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A Review and Classification of Grid Computing Systems

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Abstract

Grid Computing is used for high throughput computing at a lower-cost. It has the ability to accumulate the power of geographically scattered and heterogeneous resources to form a cohesive resource for performing higher level computations. Today's multidimensional and multidomain applications need multiple resources with diverse characteristics, i.e. huge computational power, larger storage capacity, higher processing speed and quicker accessibility of data. In recent past, many Grid Systems emerged in the form of various projects to solve many real-world complex problems. The resources required for efficient and reliable execution of the applications should be selected in accordance with the application requirements. This may be possible by classifying the Grid resources based on their major characteristics. The distinction of various Grid Systems into different categories aims towards supporting resource selection process in accordance with the application requirements. This paper presents a review and the state-of-the-art classification of Grid Systems in the perspective of scheduling and selection. A sequence of Grid System classification is presented based on Application type, Functionality, Scale, and Scope, including a brief study on each type. Finally, concluding remarks provides an assessment of various Grid Systems with the help of information collected from different sources.

Keywords- Grid Computing, Grid Systems, Layered Architecture, Taxonomy, Application, Functionality, Scale and Scope etc.

I. INTRODUCTION

In recent years, the growing requirements of the applications continued to pose tremendous challenges for traditional parallel and distributed computing systems, regardless of the availability of huge parallelism, computing power, multi-core solutions and storage in a single organization or site, such as Top500 project with 13124 cores [2]. New generation complex problems, such as high energy physics, molecular modelling, and earth science, etc. are always in need of more computational power, larger storage capacity, higher processing power and quicker accessibility of data at a lower cost. The need of applications for powerful resources has been met with progresses made in the information processing and communication technologies.

The never ending demands of the user applications could only be addressed through an evolutionary platform. The kind of platform required could only be created by accumulating together the capabilities of numerous heterogeneous, decentralized, local and remote resources, spread across geographical places. In the mid 1990s, an evolutionary platform developed by means of expanding collaborations, coupled with increasing computational and networking capabilities stimulated a new era of computing, called “Grid Computing" [3]. ‘Grid Computing’ can be stated as an abstraction that enables accumulation of very wide range of networked computing systems with the capability of combining processing speed, storage space, etc. of geographically distributed, dynamic available, and heterogeneous resources to provide a secure and user friendly environment for facilitating the execution of users’ applications in an efficient manner, hiding much of its technical details and complexities from the outside world [4]. The basic Grid Computing environment is depicted in figure 2.

The rest part of this paper is organized as follows. Section 2 highlights various computing platforms, common terminologies used in Grid Computing, challenges in Grid Computing and architecture of the Grid Computing platform. Section 3 provides an overview on previous Grid classifications and introduces a proposed classification for Grid Computing Systems. Finally, the conclusion part presents an assessment of the study done on Grid Systems.

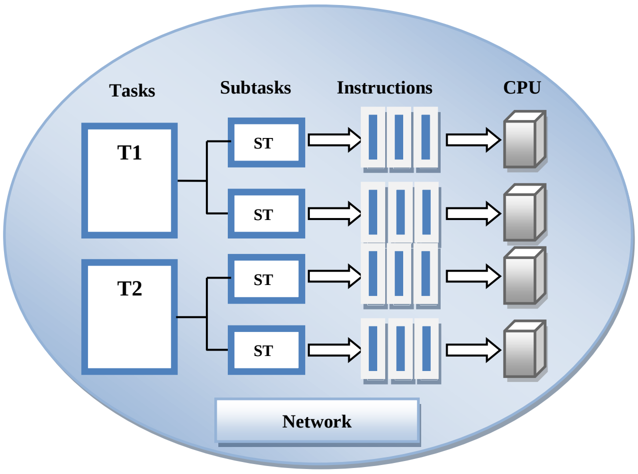

Figure 1. Parallel Computing

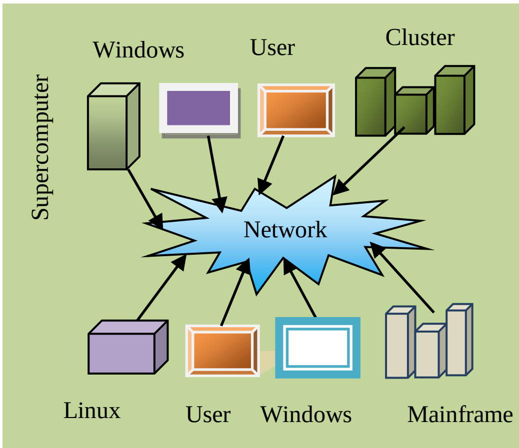

Figure 2. Grid Computing Environment

II. GRID COMPUTING: IT'S EVOLUTION INTO MAIN STREAM COMPUTING

Grid Computing mostly relies on the use of existing computing technologies and maintains a higher degree of correlations among Grid users and Grid technologies. Grid acquires some standardized properties from traditional parallel & distributed systems and appends numerous distinct characteristics of its own. So, Grid inherently maintains a strong relationship with its ancestor, i.e. traditional distributed systems and yet strengthens its existence as an exceeding technology for high performance computing. The concept of Grid computing has transformed the mode of computing than that of a traditional distributed system, i.e. the manner in which the applications were executed and resources were utilized.

A. Grid Computing: Yesterday, Today and Tomorrow

Developing and establishing a new system would not happen in a day or a week, so Grid is not an exception too. The evolution towards Grid has gone through several distinct steps. By 1990s, a standard framework had begun to surface for high performance computing applications. At that time, Super Computers were able to share resources. This may be called the first generation of Grid [5]. The idea of Grid Computing was first envisioned by Leonard Kleinrock in 1969, when he described, "like electricity and telephone utilities, the spread of computer utilities will be extended to individual homes and offices across the country" [6] [7]. In the beginning, Grid was introduced in the form of distributed supercomputing platform for managing mathematically intensive problems. The term "Grid" was used during the mid-90's to symbolize a proposed distributed computing infrastructure for advanced science and engineering projects [8]. It refers to systems and applications that integrate resources and services distributed across multiple control domains [3]. If one considers the internet as a network of communication, Grid Computing can be considered as the network of computation [9]. The Grid offers a next generation platform for high performance computing, analogous to a power Grid that supplies consistent, pervasive, dependable, and transparent access to electricity, irrespective of where it is generated [10].

In the late 1990s, the momentum was towards the development of Grid Middlewares. The main purpose of the Grid Middleware is to link several Grid technologies for resource sharing [3]. The major innovation in Grid was initiated through the collaboration of technology domains. Grid with the power of web technologies tends to provide transparent access and easy management of resources with the notion of virtual organizations. Today's Grids are developed to incorporate the concept of soft computing to make the Grid Systems more intelligent and automatic. Integrating Grid with Service Oriented Architectures and various business models may lead towards next generation Grid. In future, it is not only about the speedup, performance, increased collaboration or dealing with growing size of data, but also doing these things elegantly with intelligence [11].

B. Grid Computing System vs. Other Computing Systems

In the era of 1980s, the technological innovations revolutionized the whole perception of how computing was done. The technological momentum was intended towards fabrication of high-performance processors, high-speed communication networks and the development of standard tools for high performance distributed computing [12]. The availability of such technologies at a moderate price leads to the development of Cluster Computing, which is shown in figure 3 [21]. The distinguishable features of

Cluster Computing are – a) It supports high bandwidth, b) Low latency in inter-process communication and c) MPI (Message Passing Interface).

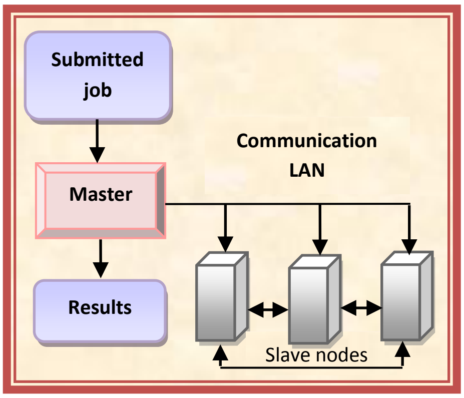

Figure 3. Cluster Computing

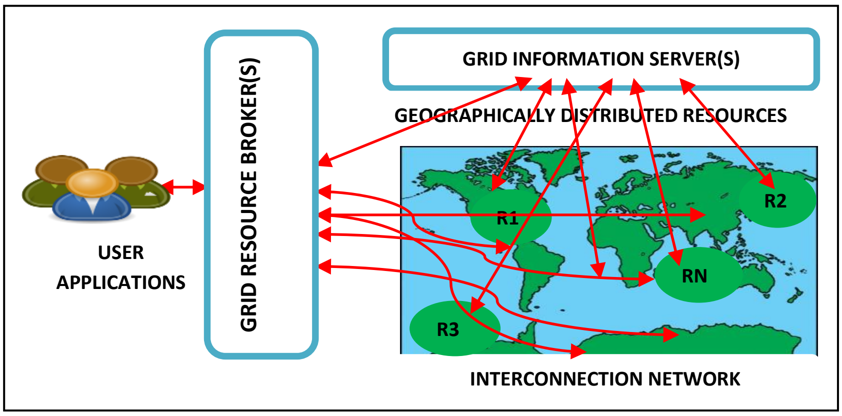

Figure 4. Grid Computing Systems

Grid Computing and Cluster Computing [1] are almost similar in terms of application performance and resource sharing. In case of Cluster Computing, not only computing nodes are homogeneous in nature (in terms of hardware and software configuration), but also tightly coupled over a local area network. In contrast, Grid is a distributed, heterogeneous and dynamic environment, wherein computing nodes are dispersed over several geographical domains, performing high performance computing only. Clusters are built using commodity-off-the-shelf (COTS) hardware components and software configuration. Clusters can be incorporated as a part of the Grid by linking several Clusters available over a dispersed area. Traditional Distributed Computing System usually manages hundreds or thousands of computing nodes that may be individually more limited in their memory availability and processing capability. In contrast, the nodes on a Grid can be more loosely-coupled, e.g. they may span across multiple administrative domains. Grid includes multiple distributed processing environments scattered over a local, metropolitan, or wide-area networks as depicted in figure 4 [21, 17].

Cloud Computing performs large-scale Distributed Computing, which is known as the superset of Grid Computing. It exhibits infrastructures and services that are delivered on-demand basis to the customers via the internet, which is presented in figure 5. Cloud involves a pool of resources, working together, and controlled by the resource managers.

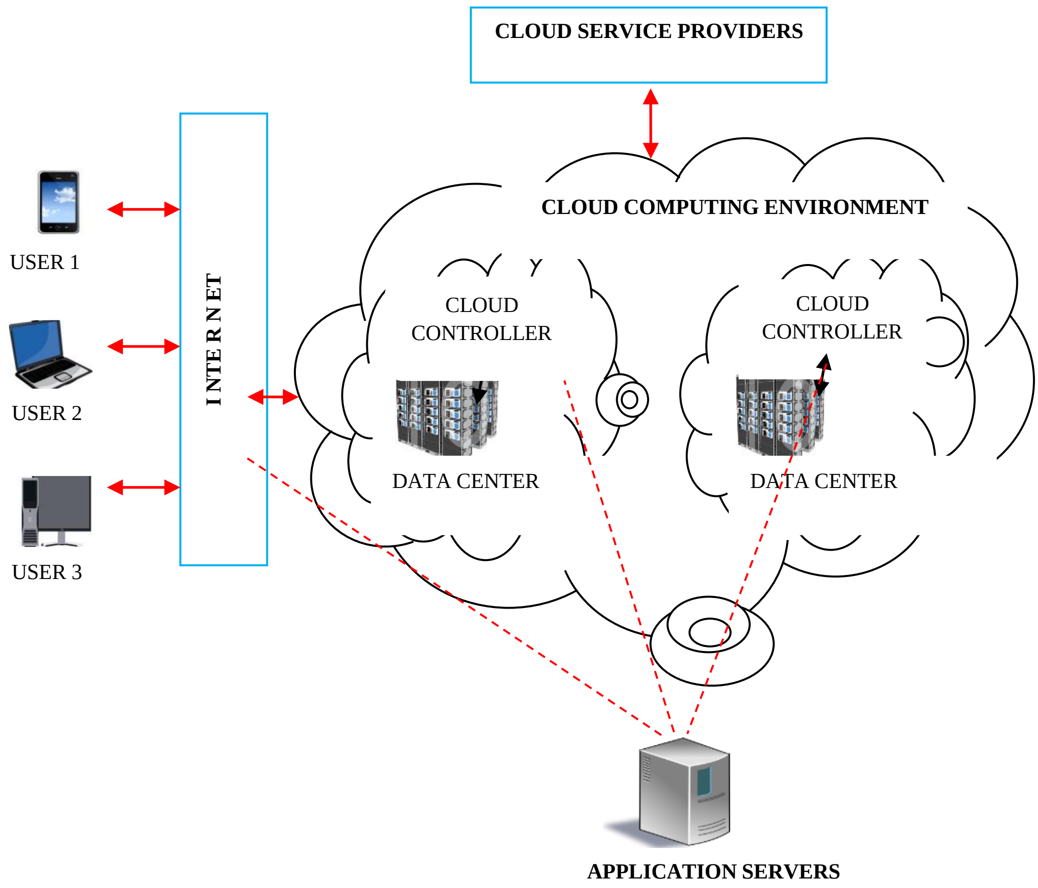

Figure 5. Cloud Computing Environment

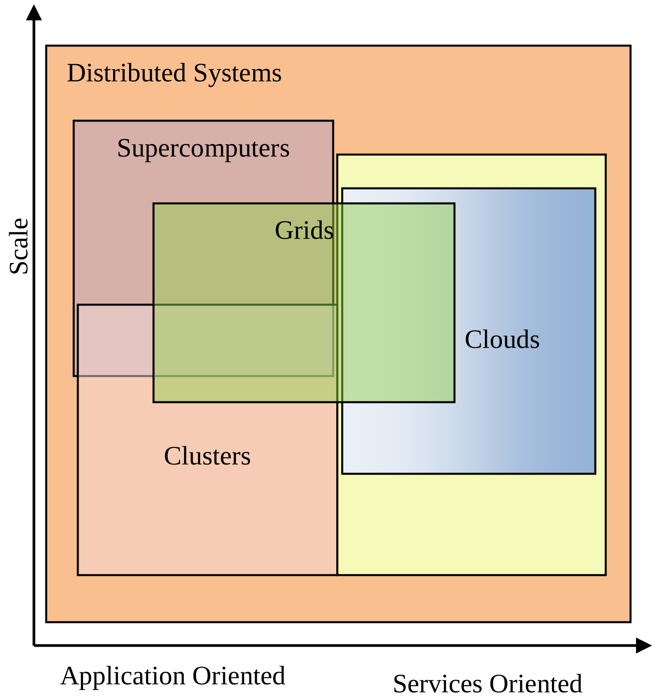

Figure 6. The Relationship among various Computing Platforms

It follows the concept of pay-per-use model, in which services are made available to the customers' on-demand basis. It offers effortless access and economical use of efficient technologies. Cloud Computing is the most recent and evolving technology in the world of networking. It comprises data centers that are owned by the same organization, like Amazon's application. In contrast to Grid Computing, Cloud maintains the feature of homogeneity within each data center. It provides a high level of abstraction (eliminate details), more scalability, unlimited resources, real-time services, single ownership, faster transmission and transparency in contrast to Grid [13]. Different type of computing platforms and their relationship with each other is depicted in figure 6 [13]. Computing platforms that overlap with Web 2.0, mainly Cloud computing enclose entire spectrum of service-oriented applications, whereas Supercomputing and Cluster Computing platforms are mostly centered on traditional non-service oriented applications. However, Grid Computing overlaps with all these domains.

C. Preliminaries of Grid Systems

This section introduces some basic terminologies frequently used for Grid Computing environment [14] [15] [16].

(i) Site: It is an autonomous node formed with a single or multiple numbers of resources.

(ii) Resource: Resources can either be software such as program files, software programs, and so on, or hardware such as processors, computers, display devices, mobile devices or networks of supercomputers, etc. A resource may be a machine, which may contain an individual or multiple numbers of processors to perform job execution. According to the organization, resources are divided into several categories such as, Large Scale, Geographical Distributed, Multiple Administrations Domain, and Heterogeneity. According to the accessing modes, resources are divided into Transparent, Pervasive and Secure access. Based on Resource Allocation, resources are classified as Resource Sharing and Resource Coordination. According to Resource efficiency, it is classified as Scalability, Fault Tolerance, High Performance, Dynamicity, Flexibility and Extensibility.

(iii) Resource Providers: Resources are accessed or used for a particular amount of time. Each resource owner charges the users based on their usage. Resources can be either shared or accessed in an exclusive mode. Resource owners are known to be resource providers or resource managers [18].

(iv) Application: It is a set of jobs or tasks. Usually, a job may be a single unit or a collection of tasks. The term Job or task may be used as a synonym to each other. It can be a collection of dependent jobs like workflow applications or can be independent jobs like atomic applications. Each job may have its own attributes like completion time, execution time, deadline, etc.

(v) Users: The User is known to be a primary component of Grid System. The User submits the applications through user-portal with the required specifications. The Users may specify the requirements such as application types, resource requirements, objectives for optimization, performance models, etc. for the purpose of scheduling.

(vi) Protocols and Interfaces: It provides a set of protocols and necessary interfaces for proper authentication and communication to facilitate an easy and secure access to the Grid resources. Interfaces provide a platform to the Users, Providers and Grid brokers to communicate effectively for selecting and utilizing Grid resources to run the applications.

(vii) Grid Resource Broker (GRB): It acts as an interface between Users and Grid resources with the help of Middleware services. Its basic responsibility is to perform Resource Discovery, Resource Selection and Resource Allocation etc.

(viii) Grid Information Service (GIS): GIS is responsible to collect updated status of available resources in a Grid and provide them as and when required by the users.

(ix) Dispatcher: The basic functionality of Dispatcher is to send the jobs to the corresponding matched resources. The mapping of job(s) to their corresponding resources is decided by some scheduling heuristics. It collects results and other computed information of jobs from the resources [20].

(x) Optimization Criterion: Optimization criterion is specified to make better scheduling decisions for achieving the desired goals. It is supplied in terms of the objective functions to the scheduling problem.

(xi) Quality of Service (QoS): Quality of Service (QoS) is the degree of satisfaction of a customer for using the Grid services at desired level of performance.

(xii) Grid Middleware: The Grid Middleware resides in between Grid applications and networked resources. It manages the execution of Grid applications and provides an interface to the users for accessing preferred computing resources, irrespective of its geographical locations. It offers a collection of Core Services with some User level Services. Middleware is the backbone of a Grid System and facilitates the access to information about various Grid resources [21]. Globus, Legion and UNICORE are some examples of the Grid Middleware. The main constituents of a Grid System are Resource, Application, Users and Protocol-and-Interfaces. Their involvement in a Grid environment is illustrated in the form of a diagrammatic presentation as shown in figure 7.

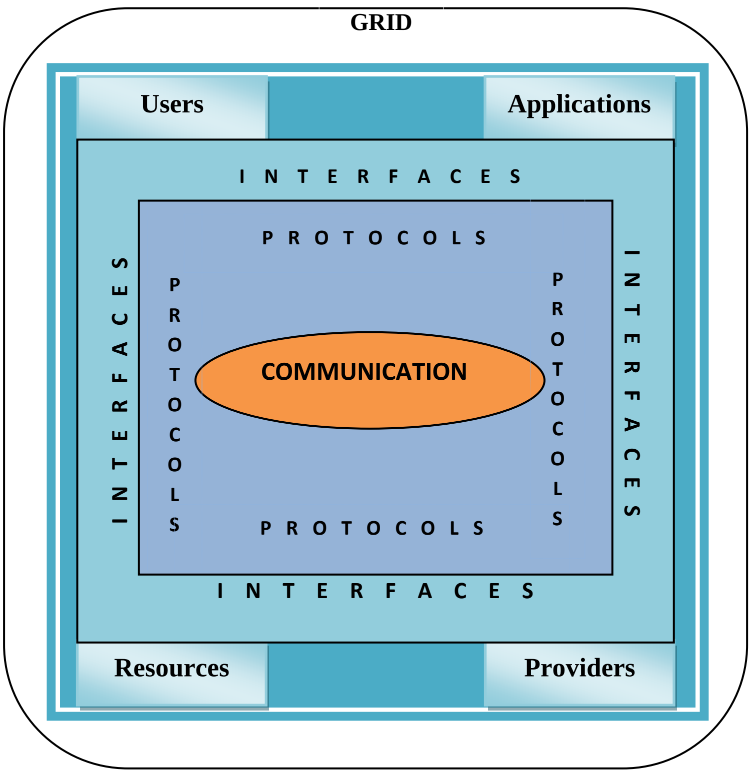

Figure 7. Grid Elements

D. Challenges in Grid Computing

Grid technology is not entirely different from traditional distributed systems. It has got some unique characteristics, including some characteristics inherited from its ancestors. It has got a number of significant challenges. Therefore, realizing the actual potential of the Grid is the real challenge. This is the reason why scheduling in Grid is more challenging than other form of computing paradigm. Various challenges in Grid Computing are taken from [3], [13], [14], [21], [22], [23], [24], [25], [26], [27], [28], [29], [30], [31] and are listed as follows:

(1) Reliability, (2) Robustness, (3) Job Scheduling, (4) Load Balancing, (5) Monitoring of Resources, (6) Availability of Services, (7) Distributed Management, (8) Data Availability, (9) User-friendly Environment, (10) Development of Grid Application, (11) Standard Protocols, (12) Efficient and Problem Solving Methods, (13) Programming Tools and Models, (14) Administration and Management of Grid, (15) Performance Analysis of Grid, (16) Standardization, (17) Interoperability, (18) Centralized Management, (19) Security, (20) Sharing of Applications and Data, (21) Heterogeneity, (22) Autonomy, (23) Performance Dynamism, (24) High Resource Utilization, (25) Multiple Administrative Domain, (26) Scalability, (27) Substrate, (28) Policy Extensibility, (29) Coallocation, (30) Online Control, (31) Adaptability, and (32) Resource Management.

E. A Layered Architecture of Grid System

The major components of Grid Systems necessary for the management of Grid applications, infrastructures and resources are discussed in the articles [21], [10] and [32]. It helps the users to connect the essential resources, without knowing its geographical locations. A layered architecture of Grid System is shown in figure 8. The various layers of Grid System architecture are underlined as follows:

(i) Fabric Layer: It is at the bottom of the layered architecture. It comprises geographically distributed and sharable resources such as storage devices, computing devices, high bandwidth networks and scientific instruments, etc. These resources are accessible from anywhere in the internet.

(ii) Connectivity Layer: This layer is responsible to provide an easy and secure access of the resources through some standardized protocols. Protocols are necessary to provide proper authentication and communication. The authentication protocols are used to provide proper verification of users and resources with the help of some cryptographic mechanisms. The communication protocols provide a mechanism for transmission of data between the fabric and the resource layer.

(iii) Resource Layer: This layer is used to specify the necessary protocols to operate among shared resources. It is primarily built upon the communication and authentication protocols of connectivity layer. It defines the APIs (Application Program Interfaces) and SDK (Software Development Kit) to make secure the initiation, accounting, negotiation, controlling and monitoring of resources.

(iv) Collective Layer: It is used for common functional utilities. The operations such as collaboration among the shared resources are performed in this layer. It provides services like brokering, monitoring, scheduling, discovery, replication and co-allocation, etc.

(v) Application Layer: It is placed at the top of this layered architecture. This layer offers communication interfaces to the users and the administrators for interacting with the Grid.

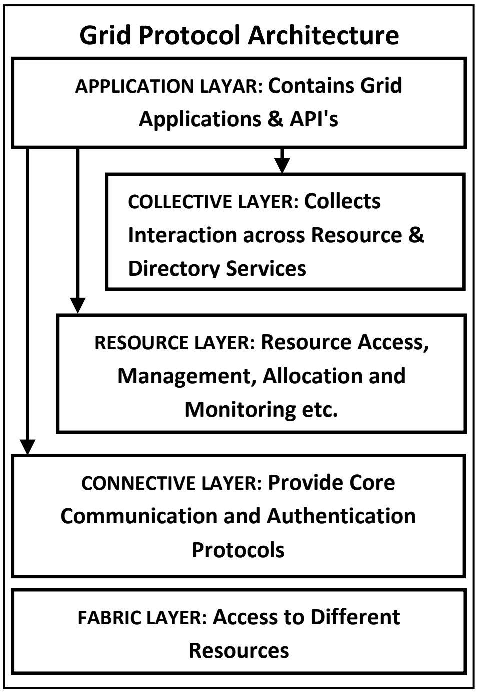

Figure 8. Layered Architecture of Grid System reproduced from [21], [71]

III. A STATE-OF-THE-ART SURVEY AND CLASSIFICATION OF GRID SYSTEMS

Classification of Grid Systems implies taxonomic grouping of Grid Systems in a hierarchical manner. The classification is possible from knowledge acquired on those systems and then identifying the common characteristics. In the following section, some features used in existing classifications are surveyed and some new features are identified to make the proposed classification.

A. Recent Works

In the recent past, a few studies have been carried out on classification of Grid Systems. The article in [33] classifies the Grid Systems based on the notion of design objectives, i.e. (i) Improving application performance (ii) Data access, and (iii) Enhanced service. In this classification, Grid System is classified as the Computational, Data and Service Grid. A state of the art categorization is also reported in [33]. The rapidly evolving Grid technologies motivates the authors to identify the shortcomings of the previous generation Grids while considering the most apparent design features of emerging Grids. So, their classification includes primitive features as well as the features identified by European experts. The parameters used for Traditional Grid Systems classification are Size and Solutions. The emerging features are Accessibility, User-Centricity, Interactivity, and Manageability. The classification of Grid Systems Presented in [34] depends on the convenient usage of substantial Grid resources. According to the convention, Grid System is classified as, National, Private, Project, Goodwill, Peer-to-Peer, and Consumer Grid. National Grids are established over the internet to allow the use of Grid resources for a single national problem. Private Grids are relatively small and generally built for hospitals, corporation, and small firms. Project Grids are solely dedicated to multi-institutional research groups in a particular project. Goodwill Grid is created by anyone at home by donating their spare computing capacity. Peer-to-Peer Grid System is only concerned for sharing of data between two parties with a central control. In Consumer Grid, resources are shared on a commercial basis. A technical report titled “A Survey on Grid Scheduling Systems” classifies Grid Systems into three categories, i.e. Computational Grid to achieve highest aggregate computational power, Data Grid to access data around multiple organizations and Storage Grid to aggregate the additional storage space in Grid environments [22].

B. Proposed Classification of Grid Systems

In the recent past, Grid Computing is becoming more multifaceted with the inclusion of new Grid technologies and resources in the form of various projects, and more so by the day. The fast evolving Grid technologies need periodic attention to keep track of recent developments in the field of Grid computing. Grid System classification reported in this paper is a necessary initiative towards the recent developments made in the state-of-the-art Grid technologies. An updated classification may help to promote (i) Further Research, (ii) Better Support for Multi-Domain Applications, (iii) Improved Data and Resource Management for new applications, (iv) Allocation of Resources based on users’ QoS requirements, and (v) Secure and Pervasive Access. In this paper, Grid System classification presents recent initiatives made in the areas of Grid Computing and its related technologies. In this paper, the features identified for facilitating Grid classification includes Type of Application, Functionality, Scale, and Scope.

C. Taxonomy based on Type of Applications

Many Grid Systems around the globe have infrastructure set-up to perform diverse applications, which are effectively functioning to provide potential, consistent, and integrated services. It is helpful to note that a number of projects from different application fields, viz. research, scientific, commercial, academic, and health-care, etc. have diverse requirements in terms of (i) Resources, (ii) QoS requirements, (iii) Services, and (iv) Grid environments, etc. such as research, scientific, commercial, academic, healthcare, etc. have different types of requirements, in terms of (i) Resources, (ii) QoS requirements, (iii) Services, (iv) Grid environments, etc. Application types belonging to major disciplines are identified for categorizing various Grid Systems.

Many Grid Projects are studied and classified based on the following disciplines, which is shown in figure 9 and Table 1.

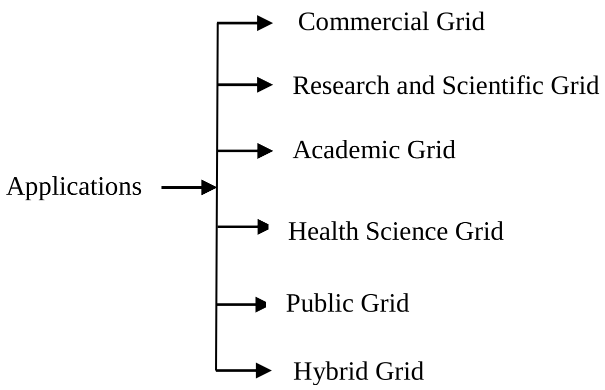

Figure 9. Taxonomy of Grid Systems based on type of Applications

1) Commercial Grids: Grid Computing has become an important platform for commercial applications. The popularity and benefits extended by Grid technologies [76] have attracted lots of interests among the business communities to use it for minimizing the cost of business operations. It is not only because of its low cost, but also for better use of computing resources for high performance computing. Since, the growth and the scope of business operations are becoming more and more consumers centric, commercial enterprises need better integration of their operations to provide quick response for better management of market dynamics and consumer demands. Commercial Grid is managed by specific business entities for running commercial applications to meet a particular set of business goals.

Today's e-commerce occupies a range of applications that are used in data centers and application clusters to distribute workloads of the applications [35]. Various Commercial Grid projects such as IBM Grid, Sun Grid Engine and HP Grid, and so on [23] are listed in Table 2.

2) Research & Scientific Grids: In these days, the contribution of Grid Computing towards research and scientific communities around the globe is impressive. It is providing huge computing and storage functionalities for research and analysis. The characteristics of Grid such as Parallel computing ability, Availability, Scalability, Reliability, Higher efficiency, Lower-cost and Resource-balancing provide a potential platform for leveraging research and scientific activities.

There exist some Grid Systems that are primarily established for contributing towards science and research projects, e.g. particle physics, astronomy, cosmology, fusion and nuclear physics, etc. [36]. Research and Scientific projects are mentioned in Table 4. SETI@home is one such exciting example that is meant for large scale global extraterrestrial scientific project, whose goal is to detect intelligent life outside the earth. The project initiated by University of California together with Sun Microsystems, Planetary Society, and others uses the accumulated power of both Data-Intensive and Compute-Intensive Grids Table 3.

3) Academic Grids: In Socio-technical sense, Grid may be used in academics to leverage research activities beyond state boundaries, i.e. making it available to the geographically dispersed students and researchers belonging to various educational organizations. The contribution of Grid in academics is twofold. In one hand, it supports many educational needs and on the other, it gives a platform for research activities in academics through sharing of information. Academic Grid offers high performance computing with faster access to huge storage space. The contribution of Grid in Education is accomplished through virtualization of classrooms, multimedia applications, the digitization of books and the e-book applications [37]. Distance and Higher Education is one such academic field that can be benefited by the use of large scale recorded tutorials and video lectures that may be made available through various applications. The use of Grid in academics promotes an interactive way of sharing knowledge through collaborative learning, classroom virtualization, report presentation and P2P discussions [36], etc.

Examples of research activities in Academic Grids like Discovery of Largest Prime Number, Game Theory, Geometry Rectilinear Crossing No. of 18 pts, Wrapper to help saving, RC5-72, Motion of Objects in Physics, Nano Technology, and Biotechnology are given in Table 4. The article "ITR: Distance Collaboration-Education and Training on the Access Grid" states that Academic Grid application in education signifies a motivated venture in a way that considerably boosts the ability of groups to cooperate and realizes a sense of collaborative community even though they are dispersed across the planet [38]. A few other Academic Projects are also given in the Table 4.

4) Health Science Grids: In these days, due to the availability of high performance computing technologies at a lower cost, Grid computing is more integrated into our lives than ever before. It has strengthened itself as an exceeding paradigm for providing solutions in many spheres of our real life problems. So, health care is not an exceptional one. Massive parallel processing as well as growing data requirements of the applications related to health science takes only a few hours of time to complete the work with the help of Grid computing than that would otherwise take months and years without it. The use of Grid in health science may be an effective platform for its higher computing ability, huge storage facility and faster access. The intended platform facilitates the sharing of medical data among the members of healthcare systems around the world in a secure manner. This could potentially help the physicians and researchers of different continents to work together on a large amount of medical data. The analysis of huge medical data would help them to discover new ways of diagnosis and could become an excellent tool for prescribing faster treatment to patients, regardless of their geographical locations. Beginning from a patient's heart monitoring to the disease investigation, molecular structure analysis of protein to the development of new pharmaceutical drugs and taking images of the body’s organs to determine the type of treatments, Grid computing plays an important role in every field of biomedical science [39].

A few successful Health Science projects are "Compute against Cancer" concentrate on Cancer research, "FightAIDS@Home" focused on HIV and AIDS research and some more is given in the Table 5.

5) Public Grids: It is mainly based on the concept of non-commercial service platform, like public distributed systems that offer greenest and cheapest computing platform. It relies on the availability of surplus CPU cycles and storage space, etc. donated by the world-wide home computers to solve complex problems related to public issues. The accumulated potential of the Grid extends wide range of services for the public on a non-commercial basis. For example, BURP (Big and Ugly rendering project) is known to be the volunteer Grid software that is used for rendering of 3D images and animation submitted by the users. Other significant projects of this category are Charity Engine and Hun grid [40], presented in Table 6.

6) Hybrid Grids: A Grid that is capable of providing services towards diverse disciplines is termed as Hybrid Grid. It is capable of providing services to more than one discipline. For instance, Akogrimo project widely applied in Business, Education and Health-Science. Similarly, TeraGrid is another platform widely applied in Research, Education and Health-Science. The Grids with hybrid nature are provided in Table 7.

D. Taxonomy based on Type of Functionality

Resources in Grid Systems are best described by their major characteristics. The Functionality of Grid System describes those attributes of Grid resources that are expected to fulfill the key requirements of the applications. Alternatively, Functionality is the one type of service provided by the Grid Systems to their users. The Functionality of Grid Systems is specified in Table 2, 3, 4, 5, 6, and 7. Thus, Functionality of the Grid System can be classified as shown in figure 10.

1) Compute Intensive Grids:

Compute-Intensive Grids are most preferably to offer computational types of resources to their users. Major Functionality of this Grid is to offer powerful CPU resources, whereas other characteristics are trivial. It intends to provide aggregated CPU cycles of several resources for fulfilling computational need of a particular application. The application developed to factorize huge integers in CROWN project is an example of compute-intensive problem [41]. Some other applications like fluid dynamics, weather modelling, nuclear simulation, molecular modelling, and complex financial analysis requires computational power as their main requirements. The Compute-Intensive Grid can be further classified as shown in Figure 11.

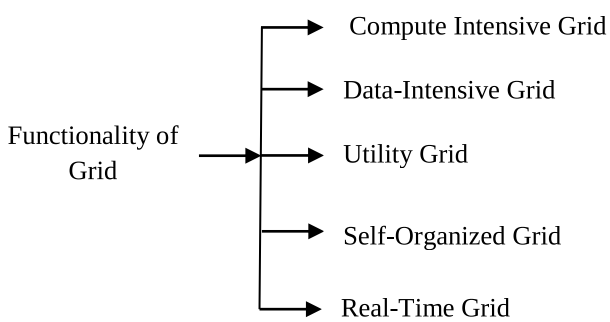

Figure 10. Taxonomy of Grid Systems based on the type of Functionality

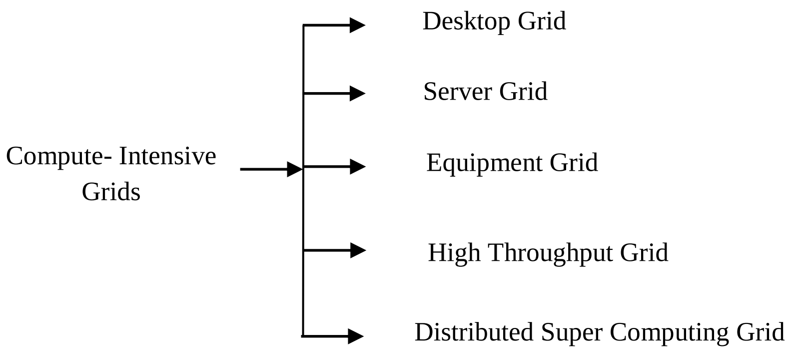

Figure 11. Taxonomy of Compute-Intensive Grid

Geographically dispersed desktop computers can be logically assembled to provide a substantial amount of resources to the Grid users. This form of computing is called Desktop Grid. But resources are limited in case of Server Grid where only those resources are available which are connected to the server.

The Grid may include equipments or electronic instruments such as the world wide telescope [4]. It uses Grid infrastructure to collect, analyze and categorize data from many individuals and from remotely connected telescopes in global level to make various observations. This is called Equipment Grid.

High Throughput Grid is used to schedule large numbers of independent jobs, with the goal of maximizing throughput, for instance Montecarlo simulations [42] [43]. It provides enough computing power by the accumulation of unused processor cycles from idle workstations or other type of systems.

Distributed Supercomputing uses multiple machines for faster execution of applications in parallel to minimize the completion time of jobs. Weather modeling and nuclear simulation are two examples of compute-intensive problems that require Distributed Supercomputing Grid.

2) Data Intensive Grids:

Data-Intensive Grid offers large storage space for data discovery, data management and data processing. Functionality of Grid for data intensive applications describes storage as its principal resource characteristics. Various types of data from around the world such as digital libraries, data houses and data repositories are consistently distributed over several administrative domains across diverse geographical regions. Grid users perform various operations on the huge amount of distributed data. Data Grid is intended to provide, (a) A mechanism for reliable data transfer, (b) A scalable replica discovery and management system [44], (c) A Meta-data management system [23], and (d) A data filtering and reduction technique [23].

DSS (Digital Sky Services) is an example of data intensive applications, where it needs at least 60 GB space to store a variety of data collected through the use of space telescope [45]. Generally, Data-Grid deals with massive sets of data [23]. One such experimental Data-Grid is mentioned in [46], where CMS (Compact Muon Solenoid) at the LHC produces 1 PB (1015 bytes) of raw data and 2 PB of event summary data (ESD) on an annual basis. Similarly, High energy physics applications need to process massive data generated (in the order of GB/second) through an experiment that uses the LHC (Large Hadron Collider). The two popular Data-Grid initiatives, CERN Data-Grid and Globus are working on developing large-scale data organization, catalog management, and access technologies.

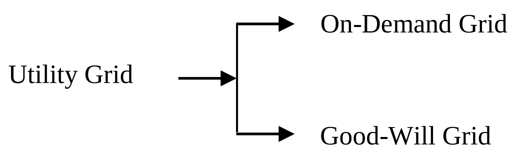

Figure 12. Taxonomy of Utility Grid

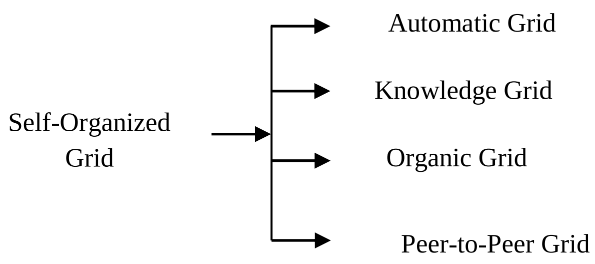

Figure 13. Taxonomy of Self-Organized Grid

3) Utility Grids:

Utility Grid pools dynamically available resources to match the requirements of the applications. This enables the Utility Grid to provide services that cannot be provided by any single machine. The services provided, can be Pay-Per-Use service model or Public service model as classified in figure 12. Usually, Pay-Per-Use model is called On-Demand Grid, which is meant for the commercial and business purpose and its usage is determined by cost-performance concerns rather than absolute performance.

The Public-Service model is accessible at free of cost such as Good-Will Grids. Its main aim is to provide services for a good cause. The resource requirement is fulfilled by collecting voluntary donation of computing power, which is contributed by anyone owning a computer. So far, this is limited to "@home" projects.

4) Self-Organized Grid:

Grid management is extremely challenging due to its complex dynamic environment. However, Self-Organized Grid includes some intelligence embedded into its infrastructure to automate its control, organization, and monitoring procedure. It can heal itself in changing and uncertain environments for maximizing reliability and resource utilization. It can be categorized into Autonomic Grid [50], Knowledge Grids [3], Organic Grids [51] and Peer-to-Peer Grids as shown in Figure 13.

Autonomic computing [52] imitates the human body's autonomic nervous system, which is initiated by IBM in 2001. The purpose of the system is to manage the functioning of Grid without any intervention from the users and thus hides most of its complexities from the outside world. Some examples are the AutoMAGI [53] and IBM Optimal Grid [54].

Knowledge Grid is a logical extension of Modern Grid, which uses the knowledge related technologies to define data, services and resources in a distinct manner. It uses semantic metadata for interpretation and then presenting in a format that is recognized by both the machines as well as the humans. The well known knowledge Grid projects are InteliGrid (www. Inteli grid.com), K-Wf Grid (www. Kwfgrid.eu) and OntoGrid (www.ontogrid.net /ontogrid /index.jsp), etc.

Organic Grid is in the beginning phase of its development. It is based on a decentralized based approach and known to be a novel framework for Desktop Grids. It uses the concept of ant colony concept where mobile agents interact to form various complex patterns. The main components involve distributed scheduling strategy, mobile agents and decentralized point-to-point technique. Organic Grid [55] is an example of one such Grid.

Peer-to-peer Grid technology [51], [56] is used to connect several computers that allow easy sharing of data and files among them. It uses decentralized approach, i.e. sharing without going through a central server.

5) Real Time Grid:

Traditional Grid could not support certain requirements of many real time applications. Technological advancement with increasing number of real time applications initiated the emergence of Grids for real time applications. It provides an infrastructure that can deal with the rich variety of real time interactions between the users and the applications through virtual workspace. Therefore, Grids that support Real time applications such as disaster management, e-healthcare, e-learning etc. can be termed as Real-Time Grid. The taxonomy of Real-Time Grid is shown below in Figure 14.

The Adhoc Grid is a platform, where heterogeneous computing nodes are cooperatively assembling to form a logical structure without having any prior configuration of fixed infrastructure. It incurs minimal administrative controls [57]. The Adhoc Grids can dynamically build an infrastructure by gathering nodes with high resource capability [58]. Generally, Adhoc Grid is defined by its adhoc nature rather than nodes' mobility [59]. However, if it is defined by the nodes' mobility nature [58] [61], then it is referred to as Mobile-Adhoc Grid.

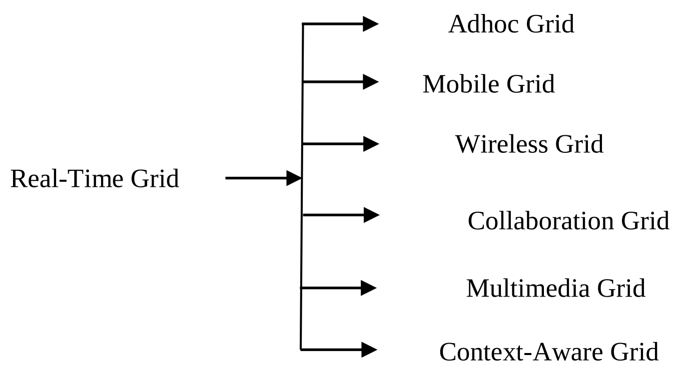

Figure 14. Taxonomy of Real Time Grid

The Wireless Grid is formed by establishing the resource sharing networks with the deployment of wireless devices of varying sizes and capabilities. Wireless devices such as mobile phones, wireless sensors, edge devices and laptops are connected with wired Grids to establish the communication between Grid nodes. The devices may be mobile or nomadic but perform storage and processing of data same as actual Grid nodes [62]. Some examples of Wireless Grids are Office Grid, Home Grid, etc. There are some Wireless Grids in which all wireless devices are used as pure access points without having any processing or storage capability [63]. So, the resources required for processing or storage ability may be obtained from a backbone Grid.

Mobile Grids are mobile devices such as smart phones to access various Grid services. It is useful in situations, where users are mobile in nature. The increasing sell of mobile devices and their limitations in terms of storage, processing power and connectivity, etc. are quite relevant for Mobile Grid environment [64]. Some examples of Mobile Grids are MADAM (Mobility and Adaptation Enabling

Middleware) and ISAM (Support Infrastructure for Mobile Applications). Details regarding Mobile Grid challenges can be found in [64] [65], [53] and [67]. Various techniques for implementing Mobile Grids can be referred from [65], [53], [67], [56], [68] and [69].

Multimedia Grid offers an infrastructure for supporting real-time multimedia applications. Deploying Multimedia applications on many resources need to maintain QoS among them, but deploying the same on a single resource does not need to maintain any QoS [70].

Collaborative Grid is a typical Real-Time Grid that enables real-time interactions between human-to-human and human-to-applications, and that communication pattern lead to form some collaborative workgroups by the use of virtual services [33].

Context-Aware Grid infrastructure is formed using a network of wireless sensors and then integrating it into the main Grid infrastructure. Wireless Sensors quickly adapt to a given surroundings when deployed in a large geographical area to collect real time data, and thus quite useful for real time monitoring and surveillance. It allows sharing of computational resources for the processing and management of sensor data. Tasks such as environmental and habitat monitoring, weather monitoring, healthcare monitoring, military surveillance, homeland security surveillance, etc. can be benefitted from Context-Aware Grid [71] Some projects like Discovery Net [72] [73], SENSE (Smart Embedded Network of Sensing Entities) [71] are the examples of Context-Aware Grid.

E. Taxonomy based on Scale

The number of users' participation in a Grid System defines its scale. Based on this, Grid System is further categorized into three broad categories, such as small scale (S), medium scale (M), and large scale (L) Grid, which is shown in Figure 15. Grid Systems based on Scale are given in Table 2, 3, 4, 5, 6, and 7.

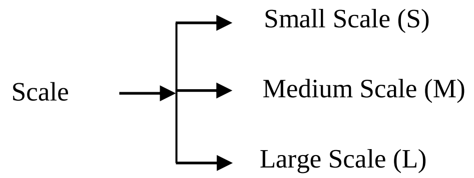

Figure 15. Taxonomy of Grid Systems based on Scale

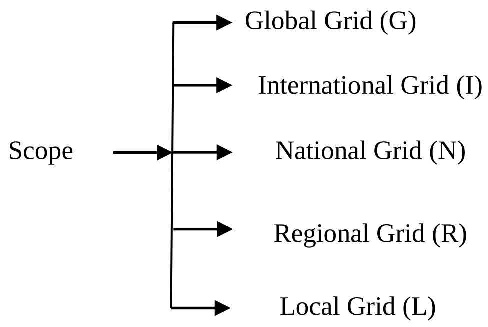

Figure 16. Taxonomy of Grid Systems based on the Scope

F. Taxonomy based on Scope

The meaning of Scope in the context of Grid refers to "reachability", i.e. from one node to another node within its defined boundary. According to Scope, Grid can be identified into four different categories such as Global (G), International (I), National (N), Regional (R) and Local Grid (L) as depicted in Figure 16. Scope of various Grid Systems is given in Table 2, 3, 4, 5, 6, and 7.

In Global Grids, a number of scientists, academicians and researchers of different nationalities from around the globe may participate in a Grid Project and may need to collaborate for a common interest. It is termed as a globally functioning project. One such project from Research and Scientific branch is Einstein@Home (http://boinc.berkey.edu/wiki/Einstein@Home) that has been concerned with the detection of gravitational wave emission and sky research.

International Grids spans over the national boundaries and they are connected through internet. International Grid is such a Grid, where the scientists and researchers come together to participate in projects that can be initiated from anywhere within the Grid boundary, but its functioning is managed by many participants belonging to different nations. The remarkable growth in network technologies made the international Grid a reality. This helps to send and share large amount of data among Grid users across the national boundaries to support end-to-end processing [74]. International Grids are similar to InterGrid [22]. Folding@Home (http://folding.stanford.edu) is one such international Grid Project, whose domain covers protein folding, molecular dynamics and disease research.

In case of National Grid, computing resources available within a country or within a national boundary are connected through internet to form a powerful Grid called National Grid. Enterprise Grids are similar to National Grids. The Grid System is formed by acquiring computing resources from across the regions of that particular country, over and above providing the services only to the stakeholders of that concerning country. Human Proteome folding-phase-II is one such project initiated by and operating from Institute for System Biology, New York University, U.S.

The Regional Grid is formed with resources belonging to more than one administrative domain within a region, which are connected through MAN. Regional Grid allows all its members to access the resources within a defined or regional boundary. For example, more than one departmental Grid belonging to different organizations can be connected to MAN to form a Regional Grid. Africaclimate@Home (www. Worldcomm unitygrid.org/research/arch/details.do) is a project that only focuses on African Climate.

In a Local Grid, Computing Resources within a single organization are linked through the local area network (LAN). Usually, Local Grid also called Campus Grid is confined within a single administrative domain consisting of relatively static set of resources and offers bandwidth guarantee. Some small organizations, colleges, departments also come under Local Grid, where computing resources are only available for the members within the organization. Some Local Grid projects are Leiden classical, Lattice project, etc.

G. Origin of Grid Systems

The term Origin mentions the place, institution or nation, etc. from where the Grid Project is initiated. The Origin of different Grid Projects is provided in Table 2, 3, 4, 5, 6, and 7.

IV. CONCLUSIONS

In this paper, the emergence of Grid System and its evolution into mainstream usages have been discussed. The rest of the paper presented a comprehensive review for classifying some popular Grid Computing Systems. The Survey and Classification has been introduced in the perspective of scheduling and selection in Grid scheduling environment. The assessment includes 51 Grid projects for analysis and classification. Grid system classification and sub-classifications based on the application, functionality, scale and scope of Grids are presented in the form of pi-charts as shown in Figure 17, 18, 19 and 20 respectively from the data available in Table 2, 3, 4, 5, 6, 7 respectively. Out of this 23%, 20%, 61% projects fall into Academic, Research-and-Scientific, and Compute-Intensive respectively as depicted with the help of pie-charts in Figure 17 and 18. Apart from this, it has been analyzed that 51% and 32% of the Grid Projects are Large Scale and Regional Scope respectively, which are shown in Figure 19 and 20 respectively in the from pie-charts. The classification of Grid Systems could help to develop mechanisms for resource discovery and resource selection according to the application requirements and user constraints. It has been observed that different types of Grid resources are suitable for different scenarios and is suggesting the necessity of resource selection in Grid scheduling environment.

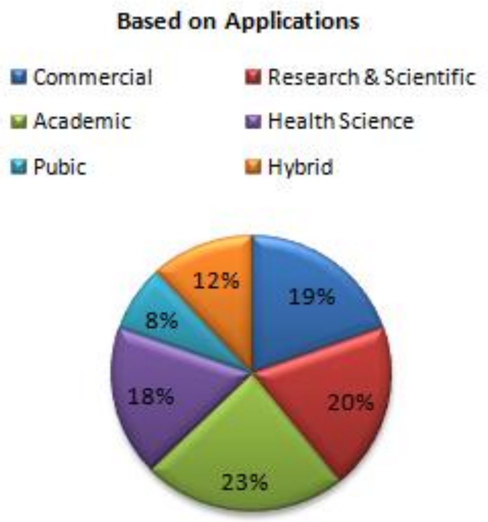

Figure 17. Pie-chart based on Applications

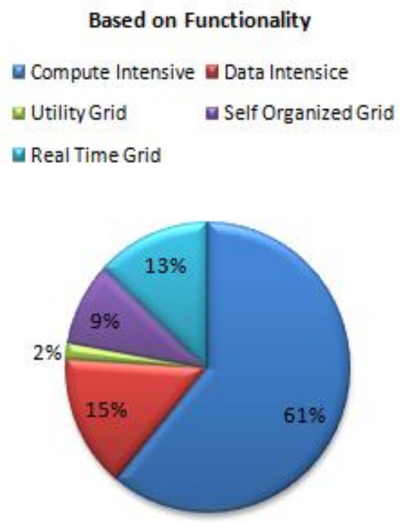

Figure 18. Pie-chart based on Functionality

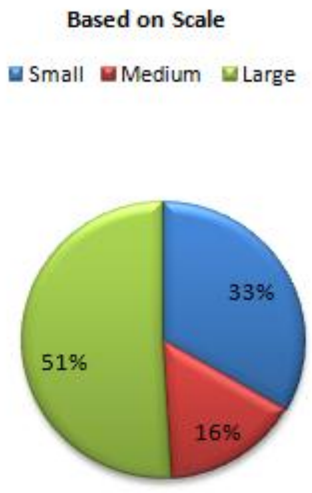

Figure 19. Pie-chart based on Scale

Figure 20. Pie-chart based on Scope

Table 1. Taxonomy of Grid Systems

1. Application	**2. Functionality**					**3. Scale**	**4. Scope**
Commercial Grid	Compute Intensive Service	Data Intensive Service	Real Time Service	Utility Service	Self organized Grid	Large	Global
Academic Grid							
Research & Scientific Grid	Desktop Grid		Adhoc Grid	On Demand Grid	Automatic Grid	Medium	International
Health Science Grid	Server Grid		Mobile Grid	Good will Grid	Knowledge Grid	Small	National
Public Grid	Equipment Grid		Wireless Grid		Organic Grid		Regional
Hybrid Grid	High Throughput Grid		Collaboration Grid		Peer-to-Peer Grid		Local
	Distributed Super Computing Grid		Multimedia Grid				
			Context Aware Grid				
			Explicit Grid				

Table 2. Commercial Applications

COMMERCIAL APPLICATIONS						
Project Name	**Domain**	**Scale**	**Scope**	**Origin**	**Functionality**	**Remarks**
Alchemi	Constructing and deploying several science and commercial applications on the enterprise	L	G	Melbourne University, Australia	Compute Intensive	http://www.cloudbus.org/~alchemi/
Grenade	Web portals, Industrial Applications, Desktop Environment	M	N	University of Manchester, Manchester, UK	Compute Intensive	http://www.rcs.manchester.ac.uk/research/grenade
Harmony	To optimize world transactions, Enterprise applications, enterprise IT	L	G	University of Southern Maine	Compute Intensive	
Condor	Work load management system	L	R	University of Wisconsin Madison	Compute Intensive	http://research.cs.wisc.edu/htcondor
XTerm Web	Scientific issues and applications, to explore scientific issues, desktop grid	L	G	University Paris Sud	Compute Intensive	http://www.XtremWeb.net
SETI@Home	Extraterrestrial Intelligence	L	G	Space Science Laboratory, University of California, US	Compute Intensive	http://setiathome.ssl.berkeley.edu
MP Grid System	Enterprise IT	L	G	United Devices Company, Austin, Texas	Compute Intensive	http://www.ud.com/rescenter
Entropia	Molecular docking, sequence analysis, chemical structure modeling, and risk management	L	I	University of California, San Diego	Compute Intensive	http://www.entropia.com

Sun Grid Engine/ Oracle Grid	Enterprise IT	L	G	Sun Microsystems and later Oracle	Compute Intensive	http://www.oracle.com/us/products/tools/oracle-grid-engine-075549.html
Akogrimo	Business	L	R	EC under the FP-6-IST program	Real time	www.mobilegrids.org

Table 3. Research & Scientific Applications

RESEARCH AND SCIENTIFIC APPLICATIONS						
Project Name	**Domain**	**Scale**	**Scope**	**Origin**	**Functionality**	**Remarks**
ClimatePrediction.net	Climate Research	L	G	Oxford University, England	Data Intensive	http://climateprediction.net
SETI@Home	Extraterrestrial Intelligence	L	G	Space Science Laboratory, University of California, US	Compute Intensive	http://setiathome.ssl.berkeley.edu
Einstein@Home	Sky Research	L	G	California Institute of Tech, Germany	Compute Intensive	http://boinc.berkey.edu/wiki/einstein@Home
Africaclimate@Home	Climate Research	L	R	University of Cape town, UK	Compute Intensive	www.worldcommunitygrid.org/research/arch/details.do
LHC@Home	Nuclear Research	L	G	Europe	Data Intensive	http://lhcathomeclassic.cern.ch/sixtrack
Cosmology@Home	Astronomical, particle Physics data	L	G	University of Illinois at urban a campaign	Compute Intensive	http://www.cosmologyathome.org/
Leiden Classical	Motion of Object, Physics	S	L	Leiden University	Compute Intensive	http://boinc.gorlaeus.net
Spinhenge	Nano Technology, Biotechnology	M	L	University of Applied Science Bielefeld	Data Intensive	http://spin.th-bielefield.de/
MindModeling@home	Cognitive process to understand mind	S	L	Cognitive Engg. .research institute	Selective	http://mindmodeling.org/beta/
TeraGrid	Gateway toolkit Geosciences	S	R	Sun, IBM, Oracle, HP, Intel	Compute intensive	www.xsede.org/home/tg-archives

Table 4. Academic Applications

ACADEMIC APPLICATIONS						
Project Name	**Domain**	**Scale**	**Scope**	**Origin**	**Functionality**	**Remarks**
GIMPS	Discovery of Largest Prime No	S	I	Central Missouri State University, U.S	Compute Intensive	www.mersenne.org
Chess 960	Game theory	S	I	Developed by Bobby Fisher	Compute Intensive	www.chess960athome.org/

ABC@Home	Greatest open problem in Mathematics	S	I	Mathematical Institute of Leiden university	Compute Intensive	www.abcathome.com
Rectilinear Crossing	Geometry Rectilinear Crossing No. of 18 pts	M	I	Austria	Compute Intensive	http://dist.ist.tugraz.at/cape5/
Moo! Wrapper	Wrapper to help saving RC_5-72	M	I	Teemumanner maa	Compute Intensive	http://moowrap.net/
Leiden Classical	Motion of Object, Physics	S	L	Leiden University	Compute Intensive	http://boinc.gorlaeus.net
Spinhenge	Nano Technology, Biotechnology	M	R	University of Applied Science Bielefeld	Data Intensive	http://spin.th-bielefield.de/
WEP-M+2 (Wireless 2)	Number Theory	S	L	London, UK	Compute Intensive	http://bearnot.is_a_queek.com/wireless
Access Grid	E-learning, Multimedia	L	G	Argonne National Laboratory	Compute Intensive/Real Time	burp.renderfarming.net
TeraGrid	Solve the problem of emerging terascale applications	S	R	Sun, IBM, Oracle, HP, Intel	Data intensive	www.xsede.org/home/tg-archives
Akogrimo	E-Learning	L	R	EC under the FP-6-IST programme	Real time	www.mobilegrids.org
Our Grid	Sweep Simulation, Optimization algorithm	S	G	Federal University of Campina Grande (Brazil)	Real time	www.ourgrid.org

Table 5. Health & Science Applications

HEALTH AND SCIENCE APPLICATIONS						
Project Name	**Domain**	**Scale**	**Scope**	**Origin**	**Functionality**	**Remarks**
Compute Against Cancer	Cancer Research	L	G	National Cancer Institute, West Virginia University, University of Maryland	Compute Intensive	http://globalgridexchange.com/grid/projects/cal.aspx or www.gridcafe.org
FightAIDS@Home	HIV and AIDS Research	L	G	Olson Laboratory, The Script Research Institute	Compute Intensive	http://fightaidsathome.org/
Folding@Home	Protein Folding, Molecular dynamics	S	I	Stanford University	Compute Intensive	http://folding.stanford.edu
Human Proteome Folding-phase 2	Protein Structure Prediction	M	N	Institute for System Biology, New York University	Compute Intensive	www.worldcommunitygrid.org/researchpf2/details.do
Lattice Project	Evolutionary relationship based on DNA sequence data	S	L	Laboratory of Molecular Evolution, University of Maryland	Compute Intensive	http://boinc.umiacs.umd.ed.ul/
Docking@Home	HIV research, development of Pharmaceutical drug	L	G	National Science foundation, INNOBASE, University of	Compute Intensive	http://docking.cis.udel.edu/

				Delaware		
HealthGrid	Medical and Biomedical applications	L	G	France	Service Intensive	http://www.healthgrid.org/
TeraGrid	To study drug interactions with cancer cells	S	R	Sun, IBM, Oracle, HP, Intel	Data intensive	www.xsede.org/home/tg-archives
Akogrimo	Healthcare services (e.g. chronic diseases),	L	R	EC under the FP-6-IST programme	Real time	www.mobilegrids.org

Table 6. Public Applications

PUBLIC APPLICATIONS						
Project Name	**Domain**	**Scale**	**Scope**	**Origin**	**Functionality**	**Remarks**
The Charity Engine	Idle cycles into a charity supporting a super computer	L	G	Manchester, England, UK	Compute Intensive	www.charityengine.com
Hun grid	Job submission storage services, Information Systems and Web interface	M	N	Hungary	Selective	grid.kfki.hu/hungrid/mainen.html
BURP(Big and Ugly rendering project)	Rendering 3D Animation	S	I	Laurea University of applied Science	Real Time	burp.renderfarming.net
Our Grid	Image rendering	S	G	Federal University of Campina Grande (Brazil)	Real time	www.ourgrid.org

Table 7. Hybrid Applications

HYBRID APPLICATIONS						
Project Name	**Hybrid Nature**	**Scale**	**Scope**	**Origin**	**Functionality**	**Remarks**
Our Grid	Academic, Public	S	G	Federal University of Campina Grande (Brazil)	Real time	www.ourgrid.org
Akogrimo	Commercial, Academic, Healthcare Environment	L	R	EC under the FP-6-IST programme	Real time	www.mobilegrids.org
Accessgrid.org	Research & Scientific, Academic	L	G	Argonne National Laboratory	Compute Intensive	burp.renderfarming.net
TeraGrid	Research & Scientific, Health Science, Academic	S	R	Sun, IBM, Oracle, HP, Intel	Data intensive	www.xsede.org/home/tg-archives
SETI@Home	Research & Scientific, Commercial	L	G	Space Science Laboratory, University of California, US	Compute Intensive	http://setiathome.ssl.berkeley.edu
Spinhenge	Academic, Research & Scientific	M	R	University of Applied Science Bielefeld	Data Intensive	http://spin.th-bielefield.de/

REFERENCES

[1] Greg Pfister, "In Search of Clusters", 2nd Edition, PTR, NJ, 1998.
[2] "TOP500 Supercomputing Sites;", http://www.top500.org, 2014.
[3] Ian Foster and Carl Kesselman, “The Grid: Blueprint for a New Computing Infrastructure;” Elsevier Inc., Singapore, Second Edition 2004.
[4] M. K. Mishra, P. Mohanty and G B Mund, "A Time-Minimization Dynamic Job Grouping-based Scheduling in Grid Computing;", International Journal of Computer Applications, , Published by Foundation of Computer Science, New York, USA, 40, 16 (February 2012), pp. 16-25.
[5] H. Kurdi, M. Li, and H. Al-Raweshidy, “A Classification of Emerging and Traditional Grid System;” IEEE Computer Society, 9, 3, 2008.
[6] Jeremy M. Norman (edited), "From Gutenberg to the Internet: A Sourcebook on the History of Information Technology", 2005.
[7] L.Klienrock, “UCLA press release”1969.
[8] I.Foster, and C. Kesselman, "Globus: a metacomputing infrastructure toolkit;"International Journal of High Performance Computing Applications,2,(1997), pp. 115– 128.
[9] Myer, Thomas, “Grid Computing: Conceptual Flyover for Developers”, http://www- 106.ibm.com/developerworks/library/gr-fly.html gridsrc.pdf, May 2003.
[10] M. Baker, R. Buyya, D. Laforenza, “Grids and Grid Technologies for Wide-area Distributed Computing;” Software Practice & Experience, 32, 15, 2002, 1437-1466.
[11] Elias Kourpas, "Grid Computing: Past, Present and Future-An Innovation Perspective", IBM, 2006.
[12] Chee Shin Yeo, Rajkumar Buyya, Hossein Pourreza, Rasit Eskicioglu, Peter Graham, Frank Sommers, "Cluster Computing: High-Performance, High-Availability, High-Throughput Processing on a Network of Computers", 2006.
[13] I. Foster, Y. Zhao, I. Raicu and S. Lu, “Cloud Computing and Grid Computing 360-Degree Compared”, IEEE Grid Computing Environments Workshop, 2008, pp. 1-10.
[14] F. Dong, S.K. Akl, "Scheduling algorithms for grid computing: State of the art and open problems;", Technical Report No. 2006-504, School of Computing, Queen’s University, Canada, January 2006.
[15] Dalibor Klusacek. "Scheduling in Grid Environment;" PhD thesis, Masaryk University, Brno, 2008.
[16] Jca Ksrce, Survey On Grid Scheduling, Journal of Computer Applications, 3, 3, (July - Sept 2010), pp. 22-29.
[17] R. Buyya, D. Abramson, J. Giddy, “An Economy driven Resource Management Architecture for global Computational power Grids;”, PDPTA, 2000.
[18] Rajkumar Buyya, Steve Chapin, and David DiNucci, "Architectural Models for Resource Management in the Grid;", 2000.

[19] Raksha Sharma, Vishnu Kant Soni, Manoj Kumar Mishra, Prachet Bhuyan, “A Survey of Job Scheduling and Resource Management in Grid Computing;” World Academy of Science, Engineering and Technology, 64, 2010, pp. 461-466.

[20] Manoj Kumar Mishra, Yashwant Singh Patel, Yajnaseni Rout, G.B. Mund “A Survey on Scheduling Heuristics in Grid Computing Environment;” I.J. Modern Education and Computer Science, 10, 2014, pp. 57-83.

[21] Parvin Asadzadeh, Rajkumar Buyya, Chun Ling Kei, Deepa Nayar, and Srikumar Venugopal,"Global Grids and Software Toolkits: A Study of Four Grid Middleware Technologies" 2004.

[22] Yanmin Zhu, Lionel M. Ni, "A Survey on Grid Scheduling Systems", Technical Report, Department of Computer Science and Engineering, Shanghai Jiao Tong University, 2013.

[23] Fatos Xhafa, Ajith Abraham, "Meta-heuristics for Grid Scheduling Problems, Springer", 2008.

[24] I.Foster, “What is Grid? A three point checklist, Grid Today;” 1, 6, 2002, pp. 22-25

[25] Poonam Dabas, Anoopa Arya, "Grid Computing: An Introduction", 3, 3, International Journal of Advanced Research in Computer Science and Software Engineering, 2013.

[26] Heba Kurdi, Maozhen Li, and Hamed Al-Raweshidy, "Grid Computing: A Classification of Emerging and Traditional Grid Systems", IEEE, 9, 3, March 2008.

[27] Shajulin Benedict, Matthias Brehm, Michael Gerndt, Carla Guillen, Wolfram Hesse, Ventsislav Petkov," Automatic performance analysis of large scale simulations;" International conference on Parallel processing,2009, pp. 199-207.

[28] Buyya R., Abramson D., Venugopal S.: The Grid Economy. Proceedings of the IEEE, 93, 3, 2005, pp. 698-714.

[29] Arenas, A., "State of the art survey on trust and security in Grid computing systems", Technical Report (RAL-TR-2006-008), 2006.

[30] Huaglory Tianfield, "Towards Agent Based Grid Resource Management", IEEE International Symposium on Cluster Computing and the Grid, 2005.

[31] Junyan Wang, Yuebin Xu, Guanfeng Liu, Zhenkuan Pan, and Yongsheng Hao, "A New Resource Discovery Mechanism with Negotiate Solution Based on Agent in Grid Environments", The 3rd International Conference on Grid and Pervasive Computing -Workshops, 2008.

[32] S. Venugopal, R. Buyya, and K. Ramamohanarao,” A taxonomy of Data Grids for Distributed Sharing management and processing;”, ACM Computing surveys, 38,1, April 2006), pp. 1-53.

[33] K. Krauter et. al. in “A taxonomy and survey of grid resource management systems for distributed computing", 2004.

[34] Rakesh Kumar et al., "Job Scheduling in Grid Computers" IJCA, 2007, pp. 65-69.

[35] S Haque, Enterprise Grid Computing: A Potential IT Infrastructure for Small Business Enterprises, 2010.

[36] "Grid Computing in Research and Education", IBM, 2005, http;// ibm.com/red books.

[37] Access Grid http:// www.accessgrid.org

[38] Morton et al "ITR: Distance Collaboration - Education and Training on the Access Grid", http://www.motlabs.com/user/papers/crystamProjectSummaryFinal.pdf.

[39] Grid Talk, "The future of healthcare: e-health and grid computing", 2009.

[40] József Patvarczki, Gergely Debreczeni, Róbert Lovas, István Lagzi, Péter Kacsuk, Tamás Turányi, MTA SZTAKI "The introduction of HunGrid and its application for air pollution forecast", 2005.

[41] "CROWN Project", 2005, http:// www.crown.org.cn/en.

[42] D. Abramson, J. Giddy, and L. Kotler. 'High performance parametric modeling with nimrod/g: Killer application for the global grid? ;" In 14th International Parallel and Distributed Processing Symposium (IPDPS 2000), April 2000.

[43] R. Buyya, D. Abramson, and J. Giddy. Nimrod/G: "An architecture for a resource management and scheduling system in a global computational Grid", Int'l Conference on High Performance Computing in Asia-Pacic Region (HPC Asia 2000), May 2000.

[44] Chervenak et al., Giggle: A framework for constructing scalable replica location services. IEEE/ACM Conference on Supercomputing (SC ’02), 2002.

[45] "DSS", 2005, www.crownresearch.com/California.htm.

[46] Holtman, K. et al. "CMS Requirements for the Grid;", In Proceedings of 2001 Conference on Computing in High Energy Physics (CHEP 2001), Beijing, China, Science Press, 2001.

[47] "On-demand computing: What are the odds?;", ZD Net, Nov 2002

[48] Ovaise Khan, “Types of Grid”, 2005.

[49] C. S. Yeo, M. Dias de Assuno, J. Yu, A. Sulistio, S. Venugopal, M. Placek, and R. Buyya, "Utility Computing and Global Grids", Hossein Bidgoli (ed), The Handbook of Computer Networks, Wiley Press, USA, April 2006.

[50] J. Joseph and C. Fellenstein, "Grid Computing", IBM Press, 2004.

[51] A.J. Chakravarti, G. Baumgartner, and M. Lauria, “Self-Organizing Scheduling on the Organic Grid;,” Int’l J. High Performance Computing Applications, 20, 1, 2006, pp. 115–130.

[52] J.O. Kephart and D.M. Chess, “The Vision of Autonomic Computing,” Computer, 36, 1, 2003, pp. 41–50.

[53] A. Sajjad et al., “AutoMAGI—An Autonomic Middleware for Enabling Mobile Access to Grid Infrastructure,” Proc. Joint Int’l Conf. Autonomic and Autonomous Systems and Int’l Conf. Networking and Services, 2005, pp. 73–79.

[54] T.J. Lehman and J.H. Kaufman, “OptimalGrid: Middleware for Automatic Deployment of Distributed FEM Problems on an Internet-Based Computing

Grid;," Proc. IEEE Int'l Conf. Cluster Computing, IEEE Press, 2003, pp. 164–171.

[55] A.J. Chakravarti, G. Baumgartner, and M. Lauria, "The Organic Grid: Self-Organizing Computation on a Peer-to-Peer Network;," IEEE Trans. Systems, Man, and Cybernetics Part A: Systems and Humans, 35, 3, 2005, pp. 373–384.

[56] L. d.S. Lima et al., "Peer-to-Peer Resource Discovery in Mobile Grids," Proc. 3rd Int'l Workshop Middleware for Grid Computing (MGC 05), ACM Press, 2005, pp. 1–6.

[57] T. Friese, M. Smith, and B. Freisleben, "Hot Service Deployment in an Ad Hoc Grid Environment", Proc. 2nd Int'l Conf. Service Oriented Computing (ICSOC 04), ACM Press, 2004, pp. 75–83.

[58] D. C. Marinescu et al., "Ad Hoc Grids: Communication and Computing in a Power Constrained Environment," Proc. 22nd IEEE Int'l Performance, Computing, and Communications Conf., IEEE Press, 2003, pp. 113–122.

[59] K. Amin, G. Laszewski, and A. Mikler, "Toward an Architecture for Ad Hoc Grids;," Int'l Conf. Advanced Computing and Communications (ADCOM 04), 2004.

[60] D. C. Marinescu et al., "Ad Hoc Grids: Communication and Computing in a Power Constrained Environment," Proc. 22nd IEEE Int'l Performance, Computing, and Communications Conf., IEEE Press, 2003, pp. 113–122.

[61] S. Shivle et al., "Static Allocation of Resources to Communicating Subtasks in a Heterogeneous Ad Hoc Grid Environment," J. Parallel and Distributed Computing, vol. 66, no. 4, 2006, pp. 600–611.

[62] L.W. McKnight, J. Howison, and S. Bradner, "Wireless Grids: Distributed Resource Sharing by Mobile, Nomadic, and Fixed Devices;," IEEE Internet Computing, v8, 4, 2004, pp. 24–31.

[63] S. H. Srinivasan, "Pervasive Wireless Grid Architecture;," Proc. 2nd Ann. Conf. Wireless on-Demand Network Systems and Services, IEEE CS Press, 2005, pp. 83–88.

[64] T. Phan, L. Huang, and C. Dulan, "Challenge: Integrating Mobile Wireless Devices into the Computational Grid," Proc. 8th ACM Ann. Int'l Conf. Mobile Computing and Networking, ACM Press, 2002, pp. 271–278.

[65] K. Ohta et al., "Design and Implementation of Mobile Grid Middleware for Handsets," Proc. 11th Int'l Conf. Parallel and Distributed Systems (ICPADS 05), IEEE CS Press, 2005, pp. 679–683.

[66] Ali Sajjad, Hassan Jameel, Umar Kalim, Young-Koo Lee, Sungyoung Lee "A Component-Based Architecture for an Autonomic Middleware Enabling Mobile Access to Grid Infrastructure;," Proc. Embedded and Ubiquitous Computing Workshops (EUC 2005), LNCS, Springer, 3823, 2005, pp. 1225–1234.

[67] Bhagyavati and S. Kurkovsky, "Emerging Issues in Wireless Computational Grids for Mobile Devices", Proc. 8th World Multiconf. Systemics, Cybernetics, and Informatics (SCI-2004), www.cs.ccsu.edu/~stan/research /Grid/Pubs/SCI2004.pdf.

[68] S. Kurkovsky, Bhagyavati, and A. Ray, “Modeling a Grid-Based Problem-Solving Environment for Mobile Devices,” J. Digital Information Management, 2, 2, 2004, pp. 109–114.
[69] D.C. Chu and M. Humphrey, “Mobile OGSI.NET: Grid Computing on Mobile Devices”, Int’l Workshop Grid Computing, IEEE CS Press, 2004, pp. 182–191.
[70] K. Nahrstedt, H. Chu, and S. Narayan. "Qos-aware resource management for distributed multimedia". Journal on High-Speed Networking (Special Issue on Multimedia Networking), Dec. 2000.
[71] Ma, Y.; Richards, M.; Ghanem, M.; Guo, Y.; Hassard, J., "Air Pollution Monitoring and Mining Based on Sensor Grid in London". Sensors 8, 6, 2008.
[72] M Ghanem, Y Guo, J Hassard, M Osmond, M Richards , "Sensor grids for air pollution monitoring;", 3rd UK e-Science All Hands Meeting, Nottingham, UK, 2004.
[73] M Richards, M Ghanem, M Osmond, Y Guo, J Hassard,"Grid-based analysis of air pollution data;", Ecological modelling, 2006.
[74] "Grid Café", 2014, http://www.gridcafe.org.
[75] I.Foster, C. Kesselman, and S.Tuecke, "The Anatomy of the Grid: Enabling Scalable Virtual Organizations", International Journal of High Performance Computing Applications, 15, 2, 2001.
[76] Manoj Kumar Mishra , Yashwant Singh Patel, "The Role of Grid Technologies: A Next Level Combat with Big Data", Chapter Techniques and Environments for Big Data Analysis, 17, Springer series Studies in Big Data, Springer International Publishing, 2016, pp. 181-191.

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