



15CSE337

Cloud Computing and Services

Lecture 1

Course Introduction

Dr Ganesh Neelakanta Iyer

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About Me



- Associate Professor, Amrita Vishwa Vidyapeetham
- Masters & PhD from National University of Singapore (NUS)
- Several years in Industry/Academia
- Architect, Manager, Technology Evangelist, Visiting Faculty
- Talks/workshops in USA, Europe, Australia, Asia
- Cloud/Edge Computing, IoT, Software Engineering, Game Theory, Machine Learning
- Kathakali Artist, Composer, Speaker, Traveler, Photographer



GANESHNIYER

<http://ganeshniyer.com>



Why did you choose this course?



What do you expect from this course?



Have you used any Cloud systems?



ABOUT THIS COURSE...



Outline of the course

- Understand the basics of Cloud computing
 - Types of Cloud
 - Virtualization and Containerization (Dockers)
 - Microservices, Kubernetes
 - Understand popular Cloud systems such as AWS
- Learn related technologies which helps you learn web scale programming for Cloud and beyond
 - Javascript-native Application Development
 - Node.js, MongoDB, ExpressJS, React



Mode of delivery

- Lecture classes
- Practical hands-on
 - Request you to bring your laptops in the classes from next class onwards
 - Mobile data connections to be used for accessing internet
 - To start with, have Visual Studio Code / Atom or any of your favorite JS editor setup in your computer to experiment JavaScript based application development



Evaluation Pattern

Evaluation mechanism	Weightage
Periodical 1	20%
Periodical 2	20%
Continuous Evaluation	30%
End-semester examination	30%



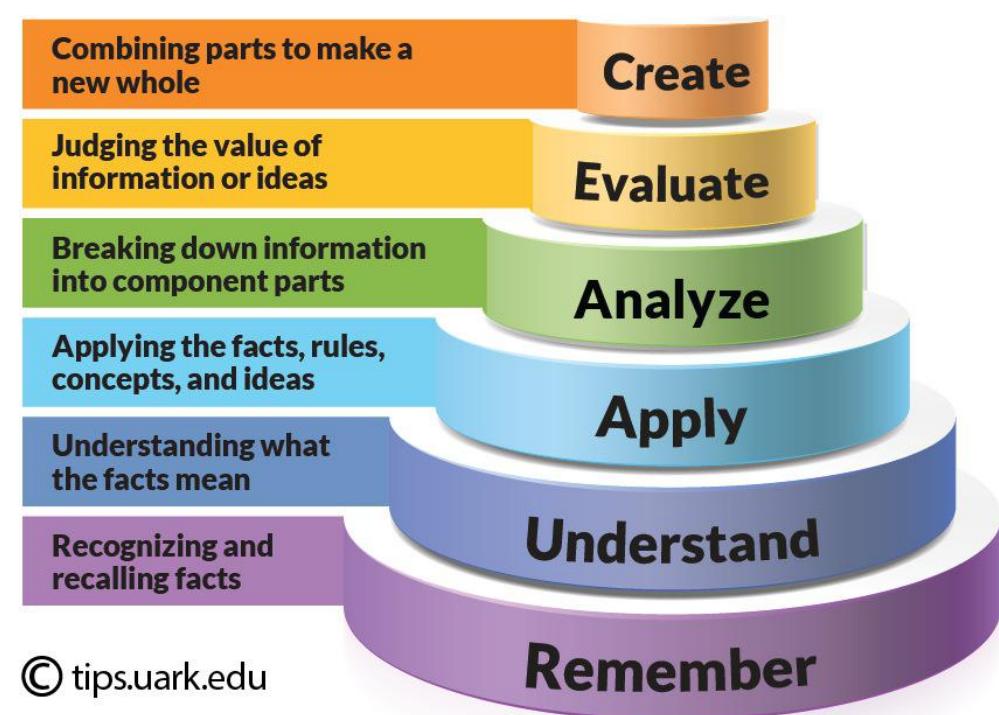
Pre-requisites

- Need to
 - Know how to use google efficiently ☺
 - Bring your laptops to classes and labs
 - Have your data connection ready to explore the world
- Willingness to
 - Learn a lot of new technologies that shape the future
 - Do a lot of experiments of your own at your spare time



Course outcomes

CO No	Course Outcome Description	BTL
CO1	Understand the basic principles of cloud computing	L2
CO2	Learn how Cloud Native application development happens	L3
CO3	Apply cloud native application development for containerization and container orchestration	L3
CO4	Distinguish different types of cloud services – Delivery models, Deployment models	L4
CO5	Implement different solution approaches in Cloud – containers in public cloud, setting up private cloud and convert monolithic applications to containers	L3





Tentative Course Plan – Before P1

Lecture No(s)	Topics	Key-words	Objectives
1-2	Basics of Cloud Computing	Definition, usage scenarios and applications, benefits of cloud, types of clouds, multi-tenancy, elasticity, resiliency, data center	To understand the basics of Cloud Computing and its related terms.
3-5	Cloud Computing Services	Cloud Delivery Models - Infrastructure as a Service, Platform as a Service, Software as a Service; Cloud Deployment Models – Public, Private, Hybrid Community	To learn about various types of services in cloud computing
6-11	JavaScript Cloud native development – Client side and DB connection	Overview of JavaScript, Client side JavaScript - React	To develop and deploy cloud applications using a MERN stack
12-16	JavaScript Cloud native development - server-side	server-side JavaScript in Node.js platform using Express.js framework, Database Application - MongoDB	To develop and deploy an cloud applications using a MERN stack
17	Use cases, Challenges	Disadvantages of cloud, best practices, security	Characteristics of Cloud, Major use cases of Cloud; disadvantages and best practices; Major public cloud players in the market; Security Issues and challenges;



Tentative Course Plan – P1-P2

Lecture No(s)	Topics	Key-words	Objectives
18-23	Public Cloud Infrastructure	EC2, S3, RDS	To learn On demand public cloud Services
24-29	Public Cloud – Beyond infrastructure	Elastic Beanstalk, Lamda	Use on-demand computing resource offered by public cloud in terms of function-as-a-service
30-31	Virtualization	Basics, Cloud vs Virtualization, Virtualization in Cloud Computing, Types of virtualization	To understand how cloud helps in providing Resource Isolation, Resource sharing, Aggregation of resources, and Dynamical resource
32-36	Containerization	Docker, Docker-Images, Pull and Push Images	Containers – Introduction to dockers and containers, containerization vs virtualization, docker architecture, Use cases, Learn how to build container images, Operations on container images;



Tentative Course Plan – After P2

Lecture No(s)	Topics	Key-words	Objectives
37-41	Container Orchestration	Kubernetes	To design our own cluster and Manage Containers with an Isolated and Secure App Platform.
42-45	Microservices	Introduction, Microservice architecture, Introduction to Design patterns for Microservices	Facilitate creating each application as set of services, where each service can be accessed through Application Programming Interfaces (API)
46-49	Containers in Public Cloud	ECS, ECR	To use fully-managed Docker container services extended by public cloud
50-54	Use case study in containers and Microservices	-	Use case on Microservices using containerization and scaling them through Kubernetes
Self-study	Open Stack Case study		



Materials

- No single text book for the course
- Primary reference shall be the materials used in the class
- Supplement materials will be given
- Make Google your best friend



Time and Location

- Classes @ C302
 - Monday 1440-1530
 - Tuesday 1210-1300
 - Thursday 1210-1300
- Lab
 - Thursday 0840-1110 @ABII, GF CPLab2
- Office Hours
 - Thursday 1350-1440 @ My office (GF 3rd Office room)



Important points

- Need to maintain an evaluation book to keep track of all lab experiment evaluations
 - Either write your code/results and evaluation scheme
 - Or print expected matter and paste it in the book
- Any discussions/meetings for the course related matter should be during office hours scheduled
 - Thursday 1350-1440 @ My office (GF 3rd Office room)



DISTRIBUTED SYSTEMS – TAXONOMY

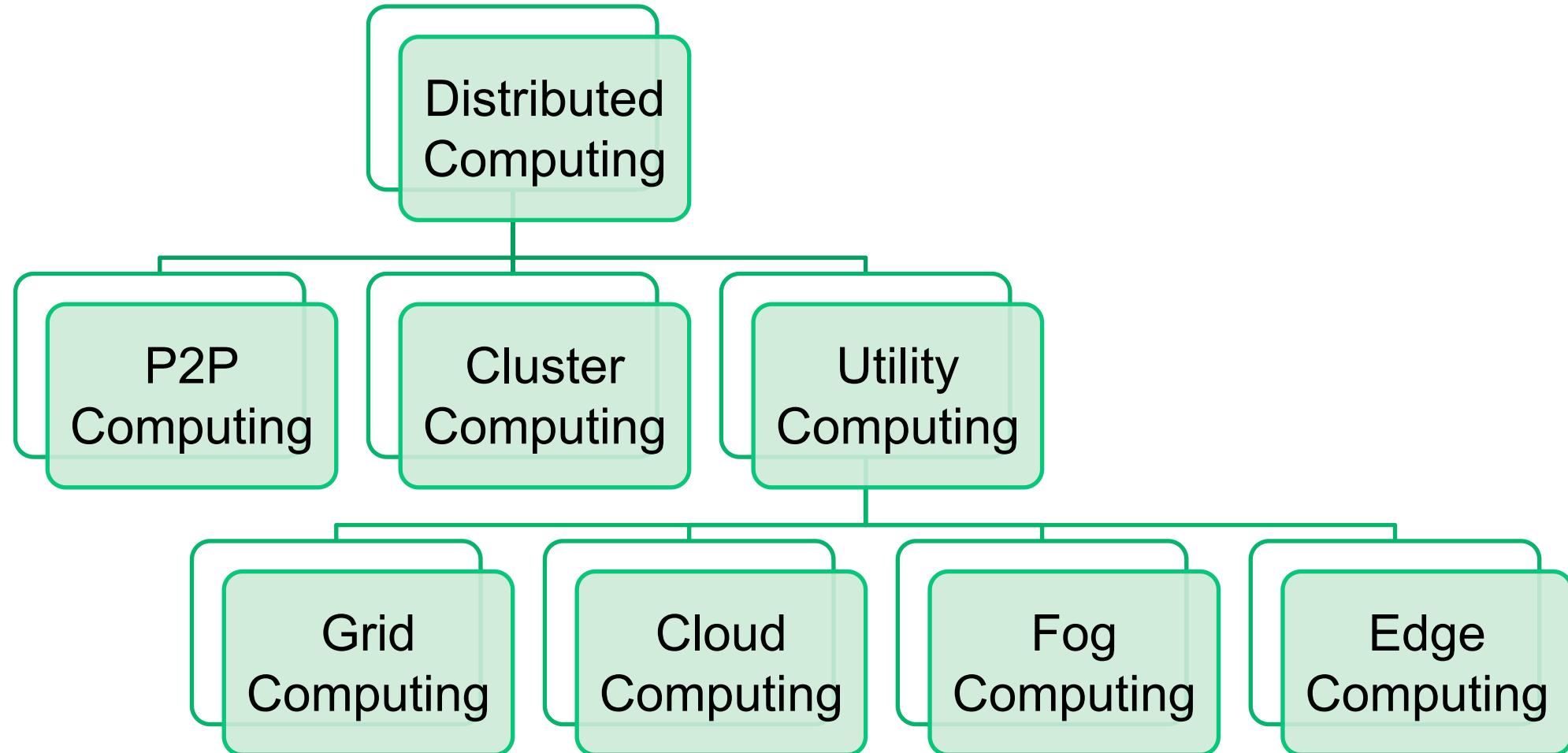
Distributed Computing

- A method of computer processing in which different parts of a program are executed simultaneously on two or more computers that are communicating with each other over a network is termed distributed computing
- Three significant characteristics
 - concurrency of components
 - lack of a global clock and
 - independent failure of components.





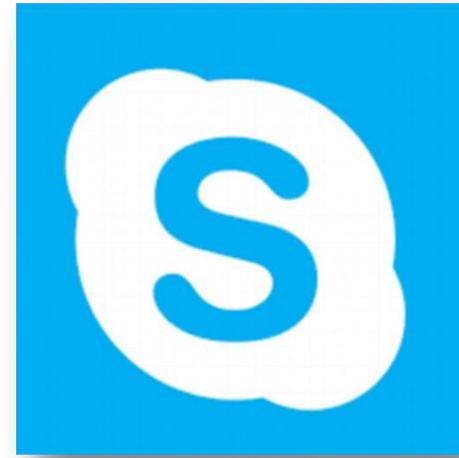
Taxonomy of Distributed Computing





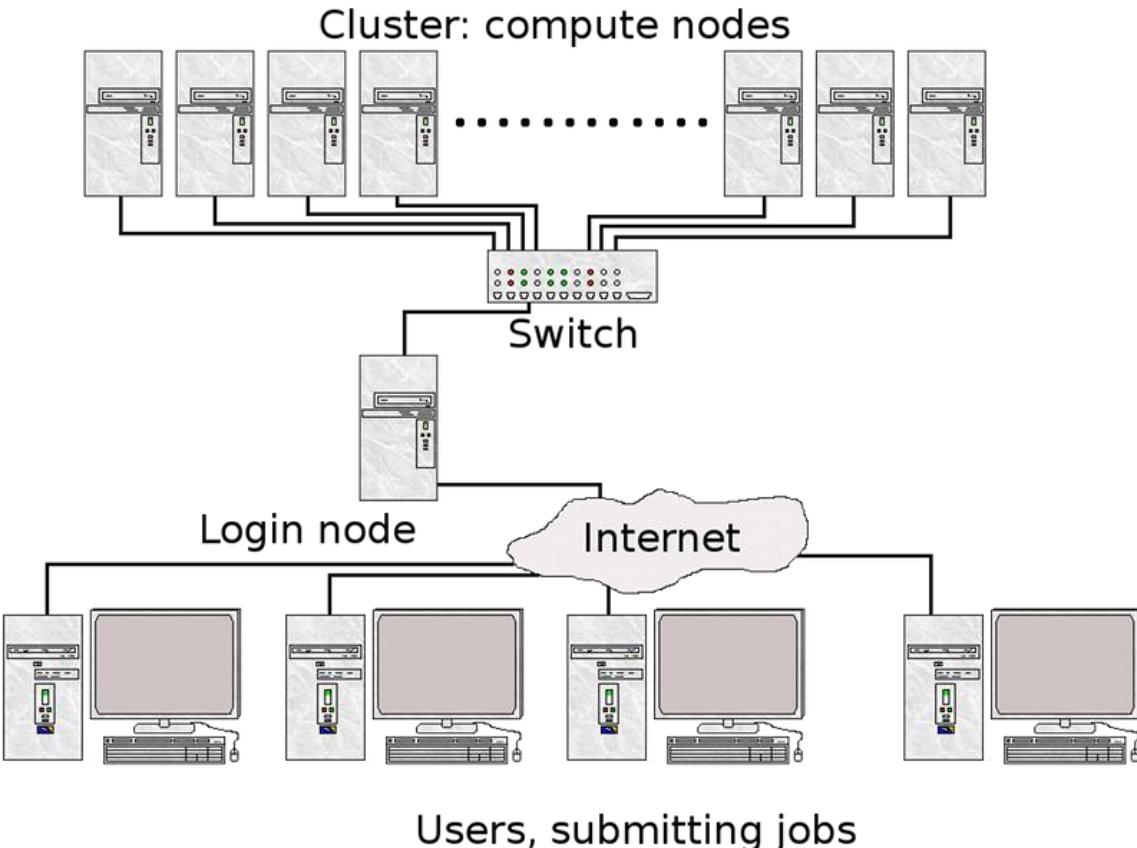
P2P computing

- Peer-to-peer (**P2P**) **computing** or networking is a distributed application architecture that partitions tasks or workloads between peers
- Peers are equally privileged, equipotent participants in the application.



Cluster Computing

- Cluster computing consists of a collection of interconnected standalone computers cooperatively working together as a single integrated computing resource to take advantage of the parallel processing power of those standalone computers
- Clustered computer systems have proven to be effective in handling a heavy workload with large datasets
- Deploying a cluster increases performance and fault tolerance
- E.g. - Sony PlayStation clusters and Microsoft Xbox clusters





Utility Computing

- Utility computing is a service provisioning model in which a service provider makes computing resources and infrastructure management available to the customer as per the need, and charges them for specific usage rather than a fixed rate





Grid Computing

- Computing grid offers an infrastructure that couples computers, software/middleware, special instruments and people and sensors together
- The grid is often constructed across LAN, WAN or even internet backbone networks at a regional, national or global scale





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Thank
you!



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Cloud Computing and Services

Lecture 2

**Taxonomy of distributed computing,
Introduction to Cloud Computing**

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What is Cloud Computing?



Cloud Computing - A vision to reality

Three decades ago, John Gage (Sun Microsystems) made the prophetic statement that:

“The network is the computer.”

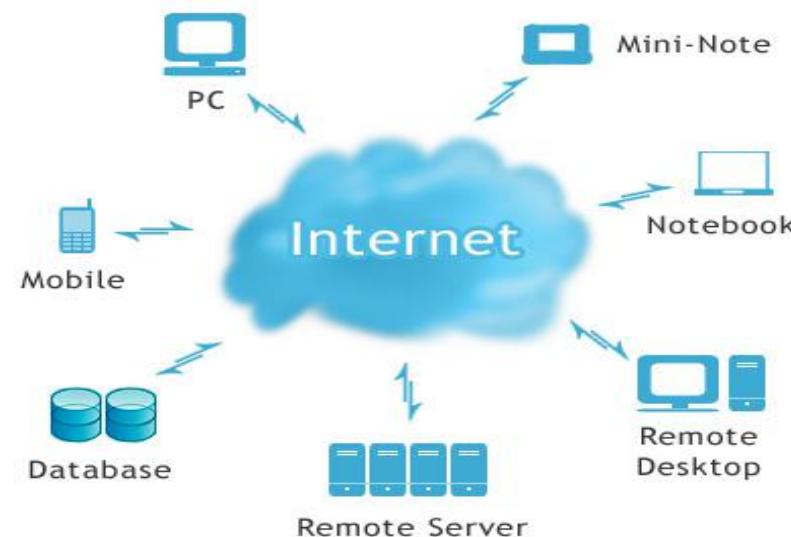
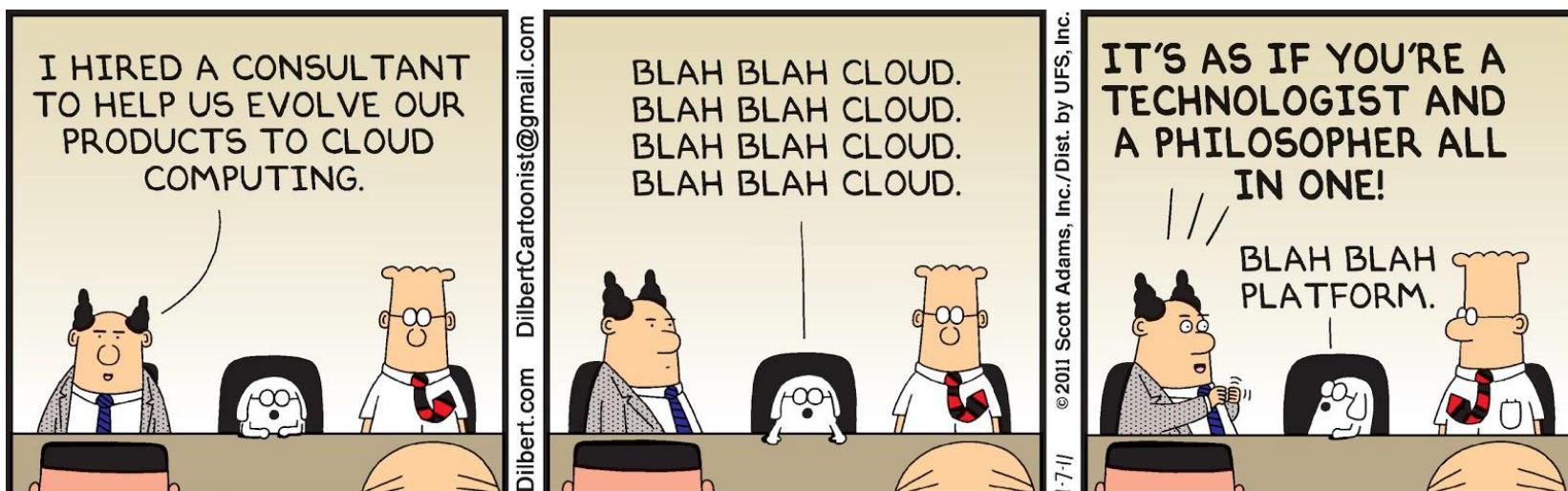
Twenty-five years later, the advent of Cloud Computing has finally made this a reality.





Definition of Cloud Computing

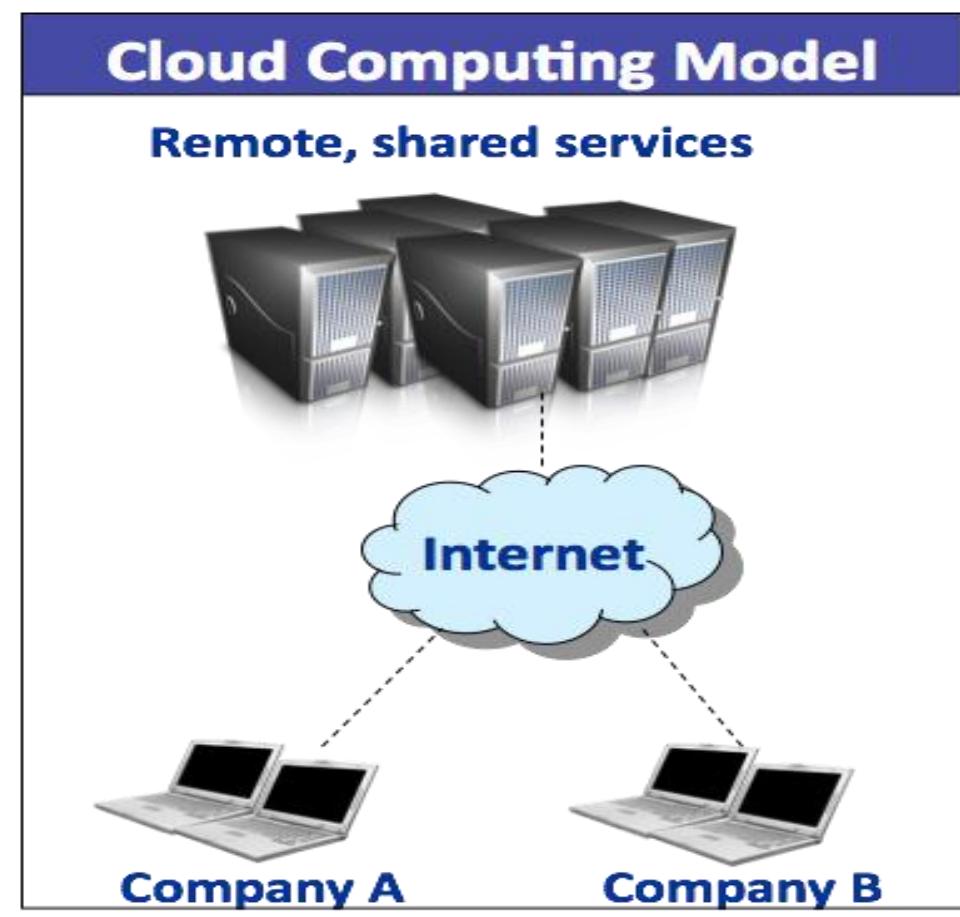
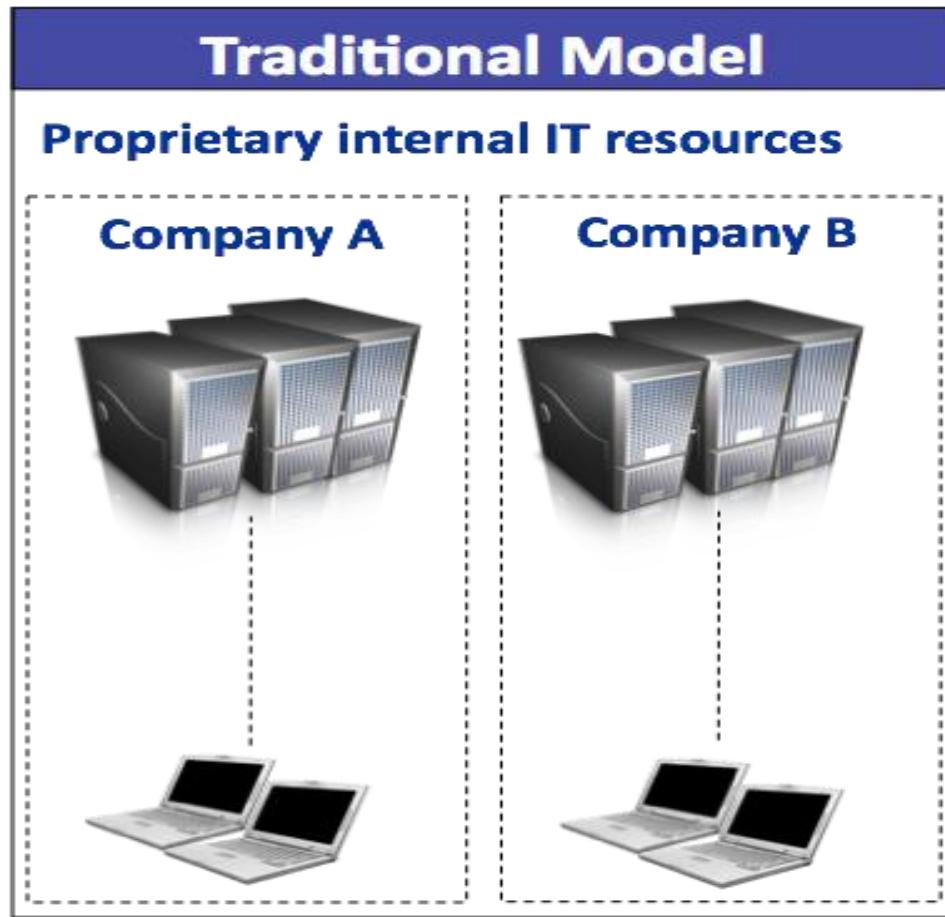
NIST defines Cloud Computing as¹: “Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.”



<http://cloudcomputingcompaniesnow.com/>

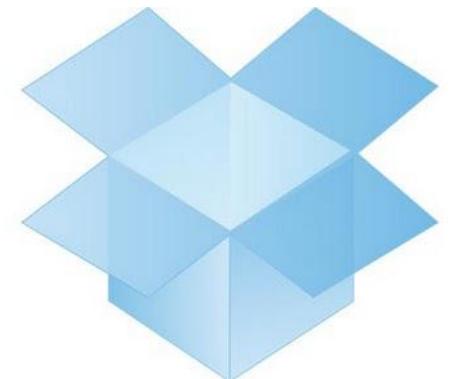


Business Model: Conventional vs Cloud





Some examples from your daily life....



Dropbox



Coursera



YouTube™



Cloud Delivery Models....

Cloud Service Models

Software as a Service
(SaaS)

A software distribution model in which applications are hosted by a service provider and made available to customers over Internet

Platform as a Service
(PaaS)

A way to rent resources (e.g. hardware, operating systems etc) over the Internet. The service delivery model allows the customer to rent virtualized servers and associated services for running existing applications or developing and testing new ones.

Infrastructure as a Service
(IaaS)

A provision model in which an organization outsources the equipment used to support operations, including storage, hardware, servers and networking components.

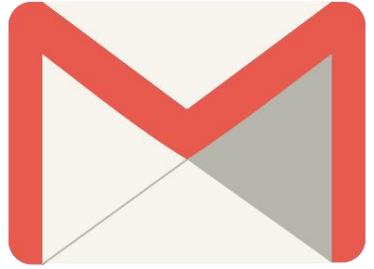




SaaS

- Software as a service
- Ready made software which can be altered to suit your requirements
- Often delivered from a public server (public cloud)





A more human resource.™



Payroll



Cisco



Adobe®
Creative Cloud™



Office 365



SaaS: Starbucks

Starbucks wanted to know what customers think about them

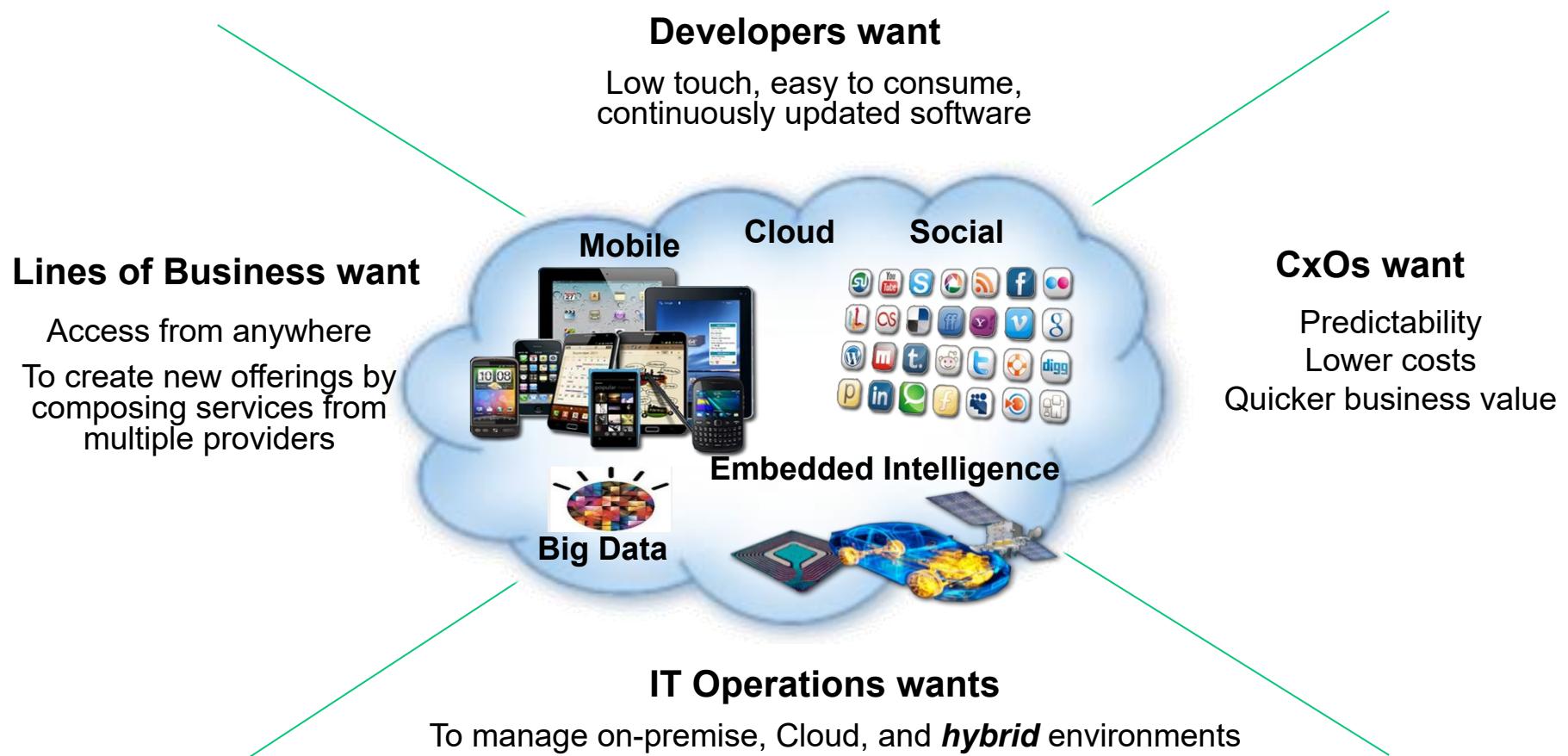
- Wanted a quick customized CRM application
- Starbucks used Salesforce's Force.com service to quickly build out websites that tie into new customer campaigns, as the coffee giant attempts to transform it business





What is driving the move to SaaS?

Market dynamics and disruptive technologies are driving the shift to SaaS consumption models





IaaS

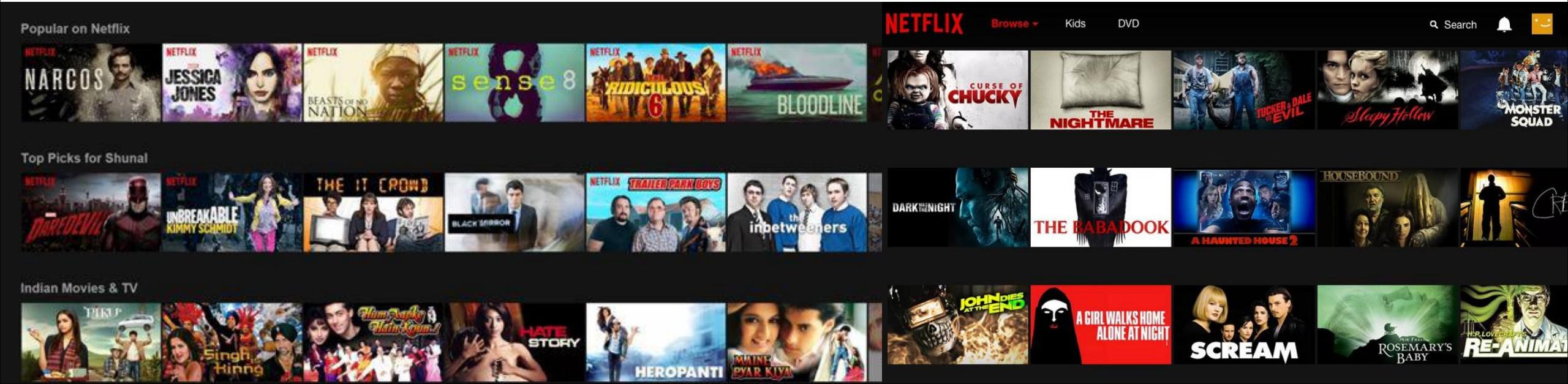
- Raw infrastructure provided to users
 - Compute resources
 - Storage
 - Database
- Users can do whatever they want to on that IaaS offering



IaaS: Netflix



- Needed an infrastructure to manage heavy lifting – Off load all infrastructure complexity
- AWS helped achieve scalability, productivity, adapt to new features
- Netflix now: 86M users, 190 countries, 150M hours of streaming per day, 3 AWS regions and 12 availability zones, 100,000+ AWS instances





PaaS

- Platform as a service (PaaS) is a complete development and deployment environment in the cloud, with resources that enable you to deliver everything from simple cloud-based apps to sophisticated, cloud-enabled enterprise applications
- You purchase the resources you need from a cloud service provider on a pay-as-you-go basis and access them over a secure Internet connection
- Like IaaS, PaaS includes infrastructure—servers, storage and networking—but also middleware, development tools, business intelligence (BI) services, database management systems and more
- PaaS is designed to support the complete web application lifecycle: building, testing, deploying, managing and updating

PaaS: Dominos

For Dominos, already more than 60 per cent of orders come through the online system. Scalability and availability are crucial

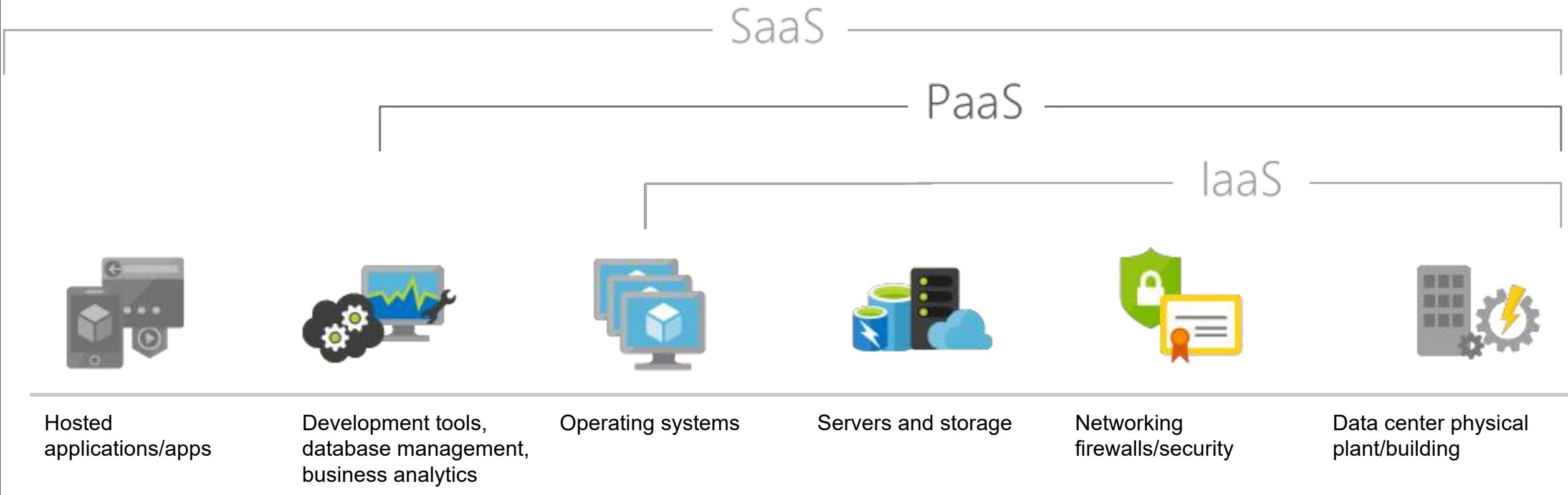


- Underpinning that is a highly scalable, robust, reliable platform that can be deployed right around the world, reaching each and every customer wherever they are and whenever they want us
- All their core business systems – their digital ordering systems, Dynamics ERP, back office operations and supply chain systems – are in Microsoft cloud platform.





Cloud Delivery Models in a nutshell



Characteristics of Cloud



1. On-demand self service

- Cloud computing resources can be provisioned without human interaction from the service provider
- In other words, a customer can provision additional computing resources as needed without going through the cloud service provider
- This can be a storage space, virtual machine instances, database instances, and so on



2. Broad network access



- Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, tablets, laptops, and workstations)
- Network bandwidth and latency are very important



3. Multi-tenancy and resource pooling

- Multi-tenancy allows multiple customers to share the same applications or the same physical infrastructure while retaining privacy and security over their information
- Resource pooling means that multiple customers are serviced from the same physical resources
- Providers' resource pool should be very large and flexible enough to service multiple client requirements and to provide for economy of scale.





4. Rapid elasticity and scalability

- Ability to quickly provision resources in the cloud as customer need them
- And then to remove them when they don't need them
- Cloud computing resources can scale up or down rapidly and, in some cases, automatically, in response to business demands
- Elasticity means rapidly provision and de-provision any of the cloud computing resources





5. Measured Service

- Ability to quickly provision resources in the cloud as customer need them
- And then to remove them when they don't need them
- Cloud computing resources can scale up or down rapidly and, in some cases, automatically, in response to business demands
- Elasticity means rapidly provision and de-provision any of the cloud computing resources

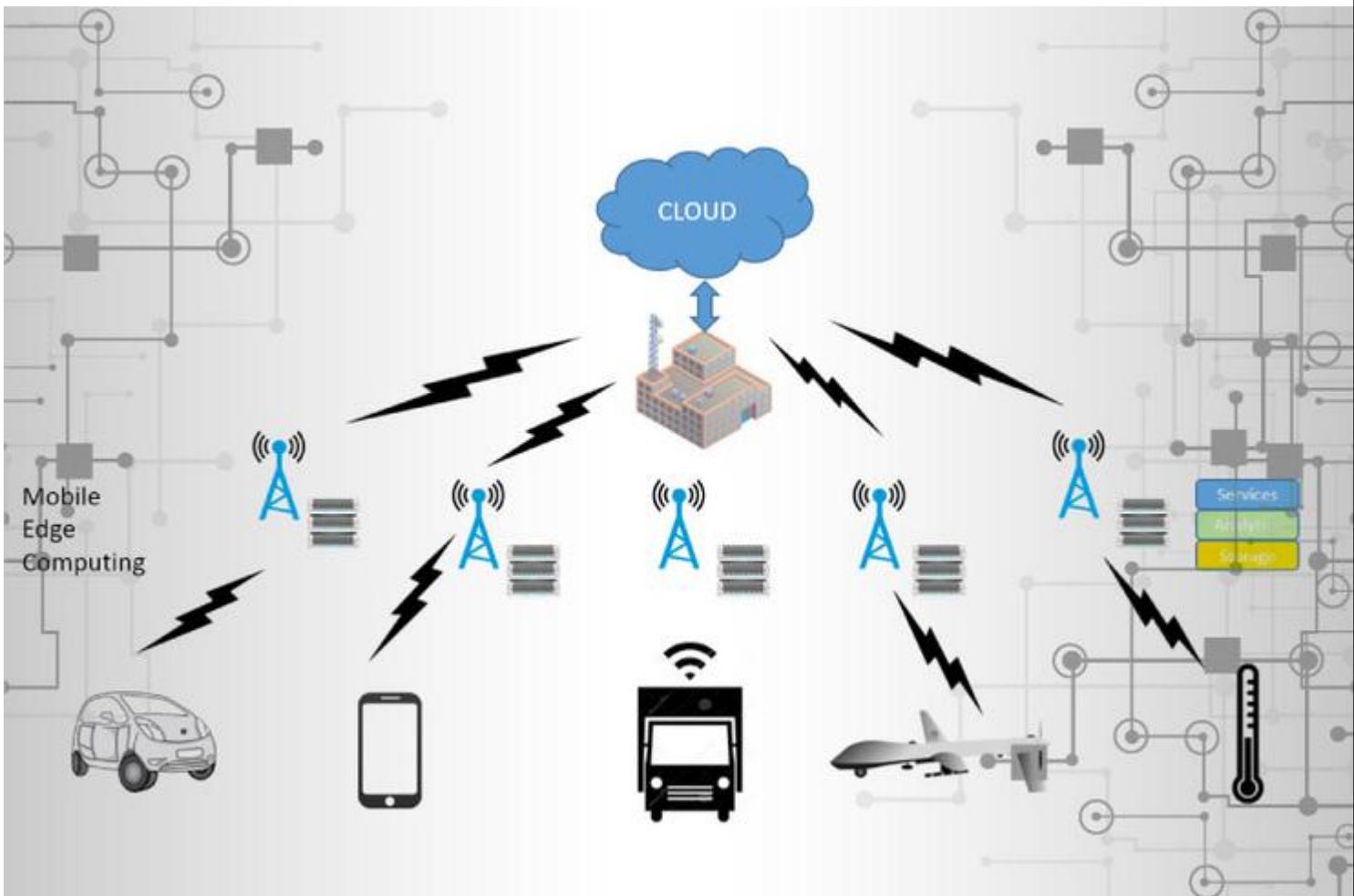




EDGE AND FOG COMPUTING

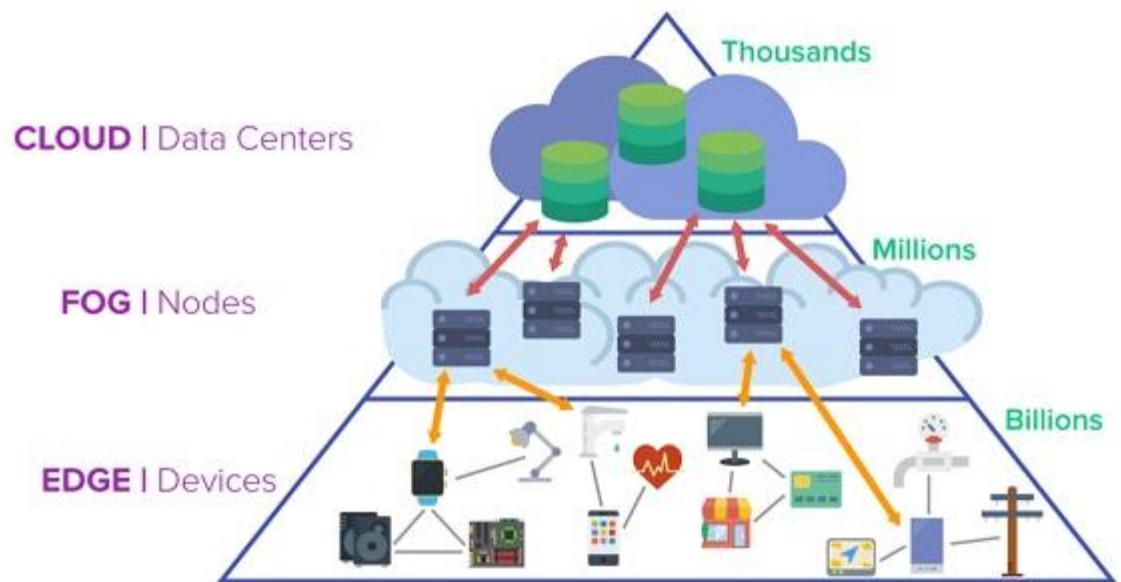
Edge Computing

- Edge computing is a method of optimizing cloud computing systems "by taking the control of computing applications, data, and services away from some central nodes (the "core") to the other logical extreme (the "edge") of the Internet" which makes contact with the physical world - Wikipedia



Fog Computing

- **Fog computing** pushes intelligence down to the local area network (LAN) level of network architecture, processing data in a fog node or IoT gateway
- **Edge computing** pushes the intelligence, processing power, and communication capabilities of an edge gateway or appliance directly into devices
- Cisco created the term fog computing years ago to describe a layer of computing at the edge of the network that could allow pre-processed data to be quickly and securely transported to the cloud.





Closing note

- Computing paradigms continues to emerge
- Each one to be chosen based on what we are trying to achieve
- Cloud computing has made a strong influence in the way current day software development and software management happens



CLOUD DEPLOYMENT MODELS



Deployment

deployment

dɪ'plɔɪm(ə)nt/

Noun

1. the movement of troops or equipment to a place or position for military action.

"the authorities announced deployment of extra security forces in towns and cities to prevent violence"

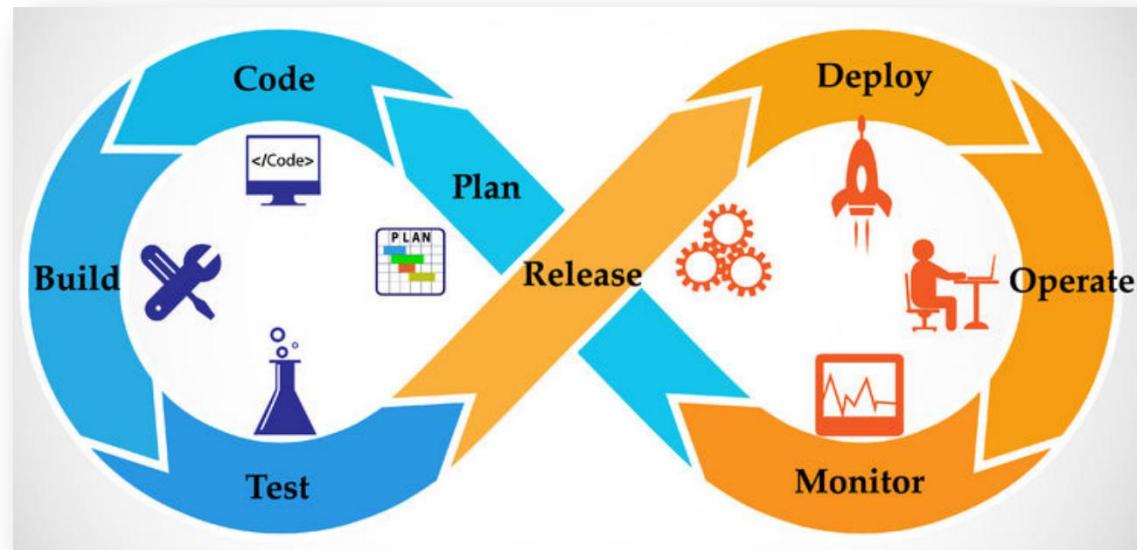
2. the action of bringing resources into effective action.

"the rapid deployment of high-speed cable Internet services to consumers"



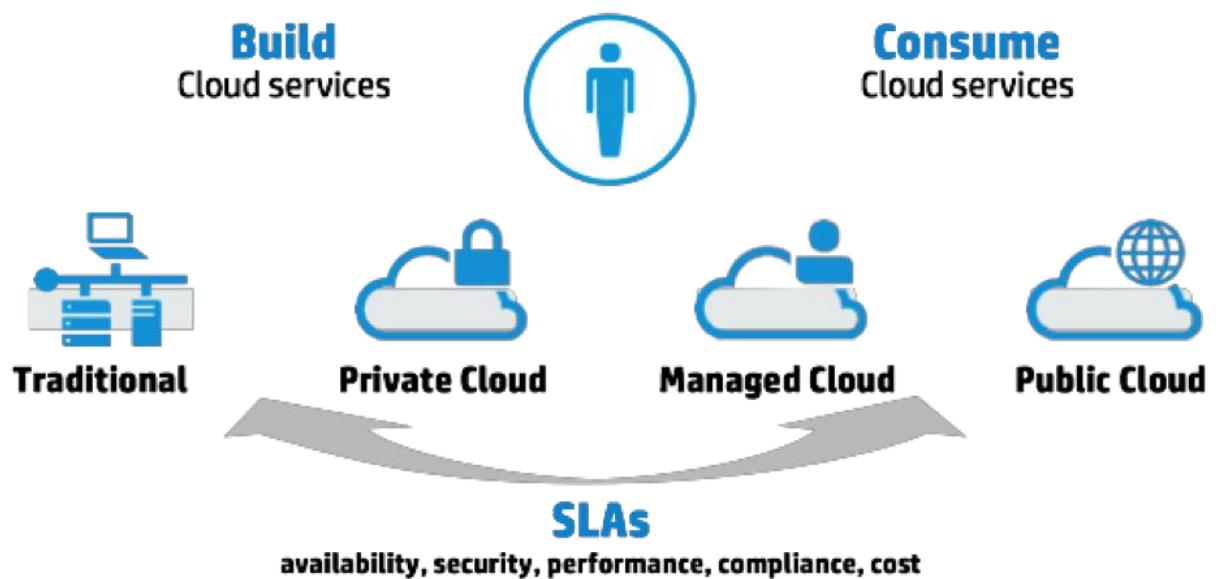
Software Deployment

- Software deployment is all of the activities that make a software system available for use
 - Get the software out to the customers
 - Creating Installation Packages
 - Documentation – Installation Guide etc
- Deployment strategies may vary depending of what kind of software we create (Web, Desktop, Mobile), , etc.



Cloud Deployment models

- Cloud allows you to deploy your applications in multiple ways





Public Cloud

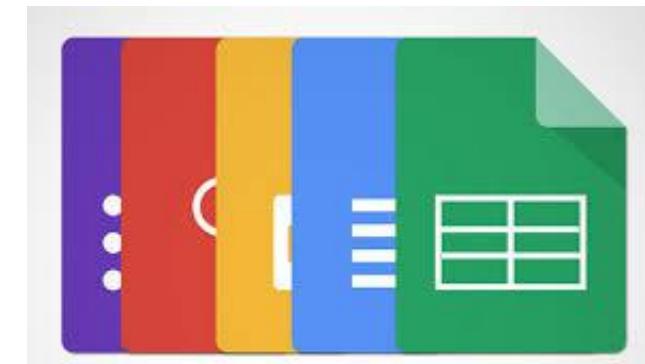
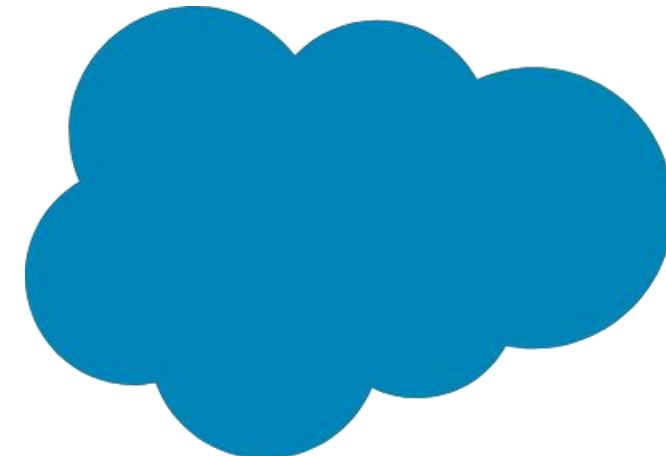
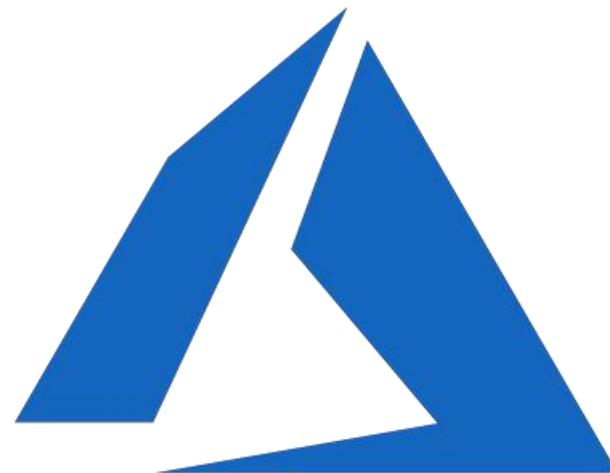
- The public cloud is defined as computing services offered by third-party providers over the public Internet, making them available to anyone who wants to use or purchase them
- They may be free or sold on-demand, allowing customers to pay only per usage for the CPU cycles, storage or bandwidth they consume
- Using public cloud services generates the types of economies of scale and sharing of resources that can reduce costs and increase choices of technologies.



GK QUIZ TIME...



Identify the logo...





Public Cloud - Features

- Cloud is open to the wide public
- Offers solutions for minimizing IT infrastructure costs
- Multi-tenancy is key
- A public cloud can offer any kind of services
- Most likely one or more datacenters constitutes the physical infrastructure
- Pay as you use



Public Cloud - concerns

- Loss of control – Provider has full control on the infrastructure and the data lying there
- Security
- Regulatory issues



Private Cloud

- Virtual distributed systems that rely on a private infrastructure and provide internal users with dynamic provisioning of computing resources
- Core business operations are in-house
- Key advantages
 - Customer information protection
 - Infrastructure ensuring SLAs
 - Compliance with standard procedures and operations
- Major drawback – Inability to scale elastically on-demand

PUBLIC VS PRIVATE

Publicly Shared
Virtualized Resources



Supports Multiple
Customers



Supports Internet
Connectivity



Suited for Less
Confidential Information



Privately Shared
Virtualized Resources

Cluster of Dedicated
Customers

Connectivity Over Internet,
Fiber, and Private Network

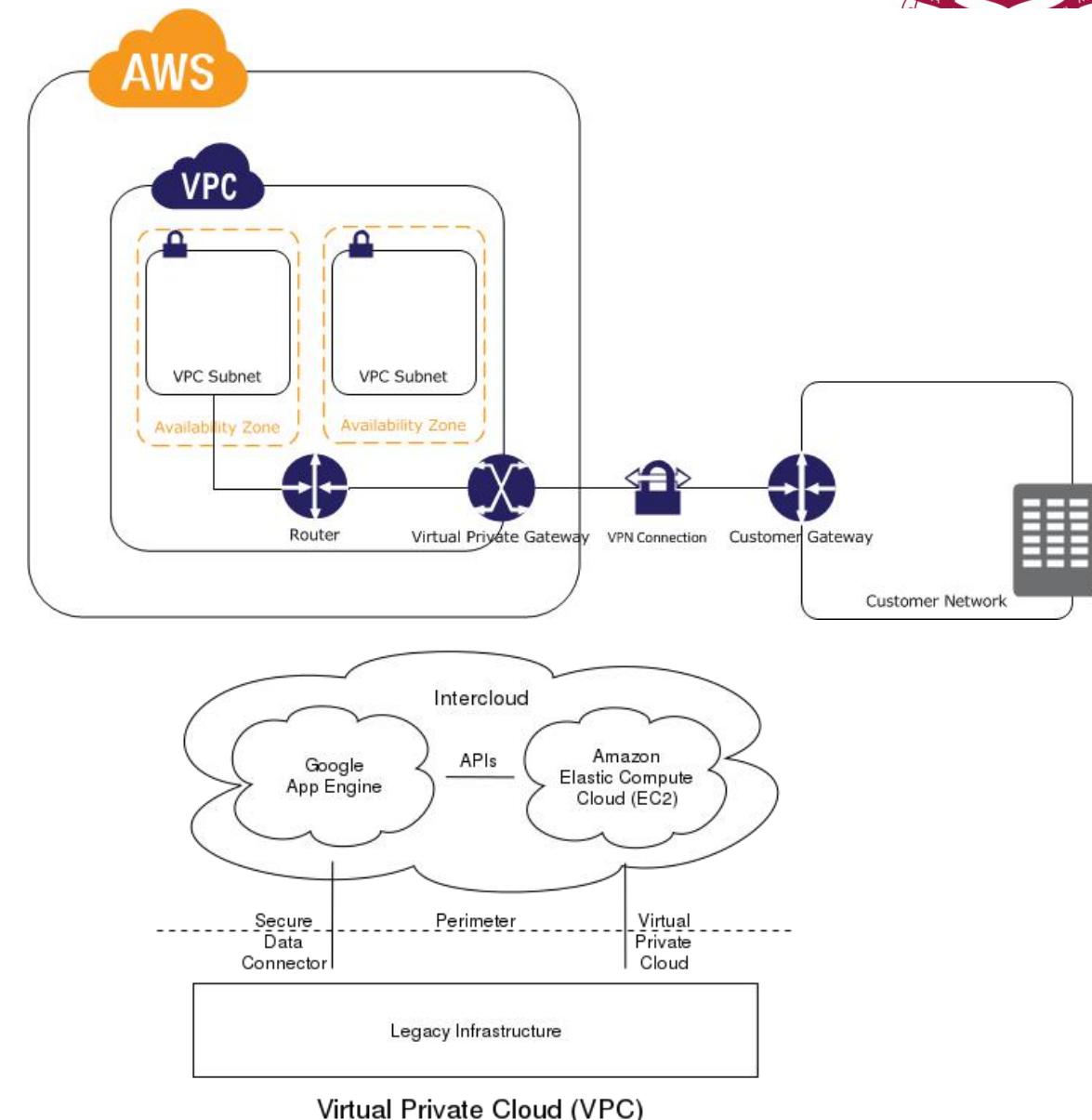
Suited for Secured
Confidential Information and
Core Systems



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Virtual Private Cloud

- On-demand configurable pool of shared computing resources allocated within a public cloud environment, providing a certain level of isolation between the different organizations using the resources
- In a VPC, providing isolation within the cloud, is accompanied with a VPN function that secures, by means of authentication and encryption, the remote access of the organization to its VPC cloud resources





Community Cloud

- A community cloud is a cloud service model that provides a cloud computing solution to a limited number of individuals or organizations that is governed, managed and secured commonly by all the participating organizations or a third party managed service provider





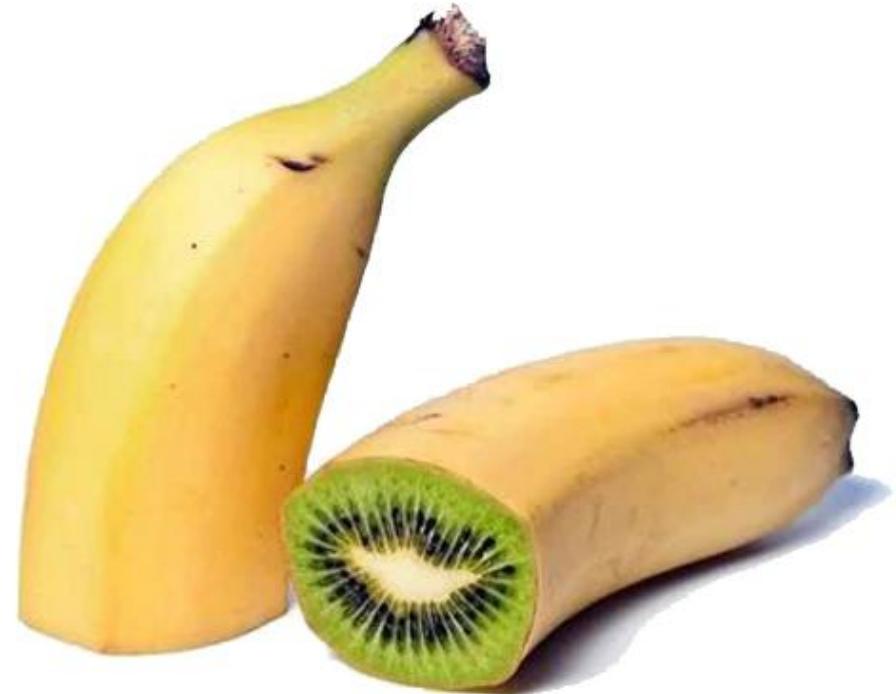
Examples

- **QTS Healthcare Community Cloud**
- Healthcare Community Cloud provides a solution for people at different endpoints to access this information conveniently and securely
- Physician groups, hospitals, health plan administrators, healthcare clearinghouses, and other members of the healthcare community are revolutionizing the way they collaborate via the cloud
- **The Northwest Regional Data Center**
- Established in 1972, NWRDC initially offered mainframe services to universities across the state as a community cloud system
- A self-governance model makes NWRDC a computing cooperative of over 70 member orgs with access to enterprise-level services and facilities that would be difficult and expensive to implement individually
- Still heavily rooted in education, NWRDC now provides services to a wide range of universities, colleges, and state, county, and city governments

<https://www.qtsdatacenters.com/resources/blog/2016/05/18/introducing-healthcare-community-cloud>

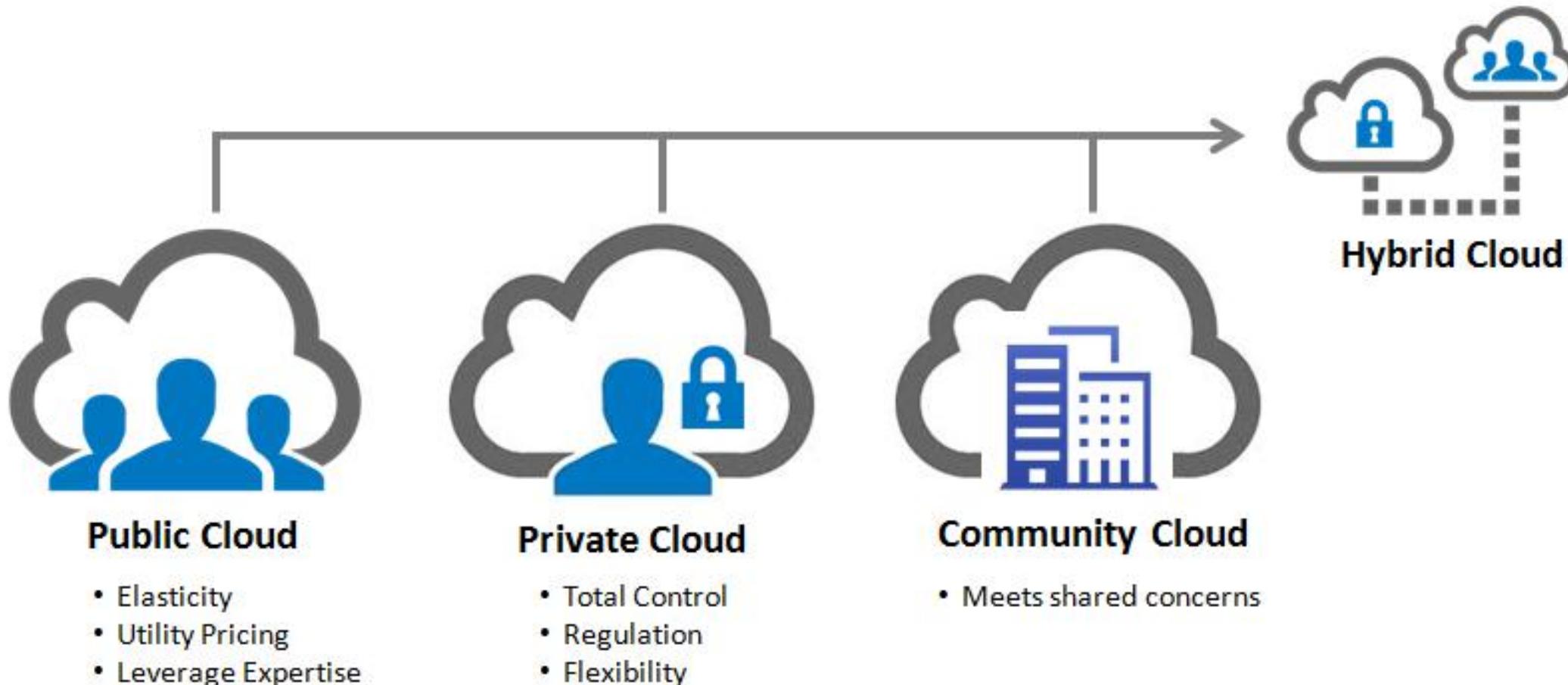
Hybrid Cloud

- A hybrid cloud is a computing environment which combines a public cloud and a private cloud by allowing data and applications to be shared between them
- When computing and processing demand fluctuates, hybrid cloud computing gives businesses the ability to seamlessly scale their on-premises infrastructure up to the public cloud to handle any overflow - without giving third-party datacenters access to the entirety of their data
- Organisations gain the flexibility and computing power of the public cloud for basic and non-sensitive computing tasks, while keeping business-critical applications and data on-premises, safely behind a company firewall.





Cloud deployment models





Thank
you!

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Cloud Computing and Services

Lecture 3

Cloud user persona

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One definition



An aerial photograph of one of Amazon's data centers near Dulles International Airport in northern Virginia. (CJ photo by Don Carrington)



*Microsoft's newest datacenter in the ocean off the coast of Scotland –
environmentally sustainable*

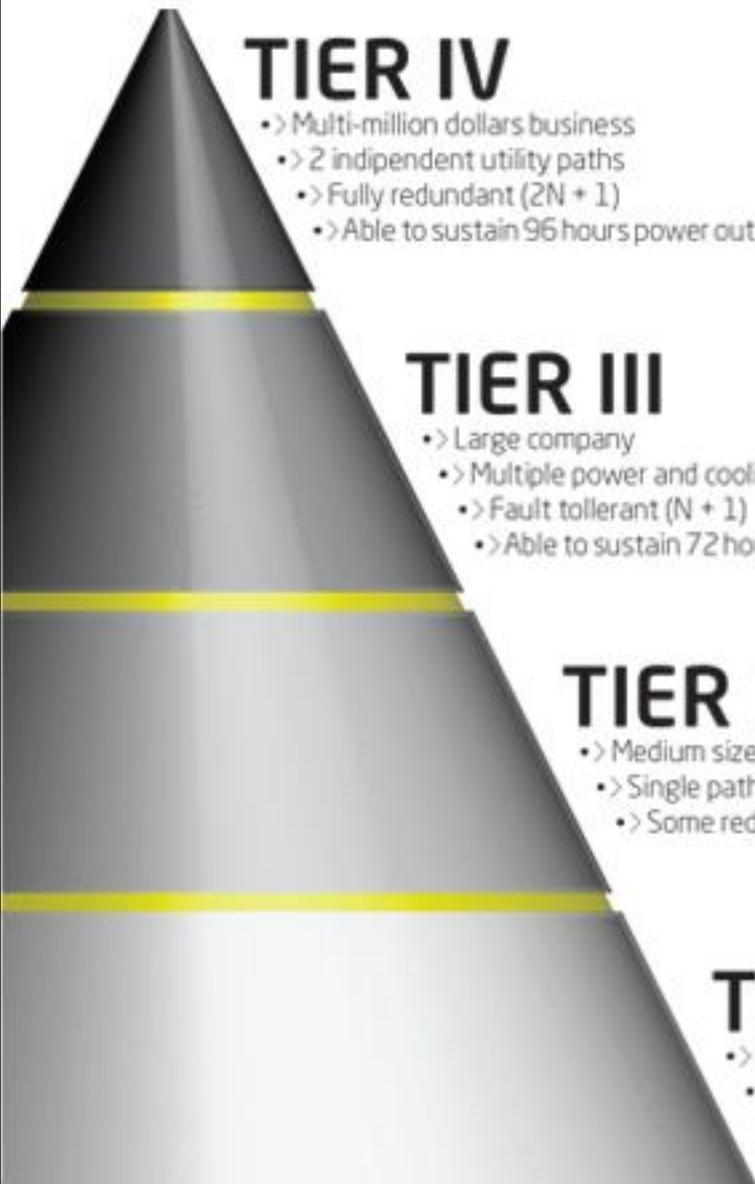


Datacenter

- A data center is a repository that houses computing facilities like servers, routers, switches and firewalls, as well as supporting components like backup equipment, fire suppression facilities and air conditioning
-



Datacenter Tiers



99.995% availability
25 minutes downtime

99.982% availability
1,6 hour downtime

99.749% availability
22,7 hours downtime

99.671% availability
28,8 hours downtime

- Tiers are a standardized way to define uptime of a datacenter. It is useful in measuring:
 - Datacenter performance
 - Investment
 - ROI



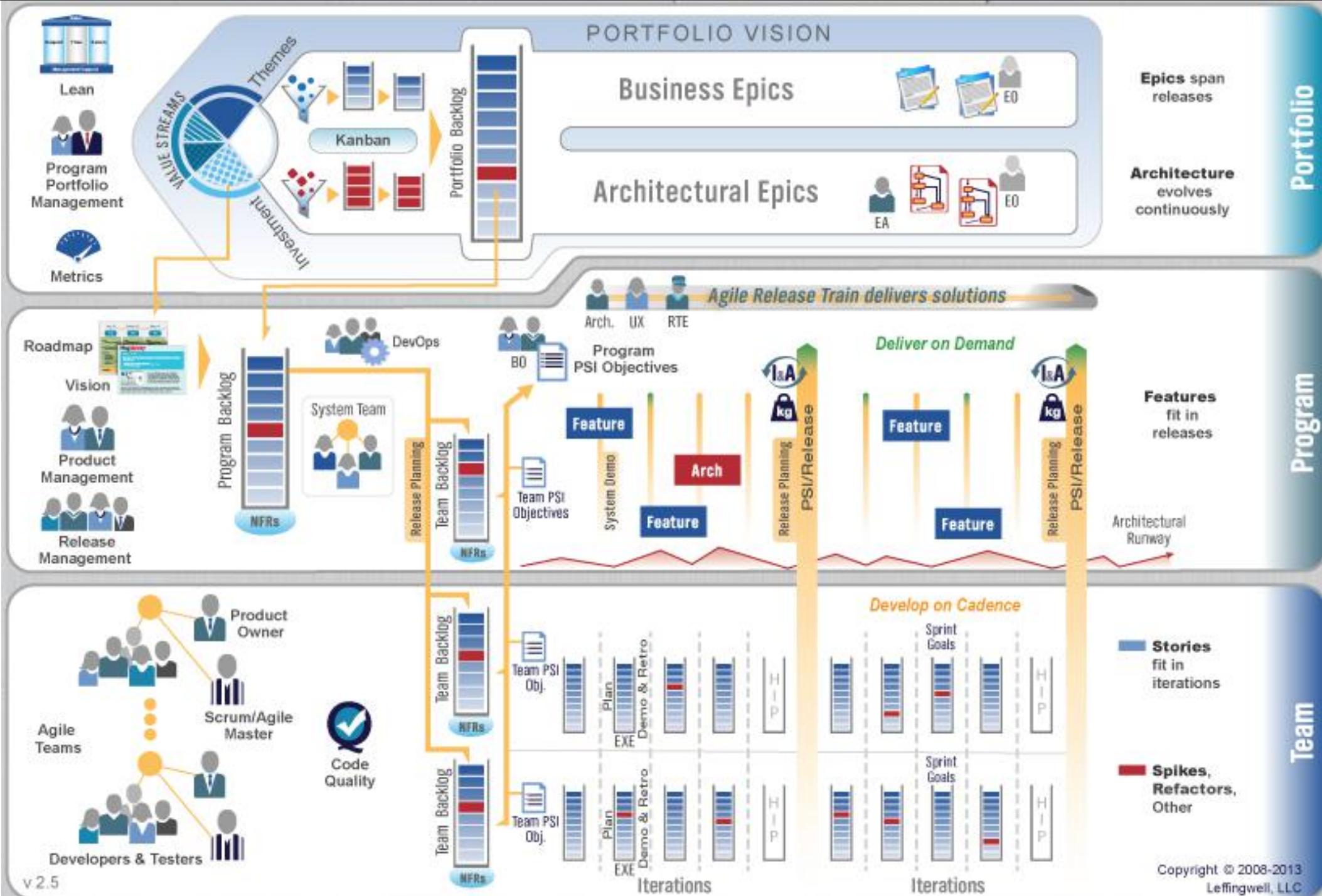
User persona in traditional software development

- Architects
- Developer
- QA
- IT operations
- System Administrators
- Technical Support



Changes with Cloud

- Architects
- Developer
- QA
- IT operations
- ~~System Administrators~~ DevOps
- Technical Support

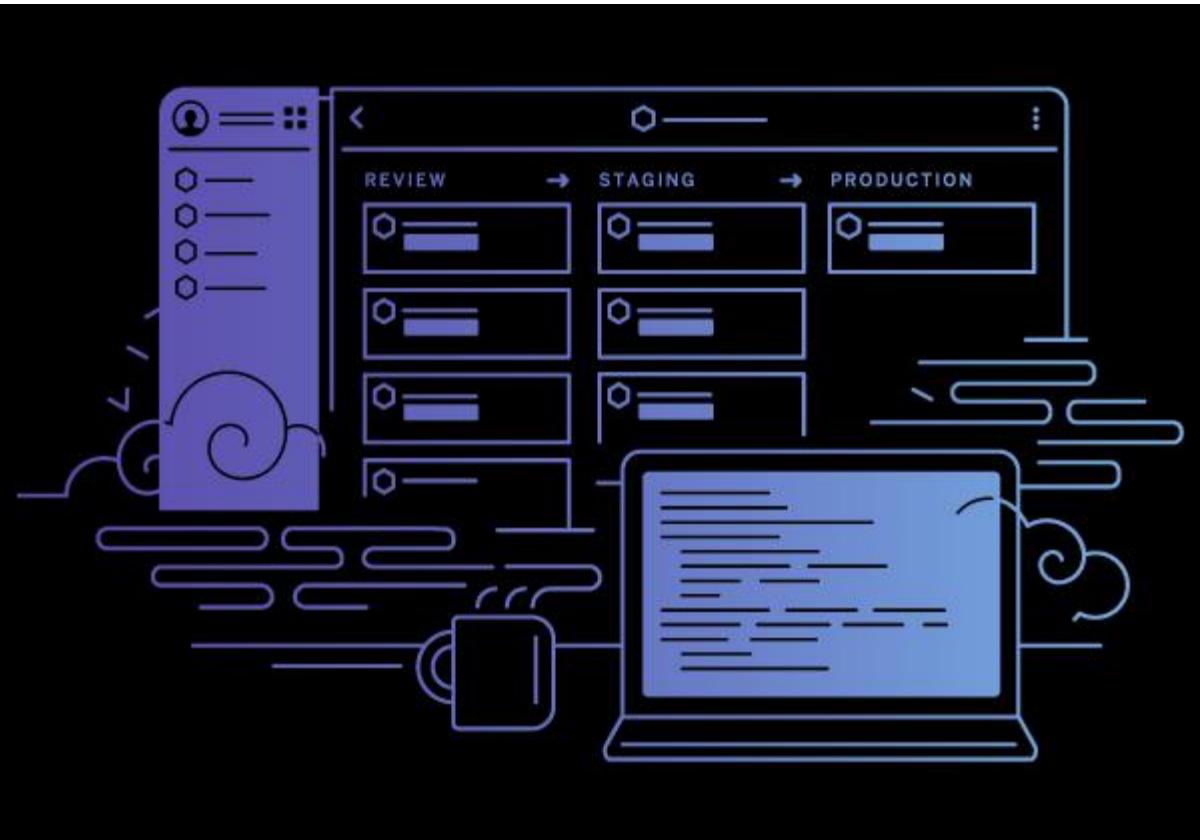


Usecases



Create new apps and services

- Quickly build, deploy and scale applications—web, mobile and API—on any platform
- Access the resources you need to help meet performance, security and compliance requirements

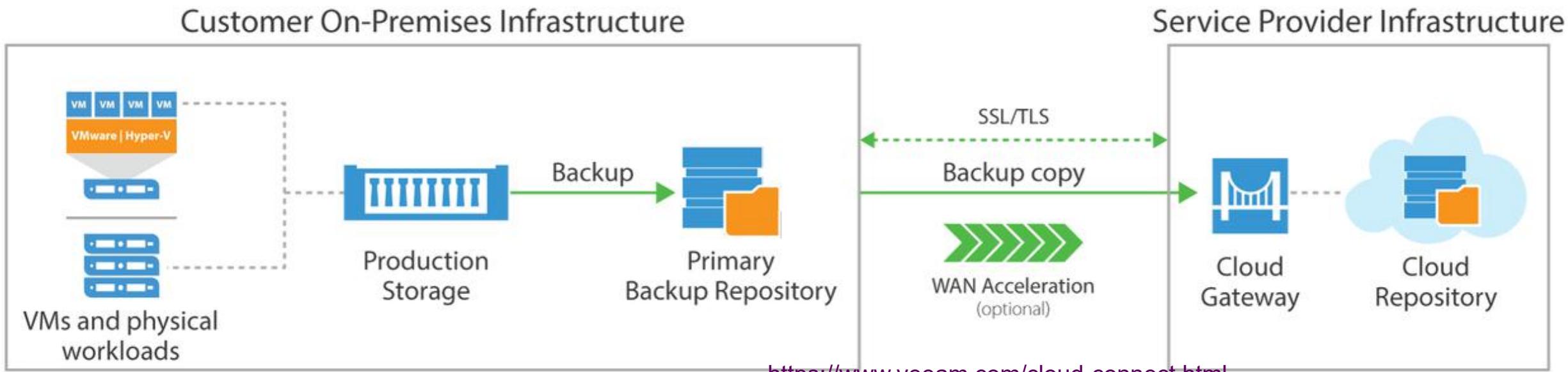


<https://www.heroku.com/>



Store, back up and recover data

- Protect your data more cost-efficiently—and at massive scale—by transferring your data over the Internet to an offsite cloud storage system that is accessible from any location and any device

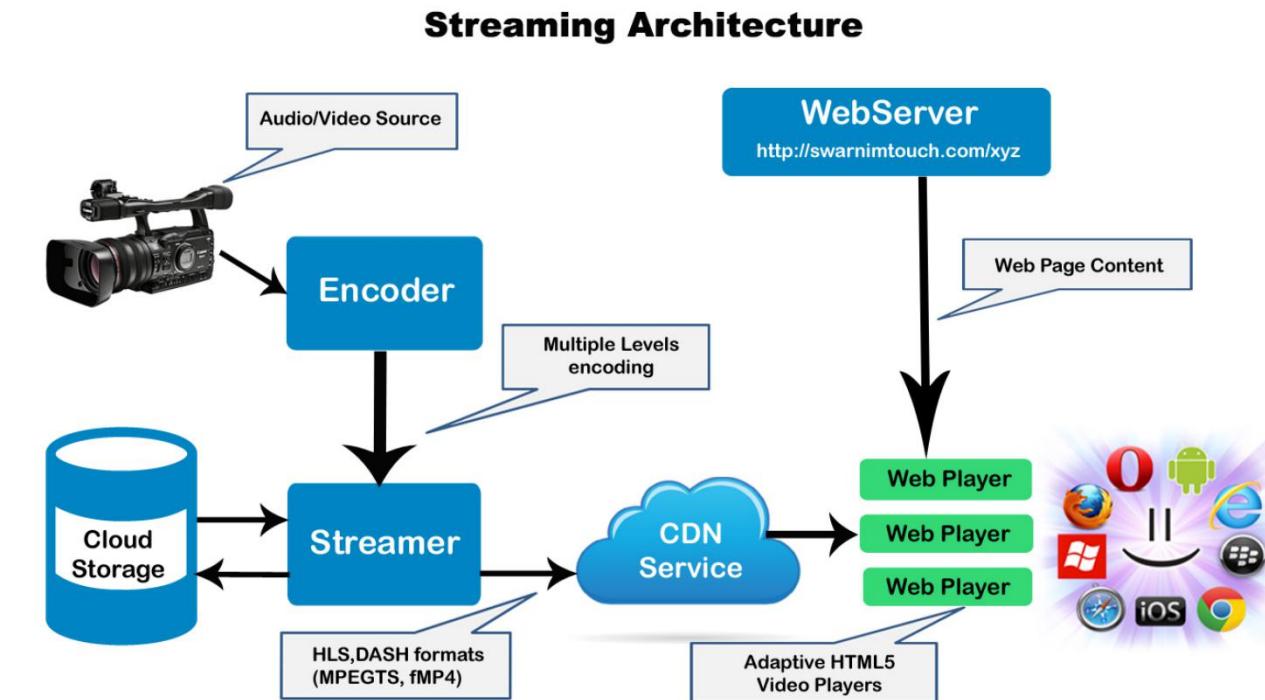


Stream audio and video

- Connect with your audience anywhere, anytime, on any device with high-definition video and audio with global distribution



<https://www.indiamart.com/proddetail/audio-video-streaming-15124884897.html>



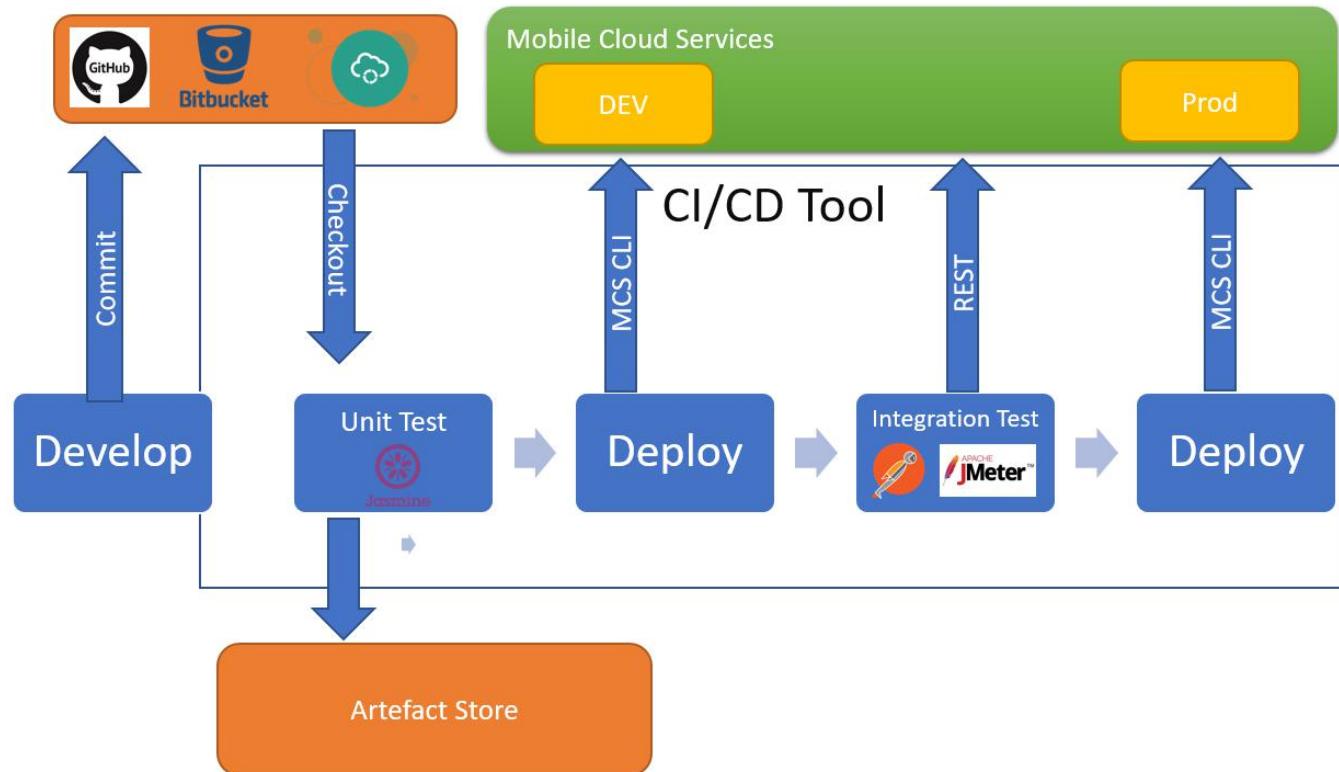
<http://www.swarnimtouch.com/about-us.php>

Deliver software on demand

- Also known as software as a service (SaaS), on-demand software lets you offer the latest software versions and updates around to customers—anytime they need, anywhere they are



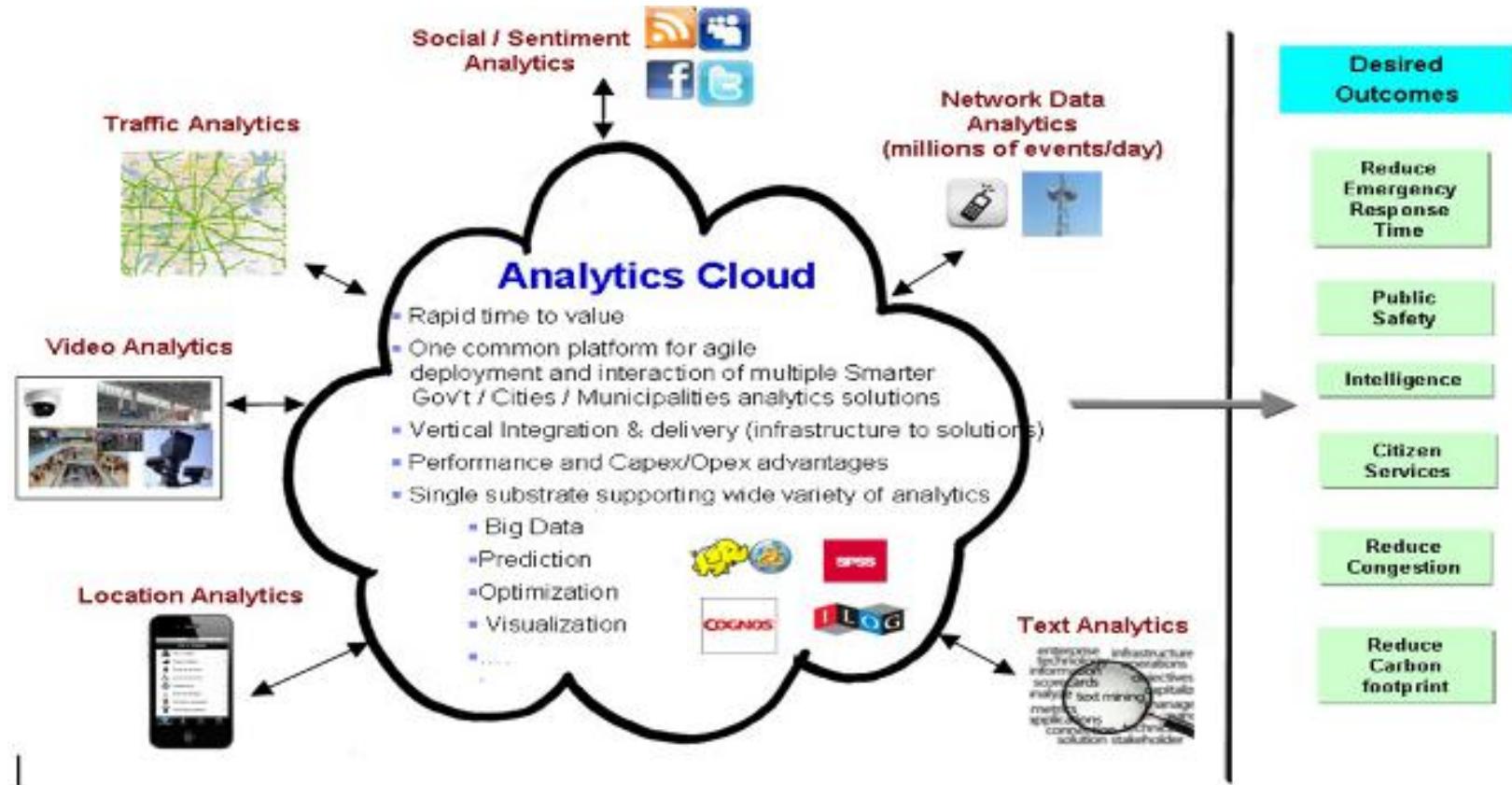
Test and build applications



Reduce application development cost and time by using cloud infrastructures that can easily be scaled up or down

Analyse data

- Unify your data across teams, divisions and locations in the cloud
- Then use cloud services, such as machine learning and artificial intelligence, to uncover insights for more informed decisions



https://researcher.watson.ibm.com/researcher/view_group.php?id=4811

Embed intelligence

- Use intelligent models to help engage customers and provide valuable insights from the data captured



<https://msdnshared.blob.core.windows.net/media/2017/01/image385.png>

Disadvantages of Cloud

<https://cloudacademy.com/blog/disadvantages-of-cloud-computing/>



1. Downtime

- Since cloud computing systems are internet-based, service outages are always an unfortunate possibility and can occur for any reason
- Can your business afford the impacts of an outage or slowdown?
- An outage on Amazon Web Services in 2017 cost publicly traded companies up to \$150 million dollars and no organization is immune, especially when critical business processes cannot afford to be interrupted

Best Practices for minimizing planned downtime in a cloud environment



- Design services with high availability and disaster recovery in mind. Leverage the multi- availability zones provided by cloud vendors in your infrastructure
- If your services have a low tolerance for failure, consider multi-region deployments with automated failover to ensure the best business continuity possible
- Define and implement a disaster recovery plan in line with your business objectives that provide the lowest possible recovery time (RTO) and recovery point objectives (RPO)
- Consider implementing dedicated connectivity such as AWS Direct Connect, Azure ExpressRoute, or Google Cloud's Dedicated Interconnect or Partner Interconnect
 - These services provide a dedicated network connection between you and the cloud service point of presence
 - This can reduce exposure to the risk of business interruption from the public internet



2. Security and Privacy

- Any discussion involving data must address security and privacy, especially when it comes to managing sensitive data
- Of course, any cloud service provider is expected to manage and safeguard the underlying hardware infrastructure of a deployment
 - However, your responsibilities lie in the realm of user access management, and it's up to you to carefully weigh all the risk scenarios
- Though recent breaches of credit card data and user login credentials are still fresh in the minds of the public, steps have been taken to ensure the safety of data
 - One such example is the General Data Protection Rule (GDPR), recently enacted in the European Union to provide users more control over their data
 - Nonetheless, you still need to be aware of your responsibilities and follow best practices

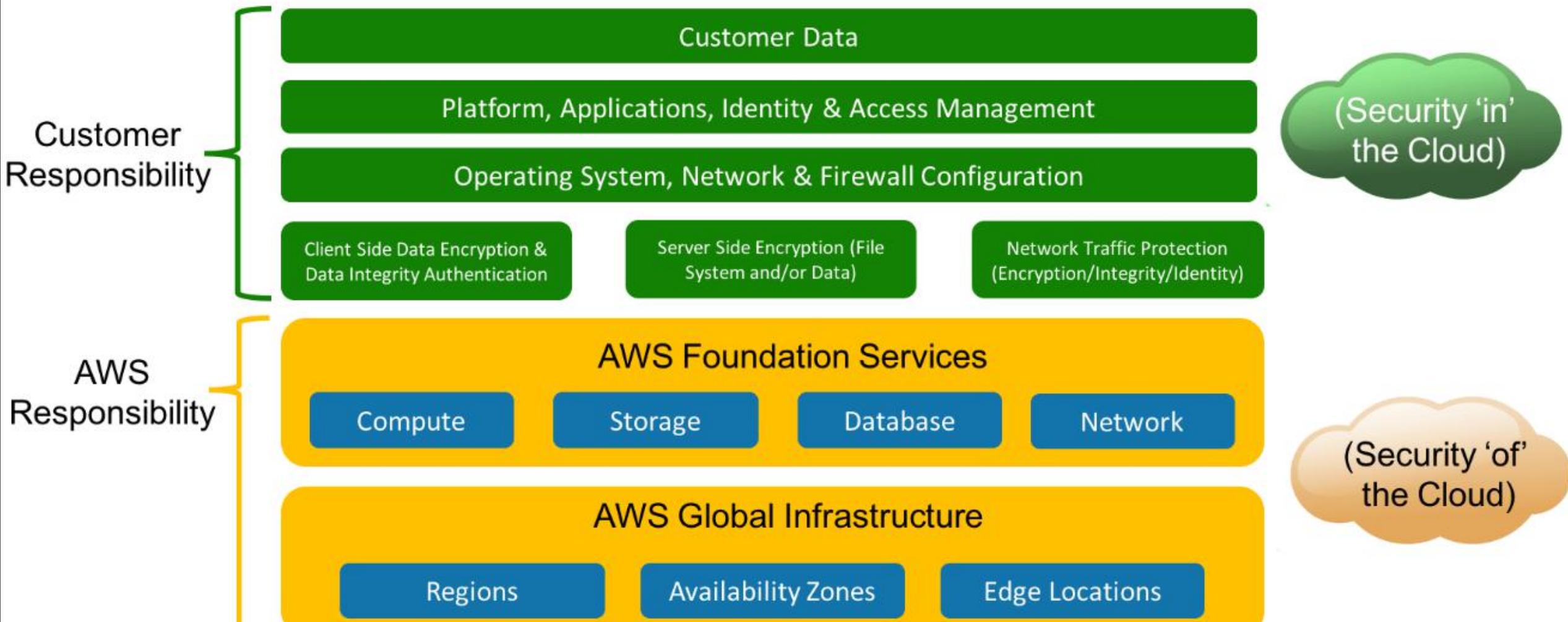


Best practices for minimizing security and privacy risks

- Understand the shared responsibility model of your cloud provider.
- Implement security at every level of your deployment.
- Know who is supposed to have access to each resource and service and limit access to least privilege.
- Make sure your team's skills are up to the task: Solid security skills for your cloud teams are one of the best ways to mitigate security and privacy concerns in the cloud.
- Take a risk-based approach to securing assets used in the cloud
- Extend security to the device.
- Implement multi-factor authentication for all accounts accessing sensitive data or systems



AWS Shared Responsibility Model





3. Vulnerability to Attack

- In cloud computing, every component is online, which exposes potential vulnerabilities
- Even the best teams suffer severe attacks and security breaches from time to time
- Since cloud computing is built as a public service, it's easy to run before you learn to walk
- After all, no one at a cloud vendor checks your administration skills before granting you an account: all it takes to get started is generally a valid credit card



Best practices to help you reduce cloud attacks

- Make security a core aspect of all IT operations.
- Keep ALL your teams up to date with cloud security best practices.
- Ensure security policies and procedures are regularly checked and reviewed.
- Proactively classify information and apply access control.
- Use cloud services such as AWS Inspector, AWS CloudWatch, AWS CloudTrail, and AWS Config to automate compliance controls.
- Prevent data exfiltration.
- Integrate prevention and response strategies into security operations.
- Discover rogue projects with audits.
- Remove password access from accounts that do not need to log in to services.
- Review and rotate access keys and access credentials.
- Follow security blogs and announcements to be aware of known attacks.
- Apply security best practices for any open source software that you are using



4. Limited control and flexibility

- To varying degrees (depending on the particular service), cloud users may find they have less control over the function and execution of services within a cloud-hosted infrastructure
- A cloud provider's end-user license agreement (EULA) and management policies might impose limits on what customers can do with their deployments
- Customers retain control of their applications, data, and services, but may not have the same level of control over their backend infrastructure



Best practices for maintaining control and flexibility

- Consider using a cloud provider partner to help with implementing, running, and supporting cloud services
- Understanding your responsibilities and the responsibilities of the cloud vendor in the shared responsibility model will reduce the chance of omission or error
- Make time to understand your cloud service provider's basic level of support
 - Will this service level meet your support requirements?
 - Most cloud providers offer additional support tiers over and above the basic support for an additional cost
- Make sure you understand the service level agreement (SLA) concerning the infrastructure and services that you're going to use and how that will impact your agreements with your customers



5. Vendor Lock-In

- Vendor lock-in is another perceived disadvantage of cloud computing
- Differences between vendor platforms may create difficulties in migrating from one cloud platform to another, which could equate to additional costs and configuration complexities
- Gaps or compromises made during migration could also expose your data to additional security and privacy vulnerabilities



Best practices to decrease dependency

- Design with cloud architecture best practices in mind
 - All cloud services provide the opportunity to improve availability and performance, decouple layers, and reduce performance bottlenecks
 - If you have built your services using cloud architecture best practices, you are less likely to have issues porting from one cloud platform to another.
- Properly understanding what your vendors are selling can help avoid lock-in challenges
- Employing a multi-cloud strategy is another way to avoid vendor lock-in
 - While this may add both development and operational complexity to your deployments, it doesn't have to be a deal breaker
 - Training can help prepare teams to architect and select best-fit services and technologies
- Build in flexibility as a matter of strategy when designing applications to ensure portability now and in the future.



6. Costs

- Adopting cloud solutions on a small scale and for short-term projects can be perceived as being expensive
- Pay-as-you-go cloud services can provide more flexibility and lower hardware costs, however, the overall price tag could end up being higher than you expected
- Until you are sure of what will work best for you, it's a good idea to experiment with a variety of offerings
- You might also make use of the cost calculators made available by providers like Amazon Web Services and Google Cloud Platform



Best practices to reduce costs

- Try not to over-provision, instead of looking into using auto-scaling services
- Scale DOWN as well as UP
- Pre-pay if you have a known minimum usage
- Stop your instances when they are not being used
- Create alerts to track cloud spending



Thank
you!

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