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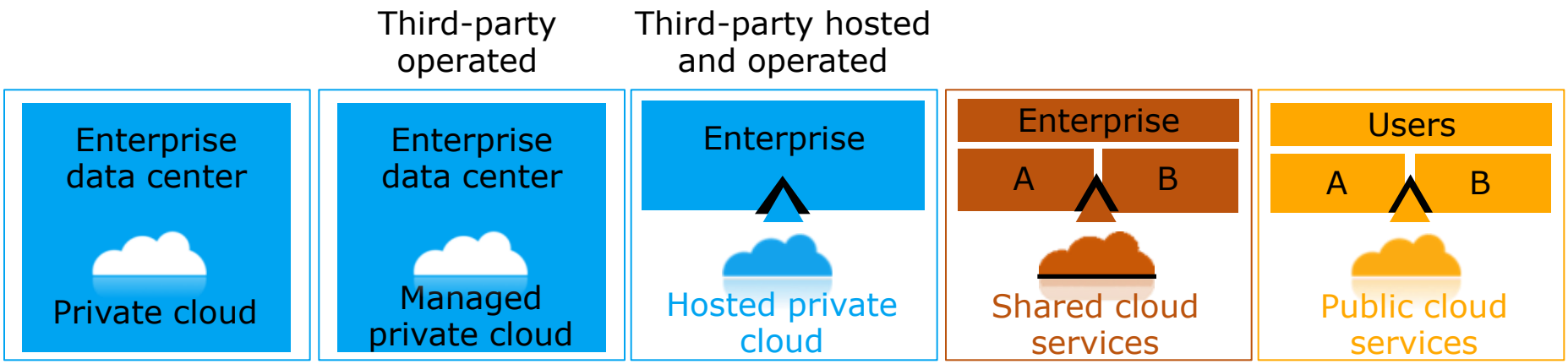
Cloud Networking – an Enterprise View

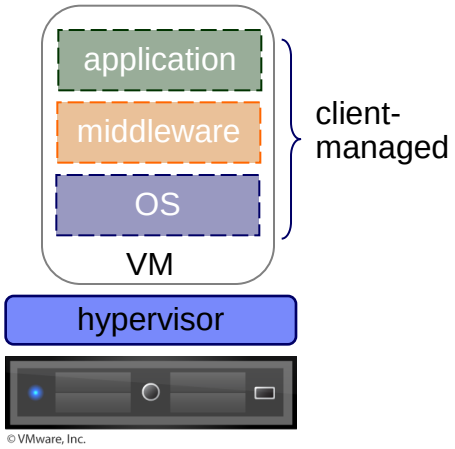
Enterprise clouds – multiple delivery models



- implications on the delivery network
- levels of sharing (infrastructure, services, management …)
- security / isolation / privacy / compliance

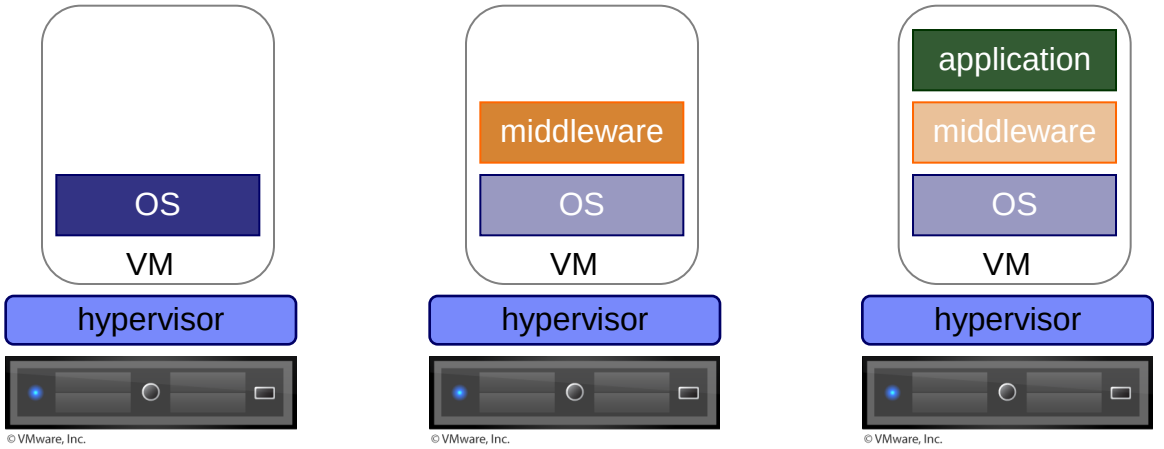
Enterprise clouds – management “up the stack”

public cloud service



- hypervisor security patching
- hypervisor incident mgmnt
- storage for virtual images
- shared services
- …

managed cloud service

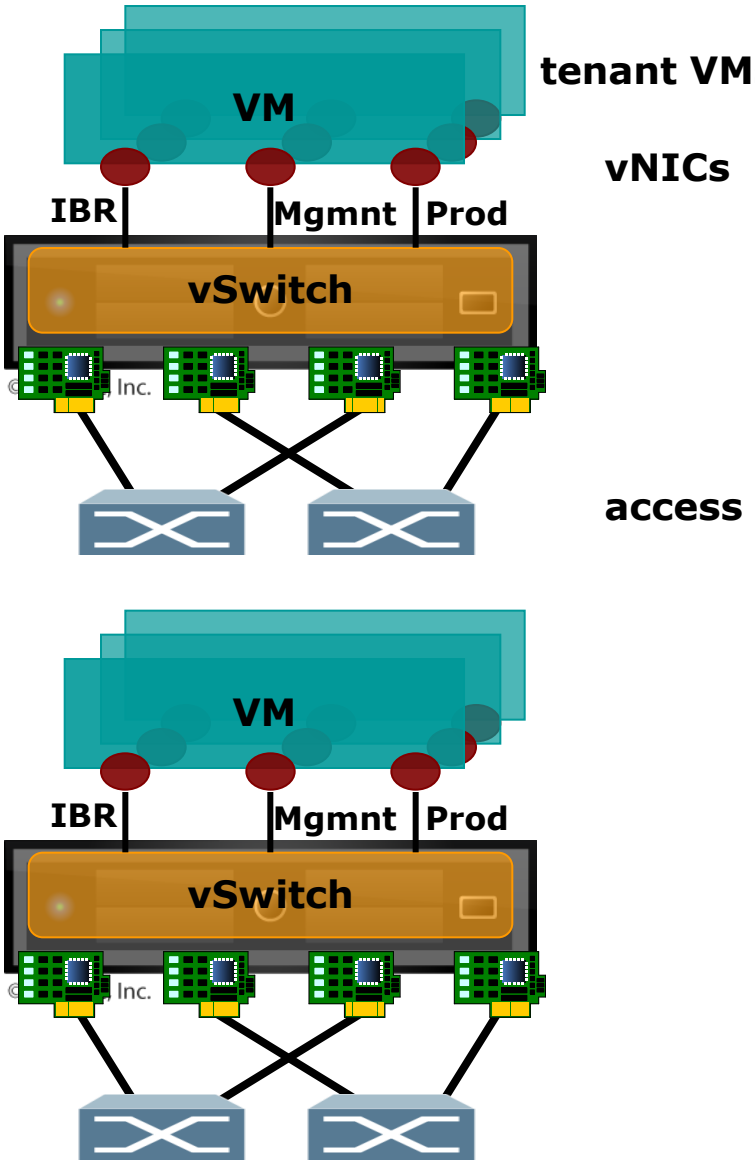


- security patching, software updates
- high-availability, cluster management
- monitoring
- backup / recovery
- SLAs and reporting
- user management
- storage configuration (related to OS)
- application onboarding
- …

Enterprise clouds – tools and infrastructure complexity

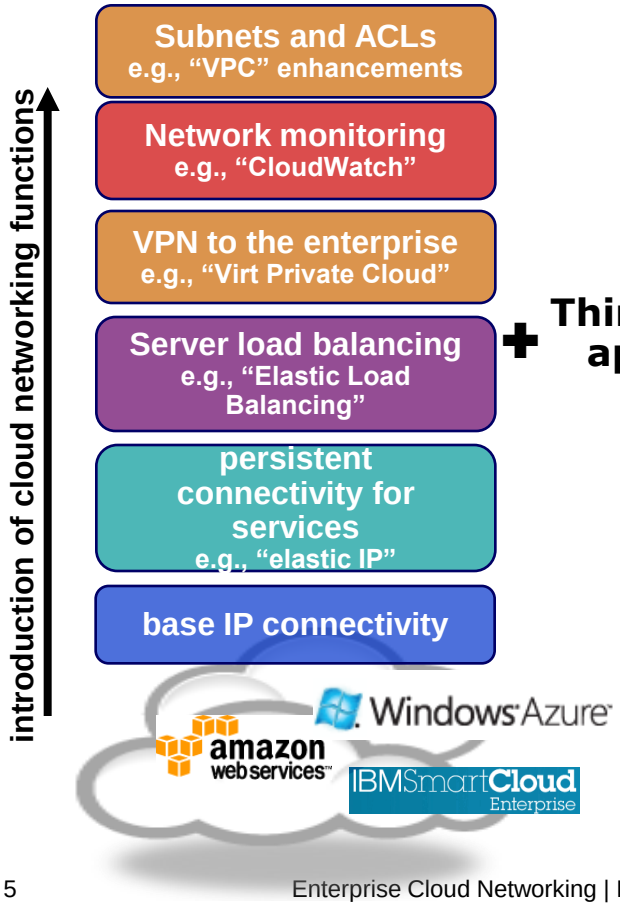
- **VM provisioning**
- **asset and sw license management**
- **change and config management**
- **endpoint patch management**
- **security / policy compliance checking**
- **monitoring and usage accounting**
- **backup and recovery**
- **identity management**

- multitude of tools – some need globally unique endpoints
- multiple isolated networks for management, mobility, backup
- integration with on-premise tools and systems
- multiple risks of address overlap



Networking support in current cloud offerings

- Adding features but limited control of the network
  - requires integration of third-party solutions
  - limits the opportunity to migrate production applications



Third-party virtual appliances

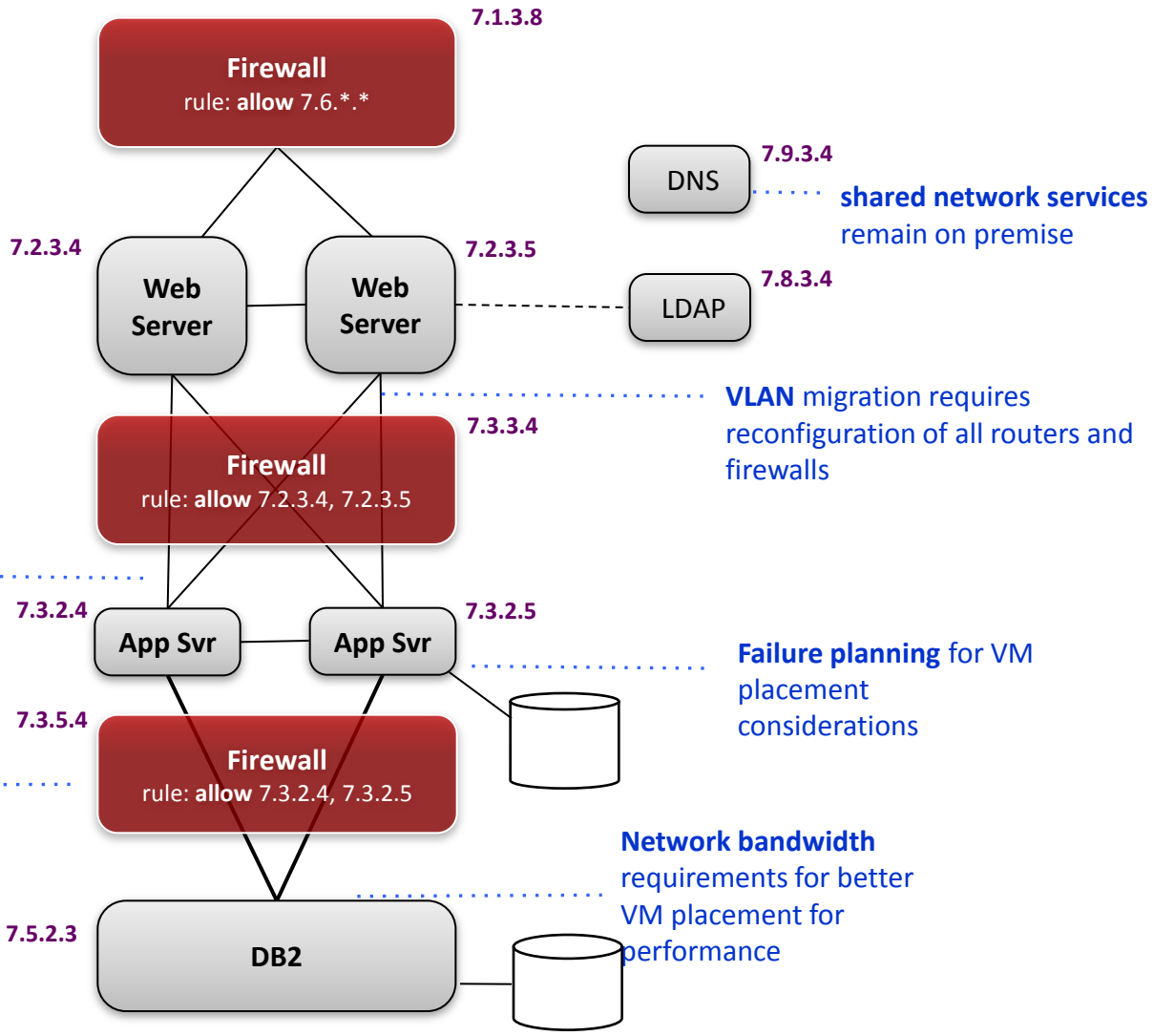
Examples of Missing Features

- **No multicast or broadcast**
- **No ability to create VLANs**
- **No facility for bandwidth or QoS**
- **Limited crafting of network segments**
- **No dynamically structured networks**
- **Limited network mgmnt or visibility**
- **No IPv6 support**

reference: http://broadcast.oreilly.com/2010/12/cloud-2011-the-year-of-the-network-in-the-cloud.html

Anatomy of an enterprise application moving to the cloud

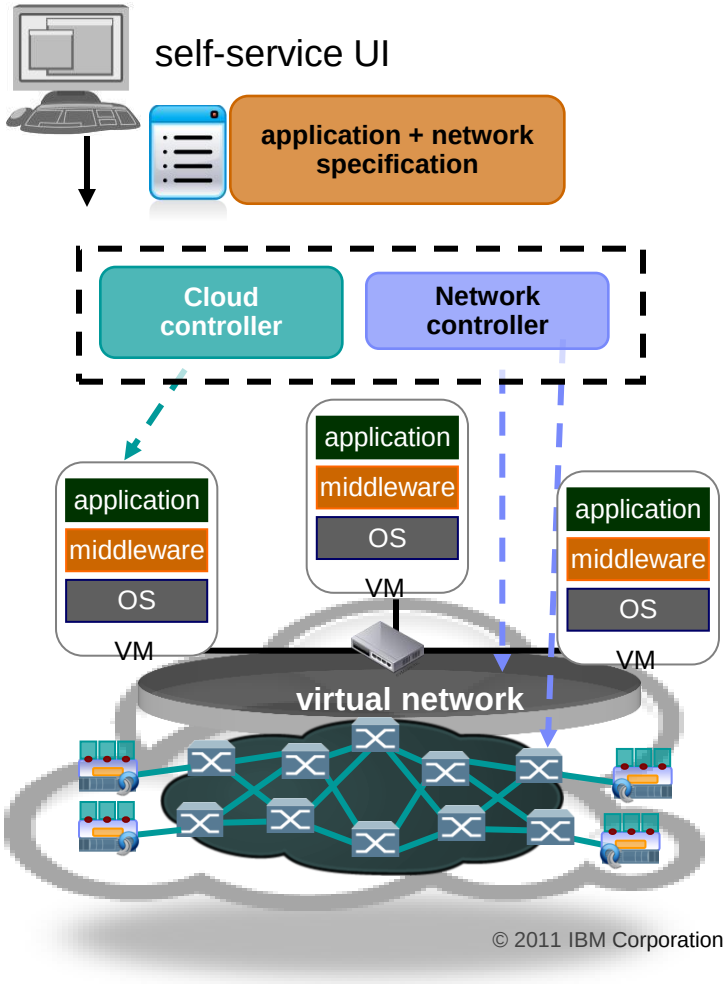
Configurations to preserve: IP addresses, logical topology, firewall rules, VLAN, network bandwidth, fail-over plan, LDAP, DNS, …



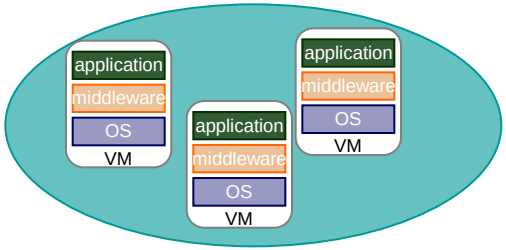
Networking-as-a-service for enterprise clouds

- Allow enterprises to re-create their on-premise network configuration in the cloud
- Unified framework for deploying applications and corresponding network services
- Provide a service-centric, rather than network device centric view

- Cloud controller
  - provides base IaaS service for managing VM instances and images
  - self-service provisioning UI
  - connects VMs via host virtual switches
- Network controller
  - works with cloud controller to provision virtual network services
  - provides VM placement directives to cloud controller
  - configures physical and virtual switches

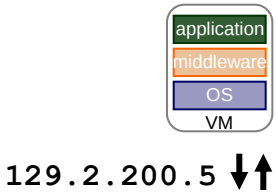


User abstractions for specifying cloud networking functions



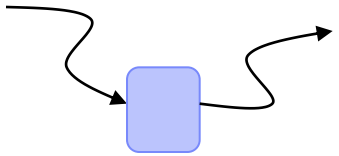
`group`

logical grouping of VMs



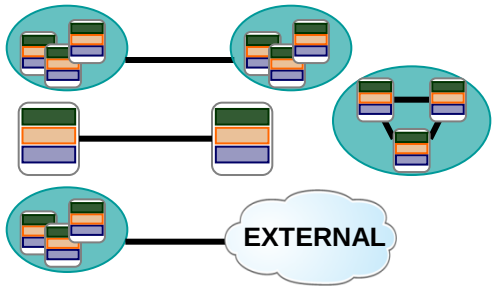
`address`

assign a custom address to the VM



`middlebox`

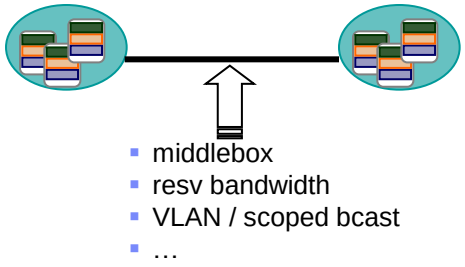
instantiate and config a new middlebox



`virtualnet`

- segments connect groups of VMs

- associated with network services



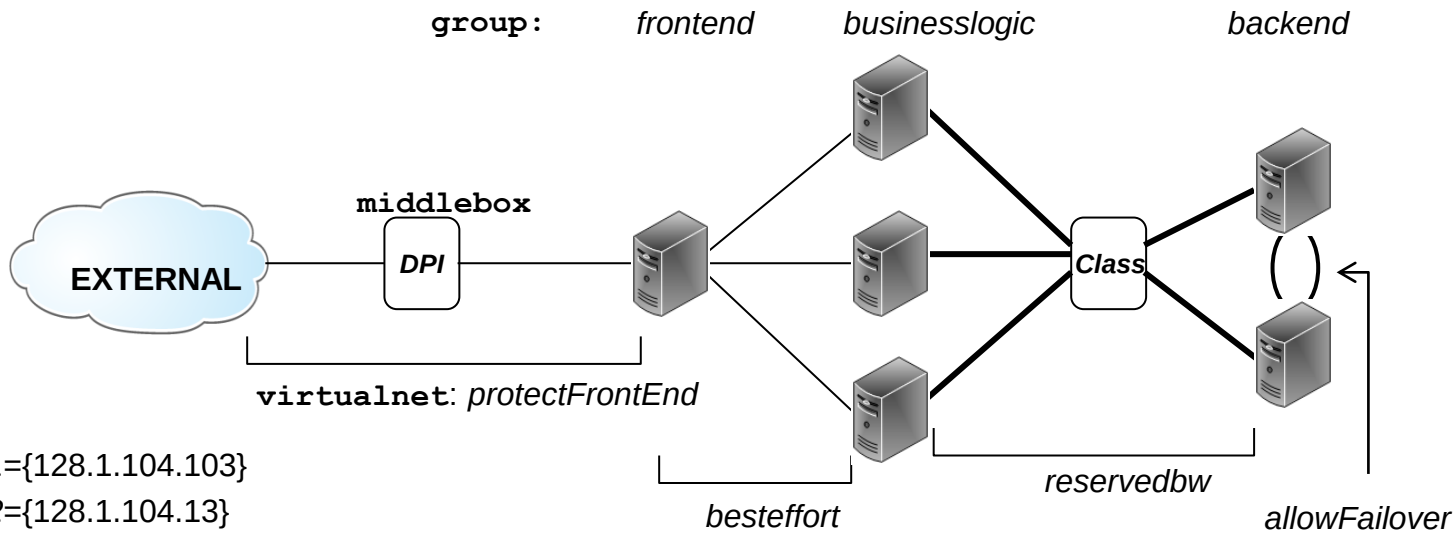
`networkservice`

- attach capabilities to a `virtualnet`

- supports combination of network services

- traffic is allowed to flow only over explicitly defined virtual network segments (“default off”)
- can provide standard templates to implement security policies, or application requirements

Example application with network policy specification



1. **address** *dbserver1*={128.1.104.103}
2. **address** *dbserver2*={128.1.104.13}
3. **group** *frontend*={httpdserver}
4. **group** *businesslogic* = {jboss1,jboss2, jboss3}
5. **group** *backend*={dbserver1,dbserver2}
6. **middlebox** *Class*={type=classifier,config=""}
7. **middlebox** *DPI*={type=dpi,config=""}
8. **networkservice** *protectfrontend*={l2broadcast=no, qos=standard, mb=DPI}
9. **networkservice** *besteffort*={l2broadcast=no, qos=standard, mb=none }
10. **networkservice** *reservedbw* ={l2broadcast=no, qos=10mbs, mb=Class}
11. **networkservice** *allowfailover*={l2broadcast=yes, qos=standard, mb=none}
12. **virtualnet** *allowFailover* (backend)
13. **virtualnet** *protect FrontEnd(frontend,EXTERNAL)*
14. **virtualnet** *besteffort(frontend,businesslogic)*
15. **virtualnet** *reservedbw(businesslogic,backend)*

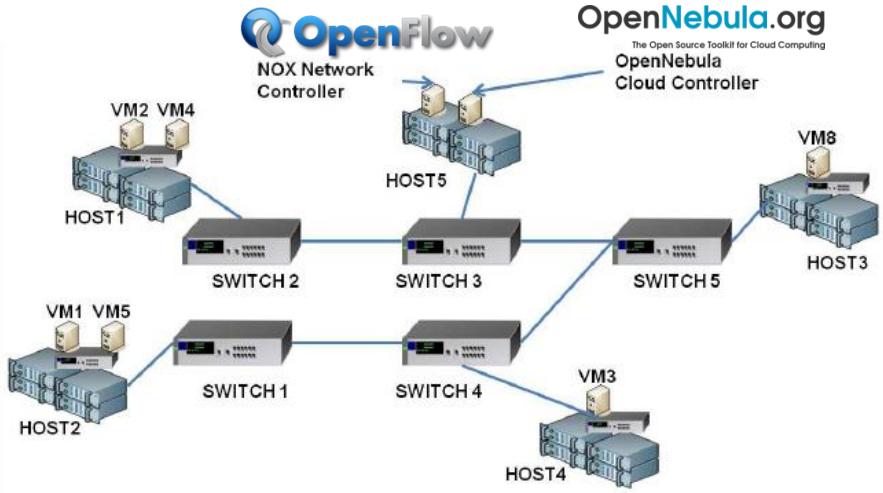
CloudNaaS: A Cloud Networking Platform for Enterprise Applications

IBM Research / University of Wisconsin collaboration

T. Benson, A. Akella, A. Shaikh, S. Sahu, in 2011 ACM Symposium on Cloud Computing (SOCC)

- Cloud Controller: OpenNebula 1.4
  - modified to accept user-specified network policies and interact with the Network Controller
  - minimal modifications (~250 LOC)
  - network policy parser (~250 LOC)

- Network Controller: NOX and OpenFlow-enabled switches
  - HP Procurve 5400 switches w/ OpenFlow 1.0 firmware
  - network controller implemented as a C++ NOX application (~2500 LOC)
  - pulls new / updated communication matrices and VM mappings from Cloud controller
  - interfaces to non-OpenFlow switch-specific functions (e.g., queue management)



- End-host virtual switches: Open vSwitch
  - built-in support for OpenFlow protocol

Challenges at Cloud scale

- Evaluation: experimental and emulated
  - workloads:
    multi-tier business application (e.g., SAP R/3)
    enterprise search / analytics (e.g., MS SharePoint)
  - topologies: standard 3-tier, fat tree
    6K – 30K hosts, 200 – 1000 ToRs, 20 – 100 agg

- Computation and instantiation of network services
  - ~16K instances of 3-tier Web service (270K VMs) requires about 120s in experiments

- Recovering network paths / services when links or switches fail
  - Network controller takes 2 – 10s for recomputation in a large DCN (1000 ToR/100 agg/270K VMs) when a link fails
  - Can be reduced to 0.2s by precomputing solutions for core links
  - Switch failures require an order of magnitude more time to recover

- Managing hardware device limitations
  - $O(V*N^2)$ forwarding entries per device (V = #virtual networks; N = #VMs)
  - TCAM space in switches may only support 2000 flow table entries
  - Optimizations can reduce in-network state (e.g., destination-based forwarding, entry aggregation with network-aware VM placement)

Research implications of enterprise clouds on the network

- Overcoming the scaling limitations of current network devices
  - table sizes: MAC addrs, ACL / TCAMs, VLANs, priority levels, …
  - dynamic updates: changing forwarding tables, queuing rules, etc.
  - take better advantage of device capabilities
- Management integration
  - provide a more comprehensive network management view to tenants
  - integrate the network with adjacent processes and tools
  - compensating for legacy tools and applications in the cloud
- Flexibility with simplicity – make it easy to write network apps
  - reconfigurable / optimized topologies, agile routing
  - leverage the emerging SDN abstractions approach
  - get above the “CCIE interface” to the network

Additional material

Cloud networking standards and models are evolving quickly

- OpenStack Project: open source cloud operating system
  - base Nova networking focuses on address management
    - flat subnet, flat subnet + DHCP, per-project private VLAN with OpenVPN access

Networking services development

  - **Melange**: flexible services for IP addr management
  - **Quantum**: virtual network service to create L2 networks, ports, attachments, connectivity
    - Open vSwitch Quantum plugin available (Nicira), Cisco Nexus/UCS
  - **Donabe** (Network Containers): APIs to manage generalized resource container abstraction – network containers are a first instance of containers

- Commercial cloud solutions
  - Amazon: variety of network functions, incl. VPCs with subnets / ACLs
  - MS Azure: basic addresses / connectivity, VPC, CDN
  - VMWare: vCloud Director Networking (VXLAN) – isolated virtual networks

Related work from industry and academic research

- Network-related services and appliances from 3rd party ISVs / providers
  - HyperIP by NetEx, cohesiveFT assemble. deploy. manage, Aryaka THINK BEYOND THE BOX!, SOURCEfire
  - require integration of multiple solutions, individual service models and functions

- Research proposals on cloud networking abstractions
  - single virtual router [Keller:10]; virt data center + bw guarantees [Guo:10]
  - access control services [Popa:10]
  - virt private cloud [Wood:09], WAN workload migration [Wood:11]

- Multi-tenant virtual networks
  - many proposals (see recent SIGCOMM, NSDI, CoNEXT for examples)

Results

- Optimizations allow support of 3X more VNs
  - Most savings at the core
- VM placement allows even better scaling
  - Applications supported: 4X

Algorithms	Virtual switch	ToR	Aggregation	Core	# of Apps
Default Placement	313	13K	235K	1068K	4k
Default placement + Optimizations	0%	93%	95%	99%	12.2K
Placement Heuristic + Optimizations	0%	99.8%	99%	99%	15.9K