

Lecture 01

Computing Paradigms

We are into a post-PC era, in which a greater number and a variety of computers and computing paradigms with different sizes and functions might be used everywhere and with every human being.

The term paradigm conveys that there is a set of practices to be followed to accomplish a task. In the domain of computing, there are many different standard practices being followed based on inventions and technological advancements. As computing systems become faster and more capable, it is required to note the features of modern computing in order to relate to cloud computing, and therefore it becomes essential to know little on various computing paradigms.

1. High-Performance Computing

In high-performance computing systems, a pool of processors (processor machines or central processing units [CPUs]) connected with other resources like memory, storage, and input and output devices, and the deployed software is enabled to run in the entire system of connected components. The processor machines can be of homogeneous or heterogeneous type.

Examples of HPC include a small cluster of desktop computers or personal computers (PCs) to the fastest supercomputers. HPC systems are normally found in those applications where high performance computation is required or solve scientific problems.

2. Parallel Computing

Parallel computing is also one of the facets of HPC. Here, a set of processors work cooperatively to solve a computational problem. These processor machines or CPUs are mostly of homogeneous type. Therefore, this definition is *the same* as that of HPC and is broad enough to include supercomputers that have hundreds or thousands of processors interconnected with other resources.

In parallel computing, since there is simultaneous use of multiple processor machines, the following apply:

- It is run using multiple processors (multiple CPUs).
- A problem is broken down into discrete parts that can be solved concurrently.
- Each part is further broken down into a series of instructions.
- Instructions from each part are executed simultaneously on different processors.

- An overall control/coordination mechanism is employed.

3. Distributed Computing

Distributed computing is also a computing system that consists of multiple computers or processor machines connected through a network, which can be homogeneous or heterogeneous, but run as a single system. The connectivity can be such that the CPUs in a distributed system can be physically close together and connected by a local network, or they can be geographically distant and connected by a wide area network. The heterogeneity in a distributed system supports any number of possible configurations in the processor machines, such as mainframes, PCs, workstations, and minicomputers. The goal of distributed computing is to make such a network work as a single computer.

4. Cluster Computing

A cluster computing system consists of a set of the same or similar type of processor machines connected using a dedicated network infrastructure. All processor machines share resources such as a common home directory and have a software such as a message passing interface (MPI) implementation installed to allow programs to be run across all nodes simultaneously. This is also a kind of HPC category. The individual computers in a cluster can be referred to as *nodes*. The reason to realize a cluster as HPC is due to the fact that the individual nodes can work together to solve a problem larger than any computer can easily solve. And, the nodes need to communicate with one another in order to work cooperatively and meaningfully together to solve the problem in hand.

5. Grid Computing

The computing resources in most of the organizations are underutilized but are necessary for certain operations. The idea of grid computing is to make use of such non utilized computing power by the needy organizations, and thereby the **return on investment (ROI)** on computing investments can be increased.

Thus, grid computing is a network of computing or processor machines managed with a kind of software such as middleware, in order to access and use the resources remotely. Grid computing differs from clustering in that grid systems are much more loosely coupled and distributed. The managing activity of grid resources through the middleware is called **grid services**. Grid services provide access control, security, access to data including digital libraries and databases, and access to large-scale interactive and long-term storage facilities.

Grid computing is more popular due to the following reasons:

- Its ability to make use of unused computing power, and thus, it is a cost-effective solution (reducing investments, only recurring costs).
- As a way to solve problems in line with any HPC-based application.

- Enables heterogeneous resources of computers to work cooperatively and collaboratively to solve a scientific problem.

Researchers associate the term **grid** to the way electricity is distributed in municipal areas for the common man. The grid is also *pervasive* in the sense that the remote computing resources would be accessible from different platforms, including laptops and mobile phones, and one can simply access the grid computing power through the web browser.

The grid computing is also a *utility*: we ask for computing power or storage capacity and we get it. We also pay for what we get.

6. Cloud Computing

The computing trend moved toward cloud from the concept of grid computing, particularly when large computing resources are required to solve a single problem, using the ideas of computing power as a *utility* and other allied concepts. However, the potential difference between grid and cloud is that grid computing supports leveraging several computers in parallel to solve a particular application, while cloud computing supports leveraging multiple resources, including computing resources, to deliver a unified *service* to the end user.

In cloud computing, the IT and business resources, such as servers, storage, network, applications, and processes, can be dynamically provisioned to the user needs and workload. In addition, while a cloud can provision and support a grid, a cloud can also support non-grid environments, such as a three-tier web architecture running on traditional or Web 2.0 applications.

7. Bio-Computing

Biocomputing systems use the concepts of biologically derived or simulated molecules (or models) that perform computational processes in order to solve a problem. The biologically derived models aid in structuring the computer programs that become part of the application. Biocomputing provides the theoretical background and practical tools for scientists to explore proteins and DNA.

8. Mobile Computing

In mobile computing, the processing (or computing) elements are small (i.e., handheld devices) and the communication between various resources is taking place using wireless media. Mobile communication for voice applications (e.g., cellular phone) is widely established throughout the world and witnesses a very rapid growth in all its dimensions including the increase in the number of subscribers of various cellular networks. An extension of this technology is the ability to send and receive data across various cellular networks using small devices such as smartphones. There can be numerous applications

based on this technology; for example, video call or conferencing is one of the important applications that people prefer to use in place of existing voice (only) communications on mobile phones.

9. Quantum Computing

Manufacturers of computing systems say that there is a limit for cramming more and more transistors into smaller and smaller spaces of integrated circuits (ICs) and thereby doubling the processing power about every 18 months. This problem will have to be overcome by a new *quantum computing*-based solution, wherein the dependence is on quantum information, the rules that govern the subatomic world. Quantum computers are millions of times faster than even our most powerful supercomputers today. Since quantum computing works differently on the most fundamental level than the current technology, and although there are working prototypes, these systems have not so far proved to be alternatives to today's silicon-based machines.

10. Optical Computing

Optical computing system uses the photons in visible light or infrared beams, rather than electric current, to perform digital computations. An electric current flows at only about 10% of the speed of light. This limits the rate at which data can be exchanged over long distances and is one of the factors that led to the evolution of optical fiber. By applying some of the advantages of visible and/or IR networks at the device and component scale, a computer can be developed that can perform operations 10 or more times faster than a conventional electronic computer.

11. Nano Computing

Nano computing refers to computing systems that are constructed from nano scale components. The silicon transistors in traditional computers may be replaced by transistors based on carbon nanotubes. The successful realization of nanocomputers relates to the scale and integration of these nanotubes or components. The issues of scale relate to the dimensions of the components; they are, at most, a few nanometers in at least two dimensions. The issues of integration of the components are twofold: first, the manufacture of complex arbitrary patterns may be economically infeasible, and second, nanocomputers may include massive quantities of devices. Researchers are working on all these issues to bring nanocomputing a reality.

12. Network Computing

Network computing is a way of designing systems to take advantage of the latest technology and maximize its positive impact on business solutions and their ability to serve their customers using a strong underlying network of computing resources. In any

network computing solution, the client component of a networked architecture or application will be with the customer or client or end user, and in modern days, they provide an essential set of functionality necessary to support the appropriate client functions at minimum cost and maximum simplicity. Unlike conventional PCs, they do not need to be individually configured and maintained according to their intended use. The other end of the client component in the network architecture will be a typical *server* environment to *push* the services of the application to the client end.

Introduction to Cloud Computing

Cloud computing has been coined as an umbrella term to describe a category of sophisticated on-demand computing services initially offered by commercial providers, such as Amazon, Google, and Microsoft. Cloud computing gets its name as a metaphor for the Internet. Typically, the Internet is represented in network diagrams as a **cloud**. The **cloud** icon represents “**all that other stuff**” that makes the network work.

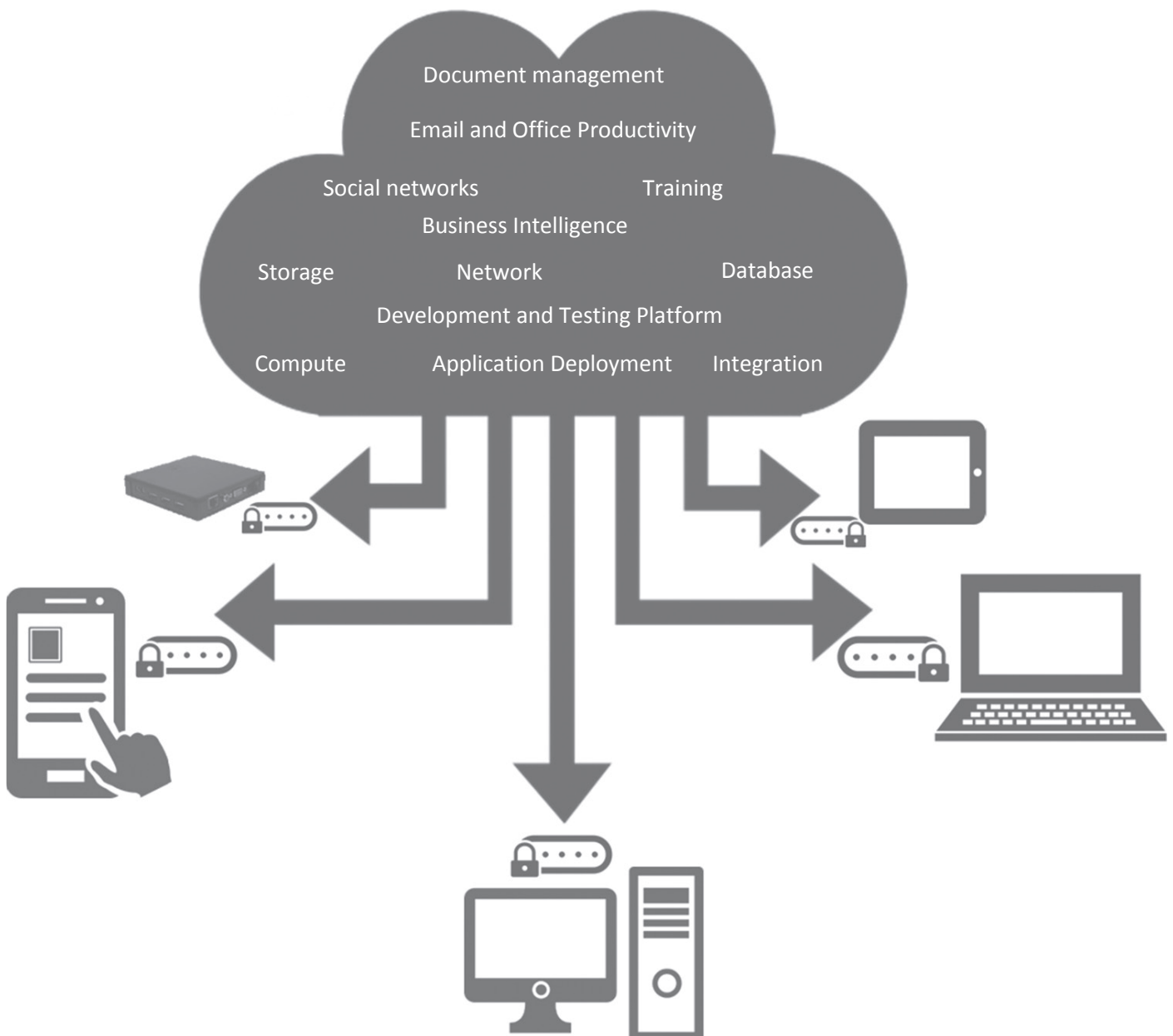
It denotes a model on which a computing infrastructure is viewed as a “**cloud**,” from which businesses and individuals access applications from anywhere in the world on demand. The main principle behind this model is offering computing, storage, and software “**as a service**.”

With the advent of this technology, the cost of computation, application hosting, content storage and delivery is reduced significantly. Cloud computing is a practical approach to experience direct cost benefits and it has the potential to transform a data center from a capital-intensive set up to a variable priced environment.

The users who are in need of computing are expected to invest money on computing resources such as hardware, software, networking, and storage; this investment naturally costs a bulk currency to the users as they have to buy these computing resources, keep these in their premises, and maintain and make it operational—all these tasks would add cost. And, this is a particularly true and huge expenditure to the enterprises that require enormous computing power and resources, compared with classical academics and individuals.

On the other hand, it is easy and handy to get the required computing power and resources from some provider (or supplier) as and when it is needed and pay only for that usage. This would cost only a reasonable investment or spending, compared to the huge investment when buying the entire computing infrastructure. This phenomenon can be viewed as **capital expenditure** versus **operational expenditure**. Therefore, cloud computing is a mechanism of *bringing–hiring or getting the services of the computing power or infrastructure* to an organizational or individual level to the extent required and paying only for the consumed services.

The idea of cloud computing is based on a very fundamental principal of “**reusability of IT capabilities**”.



Defining Cloud Computing

Many practitioners in the commercial and academic spheres have attempted to define exactly what “cloud computing” is and what unique characteristics it presents. Some of the Common definitions are:

1. *“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. This cloud model is composed of five essential characteristics, three service models, and four deployment models.”(NIST)*
2. *“Clouds are a large pool of easily usable and accessible virtualized resources (such as hardware, development platforms and/or services). These resources can be dynamically reconfigured to adjust to a variable load (scale), allowing also for an optimum resource utilization. This pool of resources is typically exploited by a pay-per-use model in which guarantees are offered by the Infrastructure Provider by means of customized Service Level Agreements.”*
3. *“Cloud computing is a subscription-based service where you can obtain networked storage space and computer resources. It is a computing paradigm, where a large pool of systems are connected in private or public networks, to provide dynamically scalable infrastructure for application, data and file storage.”*
4. *“Cloud computing is a specialized form of distributed computing that introduces utilization models for remotely provisioning scalable and measured resources.”*