Cloud Computing Technologies

DAT515 - Fall 2025

Introduction

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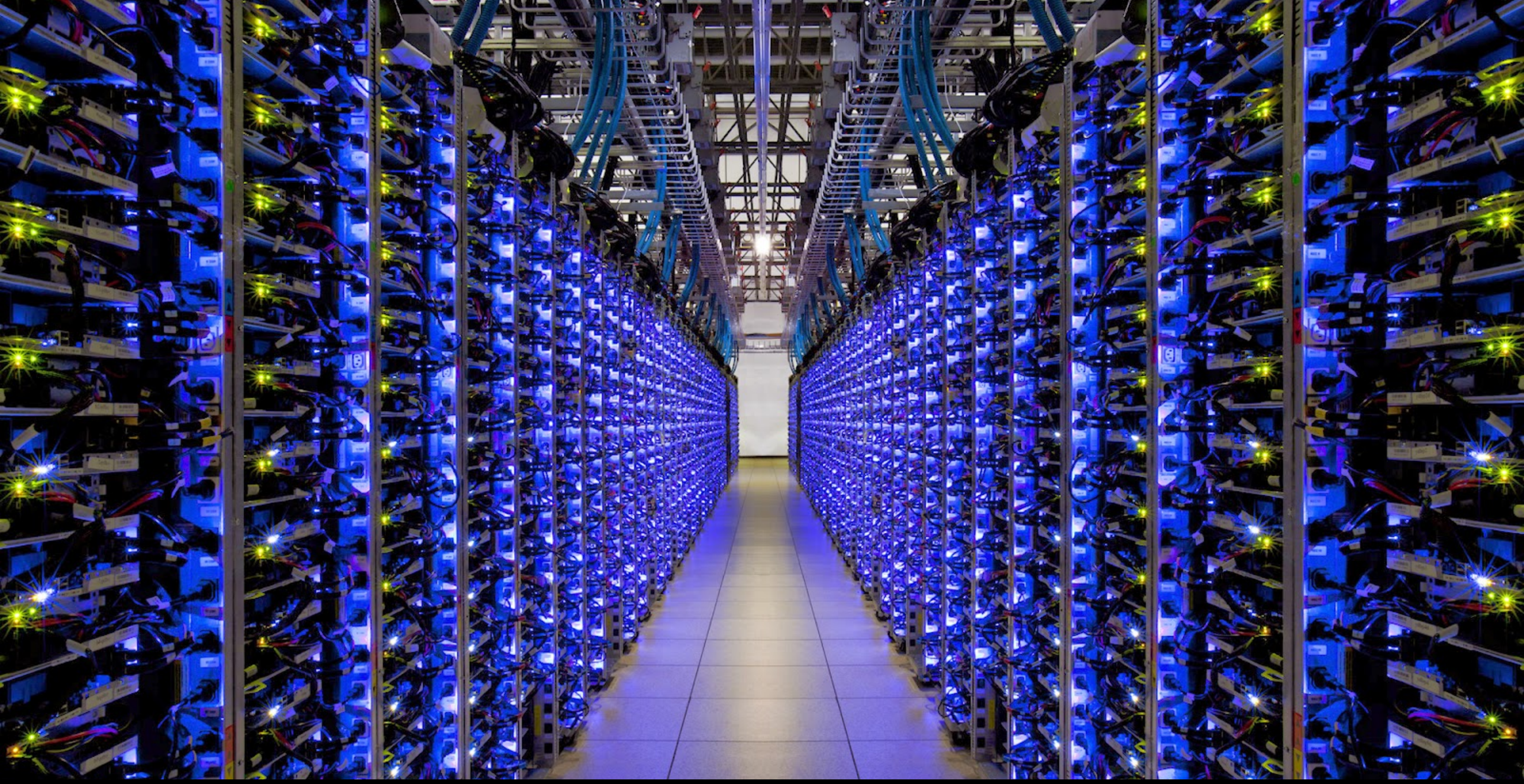
CLOUD
SERVER
SERVERS
CLOUD
BOSS

Agenda

- What? — What is Cloud Computing?
- Economic — Cloud Computing Economics
- Models — Cloud Service and Deployment Models
- Case Study — Case Study: Dropbox
- ~ — Conclusions

Why is it called Cloud Computing?

Electric Power Grid ~ Grid / Utility Computing



Google Data Center ~ Cloud Computing

Why is it Called Cloud Computing?

The term "cloud computing"

- Emerged from using a **cloud symbol** in network diagrams to represent the internet or an abstracted network
- Became popular in the mid-2000s

What is Cloud Computing?

"The cloud is just someone else's computer

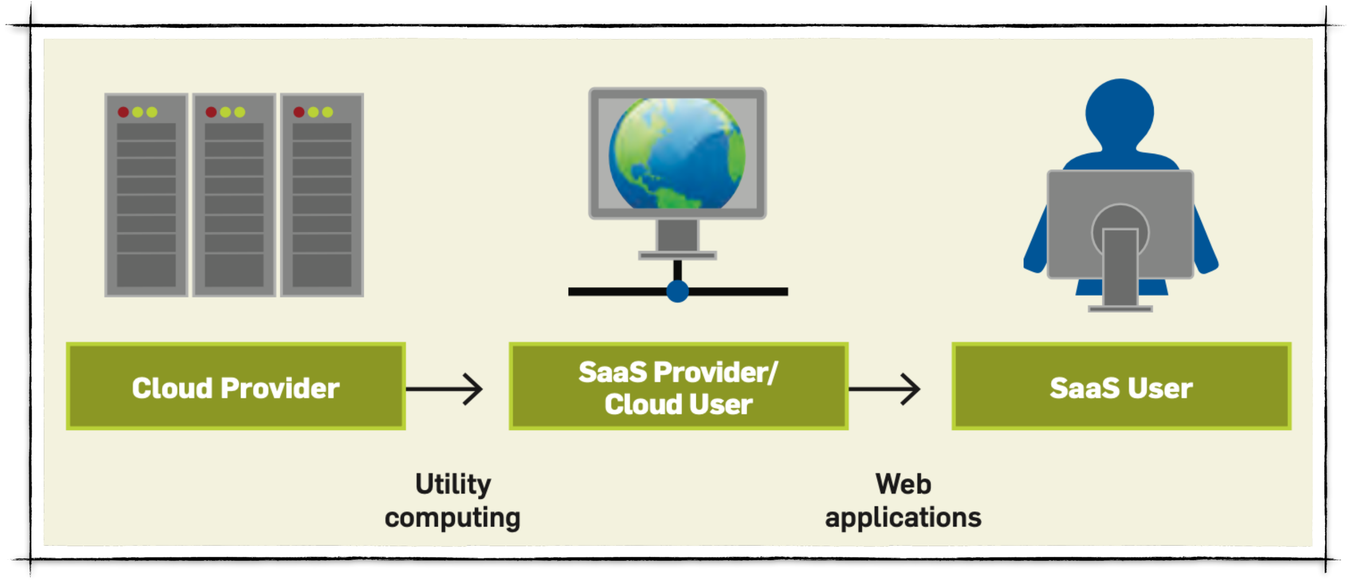
https://www.drewlyton.com/story/the-future-is-not-self-hosted/


Cloud
Computing
Data
Google
Azure
AWS
IaaS
PaaS
saas
Containers
Serverless
Kubernetes
Public
Virtualization
Microservices
Networking
Load
Storage
Center
Multi
High
Cost
Latency
Machine
CDN
Private
Elasticity
Infrastructure
Deployment
Availability
CD
AI
Code
Disaster
Learning
Hybrid
Edge
Orchestration
DevOps
Scalability
Compliance
Security
APIs
Balancing
Recovery
Backup
Optimization
CI
Automation
IoT
Big

What is Cloud Computing?

Definition: Cloud Computing

- Applications **delivered as services** over the Internet,
- Plus the **hardware** and **systems software** in the **data centers** that provide these services.



Source: A View of Cloud Computing

What is Cloud Computing?

NIST's Definition

"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.

The Utility Computing Paradigm

Core Advantages of Cloud Computing

- Lower Costs: No large capital outlays for hardware
- Pay-per-use model
  - Align costs with actual usage, reducing waste
- Elastic resource allocation
- Rapid scalability

Public vs. Private Clouds

- Public cloud
  - A service made available to the general public on a pay-as-you-go basis
  - Utility computing
- Private cloud
  - Internal data centers of an organization not available to the public

Public vs. Private Clouds

Advantage	Public Cloud	Conventional Data Center
Appearance of infinite computing resources on demand	Yes	No
Elimination of an up-front commitment by Cloud users	Yes	No
Ability to pay for use of computing resources on a short-term basis as needed	Yes	No
Economies of scale due to very large data centers	Yes	Usually not
Higher utilization by multiplexing of workloads from different organizations	Yes	Depends on company size
Simplify operation and increase utilization via resource virtualization	Yes	No

Joke time

Why did the cloud break up with the data center?

Because it found someone with more uptime!

Cloud Computing Economics

Cost Example for Batch Task

- Large computing tasks can get results as quickly as their programs can scale.
- Consider
  - Using 1000 servers for **one hour**

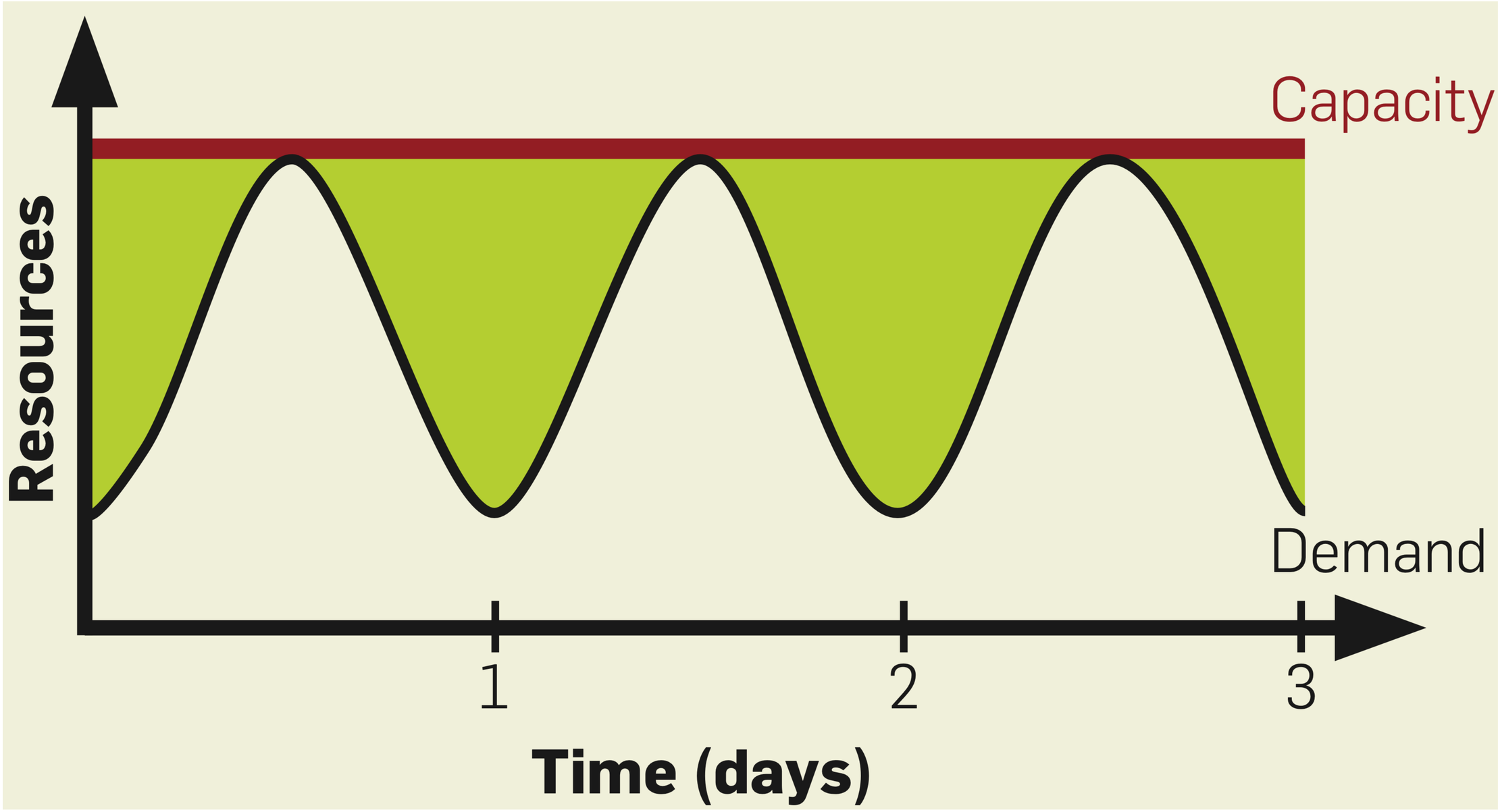
    vs

  - Using **one server** for 1000 hours
- *Cost the same for the user*

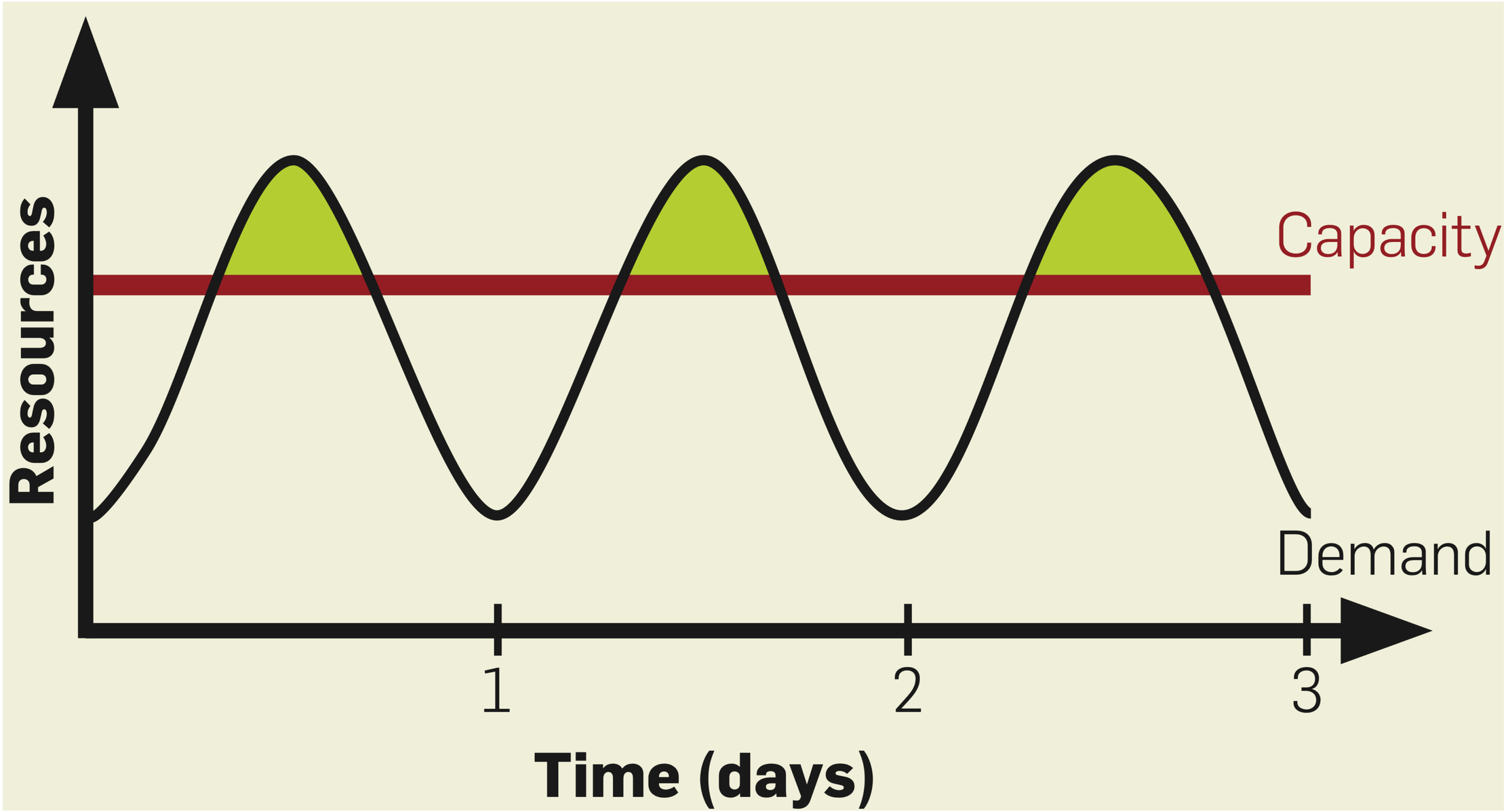
Cost Example for Predictable Demand

- Peak @ noon: 500 servers
- Trough @ midnight: 100 servers
- Average utilization over a day: 300 servers
- Actual cost per day: 300 x 24 = 7,200 server-hours
- Must provision for peak (500 servers) and pay: 500 x 24 = 12,000 server-hours
- *Utility computing is cheaper* if 3-year pay-as-you-go costs < 1.7x purchase cost

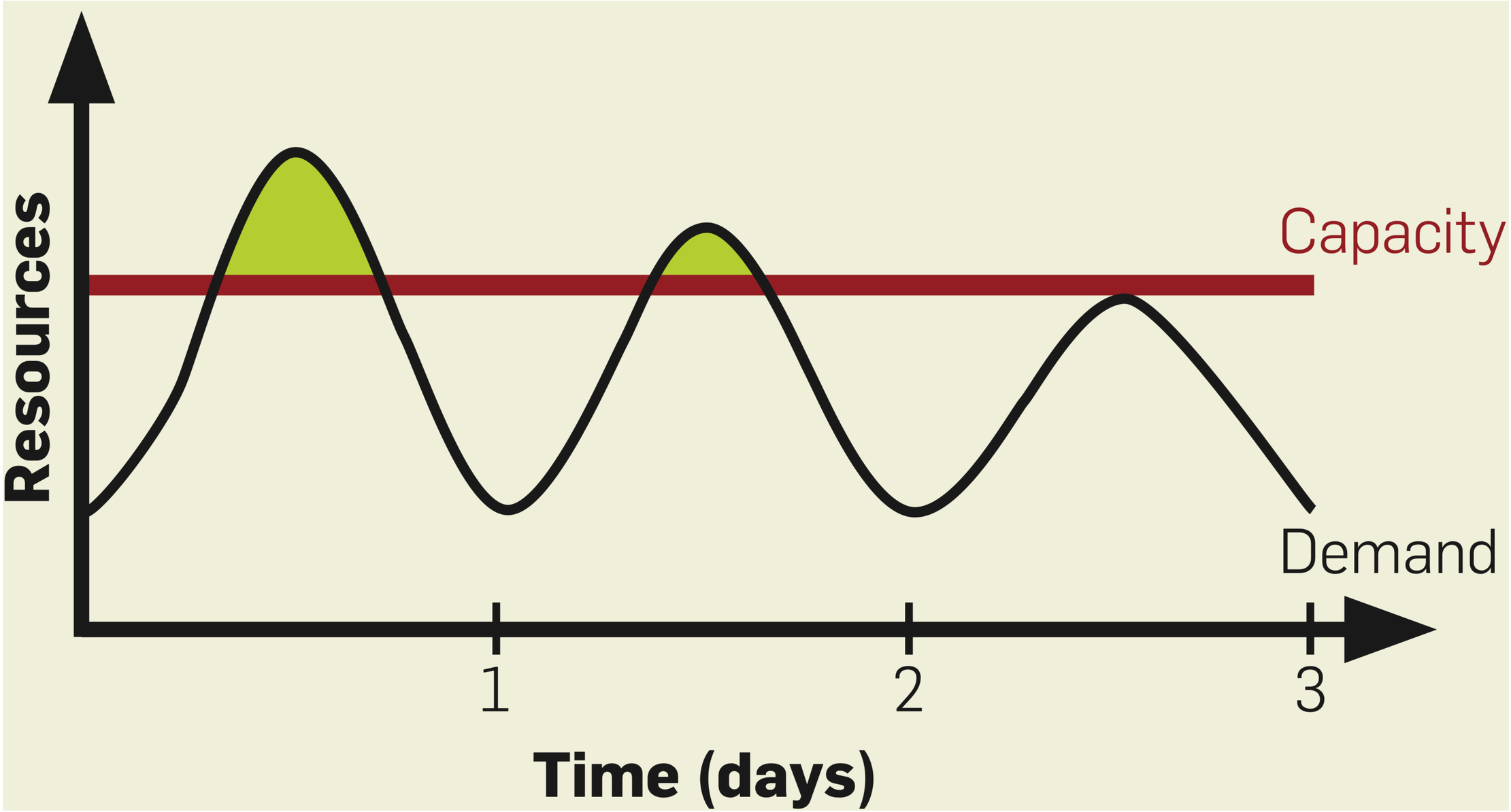
Provisioning for peak load



Underprovisioning Case 1



Underprovisioning Case 2



Economics of Scale

Reduced Costs

- Electricity: Install own power generation capacity (Data Center Solar)
- Bandwidth: Build own networks (Google's Global Network)
- Hardware: Build custom hardware (Google's TPU, custom NICs)
- Software: Custom data center software — Hire the best engineers
- Cloud providers have greater leverage to negotiate prices on all of the above.

Cloud Service Models

Cloud Applications

Not hosted on a cloud platform

Non-Cloud Application

Hosted on a cloud platform

Cloud Application

Not built for a cloud platform

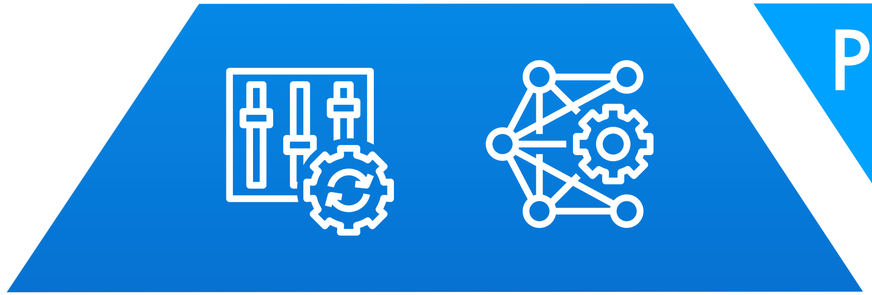
Cloud Native Application

Built for a cloud platform

* as a Service

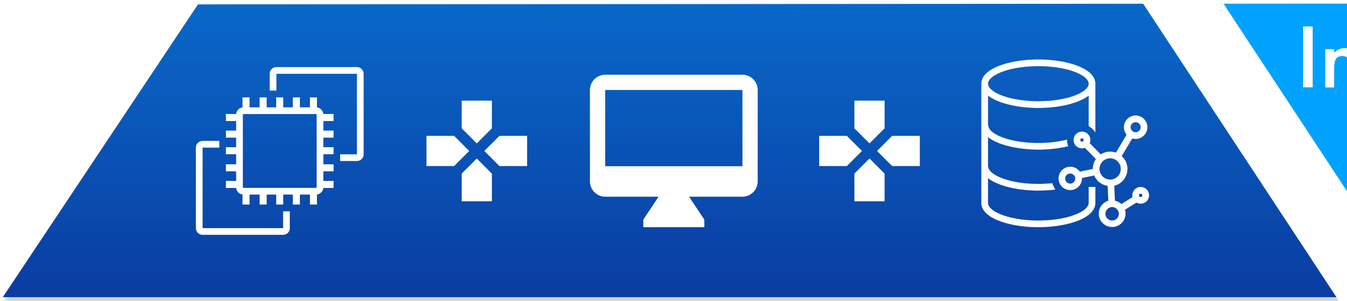
Software as a Service (SaaS)

Dropbox, Slack, GMail, Overleaf
(delivered over internet, browser-based UI)



Platform as a Service (PaaS)

Google App Engine, Windows Azure, AWS Lamda
(platform for software development)



Infrastructure as a Service (IaaS)

Amazon Web Services, Google Compute Engine
(rent out storage and compute capacity)

Infrastructure as a Service

- Provides virtualized computing resources over the internet, including servers, storage, and networking
- Enabling users to run and manage operating systems, applications, and data **without managing physical hardware**
- Gives users more control

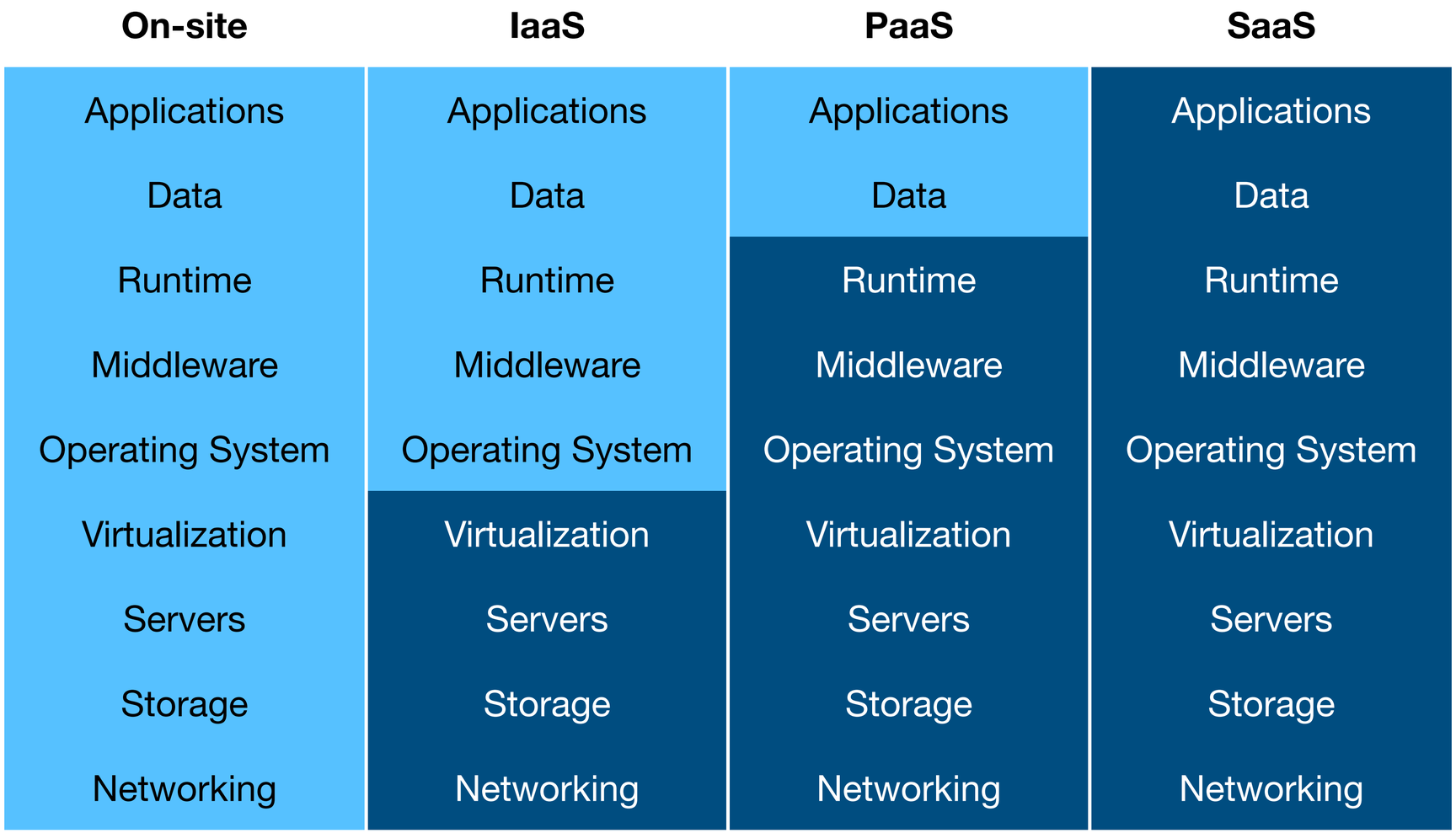
Platform as a Service

- Offers a development environment and tools to build, deploy, and manage applications, abstracting the underlying infrastructure
- Developers **focus on writing code** without worrying about hardware and software setup
- Less control to the user than IaaS
  - Issue: PaaS is less standardized across vendors

Software as a Service

- Delivers software applications over the internet (often on a subscription basis), accessible via web browsers
- Eliminate the need for users to install, manage, or maintain **software on their local devices**
- SaaS users have no control over
  - Developer/Company of SaaS app decide where/how to host

Service Model Comparison



Cloud Providers

An Incomplete List of Cloud Computing Providers

SaaS

- Salesforce
- Cisco WebEx
- Dropbox
- ZenDesk
- MailChimp
- Slack
- HubSpot
- DocuSign
- Google Apps
- Microsoft Office 365

PaaS

- Google App Engine
- OpenShift
- Heroku
- Force.com
- Windows Azure
- AWS Elastic Beanstalk
- Apache Stratos
- Magento Commerce
- AWS Lamda
- SAP Cloud

IaaS

- Amazon Web Services (AWS)
- Google Compute Engine (GCE)
- IBM Cloud
- Microsoft Azure
- Rackspace
- Linode
- Cisco Metacloud
- Digital Ocean
- Vultr
- Oracle Cloud

Source: https://www.leanix.net/en/wiki/apm/iaas-vs-paas-vs-saas

Cloud Deployment Models

Hybrid Cloud Infrastructure

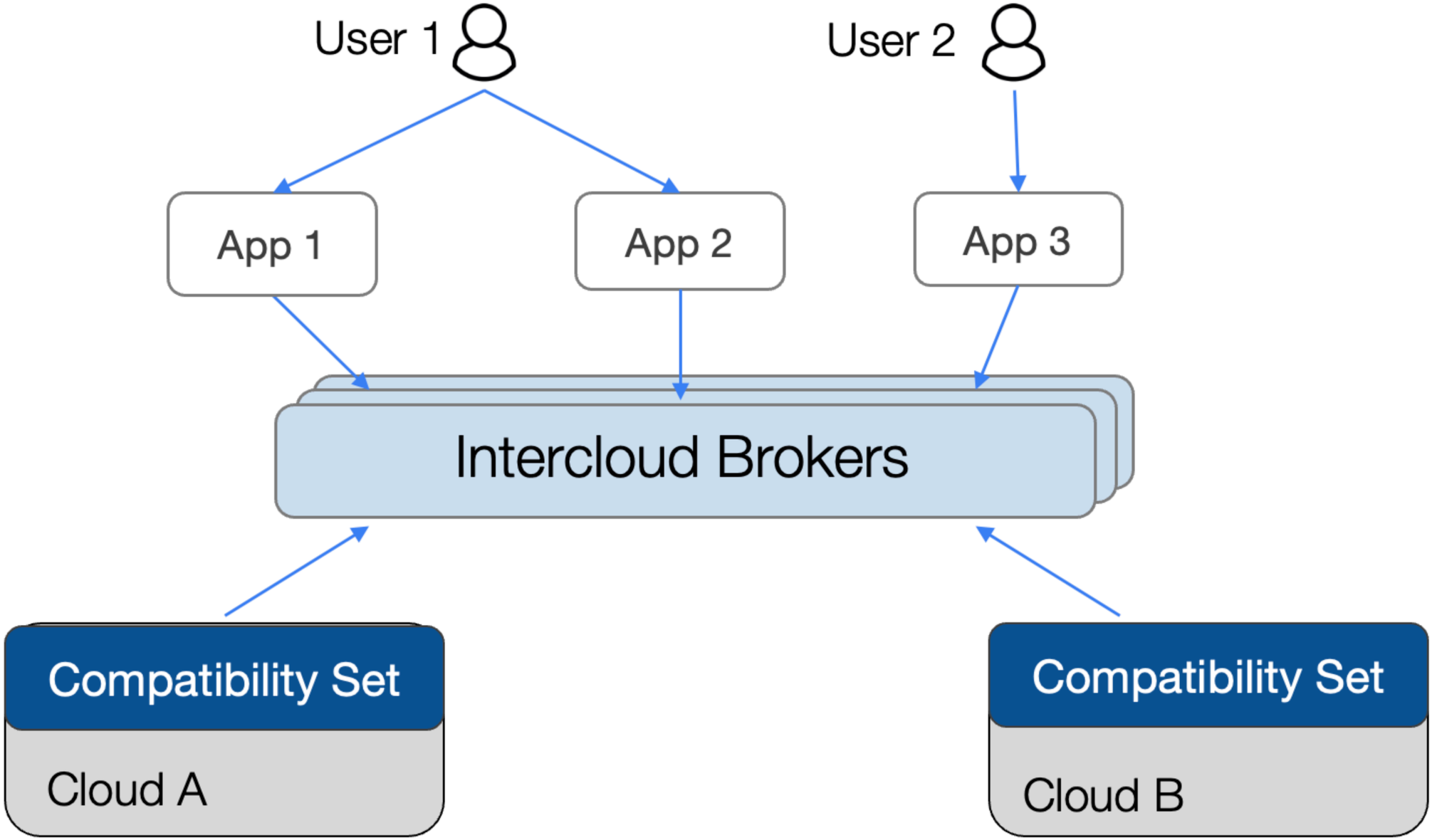
Mixed Computing Environment

- Design systems/applications with same/similar technology
- Makes it easy to deploy to different environments
  - Public cloud providers
  - Private cloud
- Load surges can be offloaded to public cloud providers

Private Cloud Infrastructure

- On-premise (owned by organization) or
- Off-premise (rented from infrastructure providers)
  - Vendor-owned data center
  - Dedicated resources to a single customer (isolated access)
- Example: Red Hat's OpenStack Platform

Sky Computing



Case Study: Dropbox

The Dropbox Case

- Dropbox: Popular file hosting and sharing service
- Challenge
  - Storing and synchronizing vast amounts of user data
  - Scale to accommodate growth

The Dropbox Case

AWS Solution

- Initially, Dropbox relied heavily on
  - AWS Cloud Storage and Services
- Benefits:
  - **Scalability**: Quickly expand storage capacity with user growth (without investing in physical infrastructure)
  - **Data Redundancy**: Improved data availability and resilience
  - **Security**: Enhanced user data protection

The Dropbox Case

AWS Solution

- Successfully handled storage needs of millions of users
- Streamlined operations and improved data security
- Focus on **building features** and enhancing **user experience**

The Dropbox Case

Migration to In-House Infrastructure

- Project **Magic Pocket** completed in 2016
- Migrated most of their data storage from AWS S3 to their custom-built infrastructure
  - Driven by the desire to reduce costs
  - Gain more control over their hardware
  - Tailor the storage system specifically for their needs

The Dropbox Case

Hybrid Approach

- After the migration, Dropbox continues to use AWS for certain services and workloads
- Primary data storage and most of their computing infrastructure are hosted on their own servers
- Allows Dropbox to leverage the benefits of both cloud and on-premises infrastructure

Questions?

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Clearing the clouds away from the true potential and obstacles posed by this computing capability.

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A View of Cloud Computing

CLOUD COMPUTING, THE long-held dream of computing as a utility, has the potential to transform a large part of the IT industry, making software even more attractive as a service and shaping the way IT hardware is designed and purchased. Developers with innovative ideas for new Internet services no longer require the large capital outlays in hardware to deploy their service or the human expense to operate it. They need not be concerned about overprovisioning for a service whose popularity does not meet their predictions, thus wasting costly resources, or underprovisioning for one that becomes wildly popular, thus missing potential customers and revenue. Moreover, companies with large batch-oriented tasks can get results as quickly as their programs can scale, since using 1,000 servers for one hour costs no more than using one server for 1,000 hours. This elasticity of resources, without paying a premium for large scale, is unprecedented in the history of IT.

As a result, cloud computing is a popular topic for blogging and white papers and has been featured in the title of workshops, conferences, and even magazines. Nevertheless, confusion remains about exactly what it is and when it's useful, causing Oracle's CEO Larry Ellison to vent his frustration: "The interesting thing about cloud computing is that we've redefined cloud computing to include everything that we already do.... I don't understand what we would do differently in the light of cloud computing other than change the wording of some of our ads."

Our goal in this article is to reduce that confusion by clarifying terms, providing simple figures to quantify comparisons between of cloud and conventional computing, and identifying the top technical and non-technical obstacles and opportunities of cloud computing. (Armbrust et al[4] is a more detailed version of this article.)

Defining Cloud Computing

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).[a] Some vendors use terms such as IaaS (Infrastructure as a Service) and PaaS (Platform as a Service) to describe their products, but we eschew these because accepted definitions for them still vary widely. The line between "low-level" infrastructure and a higher-level "platform" is not crisp. We believe the two are more alike than different, and we consider them together. Similarly, the

a For the purposes of this article, we use the term Software as a Service to mean applications delivered over the Internet. The broadest definition would encompass any on demand software, including those that run software locally but control use via remote software licensing.