5. Different types of virtualization are possible. Among them *Network Virtualization*, *Storage Virtualization*, *Operating System Virtualization* and *Machine Virtualization*. Describe each of them briefly, highlighting:

   - its basic functioning and key components (if discussed during the course),
   - its purpouses,
   - which are the advantages of their use with the respect of the same non virtualized resource type.

   SOLUTIONS:
   Network Virtualization: slides 55-56
   Storage Virtualization: slides 57-58
   Operating System Virtualization: slides 59-61
   Machine Virtualization: slides 62-66

6. A virtual infrastructure is composed by 3 Physical Servers (Hosts) and 4 Virtual Machines (VM).

   - $Host_1$ @192.168.10.1 runs VM_1, attached to its NAT adapter
   - $Host_2$ @10.0.0.1 run VM_2 and VM_3, both attached to the same Bridge adapter
   - $Host_3$ @192.168.10.2 runs VM_4, attached to its NAT adapter

   Assuming that the network connecting all the hosts is configured to enable them to see each others (i.e.: $Host_1$ can see $Host_2$):

   (a) Assign to each of the VMs a correct IP address.

   (b) Using the addresses set in point (a), specify at which address does VM_1 contact a service on port 80 at $Host_2$?

   (c) At which address does VM_2 contact a service on port 80 at VM_3?

   (d) At which address does VM_3 contact a service on port 80 at VM_4?

   Motivate the answer! If port forwarding rules are required, consider that host's port 8080 is mapped on port 80 of the guest.

   SOL:
   a. 10.0.2.15 (no port fwr required) / 10.0.0.2, 10.0.0.3 / 10.0.2.15 b. 10.0.0.1:80
   c. 10.0.0.3:80 (assuming that this is the IP assigned to VM_3)
   d. 192.168.10.2:8080, where p is the port on which @VM_2:80 is mapped.

5. A DMZ is composed by 3 physical machines ($Host_1$, $Host_2$, $Host_3$). $Host_1$ is used as the proxy for the DMZ and does not have any VM attached to it. Three Virtual Machines, VM_1, VM_2, VM_3 run over $Host_2$, connected in internal mode. A fourth VM, VM_4 is run over $Host_3$, connected in bridged mode. Considering that 192.168.x.x is the subnet address for the physical machines, and 10.x.x.x is the subnet address for the Virtual Machines, answer the following questions:

   (a) Which are the IP address that can be associated both to the 3 Physical Machines both the 4 Virtual ones?

   (b) Which address must be given to the port-forwarding rule of the proxy to allow a web request to contact a service listening at the port 8081 of the VM_4?

   (c) At which address a service listening at port 80 of VM_3 can be contacted by VM_1?

   (d) Considering that each VM running on $Host_2$ have only one virtual network adapter, at which address can the $Host_1$ contact VM_2?

   (e) If a new virtual adapter is attached to both $Host_2$ both VM_2 in NAT, at which address will now the $Host_1$ contact VM_2?

   Always motivate your answer.

4. A system is composed by 3 physical machines ($Host_1$, $Host_2$, $Host_3$). $Host_1$ is used as a router and it does not have any VM attached to it. Two Virtual Machines, VM_1 and VM_2 run over $Host_2$, connected in bridged mode. Two more Virtual Machines, VM_3 and VM_4 run over $Host_3$, connected in NAT mode. Consider that 192.168.x.y is the subnet address for the physical machines and 10.x.y.z is the subnet address for the Virtual Machines, and that the default subnet mask is 255.255.255.0. In case of port forwarding rules, assume that port 8080 of the $Host$ is forwarded over 8089 of a VM. Answer the following questions:

   (a) Assign IP addresses to the 3 Physical Machines and the 4 Virtual ones.

   (b) At which address a service listening at port 8089 of VM_3 can be contacted by VM_1?

   (c) At which address a service listening at port 8089 of VM_2 can be contacted by VM_4?

   (d) Supposing a new VM_5 is started on $Host_1$ in internal mode, will it be able to contact VM_3? If so, how? At which address?

   (e) If the connection mode between $Host_3$ and its VMs is changed in Host-Only, will be still possible for $Host_1$ to contact VM_3? If so, at which address?

   Always motivate your answer.

   SOLUTIONS:

   (a) Physical: $Host_1$ = 192.168.x.1, $Host_2$ = 192.168.x.2, $Host_3$ = 192.168.x.3. Virtual: VM_{1-2} = 192.168.x.4, 192.168.x.5, VM_{3-4} = 10.x.x.1, 10.x.x.2

   (b) 192.168.x.3:8080 with port forwarding 8080→8089

   (c) 192.168.x.5:8089

   (d) Not possibile

   (e) Possible with IP forwarding at address 10.x.x.1.

4. A system is composed by 2 physical machines ($Host_1$, $Host_2$). Two Virtual Machines, VM_1 and VM_2 run over $Host_1$, connected in NAT mode. Three other Virtual Machines, VM_3, VM_4 and VM_5 run over $Host_2$. VM_3 and VM_4 are connected in bridged mode while VM_5 in internal mode. Consider that 192.168.x.x is the subnet address for the physical network, 10.x.x.x is the subnet address for the virtual networks, and that the default subnet mask is 255.255.255.0. In $Host_1$ assume a port forwarding rule that connects port 8080 of the $Host_1$ to port 8089 of VM_2. Answer the following questions:

   (a) Assign IP addresses to the 2 Physical Machines and the 5 Virtual ones.

   (b) At which address a service listening at port 8089 of VM_3 can be contacted by VM_1?

   (c) At which address a service listening at port 8089 of VM_2 can be contacted by VM_4?

   (d) Is VM_2 able to contact VM_5? If so, at which address?

   (e) Is VM_5 able to contact VM_3? If so, at which address?

   Always motivate your answer.

5. The infrastructure in Figure is composed by 4 Physical Servers (Hosts) and 9 Virtual Machines (VM). Hosts (H_1, H_2, H_3 and H_4) are connected to a DHCP server that assigns them the following IP addresses 192.168.10.1, 192.168.10.2, 192.168.10.3 and 192.168.10.4 respectively.

   Assuming that the network configuration enables all the hosts to see each others (i.e.: H_1 can see H_4):

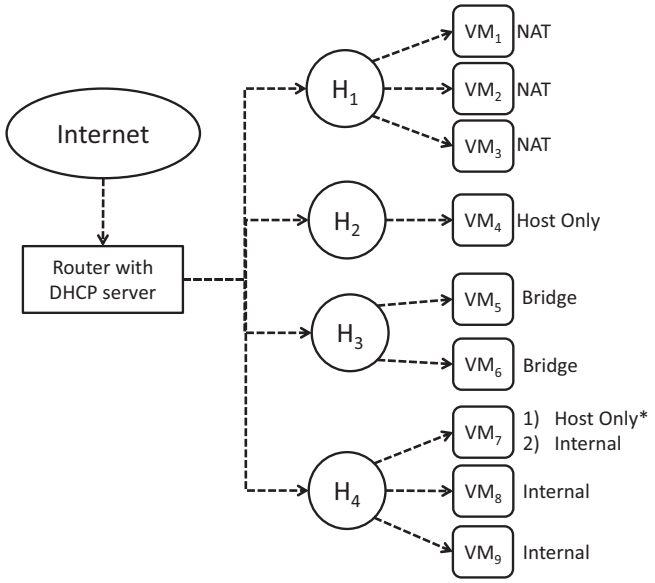
   (a) Assign to each of the 9 VMs correct IP addresses, considering that:
   - Sub-nets for VMs are in the form $10.0.x.x$.
   - For security reasons, the router enables only ports 8080 and 8090 to be forwarded on each adapter.
   - VM_7 has 2 network adapters. Assign an IP address to both of them.
   - A packet forwarding mechanism on H_4 allows VM_7 to see the other hosts using its host-only adapter.

   (b) Using the addresses set in point (a), specify at which address does VM_1 contact a service on port 80 at VM_4?

   (c) At which address does VM_7 contact a service on port 80 at VM_9? At which address can VM_7 contacts a service on port 80 of VM_2?

   (d) At which address does H_2 contact a service on port 80 at VM_8?

   Motivate the answer when required! If port forwarding rules are required, consider that host's port 8080 is mapped on port 80 of the guest.



SOLUTIONS:
Unless other bridging/forwarding rules are specified by the students:

4. In the context of virtualization:

   (a) Define the concept of *Virtual Machine* (VM). Briefly describe when a VM is considered a *process* VM, and when a *system* VM.

   (b) A user would like to test a three-tier architecture composed of a web server (WS), an application server (AS) and a DBMS on her laptop. She would like to install each tier in three different VMs running on her PC: VM_1 for the WS, VM_2 for the AS, VM_3 for the DBMS. All the VMs are characterized by a single virtual network card in NAT mode, and the Host address is 192.168.5.13.

      i. Assuming that the WS runs on port 80, the AS runs on port 9000 and the the DBMS on port 1234, describe the port-forwarding rules required on the Host.

      ii. Which address must be used by the Host to access the WS? At which address the WS can contact the AS? At which address the AS can contact the DB?

SOLUTIONS
a) Slides $21 - 28$ Lesson 1 on Virtualization.
b.i)
Port 8080 on the host $\rightarrow$ port 80 on VM_1,
Port 9000 on the host $\rightarrow$ port 9000 on VM_2 and
Port 1234 on the host $\rightarrow$ port 1234 on VM_3
b.ii) $192.168.5.13 : 8080$, $192.168.5.13 : 9000$ and $192.168.5.13 : 1234$.

3. In a datacenter a total of 10 servers (S_{1-10}) are connected together over the same LAN. The router of this LAN assigns to each machine its IP address starting from 192.168.1.1 to the first machine S_1 and ending at 192.168.1.10 to S_{10}. Machines S_2, S_5, S_6 are used as hosts of virtual machines. VM_1 and VM_2 are guests of S_2, connected in NAT mode; VM_3 is guest of S_5, connected in *internal* mode while VM_4, VM_5, VM_6 are guests of S_6 and connected respectively in *internal*, *bridge* and *host only* modes.

   NAT addresses are given in the form 10.0.x.x, while $Internal$ addresses are in the form 126.10.x.x. Bridged addresses are distributed following the 192.168.1.x form and *host only* are in the form 10.10.x.x.

   Answer the following questions, considering that no routing mechanism is or can be enabled, except for two port forwarding rules S_2 that forward packets directed to port 8080 to a service on VM_1, and forward packets from port 8090 to a service on VM_2.

   (a) Given that the addresses of S_2, S_5 and S_6 are respectively 192.168.1.2, 192.168.1.5 and 192.168.1.6, assign the correct IP to all the VMs.

   (b) At which address S_2 can contact VM_1 and VM_2? At which address those two machines can be contacted by the other servers of the LAN?

   (c) Are there other VMs that can be seen by VM_3?

   (d) Which servers or VM can contact VM_6? At which address?

   SOLUTIONS

   (a) VM_1 = 10.0.1.15, VM_2 = 10.0.1.15, VM_3 = 126.10.0.1, VM_4 = 126.10.0.1, VM_5 = 192.168.1.11, VM_6 = 10.10.0.1

   (b) All the servers, including S_2, can contact VM_1 and VM_2 respectively at 192.168.1.2 : 8080, 192.168.1.2 : 8090

   (c) No

   (d) Only its host (S_6) can contact VM_6 at its address 10.10.0.1.

3. A LAN network connects two physical machines, $host_1$ and $host_2$.

   The first one has 3 virtual machines running on it. VM_1 is a router machine with two network adapters: the first one ($VM_1(eth0)$) is in $Bridged$ mode and connects the VM to its host, the second $VM_1(eth1)$ is in $Internal$ mode. The second VM on $host_1$, VM_2 is connected in $Internal$ mode, while the third VM_3 is in NAT.

   The second machine, $host_2$, has 2 virtual machines running on it: VM_4, connected in $Bridged$ mode, and VM_5 connected in $Hostonly$ mode.

   The router of the LAN to which the hosts are attached is at address 192.168.1.1. Considering that NAT addresses are usually in the form 10.0.x.x, while $Internal$ addresses are in the form 126.10.x.x and $Bridged$ addresses are distributed following the 192.168.x.x form, answer the following questions:

   (a) Attribute the right addresses to all the machines of the LAN, both virtual both physical.

   (b) Can an application listening on port 12345 on $host_1$ be contacted by VM_4? If yes, at which address?

   (c) Is it possible for VM_5 to reach VM_4? At which address?

   (d) Is it possible for $host_2$ to reach VM_3? At which address?

   (e) If $VM_1(eth0)$ mode is changed to $Notattached$, can VM_3 see VM_2? How? At which addresses?

   When more than one address:port is required to perform an operation, please list them in the answer in the correct sequence.

   SOLUTIONS