Introduction

CCS3341 Cloud Computing

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Unit

- Layout

#1	**Introduction to Cloud Computing** Unit structure, what is cloud computing, history, path to cloud computing, principles of cloud computing, benefits of cloud computing
#2	**Virtualisation Technologies** Understanding virtualisation, multitenancy, advantages of virtualisation, types of virtualisation (container virtualisation, full virtualisation, paravirtualisation, hardware-assisted virtualisation)
#3	**Service Models** IaaS and EC2 live demo, PaaS (Heroku platform), SaaS
#4	**SOA** Introduction to SOA, introduction to Web services, service composition, service roles, SOA benefits, WSDL, SOAP
#5	**Microservices-based Architectures** Design patterns and data management for microservices-based applications, micro-frontends,
#6	**Microservices-based Architectures (contd.) & Serverless** Docker, Kubernetes, FaaS
#7	**Consolidation week**
#8	**REST & Development and Design of RESTful Cloud Applications** HTTP methods, HATEOAS, Web containers, Servlets, implementing a cloud application (hands on)
#9	**Development and Design of RESTful Cloud Applications (contd.)** Java Jersey, Jersey annotations, Client requests, filters, interceptors, implementing a cloud application (hands on), CORS, JQuery
#10	**Microservices Development** MVC, Inversion of Control, Spring Framework, Beans, Autowiring, Registration service
#11	**Microservices Development (contd.)** Hands-on implementation
#12	**Revision**

Unit

- Assessment

Weight %	Group / Indiv	Assessment Type	W8	W9	W10	CB	CB	CB	W11	R12	E13	E14
40%	Groups of 2	Project	#	#	#	#	#	#	D			
60%	Individual	Final exam										EX

Google classroom code: **r22ykxx**

What is Cloud Computing

A distinct approach to **resource provisioning** that departs from traditional approaches

- Traditionally organisations

Owned & managed their **SW resources**

Owned or leased **HW resources**

- Own data centre model
- Colocation model
  - An organisation purchases/leases HW resources but hosts them within 3rd party colocation facility
  - Rack space, power, cooling mechanisms, network connectivity and physical security are provided by the colocation centre

Drawback of Traditional Resource Provisioning

Capital Expenditure (CAPEX)!

Purchase **SW resources** (licenses) $$$...

Purchase/lease **HW resources** $$$...

Overprovisioning inevitable... $$$...

- Acquire professional skills required for managing/operating resources
- Time investment $$$...

- Risk of investment

For many organisations it would be much more cost effective if they were able to utilise IT resources as a service

- ✓ No ownership
- ✓ No overprovisioning
- ✓ Pay for as much as you use...

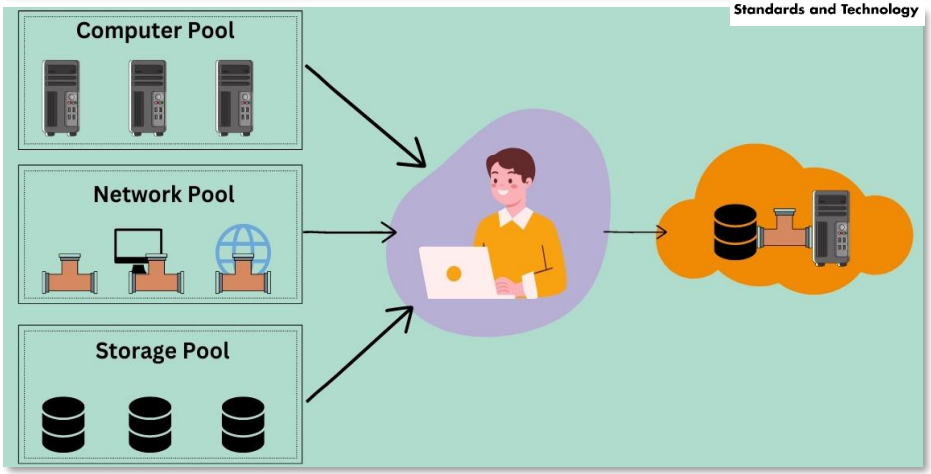
Definitions of cloud computing

Definition of Cloud Computing

Co-evolution of technology and business models

"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."

NIST National Institute of Standards and Technology



"Cloud computing is the on-demand delivery of compute power, database storage, applications, and other IT resources through a cloud services platform via the internet with pay-as-you-go pricing."

aws

"Cloud computing is the delivery of computing services—including servers, storage, databases, networking, software, analytics, and intelligence—over the internet to offer faster innovation, flexible resources, and economies of scale."

Microsoft

University of York Europe Campus
CITY College

Everything as a service!

Cloud computing offers services

HW services

- Computing power
  - General purpose VMs
  - HPC
- Storage
  - Block storage
  - Object storage
  - File storage
- Network bandwidth
  - CDN
  - Load balancing

IaaS

SW services

SaaS

- Out-of-the-box application usage

PaaS

- Applications-tools that facilitate app development

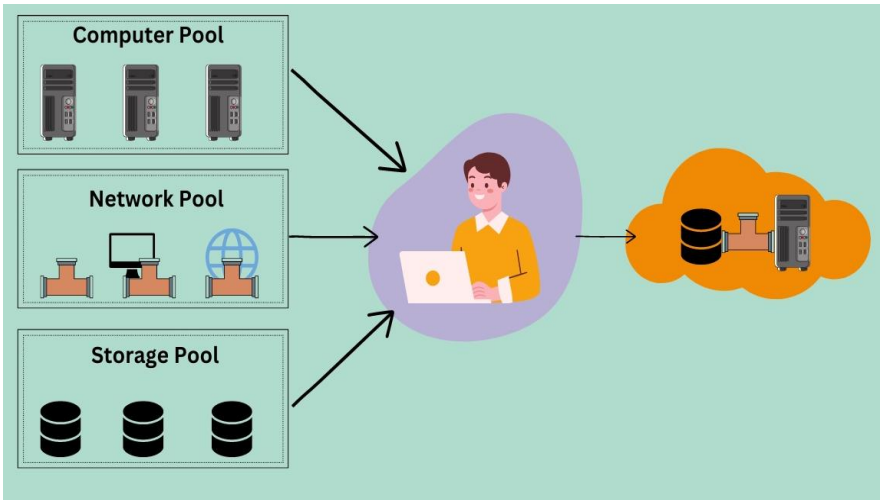
Other Cloud (SW) Services

- Function as a Service
- Database as a Service
- Analytics as a Service
- Security as a Service
- AI as a Service
- …

Principles of Cloud Computing

Resource pooling

- Aggregation of HW resources such as servers, storage, and networking, to serve multiple users
- A fundamental concept underpinning **on-demand availability**
- The cloud provider dynamically allocates these resources based on demand (no need for prior reservations), enabling efficient use of infrastructure



Resource allocation is optimised through **load balancing** and **intelligent scheduling** that prioritises critical workloads and uses predictive analytics to anticipate future demand

As opposed to statically pre-reserving and pre-allocating resources

Pre-reservation/allocation is the traditional approach to resource provisioning!

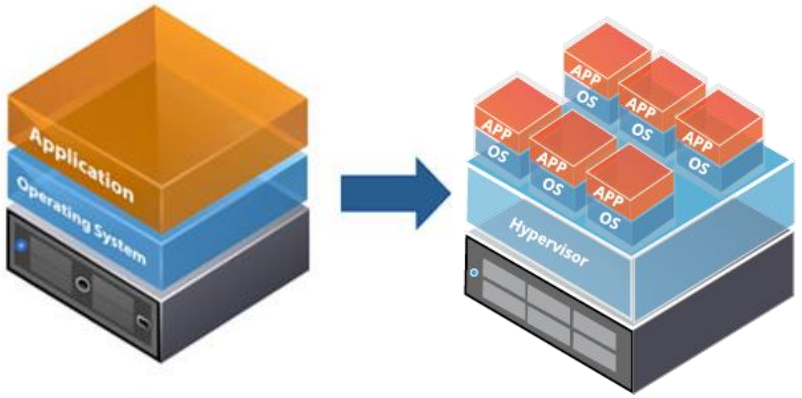
Principles of Cloud Computing contd.

Multitenancy

Allows multiple users or tenants to share the same physical infrastructure while maintaining isolation between them (one user's activities do not impact another's)

Achieved through **virtualisation**

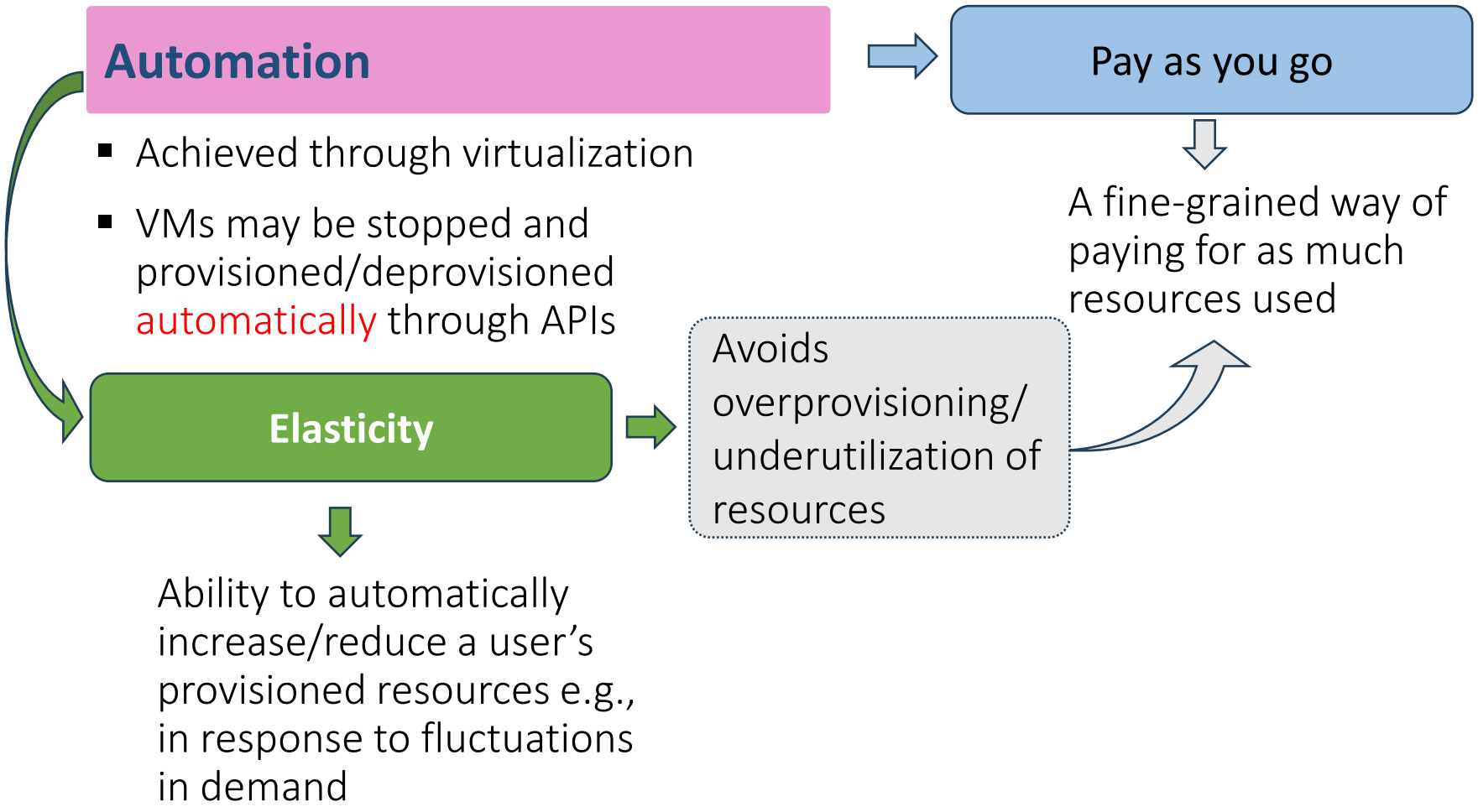
Virtual machines hosted on the same physical machine allocated to different users



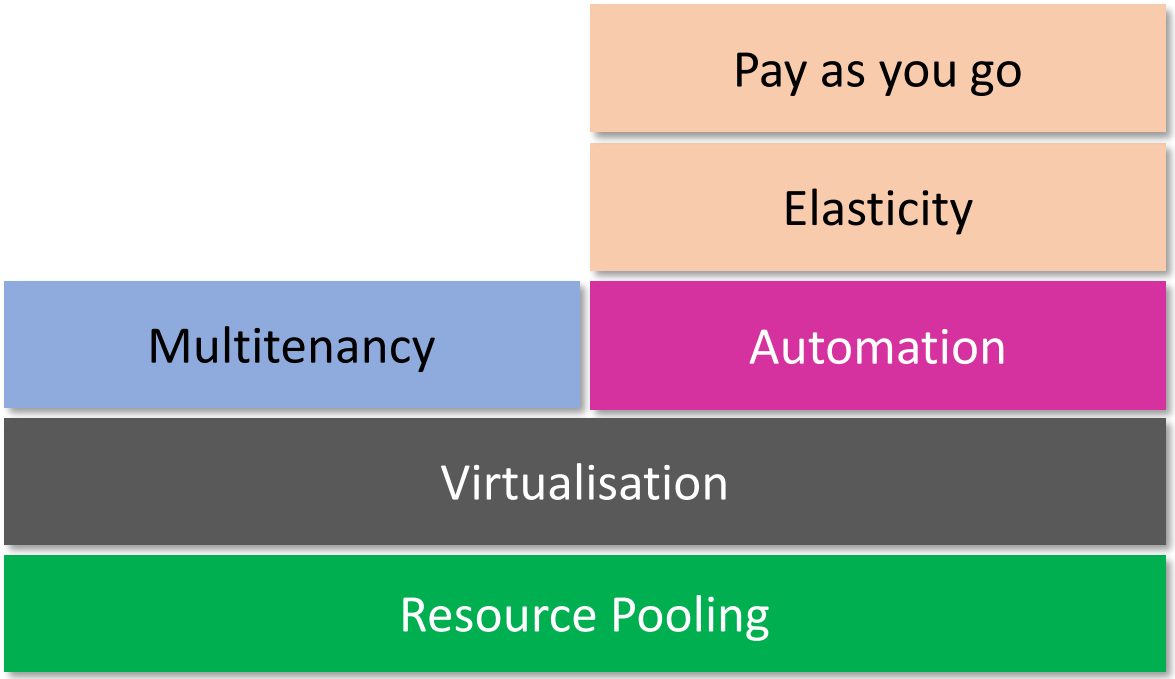
Virtualised servers are the primary units of HW consumption in the cloud

Virtualisation also leads to a greener form of computing as it reduces the space and power required for housing physical servers

Principles of Cloud Computing contd.



Principles of Cloud Computing - Recap



Benefits of Cloud Computing

Main **economic** benefit:

CAPEX ⇨ **OPEX**

Capital Expenditure → Operational Expenditure

Alleviates risk of investment!

Remember:

Cloud Computing is a co-evolution of computing technology and **business models**

- The costs for running an application become proportional to the application's uptake
- In other words, the costs for running an application rise only if the profits from the application rise

Amount of value equipment loses every year until the point where it no longer holds any residual value

No depreciation costs

No overprovisioning/ underutilisation costs (**elasticity!**)

Also:

Costs of running an app are cheaper:
- economies of scale (see here)
- global reach (reduced labour costs for maintenance)

Benefits of Cloud Computing

Case study

HuaNews a hypothetical start-up is about to enter the market engaging into the translation and display of foreign news from all around the world.

Calculate total cost of ownership (TCO) for IT infrastructure

Case 1: Own data centre

OPEX

OpEx (3 years)		Price	Annual Cost	Three Year Cost
Actual Operating Power	308 Watts per server	0,22€/kwh	2.962 €	8.885 €
Actual Cooling Power	385 Watts per server	0,22€/kwh	3.702 €	11.106 €
Real Estate Rent	5 sq.m	5€/sq.m	300 €	900 €
Operating Expenditures			**6.964 €**	**20.891 €**

Reference:

Katsantonis, K., Mitropoulou, P., Filiopoulou, E., Michalakelis, C., and Nikolaidou, M. "*Cloud computing and economic growth*" In Proceedings of the 19th Panhellenic Conference on Informatics, PCI 2015, Athens, Greece, ACM 2015, ISBN 978-1-4503-3551-5

Similar case study:

A. Khajeh-Hosseini, D. Greenwood and I. Sommerville, "*Cloud Migration: A Case Study of Migrating an Enterprise IT System to IaaS*," 2010 IEEE 3rd International Conference on Cloud Computing, Miami, FL, USA, 2010, pp. 450-45

Also: 3' read of the case of NETFLIX

CAPEX

Initial Cost of Infrastructure	Quantity	Three Year Cost
Servers	5	17.500 €
Total Storage (SAN)	5TB	35.000 €
Networking (Switch)	4	14.710 €
Faclities (PDU,KVM etc.) per rack	1	897,00 €
Cooling equipment per rack	1	717,00 €
Capital Expenditures		**68.824€**

- Intel® Xeon® E5-2640 v2 (8 core, 2 GHz) servers
- 16GB RAM
- 4 NICs
- size U
- 460W power supply
- Total storage of 5TB

Benefits of Cloud Computing

Case 2: Cloud deployment

AWS VM (24/7)	Cost per month	Three Years
EC2 m2.xlarge + 1 TB SSD EBS	145 €	5.398 €
Transfer	75 €	2.707 €
Load balancer:	22 €	780 €
Cloud Object Storage capacity	28 €	991 €
Cloud Object Storage requests	48 €	1.743 €
Total	**323 €**	**11.619 €**

- VMs running on Linux 24/7 for three years
- 50TB data transfer in
- 500GB data transfer out
- 10 million GET requests
- 10 million PUT requests
- Load Balancer 500GB/h

EC2 provides a wide variety of small, medium and large machines to serve a wide range of different needs in a fine-grained manner

Case 1 vs Case 2

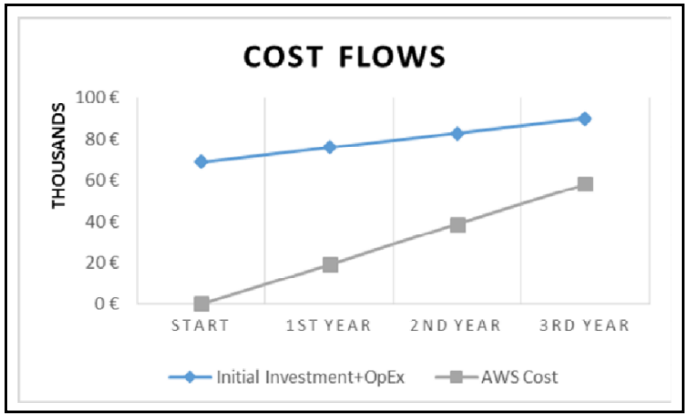
Period	Initial Investment+OpEx	AWS Cost
Start	68.824 €	0 €
1st Year	6.964 €	19.364 €
2nd Year	6.964 €	19.364 €
3rd Year	6.964 €	19.364 €
Total	**89.715 €**	**58.093 €**

Future outflows

Present value (10% annual discount)

case 1: €86,142

case 2: €48,155



Benefits of Cloud Computing

Other **economic** benefits

Agility

Reduced time required for planning, purchasing, provisioning and configuring IT infrastructure

Decreasing time to market increases **competitive advantage**

In case of software development agility may be significantly boosted using such services as:

- Data storage services
- Monitoring services
- Logging services
- Email/SMS, alert and notification services
- Messaging and queueing services
- etc…

Benefits of Cloud Computing

Other **economic** benefits

Device location independence

Boosts productivity!

Other benefits

- Performance
- Availability
- Reliability

Security benefit

Cloud computing improves some aspects of security, e.g. physical security, intrusion detection and prevention

But:

The fact that an organisation outsources its data/operations to an external provider poses a tremendous security threat!!

Perspective

- The idea of cloud computing is not new
- Neither are its technological underpinnings

1960s-70s

- Mainframes!
- Initially for batch processing by large organisations (50s)
- Later commercial mainframes supported multi-tasking and multiple users through time-sharing

CTSS – Compatible Time Sharing System by IBM (1961)

Ancestor of Multics and Unix

Eventually, the idea of VMs to support multiple users emerged to cope with:

- Reliability and security concerns
- Each user only executes SW compatible with the underlying HW

CP/CMS (1968)

Analogous to data cloud centres!!

- Support for multiple users through **virtualisation**
- CP (Control Program) responsible for creating VMs and providing time-sharing functions
- CMS (Console Monitor System) – a single-user OS running on each VM
- Dumb terminals

Perspective

1980s-90s-00s

- Advent of microprocessor
- Focus shifted from mainframes to distributed systems of commodity servers
- Deprecation of dumb terminals
- Client-server paradigm

- Client-side applications making requests to server-side applications
- Server-side applications responsible for persistence

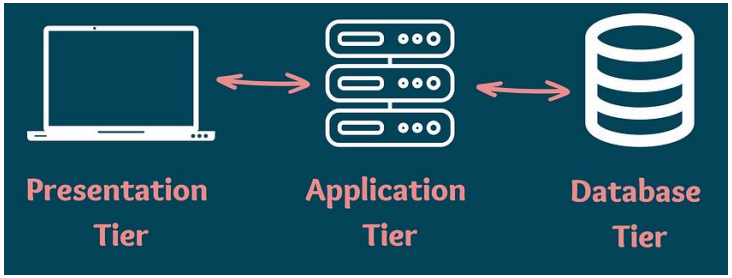
Advantages over mainframes:

- Unlimited resources
- Heterogeneous technologies

2000s-10s

With the ascendancy of the web in the mid 2000s and the need to access data ubiquitously, possibly through mobile devices with limited capabilities, the pendulum was swung back to thin clients…

3-tier paradigm



Perspective

2000s-10s contd.

Grid computing

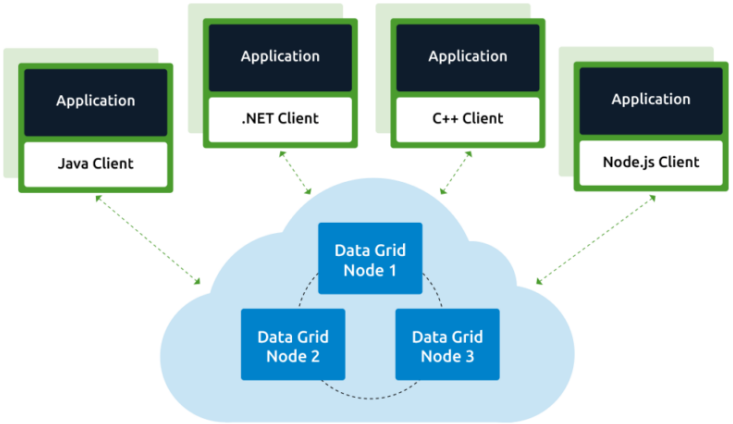
The practice of leveraging multiple computers, often geographically distributed but connected by networks, to work together to accomplish joint tasks. It is typically run on a "data grid," a set of computers that directly interact with each other to coordinate jobs

Grid computing works by running specialized software on every computer that participates in the data grid

- Acts as **manager** of the entire system
- Determines which task each node executes
- Aggregates outputs and yields final output

Difference with Cloud Computing

Flexibility of purpose!



Grid computing is useful when different subject matter experts need to collaborate on a project but do not necessarily have the means to immediately share data and computing resources in a single site

Concept of **Virtual Organisation** (**VO**) or **Virtual Enterprise** (**VE**)

The Grid has been successful in performing large scale scientific computations e.g., SETI HOME