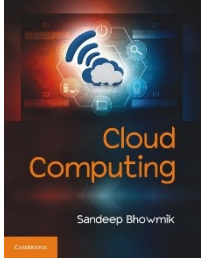
Cloud Computing

Chapter 2

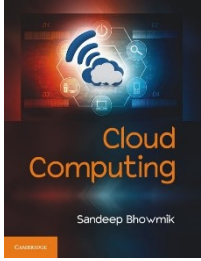
Evolution and Enabling Technologies

Cambridge University Press



The Evolution

- The cloud technology has matured over the years with constant advancements in the field of computing since the mainframe age.
- The development of cloud computing happened with continuous innovations in the field of electronic and computing hardware.
- Several decades of research, particularly in the domain of parallel and distributed computing have paved the way for cloud computing.

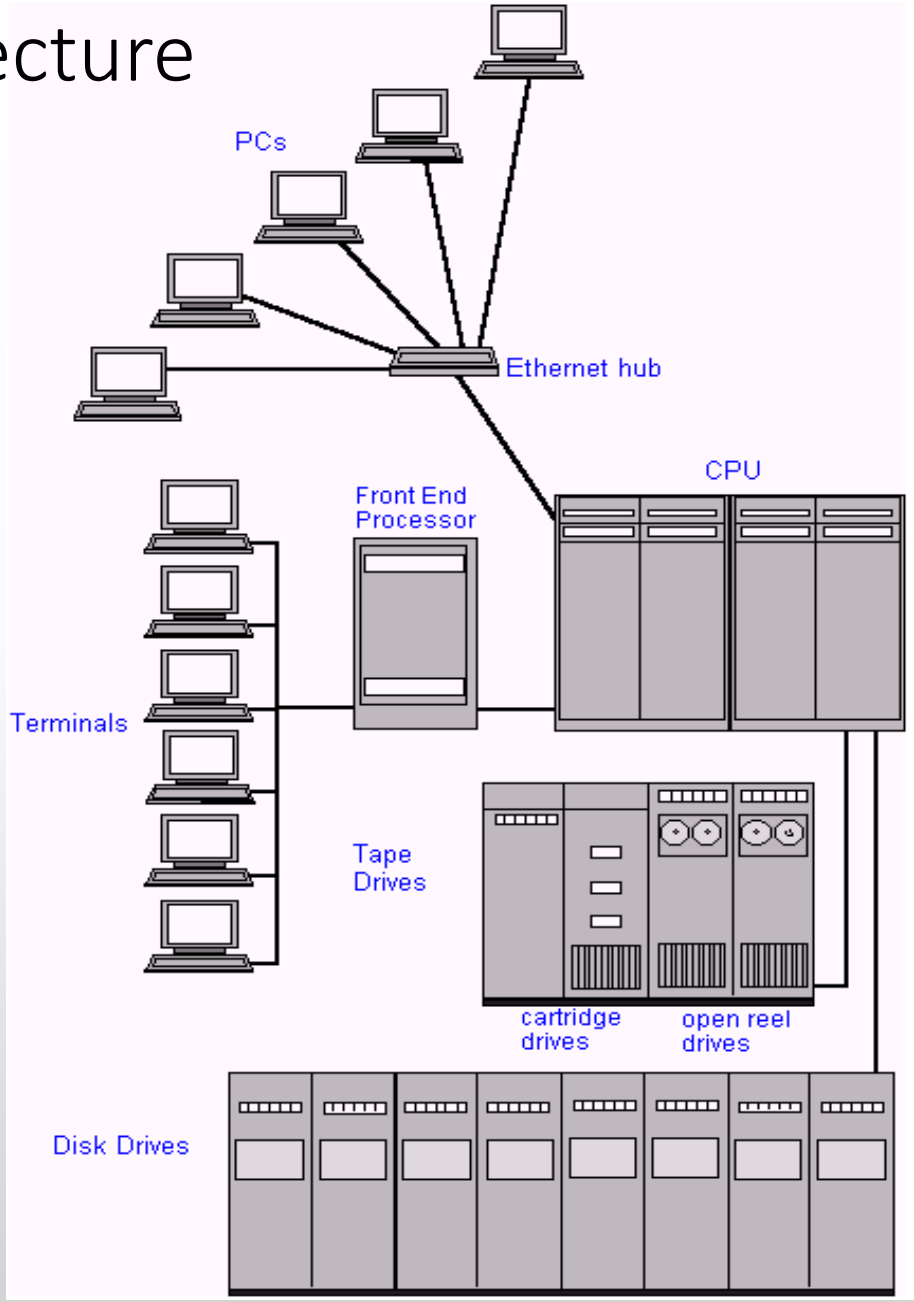


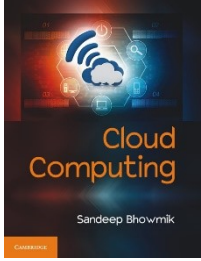
Evolution of Computing (Phase 1)

- **Mainframe Architecture**

  - Large and costly supercomputers.
  - Organizations used such systems to automate basic data processing tasks.
  - Introduction of Time-Sharing System around 1970.
  - Organizations started accessing single mainframe system from different offices or departments using computer terminals.
  - Such terminals were known as dumb terminals.

Mainframe Architecture

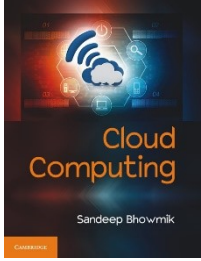




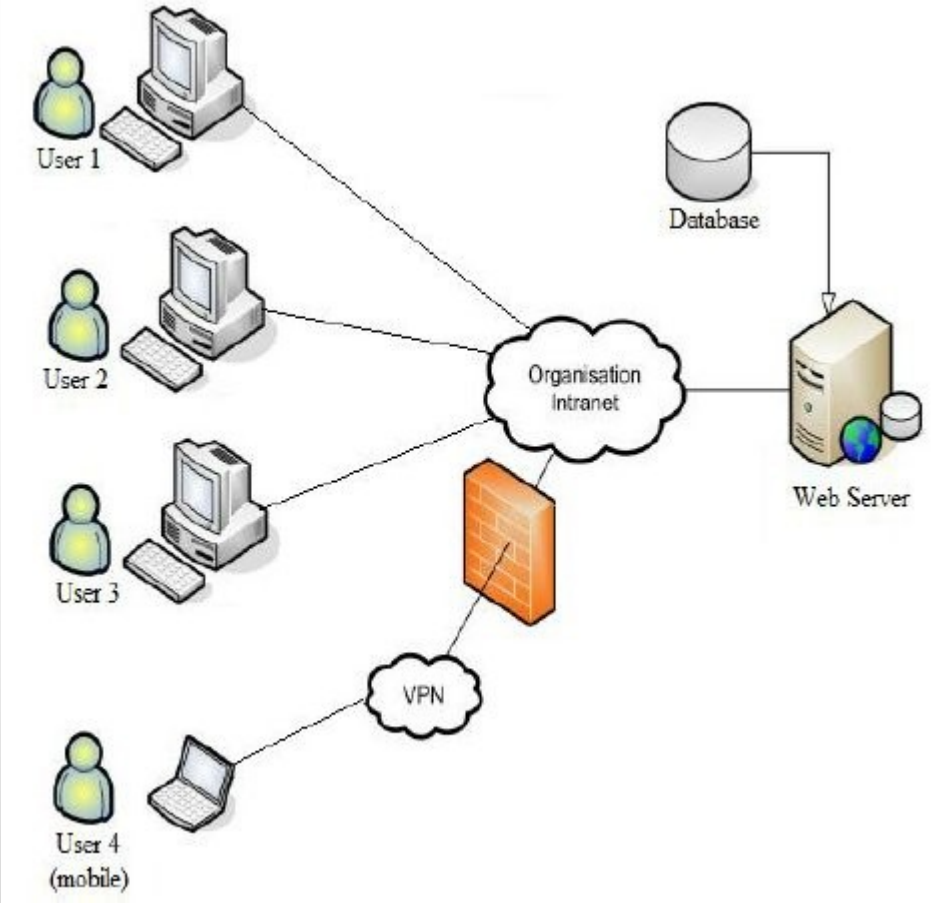
Evolution of Computing (Phase 2)

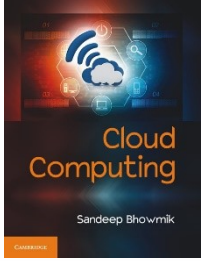
- **Client-Server Computing**

  - Mainframe systems accessed through dumb terminals had limitations.
  - Mainframe systems had a limit on the number of parallel active users.
  - Users often had to wait for a long time in queue.
  - With the arrival of low-cost microprocessor technology in 1970s, dumb terminals were replaced by intelligent terminals with some processing capability.
  - This was the introduction of client-server computing.



Client-Server Architecture

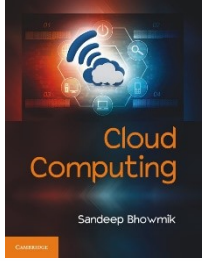




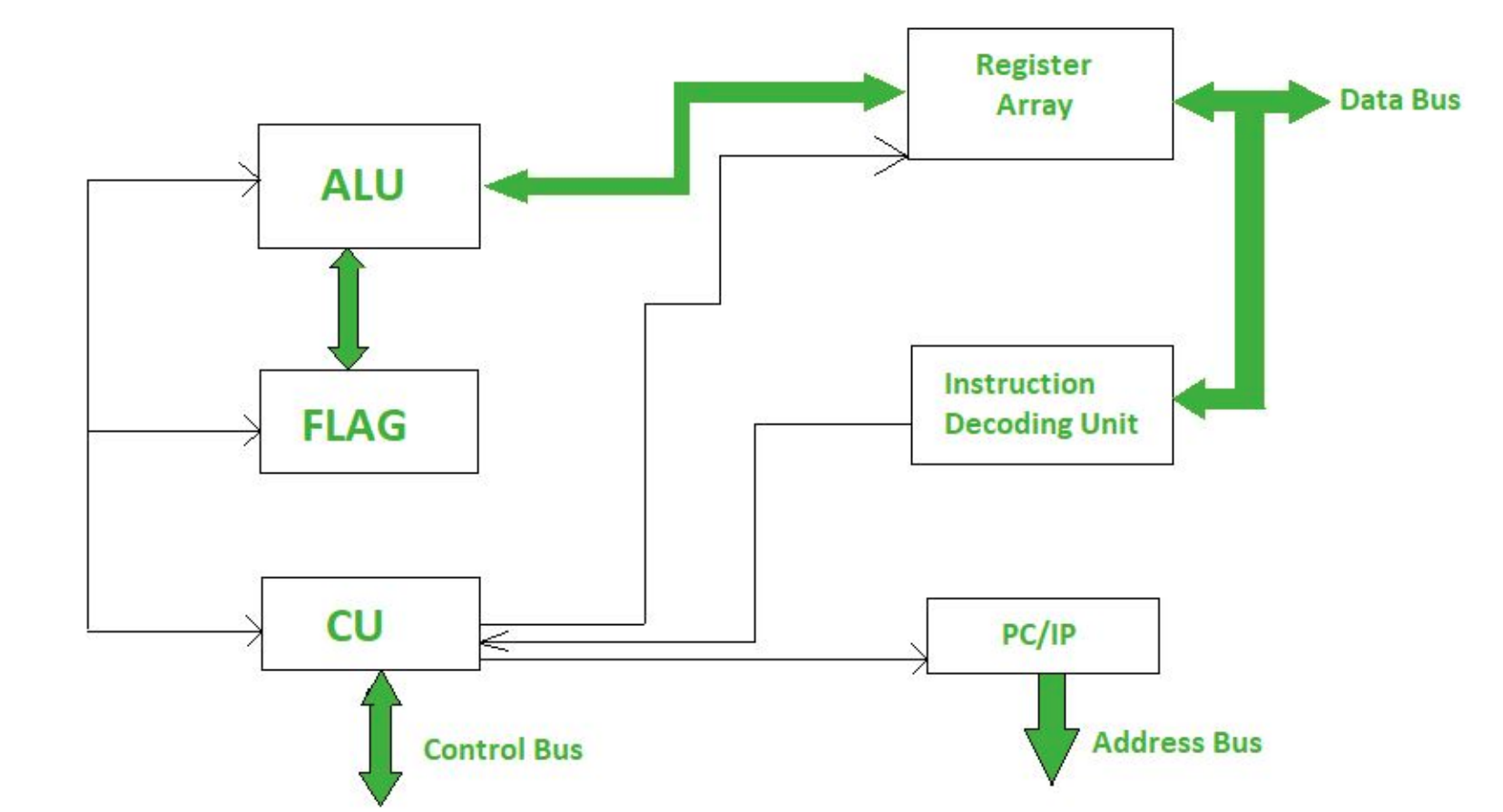
Evolution of Computing (Phase 3)

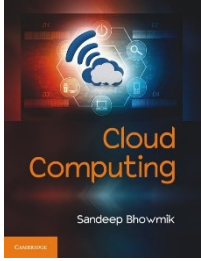
- **The PC Revolution**

  - During client-server age, The client systems had very limited processing capability.
  - One problem faced for this was the drastic increase in response time due to arise of bottleneck problem at server end.
  - In the meantime, microprocessor technology advanced.
  - This development created scope for producing produce general purpose computing machines for users, known as personal computer.



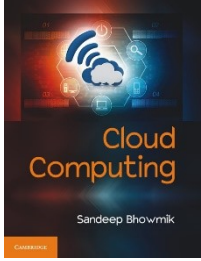
Microprocessor



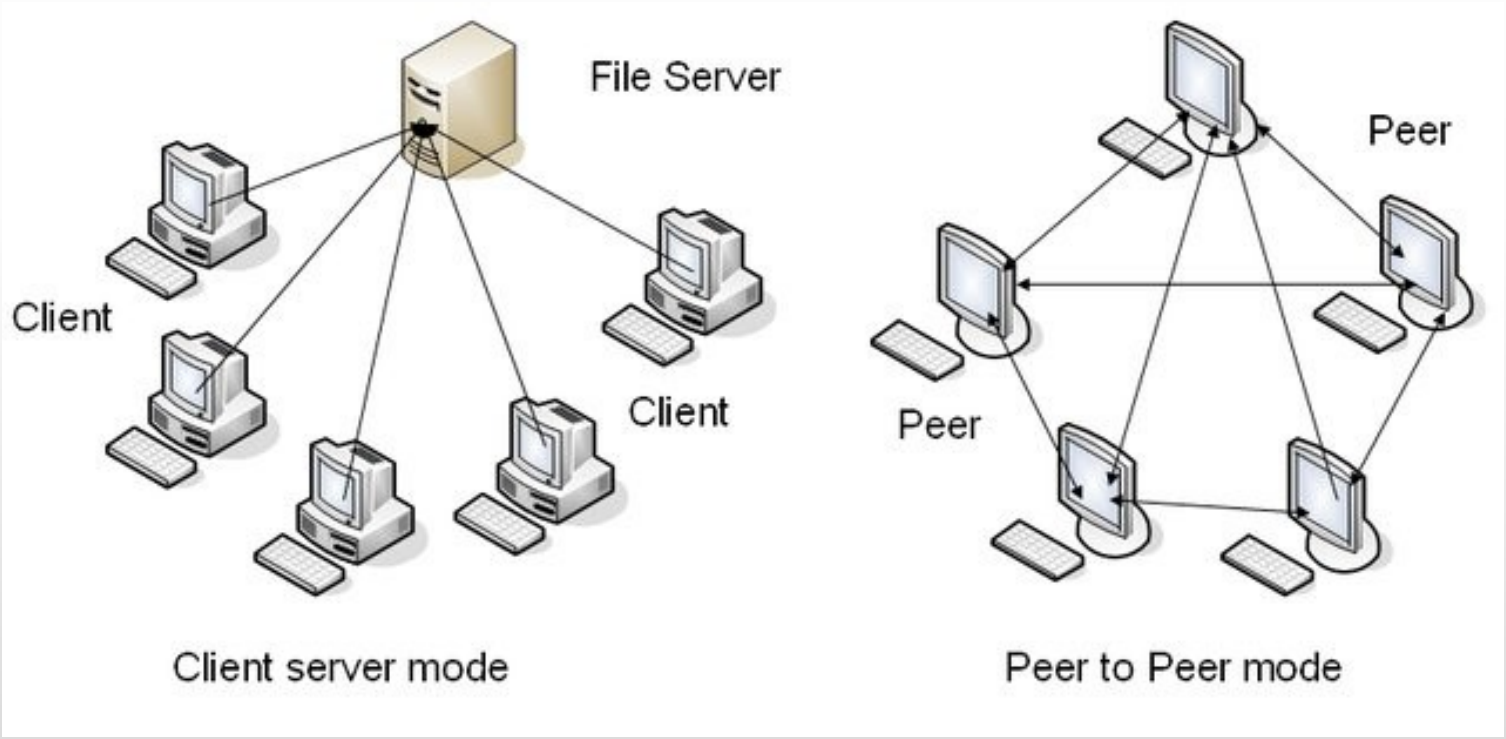


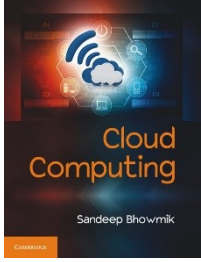
Evolution of Computing (Phase 4)

- **Network of PCs**
  - Advancement in network communication technology allowed to establish interaction between systems situated little far from one another.
  - Data transfer rate improved.
  - LAN (local area network) and WAN (wide area network) were major inventions during this period.
  - Computing technology moved from centralized client-server era to of peer-to-peer computing (P2P computing).



Peer to Peer Computing





Evolution of Computing (Phase 5)

- **Distributed Computing**
  - In parallel processing, multiple processors work together to solve a single computational task.
  - Distributed computing took the parallel processing concept one step ahead.
  - It forms one powerful computing system by combining multiple computing systems.

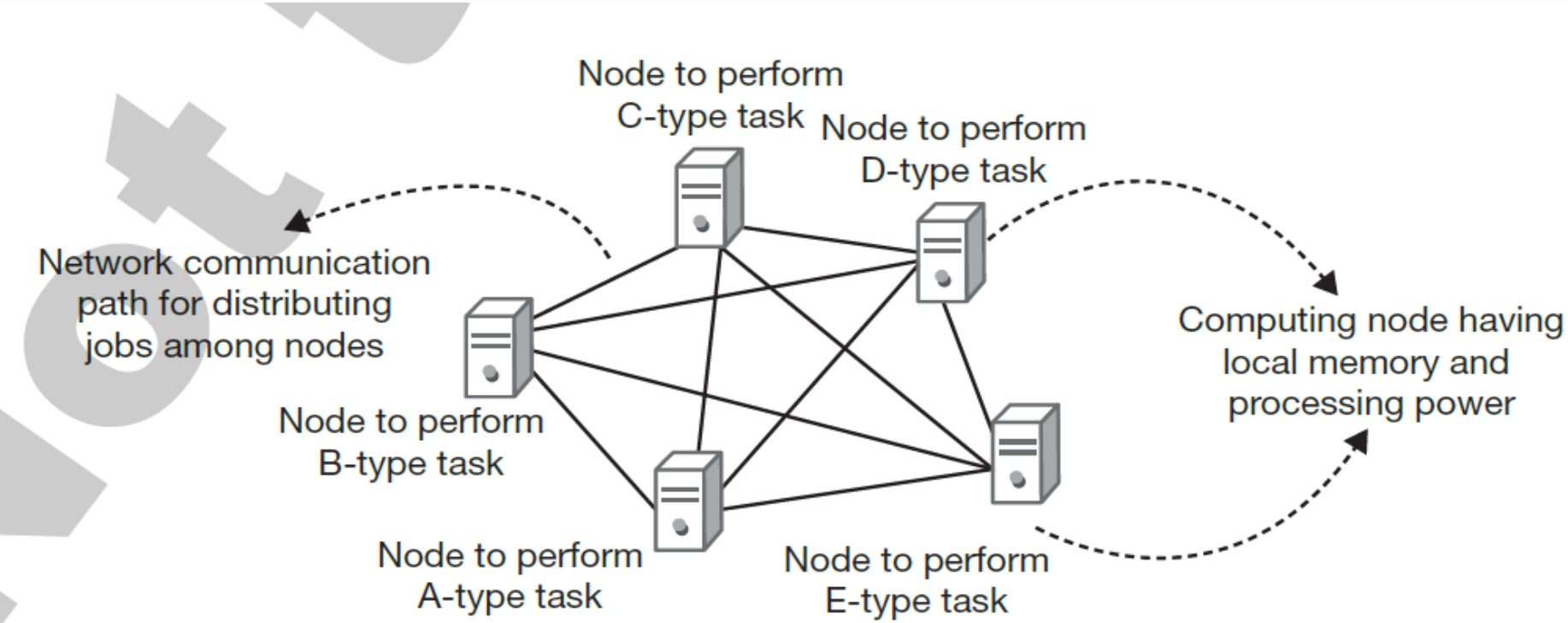
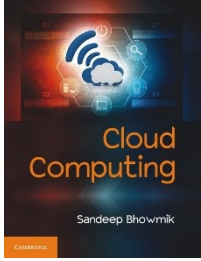
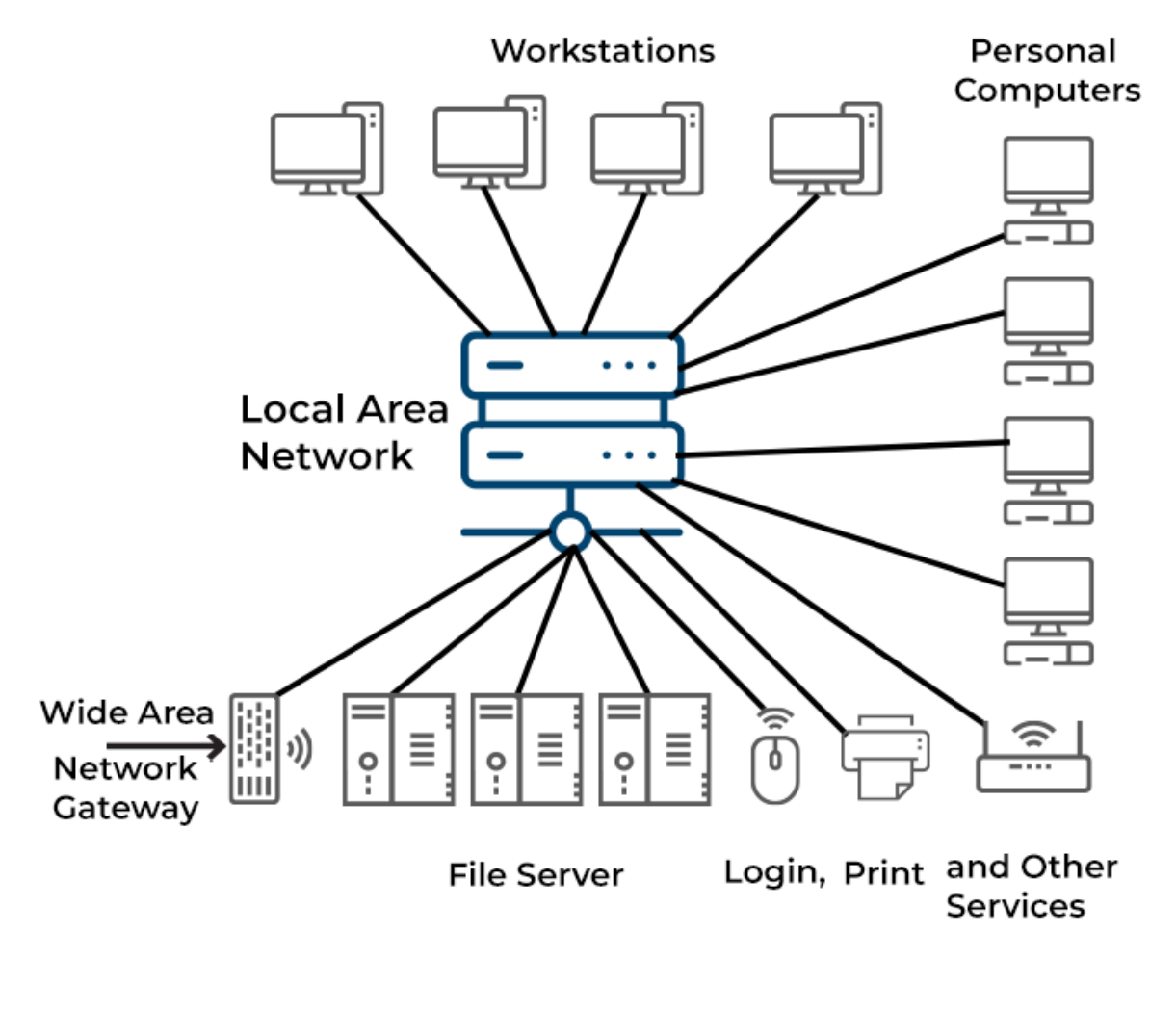
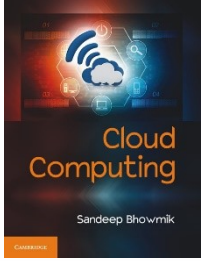


FIG 2.1: A model of distributed computing environment



Distributed Computing





Evolution of Computing (Phase 6)

- **Cluster Computing**
  - Computing clusters are made of multiple nodes (computers) connected via network, those perform similar tasks.
  - Thus execution of a task can be faster.
  - All the nodes of a cluster together give impression of a single system. This also creates resource pool.
  - In each cluster, one computer is assigned the job of controlling the cluster, known as cluster head.

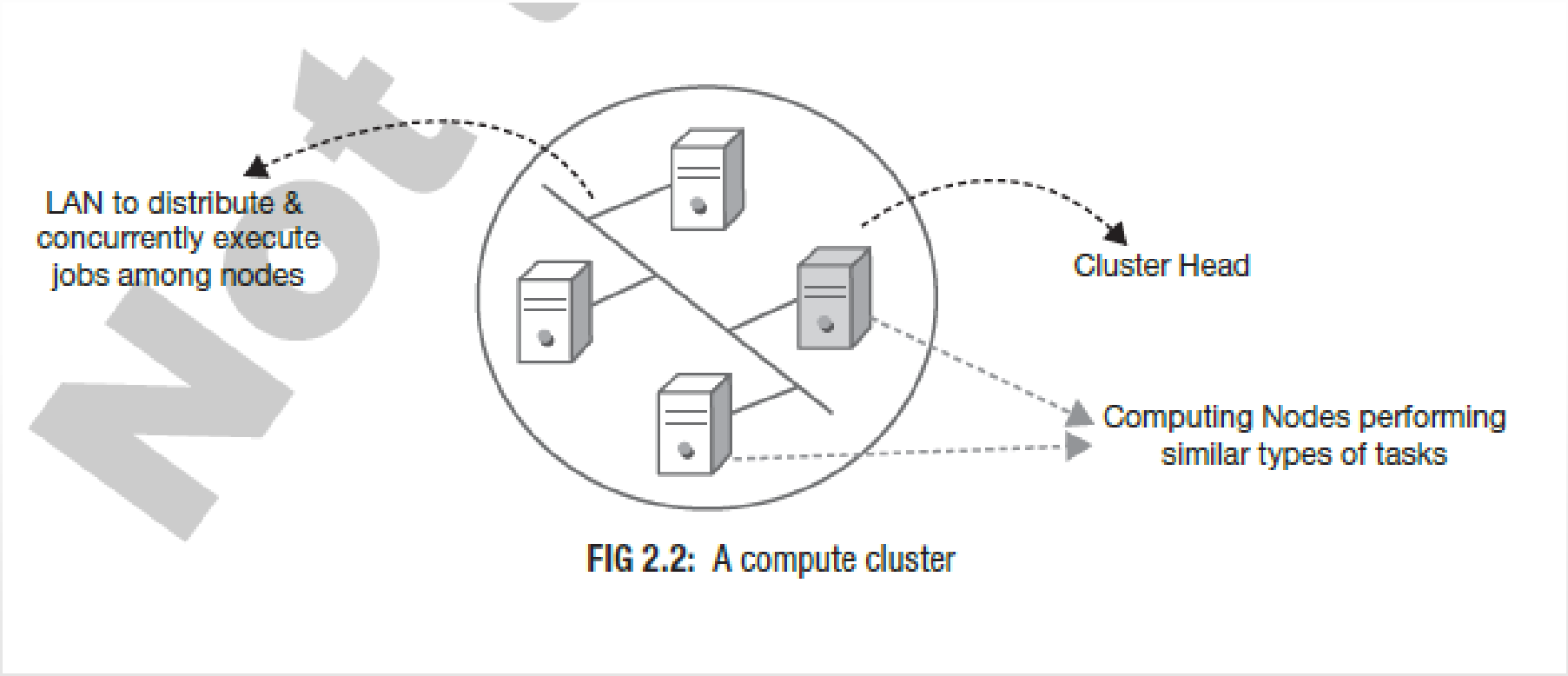


FIG 2.2: A compute cluster

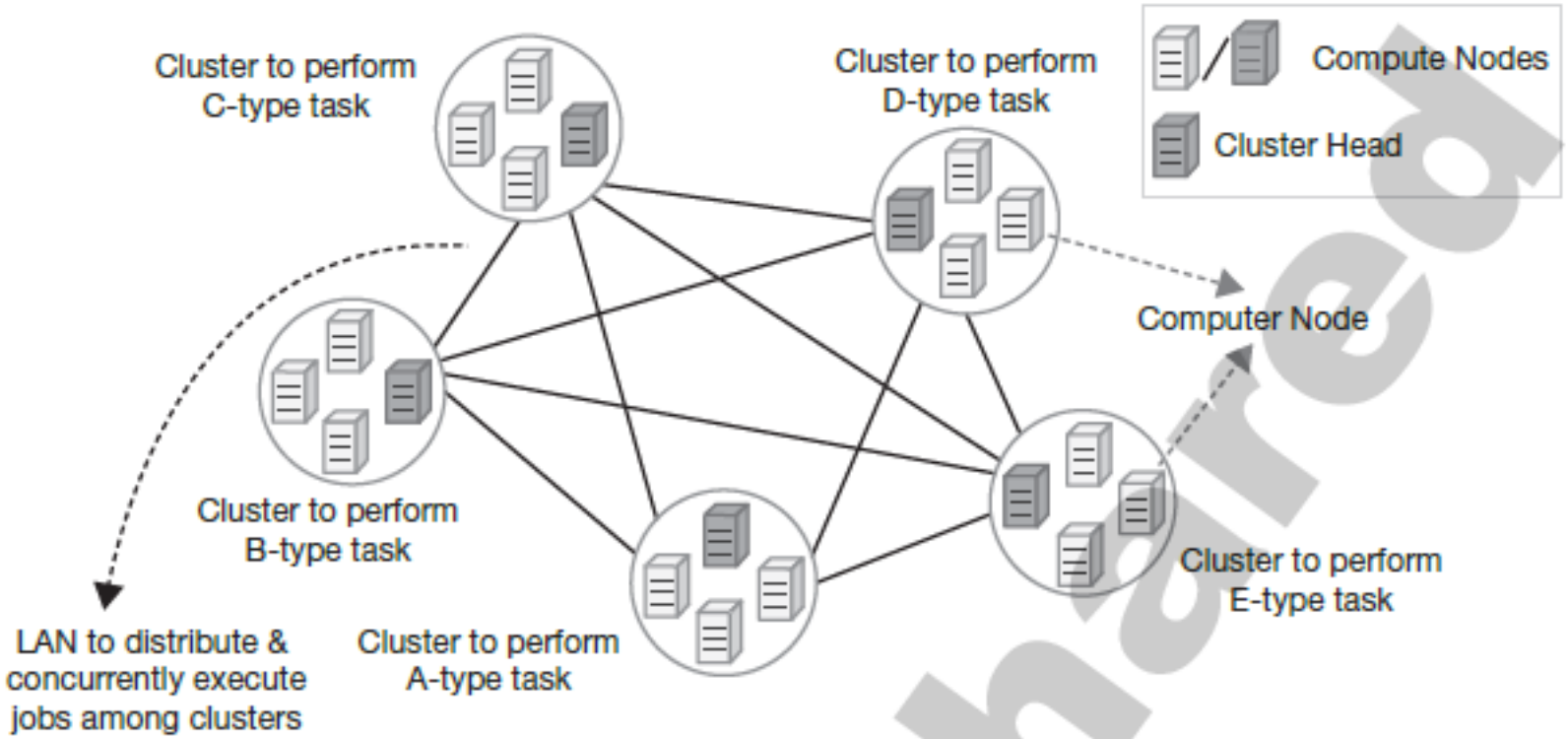
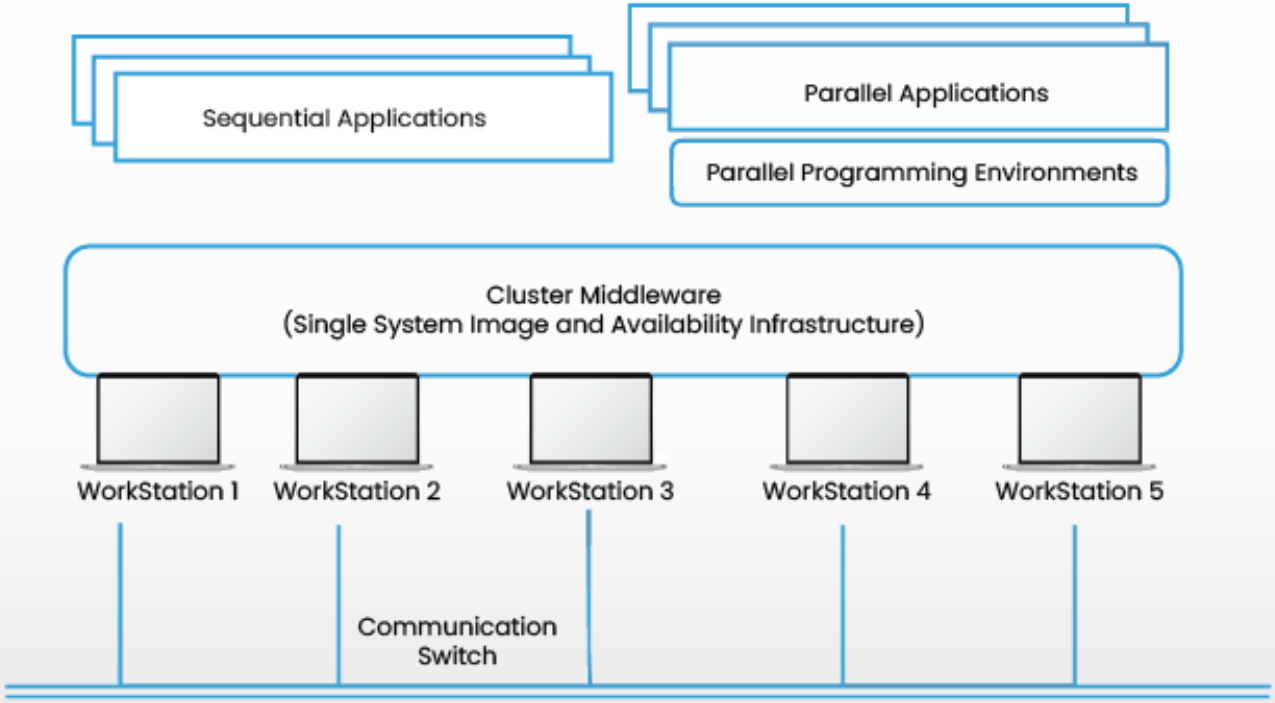
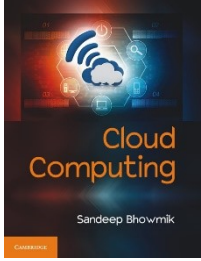


FIG 2.3: A cluster computing model



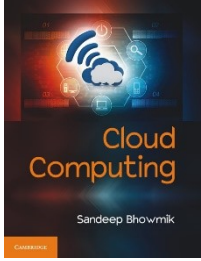
Source: https://www.esds.co.in/blog/cluster-computing-definition-architecture-and-algorithms/



Evolution of Computing (Phase 7)

- **Grid Computing**

  - Existence of cluster head in cluster computing raises possibility for single point of failure.
  - New computing model was needed to eliminate the cluster head problem, where each node belonging to a cluster will have same priority.
  - This new architecture was introduced in early 1990s, and was called a grid.
  - Other than decentralization of control, grid computing also capable of being built with heterogeneous system.



Grid Computing (Contd.)

- Grid concept promises to deal with computing resources going up to millions.
- Computing resources could be located at distant places.
- Being a distributed computing model, it allows easy growth of system capacity by adding more resources into an existing system.
- This introduced scope for another important system feature, known as *scaling*.

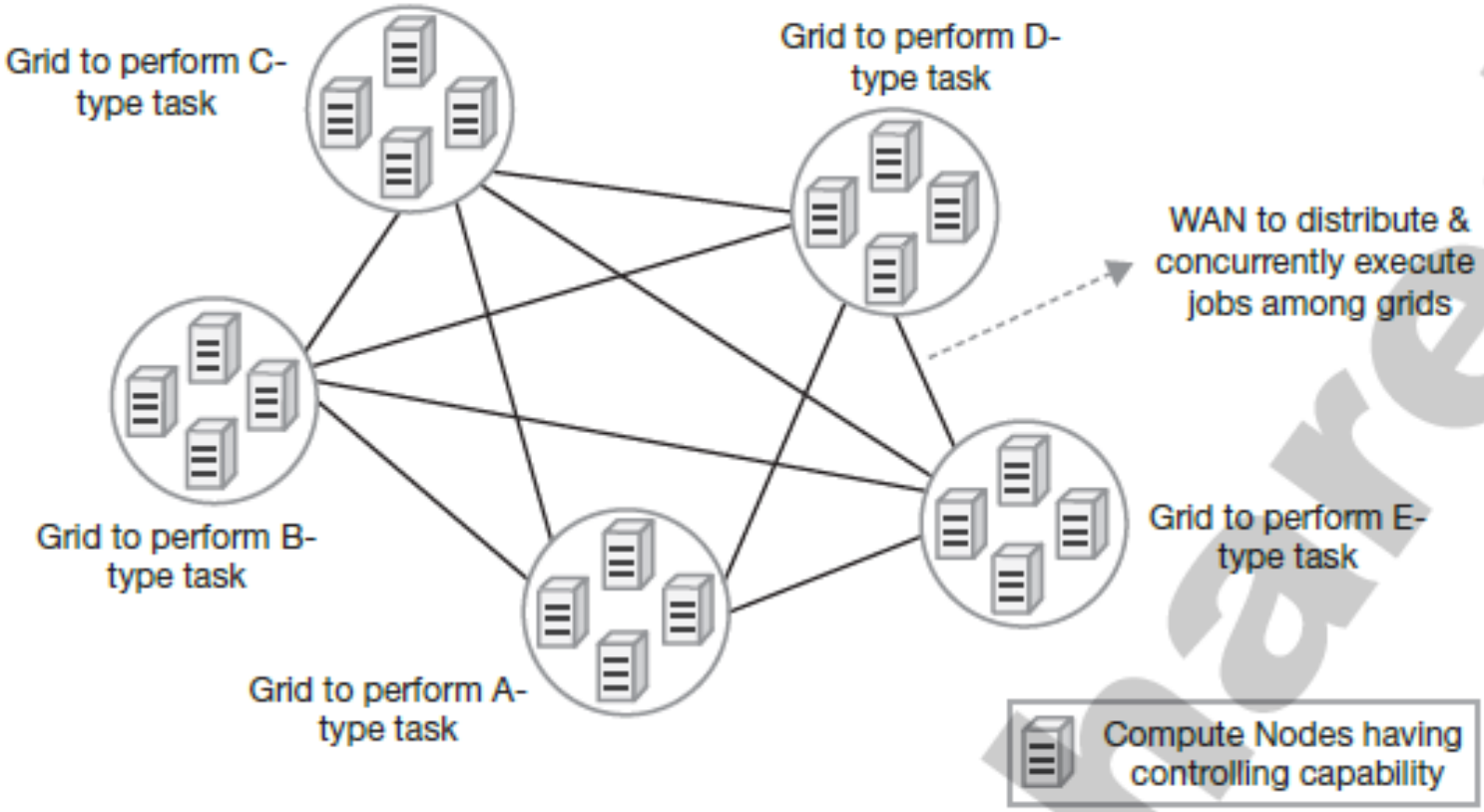
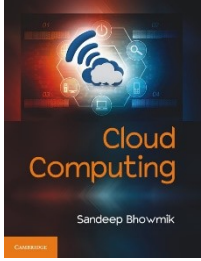
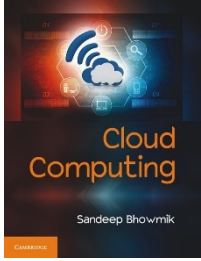


FIG 2.4: A grid computing model



Evolution of Computing (Phase 8)

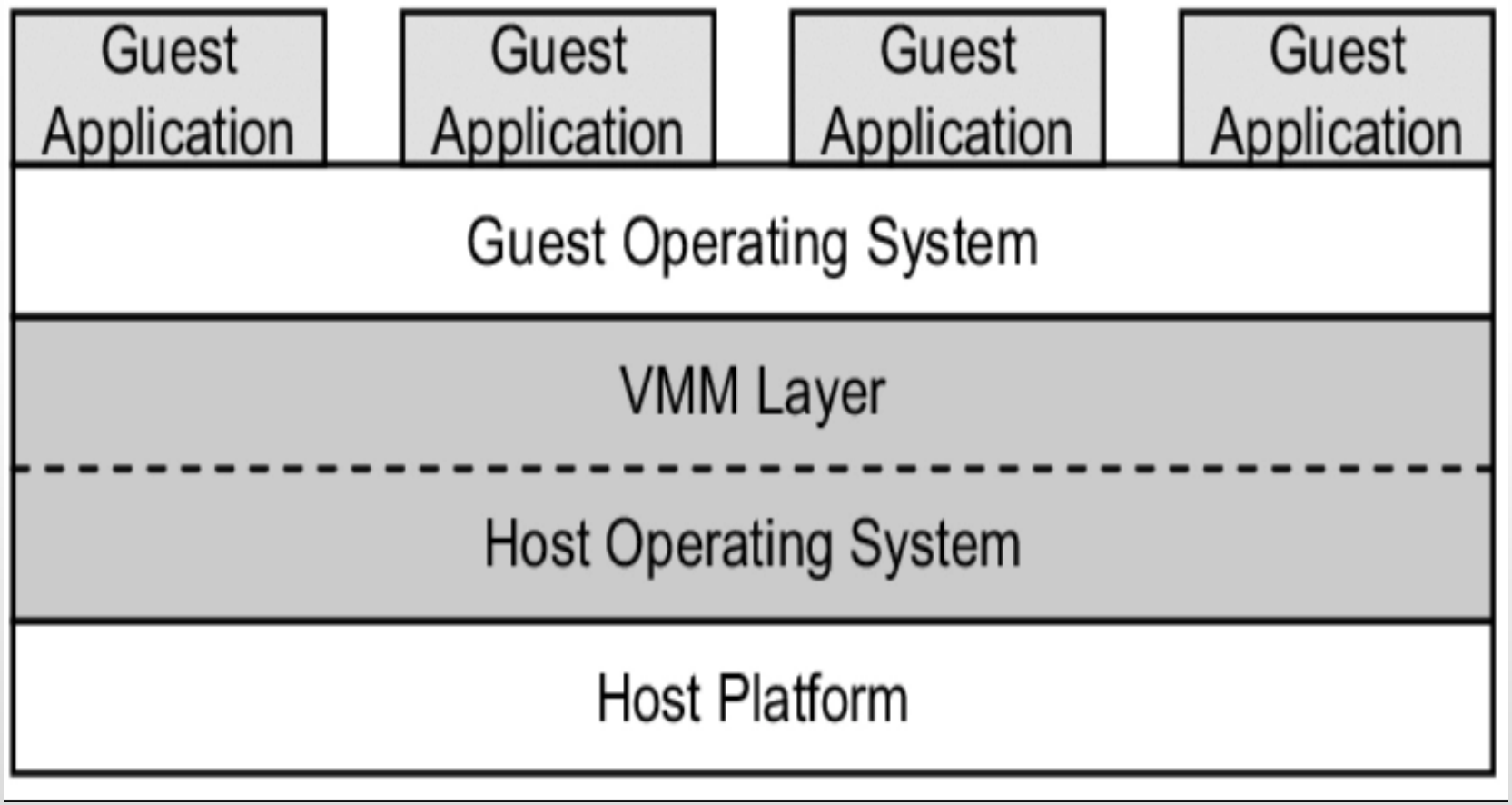
- **Hardware Virtualization**
  - Computing system with heterogeneous pool of resources could be created with scalable system architecture.
  - Next biggest challenge was to achieve real-time scaling capability.
  - The primary hurdle for achieving this was to decouple software systems from underlying physical resources.

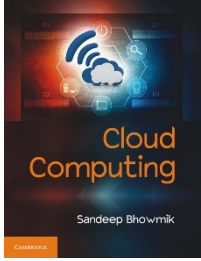


- **Hardware Virtualization (Contd.)**

  - In virtualization, a layer of software is created over the hardware system which simulate any physical system environment.

  - Virtualization coupled with resource pooling technique introduced dynamism and flexibility in systems.

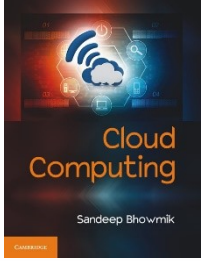

Guest Application
Guest Application
Guest Application
Guest Application
Guest Operating System
VMM Layer
Host Operating System
Host Platform



Evolution of Computing (Phase 9)

- **Group Collaboration**

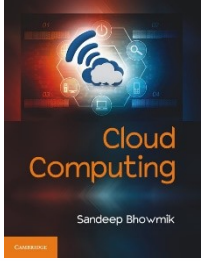
  - As grid computing concept empowered to develop large computing system spread across wide geographic location, collaboration capability was the next need.
  - With advancements in internet technology, communication over web also started to show its strength.
  - Development of Web Service (WS) standard made collaboration possible.
  - The major developments in web service standards were - Web 2.0 and Mashup.



Evolution of Computing (Phase 10)

- **Service Oriented Architecture**

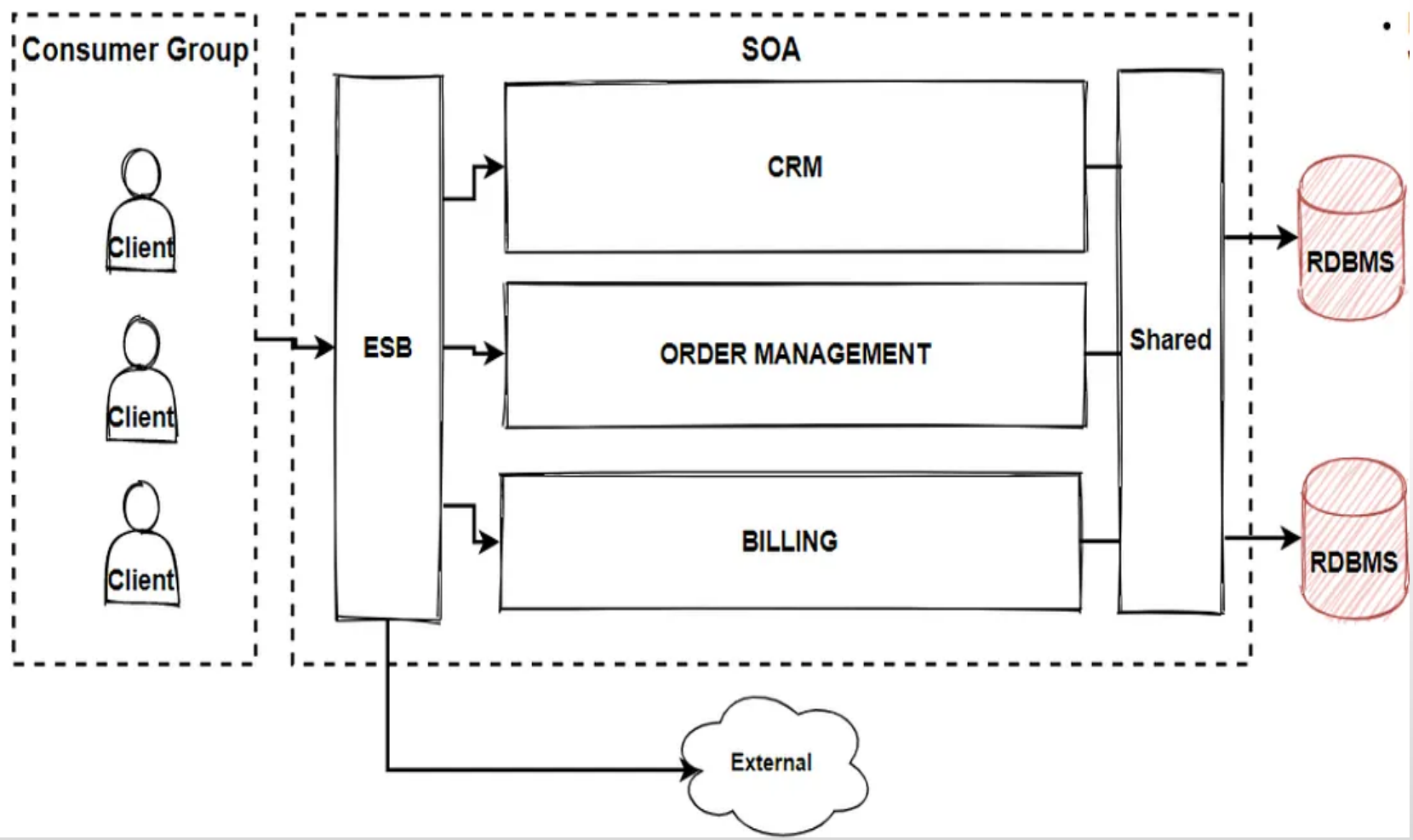
  - Large software systems are difficult to build without language independency and loose-coupling among modules.
  - Service oriented concept in application or software system development bridged this gap.
  - SOA is more a methodology than technical approach.
  - It makes systems flexible to adapt changes as per business requirements.

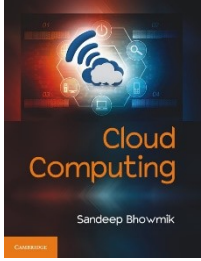


Evolution of Computing

Computing era reached a point where it was empowered with the following characteristics:

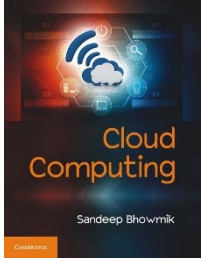
- Scalable computing infrastructure made of heterogeneous resources.
- Single distributed computing environment spread across the globe.
- Collaborative work facility from different locations.
- Flexible application architecture based on SOA.
- Virtualized computing infrastructure.


Consumer Group
Client
Client
Client
SOA
ESB
CRM
ORDER MANAGEMENT
BILLING
Shared
RDBMS
RDBMS
External

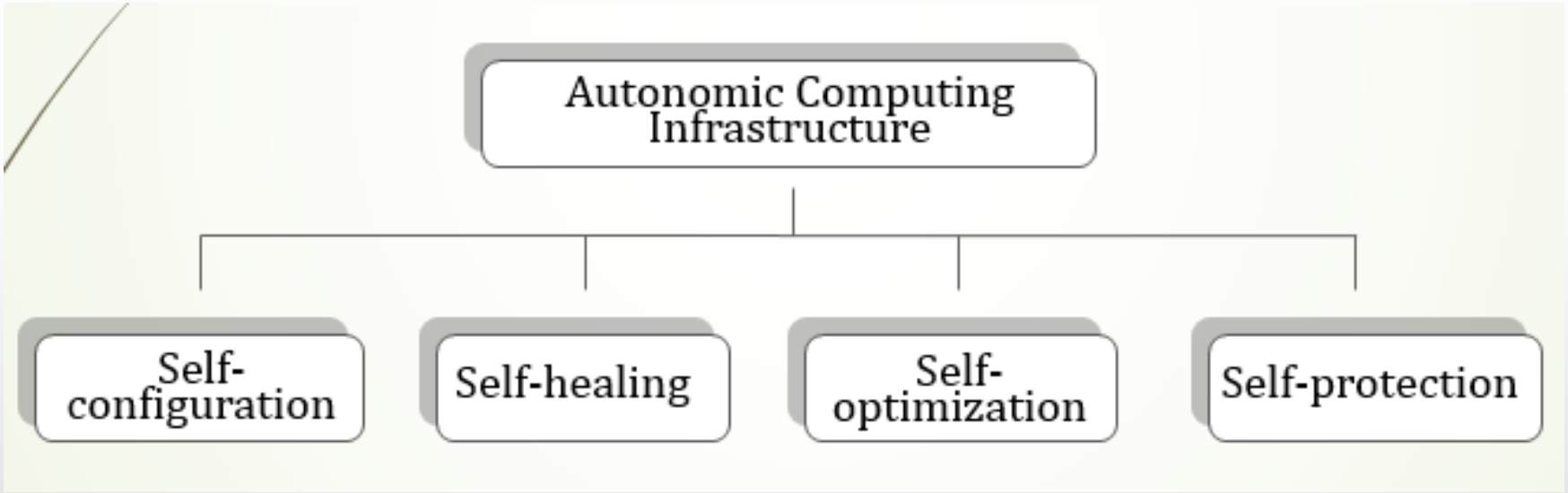


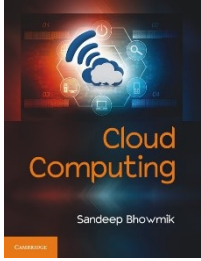
Evolution of Computing (Phase 11)

- **Utility Computing**
  - Vendors would arrange all required computing facilities.
  - Users can consume on payment basis.
  - Payment is calculated on use basis.
  - This model possess two important features, service is available on-demand and use-basis mode of payment.



- Characteristics of autonomic computing





Evolution of Computing (Phase 12)

○ Autonomic Computing

- As any system grows, it becomes difficult to manage day to day hardware or software issues through human interventions.
- Manual management of massive setup is never a likely idea.
- Autonomic computing refers to the ability of an intelligent computing system that can manage itself without any human intervention.
- The development of autonomic computing system could be possible through application of artificial intelligence (AI) concepts.

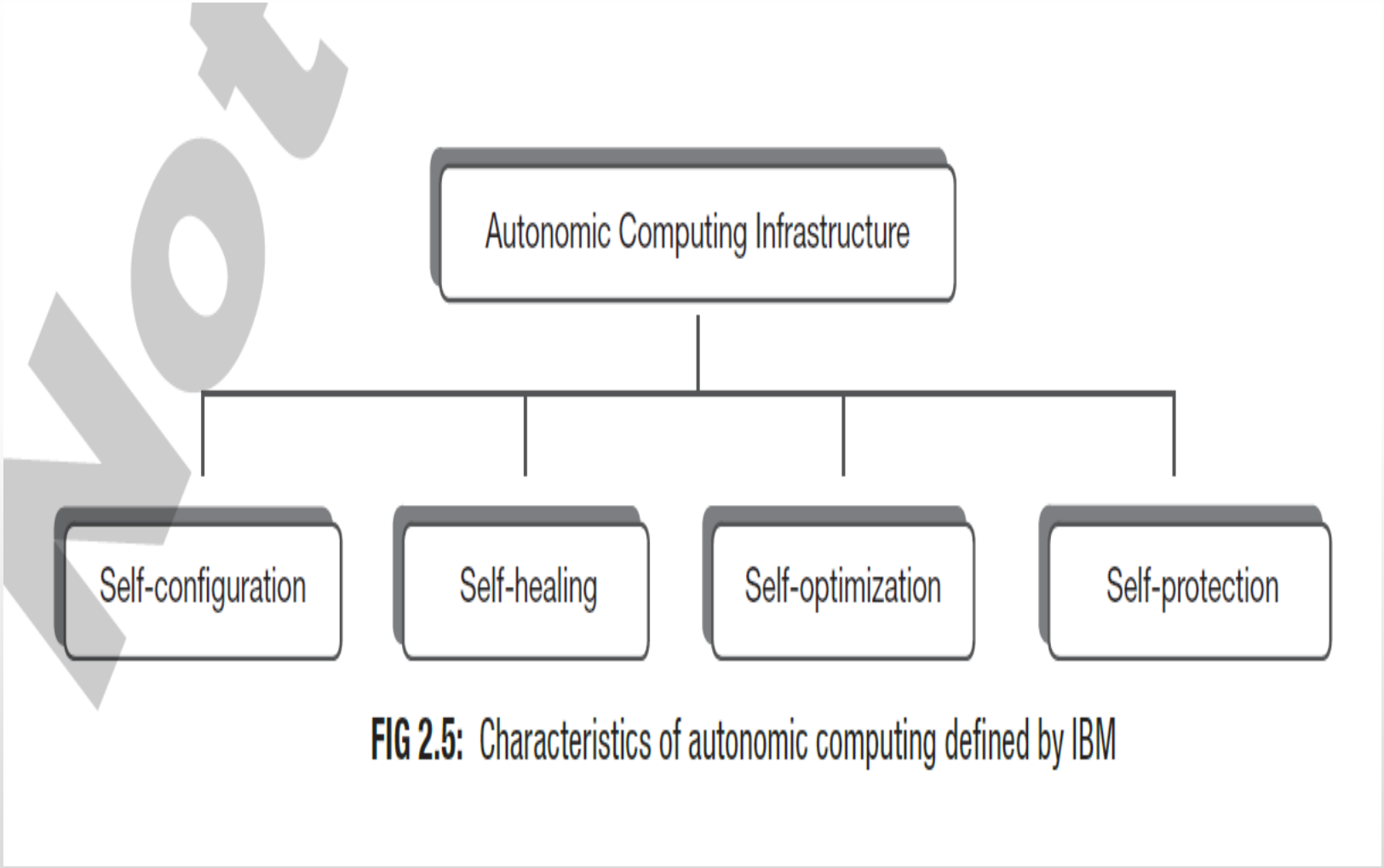
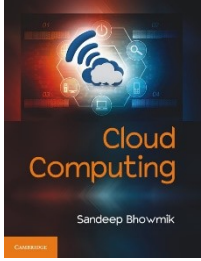


FIG 2.5: Characteristics of autonomic computing defined by IBM



Cloud Computing

- Major advantage of cloud is its capability of real-time scaling.
- With advancements made to grids, computing resources in cloud can be added in real-time to meet demand of computing.
- Cloud computing evolution has been an outcome purely based on the technological advancements in different fields of computing.
- Different technologies have been combined together towards the emergence of cloud computing.

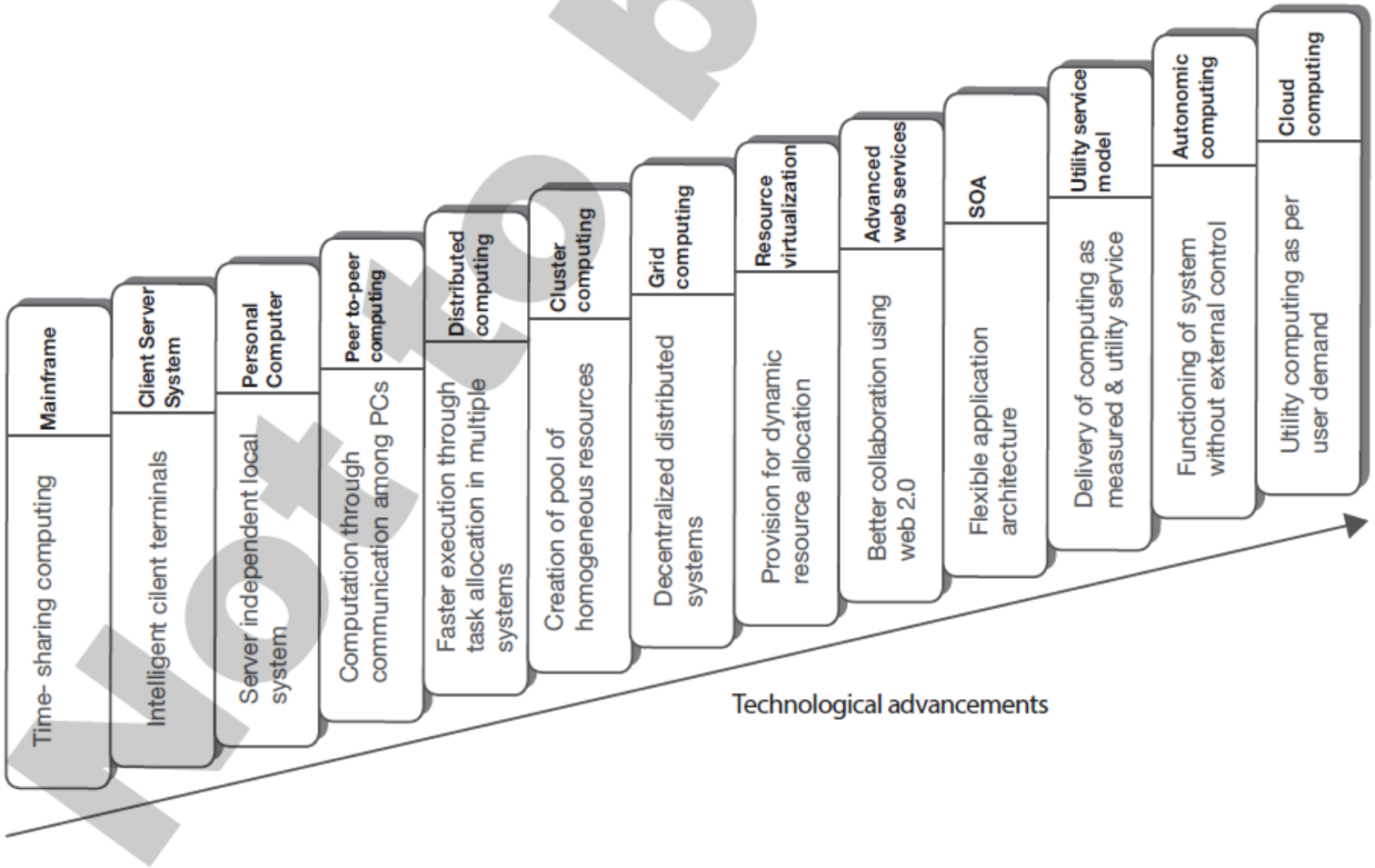
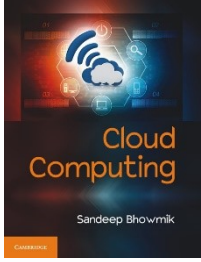
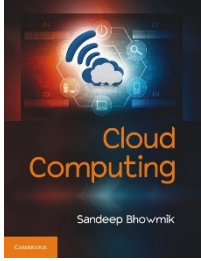
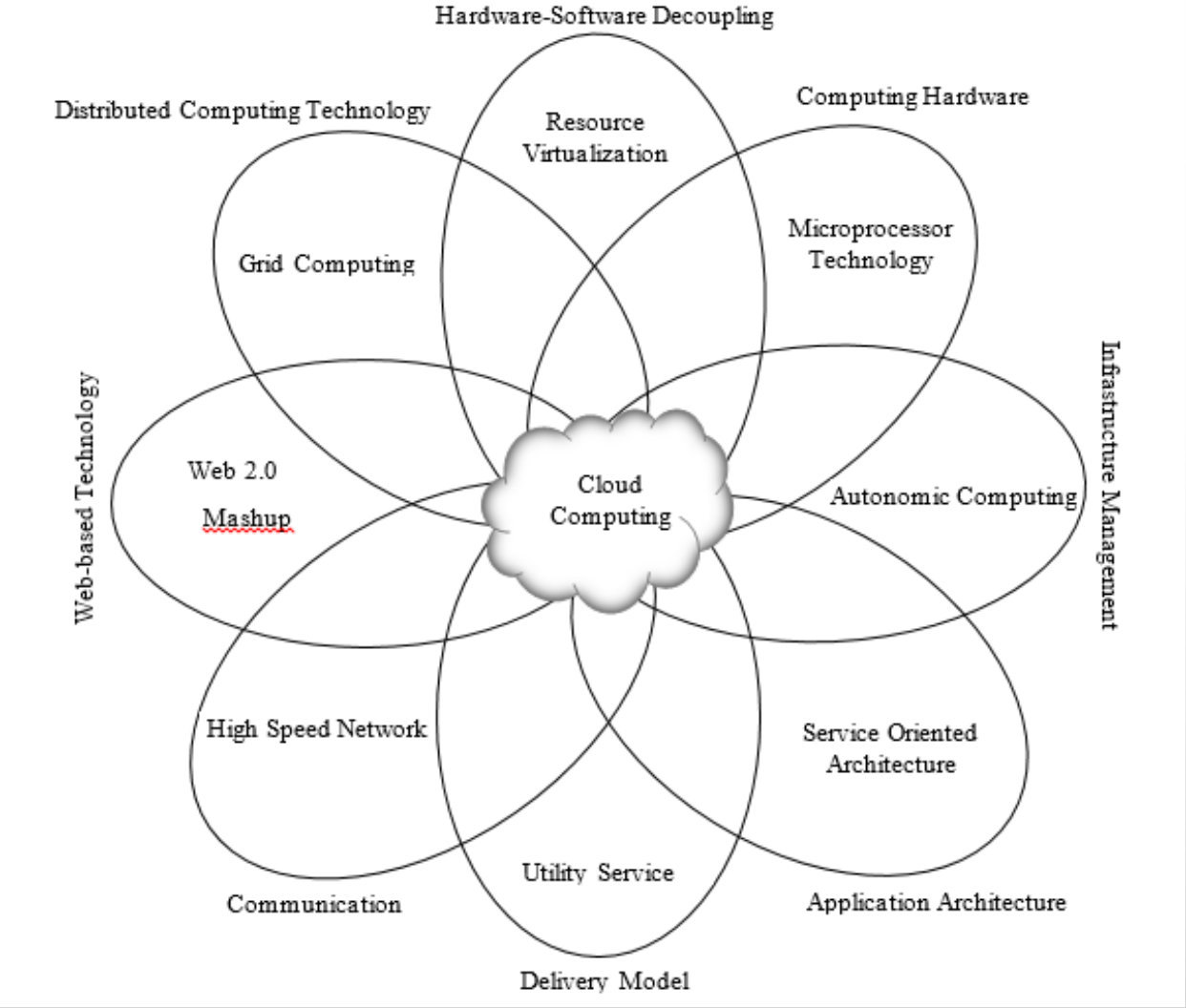


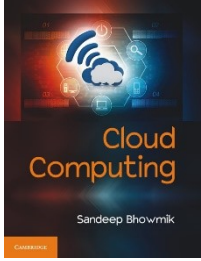
FIG 2.6: Technological advancements towards maturity of cloud computing



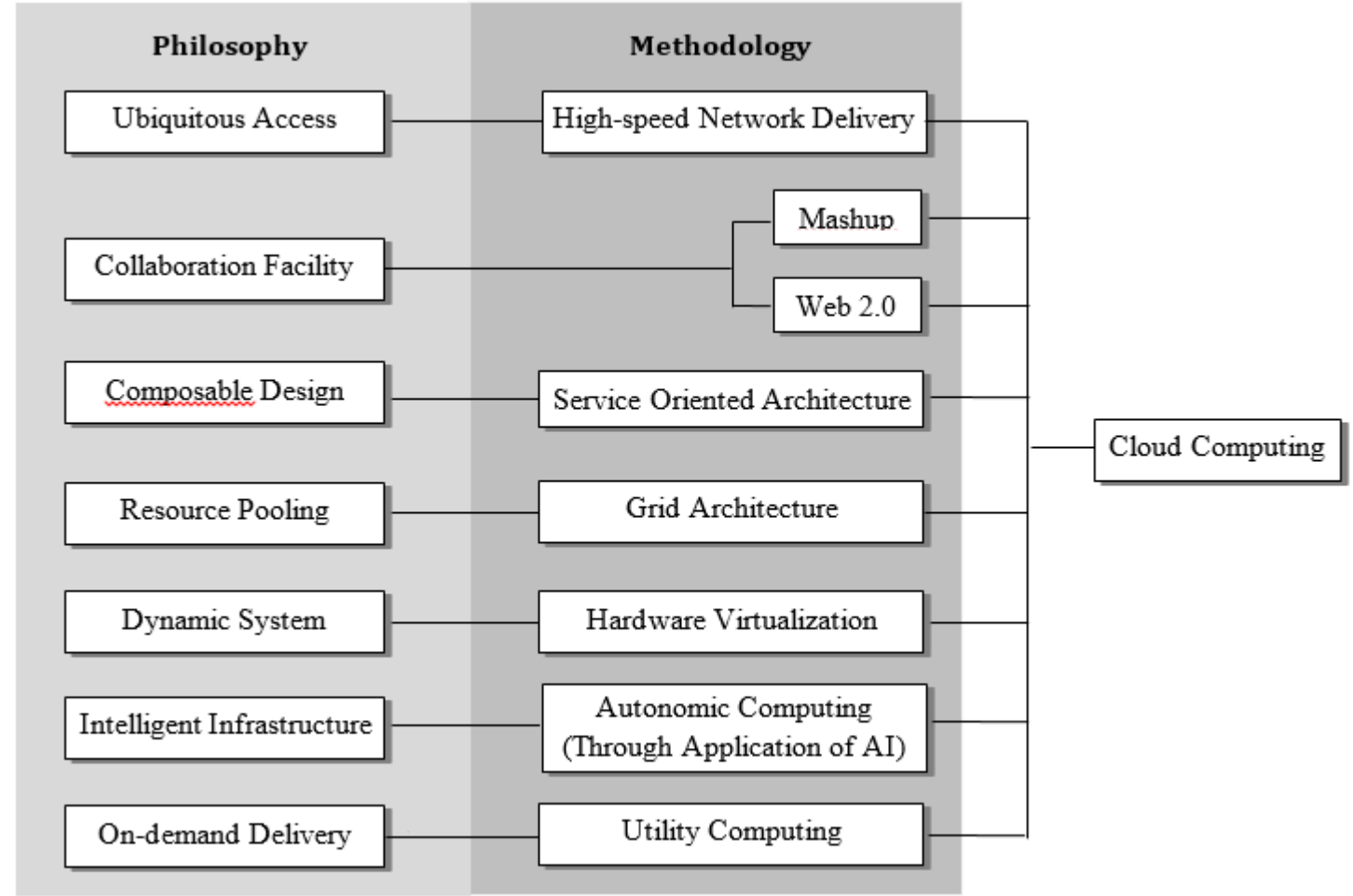


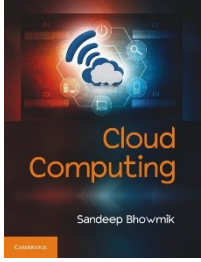
Convergence of Technologies





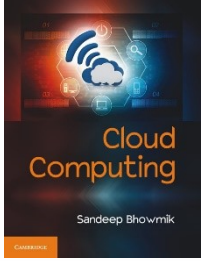
How Philosophies Converged





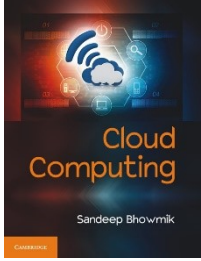
Comparison among Cluster, Grid and Cloud Computing

Cluster Computing	Grid Computing	Cloud Computing
A cluster is normally formed with computers of a single location, otherwise the system becomes complex.	Grid is inherently more distributed by its nature. The computers need not to be in the same geographical location.	Allows total distribution of resources like the grids. Hardware resources are maintained in multiple data centers.
Computation job takes place in one administrative domain owned by a single party.	Computation could occur over many administrative domains, owned by multiple parties, connected together.	Computing resources are usually owned by a single party. But multiple administrative domains can be combined together.



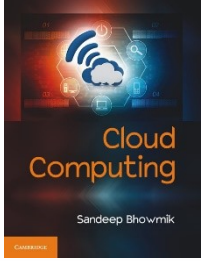
Comparison among Cluster, Grid and Cloud Computing (contd.)

Cluster Computing	Grid Computing	Cloud Computing
In a cluster, all computing nodes should have similar hardware systems. That is, the system should be.	It can be heterogeneous in nature. The computers that are part of a grid can of different hardware architectures.	Can use heterogeneous collection of commodity hardware.
Centralized task management & scheduling system.	Distributed task management & decentralized scheduling.	Decentralized task management with more dynamic computing infrastructure.



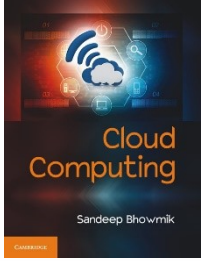
Comparison among Cluster, Grid and Cloud Computing (contd.)

Cluster Computing	Grid Computing	Cloud Computing
Resources are generally pre-reserved for specific type of task.	Resources are generally pre-reserved for specific type of task.	Resources are not pre-reserved for specific task. Resource utilization is demand driven.
System is not dynamic in nature. Application mobility not possible.	System is not dynamic in nature. Application mobility not possible.	Dynamic system. Mobility of application is an inherent feature.



Comparison among Cluster, Grid and Cloud Computing (contd.)

Cluster Computing	Grid Computing	Cloud Computing
One whole cluster behaves like a single system. As resources are managed by centralized resource manager, individual computers can't be operated as separate computers.	Every node is autonomous i.e. it has its own resource manager and behaves like an independent entity. So, each computer can be operated independently as distinct computer.	There is no concept of directly accessing any particular physical computing nodes. Underlying computing infrastructure remains hidden form users.



Thank You