

ECE4574 – Large-Scale SW Development for Engineering Systems

Lecture 10 – Cloud Computing

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Course Updates

- Project
 - hope Sprint 1 is going well 😊
- Quiz 4 is next Monday, October 2

Next Week – Oct 2 and 4

Monday, Oct 2 – Project Day

- Come to class and sit in your project groups
 - Online team members should join by zoom or similar
- Use the day to catch up on your project work
 - Stand-up meeting
 - Start on the sprint retrospective
- I will meet briefly with each group

Wednesday, Oct 4 – NO CLASS

No office hours on Tuesday, Wednesday or Thursday (Oct 3, 4 and 5)

Key Topics for Today

- Cloud computing basics
- Cloud service providers
- A simple code example
- Virtual machines
- Kubernetes
- Docker

CLOUD COMPUTING

Cloud computing is the use of online resources for computation, storage and other key services – in a flexible and automatic manner

- In a cloud system, user management is not needed to request and release resources
- Cloud systems are built on the concept of virtualization – software runs on virtual machines that do not correspond to specific physical platforms
 - virtualization software provides software-based computers with flexible configurations
 - cloud providers make these resources available in a variety of pricing models
- The big three cloud providers these days are:
 - Amazon Web Services (AWS)
 - Google Cloud
 - Microsoft Azure
 - also IBM, Oracle, Adobe, Cisco...

The convenience of cloud computing comes from the concept of delivering *services*

- Software as a Service (SaaS)
- Software is licensed and provided over the web – apps run on the cloud and are accessed via web protocols – often through a browser
- GoogleDocs, Salesforce, Slack
- Many more specific areas of functionality are being touted as “as a service” technologies
 - Analytics as a Service
 - Blockchain as a Service
 - Payments as a Service



What is Cloud Computing?



Cloud Computing Services: Who Manages What?

I: Infrastructure P: Platform S: Software

Traditional IT	IaaS	PaaS	Serverless	SaaS
Applications	Applications	Applications	Applications	Applications
Data	Data	Data	Data	Data
Runtime	Runtime	Runtime	Runtime	Runtime
Middleware	Middleware	Middleware	Middleware	Middleware
OS	OS	OS	OS	OS
Virtualization	Virtualization	Virtualization	Virtualization	Virtualization
Servers	Servers	Servers	Servers	Servers
Storage	Storage	Storage	Storage	Storage
Networking	Networking	Networking	Networking	Networking

 You manage  Provider manages

CLOUD SERVICE PROVIDERS

AWS Management Console

AWS services

Find Services

You can enter names, keywords or acronyms.

Example: Relational Database Service, database, RDS

► All services

Build a solution

Get started with simple wizards and automated workflows.

Launch a virtual machine

With EC2
2-3 minutes



Build a web app

With Elastic Beanstalk
6 minutes



Build using virtual servers

With Lightsail
1-2 minutes



Register a domain

With Route 53
3 minutes



Connect an IoT device

With AWS IoT
5 minutes



Start migrating to AWS

With CloudEndure Migration
1-2 minutes



Start a development project

With CodeStar
5 minutes



Deploy a serverless microservice

With Lambda, API Gateway
2 minutes



Stay connected to your AWS resources on-the-go



Download the AWS Console Mobile App to your iOS or Android mobile device. [Learn more](#)

Explore AWS

Amazon SageMaker Autopilot

Get hands-on with AutoML. [Learn more](#)

AWS Storage Gateway

Get on-premises low latency access to virtually unlimited cloud storage with this hybrid cloud storage service. [Learn more](#)

AWS Lambda Extensions

Use AWS Lambda with your favorite operational tools for monitoring, observability, security, and governance. [Learn more](#)

AWS Certification

Explore the resources available to help you prepare for your AWS Certification. [Learn more](#)

us-east-2.console.aws.amazon.com/console/home?nc2=h_ct®ion=us-east-2&src=header-signin#

AppsVT gmailVT calECE internalECEW WOneCampusCanvasIEEEBBCMsVTCTICIVL WikiLibrary CommiLibr CommTIAACChrome RiverDLnCoVORCoVAVT CoV

awsServices

Globe trial accountOhioSupport

★ Favorites

Resource Groups & Tag Editor

Recently visited

Console Home

All services

Find services by names, keywords or acronyms.

Compute

EC2

Lightsail

Lambda

Batch

Elastic Beanstalk

Serverless Application Repository

AWS Outposts

EC2 Image Builder

Storage

S3

EFS

FSx

S3 Glacier

Storage Gateway

AWS Backup

Database

RDS

DynamoDB

ElastiCache

Neptune

Amazon QLDB

Amazon DocumentDB

Amazon Keyspaces

Amazon Timestream

Migration & Transfer

AWS Migration Hub

Customer Enablement

AWS IQ

Support

Managed Services

Activate for Startups

Blockchain

Amazon Managed Blockchain

Satellite

Ground Station

Quantum Technologies

Amazon Braket

Management & Governance

AWS Organizations

CloudWatch

AWS Auto Scaling

CloudFormation

CloudTrail

Config

OpsWorks

Service Catalog

Systems Manager

AWS AppConfig

Trusted Advisor

Control Tower

AWS License Manager

AWS Well-Architected Tool

Machine Learning

Amazon SageMaker

Amazon Augmented AI

Amazon CodeGuru

Amazon Comprehend

Amazon Forecast

Amazon Fraud Detector

Amazon Kendra

Amazon Lex

Amazon Personalize

Amazon Polly

Amazon Rekognition

Amazon Textract

Amazon Transcribe

Amazon Translate

AWS DeepComposer

AWS DeepLens

AWS DeepRacer

Analytics

Athena

Amazon Redshift

EMR

CloudSearch

Elasticsearch Service

Kinesis

QuickSight

Data Pipeline

AWS Data Exchange

AWS Glue

AR & VR

Amazon Sumerian

Application Integration

Step Functions

Amazon AppFlow

Amazon EventBridge

Amazon MQ

Simple Notification Service

Simple Queue Service

SWF

Managed Apache Airflow

AWS Cost Management

AWS Cost Explorer

AWS Budgets

AWS Marketplace Subscriptions

Customer Engagement

Amazon Connect

Pinpoint

Simple Email Service

Business Applications

Alexa for Business

Amazon Chime

WorkMail

Amazon Honeycode

End User Computing

Amazon WorkSpaces

FeedbackEnglish (US)

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Cloud providers offer families of services – for example, here are the choices for “Storage” for AWS

Free Trial Available

Amazon Simple Storage Service (S3)

Scalable Storage in the Cloud

Free Trial Available

Amazon Elastic Block Store (EBS)

EC2 block storage volumes

Free Trial Available

Amazon Elastic File System (EFS)

Fully managed file system for EC2

Amazon FSx for Lustre

High-performance file system integrated with S3

Amazon FSx for Windows File Server

Fully managed Windows native file system

Amazon S3 Glacier

Low-cost Archive Storage in the Cloud

AWS Backup

Centralized backup across AWS services

AWS Snow Family

Physical edge computing and storage devices for rugged or disconnected environments

Free Trial Available

AWS Storage Gateway

Hybrid Storage Integration

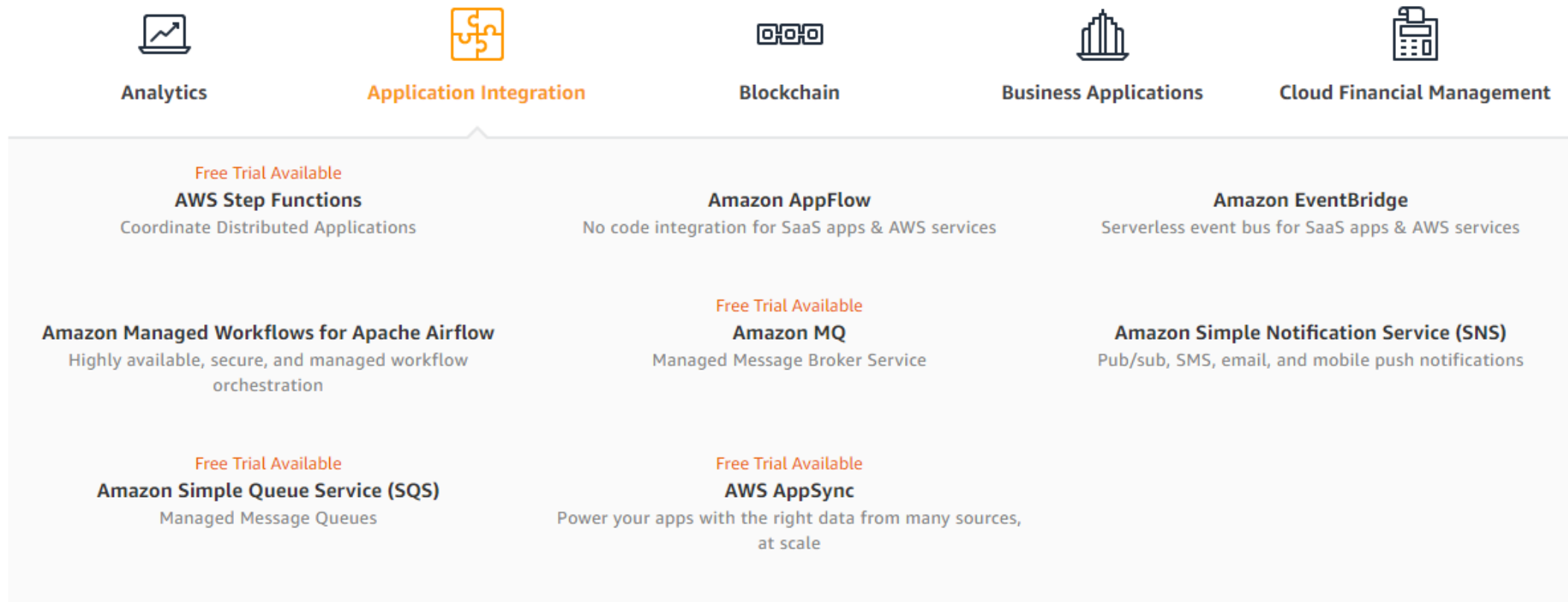
CloudEndure Disaster Recovery

Highly automated disaster recovery

“Storage” is not to be confused with “Database” – here are the AWS offerings in that family

<p>Amazon Aurora High Performance Managed Relational Database</p>	<p>Amazon Aurora Serverless v2 (Preview) Instantly scale to >100,000 transactions per second</p>	<p>Free Trial Available Amazon DynamoDB Managed NoSQL Database</p>
<p>Amazon DocumentDB (with MongoDB compatibility) Fully managed document database</p>	<p>Free Trial Available Amazon ElastiCache In-memory Caching System</p>	<p>Free Trial Available Amazon Keyspaces (for Apache Cassandra) Managed Cassandra-compatible database</p>
<p>Amazon MemoryDB for Redis Redis-compatible, durable, in-memory database that delivers ultra-fast performance</p>	<p>Amazon Neptune Fully Managed Graph Database Service</p>	<p>Amazon Quantum Ledger Database (QLDB) Fully managed ledger database</p>
<p>Free Trial Available Amazon RDS Managed Relational Database Service for MySQL, PostgreSQL, Oracle, SQL Server, and MariaDB</p>	<p>Amazon RDS on VMware Automate on-premises database management</p>	<p>Free Trial Available Amazon Redshift Fast, Simple, Cost-effective Data Warehousing</p>
<p>Amazon Timestream Fully managed time series database</p>	<p>Free Trial Available AWS Database Migration Service Migrate Databases with Minimal Downtime</p>	<p>AWS Glue Simple, scalable, and serverless data integration</p>

Middleware and messaging components are offered in the “Application Integration” family of AWS



Here is a simple example of using a cloud service; I am using Amazon Web Services S3 to store and retrieve a simple text file

1. Sign up for an AWS account – there is a free tier
<https://aws.amazon.com/free/>
2. Create a user and obtain credentials
aws_access_key_id and aws_secret_access_key
See <https://docs.aws.amazon.com/sdk-for-cpp/v1/developer-guide/credentials.html> for more information
3. Install the libraries for the AWS C++ client
<https://docs.aws.amazon.com/sdk-for-cpp/v1/developer-guide/setup-windows-vcpkg.html>
4. Write code to use the C++ client libraries to access the cloud service you need


```

#include <iostream>
#include <fstream>
#include <sys/stat.h>
#include <aws/core/Aws.h>
#include <aws/s3/S3Client.h>
#include <aws/s3/model/PutObjectRequest.h>
#include "s3_examples.h"
//snippet-end:[s3.cpp.put_object.inc]

/* ////////////////////////////////////// */
* Purpose: Adds an object to an Amazon S3 bucket.
* For an example of a multipart upload, see the s3-crt code example.
*
* Prerequisites: An Amazon S3 bucket and the object to be added.
*
* Inputs:
* - bucketName: The name of the bucket.
* - objectName: The name of the object.
* - region: The AWS Region for the bucket.
*
* Outputs: true if the object was added to the bucket; otherwise, false.
* ////////////////////////////////////// */

int main()
{
    Aws::SDKOptions options;
    Aws::InitAPI(options);
    {
        //TODO: Change bucket_name to the name of a bucket in your account.
        const Aws::String bucket_name = "ece4574fa21";
        //TODO: Create a file called "my-file.txt" in the local folder where your
        executables are built to.
        const Aws::String object_name = "c:\\Data\\my-file.txt";
        //TODO: Set to the AWS Region in which the bucket was created.
        const Aws::String region = "us-east-2";

        if (!AwsDoc::S3::PutObject(bucket_name, object_name, region)) {

            return 1;
        }
    }
    Aws::ShutdownAPI(options);

    return 0;
}

```

```

bool AwsDoc::S3::PutObject(const Aws::String& bucketName,
    const Aws::String& objectName,
    const Aws::String& region)
{
    struct stat buffer;
    if (stat(objectName.c_str(), &buffer) == -1) {
        std::cout << "Error: PutObject: File '" <<
            objectName << "' does not exist." << std::endl;
        return false;
    }

    Aws::Client::ClientConfiguration config;

    if (!region.empty()) {
        config.region = region;
    }

    Aws::S3::S3Client s3_client(config);

    Aws::S3::Model::PutObjectRequest request;
    request.SetBucket(bucketName);
    //We are using the name of the file as the key for the object in the bucket.
    //However, this is just a string and can set according to your retrieval needs.
    request.SetKey(objectName);

    std::shared_ptr<Aws::IOStream> input_data =
        Aws::MakeShared<Aws::FStream>("SampleAllocationTag",
            objectName.c_str(),
            std::ios_base::in | std::ios_base::binary);
    request.SetBody(input_data);

    Aws::S3::Model::PutObjectOutcome outcome =
        s3_client.PutObject(request);

    if (outcome.IsSuccess()) {

        std::cout << "Added object '" << objectName << "' to bucket '"
            << bucketName << "'.";
        return true;
    } else {
        std::cout << "Error: PutObject: " <<
            outcome.GetError().GetMessage() << std::endl;

        return false;
    }
}

```

```
C:\Users\crjones4\aws\credentials - Notepad++
File Edit Search View Encoding Language Settings Tools Macro Run Plugins Window ?
mqttasyncclient.cpp x MQTTAsyncClient.h x mainwindow.cpp x S3CrClient.cpp x S3Client.h x credentials x
1 [default]
2 aws_access_key_id = 
3 aws_secret_access_key = 
length: 117 lines: 3 Ln: 3 Col: 65 Pos: 118 Windows (CR LF) UTF-8 INS
```

```
C:\Data\my-file.txt - Notepad++
File Edit Search View Encoding Language Settings Tools Macro Run
Plugins Window ?
MQTTAsyncClient.h x mainwindow.cpp x S3CrClient.cpp x S3Client.h x
1 This is a test
Ln: 1 Col: 1 Pos: 1 Windows (CR LF) UTF-8 INS
```

ece4574fa21 - S3 bucket

s3.console.aws.amazon.com/s3/buckets/ece4574fa21?region=us-east-2&tab=objects

Services Search for services, features, marketplace products, and docs [Alt+S]

Amazon S3 > ece4574fa21

ece4574fa21 Info

Objects Properties Permissions Metrics Management Access Points

Objects (1)

Objects are the fundamental entities stored in Amazon S3. You can use [Amazon S3 inventory](#) to get a list of all objects in your bucket. For others to access your objects, you'll need to explicitly grant them permissions. [Learn more](#)

Refresh Copy S3 URI Copy URL Download Open Delete Actions

Create folder Upload

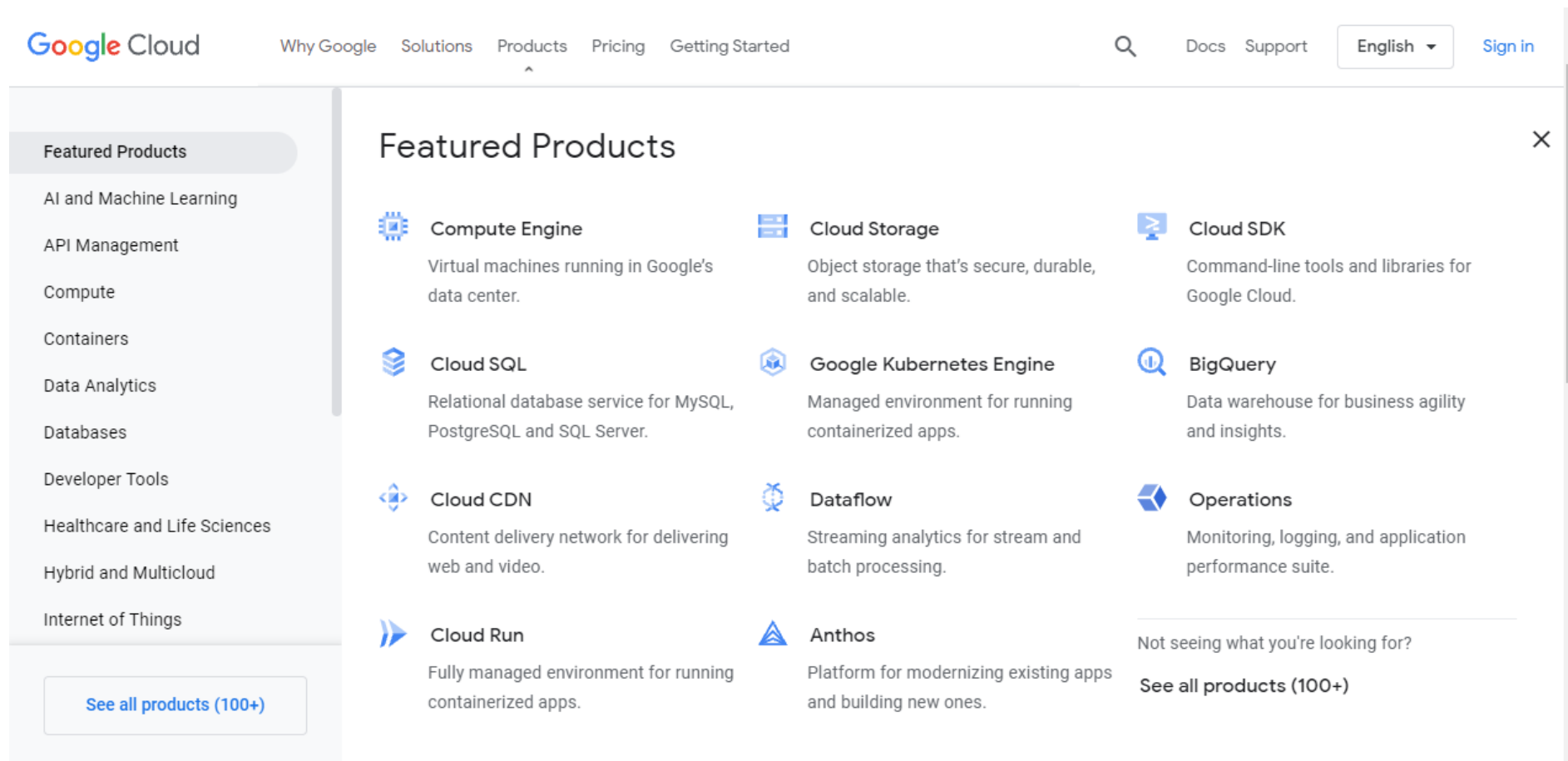
Find objects by prefix

	Name	Type	Last modified	Size	Storage class
<input type="checkbox"/>	c:\Data\my-file.txt	txt	October 25, 2021, 06:00:48 (UTC-04:00)	14.0 B	Standard

Feedback English (US) © 2008 - 2021, Amazon Web Services, Inc. or its affiliates. All rights reserved. Privacy Policy Terms of Use Cookie preferences

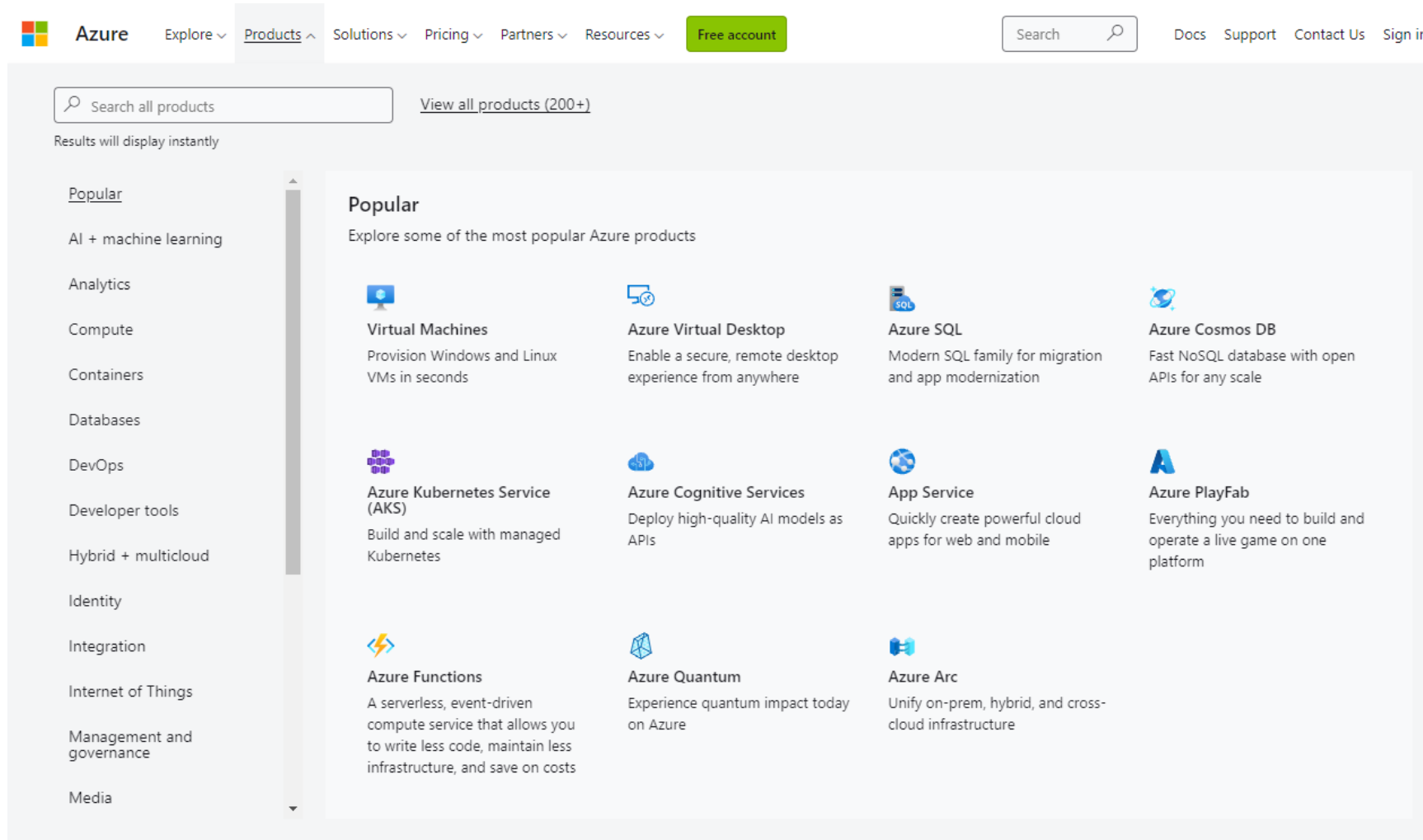
```
c_Data_my-file.txt - ...
File Edit Format View Help
This is a test
100% Windows (CRLF) UTF-8
```

Google offers a similar set of service families – storage, database, etc.



The screenshot shows the Google Cloud homepage. At the top, there's a navigation bar with links for 'Why Google', 'Solutions', 'Products', 'Pricing', and 'Getting Started'. On the right, there's a search icon, 'Docs', 'Support', a language dropdown set to 'English', and a 'Sign in' link. A left sidebar lists various product categories: 'Featured Products', 'AI and Machine Learning', 'API Management', 'Compute', 'Containers', 'Data Analytics', 'Databases', 'Developer Tools', 'Healthcare and Life Sciences', 'Hybrid and Multicloud', and 'Internet of Things'. At the bottom of the sidebar is a button that says 'See all products (100+)'. The main content area is titled 'Featured Products' and displays a grid of product cards. Each card includes an icon, the product name, and a brief description. The products shown are: Compute Engine (Virtual machines running in Google's data center.), Cloud Storage (Object storage that's secure, durable, and scalable.), Cloud SDK (Command-line tools and libraries for Google Cloud.), Cloud SQL (Relational database service for MySQL, PostgreSQL and SQL Server.), Google Kubernetes Engine (Managed environment for running containerized apps.), BigQuery (Data warehouse for business agility and insights.), Cloud CDN (Content delivery network for delivering web and video.), Dataflow (Streaming analytics for stream and batch processing.), and Operations (Monitoring, logging, and application performance suite.). At the bottom right of the featured products grid, there's a link that says 'Not seeing what you're looking for? See all products (100+)'. A vertical scrollbar is visible on the right side of the page.

Microsoft offers the Azure set of cloud services



The screenshot shows the Azure website interface. At the top, there is a navigation bar with the Azure logo, links for Explore, Products, Solutions, Pricing, Partners, and Resources, a Free account button, a search bar, and links for Docs, Support, Contact Us, and Sign in. Below the navigation bar, there is a search bar with the text "Search all products" and a link to "View all products (200+)". The main content area is divided into two sections: a left sidebar with a list of categories and a main grid of popular products.

Popular
Explore some of the most popular Azure products

Product	Description
Virtual Machines	Provision Windows and Linux VMs in seconds
Azure Virtual Desktop	Enable a secure, remote desktop experience from anywhere
Azure SQL	Modern SQL family for migration and app modernization
Azure Cosmos DB	Fast NoSQL database with open APIs for any scale
Azure Kubernetes Service (AKS)	Build and scale with managed Kubernetes
Azure Cognitive Services	Deploy high-quality AI models as APIs
App Service	Quickly create powerful cloud apps for web and mobile
Azure PlayFab	Everything you need to build and operate a live game on one platform
Azure Functions	A serverless, event-driven compute service that allows you to write less code, maintain less infrastructure, and save on costs
Azure Quantum	Experience quantum impact today on Azure
Azure Arc	Unify on-prem, hybrid, and cross-cloud infrastructure

Left Sidebar Categories:

- Popular
- AI + machine learning
- Analytics
- Compute
- Containers
- Databases
- DevOps
- Developer tools
- Hybrid + multicloud
- Identity
- Integration
- Internet of Things
- Management and governance
- Media

One important cloud service is allocation of “virtual machines” – virtual Linux or Windows machines that can be used to run application code, and can be allocated/deallocated on demand



Virtual Machines



Virtual Machine Scale Sets



Batch



Cloud Services



Service Fabric



Container Service



Container Registry



Functions



Web Apps

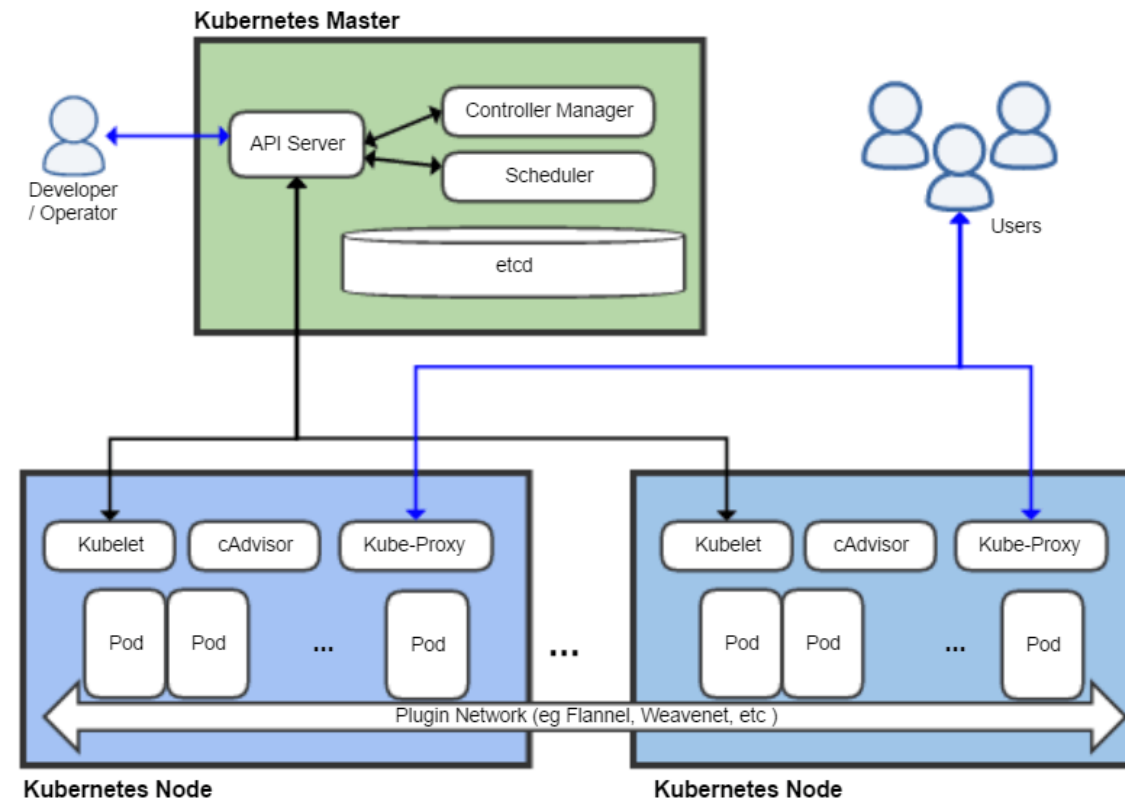
Find the compute product you need

IF YOU WANT TO	USE THIS
Provision Linux and Windows virtual machines in seconds with the configurations of your choice	Virtual Machines
Achieve high availability by autoscaling to create thousands of VMs in minutes	Virtual Machine Scale Sets
Get deep discounts when you provision unused compute capacity to run your workloads	Azure Spot Virtual Machines
Build and scale with managed Kubernetes	Azure Kubernetes Service (AKS)
Accelerate app development using an event-driven, serverless architecture	Azure Functions
Develop microservices and orchestrate containers on Windows and Linux	Service Fabric
Quickly create cloud apps for web and mobile with fully managed platform	App Service
Containerize apps and easily run containers with a single command	Container Instances
Cloud-scale job scheduling and compute management with the ability to scale to tens, hundreds, or thousands of virtual machines	Batch
Create highly available, scalable cloud applications and APIs that help you focus on apps instead of hardware	Cloud Services
Deploy your Azure virtual machines on a physical server only used by your organization	Azure Dedicated Host

Kubernetes is a tool for managing collections of computing resources and allocating what runs on each

- Kubernetes can be used on physical clusters of machines
 - But its most common use is for cloud services
- Kubernetes is built on the concept of *containers*
 - A container is a portion of a computer's resources (CPU cores, memory, interfaces) that can be allocated to a process
 - A *pod* is a set of containers co-located on the same *node* (compute machine)
- “Kubernetes maps out how applications should work and interact with other applications. Due to its elasticity, it can scale services up and down as required, perform rolling updates, switch traffic between different versions of your applications to test features or rollback problematic deployments.”
 - Ubuntu

Code developed using the Kubernetes API manages pods and nodes to achieve performance and scale



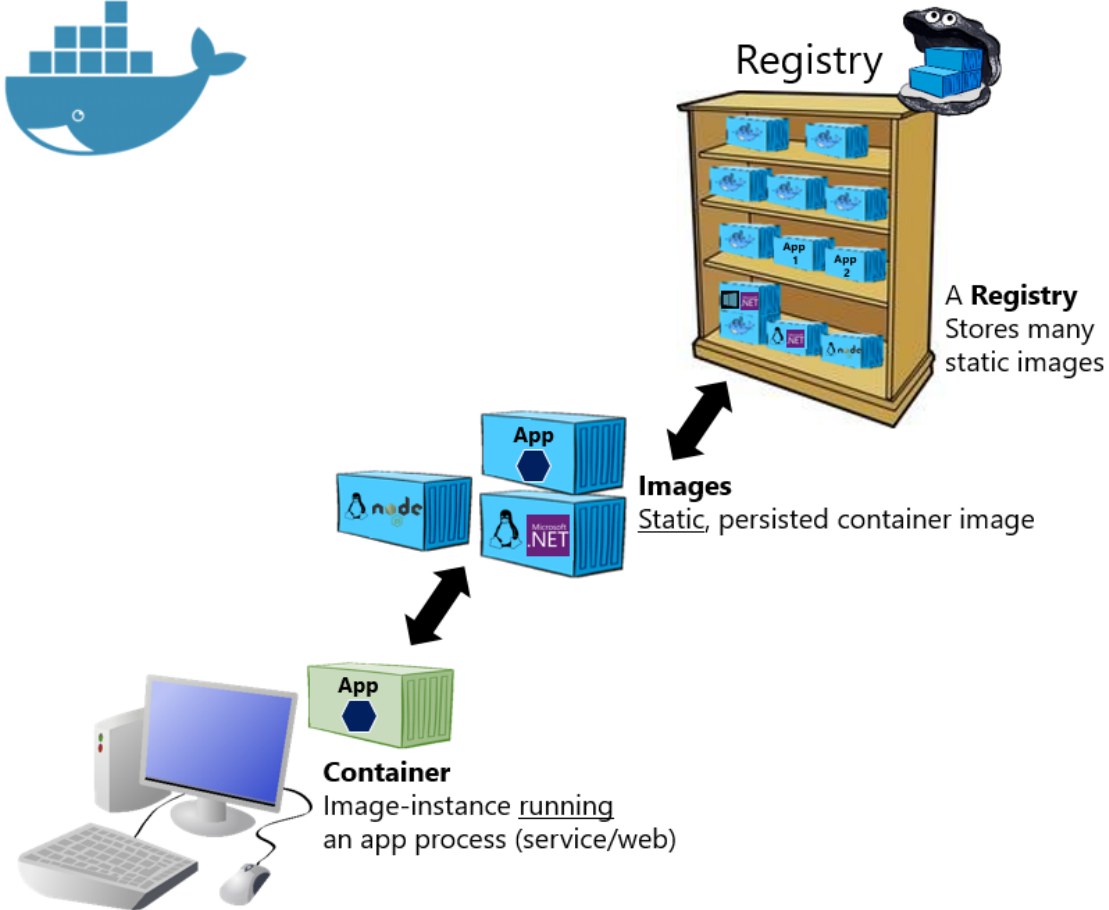
More information on Kubernetes

- <https://ubuntu.com/kubernetes/what-is-kubernetes>
- <https://docs.microsoft.com/en-us/azure/aks/tutorial-kubernetes-deploy-cluster>
- Online implementations:
 - <https://cloud.google.com/kubernetes-engine>
 - <https://aws.amazon.com/eks>
 - <https://azure.microsoft.com/en-us/services/kubernetes-service>
 - <https://www.oracle.com/cloud-native/container-engine-kubernetes>

Docker is a commonly used package for running containers

- “While Docker is a container runtime, Kubernetes is a platform for running and managing containers from many container runtimes. Kubernetes supports numerous container runtimes including Docker, containerd, CRI-O, and any implementation of the Kubernetes CRI (Container Runtime Interface).
- A good metaphor is Kubernetes as an “operating system” and Docker containers are “apps” that you install on the “operating system”.”

Basic taxonomy in Docker



Hosted Docker Registry

Docker Trusted Registry on-prem.

On-premises
(‘n’ private organizations)

Docker Hub Registry

Docker Trusted Registry on-cloud

Azure Container Registry

AWS Container Registry

Public Cloud
(specific vendors)

Google Container Registry

Quay Registry

Other Cloud

More information on Docker

- <https://www.docker.com/>
- <https://aws.amazon.com/docker/>
- Docker in action: <https://viriniatech.on.worldcat.org/oclc/1139335604>

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- Docker