Chapter 2 – Addendum (More on Virtualization)

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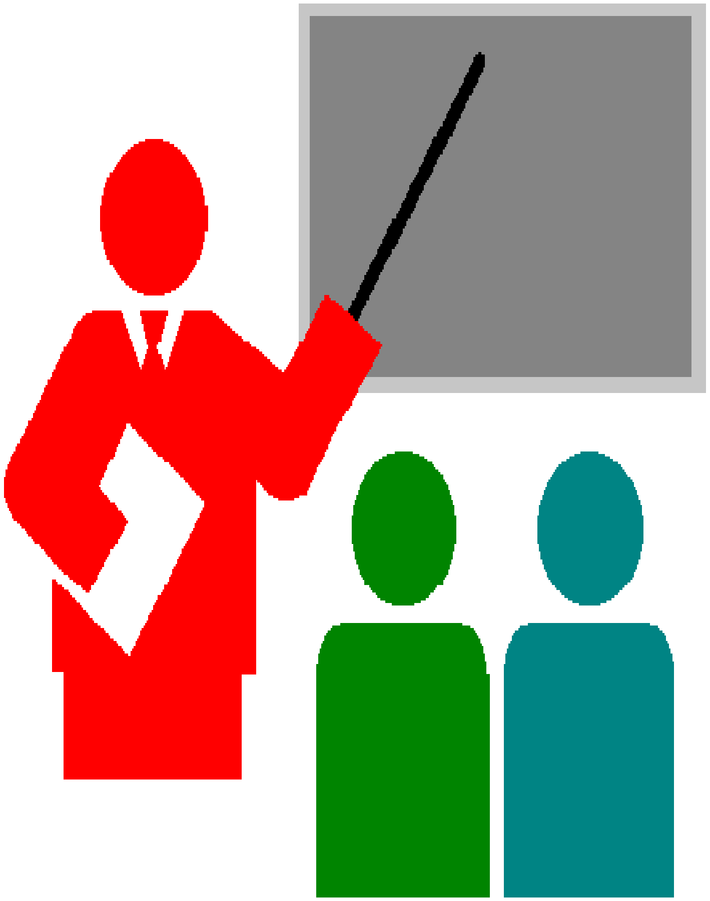
More on Systems Virtualization



- Type I (bare metal) vs. Type 2 (hosted)
- Full virtualization vs. para-virtualization
- Network virtualization

References (Systems Virtualization)

1. M. Pearce et al., Virtualization: Issues, Security, Threats, and Solutions, ACM Computing Survey, February 2013

2. P. Barham et al., XEN and the Art of Virtualization, SOSP '03 Proceedings of the nineteenth ACM symposium on Operating systems principles, Pages 164-177

Type I vs Type II Hypervisor

Types of hypervisor

- Type I – bare metal
  - Installed on bare hardware
  - Examples
    - Citrix XEN server
    - VMWARE ESX/ESXI

Type I vs Type II Hypervisor

Types of hypervisor

- Type 2 – hosted
  - Runs on top of host operating system
  - Examples:
    - VMWare workstation
    - VirtualBox

Type I vs Type II Hypervisor

Type I - Bare metal

- Hypervisor installed on bare hardware
  - Advantages (compared to type II)
    - Performance (No additional software layer to go through)
    - Security (No possible attack through host operating system)
  - Drawbacks (compared to type II)
    - Host operating system needs to be “ported” on top of hypervisor
    - Complexity depends on the type of virtualization (Full virtualization vs. para-virtualization)

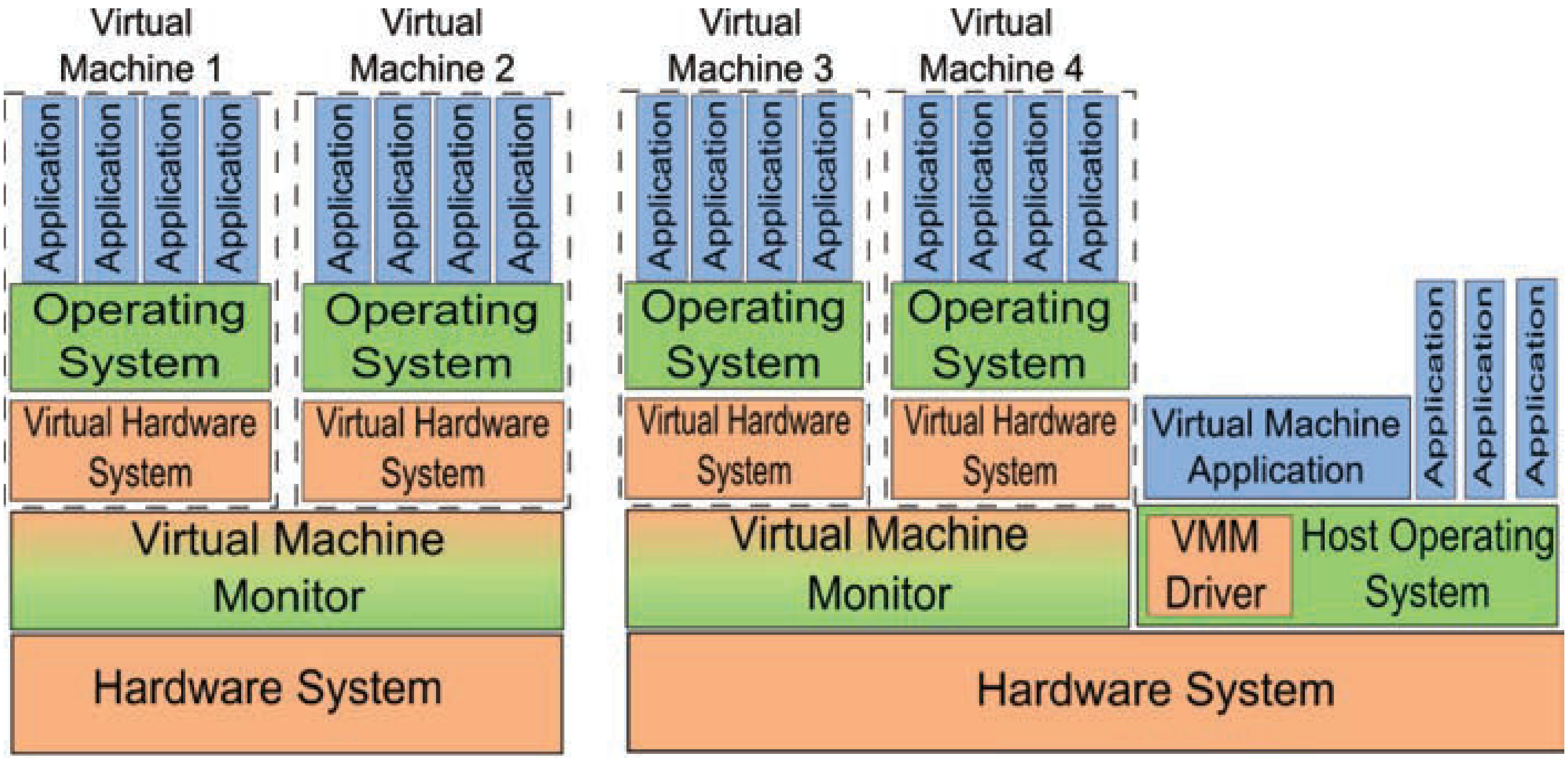
Type I vs Type II Hypervisor

Type II - Hosted

- Hypervisor installed on top of host operating system
    - Drawbacks (compared to type I)
        - Performance (need to go through host operating system)
        - Security (i.e. Possibility to attack through host operating system)
    - Advantages (compared to type I)
        - Host operating system is re-used as it is (No need to port it)
        - No change required to applications running on top of host operating system

Type I vs Type II Hypervisor (Summary)

Types of hypervisor/virtual machine monitor (From ref. 2)



[Sugerman et al. 2001]

Full virtualization vs. Para-virtualization

More on operating systems fundamentals

- Privileged vs. non privileged instruction
  - Privileged
    - If called in user mode, the CPU needs to trap it and switch control to supervisory software (e.g. hypervisor) for its execution

Full virtualization vs. Para-virtualization

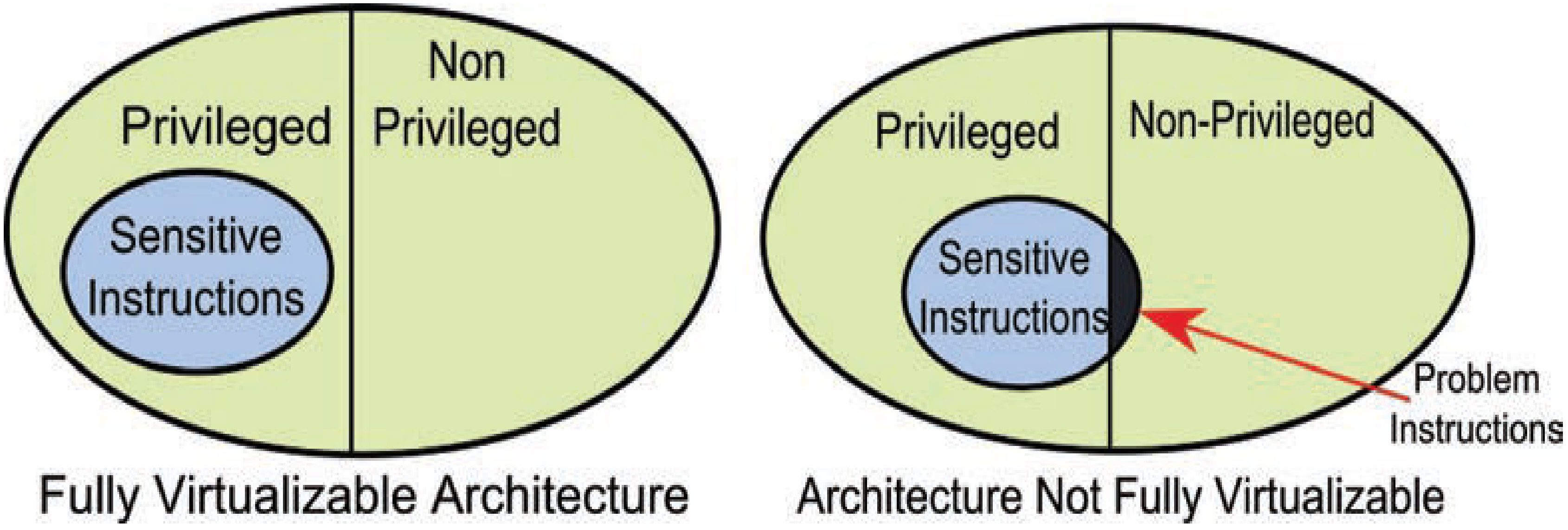
More on operating systems fundamentals

- Sensitive vs. non sensitive instruction
  - Sensitive
    - Has the capacity to interfere with supervisor software functioning (e.g. Hypervisor)
      - Write hypervisor memory vs. read hypervisor memory

Full virtualization vs. Para-virtualization

Could all CPU architectures be fully virtualized ?

- Could be fully virtualized only if the set of sensitive instructions is a subset of the privileged instructions



From reference [1]

Full virtualization vs. Para-virtualization

Could all CPU architectures be fully virtualized ?

- The case of Intel x86 CPU architectures
  - Cannot be fully virtualized
    - “Certain instructions must be handled by the VMM for correct virtualization, but these with insufficient privilege fail silently rather than causing a convenient trap” – Reference [2]

Full virtualization vs. Para-virtualization

Definitions

Full virtualization

- Hypervisor enables virtual machines identical to real machine
  - Problematic for architectures such as Intel x86

Full virtualization vs. Para-virtualization

Definitions

Para-virtualization

- Hypervisor enables virtual machine that are similar but not identical to real machine
  - A solution to the problem of CPU architectures that cannot be virtualized
    - Prevents user programs from executing sensitive instructions
  - Note:
    - Para-virtualization is not the only solution to the problem

Full virtualization vs. Para-virtualization

Full virtualization

- Advantages
  - Possibility to host guest operating systems with no change since virtual machines are identical to real machines
- Disadvantages
  - Not always feasible (e.g. Intel x86)
    - There are work around (e.g. binary translation)
  - Some guest operating systems might need to see both virtual resources and real resources for real time applications

Full virtualization vs. Para-virtualization

Para - virtualization

- Advantages
  - Feasible for all CPU architectures
  - Performance – Compared to:
    - Full virtualization
    - Other approaches to architectures that could not be virtualized (e.g. binary translation)
- Disadvantages
  - Need to modify guest operating systems

Full virtualization vs. Para-virtualization

Para - virtualization

- Alternatives to para-virtualization
    - Binary translation (e.g. VMWare ESX server)
        - Leads to full virtualization
        - No need to re-write “statically” guest operating systems
            - i.e. guest OS can be installed without change
        - Interpretation of guest code (OS + application)
            - “Rewrites” dynamically guest code and insert traps when necessary

Full virtualization vs. Para-virtualization

Para - virtualization

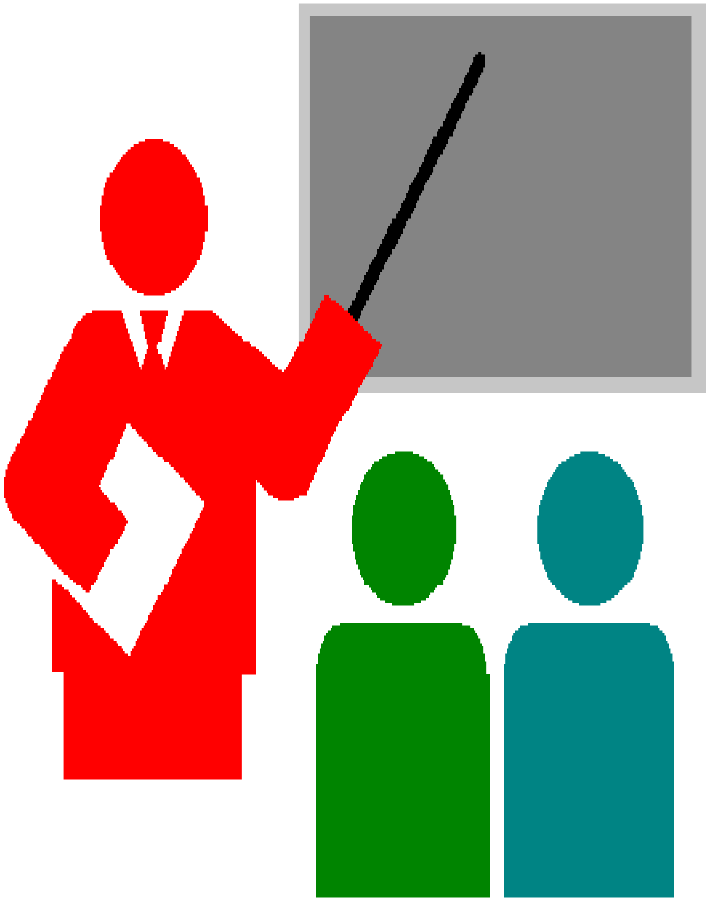
- Alternatives to para-virtualization
  - Binary translation
    - Disadvantages / penalties
      - Performance
      - However, optimization is possible, e.g.
        - » Adaptive translation (i.e. optimize the code being translated)

Full virtualization vs. Para-virtualization

Para – virtualization

- A detailed case study on para-virtualization
  - XEN (Reference 2)

More on Network Virtualization



1. Motivations (Reminder)

2. Prior to network virtualization
   - Virtual Local Area Network
   - Virtual Private Network
   - Overlays

3. A case study on network virtualization
   - business model
   - Scenarios
   - Prototype

References (Network Virtualization)

1. N.M Chowdhury and r. Boutaba, Network Virtualization: State of the Art and Research Challenges, IEEE Communications Magazine, July 2009

2. J. Carapinha et al., Network Virtualization – A View from the Bottom, VISA '09 Proceedings of the 1st ACM workshop on Virtualized infrastructure systems and architectures, Pages 73-80

3. G. Schaffrat et al., Network Virtualization Architecture: Proposal and Initial Prototype, Proceeding VISA '09 Proceedings of the 1st ACM workshop on Virtualized infrastructure systems and architectures, Pages 63-72

4. J. Kurose and K. Ross, Computer Networking: A Top Down Approach, Pearson, 6th Edition, 2013

5. Venkateswanan, Virtual Private Networks, IEEE Potentials, Issue 20, no1

Motivations

Bring the benefits of systems virtualization to the networking world, e.g.

- Co-existence of virtual networks on top of a same physical real network with proper isolation
- Networking research (e.g. possibility to deploy brand networks for experimentation purpose on top of existing real networks)
- Network software testing and run-time debugging
- Optimization of network resource utilization
  - Nodes
  - Links
- Migration of virtual machine from node to node

Prior to Network Virtualization

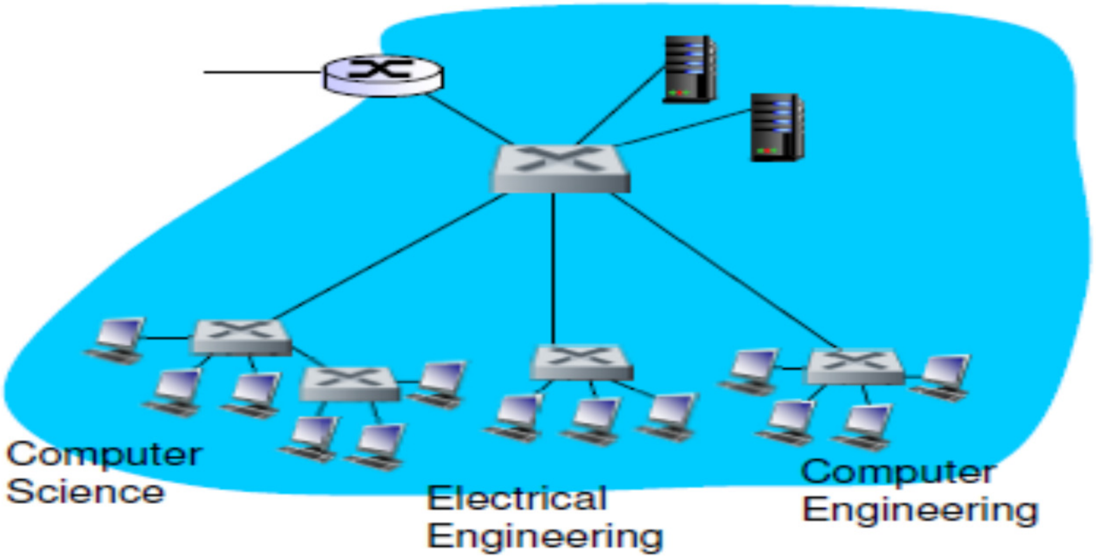
Virtual Local Area Networks (VLANs)

- Possibility to define several VLANs over a same physical LAN infrastructure
  - Each VLAN has its broadcast domain and has an id.
- However
  - Each physical node is part of one and only VLAN
    - No efficient resource usage

Prior to Network Virtualization

Virtual Local Area Networks (VLANs)

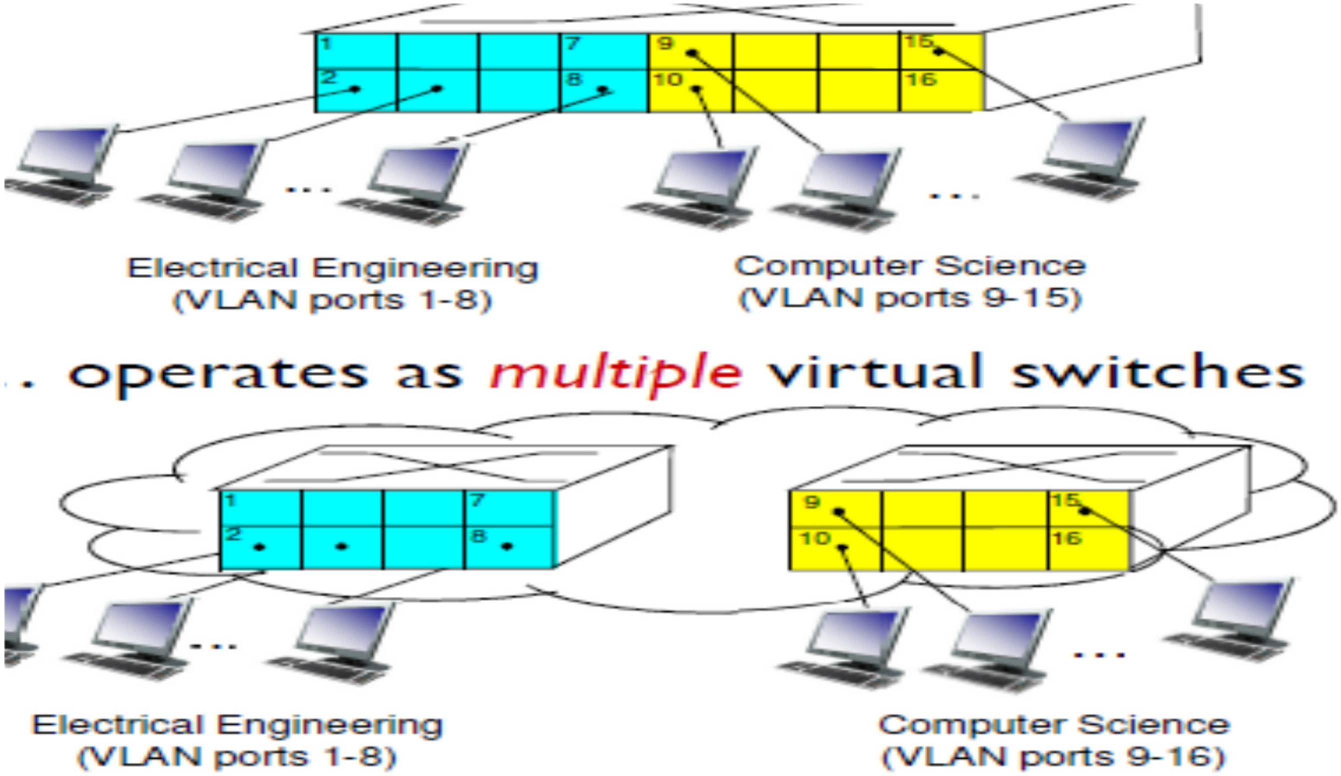
- A LAN (Reference 4)



Prior to Network Virtualization

Virtual Local Area Networks (VLANs)

- A VLAN (Reference 4)



… operates as *multiple* virtual switches

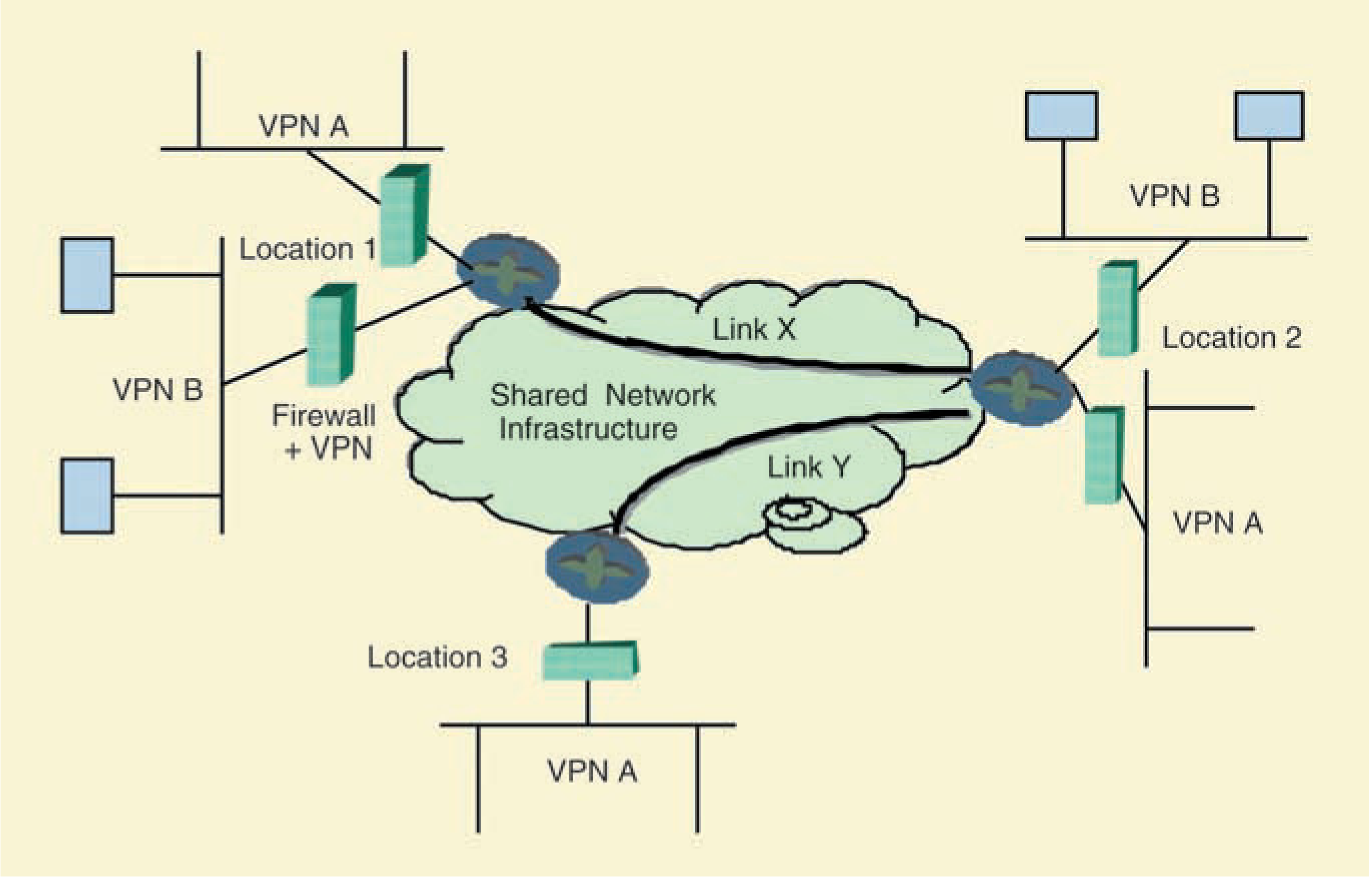
Prior to Network Virtualization

Virtual Private Networks

- Possibility to build virtual networks using a shared infrastructure (usually Internet, but might be a dedicated networks)
  - Site interconnection
  - Extranets
- But:
  - No real insolation between the different networks traffic over the shared infrastructure

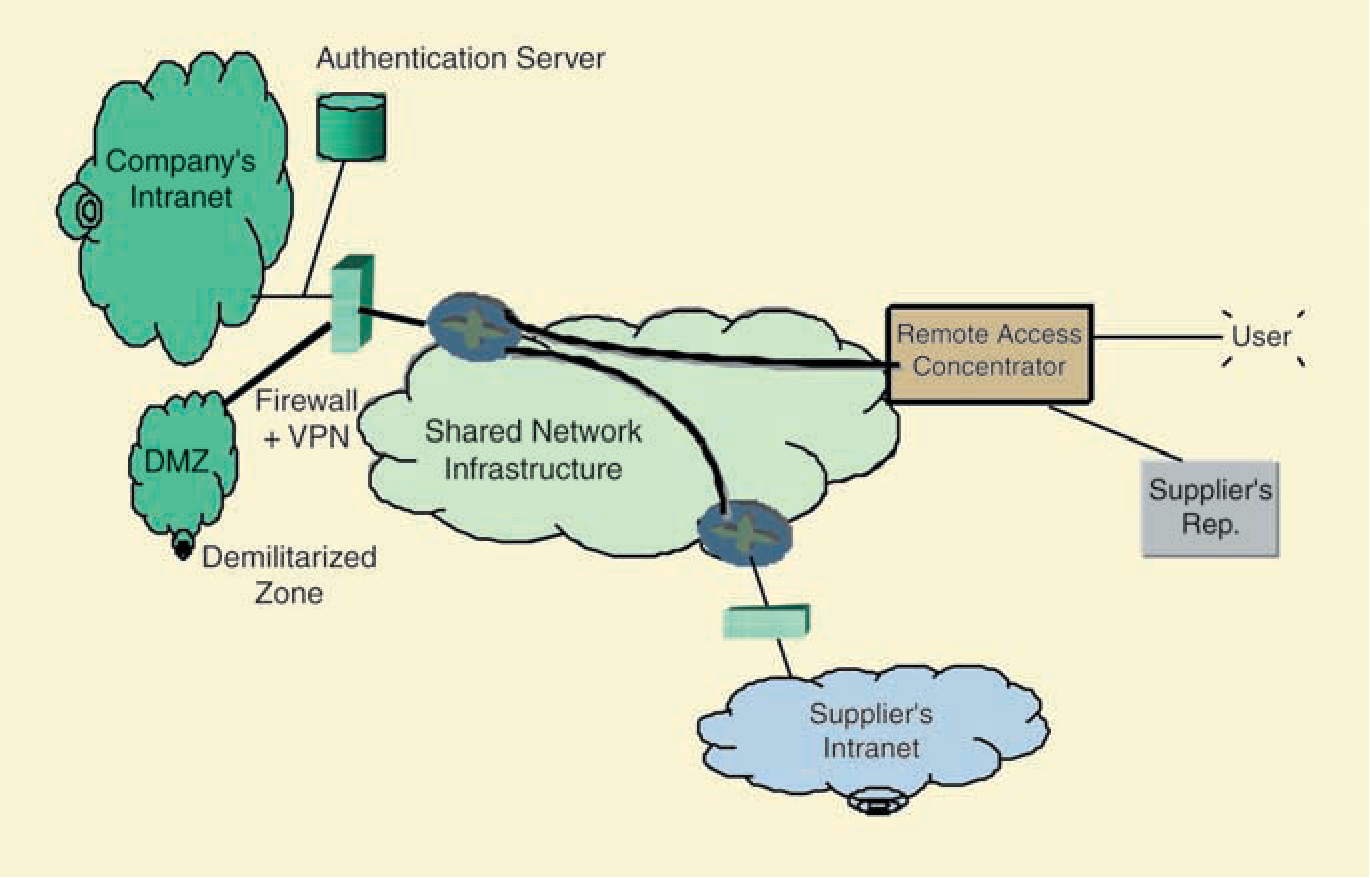
Prior to Network Virtualization

Virtual Private Networks – Reference 5 (LAN Interconnection)



Prior to Network Virtualization

Virtual Private Networks – Reference 5 (LAN Interconnection)



Prior to Network Virtualization

Overlays

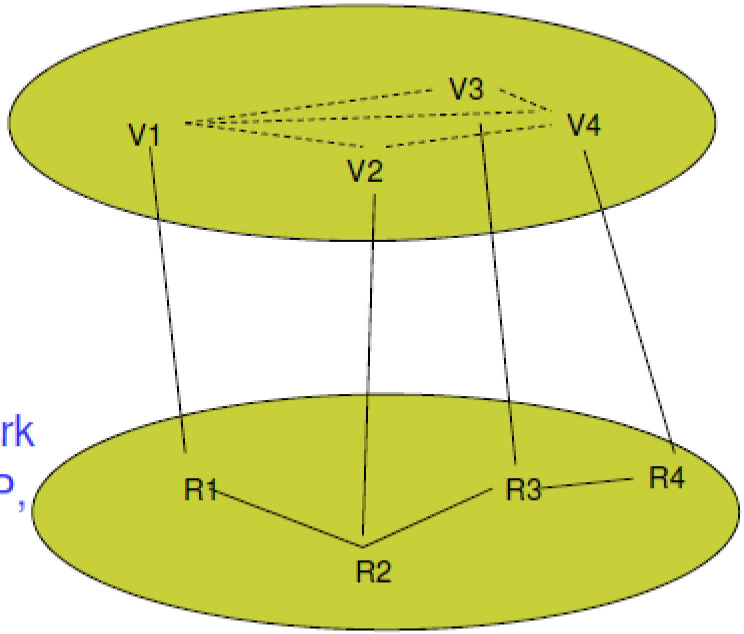
- Logical networks built on top of real networks (e.g. skype)
- A same physical node might be part of several overlays
- But:
  - Overlays might interact in a harmful way
  - Used mainly at application layer and does not enable experimentation of lower layer protocols

Prior to Network Virtualization

Overlays

P2P overlay

Overlay
(Above
Transport)



Real network
(PHY,link,IP,
Transport)

Prior to Network Virtualization

Overlays

P2P overlay

- Characteristics
  - own topology that may be different from the topology of the real network
  - Own protocols that may be different from the protocols used in the real network
  - May come with an application embedded in it (e.g. Skype) or as an infrastructure that can be used by other applications (e.g. CHORD)
  - APIs, toolkits are provided when the application is not embedded in the overlay

A Case Study on Network Virtualization (Reference 3)

Business model of current Internet:

- Internet Service Providers (ISPs) (e.g. Bell, Rogers)
- Service Providers (eg. Google, Akamai)

A Case Study on Network Virtualization Reference 3

New business model (4 roles):

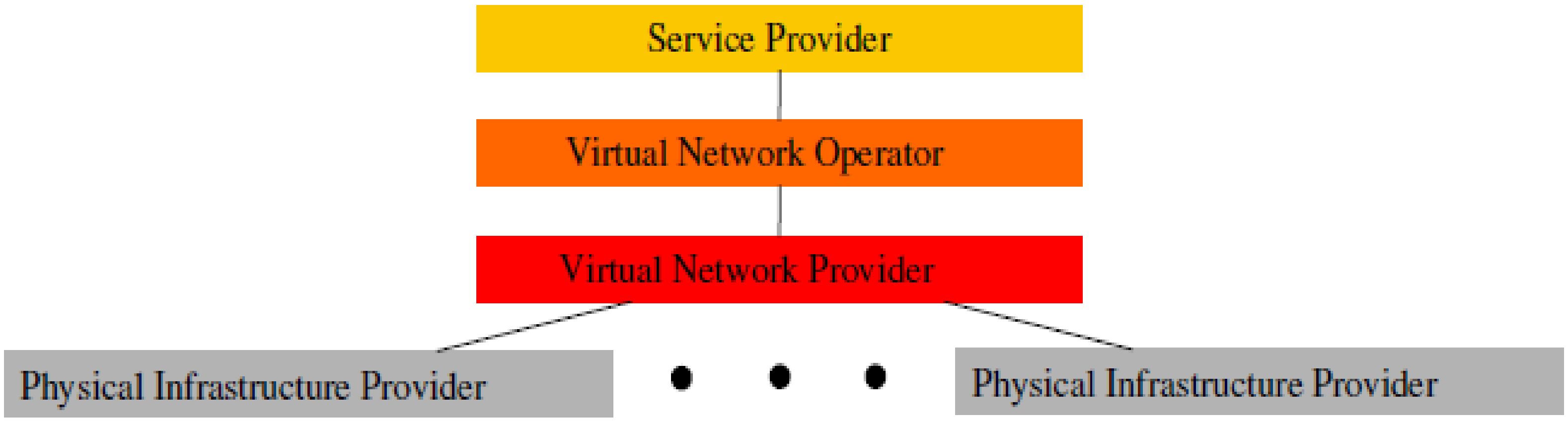
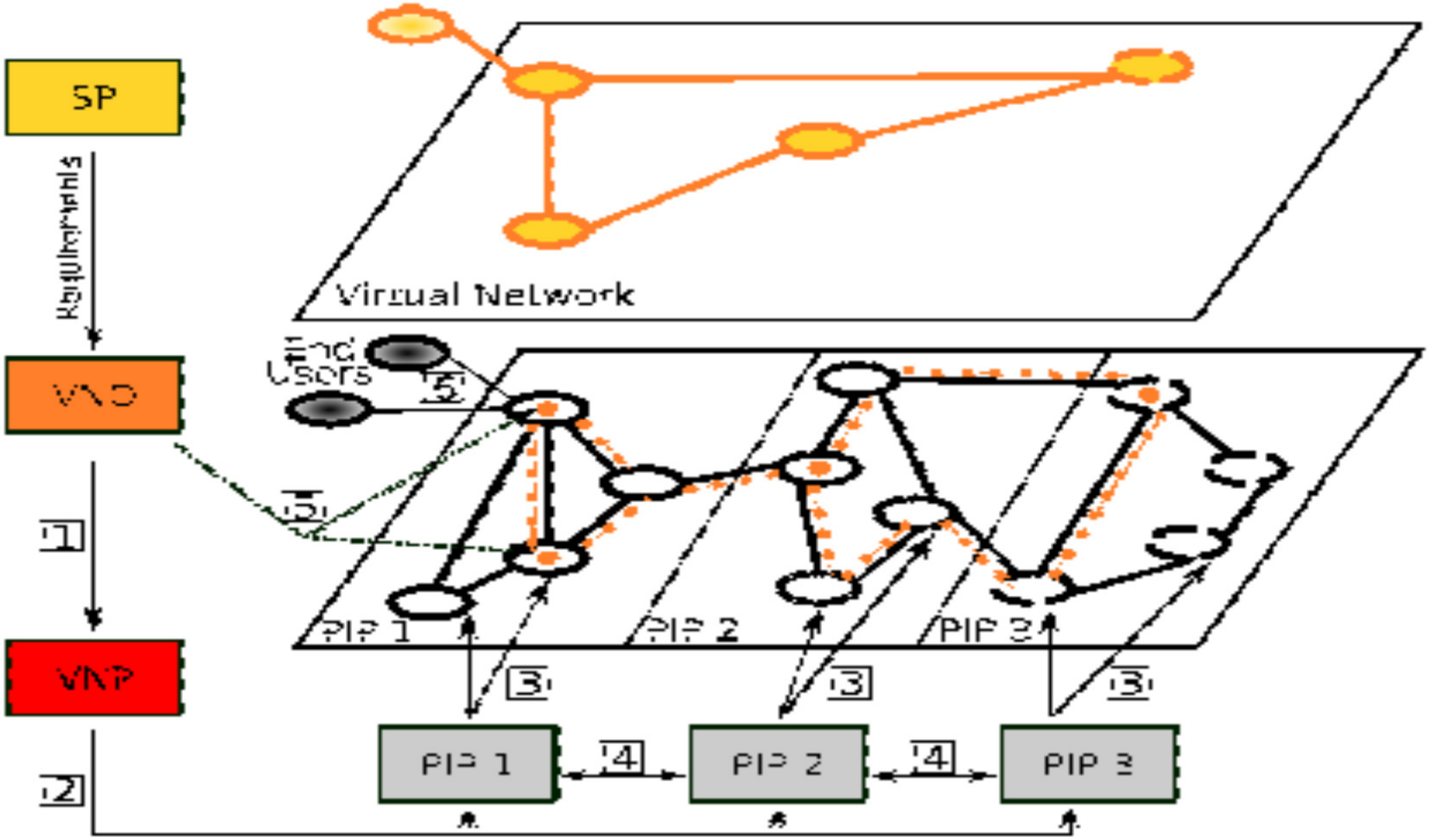


Figure 1: VNet Management and Business Roles

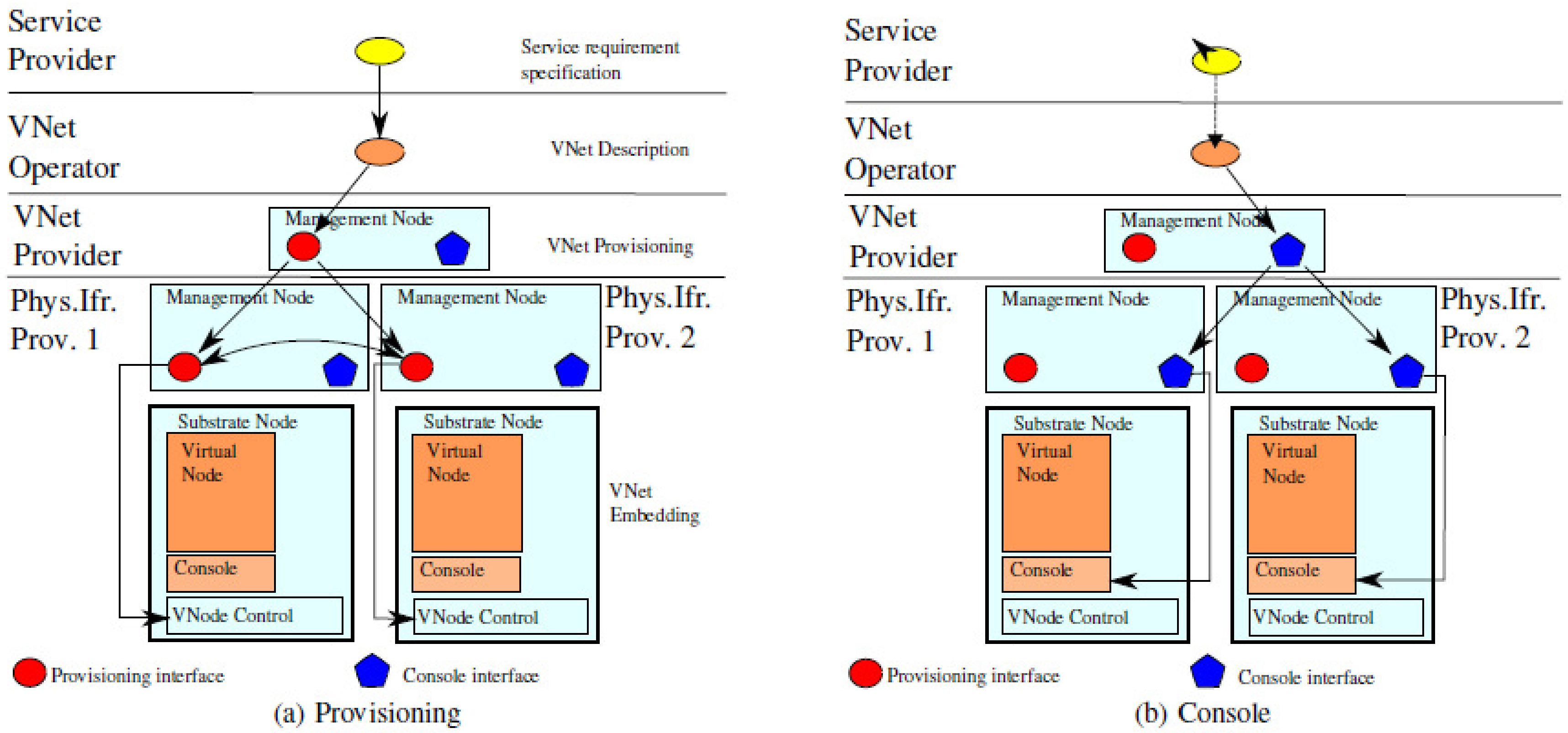
A Case Study on Network Virtualization Reference 3

New business model (6 interfaces):



A Case Study on Network Virtualization Reference 3

Simplified scenario



(a) Provisioning

(b) Console

Figure 3: VNet provisioning (a) and console architecture (b).

A Case Study on Network Virtualization (Reference 3)

Prototype

- Node level virtualization
  - XEN
- VNET description
  - XML

A Case Study on Network Virtualization (Reference 3)

Topology used for Vnet instantiation measurements (end to end from Vnet request by service provider till full provisioning of VNET

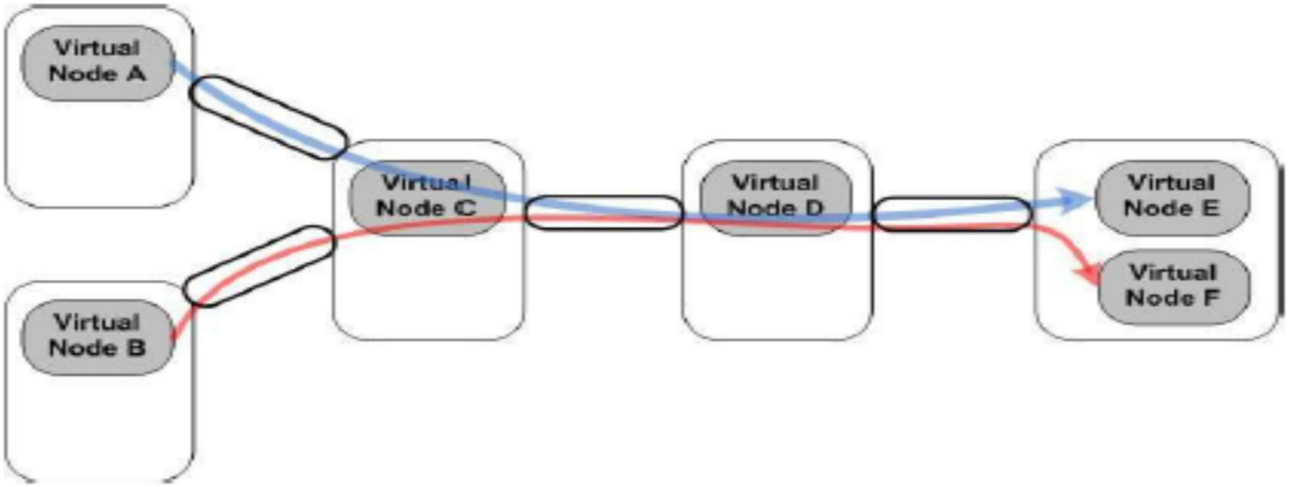


Figure 6: Experimental topology.

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