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Evolution of an Inter University Data Grid Architecture in Pakistan

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Abstract: *This paper presents an overview of a proposed grid architecture that interconnects the university campuses in Pakistan. The aim of this grid architecture is to provide access to the heterogeneous and scattered data resources, such as storage, cache and main memory by creating a virtual data store. The proposed grid is expected to facilitate research, scientific and development projects in the country. Due to resource constraints, provision of such facilities at one place is difficult to achieve in case of Pakistani universities. Keeping in view the utility and applications of data grids, a coordinated Inter-University Data Grid Infrastructure (UDGI) for Pakistani universities, has been proposed for harnessing the storage of multiple machines distributed across the networks. We provide some the details of the proposed architecture while the development, testing and implementation will be carried out in near future during the second phase of the project.*

1. INTRODUCTION

The concept of "Grid" is relatively new in the areas of distributed computing and data management. The concept was introduced in 1990's. Grid can be conceived as next generation distributed computing, providing open, standardized platform for computing, services and resources sharing in dynamic environments. We focus on investigating and proposing a collaborative research and development computing architecture between multiple universities/ institutions which requires coordinated sharing of services and resources in real-time. The coordinated resource sharing and problem solving in dynamic multi-institutional virtual organizations is the main issue in any grid design [1]. The type of sharing we are concerned with are direct access to computers, software, data, and other resources, as is required by a range of collaborative problem-solving and emerging resource brokering strategies. This sharing has to be highly controlled, with defined, clear and careful objectives by resource providers and consumers explaining what is shared, who is allowed to share, and the conditions under which sharing occurs. A set of individuals and/or institutions defined by such sharing rules form a virtual organization (VO).

In general, a grid system coordinates resources that are not subject to centralized control, using standards, open, general purpose protocols and interfaces to deliver non-trivial qualities of service [2]. These characteristics can be used to evaluate any system classified as a grid system. Grid computing is an infrastructure to harness the idle computing and data resources scattered across the networks. Grid computing, most simply stated is distributed computing taken to the next evolutionary level. The goal is to create the illusion of a simple yet large and powerful self managing virtual computer out of a large collection of connected heterogeneous systems sharing various combinations of resources [3, 4].

Grid systems can be classified into computational grids and data grids. Computational grids involve sharing heterogeneous resources (based on different platforms, hardware/software architectures, and computer languages), located in different places belonging to different administrative domains over a network using open standards. In short, it involves virtualizing computing resources. A data grid is a grid computing system that considers access to distributed data as important as access to distributed computational resources. Many distributed scientific and engineering applications require access to large amounts of data (of the order of terabytes or petabytes). Future applications are envisioned to require widely distributed access to data. For example, access in many places by many people for virtual collaborative environments allowing data grids to support scientific and engineering collaborations [5].

Pakistan Educational Research Network (PERN) [7] is a countrywide educational intranet connecting premiere educational and research institutions of Pakistan .Our study includes evaluation of various features of data grid implementations utilizing PERN. The scope and limitations of grid implementation will be evaluated using standard benchmarks. Our research identifies the issues and proposes the solutions pertaining to resource look-up, retrieval, administration, and coordination in UDGI.

In this section, next we highlight the distinction between grid and contemporary technologies including, standards, protocols, theoretical frameworks/ architectures, and programming interfaces/ toolkits available for grid implementation. Section 2 provides a general overview of data grids and we provide some information about existing data grid implementations in section 3. PERN features including network design and connection are presented in section 4. This section also includes the details of proposed UDGI architecture.

1.1 Grid and Contemporary Technologies

The concept of controlled, dynamic sharing within VOs is so fundamental that we might assume that grid-like technologies must surely already be widely deployed. In practice, however, while the need for these technologies is indeed widespread, in a wide variety of different areas we find only primitive and inadequate solutions to VO problems. In brief, current distributed computing approaches do not provide a general resource-sharing framework that addresses VO requirements. Grid technologies distinguish themselves by providing this generic approach to resource sharing thus leading to numerous opportunities for the application of grid technologies [6].

1.1.1 World Wide Web

The ubiquity of Web technologies (i.e., IETF and W3C standard protocols—TCP/IP, HTTP, SOAP, etc.—and languages, such as HTML and XML) makes them attractive as a platform for constructing VO systems and applications. However, while these technologies do an excellent job of supporting the browser-client-to-web-server interactions that are the foundation of today's Web, they lack features required for the richer interaction models that occur in VOs.

For example, today's Web browsers typically use TLS for authentication, but do not support single sign-on or delegation. Clear steps can be taken to integrate grid and web technologies. For example, the single sign-on capabilities provided in the GSI extensions to TLS would, if integrated into web browsers, allow for single sign-on to multiple web servers. GSI delegation capabilities would permit a browser client to delegate capabilities to a web server so that the server could act on the client's behalf. These capabilities, in turn, make it much easier to use web technologies to build "VO Portals" that provide thin client interfaces to sophisticated VO applications. WebOS addresses some of these issues.

1.1.2 Application and Storage Service Providers

Application service providers, storage service providers, and similar hosting companies typically offer to outsource specific business and engineering applications (in the case of ASPs) and storage capabilities (in the case of SSPs). A customer negotiates a service level agreement that defines access to a specific combination of hardware and software. Security tends to be handled by using VPN technology to extend the customer's intranet to encompass resources operated by the ASP or SSP on the customer's behalf. Other SSPs offer file-sharing services, in which case access is provided via HTTP, FTP, or WebDAV with user ids, passwords, and access control lists controlling access. From a VO perspective, these are low-level building-block technologies. VPNs and static configurations make many VO sharing modalities hard to achieve.

Means it is typically impossible for an ASP application to access data located on storage managed by a separate SSP. Similarly, dynamic reconfiguration of resources within a single ASP or SPP is challenging and, in fact, is rarely attempted. The load sharing across providers that occurs on a routine basis in the electric power industry is unheard of in the hosting industry. A basic problem is that a VPN is not a VO: it cannot extend dynamically to encompass other resources and does not provide the remote resource provider with any control of when and whether to share its resources. The integration of Grid technologies into ASPs and SSPs can enable a much richer range of possibilities. For example, standard Grid services and protocols can be used to achieve a decoupling of the hardware and software. A customer could negotiate an SLA for particular hardware resources and then use Grid resource protocols to dynamically provision that hardware to run customer-specific applications. Flexible delegation and access control mechanisms would allow a customer to grant an application running on an ASP computer direct, efficient, and securely access to data on SSP storage—and/or to couple resources from multiple ASPs and SSPs with their own resources, when required for more complex problems. A single sign-on security infrastructure able to span multiple security domains dynamically is, realistically, required to support such scenarios. Grid resource management and accounting/payment protocols that allow for dynamic provisioning and reservation of capabilities (e.g., amount of storage, transfer bandwidth, etc.) are also critical.

1.1.3 Enterprise Computing Systems

Enterprise development technologies such as CORBA, Enterprise Java Beans, Java 2 Enterprise Edition, and DCOM are all systems designed to enable the construction of distributed applications. They provide standard resource interfaces, remote invocation mechanisms, and trading services for discovery and hence make it easy to share resources within a single organization. However, these mechanisms address none of the specific VO requirements listed above. Sharing arrangements are typically relatively static and restricted to occur within a single organization. The primary form of interaction is client-server, rather than the coordinated use of multiple resources. These observations suggest that there should be a role for Grid technologies within enterprise computing. For example, in the case of CORBA, we could construct an object request broker (ORB) that uses GSI mechanisms to address cross-organizational security issues. We could implement a Portable Object Adaptor that speaks the Grid resource management protocol to access resources spread across a VO. We could construct Grid-enabled Naming and Trading services that use Grid information service protocols to query information sources distributed across large VOs. In each case, the use of Grid protocols provides enhanced capability (e.g., inter omain security) and enables interoperability with other (non-CORBA) clients. Similar observations can be made about Java and Jini. For example, Jini's protocols and implementation are geared toward a small collection of devices. A "Grid Jini" that employed Grid protocols and services would allow the use of Jini abstractions in a large-scale, multi-enterprise environment.

1.1.4 Internet and Peer-to-Peer Computing

Peer-to-peer computing (as implemented, for example, in the Napster, Gnutella, and Freenet file sharing systems) and Internet computing (as implemented, for example by the SETI@home, Parabon, and Entropia systems) is an example of the more general (“beyond client-server”) sharing modalities and computational structures that we referred to in our characterization of VOs. As such, they have much in common with Grid technologies.

2. DATA GRIDS OVERVIEW

Data Grid is a type of grid implementation which provides integrated view of distributed data scattered across the networks, providing virtual data storage. Each machine on the grid usually provides some quantity of storage for grid use, even if temporary. Storage can be memory attached to the processor or it can be “secondary storage” using hard disk drives or other permanent storage media. Memory attached to a processor usually has very fast access but is volatile. It would best be used to cache data to serve as temporary storage for running applications [3].

2.1 Data Grid Applications

Data Grid implementations help in providing virtual view of un-used data storage in various physical organizations. The physical organization in the proposed scenario can be all public and private sector educational institution with redundant computing and data resources, which often remain unused. Data resources include temporary memory required by CPU to run applications, main memory, network bandwidth or secondary storage. Following sections present the detailed applications of Data Grids.

2.1.1 Virtual Data Store

Data grid applications are data centric, and it helps in aggregating unused data resources to accomplish the data demanding task. The large amount of scattered data resources around the network can be aggregated into a large virtual data store. The virtual data store with sophisticated standardized protocols and access methods can be exploited for scientific and research development activities.

2.1.2 Backups

Data Grid enables the data replication facility on the geographically remote locations, which can be used for backup purposes. If a batch job needs to read a large amount of data, this data can be automatically replicated at various strategic points in the grid. This, if the job must be executed on the remote machine in the grid, the data is already there and doesn’t need to be moved to that remote point. This offers clear performance benefits. Also such copies of the data can be used as backups when the primary copes are damaged or unavailable.

2.1.3 Bandwidth

Data grid implementation can be used to exploit the unused bandwidth across the grid infrastructures, for example, if a user needs to increase his total bandwidth to the internet to implement a data mining search engine, the work can be split among grid machines that have independent connections to the internet. In this way, the total search capability is multiplied, since each machine has a separate connection to the internet. If the machines had the shared connection to the internet, there would not have been an effective increase in the bandwidth.

3. EVALUATION OF DATA GRID IMPLEMENTATIONS

3.1 Earth Systems Grid

The Earth Systems Grid (ESG) is an experimental data grid for scientists collaborating on climate studies. The data is collected from ground and satellite-based sensors or generated via simulations. Scientists can register and "publish" their data for use by the community. Applications allow scientists to specify parameters for climate model visualizations using intuitive settings and then gather the required data from the community's distributed data systems. A metadata catalog is used to identify relevant datasets and files, and Globus data grid technologies are used to locate "nearby" copies of the files and to transfer data to the local software using high-speed data transfer.

3.2 European DataGrid

The European DataGrid project is an international project for shared cost research and technological development. The DataGrid project is focused on solving the data management and analysis needs of the world-wide high-energy physics community and the next generation of supercolliders at CERN.

3.3 GriPhyN

The GriPhyN (Grid Physics Network) collaboration is a team of experimental physicists and information technology (IT) researchers who plan to implement the first Petabyte-scale computational environments for data intensive science in the 21st century. The CMS and ATLAS experiments at the Large Hadron Collider (LHC) at CERN will search for the origins of mass and probe matter at the smallest length scales; LIGO (Laser Interferometer Gravitational-wave Observatory) will detect the gravitational waves of pulsars, supernovae and in-spiraling binary stars; and SDSS (Sloan Digital Sky Survey) will carry out an automated sky survey enabling systematic studies of stars, galaxies, nebula, and large-scale structure.

3.4 Network for Earthquake Engineering Simulation

NEESgrid is a virtual laboratory for the earthquake engineering community. NEESgrid is funded by the National Science Foundation for a six month scoping study. The goal of the study is to develop a systems design for integrating experimental and computational facilities for use by the earthquake engineering community, which includes structural engineering, geotechnical engineering, and tsunami research.

3.5 Particle Physics Data Grid

The Particle Physics Data Grid (PPDG) collaboration, like the European DataGrid project, focuses on the needs of high-energy physicists. Composed mainly of American institutions, PPDG is working toward the creation of a collaboratory for particle physicists attempting to experimentally verify theories regarding the fundamental nature of matter and energy.

3.6 Grid Physics Network

The GriPhyN (Grid Physics Network) project provides the IT advances required to enable Petabyte-scale data intensive science in the 21st century. Driving the project are unprecedented requirements for geographically dispersed extraction of complex scientific information from very large collections of measured data. To meet these requirements, which arise initially from the four physics experiments involved in this project but will also be fundamental to science and commerce in the 21st century, the GriPhyN team will pursue IT advances centered on the creation of Petascale Virtual Data Grids (PVDG) that meet the data-intensive computational needs of a diverse community of thousands of scientists spread across the globe [8].

4. PAKISTAN EDUCATIONAL RESEARCH NETWORK (PERN)

PERN - Pakistan Educational Research Network is a nationwide educational intranet connecting premiere educational and research institutions of the country. PERN focuses on collaborative research, knowledge sharing, resource sharing, and distance learning by connecting people through the use of Intranet and Internet resources [7].

4.1 PERN Network

PERN network architecture shows 34 x 34 Mbps interconnectivity between three core locations i.e. Islamabad, Karachi and Lahore. Lahore router has 12 online universities with 33 MB international bandwidth. Karachi router has 22 universities online and 57 MB international bandwidth. Islamabad has 22 universities online with 65 MB international bandwidth. This connectivity demands introduction of coordinated applications to exploit the resource earmarked in the PERN project.

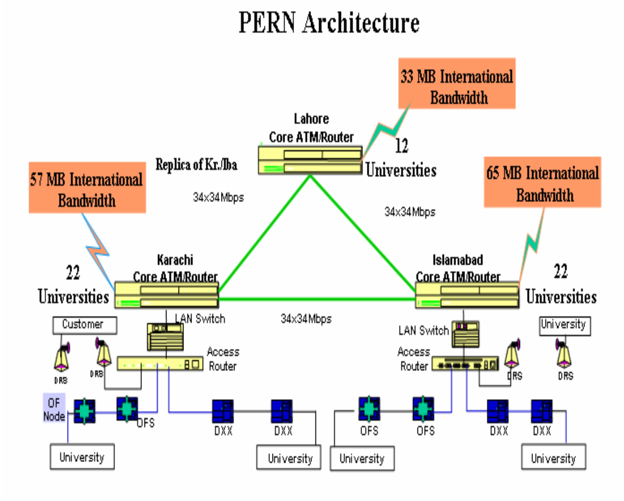

Figure 1: PERN Architecture
Source: http://www.pern.edu.pk

4.1.2 PERN Connection Summary

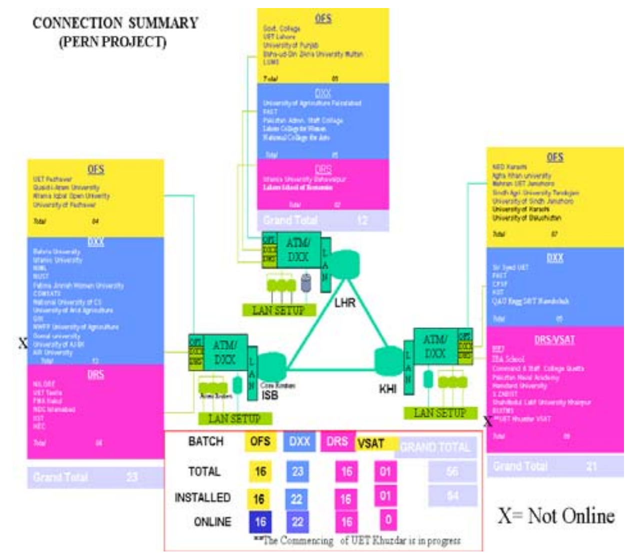

Figure 2: PERN Connection Summary:
Source: http://pern.edu.pk

4.1.3 Network Backbone for proposed Data Grid Architecture

PERN has provided interconnectivity of 56 universities with state of art connectivity infrastructure, the level of connectivity and access to international bandwidth makes it potential network platform to use for proposed Data Grid architecture.

4.2 Data Grid for Pakistani Universities: Architecture

Research and development is believed to be a coordinated activity, which requires pool of heterogeneous, distributed resources to be made available at one place. These resources can be categorized into computational and data. This study emphasizes on the availability of scattered heterogeneous data resources--- storage, cache, main memory, catalogs, code repositories and network bandwidth etc. by creating virtual data store, for research, scientific and development projects. Due to financial and technical constraints, provision of such resources at one place is difficult to achieve in case of Pakistani Universities. Data resources scattered across the academic institutions/ universities both in public and private sector can be pooled up at one place to exploit the power of distributed storage and communication media. The Proposed infrastructure will give direct access to distributed data resources for executing the applications that required huge amount of data, network bandwidth. Members of the proposed infrastructure will be able to share the resources seamlessly in virtual environment. Keeping in view the utility and applications of Data Grids, a coordinated Inter-University DataGrid Infrastructure for Pakistani Universities, has been proposed to harnessing the storage of multiple machines distributed across the networks.

The data grid is not a technology, it is an infrastructure which can be viewed as set of protocols, services, APIs and SDK's which retains local setting and control of machines contributing in sharing process.

The proposed UDGI architecture utilizes the grid reference architecture proposed in [1]. The architecture presents a layered approach for integrating components for implementing the Grid infrastructure.

UDGI inherits the basic attributes of grid providing coordinated data resources that are not subject to centralized control, using standards, open, general purpose protocols and interfaces to deliver nontrivial qualities of services.

The proposed infrastructure would provide coordinated resources that live within different control domains and addresses the issues of security, policy, payment, membership. The proposed architecture will be build from multi-purpose protocols and interfaces that addresses such fundamental issues as authentication, authorization, resource discovery, and resource access providing various qualities of service relating to response time, throughput, availability and security and/or co-allocation of multiple resource types to meet complex user demands.

The referred infrastructure comprises on Fabric, Connectivity, Resources, Collective and Application layers. Figure 3 shows integrated UDGI architecture along with tools, protocols, services and communication media identified for the purpose. All components will be integrated to share the data resources using PERN network as backbone.

The bottom level fabric layer comprises on data resources to be shared across the UDGI, data resources include: storage, cache, main memory, catalogs, code repositories and network bandwidth etc. This layer also hosts the protocol services for resource reservation, co-scheduling, enquiry, and aggregation.

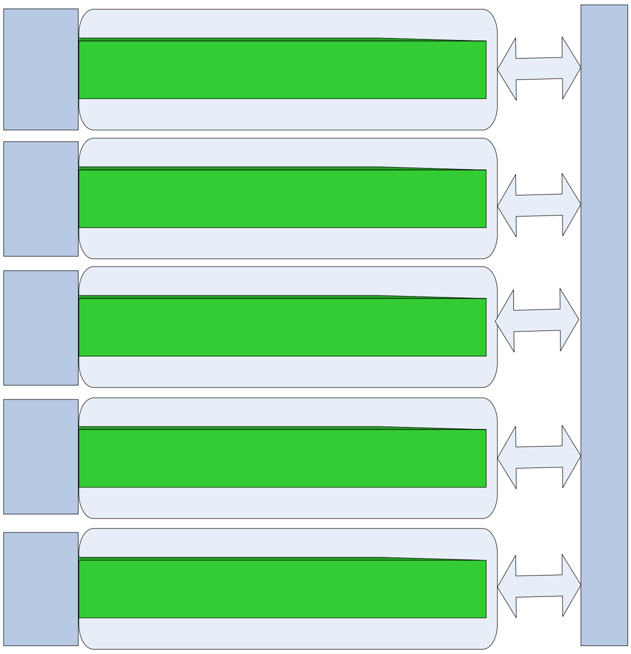

Figure 3: Proposed UDGI architecture showing integrated components for sharing dynamic data resources.

Connectivity layer build on the fabric layer, deals with communication and authentication protocols. Communication protocols provide the mechanism to access data resources at fabric layer. Authentication provides the protocols and services for user and resource authentication.

Resources layer build on the communication layer deals with the access mechanisms, monitoring, control, accounting, and payment of sharing operations on individual resources.

Collective layer deals with collective policies regarding management, schedule, planning, replication, and diagnostics. In UDGI implementation all participating organization will be brought closer to develop a mutual agreed upon policies for important data resource sharing, to make sure its availability for data centric applications.

Application layer deals with the identification, aggregations, membership, and availability of the data resources for research and development activities in UDGI scenario.

4.2.1 UDGI Construction

Initially, the UDGI architecture will be installed at Shaheed Zulfikar Ali Bhutto Institute of Science and

Technology (SZABIST). Actual implementation of the UDGI would be used by researchers and developers from various private and public educational institutes of the country. The key activity of the UDGI implementation would be to understand the inter-university requirements and selection of grid technologies that best fit these requirements. This section discussed some of the planning considerations and grid components that address the requirements.

4.2.2 Deployment Planning

The inception of UDGI is a result of a need for increased aggregated data resources to serve the research and development needs. Key participants in the infrastructure would be private and public educational institutes of Pakistan, availability of hardware i.e. Storage devices, network bandwidth, memory, and means of connectivity via a LAN or WAN is also an important consideration, in UDGI. The redundant availability of data resources and PERN solve the aforesaid problems. It is important to understand the nature and characteristics of the data resources to be used on the grid. Their characteristics can affect the decisions of how to best choose and configure the hardware and its data connectivity, which could be understood and refined by using the modeling and simulation approach [9].

4.2.3 Security

Security is a much more important factor in planning and maintaining UDGI than in conventional distributed computing, where data sharing comprises the bulk of the activity. In UDGI, the member machines are configured to lookup, discover, and move data. This makes an unsecured grid potentially fertile ground for viruses and Trojan horse programs. For this reason, it is important to understand exactly which components of the infrastructure must be rigorously secured to deter any kind of attack. Furthermore, it is important to understand the issues involved in authenticating users and properly executing the responsibilities of a certificate authority.

4.2.3 Organization

The technological considerations in the proposed UDGI infrastructure are key elements, but social and operational issues in the participating organizations are equally important. It is important to understand that how departments in different universities would work, interact and share data for the UDGI, understanding their method of business is equally important. Identification, availability, security, and overall management of data resources through standardized policies are the key considerations for the implementing UDGI.

5. CONCLUSION AND FUTURE DIRECTION

The grid is a promising infrastructure which provides means to harness and aggregate computational and data resources distributed across various institutes. The aggregation of such type of resources helps in forming a virtual organization with supercomputing and virtual data stores. Private and publics sector educational institutes in Pakistan are envisaged as potential contributors in the proposed Inter-University DataGrid Infrastructure for Pakistani Universities (UDGI). Such a high level sharing of active resources certainly requires state of the art network infrastructure for connecting participating organizations in the proposed UDGI implementation. Pakistan Educational Research Network (PERN) provides connectivity to approximately 56 universities across the Pakistan. PERN implements an educational intranet with connectivity to international bandwidth has been proposed to exploit as a potential networking platform. The future plan of the study will be “Data-Grid for Pakistani Universities: Resources & Infrastructure Identification, Feasibility Analysis, MoU, and documentation between participating universities”.

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