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Review

Grid computing in Pakistan: A case study of opening to large hadron collider experiments at CERN

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ABSTRACT

Performance, quality and reliability issues are becoming increasingly important for the emerging technologies like computing technology (CT). The purpose of this work is comparing and presenting operational performance of the grid nodes particularly in South Asia. The data analyzed here are derived from monitoring data of LCG (Large Hadron Collider Grid). The performance potential is analyzed by extracting data from the operational conditions of the grid sites. A grid computing facility was developed at sister institutes: Pakistan Institute of Nuclear Science and Technology (PINSTECH) and Pakistan Institute of Engineering and Applied Sciences (PIEAS), in collaboration with Large Hadron Collider (LHC) Computing Grid during early years of the present decade. The Grid facility "PAKGRID-LCG2" as one of the grid node in Pakistan was developed employing mainly local means and is capable of supporting local and international research and computational tasks in the domain of LHC Computing Grid. Functional status of the facility is presented in terms of number of jobs performed. The facility provides a forum to local researchers in the field of high energy physics to participate in the LHC experiments and related activities at European particle physics research laboratory (CERN), which is one of the best physics laboratories in the world. It also provides a platform of the emerging computing technology.

Keywords: Computing grid, large hadron collider, CERN, high energy physics, South Asia, LCG, virtual organization.

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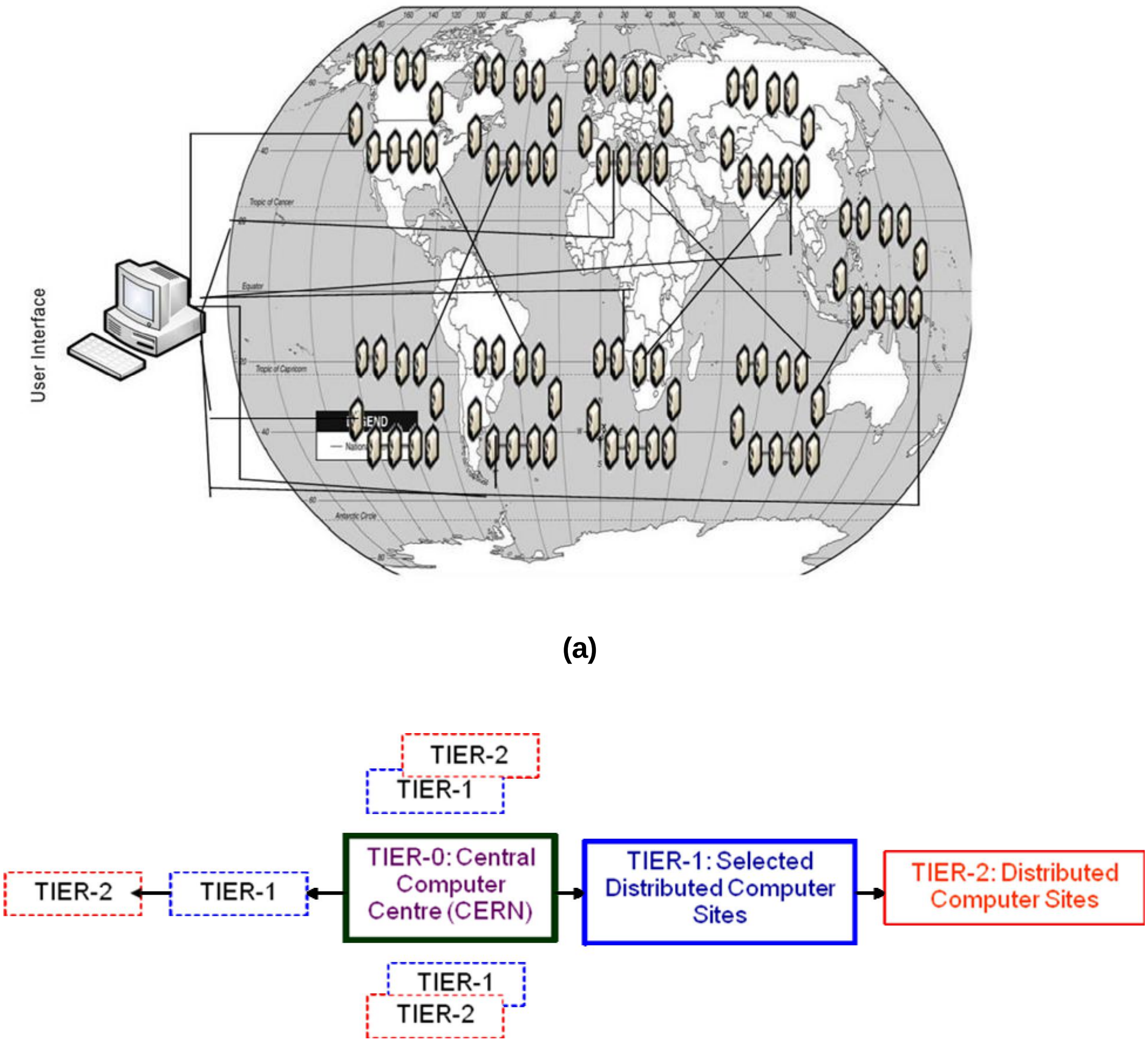
INTRODUCTION

Grid computing is a method for the coherent use of piled up power of a large number of computers present in distributed networks around the globe. A schematic of the grid computing concept is shown in Figure 1. Owing to the joint use of computers in a grid for executing computational tasks or jobs, it can perform a large number of complicated computations without a single huge computational facility. Grid computing offers the possibility of the data communication within the grid and external to the grid. Communication within the grid is important for sending jobs and their required inputs to distributed network points within the grid as some jobs require a large amount of data to be processed which may not always reside on the machine running the job. The bandwidth available for such communications can often be a critical resource that can limit utilization of the grid. External communication is also valuable as it provides the connectivity among the geographically distributed grid users. Grid technology is a part of global efforts to build service oriented science that would democratize science by decreasing the gap between "haves" and "have-nots". This technology has the potential to ample individual and collective scientific productivity and to build a culture of shared understanding (Foster, 2005). Data storage, computational capacity and access are three pillars of the expanding computing grids (Kahle and Gaillard, 2013; Girone, 2008; Caballero et al., 2008; Shiers, 2007; Opitz et al., 2008).

This paper describes the implementation and function of the grid concept at PINSTECH/PIEAS achieved in collaboration with LHC, CERN, and Switzerland. The



(a)

(b)

Figure 1. (a) A pictorial view of the grid concept; and (b) schematic explaining the concept.

functional status of the developed grid facility “PAKGRID-LCG2” is compared with similar facilities in South Asia. The aim of the paper is to introduce this facility to its potential users in Pakistan and offer them participate in the scientific challenges of this emerging CT.

LARGE HADRON COLLIDER EXPERIMENTS AND VIRTUAL ORGANIZATIONS

The LHC (Figure 2) is the world's largest and most powerful particle accelerator and is expected to answer some of the fundamental questions about the universe. The LHC will provide the highest energy proton-proton and ion-ion collisions that ever happened in the laboratory. The smashing of protons in 27 km ring of accelerator produces enormous events which are expected to unfold the various mysteries of matter, time and space. These mysteries or questions include origin of mass, dark matter and energy, nature’s favoritism for matter over antimatter, secrets of the big bang and matter of hidden dimensions. The LHC is a focal point for physics community around the world as it is expected to reply or resolve some of above mentioned big questions.

There are six distinct experiments in which LHC will be employed to investigate the aforementioned issues.

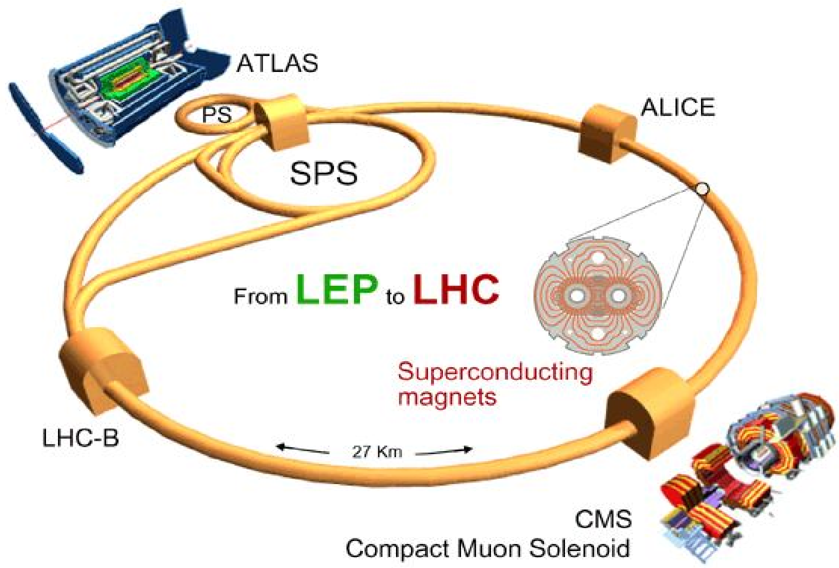


Figure 2. Layout of LHC. LEP, Large Electron Positron collider; SPS, Super Proton Synchrotron, PS Proton Synchrotron.

These experiments are run by international collaborations which bring together scientists from various institutes from all over the world. Subject of the two large experiments Compact Muon Solenoid (CMS) and A Toroidal LHC ApparatuS (ATLAS) involves a wide range of physics. These experiments will measure and analyze the myriad of particles produced by the collisions in the accelerator. These experiments have two independently detection systems for cross-confirmation of any new discovery made. Two medium-size experiments are A Large Ion Collider Experiment (ALICE) and Large Hadron Collider beauty experiment (LHCb). ALICE will study lead-lead ion collisions (quark-gluon plasma) whereas the LHCb experiment will investigate why universe is composed almost entirely of matter, but no antimatter. TOTal Elastic and diffractive cross section Measurement (TOTEM) and Large Hadron Collider forward (LHCf) are two other small size experiments. They focus on 'forward particles' (protons or heavy ions) which just brush past each other as the beams collide, rather than meeting head-on (http://public.web.cern.ch/public/en/LHC/LHCExperiments-en.html; Cancio et al., 2004).

The whole community of scientists and supporting staff, distributed around the globe, from LHC experiments are grouped into Virtual Organizations (VOs). These VOs operate under the umbrella of Worldwide LHC Computing Grid (WLCG). The service oriented architecture provides the standard procedures for users to access VOs to use these distributed resources. So, the CERN operates in a massively complex, worldwide collaboration, comprising more than fifty four countries. Pakistan-CERN collaboration is mostly with CMS experiment and recently started with ALICE experiment as well.

LHC GRID COMPUTING

The computational requirements of the LHC experiments are approximately 15 Peta Bytes of data (equivalent to more than 20 million CDs), which will be generated each year and more than 70,000 of today's fastest PCs processors would be required to analyze this data. The LHC experiments ALICE, ATLAS, CMS and LHCb are preparing for data acquisition planned to start in 2009. The LHC experiments are relying on WLCG (Stonjek et al., 2005). The LHC grid infrastructure is based upon a Multi-Tier distributed model, addressing the needs of a computing system capable to handle LHC data, analysis and archival (Evans and Bryant, 2008). Figure 3 illustrates the 4-Tier Model, where CERN as Tier-0 is the central production centre and will be responsible for distributing the raw data, and the Tier-1 centers spans several organizational units at sites distributed over a large geographical area, will be responsible for all the production/processing phases associated with the real data. The Tier-2 centers will be primarily Monte Carlo production centers, with both CERN and the Tier-1 centers acting as the central repositories for the simulated data (Foster et al., 2004). The Tier-2 grid sites (Stonjek et al., 2005) provide services for CERN experiments and to local researcher's communities for grid-based analysis. The resources available with Tier-2 centers are accessible for accelerator experiments through the grid infrastructure. Tier-3 is bottom of the grid chain and it is the first level at which physicists have access to data under their own control. There are fewer constraints on bringing up a Tier 3 which is really the growth area. At Tier-3, scientists have more freedom to run the analyses they want and more flexibility in testing

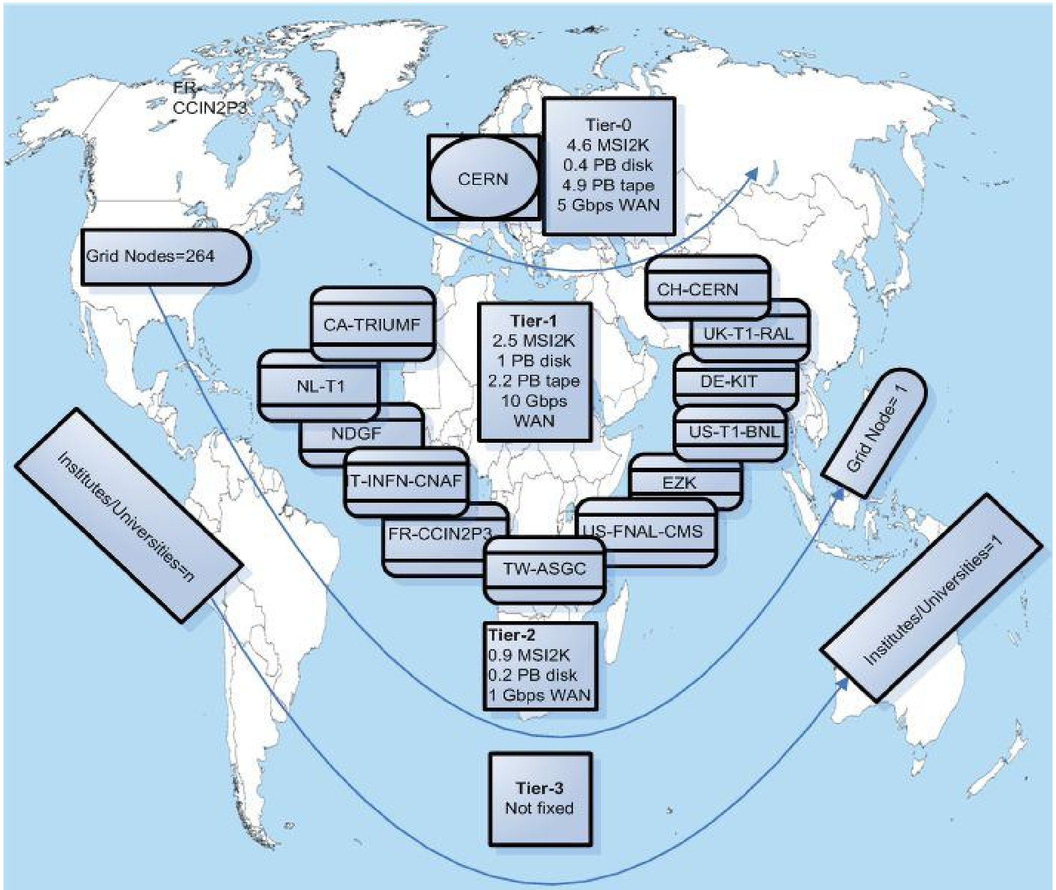


Figure 3. Tier Model of LHC computing grid.

and debugging the code before it is used (Grim, 2009). The participating sites have varying level of resources, organized hierarchically in Tiers. An important benefit of this approach is facilitating scientists all over the world to contribute intellectually without their presence at CERN (Andreeva et al., 2008).

The requirements for LHC data handling are very large, in terms of computational power, data storage capacity, data access mechanism, inter-tiers/inter-sites communication, performance and the associated human resources for development/operation/ support. It is not possible to get consolidated resources at CERN and even not considered feasible to find all of the resources at few sites; so that the WLCG computing service is implemented as a geographically distributed resource platform (Figure 3). This means that computing resources, both computational and storage, installed at a large number of regional computing centers in many different countries, interconnected by fast networks. All the WLCG distribution is further handled under five virtual organizations, users are grouped and access to resources is provided under the umbrella of VOs such as CMS, ATLAS and ALICE, etc. To use WLCG resources, one must be affiliated at least with one of the VOs of CERN. The registration with VO is required so that the information will be forwarded to the VO administration and grid resource providers for validation. The VOs manage immediate allocation, provisioning of resources, based on their availability and the provision of secure access to the resources. A VO must be capable of providing facilities for dynamic collection of resources based upon users to solve specific problems associated with its task. The associated grid production infrastructure is comprised of more than 250 sites across 54 countries and approximately 140 Regional Centers which are participating as Tier-2 centers of CERN computing infrastructure. The WLCG architecture is developed for Particle Physics; it is also suited for other compute-intensive applications.

The Grid has witnessed rapid development in the last few years. It currently provides reliable software components for resource integration, task scheduling and computer safety, adapted to distributed, heterogeneous, and dynamic resources. Tier-0 center located at CERN while the data will be distributed to a series of large computer centers which are part of Tier-1 in the model. These centers provide services for data archiving, reconstruction, calibration and other data-intensive

Table 1. Comparison of technical specifications between PAKGRID and other similar grid nodes.

Site name	CPU	SE Available TB	Bandwidth
PAKGRID-LCG2	11	4.07	4 Mbps
NCP-LCG2	38	1.68	10 Mbps
INDIACMS-TIFR	193	72.30	34 Mbps*
IN-DAE-VECC-01	26	0.11	34 Mbps*
IN-DAE-VECC-02	156	67.63	34 Mbps*
IN-DAE-VECC-EUINDIAGRID	18	1.24	

*TIFR Mumbai, VECC Kolkata at 34 Mbps; Data taken at PAKGRID-LCG2 on 09-03-2009 (Singh, 2007).

analysis operations. Tier-1 centers will make data available to Tier-2 centers which provide adequate computing power for end-user analysis tasks and Monte Carlo simulations (Bonacorsi and Ferrari, 2007). The job of the WLCG is to prepare the computing infrastructure for the simulation, processing and analysis of all detectors before and after the LHC experiments. This includes both the common infrastructure of libraries, tools and frameworks required to support the physics application software and the development and deployment of the computing services needed to store and process the data, providing batch and interactive facilities for the worldwide community of scientists.

PAKGRID COMPUTING FACILITY CASE

The cooperation between Pakistan and CERN has started since 1994, to participate in innovative and challenging initiatives by CERN. Pakistani engineers and scientists are taking active part in CMS and ALICE experiments, such as, Fabrication of Magnet Support Structure for the CMS Magnet Barrel Yoke, Fabrication and Production of RPCs, Precision Position Monitoring/Alignment System specific activities of WLCG. Pakistan participated in Grid developments at CERN since 2002, although at the early stages more than five establishments started developing the grid site but later on two institutes PINSTECH, Pakistan Atomic Energy Commission (PAEC), Islamabad and National Center of Physics (NCP), Islamabad succeeded in this effort. The PINSTECH-CMS Production Center project began in 2002; initially, a test-bed was installed with the dial-up link to CERN. The lab is renovated for CERN CMS production activities and established the Giga Bit LAN to setup a PCs Farm. High computing resources and storage devices were deployed to replicate the CERN computing environment.

A PCs Cluster using Linux environment was established at PINSTECH to offer computing resources since 2003 and computed millions of events (collision of two particles in a bunch of particles is termed as an event). It produced simulated data for CMS detector in collaboration with other countries. In mid-2003, PAKGRID emerged as one of the first production-level Grid site in Pakistan and continued the grid activities up-till now. Events were assigned to computing collaborators of CERN according to their capacity. The site is registered with the name of PAKGRID-LCG2 and participating in WLCG. The first big goal of all such activities is to establish as Tier-2 production center and establish the grid node. The main focus of the project is to collaborate with large-scale scientific research carried out through distributed global collaborations by CERN and to promote a grid infrastructure in Pakistan which is an emerging technology. Following the vision of Grid about access of computing resources to all, PAKGRID-LCG2 has a collaborated work with a number of institutes at national level to provide high end computing solutions to local professionals. This group helps local researchers to share the experience of deployment of PCs Cluster infrastructure. PAKGRID-LCG2 production grid exploits a total of 11 CPU’s including core services and Worker Nodes (WNs). Scientific Linux Operating System 4.6 and grid deployment software Glite 3.10 are being used at this computing facility. The facility is available to users 24 h a day, 7 days a week.

There are some basic parameters which can be analyzed for generic comparison of grid sites of South Asia, such as computing resources, storage resources and the connectivity of these sites with rest of the grid frame-work. The Grid infrastructure at all the sites in this region is more or less same, based on the most recent LCG-2 middleware and contains most of the important elements so as to be a Grid Node, such as; Computing Element (CE) with WN, Information index, User Interface (UI) and a Storage Element (SE) with an attached storage system. The Grid Information System provides the information about the structure of the grid using a set of rules which is same for all. While analyzing and reviewing these sites the other important factor is the connectivity and bandwidth allocation which plays the main role in performance. The overall resource structure of all these sites is given in Table 1 (Singh, 2007).

The Tier-2 centers are intended to provide computing resources for processing and analysis capabilities to local and remote user communities. Tier-1 centers are expected to store a portion of the raw data, and Tier-2

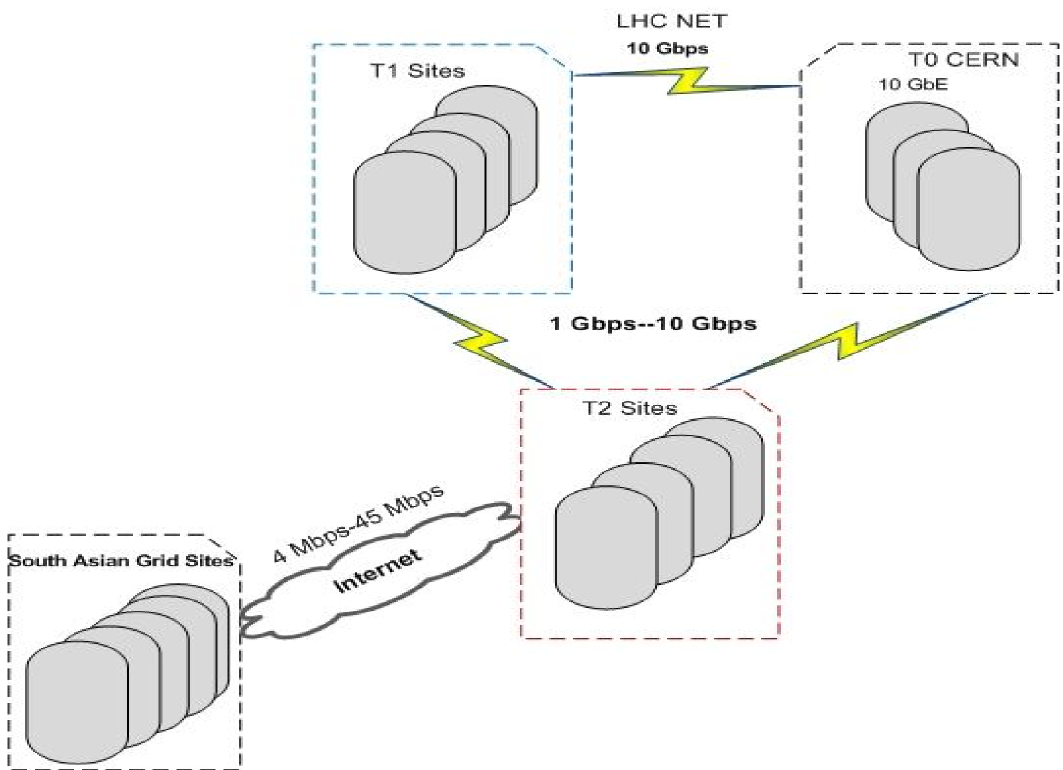


Figure 4. Limitation of internet connectivity of South Asian grid sites.

sites needs to provide minimal set of services and expected to provide the network capacity so as quality of data transfer can be maintained. The user's jobs requirements are commonly based on the bandwidth capacity of the end-to-end network path. The operational model for Tier-2 sites is developed with an understanding that set of network capacity requirements for Tier-2 should be flexible enough so as to manage the service, the minimum 2.5 Gbps (http://lcg.web.cern.ch/LCG/) is recommended.

The sites operational in the South Asia region are generally using South-East Asia, Middle East, and Western Europe (SEAMEWE-3,4) submarine optical fiber link (http://www.seamewe3.com/inpages/cable_system.asp). Pakistan has so far been connected to the outside world using various circuits having the capacity of 2.4 to 10 Giga band-width. The most important link is the 155 Mbps SEAMEWE-3 submarine optical fiber link while the bandwidth in India at the moment, is slightly higher (http://www.seamewe3.com/inpages/cable_system.asp, Ratnakar, 2008 20-21). However, the limited bandwidth is allocated to all grid infrastructures (Table 1) in South Asia as compare to rest of the grid sites associated with LCG. The smoke ping results (https://osadm.grid.sinica.edu.tw/smokeping/smokeping.cgi) show the packet loss and delays which the South Asian Grid sites experience because of the unavailability of dedicated WAN links to LCG (Figure 4).

PERFORMANCE ANALYSIS

A performance perspective of the grid sites monitoring is carried out from any server which is geographically in some remote place, the checks and results depends upon the speed and stability of inter link (internet or dedicated link) of the site with grid. Additionally, the availability/reliability (von Rueden and Mondardini, 2003) of grid site is again directly or indirectly associated with the traffic on the link and routes involved in the grid infrastructure communication and the constraints to shutdown the site. Instead of exhaustive study of performance parameter only investigated the limited parameters which are helpful to tune for improvement of both the performance and maintainability in general. System performance analysis is not always straight forward plugging the right numbers into the standard formulas for grid performance analysis results; it varies from region to region and from site to site. In our investigations, main focus is South Asian Grid Sites in WLCG scenario. One of the major ongoing issues for any site is the rectification of SAM tests (https://lcg-sam.cern.ch:8443/sam/sam.py) usually operational verification of CE-sft-lcg-rm, CE-sft-lcg-rm-cp, CE-sft-lcg-rm-cr and others which are directly or indirectly related to capability of network to respond within specified time.

The grid model (Li and Buyya, 2009) impact of workload and other correlating factors on performance is taken in account. The requirements therefore are manifold;

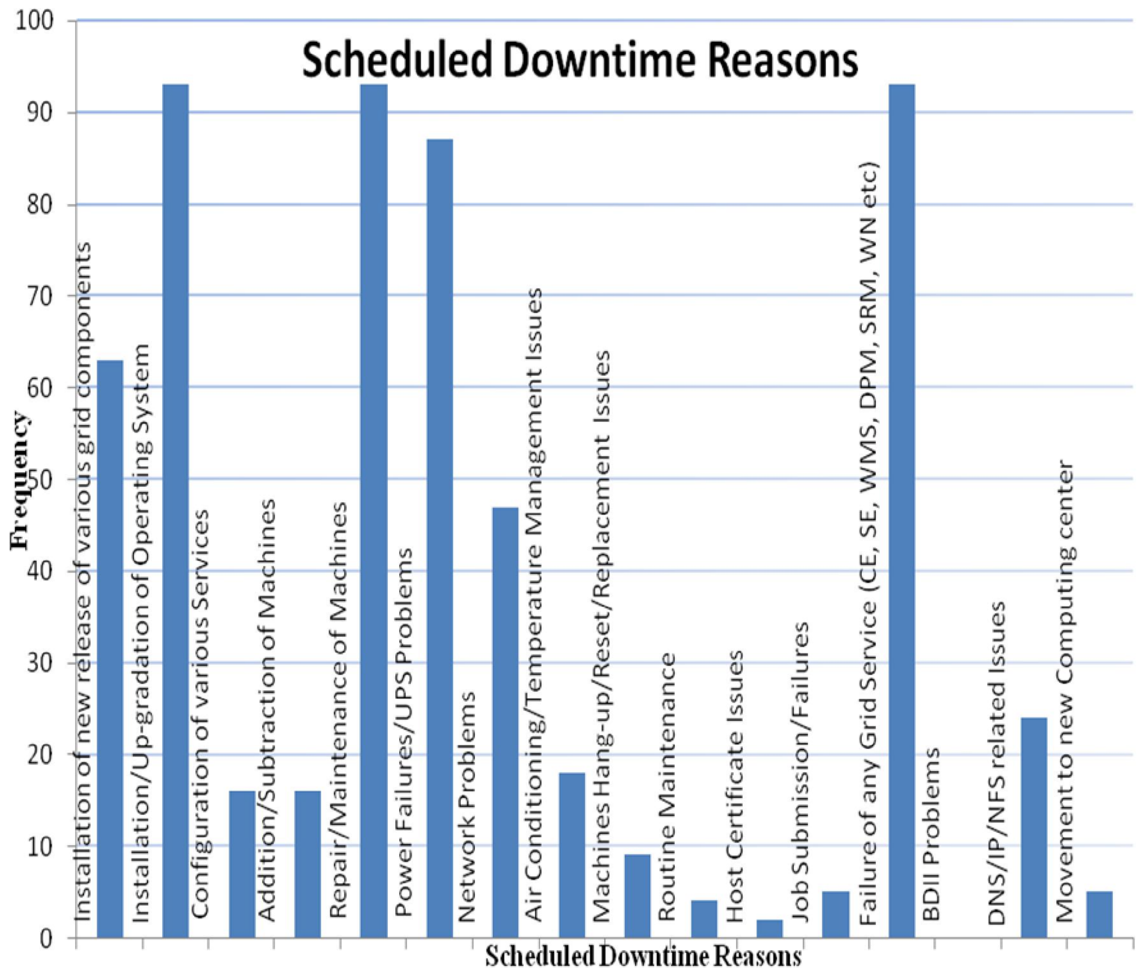


Figure 5. Scheduled down-time reasons.

adequate approaches must combine appropriate performance metrics, realistic workload models, and flexible tools for workload generation, submission, and analysis. In fact there are so many variables having considerable weight-age towards efficiency and performance in grid environment, such as: scheduled down-time, network integrity/stability and sites resource infrastructure.

Scheduling

Grid monitoring and testing is an important contributing service for all the mesh and there are number of monitoring tools to check the status of sites as well as the infrastructure. The schedule downtime is an important factor to analyze the sites major failure reasons, its analysis helps to reduce and remove the breaches from similar incidents in future. A surgical survey of scheduled down time under GStat (http://goc.grid.sinica.edu.tw/gstat//Region.html) data base portray a picture about sources of failures associated with this indicator. The analytical monitoring, facts and typical features of data represent rather comparable values with reference to region. The major reasons (Figure 5) are installation/up-gradation of OS, Grid releases and issues related to grid services but it varies in European sites and South Asian sites having same computing capacity shown in Figure 6. Specifically, some major reasons for scheduled down time in South Asia varies from European sites having same computing capacity Table 2. The frequency for power failure is 57 for only five sites of South Asia as compare to rest of the sites which shows that the major reason for South Asian grid sites are Power Failure and Network problems. On the other hand, for other grid sites, the major reason is “installation/up-gradation of new releases of grid components/operating system”. This indicator might reflect about the fact that problem is not with computing capability of grid site rather with infrastructure. This indicator provides a scope to furnish some counteractive procedure so as where infrastructure is not supportive but clusters for WLCG can work efficiently. Although, such analysis can be utilized further to extend the collaboration with centers/institutions having

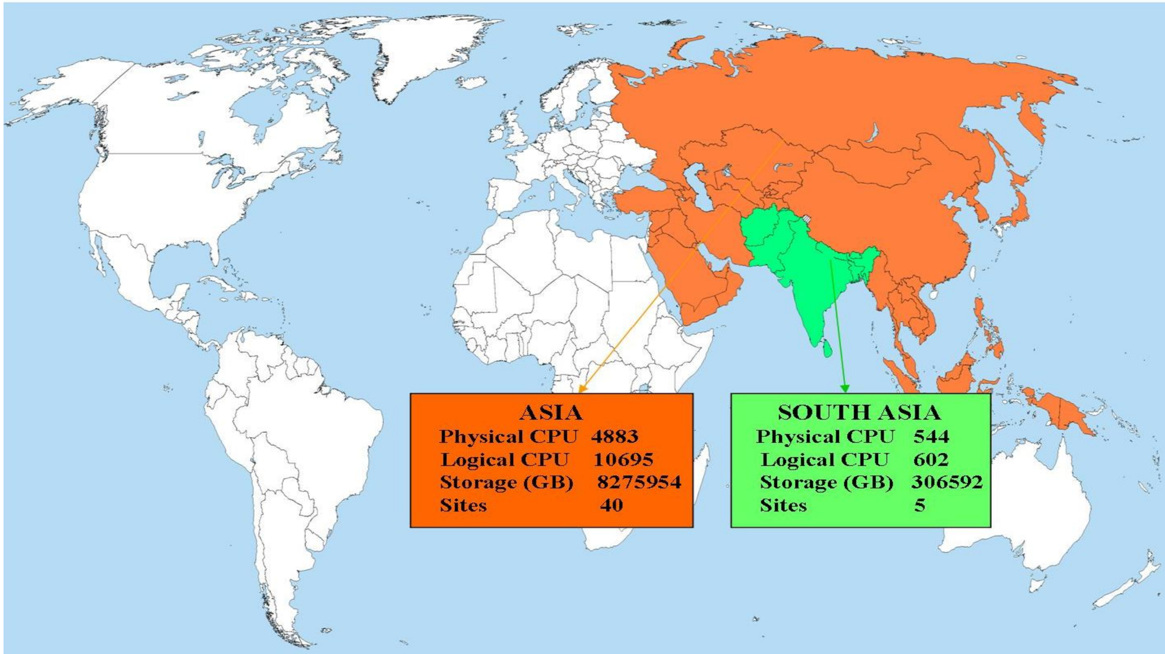


Figure 6. South Asian sites.

Table 2. Reason for scheduled down time.

S/N	Reason for scheduled down time	Frequency (%)
1	Installation of new releases of various grid components	20
2	Installation/Up-gradation of Operating Systems	65
3	Configuration of various services	22.5
4	Addition/Subtraction of Machines	5
5	Repair/Maintenance of Machines	57.5
6	Power Failures/UPS Problems	142.5
7	Network Problems	80
8	Air Conditioning/Temperature Management Issues	45
9	Machines Hang-up/Reset/Replacement Issues	5
10	Routine Maintenance	5
11	Host Certificates Issues	12.5
12	Job Submission/Failures	15
13	Failure of any grid service (CE, SE, WMS, DPM, SRM, WN,SAM, CA etc)	75
14	BDII Problems	5
15	DNS/IP/NFS related Issues	10
16	Movement to a new computing centre	15
17	Investigation of different problems	42.5

cluster platforms but with limitations of infrastructure.

Communication link

The network infrastructure of WLCG is providing computing resources for LHC, though it is well defined according to LCG Tier model (Bonacorsi and Ferrari, 2007). There is lot of variation regarding computing and network resources of Tier-2 sites. Further this network infrastructure is in most cases being provided by national and regional network providers according to bandwidth. The ultimate goal of connected sites in WLCG collaboration is to satisfy the LHC experiments' computing requirements, and offer resources to remote users across the internet. Grid computing is becoming a common technology platform for solving large scale computing tasks so many organizations/institutes wants to participate in this peta scale science event of CERN with the limitation of resources. However, the inter- and intra-tier networks are not supportive as minimum link of 40 Mbps is required for Tier-2 site (Duncan, no date).

Many approaches has been used for grid network analysis (Chun et al., 2004), our approach aims to be an initial and necessary step towards a common performance evaluation so as to improve early diagnosis of common problems and to overcome the bottlenecks. As a first step towards this goal, we have developed a set of probes including routes and network topology for grid transactions from end-to-end network scenario. The measurement data obtained by running *traceroute, mtr, pingER, iperf* and IP reverse resolution to check the issues related to delays, time-out and latencies. The results help provide insight into the stability, and performance of grid site with reference to network. The adopted procedures help in delivering significant gains in terms of performance evaluation.

Since the end nodes and network paths are globally distributed, usually across organizational and management boundaries, it can be very difficult to locate and identify the factors that are effecting the grid sites performance. In order to analyze these types of performance problems, the role of ISPs and the configuration of IPs at their end matters a lot. The core of our approach is to narrow down the pros and cons and strategy to rectify such issues. Within a domain, routing uses hop-count as a metric, but because intra-domain routing protocols support hierarchies, the resulting paths are not necessarily shortest in terms of hops (Chun et al., 2004). To our knowledge/experience the impact of hops and packet delivery performance of paths plays main role for grid monitoring. However, we shifted the IP pool and changed ISP, ultimately resulted, in lower delay, higher throughput and removal of SAM errors (Park and Willinger, 2000). It seems that ISP only propagates the client's addresses but not bothers to configure the routs properly. Though, the network path problems are obviously beyond the scope and control of grid sites local setups.

The performance is hampered due to such issues like network outages or overloading, the destination may experience a time lag to communicate with source until the connection is re-established. As if the local routing table is correct, the problem may be occurring some distance away from the local host. Remote routing problems can cause the "no answer" and the "network unreachable" error messages. But the "network unreachable" message does not always signify a routing problem. It can mean that the remote network cannot be reached because something is down between the local host and the remote destination. Various tools were used to locate the routing problem. Examining the various hops on one of the paths, more than 10% losses are observed from the local host to a remote host. It ends at the "no response" or "time out" error in between the gateways "khi77.pie.net, pos1-2.rwp44gsrc 2.pie.net.pk and rwp44.pie.net.pk". The ill configured route from source to remote host ends at error. As a result, tests of SAM (Service Availability Monitoring Framework) monitoring system (Park and Willinger, 2000) fails exhibiting the errors such as "CE-sft-lcg-rm-cr" and SE core service fails due to the error of "LFC endpoint not found". Finally, the site availability/reliability (http://gridview.cern.ch/GRIDVIEW/same_index.php) criterion endures down scaling.

We discuss the solutions chosen to address the failure of SAM tests and the impact on the grid site overall functionality. This includes the cluster services framework, integration with a system that influences the availability and quality of the network connection to link entire grid. The transaction of any information from source node to destination node passes through series of gateways and crosses n^{th} number of hops as shown in Figure 7. During this process, the site does a reverse DNS lookup of an IP address by searching domain name registry (https://lcg-sam.cern.ch:8443/sam/sam.py) any delay or failure again ends on the error. The role of reverse DNS lookup feature cannot be ignored to achieve the accessibility. We report on our experience, that the impact of IP Pool replacement from PAKNET (paknet.com.pk) to PERN (http://www.pern.edu.pk/) is very effective. Ultimately, the routes behind is changed, as a result achieved the decrease in packet loss from 19.7 to currently 0.17 (Figure 8). SAM (Service Availability Monitoring) is a framework for the monitoring of production and pre-production grid sites. It provides a set of probes which are submitted at regular intervals, and a database that stores test results. In effect, SAM provides monitoring of grid services from a user perspective.

DISCUSSION

Present activities concerning distributed analysis are in at R&D stage with the focus on providing an end-to-end analysis system (Andreeva et al., 2004). In general, end-user analysis is a chaotic, non-organized task, carried on concurrently by many independent users that do not have a deep knowledge of distributed environment. Some of the tools that act as an interface to the physicist have been deployed at PAKGRID for global grid file systems ROOT and ALIEN to provide analysis environment for ALICE and CMS experiments. Monitoring services are needed to monitor and archive information about site resources (collecting e.g. host-related metrics, network activity, disk space, etc). Job monitoring allows the user to extract job specific information and thus to monitor the job status in real time. The Grid as a whole is monitored after every hour, jobs processing/replication status, checking network stability and reliability during the daily grid sites activities. The grid network infrastructure worldwide is mostly based on dedicated wide area network (WAN) links with 10 Gbps bandwidth support. Our limitation is to access the same

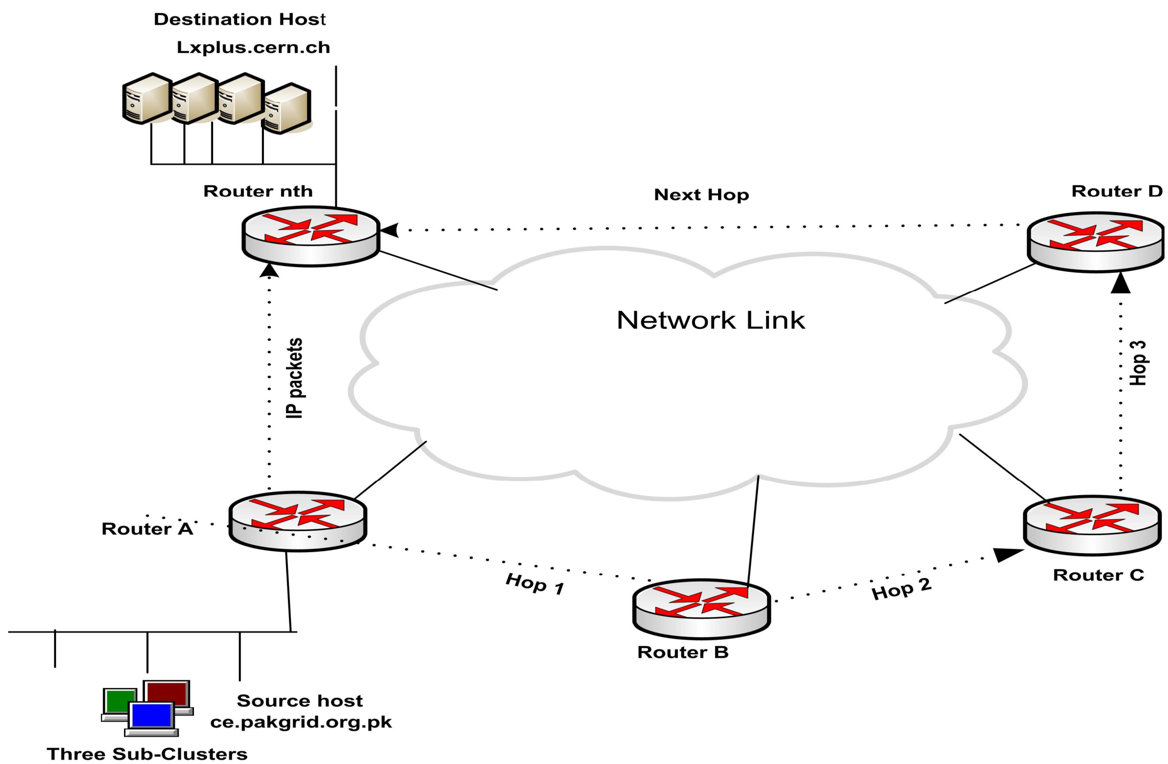


Figure 7. Routers hops.

Figure 8. Packet loss (smoke ping results).

Grid infrastructure by using the limited bandwidth of about 4 Mbps.

Considering the IT infrastructure in Pakistan, it has been a difficult task to establish and then maintain its functional status. A workload of 6000 to 10000 jobs/month was achieved by PAKGRID-LCG2. Figure 9 shows total number of computational jobs completed at PAKGRID-LCG2 during the period of 1 year (November 2007 to October 2008). Computational jobs related to various LHC experiments were completed as clear from Figure 9. Since the end nodes and network paths are globally distributed, usually across organizational and management boundaries, it can be difficult to locate and identify the factors that are effecting the grid sites

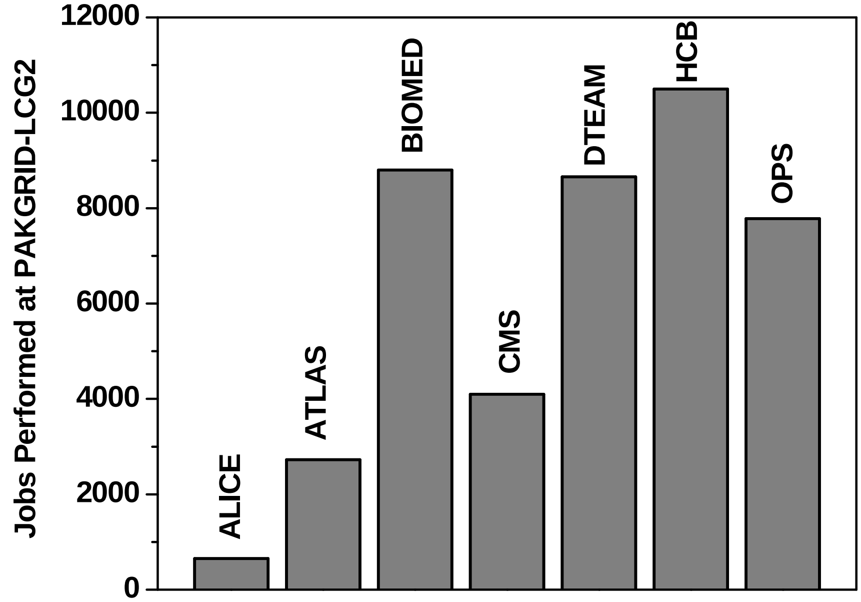


Figure 9. Total number of jobs (SITE and VOs) at PAKGRID-LCG2 during November 2007 – October 2008.

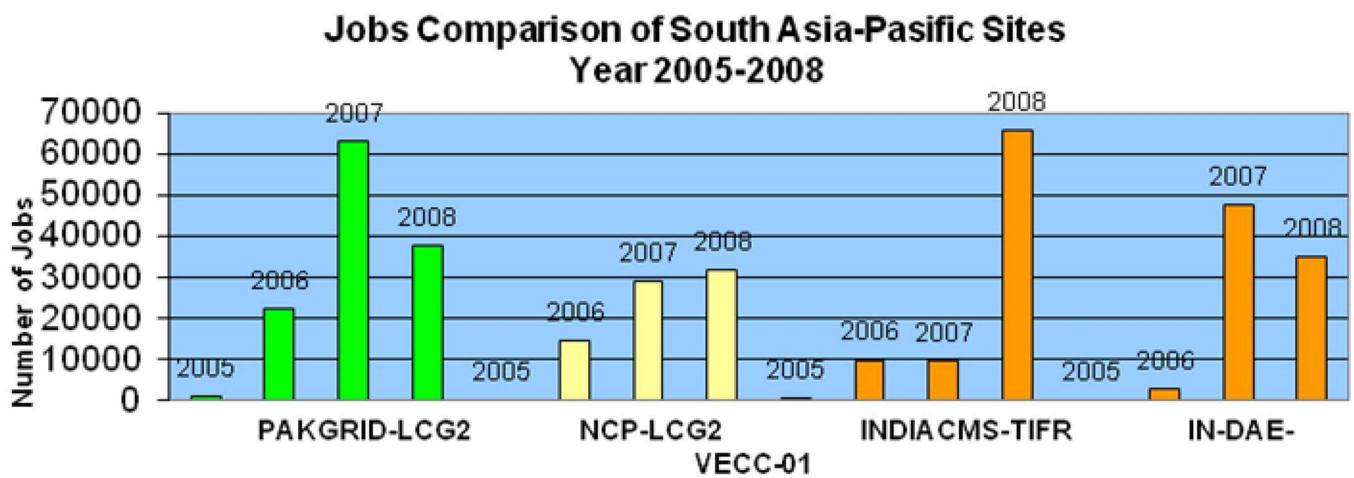


Figure 10. Jobs comparison of South Asia Pacific sites (2005-08).

performance. In order to analyze these types of performance problems the role of ISPs and the configuration at their end, matters. The network path problems are obviously beyond the scope and control of grid sites' local setups. If the bandwidth analysis does not uncover significant concerns, then "number of jobs" analysis of sites (Ratnakar, 2008) provides the comparison of expected versus actual performance pattern of the grid sites. The accounting scenarios, which can be viewed as potential of all the sites in this region (Figure 10), exhibit its status briefly. The statistics shown corresponds to the period of 2005 to 2008 (http://www3.egee.cesga.es/gridsite/accounting/CESGA/tier2_view.html). The number of jobs on PAKGRID-LCG2 decreased in 2008 due to down time of 2 months in which physical shifting of grid facility from PINSTECH to PIEAS was carried out. Internet service provider (ISP) PAKNET was merged with another ISP Pakistan Telecommunication Corporation Limited (PTCL) with future responsibility of the service on PTCL. Problem related to resolution of grid machines IPs in the new merged environment added an additional down time of 5 weeks.

Like any deployed grid node, PAKGRID-LCG2 has three functions which are user support, system support and grid operations. System support includes certification and testing of identified packages provided by the grid development projects or other middleware providers, system configuration and facing up the system failures or failures halting the functionality of the system. Number of grid jobs depends upon the access provided to the number of VOs. VO is a cyber environment or virtualization of a project which allows researchers of project (around the globe) to routinely access the computing resources including models and data. Our grid site PAKGRID-LCG2 provide access to seven VOs CMS, ALICE, ATLAS, OPS, DTEAM, LHCB and BIOMED. Another Pakistani grid site NCP-LCG2 does the same whereas Indian grid sites IN-DAE-VECC-01 and IN-DAE-VECC-02 are accessible to ALICE, OPS and DTEAM. Another Indian grid site INDIACMS-TIFR provides access to CMS, OPS and DTEAM.

To ensure smooth and trustworthy operation of a complex system (like WLCG) composed of interrelated data samples, stored at different centers around the globe and accessible online both locally and remotely, an exercise is needed to validate computing models, software, data models, and to ensure the correctness of all technical choices. This exercise is termed as Data Challenge which involves tens of institutes and hundreds of physicists. In a data challenge, large samples of data are simulated via advanced simulation programs and analyzed as if they were coming from the real experiment. In LHC Data Challenge 2004 and 2003 (von Rueden and Mondardini, 2003), the LCG environment was tested the functionalities for distributed computing. PAKGRID-LCG2 participated in addressing these challenges and development of infrastructure for data analysis.

CONCLUSION

This report is focused on the Grid Node essential bits and nuts as well as its uses and deployment in a research environment in Pakistan. A grid node provides an access to a layer of software that uses the Grid to gain access to data and resources related to the project involved and it also provide physicists with a user friendly interface for submitting the analysis jobs. The grid node PAKGRID-LCG2 provides access to worldwide dispersed users for the required grid services related to LHC computing grid. Major issues are related to the performances which are directly or indirectly linked to such components which are usually out of bound for grid node deployment team such as; power failure, Internet Protocol or IP resolving and internet bandwidth which is comparatively less than that required for LHC computing grid. Solution to these problems may be searched in a systematic study of functional grids in similar environments like India and some parts of China. On the other hand, these grid nodes are the gateways to participate in the scientific challenges and to launch this new CT in unexposed regions. Local adoption of this new service-oriented science and business culture will require Pakistani academic and research communities learn the use of grid technology and its evolution.

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