Co-funded by the Erasmus+ Programme of the European Union

Advanced distributed computing for IoT

University of Sumer
College of Computer Science and Information Technology

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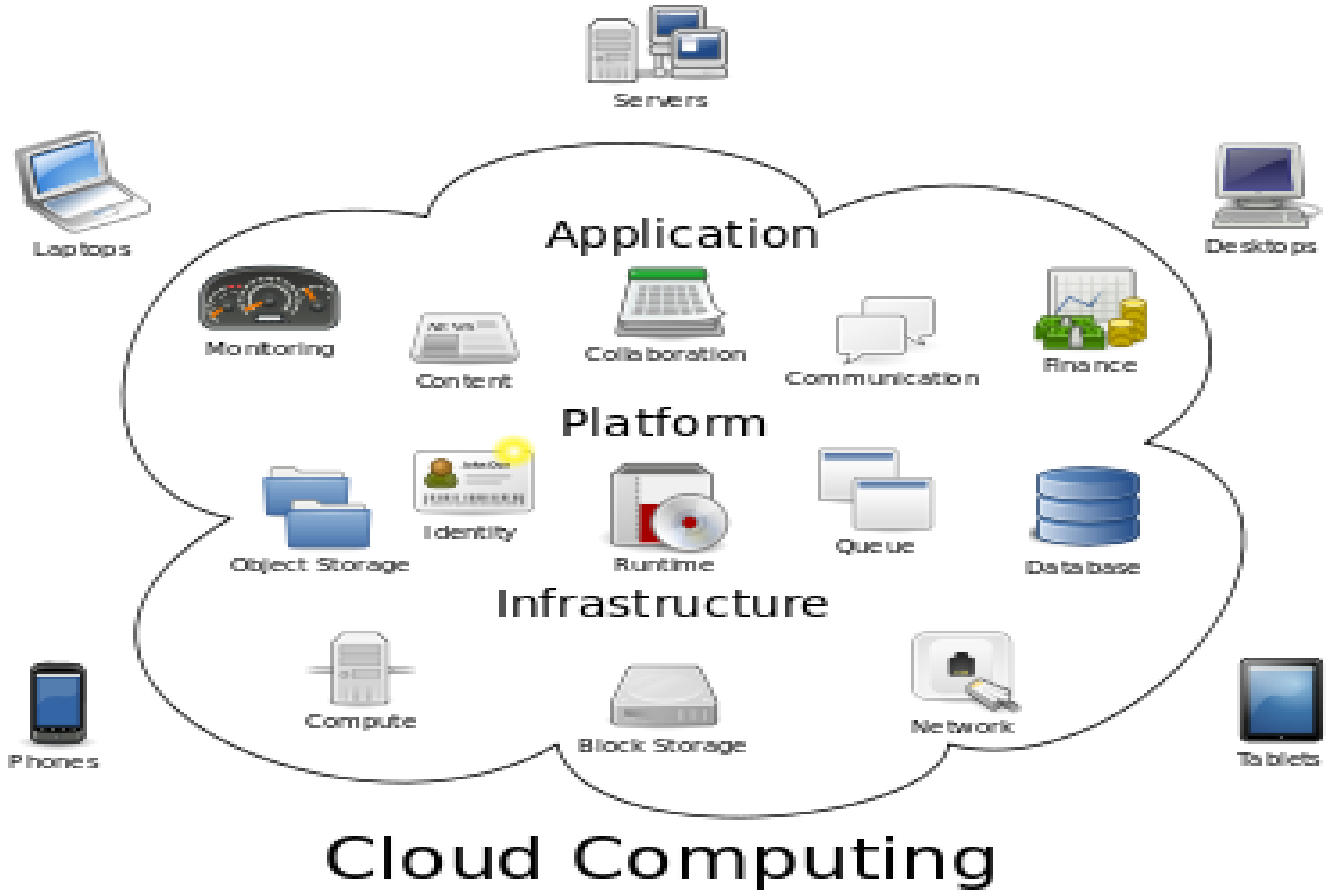
- Reference slides used for preparing this set of slides:
  - SENG 691A Introduction to Cloud Computing and the Internet of Things, West Virginia University.
  - Chapter 4, Distributed and Cloud Computing, Kai Hwang, University of Southern California)
  - IBM Cloud presentation
  - Gyu Myoung Lee, Q11/13 & Q16/13 Rapporteur, "Challenges for Standardization on Cloud Computing and Big Data considering the Internet of Things", 3rd SG13 Regional Workshop for Africa on "ITU-T Standardization Challenges for Developing Countries Working for a Connected Africa", Livingstone, Zambia, 23-24 February 2015.

Outline (Topics covered)

- What is Cloud Computing ?
- Services of Cloud Computing,
  - What can we do with Cloud Computing?
- Challenges with Clouds and Cloud Types
- Cloud Computing and The IoT
  - The Internet of Things
  - Applications of IoT: Biomedical, Wearable Technology, Smart Cities
- Conclusions

What is Cloud Computing ?



What is Cloud Computing
Utility Computing

- *Utility computing:* providers rent capacity on computing resources that they maintain
  - **Metered computing: analogous to utiltities (Pay per use)**
  - **Resources often virtualized and shared by multiple tenants**
  - **Example: Amazon Elastic Compute Cloud (estimated $30 USD/Month for one EC2 Instance for 24hrs/day-7days/week). Pay per use option**
    - **Amazon Elastic Compute Cloud (Amazon EC2) web service provides resizable compute capacity in the cloud**
    - **Designed to make web-scale computing easier for developers.**

What is Cloud Computing

- Cloud computing not only provides raw computing resources, but also hosts the applications that use these resources.
    - Applications usually can be accessed as web services.
    - User data typically stored on provider's file systems.
- Underlying computing infrastructure concealed from user.
    - Example: Gmail, Drive, Dropbox servers are concealed from users

What is Cloud Computing

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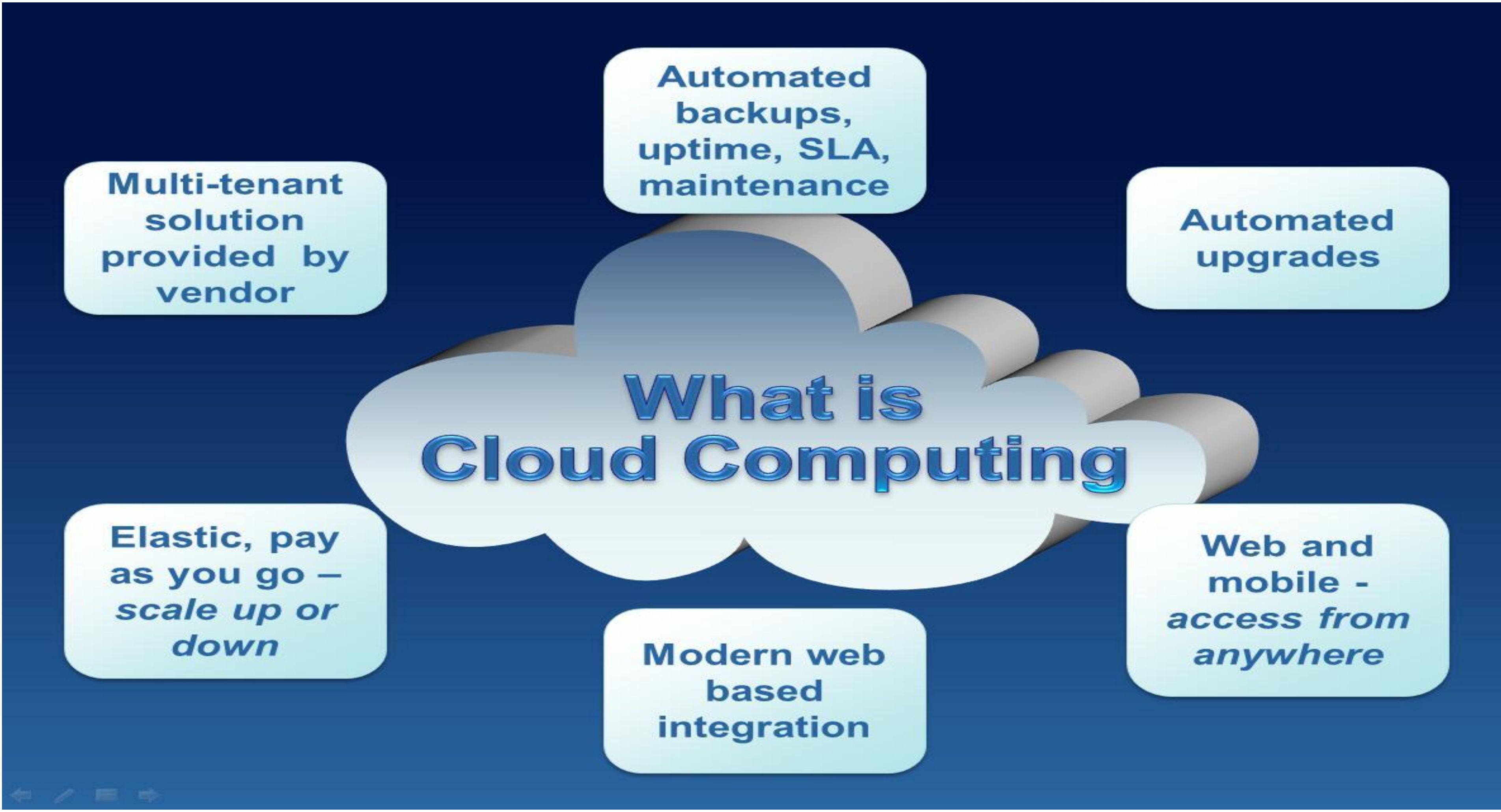

Warehouse-Scale Computer (WSC)

- Provides Internet services
  - Search, social networking, online maps, video sharing, online shopping, email, cloud computing, etc.
- Differences with HPC "clusters":
  - Clusters have higher performance processors and network
  - Clusters emphasize thread-level parallelism, WSCs emphasize request-level parallelism
- Differences with datacenters:
  - Datacenters consolidate different machines and software into one location
  - Datacenters emphasize virtual machines and hardware heterogeneity in order to serve varied customers

Design Considerations for WSC

- Cost-performance
  - Small savings add up
- Energy efficiency
  - Affects power distribution and cooling
  - Work per joule
- Dependability via redundancy
- Network I/O
- Interactive and batch processing workloads
- Ample computational parallelism is not important
  - Most jobs are totally independent
  - "Request-level parallelism"
- Operational costs count
  - Power consumption is a primary constraint when designing system
- Scale and its opportunities and problems
  - Can afford customized systems since WSC require volume purchase

Typical Datacenter Layout

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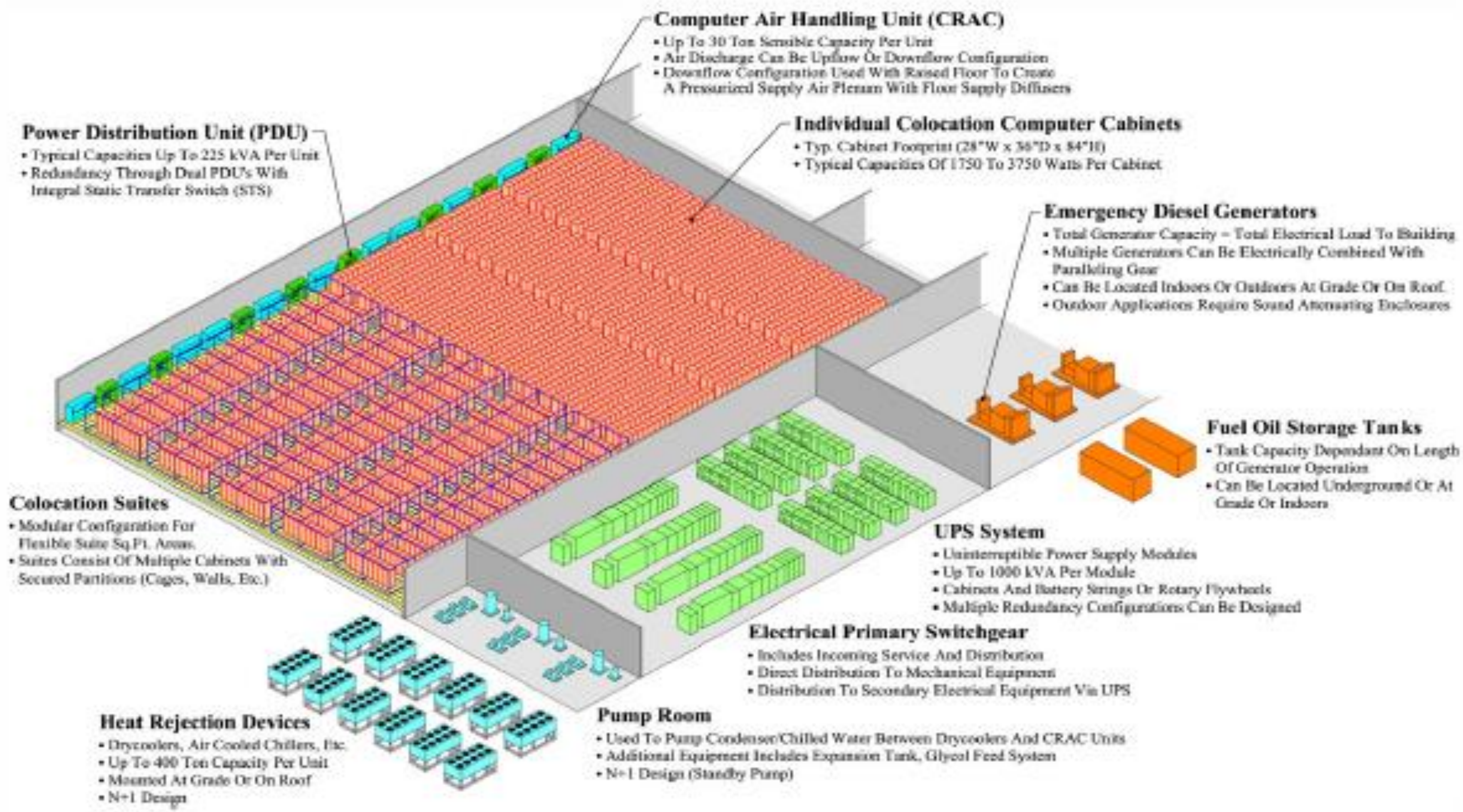


FIGURE 4.1: The main components of a typical datacenter (image courtesy of DLB Associates [23]).

Power and Cooling Requirements

- Cooling system also uses water (evaporation and spills)
  - E.g. 70,000 to 200,000 gallons per day for an 8 MW facility
- Power cost breakdown:
  - Chillers: 30-50% of the power used by the IT equipment
  - Air conditioning: 10-20% of the IT power, mostly due to fans
- How many servers can a WSC support?
  - Each server:
    - "Nameplate power rating" gives maximum power consumption
    - To get actual, measure power under actual workloads
  - Oversubscribe cumulative server power by 40%, but monitor power closely

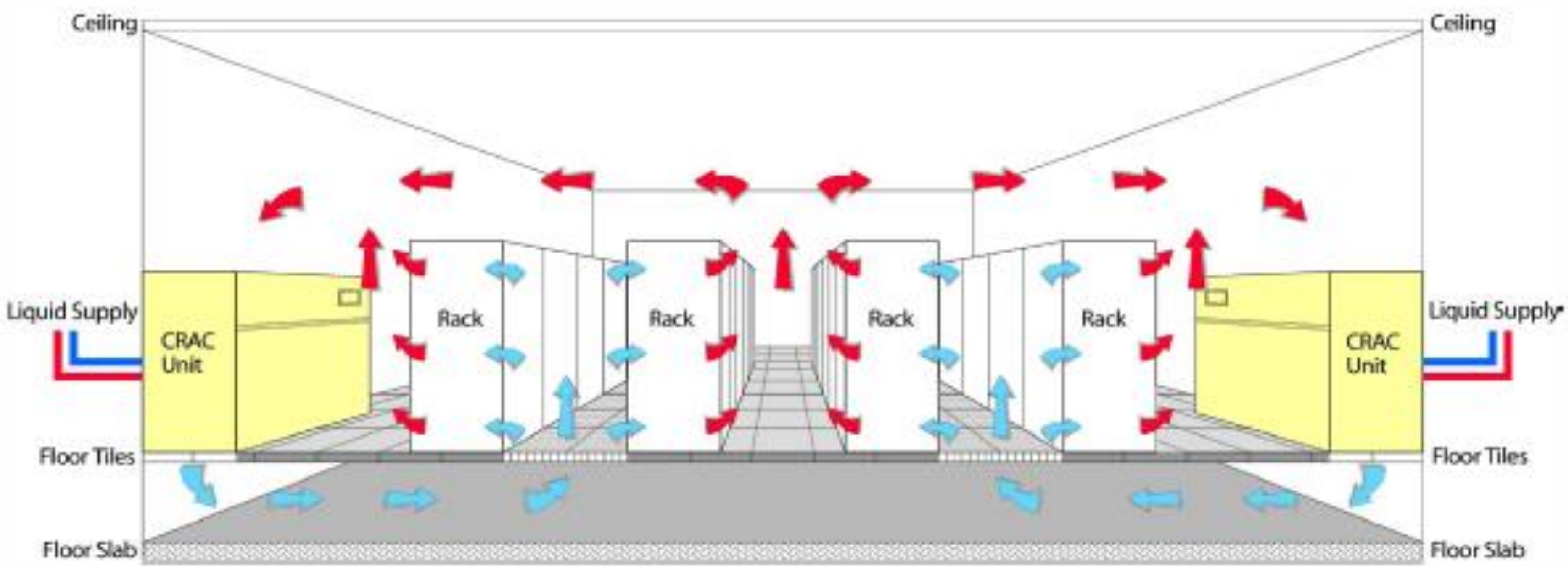


FIGURE 4.2: Datacenter raised floor with hot–cold aisle setup (image courtesy of DLB Associates [23]).

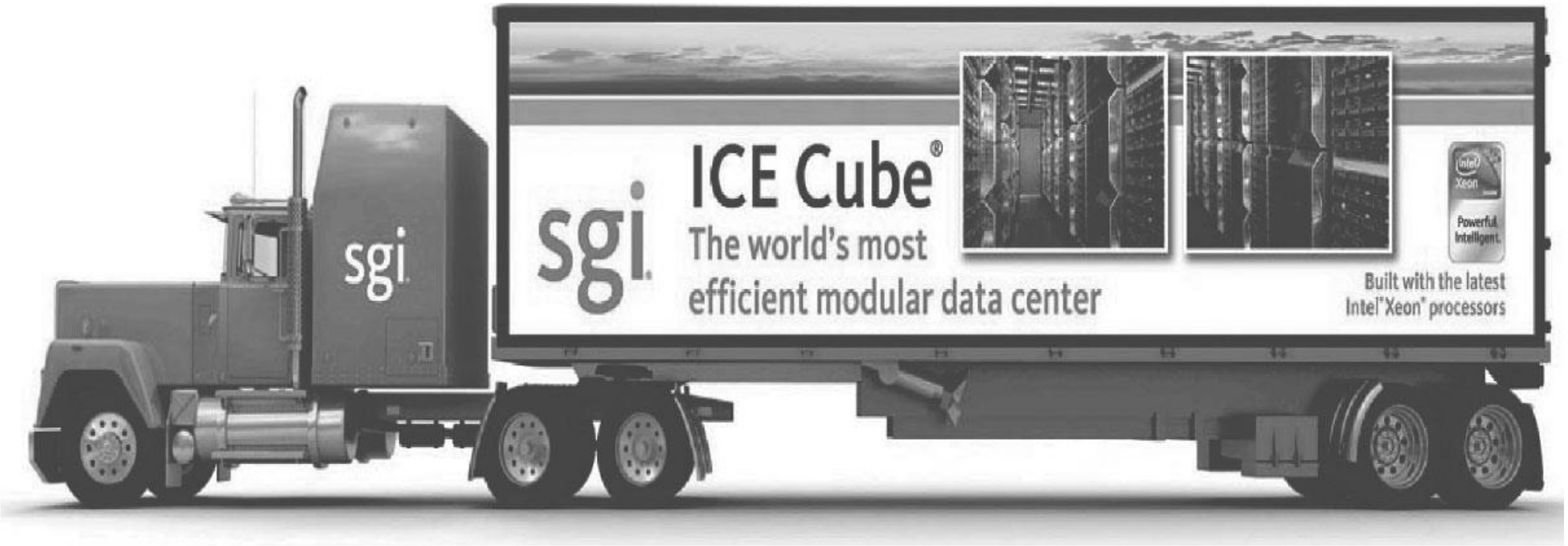
$$\text{Efficiency} = \frac{\text{Computation}}{\text{Total Energy}} = \underbrace{\left(\frac{1}{\text{PUE}}\right)}_{(a)} \times \underbrace{\left(\frac{1}{\text{SPUE}}\right)}_{(b)} \times \underbrace{\left(\frac{\text{Computation}}{\text{Total Energy to Electronic Components}}\right)}_{(c)}$$

(Courtesy of Luiz Andre Barroso and Urs Holzle, Google Inc., 2009)

Measuring Efficiency of a WSC

- Power Utilization Effectiveness (PEU)
  - = Total facility power / IT equipment power
  - Median PUE on 2006 study was 1.69
- Performance
  - Latency is important metric because it is seen by users
  - Bing study: users will use search less as response time increases
  - Service Level Objectives (SLOs)/Service Level Agreements (SLAs)
    - E.g. 99% of requests be below 100 ms

Modular Data Center



Cloud Computing

- WSCs offer economies of scale that cannot be achieved with a datacenter:
  - 5.7 times reduction in storage costs
  - 7.1 times reduction in administrative costs
  - 7.3 times reduction in networking costs
  - This has given rise to cloud services such as Amazon Web Services
    - "Utility Computing"
    - Based on using open source virtual machine and operating system software

(Courtesy of Hennessy and Patterson, 2012)

Enabling Technologies for The Clouds

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Table 4.3 Cloud-Enabling Technologies in Hardware, Software, and Networking

Technology	Requirements and Benefits
Fast platform deployment	Fast, efficient, and flexible deployment of cloud resources to provide dynamic computing environment to users
Virtual clusters on demand	Virtualized cluster of VMs provisioned to satisfy user demand and virtual cluster reconfigured as workload changes
Multitenant techniques	SaaS for distributing software to a large number of users for their simultaneous use and resource sharing if so desired
Massive data processing	Internet search and Web services which often require massive data processing, especially to support personalized services
Web-scale communication	Support for e-commerce, distance education, telemedicine, social networking, digital government, and digital entertainment applications
Distributed storage	Large-scale storage of personal records and public archive information which demands distributed storage over the clouds
Licensing and billing services	License management and billing services which greatly benefit all types of cloud services in utility computing

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Cloud Computing as A Service

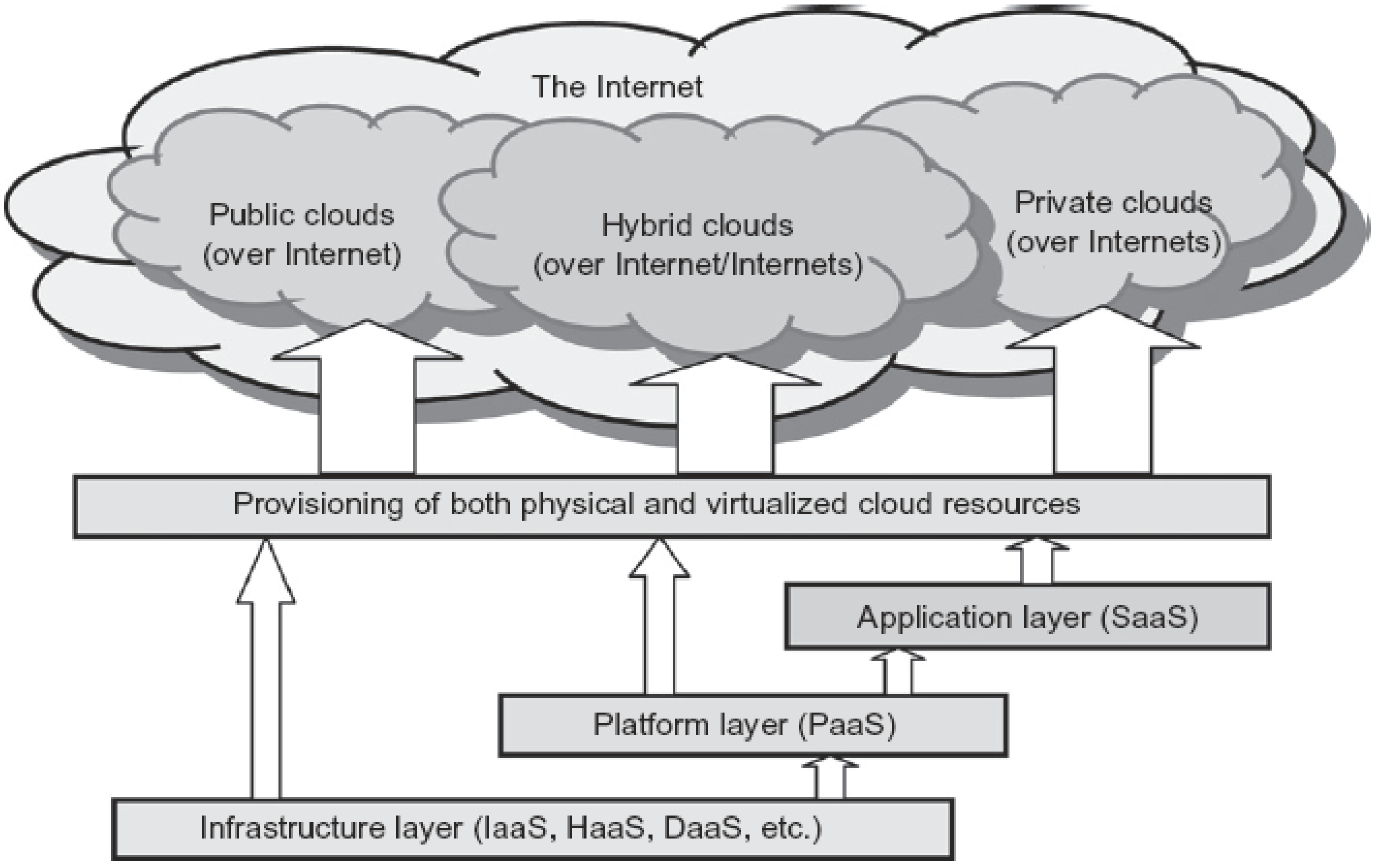


FIGURE 4.15

Layered architectural development of the cloud platform for IaaS, PaaS, and SaaS applications over the Internet.

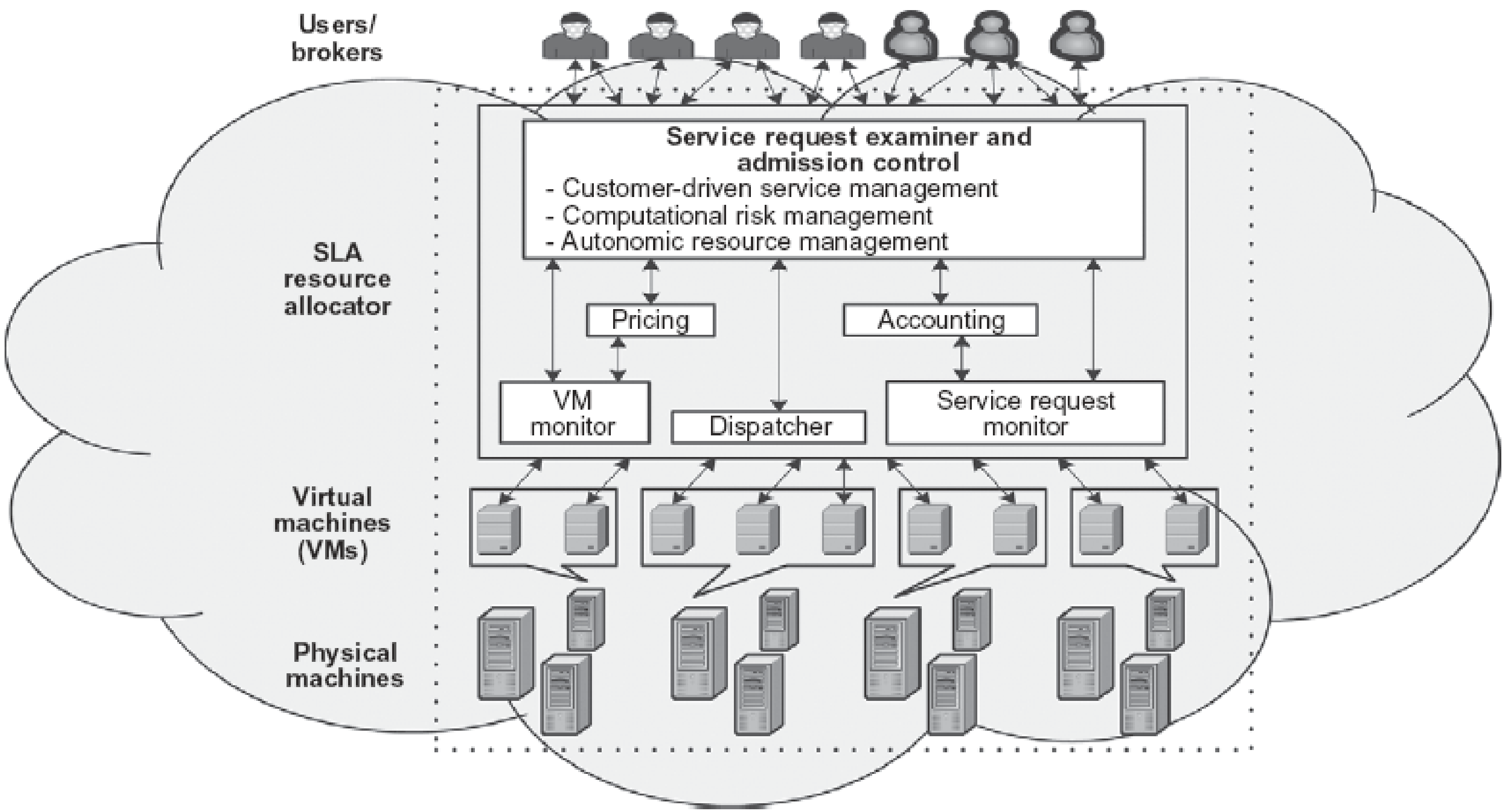
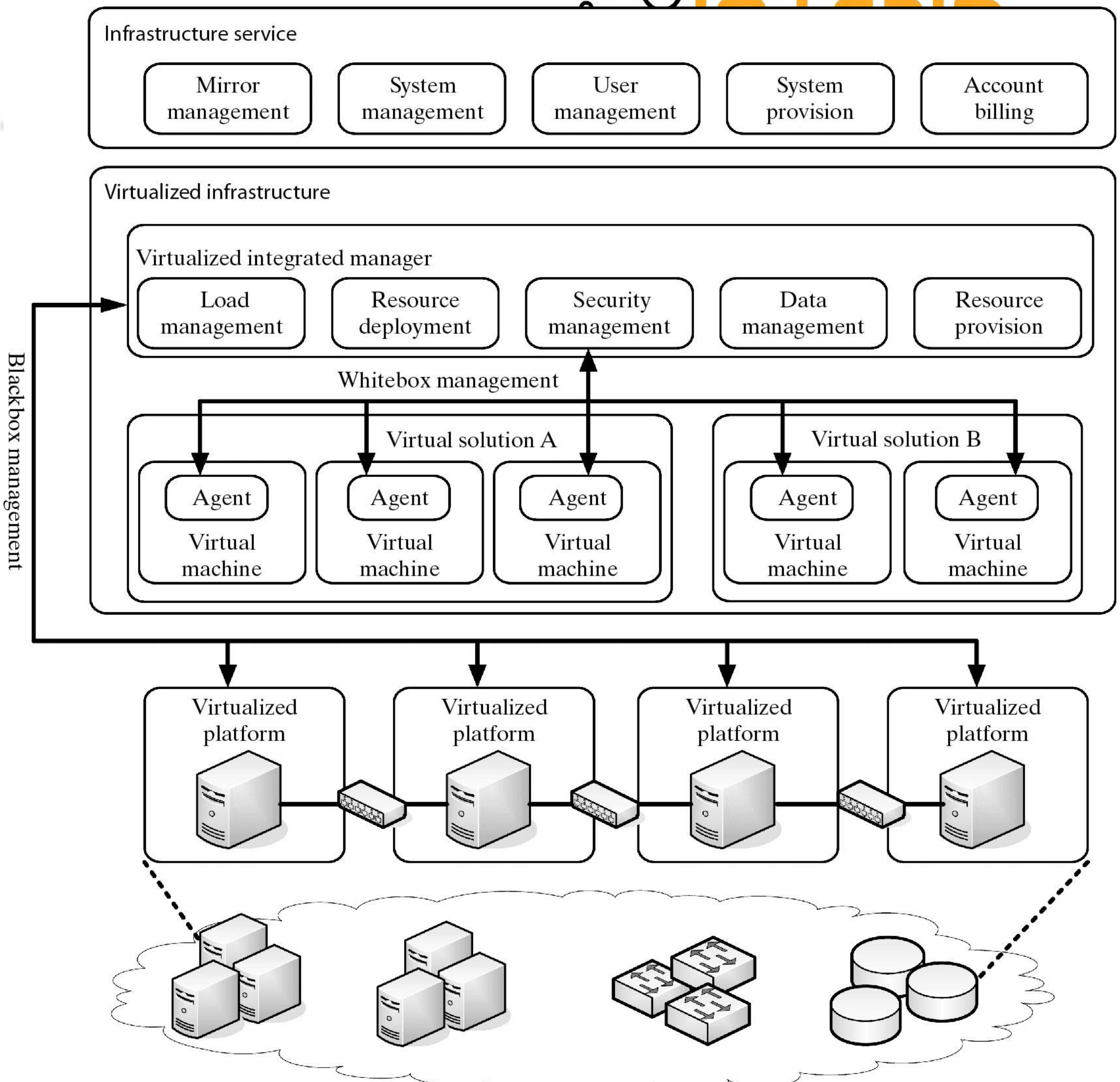


FIGURE 4.16

Market-oriented cloud architecture to expand/shrink leasing of resources with variation in QoS/demand from users.

(Courtesy of Raj Buyya, et al. [11])



Virtualized servers, storage , and network for cloud platform construction

Table 4.4 Virtualized Resources in Compute, Storage, and Network Clouds [4]

Provider	AWS	Microsoft Azure	GAE
Compute cloud with virtual cluster of servers	x86 instruction set, Xen VMs, resource elasticity allows scalability through virtual cluster, or a third party such as RightScale must provide the cluster	Common language runtime VMs provisioned by declarative descriptions	Predefined application framework handlers written in Python, automatic scaling up and down, server failover inconsistent with the Web applications
Storage cloud with virtual storage	Models for block store (EBS) and augmented key/blob store (SimpleDB), automatic scaling varies from EBS to fully automatic (SimpleDB, S3)	SQL Data Services (restricted view of SQL Server), Azure storage service	MegaStore/BigTable
Network cloud services	Declarative IP-level topology; placement details hidden, security groups restricting communication, availability zones isolate network failure, elastic IP applied	Automatic with user's declarative descriptions or roles of app. components	Fixed topology to accommodate three-tier Web app. structure, scaling up and down is automatic and programmer-invisible

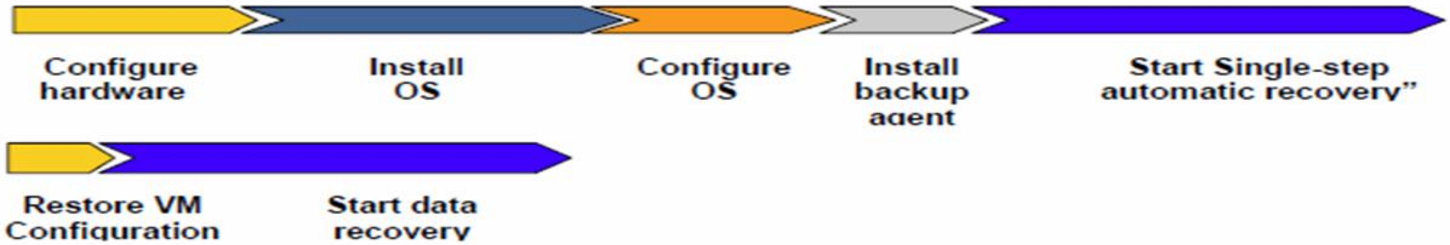
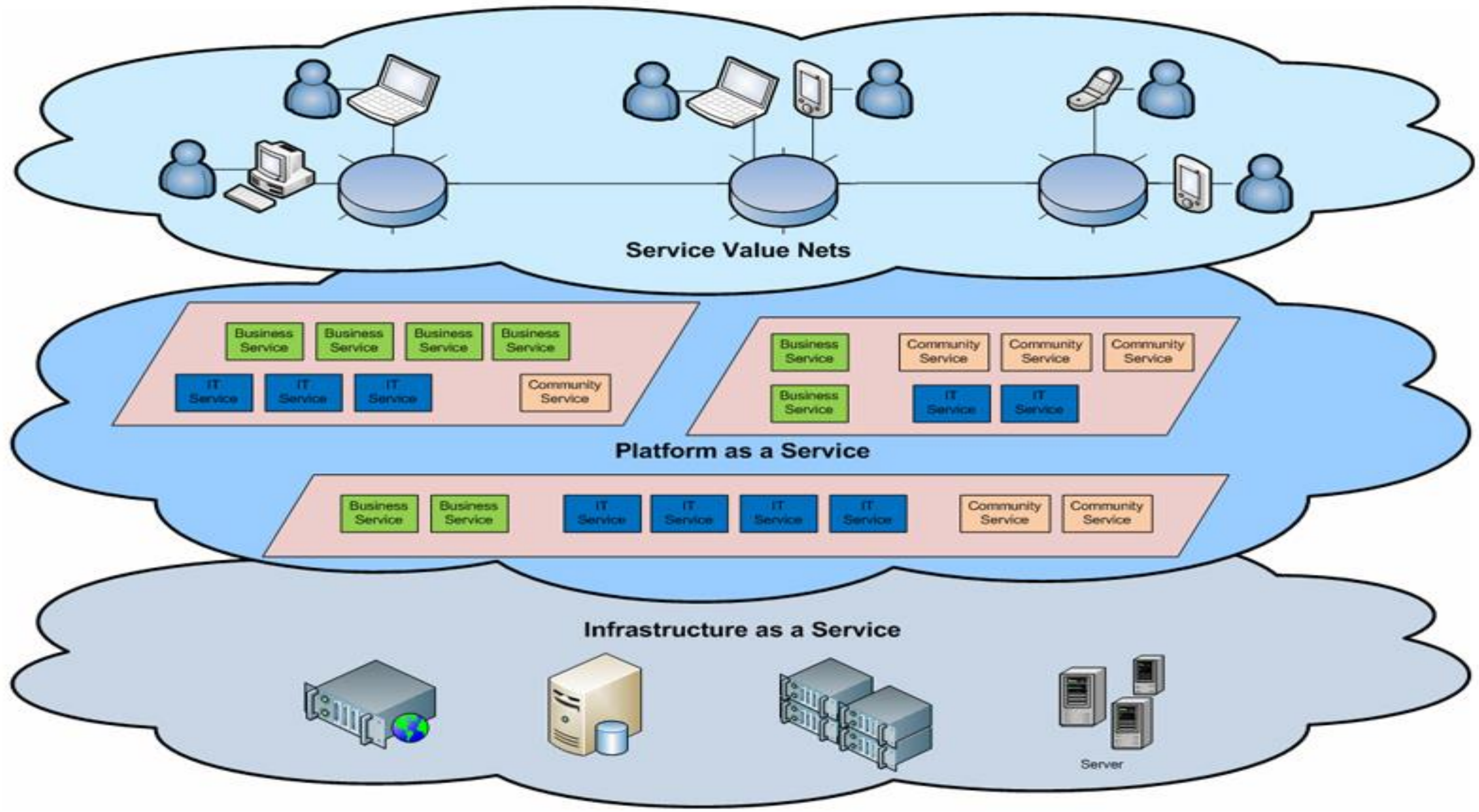


Figure 7.21 Recovery overhead of a conventional disaster recovery between physical machines, compared with that required to recover from live migration of virtual machines

Cloud Business model
Everything as a service



Cloud Business model
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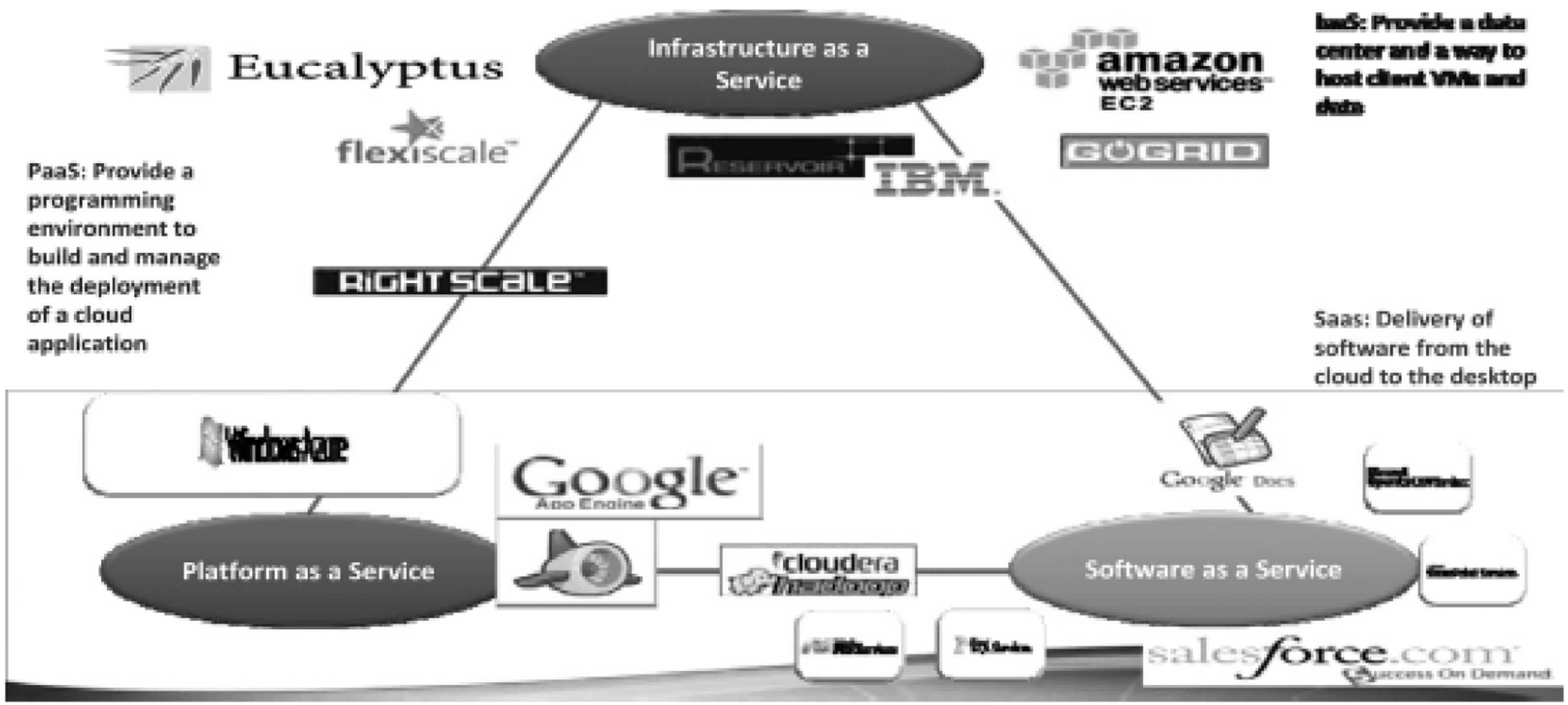

FIGURE 1.19

Three cloud service models in a cloud landscape of major providers.

(Courtesy of Dennis Gannon, keynote address at Cloudcom2010 [19])

1 - 45

Cloud Services and Major Providers

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Cloud application (SaaS)	Concur, RightNOW, Teleo, Kenexa, Webex, Blackbaud, salesforce.com, Netsuite, Kenexa, etc.
Cloud software environment (PaaS)	Force.com, App Engine, Facebook, MS Azure, NetSuite, IBM BlueCloud, SGI Cyclone, eBay
Cloud software infrastructure: Computational resources (IaaS); Storage (DaaS); Communications (Caas)	Amazon AWS, OpSource Cloud, IBM Ensembles, Rackspace cloud, Windows Azure, HP, Banknorth
Co-location cloud services (LaaS)	Savvis, Internap, NTTCommunications, Digital Realty Trust, 365 Main
Network cloud services (NaaS)	Owest, AT&T, AboveNet
Hardware/Virtualization cloud services (HaaS)	VMware, Intel, IBM, XenEnterprise

FIGURE 4.23

A stack of six layers of cloud services and their providers.

(Courtesy of T. Chou, Active Book Express, 2010 [16])

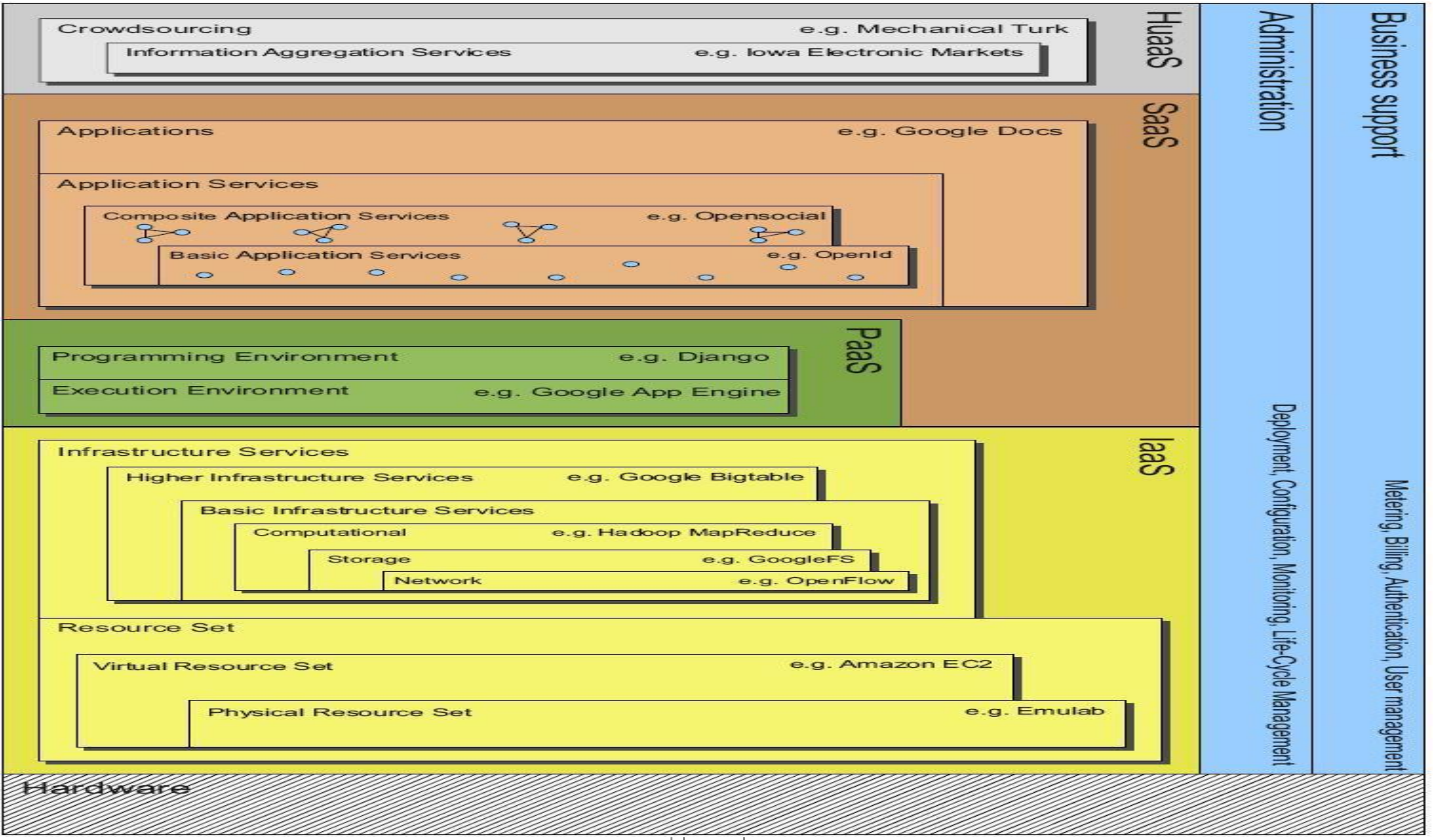
Table 4.7 Cloud Differences in Perspectives of Providers, Vendors, and Users

Cloud Players	IaaS	PaaS	SaaS
IT administrators/cloud providers	Monitor SLAs	Monitor SLAs and enable service platforms	Monitor SLAs and deploy software
Software developers (vendors)	To deploy and store data	Enabling platforms via configurators and APIs	Develop and deploy software
End users or business users	To deploy and store data	To develop and test Web software	Use business software

Table 4.8 Storage Services in Three Cloud Computing Systems

Storage System	Features
GFS: Google File System	Very large sustainable reading and writing bandwidth, mostly continuous accessing instead of random accessing. The programming interface is similar to that of the POSIX file system accessing interface.
HDFS: Hadoop Distributed File System	The open source clone of GFS. Written in Java. The programming interfaces are similar to POSIX but not identical.
Amazon S3 and EBS	S3 is used for retrieving and storing data from/to remote servers. EBS is built on top of S3 for using virtual disks in running EC2 instances.

Layered Services Architecture,ess Support



Infrastructure as a service (IaaS)

- Most basic cloud service model
- Cloud providers offer computers, as physical or more often as virtual machines, and other resources.
- Virtual machines are run as guests by a hypervisor, such as Xen or KVM.
- Cloud users deploy their applications by then installing operating system images on the machines as well as their application software.
- Cloud providers typically bill IaaS services on a utility computing basis, that is, cost will reflect the amount of resources allocated and consumed.
- Examples of IaaS include: Amazon CloudFormation (and underlying services such as Amazon EC2), Rackspace Cloud, Terremark, and Google Compute Engine.

Some IaaS Offerings from Public Clouds

Table 4.1 Public Cloud Offerings of IaaS [10,18]

Cloud Name	VM Instance Capacity	API and Access Tools	Hypervisor, Guest OS
Amazon EC2	Each instance has 1–20 EC2 processors, 1.7–15 GB of memory, and 160–1.69 TB of storage.	CLI or Web Service (WS) portal	Xen, Linux, Windows
GoGrid	Each instance has 1–6 CPUs, 0.5–8 GB of memory, and 30–480 GB of storage.	REST, Java, PHP, Python, Ruby	Xen, Linux, Windows
Rackspace Cloud	Each instance has a four-core CPU, 0.25–16 GB of memory, and 10–620 GB of storage.	REST, Python, PHP, Java, C#, .NET	Xen, Linux
FlexiScale in the UK	Each instance has 1–4 CPUs, 0.5–16 GB of memory, and 20–270 GB of storage.	Web console	Xen, Linux, Windows
Joyent Cloud	Each instance has up to eight CPUs, 0.25–32 GB of memory, and 30–480 GB of storage.	No specific API, SSH, Virtual/Min	OS-level virtualization, OpenSolaris

AWS – a leader in providing public IaaS services

- EC2 (Elastic compute cloud allows users to rent virtual computers to run their own computer applications. It allows scalable deployment. A user can create, launch, and terminate server instances as needed, paying by the hour for active servers.
- S3 (simple storage service) provides the object-oriented storage service for users.
- EBS (Elastic block service) provides the block storage interface which can be used to support traditional applications.
- Amazon DevPay is a simple to use online billing and account management service that makes it easy for businesses

AWS – a leader in providing public IaaS services (cont'd)

- MPI clusters uses hardware-assisted virtualization instead of para-virtualization and users are free to create a new AMIs
- AWS import/export allows one to ship large volumes of data to and from EC2 by shipping physical discs.
- Brokering systems offer a striking model for controlling sensors and providing office support of smartphones and tablets.
- Small-business companies can put their business on the Amazon cloud platform. Using AWS they can service a large number of internet users and make profits through those paid services.

Amazon Web Services (AWS)

Compute
- Amazon Elastic Compute Cloud (EC2)
- Amazon Elastic MapReduce
- Auto Scaling

Content Delivery
- Amazon CloudFront

Database
- Amazon SimpleDB
- Amazon Relational Database Service (RDS)

E-Commerce
- Amazon Fulfillment Web Service (FWS)

Messaging
- Amazon Simple Queue Service (SQS)
- Amazon Simple Notification Service (SNS)

Monitoring
- Amazon CloudWatch

Networking
- Amazon Virtual Private Cloud (VPC)
- Elastic Load Balancing

Payments & Billing
- Amazon Flexible Payments Service (FPS)
- Amazon DevPay

Storage
- Amazon Simple Storage Service (S3)
- Amazon Elastic Block Storage (EBS)
- AWS Import/Export

Support
- AWS Premium Support

Web Traffic
- Alexa Web Information Service
- Alexa Top Sites

Workforce
- Amazon Mechanical Turk

Amazon's Lesson

- Down for 3 days since 4/22/2011
- 1000x of businesses went offline. E.g. Pfizer, Netflix, Quora, Foursquare,Reddit
- SLA contract
  - 99.95% availability (<4.5hour down)
  - 10% penalty, otherwise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Why Amazon's cloud Titanic went down

By David Goldman, staff writer April 22, 2011: 5:37 PM ET

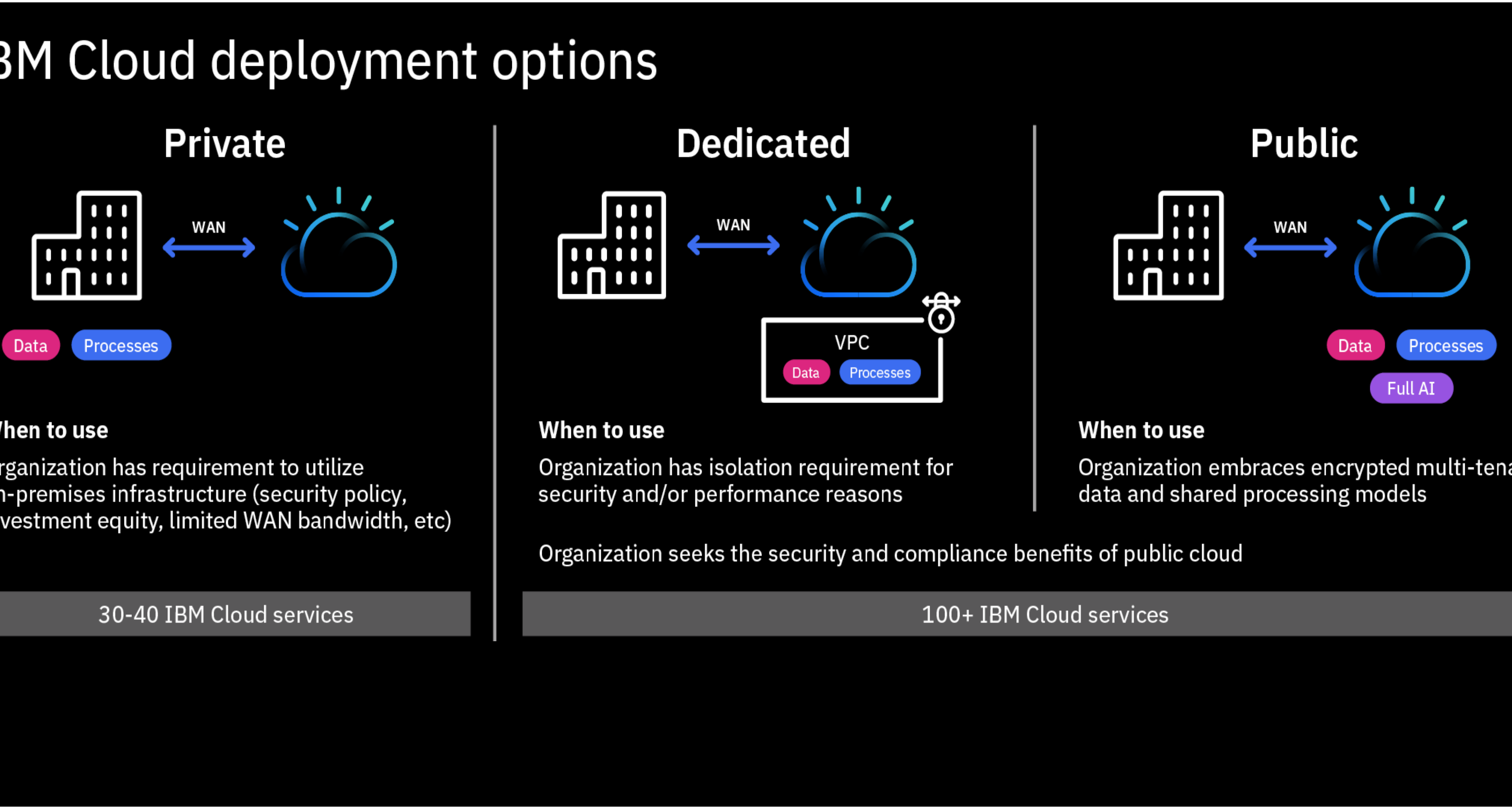
NEW YORK (CNNMoney) -- This was never supposed to happen.

Amazon Web Services is the Titanic of cloud hosting, designed with backups to the backups' backups that prevent hosted websites and applications from failing.

IBM's Cloud (IaaS)

- IBM Cloud is an enterprise grade, full stack platform, purpose built for data-intensive AI workloads and cloud-native application suites, delivered on software definable infrastructure.
- Deploy the right type of cloud to accelerate innovation

IBM's Cloud (cont'd)



IBM Cloud architecture

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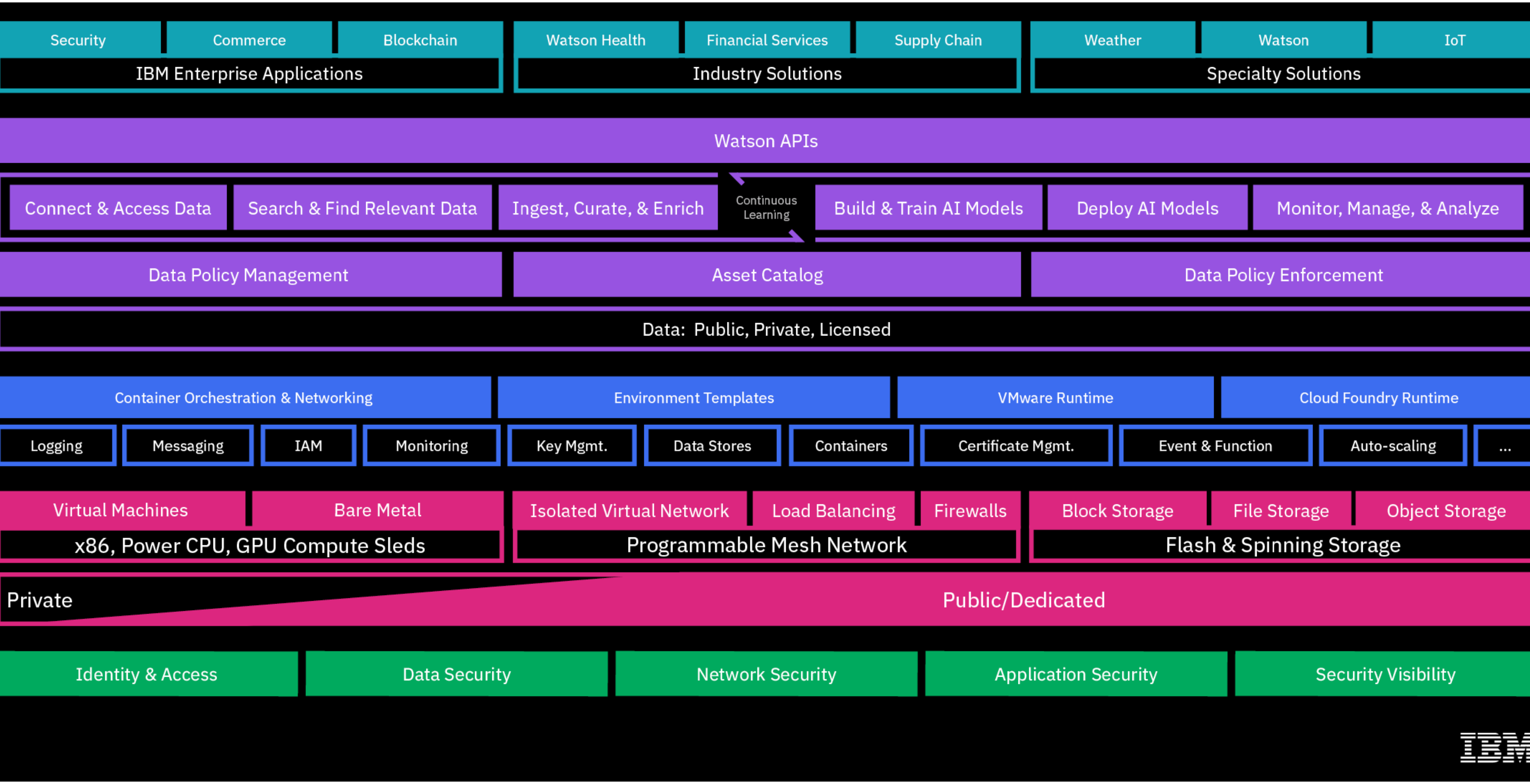


IBM is the Cloud for Business

- Innovate with the latest technologies from any cloud.

AI READY

Create innovative, cloud-native apps using AI, IoT, blockchain, high performance computing and other disruptive

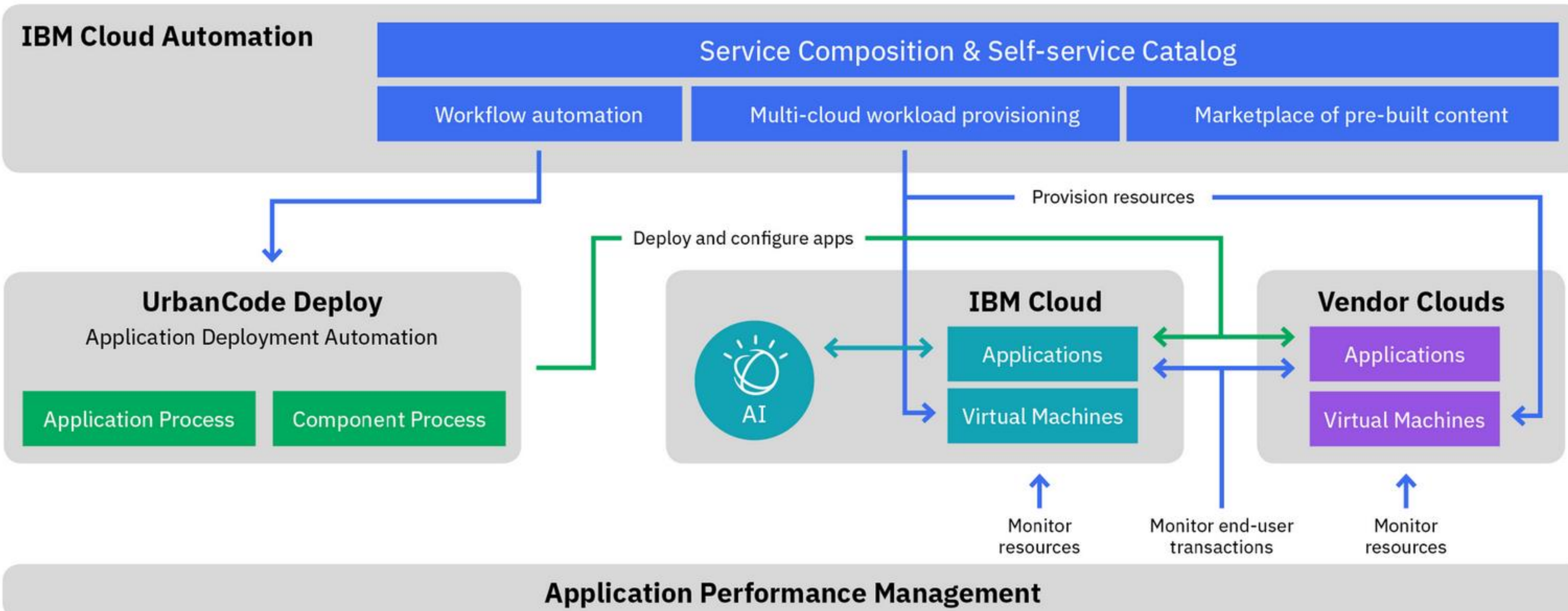
BUILT FOR ALL YOUR APPLICATIONS

Exploit unmatched choice and industry expertise

SECURE TO THE CORE

Deploy it where you need to on a secure network, without sacrificing quality and compliance

- IBM provides tools to help clients manage multi-cloud environments
- It was predicted by 2020, more than 90% of enterprises will use multiple cloud services and platforms



- Many clients are choosing a hybrid model to address evolving needs

Platform as a service (PaaS)

- Cloud providers deliver a computing platform typically including operating system, programming language execution environment, database, and web server.
- Application developers develop and run their software on a cloud platform without the cost and complexity of buying and managing the underlying hardware and software layers.
- Examples of PaaS include: Amazon Elastic Beanstalk, Cloud Foundry, Heroku, Force.com, EngineYard, Mendix, Google App Engine, Microsoft Azure and OrangeScape.

PaaS Offerings from Public Clouds

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Table 4.2 Five Public Cloud Offerings of PaaS [10,18]

Cloud Name	Languages and Developer Tools	Programming Models Supported by Provider	Target Applications and Storage Option
Google App Engine	Python, Java, and Eclipse-based IDE	MapReduce, Web programming on demand	Web applications and BigTable storage
Salesforce.com's Force.com	Apex, Eclipse-based IDE, Web-based Wizard	Workflow, Excel-like formula, Web programming on demand	Business applications such as CRM
Microsoft Azure	.NET, Azure tools for MS Visual Studio	Unrestricted model	Enterprise and Web applications
Amazon Elastic MapReduce	Hive, Pig, Cascading, Java, Ruby, Perl, Python, PHP, R, C++	MapReduce	Data processing and e-commerce
Aneka	.NET, stand-alone SDK	Threads, task, MapReduce	.NET enterprise applications, HPC

Platform as a Service (PaaS): Google App Engine

- This platform allows users to develop and host web application in Google datacenters with automatic scaling according to the demand.
- It is a free service for a certain limit and it only requires a Gmail account to access the services. After the free limit is exceeded the customers are charged for additional storage, bandwidth and instance hours.
- The current version supports Java, Python and Go as the programming languages and Google plans to add more languages in the future.
- All billed App Engine applications have a 99.95% uptime SLA. App Engine is designed to sustain multiple datacenter outages without any downtime.
- The app engine has a few restrictions - can only execute code called from an HTTP request, Java applications may only use a subset from the JRE standard edition and Java application cannot create new threads.

Google AppEgine (GAE)

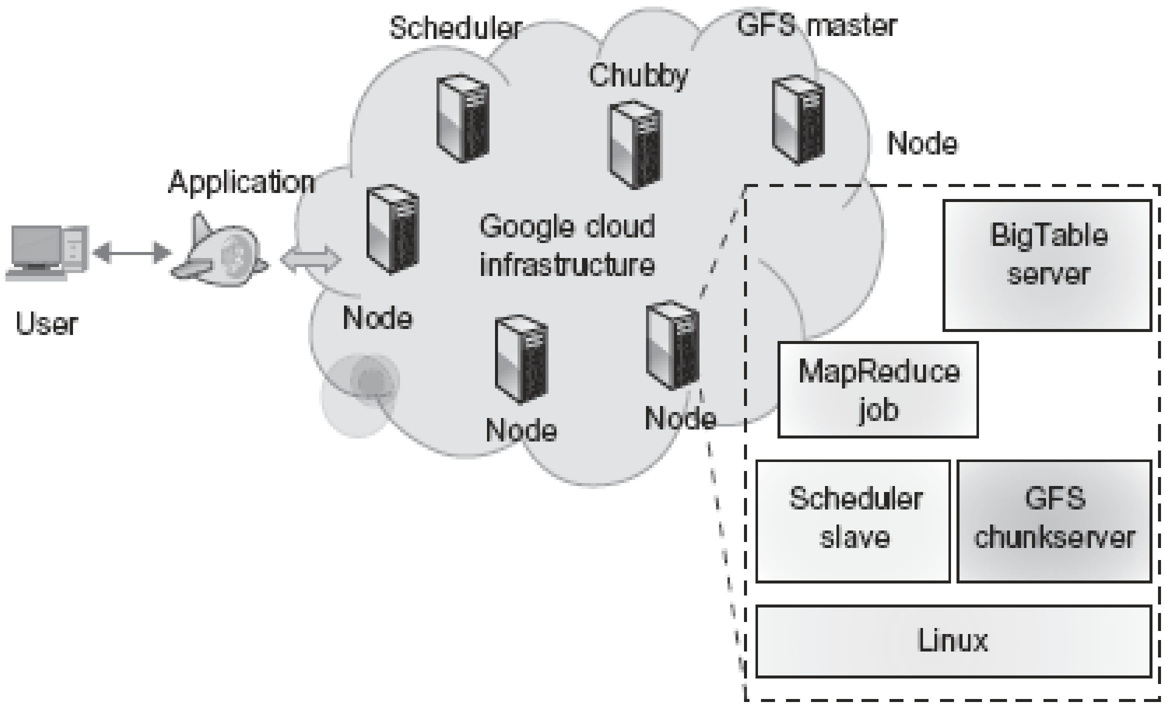


FIGURE 4.20

Google cloud platform and major building blocks, the blocks shown are large clusters of low-cost Servers.

(Courtesy of Kang Chen, Tsinghua University, China)

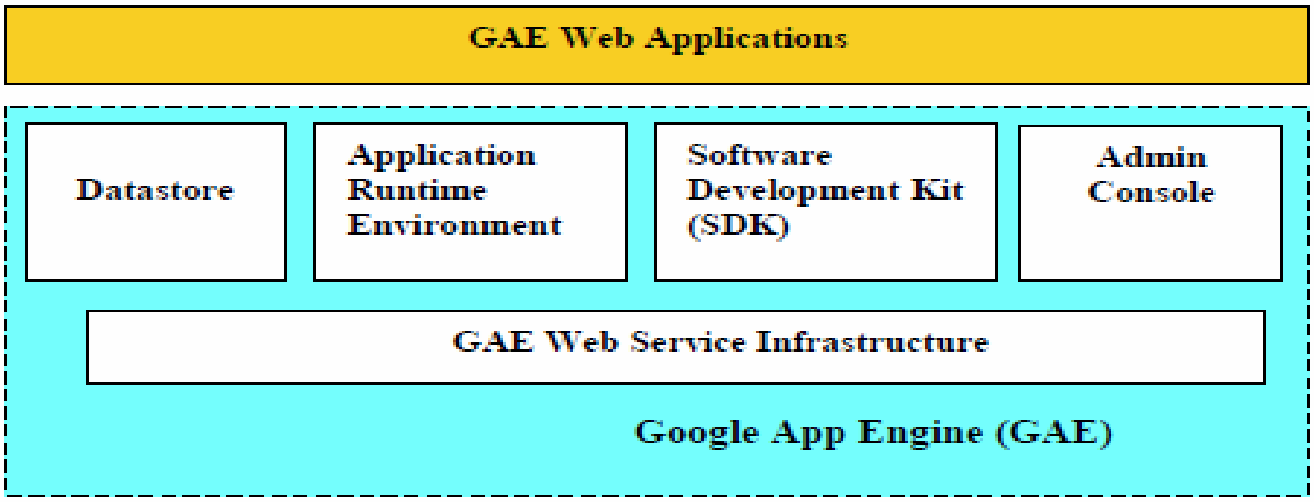


Figure 7.24 Functional components in the Google App Engine (GAE)
(Courtesy of Google, http://code.google.com/appengine/)

Google App Engine Front Page: http://code.google.com/appengine/

Signing up for an account or use your gmail account name : https://appengine.google.com/

Downloading GAE SDK : http://code.google.com/appengine/downloads.html

Python Getting Started Guide: http://code.google.com/appengine/docs/python/gettingstarted/

Java Getting Started Guide: http://code.google.com/appengine/docs/java/gettingstarted/

Quota page for free service: http://code.google.com/appengine/docs/quotas.html#Resources

Billing page if you go over the quota:
http://code.google.com/appengine/docs/billing.html#Billable_Quota_Unit_Cost

Microsoft Azure Cloud

- This is essentially a PaaS Cloud.
- Windows Azure run its cluster hosted at Microsoft's datacenters that manages computing and storage resources.
  - One can download Azure development kit to run a local version of Azure. It allows Azure applications to be developed and debugged one the windows 7 hosts.
- All cloud services can interact with traditional MS software applications such as Windows Live, Office Live, Exchange Online, etc.
- If offers a Windows-based cloud platform using Microsoft virtualization technology.
  - Applications are built on VM's deployed on the data-center services.
    - Azure manages all servers, storage and network resources of the data center.

Microsoft Windows Azure

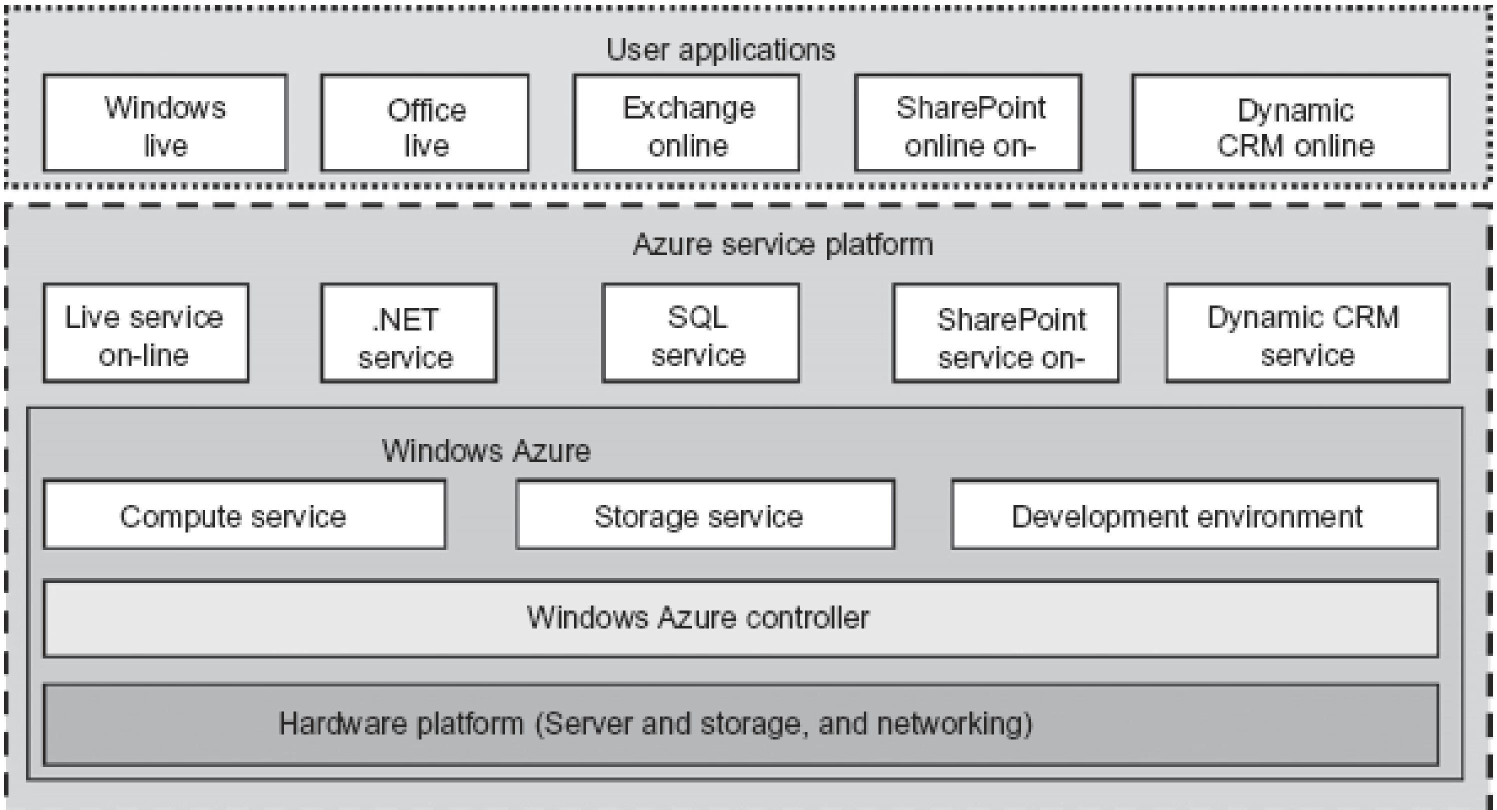


FIGURE 4.22

Microsoft Windows Azure platform for cloud computing.

(Courtesy of Microsoft, 2010, http://www.microsoft.com/windowsazure)

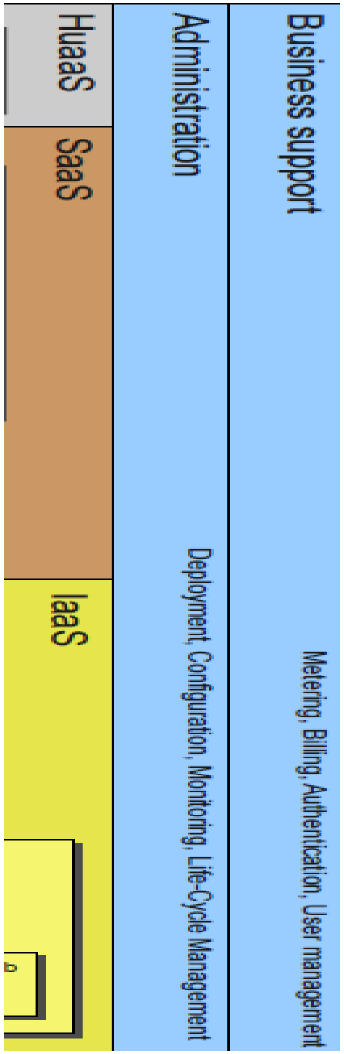
Software as a service (SaaS)

- Cloud providers install and operate application software in the cloud and cloud users access the software from cloud clients.
- The pricing model for SaaS applications is typically a monthly or yearly flat fee per user, so price is scalable and adjustable if users are added or removed at any point.
- Examples of SaaS include: Google Apps, innkeypos, Quickbooks Online, Limelight Video Platform, Salesforce.com, and Microsoft Office 365.

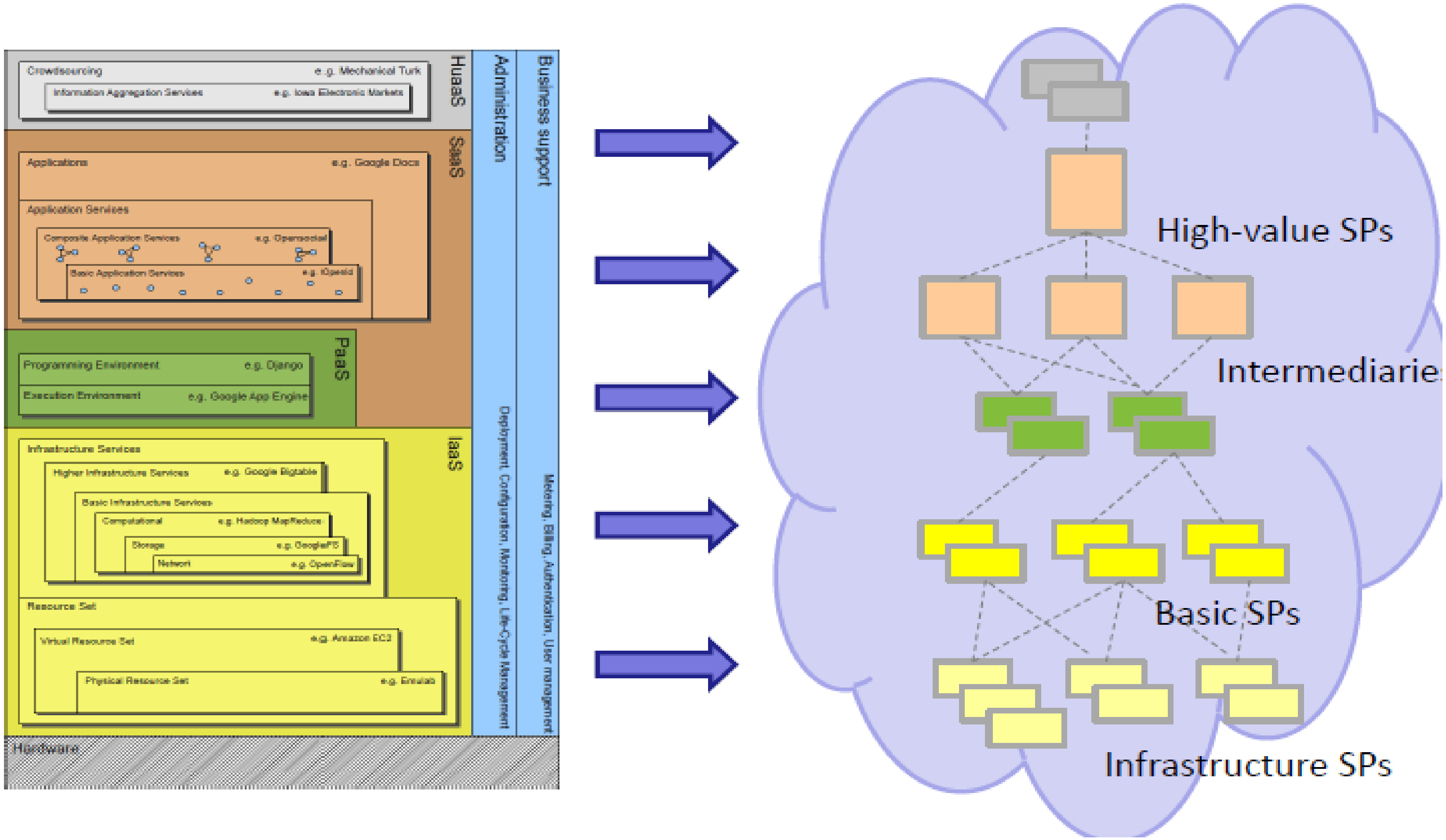
Layered Architecture
Crosscutting Layers

- Administration Layer
  - Deployment
  - Configuration
  - Monitoring
  - Life cycle management

- Business Layer
- Metering, Billing, Authentication, and
- User management



Cloud Architecture: Cloud Players



Cloud Players

Cloud infrastructure service providers – raw cloud resources
IaaS (infrastructure-as-a-service)

Cloud platform providers – resources + frameworks; PaaS (platform-as-a-service)

Cloud intermediares – help broker some aspect of raw resources and frameworks, e.g.,

server managers, application assemblers, application hosting

Cloud application providers (SaaS)

Cloud consumers – users of the above

Cloud Players: Providers

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Programmatic access via Web Services and/or Web APIs

"Pure" virtualized resources

- CPU, memory, storage, and bandwidth
- Data store

amazon web services™

Joyent Cloud Computing
Brought to you with the power of the Joyent Accelerator™

versus

Virtualized resources plus application framework (e.g., RoR, Python, .NET)

- Imposes an application and data architecture
- Constrains how application is built

Google App Engine

Live Mesh TECH PREVIEW

Infrastructure-as-a-Service Providers

Organization	Service or tool	Description	Layer
Amazon	Elastic Compute Cloud (EC2)	Virtual servers	IaaS > RS > VRS
	Dynamo	Key-value storage system	IaaS > RS > HIS
	Simple Storage Service (S3)	Storage buckets	IaaS > IS > BIS
	SimpleDB	Database-as-a-Service	IaaS > IS > HIS
	CloudFront	Content Delivery	IaaS > IS > HIS
	SQS	Queueing services	IaaS > IS > HIS
AppNexus	AppNexus Cloud	Virtual servers	IaaS > RS > VRS
Bluelock	Bluelock Virtual Cloud Computing	Virtual servers	IaaS > RS > VRS
	Bluelock Virtual Recovery	Disaster Recovery	IaaS > IS > HIS
Emulab	Emulab Network Testbed	Network testbed	IaaS > RS > PRS

Infrastructure-as-a-Service Providers (cont'd)

Organization	Service or tool	Description	Layer
ENKI	ENKI Virtual Private Data Centers	On-demand virtual data center resources	IaaS > RS > VRS
EU Reservoir project	Open Nebula	Open source virtual infrastructure engine	IaaS > RS > VRS
FlexiScale	FlexiScale Cloud Computing	Virtual servers	IaaS > RS > VRS
GoGrid	Cloud Hosting	Virtual servers	IaaS > RS > VRS
	Cloud Storage	Disk storage	IaaS > IS > BIS
Google	Google Big Table	Distributed storage system	IaaS > IS > HIS
	Google File System	Distributed file system	IaaS > IS > BIS
HP	iLO	Lights out management	IaaS > RS > PRS
	Tycoon	Market-based system for managing compute resources in clusters	IaaS > RS > VRS

Players: cloud intermediaries

Resells (aspects of) raw cloud resources, with added value propositions

- Packaging resources as bundles
- Facilitating cloud resource management,
  e.g., setup, updates, backup, load balancing, etc.
- Providing tools and dashboards

Enabler of the cloud ecosystem

Players: Application providers

Software as a Service (SaaS):

Applications provided and consumed over the Web

Infrastructure usage (mostly) hidden

Human as a Service

- Huaas (Human as a Service)

e.g., Amazon Mturk provides crowdsourcing applications in terms of Human Intelligent Tasks (HITs)

Prediction of events

- e.g. Iowa Electronic Markets,

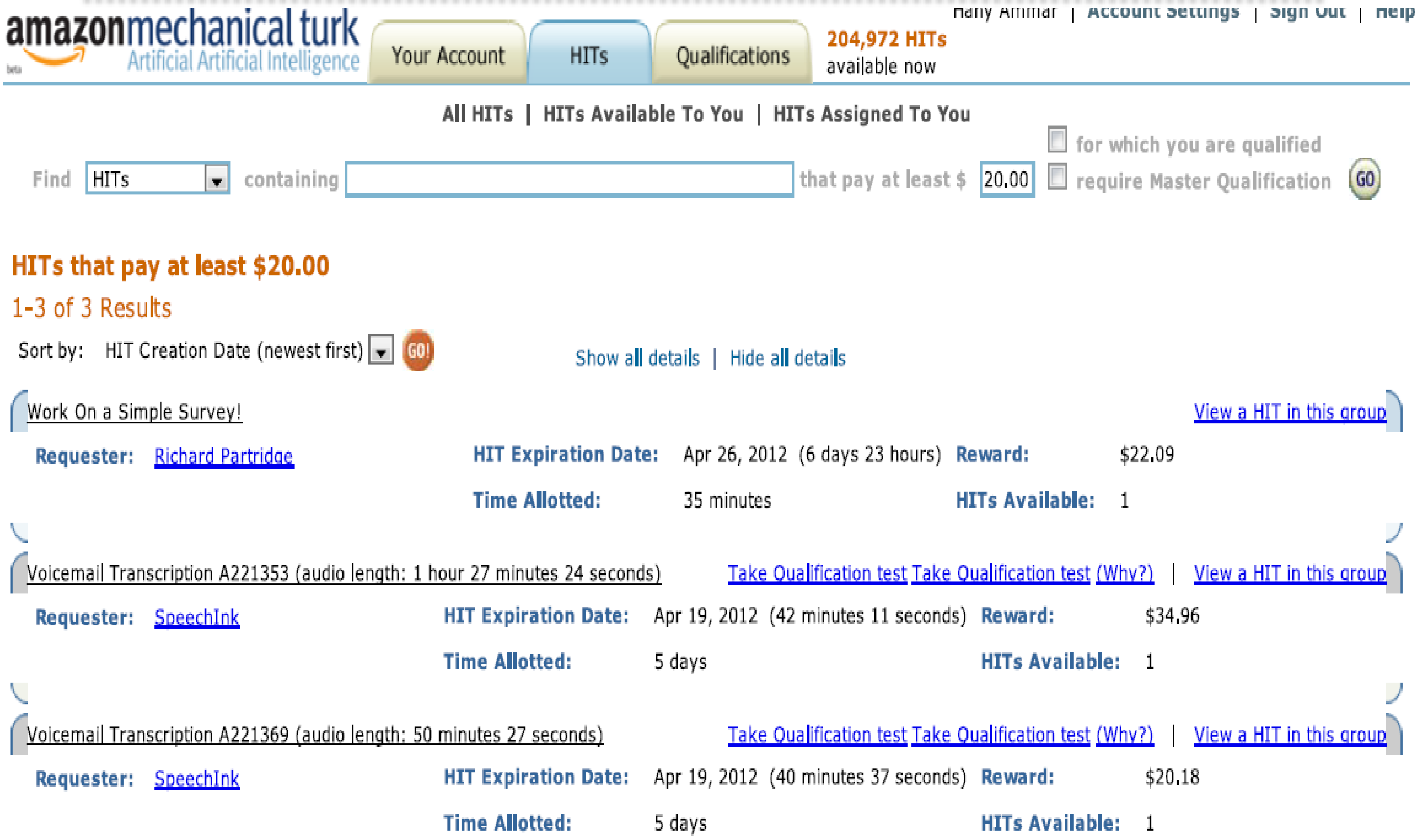
Enabling Collective Intelligence, e.g. Surveys

Human-as-a-Service Providers

Organization	Service or tool	Description	Layer
Amazon	Mechanical Turk	Scalable workforce	HuaaS > CS
Digg.com	Digg.com	News aggregation	HuaaS > CS > IAS
The University of Iowa	Iowa Electronic Markets	Future markets based on economic and political events	HuaaS > CS > IAS
Youtube	Youtube	Video portal	HuaaS > CS

"In India Cloud Computing is projected to grow from a 50 Million industry in 2009 to a $15 Billion Industry in 2013"

S. Greengard "Cloud Computing and Developing Nations," Communications of the ACM, May 2010.


amazonmechanical turk
Artificial Artificial Intelligence
Your Account
HITs
Qualifications
204,972 HITs
available now
Account Settings | Sign Out | Help
All HITs | HITs Available To You | HITs Assigned To You
Find HITs containing that pay at least $ 20.00
for which you are qualified
require Master Qualification
GO
HITs that pay at least $20.00
1-3 of 3 Results
Sort by: HIT Creation Date (newest first) GO!
Show all details | Hide all details
Work On a Simple Survey!
View a HIT in this group
Requester: Richard Partridge
HIT Expiration Date: Apr 26, 2012 (6 days 23 hours)
Reward: $22.09
Time Allotted: 35 minutes
HITs Available: 1
Voicemail Transcription A221353 (audio length: 1 hour 27 minutes 24 seconds)
Take Qualification test Take Qualification test (Why?) | View a HIT in this group
Requester: SpeechInk
HIT Expiration Date: Apr 19, 2012 (42 minutes 11 seconds)
Reward: $34.96
Time Allotted: 5 days
HITs Available: 1
Voicemail Transcription A221369 (audio length: 50 minutes 27 seconds)
Take Qualification test Take Qualification test (Why?) | View a HIT in this group
Requester: SpeechInk
HIT Expiration Date: Apr 19, 2012 (40 minutes 37 seconds)
Reward: $20.18
Time Allotted: 5 days
HITs Available: 1

Outline (Topics covered)

- What is Cloud Computing ?
- Services of Cloud Computing,
  - What can we do with Cloud Computing?
- Challenges with Clouds and Cloud Types
- Cloud Computing and The IoT
  - The Internet of Things
  - Applications of IoT: Biomedical, Wearable Technology, Smart Cities
- Conclusions

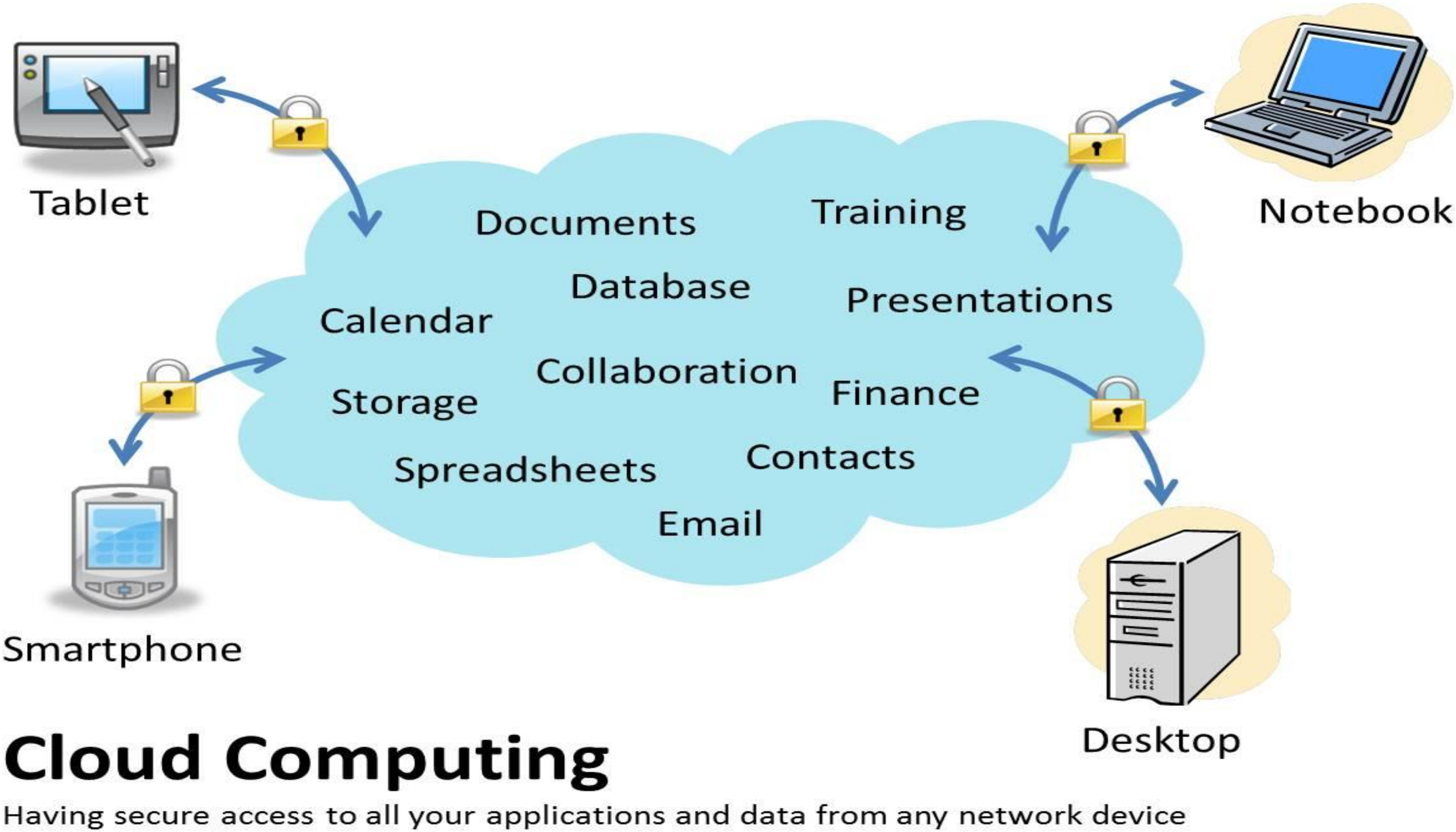
What can we do with Clouds?

Clouds reduces the need for advanced computing resources at the clients side

- Clients can use inexpensive small Net Books mobile phones to use cloud resources and ***virtually have the processing power and storage of an expandable computing system***

- No need to buy ***software or software licenses***

What can we do with Clouds?



What can we do with Clouds?

- Data is no longer confined to the local storage, users will be able to **access data and applications from anywhere** at any time. There is **no more lost data due to hard drive failures**
- Hospitals, Companies, Corporations, and Universities would save money on IT support, and No need for space to house expensive hardware and software servers

Cloud Computing and E-Learning

With Unlimited Resources

A Short Video

http://www.youtube.com/watch?v=bmZL-5h5zeE&feature=channel&list=UL

Outline (Topics covered)

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- Conclusions

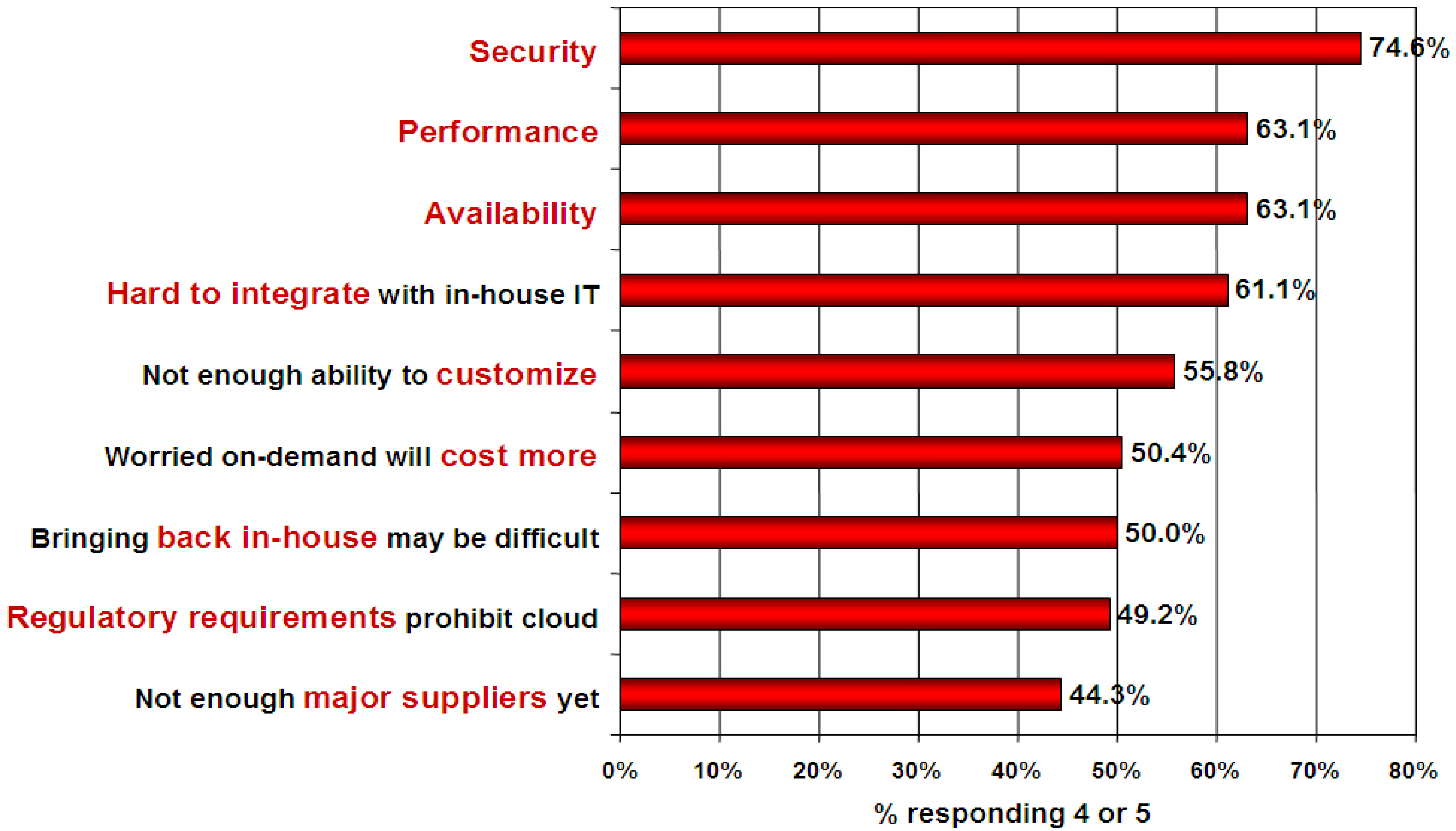
Cloud Computing Challenges

- Cloud Computing Challenges:
  Dealing with too many issues (Courtesy of R. Buyya)

Challenges/Issues in Cloud Computing

Q: Rate the challenges/issues ascribed to the 'cloud'/on-demand model

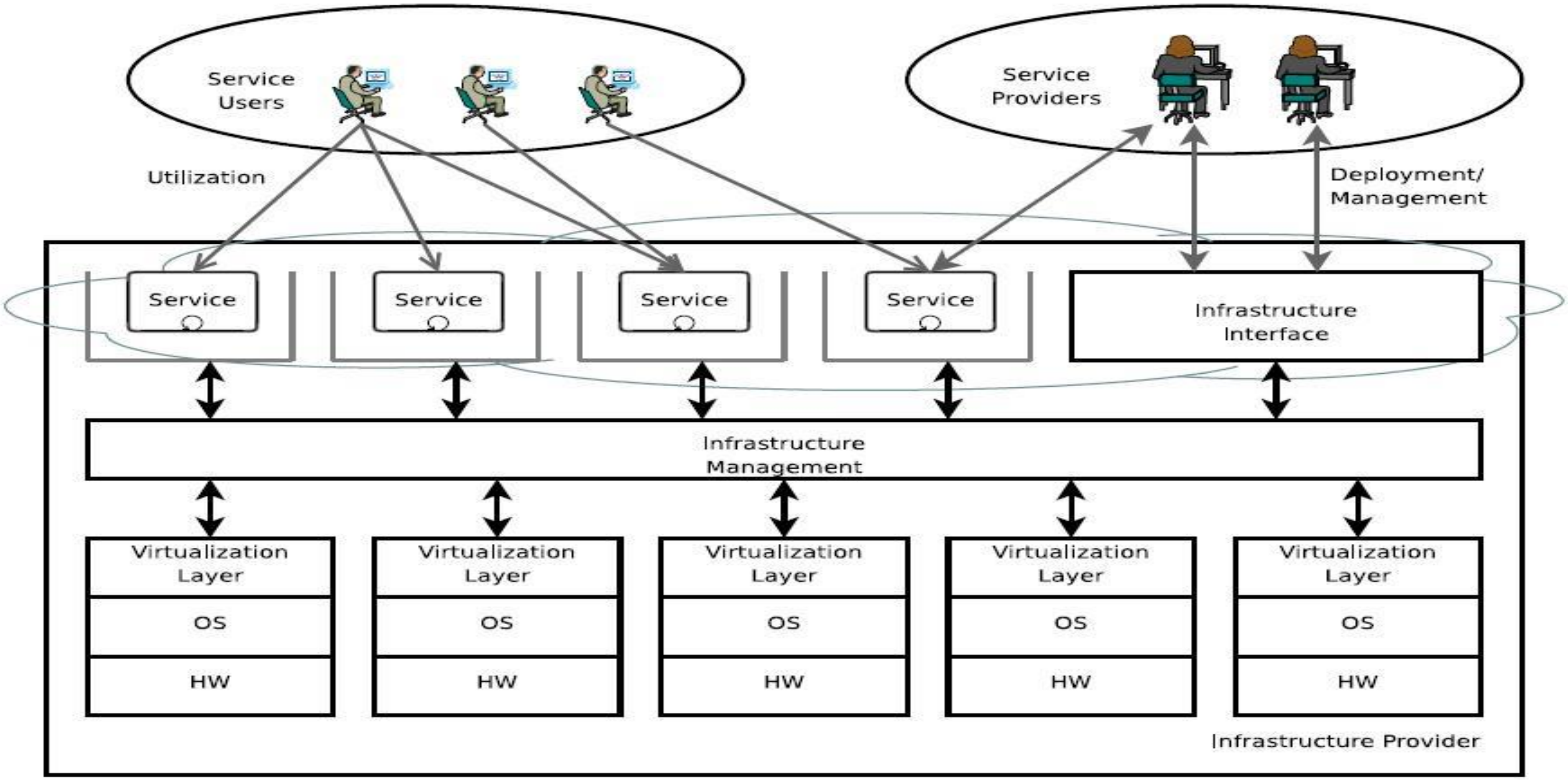
(1=not significant, 5=very significant)



Source: IDC Enterprise Panel, August 2008 n=244

Challenges with Clouds

Provide Support to different types of users and developers alike, Integration with different clouds



The RESERVOIR EUC Project

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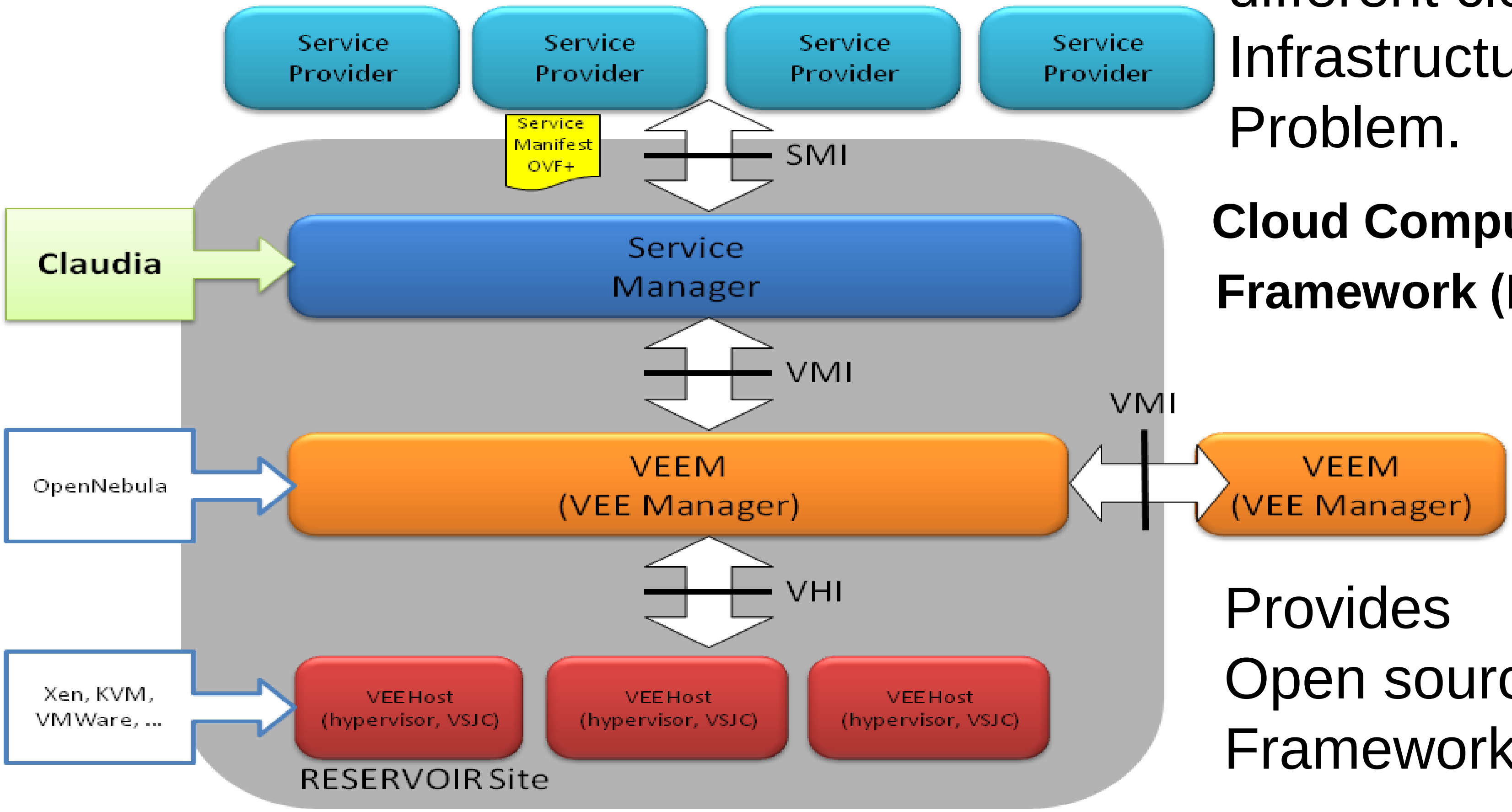
http://www.reservoir-fp7.eu/, 2008-2011

To resolve the different cloud Infrastructures Problem.

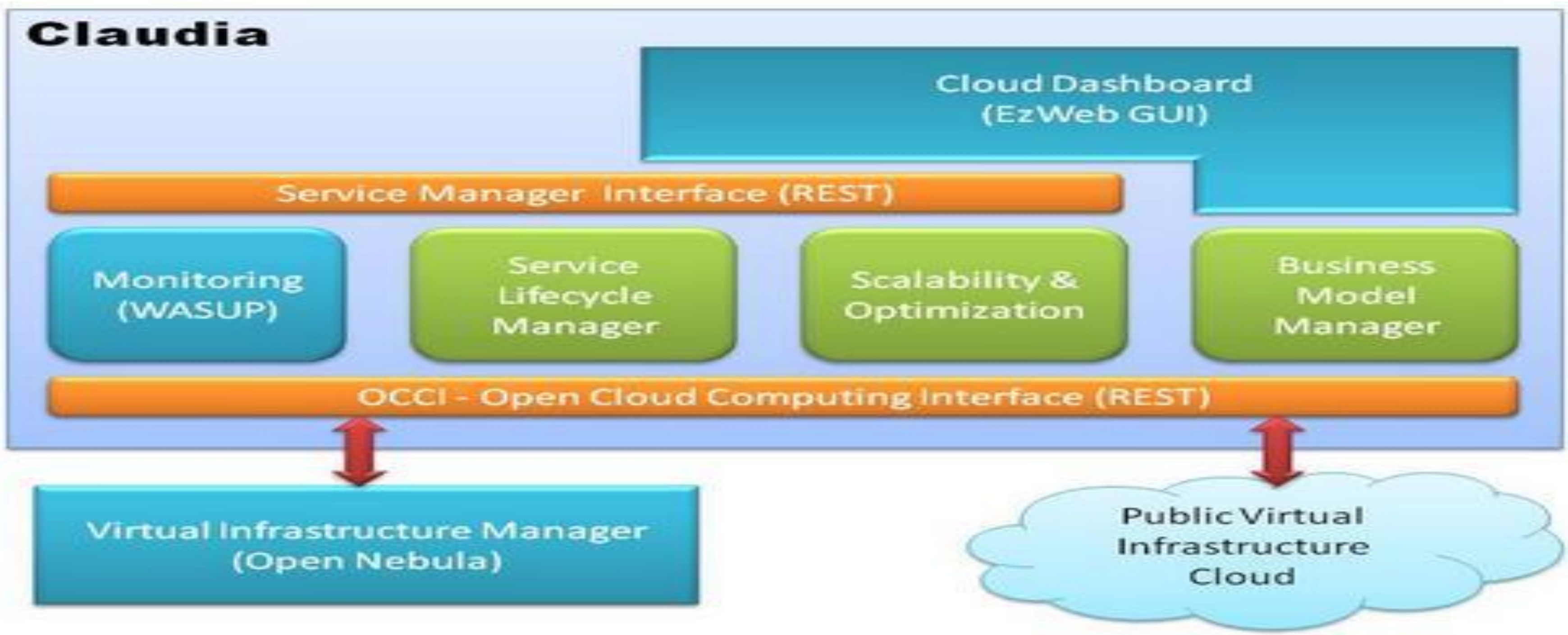
Cloud Computing Framework (Iaas)



Provides Open source Framework

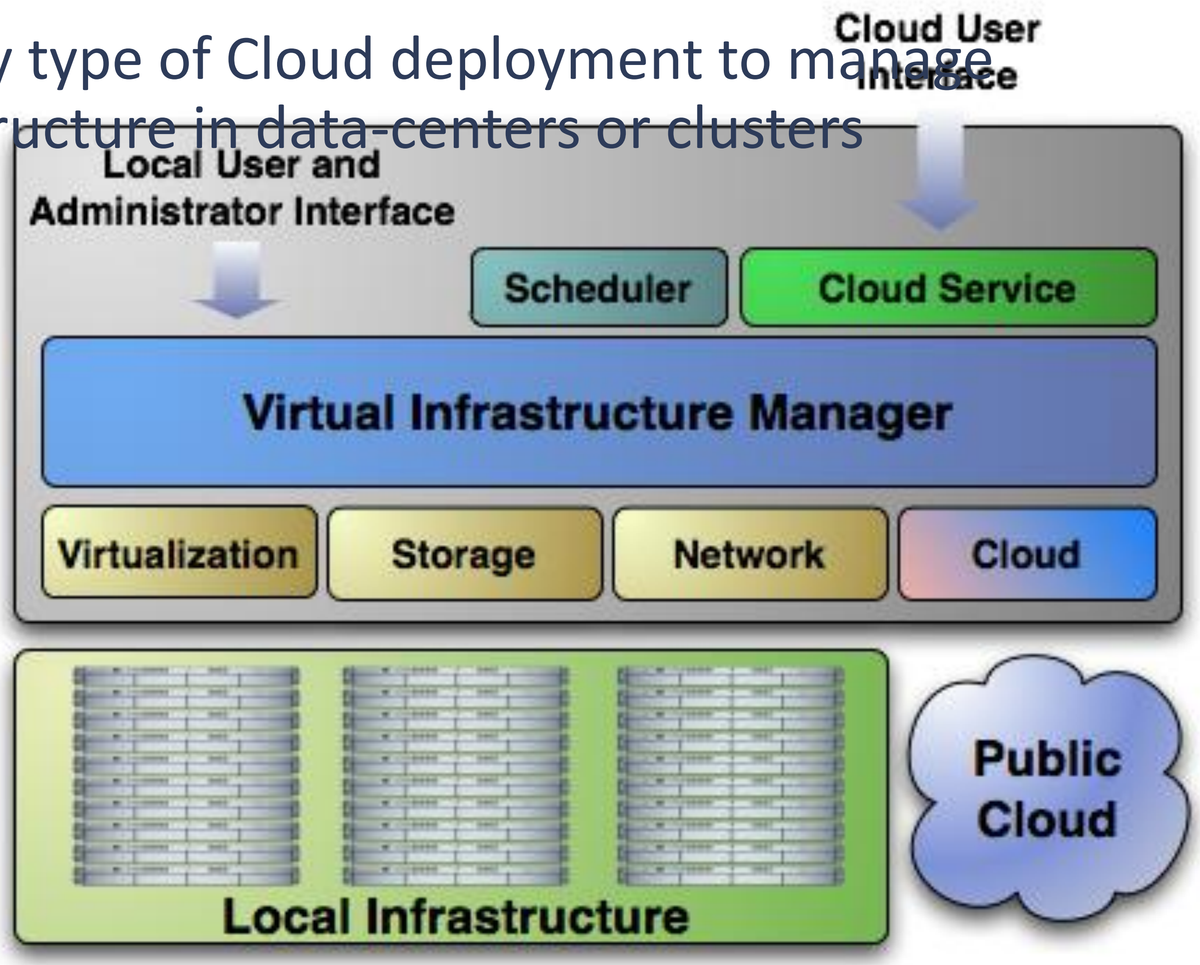
Challenges with Clouds

- The RESERVOIR Framework: The Claudia Service Manager
- Provides a Service Management toolkit to deploy and control the scalability of service among a public or private IaaS Cloud.



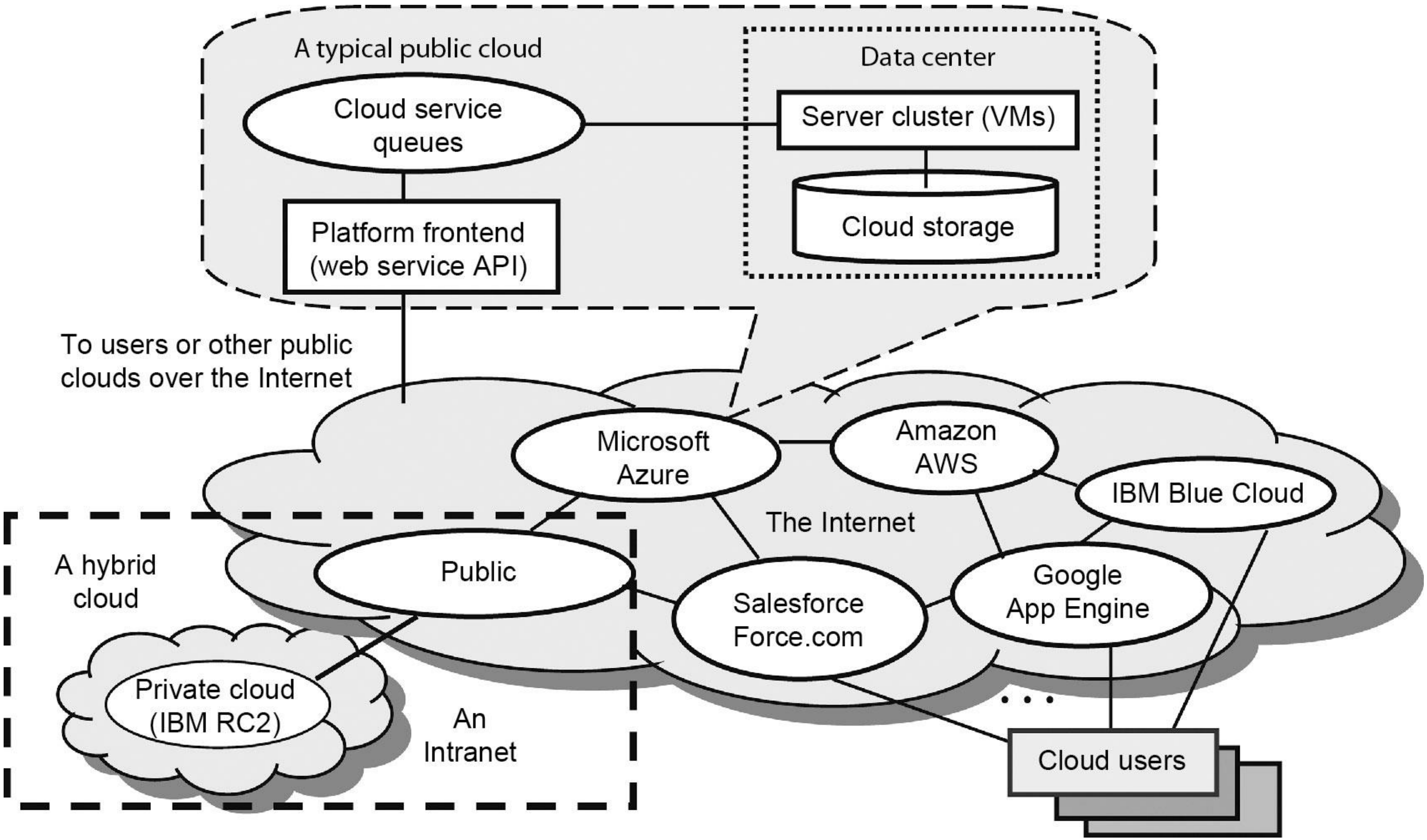
Challenges with Clouds

- The RESERVOIR Framework: The OpenNebula Virtual Execution
- A tool to build any type of Cloud deployment to manage the virtual infrastructure in data-centers or clusters

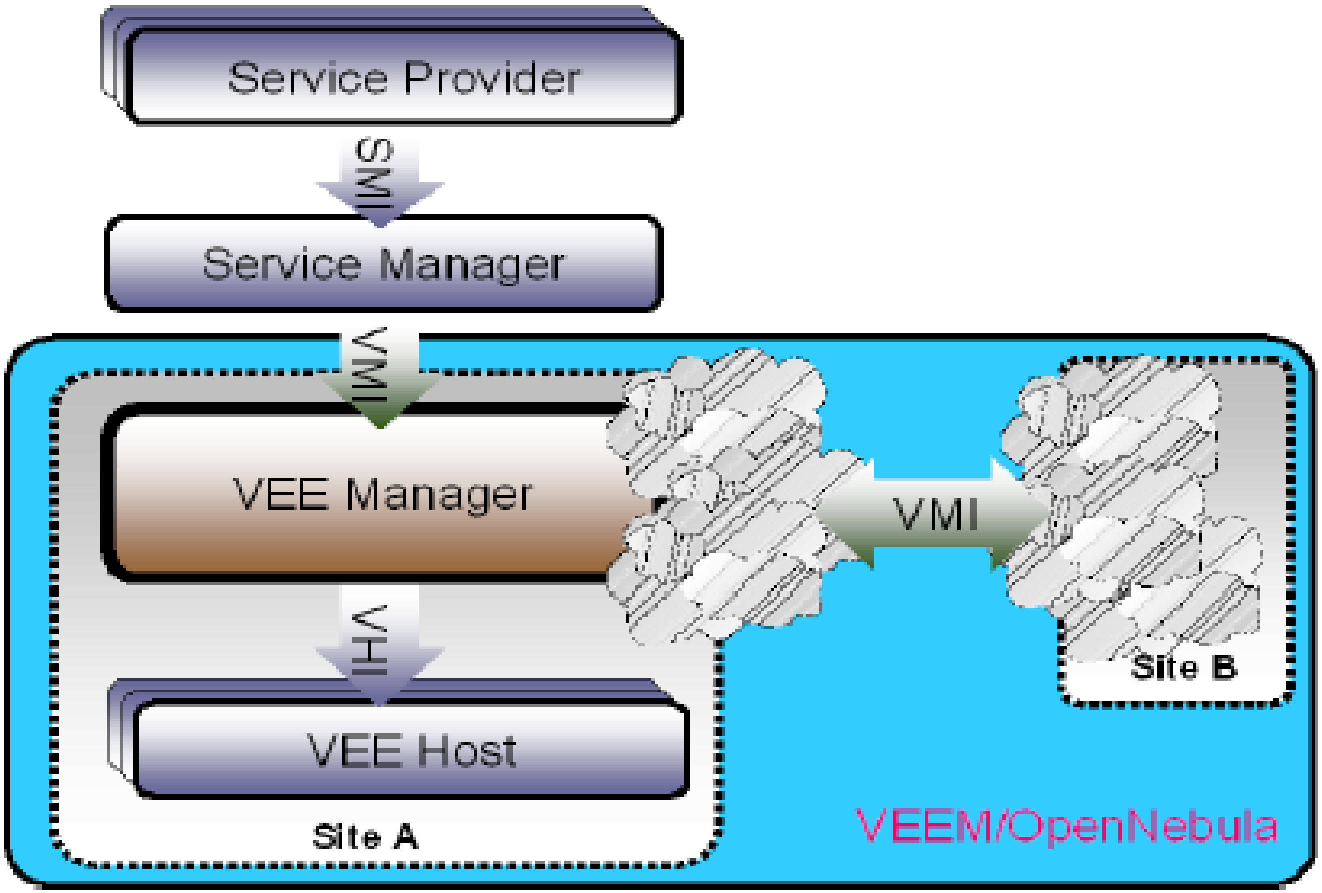


Cluster or Data Center

Public, Private & Hybrid Clouds



Types of Clouds: Private Clouds



Public Clouds and Service Offerings

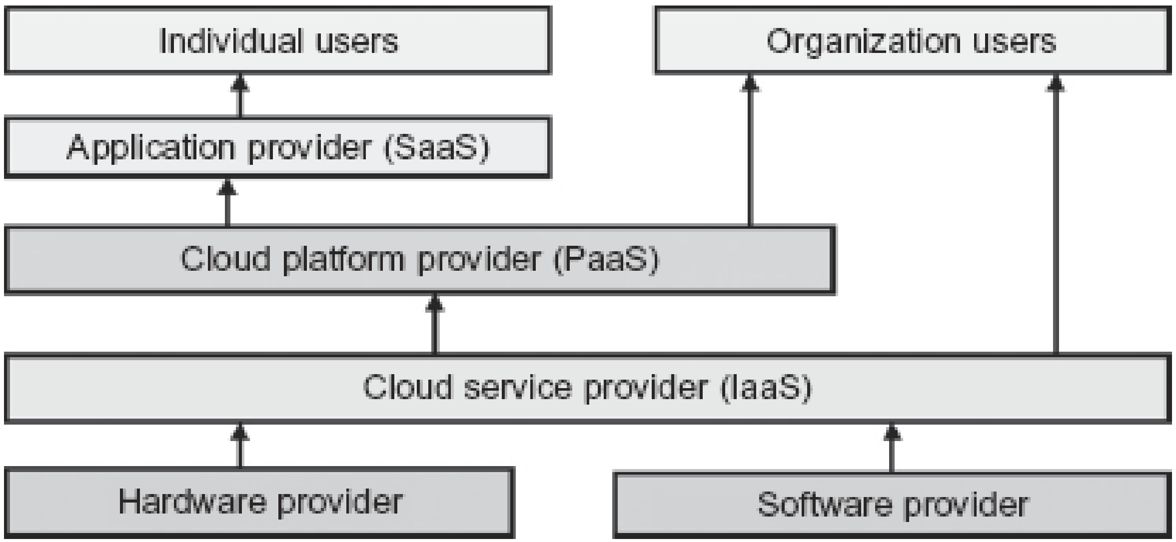


FIGURE 4.19

Roles of individual and organizational users and their Interaction with cloud providers under various cloud service models.

Table 4.5 Five Major Cloud Platforms and Their Service Offerings [30]

Model	IBM	Amazon	Google	Microsoft	Salesforce
PaaS	BlueCloud, WCA, RC2		App Engine (GAE)	Windows Azure	Force.com
IaaS	Ensembles	AWS		Windows Azure	
SaaS	Lotus Live		Gmail, Docs	.NET service, Dynamic CRM	Online CRM, Gifttag
Virtualization		OS and Xen	Application Container	OS level/ Hypel-V	
Service Offerings	SOA, B2, TSAM, RAD, Web 2.0	EC2, S3, SQS, SimpleDB	GFS, Chubby, BigTable, MapReduce	Live, SQL Hotmail	Apex, visual force, record security
Security Features	WebSphere2 and PowerVM tuned for protection	PKI, VPN, EBS to recover from failure	Chubby locks for security enforcement	Replicated data, rule-based access control	Admin./record security, uses metadata API
User Interfaces		EC2 command-line tools	Web-based admin. console	Windows Azure portal	
Web API	Yes	Yes	Yes	Yes	Yes
Programming Support	AMI		Python	.NET Framework	

Note: *WCA: WebSphere CloudBurst Appliance; RC2: Research Compute Cloud; RAD: Rational Application Developer; SOA: Service-Oriented Architecture; TSAM: Tivoli Service Automation Manager; EC2: Elastic Compute Cloud; S3: Simple Storage Service; SQS: Simple Queue Service; GAE: Google App Engine; AWS: Amazon Web Services; SQL: Structured Query Language; EBS: Elastic Block Store; CRM: Consumer Relationship Management.*

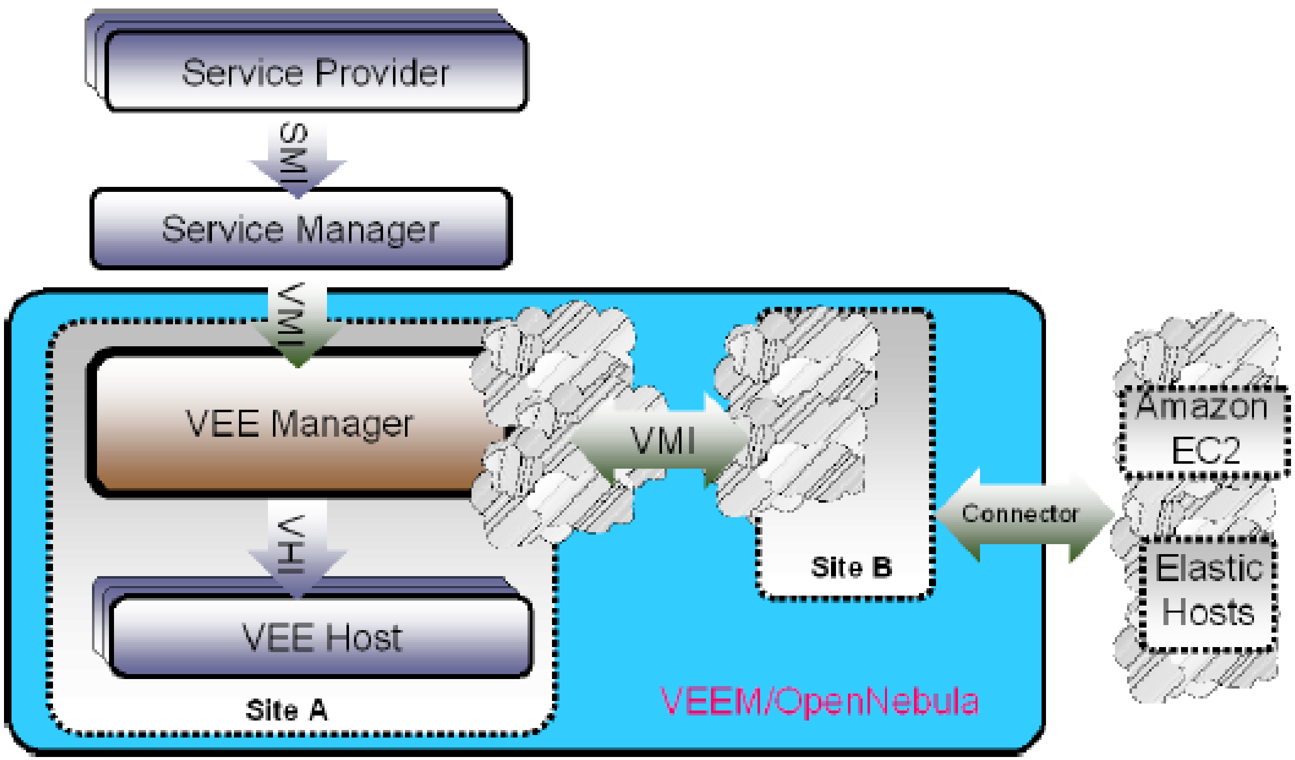
Public Clouds vs. Private Clouds

Characteristics	Public clouds	Private clouds
Technology leverage and ownership	Owned by service providers	Leverage existing IT infrastructure and personnel; owned by individual organization
Management of provisioned resources	Creating and managing VM instances within proprietary infrastructure; promote standardization, preserves capital investment, application flexibility	Client managed; achieve customization and offer higher efficiency

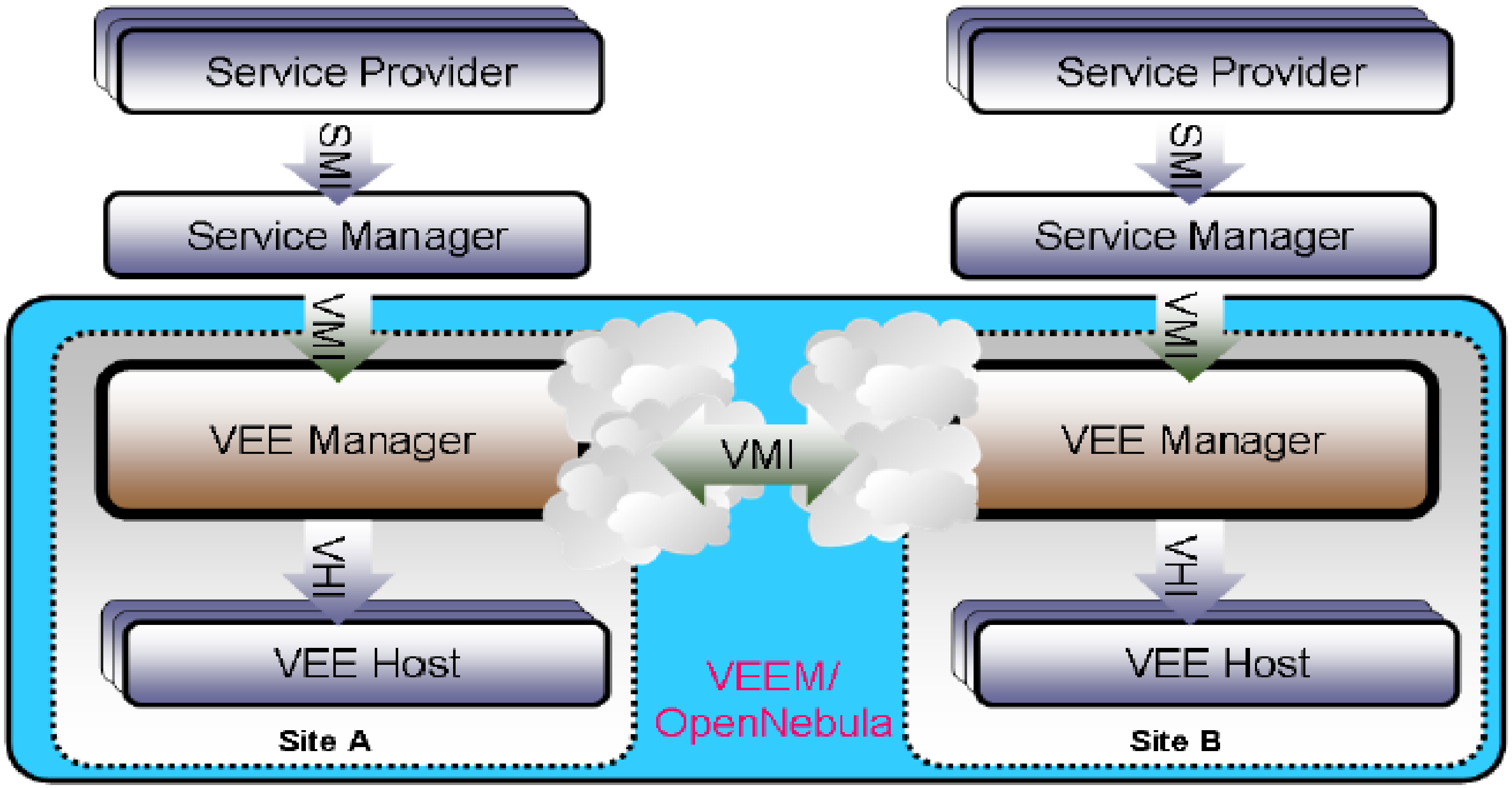
Public Clouds vs. Private Clouds (cont'd)

Characteristics	Public clouds	Private clouds
Workload distribution methods and loading policies	Handle workload without communication dependency; distribute data and VM resources; surge workload is off-loaded	Handle workload dynamically, but can better balance workloads; distribute data and VM resources
Security and data privacy enforcement	Publicly accessible through remote interface	Access is limited; provide pre-production testing and enforce data privacy and security policies
Example platforms	Google App Engine, Amazon AWS, Microsoft Azure	IBM RC2

Types of Clouds: Hybrid Clouds



Types of Clouds: Federated Clouds

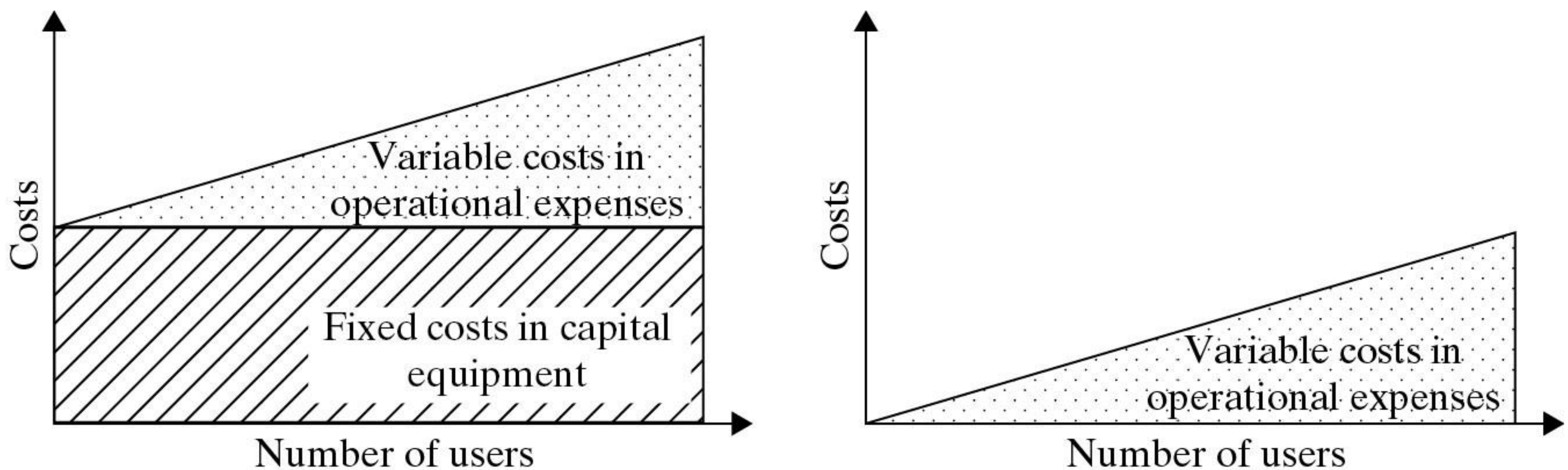


Cost-Effectiveness in Cloud Computing vs. Datacenter Utilization

- (Courtesy of M. Ambrust, et al 2009)

$$\text{UserHours}_{\text{cloud}} \times (\text{revenue} - \text{Cost}_{\text{cloud}}) \geq$$

$$\text{UserHours}_{\text{datacenter}} \times \left(\text{revenue} - \frac{\text{Cost}_{\text{datacenter}}}{\text{Utilization}}\right)$$



(a) Traditional IT cost model

(b) Cloud computing cost model

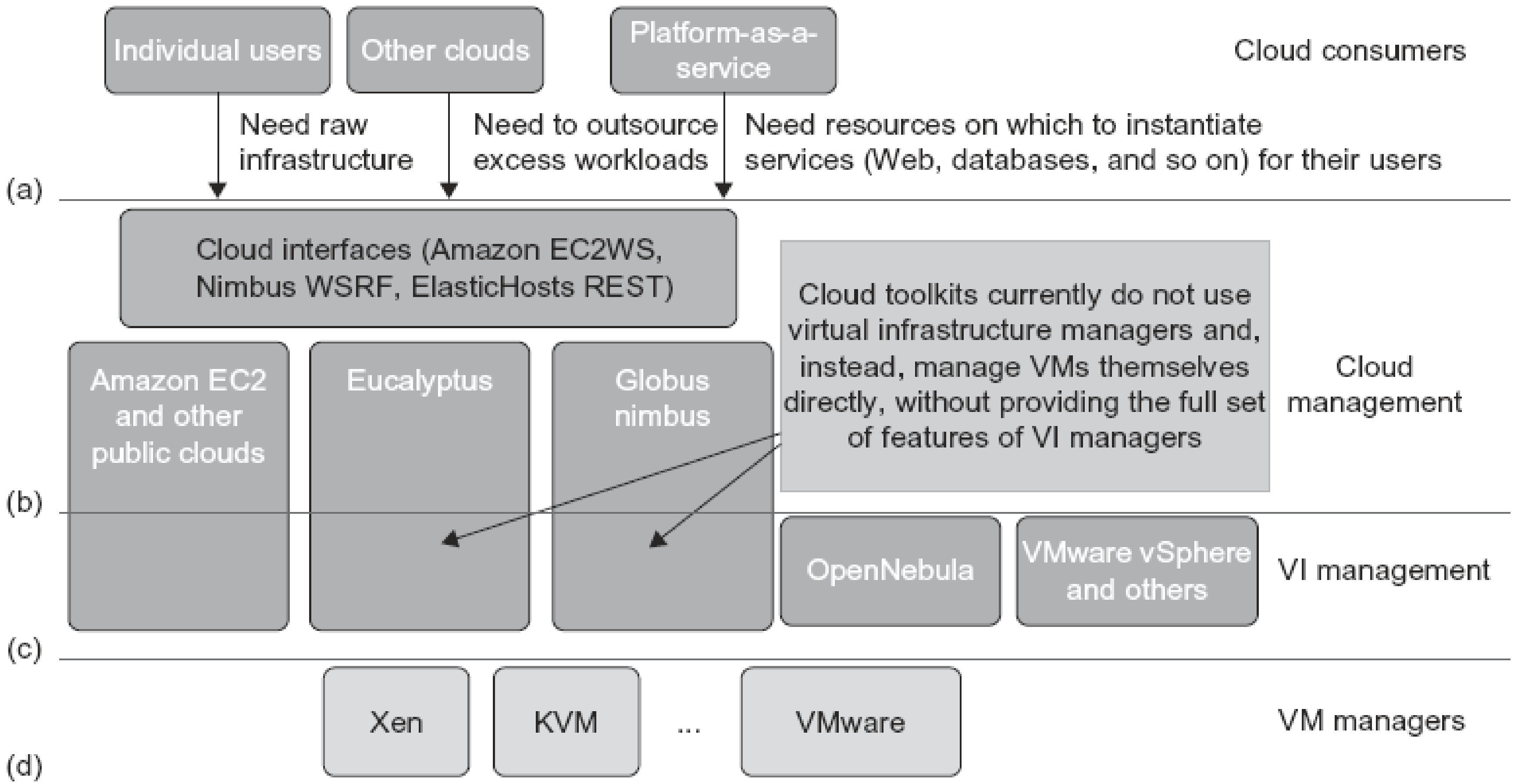


FIGURE 4.4

Cloud ecosystem for building private clouds: (a) Consumers demand a flexible platform; (b) Cloud manager provides virtualized resources over an IaaS platform; (c) VI manager allocates VMs; (d) VM managers handle VMs installed on servers.

(*Courtesy of Sotomayor, et al. [68]*)

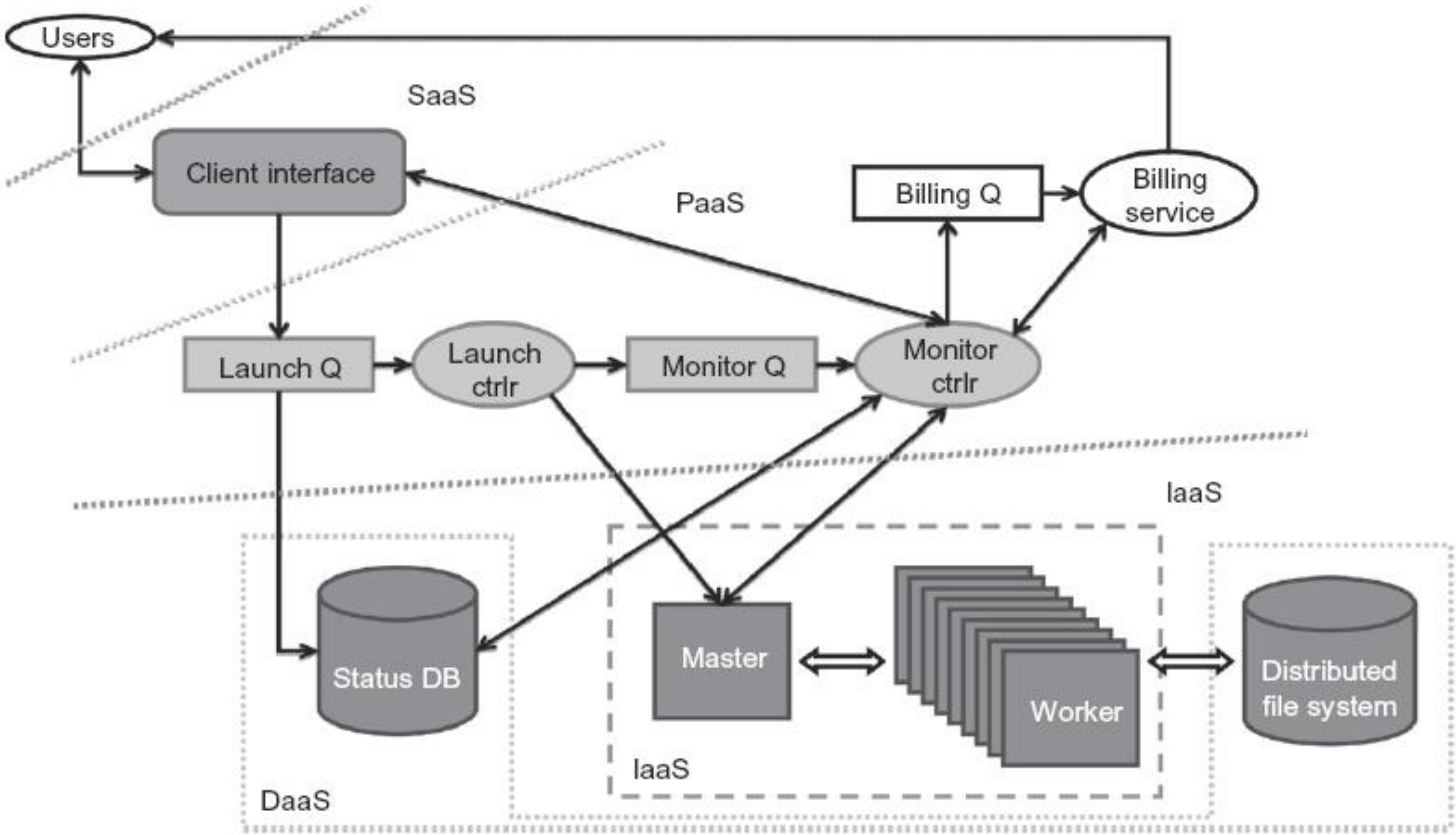


FIGURE 4.5

The IaaS, PaaS, and SaaS cloud service models at different service levels.

Challenges in Cloud Computing (1)

- Concerns from The Industry (Providers)
  - Replacement Cost
    - Exponential increase in cost to maintain the infrastructure
  - Vendor Lock-in
    - No standard API or protocol can be very serious
  - Standardization
    - No standard metric for QoS is limiting the popularity
  - Security and Confidentiality
    - Trust model for cloud computing
  - Control Mechanism
    - Users do not have any control over infrastructures

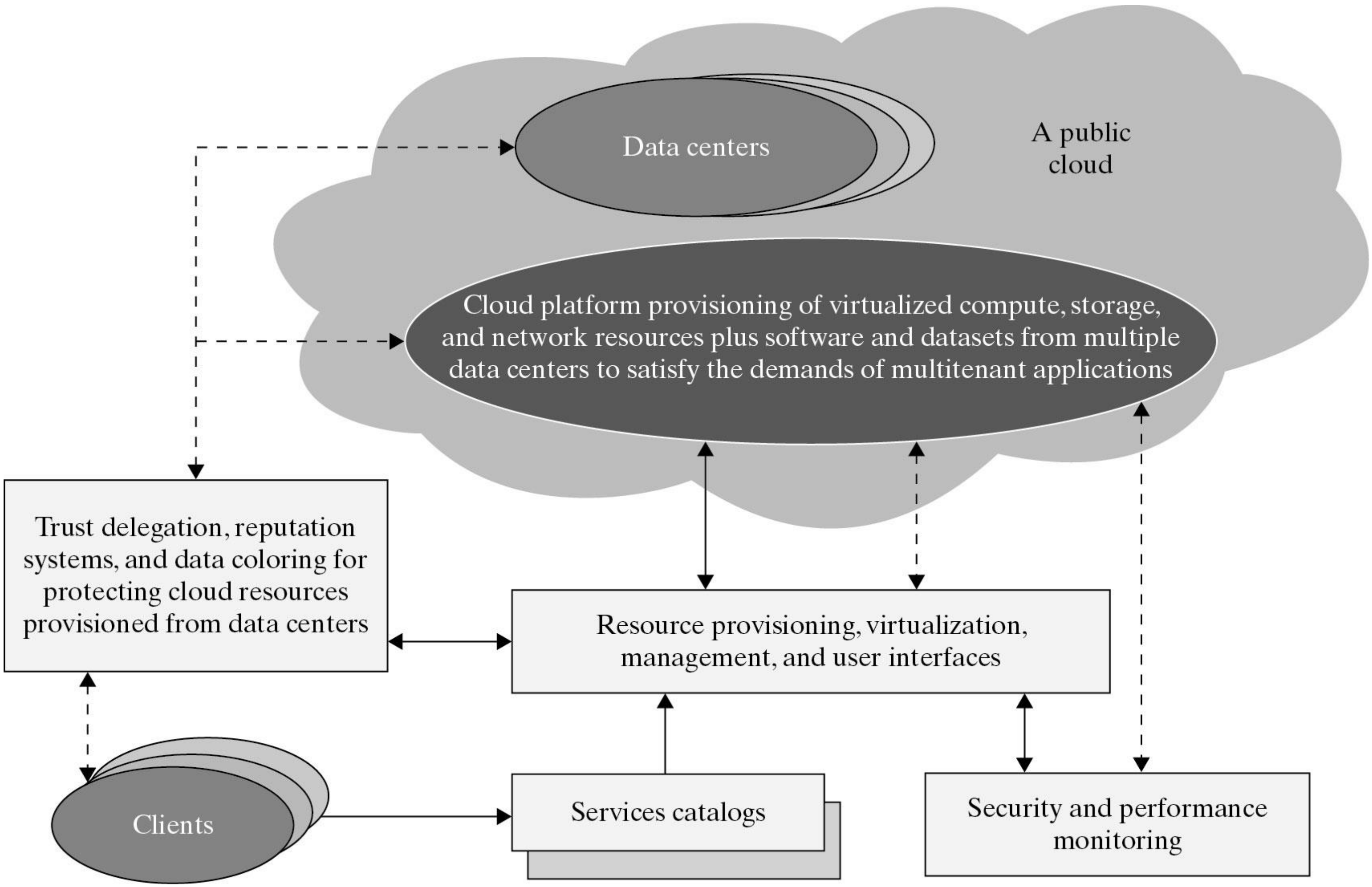
Challenges in Cloud Computing (2)

- **Concerns from Research Community :**
  - **Conflict to legacy programs**
    - **With difficulty in developing a new application due to lack of control**
  - **Provenance**
    - **How to reproduce results in different infrastructures**
  - **Reduction in Latency**
    - **No specially designed interconnect used**
    - **Very low controllability in layout of interconnect due to abstraction**
  - **Programming Model**
    - **Hard to debug where programming naturally error-prone**
    - **Details about infrastructure are hidden**
  - **QoS Measurement**
    - **Especially for ubiquitous computing where context changes**

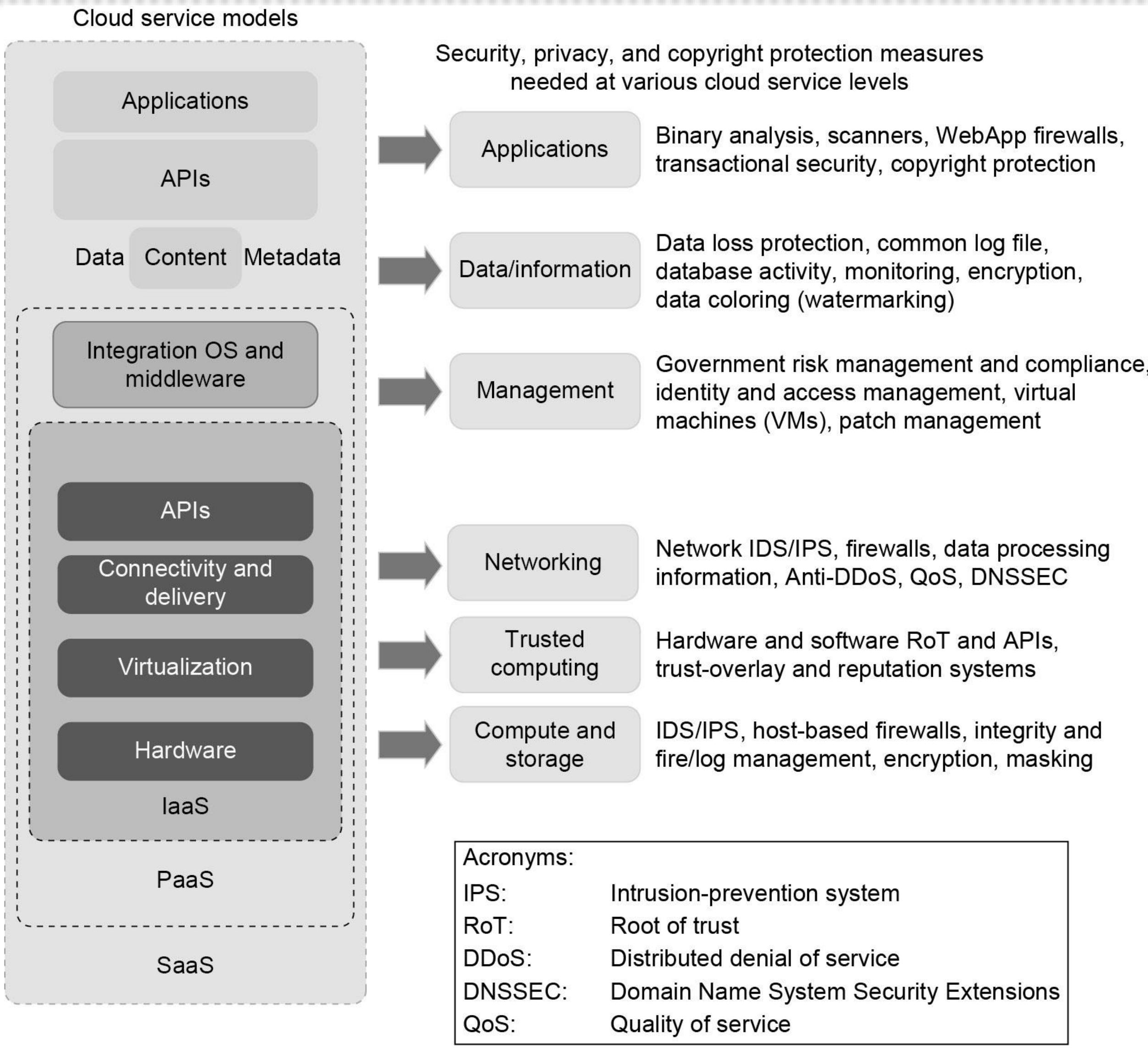
Security and Trust Barriers in Cloud Computing

- Protecting datacenters must first secure cloud resources and uphold user privacy and data integrity.
- Trust overlay networks could be applied to build reputation systems for establishing the trust among interactive datacenters.
- A watermarking technique is suggested to protect shared data objects and massively distributed software modules.
- These techniques safeguard user authentication and tighten the data access-control in public clouds.
- The new approach could be more cost-effective than using the traditional encryption and firewalls to secure the clouds.

Security Aware Cloud Platform



Cloud Service Models & Security Measures



(a) Cloud service models (b) Security, privacy, and copyright protection measures

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The Internet of Things (IoT)

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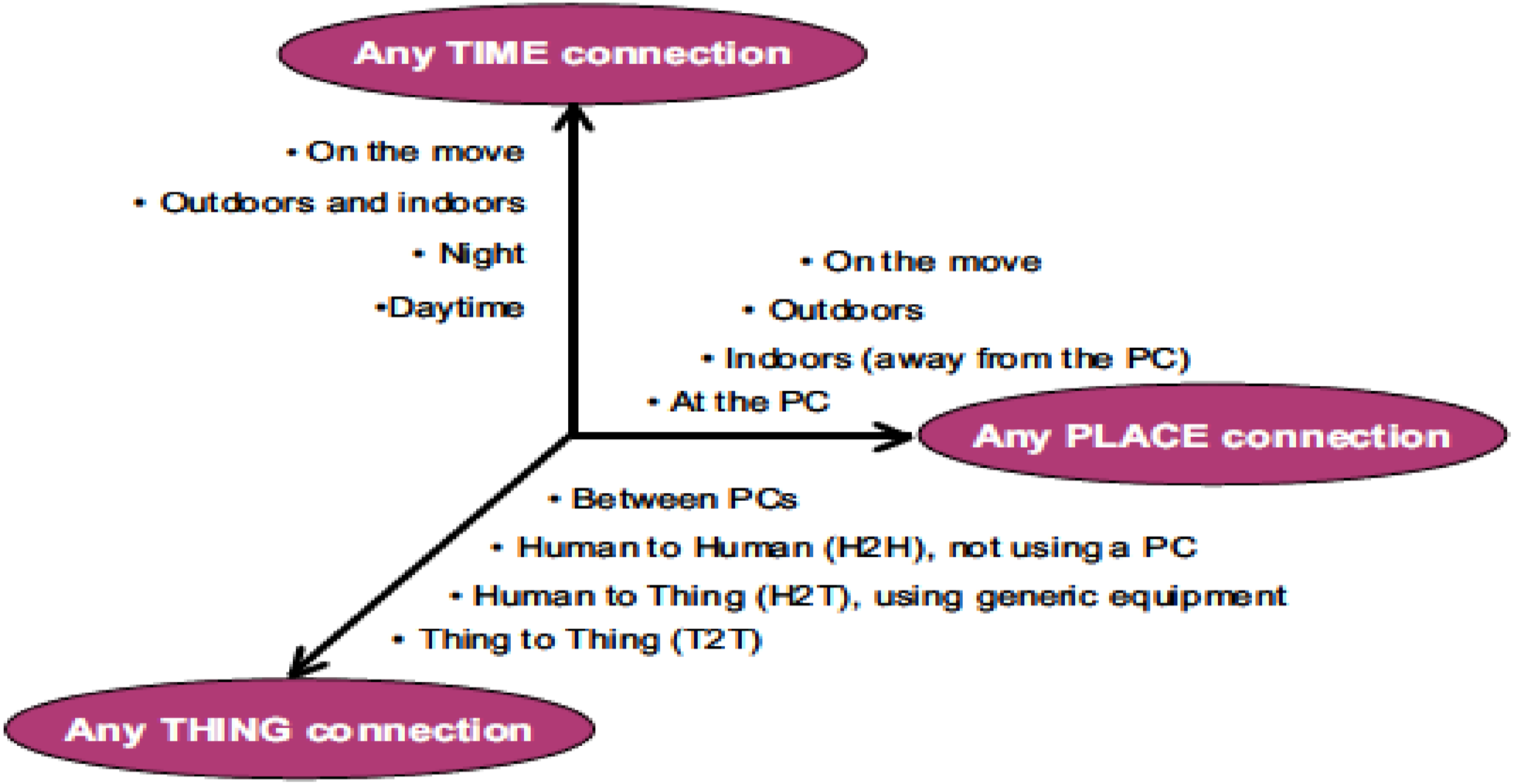

(courtesy of Wikipedia, 2010)

The Internet of Things (IoT)

- “IoT represents the most potentially disruptive technological revolution of our lifetime. With 50 to 100 billion things expected to be connected to the Internet by 2020” Guest Editors' Introduction, IEEE Computer, Jan 2013

What is the Internet of Things, IoT

- “The term Internet of Things (IoT) describes several technologies and research disciplines that enable the Internet to reach out into the real world of physical objects”

- “Technologies such as RFID, short range wireless communications, real-time localization, and sensor networks are becoming increasingly pervasive, making the IoT a reality”.

The Internet of Things (IoT) Architecture

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- Adopted from Ref 1 ch. 9

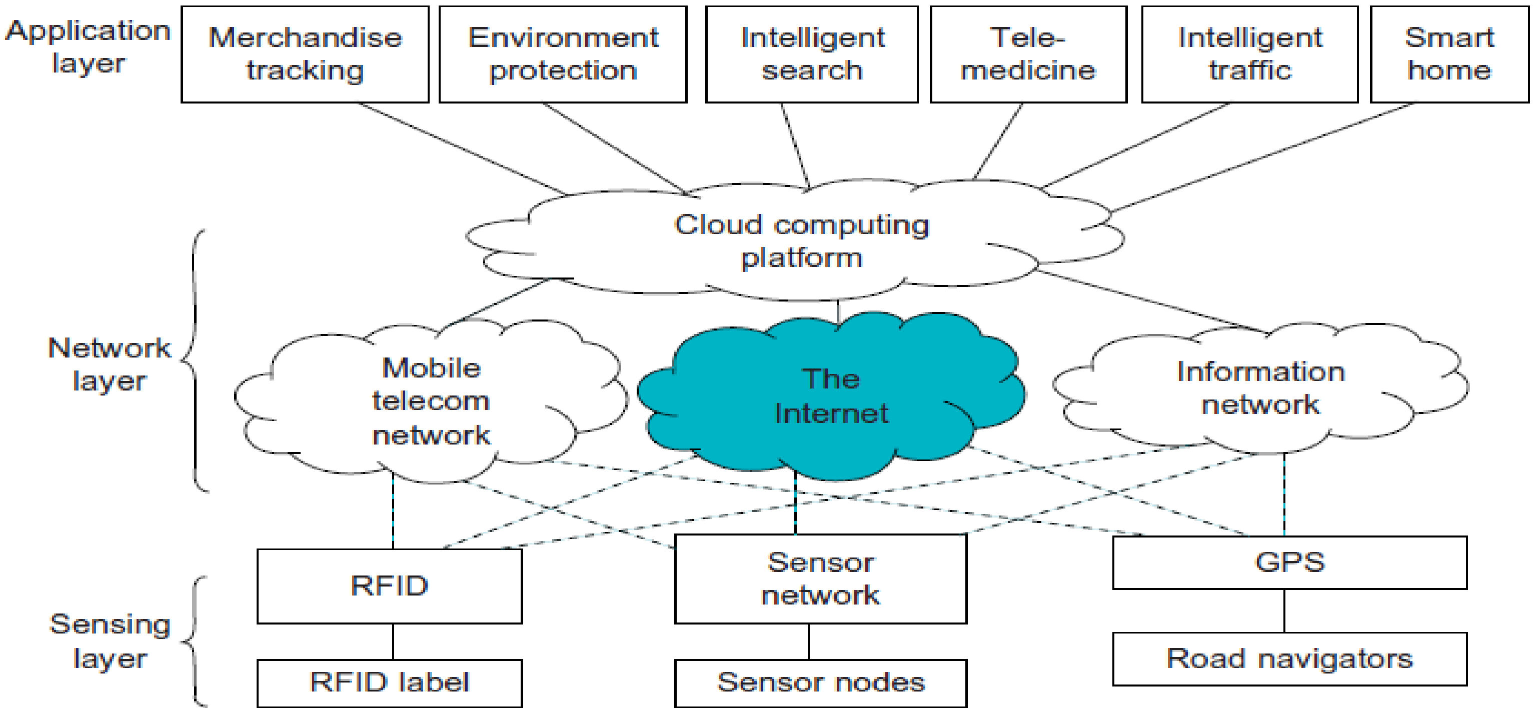

FIGURE 9.15

The architecture of an IoT consisting of sensing devices that are connected to various applications via mobile networks, the Internet, and processing clouds.

A Cloud Service Architecture for IoT

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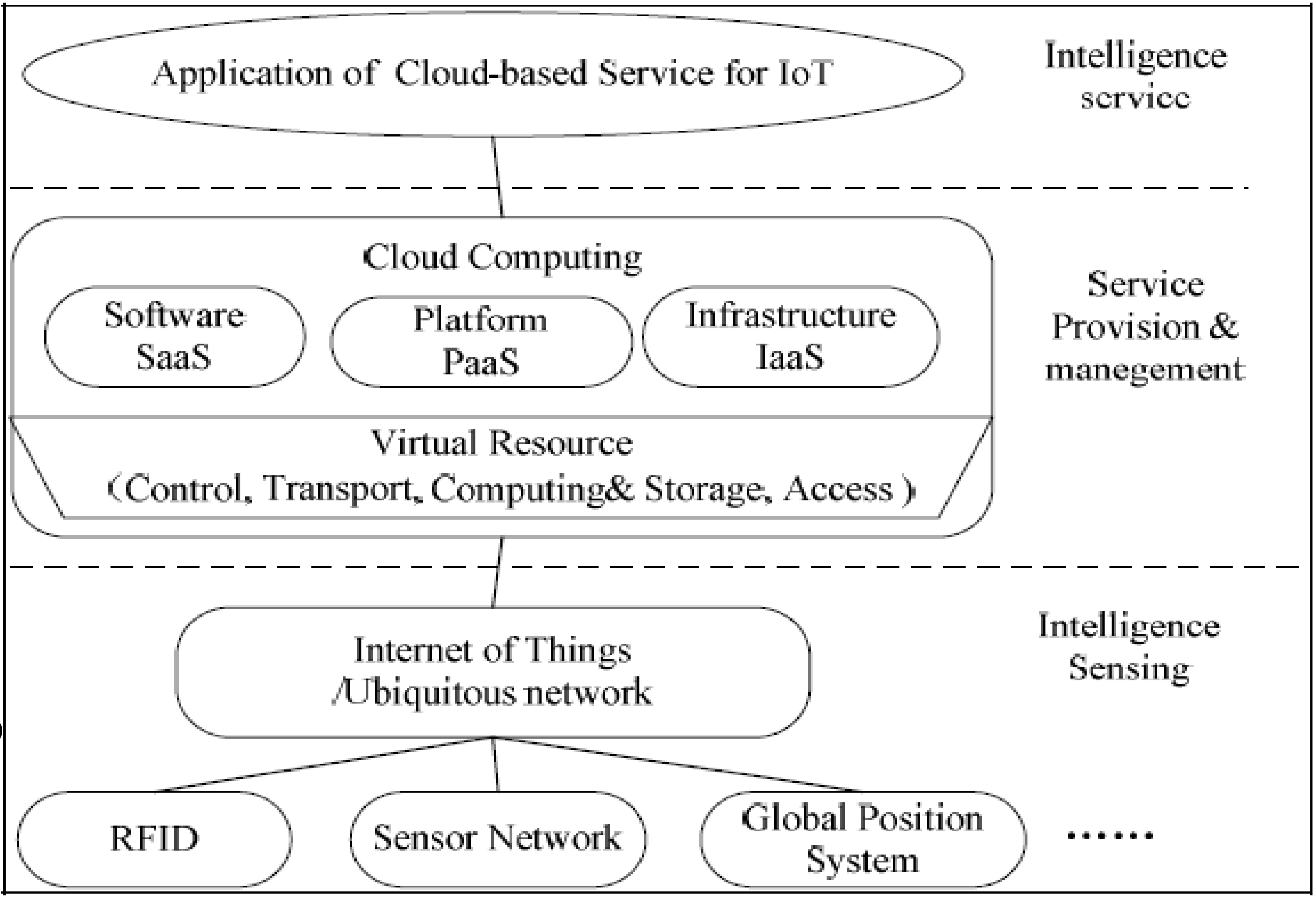
Y. Wang and X. Zhang (Eds.): IOT Workshop 2012, CCIS 312, pp. 559–564, 2012. © Springer-Verlag Berlin Heidelberg 2012

Radio-frequency Identification-RFID

Chip compared to a Grain of rice



Cloud Computing and IoT

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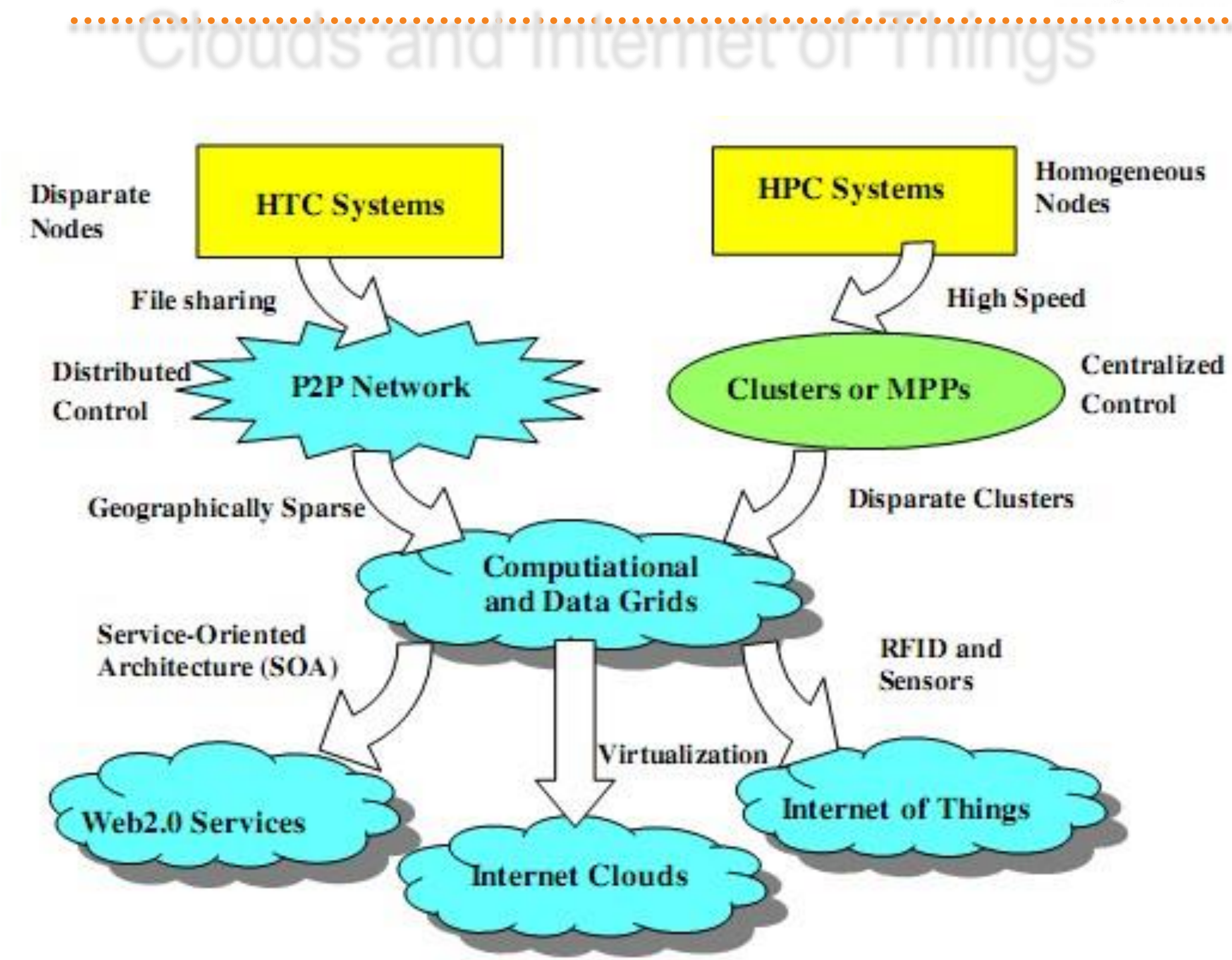

HPC: High-Performance Computing

HTC: High-Throughput Computing

P2P: Peer to Peer

MPPs: Massively Parallel Processors

Cloud Computing and IoT

- HPC for high-performance computing, which is oriented for scientific computing, such as Gflops and Pflops engineering and manufacturing applications.

- HTC for high-throughput computing, which is oriented for business computing, such as Internet searches and web services.
- Both HPC and HTC systems emphasize parallelism and distributed computing. Future systems must also satisfy the huge demand in computing power in terms of throughput, efficiency, scalability, and reliability.

Cloud Computing and IoT

- Information processing can be done more efficiently on large farms of computing and storage systems accessible via the Internet.
  - Grid computing – initiated by the National Labs in the early 1990s; targeted primarily at scientific computing.
  - Utility computing – initiated in 2005-2006 by IT companies and targeted at enterprise computing.
- The focus of utility computing is on the business model for providing computing services; it often requires a cloud-like infrastructure.
- Cloud computing is a path to utility computing embraced by major IT companies including:

Amazon, HP, IBM, Microsoft, Oracle, and others.

Cloud Computing and IoT

- Data-intensive : large scale simulations in science and engineering require large volumes of data. Multimedia streaming transfers large volume of data.
- Network-intensive : transferring large volumes of data requires high bandwidth networks.
- Low-latency networks for data streaming, parallel computing, computation steering.
- The systems are accessed using *thin clients* running on systems with limited resources, e.g., wireless devices such as smart phones and tablets.
- The infrastructure should support some form of workflow management.

Cloud Computing and IoT

Computing Paradigms:

Centralized computing, Parallel computing

Distributed computing, Cloud Computing

Alternatives could be concurrent computing, ubiquitous computing, and Internet computing.

IoT = networked collection of everyday objects including computers, sensors, humans, etc.

Internet Clouds = the result of moving desktop computing to service-oriented computing using server clusters and huge databases at data centers.

Parallel and Distributed Programming

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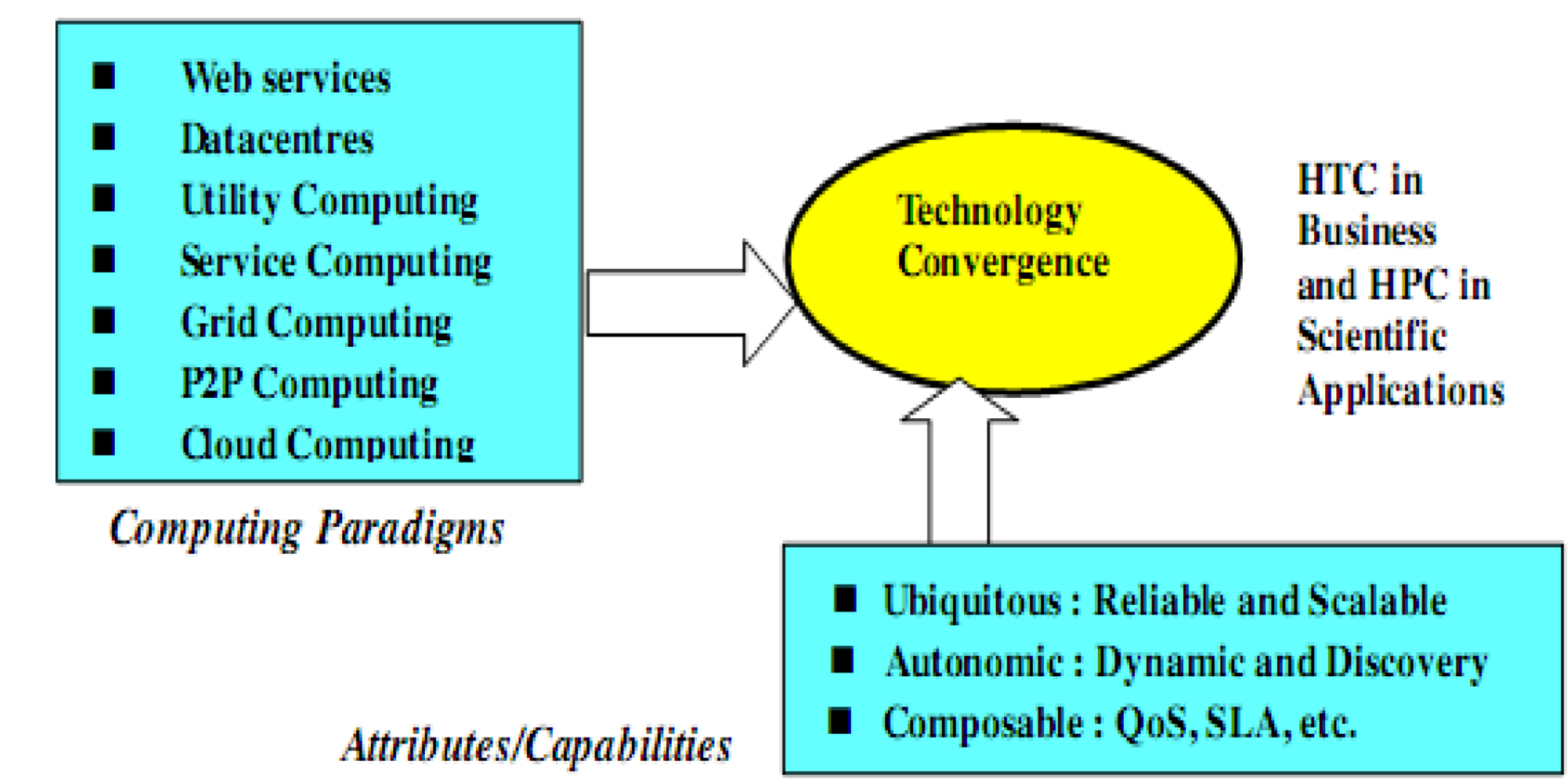
Table 1.7 Parallel and Distributed Programming Models and Tool Sets

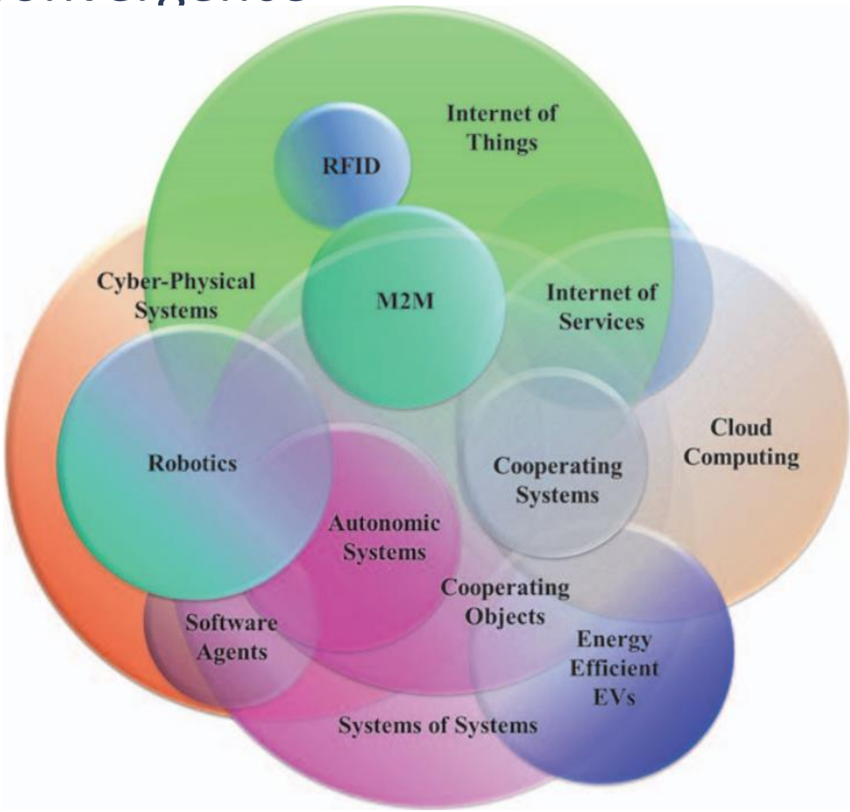
Model	Description	Features
MPI	A library of subprograms that can be called from C or FORTRAN to write parallel programs running on distributed computer systems [6,28,42]	Specify synchronous or asynchronous point-to-point and collective communication commands and I/O operations in user programs for message-passing execution
MapReduce	A Web programming model for scalable data processing on large clusters over large data sets, or in Web search operations [16]	*Map* function generates a set of intermediate key/value pairs; *Reduce* function merges all intermediate values with the same key
Hadoop	A software library to write and run large user applications on vast data sets in business applications (http://hadoop.apache.org/core)	A scalable, economical, efficient, and reliable tool for providing users with easy access of commercial clusters

Cloud Computing and IoT



Cloud, Big data and IoT

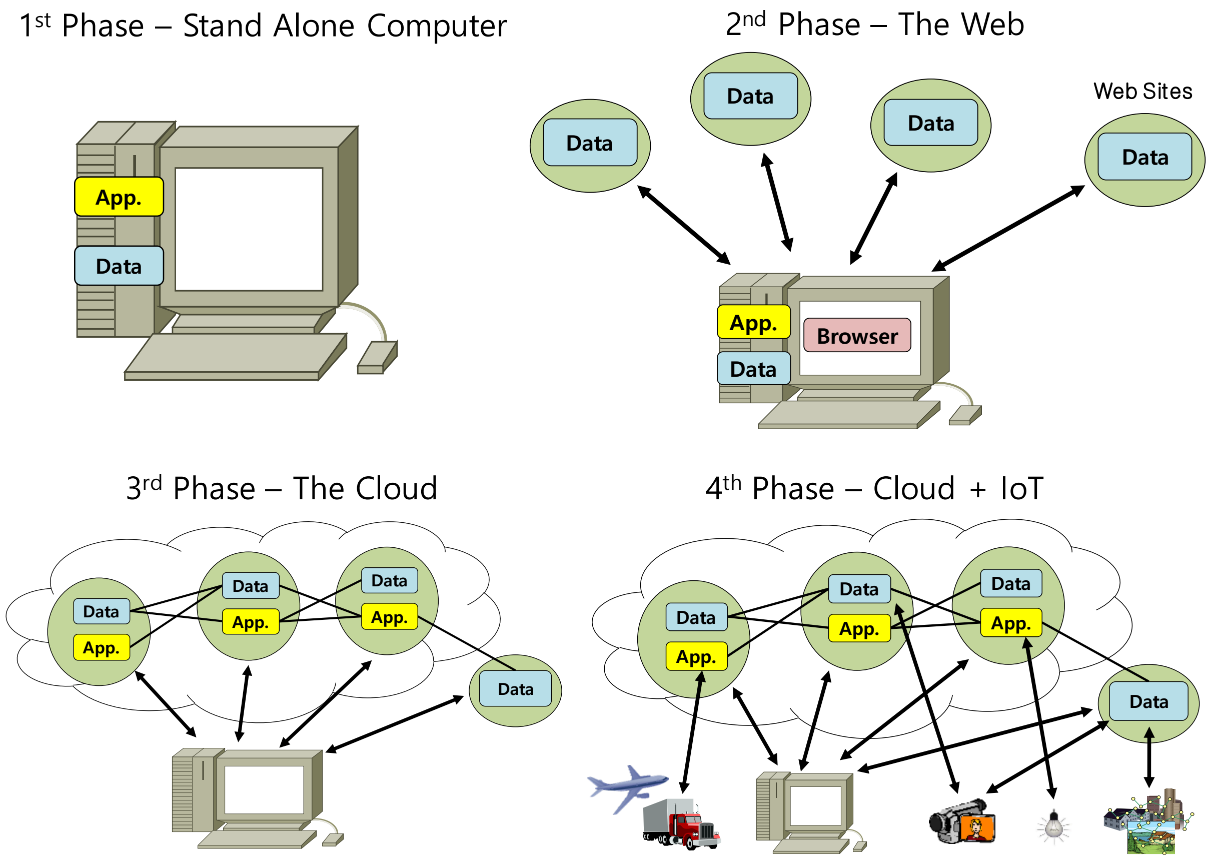
- Technology Convergence



Source: Ovidiu Vermesan “Internet of Things – Converging technologies for smart environments and integrated ecosystems” Riverpublishers, 2013.

Cloud, Big data and IoT (cont'd)

- From stand alone PC to the Cloud-based IoT



Cloud, Big data and IoT (cont'd)

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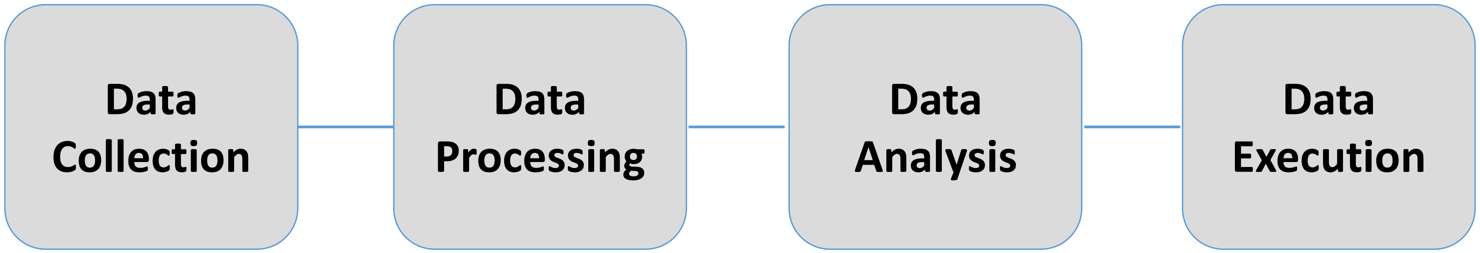
- A category of technologies and services where the capabilities provided to collect, store, search, share, analyze and visualize data which have the characteristics of high-volume, high-velocity and high-variety.



Cloud, Big data and IoT (cont'd)

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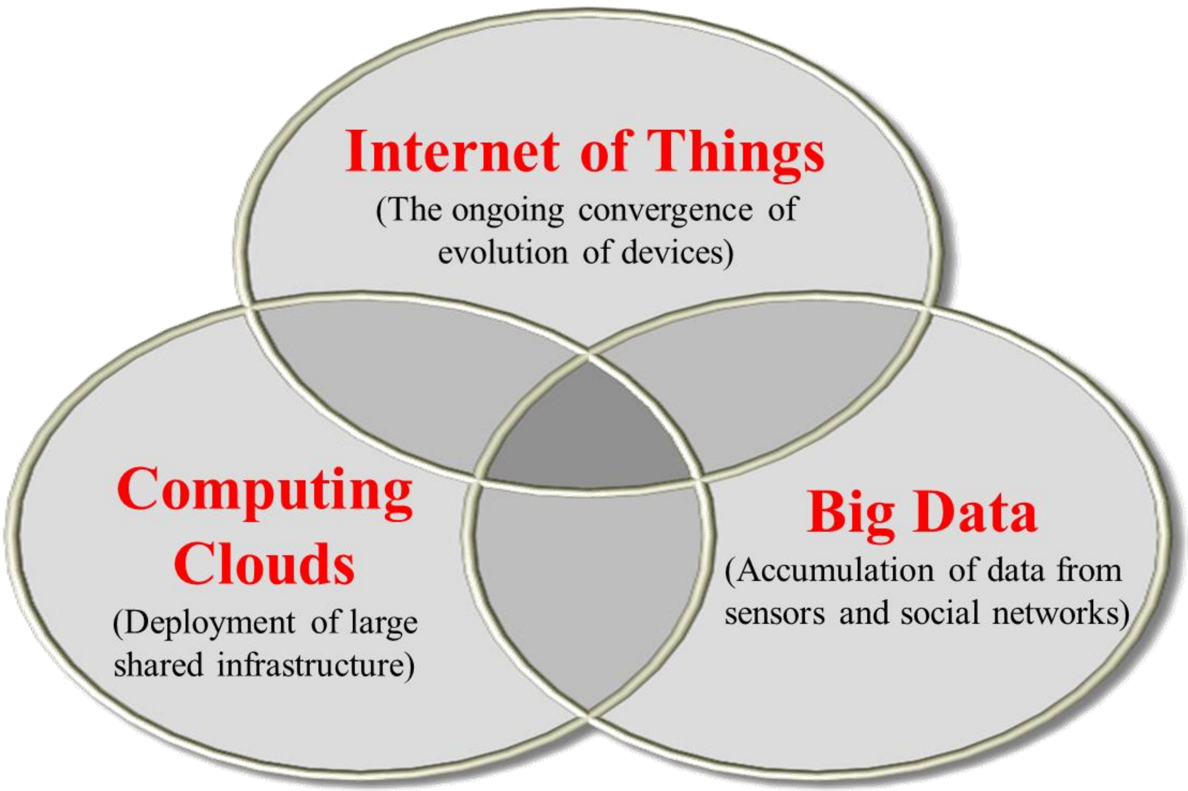
- Big Data is not just about volume
  - Volume, Velocity, and Variety
  - Geo-distribution from IoT

- Technical aspects
  - Data collected and stored continues to grow exponentially
  - Data is increasingly everywhere and in many formats
  - Traditional solutions are failing under new requirements
  - ➔ Aggregate and process data from Things in the Cloud

Cloud, Big data and IoT (cont'd)

- Exciting new challenges

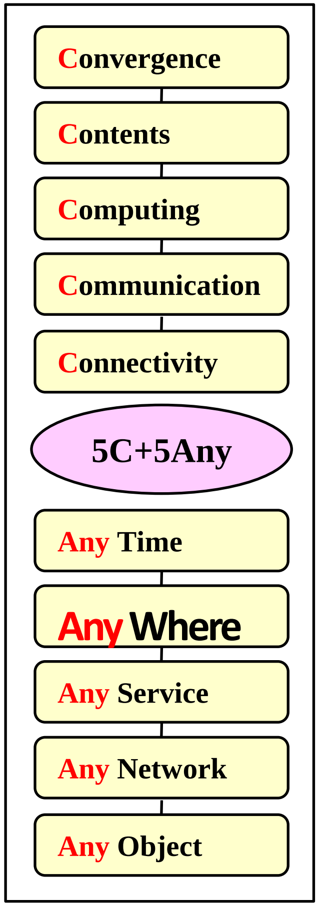


Vision - Interdisciplinary fusion revolution

- Ubiquitous connectivity
  - Allowing for whenever, whoever, wherever, whatever types of communications
- Pervasive reality
  - For effective interface to provide connectable real world environments
- Ambient intelligence
  - Allowing for innovative communications and providing increased value creation.

Cloud, Big data and IoT (cont'd)

- Data stored in the "Cloud"
- Data follows you & your devices
- Data accessible anywhere
- Data can be shared with others



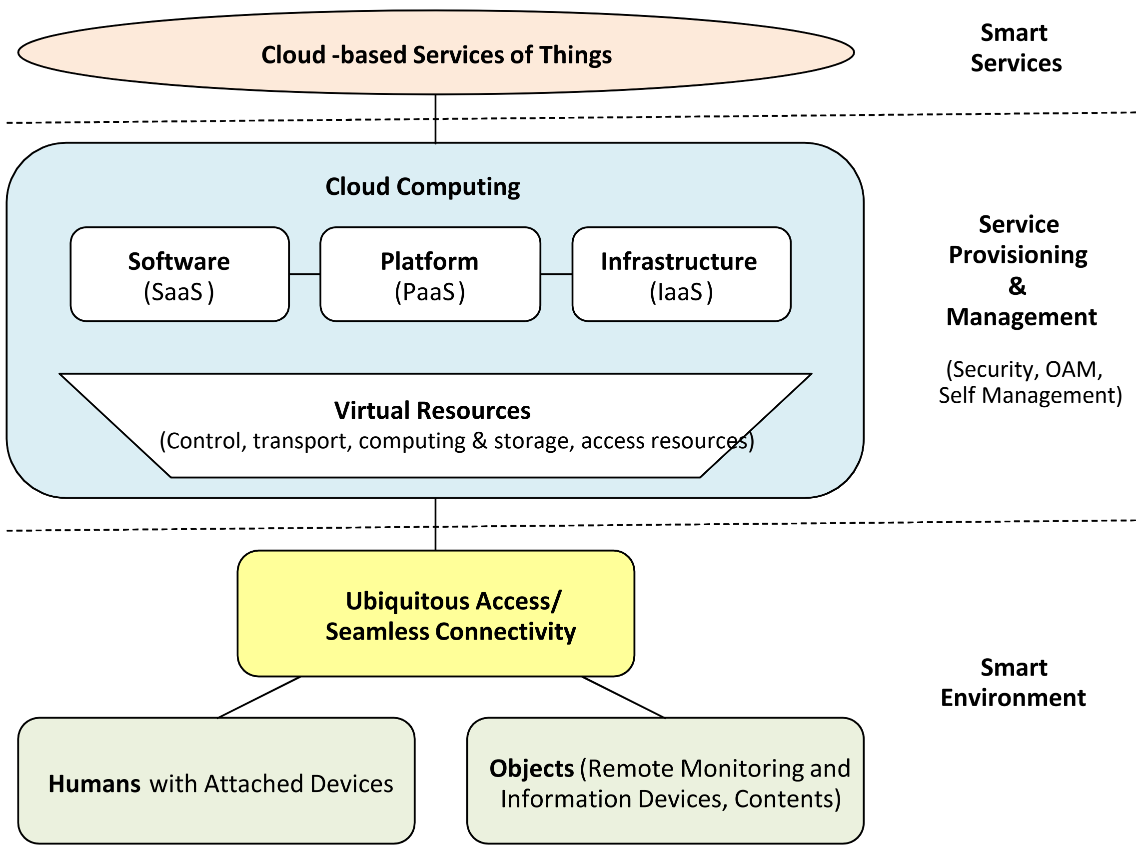
Integration of Clouds and the IoT

- Combining clouds and the IoT
  - To support required resources to increasing heterogamous objects
  - To meet the dynamic computational needs of environmental applications with existing sensor network technologies
- Benefits
  - The cloud can work on behalf of the object for increasing availability, maintaining performance and scalability.
  - The cloud can support resource continuity so that objects move freely changing access technologies while using resources from the same cloud.

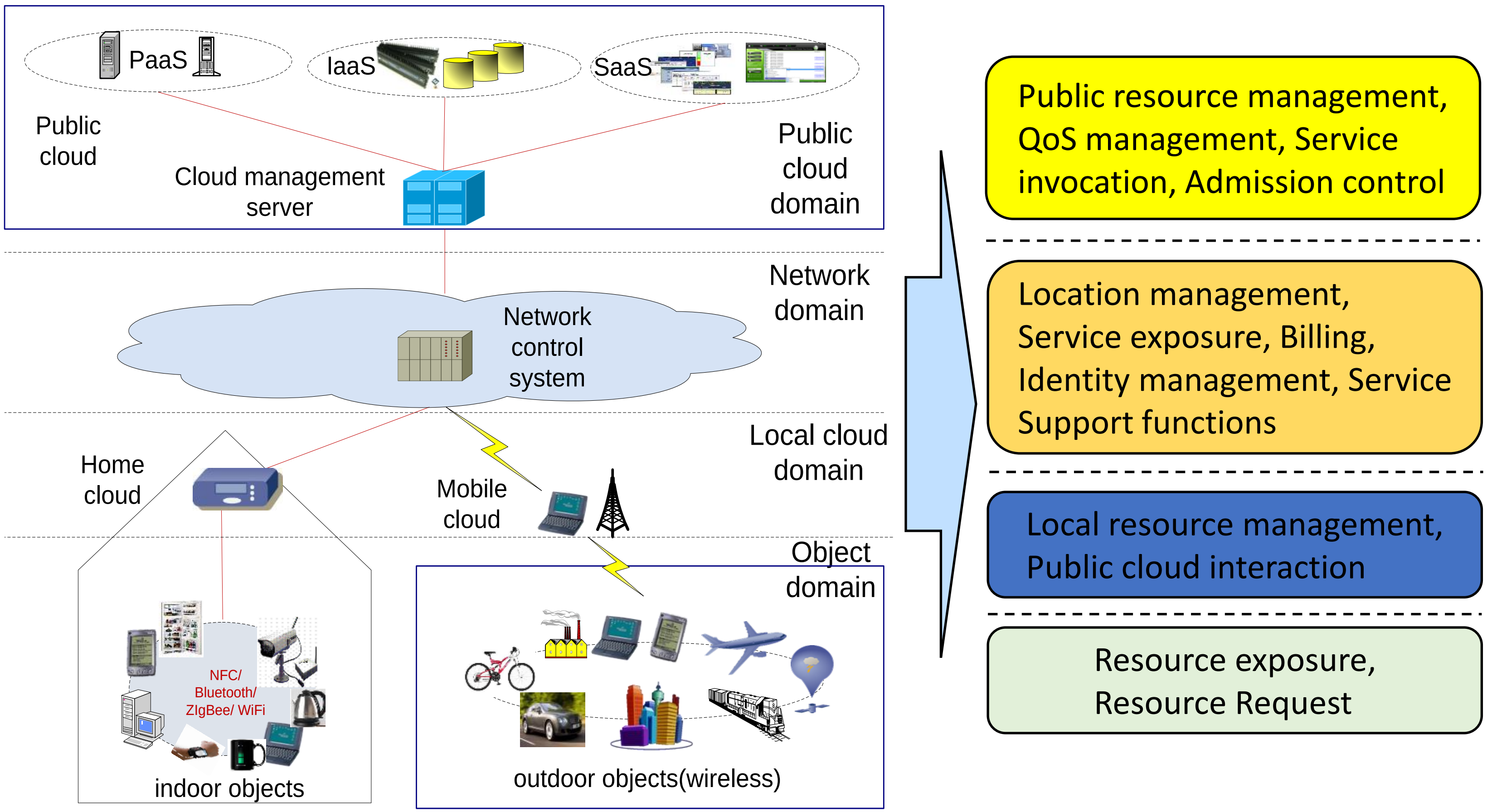
Key features of clouds to support the IoT

- Several features available in clouds are requirements of resource-constrained objects
  - Flexibility of resource allocation
  - More intelligent applications
  - Energy saving
  - No on-site infrastructure
  - Heterogeneity of the smart environment
  - Scalability and agility
  - Virtualization

- A conceptual diagram for the cloud-based Internet of Things



The IoT using local distributed clouds



Challenges for future standardization

- Technical consideration for standardization
  - Object naming
  - Virtualization
  - Inter-clouds
  - Distributed clouds (edge clouds)
  - Security
  - Geo-distribution
  - Mobility considering mobile objects
  - Resource provisioning for constraint objects
  - Application-awareness
  - Big Data considering dynamics of traffic pattern
  - Connected objects and interdisciplinary fusion services

- Conclusion:
- The cloud-based IoT service environment
  - Combines the cloud computing, big data and the IoT
  - Aims to efficiently support various services using cloud and analytics technologies from different kinds of objects (e.g., devices, machines, etc.).
- Standardization
  - The relevant standardization efforts for realization of the cloud-based IoT need to be accelerated with special consideration of their commercial viability.
  - Q11/13: a new work item on “cloud-based IoT” (living list)

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Biomedical Applications
IoT in Telemedicine

- Adopted from Ref 1, Ch 9

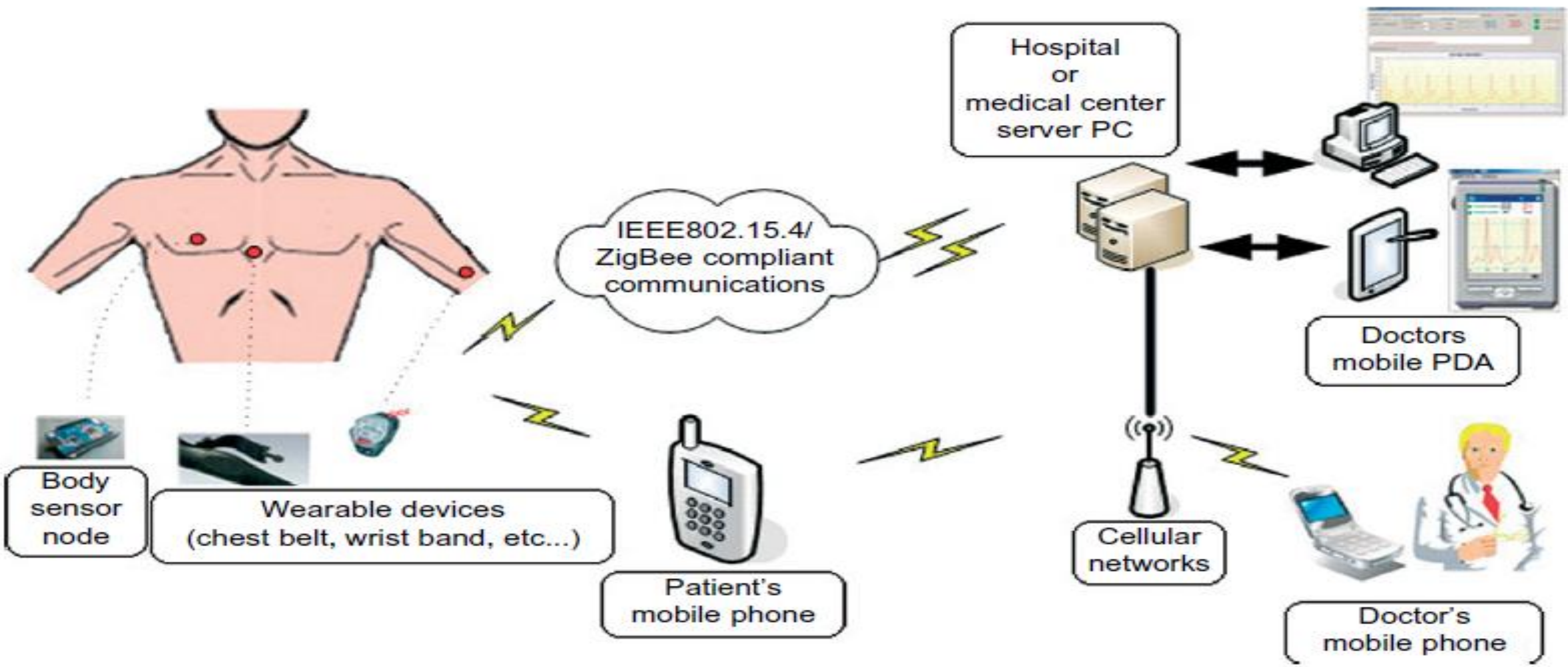


FIGURE 9.19

An example of how measured data can be transferred to doctors or medical professionals using a wireless sensor network.

Biomedical Applications and IoT

- http://www.biomedical-engineering-online.com/content/11/1/95/abstract

Estimation of human trunk movements by wearable strain Sensors and improvement of sensor's placement on intelligent biomedical clothes:

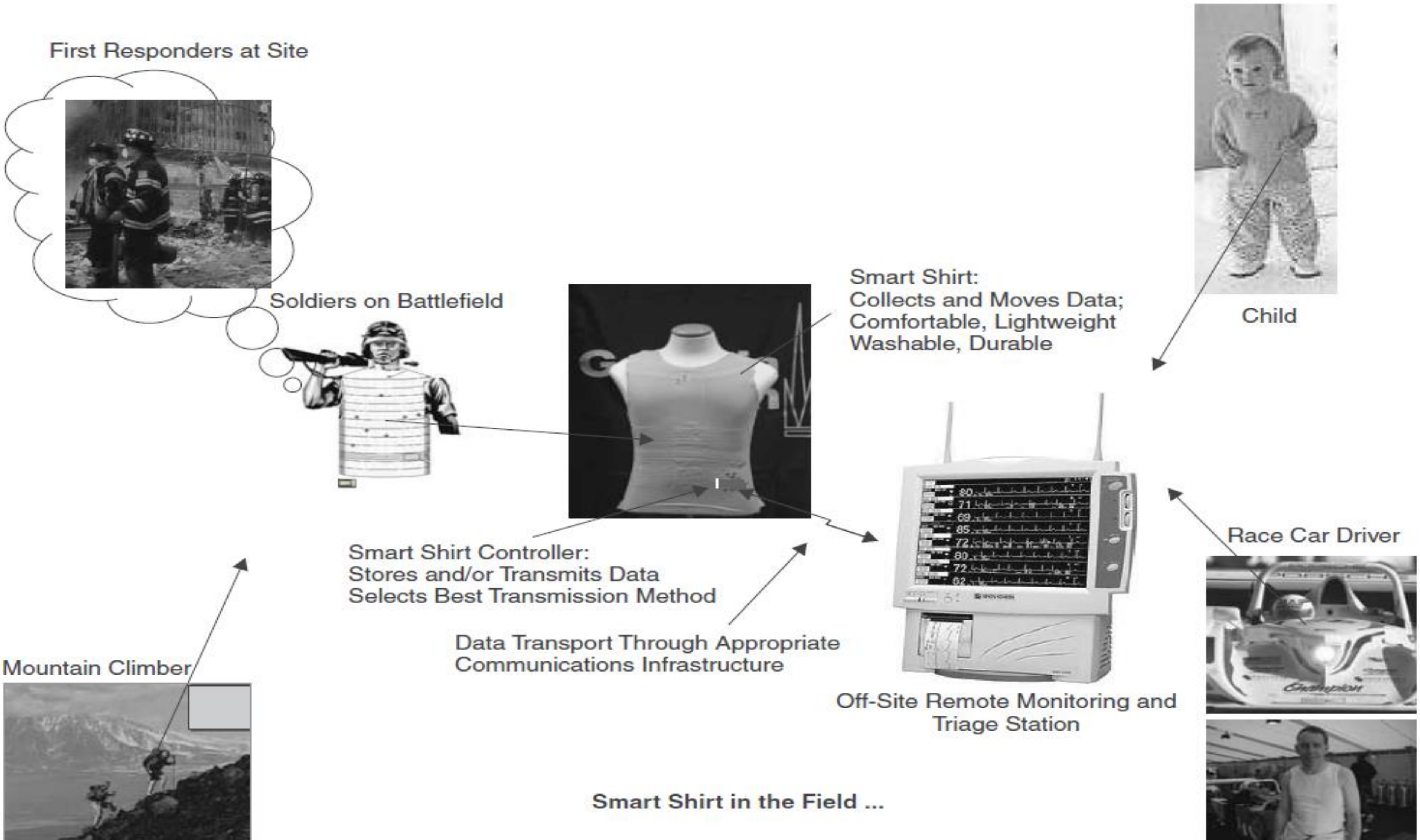
The proposed technologies and methods would offer a low-cost and unobtrusive approach to trunk motor rehabilitation

Biomedical Applications Research to Control Epilepsy

- **Predict when a seizure is likely to occur**, by analyzing
- mathematically what happens in the brain just before a seizure
- http://themelbourneengineer.eng.unimelb.edu.au/2012/03/biomedical-engineers-research-to-control-epilepsy/
- A better understanding of how electrical stimulation interacts with neural tissue may not only provide relief for epilepsy sufferers, but could have therapeutic benefits across a range of neurological disorders.
- - Design a medical bionics device, similar to a bionic ear, that can predict and control seizures.
- - David Grayden, Electrical and Electronic Engineering, the Melbourne School of Engineering.

- **Epilepsy Watch** to track and analyze the severity of seizures
  - http://magazinescanadafr.zinio.com/reader.jsp?issue=416228617&o=int&prev=sub&p=55

Wearable Technology: The Smart Shirt



Smart Shirt in the Field ...

Wearable Technology

- [WOVEN, the e-Wearable Platform](http://wearablegames.eu/platform/)
  http://wearablegames.eu/platform/
  - WOVEN is a piece of garment loaded with bend and heart-rate sensor as input, speakers, shake motors and a 12×12 pixel LED display
  - WOVEN links up with the virtual world via a Bluetooth wireless link to connect to the internet via smart-phones with it's apps or notebooks

- http://www.talk2myshirt.com/blog/archives/5857

Wearable Technology

- Google's Glass high tech eyeglasses

A user interface for important information from cell phones

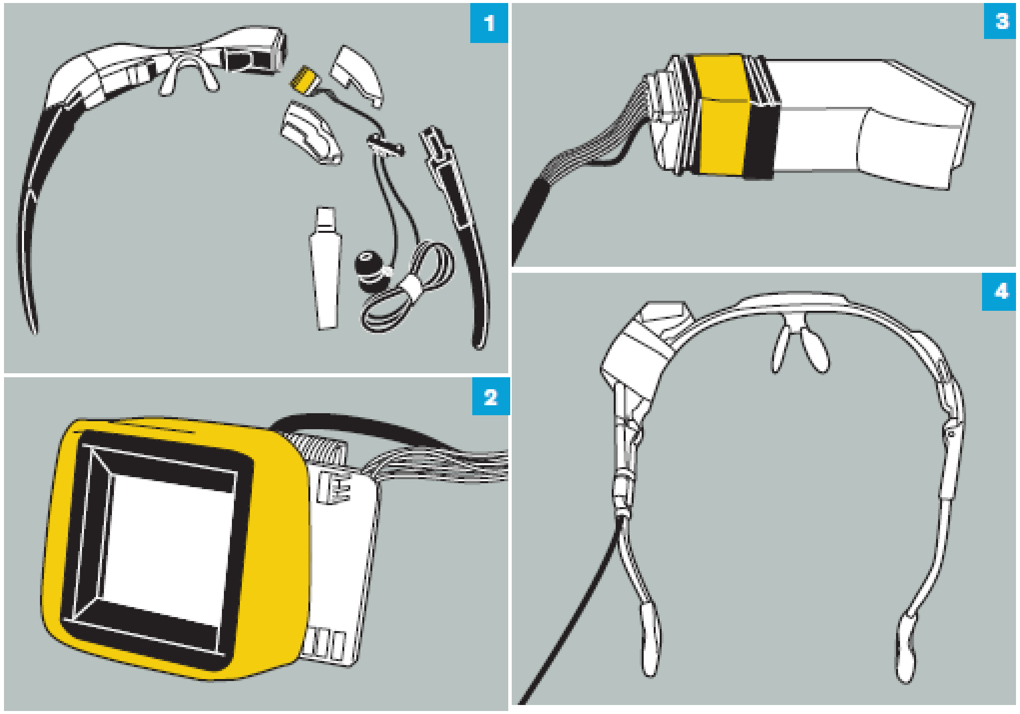
Includes Display, Camera, Audio, WiFi & Bluth, 16GB storage,

Connects to MyGlass App. http://www.google.com/glass/start/

Build Your Own Google Glass

- Rod Furlan "Build Your Own Google Glass: A wearable computer that displays information and records video", IEEE Spectrum January 2013.
  - Built with components bought on-line from a discontinued head-mounted display
  - Uses a fourth-generation iPod Touch processor
  - Extracted a micro-display and the optics required to focus the image properly
  - Mounted the components on a pair of plastic safety goggles.
- Creating the software and hardware for Such a "brain prosthesis" is certainly within the realm of possibility for the next decade, and I expect to see these features drive the mass adoption of the Google Glass technology. —Rod Furlan

Build Your Own Google Glass (cont'd)



Smart Cities

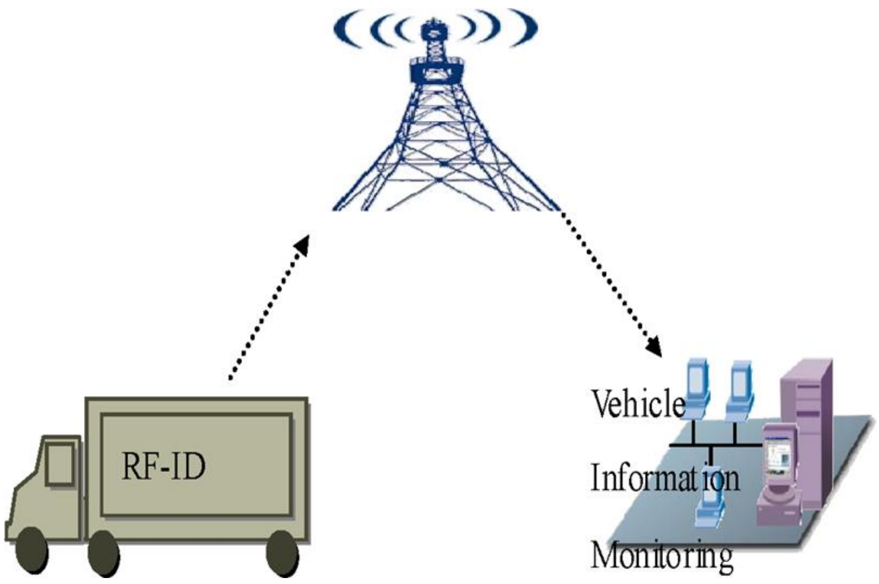
- http://www.libelium.com/top_50_iot_sensor_applications_ranking/pdf
- **Smart Grids** Energy Consumption monitoring and managements
- **Smart Environment** Detection of air pollution, water pollution, forest fires, earthquakes, landslides
- **Traffic Congestion** Monitoring of vehicles and pedestrian levels to optimize driving and walking routes.
- **Structural health** Monitoring of vibrations and material conditions in buildings, bridges and historical monuments.
- **Noise Urban Maps** Sound monitoring in special areas and centric zones in real time.
- **Smart Parking** Monitoring of parking spaces availability in the city.

Smart Cities (Cont.)

- http://www.libelium.com/top_50_iot_sensor_applications_ranking/pdf
- **Smart Lightning** Intelligent and weather adaptive lighting in street lights.
- **Waste Management**
  Detection of rubbish levels in containers to optimize the trash collection routes.
- **Smart Roads**
  Intelligent Highways with warning messages and diversions according to climate conditions and unexpected events like accidents or traffic jams.
- **Eletromagnetic Field Levels** Measurement of the energy radiated by cell stations and and WiFi routers.

Smart Cities (Cont.)

- 'Smart' cities aim to predict — and manage — traffic future
  - Enable real-time bus monitoring and management, to simulate traffic flow patterns ahead of time
  - Deploy and ensure ambulances are assured of green lights and clear sailing through intersections
  - Help commuters avoid congestion and enable transportation agencies to better understand, predict and manage traffic flow



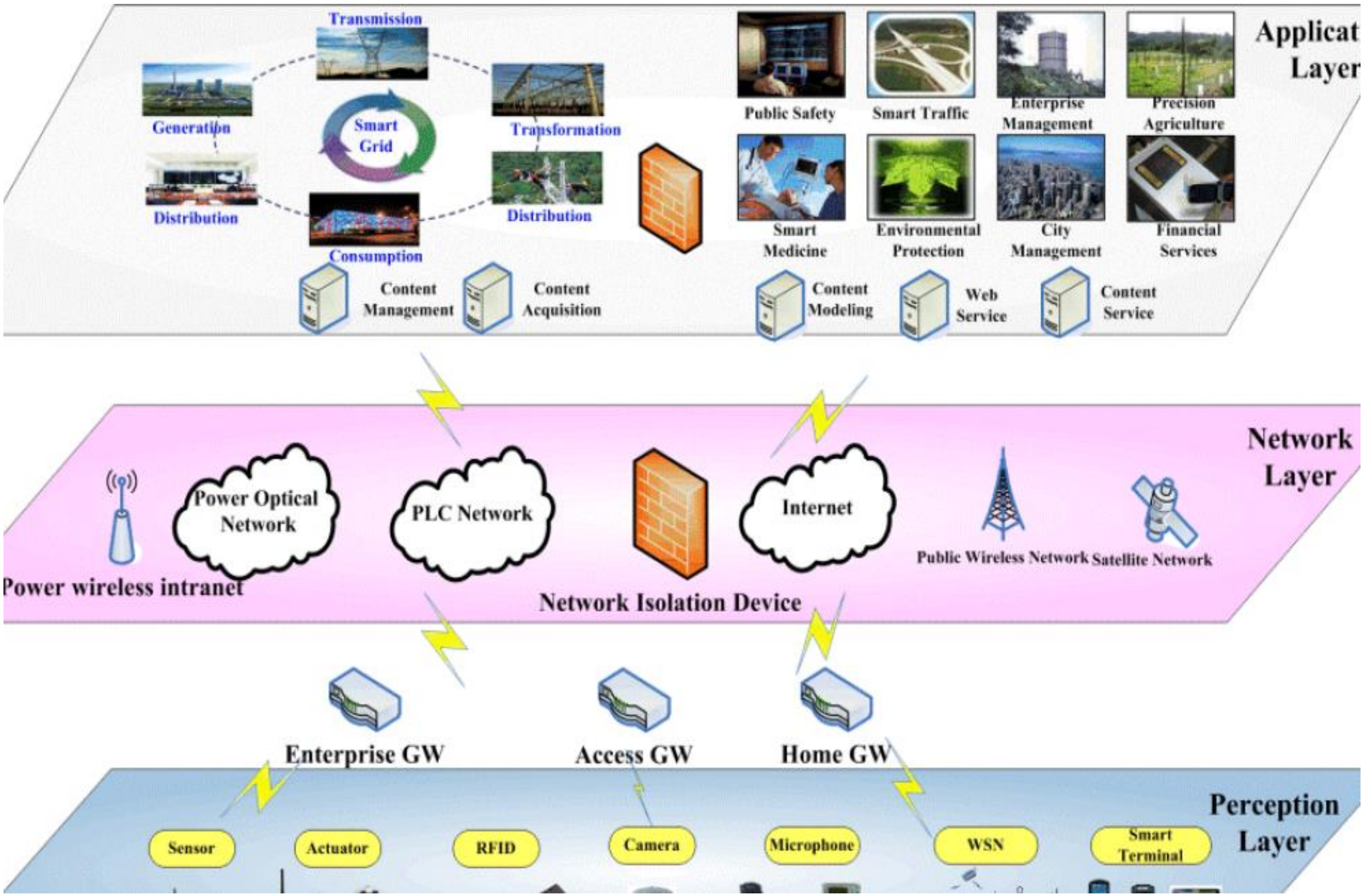
Smart Cities (Cont.)

Open road tolling (ORT) or **Free-flow tolling**

- collection of tolls on toll roads without the use of toll booths
- An RFID tag is used for electronic toll collection

- Users are able to drive through the toll plaza at highway speeds without having to slow down to pay the toll

Smart Cities, IoT, and Smart Grids

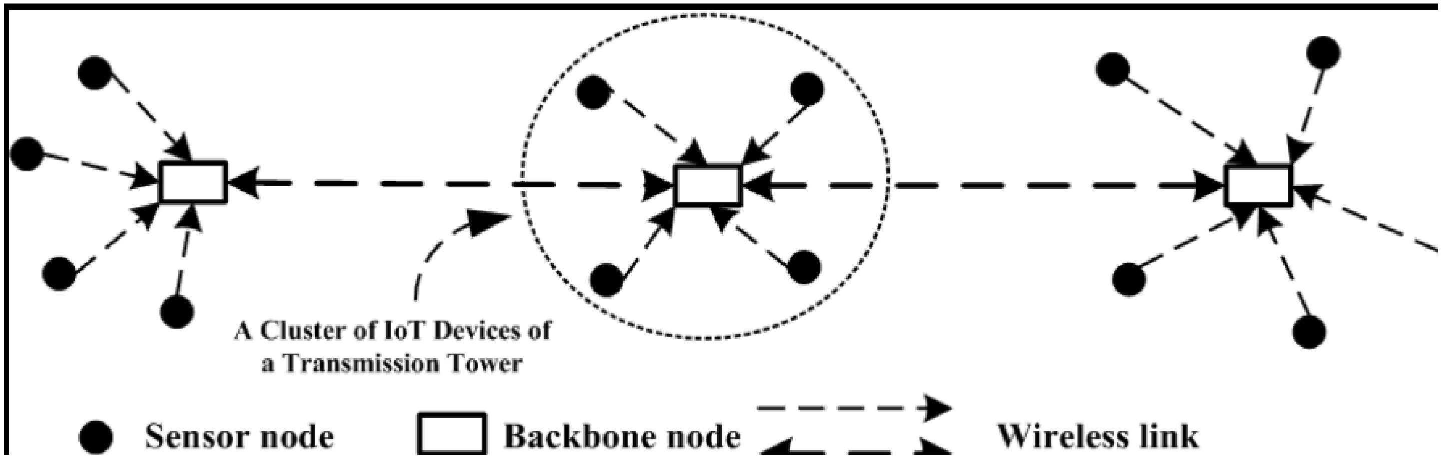


add your logo

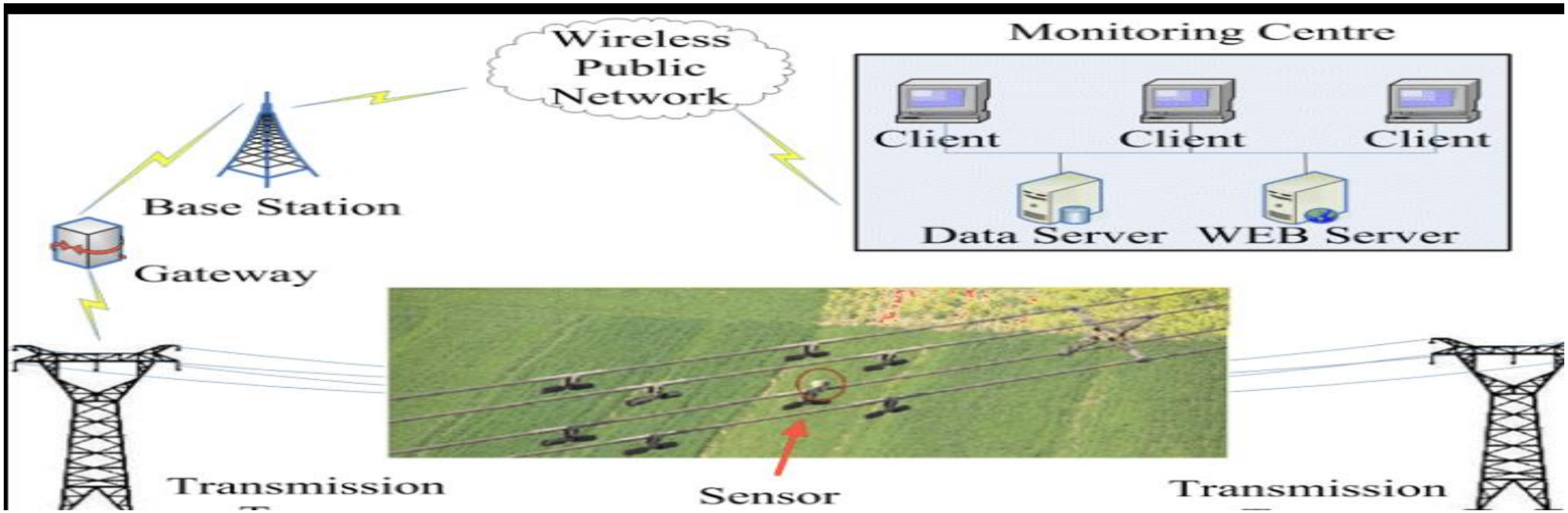
IoT and Smart Grids

- Network topology for online monitoring system of power transmission line

Data transmission
network



IoT and Smart Grids (cont'd)



IoT and Smart Homes

- Check and control things at home:
  - temperature control: as in changing the setting of the thermostat
  - Security: making sure that doors are locked
  - energy management: like lighting control

Smart Home

Control Panel

http://en.wikipedia.org/wiki/Digital_home

IoT and Smart Homes (cont'd)

IoT and Smart Appliances

- LG Smart ThinQ
- appliance line,
- Smart Fridge, smart
- robot vacuum,
- eco-friendly washing
- machine

- The smart refrigerator with LCD Panel that helps you diet and
- keeps track of your groceries
- http://mashable.com/2012/01/09/lg-smart-refrigerator/

Middlewares for IoT Applications

- **The ThingWorx Platform** http://www.thingworx.com/
  - Develop application to bring the benefits of
- the connected world to traditional industries
  - Connect existing business processes to remote and
  - mobile assets to increase business responsiveness
  - and process accuracy
  - Connect to new sensors, devices & machines directly
    - to gain control over their data, events and services to
    - create new processes and enhance existing ones

Middlewares for IoT Applications

- Example of using the ThingWorx Platform
- Ericsson Connected Vehicle Cloud provided as an option in Volvo's new cars

http://www.ericsson.com/ourportfolio/transport-and-automotive-industry/connected-vehicle-cloud

Drivers and passengers: Access applications for information, navigation, and entertainment from an integrated screen in the car, designed to minimize the risk of driver distraction.

Middlewares for IoT Applications

- Xively Cloud Services https://xively.com/
  - is a web service that enables a user to store, share and discover real-time data from objects.
  - Provides a secure, scalable platform that connects devices and products with applications to provide real-time control and data storage

Middlewares for IoT Applications-

- Examples of Products
  - The Air Quality Egg http://airqualityegg.com/ is composed of a sensor box that measures nitrogen dioxide and carbon monoxide levels and a wireless transmitter
  - A community-led air quality
  - sensing network that gives people
  - a way to participate in the
  - conversation about air quality

The Internet of Services (IoS)

IoTrain
Master of Engineering in Internet of Things

- ***EU FP7 project: SPaCIoS: Secure Provision and Consumption in the Internet of Services (IoS)*** http://www.spacios.eu/
  - In IoS, services are business functionalities that are
  - designed and implemented by producers, deployed by
  - providers, aggregated by intermediaries and used by
  - consumers.
  - This prject develops the technological foundations for a
  - new generation of analysers for automated security
  - validation at service provision and consumption time

Outline (Topics covered)

- What is Cloud Computing ?
- Services of Cloud Computing,
  - What can we do with Cloud Computing?
- Challenges with Clouds and Cloud Types
- Cloud Computing and The IoT
  - The Internet of Things
  - Applications of IoT: Biomedical, Wearable Technology, Smart Cities
- Conclusions

Conclusions

- Cloud Computing emerged to provide elastic or extensible computing resources

- Cloud Computing provides everything as a service starting from the computing infrastructure to the applications in different domains.

- Security and privacy are the biggest concerns of cloud computing users and developers

- Cloud Computing facilitated the idea of the Internet of Things with applications in all fields of our daily life

Short Videos on IoT

A cloud approach to the Internet of Things - Ubidots

http://www.youtube.com/watch?feature=player_detailpage&v=IoQQfAxTOhQ

Internet of Things by Symplio

http://www.youtube.com/watch?feature=player_detailpage&v=VfK-D6e3DdQ

The Internet of Things | Fw:Thinking

http://www.youtube.com/watch?feature=player_detailpage&v=LVlT4sX6uVs

The Internet of Everything: Relevant and Valuable Connections Will Change the World

http://www.youtube.com/watch?feature=player_detailpage&v=bVNJfUOBzJE

The Internet of Things, by IBMSocialMedia

http://www.youtube.com/watch?feature=player_detailpage&v=sfEbMV295Kk