Cloud Computing Overview

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What is the cloud?

Computer services delivered over internet

- Decentralised / remote hosting
- Service-oriented consumption (like utilities)
- Both a disruptive innovation and an "IS outsourcing" option
- CPU/GPU, RAM, storage, applications
- Usually situated @ highly-efficient data centres run by Microsoft, Amazon, Google, etc.

Use cases

Hosting: Websites, virtual learning environments (Moodle/Blackboard)

Compute: Big data analytics, machine learning

Storage & backup: Images, videos, unstructured data, databases

Applications: Test & build apps; provide on-demand software (web apps, thin clients)

Why does TU Dublin need cloud services?

Broadly: to host *some* or *all* IT services

Specifically: to host a Virtual Learning Environment (VLE)

Potential cost-savings

- Cloud providers have large **economy of scale**, **utility pricing**
- Currently: many TU Dublin services hosted "**on-premises**"
  - *Costly maintenance:* **CapEx** frontloaded (multi-year investment). Most hardware capacity not fully utilised.
- With cloud, switch to operational expense (**OpEx**)
  - Annual, monthly (or even hourly) **fees**
  - **Only pay for what you need**

Some services go hand-in-hand with cloud:



IoT, streaming, video retrieval, services

- CCTV
- In-classroom lecture recording / on-demand streaming
- Linking university services via web APIs (HR, student recruitment, finance, assessment)

Cloud features

#1 On-demand, self-service

- **Pay as you go model** & **measured service**/billing
- Automatic/unilateral **provisioning** of extra virtualised resources

#2 Resource pooling

- Physical resources **pooled dynamically and subdivided**; user not concerned w/ actual machines/location. Greatly reduced overhead.
- **Near-infinite scalability** (e.g. for future expansion)

#3 Rapid elasticity

- Quickly **acquire** + **release** resources as needed
- **Near-unlimited** resources to meet peak demand (or to reduce during off-peak)

#4 Resiliency, redundancy, distribution

- **Highly fault-tolerant / highly available**
- Access anywhere on any device. Data centres/regions provide reliability regardless of geographic location

Partly adapted from NIST definition of cloud computing; measured service merged into self-service for brevity.

Deployment models

On-prem (non-cloud)

- TU Dublin buys + maintains physical hardware
- Hardware dedicated to specific services
- ✔ **Maximum security/privacy**
- ✘ **Significant CapEx** (up-front costs)
  - Difficult to anticipate future demand/capacity
  - Limited resource pooling

Other models

Community

- TU Dublin shares private cloud with **1 or more organisations** (e.g. other Irish universities)

Hybrid

- **Integrated mixture** of on-prem, private, public, or community cloud

Private cloud

- TU Dublin buys + maintains physical hardware*
- Utilises **virtualisation** and **distributed computing/storage**
- University retains **maximum security/privacy oversight**
- ✔ **Lower CapEx** than on-prem
  - Improved resource pooling
  - Services better-distributed across campuses
- Potentially more overhead/maintenance

Public cloud

- Services reside on **industry cloud provider** (AWS, MS, etc.)
- **Multi-tenancy model.** (Customers share physical hardware via sandboxed virtual environments)
- **Flexibility** to accommodate IaaS, PaaS, or SaaS as needed
- ✓ **Maximum availability, elasticity and resource pooling**. Extensibility of load balancers, compute, storage, etc.
- ✓ Minimised overhead/maintenance: **Zero CapEx**
- ✘ **Security & privacy** a major concern

*Physical infrastructure for private cloud deployment can also be provided by a local 3rd-party host/partner.

Service types

Infrastructure-as-a-Service (IaaS)

- **Raw computing resources**. (Closest to on-prem)
  - Resources pooled via virtual machines (VMs). 1 server = many VMs.
  - Additional resources (storage, networking) configurable + attached
  - Users have direct access: install OS's (Linux/Mac), DBs, apps, etc.

✓ **Benefits**: lowest cost; more control

- **Examples**: remote desktops for students (labs), host machines for legacy university services (academic records, finance, etc.)

Software-as-a-Service (SaaS)

- **Ready-to-use cloud software**

✓ **Benefits**: no installation (access + admin via browser); works on any device; reduces complex IT management

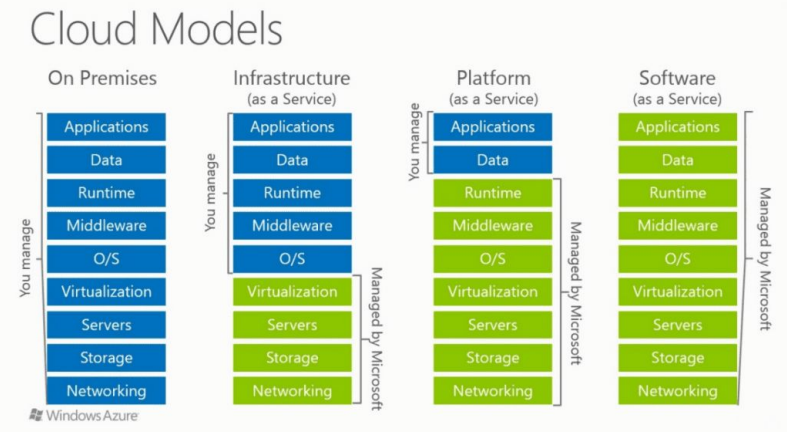
- **Examples**: Google Drive, Microsoft Outlook, Brightspace (VLE-as-a-Service)

Platform-as-a-Service (PaaS)

- **Ready-to-use environment to install/develop apps**
  - OS, database, middleware, etc. usually provided

✓ **Benefits**: less setup needed; easier to deploy apps

- **Examples**: web server (Apache, Node/Express) to host TU Dublin website; deploy a custom VLE like Moodle; app framework/environments (RoR, Django) for student projects



Source: Super Admins / Microsoft

Virtualisation & containers

Virtualisation

- **Virtual machine** (VM): an **emulation** of physical computer on top of another machine
- **Hypervisor** - native execution allowing multiple isolated environments on top of an OS (e.g. Windows, Linux)
- **IaaS** gives direct control/installation of full VMs; **PaaS** and **SaaS** also run on VMs but this is abstracted away from users

Use cases:

- **Cloning images** for distributed computing (i.e. in cloud)
- Testing multiple **operating systems**
- Special **software development environments**
- **Remote desktops** (student labs)

Containers

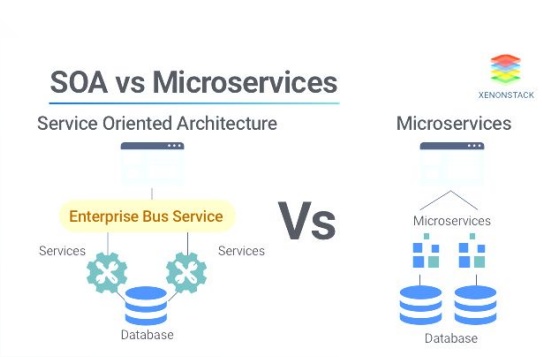
Docker

- **Slimline**, efficient type of virtualisation
- **Shares kernel** with physical machine or underlying layer while maintaining isolation
- Greatly **reduced overhead** (memory, etc.)
- Easy to create "**images**" of software and its environment; simplifies **version control & updates**

Kubernetes

- **Container-orchestration system**
- Automates **app deployment**, **scaling** and **management**

Service-oriented architectural model (SOA)



Source: XenonStack

Applicable to TU Dublin cloud services

- Using RESTful architecture

Properties of "services" in SOA

1. Logically represents a business activity with specified outcome. (E.g. Student records API)
2. Self-contained
3. Black box for consumers (inner workings not exposed)
4. May consist of underlying services

What are the benefits of SOA?

Allows university systems to be better integrated, easier to modify/upgrade, and cheaper to maintain.

On-prem SOA architecture can be integrated with cloud services via a **Hybrid Model.**

Microservices: an alternative model more closely aligned to cloud computing and distributed services

Vendor comparison

	Microsoft Azure	aws	Google Cloud	salesforce	DigitalOcean
VENDOR					
SERVICE MODELS	**IaaS + PaaS + SaaS**	**IaaS + PaaS**	**IaaS + PaaS + SaaS**	**PaaS, SaaS**	**IaaS + PaaS**
USP, DETAILS	**Largest industry cloud provider**. (Revenue greater than AWS + Google combined). SaaS includes Office 365, Outlook Wide range of IaaS/PaaS services Existing TU Dublin usage/integrations	**Lowest* costs**. But potentially higher operations staffing required (maintenance & configuration) Widest range of IaaS/PaaS services. Largest number of LMS-hosting partners.	**Innovator; newest technology** Superior SaaS (Google Docs, Gmail) Specialises in big data, AI, APIs (Google Maps). But many PaaS services not necessarily relevant to TU Dublin.	**Business-oriented** (ERP, CRM, etc.) and fewer options. Industry-leader in some services (HR, Finance, etc.). But some services (PaaS, e.g. Heroku) at higher cost	**Lowest costs** (*even lower than AWS on some services) PaaS offering is very recent; not as mature as AWS/Azure. Support for some VLEs
LOCATION	Nearest data centre is **~7km from Grangegorman**	Grangegorman is **~7km from EU-WEST-1**; AWS's oldest EU data centre	Nearest data centre: **11km from Grangegorman**. Claims it is **sustainability** industry leader (i.e. energy efficiency).	**No Irish data centre.** Nearest data centre is non-EU (London)	**No Irish data centre.** Nearest data centre is non-EU (London)

Cloud summary and takeaways

Strengths

- ✅ **Economical**: reduce costs, share resources
  - Improve billing/pricing: expenses re-assessed year-on-year
  - Rapid & changeable deployment. Minimal off-peak OpEx (e.g. summer).
  - Environmental benefits. (Reduced grey emissions from hardware).
  - Relatively risk-free, “trial-and-error approach”
- ✅ **Higher performance:** near-unlimited capacity to meet peak/excess demand
- ✅ **Reduce complexity of detail** of SysOps
  - Full-service infrastructure or software.
  - Reduced staffing overhead for PaaS/SaaS models: IT staff need less time to manage complex operations (i.e. physical hardware/VMs)
  - Focus on dev + config of services/applications directly
- ✅ **Best student experience:** continuous availability (limited downtime), reduced latency/better geographic availability off-campus; rendering for certain web apps & services done on server rather than client (benefits students on weak clients).

Obstacles

- ❌ Data centres may soon consume 29% **of Ireland’s electricity output**
- ❌ Cloud has efficiency gains, but some load may be **more energy-efficient on thick clients / on-prem** (because of network transmission overhead).
- ❌ **Delegation of security/privacy** to cloud provider (lack of transparency; potential for out-of-jurisdiction processing of **sensitive data**, e.g. student details).
- ❌ Increased **legal oversight needed:** data protection assessments; scrutiny of service provider policies.
- ❌ **Vendor lock-in**. (Yearly billing changes; extra management/config to ensure IT systems not tightly coupled to provider).
- ❌ **Internet connection needed** (even on-campus systems may entail external requests)

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