Introduction to CLOUD COMPUTING
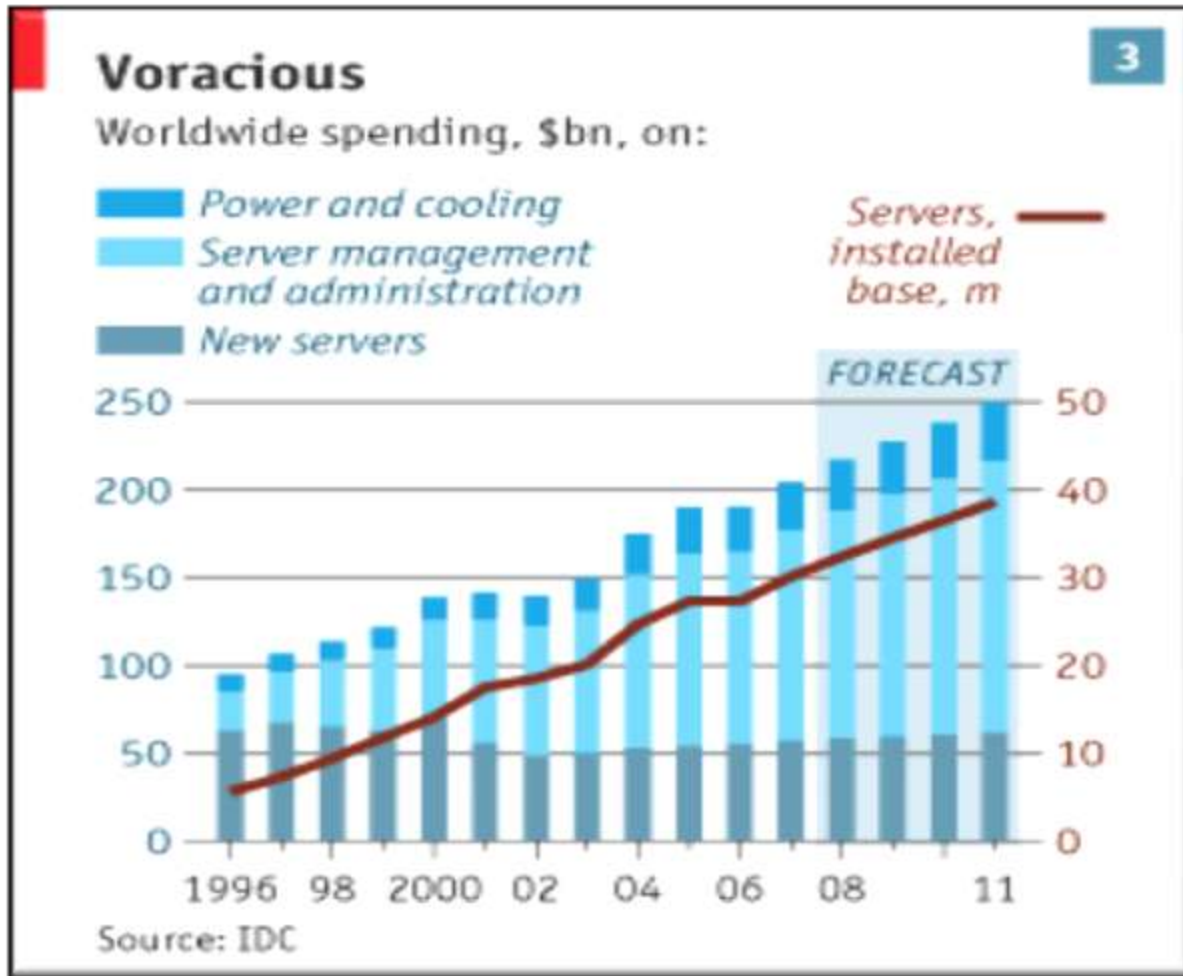
annappacse@gmail.com

Why Cloud Computing ?

- Data centers are notoriously underutilized, often idle 85% of the time
  - Over provisioning
  - Insufficient capacity planning and sizing
  - Improper understanding of scalability requirements etc.
- Thought leaders from Gartner, Forrester, and IDC—agree that cloud computing model offers significant advantages for fast-paced startups, SMBs and enterprises alike.
- Cost effective solutions to key business demands
- Move workloads to improve efficiency

Why is Cloud happening?

The Cloud model can be truly disruptive if it can reduce the IT *operational expenses* of enterprises

Voracious

Worldwide spending, $bn, on:

- Power and cooling
- Server management and administration
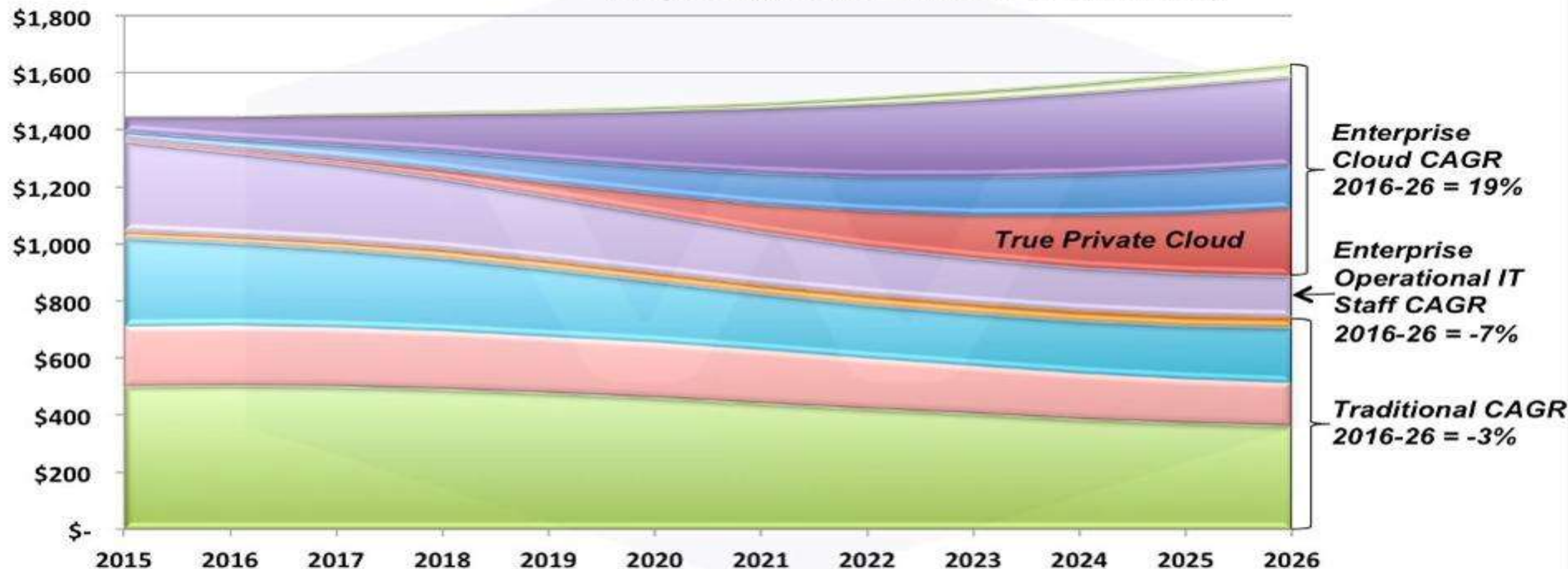- New servers

Servers, installed base, m

Source: IDC

Source: The Economist, 10-23-2008

There is a huge opportunity in minimizing OpEx costs

CapEx costs are typically being controlled by consolidation

Wikibon Worldwide Enterprise IT Projection by Vendor Revenue Segmentation 2015-2026 ($Billion)

Enterprise Cloud CAGR 2016-26 = 19%

True Private Cloud

Enterprise Operational IT Staff CAGR 2016-26 = -7%

Traditional CAGR 2016-26 = -3%

Legend:

- Business Processing Outsourcing (BPO) Cloud less IaaS & TPC Revenue
- SaaS (Including % PaaS Revenue, less IaaS & TPC Revenue)
- IaaS (Including % PaaS, SaaS & BPO Revenue)
- True Private Cloud (Including % PaaS, BPO & SaaS Revenue)
- Enterprise IT Operational Staffing Costs
- Traditional IT for Business Process Outsourcing
- Traditional Application Software & Maintenance
- Traditional Infrastructure Services (Inc. Outsourcing, Hosting)
- Traditional Hardware & Software inc. Maintenance
- Total Enterprise IT (Traditional, Cloud & Operational Staffing)

The Rapid Growth of Cloud Computing, 2015-2020

Woldwide Spending on Public Cloud Computing, 2015-2020 ($B)

Average Compound Growth Rate, YE2015-YE2020, 19%
IT Spending Average Compound Growth Rate,
YE2015-YE2020, 3%

Year	Spending ($B)
2015	$67
2016	$82
2017	$99
2018	$117
2019	$138
2020	$162
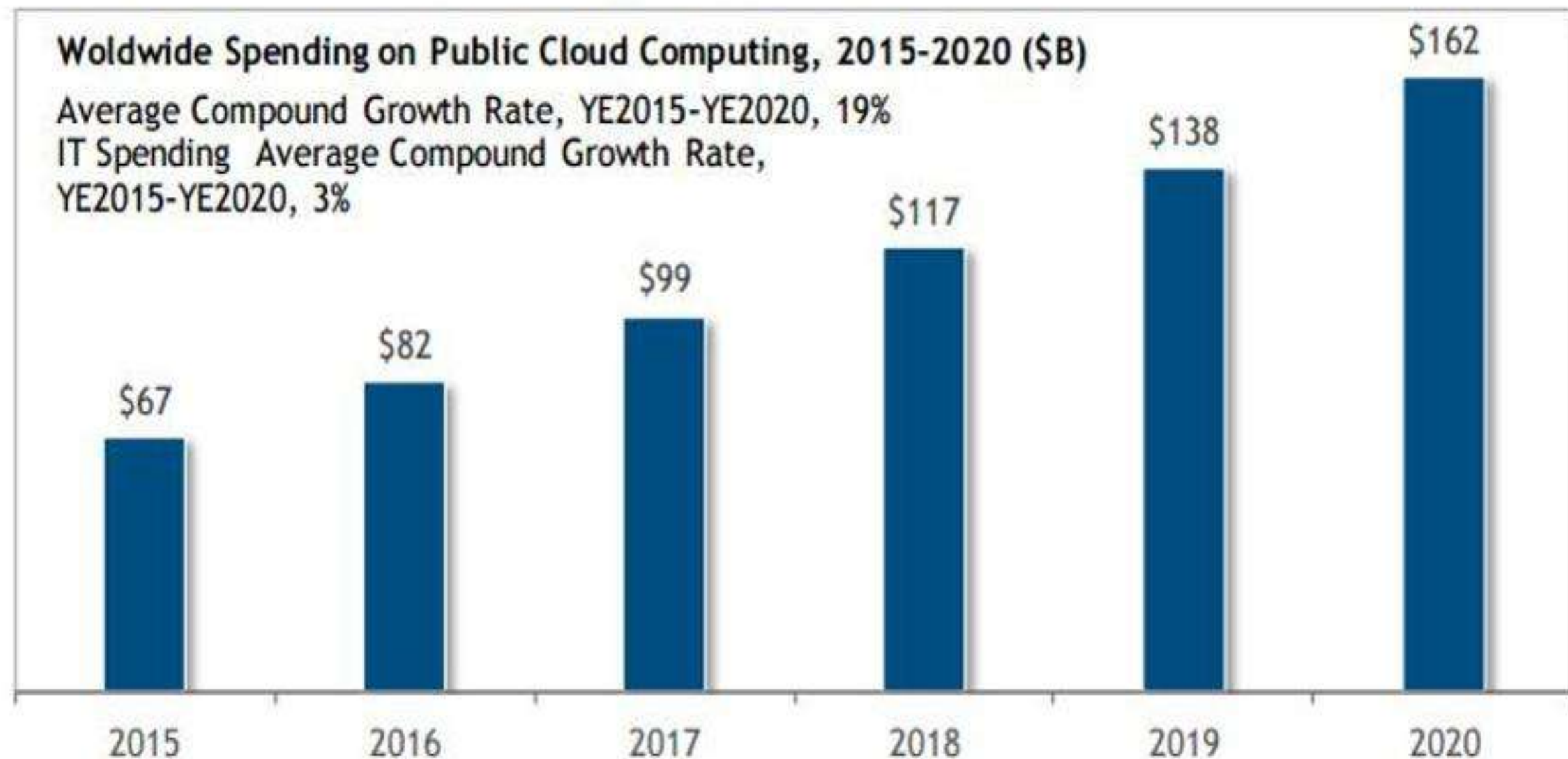
Table 1. Worldwide Public Cloud Services Forecast (Millions of Dollars)

|	2016	2017	2018	2019	2020
Cloud Business Process Services (BPaaS)	40,812	43,772	47,556	51,652	56,176
Cloud Application Infrastructure Services (PaaS)	7,169	8,851	10,616	12,580	14,798
Cloud Application Services (SaaS)	38,567	46,331	55,143	64,870	75,734
Cloud Management and Security Services	7,150	8,768	10,427	12,159	14,004
Cloud System Infrastructure Services (IaaS)	25,290	34,603	45,559	57,897	71,552
Cloud Advertising	90,257	104,516	118,520	133,566	151,091
Total Market	**209,244**	**246,841**	**287,820**	**332,723**	**383,355**

Source: Gartner (February 2017)

Figure 11. Deloitte Global estimates for IT Spending market for data centers, software and IT services ($ billions)
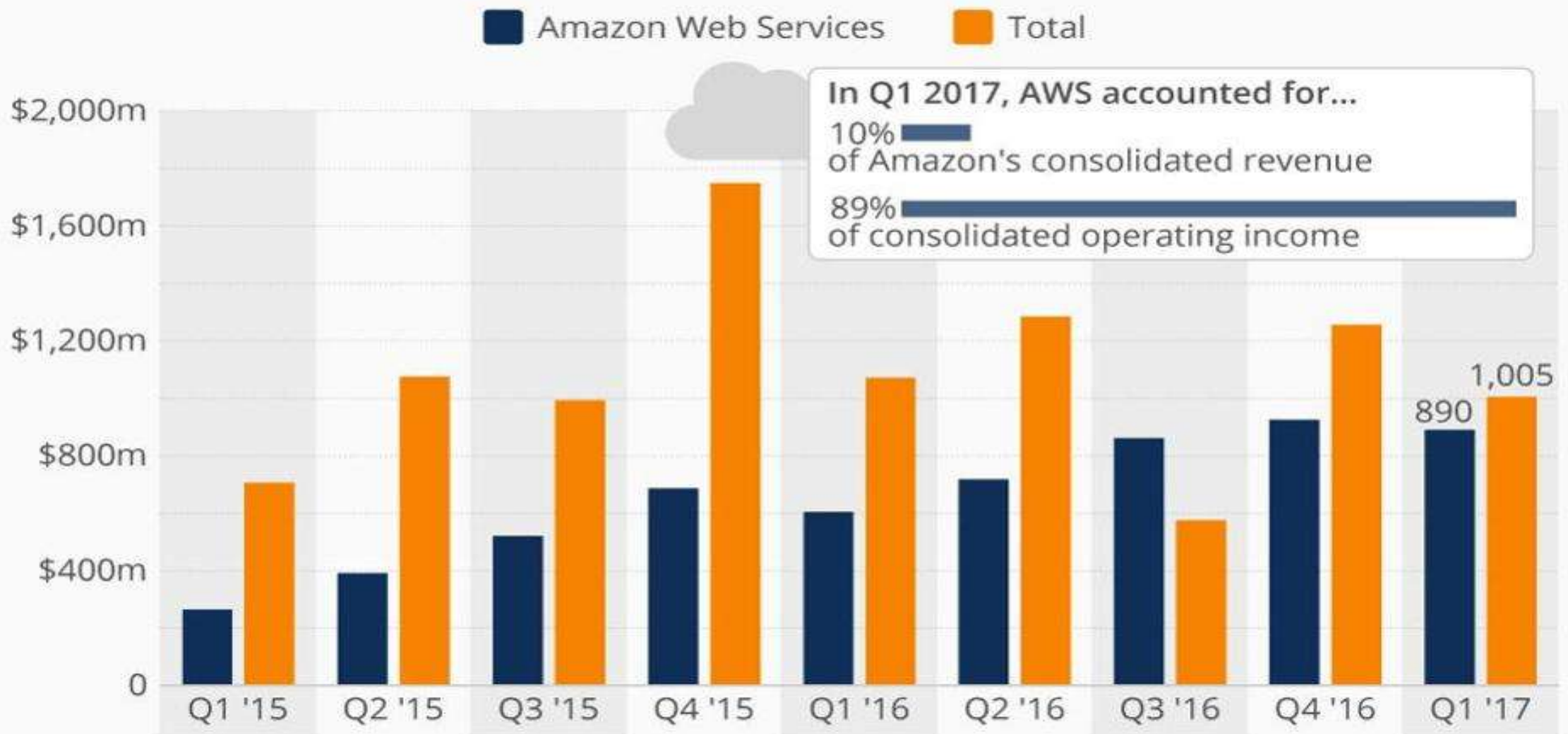
2016
100% = $1,406 billion
(Gartner estimate)

$361bn

$1,045bn

2018
100% = $1,552 billion
(Deloitte Global estimate)

$547bn

$1,005bn

IT-as-a-Service   Traditional

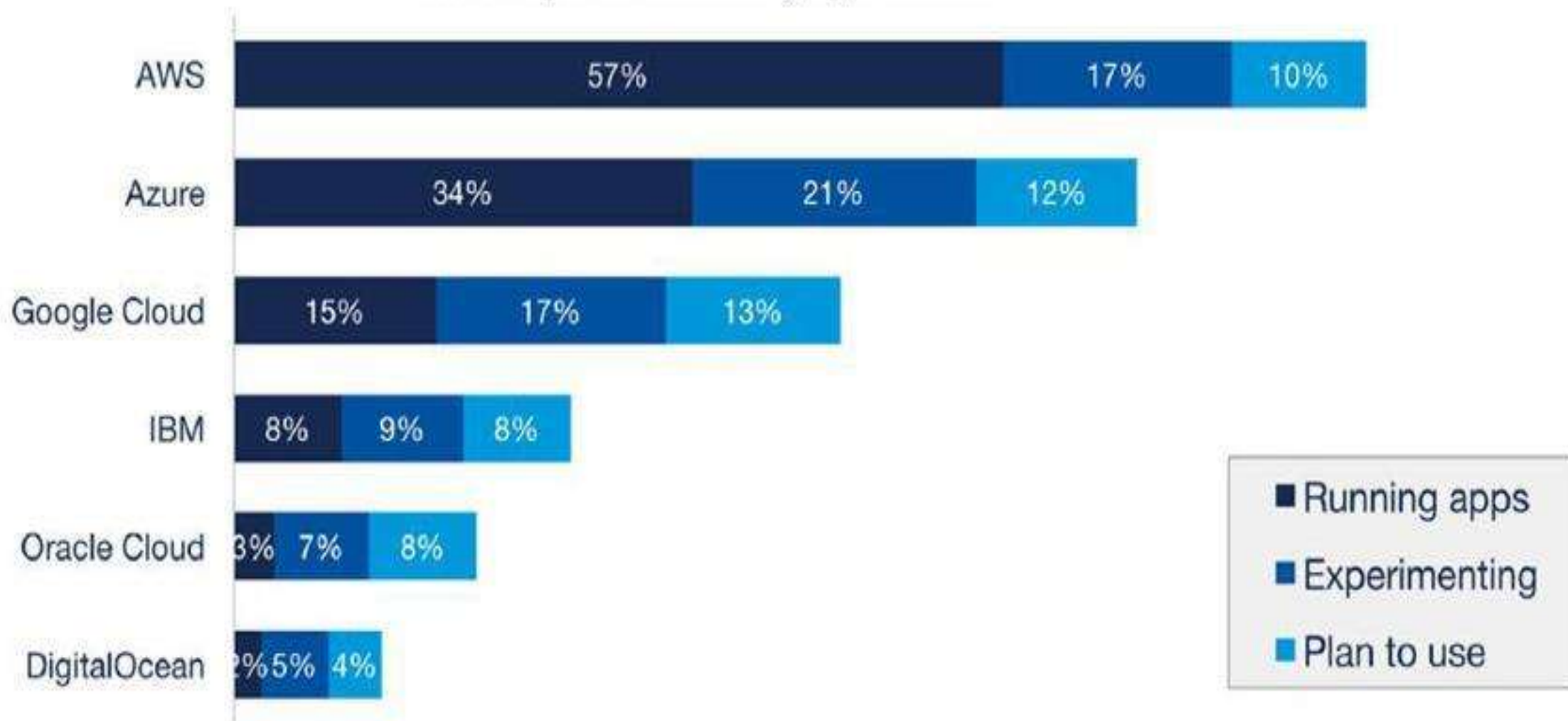Worldwide Cloud IT Infrastructure Market Forecast by Deployment Type 2015 - 2021 (shares based on Value)

Source : Worldwide Quarterly Cloud IT Infrastructure Tracker, Q4 2016
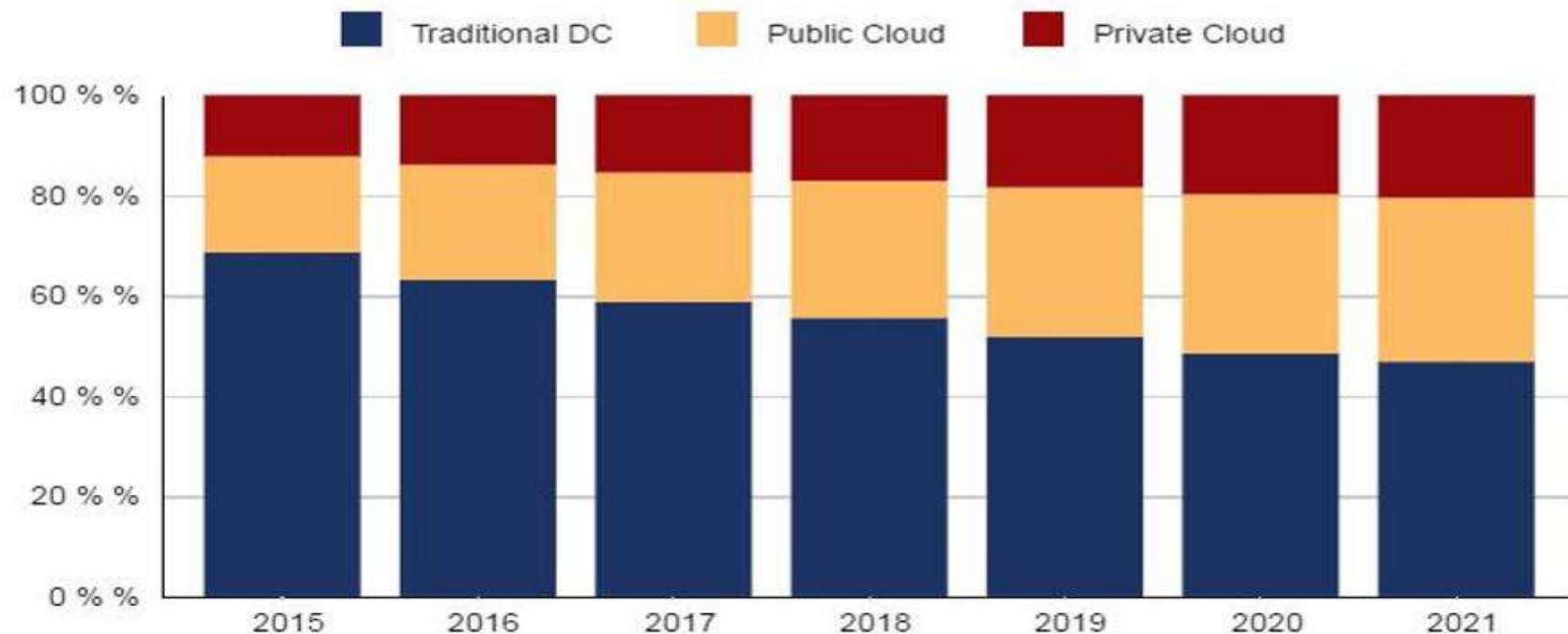
Cloud Business Drives Amazon's Profits

Amazon's quarterly operating profit (in million U.S. dollars)

■ Amazon Web Services   ■ Total

In Q1 2017, AWS accounted for...

10% ▬▬▬
of Amazon's consolidated revenue

89% ▬▬▬▬▬▬▬▬▬▬▬▬
of consolidated operating income

	Q1 '15	Q2 '15	Q3 '15	Q4 '15	Q1 '16	Q2 '16	Q3 '16	Q4 '16	Q1 '17

Q1 '17: AWS 890, Total 1,005

statista

Public Cloud Adoption

% of Respondents Running Applications

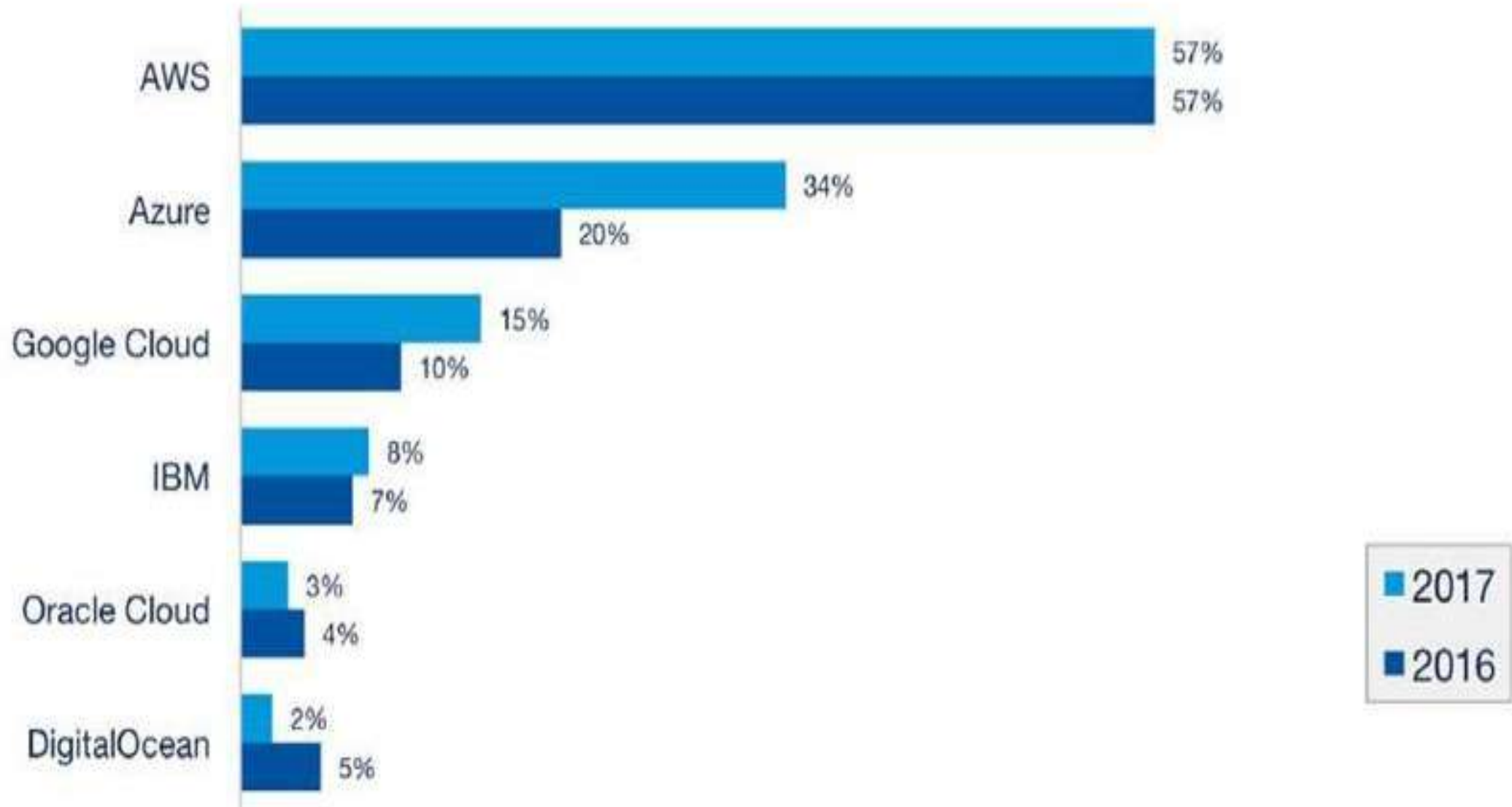|	Running apps	Experimenting	Plan to use
AWS	57%	17%	10%
Azure	34%	21%	12%
Google Cloud	15%	17%	13%
IBM	8%	9%	8%
Oracle Cloud	3%	7%	8%
DigitalOcean	2%	5%	4%

Source: RightScale 2017 State of the Cloud Report

Public Cloud Adoption 2017 vs. 2016

% of Respondents Running Applications

Provider	2017	2016
AWS	57%	57%
Azure	34%	20%
Google Cloud	15%	10%
IBM	8%	7%
Oracle Cloud	3%	4%
DigitalOcean	2%	5%

■ 2017
■ 2016

Source: RightScale 2017 State of the Cloud Report

Which of the following will have the most measurable impact on your business in 2017?

- Cloud computing
- Internet of Things
- Artificial intelligence
- 3D printing
- Virtual reality
- Blockchain

74%
58%
16%
14%
14%
8%
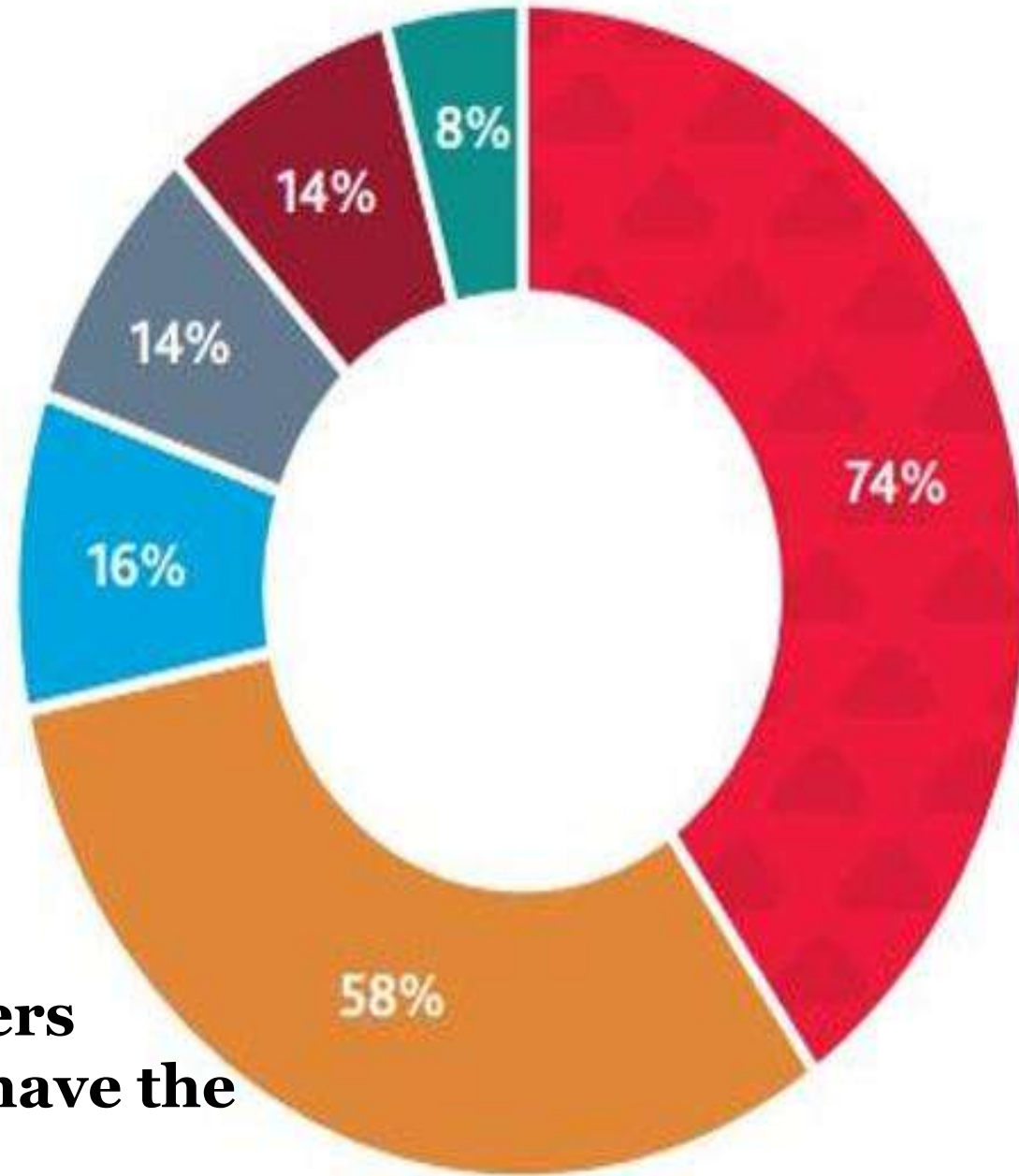
74% of Tech Chief Financial Officers (CFOs) say cloud computing will have the most measurable impact on their business

Just 23% of organizations today completely trust public clouds to keep their data secure. A year ago, only 13% trusted public clouds. This 76% jump in trust for one year is attributable to public cloud platforms investing more development effort and resources in security features and support.
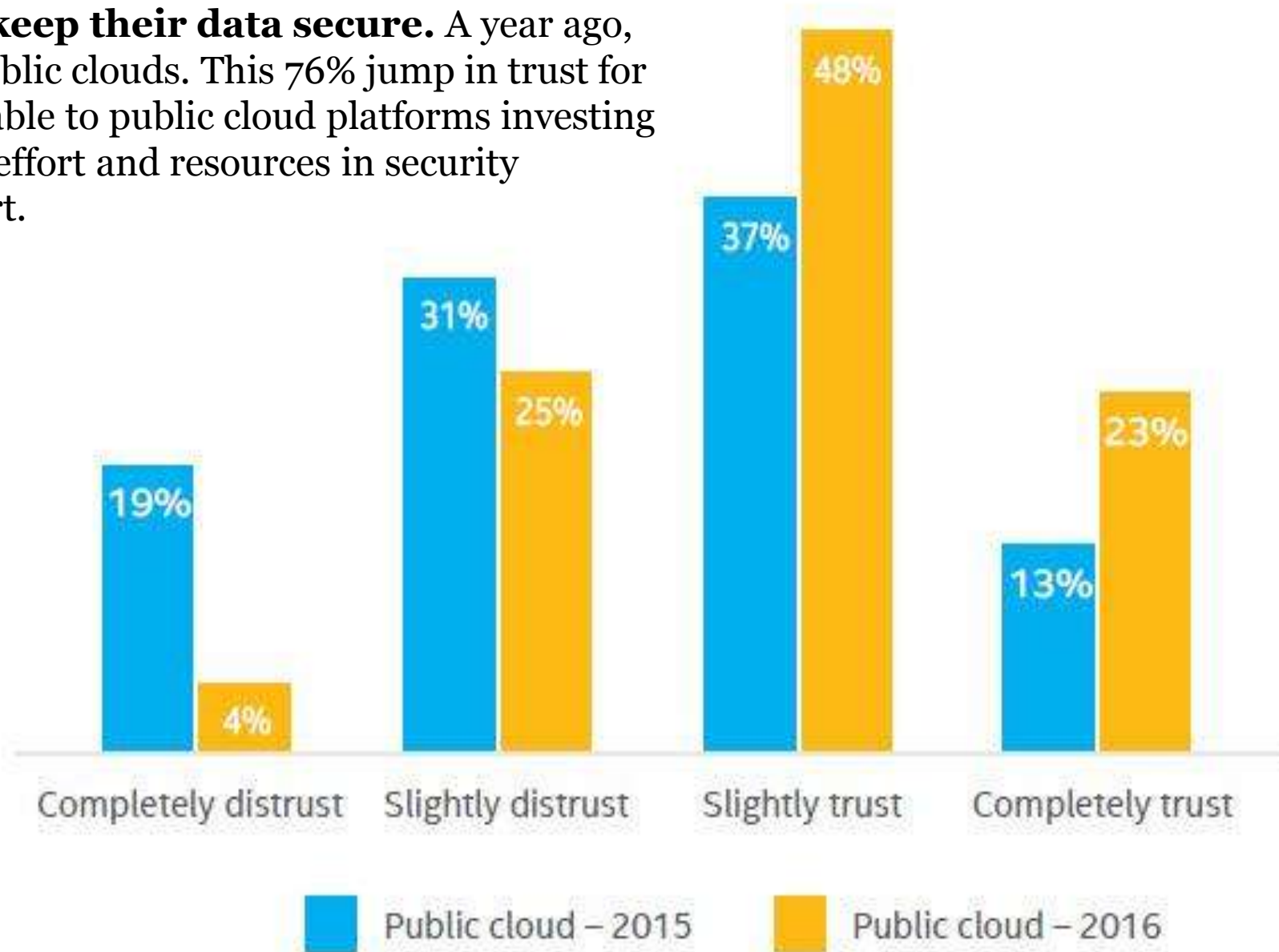

	Completely distrust	Slightly distrust	Slightly trust	Completely trust
Public cloud – 2015	19%	31%	37%	13%
Public cloud – 2016	4%	25%	48%	23%

Figure 12. To what extent do you trust the following to keep your organizations' sensitive data secure?

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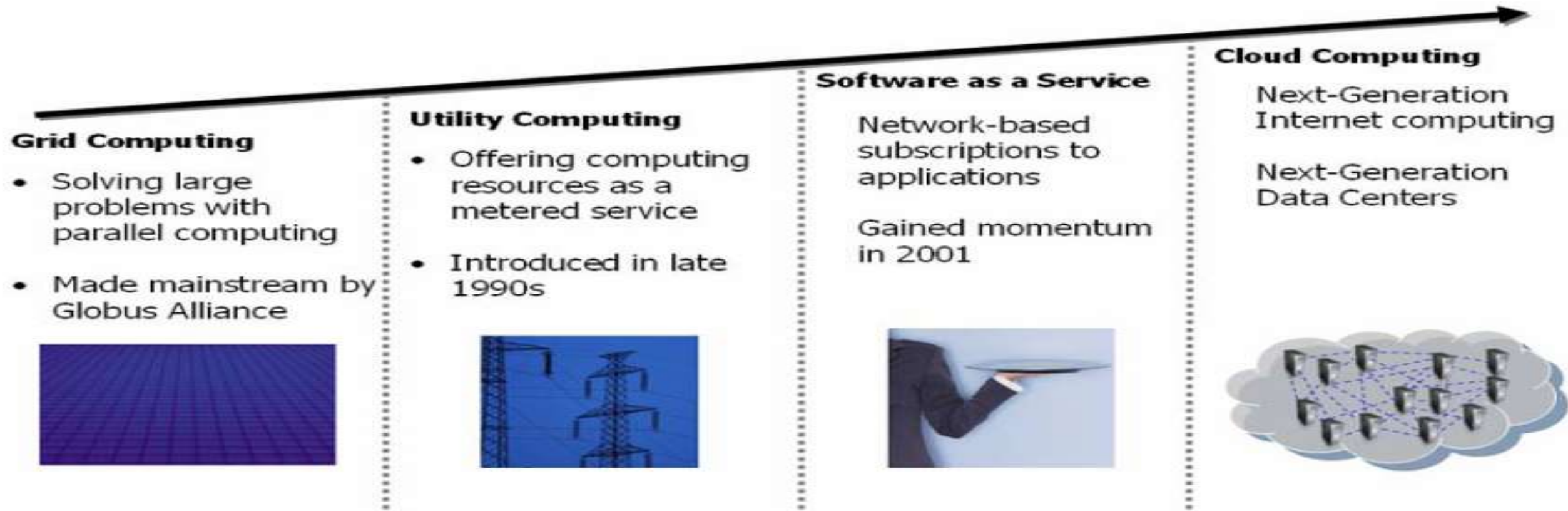
Towards Cloud

According to survey, 66% of the enterprises plan to move to hybrid cloud within the next four years. There will be a small minority that will either go to private or to public cloud.

66% of businesses will use a hybrid solution

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Cloud computing and technology

- New advances in processors, virtualization technology, distributed storage, broadband Internet access, automated management and fast, inexpensive servers have all combined to make cloud computing a compelling paradigm.

Grid Computing
- Solving large problems with parallel computing
- Made mainstream by Globus Alliance

Utility Computing
- Offering computing resources as a metered service
- Introduced in late 1990s

Software as a Service
Network-based subscriptions to applications

Gained momentum in 2001

Cloud Computing
Next-Generation Internet computing

Next-Generation Data Centers

What is Cloud Computing?

- A fundamental shift in the computing paradigm

  -Steve Ballmer, CEO Microsoft

- The return of the mainframe, and the mainframe is a set of computers. You never visit them, you never see them. But they're out there.

  -Eric Schmidt, CEO Google

- It's nothing more than a faddish term for the established concept of computers linked by networks. A cloud is water vapour

  -Larry Ellison, CEO Oracle

- You build your app, and you inherit our architecture

  -Marc Benioff, CEO SalesForce.com

Cloud computing definition

- Cloud computing is a resource delivery and usage model, it means get resource (Hardware, software)via network. The network of providing resource is called 'Cloud'. The hardware resource in the 'Cloud' seems scalable infinitely and can be used whenever and wherever required.

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What is Cloud Computing ?

Cloud computing is a compilation of existing techniques and technologies, packaged within a new infrastructure paradigm that offers improved scalability, elasticity, business agility, faster startup time, reduced management costs, and just-in-time availability of resources.

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What is Cloud Computing (cont.)?

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

U.S. National Institute of Standards and Technology (NIST)

What is Cloud Computing (cont.)? - NIST

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

U.S. National Institute of Standards and Technology (NIST)

Cloud Computing – Characteristics

Five essential characteristics of Cloud Computing

1. **On-demand self service**:
   - Cloud computing resources can be provisioned on-demand by the users, without requiring interactions with the cloud service provider. The process of provisioning resources is automated.

2. **Broad network access**:
   - Cloud computing resources can be accessed over the network using standard access mechanisms that provide platform-independent access through the use of heterogeneous client platforms such as workstations, laptops, tablets and smartphones.

Cloud Computing – Features & Characteristics

3. Resource pooling:

- The computing and storage resources provided by cloud service providers are pooled to serve multiple users using multi-tenancy. Multi-tenant aspects of the cloud allow multiple users to be served by the same physical hardware.

4. Rapid elasticity:

- Cloud computing resources can be provisioned rapidly and elastically. Cloud resources can be rapidly scaled up or down based on demand.

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5. Measured service:

- Cloud computing resources are provided to users on a pay-per-use model. The usage of the cloud resources is measured and the user is charged based on some specific metric.

Other characteristics of Cloud Computing

1. Performance:

- Cloud computing provides improved performance for applications since the resources available to the applications can be scaled up or down based on the dynamic application workloads.

Cloud Computing – Features & Characteristics

2. **Reduced costs**:
   - Cloud computing provides cost benefits for applications as only as much computing and storage resources as required can be provisioned dynamically, and upfront investment in purchase of computing assets to cover worst case requirements is avoided.

3. **Outsourced Management**:
   - Cloud computing allows the users (individuals, large organizations, small and medium enterprises and governments) to outsource the IT infrastructure requirements to external cloud providers.

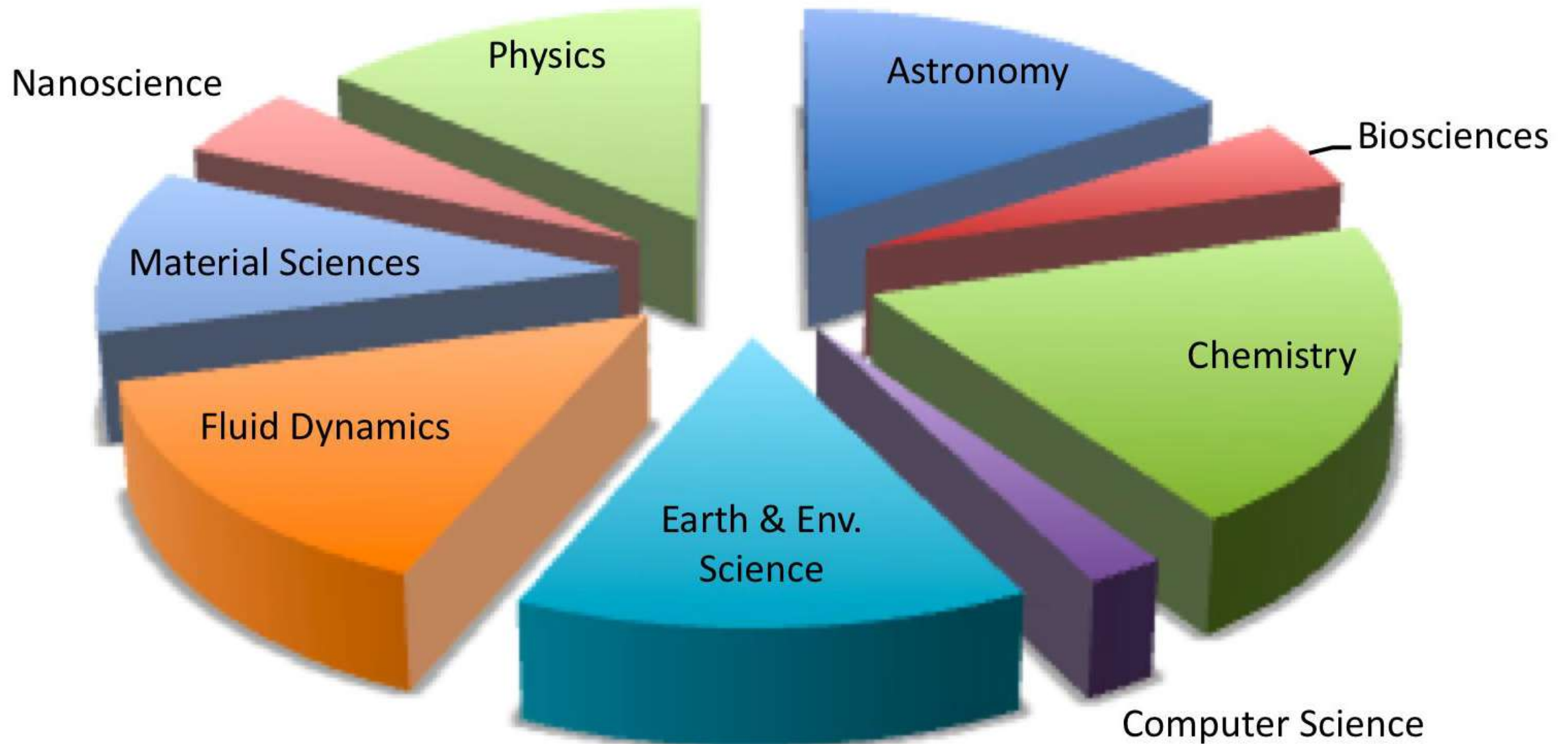# Cloud Computing – Features & Characteristics

4. Reliability:

- Applications deployed in cloud computing environments generally have a higher reliability since the underlying IT infrastructure is professionally managed by the cloud service provider.
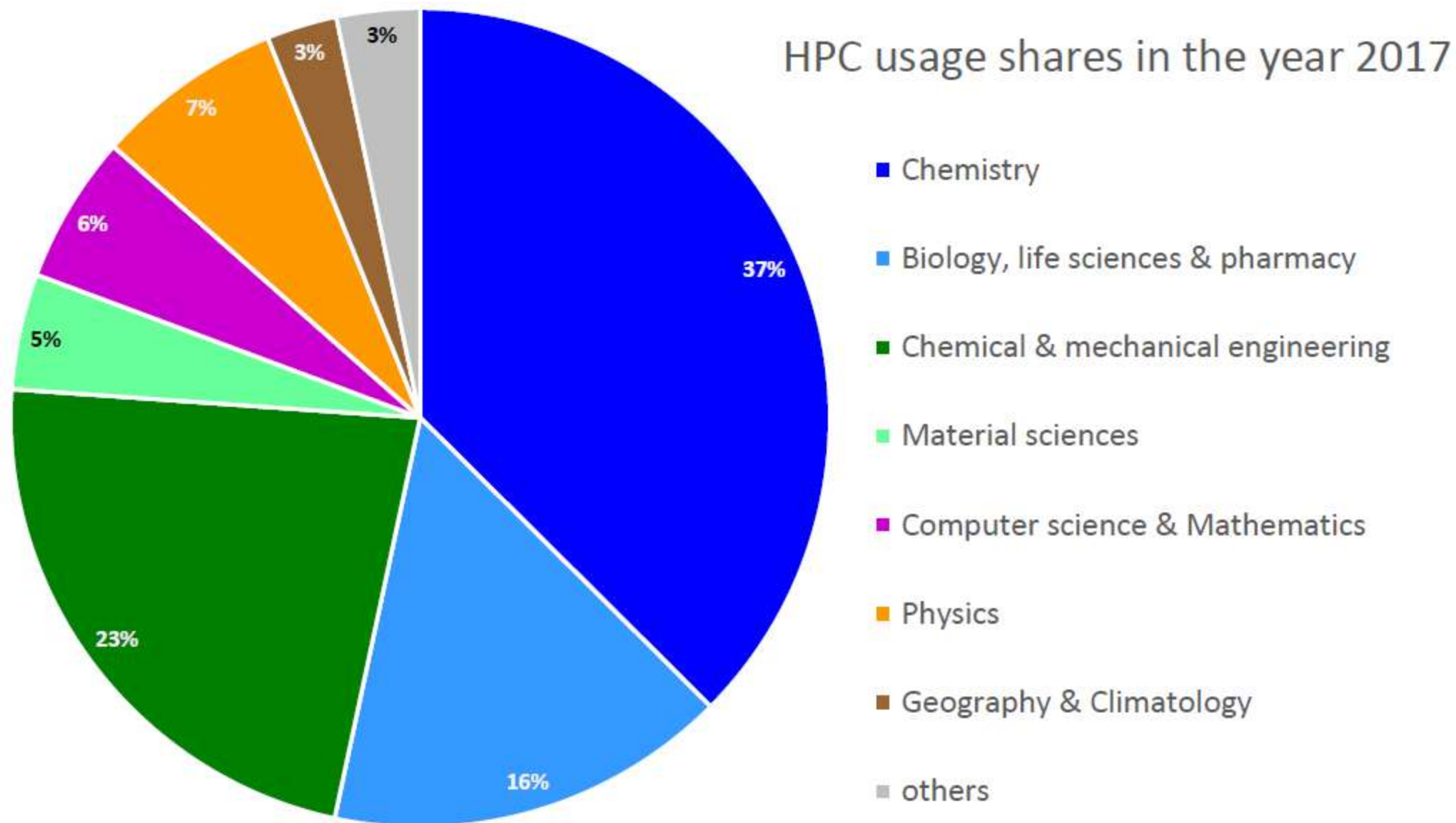
5. Multi-tenancy:

- The multi-tenanted approach of the cloud allows multiple users to make use of the same shared resources.
  - In virtual multi-tenancy, computing and storage resources are shared among multiple users.
  - In organic multi-tenancy every component in the system architecture is shared among multiple tenants

HPC Usage per domain

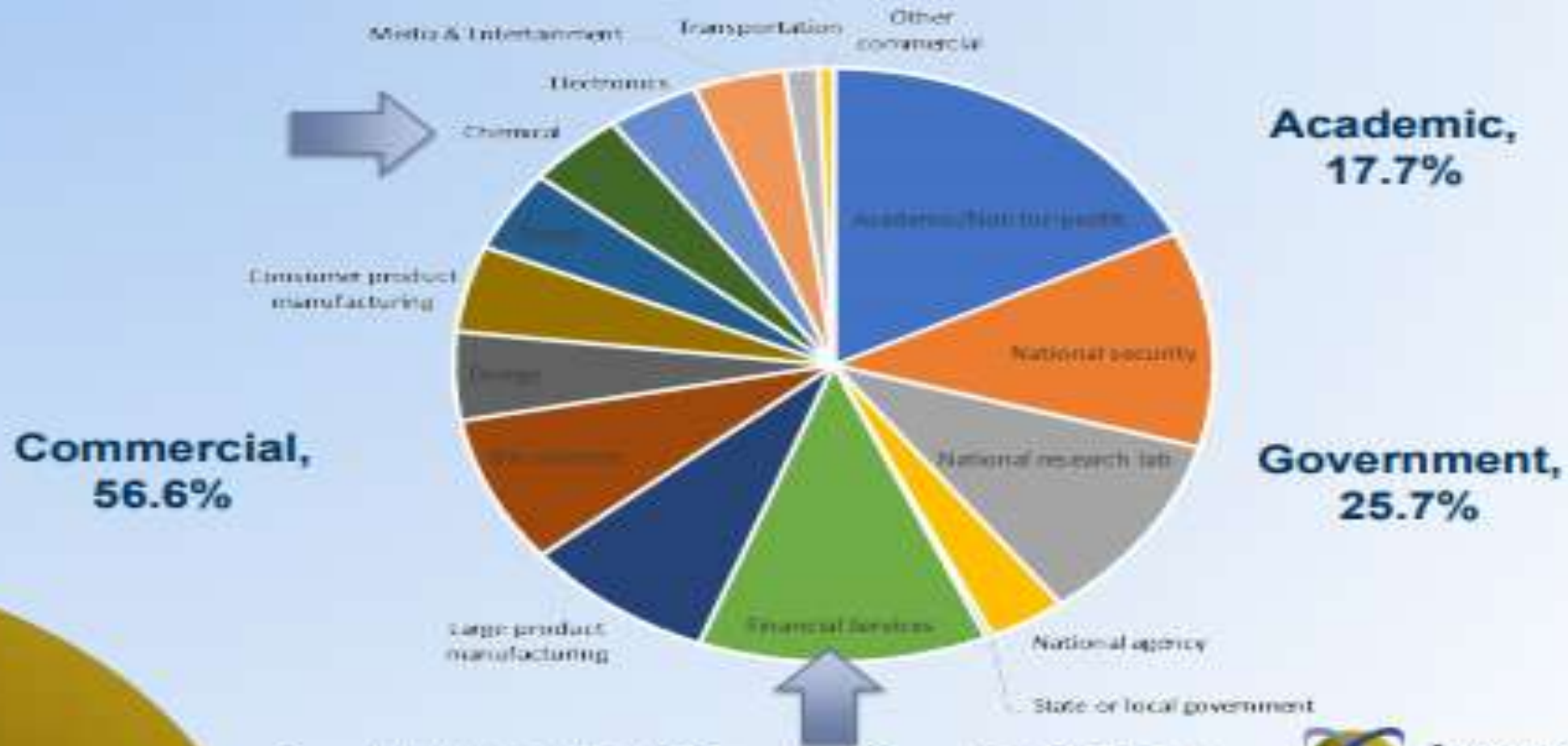# HPC usage shares in 2017

HPC usage shares in the year 2017

- Chemistry
- Biology, life sciences & pharmacy
- Chemical & mechanical engineering
- Material sciences
- Computer science & Mathematics
- Physics
- Geography & Climatology
- others

28

HPC 2017 Revenue by Vertical

Report: *Worldwide High Performance Computing 2017 Total Market Model and 2018–2022 Forecast: Vertical Markets*

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Economics of Cloud Computing

- Capex (capital expense)
  - > Typically large upfront cost of purchasing equipment
- Opex (operating expense)
  - > Monthly cost of renting equipment you don't own
- Pay as you go reduces startup costs and risk for the investor
  - > Closely track business growth
- Question: Is cloud computing significantly cheaper than traditional managed hosting?

Cloud computing – Market Prices

Amazon's Elastic Compute Cloud

United States   Europe

Standard On-Demand Instances	Linux/UNIX Usage	Windows Usage
Small (Default)	$0.10 per hour	$0.125 per hour
Large	$0.40 per hour	$0.50 per hour
Extra Large	$0.80 per hour	$1.00 per hour
High CPU On-Demand Instances	**Linux/UNIX Usage**	**Windows Usage**
Medium	$0.20 per hour	$0.30 per hour
Extra Large	$0.80 per hour	$1.20 per hour

Example Usage:
- Medium VM x 24hr x 30 days
- 100 GB stored, 10 GB xfer in+out
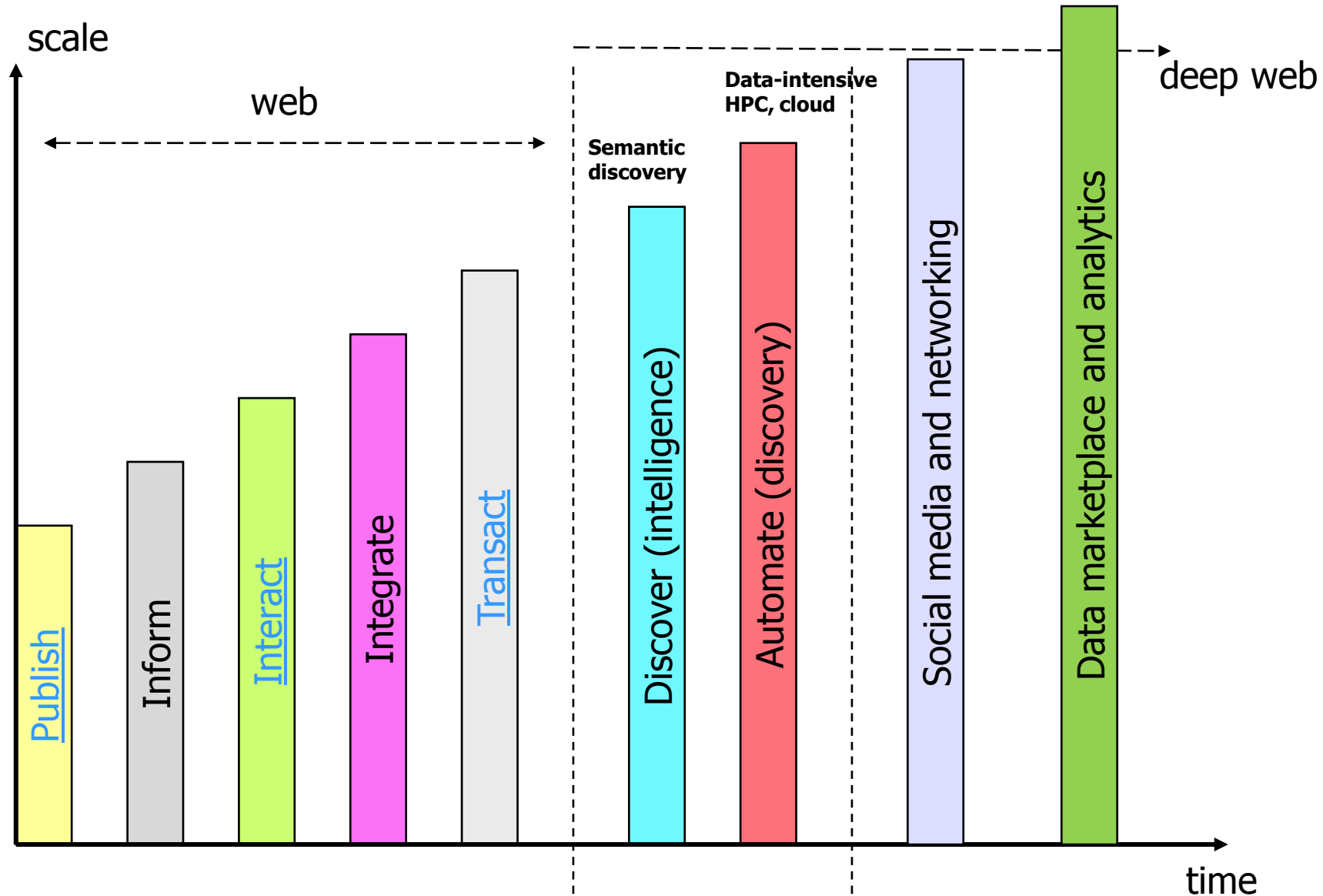

$ 144 + $ 18 = $162

S3 Storage
- $0.15 per GB per month
- $0.10 per GB transfer in
- $0.17 per GB transfer out

Natural evolution of the WEB

WEB SITES

APPLICATIONS → SaaS

DEVELOPER PLATFORMS → PaaS

COMPUTE AND STORAGE → IaaS
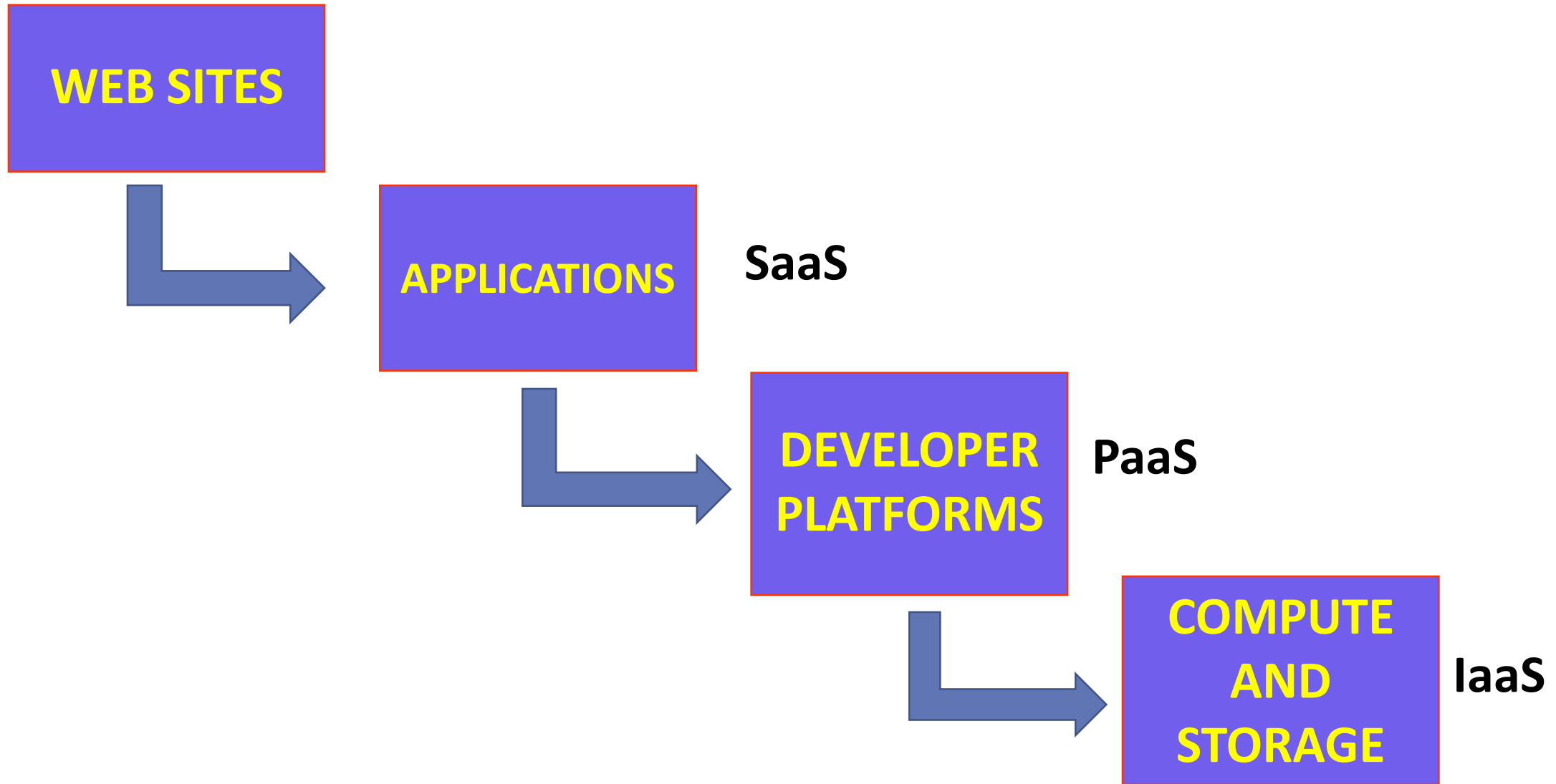
Evolution of Internet Computing

Anatomy of a Cloud

Social Networks
Scientific Computing
Financial Applications
Amusement
CDNs

Private Cloud

Public Cloud

Google Apps (Gmail, Docs,…)
Salesforce.com

Software as a Service

Web 2.0 Interface
Programming API
Scripting & Programming Languages

Platform as a Service

Google AppEngine
Microsoft Azure
Manjrasoft Aneka

Infrastructure as a Service

Virtualization
VM Management & Deployment
Amazon S3, EC2
OpenNebula, Eucalyptus
Mosso

Data Centers
Clusters
Storage
Other Grids/Clouds

Pricing and Billing | Accounting
QoS Metering | Admission Control
SLA Negotiation

Cloud Computing Models

- **Service(Delivery) Models**
  - SaaS
  - PaaS
  - IaaS

- **Deployment Models**
  - Private cloud
  - Community cloud
  - Public cloud
  - Hybrid cloud

- **Management Models (trust and tenancy issues)**
  - Self-managed
  - 3rd party managed (e.g. public clouds and VPC)

Cloud Service Models

- Software as a Service (SaaS)
  - Applications, management and user interfaces provided over a network

- Platform as a Service (PaaS)
  - Application development frameworks, operating systems and deployment frameworks

- Infrastructure as a Service (IaaS)
  - Virtual computing, storage and network resource that can be provisioned on demand

Software-as-a-Service (SaaS)

- Software/Interface
  - SaaS provides the users a complete software application or the user interface to the application itself.

- Outsourced Management
  - The cloud service provider manages the underlying cloud infrastructure including servers, network, operating systems, storage and application software, and the user is unaware of the underlying architecture of the cloud.

- Thin client interfaces
  - Applications are provided to the user through a thin client interface (e.g., a browser). SaaS applications are platform independent and can be accessed from various client devices such as workstations, laptop, tablets and smartphones, running different operating systems.

- Ubiquitous Access
  - Since the cloud service provider manages both the application and data, the users are able to access the applications from anywhere.

Software-as-a-Service (SaaS)

SaaS

Benefits

- Lower costs
- No infrastructure required
- Seamless upgrades
- Guaranteed performance
- Automated backups
- Easy data recovery
- Secure
- High adoption
- On-the move access

Characteristics

- Multi-tenancy
- On-demand software
- Open integration protocols
- Social network integration

Adoption

- Individual users: High
- Small & medium enterprises: High
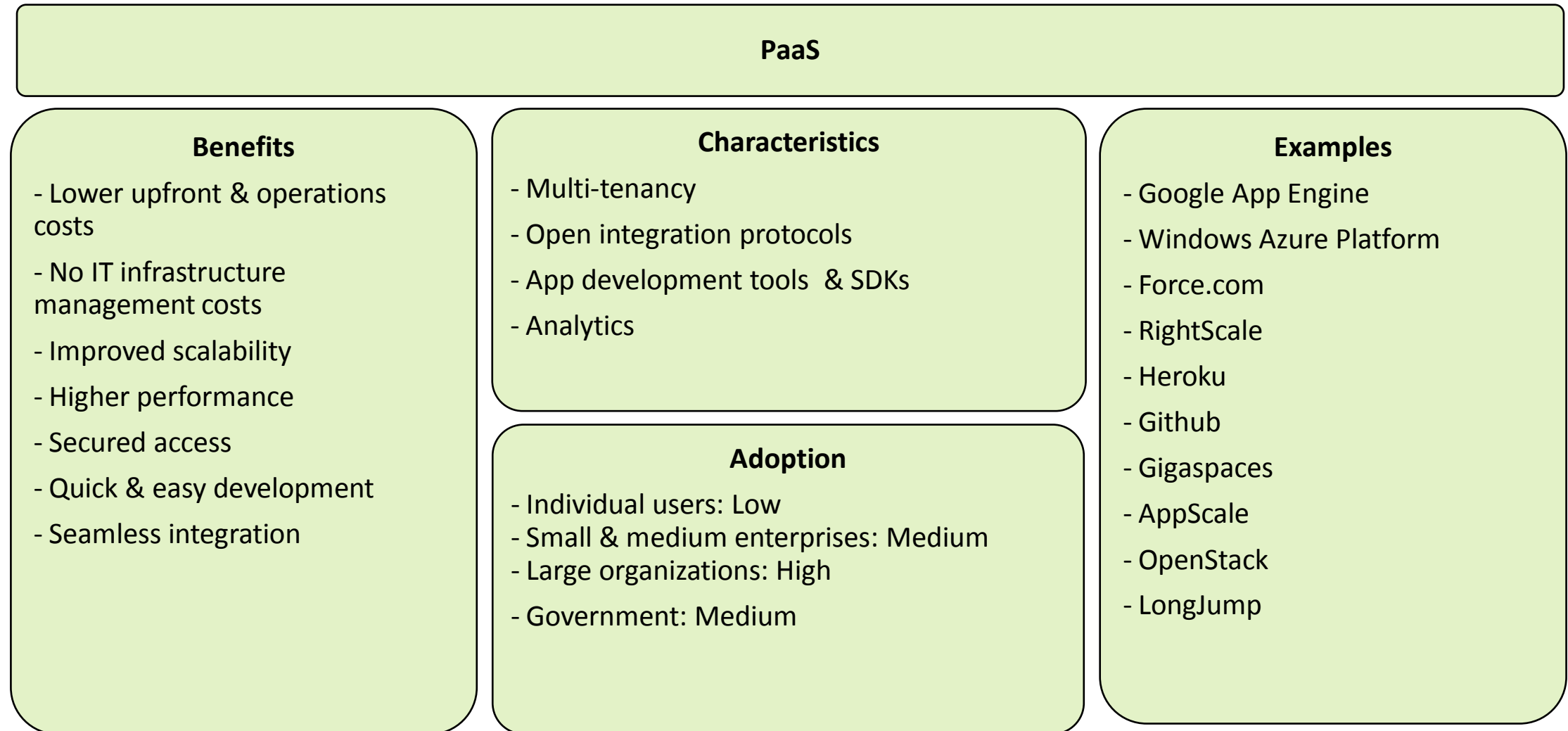- Large organizations: High
- Government: Medium

Examples

- Google Apps
- Salesforce.com
- Facebook
- Zoho
- Dropbox
- Taleo
- Microsoft Office 365
- Linkedin
- Slideshare
- CareCloud

Platform-as-a-Service (PaaS)

- Development & Deployment:
  - PaaS provides the users the capability to develop and deploy application in the cloud using the development tools, application programming interfaces (APIs), software libraries and services provided by the cloud service provider.

- Provider Manages Infrastructure:
  - The cloud service provider manages the underlying cloud infrastructure including servers, network, operating systems and storage.

- User Manages Application:
  - The users, themselves, are responsible for developing, deploying, configuring and managing applications on the cloud infrastructure.

Platform-as-a-Service (PaaS)

PaaS

Benefits

- Lower upfront & operations costs
- No IT infrastructure management costs
- Improved scalability
- Higher performance
- Secured access
- Quick & easy development
- Seamless integration

Characteristics

- Multi-tenancy
- Open integration protocols
- App development tools & SDKs
- Analytics

Adoption

- Individual users: Low
- Small & medium enterprises: Medium
- Large organizations: High
- Government: Medium

Examples

- Google App Engine
- Windows Azure Platform
- Force.com
- RightScale
- Heroku
- Github
- Gigaspaces
- AppScale
- OpenStack
- LongJump
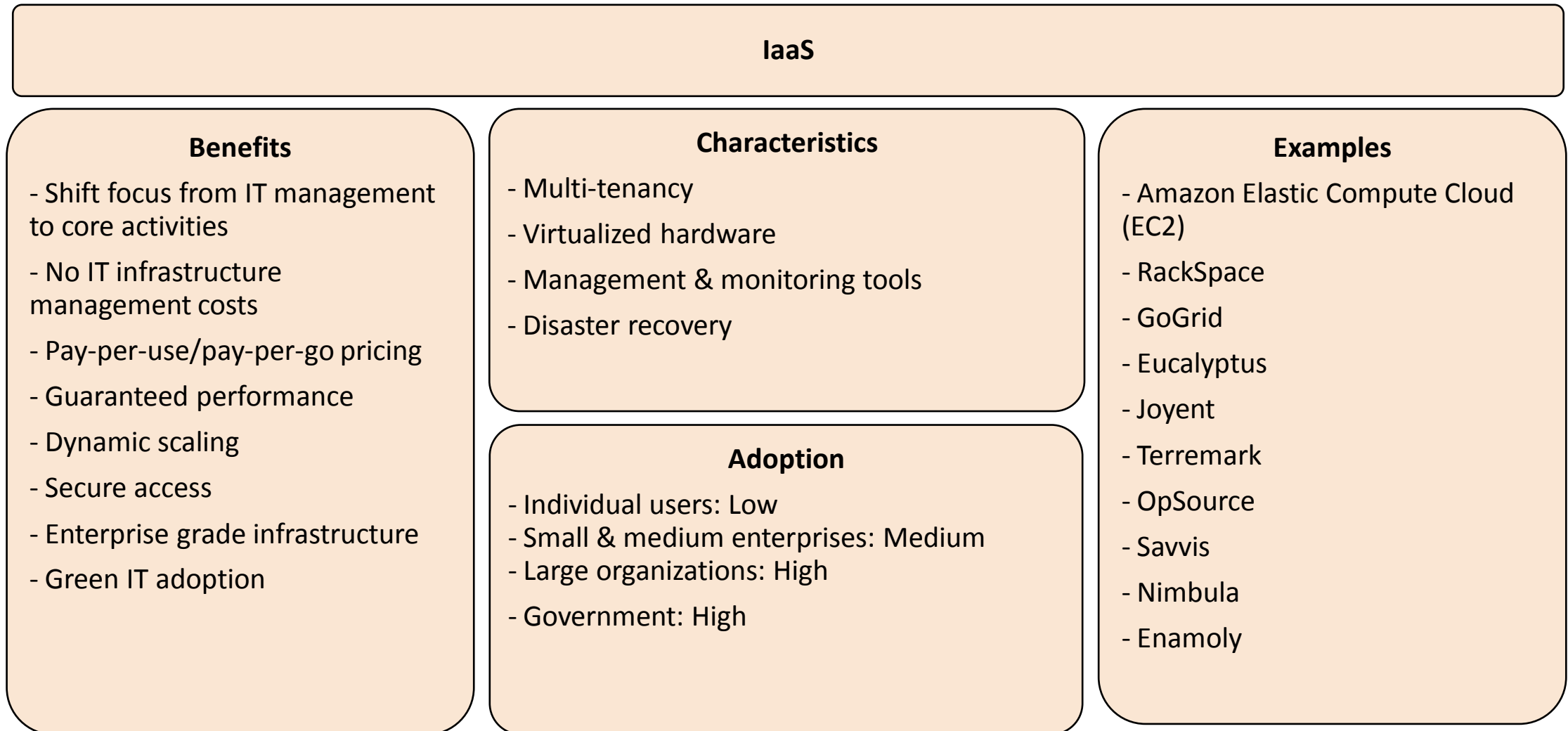
Infrastructure-as-a-Service (IaaS)

- Resource Provisioning
  - Provides the users the capability to provision computing and storage resources.

- Virtual Machines
  - These resources are provided to the users as virtual machine instances and virtual storage. Users can start, stop, configure and manage the virtual machine instances and virtual storage.

- Provider Managers Infrastructure:
  - The cloud service provider manages the underlying infrastructure.

- Pay-per-use/Pay-as-you-go:
  - Virtual resources provisioned by the users are billed based on a pay-per-use/pay-as-you-go paradigm.

Infrastructure-as-a-Service (IaaS)

IaaS

Benefits

- Shift focus from IT management to core activities

- No IT infrastructure management costs

- Pay-per-use/pay-per-go pricing

- Guaranteed performance

- Dynamic scaling

- Secure access

- Enterprise grade infrastructure

- Green IT adoption

Characteristics

- Multi-tenancy

- Virtualized hardware

- Management & monitoring tools

- Disaster recovery

Adoption

- Individual users: Low
- Small & medium enterprises: Medium
- Large organizations: High
- Government: High

Examples

- Amazon Elastic Compute Cloud (EC2)

- RackSpace

- GoGrid

- Eucalyptus

- Joyent

- Terremark

- OpSource

- Savvis

- Nimbula

- Enamoly

Cloud Deployment Models

- Public Cloud
  - Available for public use or a large industry group

- Private Cloud
  - Operated for exclusive use of a single organization

- Community Cloud
  - Available for shared use of several organizations supporting a specific community

- Hybrid Cloud
  - Combines multiple clouds (public and private) that remain unique but bound together to offer application and data portability

Public clouds

- Open for use by general public
  - Exist beyond firewall, fully hosted and managed by the vendor
  - Individuals, corporations and others
  - Amazon's Web Services and Google appEngine are examples
- Offers startups and SMB's quick setup, scalability, flexibility and automated management. Pay as you go model helps startups to start small and go big
- Security and compliance?
- Reliability concerns hinder the adoption of cloud
  - Amazon S3 services were down for 6 hours

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Public Clouds

- Large scale infrastructure available on a rental basis
  - Operating System virtualization (e.g. Xen, kvm) provides CPU isolation
  - "Roll-your-own" network provisioning provides network isolation
  - Locally specific storage abstractions
- Fully customer self-service
  - Service Level Agreements (SLAs) are advertized
  - Requests are accepted and resources granted via web services
  - Customers access resources remotely via the Internet
- Accountability is e-commerce based
  - Web-based transaction
  - "Pay-as-you-go" and flat-rate subscription
  - Customer service, refunds, etc.

Private Clouds

- Within the boundaries(firewall) of the organization
- All advantages of public cloud with one major difference
  - Reduce operation costs
  - Has to be managed by the enterprise
- Fine grained control over resources
- More secure as they are internal to organization
- Schedule and reshuffle resources based on business demands
- Ideal for apps related to tight security and regulatory concerns
- Development requires hardware investments and in-house expertise
- Cost could be prohibitive and cost might exceed public clouds

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Community Clouds

- The cloud infrastructure is provisioned for exclusive use by a specific community of consumers from organizations that have shared concerns (e.g., mission, security requirements, policy, and compliance considerations).

- It may be owned, managed, and operated by one or more of the organizations in the community, a third party, or some combination of them, and it may exist on or off premises (hosted internally or externally).

- The costs are spread over fewer users than a public cloud (but more than a private cloud).

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Community Clouds

- Supports specific community with shared concerns
    - Life Sciences industry
    - Finance industry
    - Government
- Focused on delivering community specific SaaS
    - Build on Enterprise cloud with relevant options included
    - Partnership with ISV's
    - Blueprints used to deploy pre-packaged solutions

Hybrid cloud

- The cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds).

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Business Models

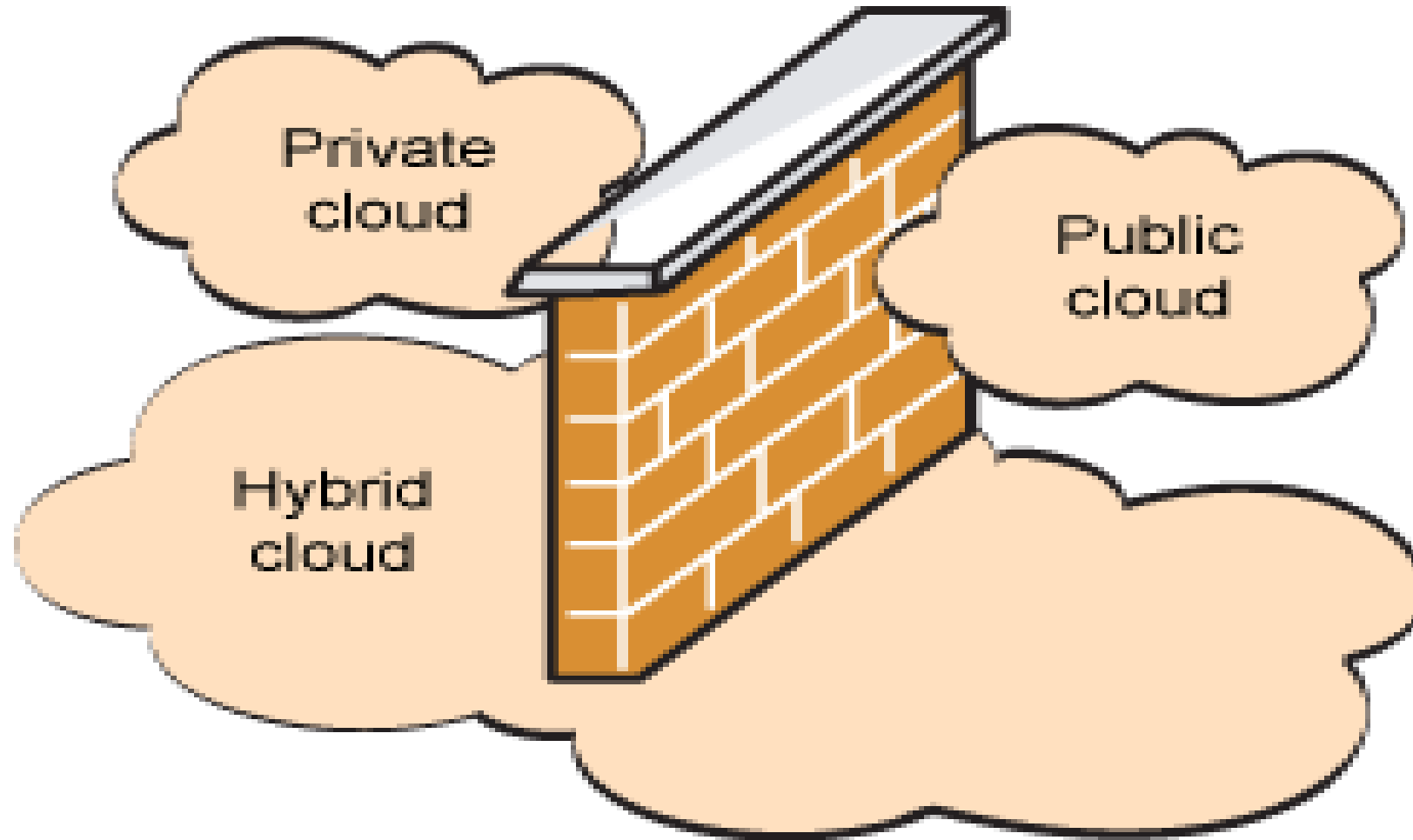| Public	Private	Hybrid
You don't know who else is on the same server, network or disk that you are	You own the server, network and disk, and decide who gets to run on it with you	You own some parts and are sharing some parts, though in a controlled way

Public, Private and Hybrid clouds

Enterprise firewall

Private cloud

Public cloud

Hybrid cloud

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Cloud Service Examples

- IaaS:
  - Amazon EC2, S3 etc.
  - Google Compute Engine, IBM Blue house, VMWare
  - Windows Azure VMs

- PaaS:
  - Google AppEngine, AWS, IBM Virtual images, Boomi, CastIron,
  - Microsoft Azure
  - Salesforce.com

- SaaS:
  - Salesforce,Gmail, GoogleCalender, IBM Lotus Live
  - Google Docs
  - Zoho

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Windows Azure

- Enterprise-level on-demand capacity builder
- Fabric of cycles and storage available on-request for a cost
- You have to use Azure API to work with the infrastructure offered by Microsoft
- Significant features: web role, worker role , BLOB storage, table and drive-storage

Amazon EC2

- Amazon EC2 is one large complex web service.

- EC2 provided an API for instantiating computing instances with any of the operating systems supported.

- It can facilitate computations through Amazon Machine Images (AMIs) for various other models.

- Signature features: S3, Cloud Management Console, MapReduce Cloud, Amazon Machine Image (AMI)

- Excellent distribution, load balancing, cloud monitoring tools

Google App Engine

- This is more a web interface for a development environment that offers a one stop facility for design, development and deployment Java and Python-based applications in Java, Go and Python.

- Google offers the same reliability, availability and scalability at par with Google's own applications

- Interface is software programming based

- Comprehensive programming platform irrespective of the size (small or large)

- Signature features: templates and appspot, excellent monitoring and management console

Cloud Software Suite and SaaS Applications for Businesses
Over 30 million users trust Zoho worldwide

Run your entire business with Zoho's suite of online productivity tools and SaaS applications. Get your work done from any browser, from anywhere.

AWARD WINNING APPS

CRM
A multichannel approach to modern sales processes.
Read More

Inventory
A centralized inventory management system for distributed sales channels like retail store, online shop, or marketplaces like Amazon or eBay.
Read More

Desk
multi-channel help desk that helps you prioritize

Recruit
Find new talent to grow your company. Designed for
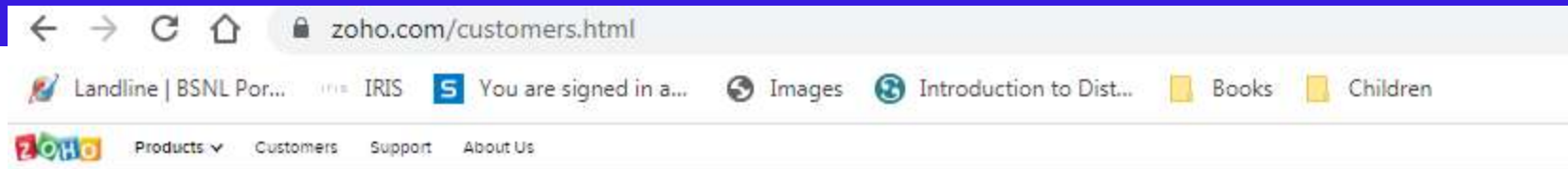
People
A central place to manage your employees, including

56

$ ₹

15-day free trial. No credit card required.

		MOST POPULAR	
STANDARD	**PROFESSIONAL**	**ENTERPRISE**	**ULTIMATE**
₹720	₹1200	₹2100	₹6000
Per user/month billed annually	Per user/month billed annually	Per user/month billed annually	Per user/month billed annually
₹900 month-to-month	₹1500 month-to-month	₹2400 month-to-month	plus tax, as applicable
plus tax, as applicable	plus tax, as applicable	plus tax, as applicable	
BEGIN FREE TRIAL	**BEGIN FREE TRIAL**	**BEGIN FREE TRIAL**	**CONTACT US**
Includes all features in Free Edition +	Includes everything in Standard +	Includes everything in Professional +	Includes everything in Enterprise +
Sales forecasting	Email integration	Territory management	Sandbox
Scoring rules	Social CRM	Zia - Artificial intelligence	Dedicated Database cluster
Reports and dashboards	Google AdWords integration	Custom buttons	Priority support
Document library	Workflows and Macros	Blueprint	Advanced customization
Roles and profiles	Inventory management	Conditional fields	Advanced CRM analytics
Mass email	Unlimited records	Page layouts	Enhanced storage
Call center connectors		Custom modules	
100,000 records		Multiple currencies	

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Cloud Computing Applications

- Banking & Financial Apps

- E-Commerce Apps

- Social Networking

- Healthcare Systems

- Energy Systems

- Intelligent Transportation Systems

- E-Governance

- Education

- Mobile Communications

If Cloud Computing is so great, why isn't everyone doing it?

- The cloud acts as a big black box, nothing inside the cloud is visible to the clients
- Clients have no idea or control over what happens inside a cloud
- Even if the cloud provider is honest, it can have malicious system admins who can tamper with the VMs and violate confidentiality and integrity
- Clouds are still subject to traditional data confidentiality, integrity, availability, and privacy issues, plus some additional attacks

What cloud computing means to service provider?

- Fast Provision
- Reduce servers scale
- Increase resource utilization rate
- Improve management efficiency
- Lower maintenance cost
- Location of infrastructure in areas with lower costs of real estate and electricity
- Provide business continuity service
- Improve management efficiency
- Improve service levels
- Complex architecture
- Change of business model and faith

What cloud computing means to users?

- Lower client workload
- Lower Total Cost Ownership
- Separation of infrastructure maintenance duties from domain-specific application development
- Separation of application code from physical resources
- Not have to purchase assets for one-time or infrequent intensive computing tasks
- Expand resource on-demand
- Make the application have high availability
- Quickly deploy application
- Pay per use – Utility computing model

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Embracing the Cloud

- Benefits
  - Infinite compute resource available on demand
    - Hardware virtualization
  - Accessibility anytime and anywhere
    - Internet (web based) access
  - Elimination of the upfront commitment of users
    - Reduced costs due to dynamic hardware provisioning
    - Pay per use basis (and also other models)
    - No need to plan for peak load in advance
  - Easy management
    - Software versioning and upgrading

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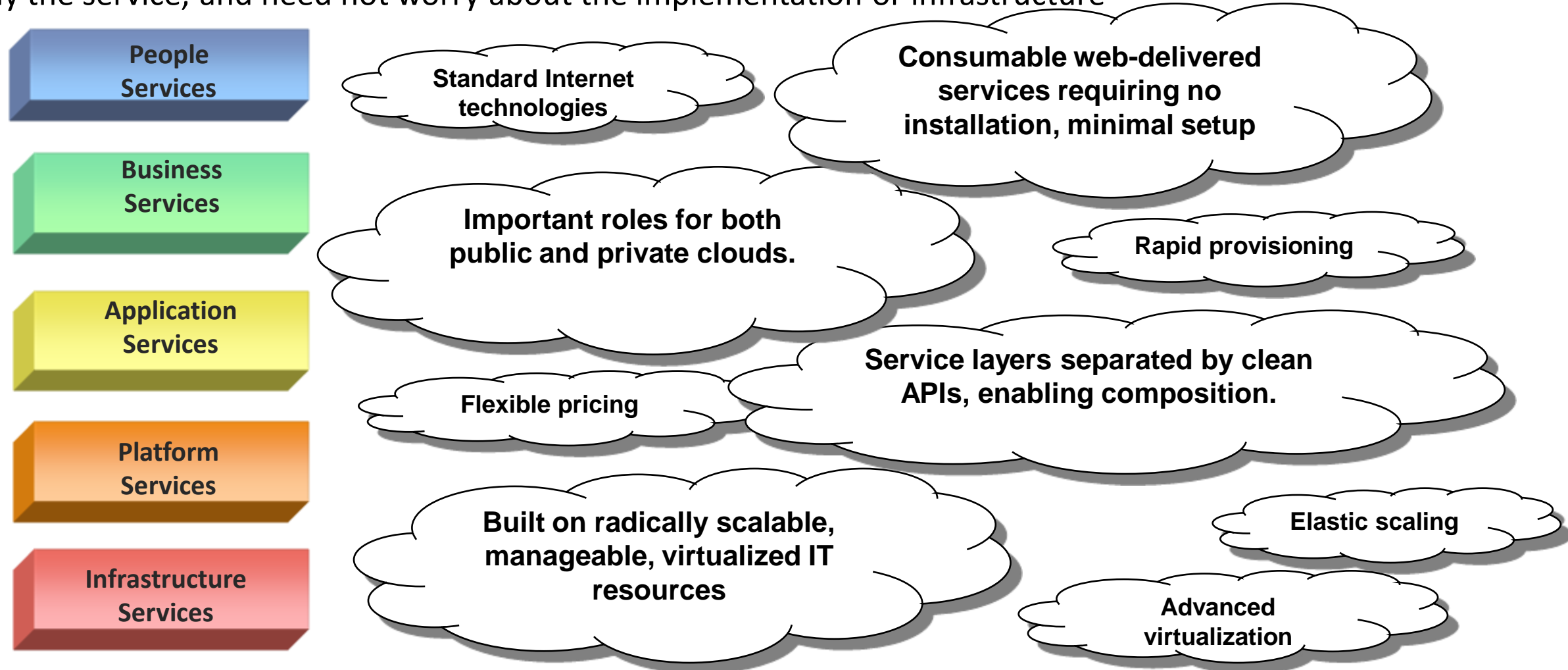
Embracing the Cloud

- Migration Risks
  - Privacy
    - Who access your data?
  - Security
    - How much you trust your provider?
    - What about recovery, tracing, and data integrity?
  - Political and legal issues
    - Who owns the data?
    - Who uses your personal data?
      - Government
    - Where is your data?
      - Amazon Availability Zones

Will it be fitting for me?

Cloud Computing is a model of shared network-delivered services, both public and private, in which the user sees only the service, and need not worry about the implementation or infrastructure

People Services

Business Services

Application Services

Platform Services

Infrastructure Services

Standard Internet technologies

Consumable web-delivered services requiring no installation, minimal setup

Important roles for both public and private clouds.

Rapid provisioning

Flexible pricing

Service layers separated by clean APIs, enabling composition.

Built on radically scalable, manageable, virtualized IT resources

Elastic scaling

Advanced virtualization

End of the chapter

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