Scuola Superiore Sant'Anna di Studi Universitari e di Perfezionamento

Functional Requirements for Grid Oriented Optical Networks

Luca Valcarenghi

Internal Workshop 4 on Photonic Networks and Technologies
Scuola Superiore Sant'Anna Pisa
June 3-4, 2003

Motivations

- Grid networking
  - connection of geographically distant machines (computers) for solving large problems
- Intelligent Optical Networks (ION)
  - provide dynamic allocation of optical resources (e.g., lightpaths) with guaranteed Quality of Service (QoS)
- Grid networking + ION
  - Grid Oriented Intelligent Optical Networks
  - Provide intelligent dynamic adaptation to grid application requests (e.g., bandwidth, dynamic logical topology, QoS, reliability, connectivity)

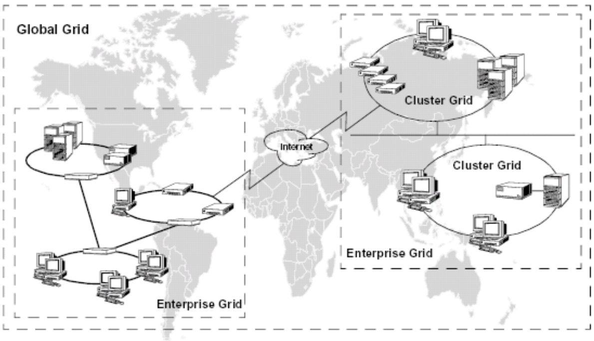
The concept of Grid networking (also known as Grid computing) is to create a scalable, wide-area computing platform. Grid networking recreates the environment within a single computer (processor(s), storage elements, operating system, and I/O) over a distributed area with heterogeneous elements including servers, storage devices, and networks.

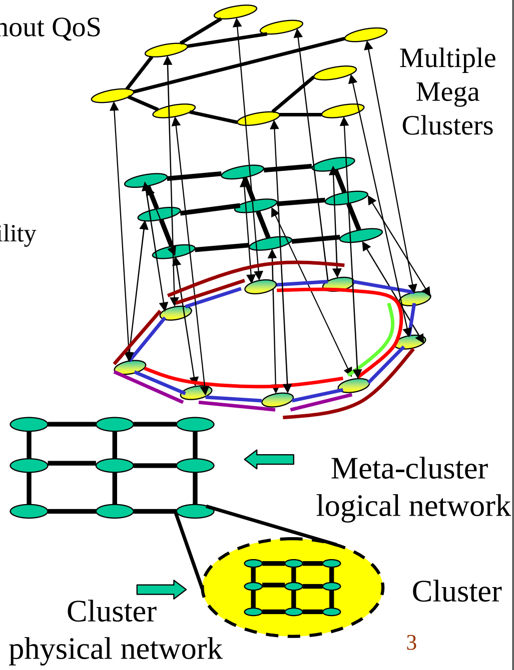
Intelligent Optical Networks (ION) have been proposed as a transport network solution for meeting the flexibility and high-bandwidth needs of data-oriented communication networks. By dynamically setting up and tearing down all-optical connections (lightpaths) between the optical transport network nodes ION are able to adapt the logical topology seen by upper layer devices (e.g., IP routers) to their connectivity requirements. Generalized Multi Protocol Label Switching (GMPLS) is among the most promising solutions for implementing signaling and control protocols necessary in IONs.

Supporting grid networking with an Intelligent Optical Network infrastructure will permit to offer to grid applications the necessary flexibility with the required Quality of Service (e.g., high bandwidth, reliability, limited delay) that is not guaranteed in today's grid deployments.

Grid Networking

- Currently based on network infrastructure without QoS support (e.g., standard TCP/IP protocol)
- Meta-cluster and Mega-cluster architectures
- General requirements
  - QoS
  - Low Latency
  - Dynamic Provisioning/Dynamic Reconfigurability
  - Bit rate/Protocol Independency





3

Current implementation of grid networking software (e.g., Globus Toolkit) are based on standard TCP/IP protocols without QoS guarantees.

The two main network architectures proposed for grid networking are meta-cluster computing and mega-cluster computing.

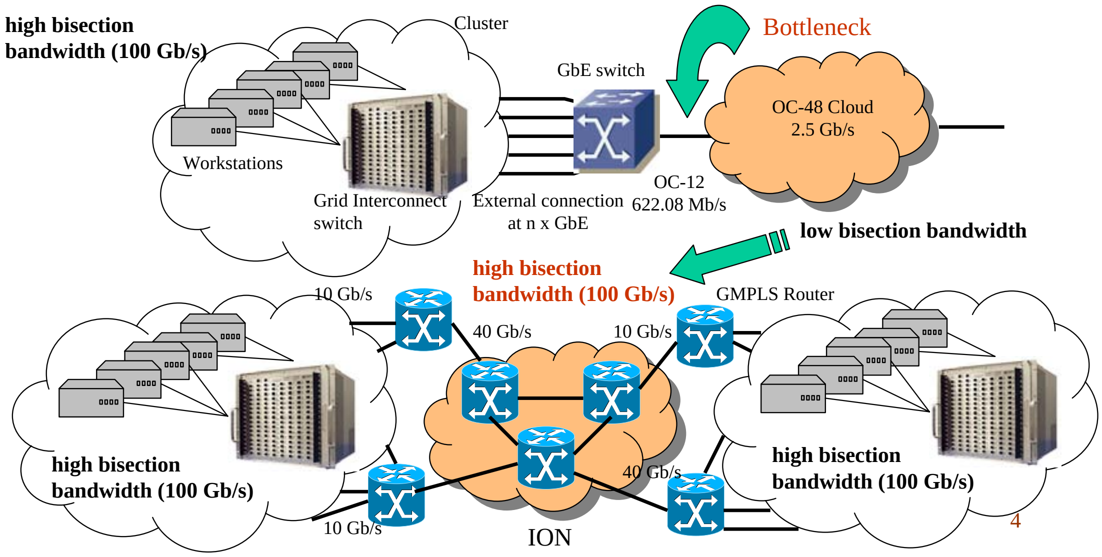
In Meta-cluster computing a set of parallel machines or clusters are linked together with the Internet to provide a large parallel computing resource. Meta-cluster computing architecture is a highly coupled configuration where an active node of the network (e.g., a router) represents the head of each cluster or parallel machine.

Mega-cluster architecture relies on thousand of connected machines. Mega-cluster computing is a loosely coupled configuration in which a network active node can be associated with each Grid node.

Both Meta-cluster and Mega-cluster architectures require a transport network that guarantees QoS, low latency, dynamic provisioning, dynamic reconfigurability, and bit rate/protocol independency.

Intelligent Optical Networks in Grid Networking

- Enhance traditional cluster network access by exploiting high bandwidth and flexible connectivity guaranteed by dynamic lightpath logical topology



Traditionally, high performance computers have been islands of capability separated by wide area networks that provide a fraction of a percent of the internal cluster network bandwidth.

The introduction of Intelligent Optical Networking (ION) aims at providing high network connectivity and bandwidth for external cluster interconnection. In ION edge systems must handle *n* x 10GbE connections and routers that handle minimum 10 x 10GbE.

GbE based interconnection could represent and alternative to ION but its distances are limited (5km) and the bandwidth is limited to either 1Gb or to 10Gb/s (10 GbE) at the most.

Moreover ION is able to meet grid networking QoS requirements.

Moving Intelligence from Grid Middleware to Transport Network

- Objective
  - Scaling typical performance of Local Area Network (LAN) computer clusters to Metropolitan Area Networks (MANs) and Wide Area Networks (WANs) clusters
- Proposed approach
  - Utilization of Intelligent Optical Networks based on the GMPLS protocol suite for connecting Grid clusters
  - Implementation of interface functions between core Grid functional elements (middleware) and Intelligent Optical Network functional elements (control and management protocols)
  - Implementation of novel algorithms (Resource Allocation Algorithms (RAA)) for matching Grid application QoS requirements

5

The objective of the study is to define the interaction between modern techniques for the control and management of communication networks and novel programming techniques to scale the typical performance of Local Area Network (LAN) computer clusters to Metropolitan Area Networks (MANs) and Wide Area Networks (WANs) clusters. The proposed approach consists in the utilization of Intelligent Optical Networks featuring the Generalized Multi Protocol Label Switching (GMPLS) framework for setting up and tearing down the different logical topologies required by Grid applications. To achieve the study objective network interface functions between Grid functional elements (i.e., middleware) and Intelligent Optical Network functional elements (i.e., ION control and management plane) must be defined. In addition novel resource allocation algorithms (RAA) for matching Grid application QoS requirements must be implemented.

Resource Discovery and State in GRID and ION

- Resource Discovery and State/Grid Persistent State
  - Grid Information Service (GIS)
    - part of the Grid middleware
    - provides information about existence and characteristic of all Grid resources
  - Functionality
    - Provide for locating all Grid resources with specified properties
    - Accommodate a dynamic resource database
    - Discover and store information relative to all Grid services
      - Data from users
      - Computing resources
      - Available Software
      - Current user allocation
      - Asynchronous Information Sources registry and data content
- ION
  - Network Control Plane
    - GMPLS based routing and signaling protocols
      - Used to build distributed network status database at each network node
  - Network Management plane
    - Operations, Administrations and Management functions
      - Configuration, Fault, Accounting, Performance, and Security (FCAPS)

6

The core Grid functions are implemented by the Grid middleware. The middleware is defined as a logical software layer placed between software applications and the various system components (operating systems, protocols) that are distributed over a network. It simplifies the development of a distributed computer system by eliminating the confusion caused from heterogeneous operating systems, communication protocols, implementation languages, hardware platforms.

A list of core grid functions is the following:

•Resource Discovery and State/Grid Persistent State

•Resource Scheduling

•Uniform Computing Access

•Uniform Data Access

•Asynchronous Information Sources (Events, Monitoring, Logging, etc.)

•Remote Authentication, Authorization, Delegation, and Secure Communications

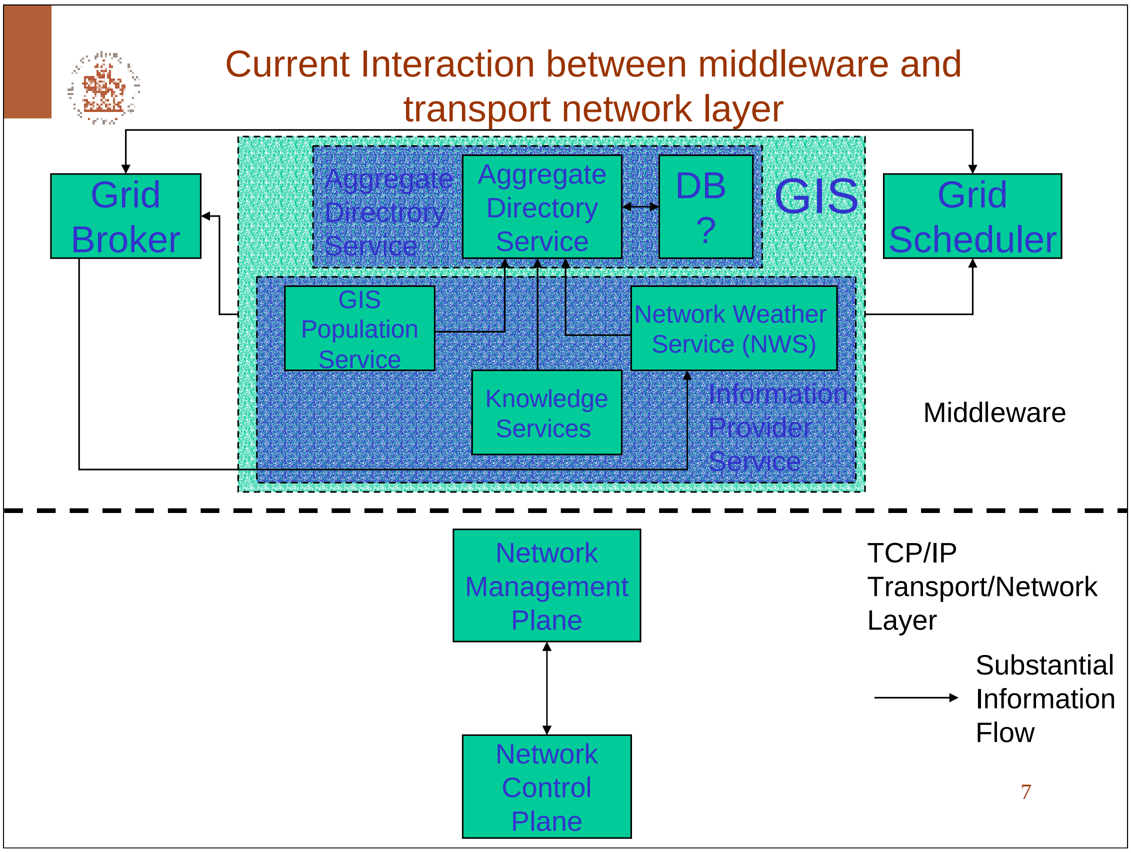
•System Management and Access

•Architectural Constraints (e.g., security)

•Bindings

Similar functions are also implemented in Intelligent Optical Network protocol framework (GMPLS). In particular network state update and resource reservation functions are implemented in the network control plane through, respectively, routing and signaling protocols.

The network management plane implements Operations, Administrations and Management (OAM) functions such as configuration, fault, accounting, performance, and security.



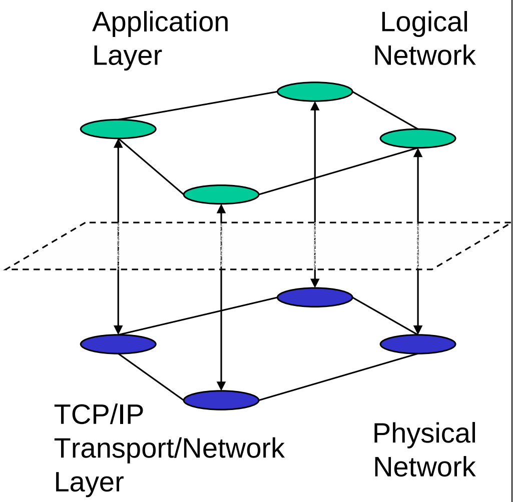
Currently the Grid logical network topology corresponds to the physical topology along which Internet connections are run. The Grid Information Provider Service collects information about Grid network resources (including network resources) and the Grid broker offers this information to the Grid applications. Applications choose connections based on their requirements. To monitor the connection status a Network Weather Service (NWS) protocol is utilized.

However if applications do not find connections with the required QoS are forced to relax their requirements.

Therefore the grid broker cannot provide application connections with the required QoS if they are not already available in the transport network. The only interaction between Grid middleware and transport network is represented by the Network Weather Service.

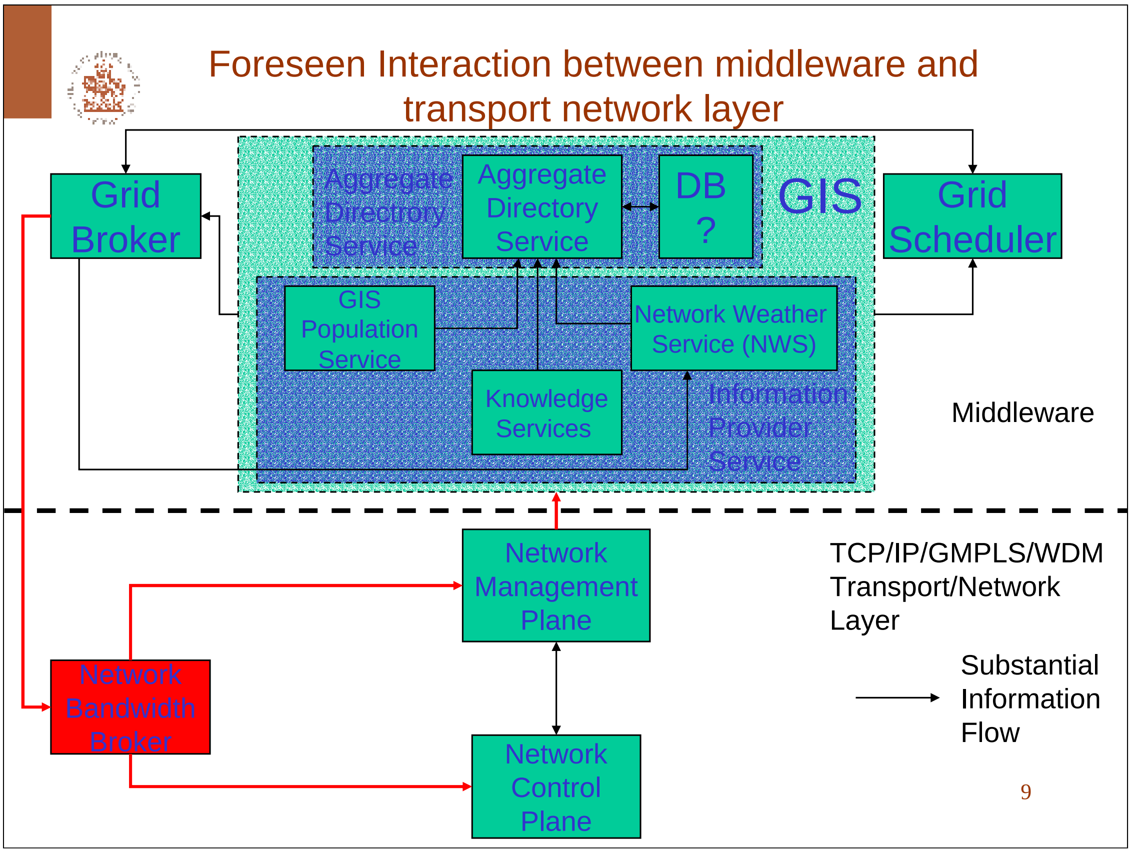
Current Interaction between middleware and transport network layer example

- Grid Broker collects information about available resources
  - Static host information (operating system version, CPU type, number of processors, etc.)
  - dynamic host information (load average, queue entries, etc.)
  - storage system information (available disk space, total disk, space, etc.)
  - LOGICAL network information via Network Weather Service (NWS) application
- Based on gathered information Scheduler schedules processes
- If requested resources (e.g., logical network connectivity, available bandwidth) cannot be guaranteed applications can only wait or accept lower quality of service



8

The Grid network logical topology corresponds with the physical transport network topology. It is not possible to dynamically connect Grid nodes with different logical topologies. In addition QoS guarantees required by Grid applications could not be assured.



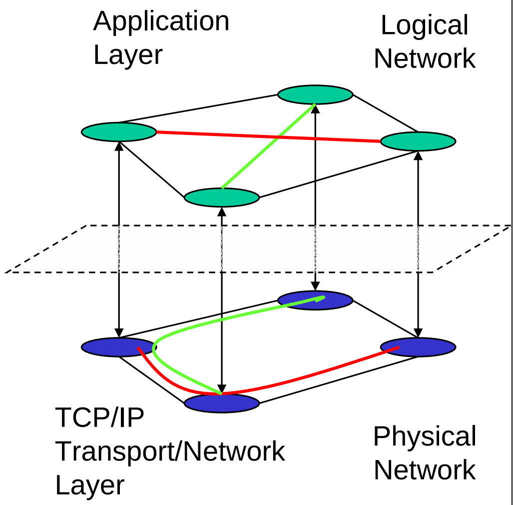
The novelty of the proposed approach consists in the interaction between Grid middleware and ION control and management protocols. In this way Grid networking that, without the aforementioned interaction, would rely only on QoS schemes (e.g., reliability schemes) implemented at the middleware layer can leverage QoS feature already embedded in ION protocols.

Moreover network state information will become through the definition of an interface between Grid middleware and ION protocols part of the Grid Information Service (database (DB) in the figure). Therefore both Grid data and control traffic will be able to choose connections with the required Quality of Service.

The Grid Broker may interact by means of interface functions with the Network Bandwidth Broker so that connection with a specific QoS requested but not yet present along the physical network links are dynamically setup.

Foreseen Interaction between middleware and transport network layer example

- Grid Broker collects information about logical network available resources
- Information about physical network status are collected through
  - Network Management Plane
  - Network Control Plane
- Information about physical network status are incorporated in GIS information
- Based on gathered information Scheduler schedules processes
- If requested resources (e.g., logical network connectivity, available bandwidth) cannot be guaranteed
  - Grid Broker interacts with Network Bandwidth Broker to setup a new (additional) logical topology
  - Network Bandwidth Broker utilizes
    - Network Management Plane
    - Network Control Plane



10

By exploiting the interaction between Grid Broker and Network Bandwidth Broker different Grid applications may set up different logical topologies with the desired QoS characteristics. In addition logical topologies seen by Grid nodes may be dynamically changed to match Grid application changing requirements. Advanced QoS features can be implemented at the transport network layer: resilience, dynamic allocation schemes for optical connections (lightpaths), and differentiated reliability schemes.

Summary

- Architectural benefits
  - Eliminate today's Meta-cluster and Mega-cluster communication bottleneck (e.g., best effort, low inter-cluster bisection bandwidth)
  - New Grid services based on GMPLS protocol
  - Guarantee requested connection QoS based on agreed classification
  - Dynamic adaptation to changing QoS requirements of connections between Grid nodes (logical Grid network topology)
- Impact
  - Mainly DIRECT and SHORT-TERM (applied research) on local and national Grid network implementation
  - GUIDELINES for LONG TERM (fundamental research) for next generation optical Grid networks

11

The introduction of intelligence in the network transport layer will permit to overcome two important bottlenecks of the current Grid networking: absence of Quality of Service and low access bandwidth. By combining high transmission bandwidth guaranteed by WDM and flexible set up and tear down of optical connections with guaranteed QoS through the GMPLS protocol framework, Intelligent Optical Networks (ION) guarantee dynamic adaptation to changing QoS requirements of connections between Grid nodes.

The short term impact of the utilization of the ION as network transport layer will be to improve the performance of Grid networking in the local and national scenario. These experiments will permit to establish guidelines for the next generation global Grid networks.