Implementing DWDM Lambda-Grids

Marlyn Kemper Littman
Nova Southeastern University, USA

INTRODUCTION

Unprecedented demand for ultrafast and dependable access to computing Grids contributes to the accelerating use of **dense wavelength division multiplexing (DWDM)** technology as a **Lambda-Grid** enabler. In the **Lambda-Grid** space, the **DWDM** infrastructure provisions dynamic lambdas or wavelengths of light on-demand to support terabyte and petabyte transmission rates; seamless access to large-scale aggregations of feature-rich resources; and extendible Grid and inter-Grid services with predictable performance guarantees (Boutaba, Golab, Iraqi, Li, & St. Arnaud, 2003).

DWDM Lambda-Grids consist of shared network components that include interconnected federations of other Grids, dense collections of computational simulations, massive datasets, specialized scientific instruments, metadata repositories, large-scale storage systems, digital libraries, and clusters of supercomputers (Naiksatam, Figueira, Chiappari, & Bhatnagar, 2005). As a consequence of the convergence of remarkable advances in **DWDM** technology and high-performance computing, **Lambda-Grids** support complex problem resolution in fields that include seismology, neuroscience, bioinformatics, chemistry, and nuclear physics.

This chapter begins with a discussion of Grid development and **DWDM** technical fundamentals. In the sections that follow, the role of the **virtual organization** (**VO**) in establishing and supporting **DWDM Lambda-Grid** initiatives; capabilities of the **Globus Toolkit** (**GT**) in facilitating Lambda-Grid construction; distinguishing characteristics of **Lambda-Grid** operations, architectures, and protocols; and major **Web services** (**WS**) specifications in the Lambda-Grid space are examined. Descriptions of **DWDM Lambda-Grid** initiatives and security challenges associated with **DWDM Lambda-Grid** implementations are presented. Finally, trends in **DWDM Lambda-Grid** research are introduced.

BACKGROUND

Originally, Grids such as factoring via networked-enabled recursion (FAFNER), Search for Extraterrestrial Intelligence (SETI), and FightAIDSAtHome relied on the donation of unused computing processes by anonymous participants to support persistent connectivity to geographically distributed information technology (IT) resources. These Grids used the transmission control protocol/Internet protocol (TCP/IP) Internet protocol suite for enabling access to distributed resources via the commodity or public Internet. Problems with TCP/IP, including an inability to transport massive information flows over long distances with quality of service (QoS) and accommodate resource reservations in advance in accordance with application requirements, contributed to the popularity of **DWDM** technology as a **Lambda-Grid** enabler.

Present-day **DWDM Lambda-Grids,** such as Data TransAtlantic Grid (DataTAG) facilitate transparent sharing of visualization, scientific, and computational resources in domains that include health care, crisis management, earth science, and climatology, and serve as testbeds for evaluating the capabilities of new network architectures, protocols, and security mechanisms. Interdisciplinary research supported by **DWDM Lambda-Grids** contributes to an understanding of planet formation and brain functions; development of new cancer treatments; and the identification and management of genetic disorders resulting in premature aging and diabetes.

DWDM Technical Fundamentals

Consisting of optical devices such as optical cross connects and tunable optical lasers, **DWDM** networks support operations over optical fiber, a medium that transports image, video, data, and voice signals as light pulses**.** **DWDM** optimizes optical fiber capacity by dividing the optical spectrum into numerous nonoverlapping lambdas to facilitate high-speed transmission of vast numbers of optical signals concurrently with minimal or zero latencies. **DWDM** facilitates network operations at the Optical Layer, a sublayer of the Physical Layer or Layer 1 of the seven-layer open systems interconnection (OSI) reference model, in metropolitan and wider area environments.

DWDM enables sophisticated **Lambda-Grid** functions including job scheduling, accounting, load balancing, and workflow management. In contrast to best-effort delivery service provided by TCP/IP networks such as the Internet, the **Lambda-Grid DWDM** infrastructure accommodates advance reservation requests to support research requiring coordinated use of bandwidth-intensive datasets, instrumentation such as automated electron microscopes, earth observing satellites, and space-based telescopes, and high-resolution models in a shared virtual space.

Barriers to seamless **DWDM** transmissions include signal attenuation, crosstalk, chromatic dispersion that necessitates signal regeneration, and manufacturing flaws in the optical fiber plant (Littman, 2002). To counter constraints, **DWDM** network management systems can be customized to monitor **Lambda-Grid** operations, bandwidth utilization, and application performance to ensure resource availability.

The **Lambda-Grid DWDM** infrastructure interworks with technologies that include wavelength division multiplexing (WDM), coarse WDM (CWDM), synchronous optical network/synchronous digital hierarchy (SONET/SDH), and 10 Gigabit Ethernet (Littman, 2002). Standards organizations in the **DWDM Lambda-Grid** space include the European Telecommunications Standards Institute (ETSI), the Internet Engineering Task Force (IETF), and the International Telecommunications Union-Telecommunications Sector (ITU-T).

Virtual Organizations (VOs)

DWDM Lambda-Grids are typically established by VOs in distributed computing environments that span multiple administrative domains, national boundaries, and time zones (Gor, Ra, Ali, Alves, Arurkar, & Gupta, 2005). A **virtual organization** (**VO**) consists of entities such as government agencies, academic institutions, and scientific consortia that conduct e-collaborative investigations and agree to coordinate functions ranging from provisioning access to massive archives and storage systems to enabling multifile transport in the absence of centralized administrative control**. VOs** also define procedures for resource sharing; authorization, accounting, and authentication services and extendible, scalable, and reliable **Lambda-Grid** operations and set policies for membership, security and privacy, and acceptable resource usage.

Established by an international **VO,** the **Global Lambda Interconnection Facility** (**GLIF**) is a wide-scale **Lambda-Grid** laboratory that promotes development and assessment of **DWDM Lambda-Grid** applications and components (van der Ham, Dijkstra, Travostino, Andree, & de Laat, 2006). **GLIF** also supports international optical interconnection switching and routing facilities such as StarLight in Chicago, NetherLight in Amsterdam, KRLight in Seoul, and CzechLight in Prague. These DWDM facilities interlink high-performance DWDM NRENs (Next-Generation Research and Education Networks) such as GÉANT2 (European NREN, Phase 2), CESnet2 (Czechoslovakia NREN, Phase 2), and GRNET2 (Greece NREN, Phase 2) to enable e-collaborative research among geographically dispersed VOs. Additionally, **GLIF** donates lightpaths to GOLE (**GLIF** Open Lightpath Exchange), an initiative that facilitates construction of a global **DWDM** infrastructure to support transnational **Lambda-Grid** implementations.

Globus Toolkit (GT)

Developed by the Globus Alliance, **GT** is the major middleware toolkit for **DWDM Lambda-Grid** construction. Consisting of an open-source suite of software development tools, programs, and libraries, **GT** enables resource monitoring and discovery, data management, real-time simulations, and bandwidth-intensive operations. Now in version 4, **GT** facilitates the design of interoperable **DWDM Lambda-Grid** applications and distributed operations that comply with **Web services** (**WS**) specifications (Foster, 2005).

DWDM Lambda-Grid Architectures

Major advances in **DWDM Lambda-Grid** construction are enabled by **OptIPuter**, a distributed architecture that is described by an acronym reflecting its utilization of optical networks, IP, and computer storage,

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