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Sustainability in Grid Computing

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***Abstract*— Grid computing are integrated environments in which software and hardware resources are pooled in ways that give any user the impression of working with a single fast computer. This paper examines the current advances in grid computers from the point of view of their structures, global attention and support. With the advancement of technology, the working of grid based computations have been simplified where each computer's resources are shared with every other computer in the system. The major resources that are considered to be vital in the grid computing platform are the processing power, memory and data storage. These are treated as communal resources rather than as individual resources and thus promoting resource sharing for all the authorized users. This provision helps to perform on-demand services over the Internet and supports a wide variety of applications that requires huge processing power and heavy storage for data. One of the challenges due to this sharing platform that provides services on adhoc basis is to maintain sustainability. The main goal of this paper is that discuss a model that is at the conceptual level and directing it for further research.**

Keywords—Grid Computing; Sustainability; Energy; Resource usage; conceptual model

I. Introduction (*Heading 1*)

The grid architecture comprises of Fabric layer, Connectivity layer, Resource layer, Collective layer and Application layer. The grid architecture is also well known for its large scale geographical heterogeneous distribution and the major challenge in resource sharing from this large sale consumer and provider scheme is the usage of energy and administration of resource sharing. To solve this challenge of having to maintain a grid computational efficacy, a large number of researchers proposed resource management policies, algorithms and architectures but energy-efficiency is still a challenge and there is lot of scope for future researchers. One proposed solution to overcome one of the issue is to have a fuzzy logic based SVM approach to secure a collision free path avoiding multiple adhoc obstacles [1] to handle dynamic resource scheduling. This Fuzzy logic based approach takes care of dynamic resource sharing while the major challenge is due to the security issues and inability to sustain itself due to its scalable nature. Handling both sustainability and energy-efficiency simultaneously can solve new open challenges existing in the resource scheduling. Different geographical weather and climatic scenarios may also be considered to take the advantage of temperature setting available for having a coolant system. Grid computing offers an effective administration of resources, which conserves or limits energy usage by curtailing the quantity of physical servers. Additionally, it lessens the administrative and management charges and offers added flexibility and scalability for commercial development. This paper includes a review of current trends in grid computing and available options; creation of awareness of the importance of grid computers; and conceptual model for sustainable grid framework.

II. Current Trend in Grid Computing

A. *Resource Discovery and Utilization:*

The growth rate in network bandwidth is progressing at a faster pace than that of CPU speed which means that the way to make best use of computing power is to grid the computers in a efficient way conserving the energy [2]. Grid Computing is realized as the indispensable computing technology allowing the progression of all sciences. The components of grid computing architecture comprise of possibly remote, dynamic, heterogenous, untrusted computing resources. For a seamless provision of grid services, the processes such as authentication that takes care of the genuine nature of the user identification, authorization that allows the users to access certain resources (Virtual Organization), Resource Access that allows authorized users to remotely access resources and Resource Discovery that enables a way to determine and identify the remote resources that they can use, are considered vital. Each process as it has to comply over the remote infrastructure, is quite challenging an requires various means to economically sustain as the challenges in deployment on such a large scale is unavoidable. Grid Economics has been in detailed discussion for years and several researches have put forth several models. One such model has been proposed for the blade servers [3], where the blade servers are considered to be akin to grid computer nodes this incentive based model that could help motivate the resource providers to come forward as they get some incentives. The performance analysis for blade operations in a commercial platform is depicted in figure 1.

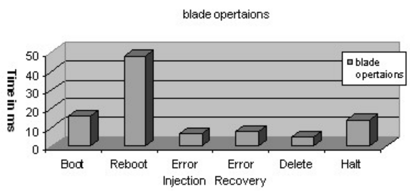

Figure 1: Performance Analysis

Owing to the performance gained, this concept is acquisitioning acceptance intended for their numerous advantages in their performance parameters such as fast

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computing, compact nature, effortlessness of management, energy efficiency etc and these parameters are akin to the grid architecture in the internet backbone.

B. *Grid Economics*

An incentive based system has been proposed [4] to motivate the resource providers for the provision of the spare CPU time and this global billing system attempts to have precision by maintaining the track of CPU time used, CPU time provided by the resource providers and also the transactions pertaining to the incentives. However, in order for a world-wide billing system to work, there will need to be some way of accurately keeping track of the CPU time used, the CPU time provided by each user and a way of transferring incentives among the users. The system [4] proposed is scalable and also trusted that makes this framework doable. VO-wide resource allocation scheme to minimize cost [4] in order to meet a user's job and increase the mutual-reliability among the users of the GRID. However, the challenge here is in terms of the revenue generation to provide these incentives. For example, if an application is run in micro seconds through grid resources rather than taking up seconds to complete, the charge could be anywhere between 10 currency units to 100 currency units or even more depending upon the resources that were deployed and their geographical location. Some of the algorithms proposed takes care of using resources that costs minimal and certainly in the above example, there are means to allot resources that cost 10 currency units and not 100 units. One such procing paradigm is the Dynamic Pricing for multi-products in Grids [5]. While the costing can be calculated based on the ISP charges, the challenge lies in the sustainability factor of this framework. Furthermore, this model computes the optimum pricing by identifying locally available resources, where the demand is given exogenously. As it is a well known fact, dynamic users who join and leave the Virtual organization is common and the resource consumer who leaves the VOs without payment is quite possible and hence this might lead to failure of the framework. Hence a model is required that could provide this grid framework in a sustainable way. This conceptual is possible as Internet of Things is advancing day by day.

III. Grid Computer Framework

A. *Cost Factors*

Grid computing provides a flexible computing ambience through virtual organisations with internet as the primary backbone. In the previous section, one of the cost factor, the charges proposed by Internet Service Providers has been described. However, there are several other cost factors that play a critical role and contribute to the costing in the framework, such as, energy that is required to run the processors, type of applications and their design, storage that is required to save and retrieve records from the database management system.

B. *Energy consumption*

It is well known fact that energy is hugely consumed for computations based in a grid computing environment as stated in the preceding section. Consider figure fig 2 which illustrates a typical computation that is carried out in a grid platform. The applications that are run could be analytical, transactional or mere report generation. However, it requires an extensive integration of collaborative execution of tasks, coordination of resources with load balancing as well critical intelligent management of data that consumes huge amount of power both by resources provider and resource consumer and in some cases also by the Broker as there is utilization of processor, storage, memory, network and coolants.

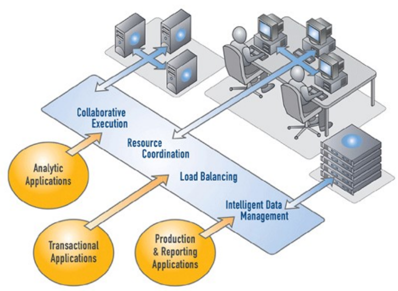

Figure 2: Computations in Grid Platform

In grid, the energy consumption varies as per the grid component. Figure fig 3 illustrates the energy consumption of different components in grid.

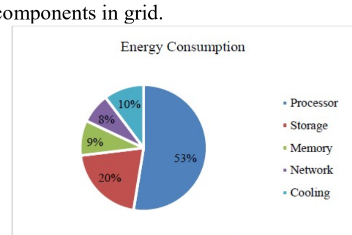

Figure 3: Energy Consumption of different parameters

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One of the sustainable development goals[6] is to "Ensure access to affordable, reliable, sustainable and modern energy for all" which is classified as goal 7: affordable and clean energy and this calls for conserving energy and also to consume it sensibly and this applies to the Grid computing architecture as the trend is moving towards Greening the computations. Either it be a static or dynamic energy consumption, the energy management technique handles resource consolidation and resource management. Proactive management administers the resource management based on the future prediction and this could be based on the fuzzy logic and also recognizing the process pattern.

C. Cooling Mechanisms

For data grids, racks of database servers are placed to serve the queries that are from remote nodes and thus this needs a constant usage of servers that easily gets heated up. Hence the heat generation process can be regulated through cooling management system and this management system must ensure that the cooling mechanism is improvised as well as conserve the energy used for cooling. Scheduling that is based on the ambient temperature as well as the servers computational duration can be taken into account for this and the parameters that could be optimized by this are the execution time, energy cost, energy consumption, internet bandwidth cost, energy consumption and power cost and all this are operable in the heterogeneous workloads with reliability of service and increased security without compromising the environment sustainability.

D. Metrics used for Energy and power cost

An energy reduction and conservation technique require a metric to measure the energy consumed at a given point of time and also must provide a cumulative pattern. Some critical metrics[7]that are required are Power Usage Efficiency(PUE), Total Cost of Ownership(TCO) and Coefficient of Performance (CoP). Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity that you use in an equation.

Expression 1:

$$PUE = \frac{\text{Total Energy Usage by ICT devices}}{\text{Energy Consumed by all the Devices(IT and non-IT)}}$$

Expression 2:

$$TCO = \text{Indirect Cost} + \text{Direct Cost}$$

Expression 3:

$$CoP = \frac{\text{Removed Heat}}{\text{Work done for heat removal}}$$

Expression 4[8] :

$$Carbon\ Usage\ Effectiveness\ (CUE) = \frac{\text{Total } CO_2 \text{ emissions produced}}{\text{Energy IT equipment}}$$

Expression 5[9]:

$$Water\ Usage\ Effectiveness(WUE) = \frac{\text{Annual Water Usage}}{\text{IT Equipment Energy}}$$

The above expression provide means to measure sustainability aspects of carbon, energy and water and the units of WUE is measure in litres per kilowatt-hour.

E. Conceptual Model for Sustainable Grids:

The above challenges must be addressed to have a long term benefit from the grid architectural framework. This also motivates the resource providers to come forward for sharing resources and thus having a world-wide integration of resources. The major components of this conceptual model is the Grid architecture, Database repository, Green Computing Resource Manager & Coolant System and User Interface via IoT. All the components are interlinked and provide inputs to others for mutually recognizing the pattern and thus attempt to achieve a long term self-sustained benefits.

F. Layered Architecture of Grid Computing System:

Consider the four-layer model of grid computing system[10] with node and interconnection layer, node system software layer, Grid system software layer and application layer. Interconnection layer consists of high performance of computer, large-scale database server, largescale file server, computer cluster, large communication equipment and high-speed interconnection network connecting these resources. Nodes system software layer includes operating system software, large-scale database system software, large-scale file system software, cluster system software, network connection protocol large equipment driver etc. Resource management, data management, user management, task management, information services, authentication and authorization are implemented in Grid system software layer. Figure 4 depicts the grid computing architecture with four layers. Additionally, a fifth layer could be added for integrating for security policies that would cater for the authentication and authorization of user nodes in the grid.

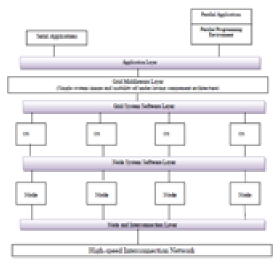

Figure 4: Layered Grid Computing Architecture

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G. Database Repository Grid:

A Database Repository Grid is an assortment of low-cost sectional storage arrays integrated and retrieved by the nodes in the Grid. With the Database Repository Grid, building up a pool of system resources is possible, and this can be accomplished dynamically, that is, allocating and deallocating the resources on demand basis which is determined by the computational priorities. Figure 5 exemplifies the Database Repository Grid in a Grid enterprise computing environment and this is linked up with the grid architecture. The incoming user workload are also managed at this layer which is transferred to the grid manager for further action.

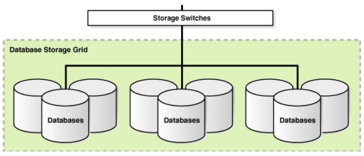

Figure 5: Database Repository

H. Green Computing Resource Manager & Coolant System:

The green computing and coolant system are primary modules of the infrastructure and they are administered by the Manager. This layer has the information pertaining to grid datacentres. The power management unit and automatic transfer Switch are used combinedly to manage the energy coming from both renewable and non-renewable sources. The provision of renewable source is to back up when the non-renewable could not generate power that would suffice. Figure 6 illustrates the infrastructure module that has both Green computing and coolant system manager. Thermal profiling and thermal scheduling is taken care at the coolant system that is integrated to the green computing unit. The ambient temperature and also the nodes temperature are all monitored by the thermal sensors. This has the significant role to switch between renewable and non-renewable source.

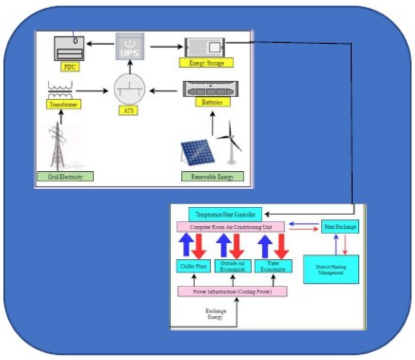

Figure 6: Infrastructure Module

I. User Interface via IoT

As the interactions via internet are becoming smaller and cheaper, and other technological advancements like IPv6, flash memory chips, smart phones usage, evolution of Internet of Things(IoT) has become prominent and thus has opened up prospects for interesting integration of applications to substantially meeting the needs in the underlying technology. The IoT paradigm is not only seen efficient, scalable, reliable, secure and trustworthy which are required for the sharing resources with in the virtual organizations of the grid architecture but also seen as the one of the module that could become indispensable for any advanced distributed paradigm such as the grid or cloud. The mobile applications and also the mobile processors, storage can also be utilized for this through a single touch of the screen. Also, the weather conditions during the mobility could change variably and this could be an added advantage for energy conservation and thus could provide inputs to the other modules such as the cooling manager and the infrastructure module. Technically the mobile nodes can also act as mobile sensors. Figure 7 exemplifies the application of IoT in Grid Computing framework.

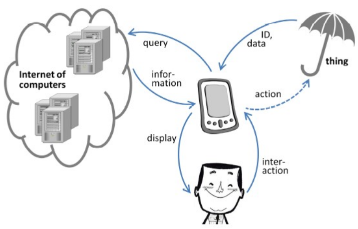

Figure 7: IoT Paradigm

IV. INTEGRATION OF THE MODULES:

As explained in the previous segments, the integration of the modules is the key to derive the proposed conceptual model for Grid Computing framework to achieve sustainability. The integration could provide sustainable and reliable service in the grid ambience. It is also believed that through this integrated model, capacity planning, usage of renewable energy where possible and utilization of waste heat generated will certainly be improvised offering the users a reliable service while the infrastructure remains sustainable and this is shown in figure 8.

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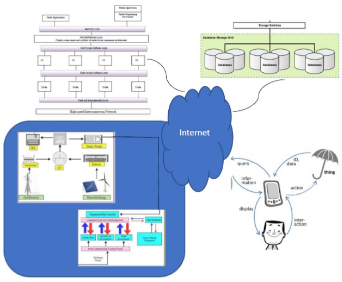

Figure 8: Integrated model for Sustainable Grid Computing

The objective of reducing power consumption certainly affects the reliability of grid services and this is could be prevented by the enhanced energy-aware resource management that needs tight integration among the four modules that could provide the amount of energy consumed from various sources and thus could conserve energy wherever possible and also without compromising the quality of grid services. The workloads that require constant power could be use the non-renewable source of energy while the workload that require minimal time duration can always switch to renewable source.

V. Conclusion

In this paper, a conceptual model for sustainable grid computations is proposed by analysing existing methods and approaches that could be applied in primary parameters such as application, energy, scheduling and internet of things paradigm. Each of the parameters were analysed with their advantages and limitations. The model also allows the provider to have the flexibility to a certain degree to allocate these jobs according to his resource utilization. Future work on this topic is required that allows to have improvised approaches that could enhance the performance of the service has been considered in this model, hoping that a detailed taxonomy for this model will be analysed that could propose various future research directions.

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