# CAB432 Study Guide | 2022 Semester 2

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# CAB432: Cloud Computing

Cloud Computing is among the most important developments in the IT industry in recent years, and one which has received enormous attention. Cloud is a natural progression from earlier trends in service and infrastructure outsourcing and virtualisation, but is distinguished by its elasticity and scale: service and infrastructure provisioning may change rapidly in response to variations in demand, allowing clients to cater for unexpected spikes in load without tying up capital in expensive and potentially underutilised assets. Cloud services and technologies are becoming increasingly diverse and sophisticated, moving rapidly from the original 'bare metal' offerings and providing a rich set of options and APIs. This unit provides a technically oriented introduction to Cloud Computing,

giving you experience in developing modern cloud applications and deploying them to the public clouds of the major vendors.

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# Week 1: Introduction

## What is Cloud Computing?

Cloud computing is, at its core, IT infrastructures and services that can be turned on when needed and are payed only when being used. These services can be scaled as needed and automatically adjust themselves based on the current load. Modern cloud computing operates as a global scale providing access to everyone, everywhere at anytime.

So what business case would there be for cloud computing?

1. Only pay for what you use
2. Don't have to spend the money, time and resources to build server rooms and run them
3. Capacity is managed through elastic provisioning
4. Most major vendors provide unlimited capacity based on how much you pay

## Public, Private, and Hybrid Clouds

| Public Cloud | Private Cloud | Hybrid Cloud |
|---|---|---|
| Services offered by the major vendors | Services hosted and managed by large companies or government | Services based on a mix of public and private clouds |
| Available globally on a commercial basis | Same elastic service model but on a smaller scale | Often used to manage regulatory requirements and client concerns over location of sensitive data sets |
| "Limited only by the size of your credit card" | Usually more limited service offerings | Government services, Major corporate's |

## Cloud Pre-requisites

| Virtualisation | Elasticity | Scale |
|---|---|---|

| Virtualisation | Elasticity | Scale |
| --- | --- | --- |
| Costly to maintain lots of small machines | Measure load and automatically scale as needed | Cloud data centres are huge |
| Better to maintain lots of virtual machines (VM) in the one place | Scale out when people are waiting. Scale in when we have too many machines | Major vendors have nodes around the world and their own undersea cables |

# Virtualisation

| Virtualisation Layers |
| --- |
| Application(s) |
| Guest OS (many) |
| Hypervisor |
| Host Operating System - Linux, Windows, UNIX... |
| Physical Hardware |

# Types of Cloud Services

| Infrastructure as a Service (IaaS) | Platform as a Service (PaaS) | Software as a Service (SaaS) |
| --- | --- | --- |
| Virtual Machine + OS | Not just the OS | Application hosting in the cloud |
| Pick your size | Pre-configured software stack on each VM | Subscription-based |
| Storage - entity storage, SQL, NoSQL, archive | Managed provisioning and scaling | All hosting and management is done for you at a fee |
| Pick your DB | | Salesforce is usually used |

# Major Providers

## Microsoft Azure

- Provide a mix of XaaS services but mainly provide IaaS and PaaS

- Their focus areas consist of big data and machine learning
- Azure SQL and SQL Server are two instances of services
- Cognitive Services and Azure ML are key offerings

### Google Cloud Platform

- Provide a mix of IaaS and PaaS
- Their focus area is IaaS at a large scale
- PaaS remains through Servlet based AppEngine
- Have application areas in search tech, data and machine learning

### Amazon Web Services

- Provide a mix of XaaS services
- Huge range of elastic application services
- Have made major improvement in machine learning services in recent years
- Developing a focus on IoT

# Week 2: Docker

## Docker

Docker is a popular container as a service application that has command-line tools to run containers, create images and do much more. Docker can also be run inside of a Linux OS that is in itself being virtualised by a VM.

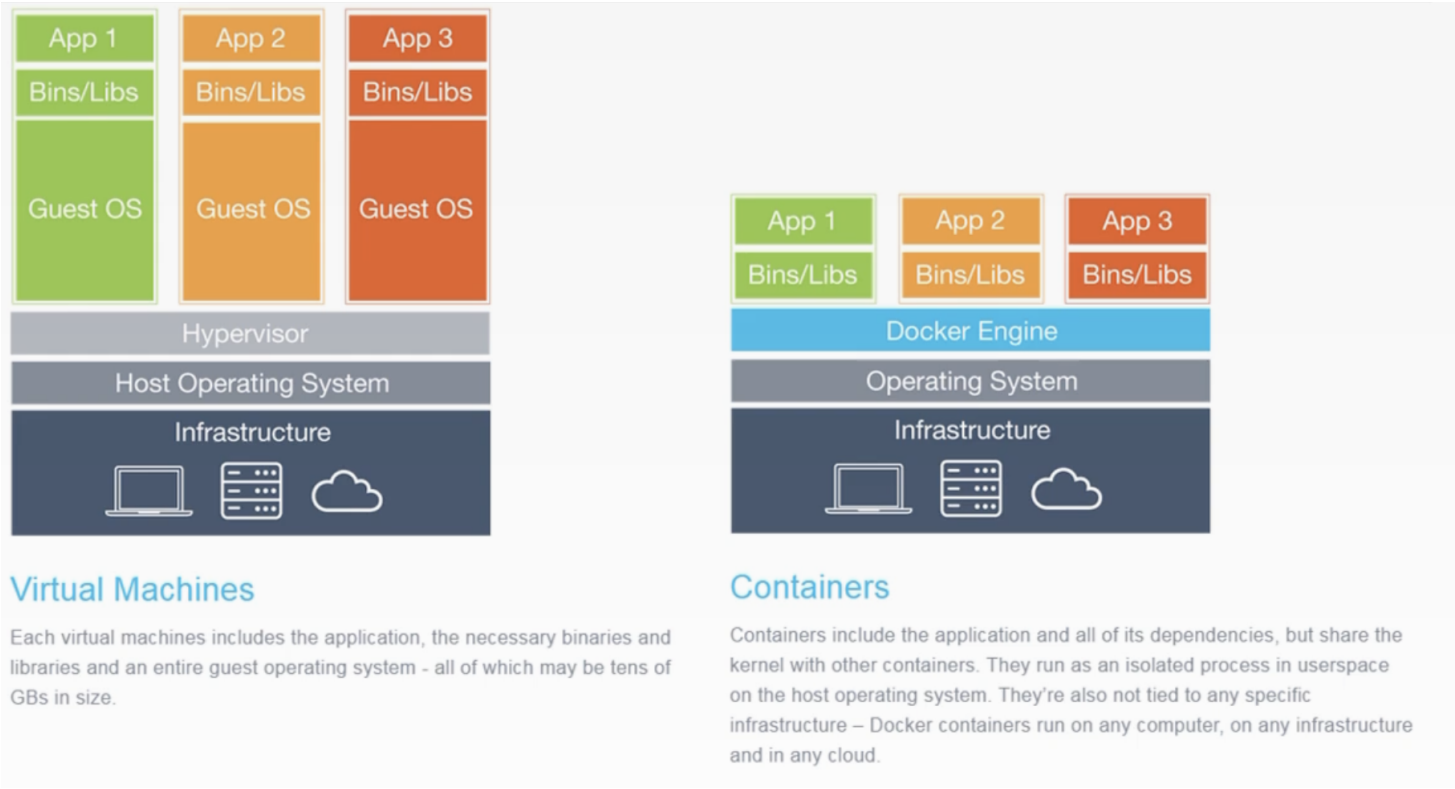
There are many reasons to use docker such as:

- Much more efficient use of "bare-metal" hardware resources
- Many more containers than virtual machines
- More efficient use of CPU cycles
- There is no need to maintain an entire operating system stack
- Easier management and orchestration
- Rebooting containers is much faster and easer than rebooting a VM

There are also however a few cons:

- Virtual machines allow for better isolation
- Containers may have port collisions

- Within containers there is no access OS-level daemons
- There is an assumption that guest software is compatible with Linux




## Containers

A container is an instance of an application(s), whether running, stopped or finished. These containers are installed on top of some "base image" with each container being isolated from other containers and from the guest OS (although they can interact with these throughout well-defined interfaces).

## Images

An image is a "pre-canned" software stack loaded from some repository, typically dockerhub.com. An image acts as a blueprint for containers and follows a cookie-cutter model where as many identical images can be deployed as we want.

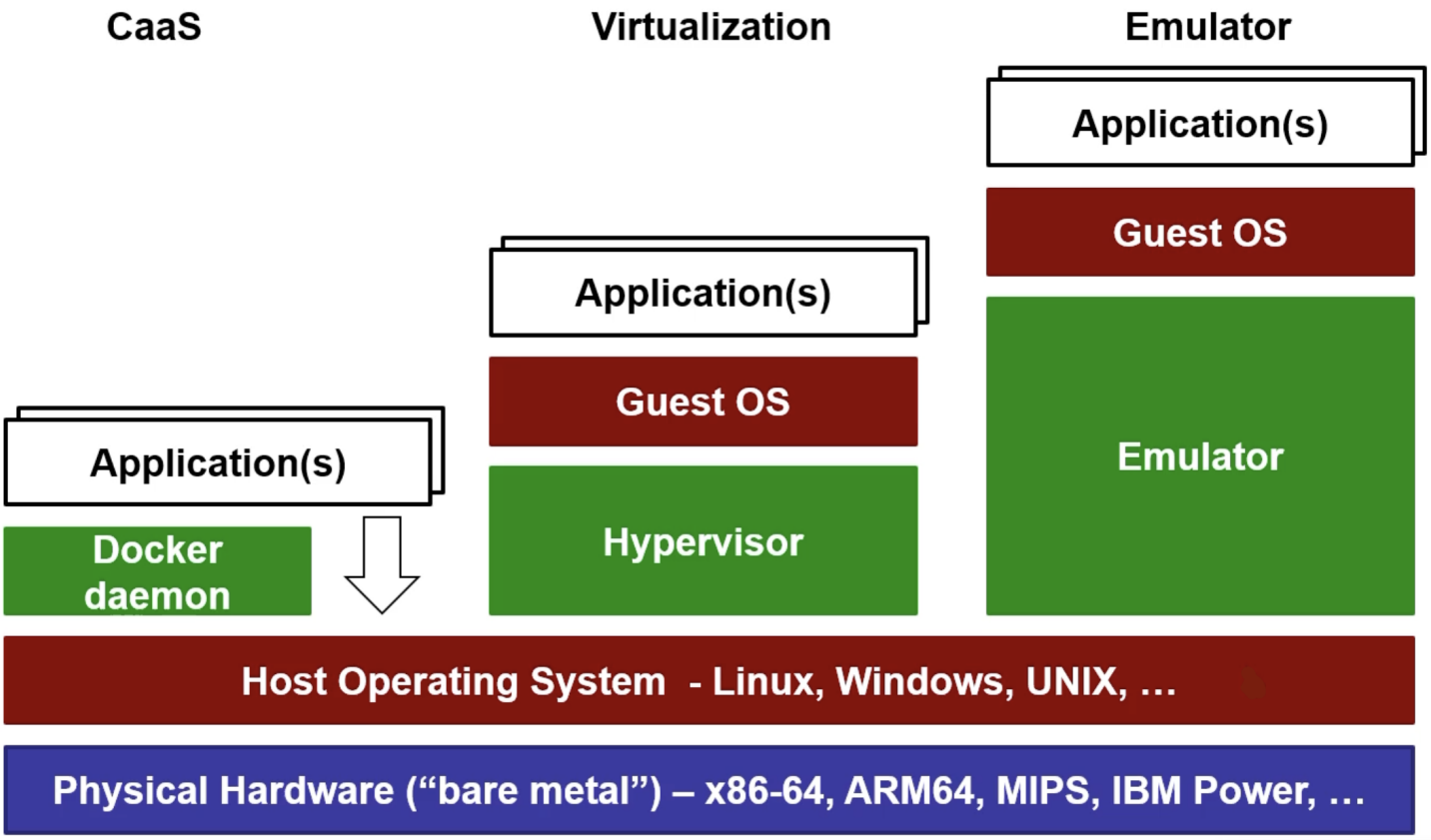
## Dockerfile

A docker file is a script used to build a docker image. These typically start with a base OS image and execute a sequence of commands consisting of installation and configuration tasks for the needed stack. A docker compose is a file that allows services and configurations for multi-container applications to be specified.

## Application Virtualisation Levels

- Typically layered on top of an operating system. This is usually Linux for a number of reasons.
- Things like hardware, firmware, OS, middleware and standard tools are not virtualised.
- Precise, user-defined set of software and configuration:
  - There is no need to clone a virtual machine leading to a faster and lighter experience
  - Scripts can instantiate a cloned container within a matter of seconds
  - Pre-canned scripts and images are able to be shared with others

## CaaS vs Virtualisation vs Emulators




## Why use Virtualisation

There are many reasons to use virtualisation such as:

- **Cost**: It is much cheeper to run virtual machines because it allows for fewer physical machines for the same amount of computation.
- **Normalisation**: With normalisation we get:
  - Cookie cutter resources: All the resources are the same
  - To define an instance and machine image
  - Easier management and maintenance of units

- **Software Lifecycle**: The ability to deploy many identical machine images and update them all the same
- **Isolation**: Using isolation we can have many users on the same hardware with hard separation of virtualised resources
- **Instance Lifecycle**: Each instance we create can be:
    - Scaled up: Quickly replace the current resources with more powerful ones
    - Scale out: Quickly start up additional, identical instances
    - Continuity: Quick fail-over to another resource

## IaaS Challenges

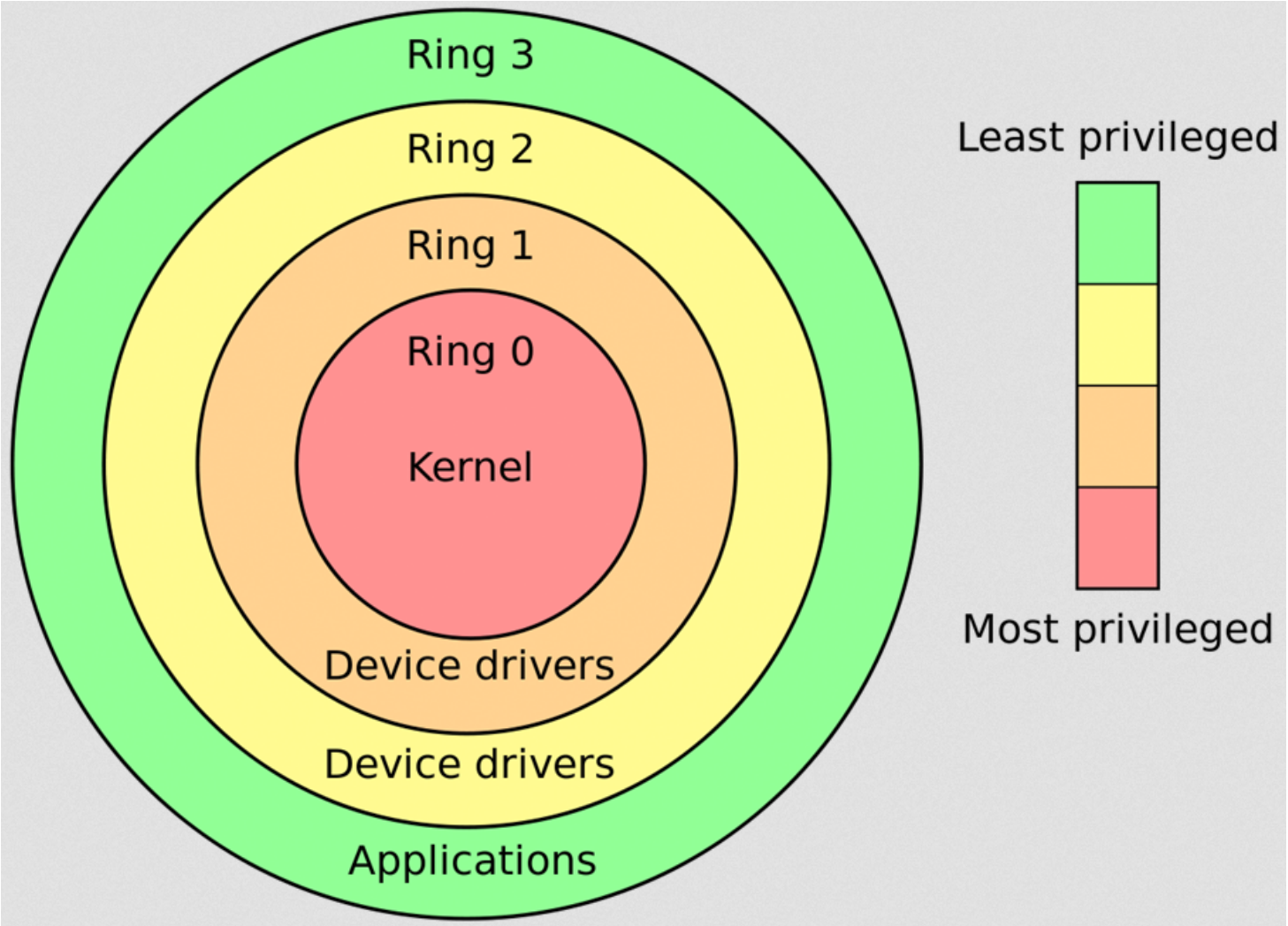
Infrastructure as a service has a few challenges that come along with it:

- A heavyweight and complex hypervisor
- Performance and resource consumption
- Virtualisation of an entire guest OS. This means virtualising things like the kernel, device drivers, the filesystem, the network protocol stack, middleware, applications and many more.

## Hardware Virtualisation Terminology

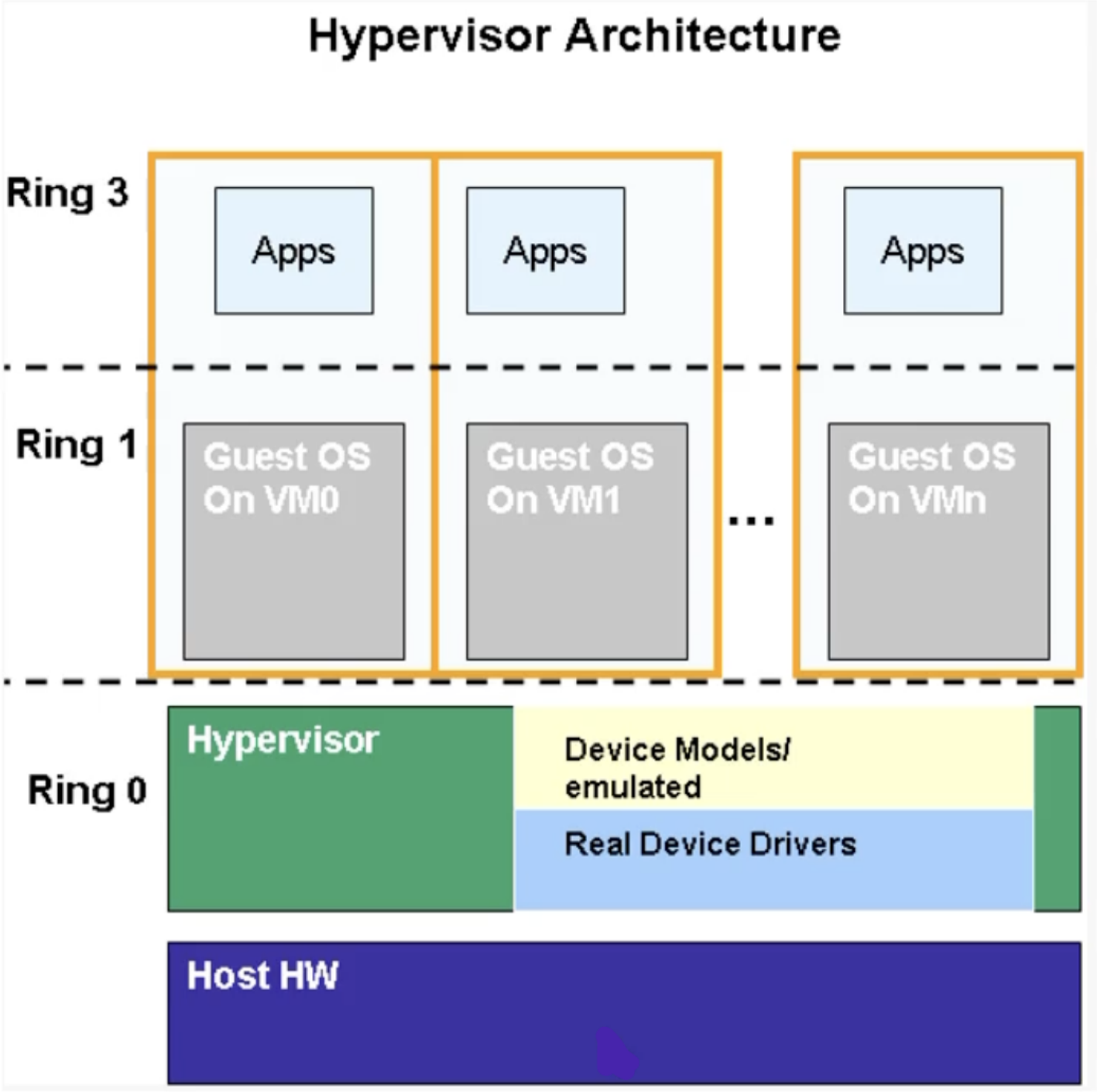
- **Host OS**: The host operating system is the non-virtualised hardware resources. This is the "bare metal" running the hypervisor/VMM (typically your physical device).
- **Guest OS**: The guest operating system is the operating system running inside of virtualised hardware.
- **Hypervisor**: Hypervisor is the software that runs the virtual machine itself. There are 2 types:
    - Type 1: This runs directly on the hardware (like an operating system)
    - Type 2: This runs inside of an operating system

## CPU Protection Layers




- **Kernal mode (ring 0)**: Privileged instructions such as interrupts or memory management. These instructions are generally reserved for the OS kernel with applications not normally being able to see them.
- **User mode (ring 3)**: Non-privileged or "safe" instructions. Application software will ask the kernel to perform privileged instructions on it's behalf. In this mode the Guest OS is given higher privileges via the hypervisor.

## Hardware Assisted Virtualisation Basics




## Hardware Emulation

Hardware emulators are full or partial software implementations of the hardware which use binary translation to convert some instruction to another e.g. ARM to x86, PowerPC to x86. One of the major pros to this is that we can emulate other instruction sets however, this comes at a huge hit to the speed as these binary translations are relatively slow depending on the complexity of the VMM.

## Para-virtualisation

Para-virtualisation is a way of modifying the guest OS to make virtualisation easier. VMM does this by implementing an API for the guest OS or by simulating privileged instructions. The obvious pro to this method is that we can avoid the costly binary translations. The downsides to this is that we must modify the guest OS and we can no longer emulate incompatible instructions sets.

## Hardware Assisted Virtualisation

Hardware assisted virtualisation is a way of creating virtual versions of operating systems and physical desktops. Using a virtual machine manager, abstracted hardware can be presented to multiple guest operating systems all sharing the same physical hardware resources.

There are many pros to this such as:

- The guest OS can continue in a privileged kernel mode
- Most ring 0 instructions do not "VMExit" to "ring -1"
- This method is much faster than full hardware virtualisation
- This method is sometimes faster than para-virtualisation and at other times not. It all depends on the circumstances
- The guest OS does not need to be modified

One of the main cons to this method is that it requires hardware support although this is quite common now days.

# Week 3: Cloud Applications, REST, and Node

## Moving to the Cloud

When moving to the cloud it's important to note that virtualisation means latency. The requests and responses that need to be sent and received are no longer free and instant. It's because of this that in cloud computing we must choose our method of data persistance carefully whether that be slow, long-term storage, fast cached storage or others.

Due to each message having an associated "flagfall" and cost associated we generally try to bundle them together when possible.

Another thing to note is that the interactions through the cloud are stateless and asynchronous. We don't always guarantee an immediate response but we do guarantee a response, clients send messages and then await the returning message from the service.

## State and Statelessness

State is the current state of some object such as the values of it's fields. In the context of cloud computing what we mean when we refer to an objects state is how we can maintain that specific objects state between different server requests.

Statelessness can be a confusing concept due to the reason that there may be some state there, it's just that we don't rely on that state being preserved. An object is stateless initially but the state of that object can be recoverable via some other means.

## REST

REpresentational State Transfer, or REST for short, is a set of principles that define how web standards, such as HTTP and URIs, are supposed to be used. Using the principles of REST we must:

- Give everything an Id:
  - https://www.flickr.com/photos/sdufva
  - https://www.flickr.com/photos/tags/golden-retrievers
  - https://www.example.com/orders/2007/11
  - https://www.example.com/products?colour=green
- Link things together:
  - Global URIs allow most unbounded linkage of resources and attributes
  - URIs can capture state, allowing state transitions to be mapped to link transitions
- Use standard methods:
  - HTTP
  - GET, POST, PUT, DELETE
- Have resources with multiple representations:
  - JSON, XML, Plain Text
- Communicate statelessly:
  - Keep the state in the URI or in the client

## GET

A GET request is a HTTP request method used to retrieve data from a data source. An example of a GET request to developer.mozilla.org is:

```
GET / HTTP/1.1
Host: developer.mozilla.org
Accept-Language: en
```

After the request is made a response will be transmitted from the host destination, here is an example of a 200 Ok response:

```
HTTP/1.1 200 OK
Content-Type: text/html; charset=utf-8
Content-Length: 55743
[More here...]

<!DOCTYPE html>
<html lang="en">
  <head>
    <meta charset="utf-8>
    <title>A simple webpage</title>
  </head>
  <body>
    <h1>Welcome</h1>
    <p>Hello, world!</p>
  </body>
</html>
```

# POST

A POST request is a HTTP method used to send some data to a data source. An example of a POST request is:

```
POST /users HTTP/1.1
Accept: application/json
Authorization: Basic XXXXXXXXXXXXXXXXX
Content-Type: application/json
Host: localhost
Connection: keep-alive
Content-Length: 984

{
  "name": "Franklin Schafer",
  "purchase": {
    "id": "Bicycle computer",
    [More here...]
  }
  [More here...]
}
```

Much like the GET request a response will be transmitted once the server receives the request.

## Cloud Requests

All these requests first come into the Elastic Load Balancer with those requests then being sent on into the Scaling Pool machines.

## Elements of the HTTP Session

A HTTP session consists of three phases:

1. The client establishes a TCP connection
2. The client sends a request and then waits for an answer
3. The server processes the requests and sends back an answer containing a status code and the appropriate data

Each request follows the general structure of:

- Method + Parameters: Path to the resource without the domain name
- The HTTP protocol version being used
- Any subsequent headers e.g. Content-Type
- An empty line above the data block

Each response follows the general structure of:

- Status line, HTTP version used + the status code and information
- Additional HTTP headers such as the timestamp, type, data size...
- The data block (with a blank line above it)

## Common Response Codes:

| Code | Name |
|---|---|
| 100 | Continue |
| 200 | OK |
| 201 | Created |
| 202 | Accepted |
| 301 | Moved Permanently |
| 400 | Bad Request |
| 401 | Unauthorized |
| 403 | Forbidden |
| 404 | Not Found |
| 500 | Internal Server Error |

| Code | Name |
| --- | --- |
| 501 | Not Implemented |
| 502 | Bad Gateway |
| 503 | Service Unavailable |
| 504 | Gateway Timeout |

## Node.js

Node.js is essentially server side JavaScript which was introduced to support rapid server connections and processing. Node.js has many advantages such as:

- It being fast due to it being compiled and being very optimised
- Having support for asynchronous javascript connection processing
- Not having to allocate a new thread for every connection
- It's open-source
- Having very strong support from major vendors such as Google, Microsoft and more

An example of a simple Node.js server:

```
const http = require("http");

const hostname = "127.0.0.1";
const port = 3000;

const server = http.createServer((req, res) => {
  res.statusCode = 200;
  res.setHeader("Content-Type", "text/plain");
  res.end("Hello World\n");
});

server.listen(port, hostname, () => {
  console.log(`Server running at http://${hostname}:${port}/`);
});
```

## Simple Storage Service

Simple storage service can be thought of as lots of very large objects each containing a collection of <key, Object> pairs. This is based on a non-relational, addressable bucket model and was the original AWS service layer.

It's important to remember that data persistence is up to the vendor you're using and that the data utility is up to you.

# Week 4: Node and Express

## NPM

NPM is an online repository of open-source Node.js projects. It is also a command-line utility that installs, removes, updates and manages installed npm packages.

To install a package locally we type:

```
npm install <package-name>
```

and to install the package globally (not recommended unless you know the utility is globally useful)

```
npm install <package-name> -g
```

These packages will be installed into your projects `node_modules` folder with all package dependencies stored in `package.json` and `package-lock.json`.

## Express

Express is an application framework designed for node. To use Express we must first install it using `npm install express -g`. Let's take a look at a very simple hello world express program:

```
const express = require("express");
const app = express();

const hostname = "127.0.0.1";
const port = 3000;

app.get("/", (req, res) => {
  res.send("Hello World!");
});

server.listen(port, () => {
  console.log(`Express app listening at http://${hostname}:${port}/`);
});
```

We can handle routing using the `Router` class.

```
const express = require("express");
const router = express.Router();

router.get("/", (req, res) => {
  res.send("Home page");
});

router.get("/about", (req, res) => {
  res.send("About page");
});

module.exports = router;
```

## Express Generator

Express generator will create and setup a lot of the necessary boilerplate for an Express application for us. To use it we must first install it using `npm install express-generator -g`. Once installed we can create an Express application using `express helloworld` in the terminal. The following files will be created inside the project directory:

```
.
├── app.js
├── bin
│   └── www
├── package.json
├── public
│   ├── images
│   ├── javascripts
│   └── stylesheets
│       └── style.css
├── routes
│   ├── index.js
│   └── users.js
└── views
    ├── error.jade
    ├── index.jade
    └── layout.jade
```

## Fetch

We can simulate GET and POST requests in Javascript using the `fetch()` function. The fetch request works by passing in the url for the data and an optional parameter containing headed data for the request being sent (i.e. authorisation tokens). Here is a simple GET request using the `fetch()` method:

```
fetch("https://jsonplaceholder.typicode.com/posts/1")
  .then((response) => response.json())
  .then((json) => console.log(JSON.stringify(json)));
```

Here is a simple POST request using the `fetch()` method:

```
const headerContent = {
  method: "POST",
  body: JSON.stringify({
    title: "foo",
    body: "bar",
    userId: 1,
  }),
  headers: {
    "Content-type": "application/json; charset=UTF-8",
  },
};

fetch("https://jsonplaceholder.typicode.com/posts", headerContent)
  .then((response) => response.json())
  .then((json) => console.log(json));
```

## Promises

A promise is a special Javascript object that can hold the future value of an asynchronous operation. A promise can be in one of three states at any given time:

- Pending: This is the initiate state, it is neither fulfilled or rejected
- Fulfilled: This state is true when the operation has been completed and the promise now contains the retrieved data
- Rejected: This state is true when the operation has failed

Promises work by chaining functions from each other using the keyword `.then()`. We can also use `.catch()` at the end of our chain to throwback any errors we retrieve. For example, let's say we want to print to the console the returned data if, and only if, the fetch request returns a valid response, without having to freeze our application waiting for the API callback. We can use promises for this as such:

```
fetch("https://jsonplaceholder.typicode.com/posts/1")
  .then((response) => {
    if (response.ok) {
      return response.json();
    }

    throw new Error("Failed network response");
  })
  .then((result) => {
    console.log(result);
  })
  .catch((error) => console.log(`Problem with error message: ${error}`));
```

We can also use Async/Await to accomplish the same thing:

```
{
    () => {
        try {
            const response = await fetch('https://jsonplaceholder.typicode.com/posts/1'

            if (!response.ok) {
            throw new Error('Failed network response');
          }

            console.log(await response.json());
        } catch (error) {
            console.log(`Problem with error message: ${error}`);
        }
    }
}
```

# Week 5: Storage and State

## Persistance with Azure, Google, and AWS

These three majors organise their offerings into three main categories:

1. Cloud Storage: Large scale general purpose storage
2. Databases: Databases of various kinds such as SQL, NoSQL and others
3. Containers: Container services such as Kubernetes and others

## Instance and Block Storage

Instance and block storage both provision for IaaS instances and are best comparable to a disk drive, either internal or mounted. Instance storage should always been seen as ephemeral while block

stores have the ability to persist independent of the instance.

There are very minor and subtle differences in the offerings of instance vs block storage.

## SQL Databases

SQL databases are great for small-scale applications but where they fail is their scalability. In a small-scale application we can simply reserve an IaaS instance or use a local relational DB installed within the private network. However, when we use SQL databases at scale we must rely on vendor DB services which are scalable with managed redundancy.

Advantages of using an SQL database:

- Support for transactions and isolation levels
- Well-defined schema that never changes
- Complex queries and updates on the scheme
- Predictable workload with a known upper limit
- Very easy to report against

Disadvantages of using an SQL database:

- There is a known upper limit
- Need stringent consistency requirements (ACID)
- Once the schema is created it is very unlikely to update and evolve

## ACID

ACID is an acronym consisting of a set of guarantees that transactions should/must follow:

- **Atomicity**: Transactions will work in an "all or nothing" mode with all effects either being committed or rolled back.
- **Consistency**: All transactions must not violate consistency rules such as integrity constraints, foreign key constraints, value restrictions, not NULL, and more.
- **Isolation**: Any transactions running concurrent to each other are not able to "see" or interact with each others effects, although this does depend on the isolation level.
- **Durability**: Any effects due to a commit transaction are permanently stored and will fail over system outages.

## NoSQL Databases

NoSQL is an entity based storage usually storing key-value pairs with proprietary API. NoSQL databases are flexible due to the schemas ability to evolve with the service. A benefit to using NoSQL over SQl is that NoSQL can serve more requests by provisioning more hardware, this is very hard for SQL databases to do. NoSQL does not follow acid due to it's allowance of eventual consistency.

## Blob Stores

A blob, also known as a binary large object, is an large object of binary data that can be stored in databases. Blobs are usually used for storing images, large files, videos and audio, log files and more.

## S3 - Simple Storage Service

S3 is an object storing service designed on storing large objects. S3 follows a non-relational, addressable bucket model where data persistence is up to the vendor and data utility is up to you.

## Shared In-Memory Caches

Shared in-memory cache occurs when data is stored in the memory of a device. This type of storage is shared low-latency, in-memory persistance with its state being synchronised across instances. This type of storage has very fast access times and is critical for application KPIs.

This type of storage is not for failover situations because there is no guarantee about what data is there.

## Static Content Distribution Services (CDN)

A CDN is a network of interconnected services designed at speeding up the loading of data-heavy webpage applications. A CDN stores the contents of a website in a closer geographical location to the user to speed up the connection speed.

A static CDN frequently serves static content that is designed to never change, This means that the served content is read only and cannot be modified in a normal operation.

## Stateless Applications

In a stateless application the server must not retain any local, unrecoverable resources. We're not able to rely on transient state, state held in memory or persistent network connections, between service calls.

However, we do need some way of being able to pass state around the application. To do this we can generally hold state in an external service between service invocations such as in a DB or in-memory cache shared by all server instances.

We try to use statelessness in a scalable cloud environment for a couple reasons:

1. **Simplicity**: Applications do not need to preserve the state of the first service invocation for any subsequent invocations. This allows the service invocations to be independent of each other.
2. **Scalability**: Due to these service invocations being independent of each other the infrastructure can be exchanged at any point in time.
3. **Robustness**: In the occurrence of an instance failure, no transient state is lost. A restarting instance can "fail over" and still recover from the persisted state.

The state for later service invocations must be able to be shared across cloud application server instances. This can be done by using a joint underlying storage service as a state synchronisation mechanism. Storage services are a way of providing consistent data synchronisation mechanics that are hidden from the application programmer. It's important to remember that shared state may also be transient, non-persistent.

## Statelessness Limitations

Although statelessness can be a blessing it also unfortunately has some pitfalls:

- **Legacy Applications**: Any existing legacy code bases may compromise components which hold state across server invocations.
- **Persistent Connections**: Asynchronous "push-based" server-to-client communications are often based on persistent connections. This setup generally sees clients maintaining a connection to the server to receive push events with low latency.
- **Low-latency Applications**: In some application scenarios needing a very high performance set of requirements, a stateful design is actually preferred.

# Week 6: Persistence

## Stateful Legacy Applications

Legacy applications are often based on dated code bases. These older architectures were often built to fixed "sizing" guidelines with an upper bound on the anticipated load. There was no need to

"elastically" scale outwards.

These architectures were also built in a controlled environment with old style computing resources and usage patterns. There was hardly any virtualisation but infrequent hardware migration. These were often easier to scale up rather than scale out.

## Persistent Connections

Persistent connections are a way of providing asynchronous server-to-client communications. With a persistent connection, a client can retain a connection to a server on which it will progressively and asynchronously receive updates.

The server instance holds state for the persistent HTTP connection (long polling and server-sent events) or WebSocket connection.

## Why is Statefulness a Problem?

Statefulness is a problem when dealing with a cloud architecture as it introduces singleton application components. These singletons hold specific data which is not shared across other instances.

This becomes a problem if some error or system outage occurs as this data becomes unrecoverable. A crash of a singleton application component instance will result in a loss of the exclusively held state.

There is also the case of multiple clients holding persistent connections where they will eventually have to reconnect and they may not be routed to the same instance they had before.

## Dealing with Statefulness

There are a few options when dealing with statefulness:

- Re-engineer the application to be stateless
- Use a distributed in-memory cache layered on top of a stateless design
- Introduce "session stickiness" to correctly route requests to the same "singleton recourse"
- Embrace an event-driven architecture using a message-oriented middleware
- Use platform services for asynchronous, push-based client communication

## Session Stickiness

Session stickiness is a way of using the load balancer to route requests relating to the same state to the same app server instance. It does this by introducing a client session concept using services such as HTTP cookers, HTTP header data, and more to tag semantically cohesive service invocations.

This however breaks the architecture principle of "separation of concerns" introducing a new dependency on correct load balancer behaviour.

## Event-driven Architecture

Event-driven architecture is a way of using a message-oriented middleware to provide asynchronous, queue-based decoupling of application components. Event-driven architecture follows a publish-subscribe based programming model.

## Push Notifications

Using PaaS and persistent connections we can provide asynchronous, push-based client notifications.

## Relational Databases

Relational databases are a way of storing data in a structured way through the use of tables (relations) comprising of rows (tuples).

Application developers define a schema, a set of table definitions with optional constraints, for the database to follow. Each table in a relational database should be normalised:

- 1NF: All attributes are atomic
- 2NF: Each non-key attribute is functionally dependent on whole primary key
- 3NF: No non-key attributes are functionally dependent on other non-key attributes

One of the issues with relational databases in the cloud is that their not designed to scale. There are two main ways of using relational databases in the cloud:

1. Replication: Storing the same data on multiple nodes
2. Sharding/Partitioning: Tables are split, horizontally into shards or vertically into column sets, across multiple nodes.

Both of these techniques however have their own problems. RDBMS often struggle on the cloud:

- The normalised relational data model implies that queries/updates "touch" multiple tables which could possibly reside on different nodes
- The stringent consistency requirements of ACID implies that updates be visible on all affected nodes and in all replicas

## Structured Query Language (SQL)

RDBMS predominantly use SQL to retrieve, create, delete and modify data from a database. SQL supports clean layering of applications on top of a data storage layer and, in principle, allow migrating applications between different RDBMS.

Querying a normalised schema typically requires joining multiple tables to satisfy the query expression.

## The CAP Theorem

The CAP theorem, created by Brewer, formalises limitations of scalable, distributed databases via:

- Consistency: When a first transaction changes some data on a first node, a subsequent transaction running on a second node will be able to see the changed data.
- Availability: Each transaction issued on a node is always answered with a "successful" or "failed" message.
- Partition tolerance: The distributed database system must continue working, even if a single node drops out or communication to other nodes is interrupted.

Databases can only ever support a maximum of two out of three CAP criteria.

When to choose CP vs AP?:

- CP (Sacrifices availability): All operations are strongly consistent, despite network partitions (failures)
- AP (Sacrifices consistency): All operations are carried out, despite "network partitions"