Outline

- NIST Cloud Computing Reference Architecture
  - Conceptual reference model
  - Actors, Activities, Components
- Cloud Computing Challenges & Opportunities
  - Cloud adoption obstacles
  - Cloud growth obstacles
  - Policy & business obstacles
- Commercial & Open Source Clouds
- Research Trends in Cloud Computing
  - Cloud resource management
  - Green cloud computing
  - Cloud security
  - Cloud simulation environments
  - Cloud-based big data analytics

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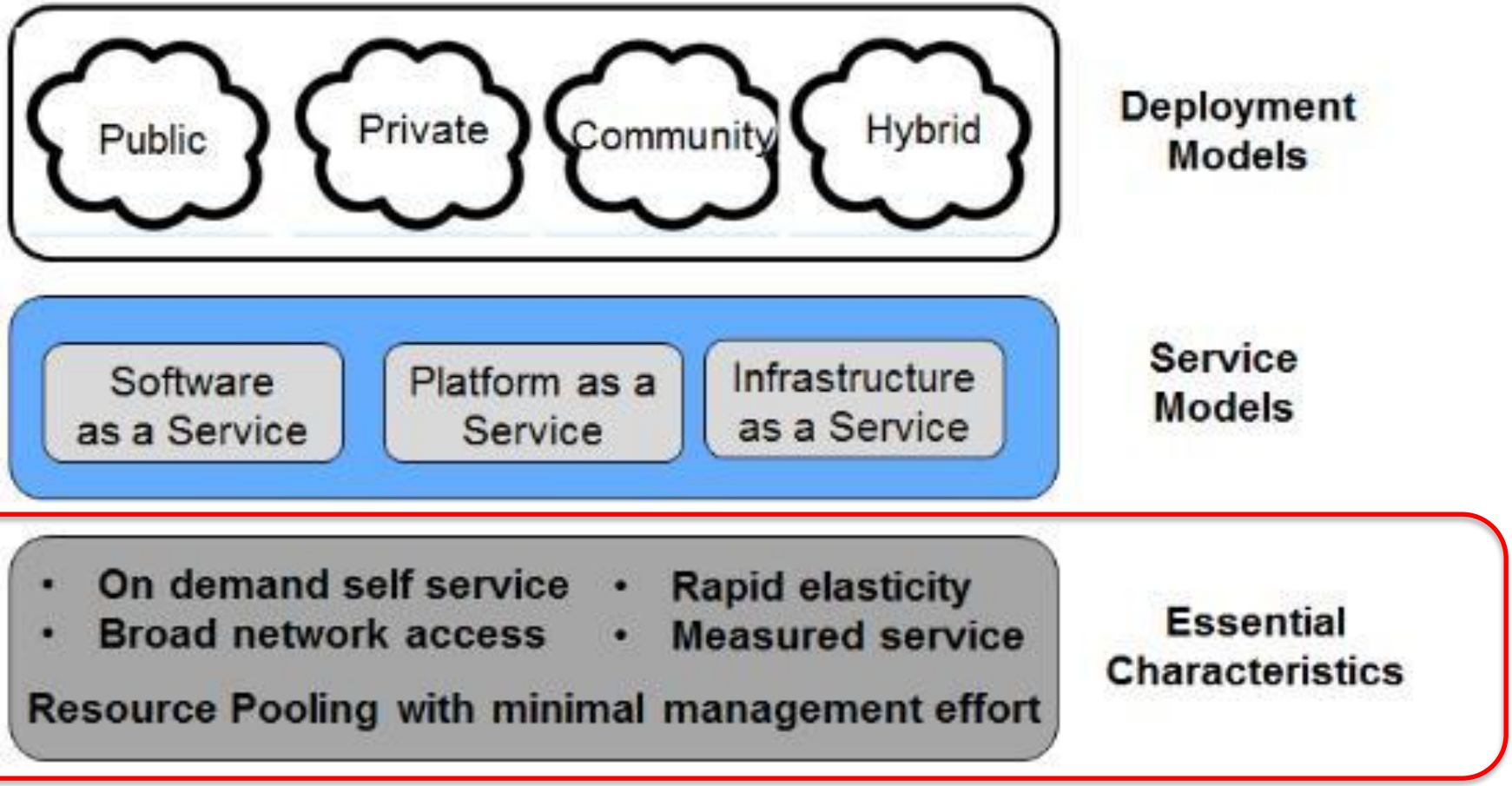
NIST Definition of Cloud Computing

- "Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction. "
- Computing Resources
  - (e.g., networks, servers, storage, applications, and services)

Reference - "**A NIST definition of cloud computing**", NIST Special Publication 800-145 by Peter Mell and Timothy Grance, 2011.

NIST Definition of Cloud Computing



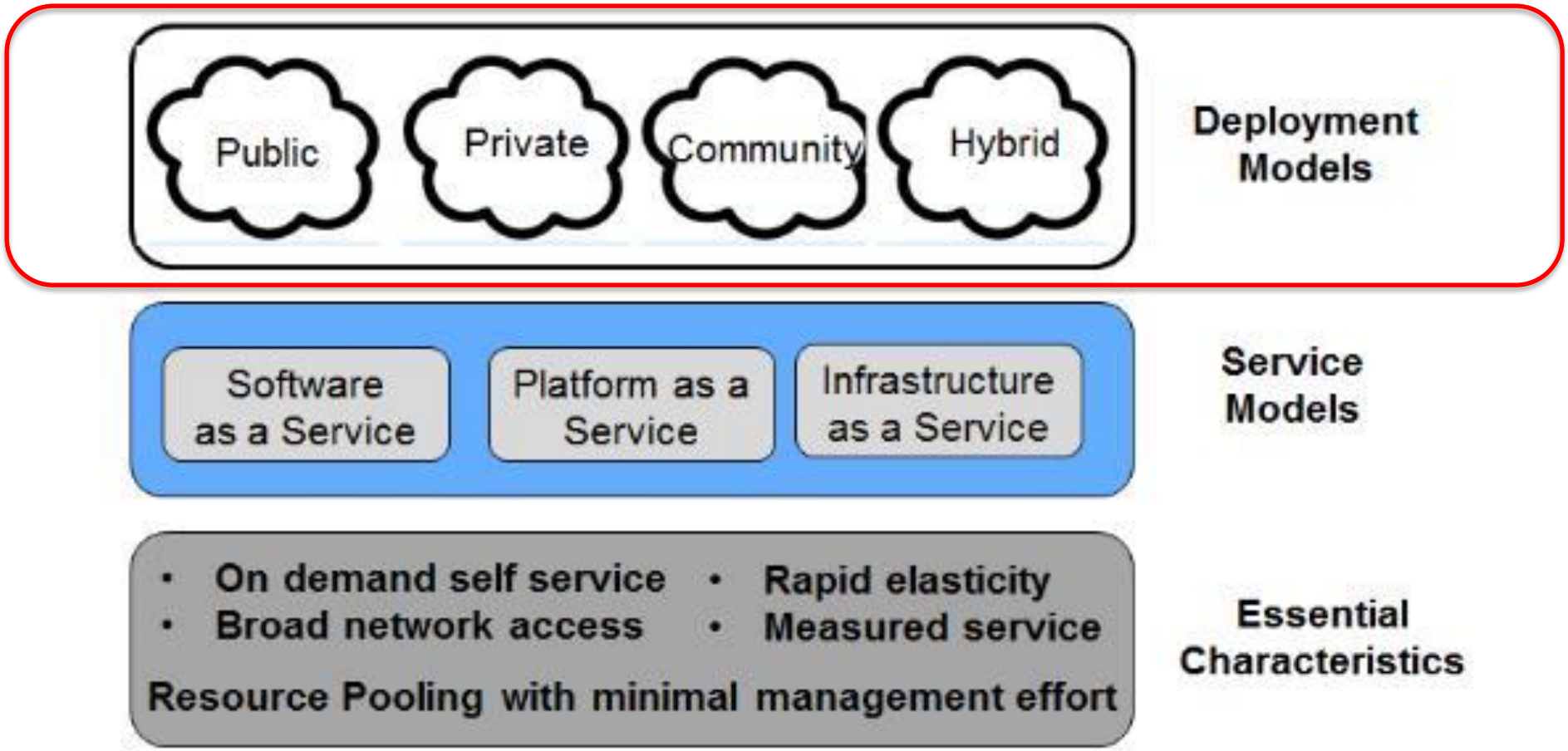
Five Cloud Computing Characteristics

- On-Demand Self-Service
  - A consumer can provision computing resources as needed automatically without requiring service provider interaction
- Broad Network Access
  - Resources are available over the network and accessed through client platforms (e.g., mobile phones, tablets, laptops, etc…)
- Resource Pooling
  - Resources are pooled to serve multiple consumers using a multi-tenant model

Five Cloud Computing Characteristics

- Rapid Elasticity
  - Resources can be elastically provisioned and released to scale rapidly with demand
- Measured Service
  - Controlling resource usage by leveraging a metering capability at some level of abstraction appropriate to the type of service or resource
  - e.g. per hour processing, per day storage, active user accounts

NIST Definition of Cloud Computing



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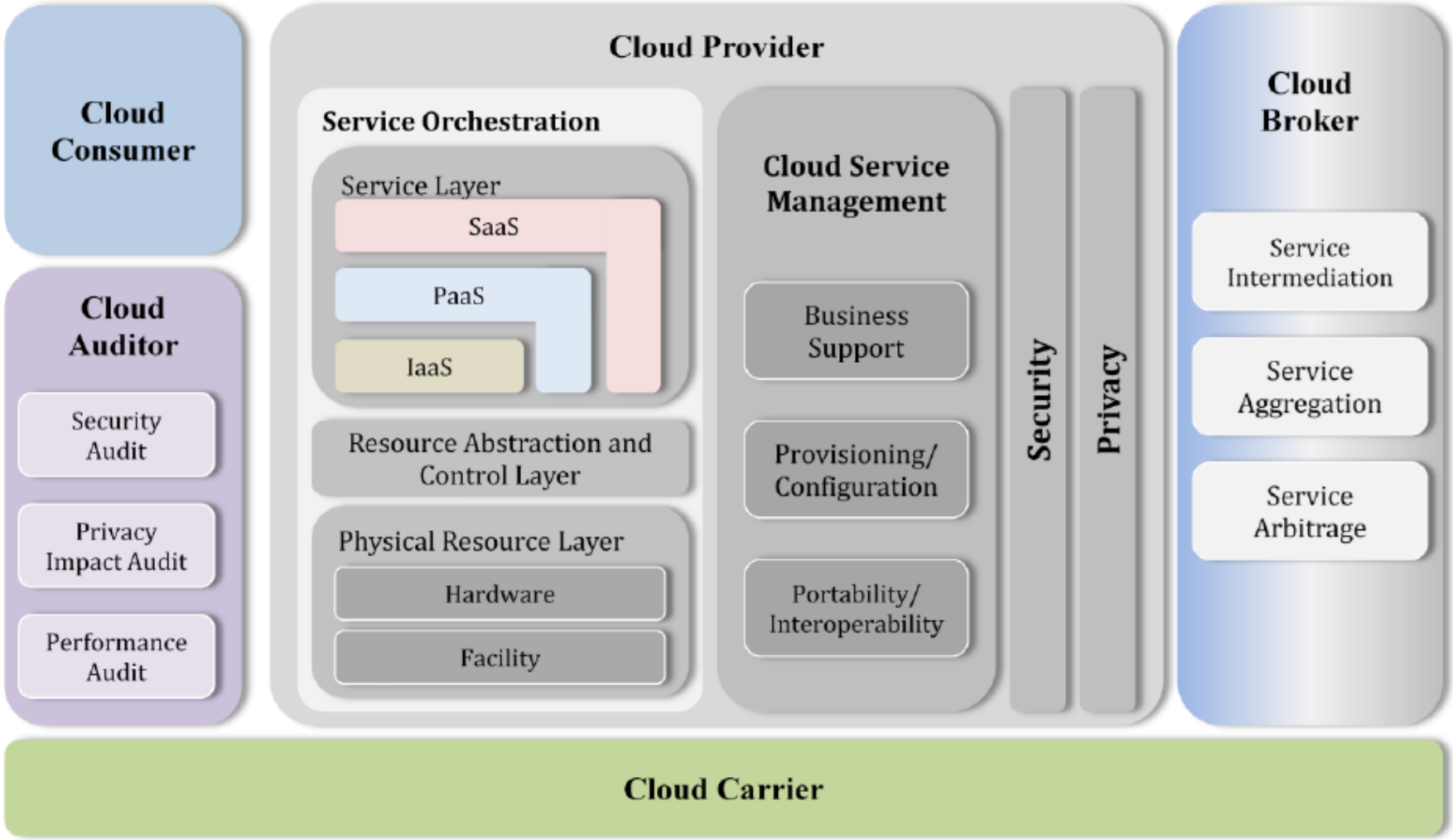
NIST Cloud Computing Reference Architecture

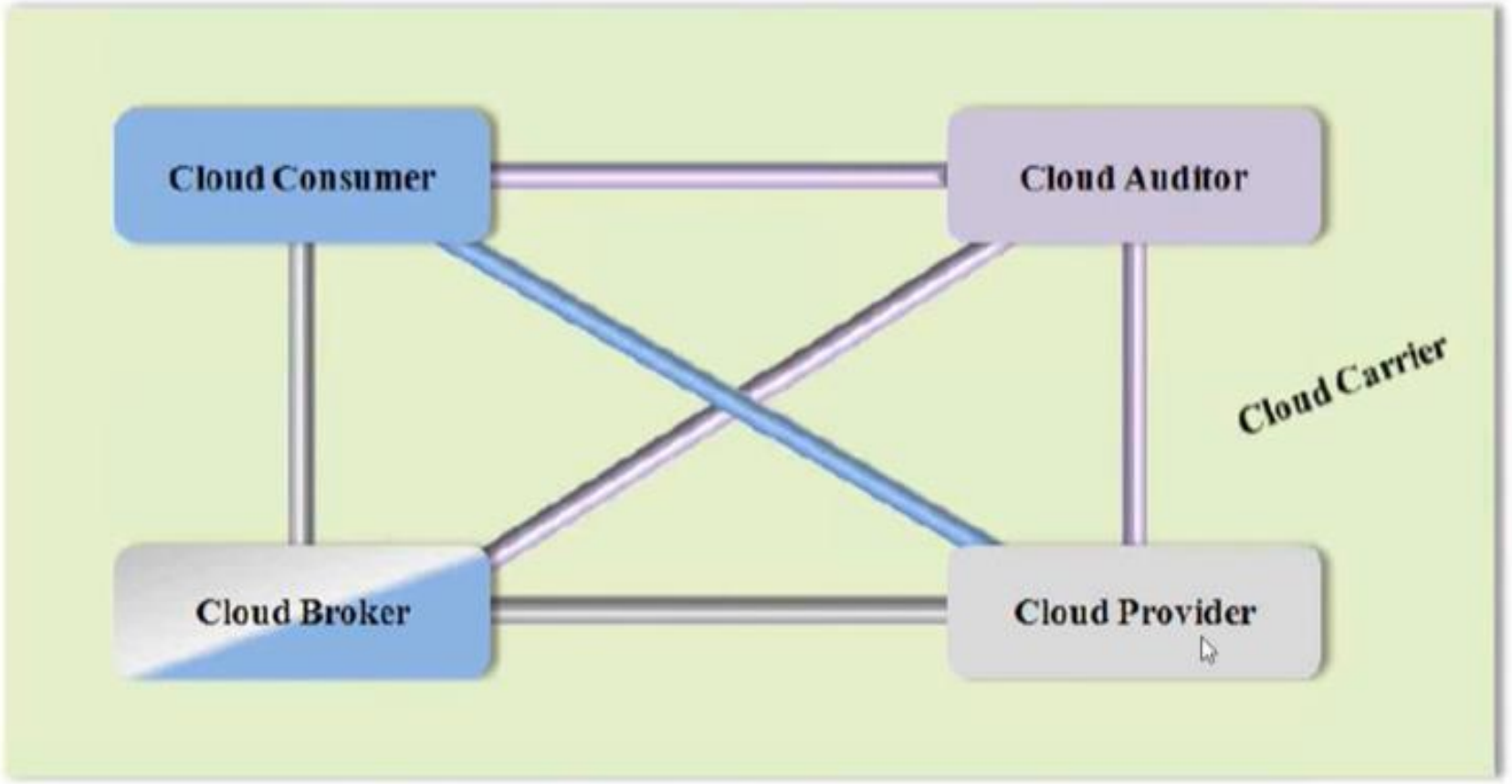


Reference - "**NIST Cloud Computing Reference Architecture**", NIST Special Publication 500-292 by Fang Liu, Jin Tong, Jian Mao, Robert Bohn, John Messina, Lee Badger and Dawn Leaf, 2011

Actors in The Cloud

Actor	Definition
Cloud Consumer	A person or organization that maintains a business relationship with, and uses service from, *Cloud Providers*.
Cloud Provider	A person, organization, or entity responsible for making a service available to interested parties.
Cloud Auditor	A party that can conduct independent assessment of cloud services, information system operations, performance and security of the cloud implementation.
Cloud Broker	An entity that manages the use, performance and delivery of cloud services, and negotiates relationships between *Cloud Providers* and *Cloud Consumers*.
Cloud Carrier	An intermediary that provides connectivity and transport of cloud services from *Cloud Providers* to *Cloud Consumers*.

Interactions between Cloud Actors



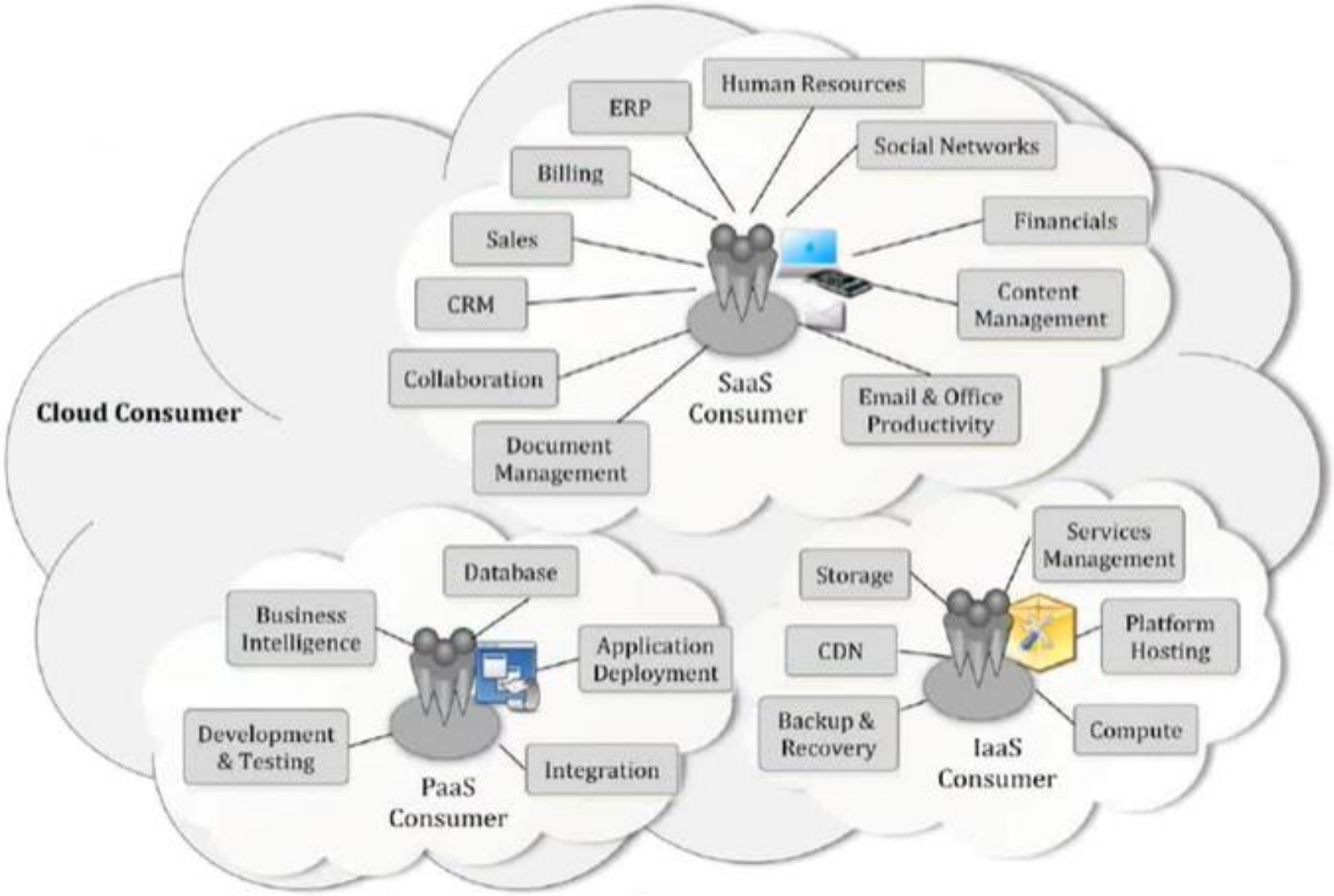
Usage Scenarios for Cloud Actors

Usage Scenario for Cloud Brokers

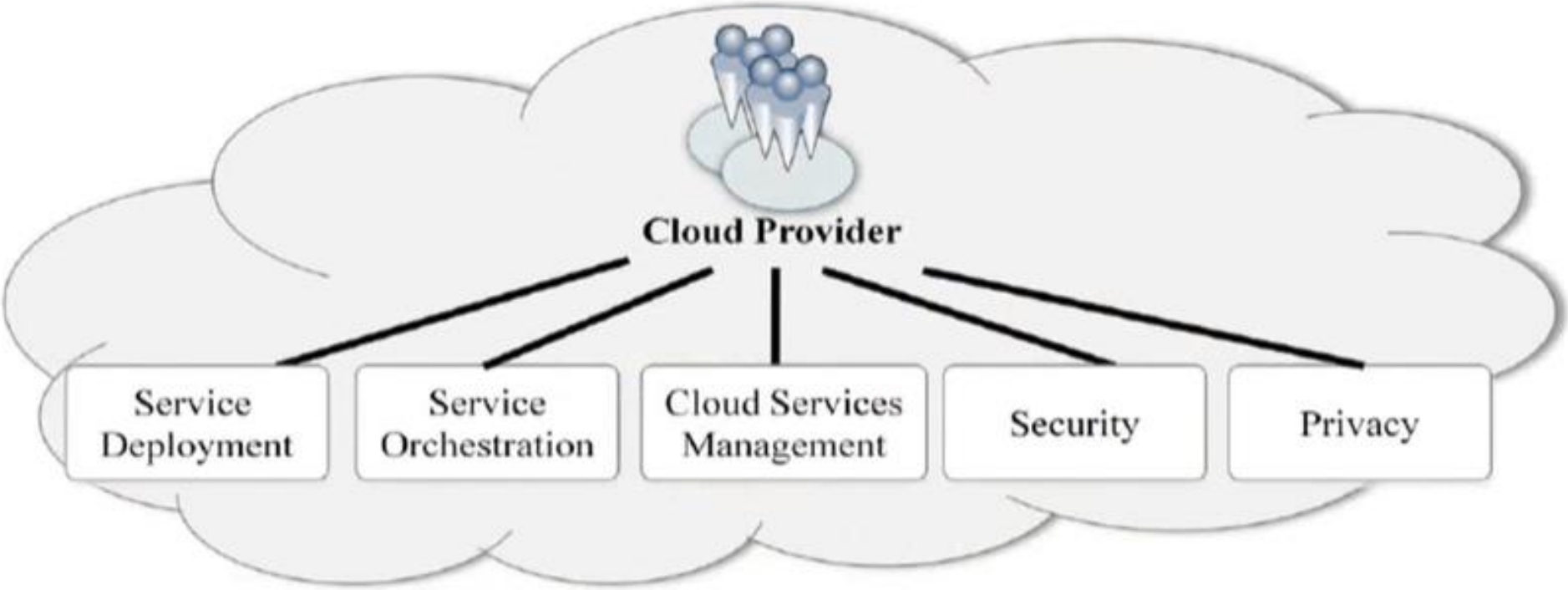
Usage Scenario for Cloud Carriers

Usage Scenario for Cloud Auditors

Cloud Consumer Services

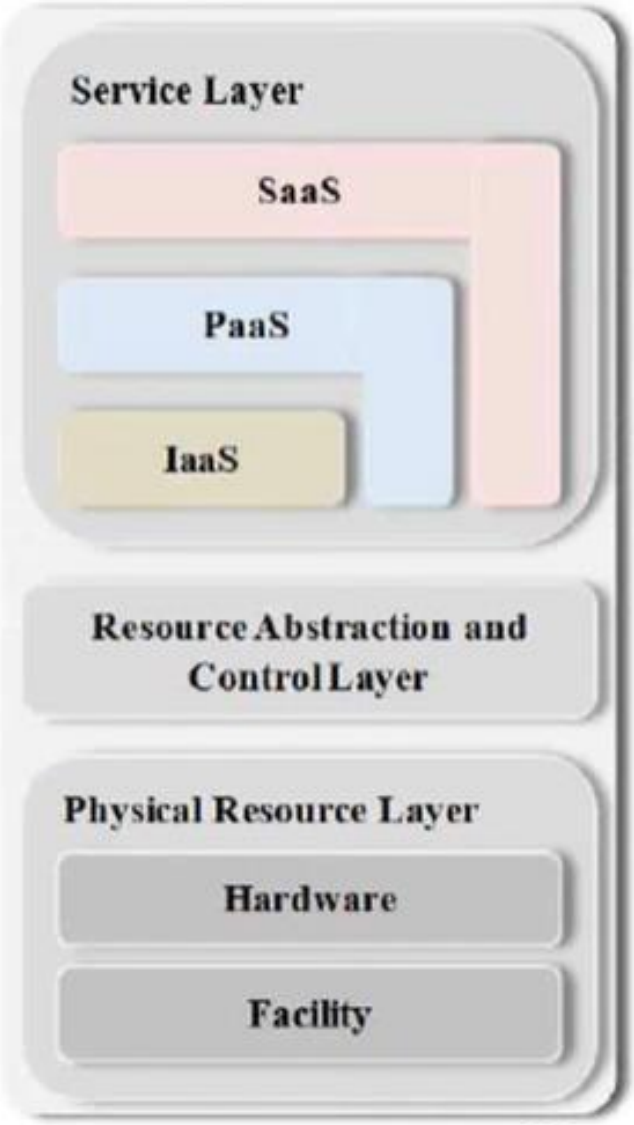


Cloud Provider Major Activities

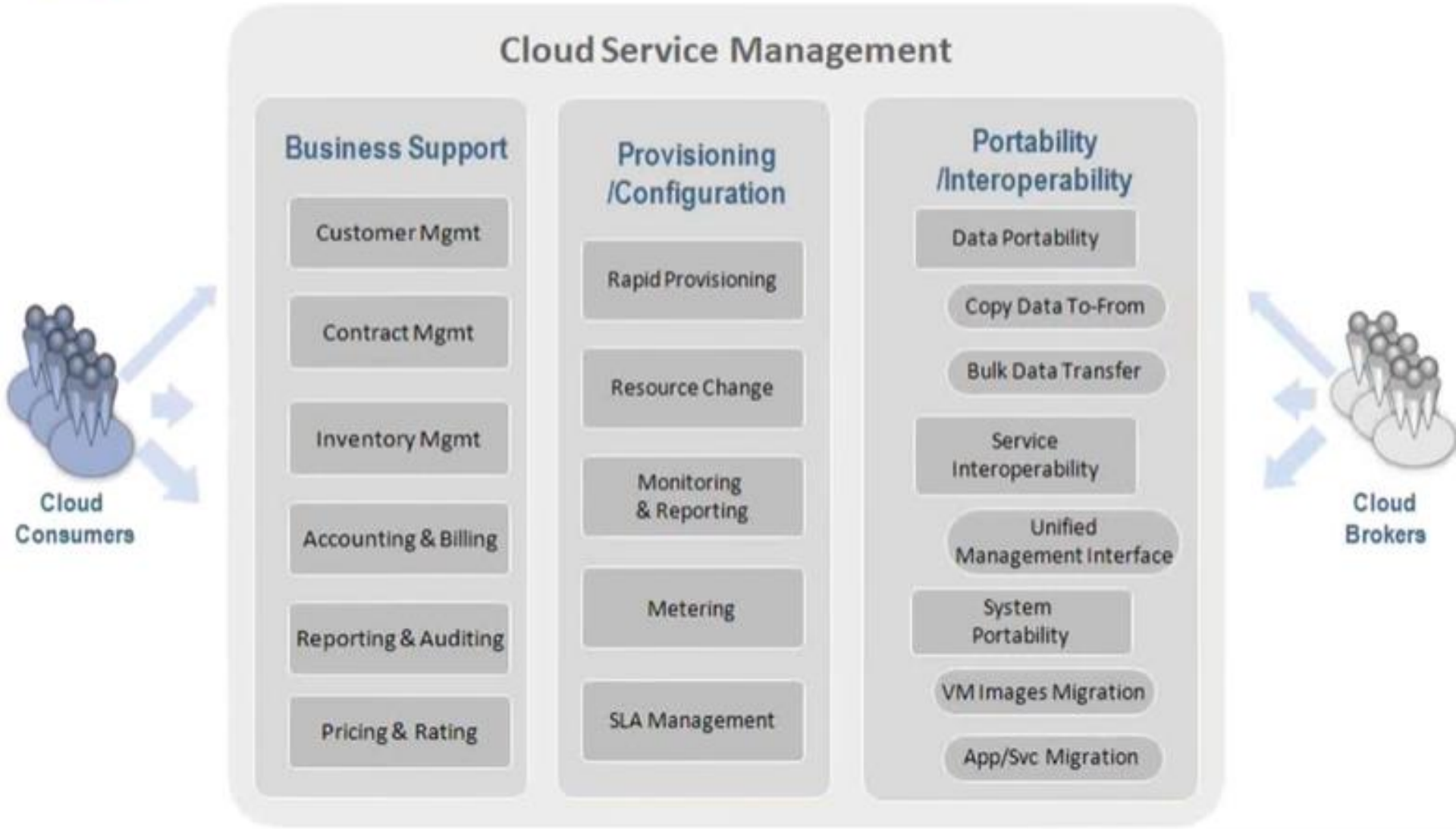


Cloud Provider Major Activities

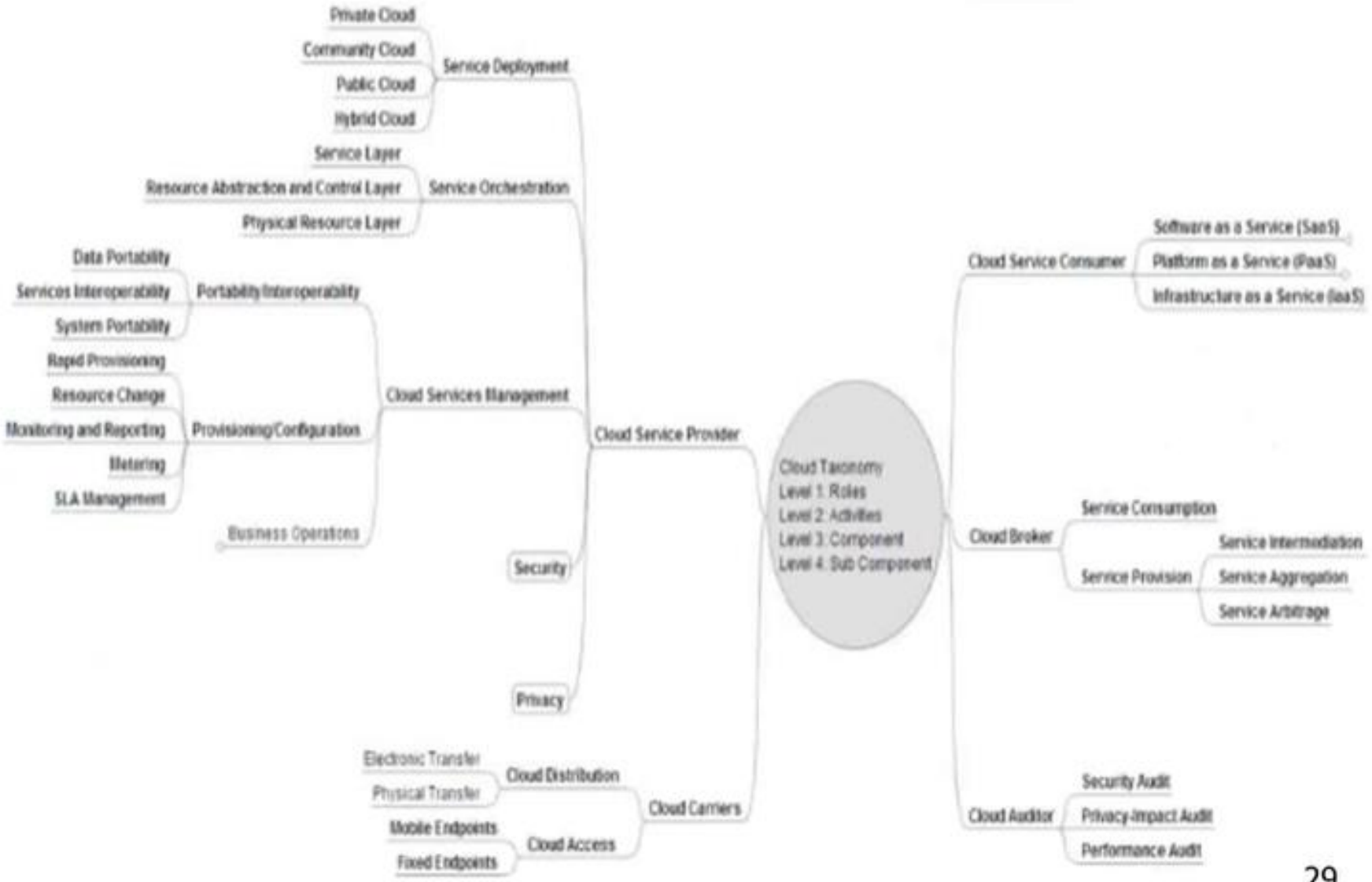
- Service Layer
  - Define interfaces for cloud consumers to access the computing services
- Resource Abstraction/Control Layer
  - Manages system components used to provide access to physical resources
  - e.g. hypervisors, virtual machines, virtual data storage, etc…
- Physical Resource Layer
  - Manages H/W resources e.g., CPU, memory, network devices, storage devices
  - Manages facility resources e.g., heating, ventilation and air conditioning ,power, communications



Cloud Provider Major Activities



Cloud Taxonomy



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Cloud Obstacles & Opportunities

	Obstacle	Opportunity	
1	Availability/Business Continuity	Use Multiple Cloud Providers	Cloud Adoption
2	Data Lock-In	Standardize APIs; Compatible SW to enable Surge or Hybird Cloud Computing	
3	Data Confidentiality and Auditability	Deploy Encryption, VLANs, Firewalls	
4	Data Transfer Bottlenecks	FedExing Disks; Higher BW Switches	Cloud Growth
5	Performance Unpredictability	Improved VM Support; Flash Memory; Gang Schedule VMs	
6	Scalable Storage	Invent Scalable Store	
7	Bugs in Large Distributed Systems	Invent Debugger that relies on Distributed VMs	
8	Scaling Quickly	Invent Auto-Scaler that relies on ML; Snapshots for Conservation	
9	Reputation Fate Sharing	Offer reputation-guarding services like those for email	Policy/ Business
10	Software Licensing	Pay-for-use licenses	

Reference - "**A view of cloud computing**", by Michael Armbrust, Armando Fox, Rean Griffith, Anthony D. Joseph, Randy Katz, Andy Konwinski, Gunho Lee, David Patterson, Ariel Rabkin, Ion Stoica, and Matei Zaharia ACM Communication 53, 4 (April 2010), 50-58.

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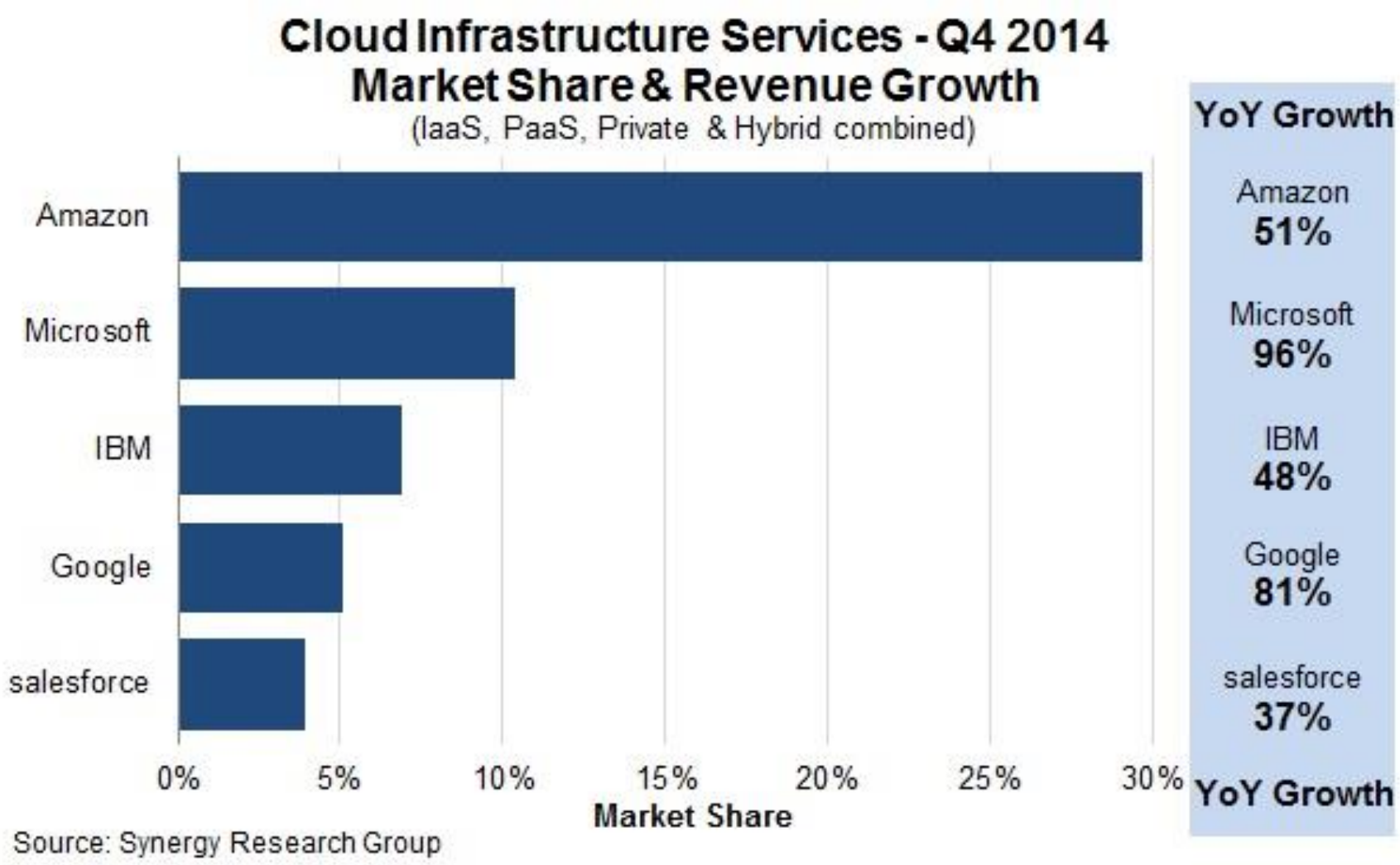
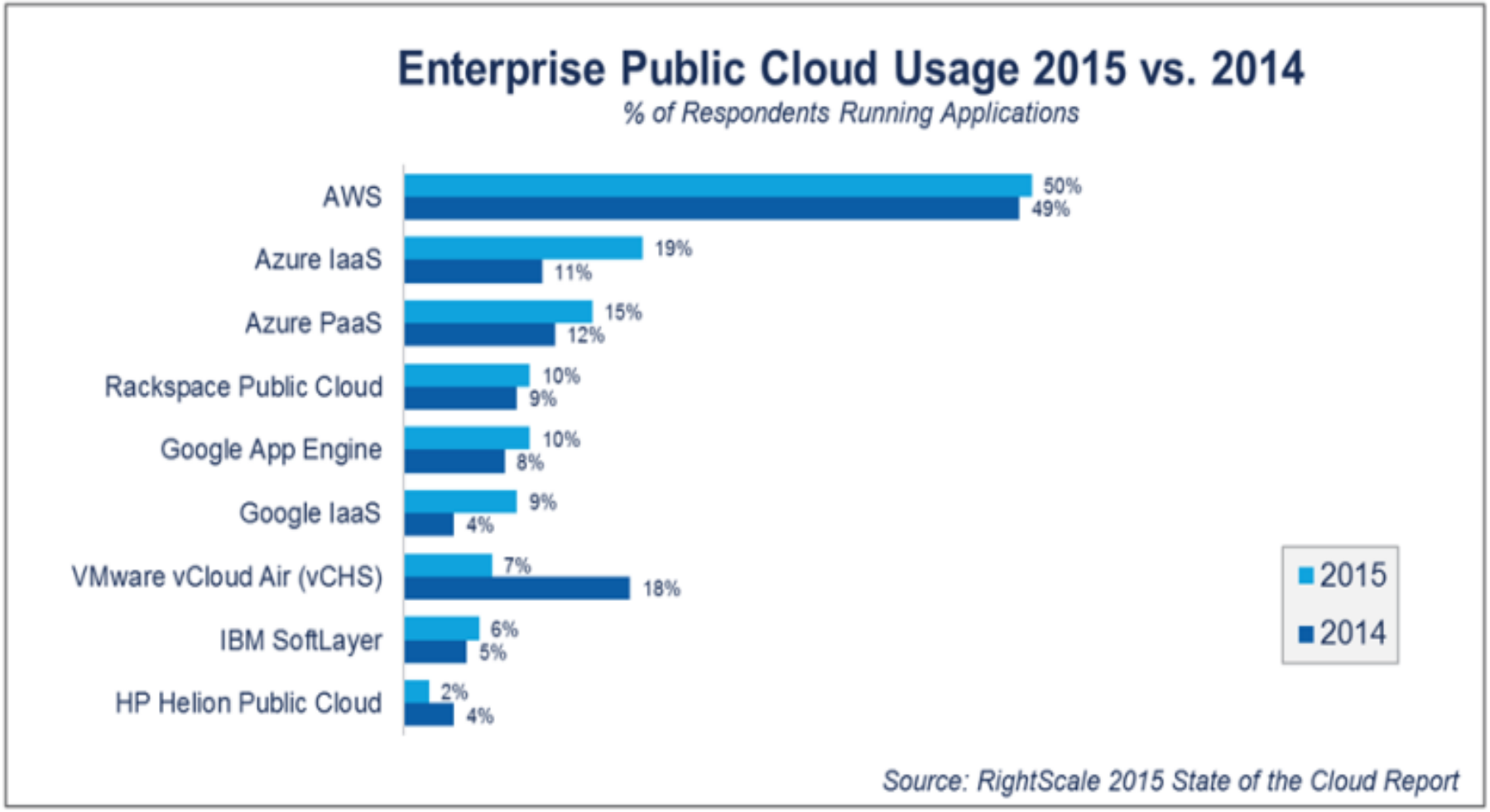
Commercial Clouds



Commercial Clouds



Open Source Clouds

15

Open Source Compute Clouds

	Year Started	License	Hypervisors Supported
cloudstack open source cloud computing	2008	GPL	Xenserver, Xen Cloud Platform, KVM, VMware
Eucalyptus Systems	2006	GPL	Xen, KVM, VMware
openstack™	2010 (Developed by NASA by Anso Labs previously)	Apache	VMware ESX and ESXi, Microsoft Hyper-V, Xen, KVM and Virtual Box

Other open source compute software include Abiquo, Red Hat's CloudForms and OpenNebula
Numerous companies are building cloud software on OpenStack including Nebula, Piston Inc.

cloudstack
open source cloud computing

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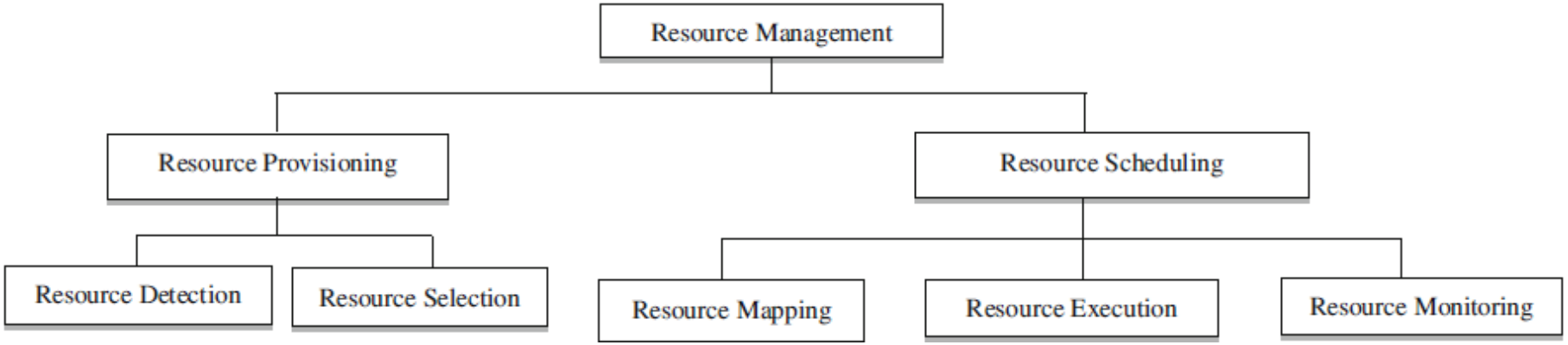
Resource Management Problems in Clouds

- Cloud resource management
  - a cloud requires an efficient way of managing resources
  - *underprovisioning* can lead to QoS violation and penalties
  - *overprovisioning* can lead to revenue losses
  - can also indirectly affect system functionality
  - must be able to handle unplanned load bursts, e.g., auto scaling
- Cloud Providers
  - maximize resource usage and profit
  - minimize penalties
  - minimize energy consumption
- Cloud Consumers
  - high QoS requirements: execution time and cost, reliability, security, availability and scalability
- Cloud Providers and Consumers have conflicting requirements

Resource Provisioning vs Resource Scheduling

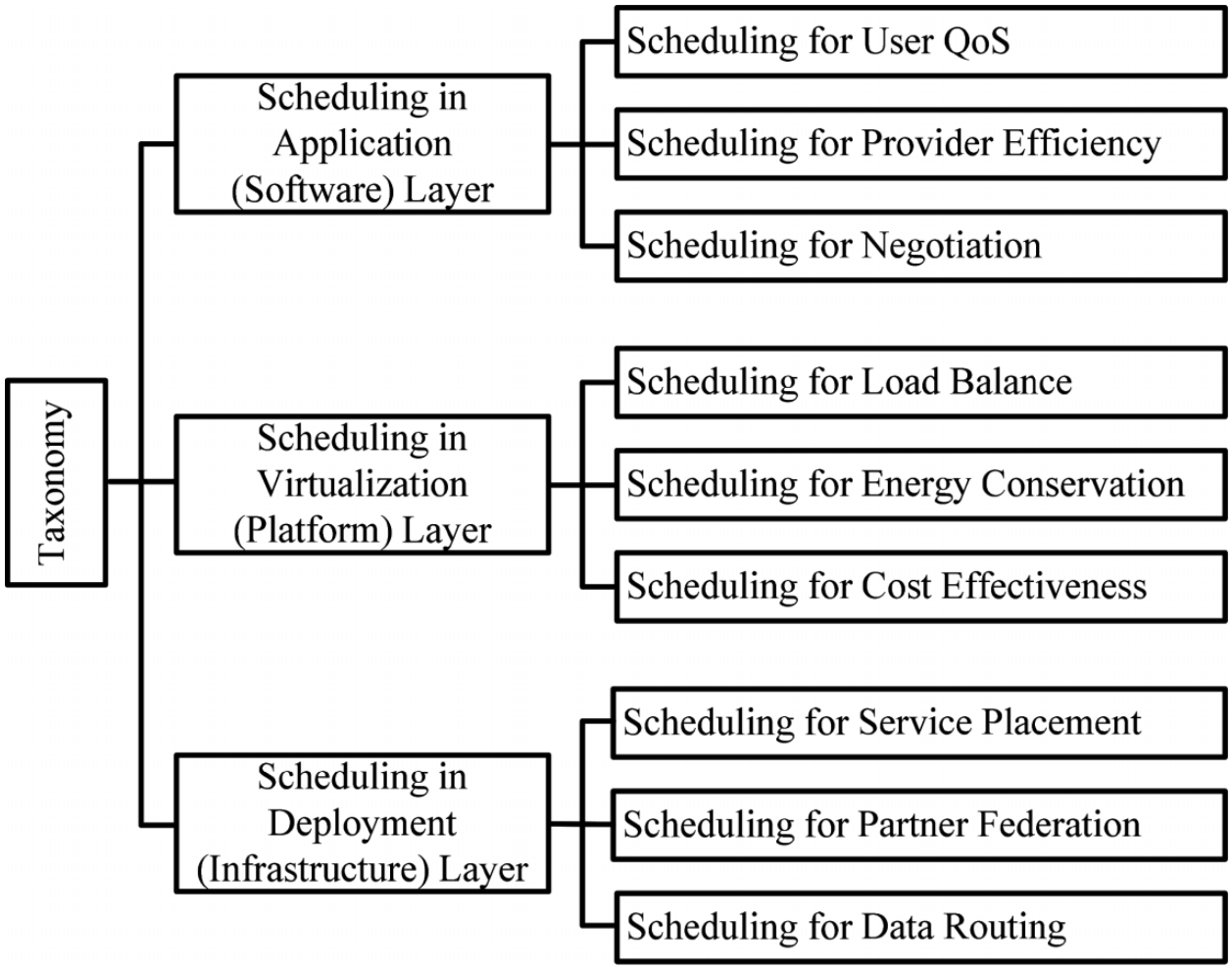


Reference - Singh S, Chana I (2016) **A survey on resource scheduling in cloud computing issues and challenges**. J Grid Comput 14:1–50

Current Research Status of Resource Management

Reference - Zhi-Hui Zhan, Xiao-Fang Liu, Yue-Jiao Gong, Jun Zhang, Henry Shu-Hung Chung, and Yun Li. 2015. **Cloud computing resource scheduling and a survey of its evolutionary approaches**. ACM Comput. Surv. 47, 4, Article 63 (July 2015), 33 pages.

Current Research Status



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Current Research Status

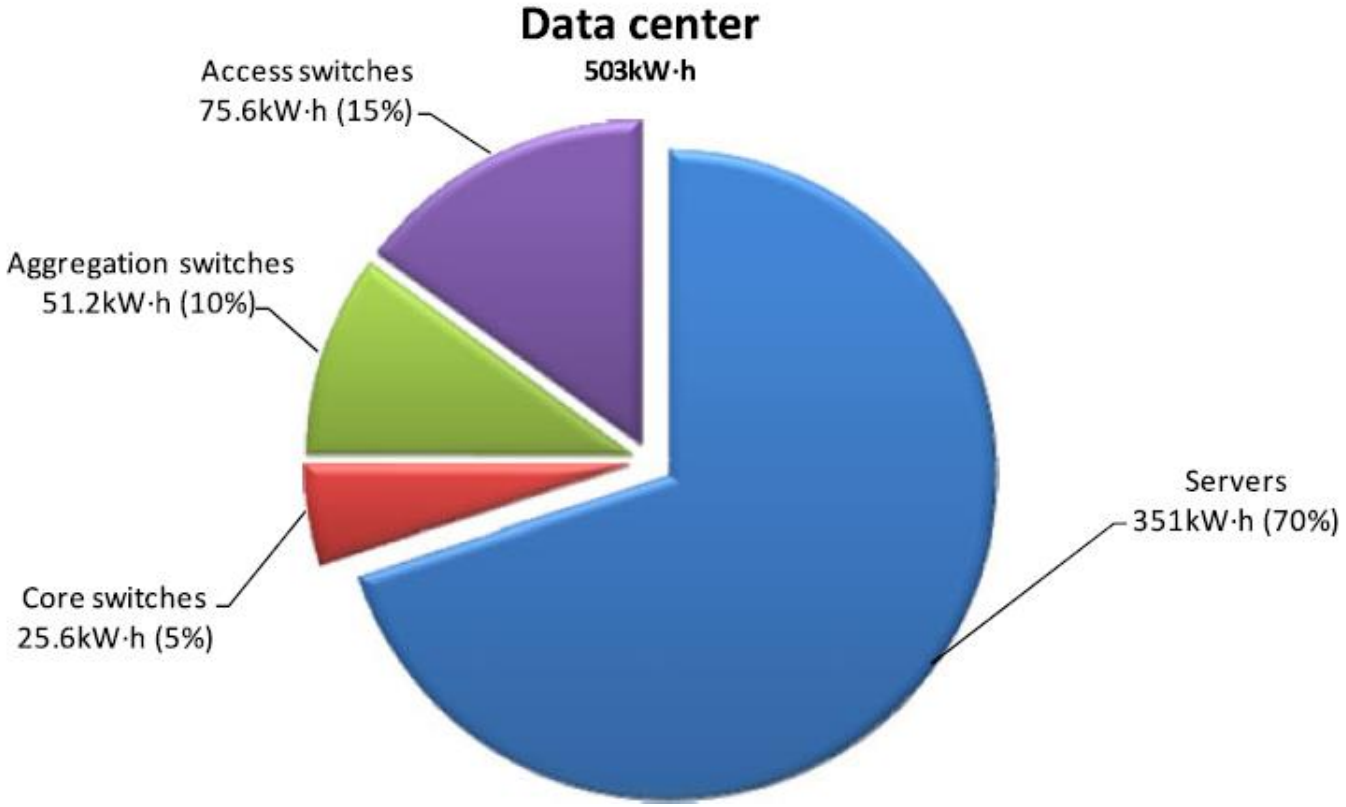
- Short term resource management
  - dynamically reacts to workload fluctuations
  - focuses on one application at a time
  - need to be complemented by long term techniques, e.g., to globally optimize resource allocation over all applications
- Long term resource management
  - a performance model is invoked to predict performance
  - cannot accurately predict performance under workload burstiness
  - a search technique is developed to obtain an optimal solution

Future Research Directions

- Integrating evolutionary approaches in scheduling
  - Genetic Algorithms
  - Ant Colony Optimization
  - Particle Swam Optimization
- Scheduling for real-time applications
  - Take into account hard and soft real time tasks
- Adapting scheduling to:
  - changing user requirements/ cloud environments
- Scheduling for large-scale of resources, users,tasks, etc…
  - Avoid being stuck in local optima
- Scheduling for distributed data centers
- Using big-data analytics to predict required resources
  - Discover trends inherent in big data to foresee customer needs, hence help scheduling cloud resources

Green Cloud Computing

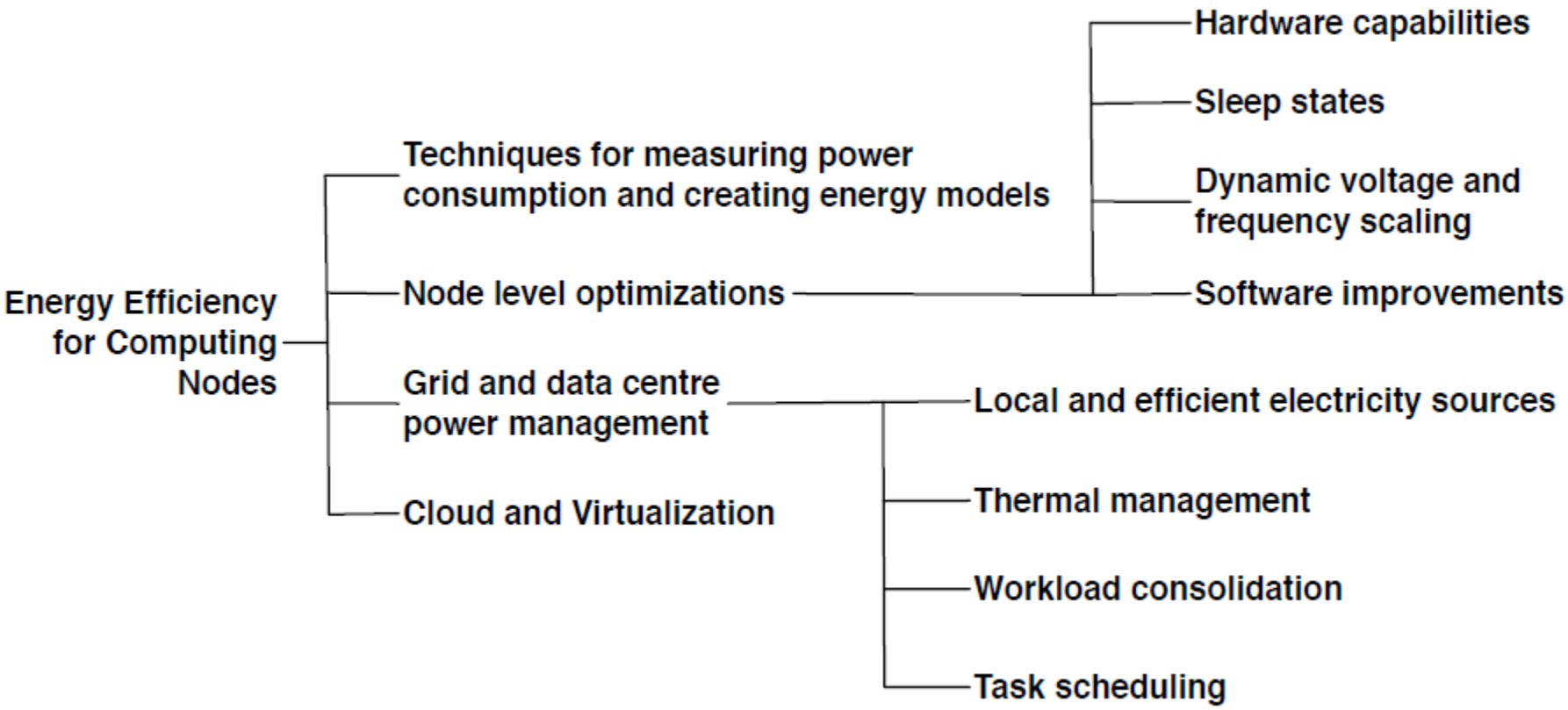
- Cloud Energy and Power Consumption
  - A key concern in cloud datacenters



Reference -. Khajehei K. **Green Cloud and Virtual Machines Migration Challenges**. Indian Journal of Science and Technology. 2016 Feb 9; 9(5):1–8.

Green Cloud Computing

- Techniques to improve efficiency of computing nodes



Reference -Anne-Cecile Orgerie, Marcos Dias de Assuncao, and Laurent Lefevre. **A survey on techniques for improving the energy efficiency of large-scale distributed systems**. *ACM Computing Surv.*eys 46, 4, Article 47 (March 2014).

Cloud Computing Security

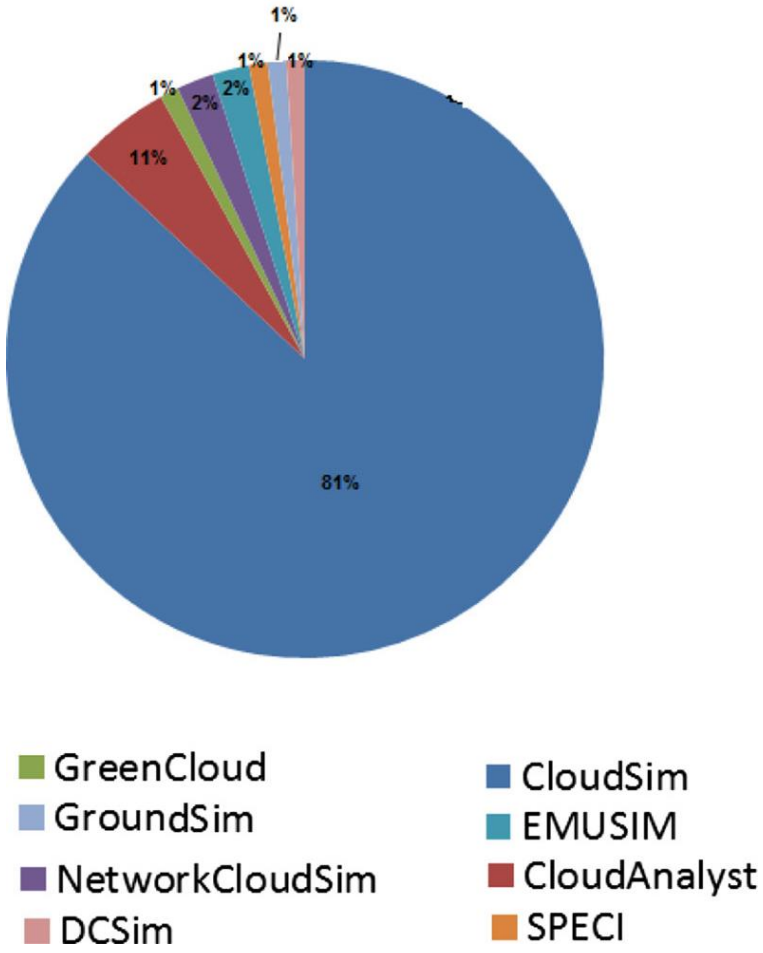
- Security Issue in the Cloud
  - Cloud Computing presents an added level of risk
  - Essential services are often outsourced to a third party
  - It is hard to maintain data security and privacy
  - This issue can prevent the rapid development of cloud computing
- Security techniques for data transmission
  - Network that interconnects the systems in a cloud has to be secure
- Virtualization in cloud computing results in security concerns
  - Mapping virtual machines to physical machines should be secure
- Data security
  - Data encryption
  - Secure data sharing

Reference - K. W. Hamlen, M. Kantarcioglu, L. Khan, and B. Thuraisingham, "**Security issues for cloud computing**," Int. Journal of Information Security and Privacy (IJISP), vol. 4, no. 2, pp. 36–48, 2010.).

Cloud Computing Simulation Frameworks

- Cloud simulation tools
  - Essentially needed to evaluate performance of research techniques and algorithms in the area of cloud computing
- Enhancing functionality of open source cloud simulators
  - Adding extensions to such tools is a major research contribution
  - building new cloud computing simulation platforms

Cloud Computing Simulation Frameworks



Reference - Singh S, Chana I (2016) **A survey on resource scheduling in cloud computing: Issues and challenges**. J Grid Comput 14(2): 1–48.

Cloud-Based Big Data Analytics

- Big Data
  - Massive, heterogeneous, and often unstructured datasets
  - Difficult to process using traditional data management tools
  - Advanced data mining tools are needed for information extraction
  - Help in making informed decisions in business and scientific applications
- Cloud-Based Analytics
  - Few cloud-based analytics platforms are available today
- Clouds for Scalable Big Data Analytics
  - Scalability inherited in the clouds can benefit huge data processing
  - Big data analytics require programming models on multiple nodes
  - MapReduce model is often used on clusters and clouds
  - More research is needed to develop scalable higher-level models

Cloud-Based Big Data Analytics

Cloud service model	Features	Users
Data analytics software as a service	A single and complete data mining application or task (including data sources) offered as a service	End users, analytics managers, data analysts
Data analytics platform as a service	A data analysis suite or framework for programming or developing high-level applications, hiding the cloud infrastructure and data storage	Data mining application developers, data scientists
Data analytics infrastructure as a service	A set of virtualized resources provided to a programmer or data mining researcher for developing, configuring, and running data analysis frameworks or applications	Data mining programmers, data management developers, data mining researchers

Reference - Domenico Talia. 2013. **Clouds for Scalable Big Data Analytics**. *Computer* 46, 5 (May 2013), 98-101.

Summary

- An introduction to cloud computing is presented
- Some Research trends in cloud computing are discussed
- Trends discussed in the following areas:
  - Cloud Resource Management
  - Green Cloud Computing
  - Cloud Computing Security
  - Cloud Computing Simulation Frameworks
  - Big Data Analytics in the Cloud

Presentation Evaluation

Presentation Guidelines (Evaluation Criteria)

- Focus of the presentation
- Clarity and coherence of the content
- Thoroughness of the ideas presented and the analysis
- Clarity of the presentation
- Effective use of facts, statistics and details
- Lack of grammatical and spelling errors
- Design of the slides
- Effective use of images
- Clarity of voice projection and appropriate volume
- Completion of the presentation within the allotted time frame
- Deliver the presentation by email before the lecture time with at least 5 hours.

Self Evaluations

- How do you think it went?
- What could you have done differently to make it better?
- What did you do that you are particularly proud of accomplishing?
- What did you learn from preparing for and delivering this presentation?
- What would you change next time?

Peer Evaluations

- Each Team is responsible for printing the evaluation form.
- All audience fill the form and deliver it to the team after the presentation including me.
- No name is needed in the feedback form.

Student Evaluation Form for Presentations

Title of Presentation _____

Presenter's Name _____

		Strongly Disagree				Strongly Agree
1.	The slides built my interest in the presentation	1	2	3	4	5
2.	The slides were well designed	1	2	3	4	5
3.	The background of the PowerPoint slides was effective	1	2	3	4	5
4.	There were only bullets and no paragraphs of prose	1	2	3	4	5
5.	The presentation was coherent	1	2	3	4	5
6.	The presentation was well conceived	1	2	3	4	5
7.	The student spoke clearly	1	2	3	4	5
8.	The student was well organized	1	2	3	4	5
9.	The student's personal presentation style created interest	1	2	3	4	5
10.	The presentation was well delivered	1	2	3	4	5
11.	Overall, the presentation was interesting and engaging	1	2	3	4	5
12.	Other _____	1	2	3	4	5

Comments and Suggestions for Improvement

_____

_____

_____