Cloud Computing

By

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https://hemanthrajhemu.github.io

The Next Revolution in IT
The Big Switch in IT

Every 18 months?

- Classical Computing
  - Buy & Own
    - Hardware, System Software, Applications often to meet peak needs.
  - Install, Configure, Test, Verify
  - Manage
  - ..
  - Finally, use it
  - $$$$....$(High CapEx)

- Cloud Computing
  - Subscrib
  - Use

$ - pay for what you use, based on QoS

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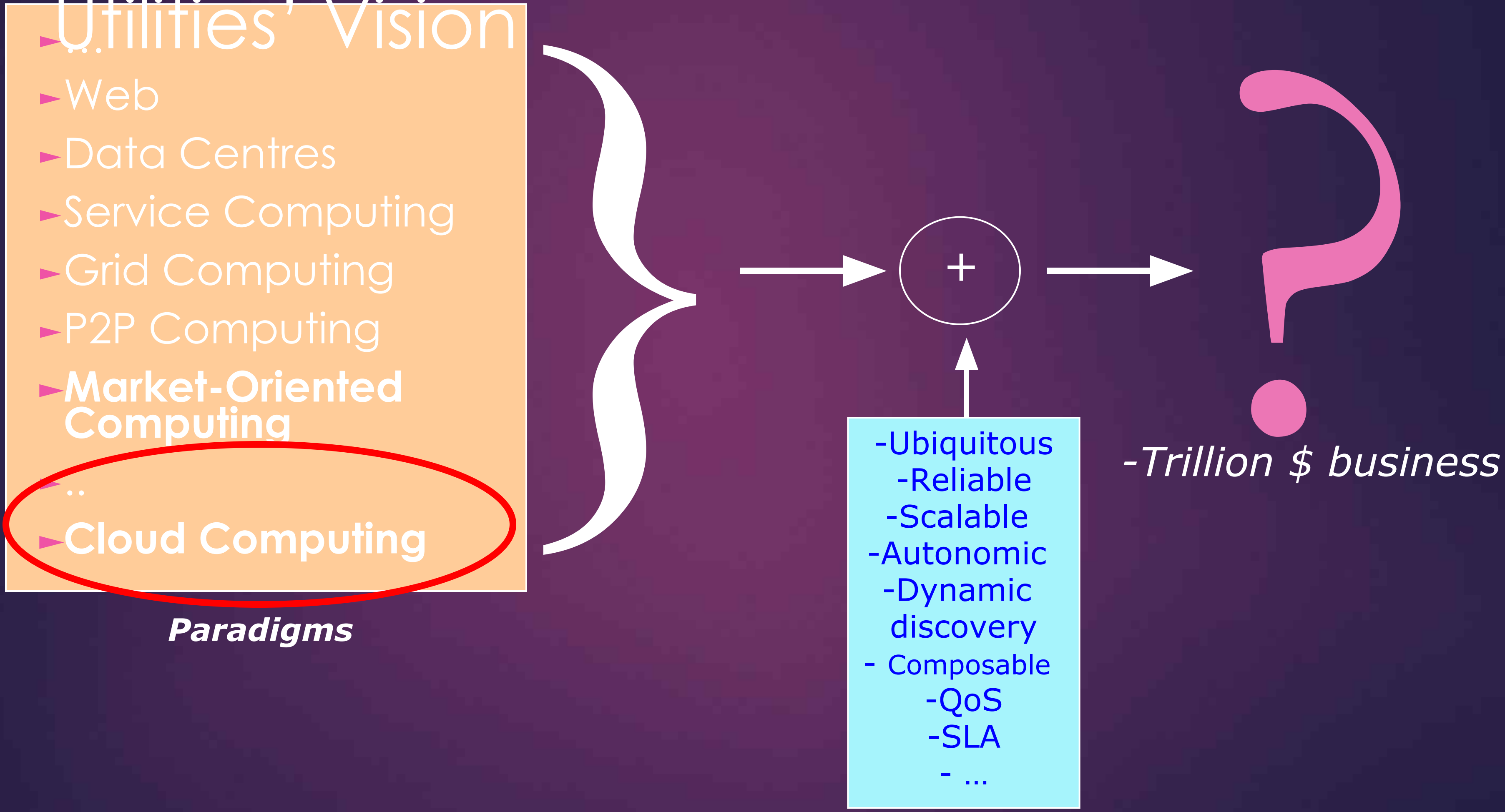
Outline

- “Computer Utilities”
  - Vision and Promising IT Paradigms/Platforms
- Cloud Computing and Related Paradigms
  - Trends, Definition, Cloud Benefits and Challenges
- Market-Oriented Cloud Architecture
  - SLA-oriented Resource Allocation
  - Global Cloud Exchange
- Aneka: A Cloud Application Platform
- Summary and Thoughts for Future

"Computer Utilities" Vision: Implications of the Internet

- 1969 – Leonard Kleinrock, ARPANET project
  - "As of now, computer networks are still in their infancy, but as they grow up and become sophisticated, we will probably see the spread of "Computer Utilities", which, like present electric and telephone utilities, will service individual homes and offices across the country".
  - During the last 44 years, several advances have taken place in both "computing" and "communications" areas that are turning the vision of "Computer Utilities" in to a reality.

Computing Paradigms and Attributes: Realizing the ‘Computer Utilities’ Vision



- …
- Web
- Data Centres
- Service Computing
- Grid Computing
- P2P Computing
- **Market-Oriented Computing**
- ..
- **Cloud Computing**

Paradigms

-Ubiquitous
-Reliable
-Scalable
-Autonomic
-Dynamic discovery
- Composable
-QoS
-SLA
- …

-Trillion $ business

Attributes/Capabilities

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- Market-Oriented Cloud Architecture
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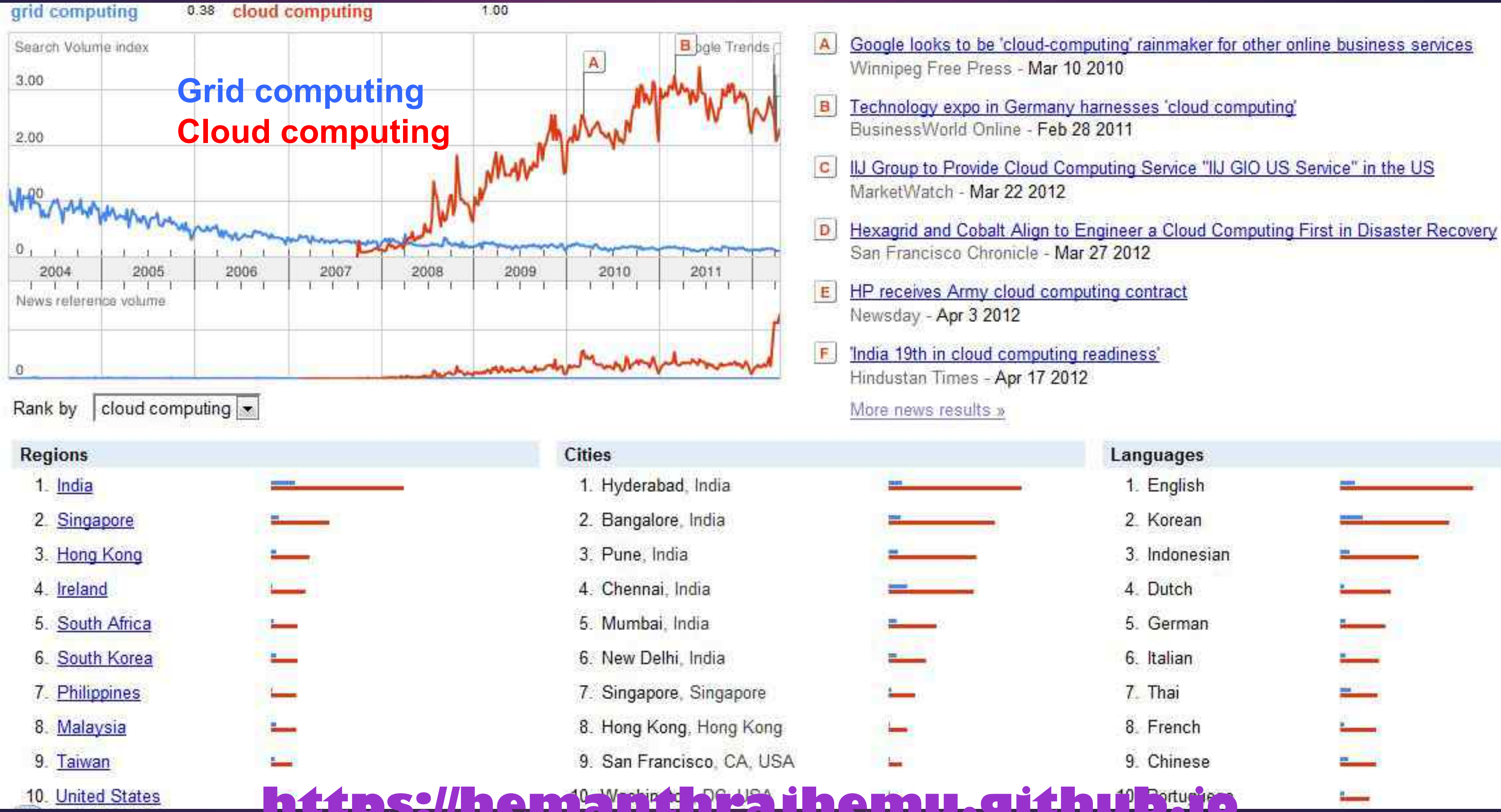
Very popular: too many are “In Search” of Cloud Computing



A Google looks to be 'cloud-computing' rainmaker for other online business services
Winnipeg Free Press - Mar 10 2010

B Technology expo in Germany harnesses 'cloud computing'
BusinessWorld Online - Feb 28 2011

C IIJ Group to Provide Cloud Computing Service "IIJ GIO US Service" in the US
MarketWatch - Mar 22 2012

D Hexagrid and Cobalt Align to Engineer a Cloud Computing First in Disaster Recovery
San Francisco Chronicle - Mar 27 2012

E HP receives Army cloud computing contract
Newsday - Apr 3 2012

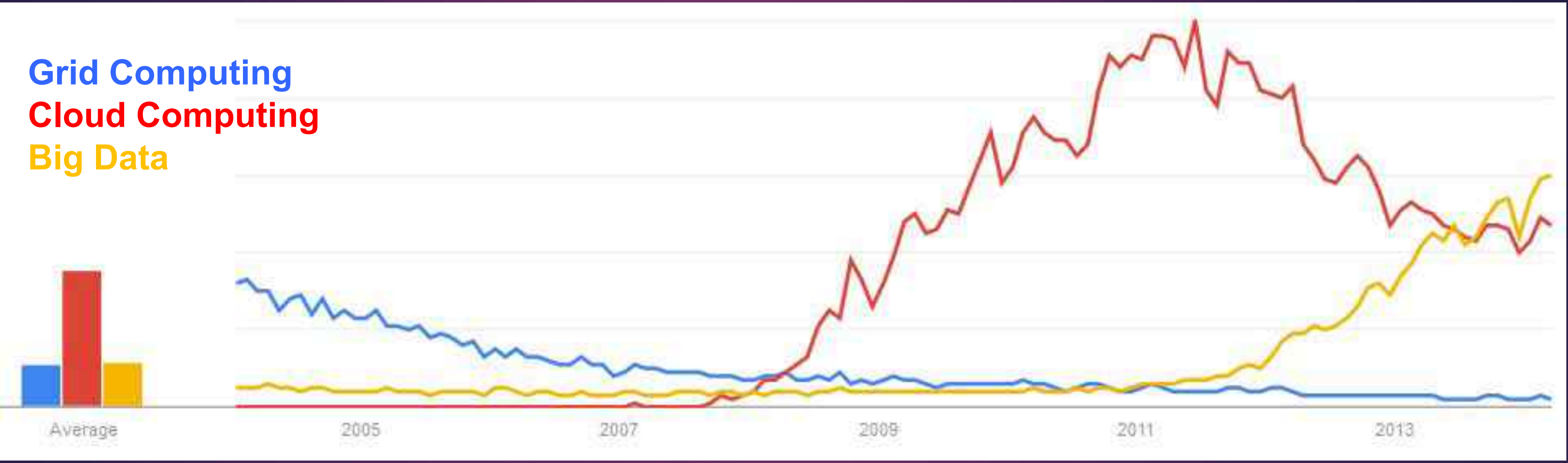
F 'India 19th in cloud computing readiness'
Hindustan Times - Apr 17 2012

More news results »

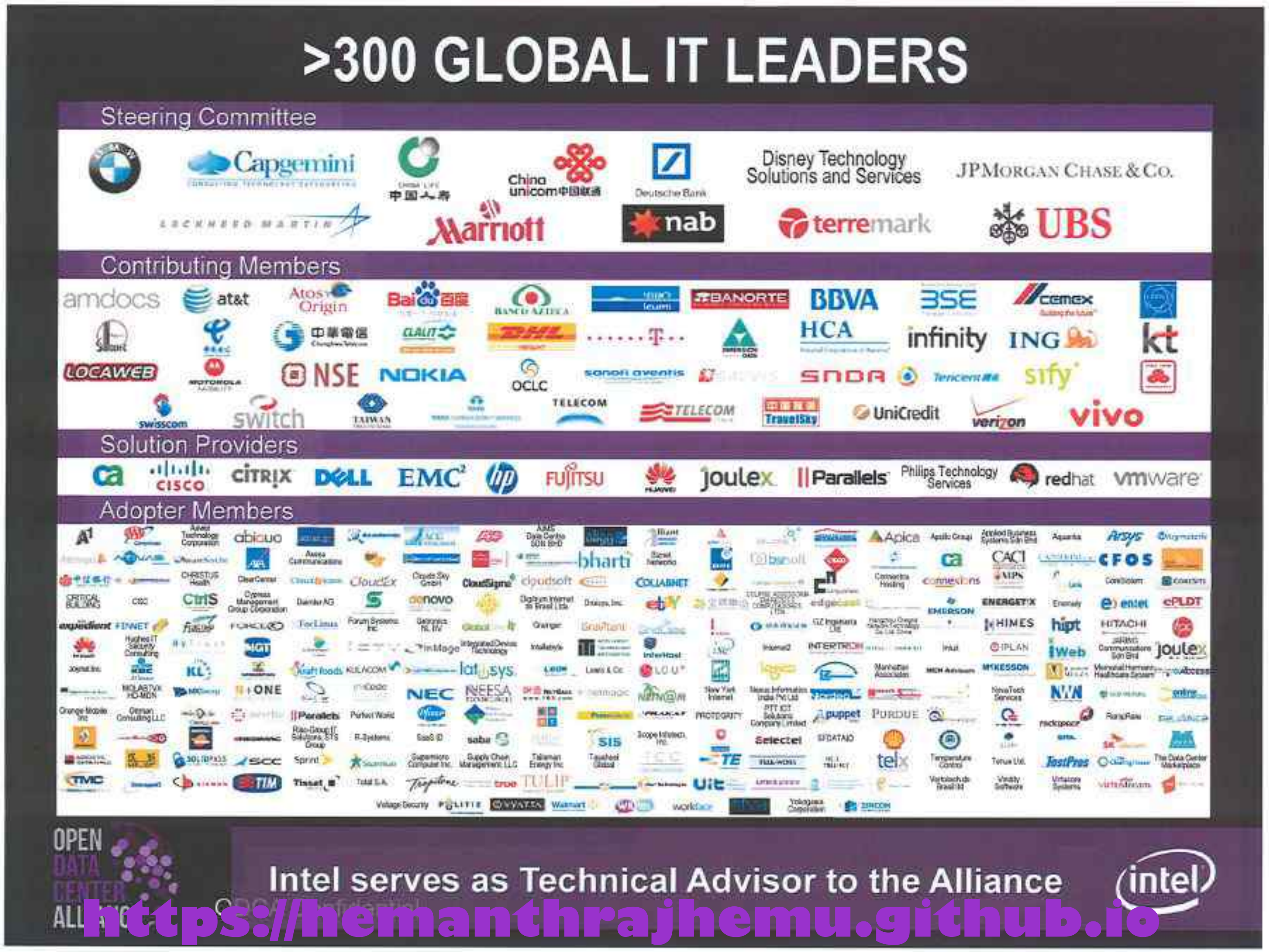
Rank by cloud computing ▾

Regions	Cities	Languages
1. India	1. Hyderabad, India	1. English
2. Singapore	2. Bangalore, India	2. Korean
3. Hong Kong	3. Pune, India	3. Indonesian
4. Ireland	4. Chennai, India	4. Dutch
5. South Africa	5. Mumbai, India	5. German
6. South Korea	6. New Delhi, India	6. Italian
7. Philippines	7. Singapore, Singapore	7. Thai
8. Malaysia	8. Hong Kong, Hong Kong	8. French
9. Taiwan	9. San Francisco, CA, USA	9. Chinese
10. United States	10. Washington, DC, USA	10. Portuguese

Interest over time
{grid, cloud, big data} computing



Open Data Center Alliance (ODCA) for Cloud Computing



>300 GLOBAL IT LEADERS

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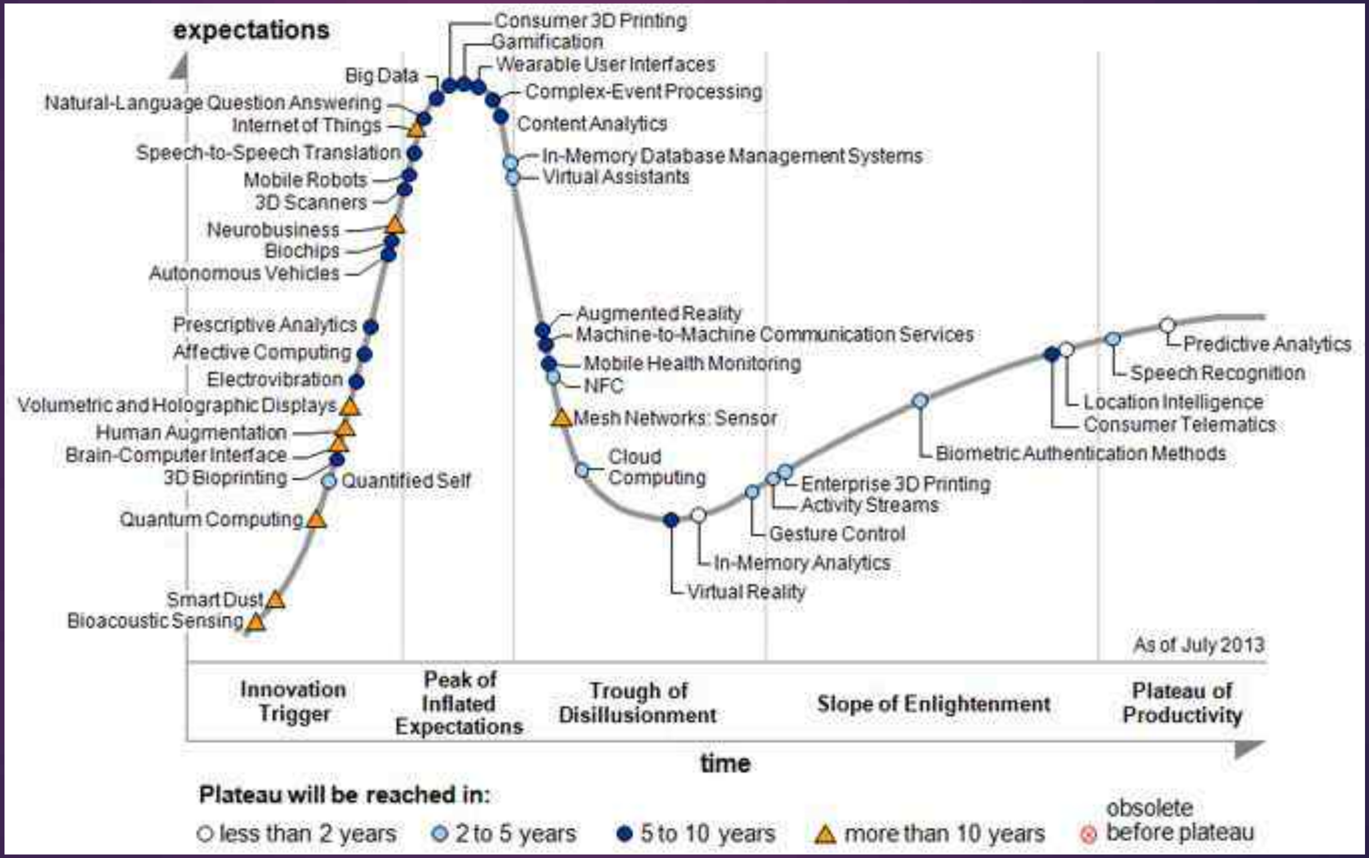
OPEN DATA CENTER ALLIANCE

Intel serves as Technical Advisor to the Alliance

intel

ODCA Confidential

2013 Gartner IT Hype Cycle



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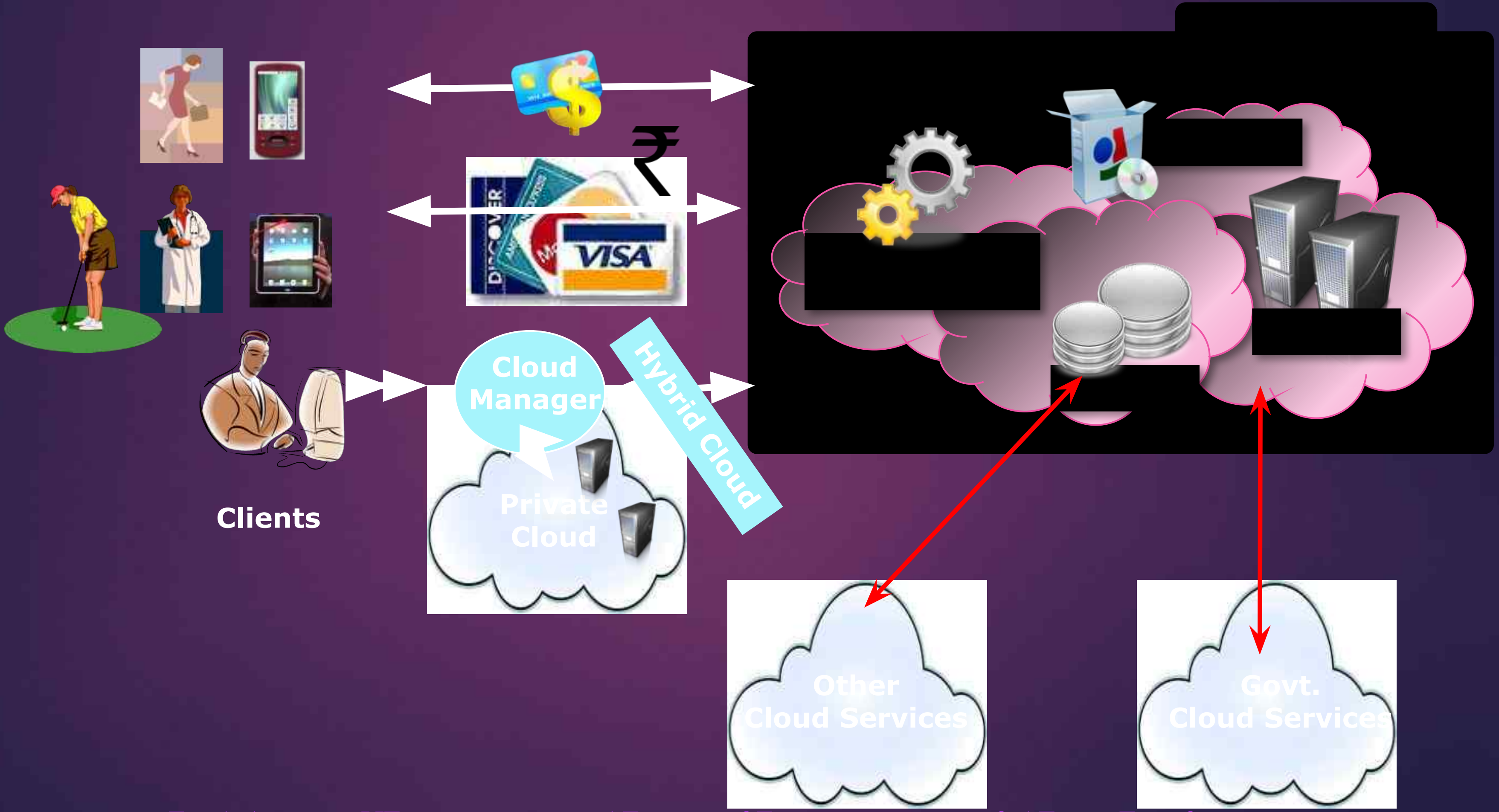
Defining Clouds: There are many views for what is cloud computing?

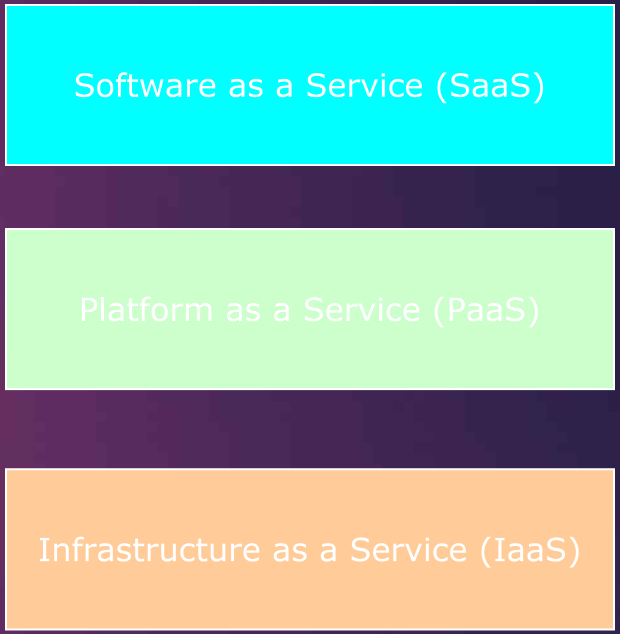
- Over 20 definitions:
  - http://cloudcomputing.sys-con.com/read/612375_p.htm
  - Renting "remote storage" □ backup
  - Renting "remote server" □ hosting Web server
  - Renting "remote more servers" □ to manage large workload
- Buyya's Scientific definition of Cloud Computing ☺
  - "Cloud is a **market-oriented** distributed computing system consisting of a collection of inter-connected and **virtualised** computers that are **dynamically provisioned** and presented as one or more unified computing resources based on **service-level agreements (SLAs)** established through **negotiation** between the service provider and consumers."
  - SLA = {negotiated and agreed QoS parameters + rewards + penalties for violation of agreement....}

Subscription-Oriented Cloud Services:
X{compute, apps, data, ..}
as a Service (..aaS)



Cloud Services

- Infrastructure as a Service (IaaS)
  - CPU, Storage: Amazon.com, Google Compute, ….
- Platform as a Service (PaaS)
  - Google App Engine, Microsoft Azure, Manjrasoft Aneka..
- Software as a Service (SaaS)
  - SalesForce.Com


Software as a Service (SaaS)
Platform as a Service (PaaS)
Infrastructure as a Service (IaaS)

Manjrasoft ….

Cloud Deployment Models

Public/Internet Clouds

3rd party, multi-tenant Cloud infrastructure & services:

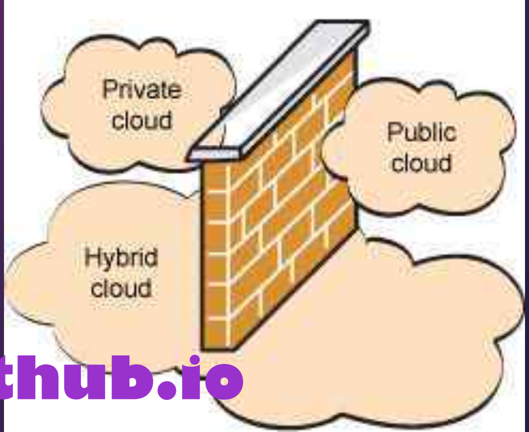
*** available on subscription basis**

Private/Enterprise Clouds

Cloud model run within a company's own Data Center / infrastructure for internal and/or partners use.

Hybrid/Inter Clouds

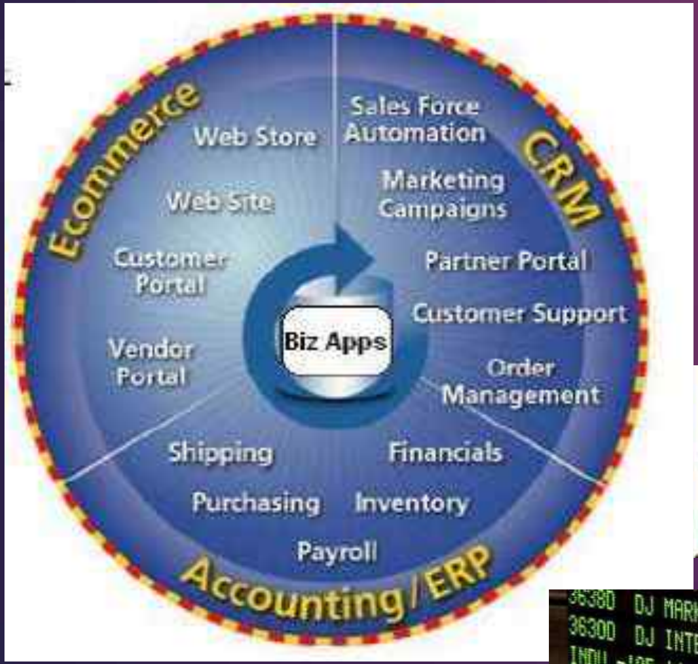
Mixed usage of private and public Clouds: Leasing public cloud services when private cloud capacity is insufficient



Cloud Applications

- Scientific/Tech Applications
- **Business Applications**
- **Consumer/Social Applications**

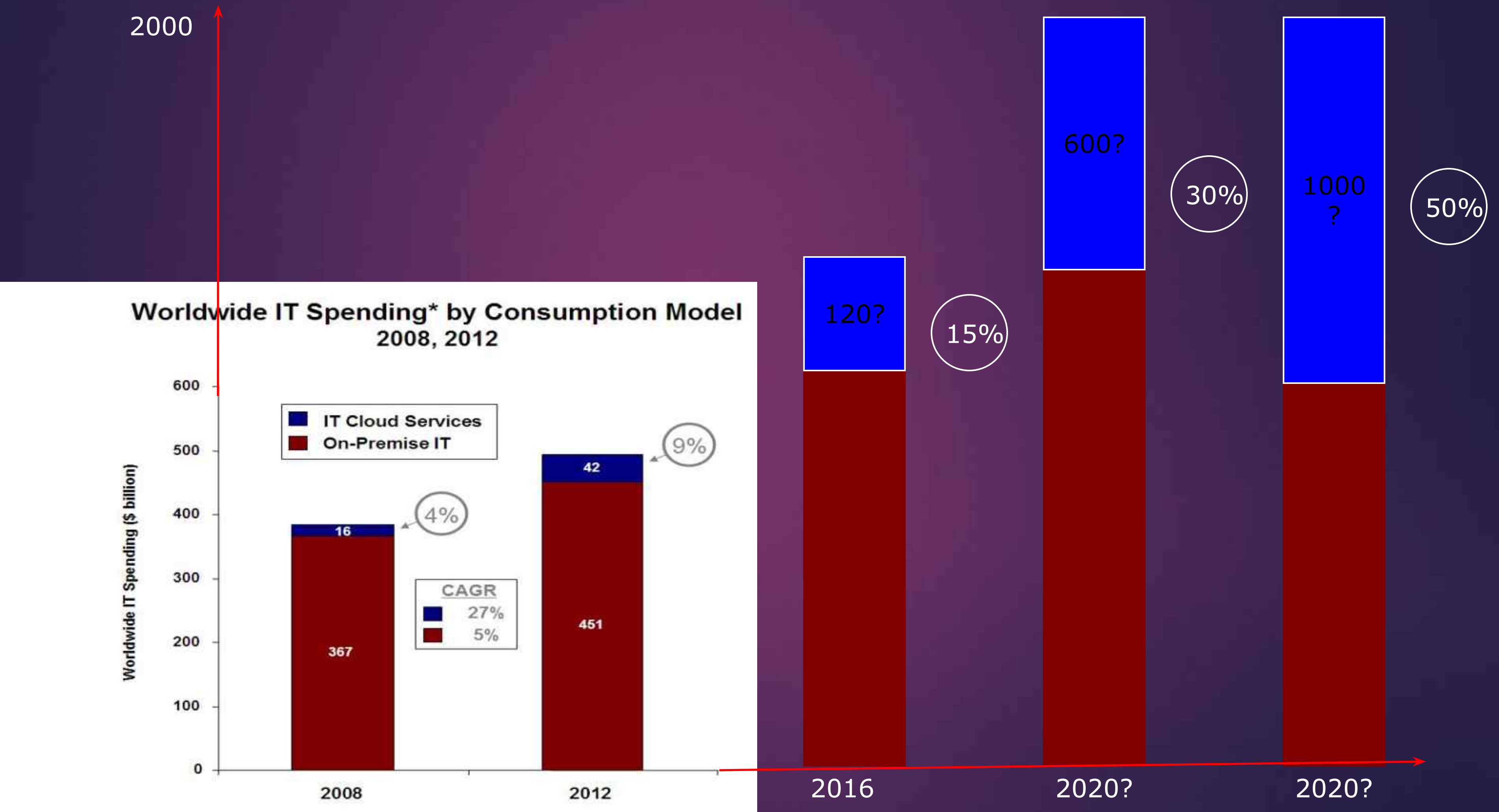
Science and Technical Applications



Business Applications

Consumer/Social Applications

Cloud Biz Potential:
a trillion $ business/year by 2020?



* Includes enterprise IT spending on Business Applications, Systems Infrastructure Software, Application Development & Deployment Software, Servers and Storage

Source: IDC, October 2008

Buyya's Guestimate!

Cloud Computing Challenges: Dealing with too many issues

Virtualization

Pricing

Scalability

Resource Metering

QoS

[redacted]

Service Level Agreements

Billing

Energy Efficiency

Provisioning on Demand

Utility & Risk Management

Security

Legal & Regulatory

Privacy

Trust

Programming Env. & Application Dev.

Software Eng. Complexity

CLOUD COMPUTING (17CS742)

3. VIRTUALISATION

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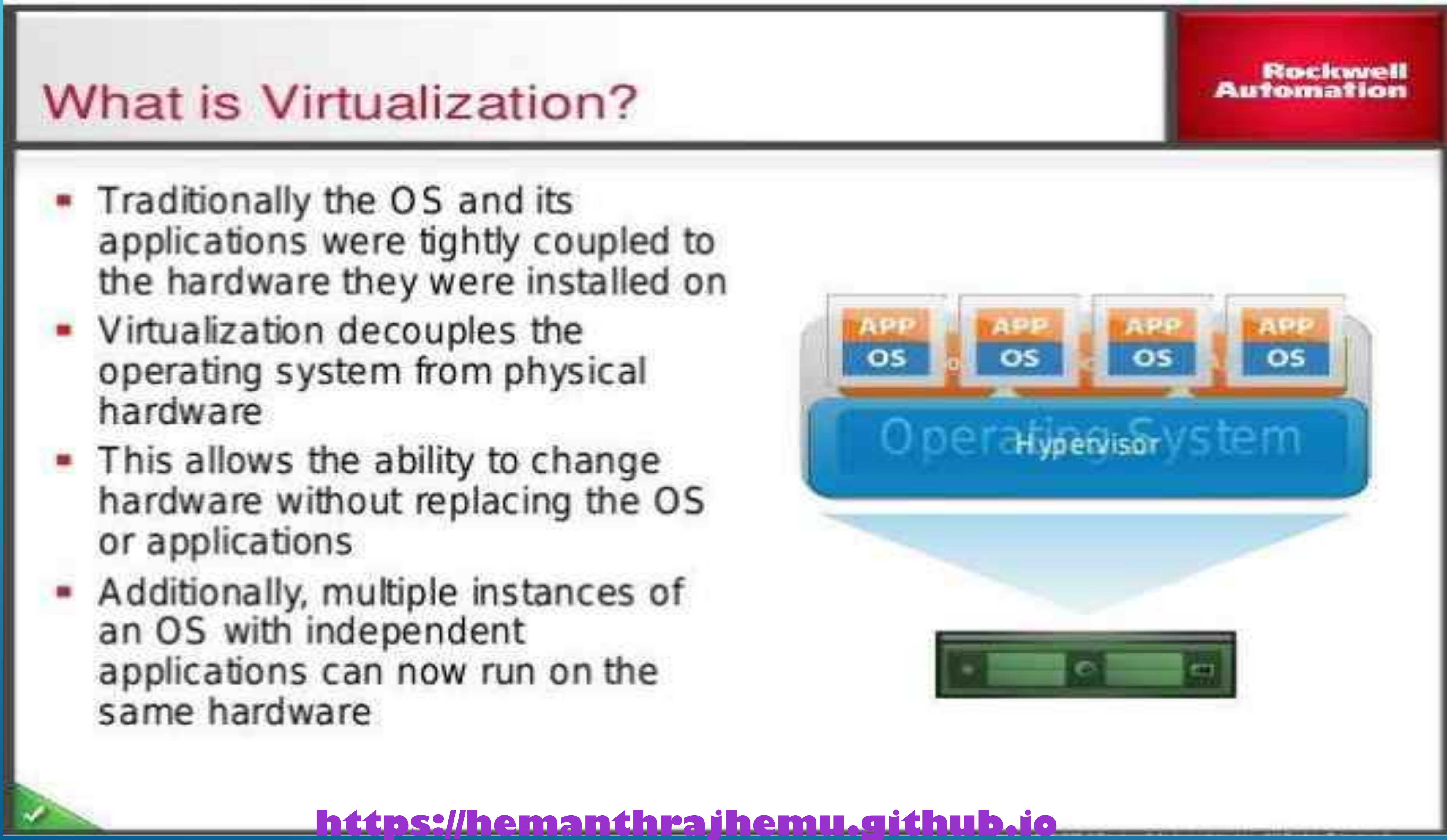
Virtualization

- **Virtualization** is the creation of a virtual rather than actual version of something, such as an operating system, a server, a storage device or network resources
- One of the fundamental Concepts of Cloud Computing

vmware

Microsoft Virtual PC

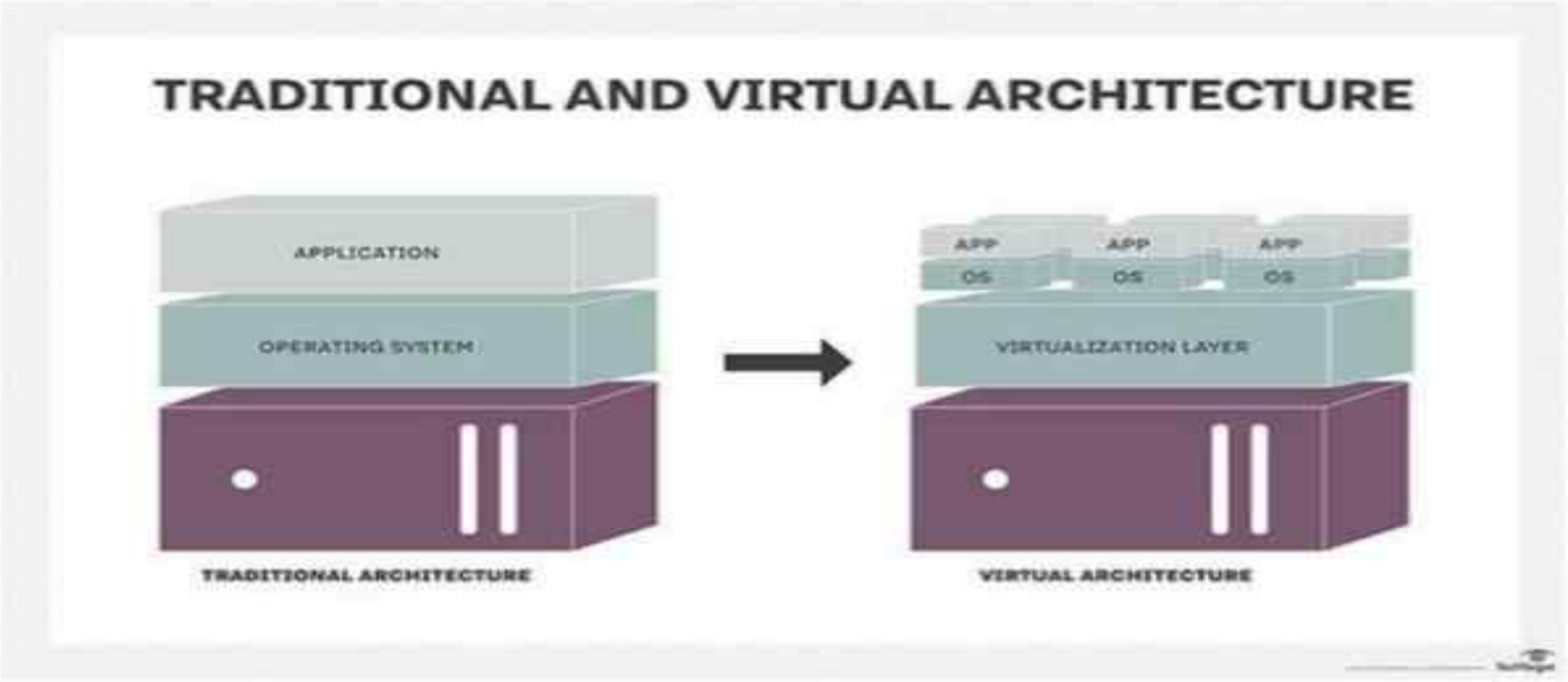
CITRIX XenServer

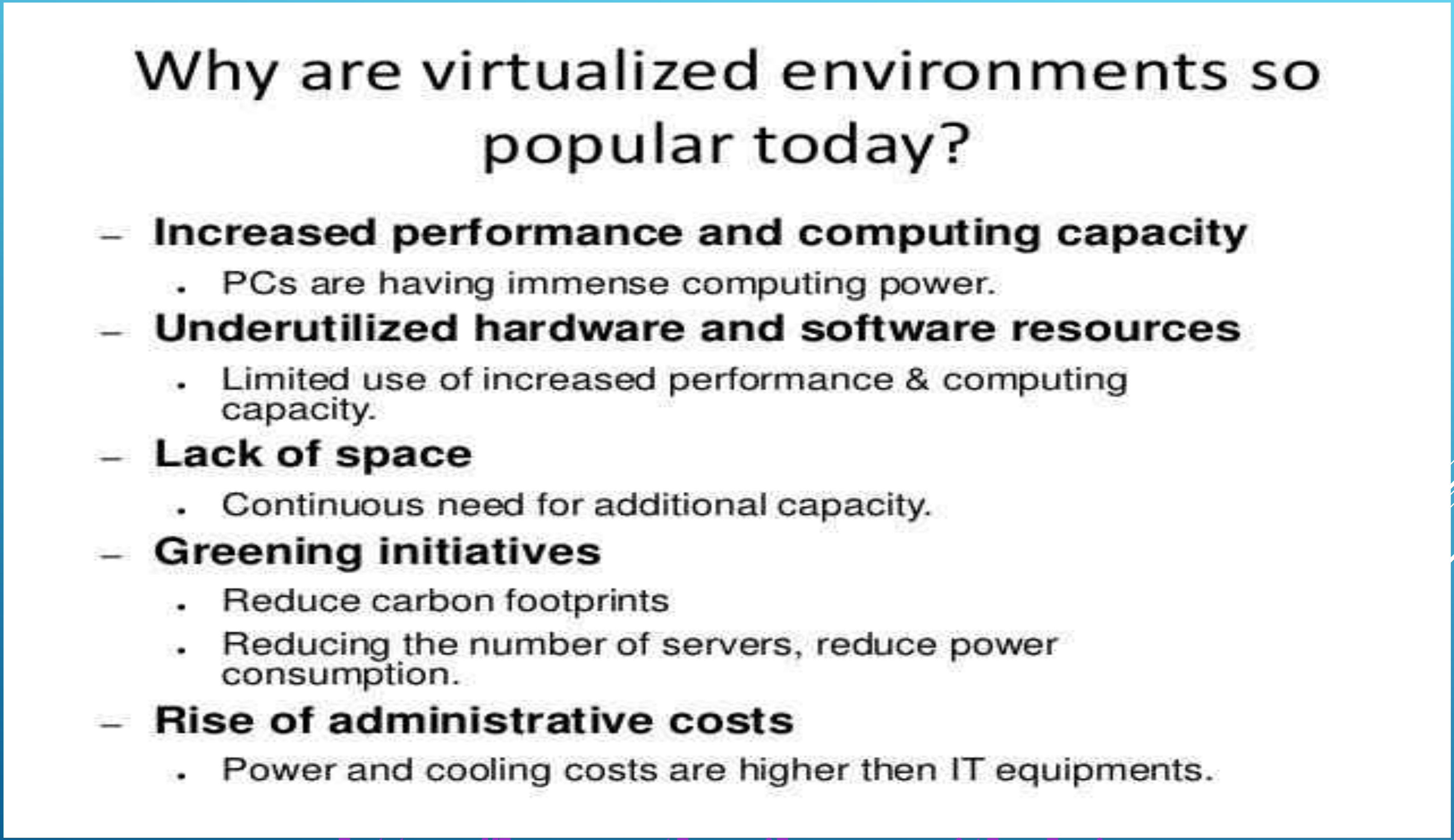


Rockwell Automation

What is Virtualization?

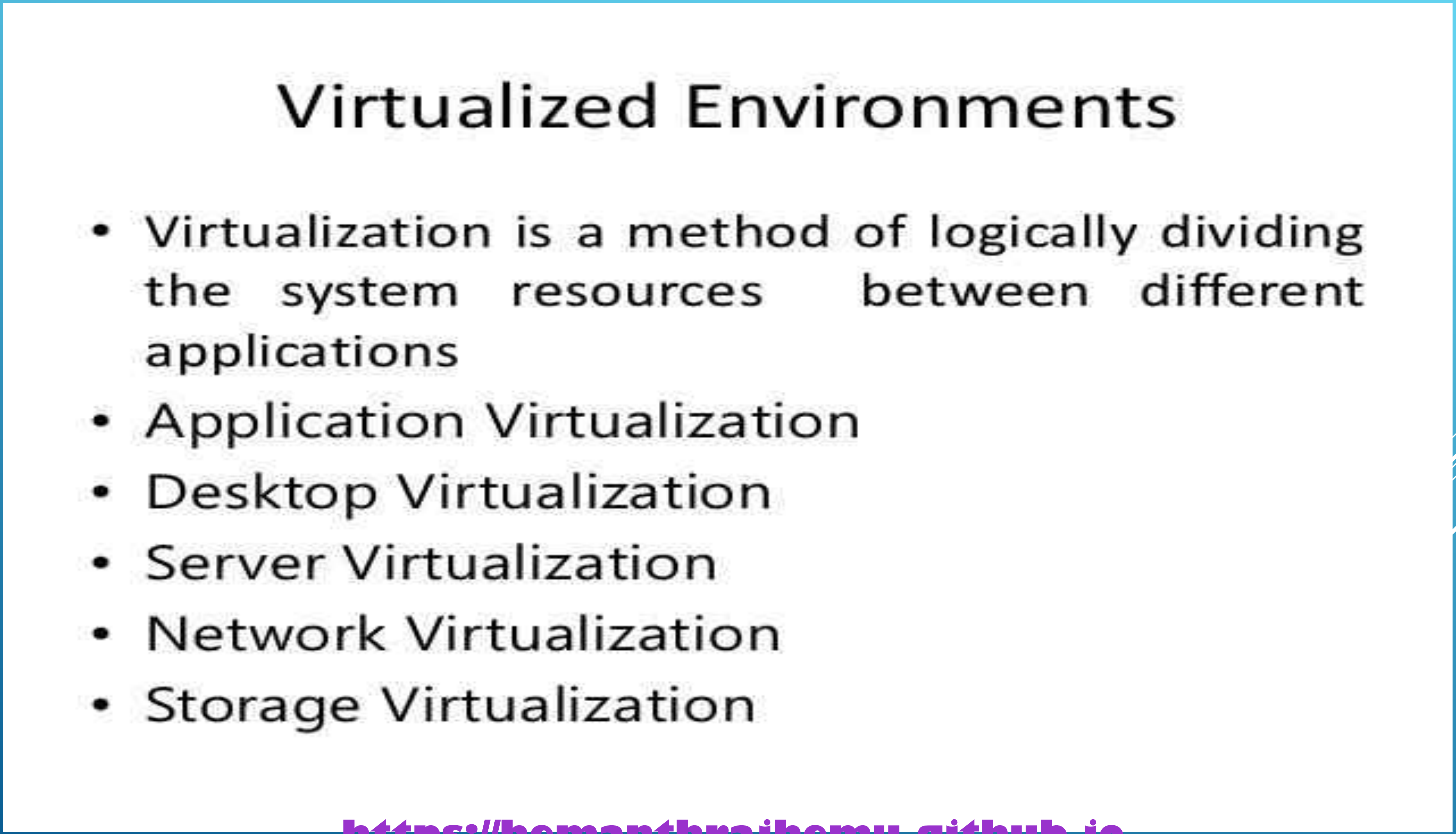
- Traditionally the OS and its applications were tightly coupled to the hardware they were installed on
- Virtualization decouples the operating system from physical hardware
- This allows the ability to change hardware without replacing the OS or applications
- Additionally, multiple instances of an OS with independent applications can now run on the same hardware


TRADITIONAL AND VIRTUAL ARCHITECTURE
APPLICATION
OPERATING SYSTEM
TRADITIONAL ARCHITECTURE
APP
APP
APP
OS
OS
OS
VIRTUALIZATION LAYER
VIRTUAL ARCHITECTURE



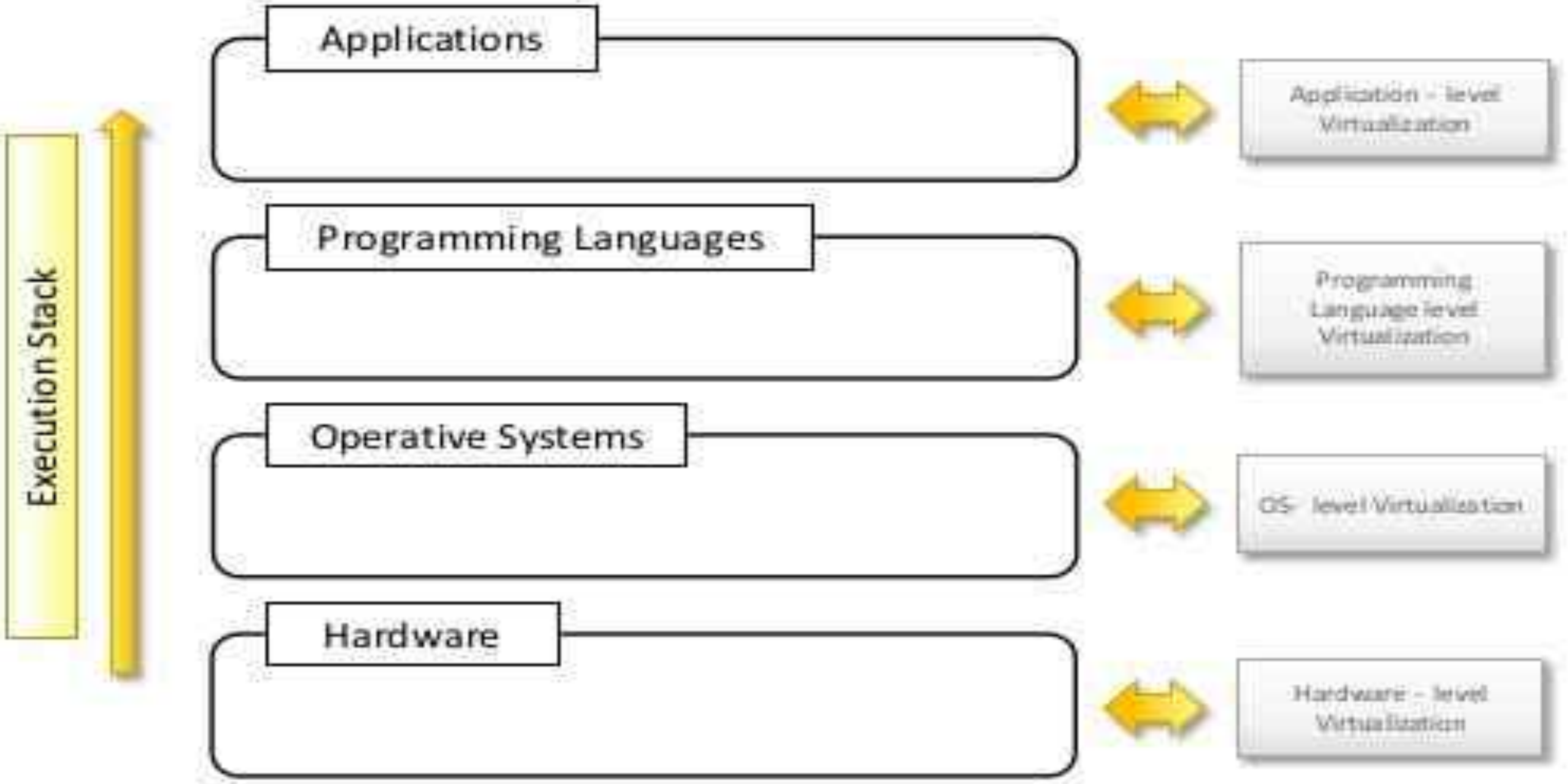
Why are virtualized environments so popular today?

- Increased performance and computing capacity
  - PCs are having immense computing power.
- Underutilized hardware and software resources
  - Limited use of increased performance & computing capacity.
- Lack of space
  - Continuous need for additional capacity.
- Greening initiatives
  - Reduce carbon footprints
  - Reducing the number of servers, reduce power consumption.
- Rise of administrative costs
  - Power and cooling costs are higher then IT equipments.



Virtualized Environments

- Virtualization is a method of logically dividing the system resources between different applications
- Application Virtualization
- Desktop Virtualization
- Server Virtualization
- Network Virtualization
- Storage Virtualization


Execution Stack
Applications
Programming Languages
Operative Systems
Hardware
Application - level Virtualization
Programming Language level Virtualization
OS- level Virtualization
Hardware - level Virtualization

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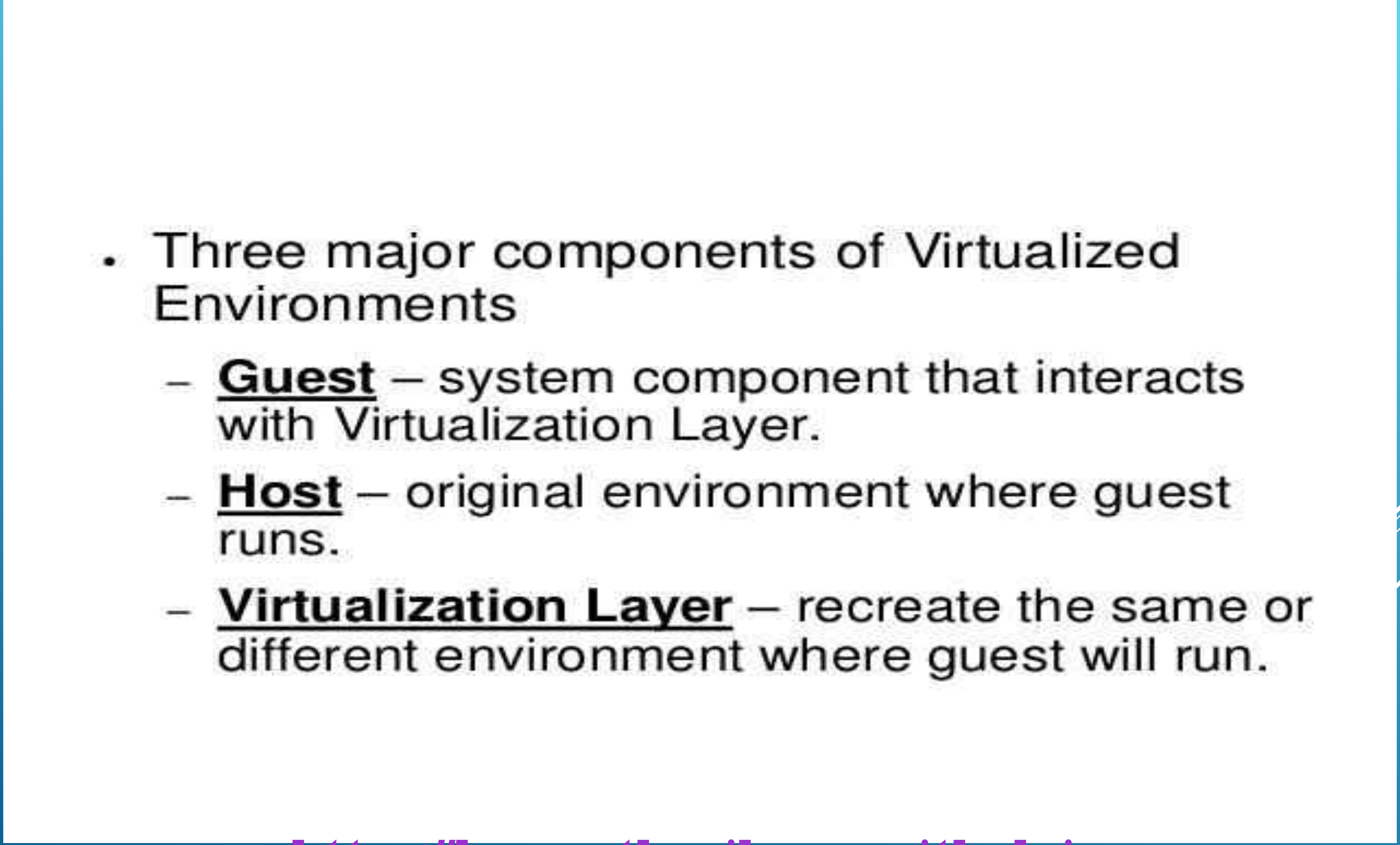
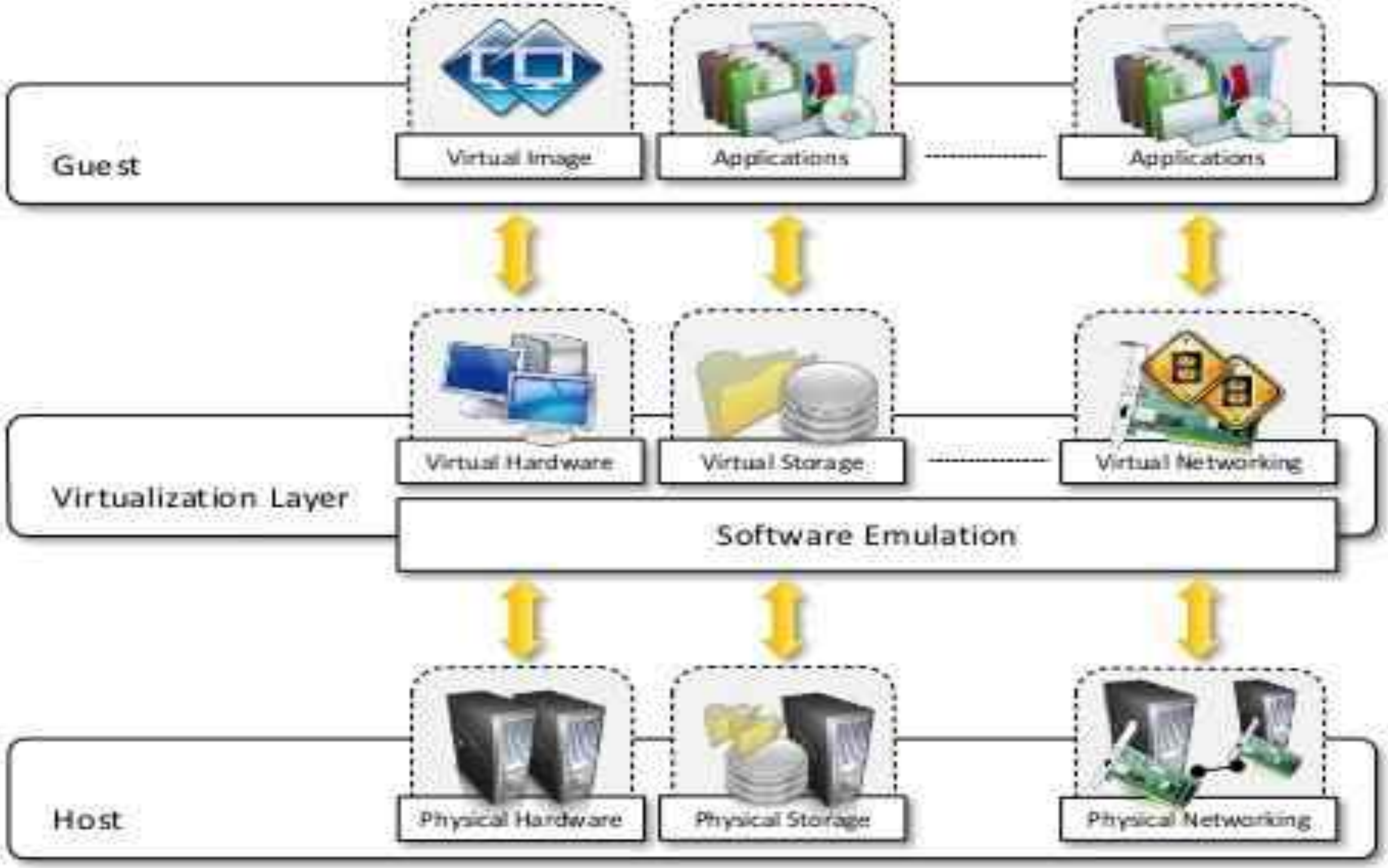
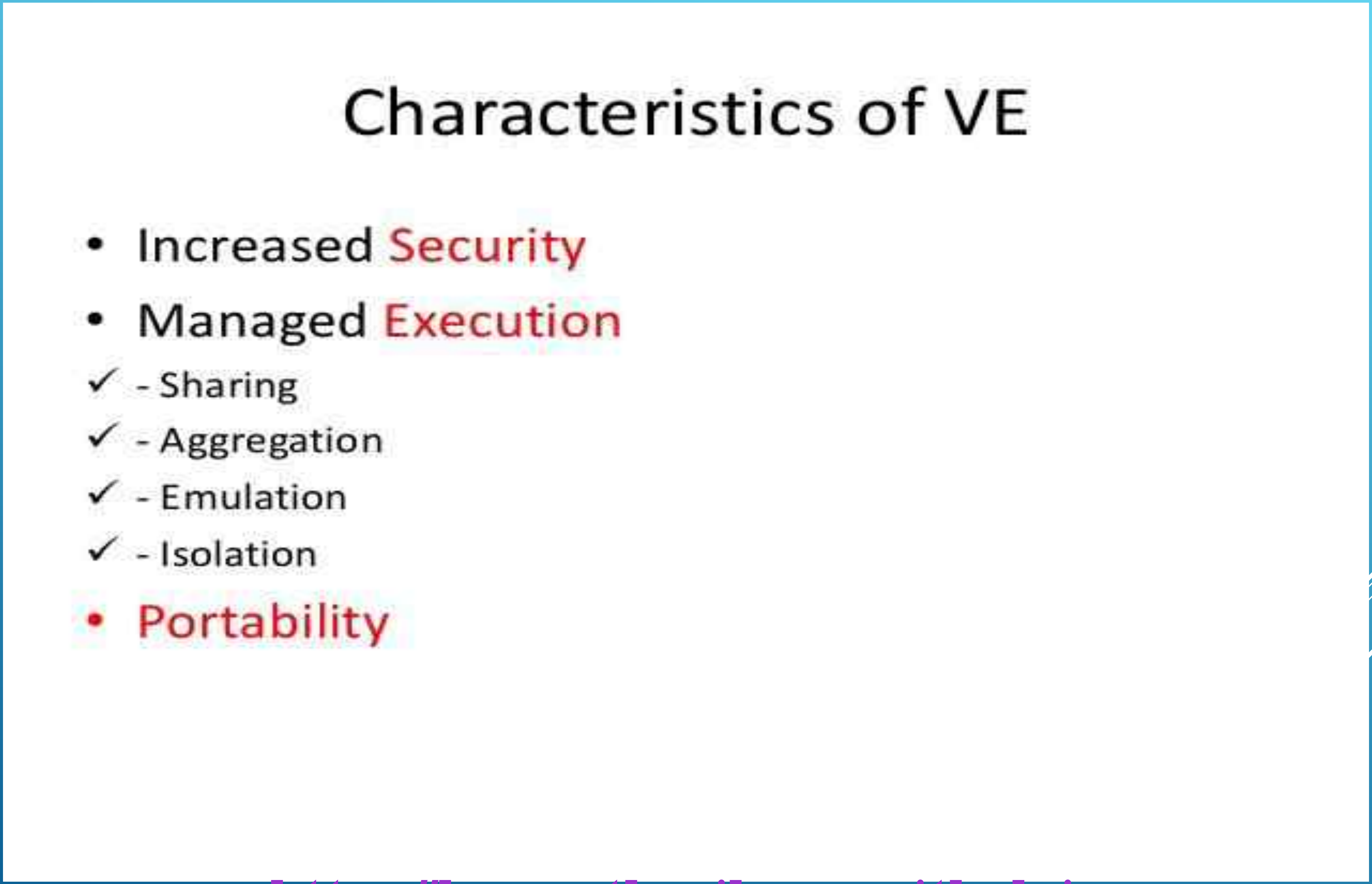


- Three major components of Virtualized Environments
  - **Guest** – system component that interacts with Virtualization Layer.
  - **Host** – original environment where guest runs.
  - **Virtualization Layer** – recreate the same or different environment where guest will run.



Virtualization Reference Model



Characteristics of VE

- Increased Security
- Managed Execution

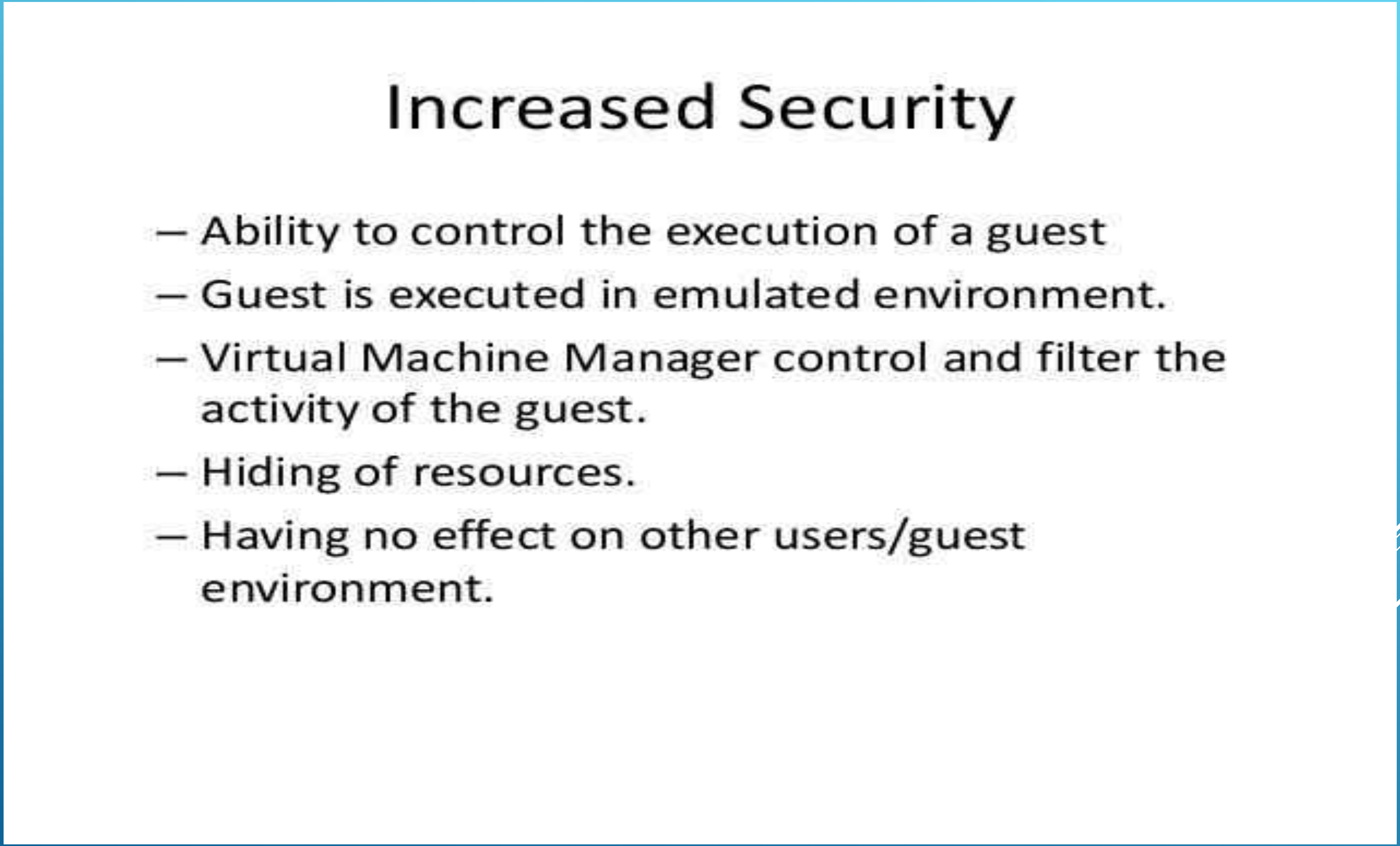
✓ - Sharing

✓ - Aggregation

✓ - Emulation

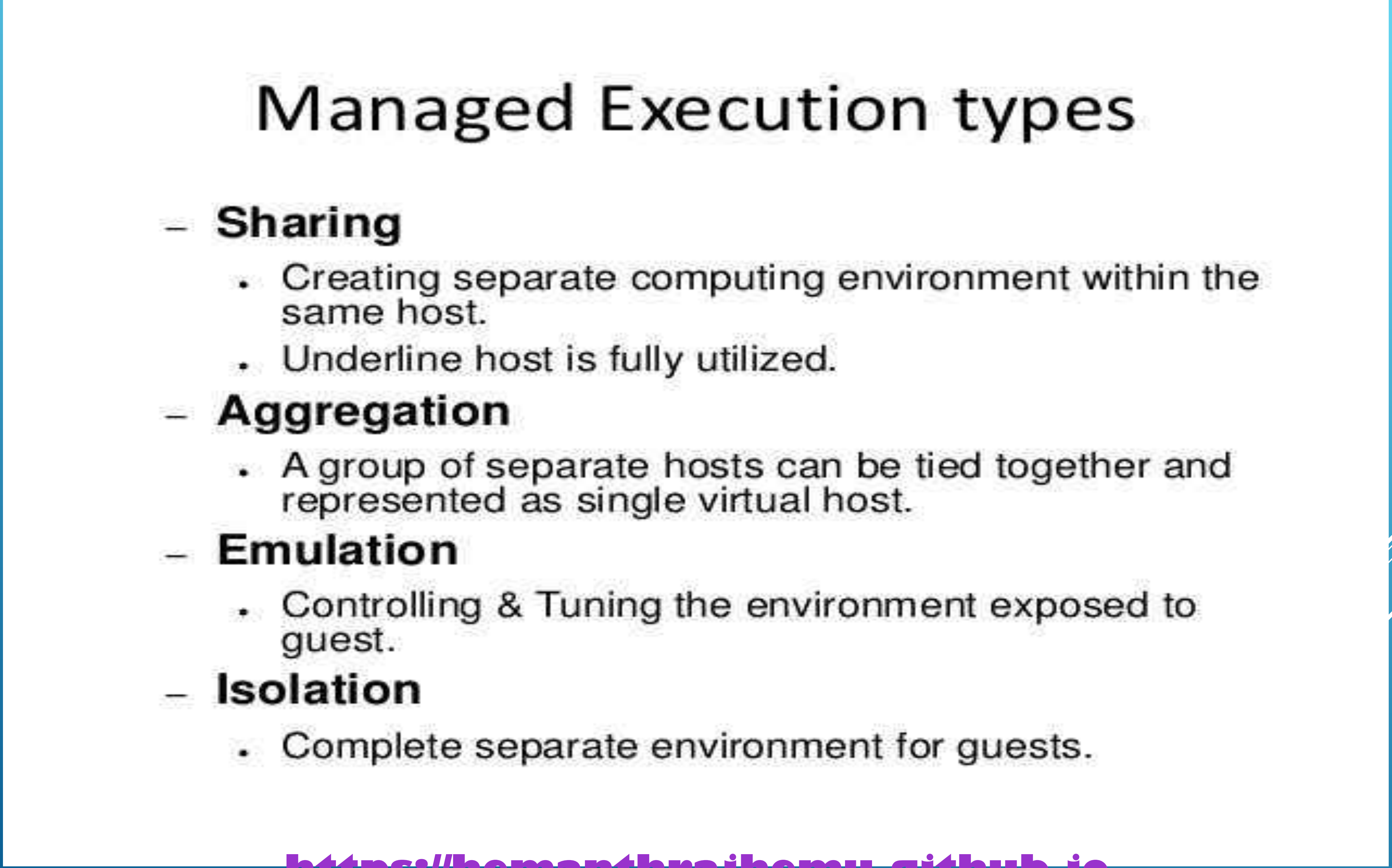
✓ - Isolation

- Portability



Increased Security

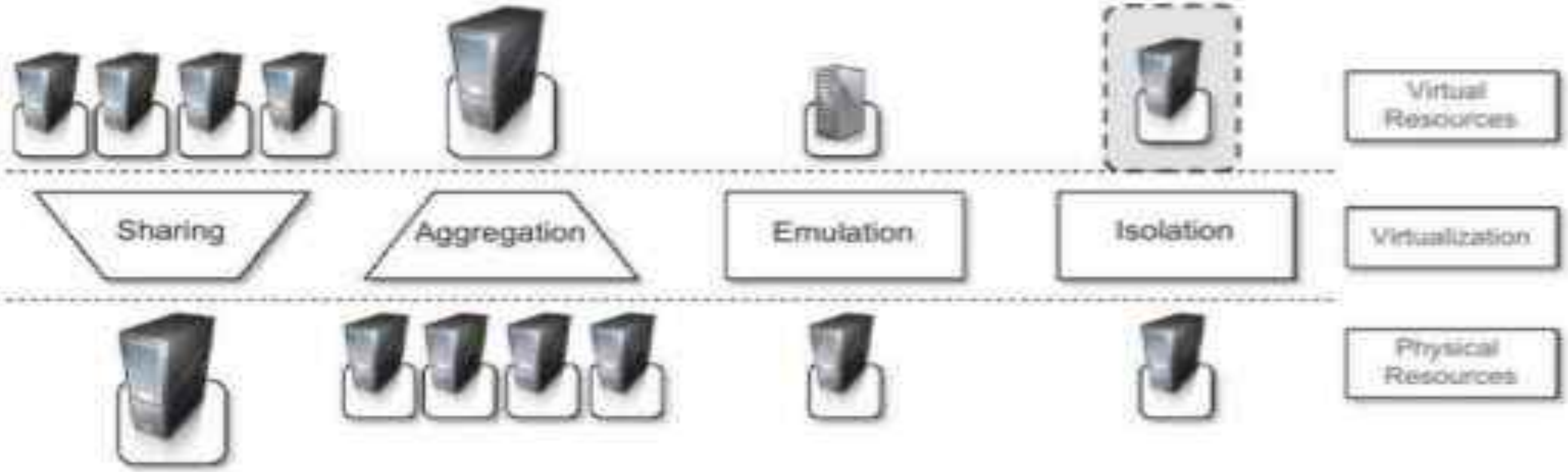
- Ability to control the execution of a guest
- Guest is executed in emulated environment.
- Virtual Machine Manager control and filter the activity of the guest.
- Hiding of resources.
- Having no effect on other users/guest environment.

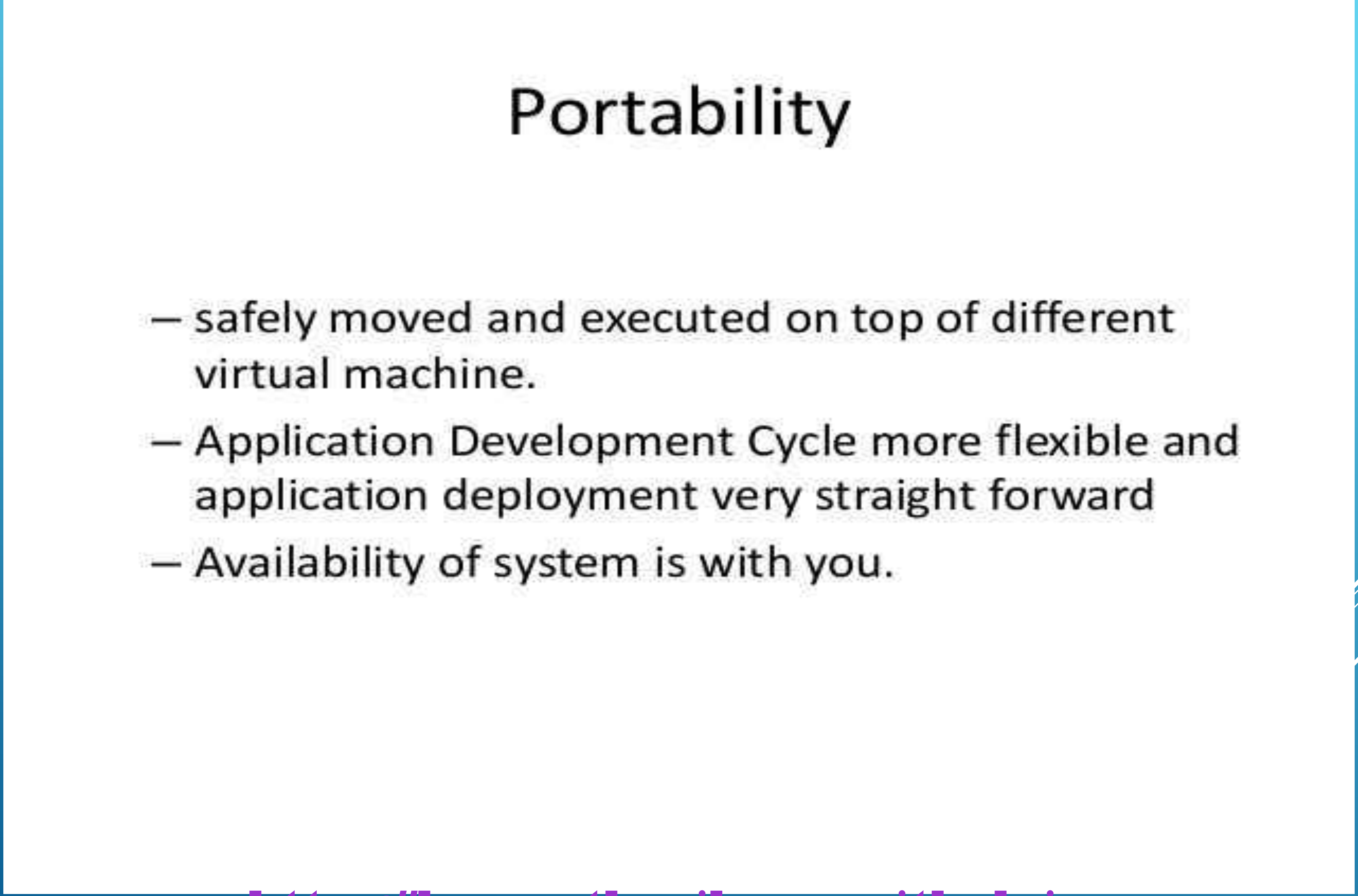


Managed Execution types

- **Sharing**
  - Creating separate computing environment within the same host.
  - Underline host is fully utilized.
- **Aggregation**
  - A group of separate hosts can be tied together and represented as single virtual host.
- **Emulation**
  - Controlling & Tuning the environment exposed to guest.
- **Isolation**
  - Complete separate environment for guests.

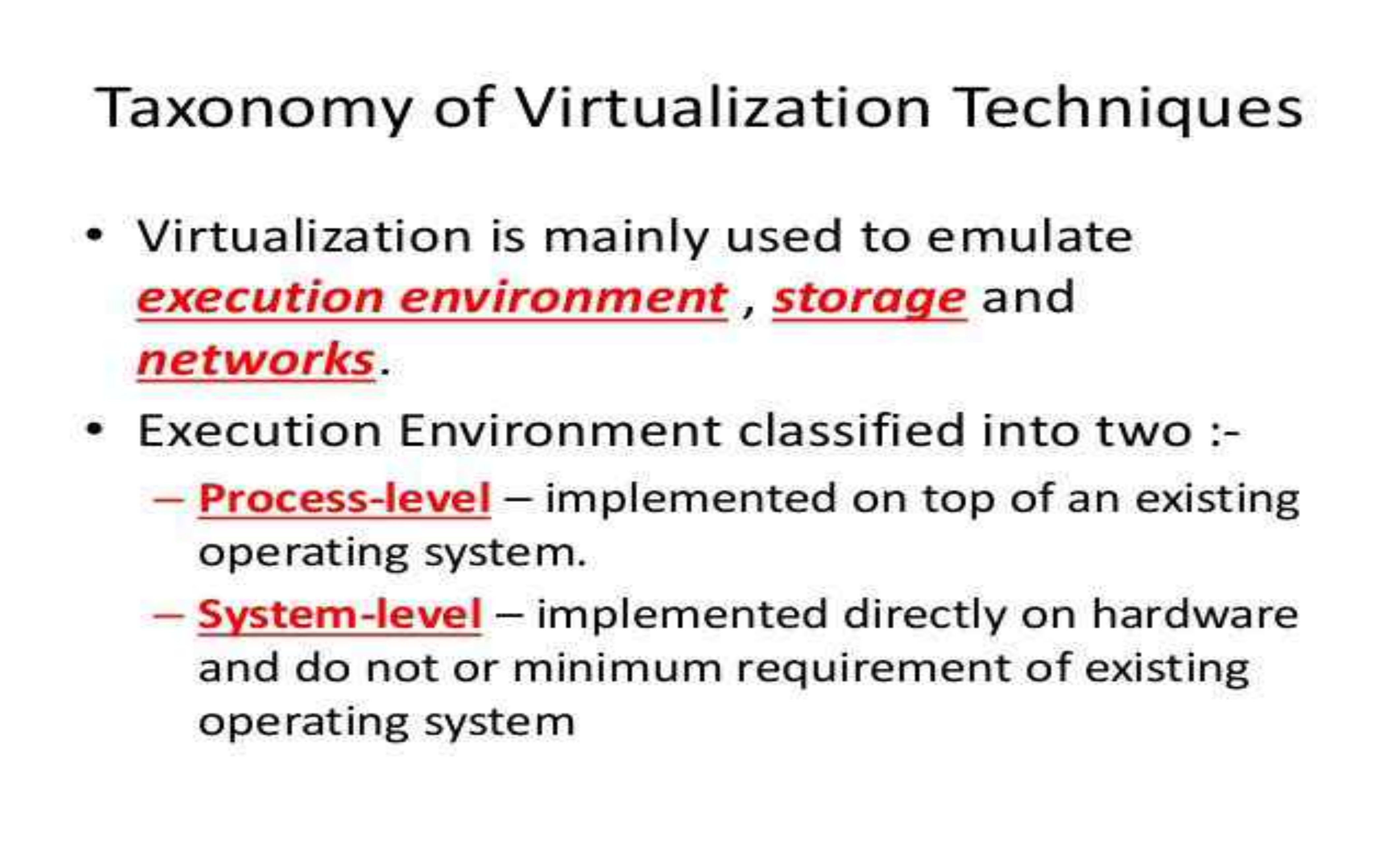
Managed Execution





Portability

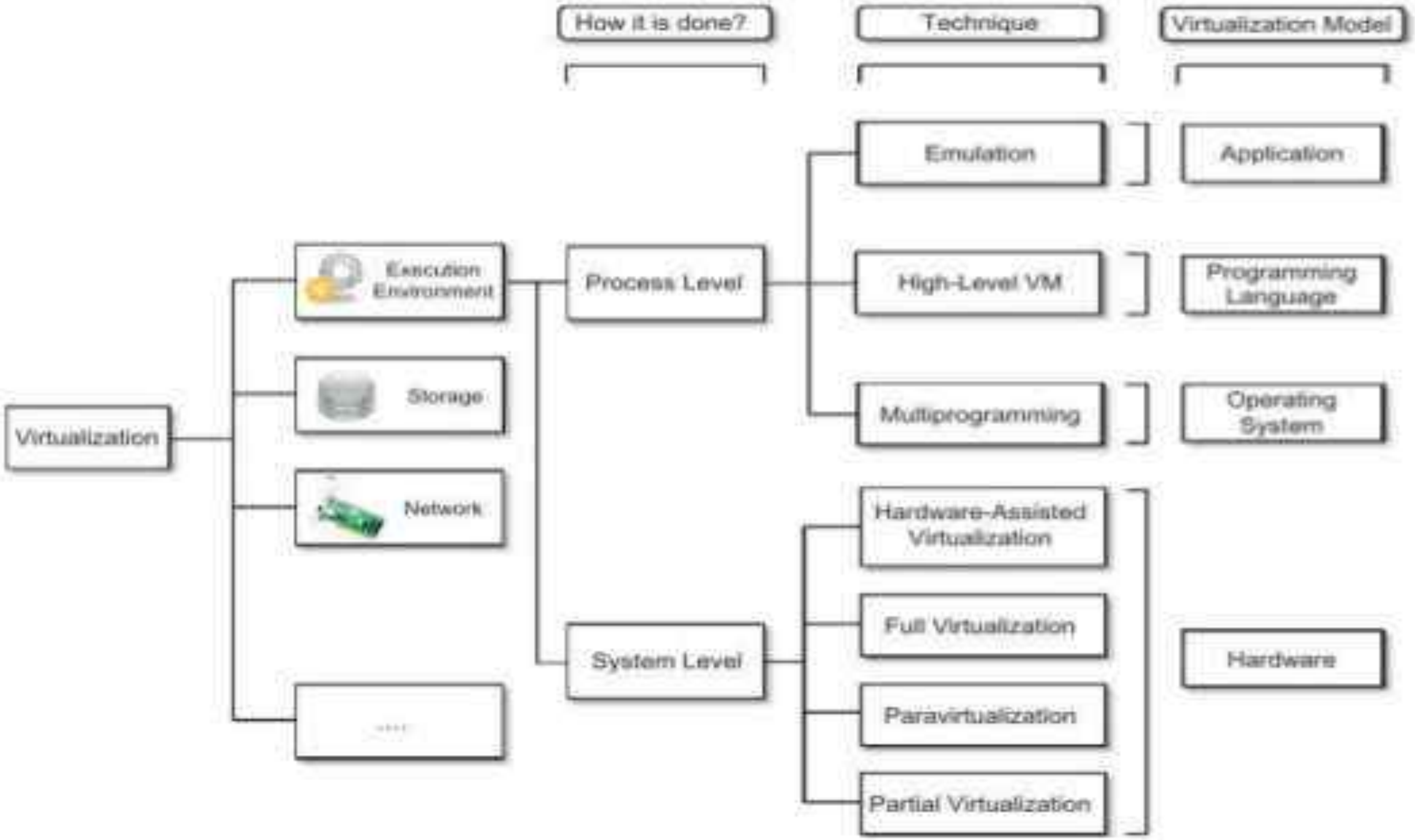
- – safely moved and executed on top of different virtual machine.
- – Application Development Cycle more flexible and application deployment very straight forward
- – Availability of system is with you.



Taxonomy of Virtualization Techniques

- Virtualization is mainly used to emulate ***execution environment*** , ***storage*** and ***networks***.
- Execution Environment classified into two :-
  - **Process-level** – implemented on top of an existing operating system.
  - **System-level** – implemented directly on hardware and do not or minimum requirement of existing operating system

Taxonomy of virtualization



How it is done?

Technique

Virtualization Model

Virtualization

Execution Environment

Storage

Network

....

Process Level

System Level

Emulation

High-Level VM

Multiprogramming

Hardware-Assisted Virtualization

Full Virtualization

Paravirtualization

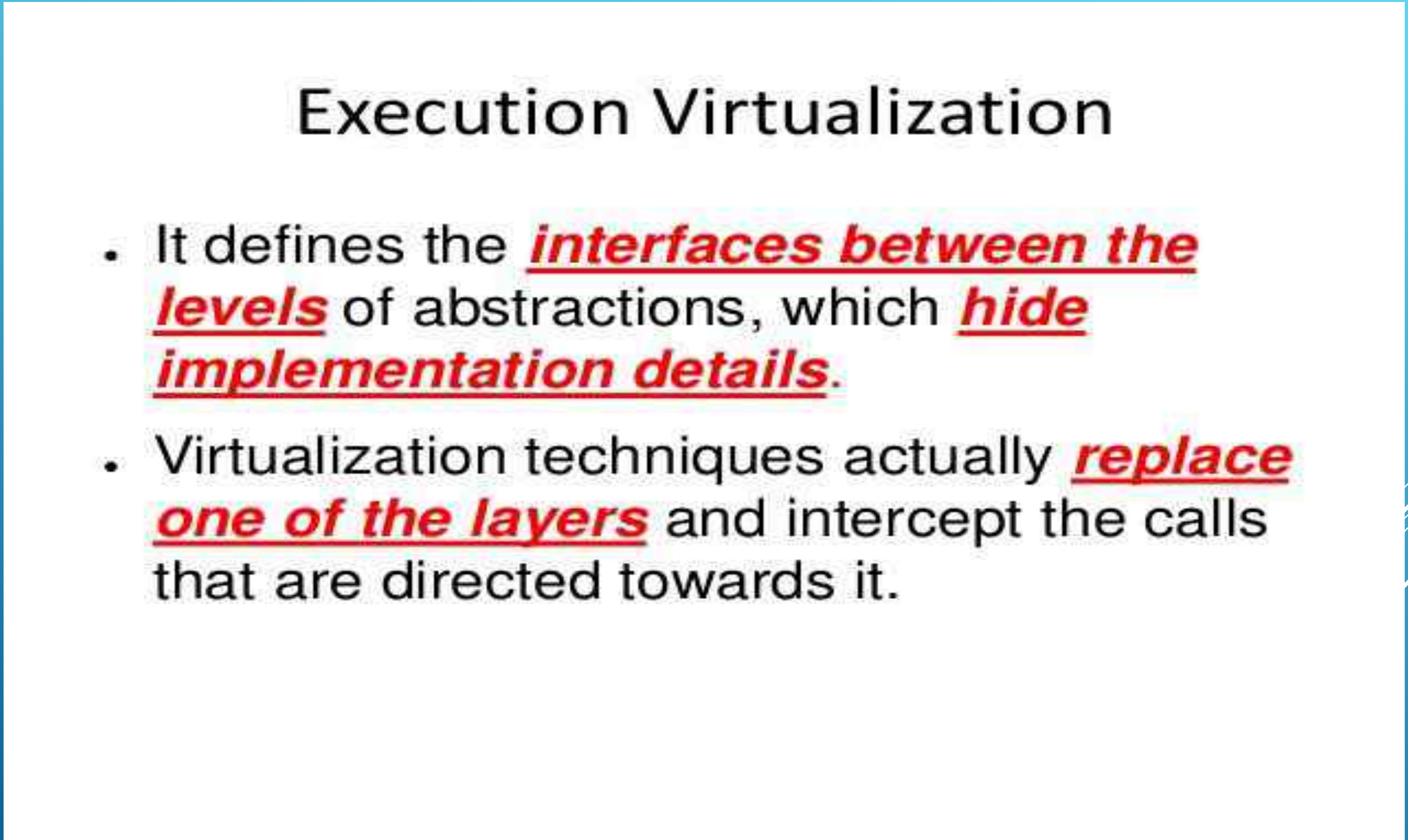
Partial Virtualization

Application

Programming Language

Operating System

Hardware



Execution Virtualization

- It defines the ***interfaces between the levels*** of abstractions, which ***hide implementation details***.
- Virtualization techniques actually ***replace one of the layers*** and intercept the calls that are directed towards it.

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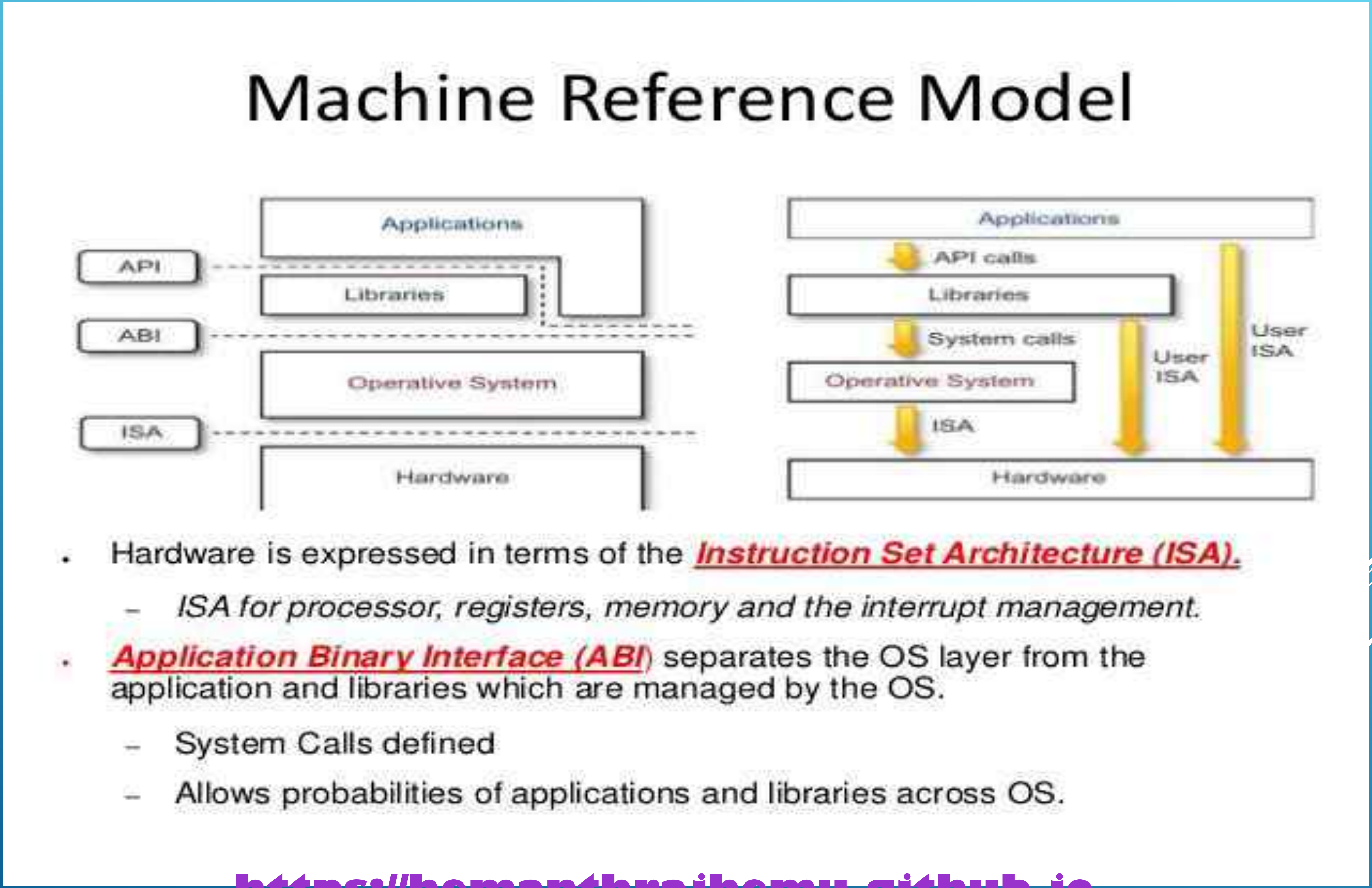
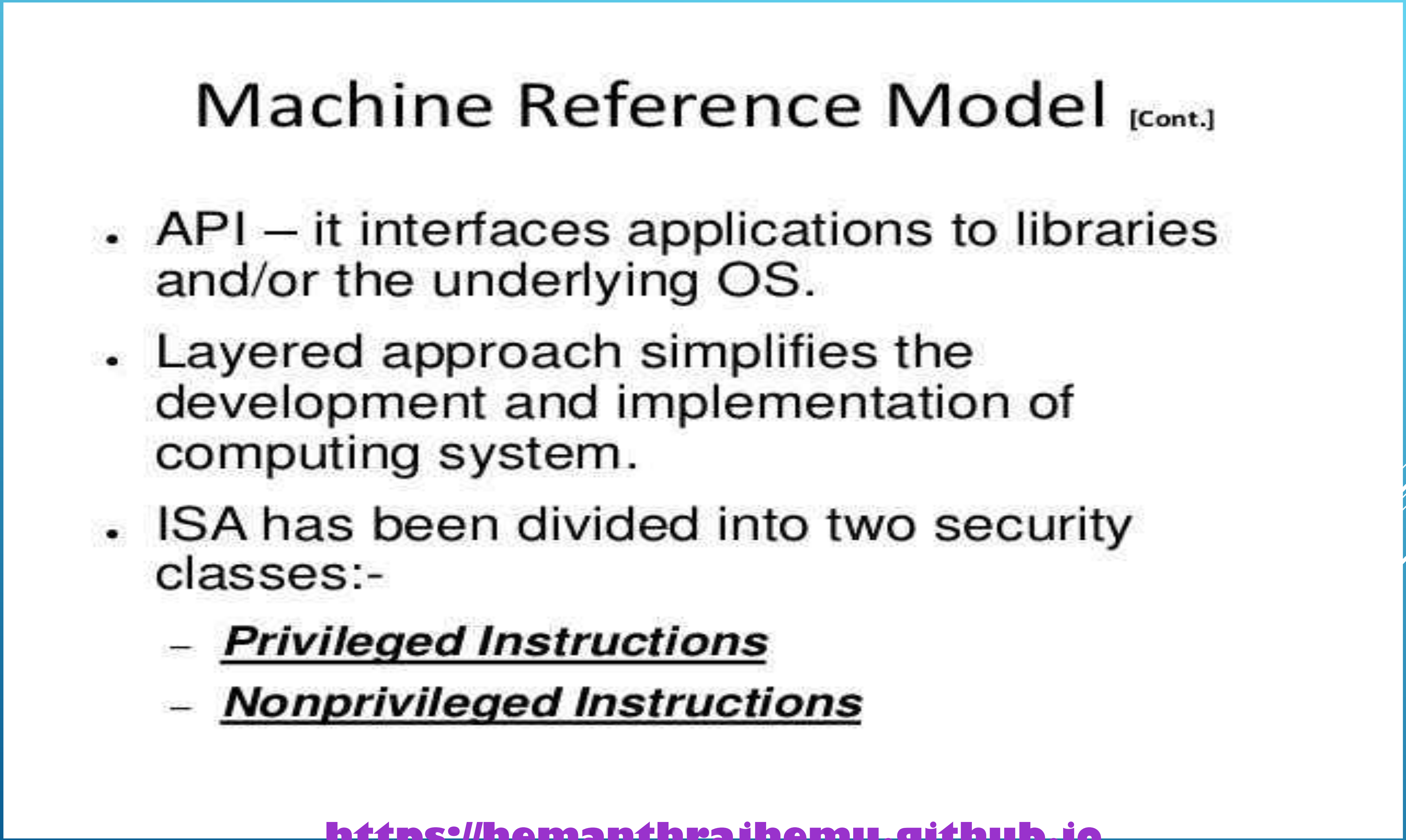


Machine Reference Model

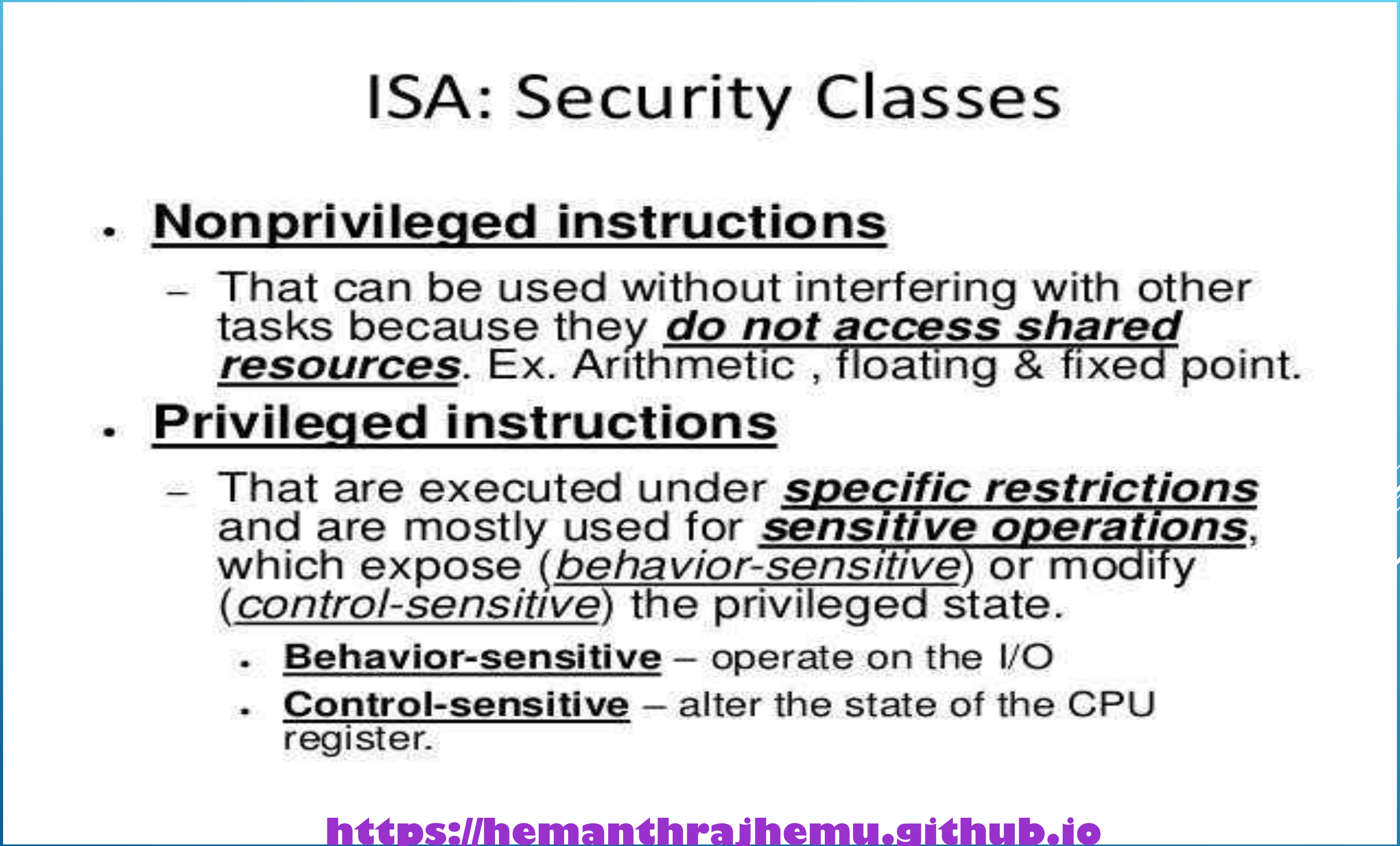
Applications
API
Libraries
ABI
Operative System
ISA
Hardware
Applications
API calls
Libraries
System calls
Operative System
ISA
Hardware
User ISA
User ISA

- Hardware is expressed in terms of the ***Instruction Set Architecture (ISA).***
  - *ISA for processor, registers, memory and the interrupt management.*
- ***Application Binary Interface (ABI***) separates the OS layer from the application and libraries which are managed by the OS.
  - System Calls defined
  - Allows probabilities of applications and libraries across OS.



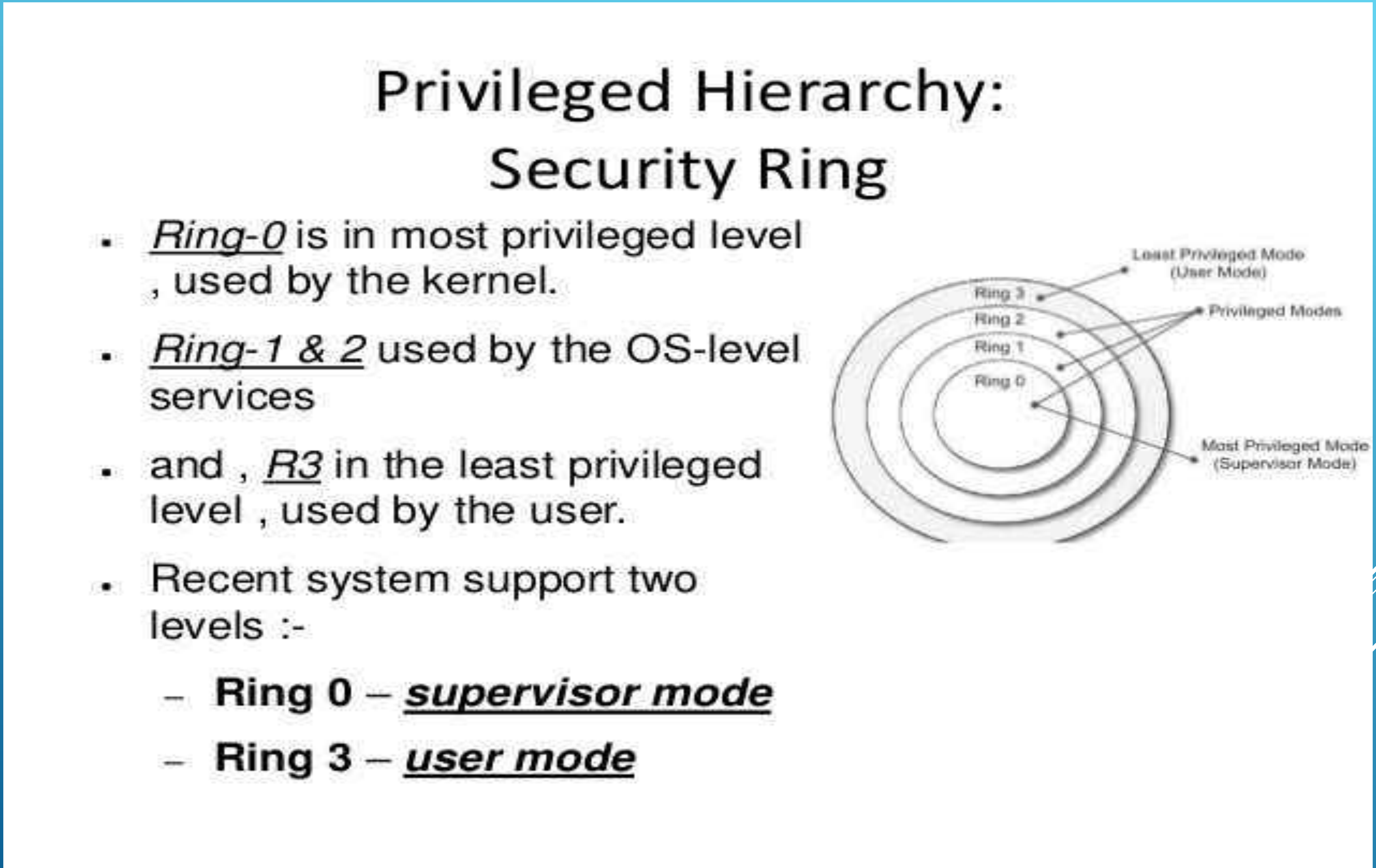
Machine Reference Model [Cont.]

- API – it interfaces applications to libraries and/or the underlying OS.
- Layered approach simplifies the development and implementation of computing system.
- ISA has been divided into two security classes:-
  - ***Privileged Instructions***
  - ***Nonprivileged Instructions***



ISA: Security Classes

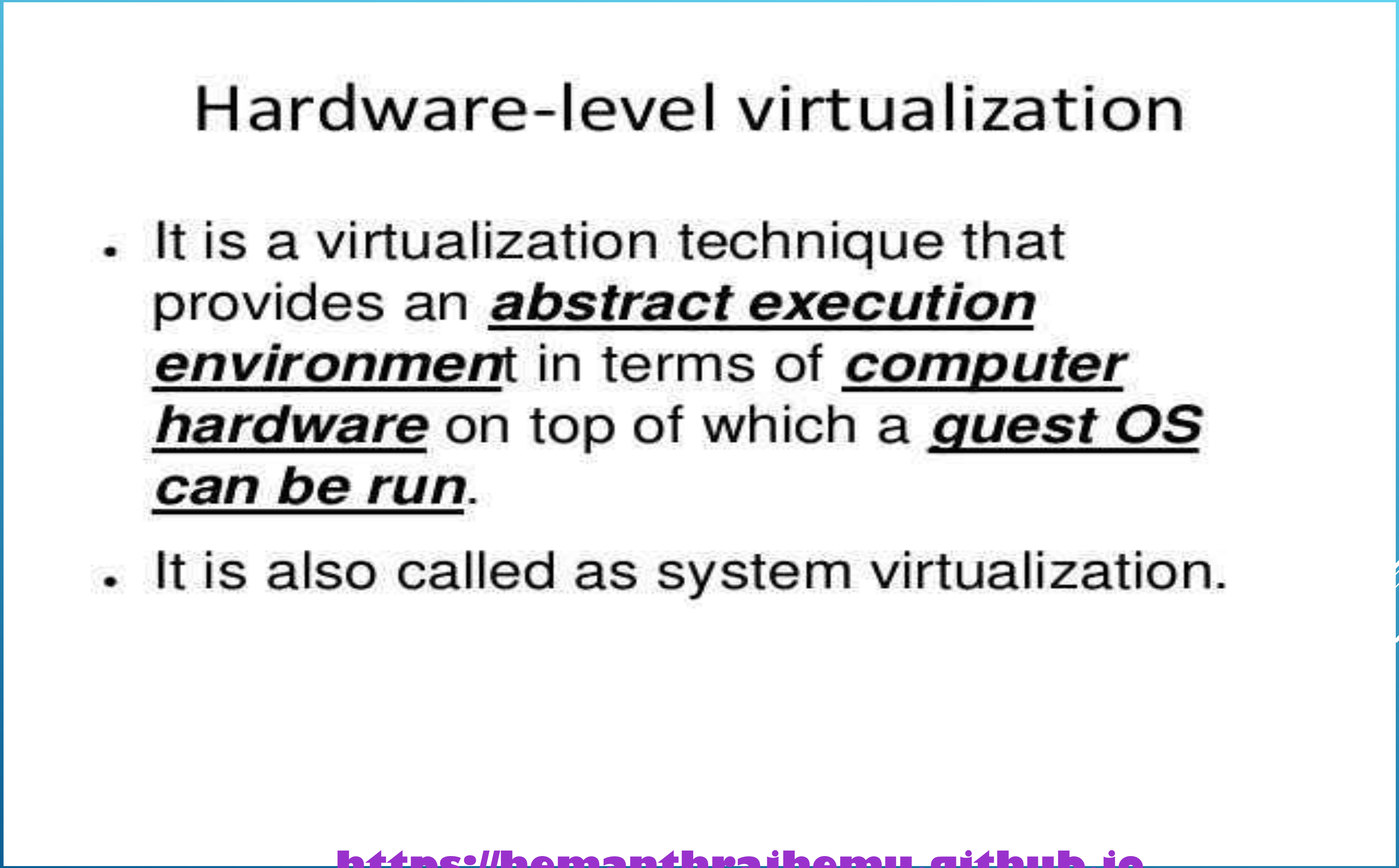
- **Nonprivileged instructions**
  - That can be used without interfering with other tasks because they ***do not access shared resources***. Ex. Arithmetic , floating & fixed point.
- **Privileged instructions**
  - That are executed under ***specific restrictions*** and are mostly used for ***sensitive operations***, which expose (*behavior-sensitive*) or modify (*control-sensitive*) the privileged state.
    - **Behavior-sensitive** – operate on the I/O
    - **Control-sensitive** – alter the state of the CPU register.



Privileged Hierarchy: Security Ring

- *Ring-0* is in most privileged level , used by the kernel.
- *Ring-1 & 2* used by the OS-level services
- and , *R3* in the least privileged level , used by the user.
- Recent system support two levels :-
  - **Ring 0 – *supervisor mode***
  - **Ring 3 – *user mode***

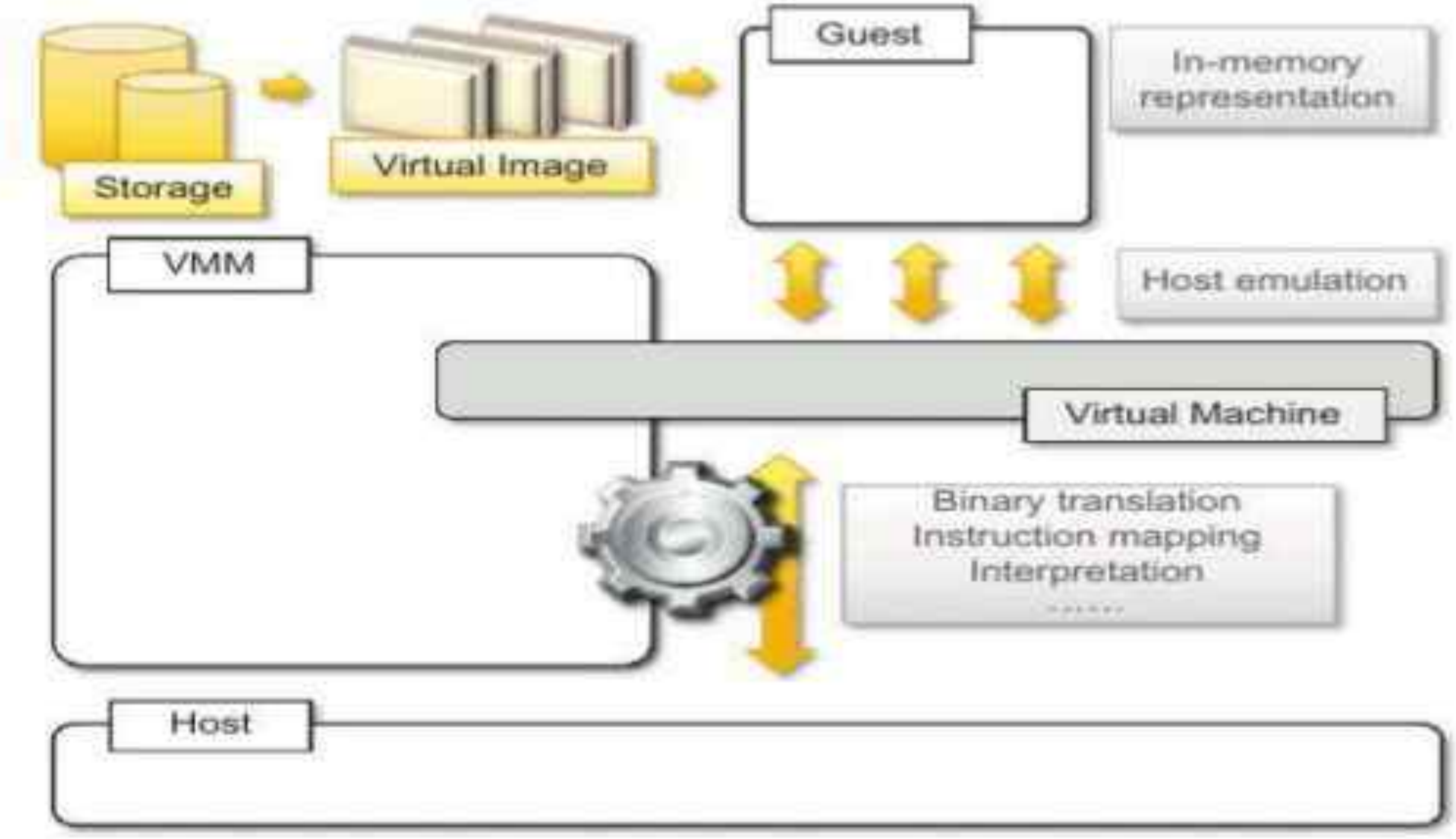
Least Privileged Mode
(User Mode)
Ring 3
Privileged Modes
Ring 2
Ring 1
Ring 0
Most Privileged Mode
(Supervisor Mode)

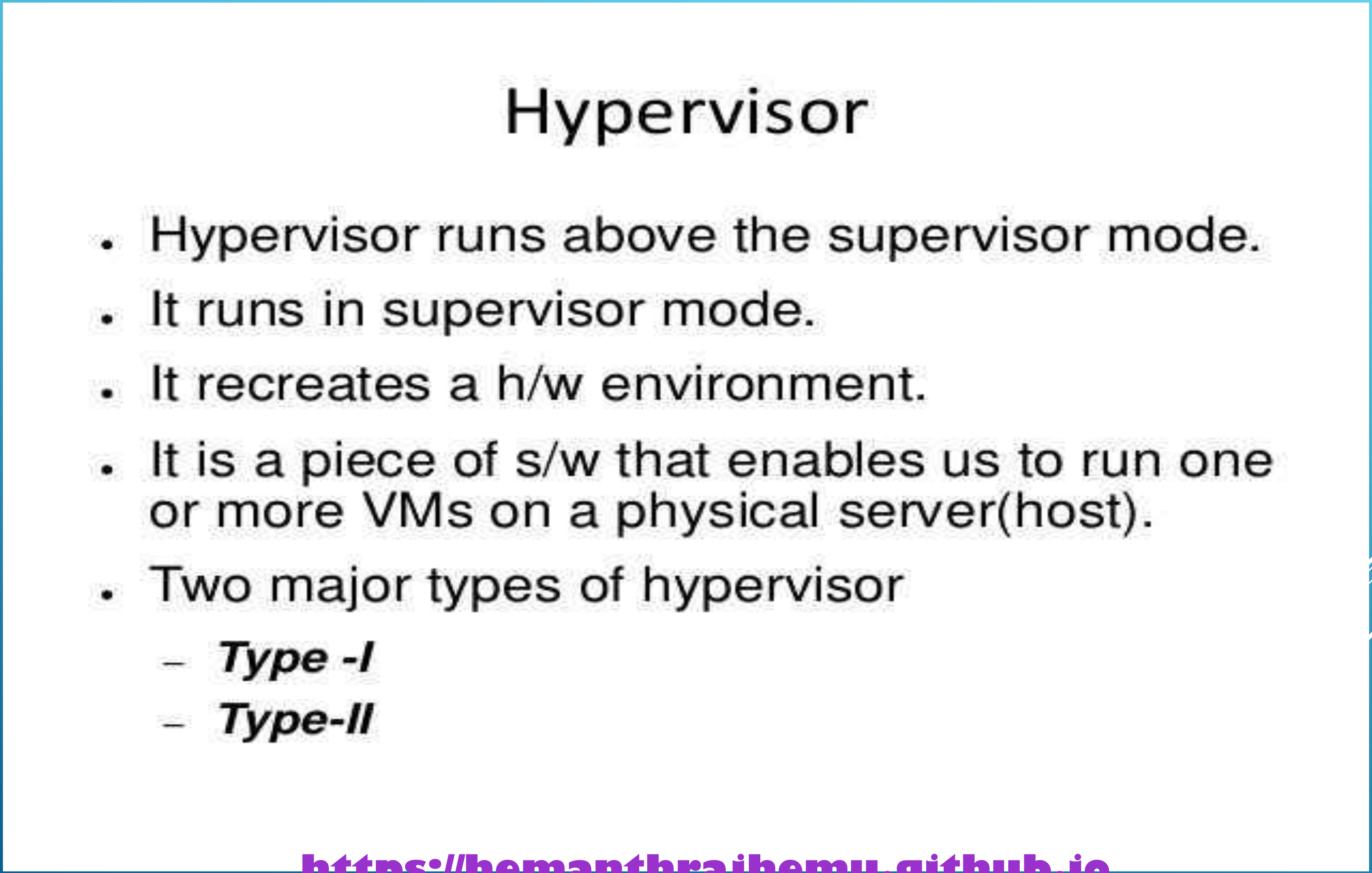


Hardware-level virtualization

- It is a virtualization technique that provides an ***abstract execution environmen***t in terms of ***computer hardware*** on top of which a ***guest OS can be run***.
- It is also called as system virtualization.

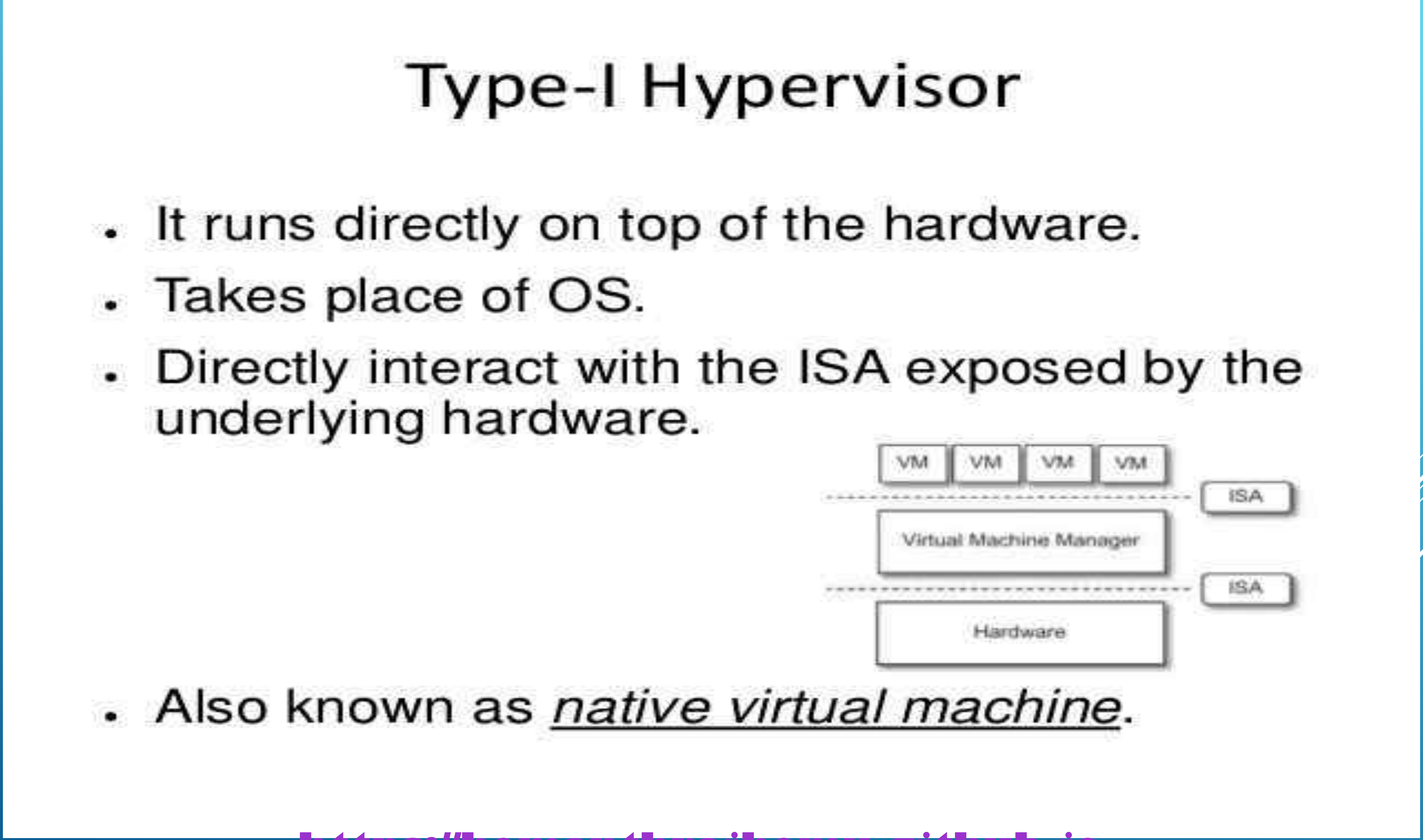
Hardware-level virtualization





Hypervisor

- Hypervisor runs above the supervisor mode.
- It runs in supervisor mode.
- It recreates a h/w environment.
- It is a piece of s/w that enables us to run one or more VMs on a physical server(host).
- Two major types of hypervisor
  - *Type -I*
  - *Type-II*



Type-I Hypervisor

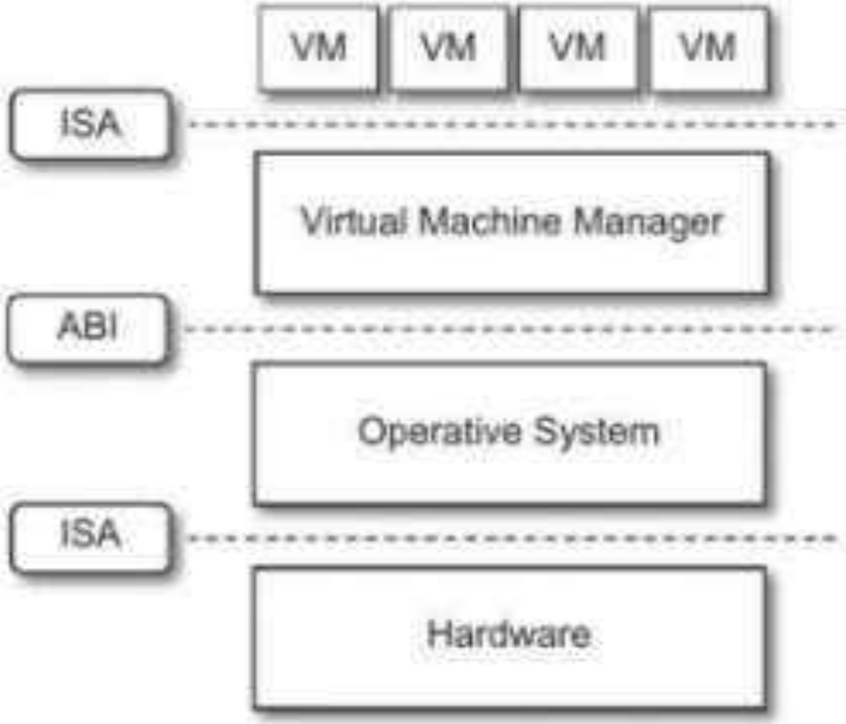
- It runs directly on top of the hardware.
- Takes place of OS.
- Directly interact with the ISA exposed by the underlying hardware.

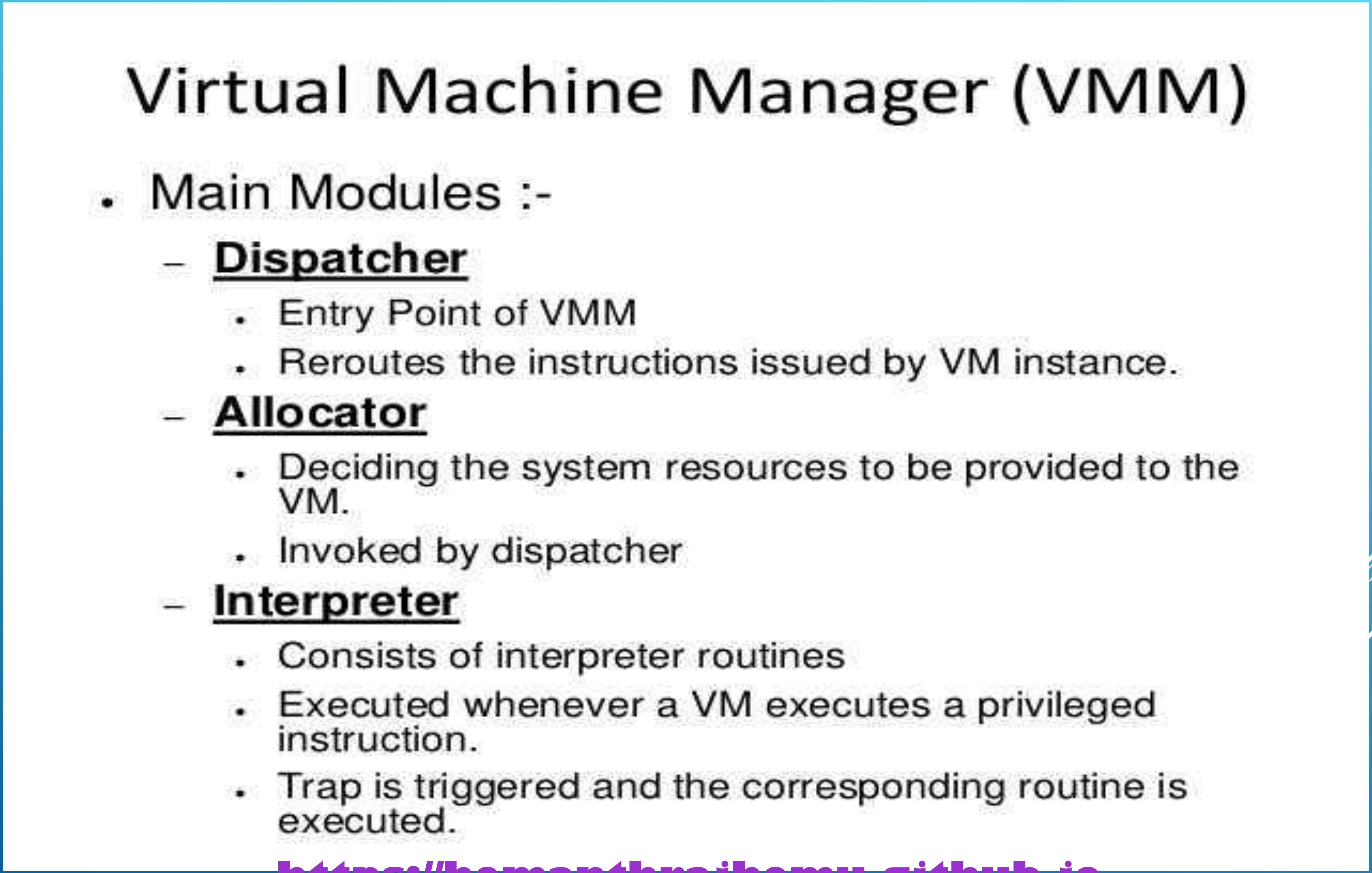
VM
VM
VM
VM
ISA
Virtual Machine Manager
ISA
Hardware

- Also known as *native virtual machine*.

Type-II Hypervisor

- It require the support of an operating system to provide virtualization services.
- Programs managed by the OS.
- Emulate the ISA of virtual h/w.
- Also called hosted virtual machine.

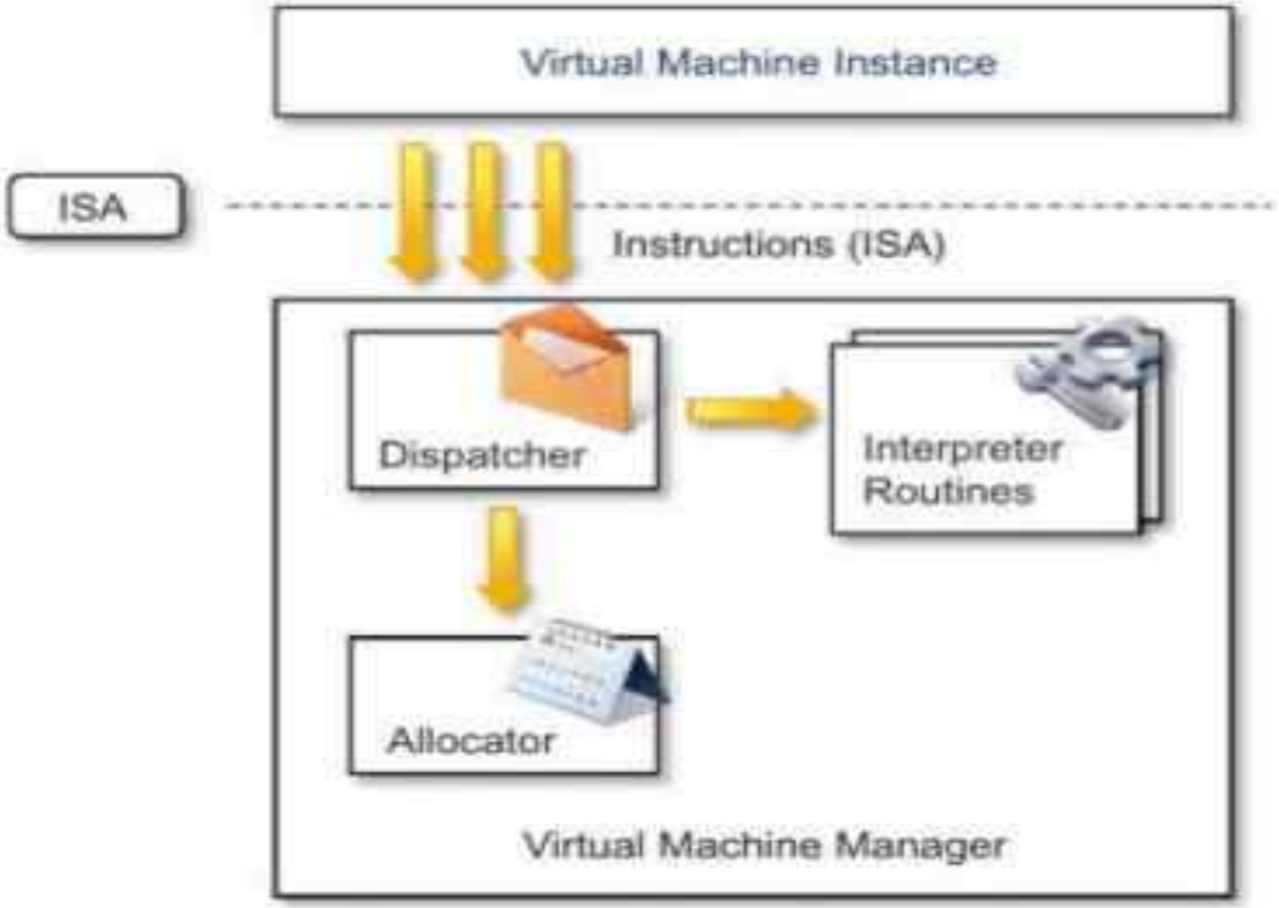


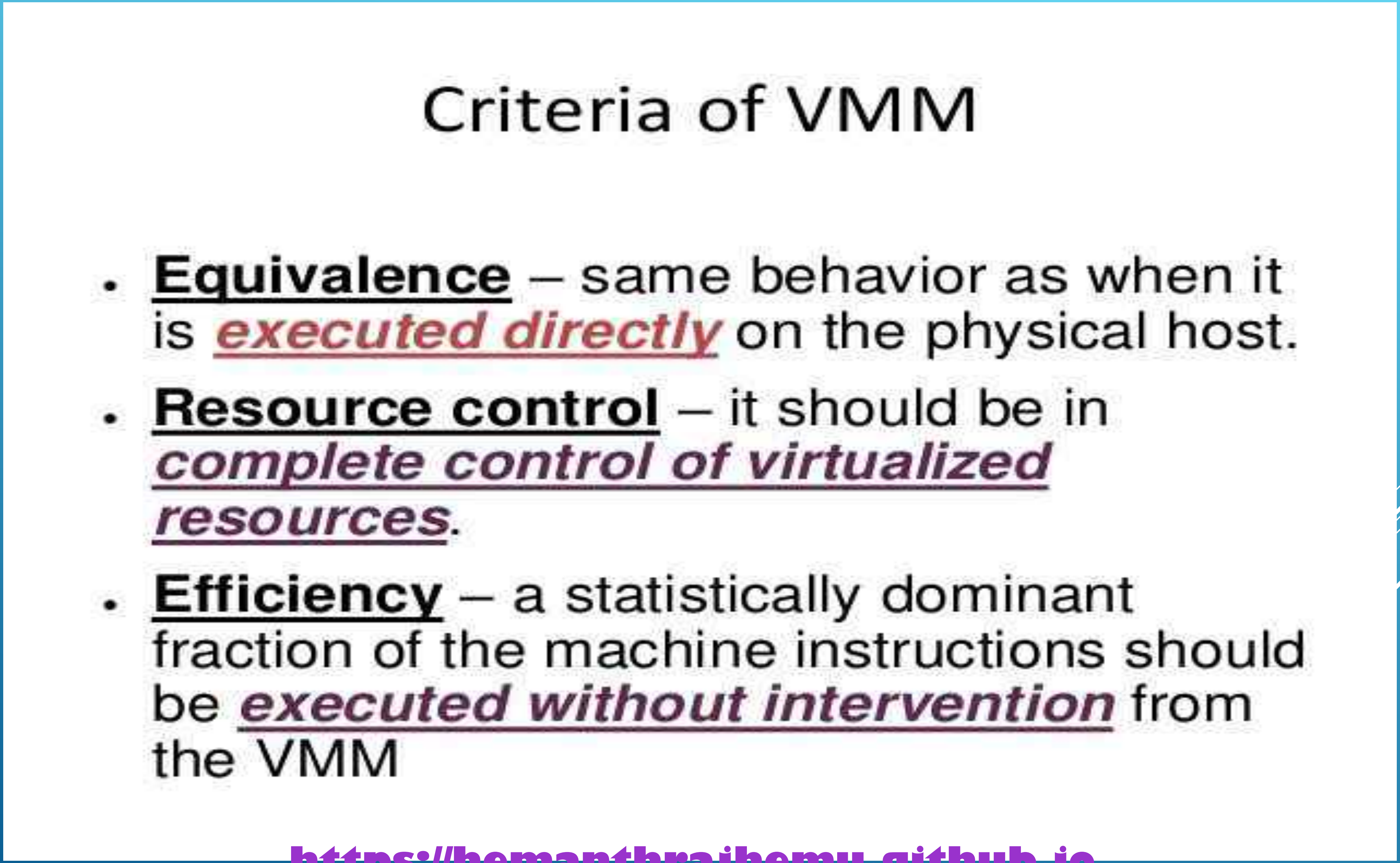


Virtual Machine Manager (VMM)

- Main Modules :-
  - **Dispatcher**
    - Entry Point of VMM
    - Reroutes the instructions issued by VM instance.
  - **Allocator**
    - Deciding the system resources to be provided to the VM.
    - Invoked by dispatcher
  - **Interpreter**
    - Consists of interpreter routines
    - Executed whenever a VM executes a privileged instruction.
    - Trap is triggered and the corresponding routine is executed.

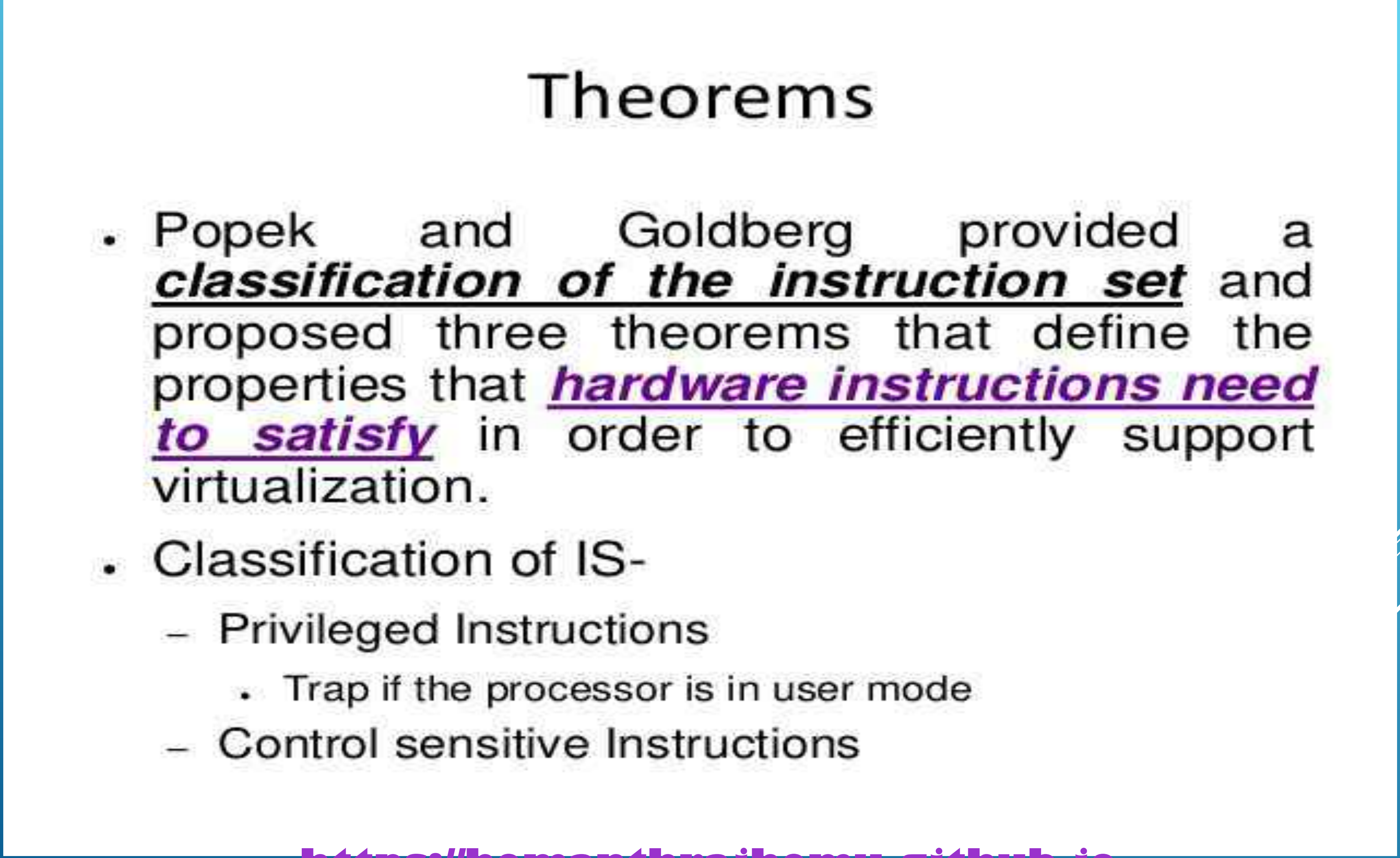
Virtual Machine Manager (VMM)





Criteria of VMM

- **Equivalence** – same behavior as when it is ***executed directly*** on the physical host.
- **Resource control** – it should be in ***complete control of virtualized resources***.
- **Efficiency** – a statistically dominant fraction of the machine instructions should be ***executed without intervention*** from the VMM

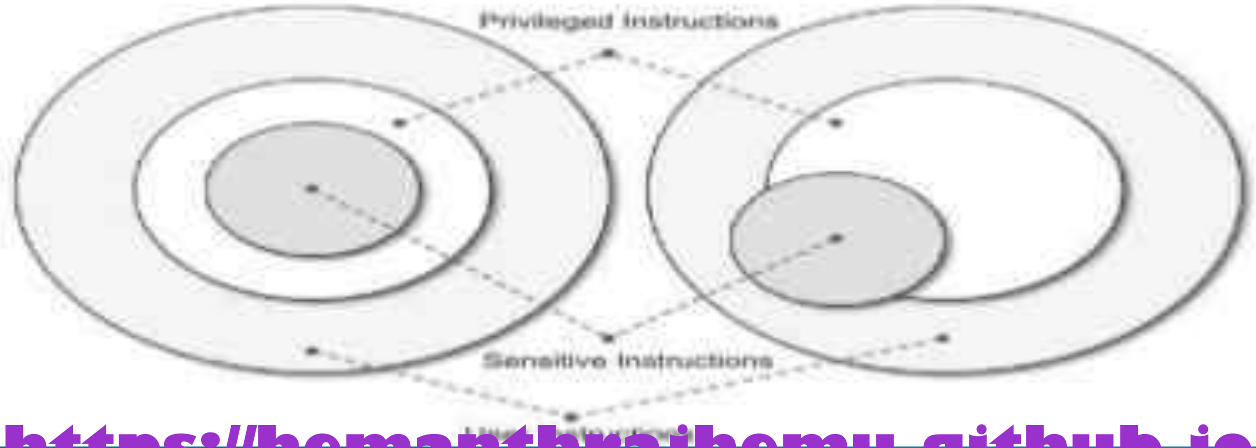


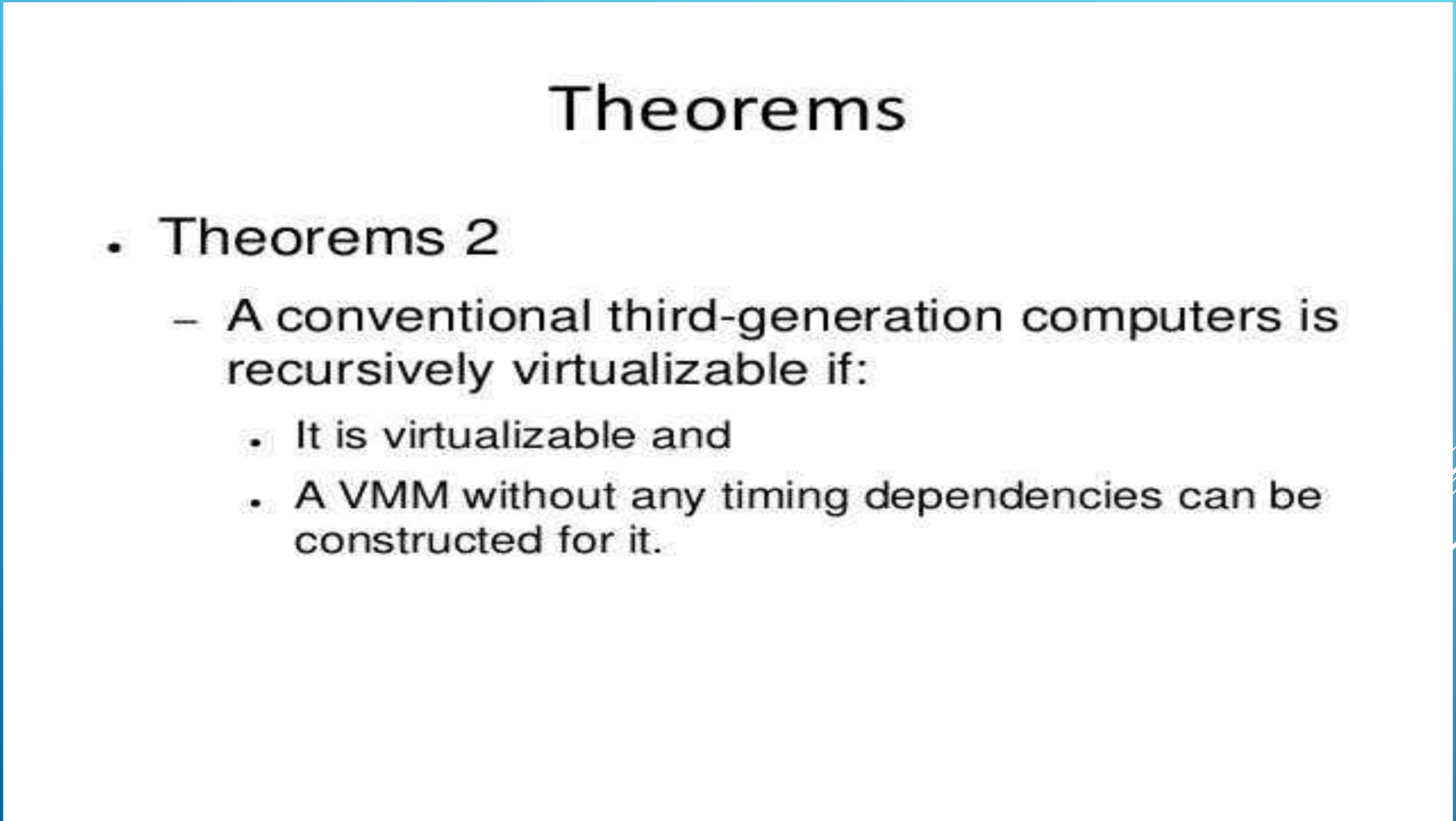
Theorems

- Popek and Goldberg provided a ***classification of the instruction set*** and proposed three theorems that define the properties that ***hardware instructions need to satisfy*** in order to efficiently support virtualization.
- Classification of IS-
  - Privileged Instructions
    - Trap if the processor is in user mode
  - Control sensitive Instructions

Theorems-1

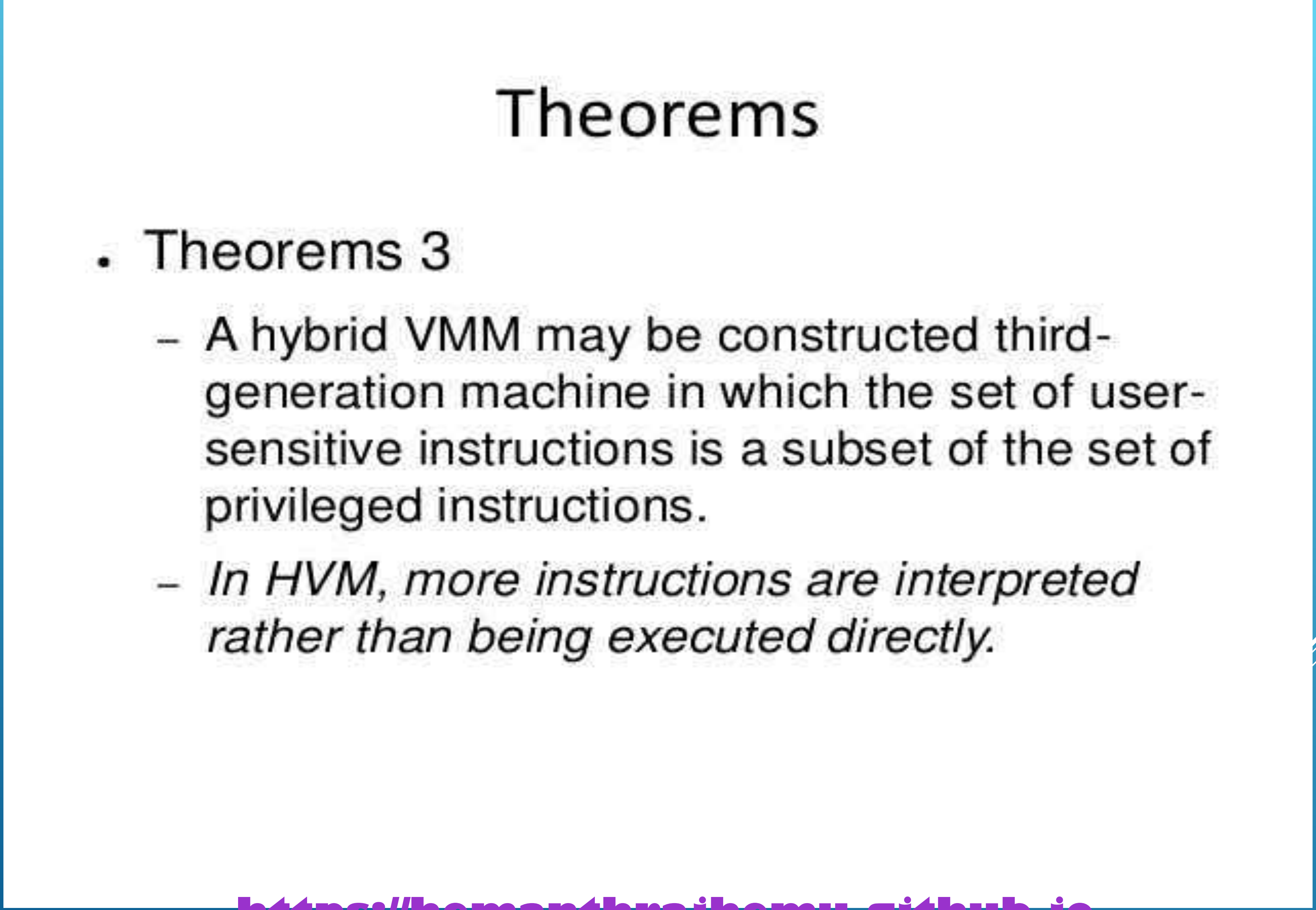
- Theorems 1
  - For any conventional third-generation computer, a VMM may be constructed if the set of sensitive instructions for that computer is a subset of the set of privileged instructions.





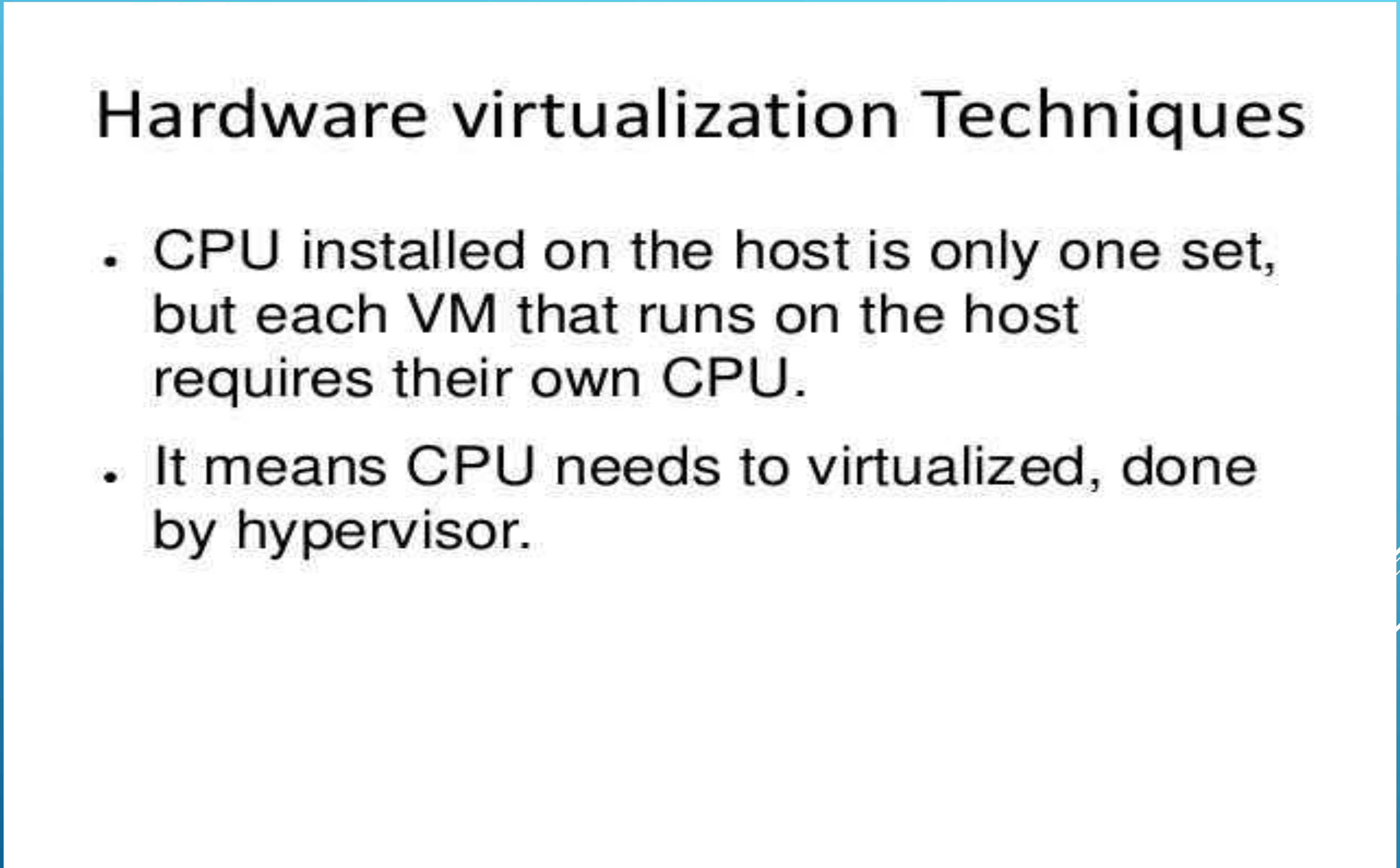
Theorems

- Theorems 2
  - A conventional third-generation computers is recursively virtualizable if:
    - It is virtualizable and
    - A VMM without any timing dependencies can be constructed for it.



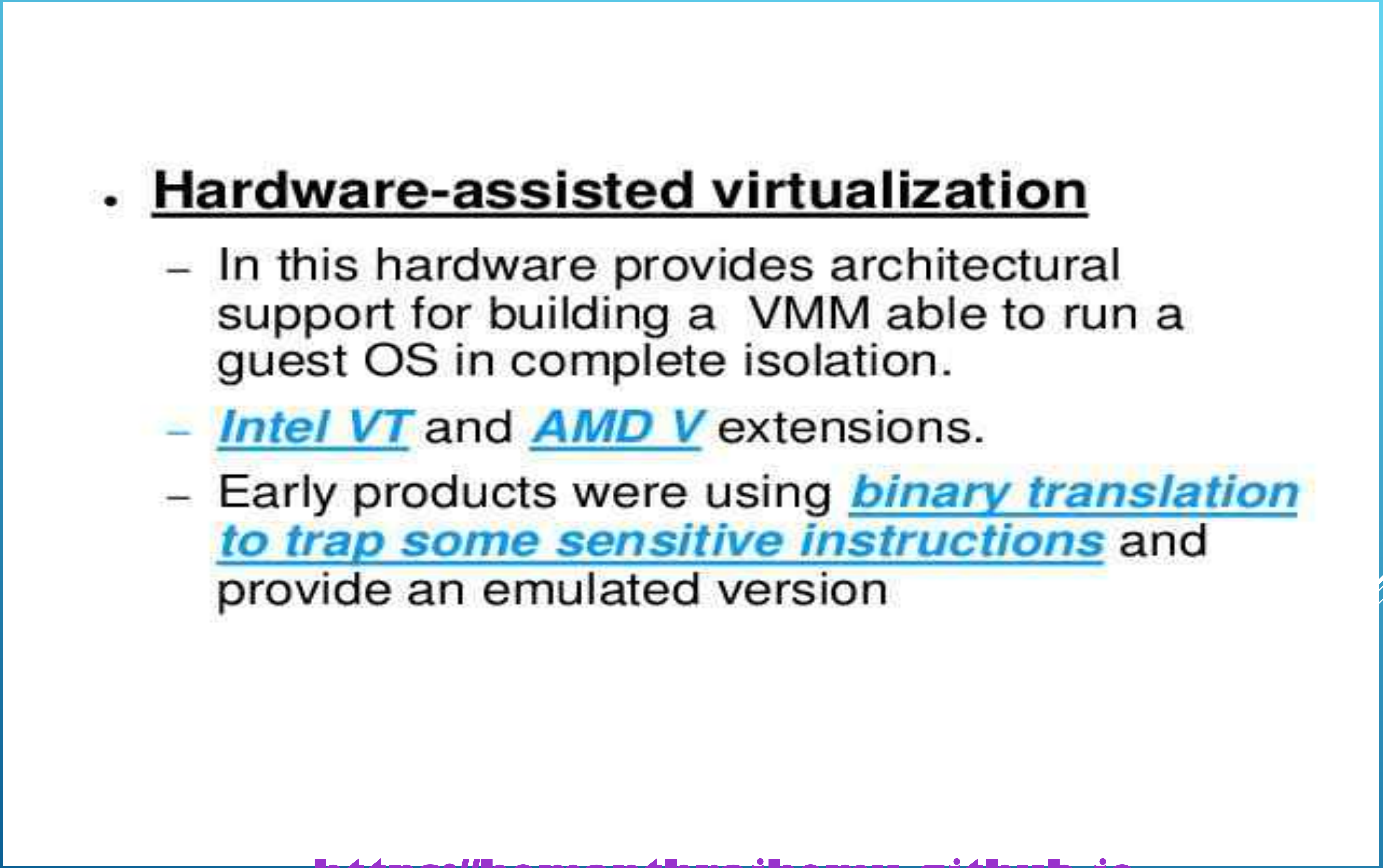
Theorems

- Theorems 3
  - A hybrid VMM may be constructed third-generation machine in which the set of user-sensitive instructions is a subset of the set of privileged instructions.
  - *In HVM, more instructions are interpreted rather than being executed directly.*

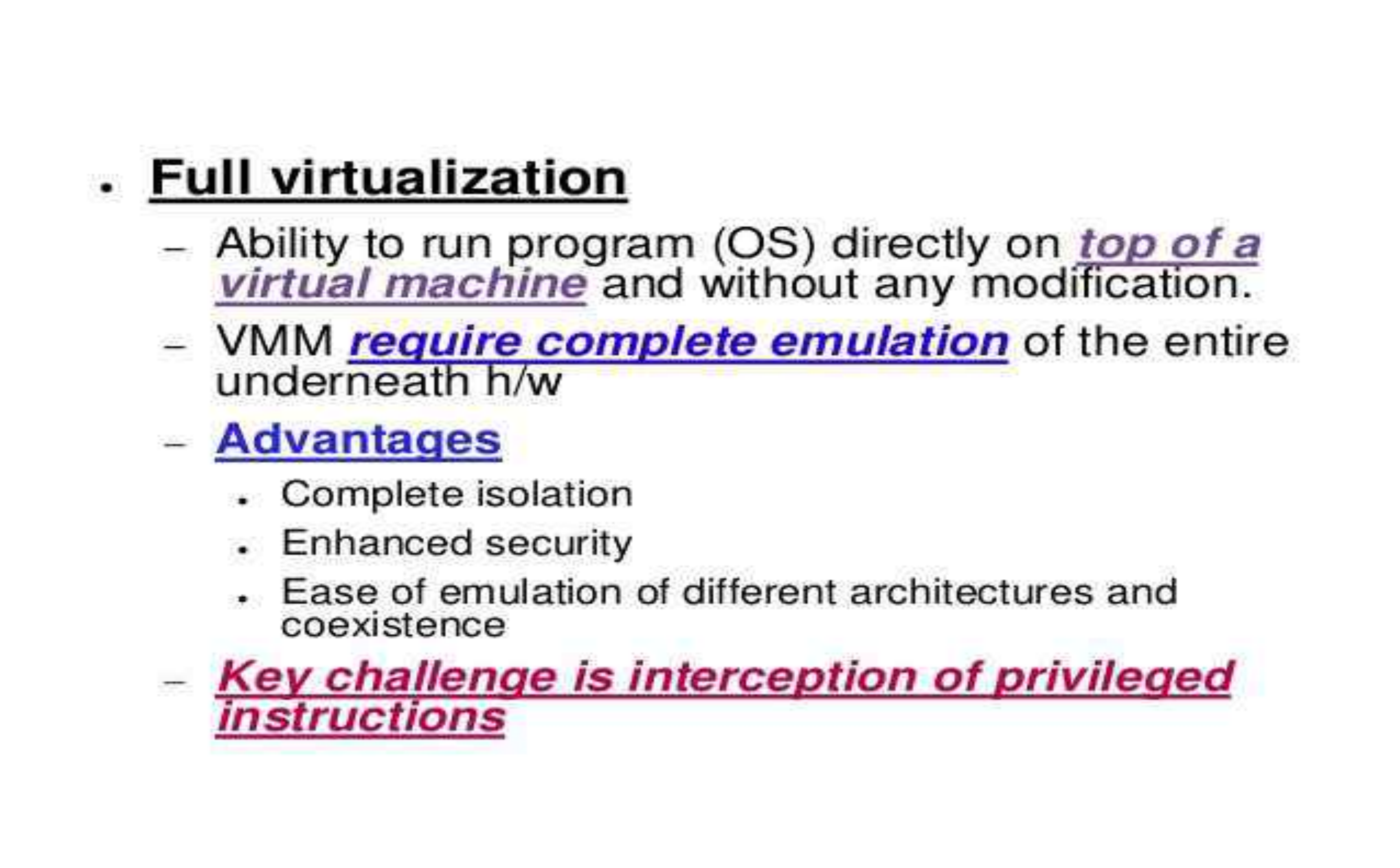


Hardware virtualization Techniques

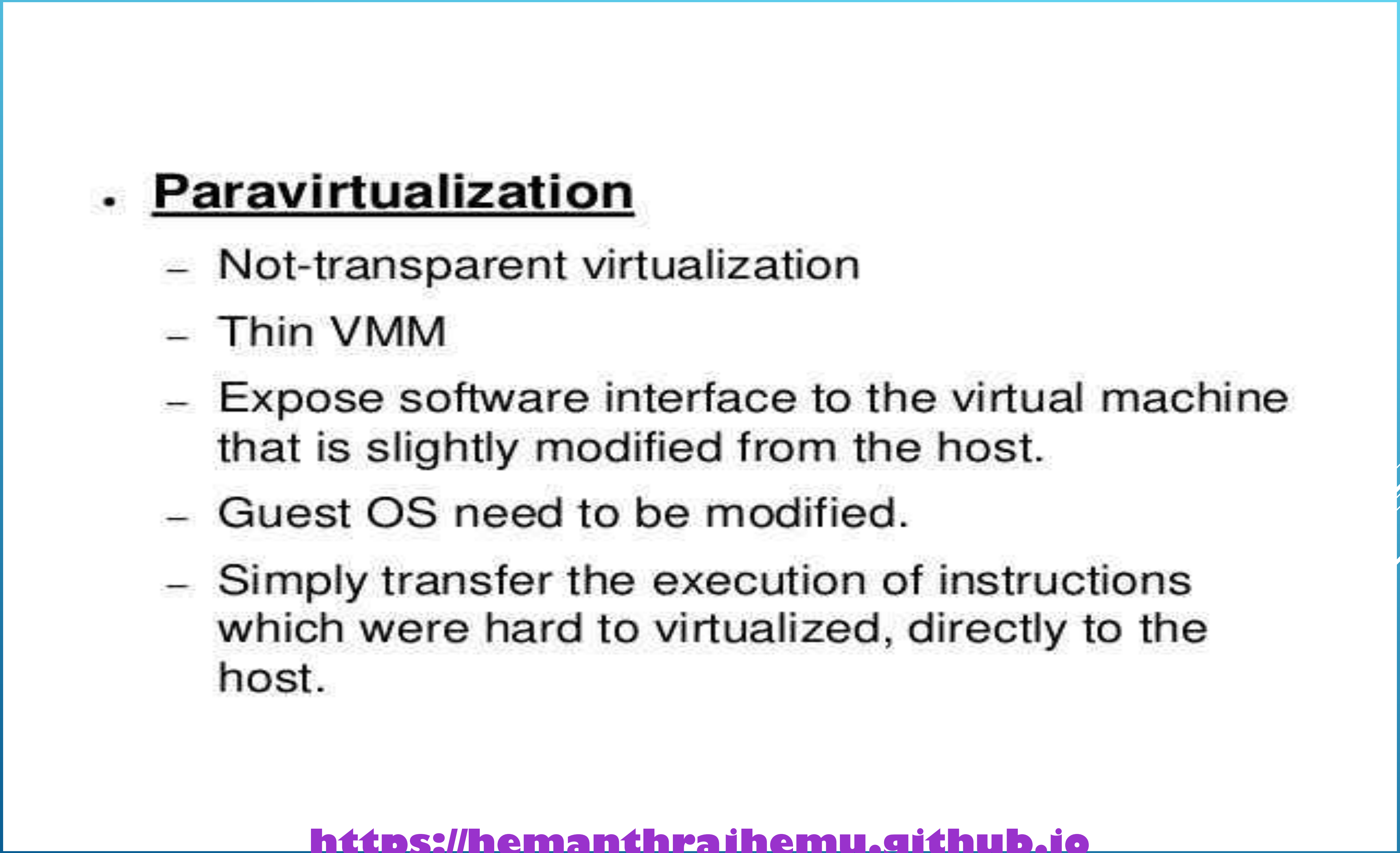
- CPU installed on the host is only one set, but each VM that runs on the host requires their own CPU.
- It means CPU needs to virtualized, done by hypervisor.



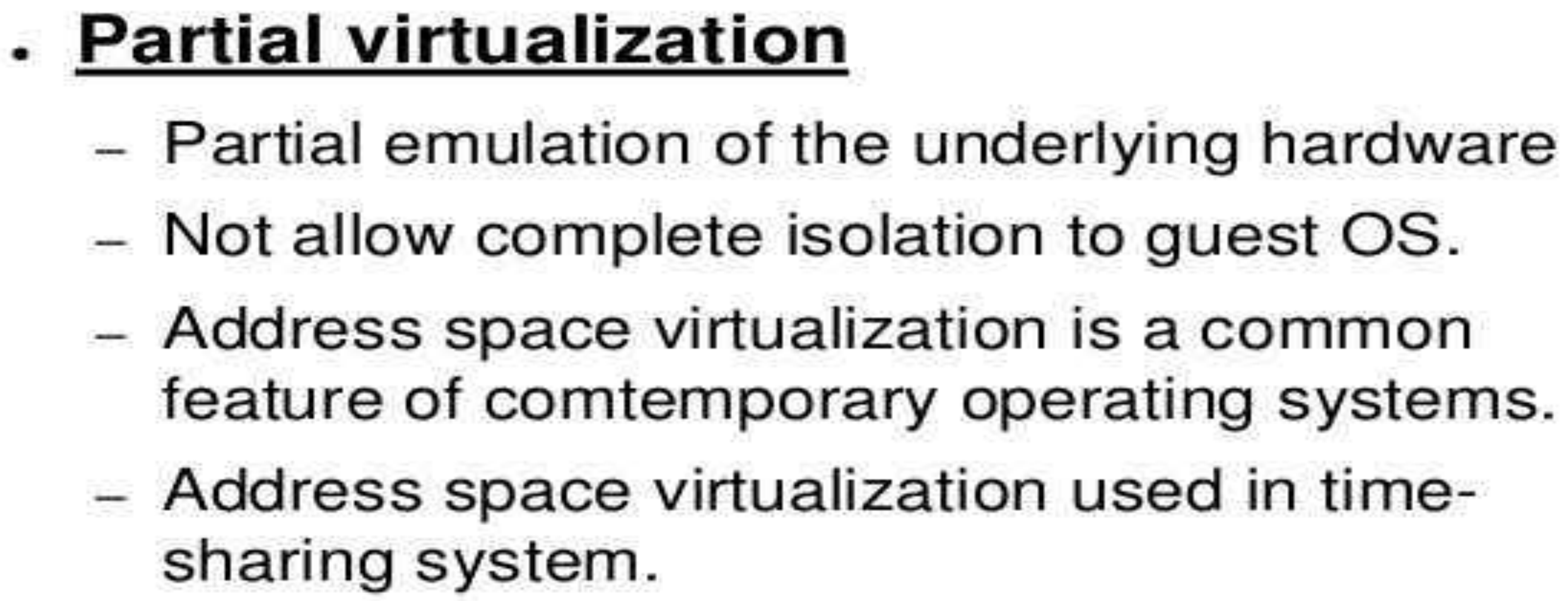
- **Hardware-assisted virtualization**
  - In this hardware provides architectural support for building a VMM able to run a guest OS in complete isolation.
  - *Intel VT* and *AMD V* extensions.
  - Early products were using *binary translation to trap some sensitive instructions* and provide an emulated version



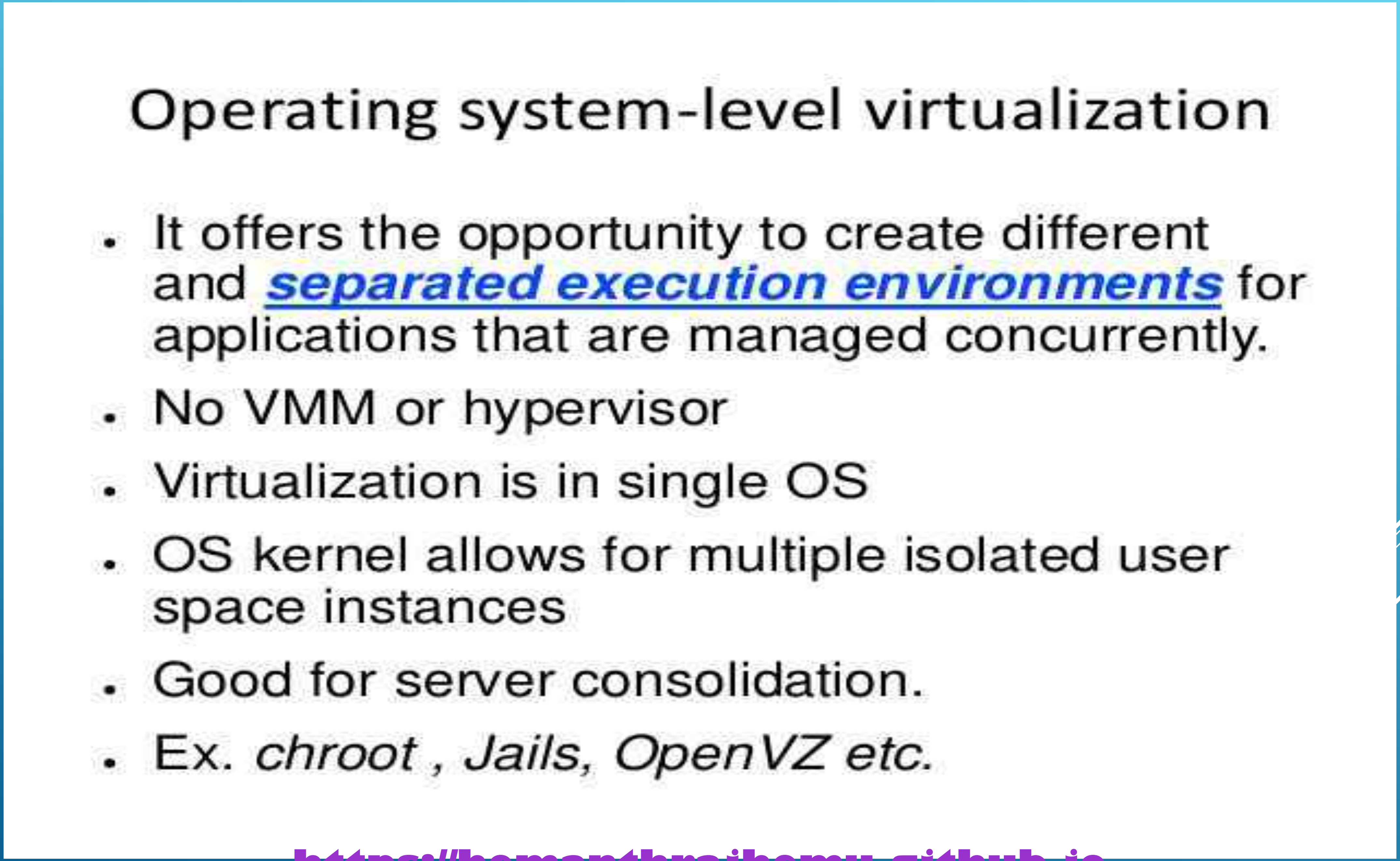
- **Full virtualization**
  - Ability to run program (OS) directly on ***top of a virtual machine*** and without any modification.
  - VMM ***require complete emulation*** of the entire underneath h/w
  - **Advantages**
    - Complete isolation
    - Enhanced security
    - Ease of emulation of different architectures and coexistence
  - ***Key challenge is interception of privileged instructions***



- **Paravirtualization**
  - Not-transparent virtualization
  - Thin VMM
  - Expose software interface to the virtual machine that is slightly modified from the host.
  - Guest OS need to be modified.
  - Simply transfer the execution of instructions which were hard to virtualized, directly to the host.

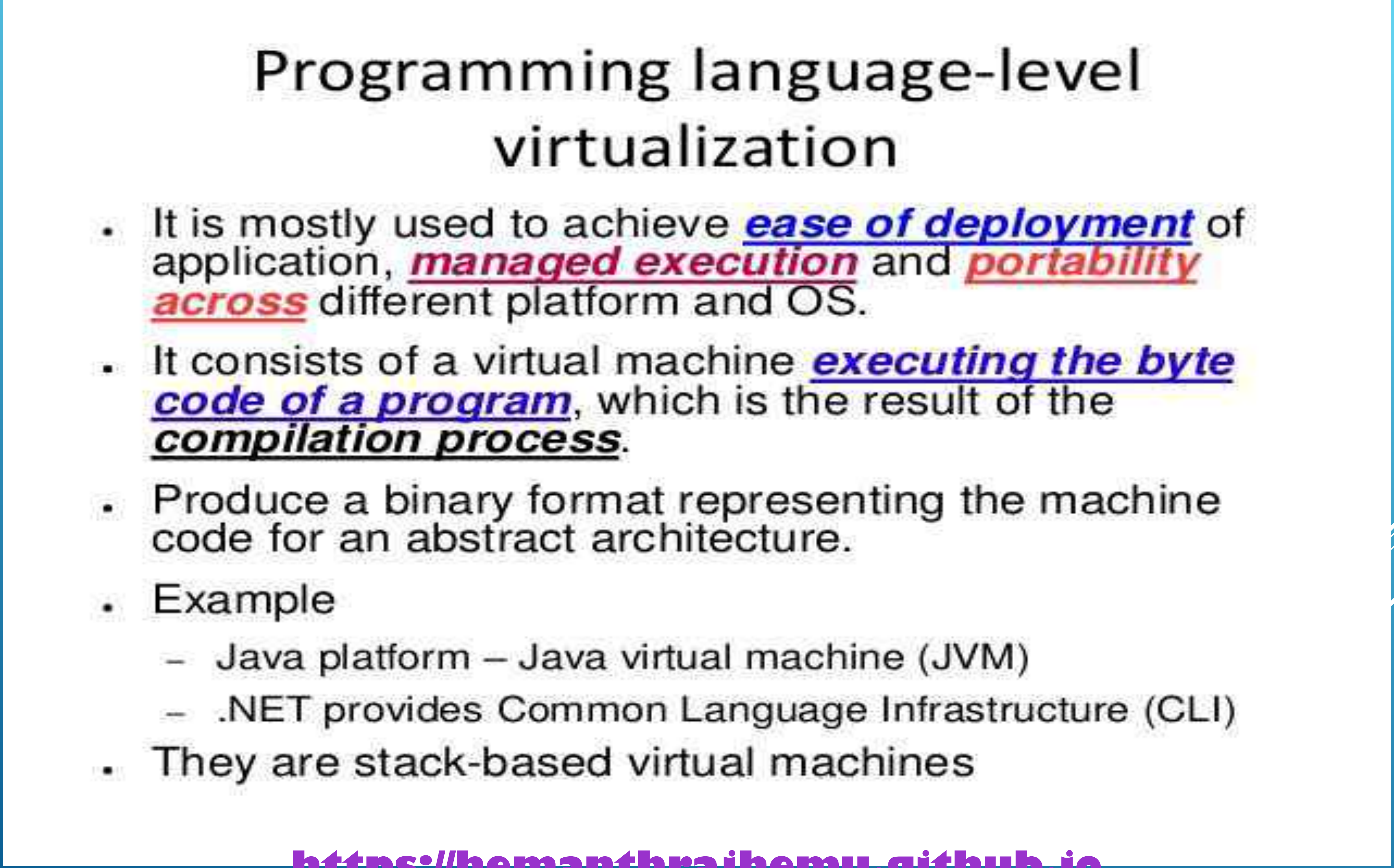


- **Partial virtualization**
  - Partial emulation of the underlying hardware
  - Not allow complete isolation to guest OS.
  - Address space virtualization is a common feature of comtemporary operating systems.
  - Address space virtualization used in time-sharing system.



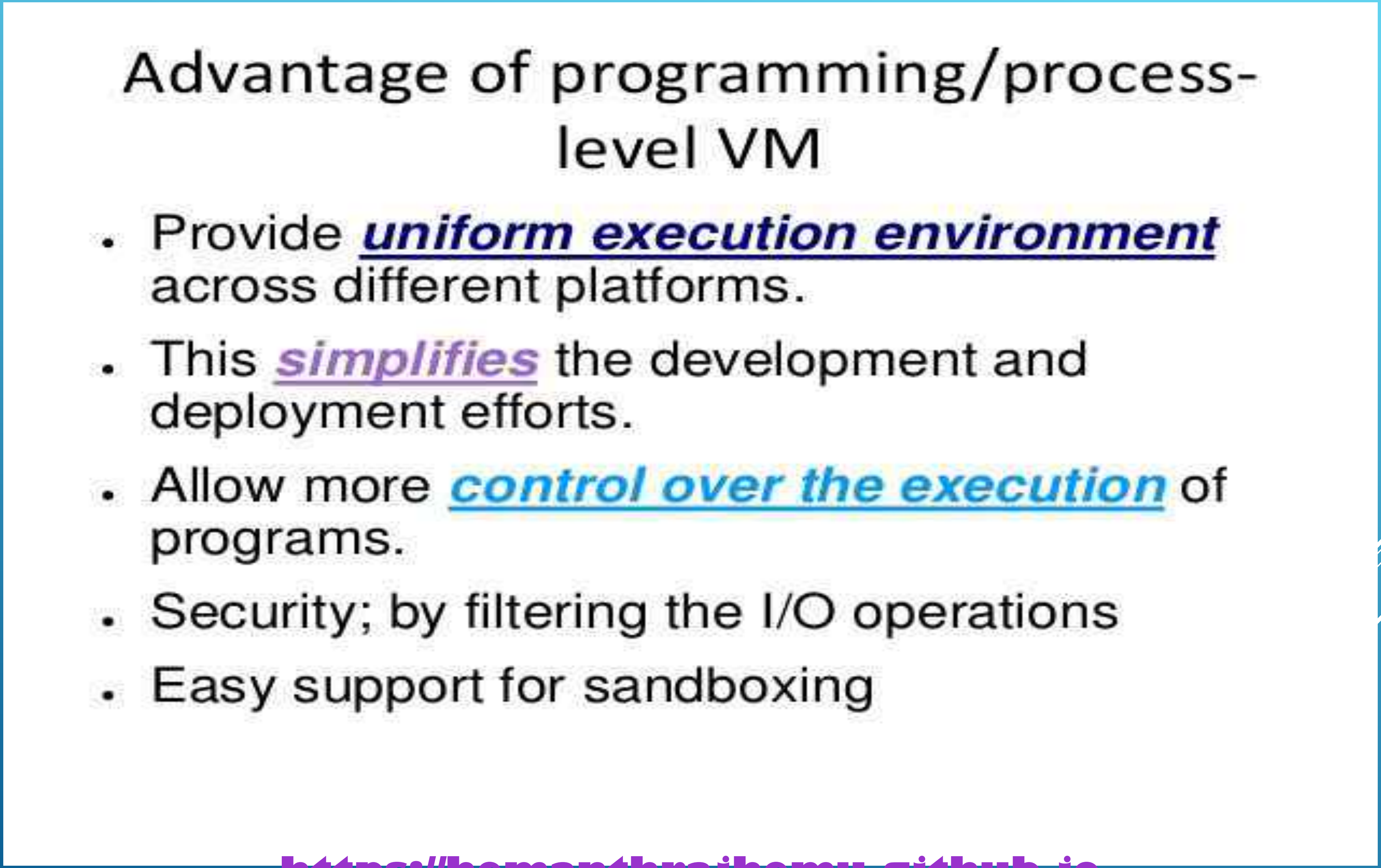
Operating system-level virtualization

- It offers the opportunity to create different and *separated execution environments* for applications that are managed concurrently.
- No VMM or hypervisor
- Virtualization is in single OS
- OS kernel allows for multiple isolated user space instances
- Good for server consolidation.
- Ex. *chroot , Jails, OpenVZ etc.*



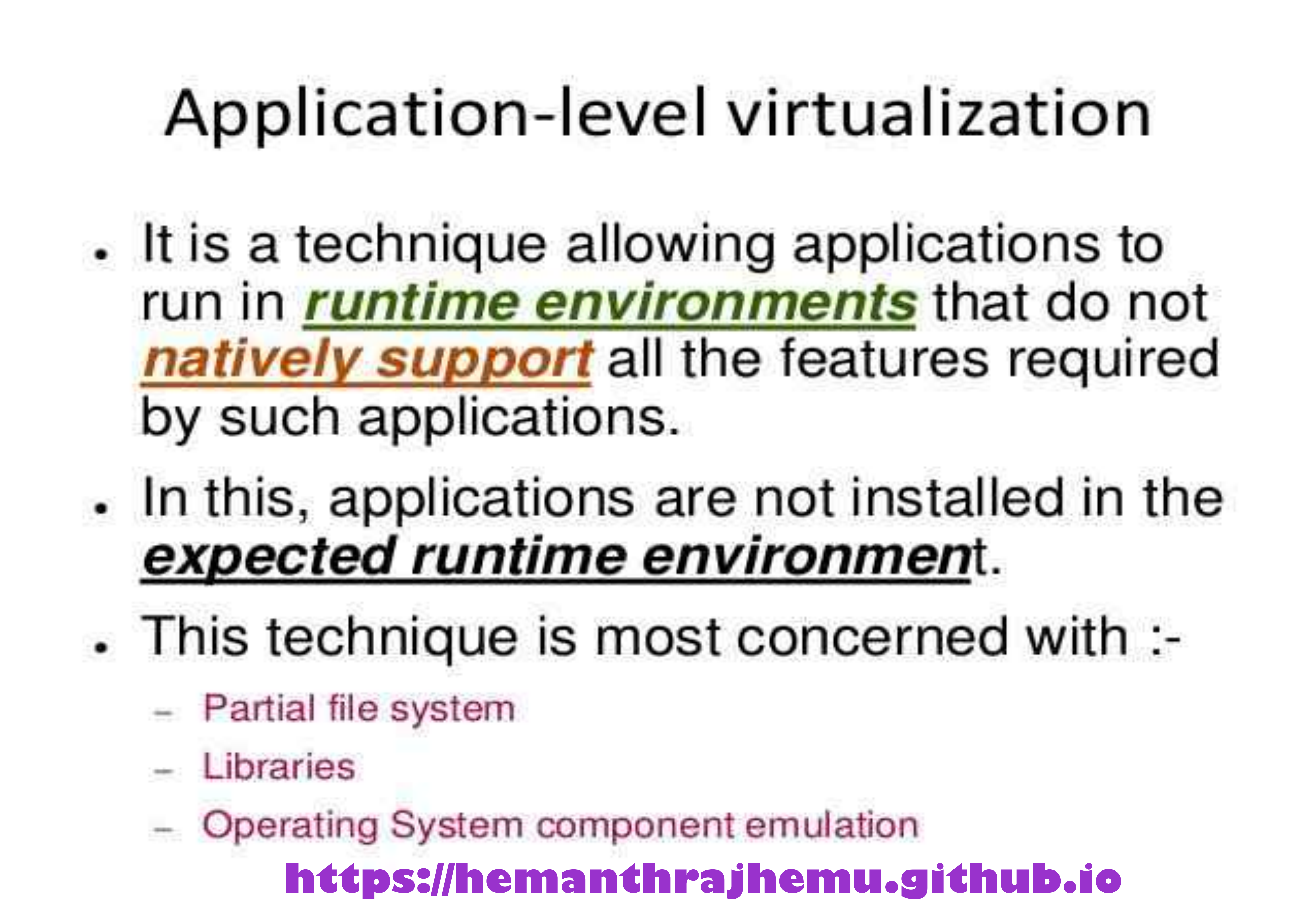
Programming language-level virtualization

- It is mostly used to achieve ***ease of deployment*** of application, ***managed execution*** and ***portability across*** different platform and OS.
- It consists of a virtual machine ***executing the byte code of a program***, which is the result of the ***compilation process***.
- Produce a binary format representing the machine code for an abstract architecture.
- Example
  - Java platform – Java virtual machine (JVM)
  - .NET provides Common Language Infrastructure (CLI)
- They are stack-based virtual machines



Advantage of programming/process-level VM

- Provide ***uniform execution environment*** across different platforms.
- This ***simplifies*** the development and deployment efforts.
- Allow more ***control over the execution*** of programs.
- Security; by filtering the I/O operations
- Easy support for sandboxing



Application-level virtualization

- It is a technique allowing applications to run in ***runtime environments*** that do not ***natively support*** all the features required by such applications.
- In this, applications are not installed in the ***expected runtime environment***.
- This technique is most concerned with :-
  - Partial file system
  - Libraries
  - Operating System component emulation

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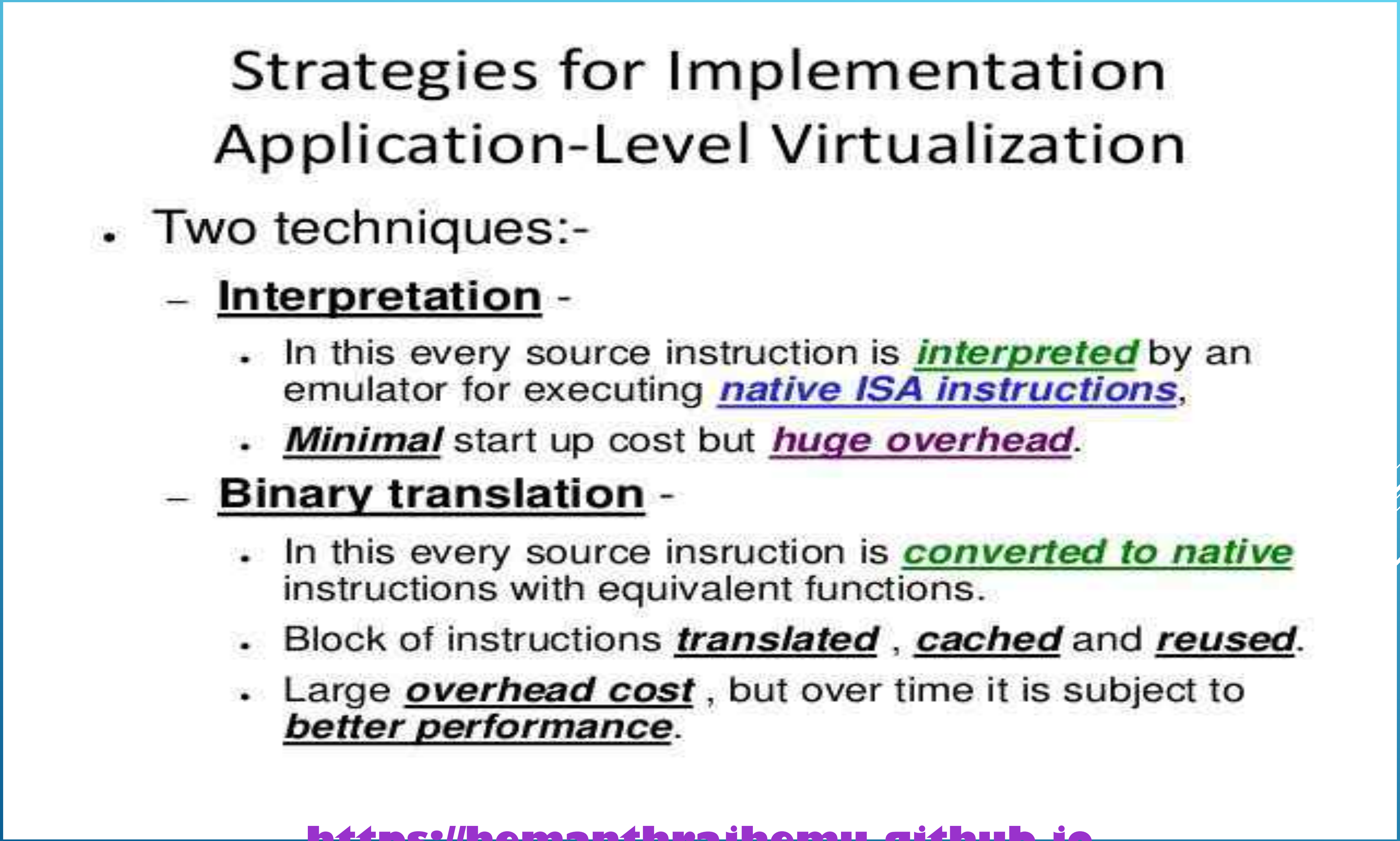
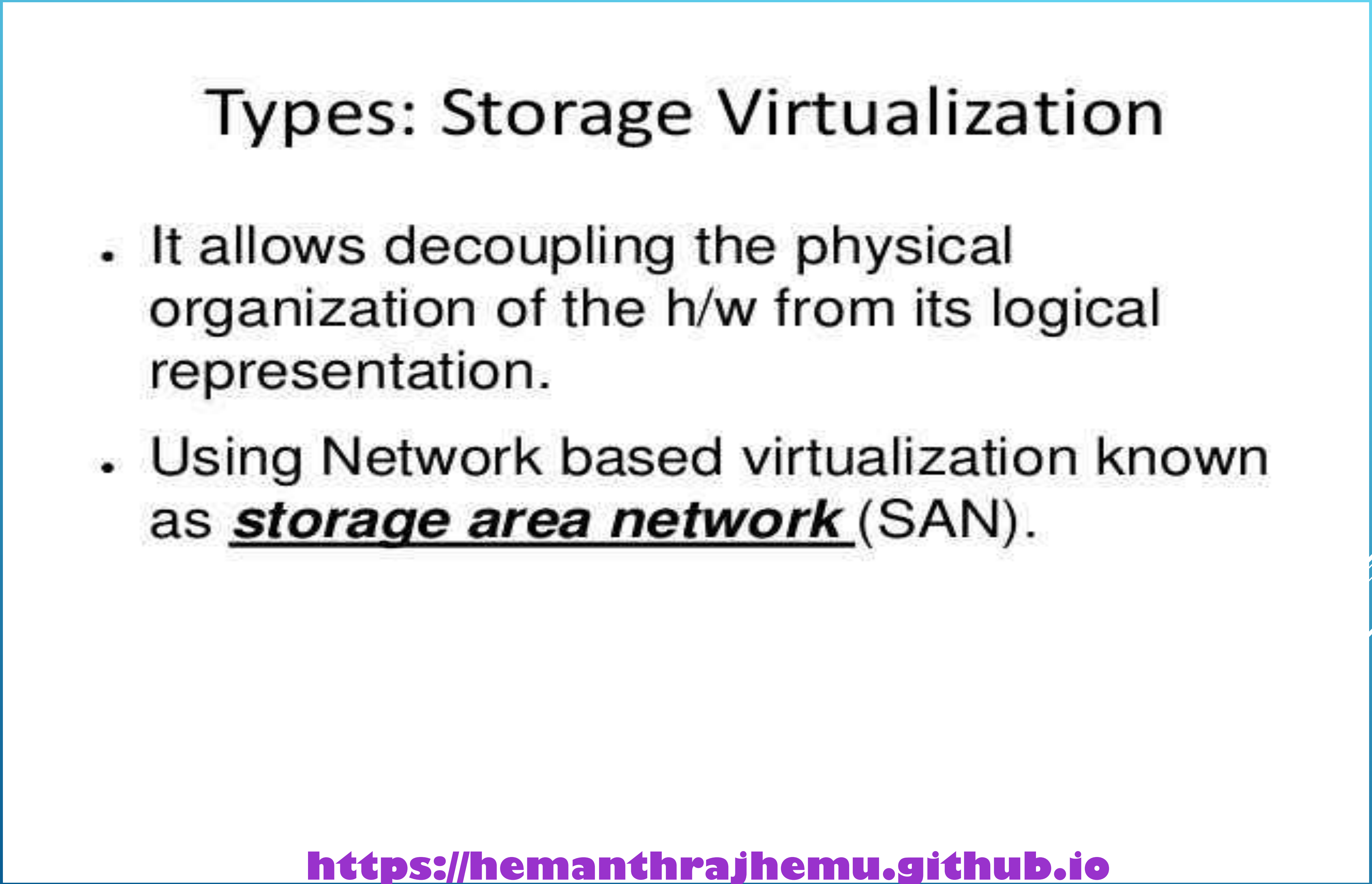


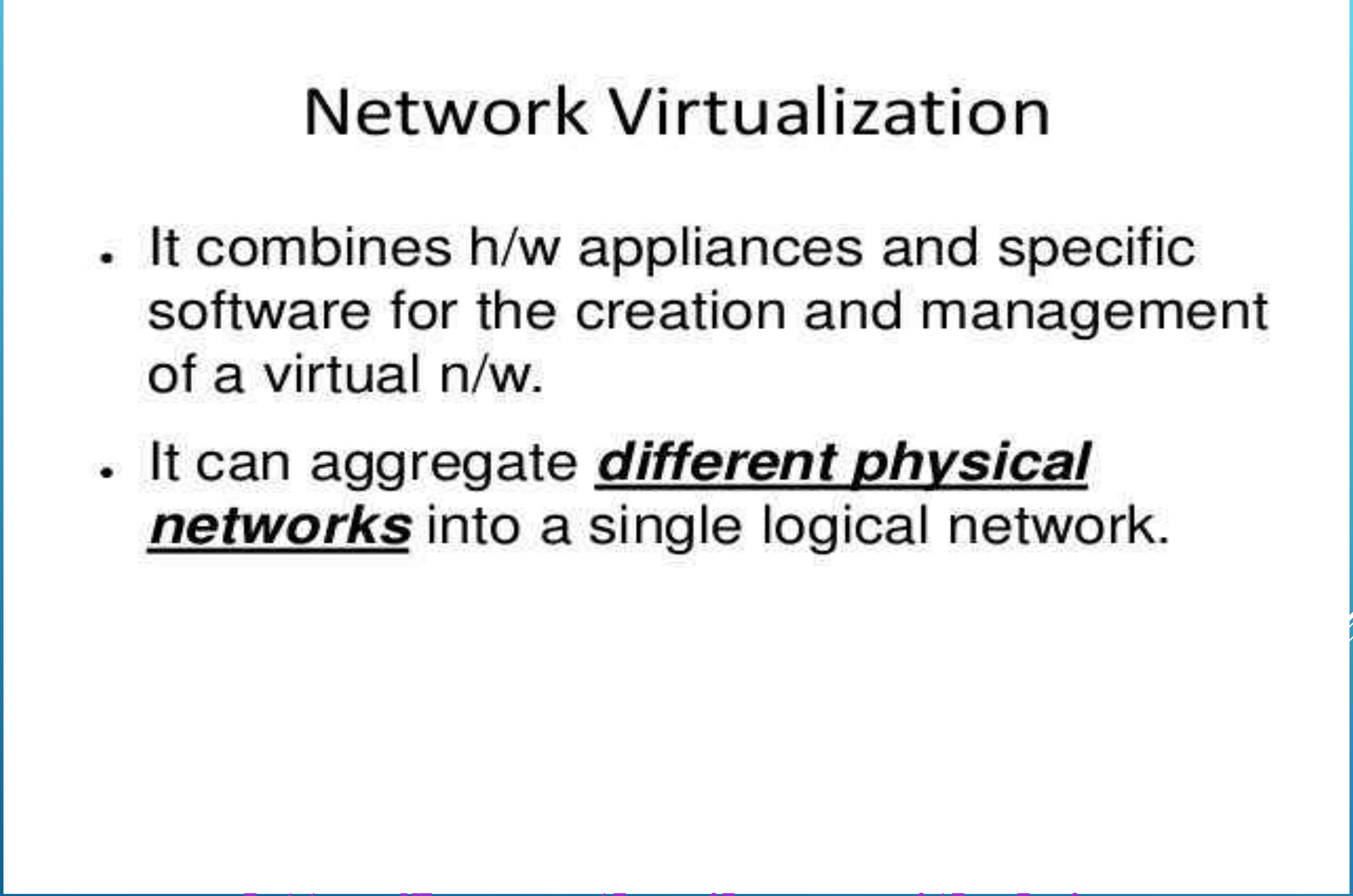
Strategies for Implementation Application-Level Virtualization

- Two techniques:-
  - **Interpretation** -
    - In this every source instruction is ***interpreted*** by an emulator for executing ***native ISA instructions***,
    - ***Minimal*** start up cost but ***huge overhead***.
  - **Binary translation** -
    - In this every source insruction is ***converted to native*** instructions with equivalent functions.
    - Block of instructions ***translated*** , ***cached*** and ***reused***.
    - Large ***overhead cost*** , but over time it is subject to ***better performance***.



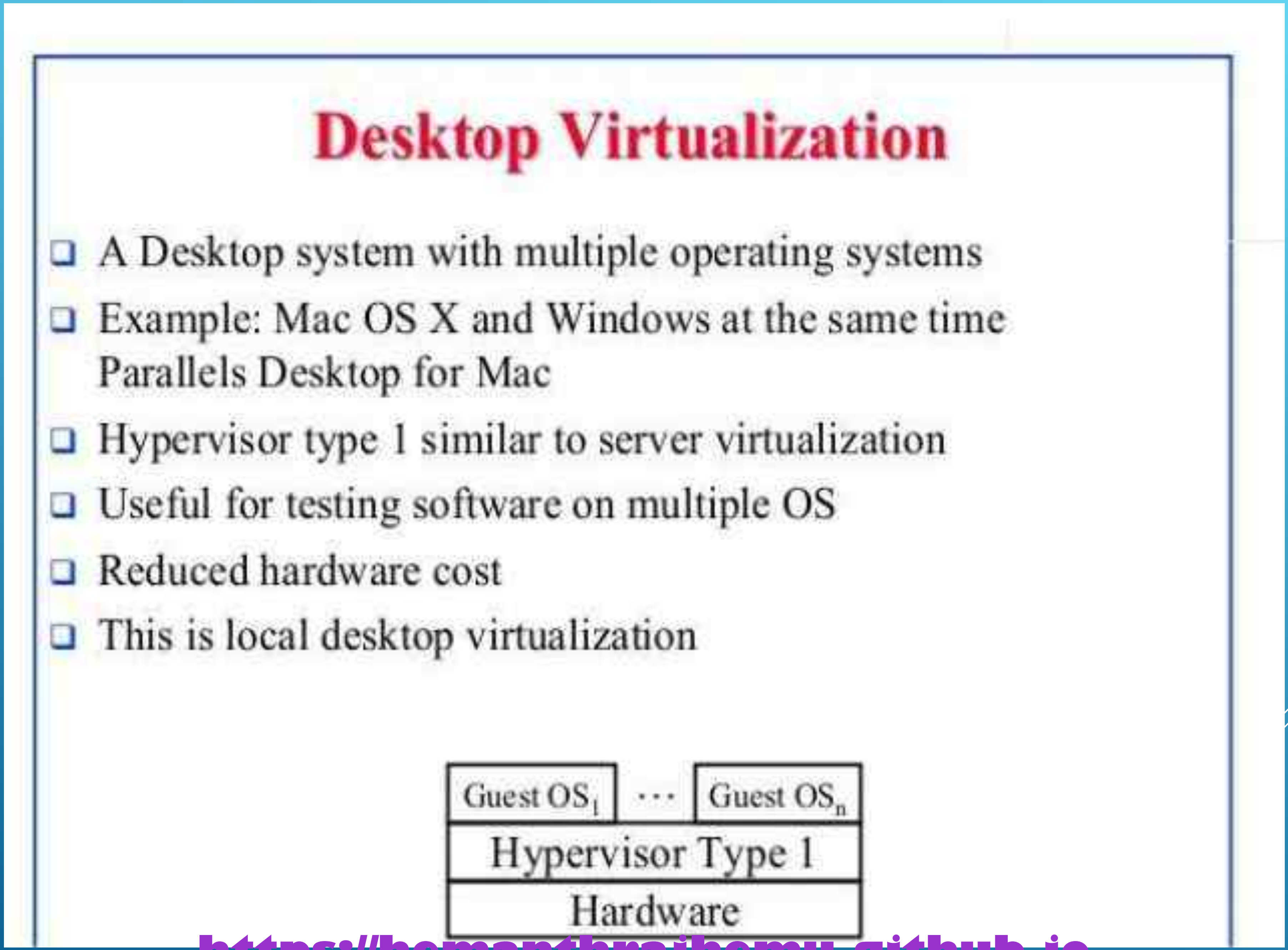
Types: Storage Virtualization

- It allows decoupling the physical organization of the h/w from its logical representation.
- Using Network based virtualization known as ***storage area network*** (SAN).



Network Virtualization

- It combines h/w appliances and specific software for the creation and management of a virtual n/w.
- It can aggregate ***different physical networks*** into a single logical network.



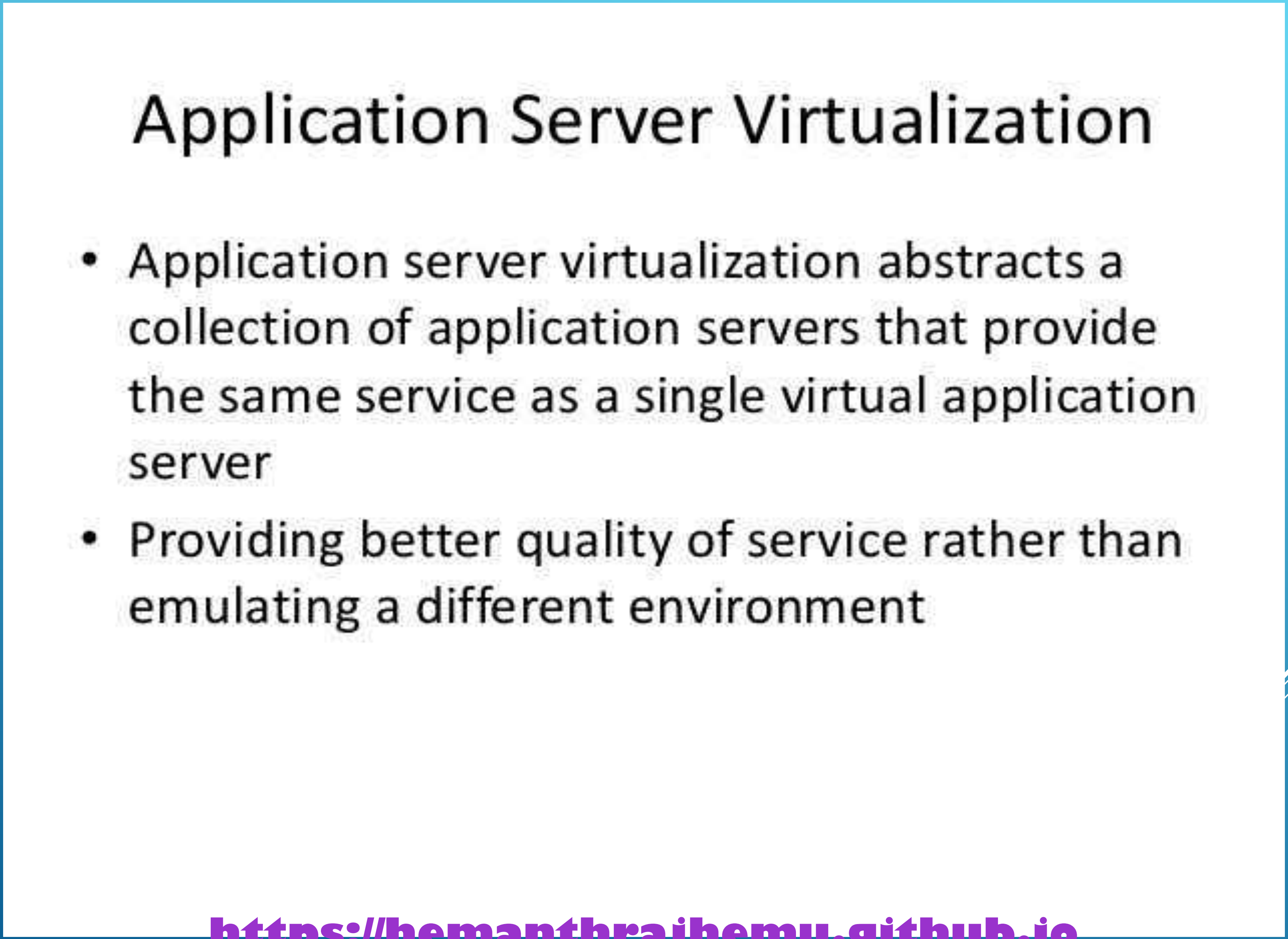
Desktop Virtualization

- A Desktop system with multiple operating systems
- Example: Mac OS X and Windows at the same time Parallels Desktop for Mac
- Hypervisor type 1 similar to server virtualization
- Useful for testing software on multiple OS
- Reduced hardware cost
- This is local desktop virtualization

Guest OS$_1$ · · · Guest OS$_n$

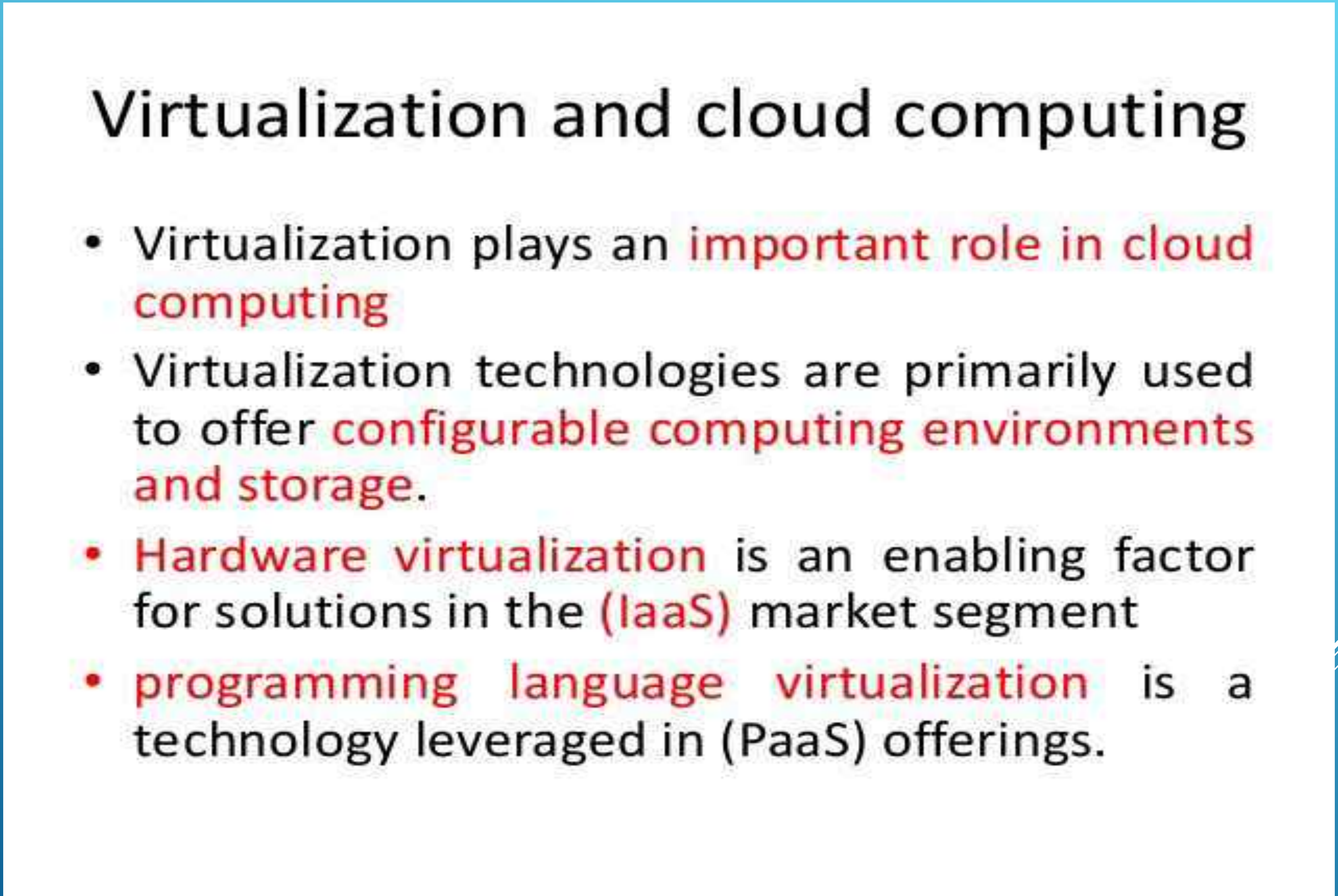
Hypervisor Type 1

Hardware



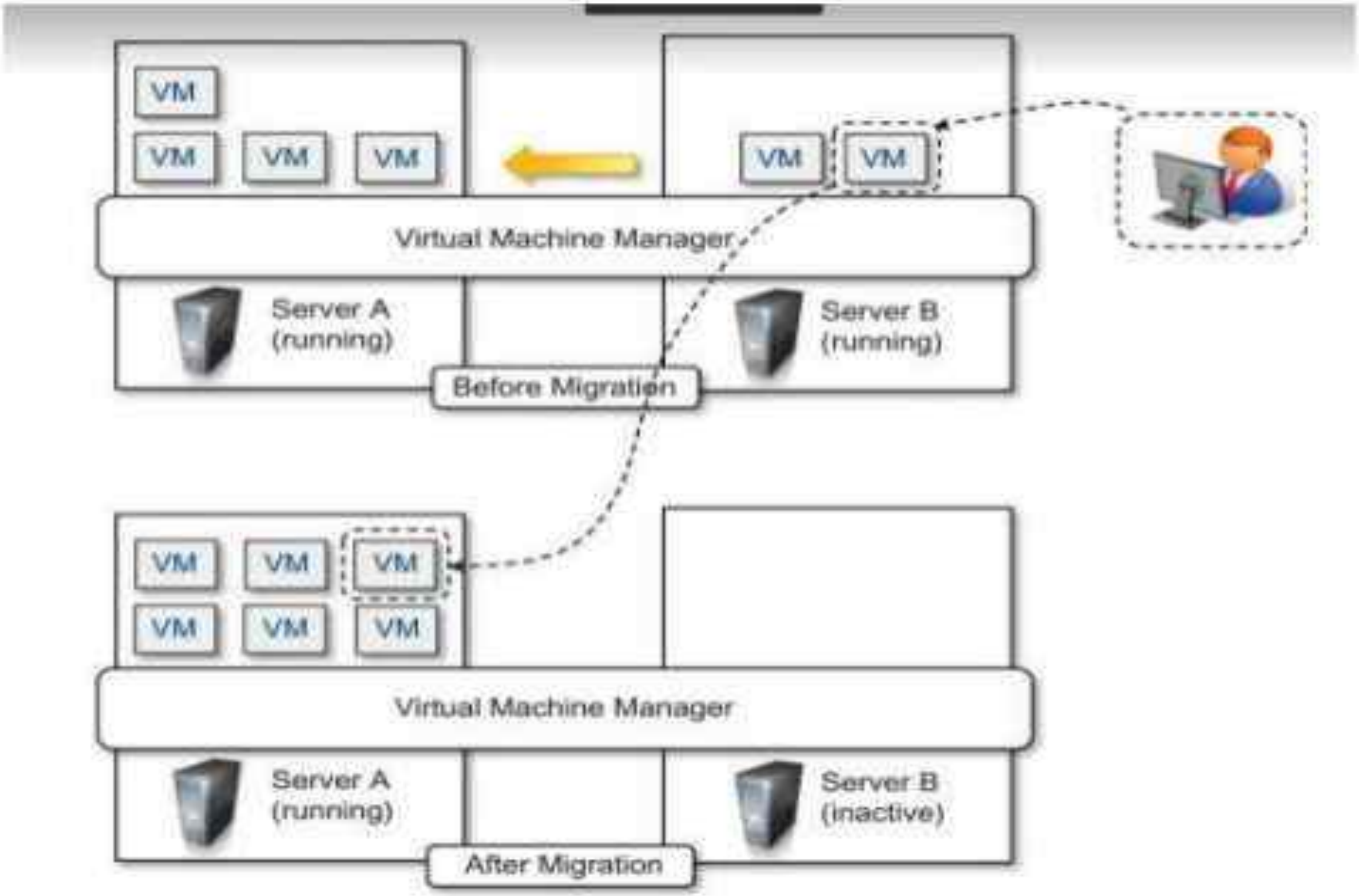
Application Server Virtualization

- Application server virtualization abstracts a collection of application servers that provide the same service as a single virtual application server
- Providing better quality of service rather than emulating a different environment

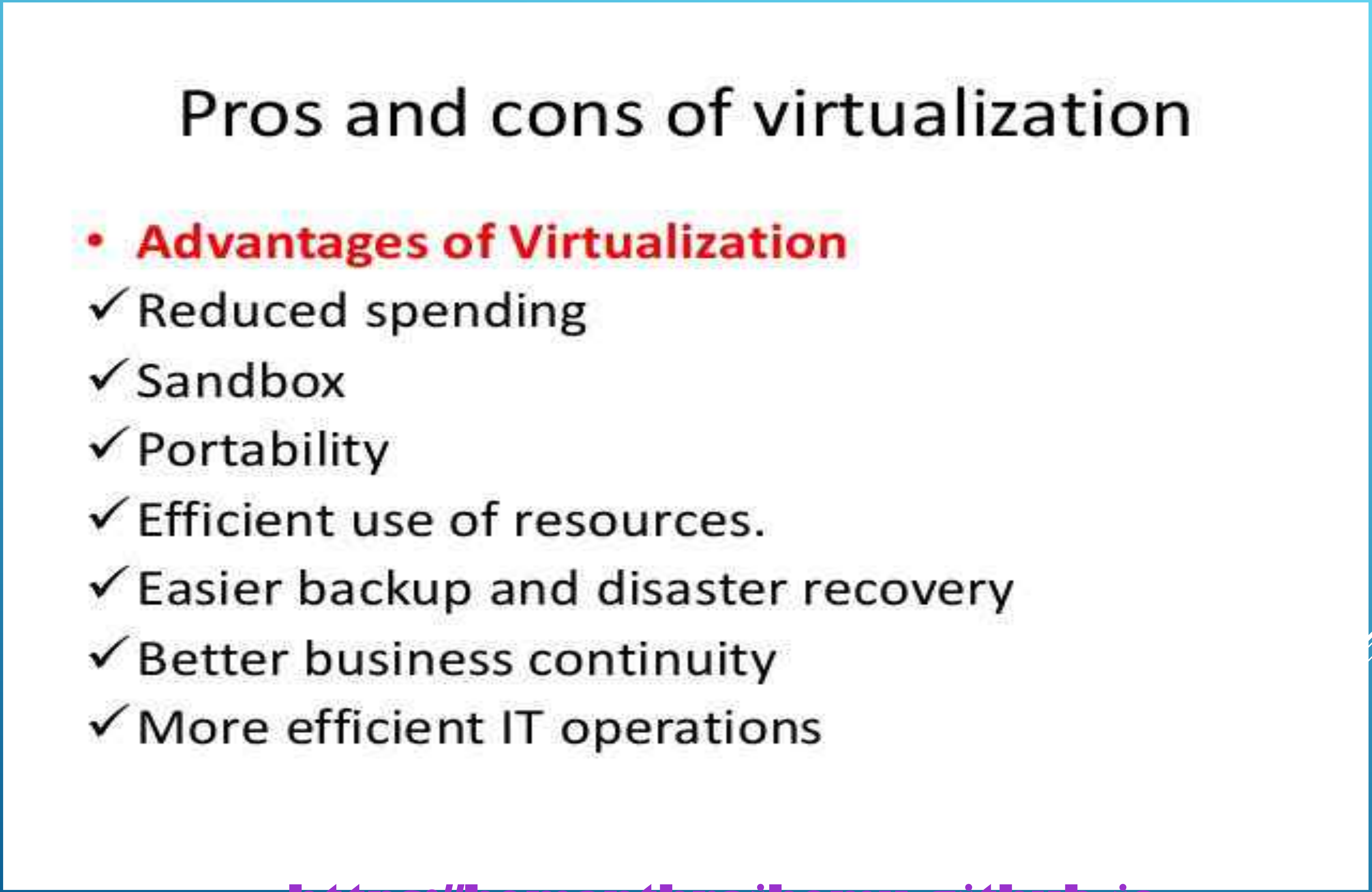


Virtualization and cloud computing

- Virtualization plays an important role in cloud computing
- Virtualization technologies are primarily used to offer configurable computing environments and storage.
- Hardware virtualization is an enabling factor for solutions in the (IaaS) market segment
- programming language virtualization is a technology leveraged in (PaaS) offerings.



Server consolidation and virtual machine migration



Pros and cons of virtualization

- **Advantages of Virtualization**

✓ Reduced spending

✓ Sandbox

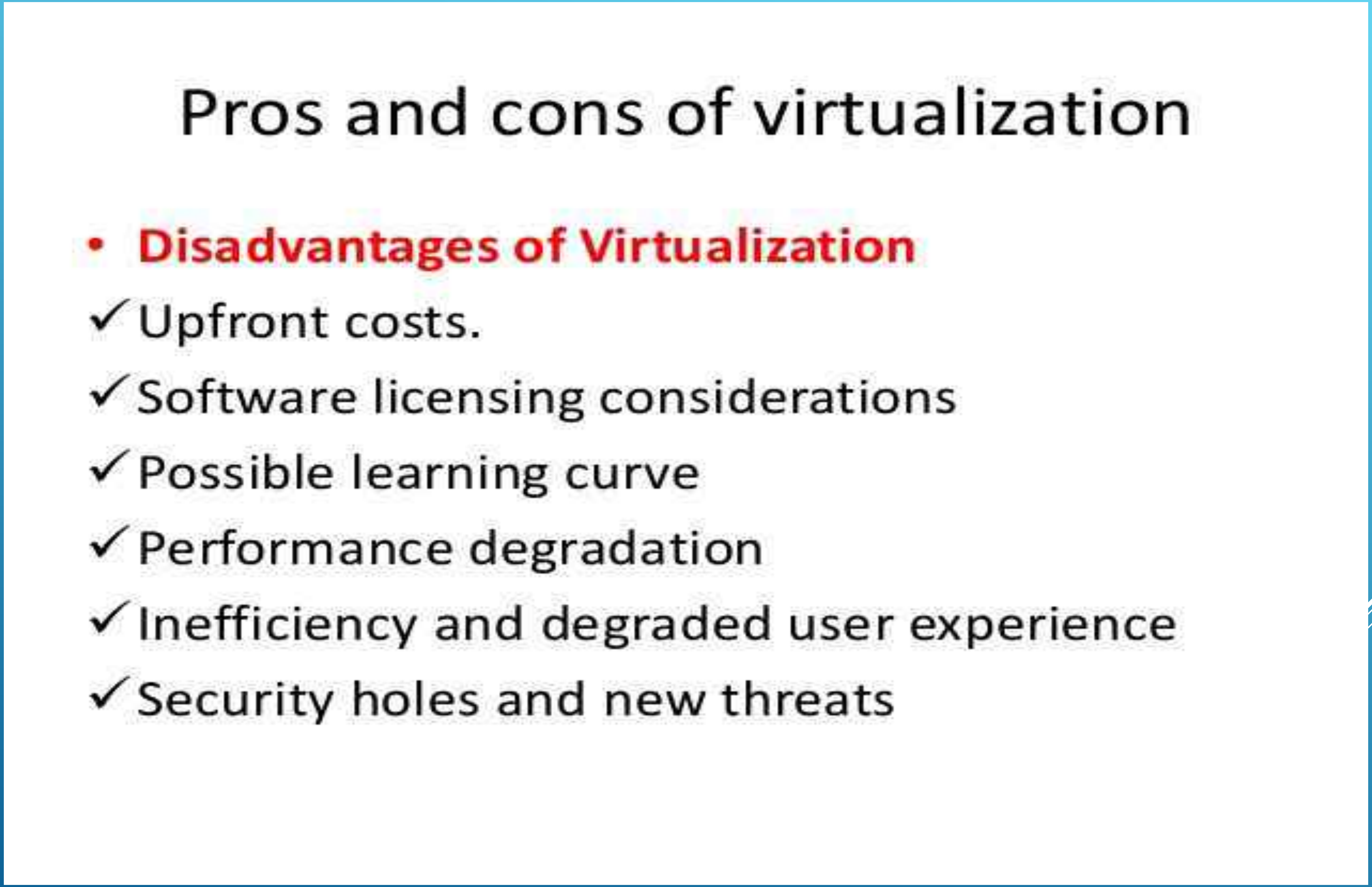
✓ Portability

✓ Efficient use of resources.

✓ Easier backup and disaster recovery

✓ Better business continuity

✓ More efficient IT operations



Pros and cons of virtualization

- **Disadvantages of Virtualization**

✓ Upfront costs.

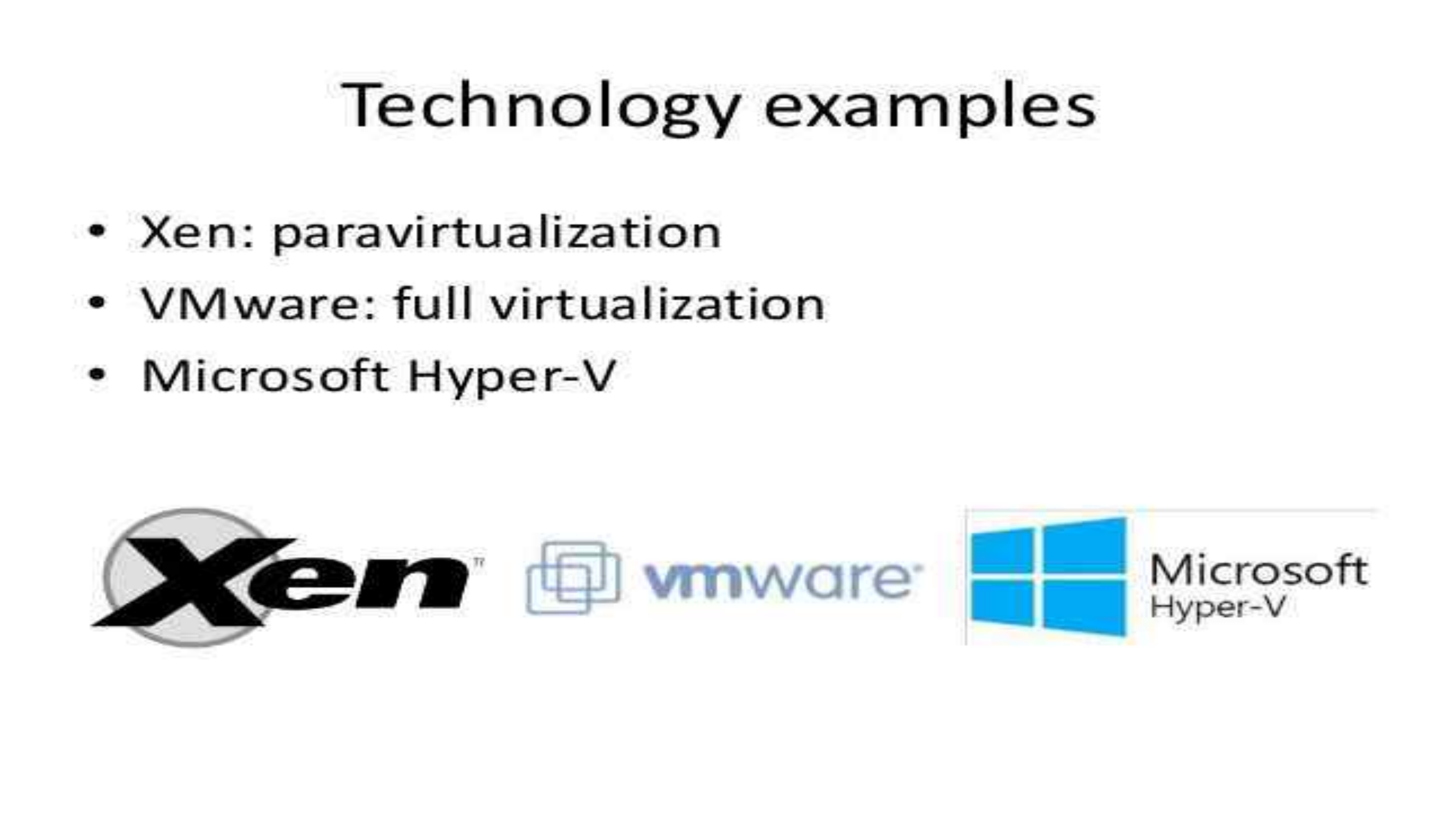
✓ Software licensing considerations

✓ Possible learning curve

✓ Performance degradation

✓ Inefficiency and degraded user experience

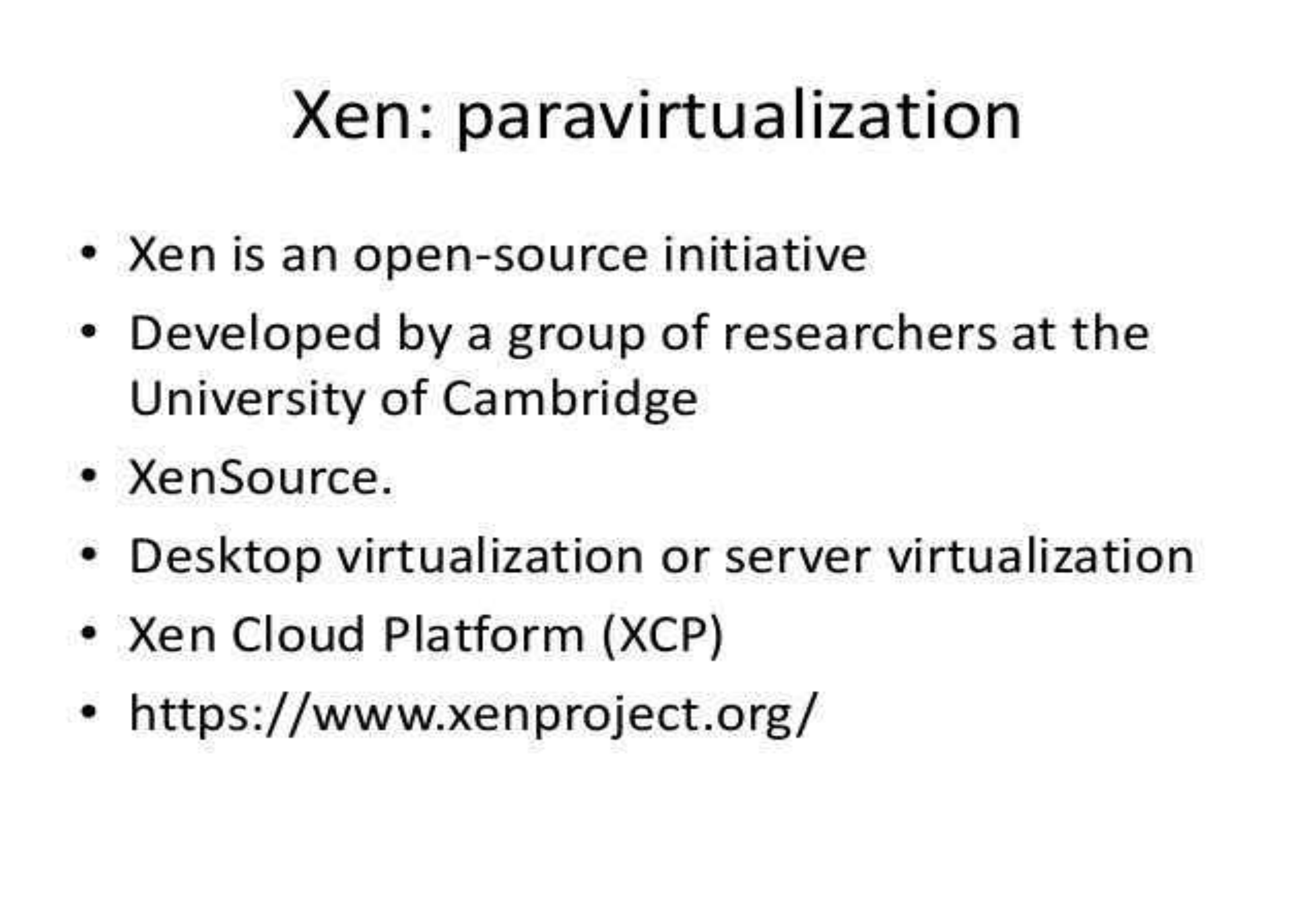
✓ Security holes and new threats



Technology examples

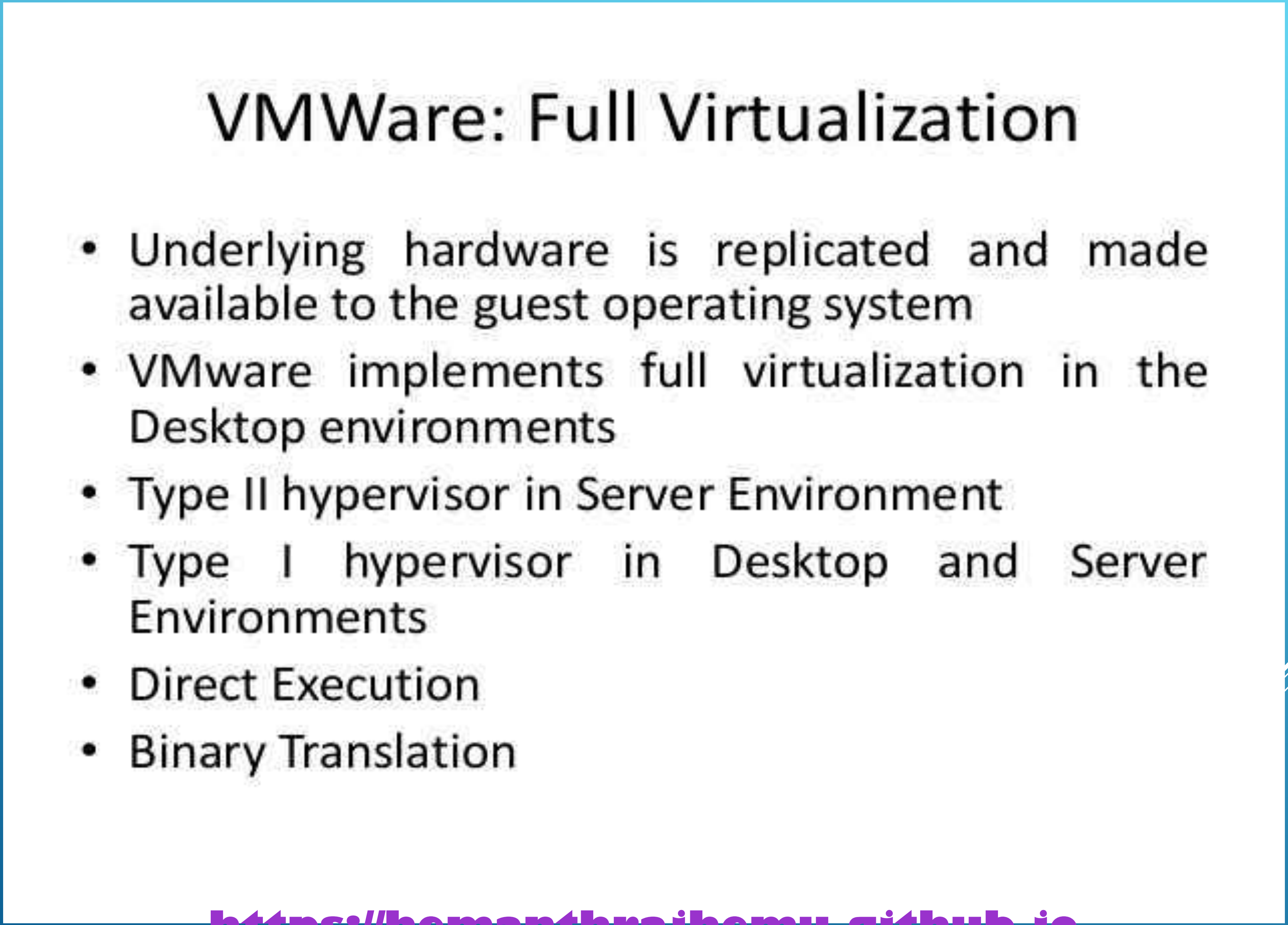
- Xen: paravirtualization
- VMware: full virtualization
- Microsoft Hyper-V

Xen
vmware
Microsoft
Hyper-V



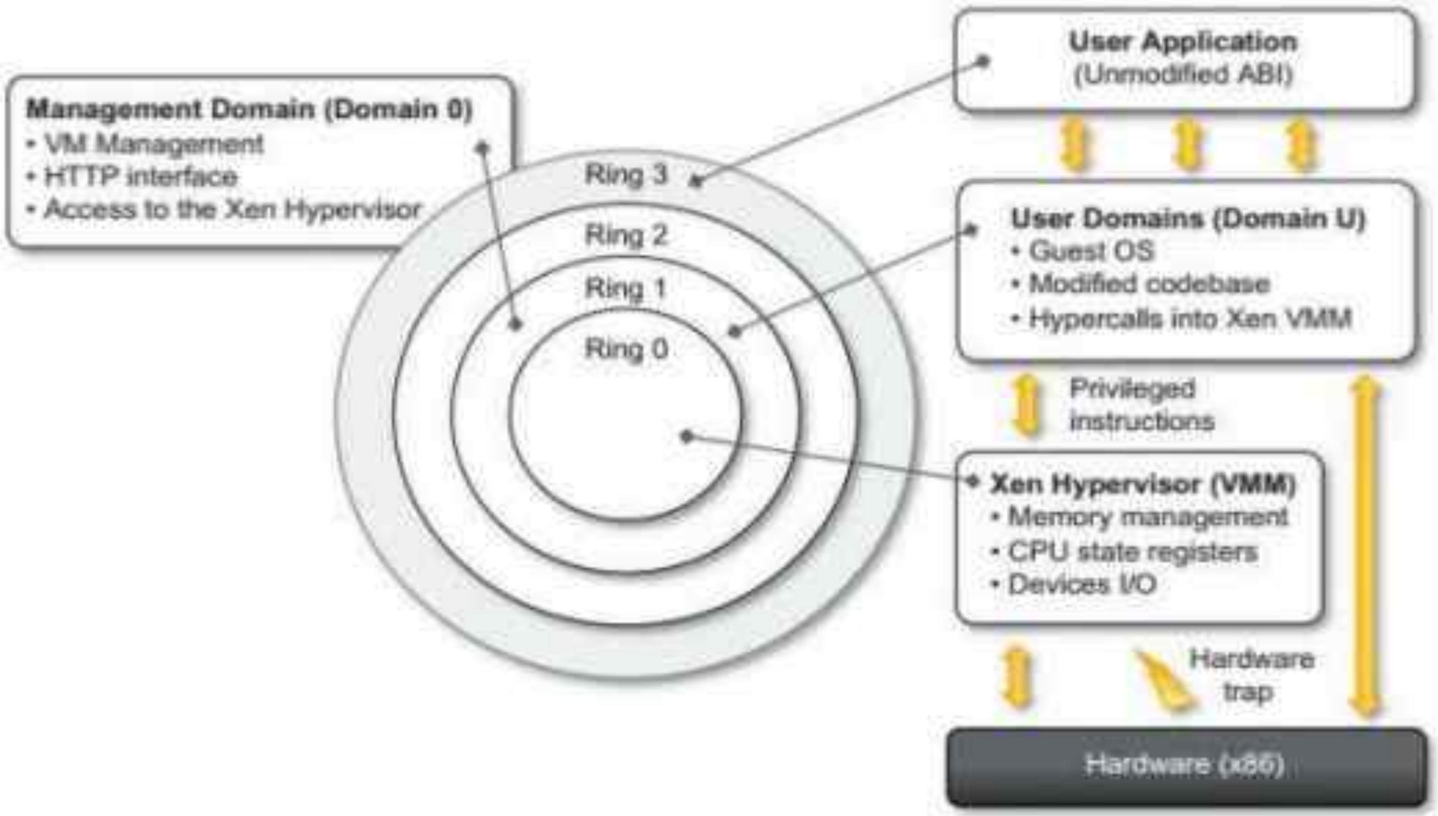
Xen: paravirtualization

- Xen is an open-source initiative
- Developed by a group of researchers at the University of Cambridge
- XenSource.
- Desktop virtualization or server virtualization
- Xen Cloud Platform (XCP)
- https://www.xenproject.org/



VMWare: Full Virtualization

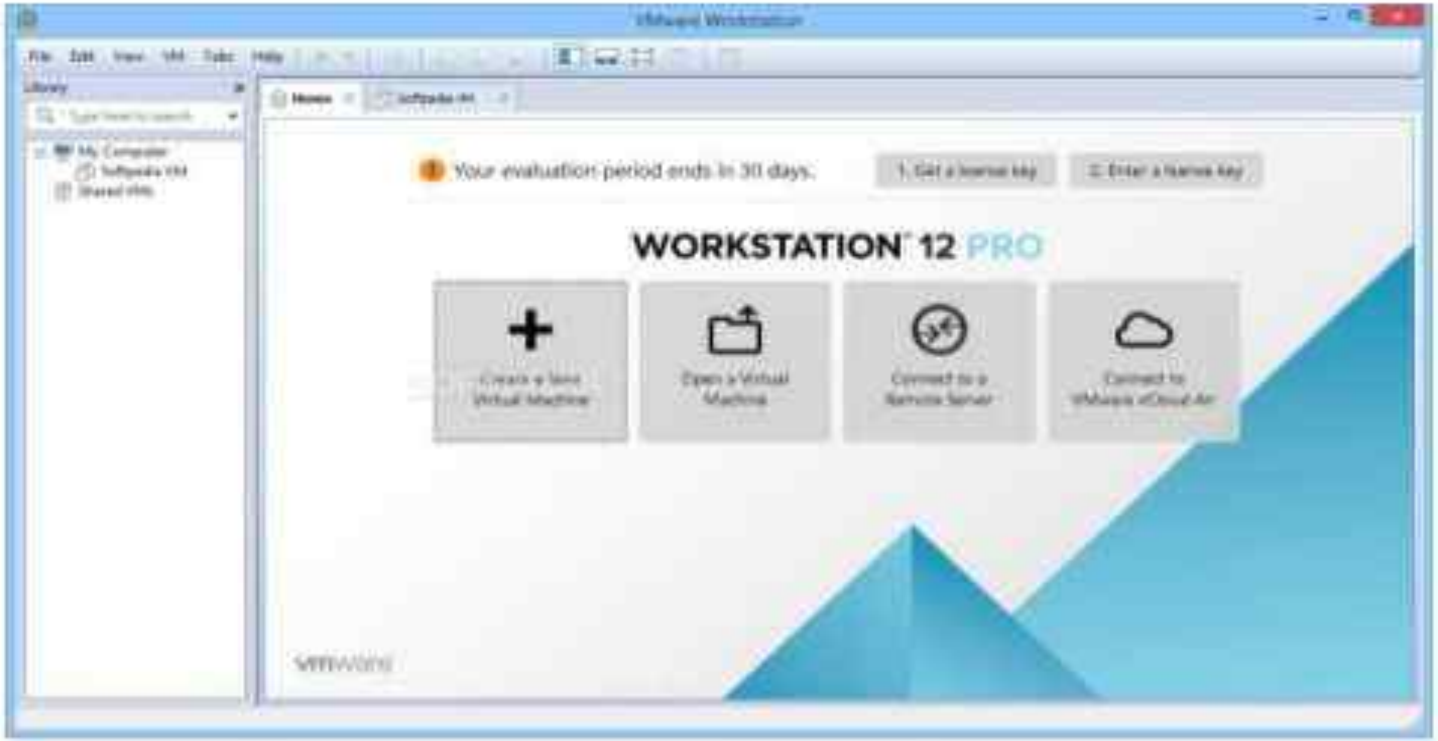
- Underlying hardware is replicated and made available to the guest operating system
- VMware implements full virtualization in the Desktop environments
- Type II hypervisor in Server Environment
- Type I hypervisor in Desktop and Server Environments
- Direct Execution
- Binary Translation



Xen architecture and guest OS management.

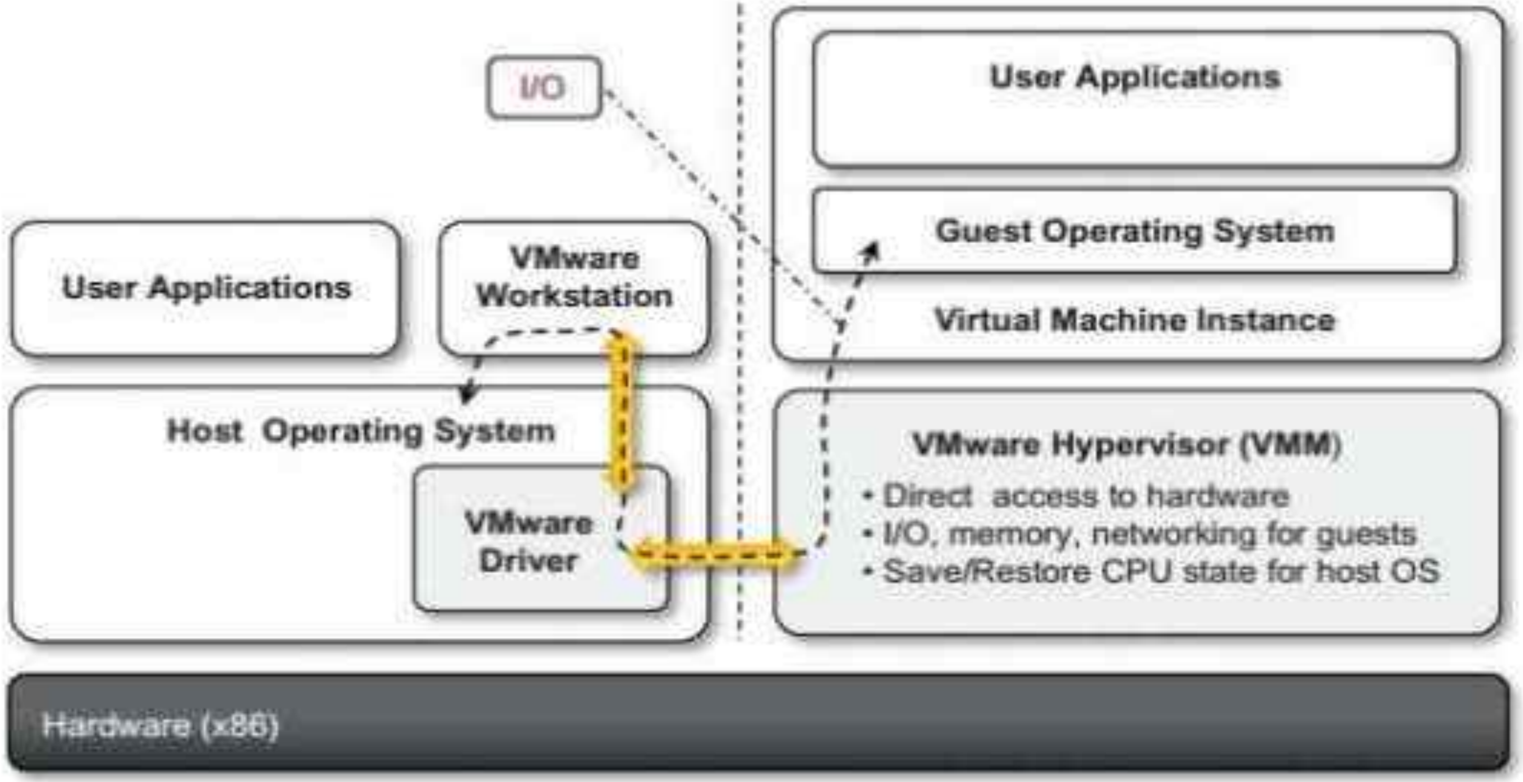
Virtualization solutions by VMware

- End-user (desktop) virtualization



Your evaluation period ends in 30 days.

VMware workstation architecture.



Virtualization solutions by VMware

- Server virtualization
- VMWare GSX
- VMWare ESXi

Local host - VMware Virtual Machine Console

VMware Virtual Machine Console

Connected to localhost running VMware GSX Server 3.1.0

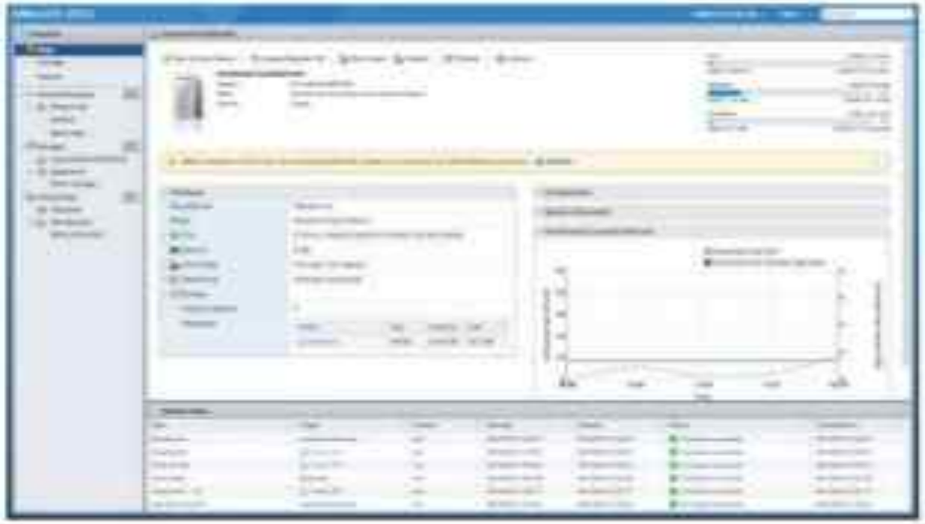
The VMware Virtual Machine Console lets you connect to virtual machines that run on VMware GSX Server or VMware ESX Server systems. Each virtual machine is equivalent to a physical server with storage, networking, memory and devices. The VMware Virtual Machine Console gives you full control over virtual machines, including keyboard, video and mouse interactions.

New Virtual Machine: Use this button to create a new virtual machine. You then can install and run a variety of standard operating systems in the virtual machine.

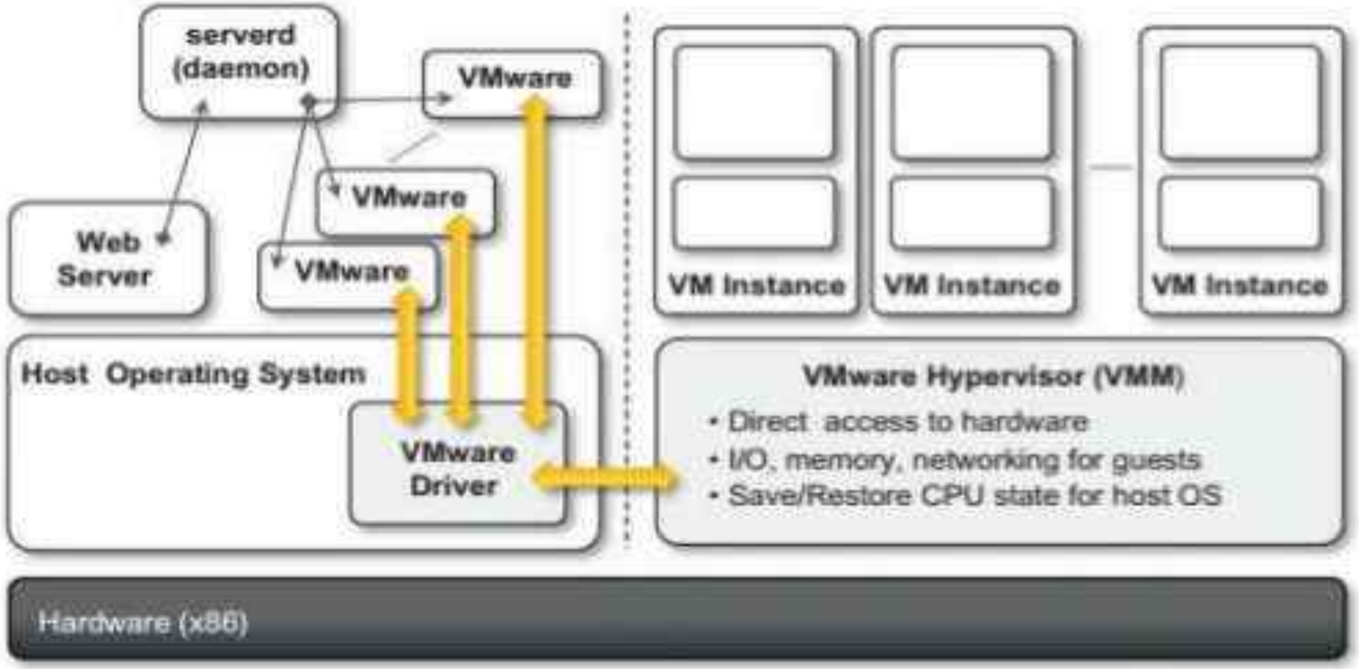
Open Existing Virtual Machine: Use this button to display a list of virtual machines available on this server and to select one to display in this panel. You then can interact with the guest operating system within this display as you would a standard PC.

Switch Host: Use this button to connect to a different GSX host. Changing hosts will allow you to access virtual machines on another server or on your local computer if it is installed with the GSX Server software.

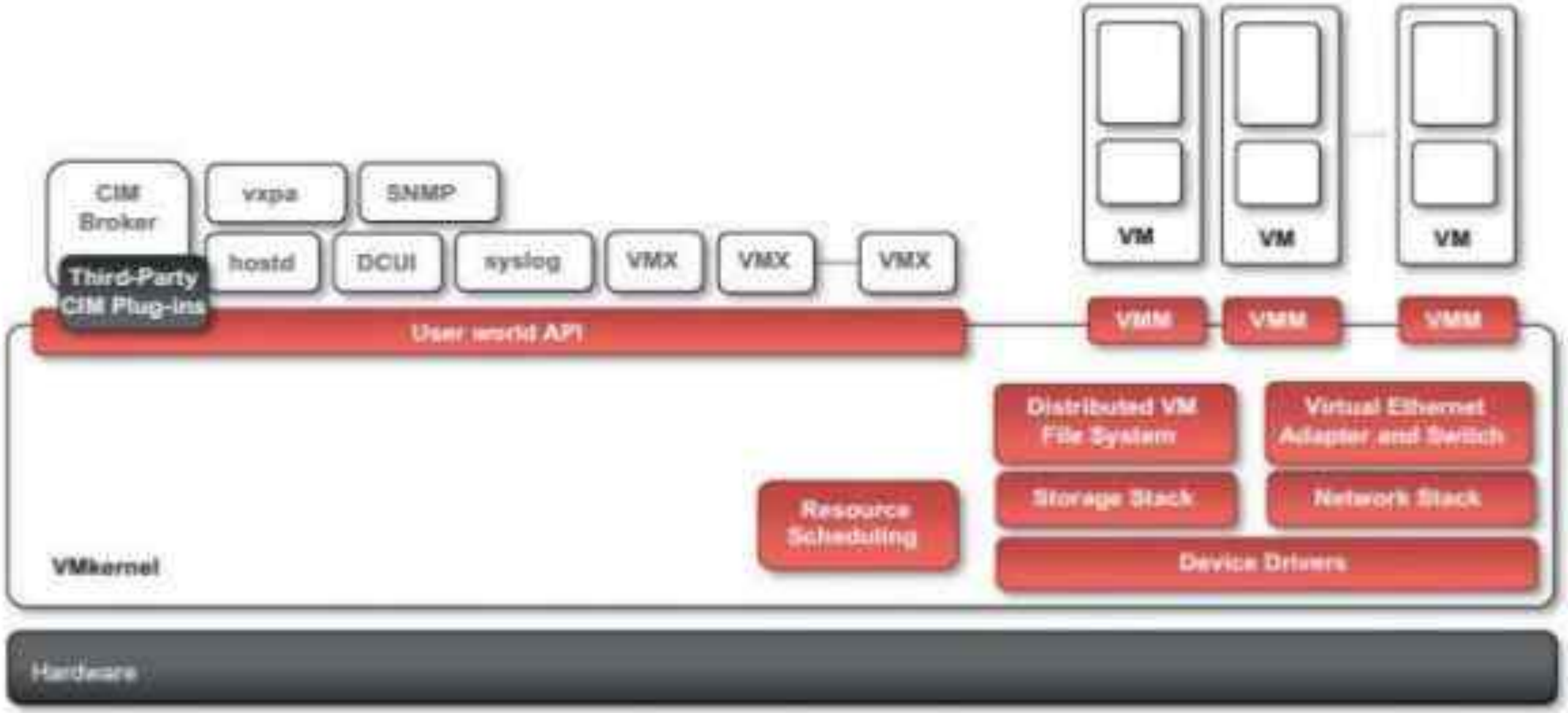
Configure Host: Use this button to display the GSX Server configuration window. From this window you can set all of the server configuration options that affect the operation and performance characteristics of the server.



VMware GSX server architecture.



VMware ESXi server architecture.



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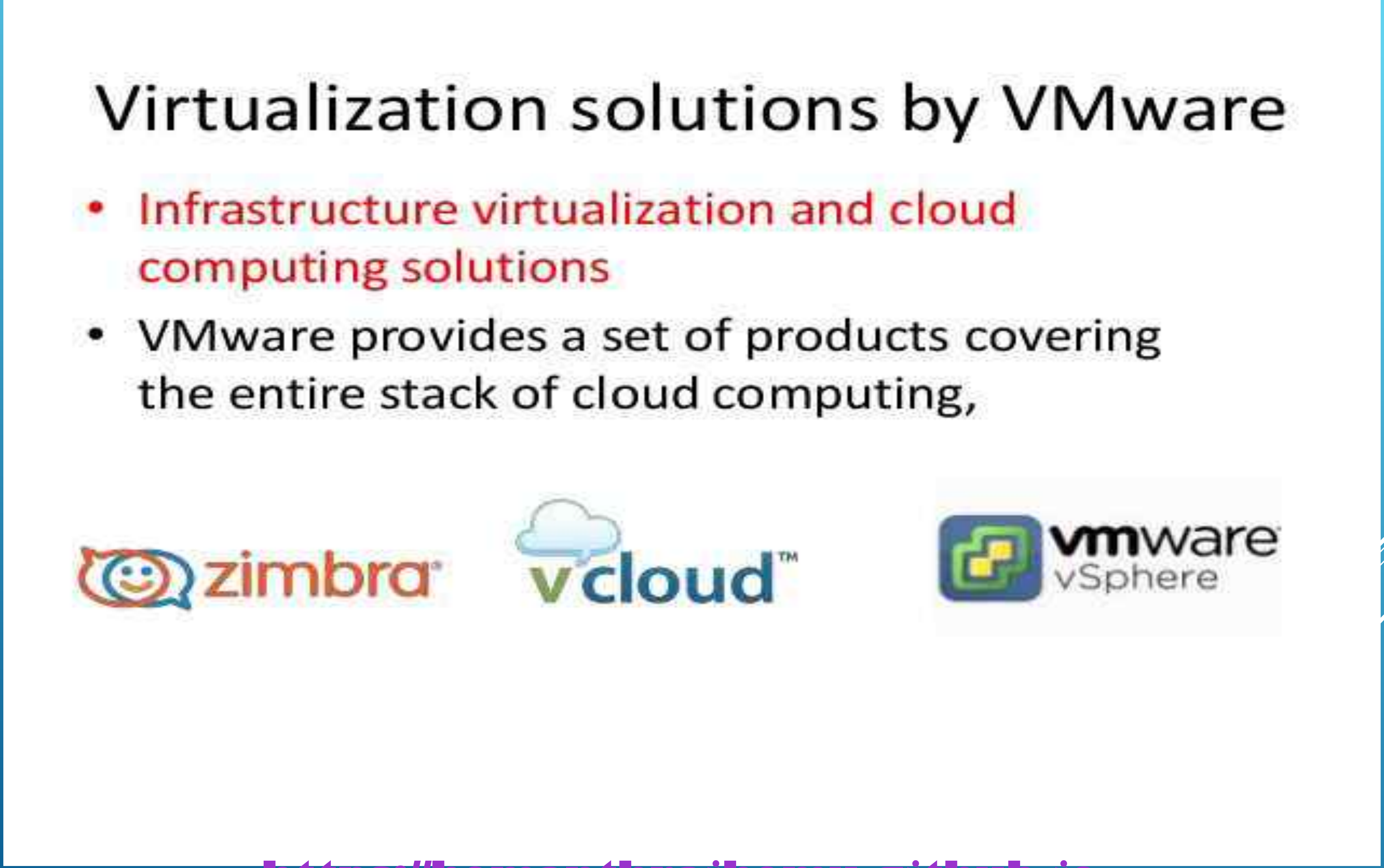
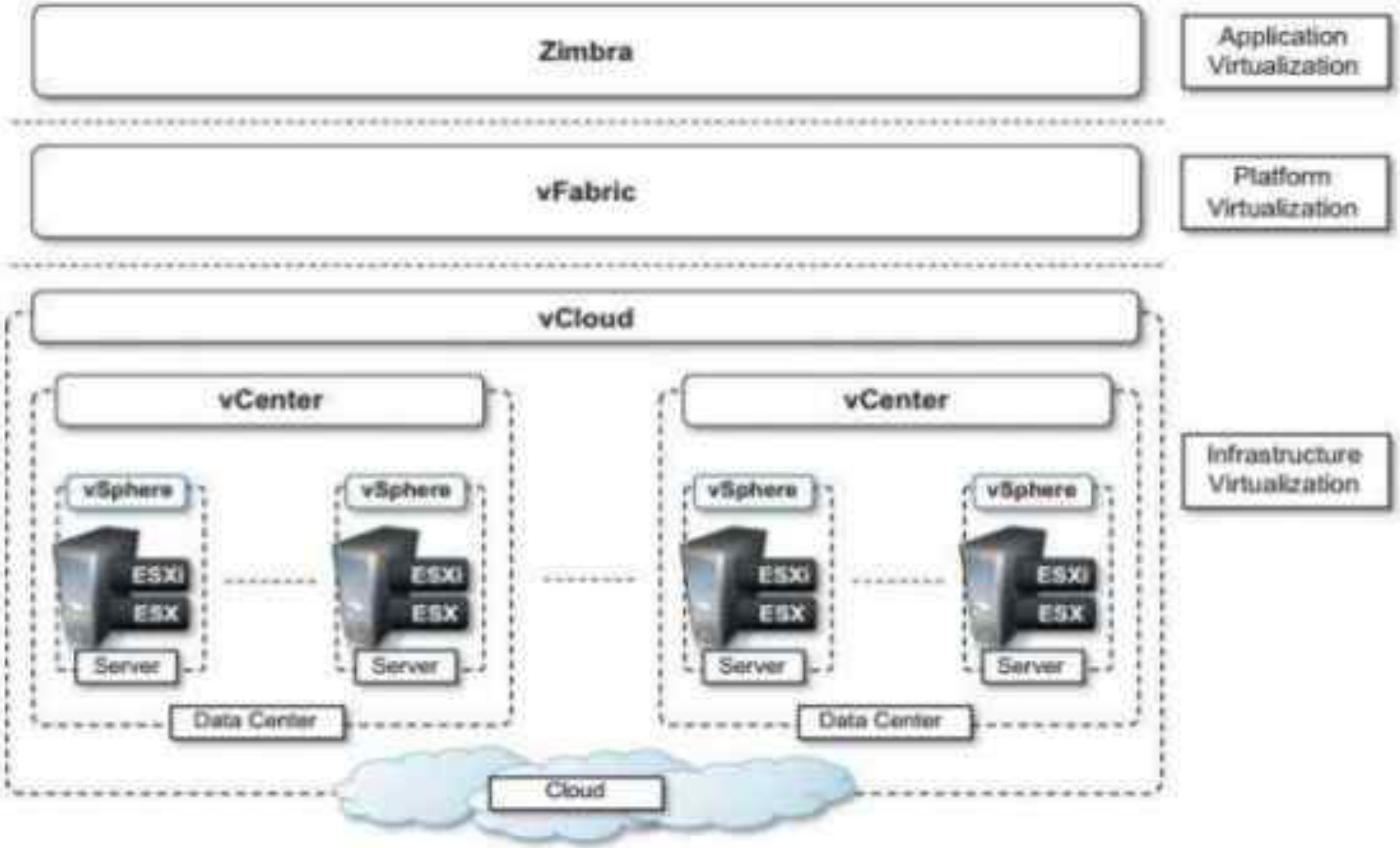
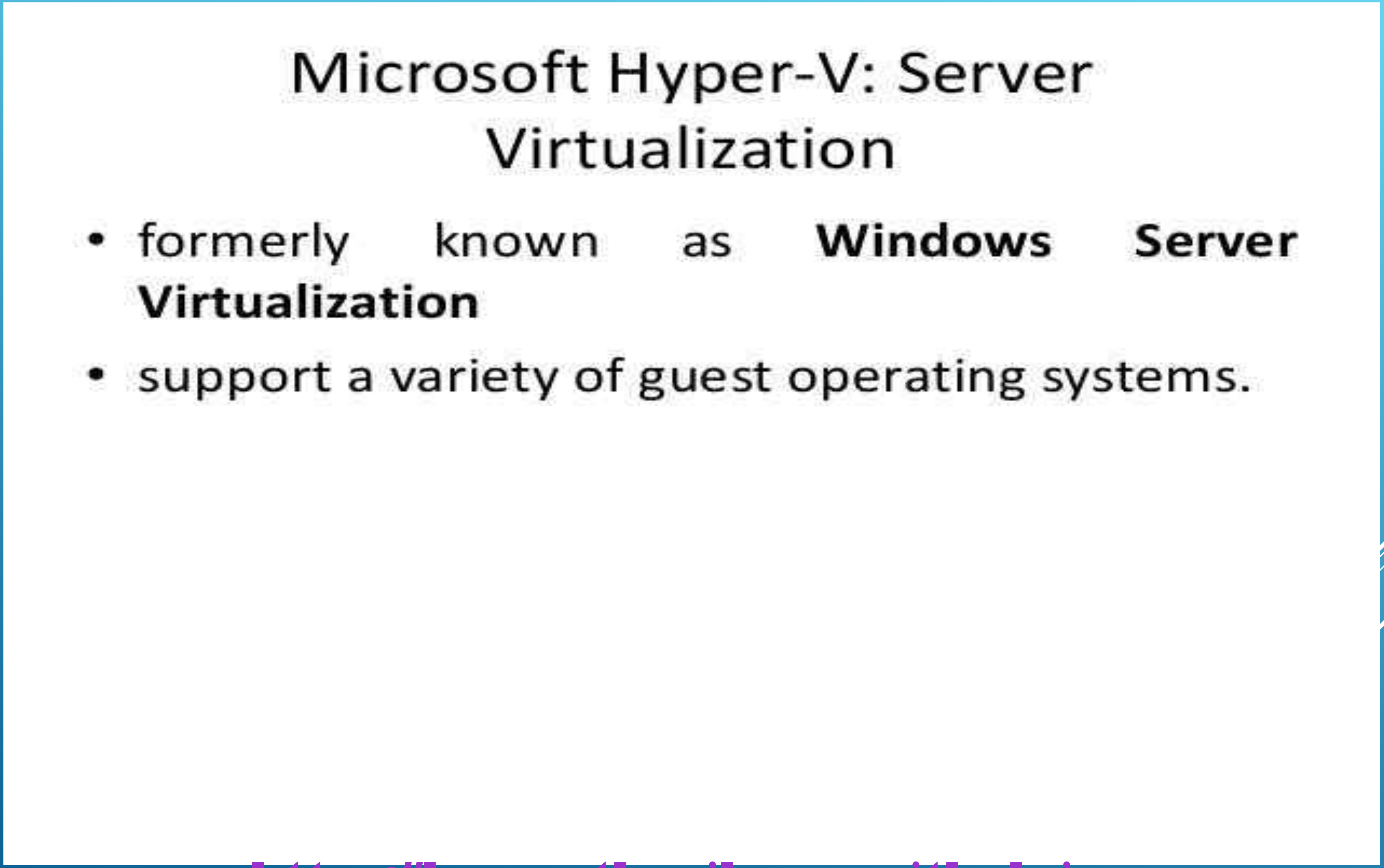


Virtualization solutions by VMware

- Infrastructure virtualization and cloud computing solutions
- VMware provides a set of products covering the entire stack of cloud computing,

VMware Cloud Solution stack.

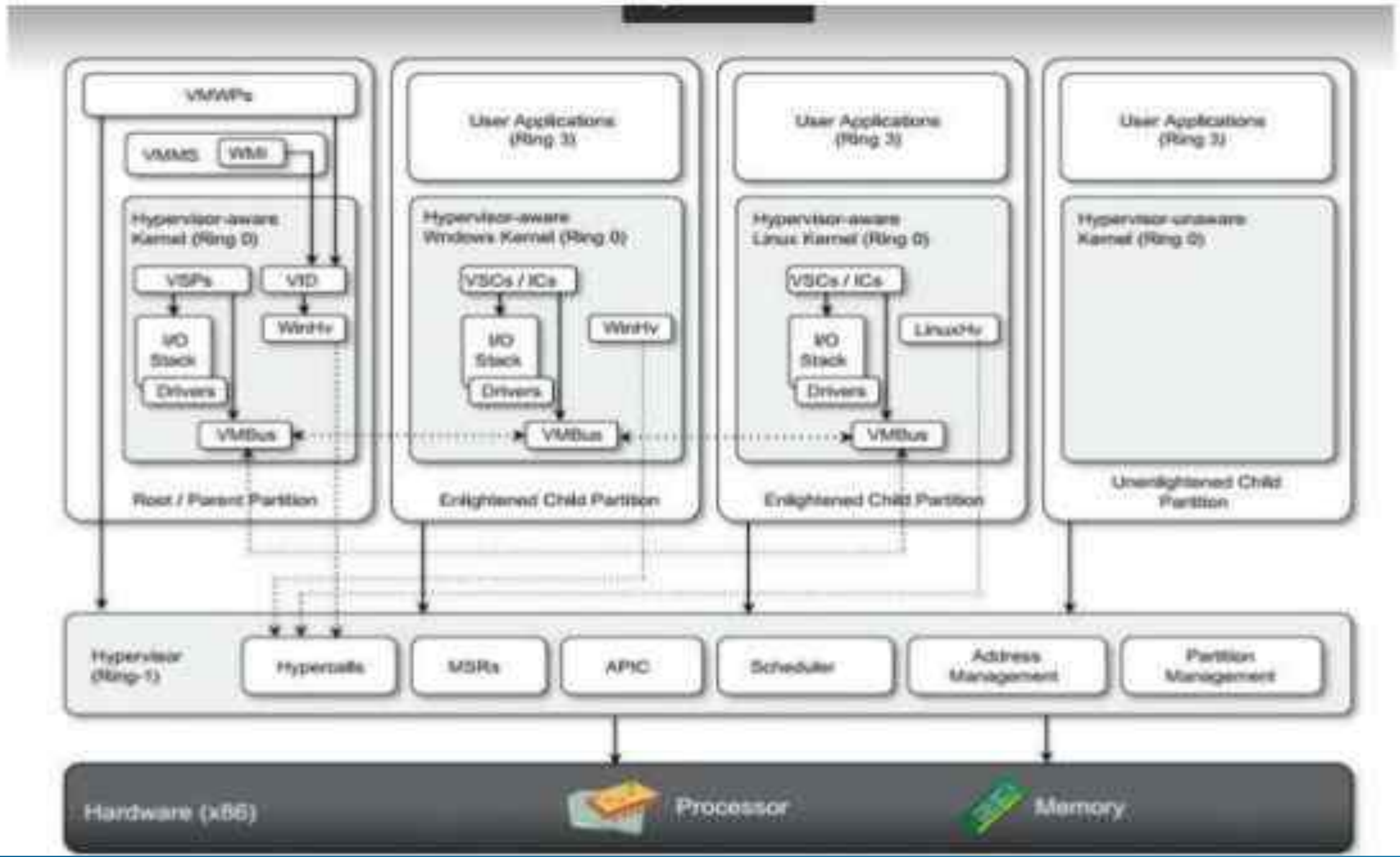




Microsoft Hyper-V: Server Virtualization

- formerly known as **Windows Server Virtualization**
- support a variety of guest operating systems.

Microsoft Hyper-V architecture.


VMWPs
VMMS
WMI
Hypervisor-aware Kernel (Ring 0)
VSPs
VID
I/O Stack
Drivers
WinHv
VMBus
Root / Parent Partition
User Applications (Ring 3)
Hypervisor-aware Windows Kernel (Ring 0)
VSCs / ICs
I/O Stack
Drivers
WinHv
VMBus
Enlightened Child Partition
User Applications (Ring 3)
Hypervisor-aware Linux Kernel (Ring 0)
VSCs / ICs
I/O Stack
Drivers
LinuxHv
VMBus
Enlightened Child Partition
User Applications (Ring 3)
Hypervisor-unaware Kernel (Ring 0)
Unenlightened Child Partition
Hypervisor (Ring -1)
Hypercalls
MSRs
APIC
Scheduler
Address Management
Partition Management
Hardware (x86)
Processor
Memory

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