Rect** (boundary of virtual display)
  - workRect

http://www.adobe.com/content/dam/Adobe/en/devnet/acrobat/pdfs/js_api_reference.pdf

Scenario #1: Detection Using Resolution

- How to Get Screen Properties

Example: the Monitors methods in Adobe Javascript API

- **Monitors Method**
  - **Primary**
  - Secondary
  - Tallest
  - Widest
  - …
- **Monitor properties**
  - colorDepth
  - isPrimary
  - **Rect** (boundary of virtual display)
  - workRect

More properties are available via the Monitors Method.

http://www.adobe.com/content/dam/Adobe/en/devnet/acrobat/pdfs/js_api_reference.pdf

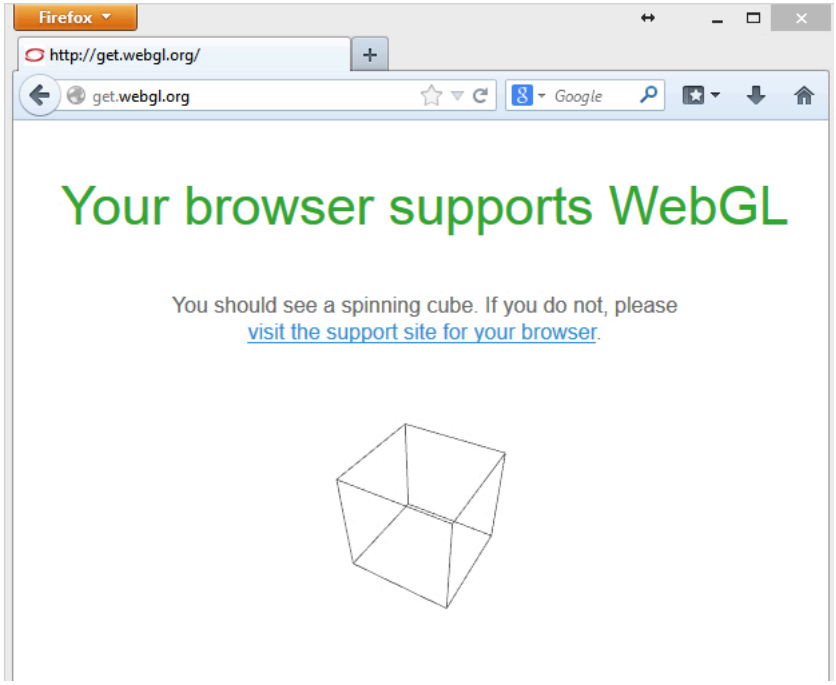
Scenario #2: Detection Using the Support of HTML5 Features

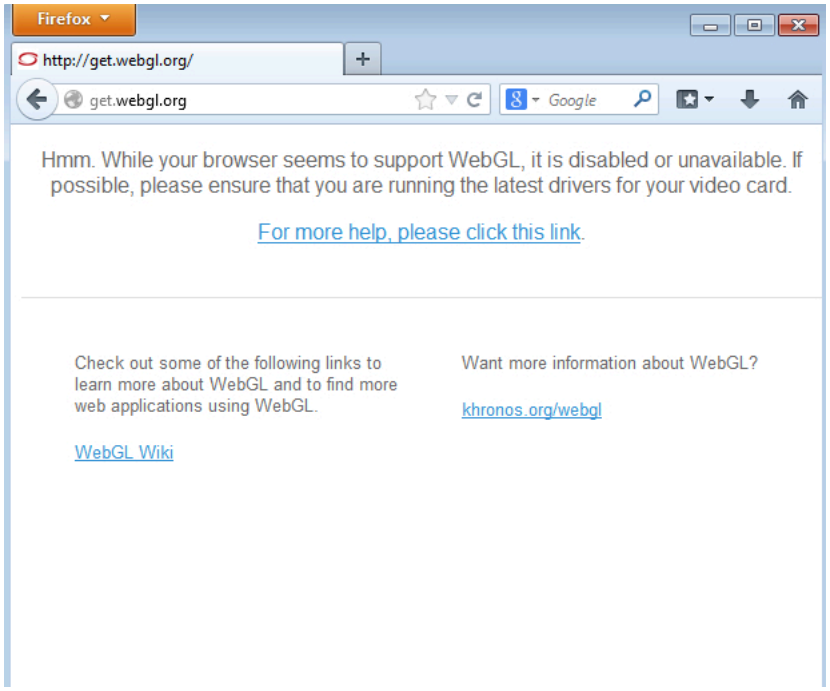
- Virtual Appliance might Not bother to implement "advanced" graphic support for web scripts.

- Example: Firefox 27.0.1 running on a Windows Host, VMware, and VirtualBox

Scenario #2: Detection Using the Support of HTML5 Features

Same version of Firefox Browser in Host and VM





Firefox 27.0.1 on Win 7 Physical Host

Firefox 27.0.1 on Win 7 Virtualbox (with add-on)

Scenario #2: Detection Using the Support of HTML5 Features

- Virtual Appliance might Not bother to implement "advanced" graphic support for web scripts.

- No Support WebGL → Virtual Appliance
  - Possible False Positives …

Scenario #3: Detection based on 3D Performance

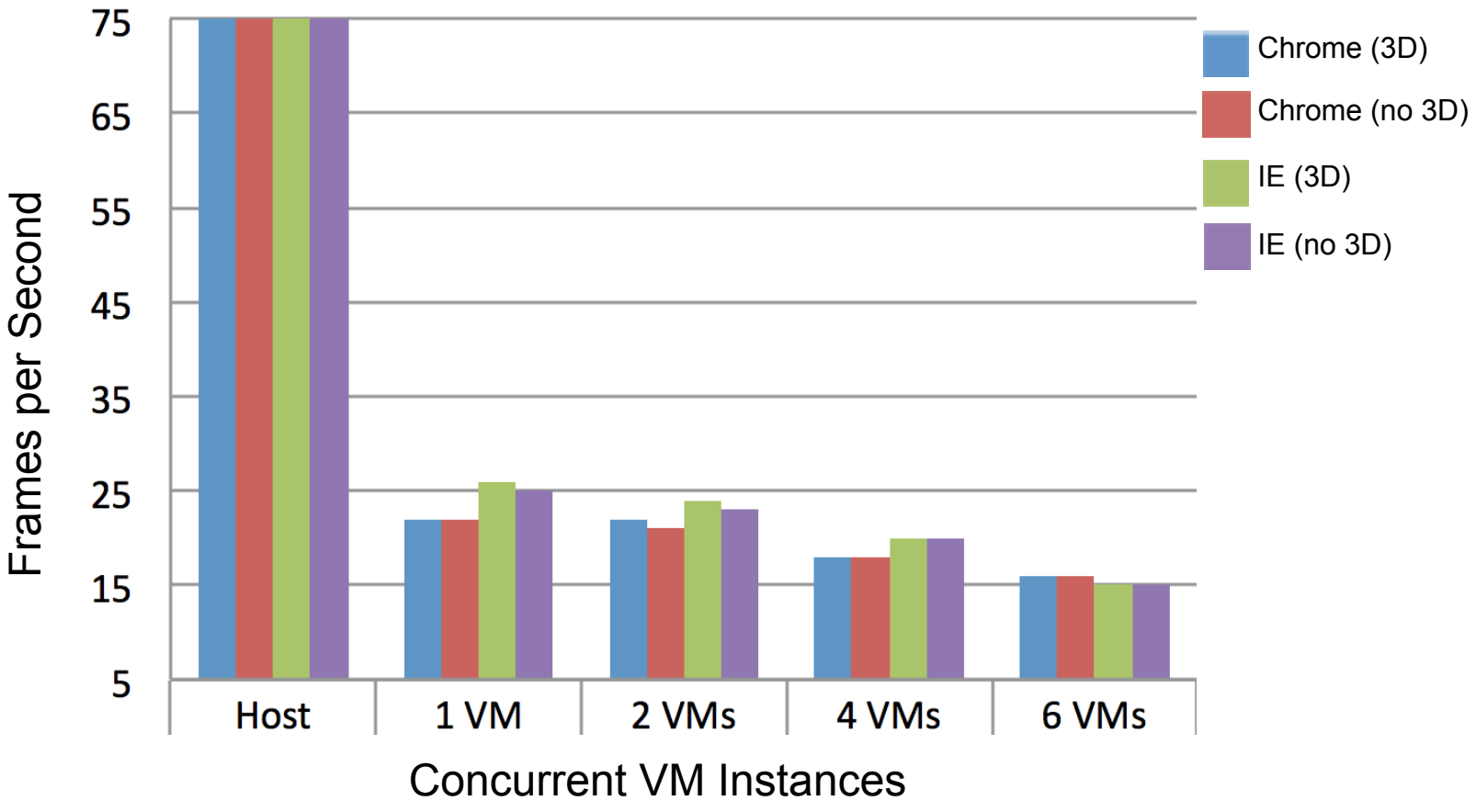
- Observations:
  - Smooth 3D graphic display heavily relies on hardware support.
  - Even with 3D support, browser performance in VM falls far behind modern host systems.
  - Often, multiple instances of Virtual Appliances are running on the same physical box.

Performance of Running this Script

Quake 3 in WebGL

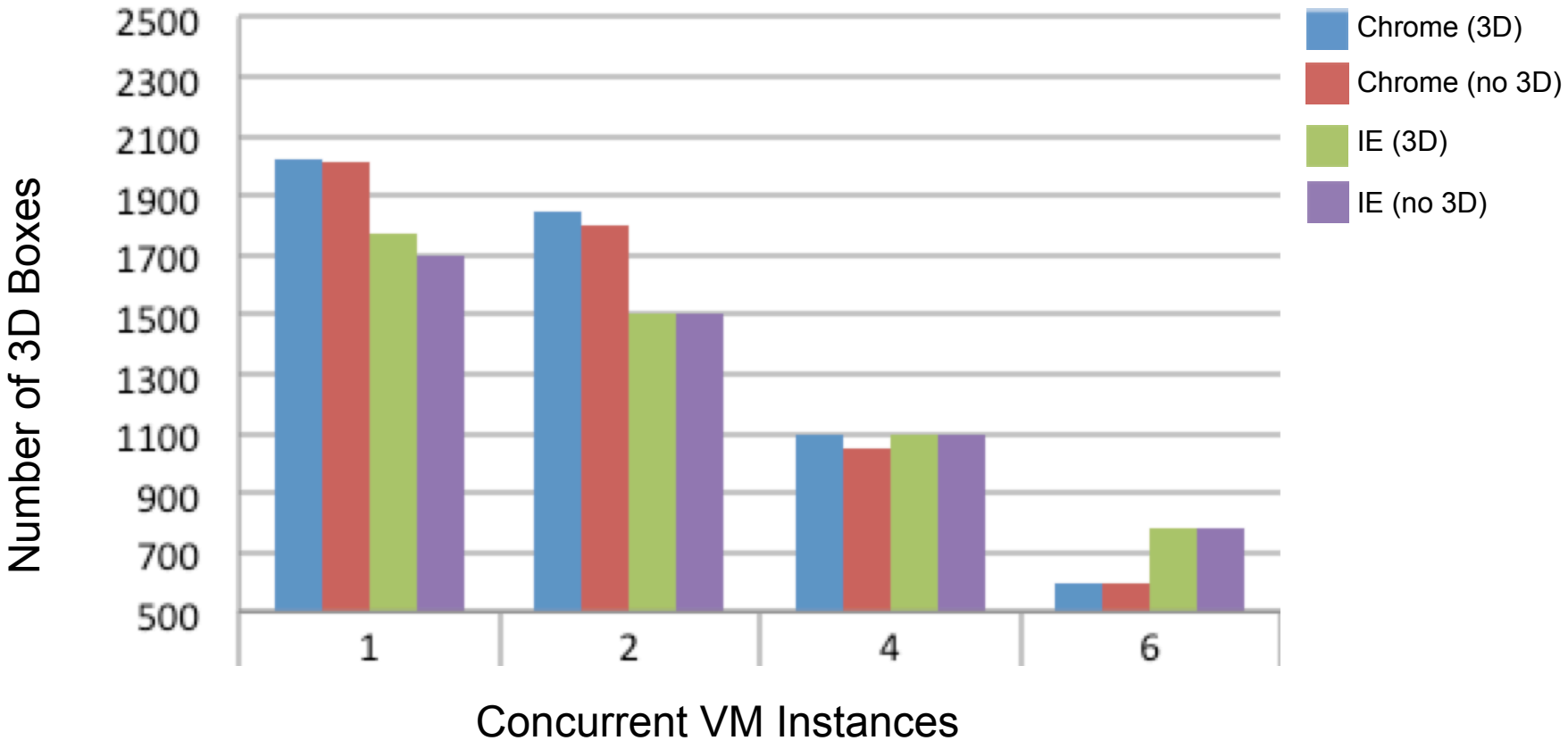
http://media.tojicode.com/q3bsp/

Observing Frame Rate of Quake 3



Frame Rate for running the same web script

Ability to Render Concurrent 3D Objects



Number of 3D objects rendered in a fixed frame rate (15 FPS)

Scenario #3: Detection by 3D Performance

- Strategy
  - Dynamically increase the number of 3D objects and detect the frame rate
    - 500 ~ 5000 Objects
    - Expect to have FPS > 30 FPS
  - Disguise test under popular games in WebGL
    - E.g. Quake3 in WebGL

Scenario #3: Detection by 3D Performance

- False Positives
  - Slow Physical Machines
    - Atom Box < 500 objects, 15 FPS>
    - Qualcomm Quad-core Table < 500 objects, 30 FPS>

- Implication to Virtual Appliance Detection

How to Get More Accurate VM Information?

If VA Chooses to Enable Native Code

- Example: ActiveX
  - Close to run a user-level application
  - Although not a good idea for security-aware users to enable,
    - likely enabled in those appliances that analyze malware
    - Likely lowered the Trustzone levels to enable automatic analysis

Peek Host Info from ActiveX

- Using Predefined APIs
  - WMI (windows management instrumentation)
  - WBEM (web-based enterprise management)
    - Allow to grab systems, networks, devices information.
- Using Known Vulnerabilities in IE/ActiveX
  - Beyond the scope of this talk

Getting Host Device Info from ActiveX

- Using the SWbemLocator
  - Scripting API from WMI

```
…
var locator    = new ActiveXObject("WbemScripting.SWbemLocator");
var service    = locator.ConnectServer(".");
var properties = service.ExecQuery(
                    "SELECT * FROM Win32_DeviceMemoryAddress");
var e          = new Enumerator(properties);
var p          = e.item();
…

// Available Properties: Device Description,  Name,  Memory Address …
```

Sample Output from Using SWbemLocator

Processor

DeviceID	Description	Name	SystemName
CPU0	x86 Family 6 Model 42 Stepping 7	Intel Pentium III Xeon processor	VIRTUALBOX-XP

BaseBoard

Name	Manufacturer	Product
Base Board	Oracle Corporation	VirtualBox

Video

DeviceID	Caption	DriverVersion	VideoMode	VideoProcessor
VideoController1	VirtualBox Graphics Adapter	4.2.18.r88780	1024 x 768 x 4294967296 colors	VBOX

BIOS

Caption	Manufacturer
Default System BIOS	innotek GmbH

DeviceMemoryAddress

Description	CSName
0xA0000-0xBFFFF	VIRTUALBOX-XP
0xE0000000-0xFFDFFFFF	VIRTUALBOX-XP
0xF0000000-0xF0000FFF	VIRTUALBOX-XP
0xF0080000-0xF00FFFFF	VIRTUALBOX-XP
0xF0400000-0xF07FFFFF	VIRTUALBOX-XP
0xF0800000-0xF0803FFF	VIRTUALBOX-XP
0xF0804000-0xF0804FFF	VIRTUALBOX-XP
0xF0805000-0xF0805FFF	VIRTUALBOX-XP

NetworkAdapter

DeviceID	Description	Manufacturer
1	AMD PCNET Family PCI Ethernet Adapter	Advanced Micro Devices (AMD)

Processor

DeviceID	Description	Name	SystemName
CPU0	Intel64 Family 6 Model 23 Stepping 10	Intel(R) Core(TM)2 Duo CPU L9400 @ 1.86GHz	X200S-GUODONG

BaseBoard

Name	Manufacturer	Product
Base Board	LENOVO	7465CTO

Video

DeviceID	Caption	DriverVersion	VideoMode	VideoProcessor
VideoController1	Mobile Intel(R) 4 Series Express Chipset Family (Microsoft Corporation - WDDM 1.1)	8.15.10.2702	null	null
VideoController2	Mobile Intel(R) 4 Series Express Chipset Family (Microsoft Corporation - WDDM 1.1)	8.15.10.2702	1280 x 800 x 4294967296 colors	Mobile Intel(R) 4 Series Express Chipset Family

Running on Host

BIOS

Caption	Manufacturer
Ver 1.00PARTTBLX	LENOVO

DeviceMemoryAddress

Description	CSName
0xE0000000-0xEFFFFFFF	X200S-GUODONG
0xFED1C000-0xFED1FFFF	X200S-GUODONG
0xFED10000-0xFED13FFF	X200S-GUODONG
0xFED18000-0xFED18FFF	X200S-GUODONG
0xFED19000-0xFED19FFF	X200S-GUODONG
0xFED45000-0xFED4BFFF	X200S-GUODONG

What if Appliance choose to emulate none-VM specific devices?

What if Appliance choose to emulate none-VM specific devices?

No Hypervisor names shown in Device and Drive info.

Real device drivers are used.

Popular Virtual Devices in VM

- Virtualbox
  - **NIC:** Intel PRO/1000 MT (82540EM)
  - **Audio:** ICH AC97
  - **IDE:** Intel 82371 PIIX4 IDE
  - **SATA:** Intel 82801HBM/HEM
- Vmware Fusion
  - **NIC:** AMD PCnet32 LANCE
  - **Audio:** Ensoniq ES1371
  - **IDE**: Intel 82371 PIIX4 IDE
  - **SCSI:** LSI Logic 53c1030

Difficult to make the behavior of Virtual Device == Physical Device

Virtual-Physical Inconsistency Example

- Intel PRO/1000 MT (82540EM)
  - Popular Virtual NIC

- After the following I/O event

  mmio_write (ICS [0xC8], 0x4)

Real NIC

- Register ICS: 0x00000004

Virtual NIC

- Register ICS: 0x80000004

Virtual-Physical Inconsistency Example2

- Intel PRO/1000 MT (82540EM)
  - Popular Virtual NIC

- After the following I/O event

  mmio_write (MDIC [0x20], 0x8000)

Real NIC

- Register ICS: 0x0

Virtual NIC

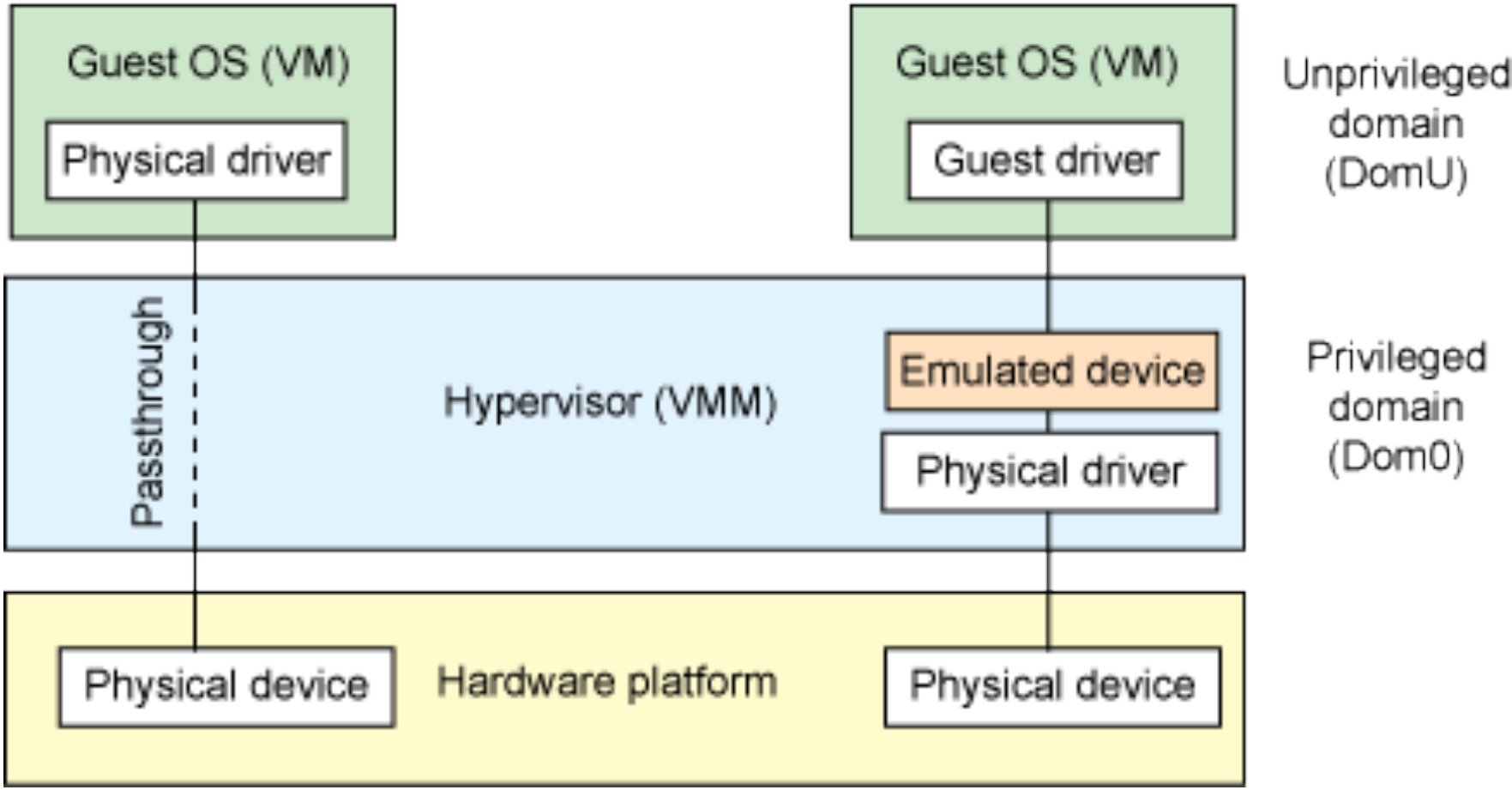
- Register ICS: 0x200

Virtual-Physical Inconsistencies

Almost all virtual devices contain differences to their physical peers.

How to detect the inconsistencies between physical and virtual devices? [Blackhat Briefing USA 2013]

What about PCI Passthrough?



http://www.ibm.com/developerworks/library/l-pci-passthrough/

What about PCI Passthrough? (cont.)

- Not Commonly used in Virtual Appliances.
  - Current practice often limited device passthrough to one VM.
    - Things might change in the future with devices like NVIDIA GRID K2
- Some Passthrough Implementation Can still be Detected
  - E.g. Intel NIC Virtualization
    - Host runs PF functions driver, VM runs VF function driver.

How to resist VM/VA detection?

Prevent Virtual Appliance Detection

- Difficult to Resist Root and Application Level Detection
  - Virtual devices have many inconsistencies with physical ones
  - Hardware virtualization support helps but often still leaves clues

- To Resist Detection at Web/Application Scripts Level
  - Not too hard to fake simple display properties
  - To resist timing/performance based detection
    - Pretend to be a low-end/old device
  - Challenging for protect against targeted attacks

Summary

- Detecting Virtual Appliances
  - Using Display Properties through Web Scripts
  - Using System Information through ActiveX
  - Using Device Inconsistencies
- The Specialty of Display Devices in VA Detection
  - Have to expose to sandboxed applications
  - Many properties are useful for detection
  - Timing and performance aspects are hard to fake

Thanks!

kangli@uga.edu
ldpatchguard@gmail.com