Unfolding the Modern Computing Paradigms in Research Perspective

Anju Pathrose[1], Boby Jose[2], Fatima Timi P.F[3]
[1,2,3]*Department of Computer Science and Engineering, Al-Azhar college of Engineering and Technology*

Abstract **- Over the last few years, internet has became so popular that, it lead to the increase in computer processing capacity, data storage and communication with one another. The computing paradigms are introduced for solving complex problems by analysing, designing and implementing complex systems. In this paper a survey on different computing paradigms is presented. Parallel computing is used for multi task handing and cloud computing for on-demand availability of computer system resources, especially data storage. In grid computing all machines on the network work under the same protocol to act like a virtual supercomputer and cluster computing execute operations all together thus creating the idea of a single system. Fog computing is a decentralized computing structure located between the cloud and devices that produce data, and edge computing is an architecture that uses edge devices to carry out a substantial amount of computation. These technologies improved the way computing functions and made it easier to the computer world. A comparison of these technologies based on google trends is provided in this paper along with usage in different application.**

Index Terms **– Cloud Computing; Cluster Computing; Distributed Computing; Grid Computing; Mobile Computing; Parallel Computing, Fog computing.**

INTRODUCTION

Rapid technological developments in the areas of computer hardware and software, availability of high-speed networks and growing popularity of internet has made computing industry one of the fastest growing industries. Millions of data are generated each day and it is need to be processed and stored in large area. Parallel computing in the simplest sense, is the simultaneous use of multiple compute resources to solve a computational problem. The program is to be run using multiple cpus. The program is broken into discrete parts that can be solved concurrently. Each part is further broken down to a series of instructions and then the instructions from each part executed simultaneously on different cpus. There are many reasons to use parallel computing, such as it saves time and money, provide concurrency, solve larger problems, etc. Furthermore, parallel computing reduces complexity.

Various definitions of distributed systems have emerged in the industry. None of them are enough, and none of them is in agreement with any of the others. However, a sufficient definition is - a distributed system is a collection of independent computers that appears to its users as a single coherent system. The important aspects of this definition is that, the first one, distributed system consists of components (i.e., computers) that are autonomous and the second one is that users (be they people or programs) think that they are dealing with a single coherent system [1].A distributed system contains multiple computers which are called nodes that are physically separate but linked together using the network. Distributed computing is divided into cluster, grid and cloud computing. Distributed computing when done on a local area network is called cluster computing. For example, when all the computers in a lab of your university are linked together using high speed network bands and give you an illusion of single system it can be called a cluster. All the computers in cluster computing are contained in one location (e.g. your lab) and have the same kind of operating systems and hardware specifications.

The major difference between cluster and grid computing is that in grid, our computer systems are distributed geographically, i.e., we are binding individual systems around the globe in a network (wide area network). All the systems here are not generally linked using high speed network bands probably because it would be a hell of expensive. Another difference is, in grid, systems we can have different operating systems and hardware

specifications. Nowadays, cloud computing became the standard of IoT data storage. In this form of computing, data and information is stored on multiple servers and can be accessed online from any device on demand. Despite of saving information in the local hard drive on a single computer, users can store it on third-party online servers. The service providers will provide you the storage space and to access data, a user needs to enter an account associated with the cloud service. Even service providers have no access to the user's contents because the data is protected by end-to-end encryption. Thus we can securely store and manage a lot of data and have immediate access to it from multiple devices, anytime, anywhere.

Fog computing and edge computing appear almost similar because they both are involved in bringing intelligence and processing closer to the creation of data. However, their difference lies mainly in two factors that include, where the location of intelligence and compute power is placed. In fog computer environment intelligence lies at the local area network (LAN) and data is transmitted from endpoints to a gateway, from where it is then transmitted to sources for processing and return the transmission. In edge computing intelligence and processing power is placed in devices such as embedded automation controllers.

II. PARALLEL COMPUTING

The concept of using multiple computers or processors to reduce the time needed to solve a heavy computational problem is called Parallel processing. It operates on the principle that large problems can often be divided into smaller ones and then solved concurrently [2]. Parallel processing is commonly used in scenarios which need massive processing power or computation, generally in supercomputers. Multiple Instruction Multiple Data Stream (MIMD) is the main architecture for multicore processor. Based on the level at which the hardware supports parallelism, Parallel computer architecture is classified into multicore computing in which all the different threads can be executed in different cores with same shared memory. These cores can be implemented on the same computer instead of using single processor with single core shared with memory [3]. And Symmetric multiprocessing in which a single operating system handles multiprocessor computer architecture having two or more homogeneous, independent processors that treat all processors equally.

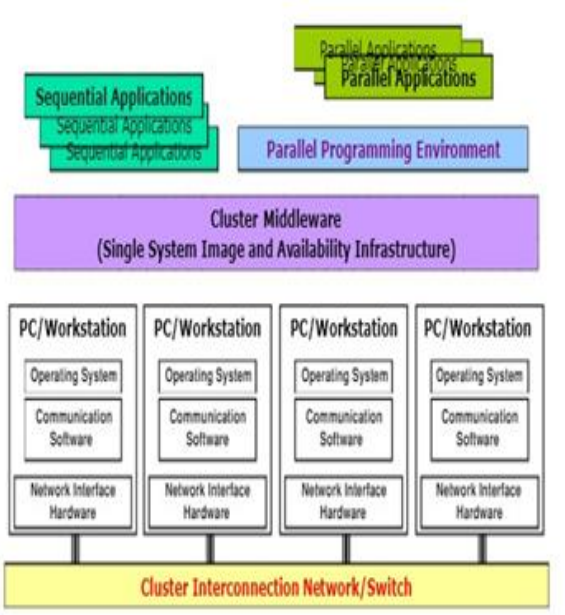
What parallel computing done is that it divides your program so that it can be parallelized in efficient way, identify the most time-consuming parts of your program and parallelize them. This could require modifying your algorithm and code's organization. It balances parallel workload, minimize time spent in communication, use simple arrays instead of user defined derived types, partition data and distribute arrays and matrices – allocate specific memory for each MPI process.

III. CLUSTER COMPUTING

Cluster is a type of parallel or distributed computer system, which consists of a collection of interconnected standalone computers working together as a single integrated computing resource [4]. A typical Cluster architecture is shown in the Figure 1. A cluster architecture includes multiple standalone computers (PCs, Workstations, or SMPs), operating systems, high-performance interconnects, middleware, parallel programming environments, and applications [4]. To enable internode communication, the individual nodes should be connected in a network. Selecting a cluster interconnection network technology depends on various parameters, including compatibility with the cluster hardware and operating system, price, and performance. Generally, there are two metrics to measure performance for interconnects: bandwidth and latency. The amount of data that can be transmitted over the interconnect hardware in a fixed period of time is bandwidth, while latency is the time to prepare and transmit data from a source node to a destination node.[4].

Cluster computing represents the most rapidly growing field within the domain of parallel computing mainly due to its property of exceptional performance/price. Unlike other parallel computer system architectures, the core computing elements, referred to as nodes, are not custom designed for high performance and parallel processing, but they are derived from systems developed for the industrial, commercial market sectors and applications [5].

Fig. 1 Cluster Architecture(R.Buyya[6])



IV. GRID COMPUTING

Grid computing was inspired by the electrical power grid. In electric power grid user needs not know the geographical location of the power plant while using the electricity [7]. The focus is given mainly the required power we are getting. This concept is applied in grid computing paradigms. The grid computing consists of heterogeneous or homogeneous hosts each of which is provided with several computational resources. Grid computing has evolved from the pre-existing technologies like distributed computing, the Internet, web services, most of the cryptographic techniques alongside powering up with the virtualization technology [8].

The four main building block of grid computing are user, resource broker, grid information service and resources. The grid broker collects request from the user for executing a task. The broker job is to split the job into several tasks and submits them to various resources that are made available for doing the job. The grid information service takes a note of information regarding the resources that took part in scheduling. In technical terms the major components that made grid computing are schedulers, load balancing and grid portals [9]. Schedulers are the task managers who collect the necessary resources for a particular task execution, distributing the tasks to work on an operation parallel, reserving the resources, keeping track of the task execution and its status. The load balancing is to eliminate delays in processing and deadlocks, the load balancing units are used. These load balancers are built upon the schedulers and resource managers. The grid portals can be identified as the access points to an internet system. It provides a structure or a domain for the user to utilize the services. It plays a major role in keeping track of network applications. Grid Portals manages the entry and authentication of the users using the information from job scheduling, file transfer and information resources. Grid computing is a five layered structure in which its protocols and structures are present. The fabric layer is placed at the bottom of the grid architecture. The resources that need to be shared are present in this layer; like processors, catalogues, network resources, and sensors. Connectivity layer is the protocols required for authentication and communication is present in this layer. Resource layer is relevant duties related to network infrastructure like negotiation, accounting, payment, monitoring, and controlling are taken care in this layer. The protocol called Grid Resource Access and Management (GRAM) is used to allocate the computational resources [10]. The collective layer helps in keeping the multiple resources in sync and its management. Application Layer is the topmost layer is the application layer where all the user friendly applications and API's are built based on the above protocols. The basic origin of grid computing is dealing with different kind of computing that is high throughput computing is used to deal with higher server data. The modern world big data is also handling larger amount of data that basic mechanism is can from data intensive computing. The grid computing, utilization of resources are taken are in an efficient manner, work permeability is reduced; huge amount of data is accessible both locally and globally.

V. CLOUD COMPUTING

The organization dealing with digital data requires a place like servers, processing units for storing and processing data. But setting up of hardware or software in a big amount for the purpose is a money induced process [11]. And that is where Cloud Computing becomes an advantage, by enabling the clients to store and make use of the services which are offered on a pay and use basis. You can run an operating system, use software, play games, stream

video, business process management and many more without actually running on local devices [12]. All you need is a good uninterrupted internet connection that can be accessed from any part of the world. The cloud started by 2010 and became at its peaks by 2020. The main reason is why cloud computing emerged fast is due to the low cost and high quality services given by the cloud hosts [13]. The virtualization concept that is powering the cloud caused this drastic breakthrough in cloud computing during the resent years. In public Cloud the cloud service providers are the providers of a public internet service by not asking to pay for hardware or software that are being used. User can use the services offered by the cloud hosts and lack the authorization to manage, change or control the cloud. While using the services, user feels that they are working on the local computer. In contract Private cloud is when an organization sets up a cloud for the private purpose or a third party vendor hosting it to different organizations differently to make use [14]. The public cloud vendor's offers service to many, private cloud. The resources are not shared with other organizations but for the sole purpose of own. Hybrid cloud is cloud bursting or Hybrid cloud is making the use of both public and private clouds together [15]. An organization uses its own private cloud for computing and also the public cloud if the computing requirements do not match up with private cloud. This ensures the better results in terms of computing. Companies who use hybrid cloud are, Netflix, Ola, Uber, Airbnb and ellipsis.

VI. FOG COMPUTING

Fog computing is a paradigm that provides services to users at the edge networks. The fog computing platform is typically sandwiched between the layers of the cloud servers and the users. In a traditional network, the devices at the edge layer usually perform operations related to networking such as routers, gateways, bridges, and hubs. However, in the case of the fog-enabled environment, researchers envision these devices to be capable of performing both computational and networking operations, simultaneously. Although these fog devices are resource- constrained compared to the cloud servers, the geographical spread and the decentralized nature of the fog architecture helps in offering reliable services over a wide area. Further, with fog computing, several manufacturers and service providers offer their services at affordable rates. Another advantage of fog computing is the physical location of the devices, which are closer to the users than the cloud servers, which eventually reduces operational latency significantly. [16].

Fog computing or fog networking, also known as fogging, is pushing frontiers of computing applications, data, and services away from centralized cloud to the logical stream of the network edge. Fog networking system works on to build the control, configuration, and management over the Internet backbone rather than the primarily control by network gateways and switches those which are embedded in the LTE network. We can illuminate the fog computing framework as highly virtualized computing infrastructure which provides hierarchical computing facilities with the help of edge server nodes. These fog nodes organize the wide applications and services to store and process the contents in close proximity of end users. Sometimes, fog computing used frequently and often interchangeably the term "edge computing." However, there is a little bit difference between those two concepts. Fog and edge computing both involve pushing the processing and intelligence capabilities down to the proximity where the information is originating. The main difference between both architectures is exactly where the computing and intelligence power is placed. In both structures data is sent by the same sources or physical assets, like pumps, relays, motors, sensors, and so on. All those devices perform a physical chore in this world such as electrical circuits, pumping water, switching, or sensing the task around them. [17]. It is a decentralized computing infrastructure in which computing resources such as data, computers, storage, and applications are located between the data source and the cloud. This term refers to a new breed of applications and services related to data management and analysis. [18]

VII. EDGE COMPUTING

Edge computing is a subset or a component of fog computing. For example, if fog computing is compared to a basket of various fruits, edge computing would be one fruit from a single variety. The origins of edge computing are in the 1990s with the creation of the first content delivery network (CDN), which put

data collecting nodes closer to end users. But this technology was limited to images and videos, not massive workloads of data. In the 2000s, the increased shift to mobile and early smart devices increased the strain on existing IT infrastructure. Creations such as pervasive computing and peer-to-peer overlay networks sought to alleviate some of that strain. However, it wasn't until the mainstream application of cloud computing that true decentralization of IT began, giving end users enterprise-level processing power with increased flexibility, on-demand scalability, and collaboration from anywhere in the world. [19] Yet, with more end users demanding cloud-based applications and more businesses working from multiple locations, it became necessary to process more data outside of the data centre right at the source and manage it from one central location. That's when mobile edge computing became a reality. Edge is a strategy to extend a uniform environment all the way from the core datacentre to physical locations near users and data. Just as a hybrid cloud strategy allows organizations to run the same workloads both in their own datacentres and on public cloud infrastructure (like Amazon Web Services, Microsoft Azure, or Google Cloud), an edge strategy extends a cloud environment out to many more locations. Edge computing is in use today across many industries, including telecommunications, manufacturing, transportation, utilities, and many others. The reasons people implement edge computing are as diverse as the organizations they support. [20]. Today, the "Era of IoT" is changing how businesses allocate IT for their business, making previously complex data collection less of an arduous task. Edge computing refers to data being analysed locally, at the point of creation. Fog computing encapsulates edge processing as well as the network connections required to bring that data from the edge (point of creation) to its endpoint. [21].

VIII. COMPUTING DOMAIN COMPARISON

a. a Comparison using google trends b.

The search volume of keywords in popular search engines can be used as an indicator of hype of a particular technology. Using the tool Google Trends, provided by Google, we can compare various search terms against each other and view how the search volume changes over time.

The Google Trends on various computing techniques is shown in below figure. It shows 10-year data from 2011 to 2021. Here blue is "parallel computing", red is "cluster computing", yellow is "Grid computing", green is "cloud computing", orange is "Fog computing", turquoise is "Edge computing".

The origin of edge computing can be traced back to the 1990s.By analysing the figure we can say that edge computing stands in first position now with only a slight difference with cloud computing. Fog computing is also in trend now leaving behind cluster, grid and parallel computing.

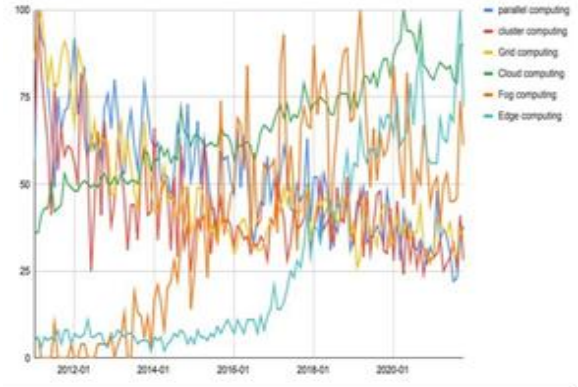


Fig. 2 Comparison of various computing using google trends

b. Usage in different application

The table 1 gives a brief study on where different computing paradigms are used exclusively in different areas. Cloud computing is almost used in most of the sectors in different ways. Cloud Computing in education sector is making both student's and teacher's life easier by enabling the online classes even in the Covid-19 pandemic. By this student can even submit their assignments and do almost many things just like a physical classroom. Government is most likely to protect data and strives to reduce the cost. It makes easier for the government to reduce relying upon IT companies providing infrastructure.

Table 1: Usage in different application

Computing paradigms	Application(sectors)				
	Education	Government	Entertainment	Banking	Finance
Cloud computing	√	√	√	√	√
Parallel computing	√	×	√	×	×
Edge computing	√	√	√	√	√
Fog computing	√	√	√	√	√
Cluster computing	×	×	√	×	√
Grid computing	√	√	×	√	×

The resources are not limited and so does the updates of the applications are much easier. For the sake of batch processing, data storage and data analytics many banks use cloud computing which is much more flexible and reliable. Content acquisition, editing, broadcasting, playing video games have been drastically improved under the entertainment industry due to the cloud computing technology. Globus toolkit that has been a part of grid computing is used for sharing resources, accessing data, providing security, and e- learning

IX. CONCLUSION

The paper discusses about different computing paradigms like parallel computing, cluster computing cloud computing, grid computing, cloud computing, fog computing, and edge computing with brief overview. The comparison is done using Google Trends and usage in different application. Using multiple processors to do a task simultaneously is parallel computing. Interconnected standalone computers working as a single computer for handling intense workloads is cluster computing. Unlike cluster computing, grid computing is a heterogeneous network in which devices have different hardware components and different OS connected together in a grid. Cloud computing provides virtualization of servers, storage, databases, networking, software and analytics, thus providing wide range of web services with a cheaper cost. Fog networking describes a decentralized computing structure located between the cloud and end devices or IoT devices. The deployment of computing and storage resources at the location where data is produced is called Edge computing.

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