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DISTRIBUTED COMPUTING ENVIRONMENTS: A REVIEW

Dr. Sunita Rani
Assistant Professor, Department of CSE & IT,
BPSMV, KhanpurKalan, Sonepat, Haryana, India

Abstract: In the recent years, the applications of distributed computing have been increasingly wide-spread. These computing environments are heterogeneous connected through computing machines to achieve high performance and to solve computational problems. In this paper, author provides a description of various computing paradigms including their definition, characteristics, benefits, applications and challenges. Author summarizes the all latest distributed computing paradigm i.e. green computing, fog computing, edge computing and mist computing.

Keywords: **Distributed computing, grid computing, cloud computing, fog computing, edge computing**

I. INTRODUCTION

In the last few years, we have seen the development of distributed network computing has become an economical, well-known and leading selection to accomplish high performance and to solve computational problems. A computing environment is a group of computing machines that are used to process and exchange data and instruction to resolve various types of computational issues. A distributed computing system is erected by heterogeneous interconnected computing machines which share their resources with each other. Distributed computing is an important component of scientific computing [1]. In distributed computing different parts of programs executed simultaneously on one or multiple machines which are connected to a network and communicating with each other over the connected network. The essential feature of distributed computing is resource sharing and to connect IT resources and users resources in efficient, cost-effective, reliable, scalable, open and transparent way [2] and these resources can be physical resources (computational resources, storage device, and communication capacity) and virtual resources (operating system, tasks, applications, and services).

Distributed computing environment is classified into different types of computing environments [1] [2] [3] [4]

1. Peer-to-Peer Computing
2. Cluster Computing
3. Utility Computing
4. Grid Computing
5. Cloud Computing
6. Jungle Computing
7. Green Computing
8. Fog Computing
9. Edge Computing
10. Mist Computing

II. RELATED WORK

Distributed computing paradigms have been analyzed by many researchers. [4] described the various form of distributed computing and provide definition, characteristics and architecture of different computing environment i.e. cloud computing, jungle computing and fog computing. [5] Explored the efficient and transparent use of jungle computing system and also discussed the fundamental methodologies of existing computing environment. [6] Described similarities and differences of the fog computing and its related computing paradigms and also discussed the fog computing taxonomy and its challenges. [7] described a complete and up-to-date- review of edge oriented computing systems including their architecture, features, management approaches and design objectives. [8] Described the resource management of fog and edge computing environment and also discussed the technical challenges to manage the limited resources in fog and edge computing. [9] analyzed the security threats and challenges for the fog computing, mobile edge computing, and mobile cloud computing.

III. DISTRIBUTED COMPUTING ENVIRONMENTS

1. Peer-to-Peer Computing: Peer- to Peer Computing is decentralized network computing, where peers are connected through ad hoc networks and provide resources to the network [10]. Peer-to-Peer computing mainly works on scalability issues of distributed computing. No master-slave relationship exists among the peers and all peers work as client and server as per requirement [1]. Peer-to-Peer computing is used in file sharing, bioinformatics, artificial intelligence

2. Cluster Computing: Cluster computing is a distributed computing with a collection of interconnected stand-alone computers working together as single integrated computing resources [1][3]. The key components of a cluster computing are personal computers, workstations, operating systems, fast communication protocol, services, and parallel programming environment [11]. Selection of cluster depends on compatibility with cluster hardware and operating system, price, and performance which depends on bandwidth and latency.

3. Utility Computing: Utility computing is simple and based on the principle of centralization and sharing of physical resources [2]. Utility computing provides the facility to users as per their demand and user pay for these facilities. Scalability, high availability, manageability, disaster recovery are some characteristics of utility computing [12]. Utility computing provides the benefits reduced hardware capital expenditure and operational cost. Utility computing solutions consist of virtual server, virtual storage, virtual software, backup and most IT solutions [3]. Utility computing takes the benefits of grid computing, virtualization and provisioning technologies [13]. On demand computing, pay-per-use computing, pay-per-services computing are different types of utility computing.

4. Grid Computing: The main objective of grid computing is to share resources that are available from individuals and institutions in secure and flexible manner and to solve the problem of multi-institutional and virtual organizations [14] [15]. Geographical distribution and heterogeneity of resources, the large scale of infrastructure, resource coordination and sharing, multiple administration, autonomy, scalability, dynamicity are characteristics of grid computing [16]. Grid computing system is classified into various categories [17] [18]: Computational Grid, Distributed supercomputing grid, High-throughput grid, Scavenging grid, Data grid, Service grid, On-demand grid, Collaborative grid and Multimedia grid. The grid computing has a wide set of applications in engineering, life sciences, physical sciences, commercial areas, research and in other areas [19]. Adaptive applications, real-time and on-demand applications, coordinated applications, poly-application, linked applications and minimal communication applications are the grid applications that use grid resources and grid infrastructure. Main challenges must be taken into consideration [18] for effective implementation of application areas of grid computing: Resource management, Reliability, Security management, Data management, Service management.

5. Cloud Computing: Cloud computing is distributed model with dynamically connected and virtualized resources and cloud computing enables on-demand and convenient access of these virtualized computing resources [20]. Virtualization, on-demand service, elastic computing, resource sharing, large computing power, reliability, security, and easiness are the main characteristic of cloud computing [21] [22]. Cloud computing architecture is based upon layered approach [23]. Amazon Web Services, Salesforce.com, Google App Engine, Azure Services Platform are an example of service providers of cloud computing [2]. Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS), Infrastructure-as-a-Service (IaaS) are three service models for cloud computing [24] [20].Scalability, flexibility, economic, reliability, easiness, higher security, lower cost are benefits [25] provided by cloud computing. Public Cloud, Private Cloud, Community Cloud, and Hybrid Cloud are different types of clouds [20] [26] [27].Cloud computing has a wide range of applications and these applications can be used by consumers at lowest cost. These applications are [26] range from scientific application to engineering applications, medical, biology, gaming, media and social networking, etc. Main issues and challenges [26] related with cloud computing are: Resource Management, Cloud Interoperability and Standards, Security, Trust, and Privacy, and Organizational Aspects.

6. Jungle Computing: Jungle computing supports high level of heterogeneity because it includes various types of computing i.e. grid, cloud, cluster, etc., to achieve maximum performance and minimum complexity [4]. Jungle computing has characteristics [4] [5] of Resource Independence, Middleware independence and interoperability, Robust connectivity and globally unique resource naming, Malleability, System-level fault-tolerance, Application-level fault-tolerance, Parallelization, Integration with external software

7. GREEN COMPUTING: Green computing is environmentally sustainable computing for IT industry. It focuses on the efficiently and effectively management of the all the resources of computer system that do not impact on environment. It includes the four steps: Green Use, Green Disposal, Green Design, Green manufacturing. To create green computing in organizations some actions i.e. virtualization, power saving, telecommuting, VoIP (Voice over Internet Protocol) etc. have taken [28].

Green computing emerges concept towards reducing hazardous material to save environment from harmful impacts of the use of the computers and other electronic products [29].The goals of green computing are power management and energy efficiency, choice of eco-friendly hardware and efficient software, material recycling. Advantages of Green Computing are: Reduced energy usage, Conserving resources, Saving energy and resources saves money, Green computing even includes changing government policy to encourage recycling and lowering energy use by individuals and businesses, Reduce the risk existing in the laptops such as chemical known to cause cancer, nerve damage and immune reactions in humans [30]. Green computing can be achieved by different approaches, i.e. Product longevity, Data center design, Software and deployment optimization, Power management, Materials recycling, Telecommuting, Telecommunication network devices energy indices.

Benefits of green computing are [31]: Reduce energy consumption of computing resources, Reduce carbon emission, Reduce harmful effects of computing resources, Reduce computing wastes, Reduce operational cost, Save energy during idle operation, Use eco-friendly sources of energy, Utilizes resources such as computers, data centers, light, etc. in an environmental friendly way ,Improve corporate image by meeting compliance and regulatory requirements

8. Fog Computing: Fog computing is geographically distributed computing with heterogeneous resources that provide elastic computation, storage and communication in an isolated environment to a large scale of clients in proximity [32]. Fog computing is considered as a non-trivial extension of cloud computing from the core network to the edge network. Hierarchical organization, large-scale sensor network, real-time interactions, support for mobility, edge location, location awareness, low latency are characteristics of fog computing [4]. Applications of fog computing are smart home, smart grid, smart vehicle, health data management and greater business agility, better security, deeper insights with privacy control, lower operating expense are benefits of fog computing [32].

Fog computing is developed to provide support for the Internet of Things (IoT). The concept of Fog computing was first introduced by Cisco in 2012 to address the challenges of IoT applications in conventional Cloud computing [33]. Fog computing faces the challenges in structural issues, service oriented issues and security aspects issues. Servers, networking devices, cloudlets, base station and vehicles are various types of fog nodes. Cluster, Peer –to –Peer and master-slave are these three techniques is used for nodal collaboration in fog computing. Computation time, communication time, data size, data flow, networking cost , deployment cost, execution cost, energy consumption are important factors that play important role in resource and service provisioning. The service level objectives in fog computing are latency management, cost management, network management, computation management, application management, data management, power management. As security vulnerability of fog computing is very high as it resides at the underlying network between end device and cloud datacenters. Authentication, privacy, encryption, DOS (Denial of Service) attack is security concern for fog computing.

9. **Edge Computing:** Edge computing is based on the CDN (Content Delivery Network). Edge computing delivers content from cache servers located at the network edge near to data sources. Edge computing works on the edges of the network and it refers to computation on a variety of systems that are closer to end users. Edge computing has its advantages of shorter response time, better geographical awareness, and more isolation from the outside world, optimized content distribution and etc. [7] Edge computing increases the management, storage and processing power of data generated by connected devices. Edge computing is well equipped to handle privacy, latency and connectivity. Multi-access edge computing (MEC) is an extension of mobile computing through edge computing. Edge computing generally use in local video observation, video collecting and traffic control. Network infrastructure provides operators for edge computing. Power consumption is low and security must be provided on edge computing [6].

10. Mist Computing: Mist computing is lightweight form of fog computing that uses microcomputers and microcontrollers to suckle into fog computing nodes [34]. Mist computing is developed from fog and cloud computing and made from large numbers of heterogeneous devices. In mist computing communication is made through sensors and actuators rather than communication network and the internet. Scalability, machine to machine communication, re-configurability, situation awareness and attention, location self-awareness are basic features of mist computing. Low latency, low mobility, insufficient security, low power, limited communication bandwidth are characteristics of mist computing. [35]. Mist computing is based on the principle of request and use. Information only provided as per the request only. Mist computing have the characteristics of situation awareness, where devices dynamically discovers the data provider and execute the application [36]. Mist computing paradigm has decreased the latency and increases the autonomy of a solution. The collection of different services which are distributed among the computing nods is the application of mist computing [37].

IV. CONCLUSION

Conclusion: In this paper, a brief description of various distributed computing paradigms has discussed. These various different computing environments include its definition, features, characteristics, benefits, application and challenges etc. All computing environments from starting to latest computing environment has been discussed. Latest computing paradigm i.e. fog computing, edge computing and mist computing is discussed

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