Cloud Computing

Definitions (I)

We have redefined Cloud Computing to include everything that we already do. I do not understand what we would do differently other then change the working of some of our ads.

Larry Ellison
Oracle CEO

It's stupidity. It's worse than stupidity: it's a marketing hype campaign. Somebody is saying this is inevitable – and whenever you hear somebody saying that, it's very likely to be a set of businesses campaigning to make it true.

Richard Stallman
GNU & FSF father

Cloud computing is the use of computing resources (hardware and software) that are delivered as a service over a network (typically the Internet).

Wikipedia

Definitions (III)

NIST

National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

Cloud computing is a model for enabling 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://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf

Definitions (III)

Cloud computing refers to both the applications delivered as services over the Internet and the hardware and systems software in the data centers that provide those services.
The services themselves have long been referred to as Software as a Service (SaaS), so we use that term.
The datacenter hardware and software is what we will call a Cloud.
When a Cloud is made available in a pay-as-you-go manner to the public [...] the service being sold is Utility Computing.

http://www.eecs.berkeley.edu/Pubs/TechRpts/2009/EECS-2009-28.pdf

Properties and Characteristics

Scalability
Elasticity

- Dynamic provision
- Multi-tenant design

Manageability
Interoperability

- Autonomic Control
- System monitoring
- Billing System

Availability
Reliability

- Fault tolerance
- System resilience
- Security

Accessibility
Portability

- Uniform access
- Thin client

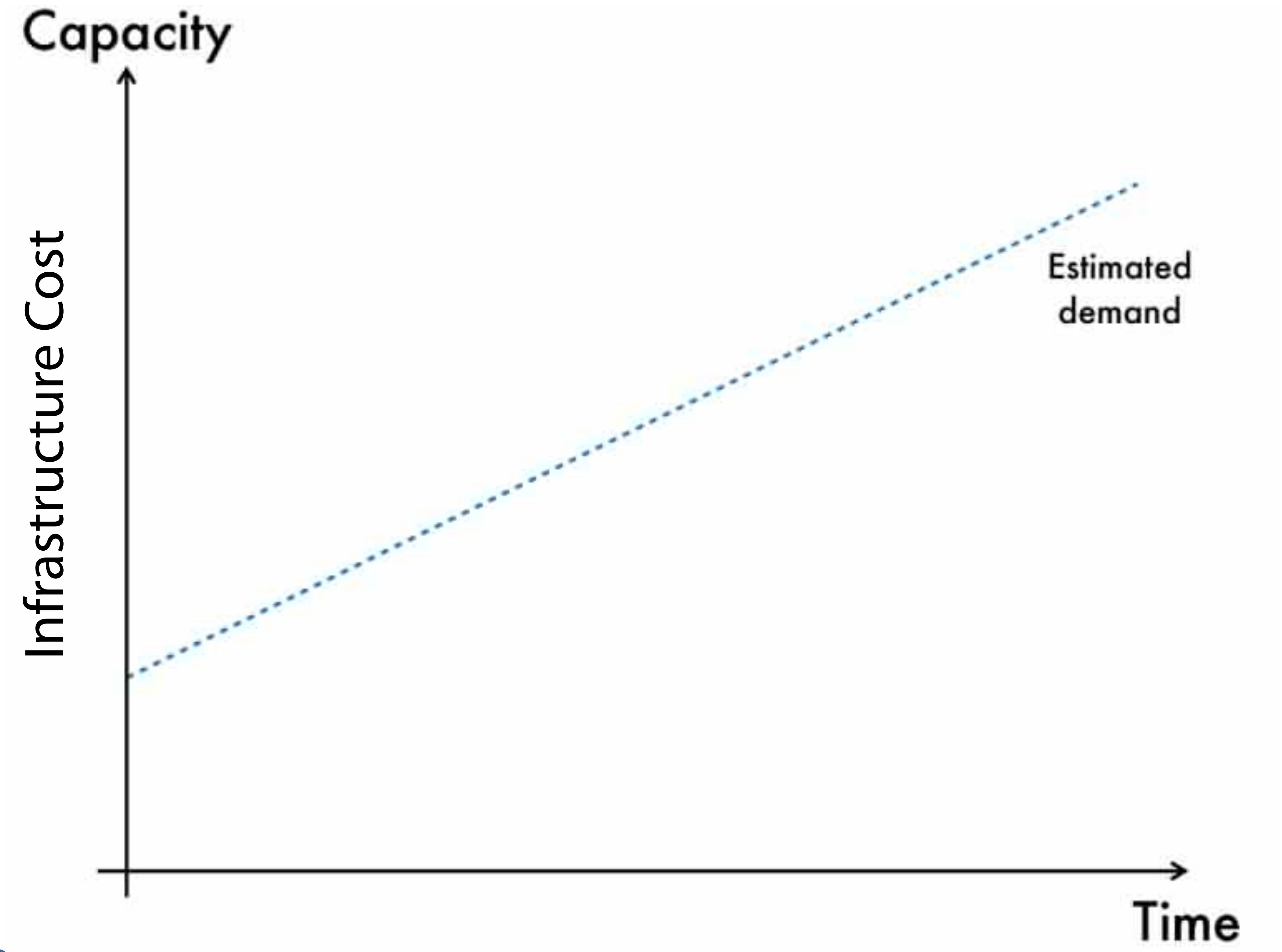
Performance
Optimization

- Parallel processing
- Load balancing
- Job scheduling

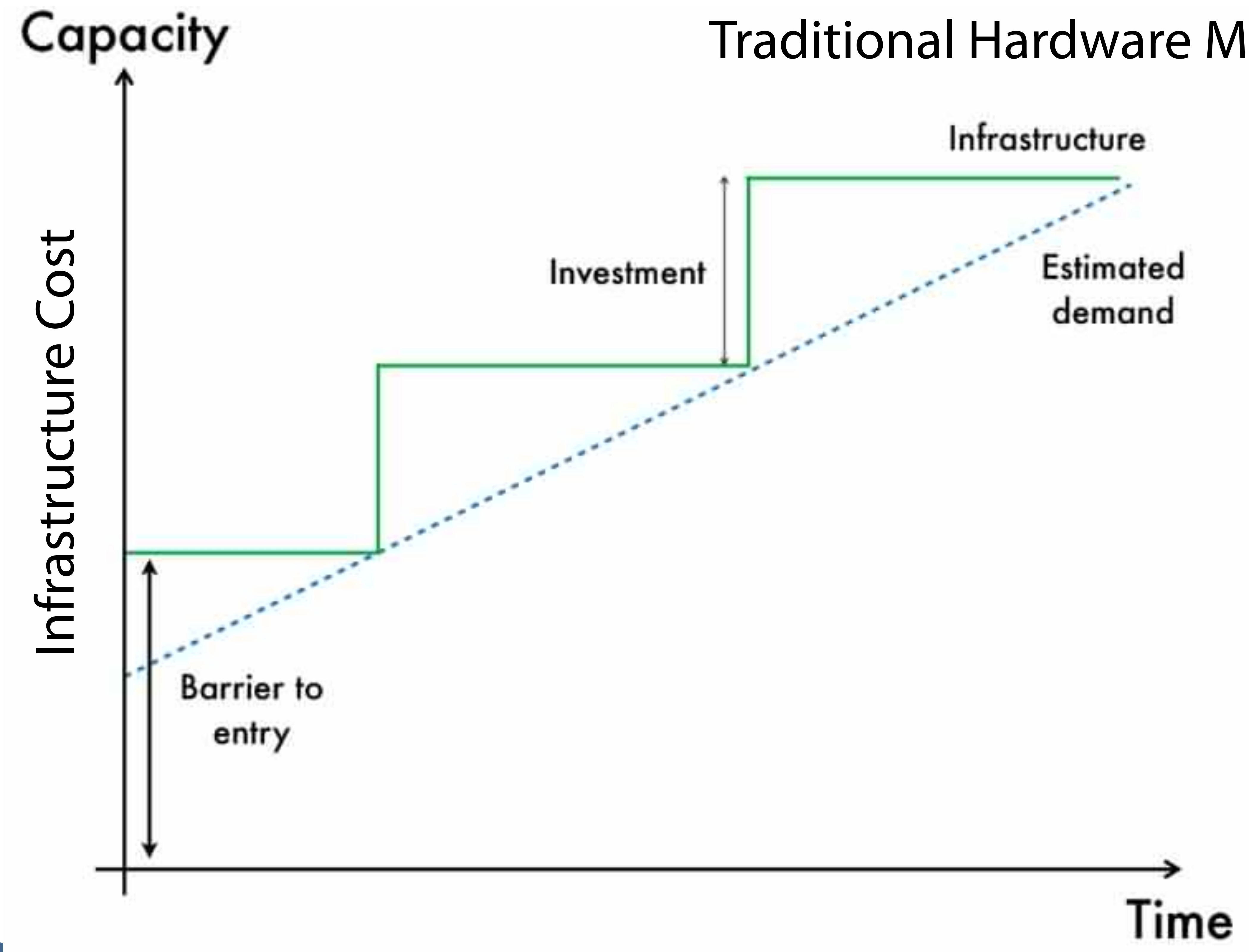
Scalability and Elasticity

- Scalability
  - A desirable property of a system, a network, or a process, which indicates its ability to either handle growing amounts of work in a graceful manner or to be readily enlarged.
- Elasticity
  - The ability to apply a quantifiable methodology that allows for the basis of an adaptive introspection with in a real time infrastructure.
- How to achieve?
  - Dynamic provisioning
  - Multi-tenant design

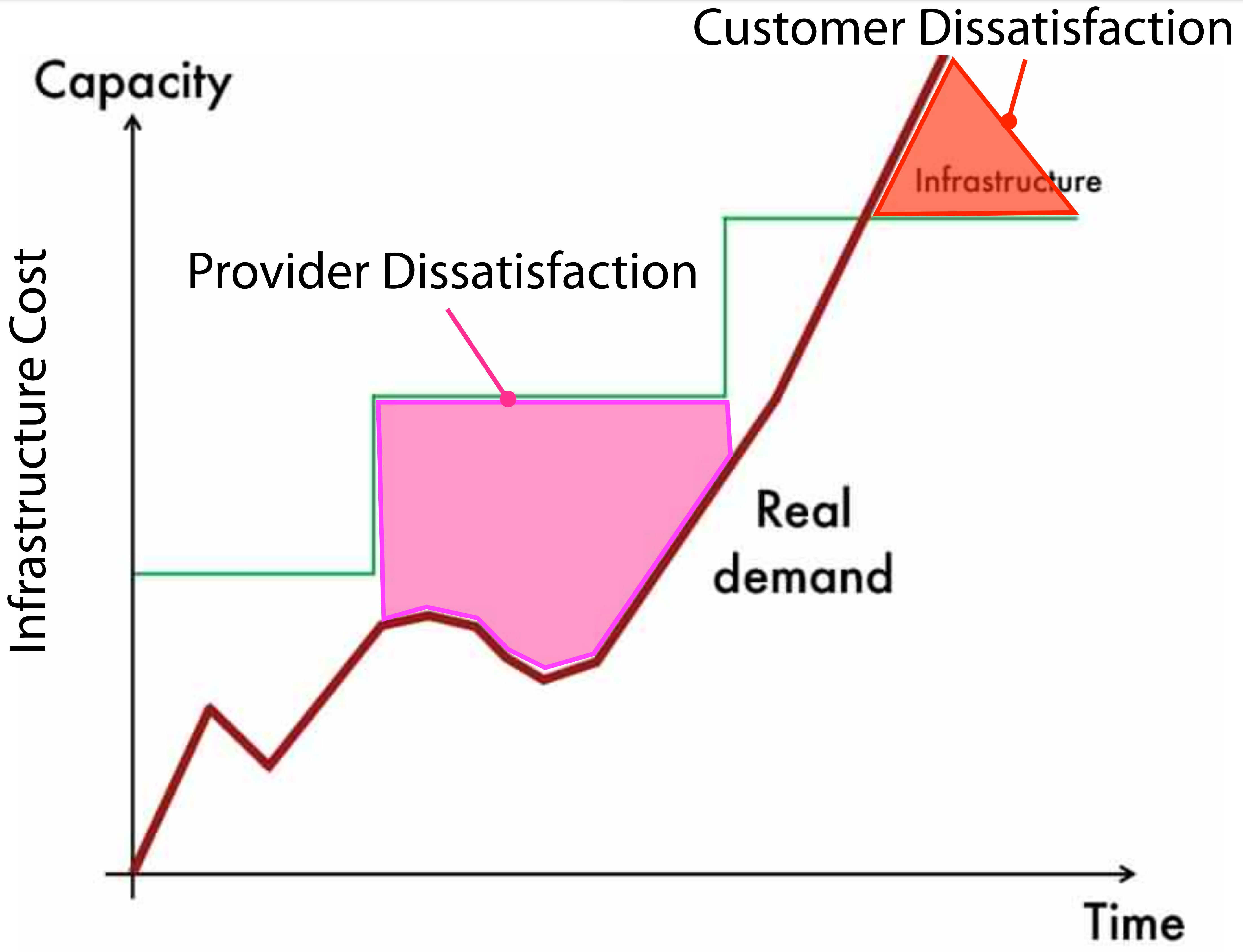
Elasticity (I)



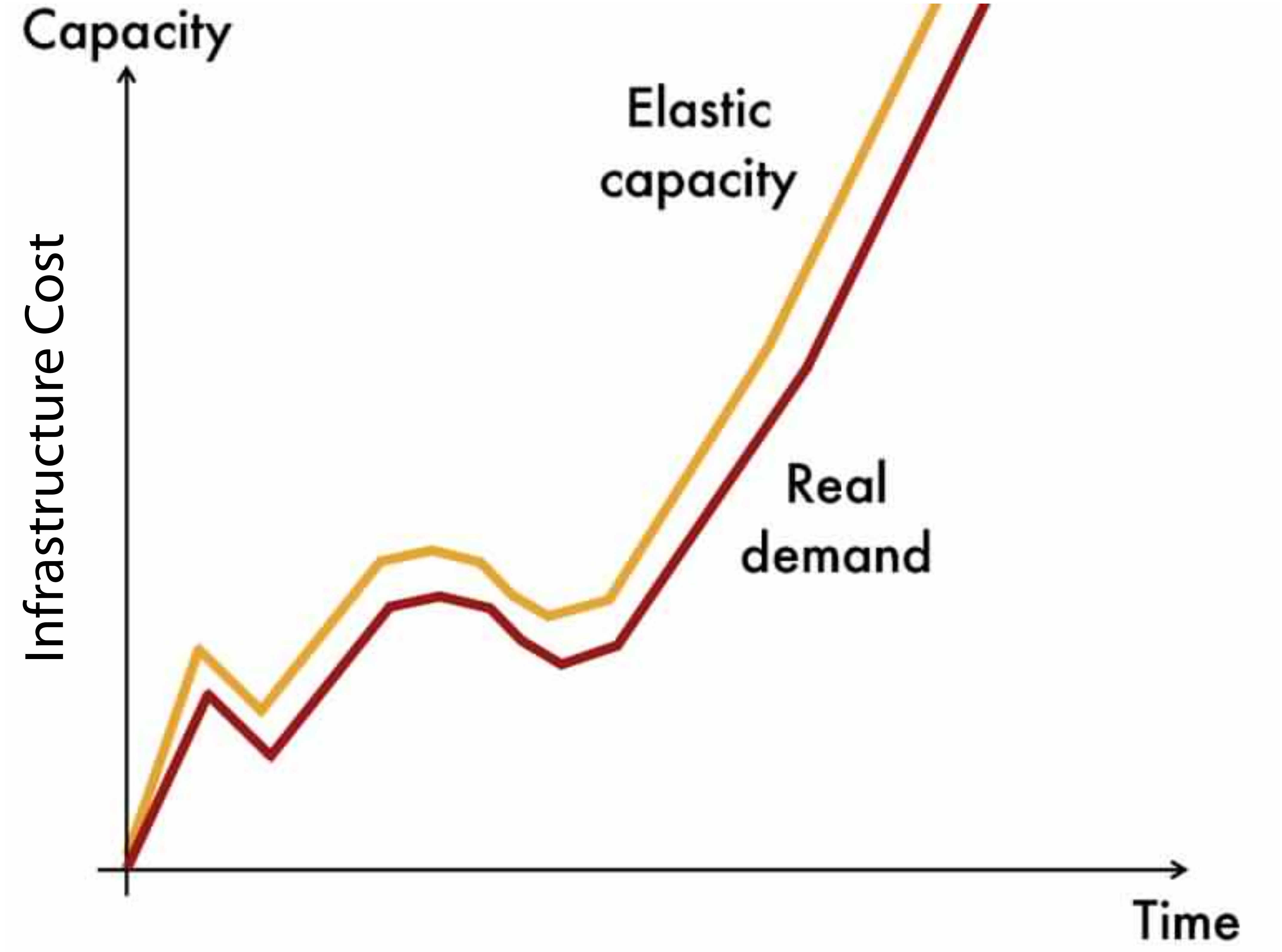
Elasticity (II)



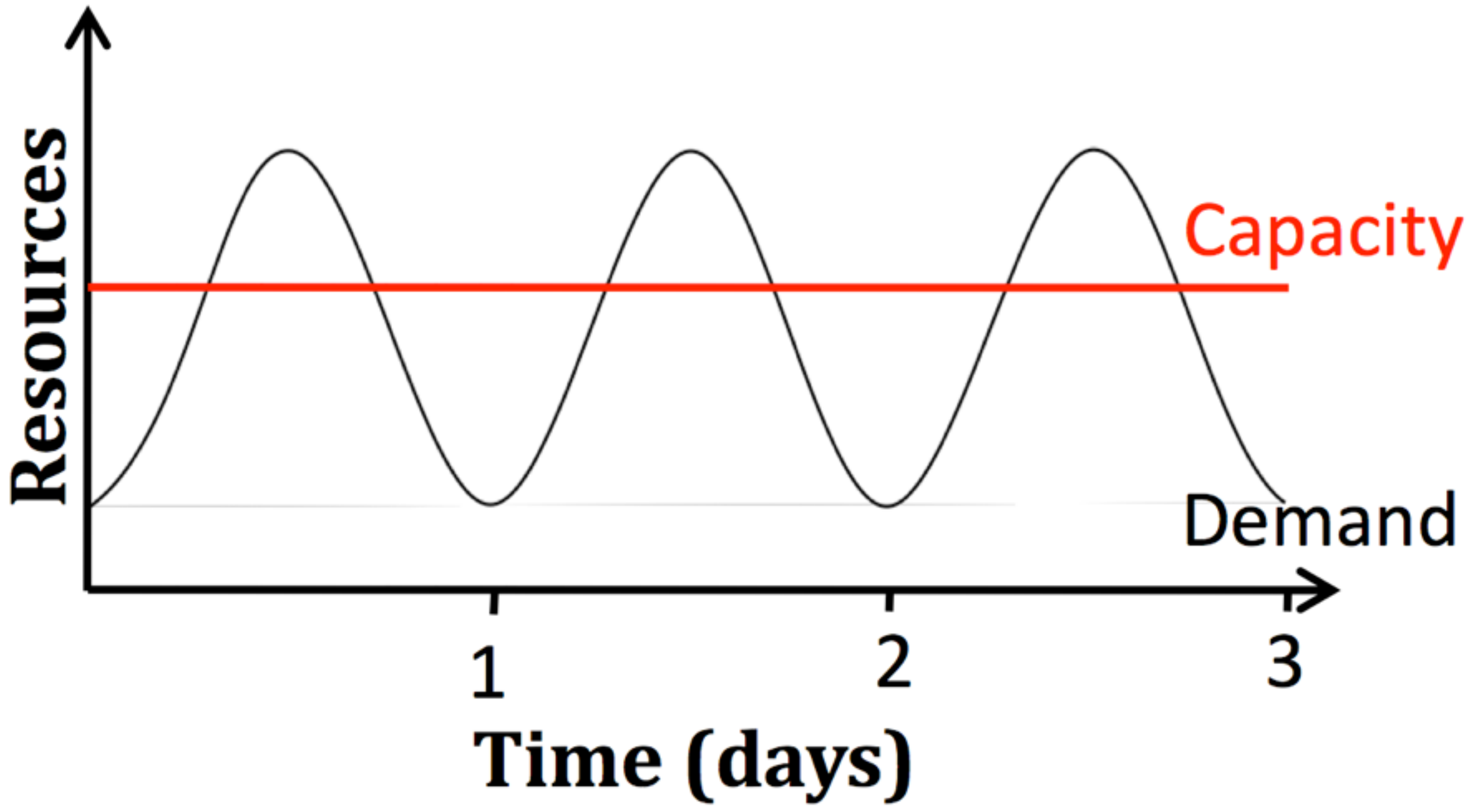
Elasticity (III)



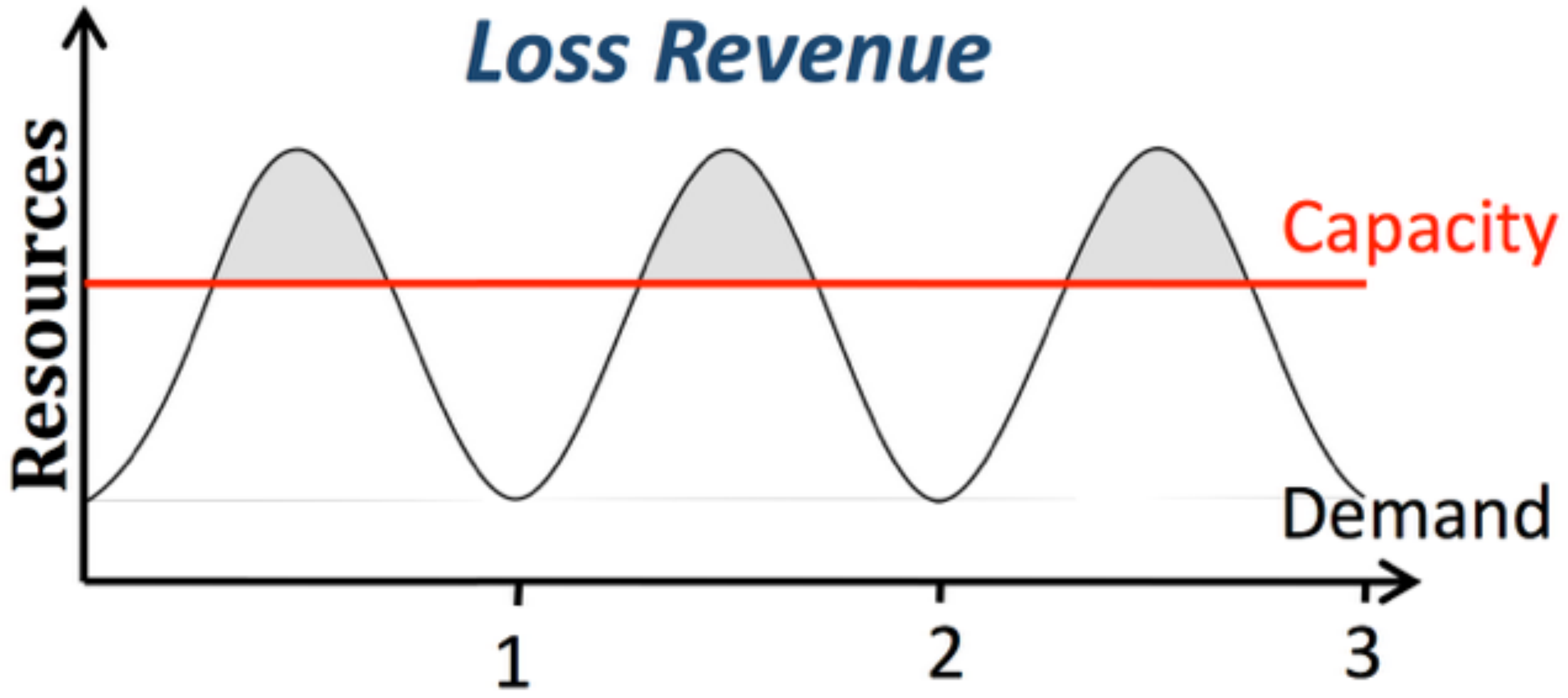
Elasticity (IV)

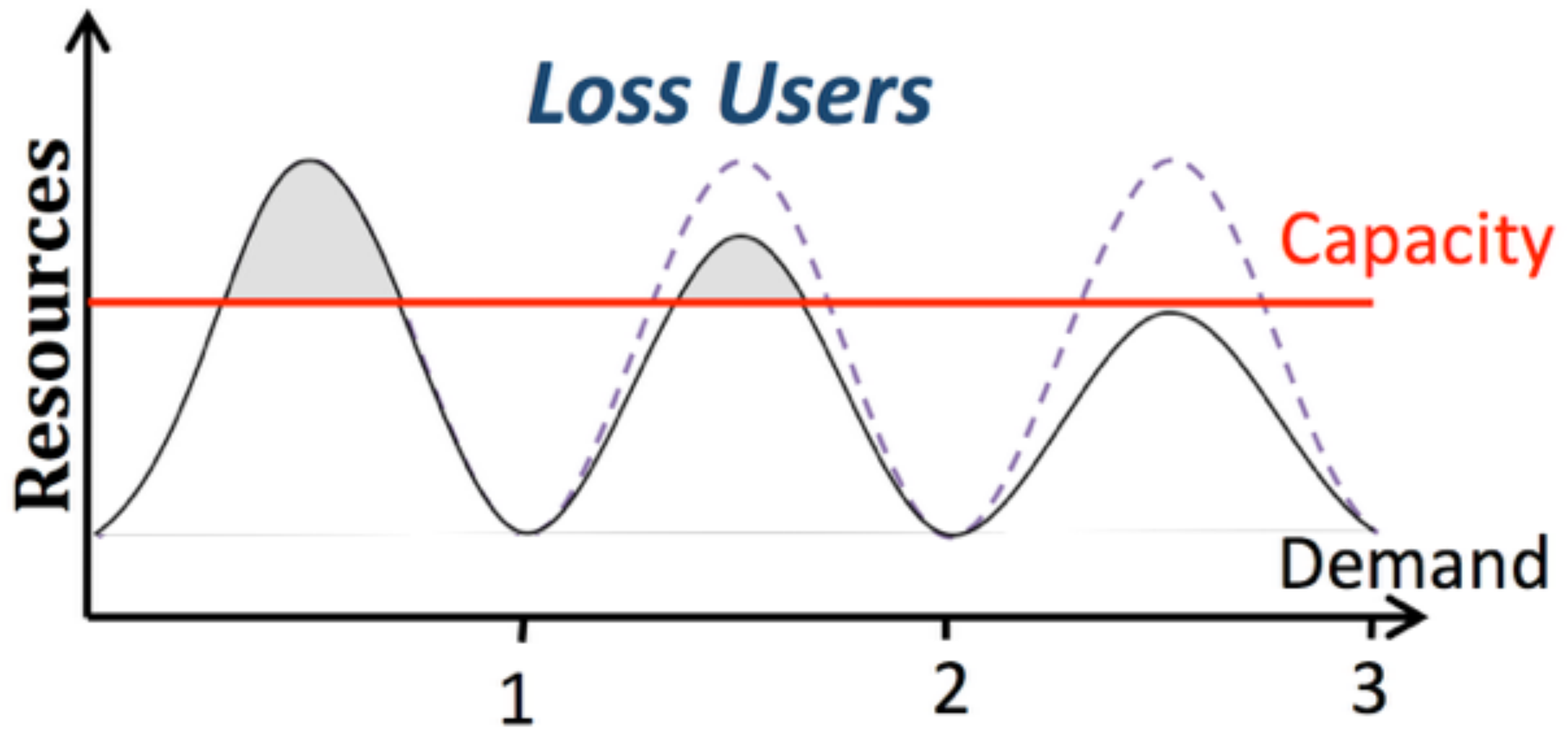


Traditional Provisioning

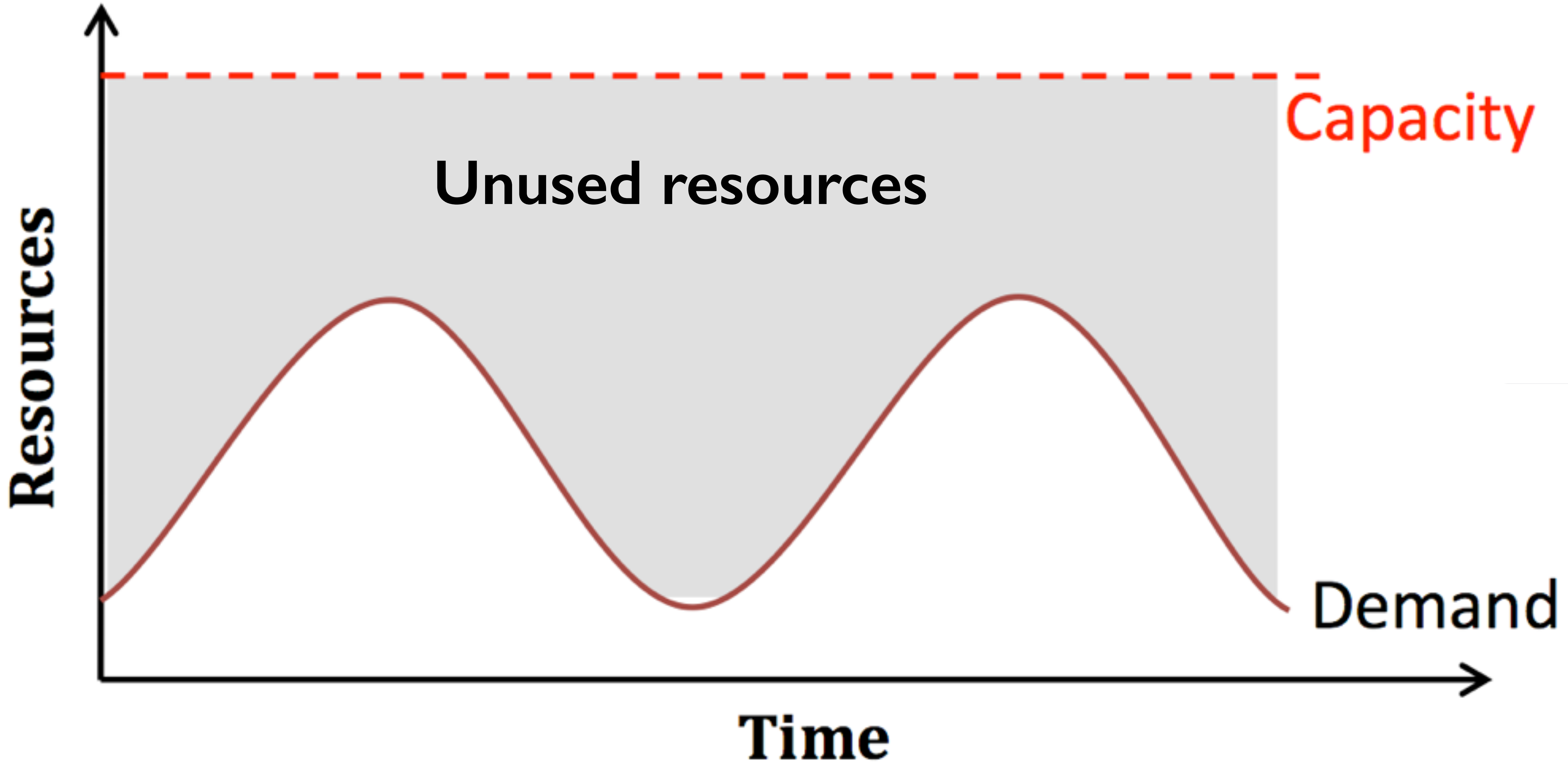


Under-provisioning



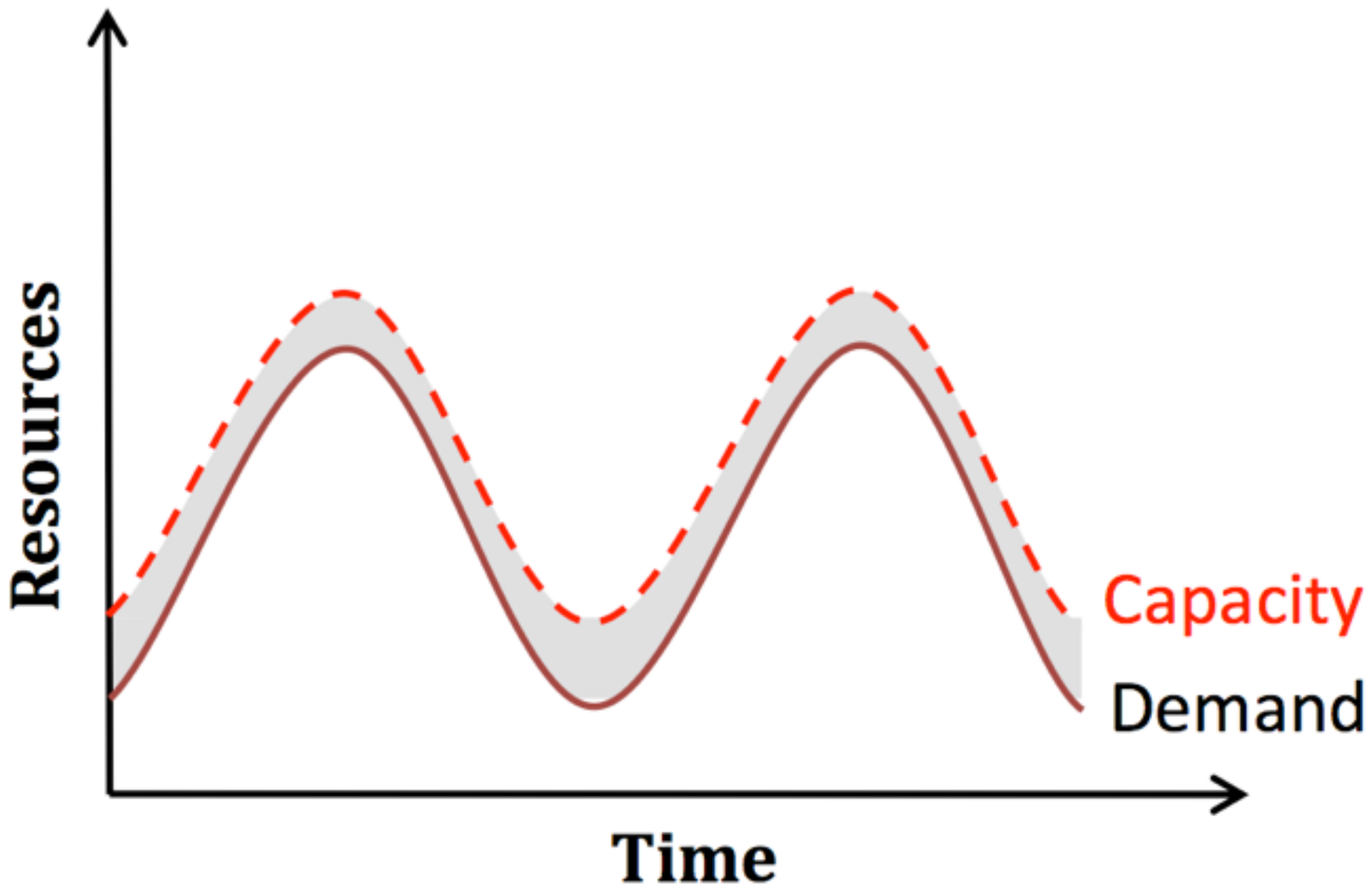


Over-provisioning



Dynamic Provisioning

- Cloud resources should be provisioned dynamically
  - Meet seasonal demand variations
  - Meet demand variations between different industries
  - Meet burst demand for some extraordinary events



Multi-tenant Design

- Multi-tenant refers to a principle in software architecture where a single instance of the software runs on a server, serving multiple client organizations.
  - Multi-tenancy is contrasted with a multi-instance architecture where separate software instances (or hardware systems) are set up for different client organizations
  - With a multi-tenant architecture, a software application is designed to virtually partition its data and configuration thus each client organization works with a customized virtual application instance.
- Client requirements:
  - Multi-tenant applications are typically required to provide a high degree of customization to support each target organization's needs.
  - Multi-tenant applications are expected to provide adequate levels of security and robustness.

Availability and Reliability

- Availability
  - The degree to which a system, subsystem, or equipment is in a specified operable and committable state at the start of a mission, when the mission is called for at an unknown time.
- Reliability
  - The ability of a system or component to perform its required functions under stated conditions for a specified period of time.
- How to achieve?
  - Fault tolerance
  - System resilience
  - Security

Fault Tolerance

- Fault-tolerance is the property that enables a system to continue operating properly in the event of the failure of some of its components.
- If its operating quality decreases at all, the decrease is proportional to the severity of the failure, as compared to a naively-designed system in which even a small failure can cause total breakdown.

- Four basic characteristics :
  - No single point of failure
  - Fault detection and isolation to the failing component
  - Fault containment to prevent propagation of the failure
  - Availability of reversion modes

Single Point of Failure

- A part of a system which, if it fails, will stop the entire system from working.

- The assessment of a potentially single location of failure identifies the critical components of a complex system that would provoke a total systems failure in case of malfunction.

- Countermeasure: preventing single point of failure
  - If a system experiences a failure, it must continue to operate without interruption during the repair process.

Fault Detection and Isolation

- A subfield of control engineering which concerns itself with monitoring a system, identifying when a fault has occurred and pinpoint the type of fault and its location.

- Countermeasure: isolate failing component
  - When a failure occurs, the system must be able to isolate the failure to the offending component.

Fault Containment

- Some failure mechanisms can cause a system to fail by propagating the failure to the rest of the system.
- Mechanisms that isolate a rogue transmitter or failing component to protect the system are required.
- Countermeasure: availability of reversion modes
  - System should be able to maintain some check points which can be used in managing the state changes.

System Resiliency

- Resilience is the ability to provide and maintain an acceptable level of service in the face of faults and challenges to normal operation.
- Resiliency pertains to the system's ability to return to its original state after encountering trouble. In other words, if a risk event knocks a system offline, a highly resilient system will return back to work and function as planned as soon as possible.
- Disaster recovery is the process, policies and procedures related to preparing for recovery or continuation of technology infrastructure critical to an organization after a natural or human-induced disaster.

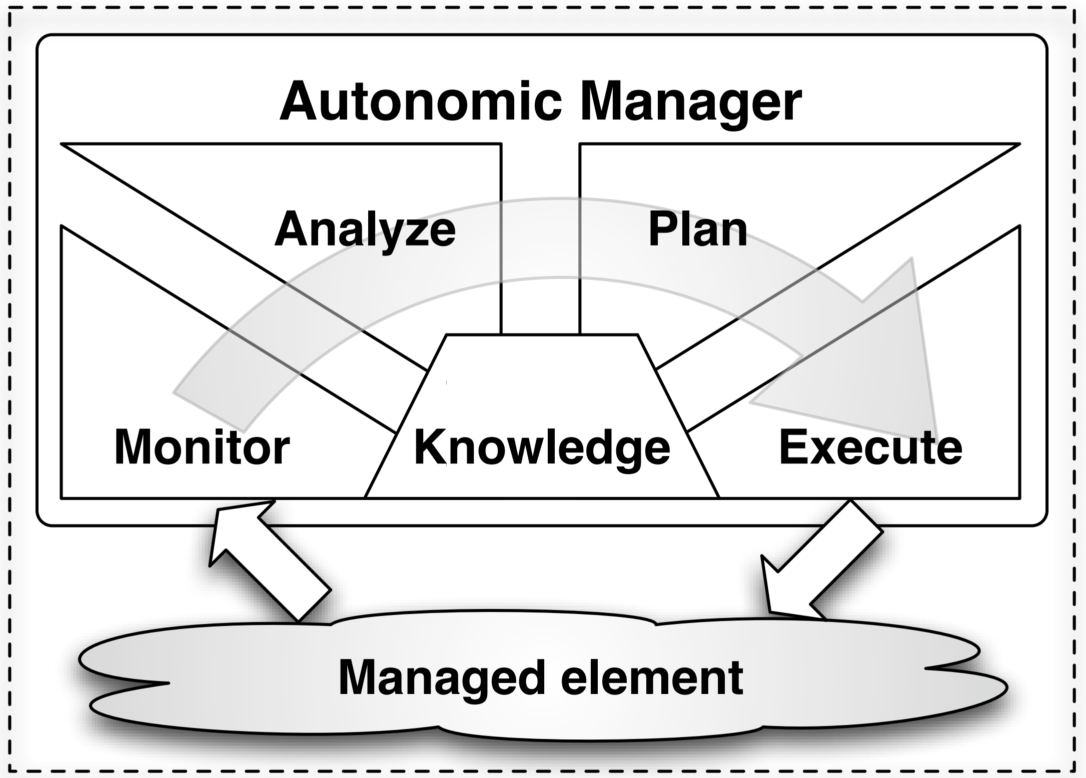
Security

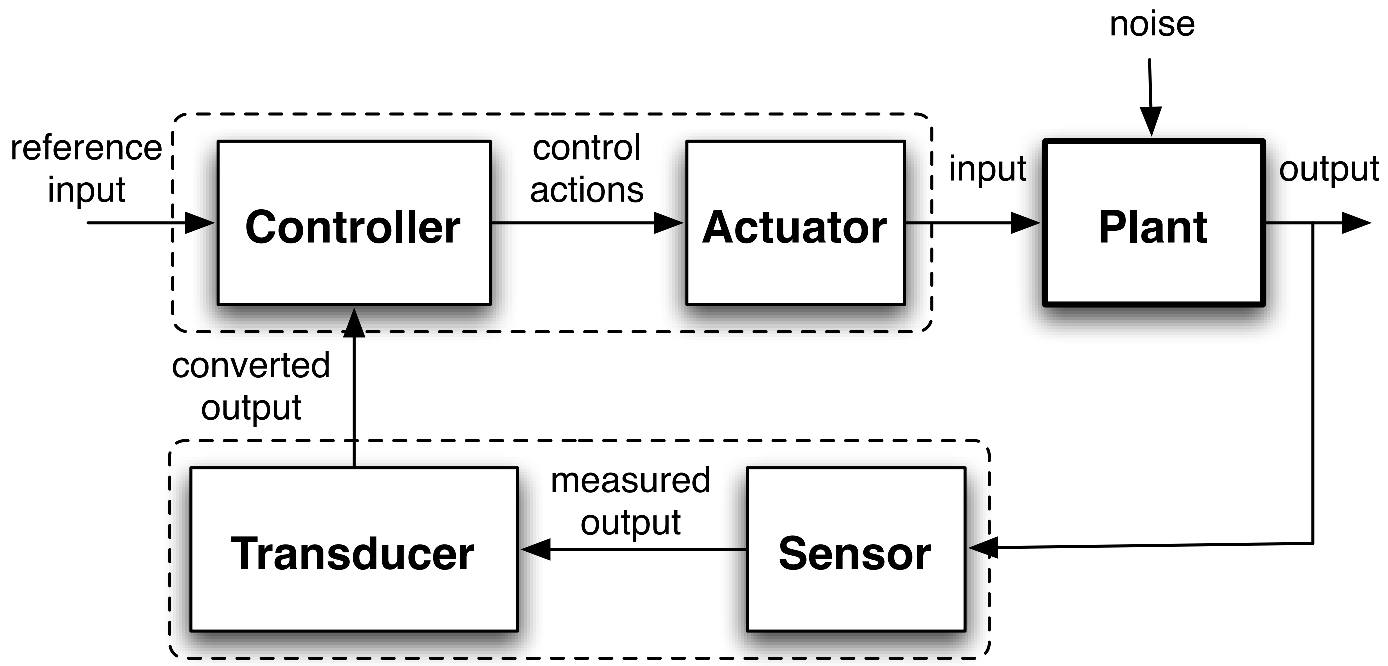
- Cloud security is an evolving sub-domain of computer security, network security, and, more broadly, information security.
- It refers to a broad set of policies, technologies, and controls deployed to protect data, applications, and the associated infrastructure of cloud computing.
- Important security and privacy issues:
  - Data Protection
    - To be considered protected, data from one customer must be properly segregated from that of another.
  - Identity Management
    - Every enterprise will have its own identity management system to control access to information and computing resources.
  - Application Security
    - Cloud providers should ensure that applications available as a service via the cloud are secure.
  - Privacy
    - Providers ensure that all critical data are masked and that only authorized users have access to data in its entirety.

Manageability and Interoperability

- Manageability
  - Enterprise-wide administration of cloud computing systems.
  - Systems manageability is strongly influenced by network management initiatives in telecommunications.
- Interoperability
  - Interoperability is a property of a product or system, whose interfaces are completely understood, to work with other products or systems, present or future, without any restricted access or implementation.
- How to achieve?
  - Autonomic Control
  - System Monitoring
  - Billing System

Autonomic Control





- Autonomic Computing
  - Its ultimate aim is to develop computer systems capable of self-management, to overcome the rapidly growing complexity of computing systems management, and to reduce the barrier that complexity poses to further growth.

Self-* Properties

- Autonomic System Functional Areas (CHOP)
  - Self-Configuration
    - Automatic configuration of components.
  - Self-Healing
    - Automatic discovery, and correction of faults.
  - Self-Optimization
    - Automatic monitoring and control of resources to ensure the optimal functioning with respect to the defined requirements.
  - Self-Protection
    - Proactive identification and protection from arbitrary attacks.

System Monitoring

- A System Monitor in systems engineering is a process within a distributed system for collecting and storing state data.

- What should be monitored in the Cloud ?
  - Physical and virtual hardware state
  - Resource performance metrics
  - Network access patterns
  - System logs
  - etc...

Billing System

- Billing System in Cloud
  - Users pay as many as they used.
  - Cloud provider must first determine the list of service usage price.
  - Cloud provider have to record the resource or service usage of each user, and then charge users by these records.

- How can cloud provider know users' usage ?
  - Get those information by means of monitoring system.
  - Automatically calculate the total amount of money which user should pay.
  - Automatically request money from use's banking account.

Performance and Optimization

- Performance
  - Is characterized by the amount of useful work accomplished by a computer system compared to the time and resources used.
  - Depending on the context, good computer performance may involve one or more of the following:
    - Short response time for a given piece of work
    - High throughput (rate of processing work)
    - Low utilization of computing resource(s)
    - High availability of the computing system or application
    - Fast (or highly compact) data compression and decompression
    - High bandwidth / short data transmission time
- Optimization
  - Improvement of performance
- How to achieve?
  - Parallel processing
  - Load balancing
  - Job scheduling

Accessibility and Portability

- Accessibility
  - Accessibility is a general term used to describe the degree to which a product, device, service, or environment is accessible by as many people as possible.
- Portability
  - Service portability is the ability to access services using any devices, anywhere, continuously with mobility support and dynamic adaptation to resource variations.
- How to achieve?
  - Uniform access
  - Thin client

Cloud Benefits

Markets & Enterprises

Users

Benefits from Clouds

- For the market and enterprises
  - Reduce initial investment
  - Reduce capital expenditure
  - Improve industrial specialization
  - Improve resource utilization
- For the end user and individuals
  - Reduce local computing power
  - Reduce local storage power
  - Variety of thin client devices in daily life

Initial Investment

- Traditional process of enterprises to initiate business:
  - Survey and analysis the industry and market
  - Estimate the quantity of supply and demand
  - Purchase and deploy IT infrastructure
  - Install and test the software system
  - Design and develop enterprise specific business service
  - Announce the business service to clients
- Some drawbacks :
  - The survey, analysis and estimation may not 100% correct
  - Infrastructure deployment is time consuming
  - Enterprises should take the risk of wrong investment

Initial Investment

- Initiate business with Cloud Computing services:
  - Survey and analysis the industry and market
  - Choose one cloud provider for enterprise deployment
  - Design and develop business service upon cloud environment
  - Announce the business service to clients
- Some benefits:
  - Enterprise do not need to own the infrastructure
  - Enterprise can develop and deploy business service in short time
  - Enterprise can reduce the business loss of wrong investment

Reduce Capital Expenditure

- Traditional capital expenditure of enterprises:
  - Each enterprise should establish its own IT department
  - IT department should handle the listing jobs
    - Manage and administrate hardware and software
    - Apply regular data backup and check point process
    - Purchase new infrastructure and eliminate outdated one
    - Always standby for any unexpected IT problems
- Some drawbacks :
  - Enterprise pays for IT investment which is not its business focus
  - Enterprise should take the risk of hardware/software malfunction
  - Replacing and updating infrastructure is time consuming and risky

Reduce Capital Expenditure

- Capital expenditure with Cloud Computing service:
  - Enterprise can almost dismiss its IT department
  - The jobs of IT department can be achieved by cloud provider
    - Dynamically update and upgrade hardware or software
    - Dynamically provision and deploy infrastructure for enterprise
    - Automatically backup data and check consistency
    - Self-recover from disaster or system malfunction

- Some benefits :
  - Enterprise can shift effort to its business focus
  - Enterprise can reconfigure its IT services in short time
  - Enterprise pays to cloud provider as many as the service used

Improve Industrial Specialization

- Traditional industry and market:
  - Each enterprise has to own its IT department
  - IT resources are managed directly by the enterprises
  - IT complexity should be addressed and managed with care by the enterprise itself

- Some drawbacks :
  - IT department is not the business focus of enterprises
  - Most enterprise do not maintain correctly their IT resources
  - Enterprises must optimize their IT resources usage

Improve Industrial Specialization

- Outsourcing to Cloud providers
  - Cloud providers centrally maintain IT infrastructure for enterprises
  - Cloud providers are business-focused on providing reliable IT resources
  - Cloud providers employ experts for management and administration
  - Enterprises only rent and pay the services they n

- Some benefits :
  - IT service performance is optimized by experts
  - Enterprises can focus on their business
  - IT resource waste is reduced

Improve Resource Utilization

- Traditional resource utilization
  - Enterprises rarely take care about IT resource utilization
  - IT resources are not well managed by the enterprises
  - IT resources usually for peak demand
- Some drawbacks :
  - Power and spaces utilization wasted
  - IT resources can not be shared across enterprises

Improve Resource Utilization

- Outsourcing to Cloud providers
  - Cloud providers centrally maintain IT infrastructure for enterprises
  - Cloud providers build performance optimized hardware
  - Cloud providers build consolidated cooling systems
  - Cloud providers take care of legal policy issues

- Some benefits :
  - IT resources can be shared among enterprises
  - IT infrastructure performance can be optimized
  - Large-scale integrated optimization can be appli

Reduce Local Computing Power

- Traditional local computing power requirements:
  - Need to buy your own personal computer
  - Buy powerful processor if you need intensive computing
  - Buy a lot of memory to meet application requirements
  - Install plenty of applications
  - Manage (security) upgrades

- Some drawbacks :
  - Hard to replicate the same system environment
  - Need to regularly update or upgrade software and hardware
  - Need to reinstall application if you reinstall the OS

Reduce Local Computing Power

- Using Cloud Computing services:
  - Can utilize remote computing power in the Cloud
  - Need a basic computer to connect to Internet
  - Applications automatically managed
- Some benefits:
  - Access personal computer anywhere through network
  - Dynamically request more resources on demand
  - Application must not be manually upgraded/managed/reinstalled

Reduce Local Storage Power

- Traditional local storage power requirement:
  - User code and data files stored in local devices
  - Manual backup regularly preventing hardware failu
  - Physical / power / heating requirements

- Some drawbacks :
  - Storage space may not be enough
  - Storage space may be too much
  - Data consistency between computers is hard
  - Need to sacrifice storage for backups

Reduce Local Storage Power

- Using Cloud Computing services:
  - User code and data files stored in the Cloud
  - Cloud provider guarantees the data availability

- Some benefits:
  - Dynamic allocation of storage on demand
  - Seamless access to data through the network
  - No need to care about data consistency
  - No need to care about data losses and backups
  - No need to care about space/power

Variety of End Devices

- Traditional computing resources:
  - Connection to the Internet through personal computers
  - Only PCs can deliver reasonable computing power
  - Small devices have hardware and power limitations

- Some drawbacks :
  - Computing power is not portable
  - Small devices can only perform small works

Variety of End Devices

- Devices integrated with Cloud Computing:
  - Devices connect to the Internet through wireless networks
  - Devices access Cloud services through Web interfaces
  - Devices outsource computing jobs to the cloud

- Some benefits:
  - Users can easily access Cloud services through small devices
  - User can access almost unlimited computing power
  - Small devices can be managed through Clouds (install/upgrade apps)

Service Models for Housing

- You look for a place to live in a new city

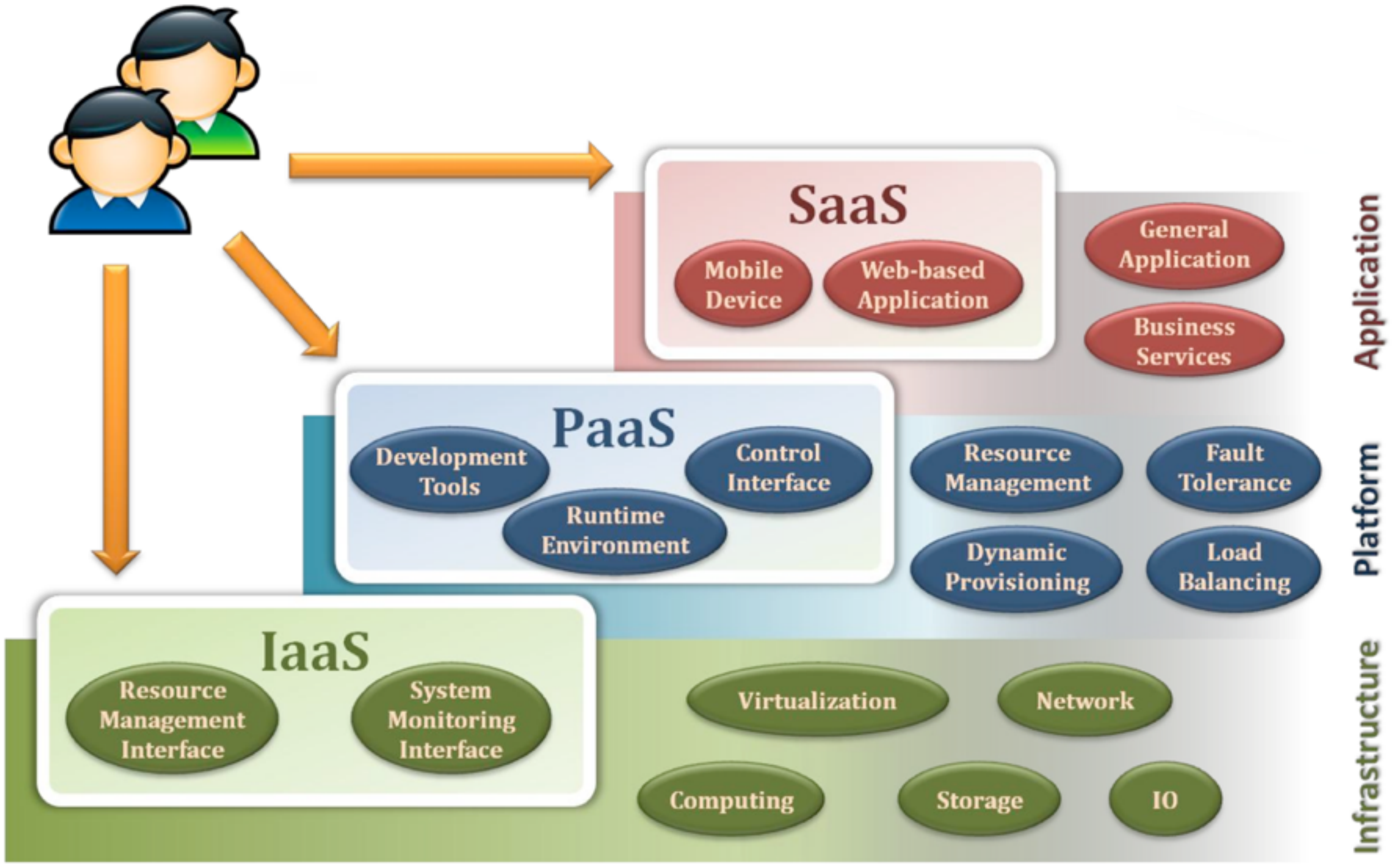
- What do you do?

- Build a new house?
  - You can fully control everything you like to have in your house
  - It is a hard work...
- Buy an empty house?
  - You can fully control only some parts of your house
  - Can not change original infrastructure
- Live in a hotel?
  - Great if you only want to enjoy your life
  - House just for living

Service Models for Clouds

- You want an IT department!
- You can rent some infrastructure and build up your IT system with these resources, under your full control
  - Build a new house
  - Technically, use **Infrastructure as a Service** (IaaS)
- You develop your IT applications through one Cloud platform, not caring about low level resource management
  - Buy an empty house
  - Technically, use **Platform as a Service** (PaaS)
- You directly use some existing IT solutions, provided by the Cloud and ignoring any further deteal
  - Live in a hotel
  - Technically, use **Software as a Service** (SaaS)

Service Models Summary



Infrastructure as a Service (I)

- The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications.

- The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, deployed applications, and possibly limited control of select networking components .

- Examples: Amazon EC2, Eucalyptus, OpenNebula

Infrastructure as a Service (II)

- Enabling technology: **virtualization**
  - An abstraction of logical resources away from underlying physical resources.
- Supported **properties**:
  - Manageability and interoperability
  - Availability and reliability
  - Scalability and elasticity
- Provided service:
  - **Virtual Machine** – As an IaaS provider, we should be able to provide the basic virtual machine operations, such as creation, suspension, resumption and termination, ... and be able to monitor some system states of each virtual machine, such as CPU loading, memory utilization, IO loading and internal network loading, ...
  - **Virtual Storage** – As an IaaS provider, we should be able to provide the basic virtual storage operations, such as space allocation, space release, data writing and data reading, ... and be able to monitor some storage states of each virtual storage, such as virtual space utilization, data duplication and storage device access bandwidth, ...
  - **Virtual Network** – As an IaaS provider, we should be able to provide the basic virtual network operations, such as IP address allocation, domain name register, connection establishment and bandwidth provision, ... and be able to monitor some network states of each virtual network, such as virtual network bandwidth, network connectivity and network load balancing, ...

Platform as a Service (I)

- The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages and tools supported by the provider.

- The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and possibly application hosting environment configurations.

- Examples: Microsoft Windows Azure, Google App Engine, Hadoop, Amazon Elastic MapReduce

Platform as a Service (II)

- Enabling technology: **runtime environment**
  - Refers to collection of software services available. Usually implemented by a collection of program libraries.
- Supported **properties**:
  - Manageability and interoperability
  - Performance and optimization
  - Availability and reliability
  - Scalability and elasticity
- Provided service:
  - **Programming IDE** – Users make use of programming IDE to develop their services among PaaS. This IDE should integrate the full functionalities which supported from the underling runtime environment. This IDE should also provide some development tools, such as profiler, debugger and testing environment.
  - **System Control Interface**
    - Police-Based Control
      - Typically described as a principle or rule to guide decisions and achieve rational outcome(s)
      - Make the decision according to some requirements
    - Workflow Control
      - Describe the flow of installation and configuration of resources
      - Workflow processing daemon delivers speedy and efficient construction and management of cloud resources

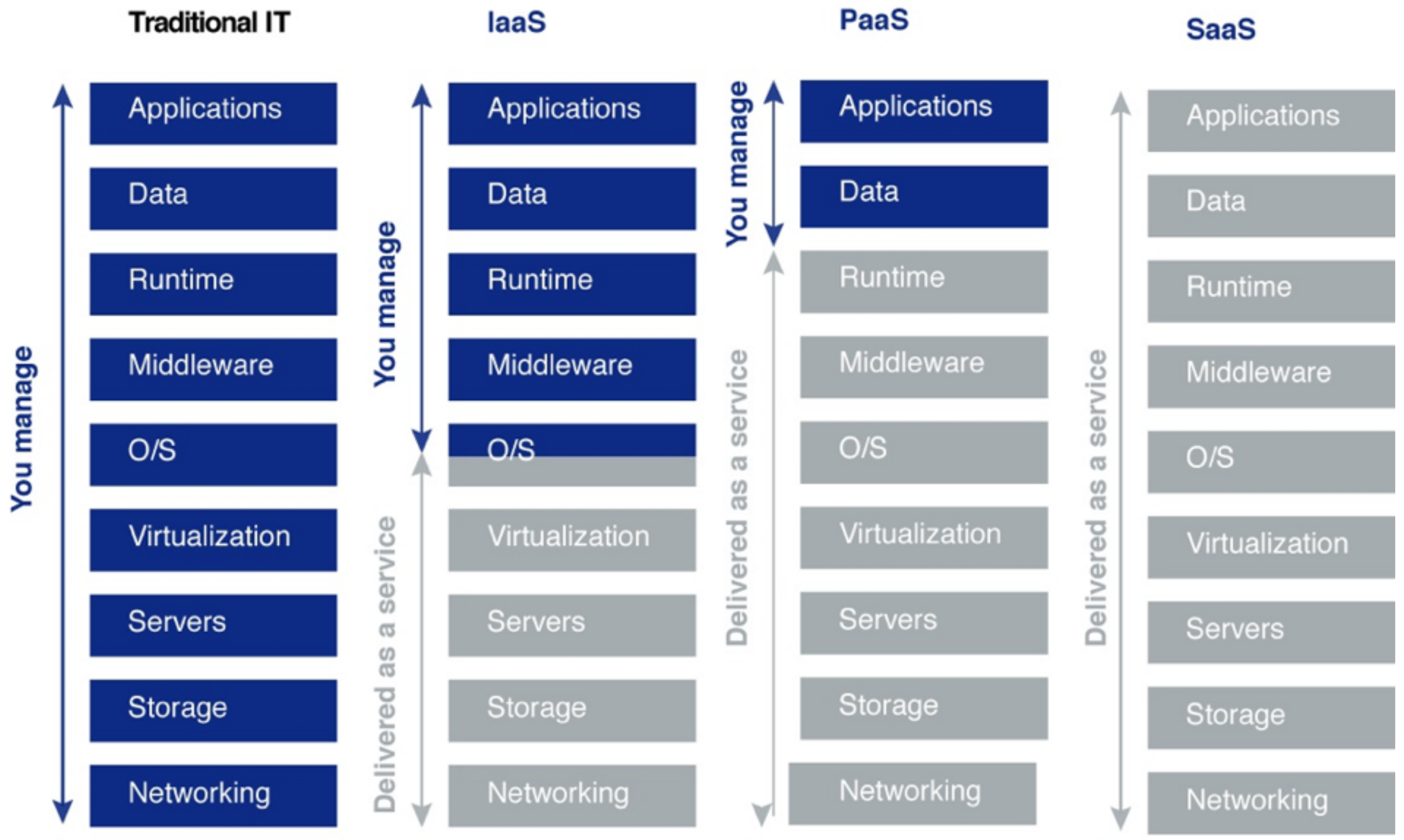
Software as a Service (I)

- The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through a thin client interface such as a web browser (e.g., web-based email).
- The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user-specific application configuration settings.
- Examples: Gmail, DropBox, Google, iCloud

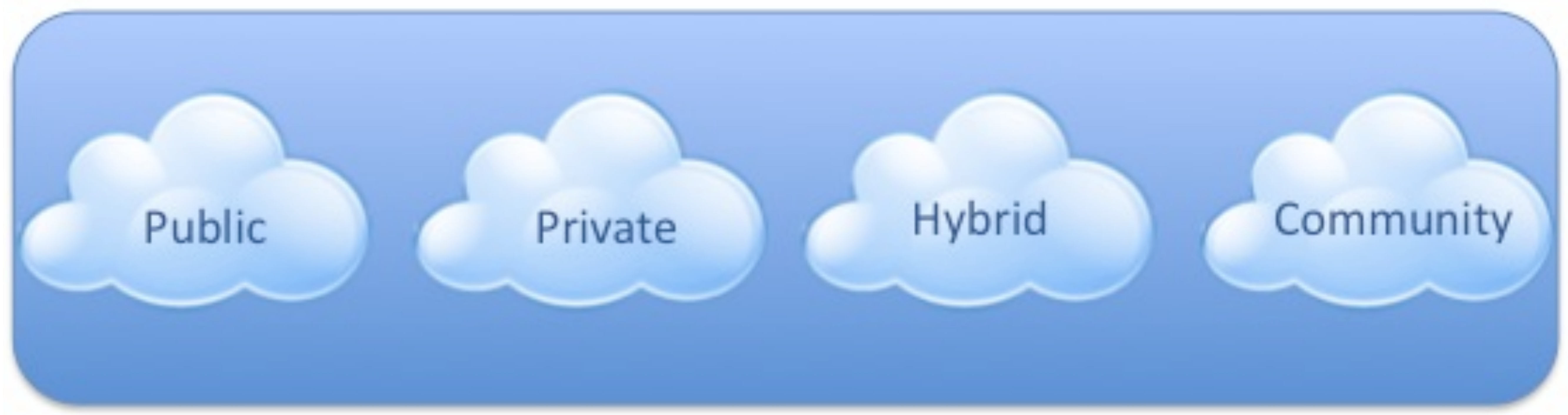
Software as a Service (II)

- Enabling technology: **web service**
  - Refers to a method of communication between two electronic devices over the World Wide Web.
- Supported **properties**:
  - Accessibility and portability
- Provided service:
  - **Web-based Applications**
    - General Applications – Applications which are designed for general propose, such as office suit, multimedia and instant message, ...
    - Business Applications – Application which are designed for business propose, such as ERP, CRM and market trading system, ...
    - Scientific Applications – Application which are designed for scientific propose, such as aerospace simulation and biochemistry simulation, ...
    - Government Applications – Applications which are designed for government propose, such as national medical system and public transportation system service, ...
  - **Web Portal**
    - Apart from the standard search engine feature, web portals offer other services such as e-mail, news, stock prices, information, databases and entertainment.
    - Portals provide a way for enterprises to provide a consistent look and feel with access control and procedures for multiple applications and databases, which otherwise would have been different entities altogether.

Service Models Summary

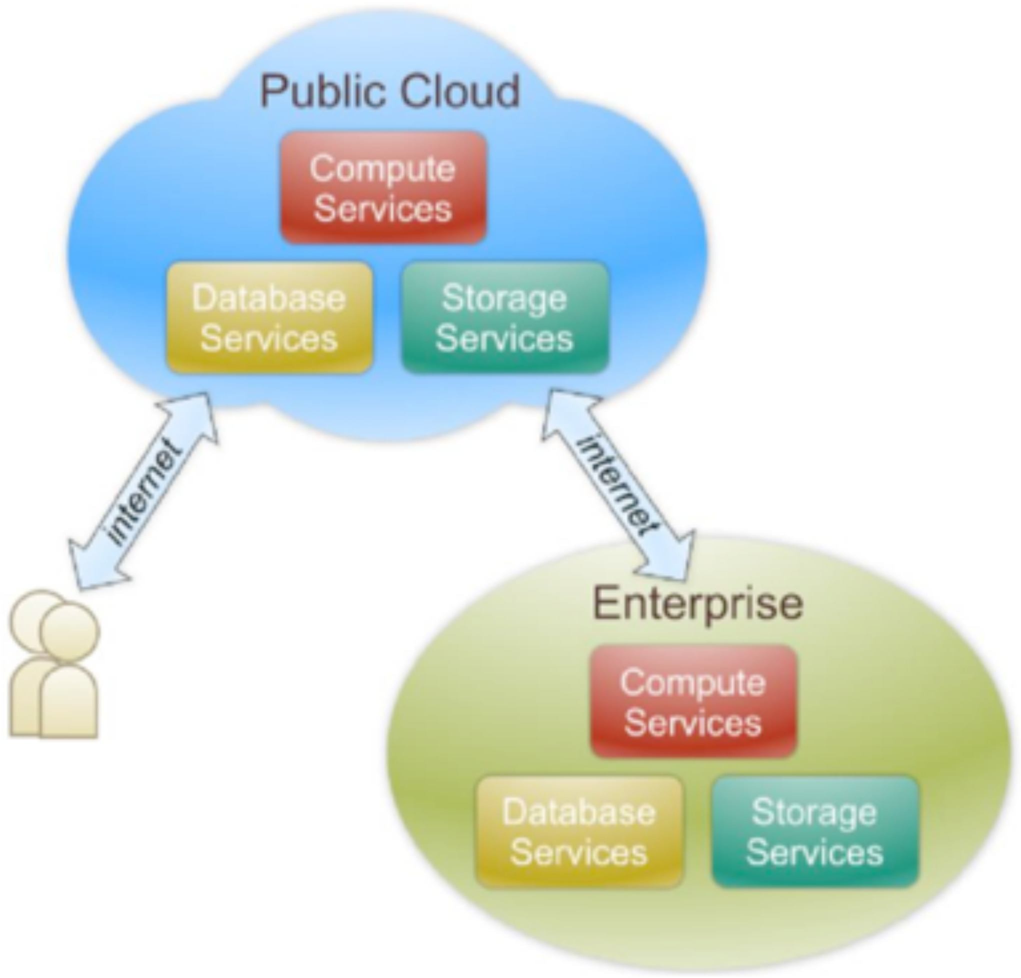


Deployment Models



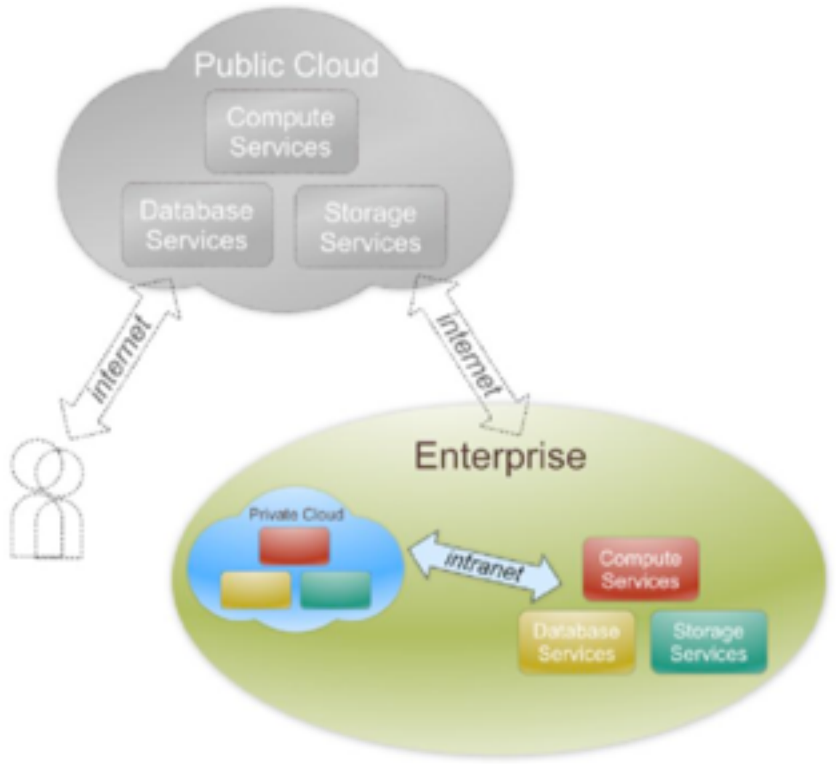
Public Cloud

- The cloud infrastructure is made available to the general public or a large industry group and is owned by an organization selling cloud services.
- Also known as external cloud or multi-tenant cloud, this model essentially represents a cloud environment that is openly accessible.



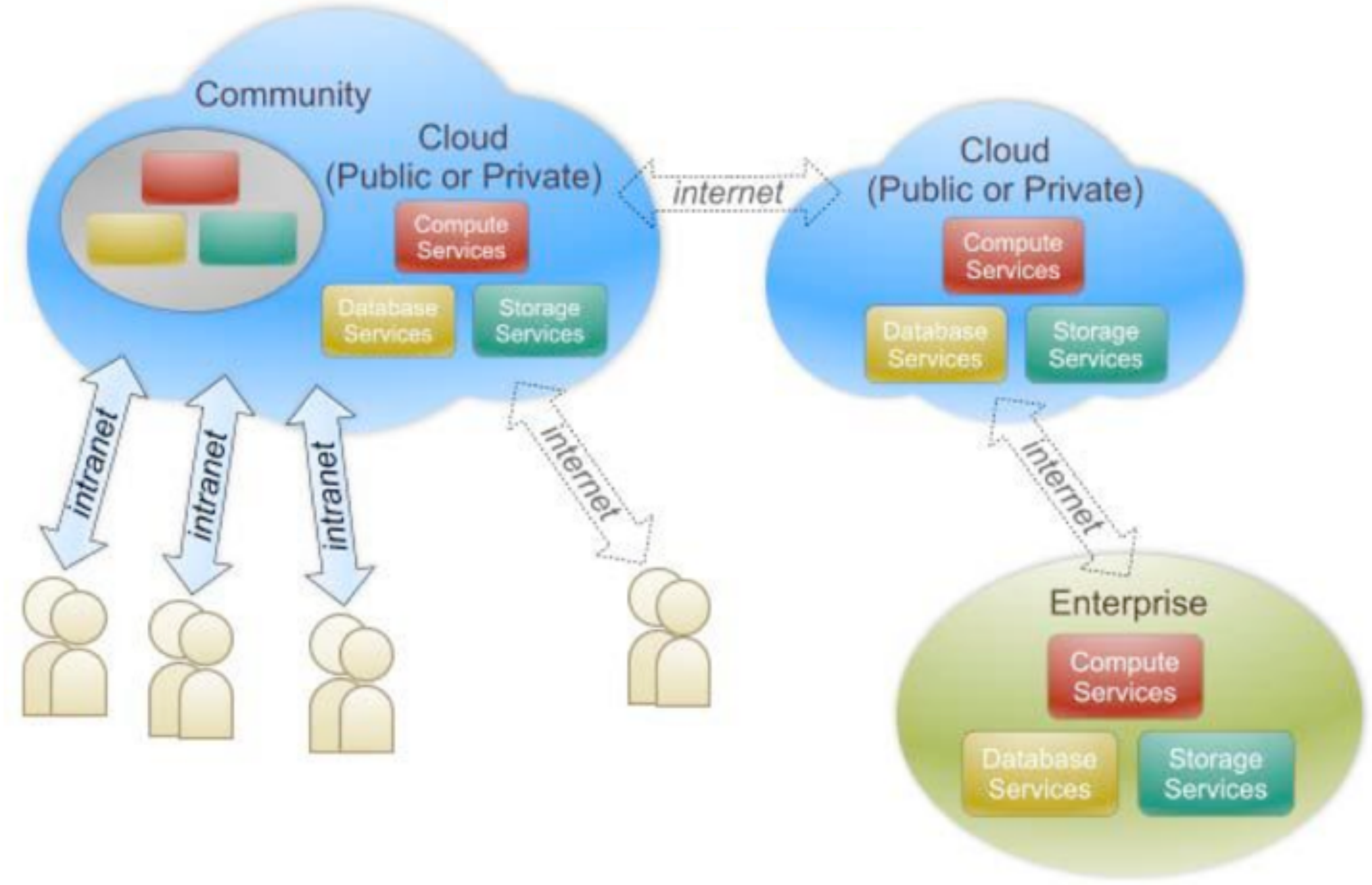
Private Cloud

- The cloud infrastructure is operated solely for an organization. It may be managed by the organization or a third party and may exist on premise or off premise.
- Also referred to as internal cloud or on-premise cloud, a private cloud intentionally limits access to its resources to service consumers that belong to the same organization that owns the cloud.



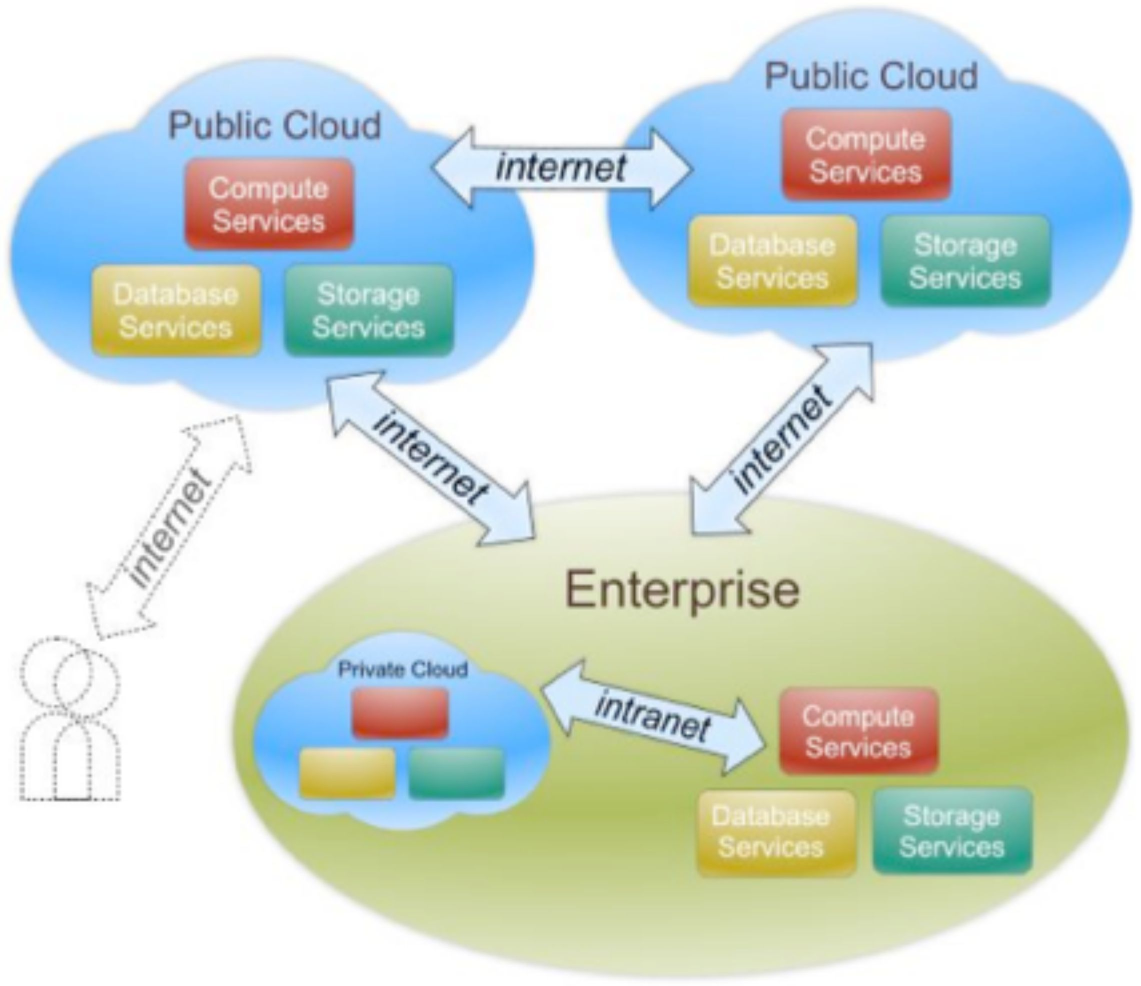
Community Cloud

- The cloud infrastructure is shared by several organizations and supports a specific community that has shared concerns (e.g., mission, security requirements, policy, and compliance considerations).



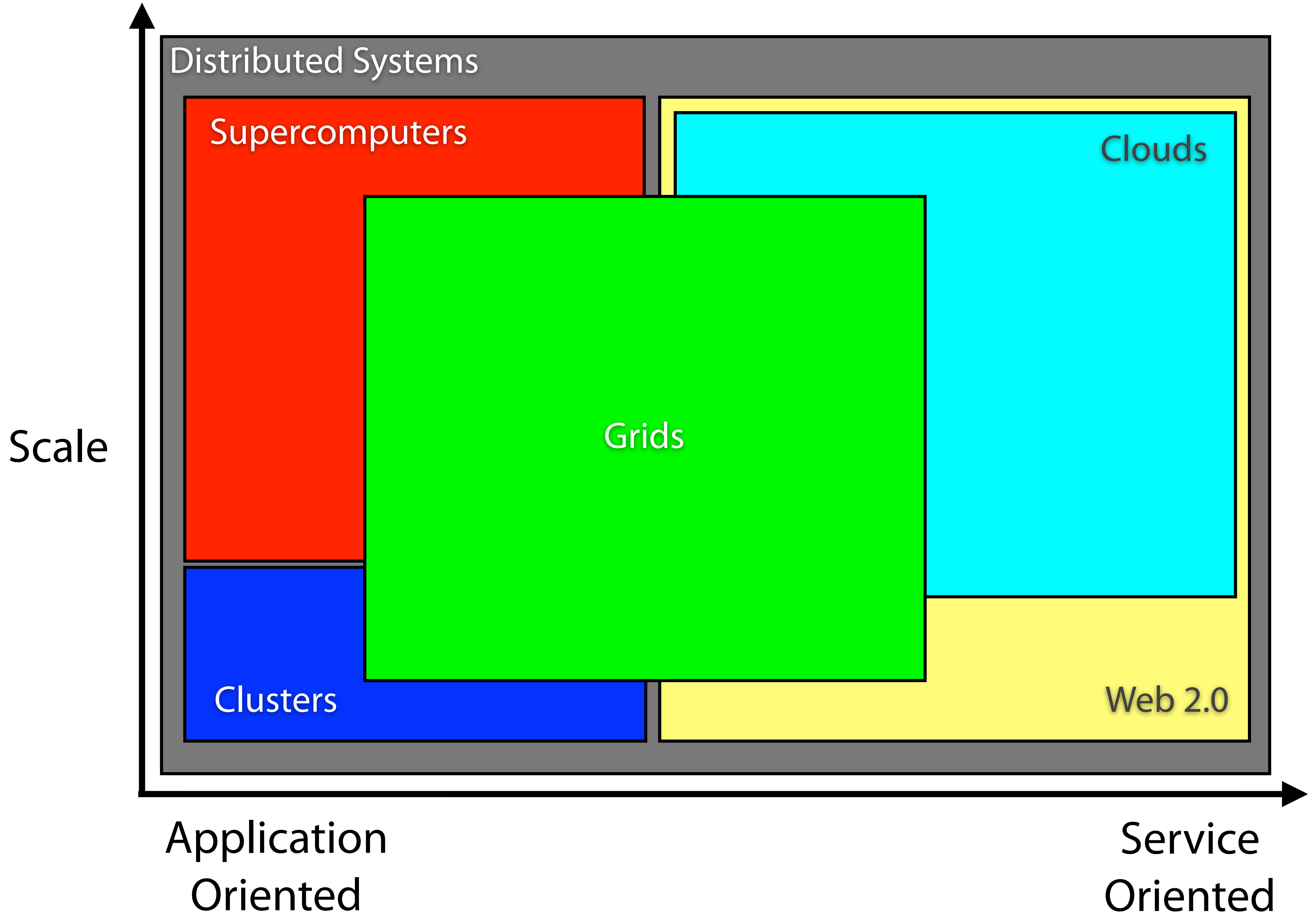
Hybrid Cloud

- The cloud infrastructure is a composition of two or more clouds (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).



Grids versus Clouds

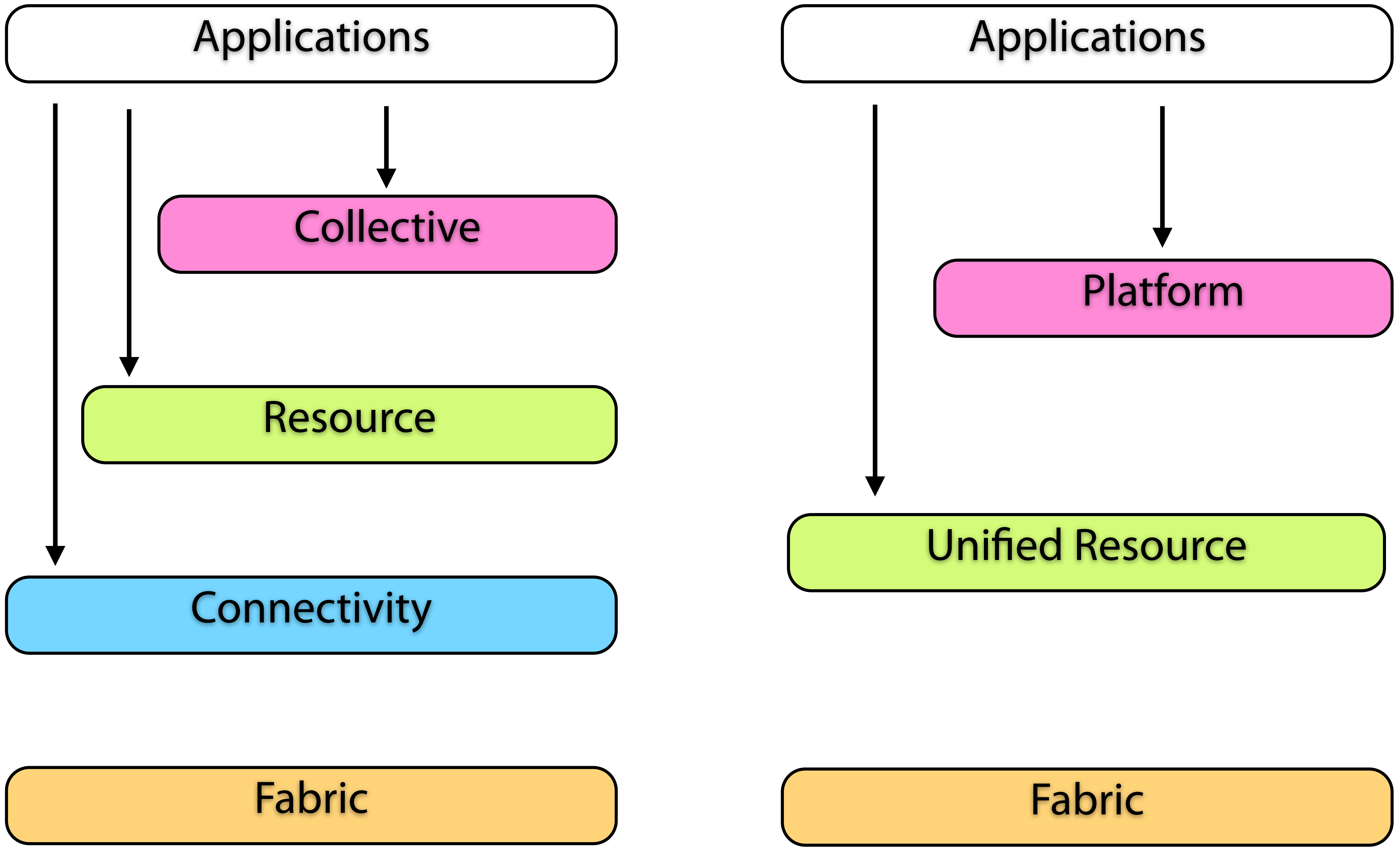
Grids and Clouds Overview



Business Model

- **Classical Computing**
  - One-time payment for unlimited use
  - Capital expenditure
  - Subject to de-pricing
- **Grid Computing**:
  - Project-oriented service units (i.e. CPU hours)
  - Prevent capital expenditure
  - Shared operational expenditure
- **Cloud Computing**
  - Pay-per-use
  - Economy of scale
  - Amazon charges instance-hours, GB/month (disk), TB/month (network)

Architecture



Compute and Data Models

- **Grid Computing:**
- Batch-scheduled compute model (LRM + GRAM)
- Dedicated resources governed by queue scheduling systems
- No native support for interactive applications
- Space-sharing allocations
- Data-to-code
- **Cloud Computing**
- Time sharing
- All users share everything
- Elasticity
- Pay-per-use
- Code-to-data (but multicores can limit)

Programming Model

- **Grid Computing**:
  - Large-scale scientific computations
  - Heterogenous resources
  - Different administrative domains
  - Fast and efficient codes
  - Complex coding (focus on non-functional logic)
  - Example: MPI
- **Cloud Computing**
  - Large-scale data processing
  - Homogeneous resources
  - Same administrative domain
  - Data crunching code
  - Simple coding (focus on business logic)
  - Example: MapReduce

Application Model

- **Grid Computing**:
- High Performance Computing
  - Tightly coupled parallel jobs
- High Throughput Computing
  - Loosely coupled parallel jobs
- Small Number of Large Batch Jobs
- **Cloud Computing**
- Still at infancy
- Independent Jobs
- Large Number of Small Interactive Jobs

Security Model

- **Grid Computing**:
- Heterogenous Resources
- Multiple Administrative Domains
- Large Interoperability
- Based on GSI, PKI, SSL/TLS, SSO, Delegation
- **Cloud Computing**
- Homogeneous Resources
- Single Administrative Domain
- Limited Interoperability
- Based on Web forms over SSL, emails, credit card

Typical Security Concerns

1. **Privileged user access**: sensitive data processed outside the enterprise needs the assurance that they are only accessible and propagated to privileged users
2. **Regulatory compliance:** a customer needs to verify if a Cloud provider has external audits and security certifications and if their infrastructure complies with some regulatory security requirements
3. **Data location**: since a customer will not know where her data will be stored, it is important that the Cloud provider commit to storing and processing data in specific jurisdictions and to obey local privacy requirements on behalf of the customer
4. **Data segregation**: one needs to ensure that one customer's data is fully segregated from another customer's data;
5. **Recovery**: it is important that the Cloud provider has an efficient replication and recovery mechanism to restore data if a disaster occurs;
6. **Investigative support:** Cloud services are especially difficult to investigate, if this is important for a customer, then such support needs to be ensured with a contractual commitment;
7. **Long-term viability**: your data should be viable even the Cloud provider is acquired by another company.

Reading Assignments

- NIST (National Institute of Standards and Technology), NIST Cloud Computing Reference Architecture, http://csrc.nist.gov/groups/SNS/cloud-computing/
- M. Armbrust et al., Above the Clouds: A Berkeley View of Cloud Computing, Technical Report No. UCB/EECS-2009-28, University of California at Berkeley, 2009.
- I. Foster et al., Cloud Computing and Grid Computing 360-Degree Compared, Grid Computing Environments Workshop, 2008. GCE '08 , pp.1-10, 12-16 Nov. 2008
- R. Buyya et al., Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility, FGCS 25(6), pp. 599-616, Jun 2009

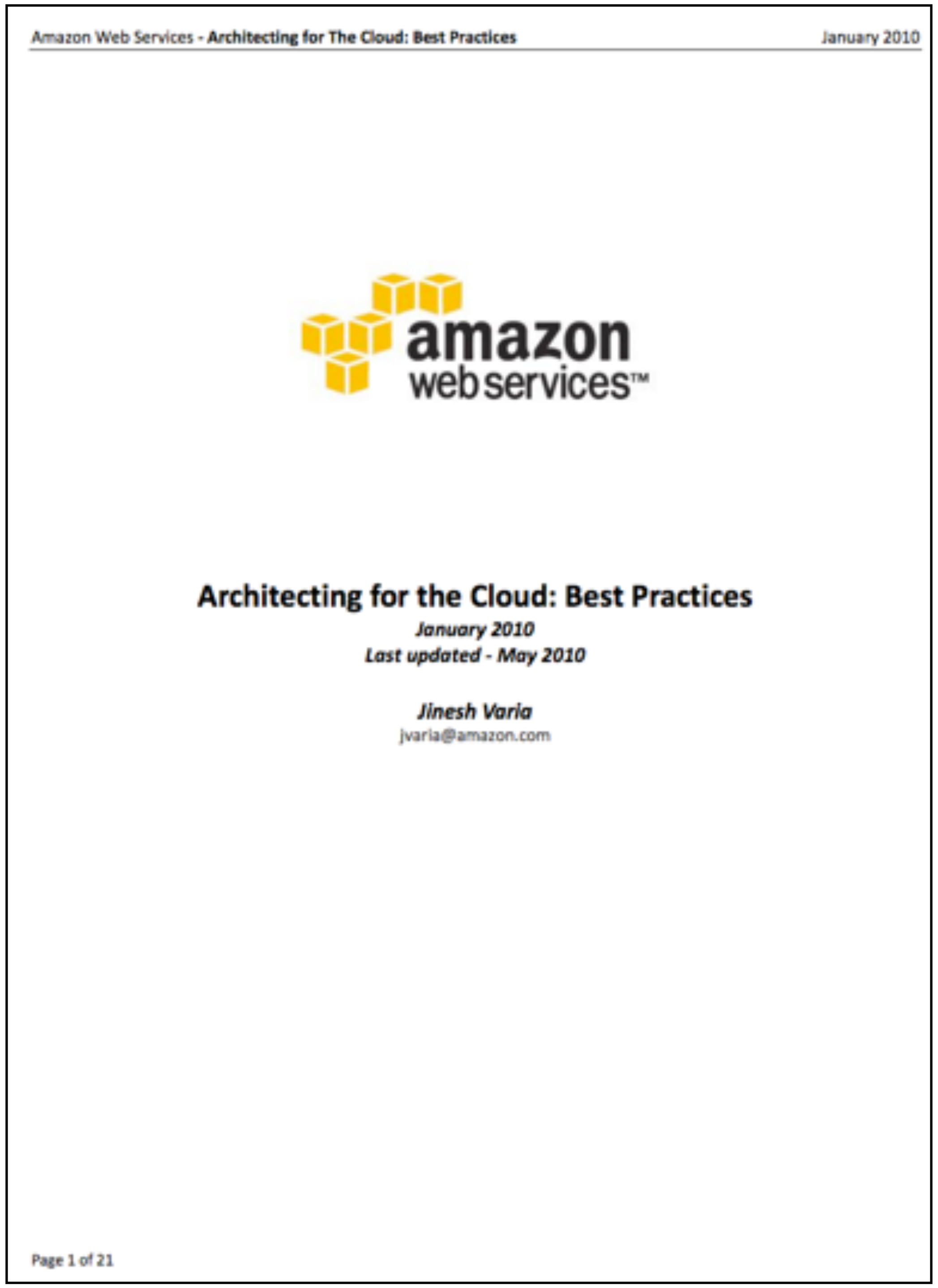
Design Patterns for the Cloud

based on

Amazon Web Services

Architecting for the Cloud: Best Practices

Jinesh Varia


Amazon Web Services - Architecting for The Cloud: Best Practices January 2010

Architecting for the Cloud: Best Practices

January 2010

Last updated - May 2010

Jinesh Varia

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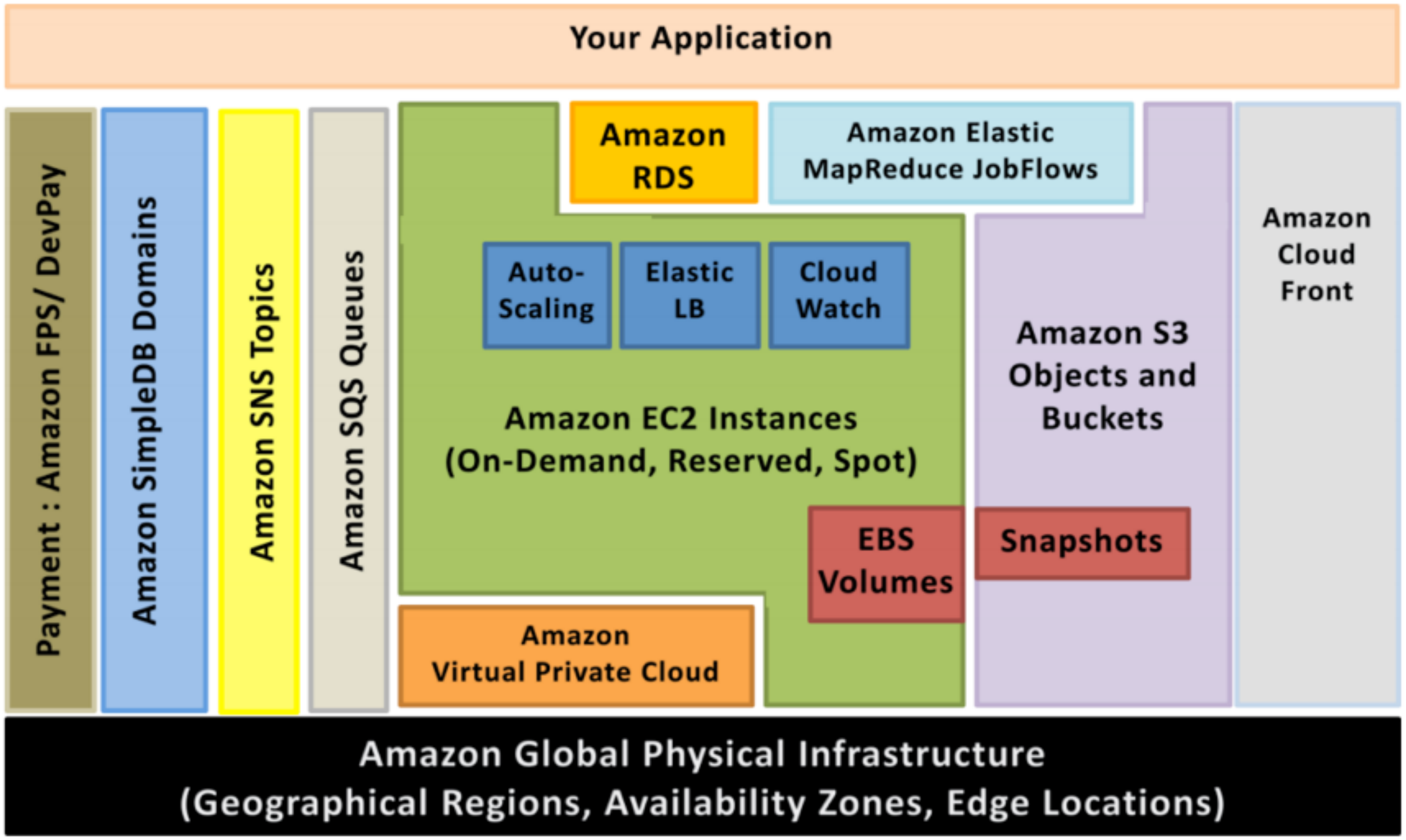
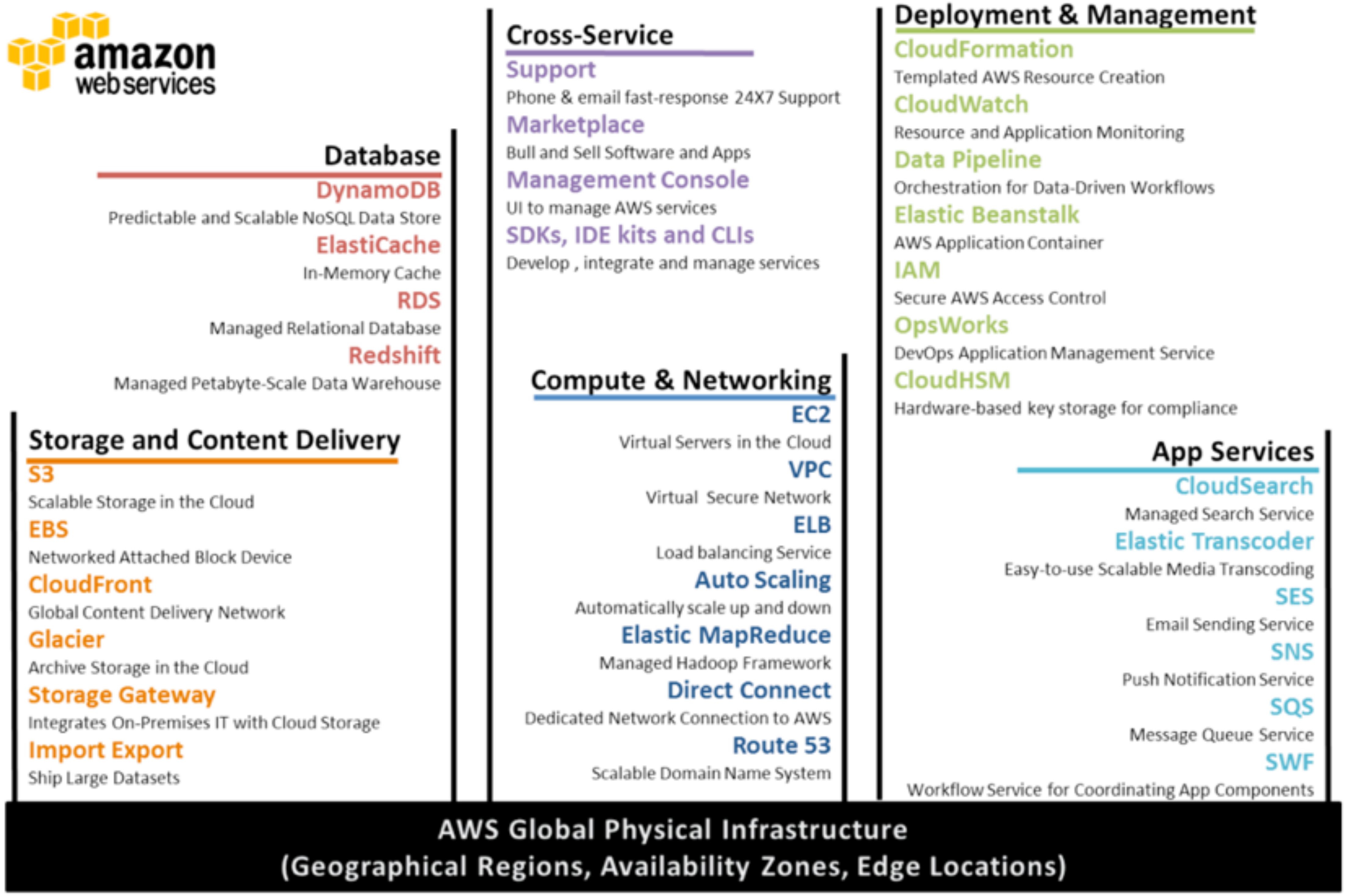
Page 1 of 21

http://media.amazonwebservices.com/AWS_Cloud_Best_Practices.pdf

Amazon Web Services


Your Application
Payment : Amazon FPS/ DevPay
Amazon SimpleDB Domains
Amazon SNS Topics
Amazon SQS Queues
Amazon RDS
Amazon Elastic MapReduce JobFlows
Auto-Scaling
Elastic LB
Cloud Watch
Amazon EC2 Instances (On-Demand, Reserved, Spot)
EBS Volumes
Amazon Virtual Private Cloud
Amazon S3 Objects and Buckets
Snapshots
Amazon Cloud Front
Amazon Global Physical Infrastructure (Geographical Regions, Availability Zones, Edge Locations)

Amazon Web Services



amazon web services

Database

DynamoDB
Predictable and Scalable NoSQL Data Store
ElastiCache
In-Memory Cache
RDS
Managed Relational Database
Redshift
Managed Petabyte-Scale Data Warehouse

Storage and Content Delivery

S3
Scalable Storage in the Cloud
EBS
Networked Attached Block Device
CloudFront
Global Content Delivery Network
Glacier
Archive Storage in the Cloud
Storage Gateway
Integrates On-Premises IT with Cloud Storage
Import Export
Ship Large Datasets

Cross-Service

Support
Phone & email fast-response 24X7 Support
Marketplace
Bull and Sell Software and Apps
Management Console
UI to manage AWS services
SDKs, IDE kits and CLIs
Develop , integrate and manage services

Compute & Networking

EC2
Virtual Servers in the Cloud
VPC
Virtual Secure Network
ELB
Load balancing Service
Auto Scaling
Automatically scale up and down
Elastic MapReduce
Managed Hadoop Framework
Direct Connect
Dedicated Network Connection to AWS
Route 53
Scalable Domain Name System

Deployment & Management

CloudFormation
Templated AWS Resource Creation
CloudWatch
Resource and Application Monitoring
Data Pipeline
Orchestration for Data-Driven Workflows
Elastic Beanstalk
AWS Application Container
IAM
Secure AWS Access Control
OpsWorks
DevOps Application Management Service
CloudHSM
Hardware-based key storage for compliance

App Services

CloudSearch
Managed Search Service
Elastic Transcoder
Easy-to-use Scalable Media Transcoding
SES
Email Sending Service
SNS
Push Notification Service
SQS
Message Queue Service
SWF
Workflow Service for Coordinating App Components

AWS Global Physical Infrastructure
(Geographical Regions, Availability Zones, Edge Locations)

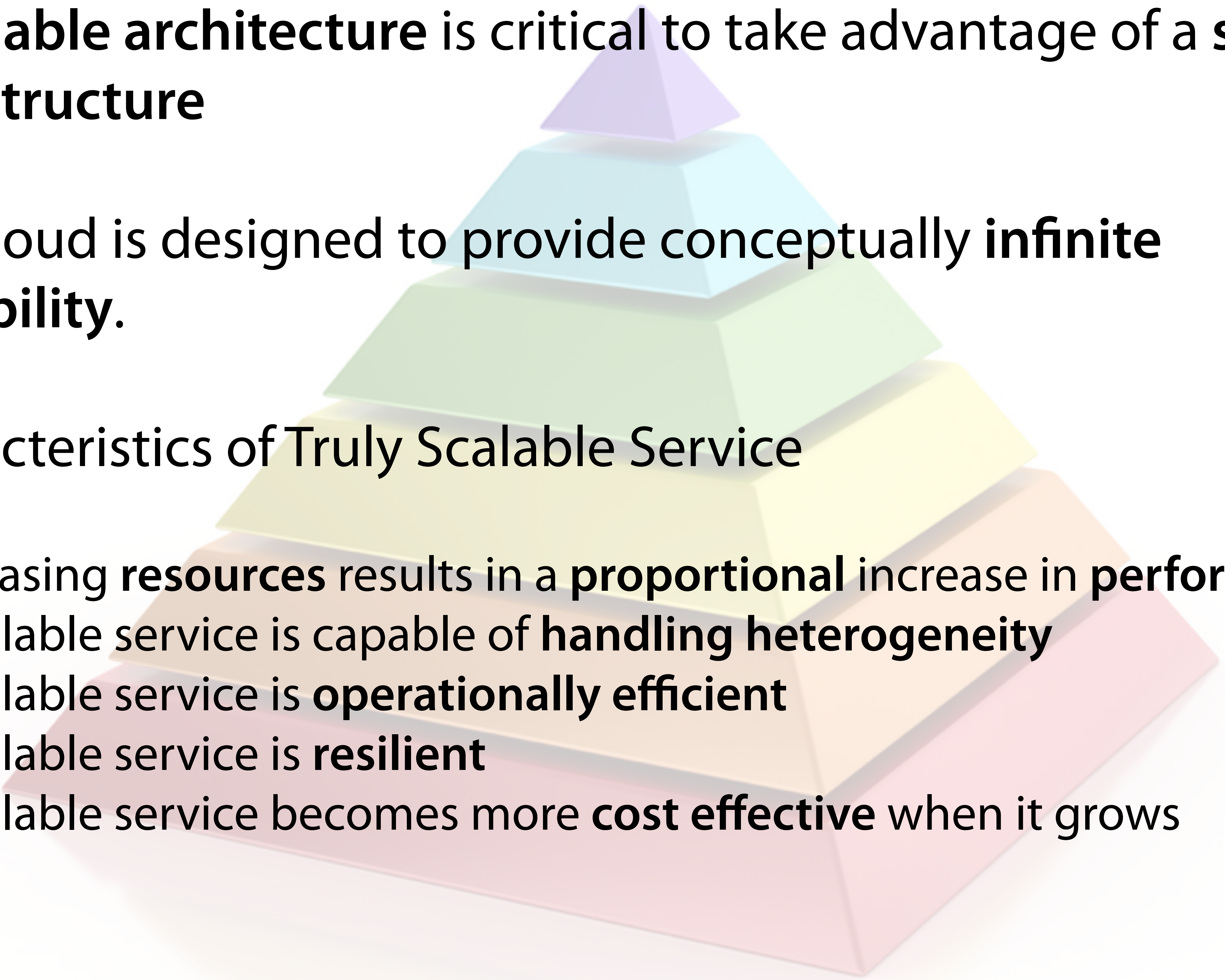
Scalable Architectures

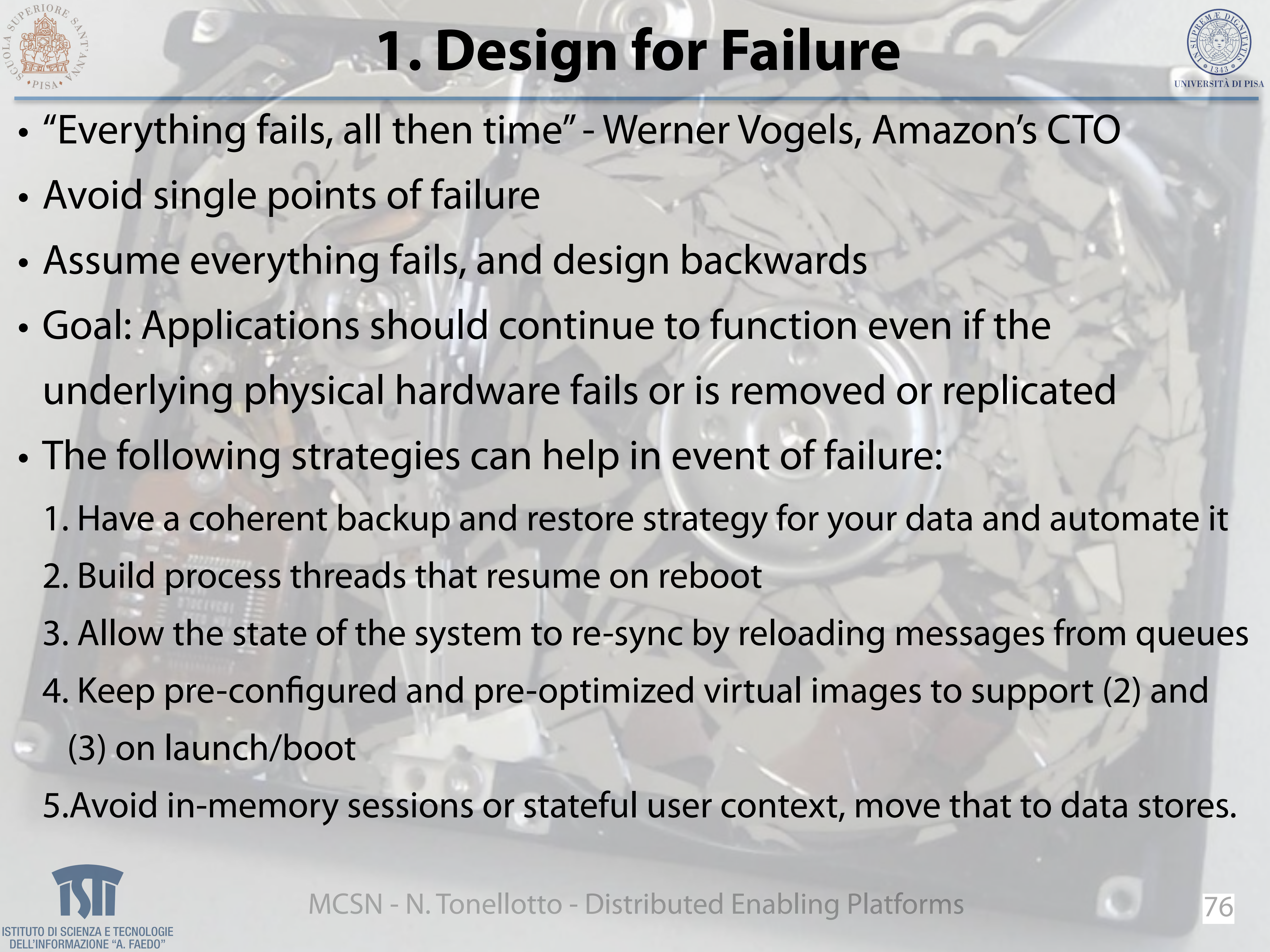
A **scalable architecture** is critical to take advantage of a **scalable infrastructure**

The cloud is designed to provide conceptually **infinite scalability**.

Characteristics of Truly Scalable Service

- Increasing **resources** results in a **proportional** increase in **performance**
- A scalable service is capable of **handling heterogeneity**
- A scalable service is **operationally efficient**
- A scalable service is **resilient**
- A scalable service becomes more **cost effective** when it grows





1. Design for Failure

- "Everything fails, all then time" - Werner Vogels, Amazon's CTO
- Avoid single points of failure
- Assume everything fails, and design backwards
- Goal: Applications should continue to function even if the underlying physical hardware fails or is removed or replicated
- The following strategies can help in event of failure:

1. Have a coherent backup and restore strategy for your data and automate it
2. Build process threads that resume on reboot
3. Allow the state of the system to re-sync by reloading messages from queues
4. Keep pre-configured and pre-optimized virtual images to support (2) and (3) on launch/boot
5. Avoid in-memory sessions or stateful user context, move that to data stores.

1. AWS Tactics

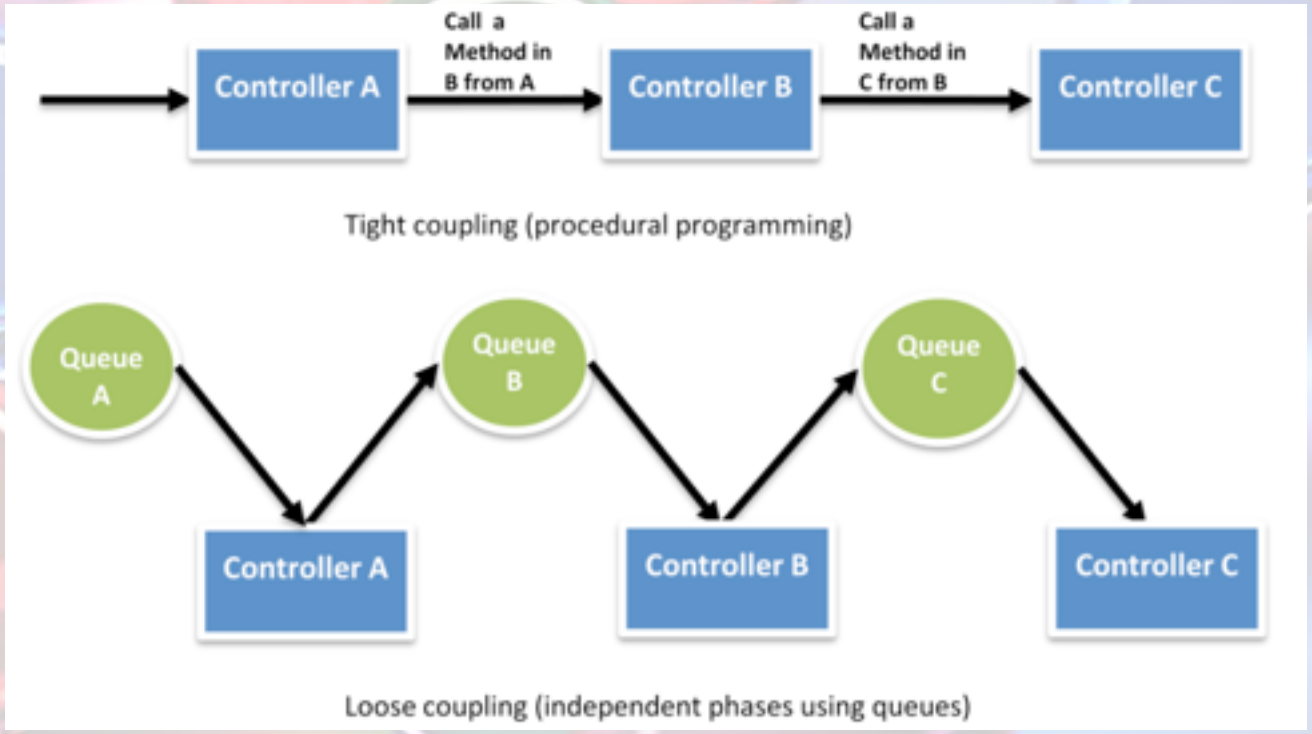
1. **Elastic IP** is a static IP that is dynamically re-mappable. You can quickly remap and failover to another set of servers so that your traffic is routed to the new servers.
2. **Availability Zones** are conceptually like logical datacenters. By deploying your architecture to multiple availability zones, you can ensure highly availability.
3. Maintain an **Amazon Machine Image** so that you can restore and clone environments very easily in a different Availability Zone.
4. Utilize **Amazon CloudWatch** (or various real-time open source monitoring tools) to get more visibility and take appropriate actions in case of hardware failure or performance degradation.
5. Setup an **Auto scaling group** to maintain a fixed fleet size so that it replaces unhealthy Amazon EC2 instances by new ones.
6. Utilize **Amazon EBS** and set up cron jobs so that incremental snapshots are automatically uploaded to **Amazon S3** and data is persisted independent of your instances.
7. Utilize **Amazon RDS** and set the retention period for backups, so that it can perform automated backups.

2. Design Loosely Coupled Systems

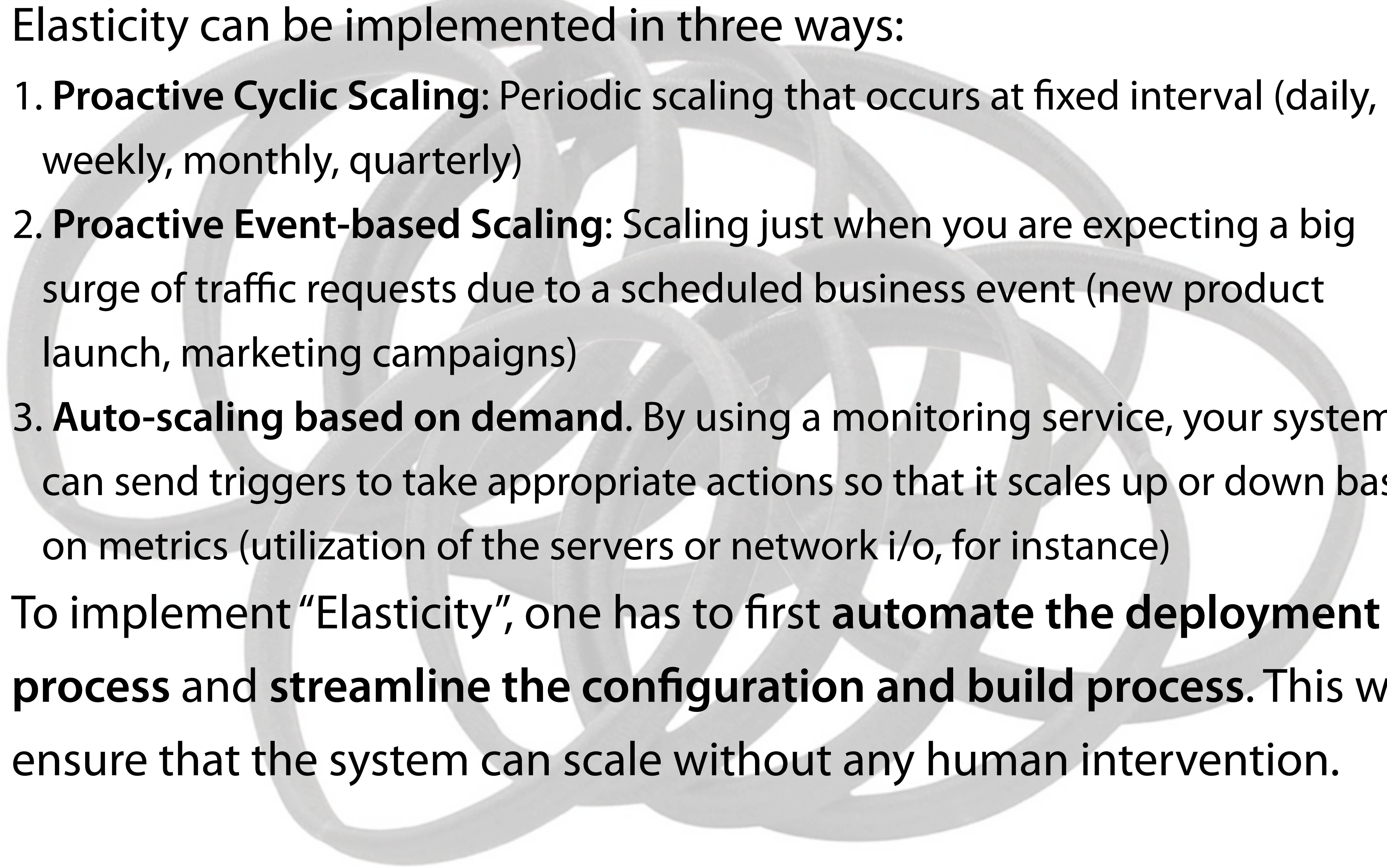
- The cloud reinforces the SOA design principle that **the more loosely coupled the components of the system, the bigger and better it scales.**
- Build components that **do not have tight dependencies** on each other.
- Build **asynchronous systems** and scaling horizontally become very important in the context of the cloud.
- Build systems to **scale out** by adding more instances of same component

2. AWS Tactics

1. Use **Amazon SQS** as buffers between components
2. Design every component such that it expose a **service interface** and is **responsible for its own scalability** in all appropriate dimensions and **interacts** with other components **asynchronously**
3. Bundle the logical construct of a component into an **Amazon Machine Image** so that it can be deployed more often
4. Make your applications **as stateless as possible**. Store session state outside of component (in Amazon SimpleDB, if appropriate)


Controller A
Call a Method in B from A
Controller B
Call a Method in C from B
Controller C
Tight coupling (procedural programming)
Queue A
Queue B
Queue C
Controller A
Controller B
Controller C
Loose coupling (independent phases using queues)

3. Implement Elasticity

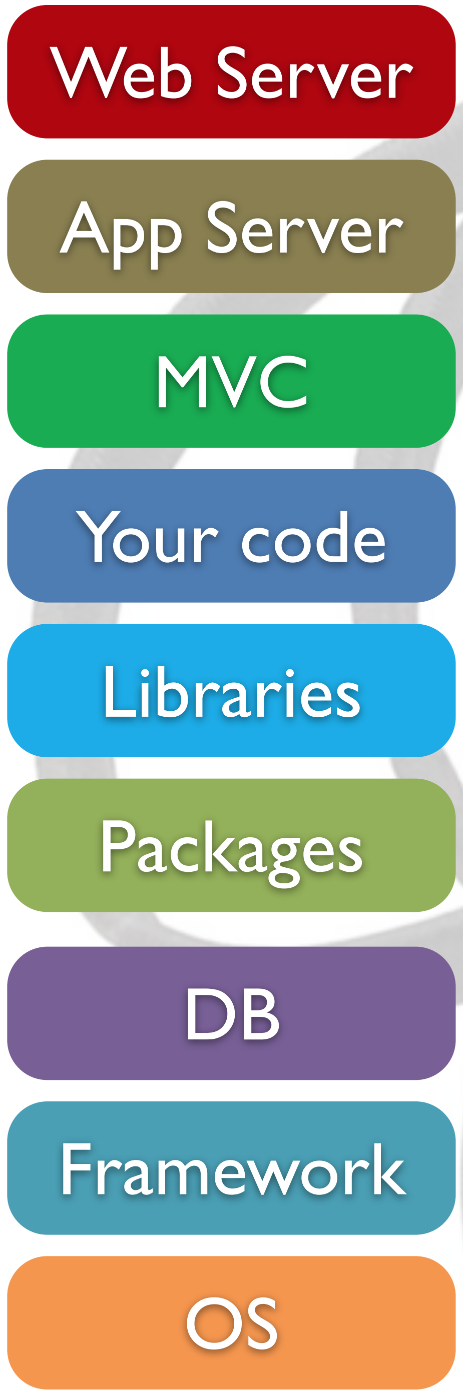


- Elasticity can be implemented in three ways:
  1. **Proactive Cyclic Scaling**: Periodic scaling that occurs at fixed interval (daily, weekly, monthly, quarterly)
  2. **Proactive Event-based Scaling**: Scaling just when you are expecting a big surge of traffic requests due to a scheduled business event (new product launch, marketing campaigns)
  3. **Auto-scaling based on demand**. By using a monitoring service, your system can send triggers to take appropriate actions so that it scales up or down based on metrics (utilization of the servers or network i/o, for instance)
- To implement "Elasticity", one has to first **automate the deployment process** and **streamline the configuration and build process**. This will ensure that the system can scale without any human intervention.

3. Design your AMI

- The cloud allows you to automate your deployment process.
- Take the time to create an automated deployment process early on during the migration process and not wait till the end.
- Creating an automated and repeatable deployment process will help reduce errors and facilitate an efficient and scalable update process.
- To automate the deployment process:
  - Create a **library of "recipes"** – small frequently-used scripts (for installation and configuration)
  - Manage the configuration and deployment process using **agents bundled inside an AMI**
  - **Bootstrap your instances**

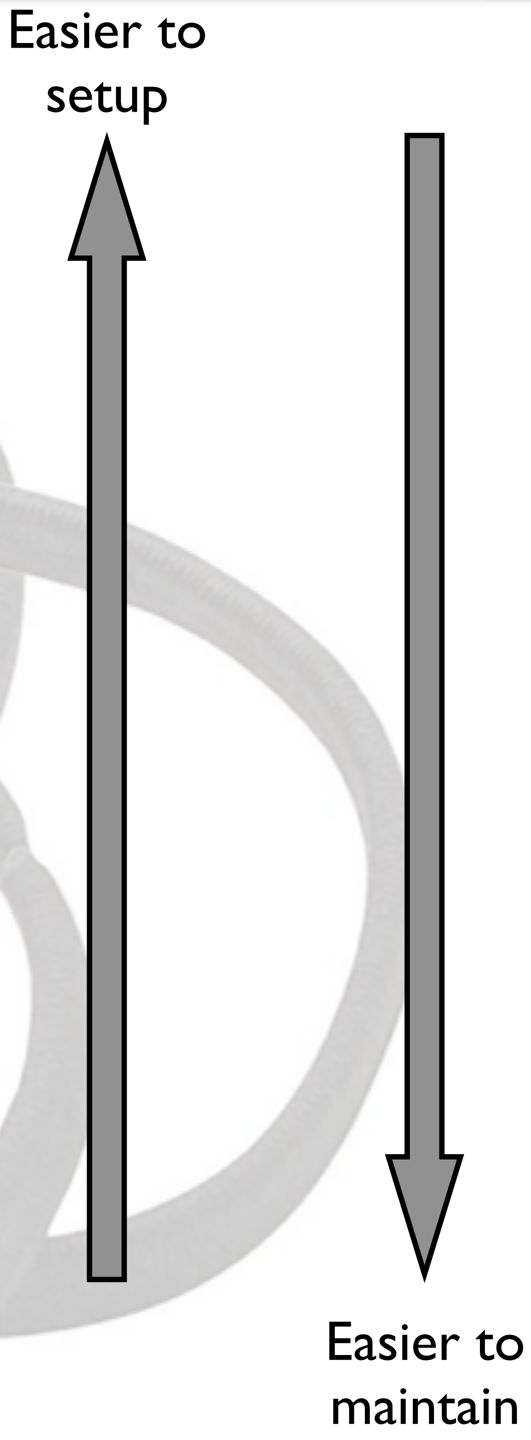
3. AMI Design Approaches



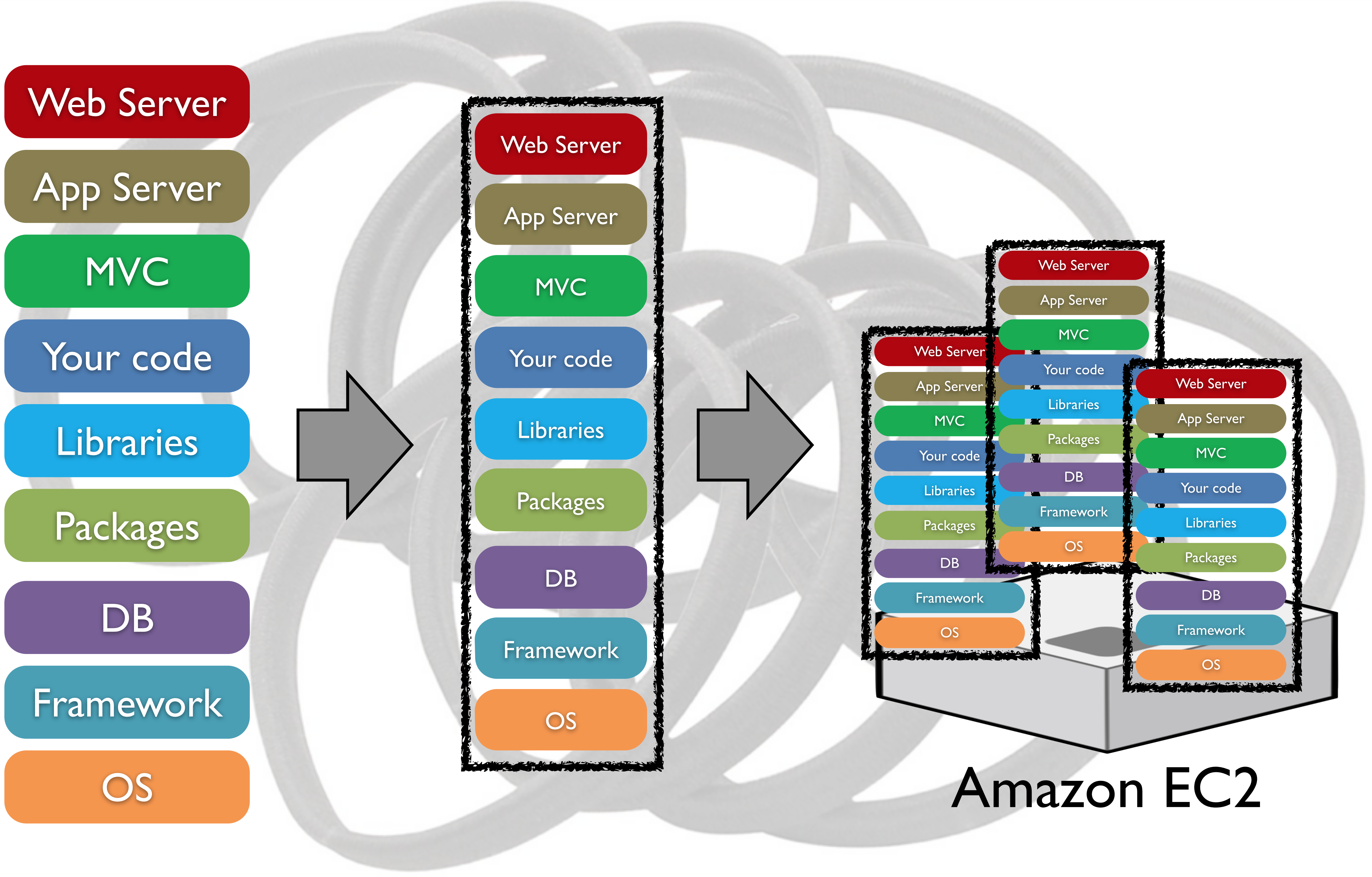
1. Inventory of static AMIs

2. Golden AMIs with fetch on boot

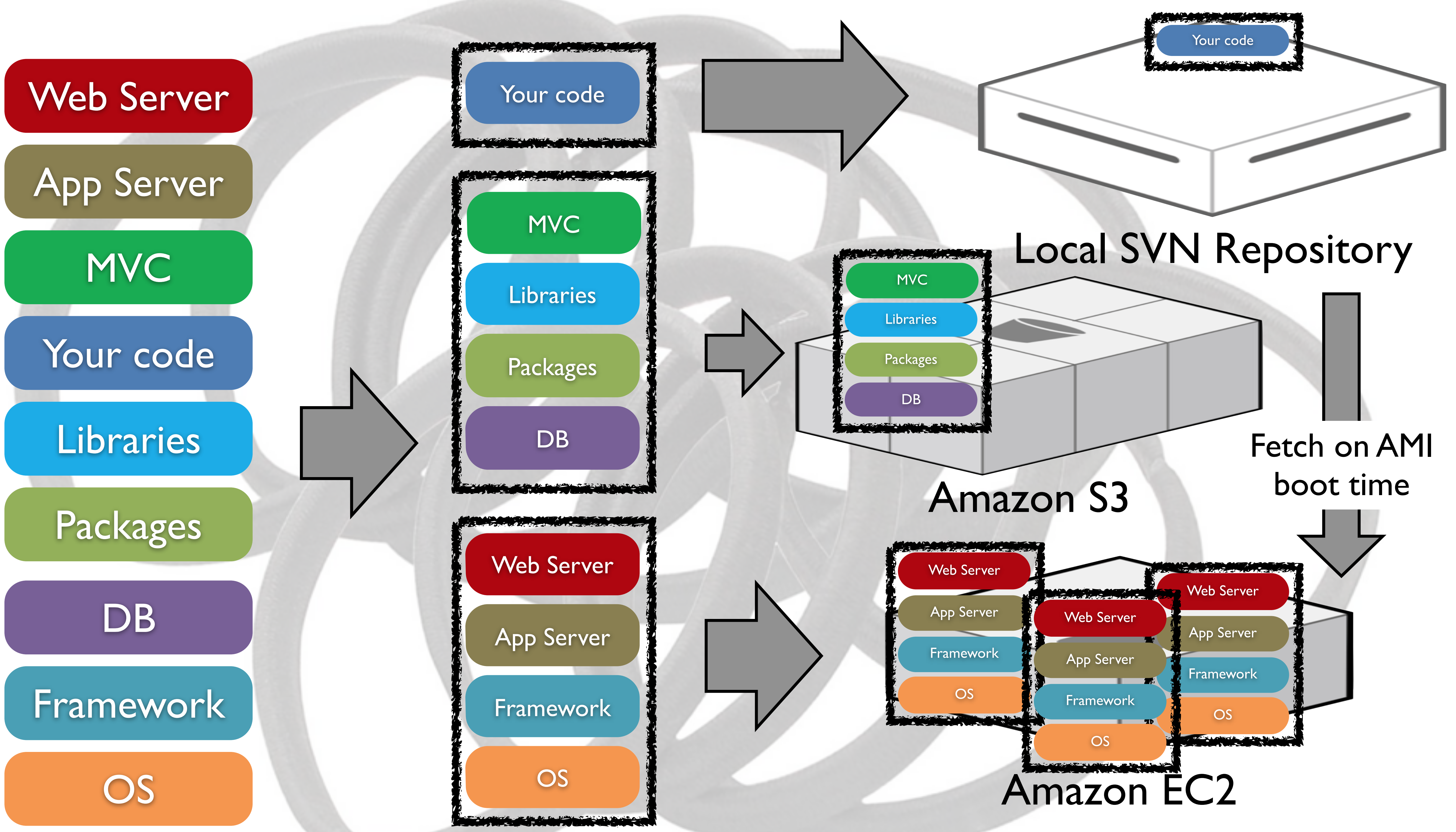
3. AMIs with Just Enough OS and agent



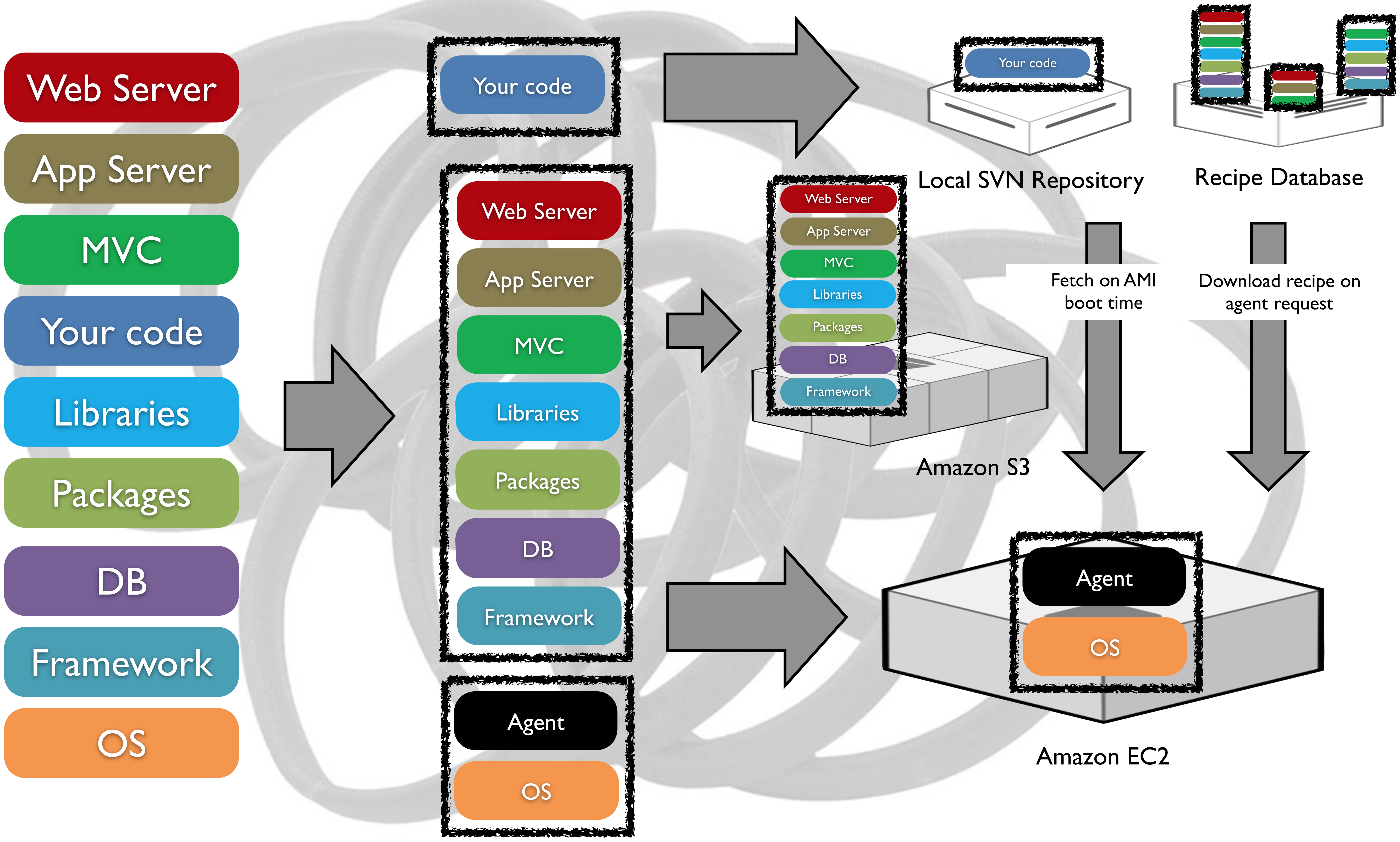
3. Inventory of static AMIs



3. Golden AMIs with fetch on boot



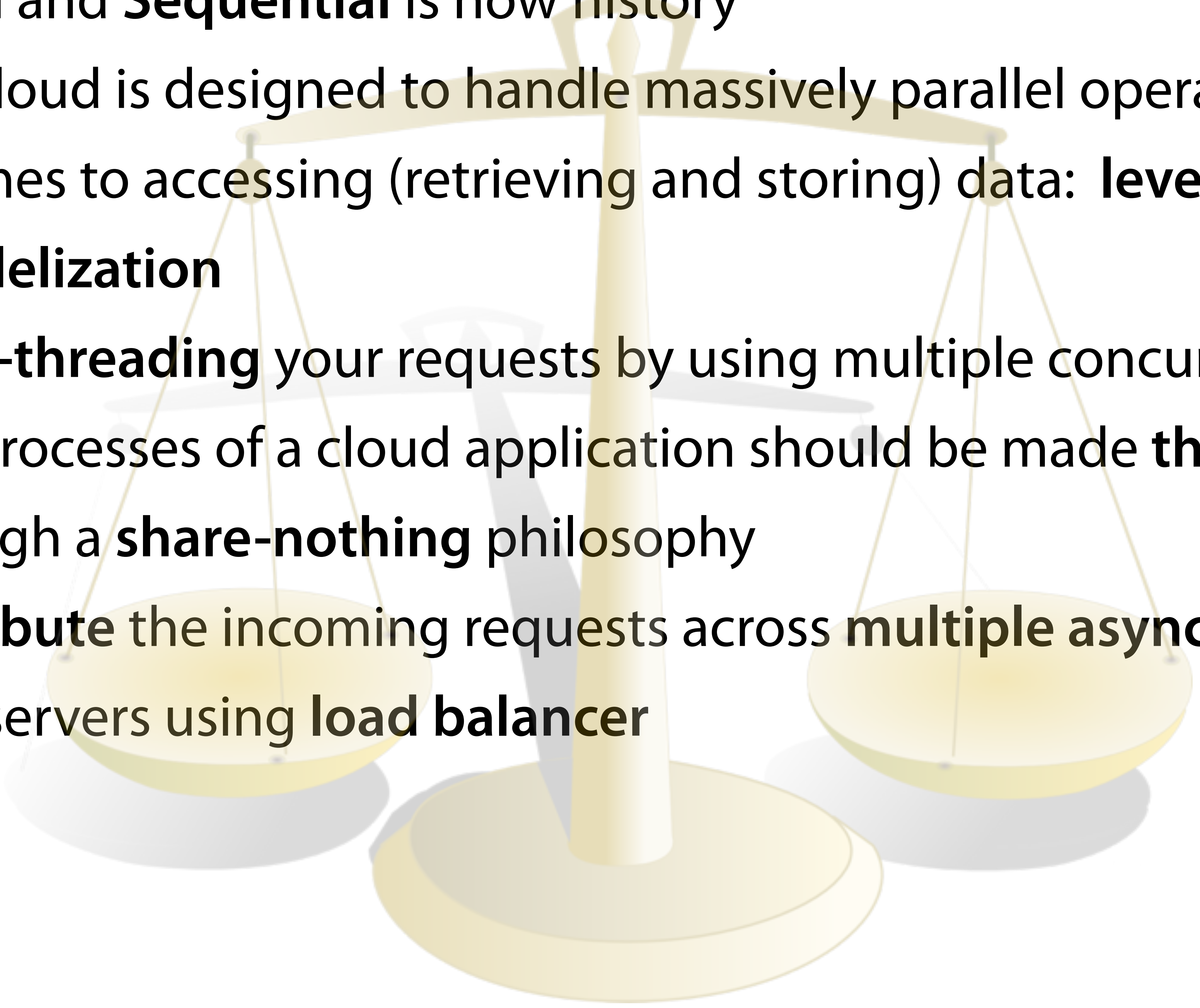
3. AMI with JeOS and agent



3. AWS Tactics

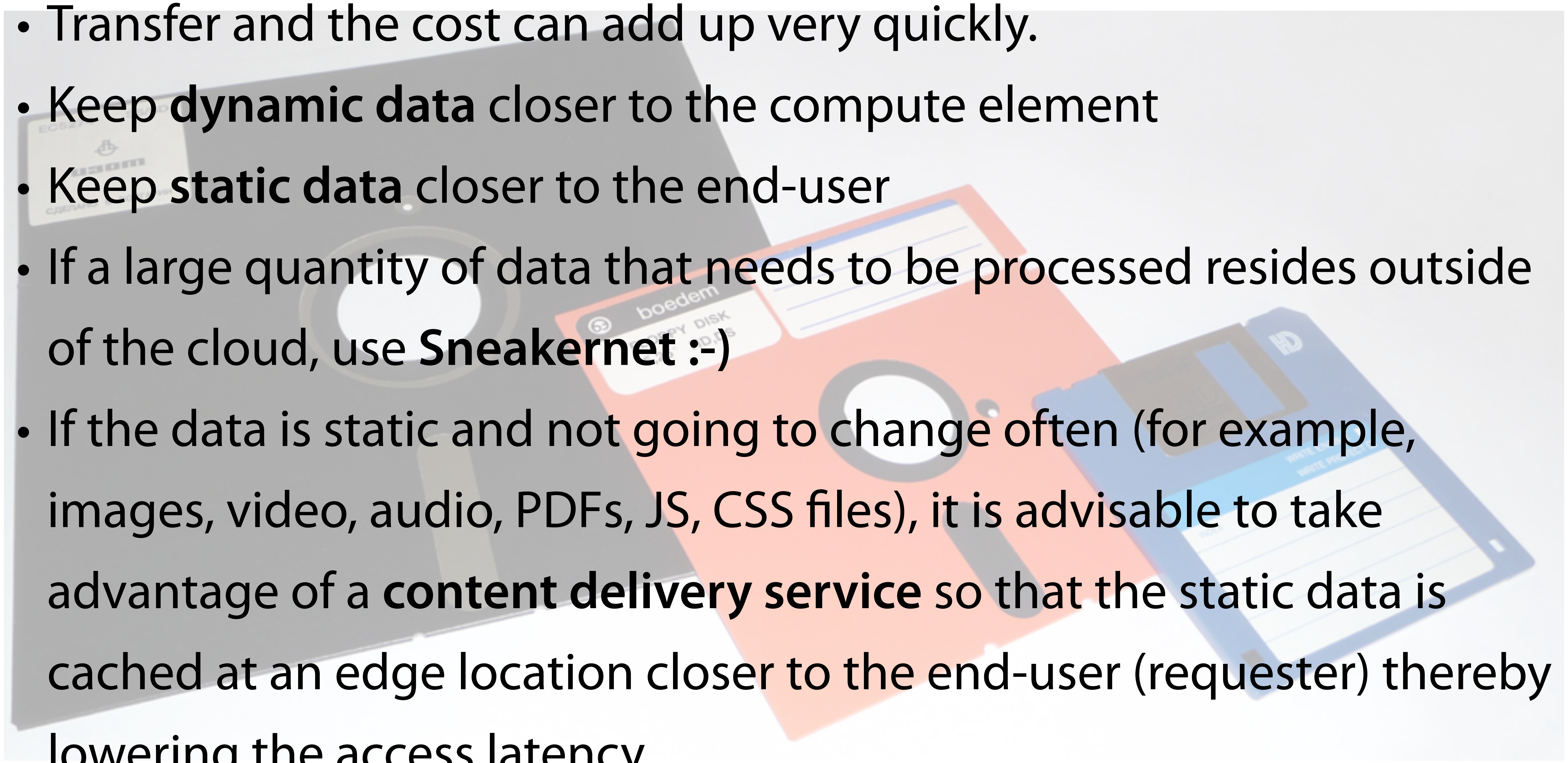
1. Define **Auto-scaling groups** for different clusters
2. **Monitor your system metrics** (CPU, Memory, Disk I/O, Network I/O) using Amazon CloudWatch and take appropriate actions (launching new AMIs dynamically using the Auto-scaling service) or send notifications.
3. **Store and retrieve machine configuration information dynamically**: Utilize Amazon SimpleDB to fetch config data during boot-time of an instance (eg. database connection strings). SimpleDB may also be used to store information about an instance such as its IP address, machine name and role.
4. Design a build process such that it **dumps the latest builds to a bucket** in Amazon S3; **download the latest version** of an application from during system startup.
5. Invest in **building resource management tools** (Automated scripts, pre-configured images) or Use smart open source configuration management tools.
6. Bundle **Just Enough Operating System** (JeOS) and your software dependencies into an Amazon Machine Image so that it is easier to manage and maintain. Pass configuration files or parameters at launch time and retrieve user data and instance metadata after launch.
7. Reduce bundling and launch time by **booting from Amazon EBS volumes** and attaching multiple Amazon EBS volumes to an instance. **Create snapshots** of common volumes and **share snapshots** among accounts wherever appropriate.
8. Application components should **not assume health or location of hardware** it is running on.

4. Think Parallel



- **Serial** and **Sequential** is now history
- The cloud is designed to handle massively parallel operations when it comes to accessing (retrieving and storing) data: **leverage request parallelization**
- **Multi-threading** your requests by using multiple concurrent threads
- The processes of a cloud application should be made **thread-safe** through a **share-nothing** philosophy
- **Distribute** the incoming requests across **multiple asynchronous** web servers using **load balancer**

5. Leverage Storage Options



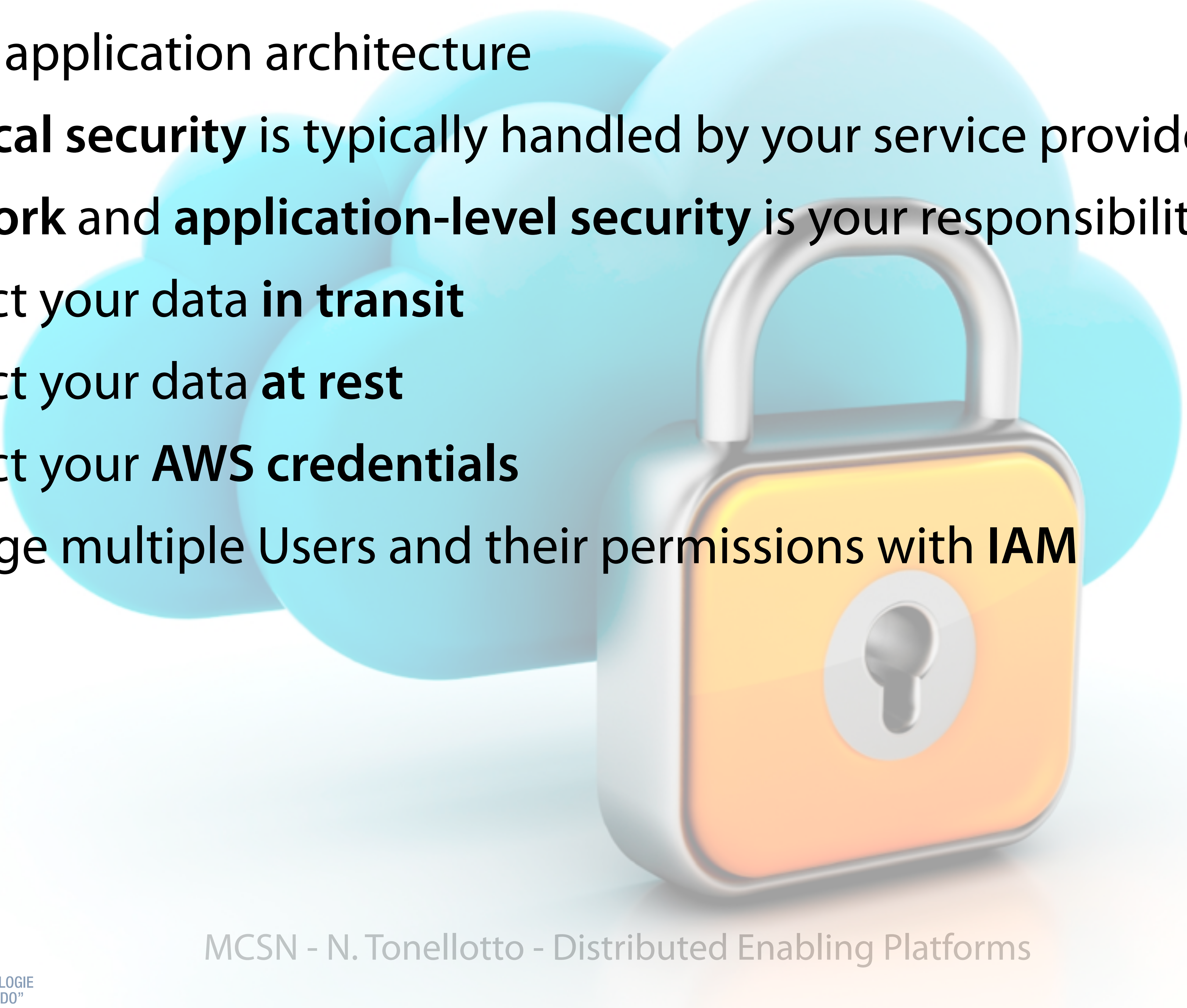
- In the cloud, you are **paying for bandwidth** in and out of the cloud
- Transfer and the cost can add up very quickly.
- Keep **dynamic data** closer to the compute element
- Keep **static data** closer to the end-user
- If a large quantity of data that needs to be processed resides outside of the cloud, use **Sneakernet :-)**
- If the data is static and not going to change often (for example, images, video, audio, PDFs, JS, CSS files), it is advisable to take advantage of a **content delivery service** so that the static data is cached at an edge location closer to the end-user (requester) thereby lowering the access latency.

5. AWS Tactics

	Amazon S3 + CF	Amazon EC2 Ephemeral Store	Amazon EBS	Amazon SimpleDB	Amazon RDS
Ideal for	Storing Large write-once, read-many types of objects, Static Content Distribution	Storing non-persistent transient updates	Off-instance persistent storage for any kind of data,	Querying light-weight attribute data	Storing and querying structured Relational and referential Data
Ideal examples	Media files, audio, video, images, Backups, archives, versioning	Config Data, scratch files, TempDB	Clusters, boot data, Log or data of commercial RDBMS like Oracle, DB2	Querying, Mapping, tagging, click-stream logs, metadata, shared-state management, indexing	Complex transactional systems, inventory management and order fulfillment systems
Not recommended for	Querying, Searching	Storing Database logs or backups, customer data		Relational (joins) query	
Not recommended examples	Database, File Systems	Sensitive data	Content Distribution	OLTP, DW cube rollups	Simple lookups

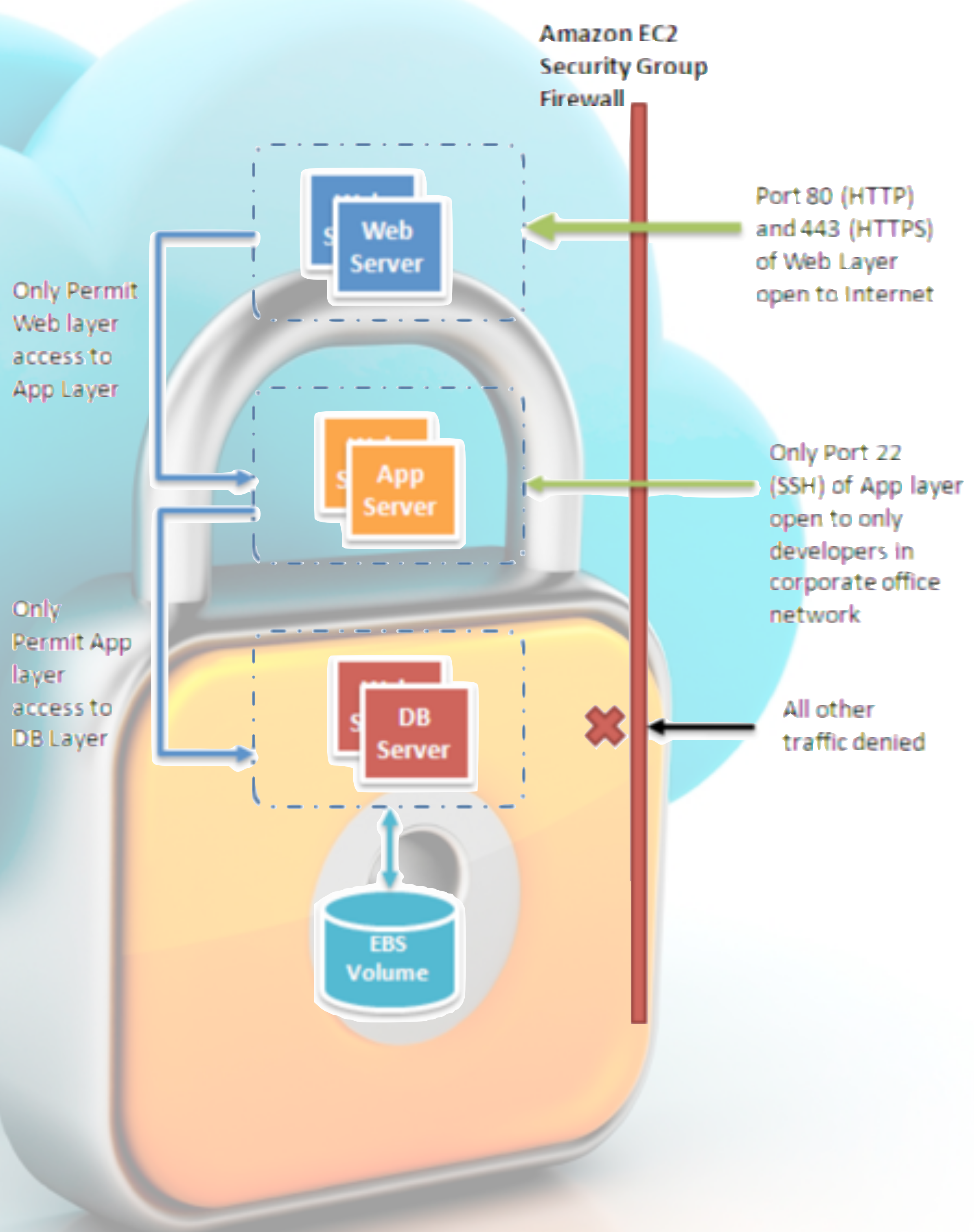
6. Security

- In the cloud, **security** should be implemented **in every layer** of the cloud application architecture
- **Physical security** is typically handled by your service provider
- **Network** and **application-level security** is your responsibility
- Protect your data **in transit**
- Protect your data **at rest**
- Protect your **AWS credentials**
- Manage multiple Users and their permissions with **IAM**



6. AWS Tactics

- Every Amazon EC2 instance is protected by one or more **security groups**
- **Named sets of rules** that specify which ingress (i.e., incoming) network traffic should be delivered to your instance.
- You can specify TCP and UDP ports, ICMP types and codes, and source addresses.
- Security groups give you basic **firewall-like protection** for running instances.


Amazon EC2 Security Group Firewall
Web Server
App Server
DB Server
EBS Volume
Only Permit Web layer access to App Layer
Only Permit App layer access to DB Layer
Port 80 (HTTP) and 443 (HTTPS) of Web Layer open to Internet
Only Port 22 (SSH) of App layer open to only developers in corporate office network
All other traffic denied

Web Application Hosting Example

Traditional Architecture

Exterior Firewall
Hardware or Software Solution to open standard ports (80, 443)

Web Load Balancer
Hardware or Software solution to distribute traffic over web servers

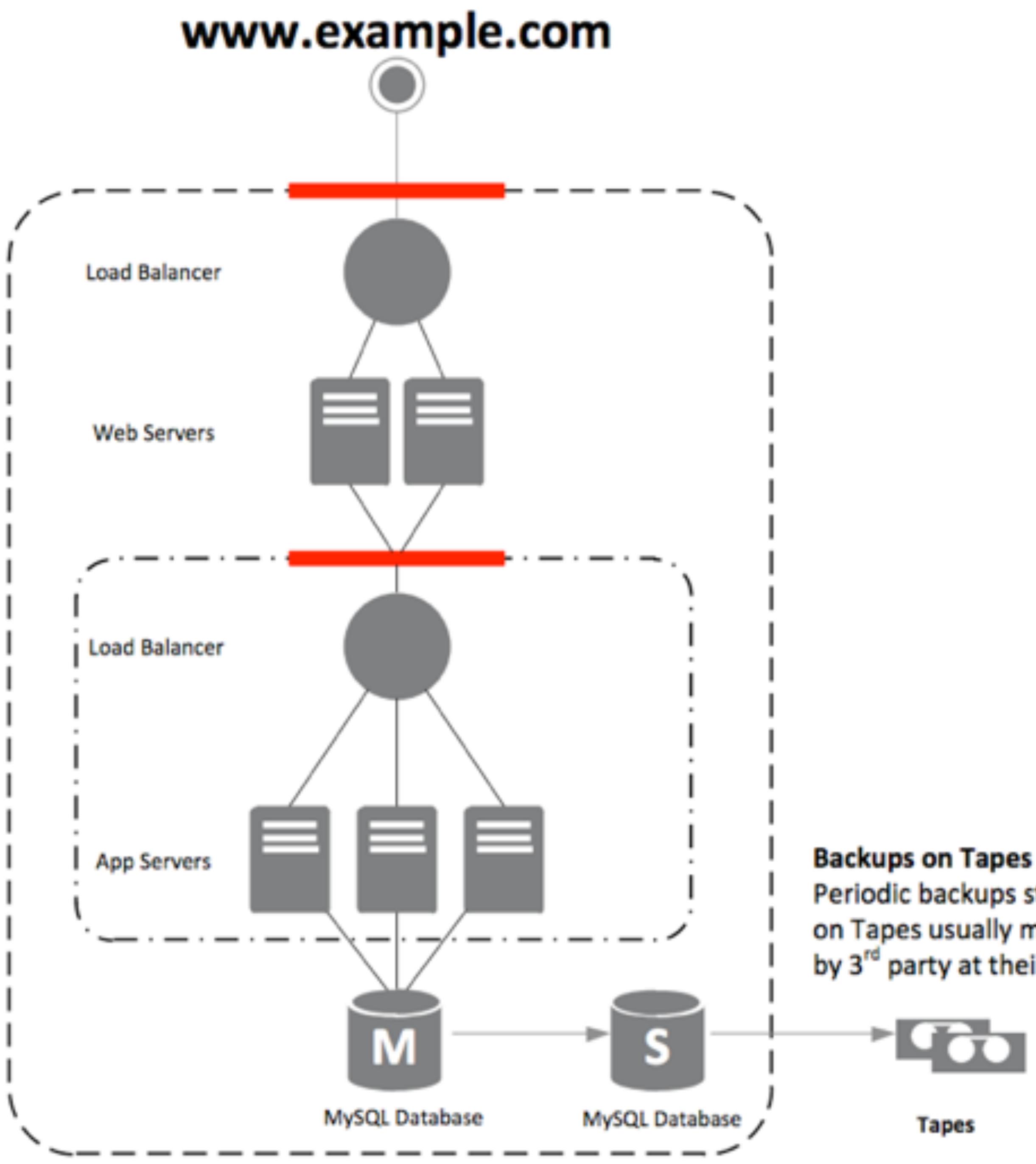
Web Tier
Fleet of machines handling HTTP requests

Backend Firewall limits access to application tied from web tier

App Load Balancer
Hardware or Software solution to spread traffic over app servers

App Server Tier
Fleet of machines handling Application specific workloads
Caching server machines can be implemented at this layer

Data Tier
Database Server machines with master and local running separately,
Network storage for static objects

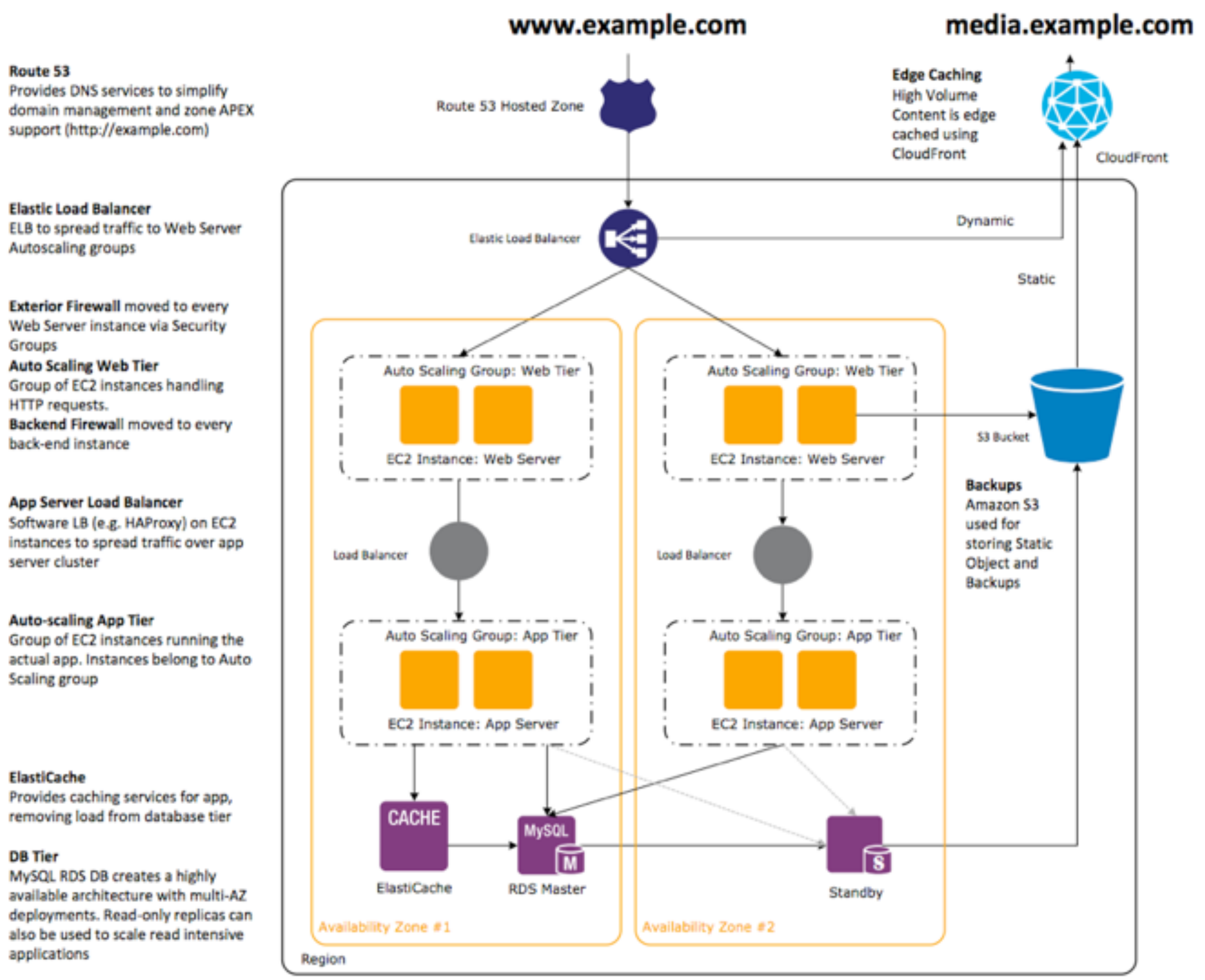


Backups on Tapes
Periodic backups stored on Tapes usually managed by 3rd party at their site

taken from: http://media.amazonwebservices.com/AWS_Web_Hosting_Best_Practices.pdf

Web Application Hosting Example

Amazon WS Architecture



Route 53
Provides DNS services to simplify domain management and zone APEX support (http://example.com)

Elastic Load Balancer
ELB to spread traffic to Web Server Autoscaling groups

Exterior Firewall moved to every Web Server instance via Security Groups

Auto Scaling Web Tier
Group of EC2 instances handling HTTP requests.

Backend Firewall moved to every back-end instance

App Server Load Balancer
Software LB (e.g. HAProxy) on EC2 instances to spread traffic over app server cluster

Auto-scaling App Tier
Group of EC2 instances running the actual app. Instances belong to Auto Scaling group

ElastiCache
Provides caching services for app, removing load from database tier

DB Tier
MySQL RDS DB creates a highly available architecture with multi-AZ deployments. Read-only replicas can also be used to scale read intensive applications

Edge Caching
High Volume Content is edge cached using CloudFront

Backups
Amazon S3 used for storing Static Object and Backups

taken from: http://media.amazonwebservices.com/AWS_Web_Hosting_Best_Practices.pdf

Top 10 Obstacles for Cloud Computing

- **Availability of a service:**
  - Organizations worry about whether Cloud services will have adequate availability
  - Very (very) high availability can be achieved by adopting multiple Cloud Computing providers
  - Even if the Cloud provider has multiple data centers in different geographic regions, it may have common software infrastructure and accounting systems, or the company may even go out of business
- **Data lock-in:**
  - Software stacks have improved interoperability among platforms, but the APIs for Cloud Computing itself are still essentially proprietary
  - Customers cannot easily extract their data and programs from one site to run on another

Top 10 Obstacles for Cloud Computing

- **Data confidentiality and auditability:**
  - My sensitive corporate data will never be in the cloud
  - Current Cloud offerings are essentially public (rather than private) networks, exposing the system to more attacks
  - There are also requirements for auditability and privacy laws (many Nations have laws requiring SaaS providers to keep customer data and copyrighted material within national boundaries)
  - There are no fundamental obstacles to making a Cloud Computing environment as secure as the vast majority of in-house IT environments, well-understood technologies (e,g., encrypted storage, VPN, firewalls,...)
- **Data Transfer Bottlenecks:**
  - Applications continue to become more data-intensive, significant costs in the Cloud
  - Avoid Internet transfers by shipping disks
  - Data Storage for free, CPU cycles sustain the business
  - WAN and LAN bandwidth are still bottlenecks

Top 10 Obstacles for Cloud Computing

- **Performance unpredictability:**
  - Multiple Virtual Machines can share CPUs and main memory surprisingly well in Cloud Computing, but I/O sharing is more problematic
  - Improve architectures and operating systems to efficiently virtualize interrupts and I/O channels
  - Flash memory adoption will decrease I/O interference
- **Scalable storage:**
  - Short-term usage, no up-front cost, and infinite capacity on-demand is more difficult to achieve with persistent storage with respect to computation
- **Bugs in large-scale distributed systems:**
  - Removing errors in very large scale distributed systems is very challenging
  - A common occurrence is that bugs cannot be reproduced in smaller configurations, so the debugging must occur at scale in the production data centers

Top 10 Obstacles for Cloud Computing

- **Scaling quickly:**
  - Pay-as-you-go certainly applies to storage and to network bandwidth, both of which count bytes used
  - Computation is slightly different, depending on the virtualization level:
    - Google AppEngine automatically scales in response to load increases and decreases, and users are charged by the cycles used
    - Amazon EC2 charges by the hour for the number of instances you occupy, even if your machine is idle
  - Automatically scale quickly up and down in response to load is important in order to save money, but without violating service level agreements
- **Reputation fate sharing:**
  - Reputations do not virtualize well. One customer's bad behavior can affect the reputation of the cloud as a whole
  - For instance, blacklisting of Amazon EC2 IP addresses by spam-prevention services may limit which applications can be effectively hosted
  - Legal issues
- **Software licensing:**
  - Current software licenses commonly restrict the computers on which the software can run

Amazon Web Services - AWS

- A set of building- block services, designed to work independently but can work well together:
  - Share a common naming convention and authentication
  - Minimize internal connections and dependencies
- Every function in AWS can be accessed by making a web service call:
  - Start a server, create a load balancer, allocate an IP address, or attach a persistent storage volume,...

AWS Key Concepts

- **Availability Zone:**
  - A set of distinct locations within an AWS Region
  - Each Availability Zone has independent power grid and network connections so that it's protected from failures in other Availability Zones
  - The zones within a Region are connected to each other with inexpensive, low-latency connections
- **Region:**
  - A set of AWS Availability Zones that are located in one geographic area
  - Use of multiple Regions for business, legal, or performance reasons

AWS Key Concepts

- **Amazon Machine Image (AMI):**
  - Contains the operating system and can also include additional software and layers of your application such as database servers, middleware, web servers,...
  - Prebuilt AMIs can be started
  - AMIs can be customized, shared, or even sold
  - Each AMI has a unique ID (e.g., ami-bf5eb9d6)
- **Instance:**
  - Represents one running copy of an AMI
  - Any number of copies of the same AMI can be launched
- **Elastic IP Address:**
  - AWS allows you to allocate fixed (static) IP addresses and then attach (or route) them to your instances
  - Each instance can have at most one such address attached

AWS Key Concepts

- **Elastic Block Store (EBS) Volume:**
  - An addressable disk volume which can be attached to any running instance in the same Availability Zone
  - The volume can then be formatted, mounted, and used as if it were a local disk drive
  - Volumes have a lifetime independent of any particular instance
  - A volume can persist even when no instances are running
- **Security Group:**
  - Defines the allowable set of inbound network connections for an instance
  - Each group is named and consists of a list of protocols, ports, and IP address ranges
  - A group can be applied to multiple instances, and a single instance can be regulated by multiple groups

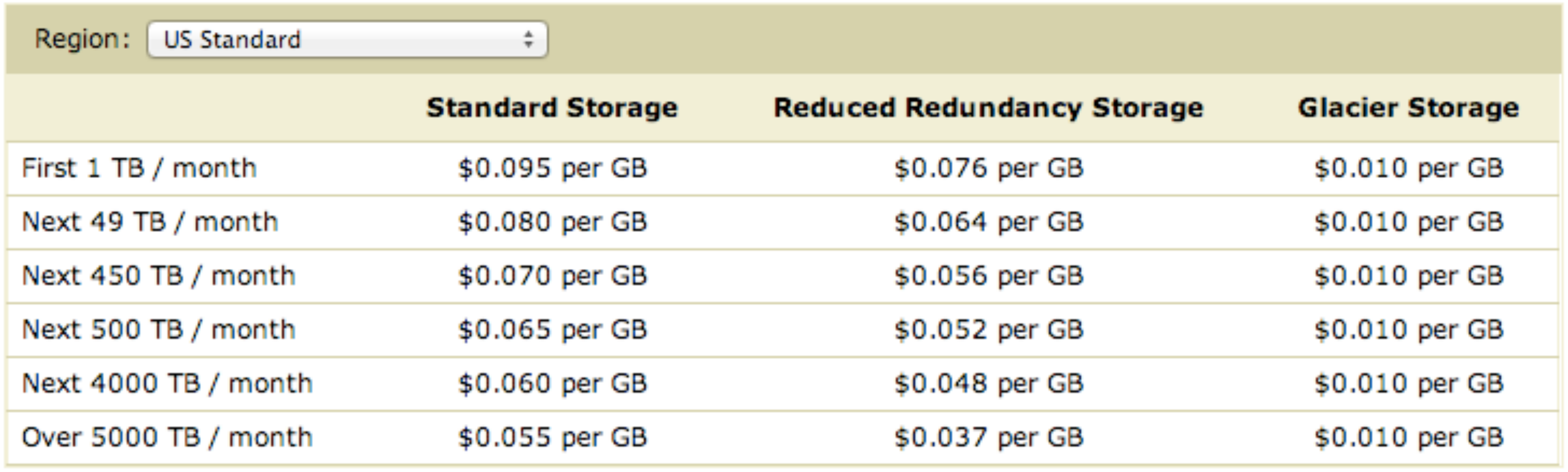
AWS Infrastructure Services

- Simple Storage Service (S3)
- CloudFront
- Simple Queue Service (SQS)
- SimpleDB
- Relational Database Service (RDS)
- Elastic Compute Cloud (EC2)
- Elastic MapReduce
- Other Services...

Simple Storage Service - S3

- Store **binary data** objects for private or public use
- The implementation is fault-tolerant and assumes that hardware failures are a common occurrence
- S3 automatically makes multiple copies of each object to achieve high **availability** and **durability**
- **Objects** size 1B-5GB
- All objects reside in **buckets**
- S3 objects can be accessed by **HTTP requests**
- Other AWS services use S3 as a storage system for AMIs, access logs, and temporary files
- Amazon S3 charges: amount of data stored, amount of data transferred in and out of S3, and the number of requests made to S3

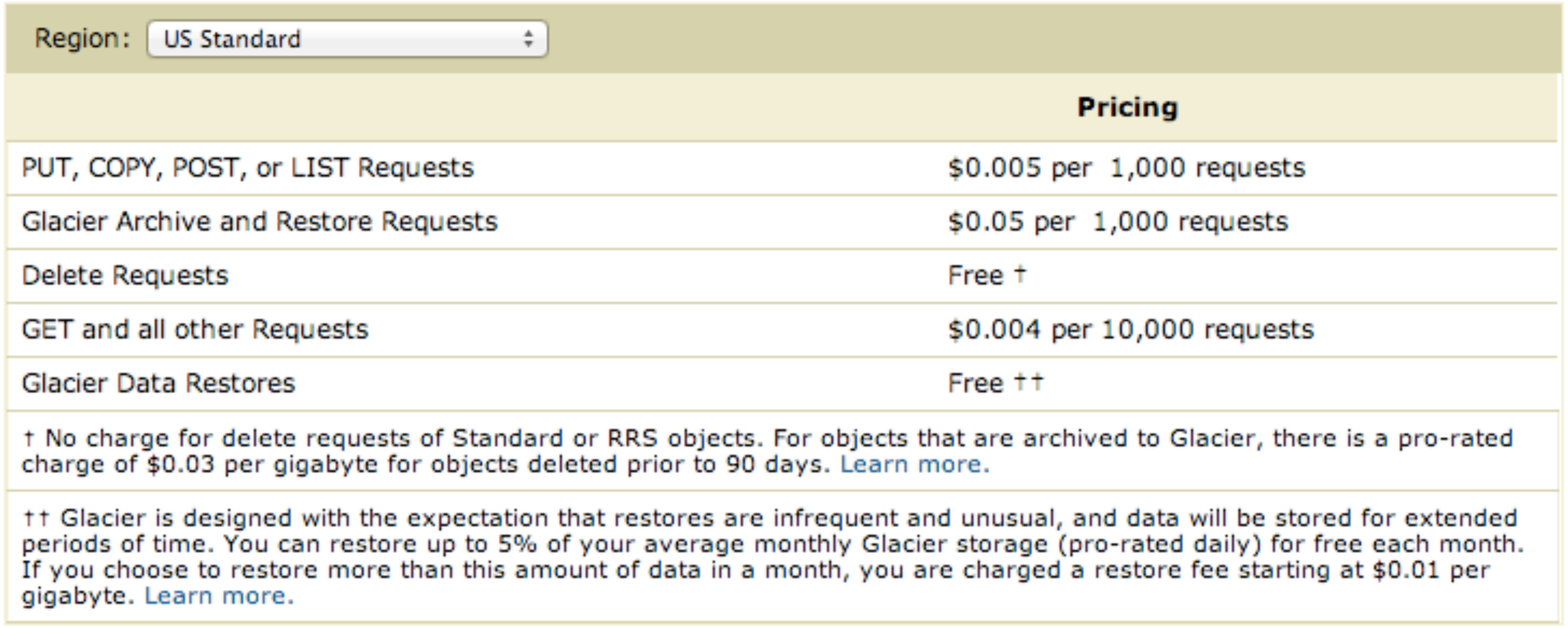
Simple Storage Service - S3



Region: US Standard

	Standard Storage	Reduced Redundancy Storage	Glacier Storage
First 1 TB / month	$0.095 per GB	$0.076 per GB	$0.010 per GB
Next 49 TB / month	$0.080 per GB	$0.064 per GB	$0.010 per GB
Next 450 TB / month	$0.070 per GB	$0.056 per GB	$0.010 per GB
Next 500 TB / month	$0.065 per GB	$0.052 per GB	$0.010 per GB
Next 4000 TB / month	$0.060 per GB	$0.048 per GB	$0.010 per GB
Over 5000 TB / month	$0.055 per GB	$0.037 per GB	$0.010 per GB

Request Pricing



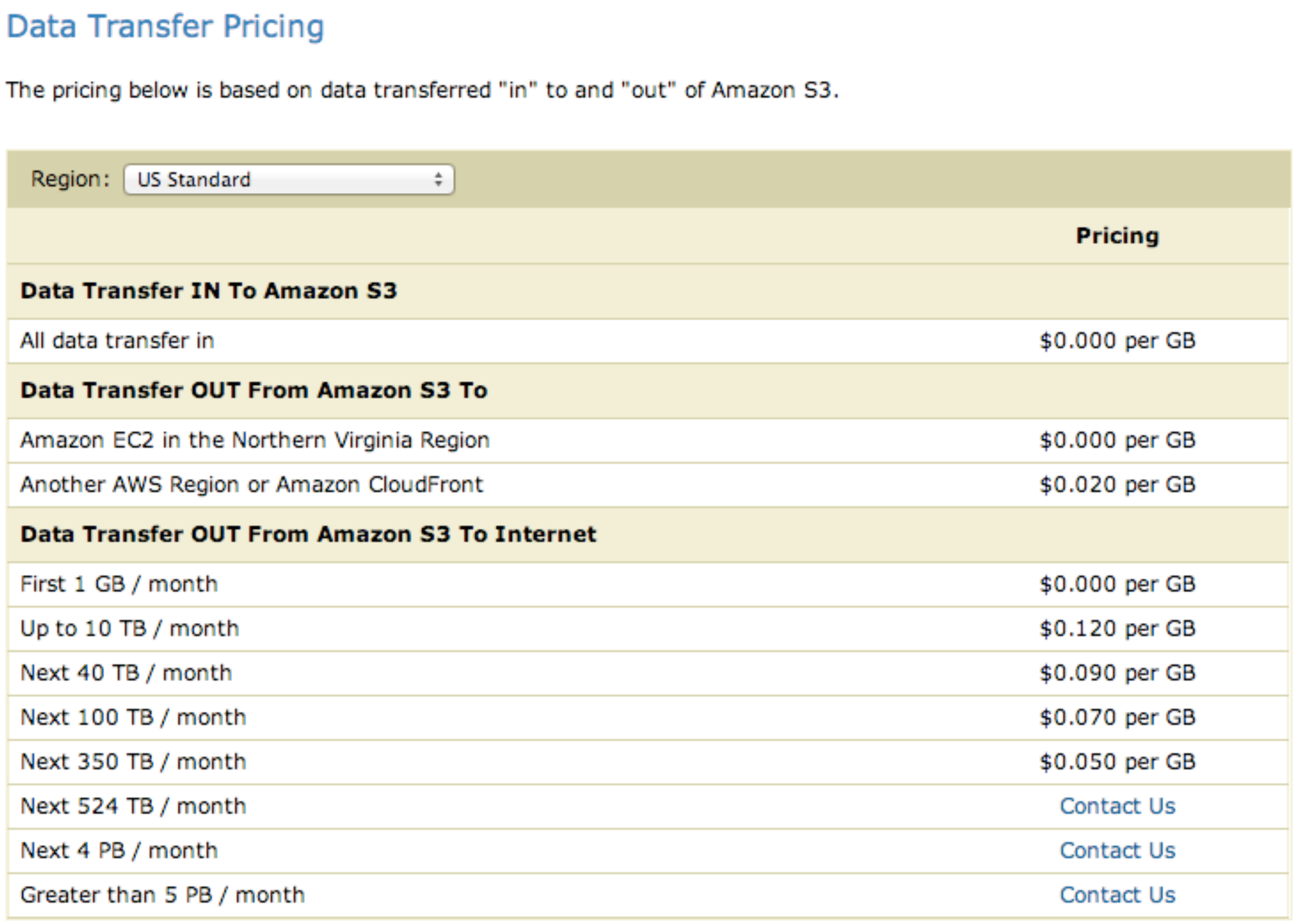
Region: US Standard

	Pricing
PUT, COPY, POST, or LIST Requests	$0.005 per 1,000 requests
Glacier Archive and Restore Requests	$0.05 per 1,000 requests
Delete Requests	Free †
GET and all other Requests	$0.004 per 10,000 requests
Glacier Data Restores	Free ††

† No charge for delete requests of Standard or RRS objects. For objects that are archived to Glacier, there is a pro-rated charge of $0.03 per gigabyte for objects deleted prior to 90 days. Learn more.

†† Glacier is designed with the expectation that restores are infrequent and unusual, and data will be stored for extended periods of time. You can restore up to 5% of your average monthly Glacier storage (pro-rated daily) for free each month. If you choose to restore more than this amount of data in a month, you are charged a restore fee starting at $0.01 per gigabyte. Learn more.

Simple Storage Service - S3



Data Transfer Pricing

The pricing below is based on data transferred "in" to and "out" of Amazon S3.

Region: US Standard

	Pricing
Data Transfer IN To Amazon S3	
All data transfer in	$0.000 per GB
Data Transfer OUT From Amazon S3 To	
Amazon EC2 in the Northern Virginia Region	$0.000 per GB
Another AWS Region or Amazon CloudFront	$0.020 per GB
Data Transfer OUT From Amazon S3 To Internet	
First 1 GB / month	$0.000 per GB
Up to 10 TB / month	$0.120 per GB
Next 40 TB / month	$0.090 per GB
Next 100 TB / month	$0.070 per GB
Next 350 TB / month	$0.050 per GB
Next 524 TB / month	Contact Us
Next 4 PB / month	Contact Us
Greater than 5 PB / month	Contact Us

Cloud Front

- Content distribution service designed to work in conjunction with Amazon S3
- All Amazon S3 data is served from central locations in the US, Europe, and Asia, access from certain parts of the world can take several hundred milliseconds
- CloudFront addresses this speed limitation with a global network of edge locations (18 today) located near end users
- After you have stored your data in an S3 bucket, you can create a CloudFront **Distribution**
- Each distribution contains a unique URL, which you use in place of the bucket name and S3 domain to achieve content distribution
- CloudFront charges accrue based on the amount of data transferred out of CloudFront and the number of requests made to CloudFront

Simple Queue Service - SQS

- Allows building highly scalable processing pipelines using loosely coupled parts (queues)
- Queues allow for flexibility, asynchrony, and fault tolerance
- Each step in the pipeline retrieves work units from an instance of the queue service, processes the work unit as appropriate, and then writes completed work into another queue for further processing
- Queues work well when the requirements—be it time, CPU, or I/O speed—for each processing step for a particular work unit vary widely
- SQS usage is charged based on the amount of data transferred and the number of requests made to SQS

SimpleDB

- Supports storage and retrieval of semi-structured data
- Unlike a traditional relational database, does not use a fixed database schema
  - Adapts to changes in the “shape” of the stored data on the fly
  - No need to update existing records when adding new fields
- Automatically indexes all stored data
- The SimpleDB data model is flexible and straightforward:
  - Similar data grouped into domains
  - Each domain can hold millions of items, each with a unique key
  - Each item can have a number of attribute/value pairs
  - The attribute names can vary from item to item as needed

Relational Database Service - RDS

- MySQL database instances
- Don't worry about procuring hardware, installing and configuring an operating system or database engine, or finding storage for backups
- You can scale the amount of processing power up or down, and increase the storage allocation in a matter of minutes, so you can respond easily to changing circumstances
- DB Instance can be backed up into Amazon S3
- Multi-AZ option to run a redundant backup copy of your DB Instance for extra availability and reliability
- Amazon RDS charges accrue based on the amount of time that each DB Instance is running, and the amount of storage allocated to the instance

Other Services

- **CloudWatch:**
  - Provides monitoring within EC2 (CPU load average, disk I/O rate, and network I/O rate)
- **Elastic Load Balancer:**
  - Distributes web traffic across any number of EC2 instances (in the same Availability Zone or across several zones in a Region)
  - Performs also periodic health checks on the instances, and will stop sending traffic to unhealthy instances
- **Auto Scaling:**
  - Uses the data collected by CloudWatch to build systems that can scale out (adding more EC2 instances) and scale in (shutting down EC2 instances) within a defined auto scaling group
  - Usually triggers on CPU/memory utilization

Amazon EC2

- Launch server instances within a set of AMIs
- Instance **types** are available with a wide range of memory, processing power, and local disk storage
- Instances can be launched in any EC2 Region and an Availability Zone can be specified if needed
- Each instance is protected by a **firewall** which, by default, blocks all internal and external connectivity
- Instances can be associated to any number of **security groups**
- One important concept: **Persistent** and **Ephemeral** resources

Persistent Resources

- Once allocated to your account, can be expected to remain operational in the face of transient or permanent hardware or software failures
- The Amazon implementation of a persistent resource makes uses of redundancy, automated failover, and automatic recovery to provide stable resources
- The following EC2 resources are persistent:
  - Elastic IP Addresses
  - EBS Volumes
  - Elastic Load Balancers
  - Security Groups
  - AMIs stored in Amazon S3 or as Amazon EBS snap-shots

Ephemeral Resources

- Without built-in redundancy and will eventually fail
- In case of failures, stored data and state information is generally lost
- Need to use other EC2 facilities to implement your own redundancy, failover, and recovery mechanisms
- **EC2 instances are ephemeral**
- What? The instances can crash at any point and take my local data with them?
  - This is a feature, rather than a bug
  - One of the most important architectural aspects of a large-scale Internet site is that **you can think of the individual servers as if they were all transient and extremely unreliable**
- You can use software to build a reliable system from unreliable parts
- The cloud also makes it easy to simulate failures so that you can ensure recovery logic works as expected

Ephemeral Resources

- A **public IP address** is assigned to each instance as part of the launch process:
  - The IP address will have the same lifetime as the instance
  - The EC2 **Elastic IP address** feature supports allocation of public IP addresses that are stable and that have a lifetime independent of any particular EC2 instance
- The **local disk** storage included with each EC2 instance is ephemeral
  - The storage will remain intact if a running instance is rebooted
  - It’s scrubbed and then reused after the instance has been terminated
  - EBS provides persistent storage with high reliability and availability:
    - Create an EBS volume and then attach it to any of your instances in the same Availability Zone
    - Create point-in-time snapshot backups to Amazon S3 and then restore the backups to the same volume