USC EE 542: USC Fall 2017
Lectures 12 ~ 13, Oct. 2 and 4, 2017

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Mobile Clouds, IoT, Mashups, and Cloud OS

Reading Assignments:
Section 3.6 and all sections in Chapter 5

Milestone Mobile Core Networks for Cellular Telecommunication

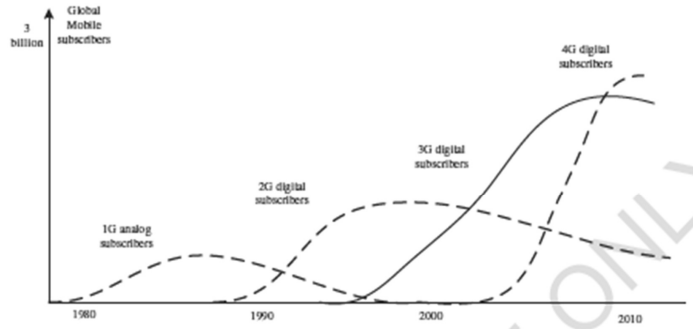


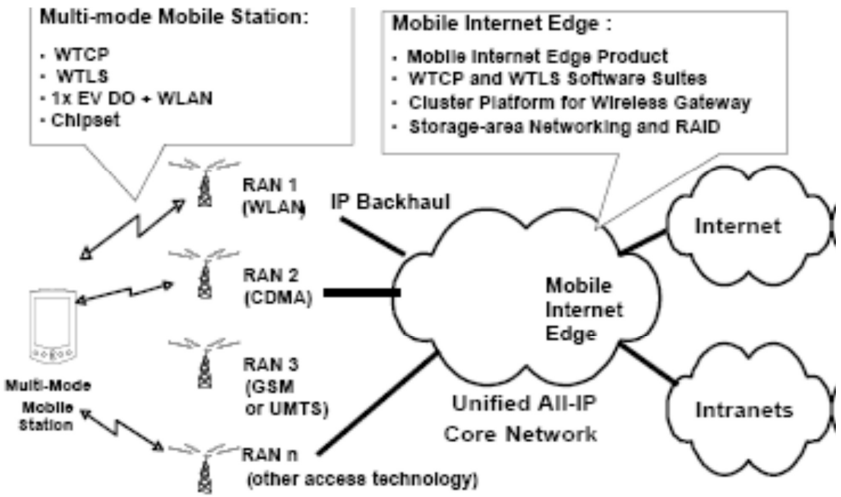
Figure 5.1
Global subscribers of four generations of smartphones and tablet computers exceeded 3 billion by early 2015.

Milestone Mobile Core Networks for Cellular Telecommunication

Table 5.1
Milestone mobile core networks for cellular telecommunication

Generation	1G	2G	3G	4G	5G
Radio and Networks Technology	Analog phones, AMPS, TDMA	Digital phones, GSM, CDMA	CDMA2000, WCDMA, and TD-SCDMA	LTE, OFDM, MIMO, software-steered radio	LTE, Cloud-based RAN
Peak Mobile Data Rate	8 Kbps	9.6 ~ 344 Kbps	2 Mbps	100 Mbps	10 Gbps~1 Tbps
Driving Applications	Voice Communication	Voice/Data Communication	Multimedia Communication	Wideband Communication	Ultra-speed Communication

Various radio-access networks (RANs) with Mobile Network, Intranets, and the Internet.



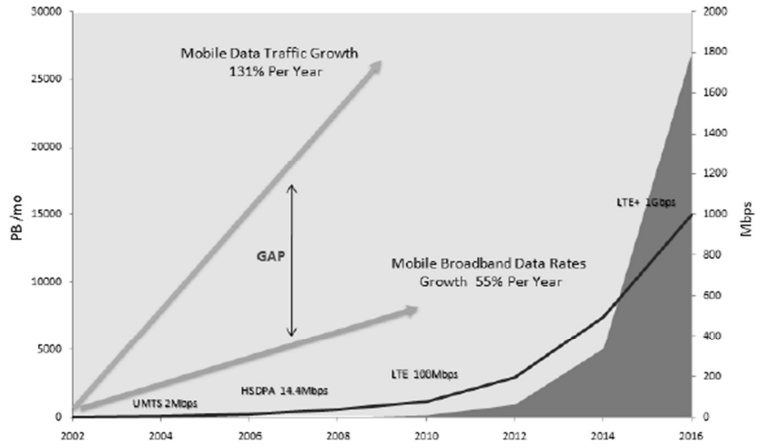


Fig. 5 Mobile Broadband Data-rates/Traffic Growth

Threats and defense concerns in protecting mobile cloud computing

Threats/Defense	Mobile Device	Cloudlet Mesh	Remote Clouds
Encryption for Data Protection	Energy cost for encryption is high on mobile devices	Encryption to secure the access of a remote cloud	Encryption fully supported to protect user data lost
Virus, Worms, or Malware Attacks	Privacy and energy cost for detecting malware is high	Protect mobile device by verifying files and content	Perform analytics on the cloud to detect new types of malware
Identity Theft and Authentication	User authentication before offloading to clouds	Need to authenticate all three parties involved	Authentication as a service (AaaS) is needed
Cloud Offloading and File Transfer	Offloading tasks in security-enforced cloudlet mesh	Data caching at cloudlet to improve performance	High latency to offload may create a QoS problem
Data Integrity and Storage Protection	May use secure storage outsourcing protocols	Data stored by the cloudlet is vulnerable to attacks	Clouds may compromise user data through phishing attacks
URL and IP and Spam Filtering	Checking blacklist of IP addresses and URLs	Alert mobile devices with intrusive attacks on clouds	Performs predictive analytics and provides database updates

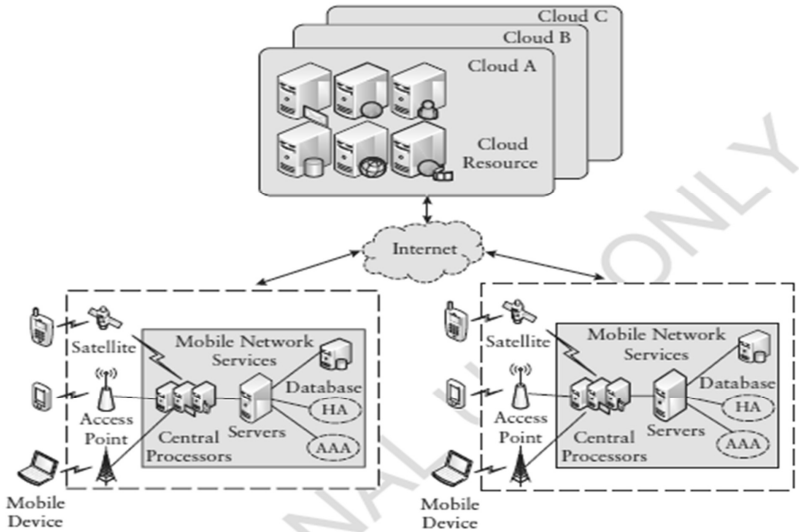


Figure 5.6
The architecture of a mobile cloud computing environment.

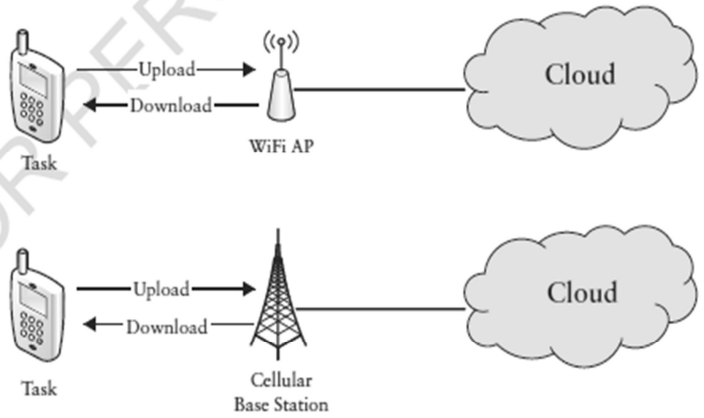


Figure 5.7
Two task offloading methods to access remote clouds (a) via Wi-FI access point and (b) via a cellular network through a base station.

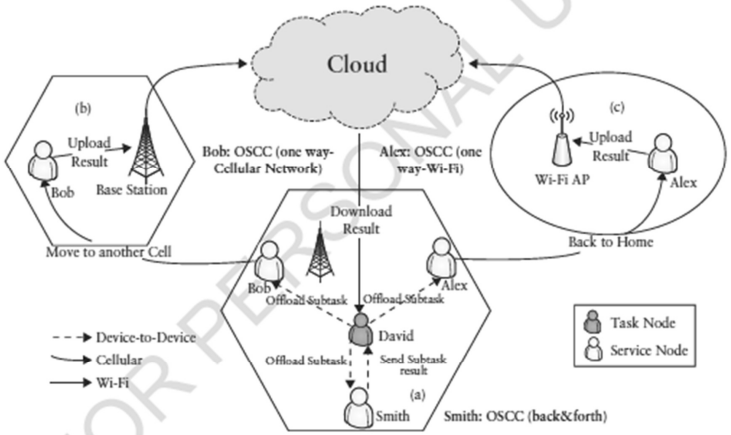


Figure 5.8
Efficient tasks offloading among colocation clouds in a mobile environment. Source: Chen and Hwang, et al., "Body Area Networks: A Survey," *ACM/Springer Mobile Networks and Applications* (MONET) 16 no. 2 (2010): 171–193.

Table 5.2
Wireless networking used in mobile IoT and cloud computing

Network Types	Cellular WAN	WMAN	WLAN	WPAN	WPAN
Market Name	GSM/GPRS	WiMaX	Wi-Fi	ZigBee	Bluetooth
Standard	CDMA/1XRTT	802.15.6	802.11n	802.15.4	802.15.1
Application focus	Wide Area Voice and Data	Data, Trans. Bandwidth	Web, E-mail, Video	Monitoring & Control	Cable Replace
Memory (MB)	18+	8+	1+	0.004–0.032	0.25+
Battery (days)	1–7	1–7	0.5–5	100–1000+	1–7
Network Size	1	1	32	2^{64} or more	7
Bandwidth (KBs)	64–128+	75,000	54,000+	20–250	720
Range (KM)	1000+	40 ~ 100	1–100	1–100+	1–10+
Success Metric	Coverage	Speed	Flexibility	Power, Cost	Low cost

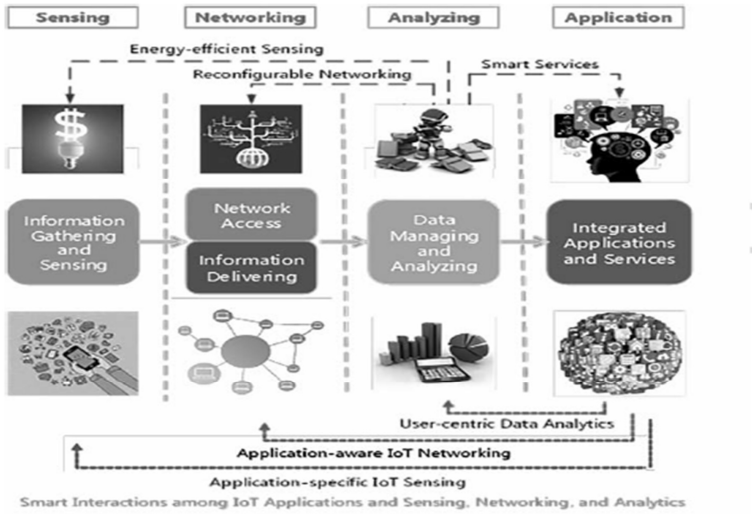


Figure 5.13
Interactions among IoT sensing, mobile monitoring, and cloud analytics. Reprinted with permission from Hwang and Chen, *Big Data Analytics for Cloud, IoT and Cognitive Learning*, Wiley, 2017.

Table 5.5
Requirements of four IoT computing and communication frameworks

Framework	WSN	M2M	BAN	CPS
Sensing Requirement	XXXX	XX	XXX	XXX
Networking Demand	XX	XXXX	XX	XXXX
Analyzing Complexity	XX	XX	XXX	XXXX
Application Industrialization	XXXX	XXX	XX	X
Security Demand	X	XX	XXX	XXXX

Body-Area Networks (BAN) for Health-Care and Personal Apps

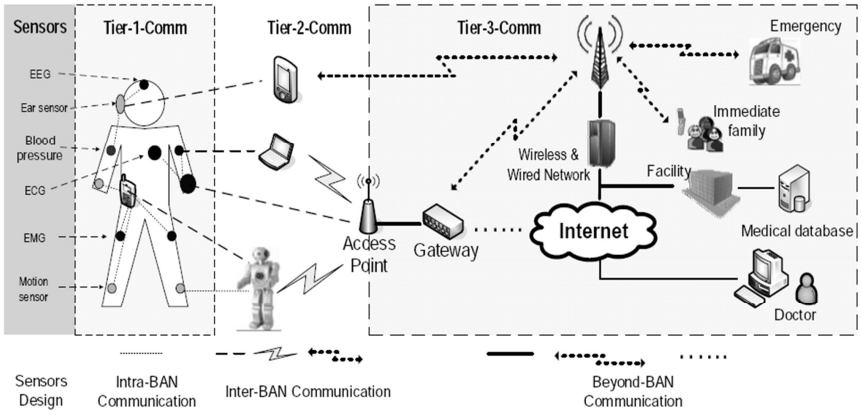


Figure 4.9 A three-tier architecture based on a BAN communications system.

IoT Counts on Cloud Storage and Processing Power

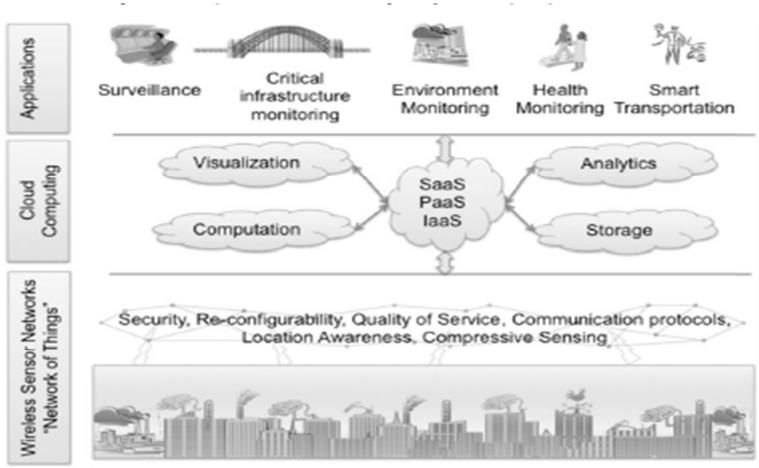
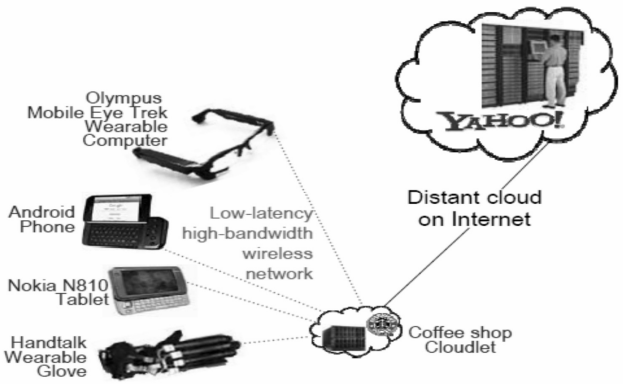


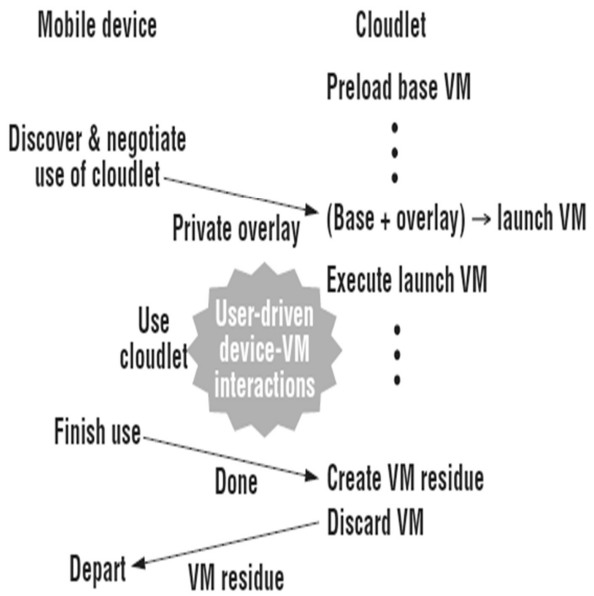
Fig. 4. Conceptual IoT framework with Cloud Computing at the center.

Cloudlets- A trusted portal for Mobile Devices with cognitive abilities and pervasive capacity to access distance cloud to catch special events, check security alerts, and make intelligent decision making, etc.



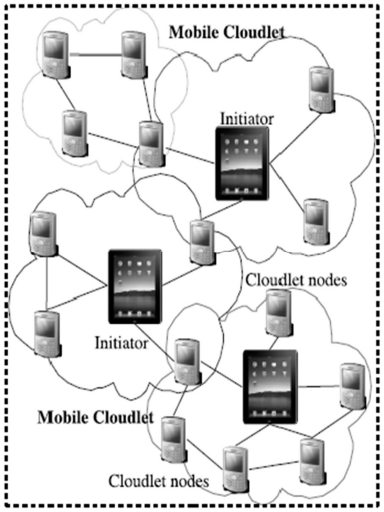
Source: Satyanarayanan, et al., "The Case of VM-based Cloudlets in Mobile Computing," *IEEE Pervasive Computing*, April 2009

- **Two approaches for Cloudlet:**
  - **VM migration (~8GB)**
  - **Dynamic VM synthesis (100 ~ 200MB)**
- **Performance is determined by local recourses:**
  - **Bandwidth**
  - **Compute power**



Basic Concept of Extending the Cloudlets into A Mobile Mesh

A proximate fixed cloud consists of one or several resource-rich, multi-core, Gigabit Ethernet connected computer aiming to augment neighboring mobile devices while minimizing security risks, offloading distance (one-hop migration from mobile to Cloudlet), and communication latency.



Mobile Cloud Offloading Environment

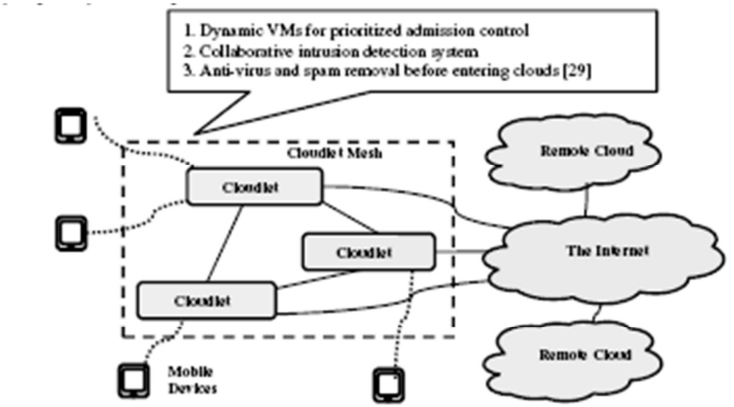
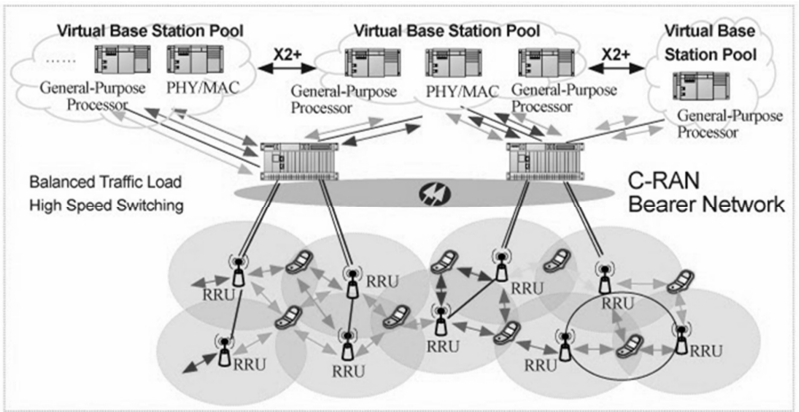


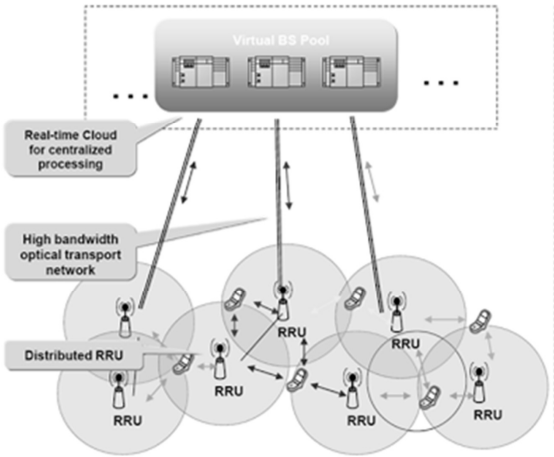
Figure 1: Cloudlet mesh architecture for securing mobile cloud computing, where the VM-prioritized admission control and collaborative IDS are newly presented here, and the spam filtering results were presented in the conference paper [29].

Is 5 G in the Near Future ?

Virtual Base Station Pool and C-RAN Bear Network (1)



Centralized Cloud Control and Processing



Centralized Control and/or Processing
- Centralized processing resource pool that can support 10~1000 cells

Collaborative Radio
- Multi-cell Joint scheduling and processing

Real-Time Cloud
- Target to Open IT platform
- Consolidate the processing resource into a Cloud
- Flexible multi-standard operation and migration

Clean System Target
- Less power consuming
- Lower OPEX
- Fast system roll-out

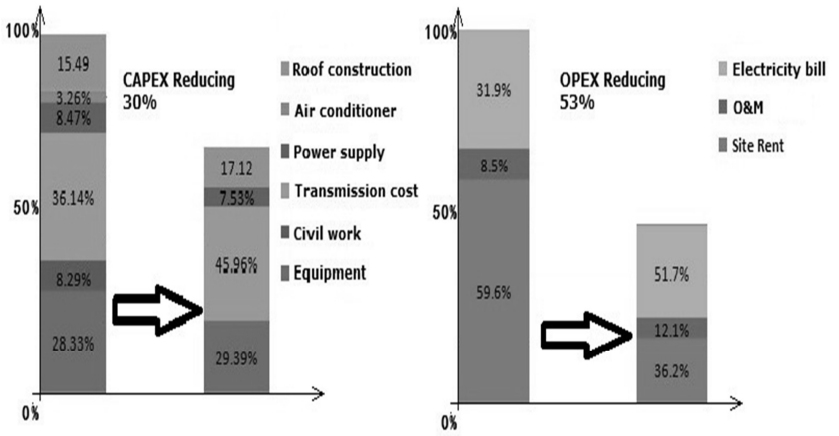


Fig. 20 Economic analysis for centralized deployment

Table 4. Power consumption comparison

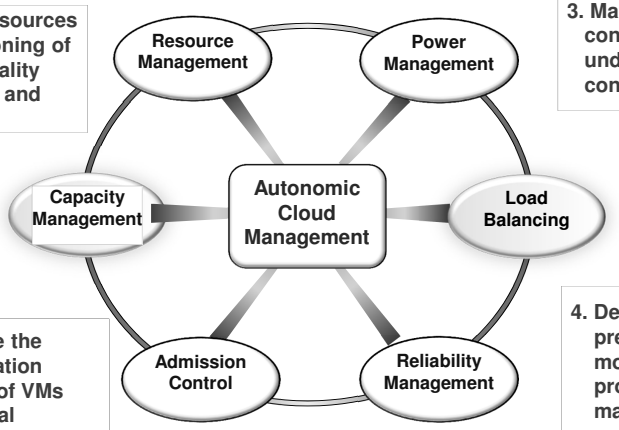
RAN architecture	Base Station equipment	Air conditioning	Switching Supply	Storage Battery	Transmission System	Total
Traditional	0.65 KW	2.0 KW	0.2 KW	0.2 KW	0.2 KW	3.45KW
C-RAN	0.55KW	0	0.2KW	0.10KW	0	0.85KW

Lecture 13: Oct.4, 2017
Autonomic Cloud Management

Develop methodologies and tools to automate the process of cloud management in 4 objectives

1. Manage resources to provisioning of service quality assurance and adaptation

3. Manage energy consumption under SLA constraints



2. Automate the configuration process of VMs and virtual clusters

4. Develop fault prediction models for proactive failure management

Virtualization for Datacenter Automation
to serve millions of clients, simultaneously

- Server Consolidation in Virtualized Datacenter
- Virtual Storage Provisioning and Deprovisioning
- Cloud Operating Systems for Virtual Datacenters
- Trust Management in virtualized Datacenters

Table 3.11
Open-source software for cloud computing (except the vSphere 6)

Software	Cloud Type, License	Language Used	Linux/ Windows	EC2/S3 Compatibility	XEN/KVM/ VMWare
Eucalyptus	IaaS, Rackspace	Java, C	Yes/Yes	Yes/Yes	Yes/Yes/Yes
Nimbus	IaaS, Apache	Java, Python	Unknown	Yes/No	Yes/Yes/ Unknown
Cloud Foundry	PaaS, Apache	Ruby, C	Yes/No	Yes/No	Yes/Yes/Yes
OpenStack	IaaS, Apache	Python	Yes/Unknown	Yes/Yes	Yes/Yes/ Unknown
OpenNebula	IaaS, Apache	C, C++, Ruby, Java, Lex, YaaS, Shell Script	Yes/Unknown	Yes/Unknown	Yes/Yes/ Unknown
ApplScale	Unknown	Unknown	Unknown	Yes/Yes	Yes/Yes/Yes
vSphere 6	Unknown	Unknown	Yes/Yes	Yes/Yes	Yes/Yes/Yes

In Homework Prob. 3.17, you are supposed to dig out more details from VMWare published material. Go visit their Web page.

Cloud Software Packages and Features

Software	Cloud Type	License(s)	Language	Linux/ Windows	EC2/S3	Xen/KVM/ VMWare	Virtual Box	OCCI/ vCloud
Fluid Operations	Iaas, Paas, LaaS, SaaS, TaaS, DaaS, BaaS	Proprietary	Java, C	Yes/Yes	Yes/No	Yes/Yes/ yes	?	No /Yes
ApplScale	Paas	BSD	Python, Ruby, Go	? / ?	Yes/ Yes	Yes/Yes/ yes	Yes	? / ?
Cloud Foundry	PaaS	Apache	Ruby, C	Yes/No	Yes/No	Yes/Yes/ yes	Yes	No /Yes
Cloud.com	IaaS	Proprietary, GPLv3	Java, C	? / ?	? / ?	Yes/Yes/ yes	?	? / ?
Eucalyptus	IaaS	Proprietary, GPLv3	Java, C	Yes/No	Yes/ Yes	Yes/Yes/ yes	?	? / ?
Nimbus	IaaS	Apache	Java, Python	? / ?	Yes/No	Yes/ Yes/?	?	? / ?
OpenNebua	IaaS	Apache	C++,C,Ruby, Java, lex, yacc, Shellscript	Yes/ ?	Yes/ ?	Yes/ Yes/?	?	Yes/Yes
OpenStack	IaaS	Apache	Python	Yes/ ?	Yes/ Yes	Yes/ Yes/?	?	? / ?

Source: http://en.wikipedia.org/wiki/Cloud_computing_comparison (read 02/02/2012)

Cloud OS for Building Private Private Clouds

Table 3.6 VI Managers and Operating Systems for Virtualizing Data Centers [9]

Manager/ OS, Platforms, License	Resources Being Virtualized, Web Link	Client API, Language	Hypervisors Used	Public Cloud Interface	Special Features
Nimbus Linux, Apache v2	VM creation, virtual cluster, www .nimbusproject.org/	EC2 WS, WSRF, CLI	Xen, KVM	EC2	Virtual networks
Eucalyptus Linux, BSD	Virtual networking (Example 3.12 and [41]), www .eucalyptus.com/	EC2 WS, CLI	Xen, KVM	EC2	Virtual networks
OpenNebula Linux, Apache v2	Management of VM, host, virtual network, and scheduling tools, www.opennebula.org/	XML-RPC, CLI, Java	Xen, KVM	EC2, Elastic Host	Virtual networks, dynamic provisioning
vSphere 4 Linux, Windows, proprietary	Virtualizing OS for data centers (Example 3.13), www .vmware.com/ products/vsphere/ [66]	CLI, GUI, Portal, WS	VMware ESX, ESXi	VMware vCloud partners	Data protection, vStorage, VMFS, DRM, HA

Eucalyptus : An Open-Source Cloud Operating System

- A software platform developed by Eucalyptus Systems, Inc., (started 2008 and stable release 2010)
- Written in Java, C, running with Linux, can host Linux and Windows VMs
- Use hypervisors (Xen, KVM and VMWare) and compatible with EC2 and S3 services
- Eucalyptus stands for "Elastic Utility Computing Architecture for Linking Your Programs To Useful Systems".
- For use in developing IaaS-style private cloud or hybrid cloud on computer cluster, working with AWS API
- license : Proprietary or GPLv3 for open-core enterprise edition and also an open-source edition available
- Web site: www.eucalyptus.com

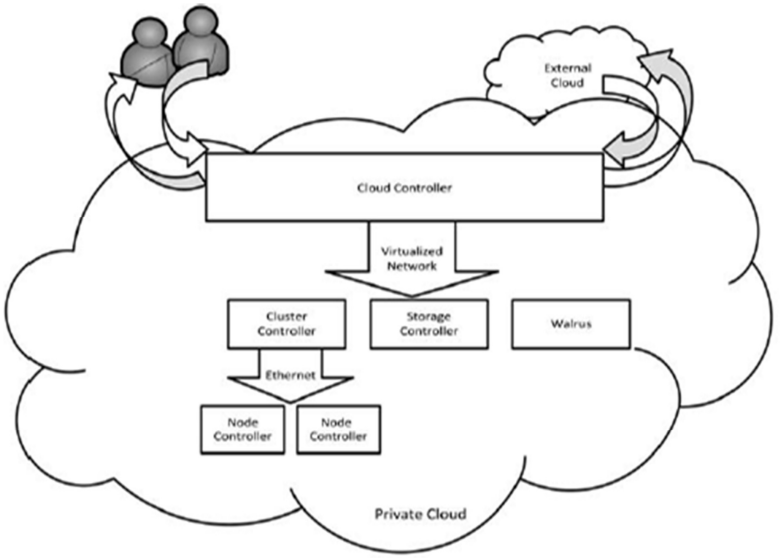


Figure 3.22
The Eucalyptus for building private cloud by establishing virtual network over the VMs linking through Ethernet and the Internet.

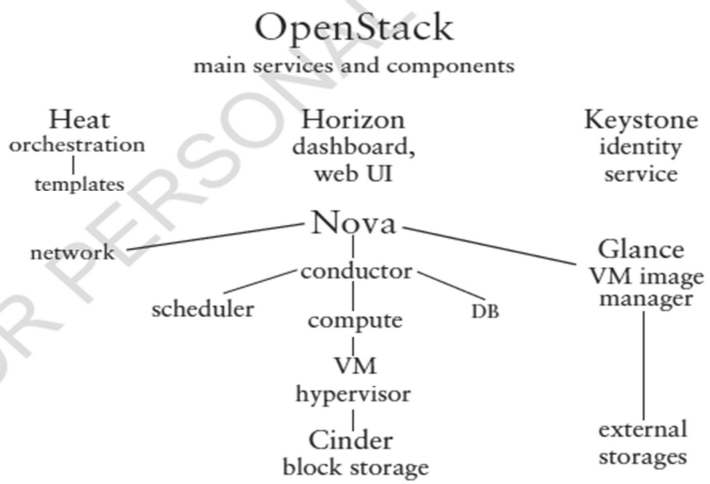


Figure 3.24
OpenStack for constructing private or public clouds in IaaS services. Courtesy of OpenStack, http://openstack.org, Apache License 2.0.

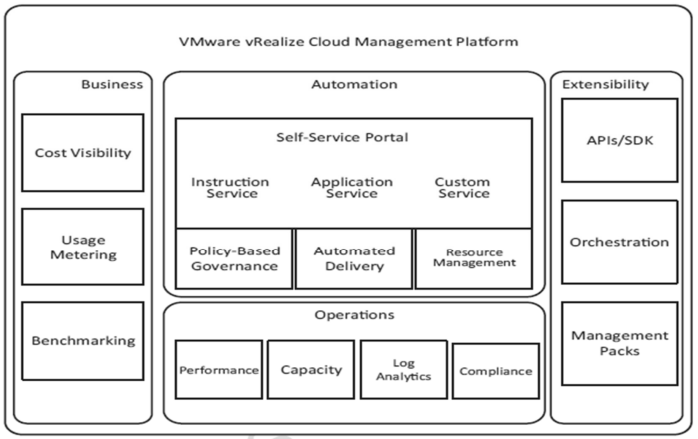


Figure 3.26
VMware software packages for building hybrid clouds: vSphere, NSX, and vSAN work in private clouds, SDN, and distributed storage operations that work jointly with public clouds.

3.17: The vSphere 6 is a cloud OS commercially available from VMware. Review the open literature that reports the porting and application experiences and measured performance by its clients or user groups. Write a short technical report to summarize your research findings.

Eucalyptus Architecture :

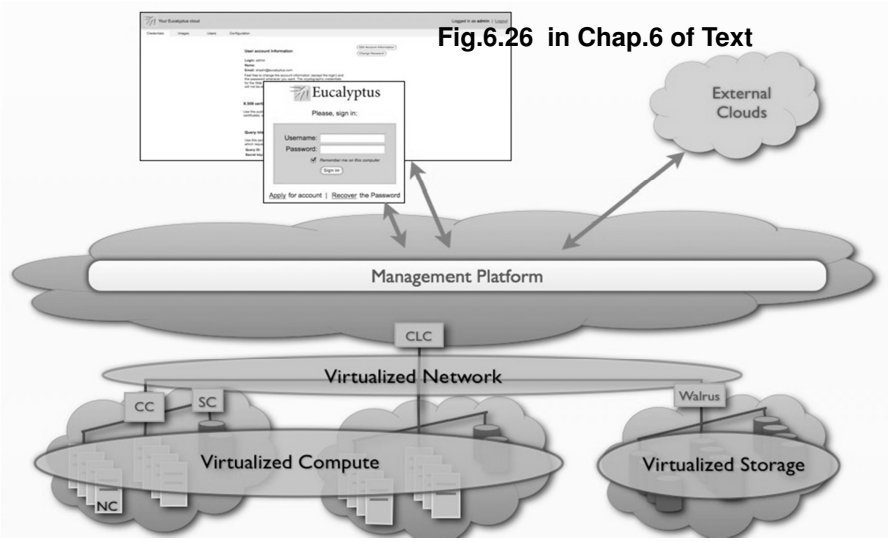


Fig.6.26 in Chap.6 of Text

Eucalyptus : An Open-Source OS for building Private Clouds (1)

Eucalyptus is an open source software system (Figure 3.27) intended mainly for supporting Infrastructure as a Service (IaaS) clouds. The system primarily supports virtual networking and the management of VMs; virtual storage is not supported. Its purpose is to build private clouds that can interact with end users through Ethernet or the Internet. The system also supports interaction with other private clouds or public clouds over the Internet. The system is short on security and other desired features for general-purpose grid or cloud applications.

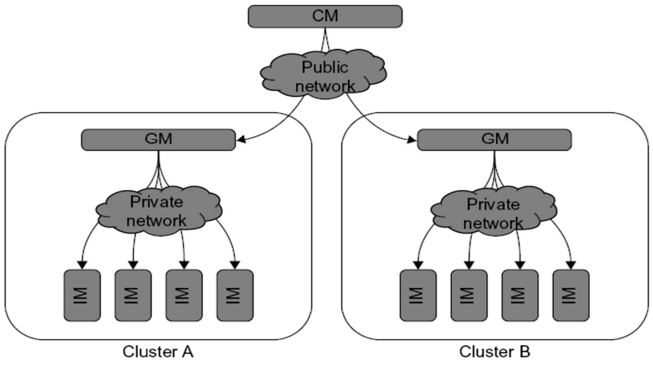


FIGURE 3.27

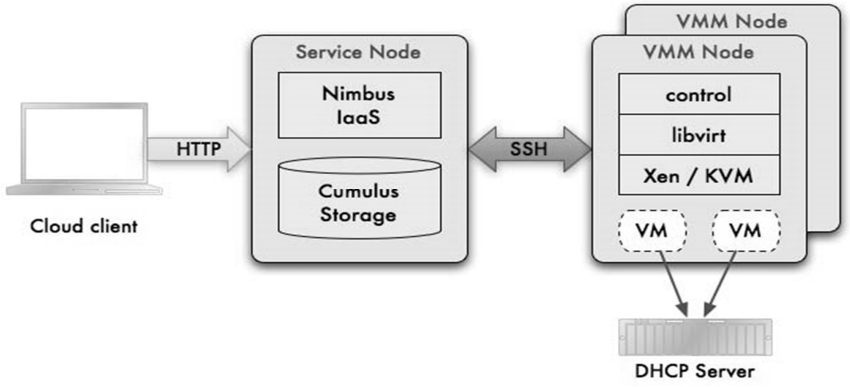
Eucalyptus for building private clouds by establishing virtual networks over the VMs linking through Ethernet and the Internet.

(*Courtesy of D. Nurmi, et al. [45]*)

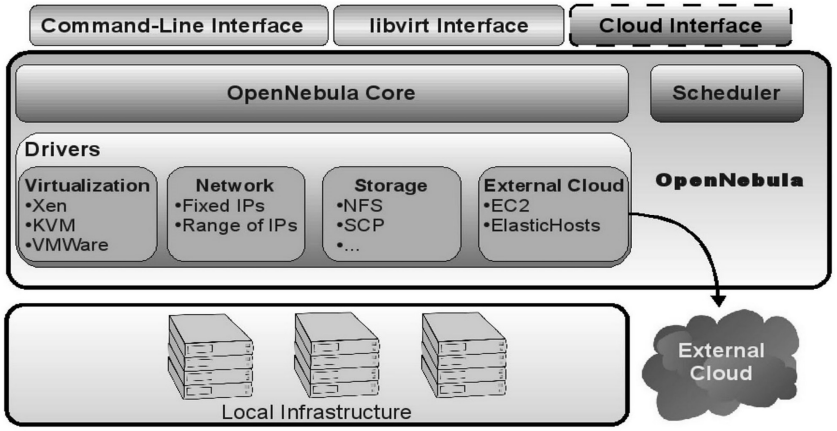
Eucalyptus : An Open-Source OS for building Private Clouds

- **Instance Manager** controls the execution, inspection, and terminating of VM instances on the host where it runs.
- **Group Manager** gathers information about and schedules VM execution on specific instance managers, as well as manages virtual instance network.
- **Cloud Manager** is the entry-point into the cloud for users and administrators. It queries node managers for information about resources, makes scheduling decisions, and implements them by making requests to group managers.

Nimbus Cloud Infrastructure



OpenNebula Architecture



Openstack：An IaaS Cloud Project

launched by Rackspace and NASA in 2010, jointly

- **Currently, 120 companies have joined the Openstack.**
- **Openstack is used to create private cloud and offer cloud compute (Nova), object storage (Swift) and image services (Glance).**
- **The project offers free open-source software under the Apache license. The Openstack cloud software is written in Python, web site: http://openstack.org/**

Openstack：

An IaaS Cloud Library

- **Nova site:**
  http://openstack.org/projects/compute/,
  http://launchpad.net/nova/
- **Swift site:**
  http://openstack.org/projects/storage/,
  http://launchpad.net/swift/
- **Glance site:**
  http://openstack.org/projects/image-service/,
  http://launchpad.net/glance/

OpenStack Nova System

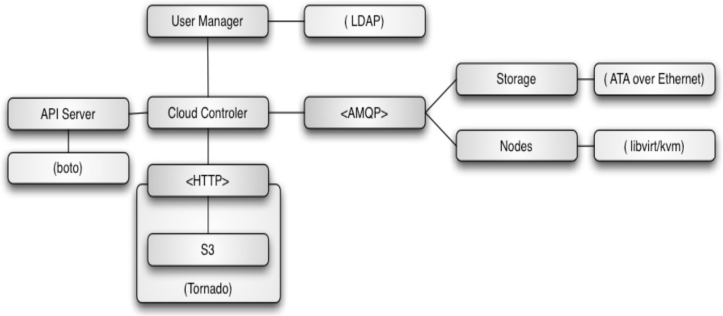


Figure 6.36 OpenStack Nova system architecture. AMQP is an Advanced messaging queuing protocol

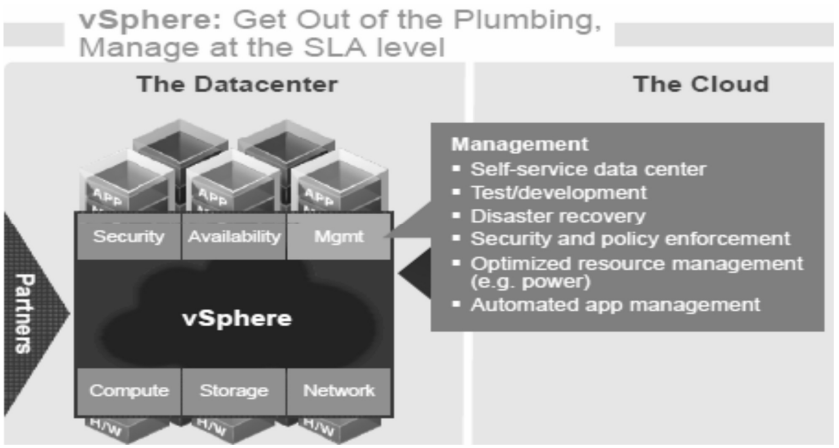
Virtualization Services (HaaS) : VMware

- **VMware provides virtualization software with a market share more than 80%. The company was acquired by EMC in 2004 for $625 million.**
- **VMware Workstation: This software suite allows users to run multiple instances of x86 or x86-64 -compatible OS on a single physical PC.**
- **VMware Fusion: This provides similar functionality like the VMware Workstation for users of the Intel Mac platform, along with full compatibility with virtual machines created by other VMware products.**

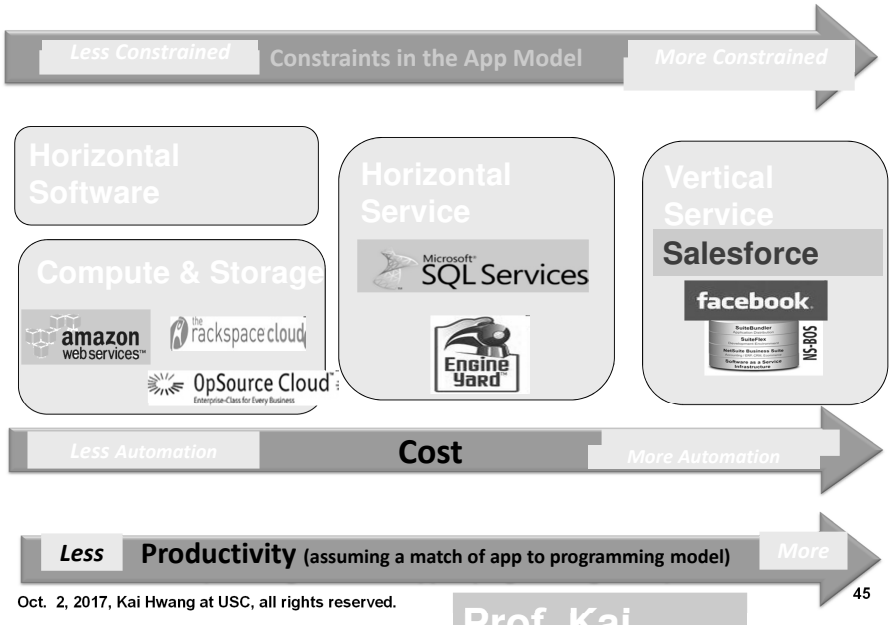
Virtualization Services (HaaS) : VMware

- **VMware Server: It is provided as freeware for non-commercial use, and it is possible to create virtual machines with it. It is a "hosted" application, which runs within an existing Linux or Windows operating system.**
- **VMware ESX : It is an enterprise-level product, can deliver greater performance than the freeware VMware Server, due to lower system overhead. VMware ESX is a "bare-metal" product, running directly on the server hardware, allowing virtual servers to also use hardware more or less directly.**
- ***VMware vSphere* is a "cloud OS" capable of managing large pools of infrastructure. We will cover cloud OS in Lectures 15 and 16.**

vSphere : A Commercial OS for converting datacenters into Cloud Platforms



Cloud Services: Constraints, Cost and Productivity



Advances in HLL for Clouds

Table 6.7: Comparison of High Level Data Analysis Languages

	Sawzall	Pig Latin	DryadLINQ
Origin	Google	Yahoo	Microsoft
Data Model	Google Protocol Buffer or basic	Atom, Tuple, Bag,Map	Partition File
Typing	Static	Dynamic	Static
Category	Interpreted	Compiled	Compiled
Programming Style	Imperative	Procedural: sequence of declarative steps	Imperative and Declarative
Similarity to SQL	Least	Moderate	A lot!
Extensibility (User defined functions)	No	Yes	Yes
Control Structures	Yes	No	Yes
Execution Model	Record Operations + fixed aggregations	Sequence of MapReduce operations	Directed Acyclic Graphs
Target Runtime	Google MapReduce	Hadoop (Pig)	Dryad

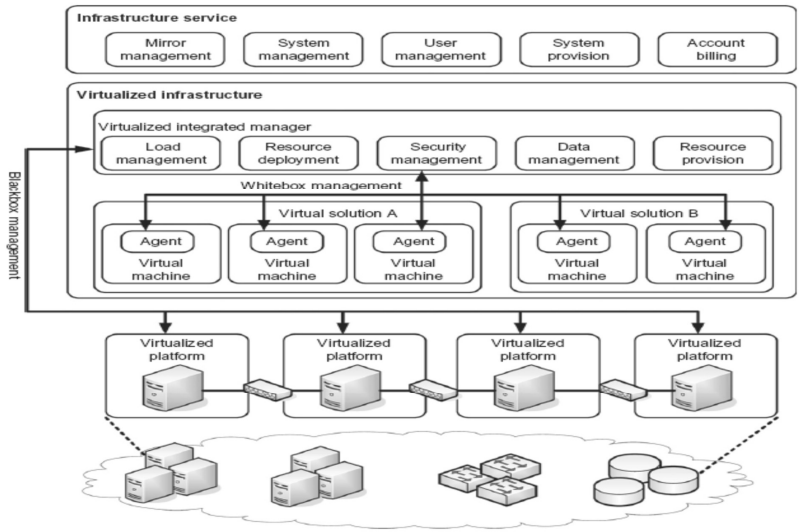


FIGURE 4.17
Virtualized servers, storage, and network for cloud platform construction.
(Courtesy of Zhong-Yuan Qin, SouthEast University, China)

Cloud Support in Internet of Things and Social Network Applications

1. **Smart and pervasive cloud applications for individuals, homes, communities, companies, and governments, etc.**
2. **Coordinated calendar, itinerary, job management, events, and consumer record management (CRM) services**
3. **Coordinated word processing, on-line presentations, web-based desktops, sharing on-line documents, datasets, photos, video, and databases, content distribution, etc.**
4. **Deploy conventional cluster, grid, P2P, social networking applications in the cloud environments, more cost-effectively.**
5. **Earthbound applications that demand elasticity and parallelism to avoid large data movement and reduce the storage costs**