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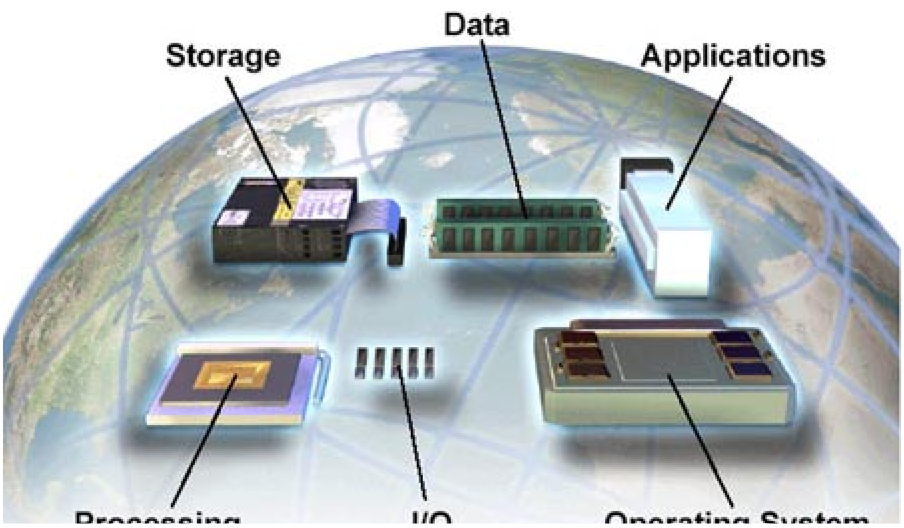
Grid Networking

Introduction

Grid networking, as a concept, is not new. What *is* relatively new is the current transition of grid networking (or "grid computing") from research and development to more significant commercial vertical markets. To that end, this report covers the vision of grid networking and the pragmatic evolution in reaching that vision. It investigates the architecture of a grid and the technologies and standards that define the architecture. In addition, it will describe the market landscape and associated taxonomy while serving to explain the association between grid deployments and the underlying network layer.

The vision of grid computing is to virtualize computing, with the goal of creating a utility computing model over a distributed set of resources. The diagrams below, provided by IBM Corp. (NYSE: IBM - message board), help to visualize the concepts. Within a single computer exist standard elements including the processor, storage, operating system, and I/O. The concept of grid computing is to create a similar environment, over a distributed area, made up of heterogeneous elements including servers, storage devices, and networks – a scaleable, wide-area computing platform, if you will. The software that handles the coordination of the participating elements is analogous to the operating system of a computer or server.

Virtualization of Computing



Deployment Scenario: TeraGrid
Part 19
Conclusion

Table 1
Grid Computing Taxonomy

TECHNOLOGY CHANNELS
NEWS, ANALYSIS, AND EDUCATION

Ethernet Channel
Metro Channel
Multiservice Channel
Testing Channel

- Editorial Calendar
- Archives
- Message Boards
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- Top 10 Lists
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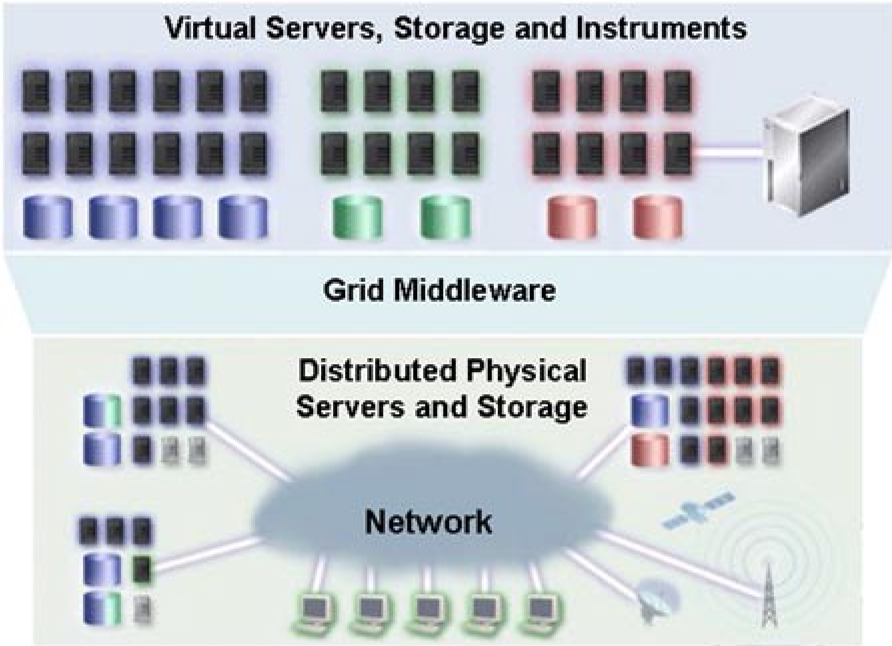
Visualizing Grid Computing



Virtualizing these resources yields a scaleable, flexible pool of processing and data storage that the enterprise can use to improve efficiency. Moreover, it will help create a sustainable competitive advantage by way of streamlining product development and allowing focus to be placed on the core business. Over time, grid environments will enable the creation of virtual organizations and advanced Web services as partnerships and collaborations become more critical in strengthening each link in the value chain.

There are many definitions for grid computing, depending on the context of the definition. The following two are pretty comprehensive:

- It's an aggregation of geographically dispersed computing, storage, and network resources, coordinated to deliver improved performance, higher quality of service, better utilization, and easier access to data.
- It enables virtual, collaborative organizations, sharing applications and data in an open, heterogeneous environment.

The common denominator for all grid deployments is the network layer. Since it is this common network fabric that connects all of the resources in a given grid, its significance is amplified. High-speed data networking technology has been the cornerstone for the evolution of grid technology from its inception and will continue to be so in the future. Distributed grid systems demand high-speed connectivity and ultra-low latency. High-performance Ethernet switching solutions are critical in meeting such requirements. Two of the primary characteristics required from such solutions are:

- Ultra-dense Gigabit Ethernet interface support
- Line-rate 10-Gigabit Ethernet performance

The requirement to aggregate large numbers of Gigabit Ethernet-attached servers, that are resources in grid deployments, drives the need to support dense Gigabit Ethernet ports. Line-rate 10-Gigabit Ethernet is required to transport the aggregated traffic over the backbone of a given grid network at line rate. In addition, 10-Gigabit Ethernet switch ports are increasingly important as the server NIC market evolves from Gigabit Ethernet to 10-Gigabit Ethernet.

The grid computing market, as a whole, is in a relatively early stage, but now is the time to initiate grid-related developments for several reasons, particularly the following:

- The emerging applications are significant, coming from increasingly important vertical markets, including energy and oil, financial services, government, life sciences, and manufacturing.
- The infrastructure to support these applications is currently underserved.
- The potential market size is substantial, predicted by several research firms to grow from today's size of several hundred million dollars (including hardware and software associated with grid deployments).
- Investment commitment and development focus from the industry's largest computing players, including Dell, HP, IBM, Microsoft, and Sun, is an indicator that this is a growth market.
- Increased deployment of blade servers coincides with the related view of blade server vendors that clusters and grids are ways of moving up the enterprise value chain.
- There is increasing pressure for enterprise IT organizations to cut costs and increase utilization of existing infrastructure.

As grids evolve from clusters to virtualized enterprise data centers to distributed campus and wide-area deployments, the underlying network must cost-effectively grow, in scale and performance, to meet the demands along the way. High-performance Ethernet, evolving from ubiquitous networking technology, continues to track the cost, performance, and scaleability curves set forth by grid networking in pursuit of this evolution.

Click on the links below to read the report, or you may read the report sequentially:

— Rick Thompson, Principal Analyst, PointEast Research LLC, and Scott Clavenna, Director of Research, *Light Reading*

To view an archive of Byte and Switch*'s Webinar* – Grid Computing: Tapping the Matrix – *which was conducted on February 19, 2003,* click here.

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Types of Grids

From an application perspective, there are two types of grids: **compute grids** and **data grids**. From a topology perspective, it can be argued that there are additional types, including clusters, intra-grids, extra-grids, and inter-grids. In reality, clusters, intra-grids, extra-grids, and inter-grids are better defined as stages of evolution. In each of these stages, which will be discussed in the next section, it is possible to support compute grids, data grids, or a combination of both. The majority of the early grid deployments have focused on enhancing computation, but as data grids provide easier access to large, shared data sets, data grids are becoming increasingly important.

A **compute grid** is essentially a collection of distributed computing resources, within or across locations, that are aggregated to act as a unified processing resource or virtual supercomputer. These compute resources can be either within or between administrative domains. Collecting these resources into a unified pool involves coordinated usage policies, job scheduling and queuing characteristics, grid-wide security, and user authentication. The benefit is faster, more efficient processing of compute-intensive jobs, while utilizing existing resources. Compute grids also eliminate the drawback of tightly binding specific machines to specific jobs, by allowing the aggregated pool to most efficiently service sequential or parallel jobs with fine-grained user attributes.

A **data grid** provides wide area, secure access to current data. Data grids enable users and applications to manage and efficiently use database information from distributed locations. Much like compute grids, data grids also rely on software for secure access and usage policies. Data grids can be deployed within one administrative domain or across multiple domains. It is these cases where the grid software and policy management become critical. Data grids eliminate the need to unnecessarily move, replicate, or centralize data, translating into cost savings. Initial data grids are being constructed today, primarily serving collaborative research communities. Software vendors and large enterprises are currently investigating data grid solutions and services for business applications. Down the road, data grids will be a key element in the rollout of Web services.

The evolution from compute grids to data grids is an important factor in repositioning grid applications from education and R&D to the large enterprise. This transition is an indicator that the market, in addition to the technology, is maturing. From a networking perspective, the impact of data grids will include a tighter integration of storage protocols and high-performance networking.

This year will likely continue to see compute grids as the primary deployment scenario in both enterprise and R&D environments. Enterprise companies will begin using the technology, looking to reduce costs and increase competitive advantage by leveraging existing resources instead of investing heavily in high-performance supercomputing solutions. The maturation of grid middleware for compute and data grids, in addition to the recent advances in data networking equipment, will provide the necessary momentum for evolving grids from local clusters to distributed, wide-area systems.

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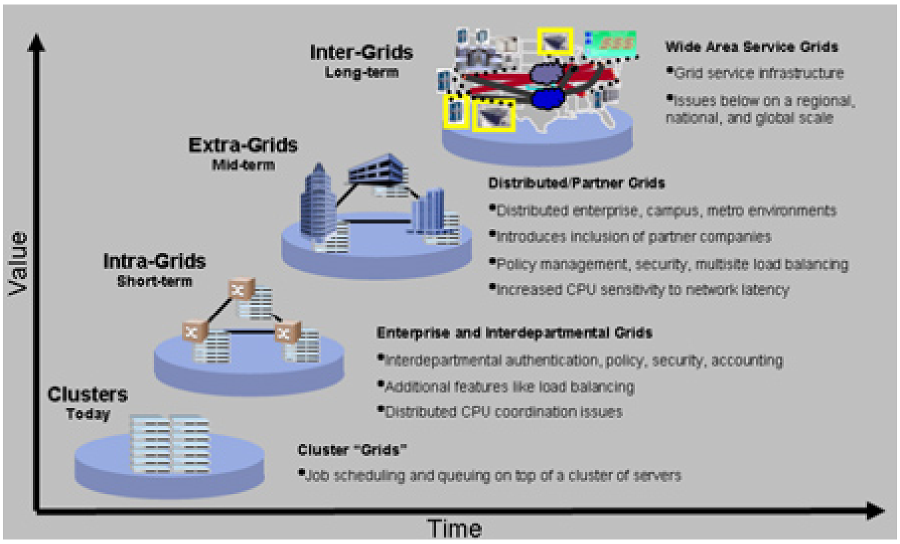
Evolution of Grid Computing

Before getting into the detailed evolutionary steps, it is important to clear up a frequent misconception about grid computing. Referring to grid computing as "The Grid," much in the way people refer to "The Internet," is not necessarily the most appropriate or accurate reference. Although it is convenient for introducing a high-level discussion, there is not one single "grid." Instead, there are many grids, some private, some public, some local to one room, and some distributed over wide geographic areas.

Understanding this is important in better understanding the evolution of grid computing. As far as network resources are concerned, these grids may or may not employ public Internet resources for extended access and reach. Below is a diagram that illustrates the evolution of grid computing.

The Evolution of Grid Computing



The first stage of grid computing is **cluster grids**, or just clusters. Because the true definition of a grid includes terms like "distributed" and "heterogeneous," it is debatable whether clusters should actually be considered grids. Semantics aside, clusters are critical in the evolution of grid computing, thus their inclusion here. Clusters are often defined as distributed file systems and/or collections of homogeneous servers aggregated for increased performance. Sun Microsystems Inc. (Nasdaq: SUNW - message board), which has more than 6,000 grids deployed, counts clusters as a majority of these deployments.

Clusters are widely used in the manufacturing domain for things like simulation-based testing and evaluation. The majority of new cluster servers have Gigabit Ethernet interfaces, and can range from a handful to literally thousands (in research environments) of servers. As a result, high-density Gigabit Ethernet support is necessary. In addition, low-latency switching is also critical in maintaining application performance across the fabric of a cluster. Although other proprietary interconnect technologies like Myrinet and Quadrics are prominent in R&D environments, it will likely be Ethernet that dominates the transition into the enterprise. Other technology contenders, such as InfiniBand, seem to be losing ground in penetrating the enterprise data center.

As mentioned above, clusters are critical in the evolution of grid computing. This is because in order to move to the next phase, known as **intra-grids**, clusters need to be interconnected. By interconnecting separate clusters, it enables the creation of enterprise and inter-departmental grids. The creation of intra-grids puts additional strain on the controlling software layer, or middleware, and the underlying network layer. The middleware must now have a better understanding of resource allocation because of additional complexity introduced by processor-sharing relationships. Things like latency are even more challenging now at the network layer, but such interconnection also introduces the need for 10-Gigabit Ethernet trunks between clusters.

Intra-grids will evolve in a very controlled fashion. For example, two or three clusters may be interconnected between departments within an enterprise to increase processing capacity and share data sets. Because the relationship between clusters is still within one enterprise domain, things like security and authentication, although important, are not as critical as in later phases. The creation of intra-grids is starting to happen as we speak. This is the current phase of grid computing evolution.

Speaking of additional challenges in later phases, this brings us to **extra-grids**. Extra-grids are essentially cluster grids and/or intra-grids that are connected between geographically distributed sites within or between enterprise organizations. The two important distinctions here include geographic distribution and inter-enterprise relationships. Because of these relationships, extra-grids are sometimes referred to as partner grids. Now that processing and/or data can be shared between two different organizations, authentication, policy management, and security become critical requirements that the middleware must address. Multisite load balancing, topology discovery, and application awareness are also important to ensure performance.

At the network layer, things like long reach (LR) interfaces, LAN/WAN PHY support, high-speed trunking, and Layer 3 routing become more important due to the distributed nature of the grid topology. An example of an extra-grid would include a life-sciences company outsourcing part of its drug discovery process to another pharmaceutical firm, thus creating the need to share processing power and database resources.

The final stage in the evolution of grid computing is the **inter-grid**. This is the most powerful stage because it embodies two of the primary visions for grid computing: utility computing infrastructure and grid services/service providers. Although this is the final stage, and we are not there yet from a commercial perspective, it should be noted that inter-grids do exist today in the research and development world. In fact, later in the paper one of the most significant inter-grids is profiled, the TeraGrid.

Inter-grids far outpace all other phases in relative complexity. For example, rather than two or three partners participating in an extra-grid, an inter-grid could service hundreds or even thousands of users. As a result, all of the complexities at the middleware layer and the network layer are increased significantly. Although this is an exciting stage in the evolution, it is not in the cards over the next few years. The consensus seems to be that this development will likely happen five to 10 years out.

What might be more interesting is the potential for grids to experience organic growth through the evolution of enterprise data centers with efforts around virtualization leading the way. This growth scenario is more realistic, considering each enterprise can optimize around cost and efficiency, rather than being driven by solving compute-intensive problems that may represent a smaller market. Once individual enterprises evolve their architectures accordingly, it will create a more natural path for interconnecting these data centers in grid-like structures. These interconnections will in turn enable an easier creation of grid services and grid service providers.

It will take time to reach the final phases in the evolution of grid computing, but two things are clear, indicating that the market is growing from both ends of the evolution spectrum. First: Cluster grids are currently evolving toward intra-grids in the commercial world. Second: Complex inter-grids are being constructed, tested, and deployed in the research world. These are signs that momentum is building and the market is moving forward. The key to successfully penetrating the market will be to establish early deployments so technology can evolve in step with the market requirements. Approaching the problem in the right series of steps as opposed to overshooting the market will be critical for future success.

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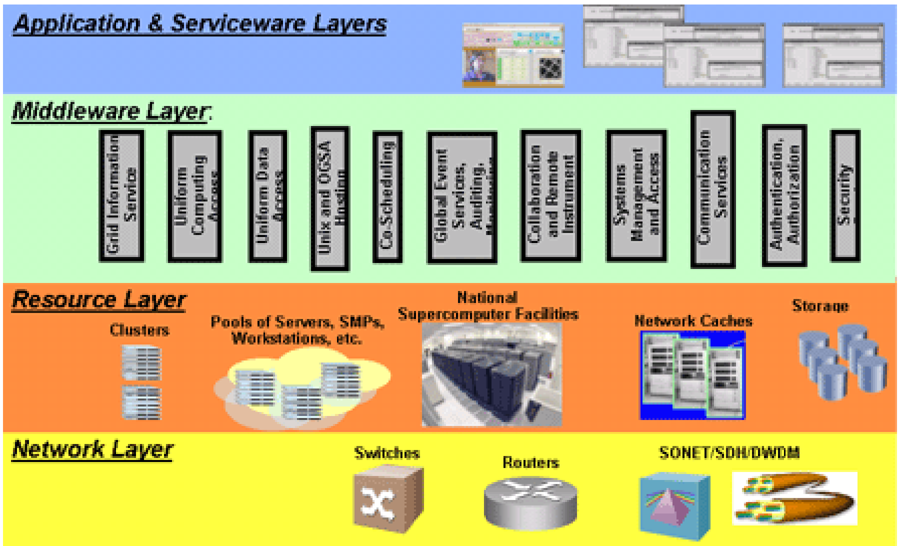
Architecture of a Grid

Designing a viable grid includes much more than aggregating the processing power of idle machines via software. There are multiple layers, each of which plays a critical role. In general, the higher layers are more software-centric, whereas the lower layers are more hardware centric. The diagram below provides a graphical view of the layers that define grid computing and the function that each layer provides.

Architecture of a Grid



Application and serviceware software defines the highest layers of the grid architecture. This includes portals and development toolkits as well. Applications vary from industry to industry, depending on the business problem, as do the portals and development toolkits supporting the applications. Serviceware provides many management-level functions including billing, accounting, and measurement of usage metrics all very important things to track as resources are virtualized for sharing among different users, departments, and companies.

The middleware layer provides the protocols that enable multiple elements (servers, storage, networks, etc.) to participate in a unified grid environment. The middleware layer can be thought of as the intelligence that brings the various elements together through software and control. There are many different functions and protocols that the middleware layer supports, which are discussed later in this section. The resource layer is made up of the actual resources that are part of the grid, including primarily servers and storage devices. The network layer is the underlying connectivity for the resources in the grid. For wide area grids, long-reach, high-capacity WDM links may be used for sheer connectivity, but the Layer 2/3 switch routers provide the connectivity, performance, and intelligence to fill such pipes.

Multilayer architectures such as grids demand strong standardization, because equipment from different suppliers will be part of distributed deployments. There are several grid-specific standards initiatives. Below is a list of the most prominent grid standards activities.

- **Global Grid Forum (GGF):** The GGF is responsible for promoting and supporting the development of grid standards. The recommendations process within the GGF mirrors that of the Internet Engineering Task Force (IETF), thus following a proven model.

  Sponsors of the GGF include Hewlett-Packard Co. (NYSE: HPQ - message board), IBM Corp. (NYSE: IBM - message board), Intel Corp. (Nasdaq: INTC - message board), Microsoft Corp. (Nasdaq: MSFT - message board), and Sun Microsystems Inc. (Nasdaq: SUNW - message board), to name a few.

- **Globus:** An R&D project focused on enabling grid applications by providing tools that make it easier to develop computational grids. Globus facilitates the development of the Globus Toolkit. The Globus project is organized around four main activities: applications, research, software tools, and testbeds.
- **Globus Toolkit:** An open architecture, open source software toolkit enabling users to more easily build computational grids. The toolkit provides a collection of protocols and service definitions for grid deployments.
- **Open Grid Service Architecture (OGSA):** A proposed evolution of the current Globus Toolkit towards a grid system architecture based on an integration of grid and Web services concepts and technologies.
- **Others:** There are other initiatives underway as well, some of which include Open Grid Service Infrastructure Working Group (OGSI-WG), Access Grid, and Condor.

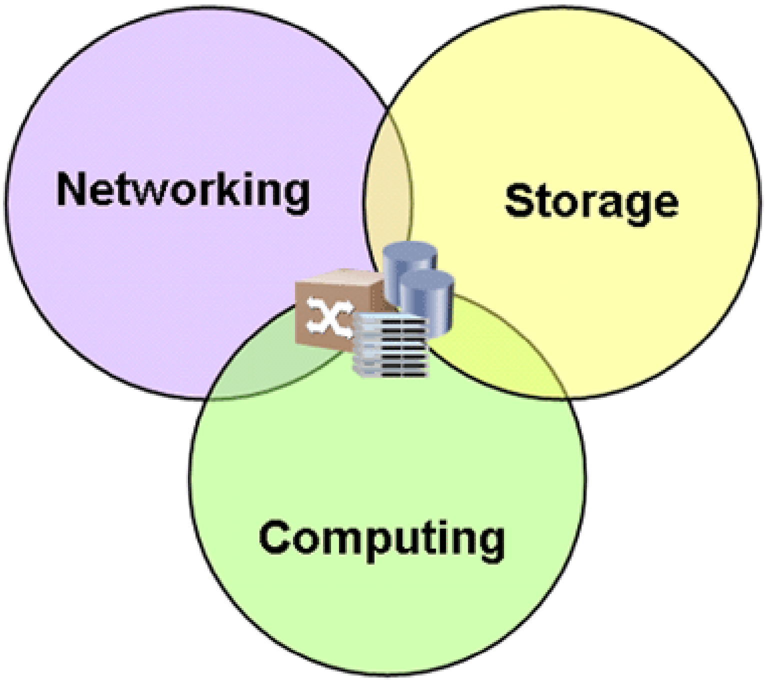
Many of these initiatives have been around for several years but are just now beginning to achieve significant momentum, as large enterprise companies begin to test and deploy grid networks. Some of the most significant companies in the server, storage, and networking industries are backers of these standards initiatives.

The Globus Toolkit is probably the most widely used set of grid protocols and services in many of the early grid deployments. As mentioned above, Globus Toolkit is open source, although there are several commercial versions of grid middleware software that perform similar functions. Below is a list of the primary elements included in the Globus Toolkit.

- **Globus Resource Allocation Manager (GRAM):** Processes resource requests and allocates resources for application execution. It also manages active jobs running on a grid and returns updated capability information to the Monitoring and Discovery Service (MDS).
- **Monitoring and Discovery Service (MDS):** An LDAP-based means of querying system information from a variety of components (e.g., processing capacity, bandwidth capacity, type of storage). MDS enables the collection of element-specific information for use in a grid environment. It allows the optional construction of a uniform namespace for resource information across a system that may involve many organizations.
- **Grid Security Infrastructure (GSI):** Provides secure authentication and communication over a grid network. In addition, it supports security across organizational boundaries and single sign-on for users of a grid, including delegation of credentials for computations that involve multiple resources. GSI is based on public key encryption, X.509 certificates, and secure sockets layer (SSL), with extensions for grid-specific applications.
- **Grid Resource Information Service (GRIS):** Provides a uniform means of querying resources on a grid for their current configuration, capabilities, and status. Such resources could include server, storage, and network nodes, in addition to databases and network links.
- **Grid Index Information Service (GIIS):** Provides a means of coordinating arbitrary GRIS services to provide a consistent system image that can be explored and searched by grid applications. In addition to an entire consistent system image, subsets of GRIS services, such as all storage within a specific subset of a grid, can be defined.
- **GridFTP:** A high-performance, secure, robust data transfer mechanism for grid environments. GridFTP is based on FTP (file transfer protocol) with extensions for grid-specific requirements. Additional features such as third-party control over data transfer, parallel data transfer, striped data transfer, and partial file transfer are included in GridFTP.
- **Replica Catalog:** Provides a mechanism for maintaining a catalog of dataset replicas. It does so by providing mappings between logical names for files and one or more copies of the files on physical storage systems.
- **Replica Management:** Provides a mechanism that ties together the Replica Catalog and GridFTP technologies, allowing applications to create and manage replicas of large datasets.

Many of the protocols and functions defined under the Globus Toolkit are analogous to protocols that exist in networking and storage today, albeit optimized for grid-specific deployments. The synergy between grid protocols defined at the middleware layer and protocols at other layers, like networking and storage, are expected to pragmatically converge over time. Grid computing applications are a convergence point for storage, networking, and computing, thus the expected convergence at the protocol and/or technology level.

Market Convergence



Many of the functions performed by grid middleware and/or grid server appliances today including things like security, quality of service, fault detection and recovery, policy management, scheduling and queuing, authentication, topology discovery, resource allocation, and load balancing are natural tasks for today s networking products and protocols. As the networking market and the computing market further converge, functions such as this will follow in hardware and software enhancements optimized for grid computing deployments.

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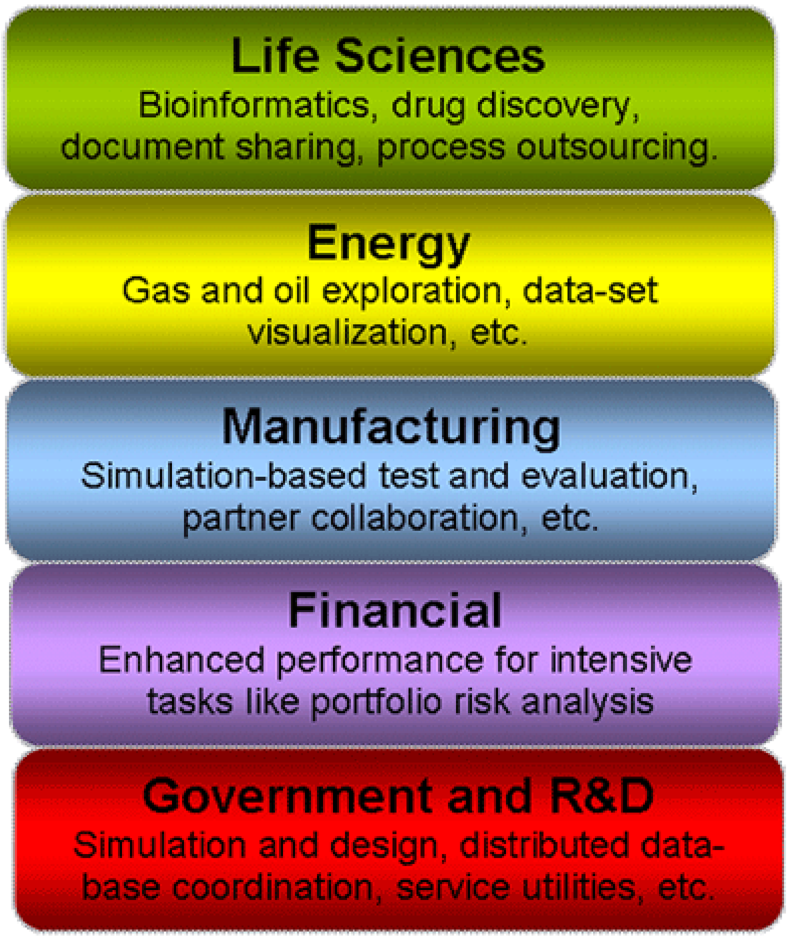
Market Outlook and Segmentation

Although initial grid computing deployments took off in R&D environments, the market evolution is starting to indicate interest from enterprises within a few primary vertical markets. The verticals that have shown the most interest in grid computing thus far include life sciences, energy and oil, manufacturing, financial services, and government. Applications vary based on the industry, but a few of the primary drivers, identified in the graphic below, include:

- Streamlining development and testing for Bioinformatics and drug discovery
- Graphically visualizing data sets for gas and oil exploration
- Simulation-based test and evaluation for technology development, including chip design
- Timely and accurate assessment of portfolio risk analysis

Markets and Applications



Although it is a bit early to call the size of the grid computing market, several research firms have put some numbers on the expected market size. One of the more optimistic views comes from Grid Technology Partners, an analyst firm specializing in grid computing. By 2005, Grid Technology Partners expects the overall grid computing market to grow as high as $4.1 billion. It is probable that this number includes hardware and software elements from all layers of the grid architecture. Other firms have more conservative estimates, viewing today s market to be in the range of several hundred million dollars and growing, albeit not quite that high in such a short time period.

Regardless of market forecasts, the majority of the opportunity will be in education and research in the short term. As the market expands into the enterprise, it will be through blade server aggregation and clusters, as well as enterprise data-center virtualization. This will translate into meaningful growth, although it will not be as rapid as some may expect. Higher-growth opportunities will exist in the long term with the creation of wide-area grid services and grid service providers.

In the previous section, we looked at the architecture of a grid and identified the various layers from a technological perspective, including application, serviceware, middleware, resource, and network. The next step is to better understand what types of vendors fit into each layer, thus putting more color around the taxonomy of the grid computing industry.

In doing so, it is important to understand that the success of some of the vendors mentioned is predicated entirely on grid computing taking off in a meaningful way (primarily at the serviceware and middleware layers). Other vendors target grid computing from more of a strategic perspective, also targeting other markets (primarily players at the resource and network layers). The table below provides a high-level view of the grid computing taxonomy.

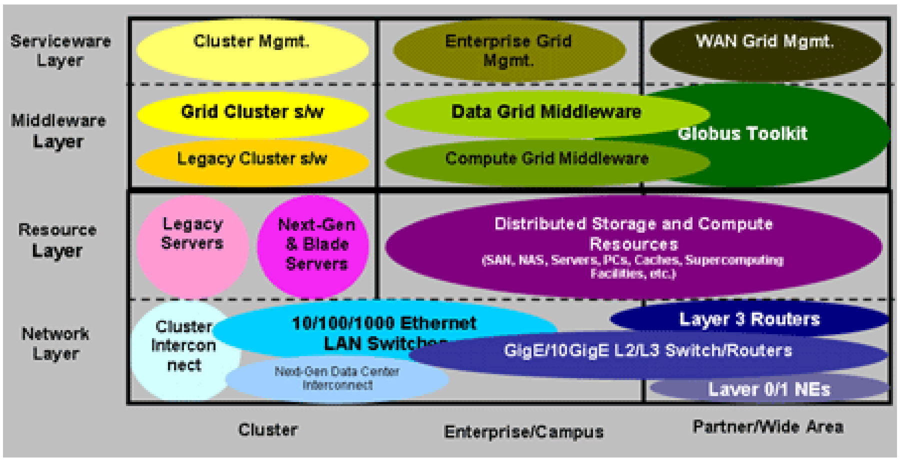
Table 1: Grid Computing Taxonomy

Layer	Description	Vendors/Industry Segment
Application Layer	Distributed and/or performance-intensive application software	Life Sciences, Energy, Manufacturing, Financial Services, Government, Education
Serviceware Layer	Service interface and tool for usage metrics, billing, accounting	Sun, IBM, HP, Oracle, Platform Computing, Avaki, Entropia, United Devices, DataSynapse, GridFrastructure, Powerllel, Globus
Middleware Layer	Grid-wide "glue" software for resource mapping, scheduling, priority-based queuing, security	Sun, IBM, HP, Oracle, Platform Computing, Avaki, Entropia, United Devices, DataSynapse, GridFrastructure, Powerllel, Globus
Resource Layer	Collection of distributed, heterogeneous storage and compute resources	Sun, IBM, HP, Dell, Egenera, EMC, SGI, other numerous storage and server startups
Fabric Layer	Performance-driven, high-speed networking (highly Ethernet-centric)	Cisco, Foundry, Force10 Networks, Juniper Networks

Although grid computing is an emerging market, it is important to start understanding the market's segmentation. Within each layer of the grid computing taxonomy, there is further segmentation of applications and technologies. The diagram below provides a current view of the market segmentation for grid computing. Listed on the x-axis are the stages of grid computing evolution. Listed on the y-axis are the layers of the grid architecture. This diagram provides a snapshot of the current view of market segmentation. As markets and technologies converge, it is quite possible that the market segmentation in the future will look different as a result. Listed below are a few comments that should help clarify the market segmentation diagram.

- **Application Layer:** Not included in the market segmentation diagram, as the focus of this report is on the infrastructure technology that supports grid computing applications
- **Serviceware Layer:** Basically the management layer of grid computing market segmentation
- **Middleware Layer:** Primarily the protocol layer of grid computing market segmentation the diagram provides context for local and distributed middleware from open source initiatives as well as commercial developments
- **Resource Layer:** Includes servers and storage resources across local clusters, enterprise data centers, and wide-area grid networks
- **Network Layer:** Provides context for high-speed server interconnection used in clusters, as well as more sophisticated routing and switching technologies used in complex grid networks

Grid Computing Market Segmentation



As the diagram depicts, the higher layers are more software-centric, whereas the lower layers are more hardware-centric. The majority of grid-specific software development is currently happening in the middleware layer, with compute- and data-grid middleware. The majority of startups focusing on grid computing are at the middleware layer. Two of the primary trends at the resource layer include storage networking/virtualization, and blade server proliferation. The most significant network layer advancement for grid computing over the last several years is the availability of 10-Gigabit Ethernet. The culmination of these trends is converging on the enterprise data center.

As pieces of these technologies are deployed within the charters of next-generation, enterprise, data-center initiatives, grids will tend to grow organically. It may or may not be the case that such initiatives even use the term "grid," but the fact remains that the associated cost reductions and increased efficiencies will be a result of these early enterprise data center and/or grid initiatives.

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