A Service Oriented Network Architecture suitable for Global Grid Computing

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***Abstract*— Grid computing frameworks built on top of the TCP/IP protocol stack are efficient in local area networks (LANs), where almost dedicated network resources are available. Supporting distributed grid computing applications connected by Wide Area Networks (WANs), i.e. global grid computing, represent a more challenging task that requires the availability of network protocols capable of guaranteeing Quality of Service (QoS).**

In this paper we propose to utilize a Service Oriented Automatic Switched Transport Network (SO-ASTN) as the transport infrastructure for supporting global grid computing. The SO-ASTN consists of the addition to the plain ASTN of an extra layer, namely the *service plane*, designed according to the ITU-T Intelligent Network Conceptual Model. The main novelty of the architecture is the network awareness that grid computing applications are provided with. Global grid computing applications can therefore experience LAN QoS level in a Wide Area Network (WAN) scenario.

We introduce a testbed, named SOON (Service Oriented Optical Network), for the evaluation of the proposed architecture. As network awareness use case we propose an implementation, in SOON, of the virtual topology request by utilizing Extensible Markup Language (XML) as an information exchange format.

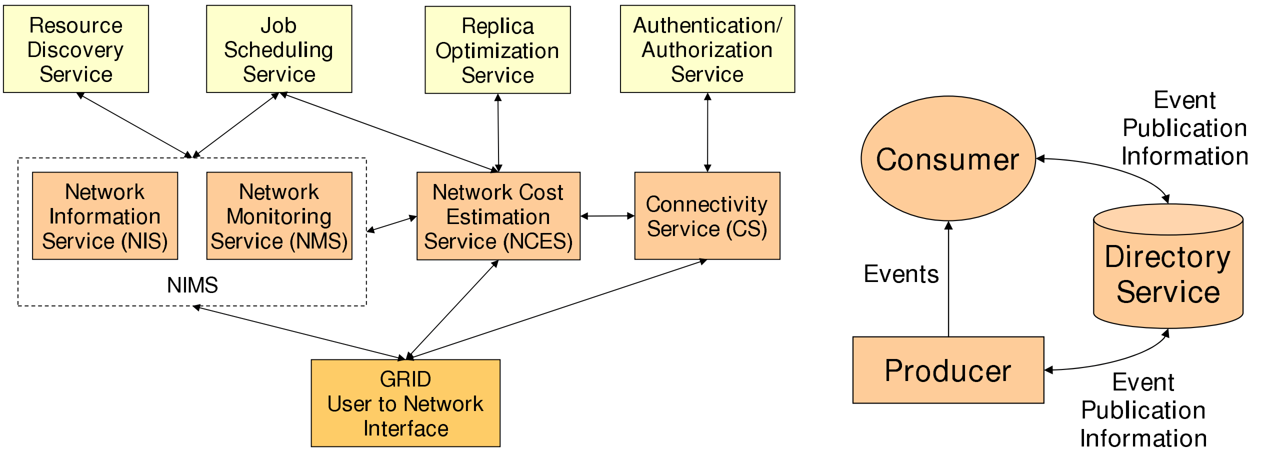
I. INTRODUCTION

Current telecommunication networks are experiencing a significant increase of data traffic caused by different bandwidth-hungry home applications as well as business applications supporting advanced services. The possibility of utilizing such applications has been given to most domestic Internet users and business customers by the availability of Digital Subscriber Loop (DSL) lines arranged in various configurations (asymmetric, high speed, etc). In addition, the introduction of client devices (e.g. routers, storage devices, and content servers) operating at optical line rates at the network edge, enables the optical transport to get closer to the customer [1].

The current challenge faced by telecommunication operators is how to evolve optical network infrastructure in order not only to support a wide range of broadband services but also to guarantee different traffic flows to be treated according to the different requirements of the associated services (e.g. Internet access, Video on Demand, Grid Computing, etc). The network should provide differentiated connections with specific QoS to reflect the value of the traffic being carried. While Quality of Services (QoS) policies are well established at various layers (e.g., DiffServ, MPLS, ATM, Carrier Class Ethernet), allowing customers, for example, to set-up a path with a particular QoS in a flexible and network-agnostic way represents a crucial feature for evolving network infrastructure.

Applications able to provide broadband services to their customers, directly supported by the network optical layer, are named in this work Next Generation Service Application (NGSA). NGSAs require in general to be provided with network awareness capability to relieve customers of the burden of maintaining physical network status information. NGSAs should not only monitor the network resource status and performance but they are required to dynamically interact with network services via a dedicated interface in order to fulfill customer requirements.

One of the most important and innovatory class of NGSA is represented by Grid Computing that enables the sharing, selection, and aggregation of a wide variety of geographically distributed computational resources (e.g., supercomputers, computer clusters, storage systems, data sources, instruments, people) and presents them as a single, unified resource for supporting large-scale and data-intensive computing applications (e.g, molecular modelling for drug design, brain activity analysis, and high energy physics). Currently, communication among grid services is based mainly on the



(a) Implemented grid network services.

(b) NIMS consumer-producer interaction [2].

Fig. 1. Grid network services and consumer-producer architecture.

standard TCP/IP protocol suite. Enhancements to application layer protocols, such as GridFTP [3], have been proposed to improve the data management service efficiency. Recently, with the aim of moving grid applications from a Local Area Network (LAN) scenario to a Wide Area Network (WAN) scenario, i.e. migrating from a *local grid computing* to a *global grid computing*, the need for guaranteeing Quality of Service (QoS) has emerged [4]. Indeed, unlike in the local grid scenario, in the global grid scenario grid applications share network resources with a number of heterogeneous applications whose required network services may vary from basic connectivity, like Internet access, to more complex services, like Virtual Private Networks (VPNs).

A possible solution for implementing a scalable and cost-effective transport network architecture able to satisfy NGSA requirements is decoupling networking aspects from service specifications. This separation permits to preserve the existing infrastructure whenever new services or upgrades of the existing ones need to be implemented [5].

Automatic Switched Optical Network (ASON) [6], and more generically Automatic Switched Transport Network (ASTN) [7], are a good starting solution for meeting the flexibility and high-bandwidth needs of NGSA. By dynamically establishing all-optical connections (lightpaths), ASON meets the flexibility requirement of the upper layer devices (e.g., IP routers). The interface dedicated to the dynamic service provisioning is called User to Network Interface (UNI) [8] and is designed for providing elementary network connectivity services.

In the ASTN architecture high service provisioning (for example VPN) is not decoupled from basic connectivity services (like lightpath establishment). For these reasons we designed and developed a new service oriented ASTN architecture (SO-ASTN) [9] that, based on the existing ASTN infrastructure, introduces a new layer, called Service Plane, between the customers and the network infrastructure. The Service Plane decouples service provisioning from the underlying network infrastructure implementation. The Service Plane applies the Intelligent Network architecture Conceptual Model (INCM) [10], [1]. INCM has been defined by ITU-T organization for describing a service-independent architectural concept applicable to all kinds of networks, in which the logic for controlling telecommunication services migrates from traditional switching points to service-independent platforms.

In this paper any Service Plane implementation is called Service Provider and any implementation of the ASTN is called Network Provider. Thanks to the separation between service and network functionality, the Service Provider and the Network Provider can be considered two distinct entities. In addition this separation permits to provide different types of services using the same network infrastructure, in particular the Network Provider is independent of the creation of new services and can concentrate its efforts on improving data transport capability.

The objective of this study is to utilize the SO-ASTN architecture for introducing network awareness in global grid computing. The SO-ASTN architecture allows to define and implement a Network Aware Programming Environment (NA-PE) able to dynamically adapt the utilized network resources to meet the grid application QoS requirements in spite of changing network utilization. The interaction between the grid network services, used by Grid applications, and the Service Plane of the SO-ASTN occurs through the Grid User to Network Interface (GUNI). The GUNI gives grid services logical network awareness by providing detailed information about Grid network logical topology, such as nodes involved as well as logical link attributes (e.g., bandwidth usage, delay, jitter).

We propose an implementation of the SO-ASTN architecture in an experimental testbed, named Service Oriented Optical Network (SOON) testbed, that includes grid network services, the Service Plane, the Network plane and the GUNI. SOON consists of a simple optical transport network infrastructure composed by a WDM ring network combined with a number of routers operating at Gigabit rate. The testbed is then completed by a number of PC running the grid application designed for investigating the actual interaction between Grid network services and ASON service provisioning functionalities.

The paper is organized as follows: in section II, we introduce Grid Computing Services, in III we illustrate the SO-ASTN architecture highlighting the proposed enhancements to the standard ASTN, in section IV we apply the SO-ASTN architecture to the Grid computing. The Service Oriented Optical Network (SOON) testbed is presented in section V as a validation of the proposed SO-ASTN. Finally, in VI conclusions are drawn.

II. GRID NETWORK SERVICES

Current efforts toward the standardization of Grid Computing are based on the Open Grid Service Architecture (OGSA) [11], that specifies the core services and the high-level functionalities of grid computing implementations, and the Web Service Resource Framework (WSRF) [12], that specifies a web service infrastructure (i.e., a set of six basic web services) retaining all the Open Grid Service Infrastructure (OGSI) concepts.

Some recently proposed grid computing frameworks are based on the WSRF. For example Globus Toolkit [13] implements a subset of OGSA services based on WSRF. Other research projects, such as the Grid.it project [14], propose to extend distributed programming environments, e.g. ASSIST [15], with the OGSA services deemed necessary to fulfill global grid computing requirements.

The Grid High-Performance Networking Research Group (GHPN-RG), within the Global Grid Forum (GGF), focuses on the relationship between network research and Grid application and infrastructure development. The objective of GHPN-RG is to bridge the gap between the networking and grid research communities. In particular it has already defined a set of *Grid Network Services* (GNS) which consider specific networking issues, such as Quality of Service (QoS), in the implementation of grid computing frameworks [16]. A selected subset of the proposed GNS represents the starting point for implementing the NA-PE. The considered Grid Network Services can be broadly classified in the following service sets: *Network Information Service* and *Network Monitoring Service*, *Connectivity Service*, and *Network Cost Estimation Service*. In Fig. 1(a) the main interaction between generic grid network service and the grid network services considered is shown.

In this study GNS implementation is based on the extension of the consumer/producer architecture proposed in [2] for the Monitoring Architecture to all the considered grid network services. As depicted in Fig. 1(b), the architecture is based on three elements: *Directory Service*, *Producer*, and *Consumer*. The *Directory Service* supports service publication and discovery, the *Producer* represents the service source and the *Consumer* represents the service sink. Three types of interactions between producers and consumers can be supported: publish/subscribe, query/response, and notification [2]. In this study the query/response interaction is first considered. In the query/response interaction the producer acts upon a specific request initiated by a consumer.

A. Network Information Services and Network Monitoring Services

Network Information Service (NIS) and Network Monitoring Service (NMS) aim at publishing performance data to Grid applications, middleware, and the network fabric [16]. In the proposed architecture NIS and NMS are considered as a single Network Information and Monitoring Service (NIMS). The NIMS contains network status information such as network topology, available bandwidth along the network links, and other additional information to be utilized by the Network Cost Estimation Service.

B. Connectivity Service

In the definition given in [16], the Connectivity Service (CS) consists of the Reachability service and of the Connectivity Establishment Service. The “Reachability Service is a service instance queried by the clients to determine reachability to remote grid resources being selected”. “Connectivity Establishment Service uses mechanism existing in the network to provide reachability” among network elements.

C. Network Cost Estimation Service

In [16], it is stated that the “Network Cost Estimation Service (NCES) allows the Grid to enhance its performance through the use of information on the status and transmission behavior of its network links.” “Through the Network Cost Estimation Service, Grid services have the possibility to use the monitoring information for dynamic adaptation to the Grid status at any given time”.

III. THE SO-ASTN ARCHITECTURE

A. The Service Oriented ASTN Architecture Overview

The proposed service oriented architecture is built on top of Automatic Switched Transport Network (ASTN) [7] defined in ITU-T G.807 Recommendation. According to ITU-T definition, ASTN is divided in 3 functional planes.

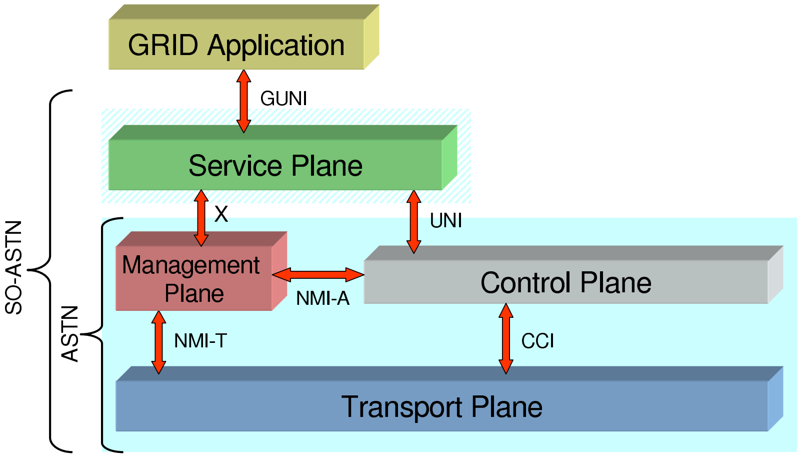
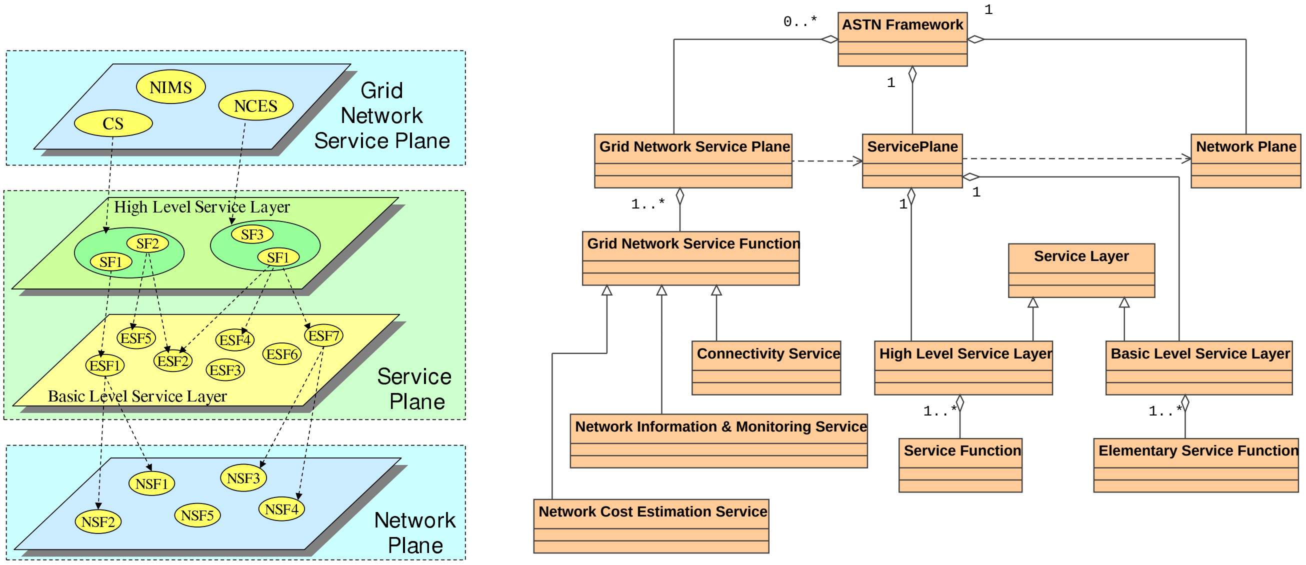


Fig. 2. Service Oriented ASTN architecture as an upgrade of standard ITU-T G.8080 ASTN



(a) SO-ASTN Functional Model

(b) SO-ASTN Class Diagram

Fig. 3. Service Oriented ASTN (SO-ASTN) architecture applied to the Grid Network Services

Transport Plane provides transfer of user information, from one location to another. It can also provide transfer of some control and network management information. Management Plane, standardized by ITU-T [17], performs management functions for the Transport Plane, the Control Plane, and the system as a whole and provides coordination between all the planes. Supported by a signalling network, Control Plane permits, on request from either a client network or the network manager, to automatically switch connections across the transport network. The internal ASTN interfaces are: the NMI (Network Management Interface) that supports the management functionality related to either control plane (NMI-A) or transport plane (NMI-T); the CCI (Connection Control Interface) that exchanges control information between each control node and the correspondent network element in transport plane for the creation and deletion of subnetwork connections.

In regard to service provisioning, ASTN architecture lacks “service scalability”. Indeed, in current ASTN architecture, the introduction of a new service usually implies the addition of sub-network infrastructure dedicated to that specific service provisioning with a consequent severe impact on the network configuration and the related signalling and management. Enlarging the network by increasing the number of network nodes is not always a good choice, because it raises the operative cost and it increases the control plane signaling converging time.

In Fig.2, we sketch the building blocks of the proposed

Service-Oriented Automatic Switched Transport Network (SO-ASTN) [9]. SO-ASTN is realized by the introduction of the Service plane as an intermediate layer between a customer and the ASTN architecture. The Service Plane takes over the task of providing different service interfaces to the customer, namely a technology-dependent Customer Service Interface (CSI), a UNI interface [7] towards the CP, and an X interface [17], [18] toward the Management plane.

The introduction of the Service Plane is done by following the engineering guidelines of the INCM where service provisioning is decoupled from the physical network infrastructure implementation. This functional separation facilitates the development and deployment of new services independently of the service/network implementation (facilitating multi-vendor scenarios).

The IN functional architecture subdivides the service functionality from a physical distribution viewpoint (global or distributed). In addition, a generic set of reusable service components can be identified for the rapid development of new services as composition of basic services. Complex services are created just by combining basic services provided by the INCM [19]. This approach also includes a set of activities for the dynamic service creation, modification, management, and real-time monitoring of service performance.

These activities can be attributed to a Service Plane from a functional viewpoint and to Service Provider from operational viewpoint, as detailed in the following subsections.

B. The Service Plane

In Fig.3(a) the SO-ASTN functional model, related to the SO-ASTN architecture presented in Fig.2, is depicted. In Fig.3(b) the UML class diagram of all the functional planes, with related layers and functional blocks, is presented. The Service Plane is placed between the standard ASTN architecture named Network Plane for short, and the Grid Network Service Plane (GNSP) that represents the application entity of Grid Application (or, in general, a customer application) that directly interacts with the service plane.

GNSP is the application functional layer able to provide network-aware services to grid applications and implements the Grid Network Services (NIMS, CS, NCES) previously described in section II.

The Service Plane consists of all the services that can be utilized by the GNSs. We identified two internal functional layers: *High Level Service layer* and *Basic Level Service layer*. The High Level Service layer represents the interface between Customer Service plane and Service plane and contains a set of *Service Functions* (SFs) utilized by the GNSs. Indeed NIMS, CS and NCES provides grid network services just by combining calls to set of SFs. The Basic Service layer represents the interface between the service plane and the network plane and refers to a set of *Elementary Service Functions* (ESFs) that represents the basic network-oriented functionalities. SFs are built by combining sets of ESFs that are in turn mapped to a set of Network Service Function (NSF) that belong to the Network Plane via UNI and are related to simple service functionality provided by the network control plane.

The definition of a separate layer for service functionality permits to unburden the ASTN control plane of service-oriented functionalities. As a consequence, in the proposed SO-ASTN architecture, the CP is focused on the basic connectivity network services, for example Generalized Label Switched Paths (GLSPs) for GMPLS Control Plane, and it can interact with its client networks using just network primitives via UNI.

C. The Service Provider vs. The Network Provider

The Service Provider (SP) is an entity that offers network services by implementing the SO-ASTN Service Plane functionalities. The Network Provider (NP) is the entity that owns, manages and maintains the physical network components and infrastructure by implementing the Network Plane functionalities described in ASTN architecture. The SP uses the NP infrastructure for delivering services to the customer but it is only responsible for the management and development of all the aspects of the service provisioning (like authentication, billing, monitoring, connectivity management, etc.). The purpose of the Service Provider is to hide the details of the Network Provider to the customer applications (e.g. Grid Applications) in order to obtain a simplified and more flexible utilization of the network resources.

Within the traditional telecommunications environment, the separation between network and service providers is not clearly distinct, while in SO-ASTN architecture the SP and NP are two different entities.

As shown in Fig. 4, SP functionalities are classified in two functional layers. The upper layer, named the Centralized Service Layer (CSL) is centralized similarly to the corresponding layers of the Telecommunications Management Network (TMN) of the transport network. The lower one, namely the Distributed Service Layer is distributed like the control plane that interacts with it. Specifically:

- **Centralized Service layer (CSL)** is responsible for all commercial aspects of service provisioning such as service marketing or billing activities related to service usage and according to SLA (Service Level Agreement)[1] contractual obligations. In particular it manages

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[1] According to Recommendation ITU-T definition [7] "*Service Level Agreement (SLA) is a contract between two parties such as a service provider and a customer. It defines the services available to the customer, and the grade of service of those services as offered to the customer. It also usually describes the service guarantee and potential penalties in cases of service degradation on failure.*"

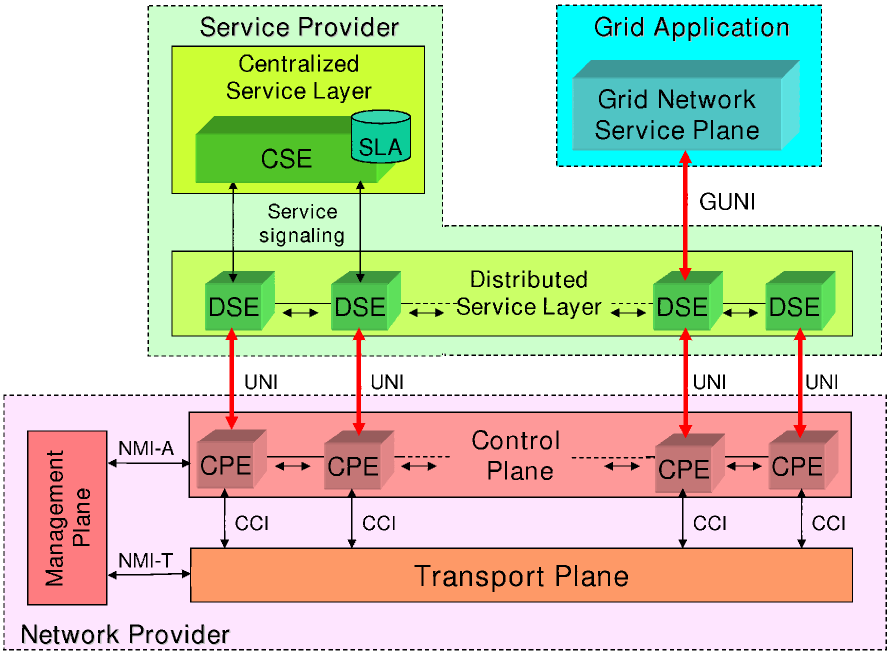

Fig. 4. Service Provider and Network Provider relationship.

the database containing customer information regarding stipulated SLA, current resource usage, and the corresponding access authorizations. Finally it interacts with Distributed Service layer in order to set up and release the services. The CSL is implemented by the *Centralized Service Element* (CSE) that in particular manages the SLA database.

- **Distributed Service layer (DSL)** deals with the dynamic aspect of service provisioning such as service discovery capability or actual service arrangement. The DSL is implemented by a set of *Distributed Service Elements* (DSE) that, by means of signalling messages, are able to satisfy user requests; in addition every DSE is able to exchange message also with the CSE through internal control signaling as reported in Fig. 4. The services are actually set-up by directly accessing the Control Plane Elements (CPEs), via a User to Network Interface (UNI).
  In fact, the DSL has a structure that is isomorphic to that of the Control Plane but with different functional rules. The CP provides the basic network services, on the contrary the DSL maps high level service requests in a set of basic network service requests suitable for being provided by the CP.

D. Service Provider interfaces

Service Provider interacts with the Network Provider through UNI and with the customer (GNSP in the case of grid application) through Customer to Service Interface (CSI).

User to Network Interface (UNI), as anticipated in the simplified architecture of Fig. 2 and further detailed in Fig. 4, consists of both signaling and transport functionalities. In particular the UNI signaling is used to invoke ASTN network service primitives according to the service mapping explained in section III. The use of a standard interface guarantees the decoupling between network technology from evolving service requirements. The logical entity that terminates UNI signaling on the transport network side is directly connected to the Control Plane that in turn is able to setup and retrieve network attributes regarding transport plane via CCI. In our work UNI is referring to ITU-T functional definition [7] instead the OIF specific implementation so that we are not bounded to a particular technology, message set or any related evolution.

On the contrary CSI depends on the particular Service Plane implementation, related to the class of service provided, and it is strictly technology dependent because tailored to the customer needs. In the next section a particular implementation of the CSI for grid computing (called GUNI) is described.

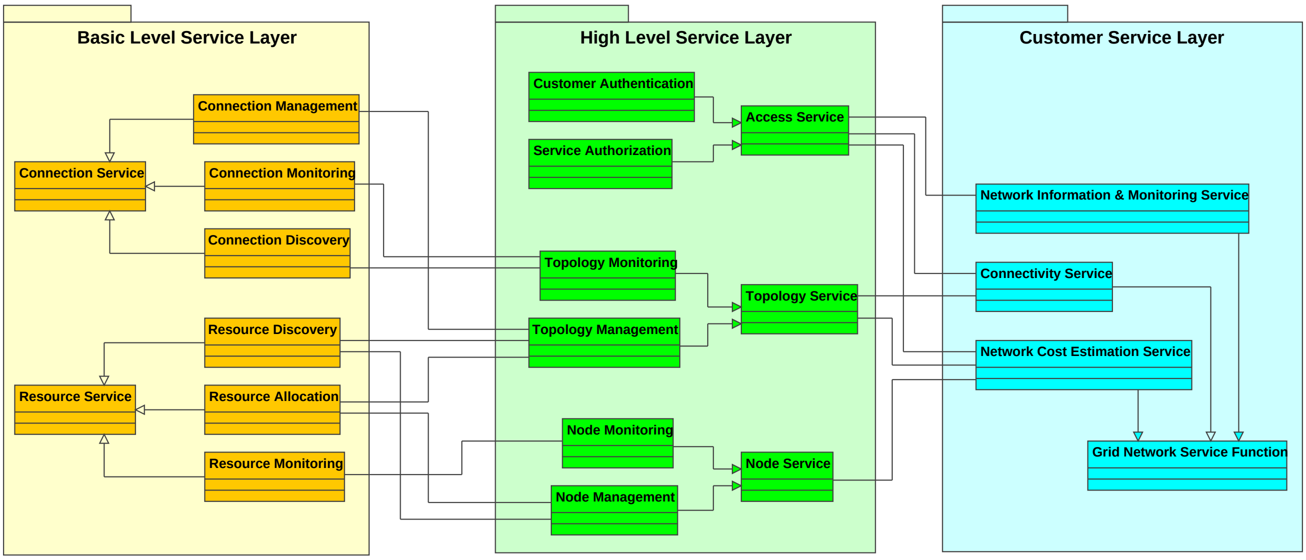

Fig. 5. Mapping Grid Network Services to Service Layer Functional blocks

IV. SO-ASTN APPLIED TO GRID COMPUTING

SO-ASTN architecture can be applied to global grid computing for implementing a Network Aware Programming Environment (NA-PE) able to dynamically adapt the utilized network resources for meeting the grid application network awareness requirements. This is achieved by designing a suitable Service Plane whose service functional blocks permit to easily manage and monitor the Grid network topology. Referring to Fig. 5 Grid Network Services, described in section II, are mapped to three categories of high level service functional blocks:

- **Access Service**: consists of *Customer Authentication Service* and *Service Authorization*. The first implements the customer identification following a service request in order to accept only trusted and “regular” customer according to network access policy (for example customer up-to-date with the payments). The second is related to service acknowledgment and provisioning according to customer’s SLA.
- **Topology Service** is composed by *Topology Monitoring Service* and *Topology Management Service* respectively for monitoring and managing information about virtual connectivity provided to the customer such as Bandwidth available, Bandwidth utilized, Delay, Jitter and BER.
- **Node Service** consists of *Node Monitoring Service* and *Node Management Service* respectively for monitoring and managing information about customer nodes. The information provided are strictly related to the kind of VPN established, in particular the VPN layer.

The aforementioned high level services are mapped to two categories of basic level service functional blocks:

- **Connection Service** composed by *Connection Management Service*, *Connection Monitoring Service*, *Connection Discovery Service* supporting the connectivity services regarding the links established for obtaining the Customer VPN. The connectivity services concerns: *Connection Creation* that allows a connection with the specific attributes to be created between a pair of access points, *Connection deletion* that allows an existing connection to be deleted, *Connection Status Enquiry* that permits the status of certain connection parameters to be queried, Connection Modification which allows parameters of an already established connection to be modified.
- **Resource Service** composed by *Resource Discovery*, *Resource Allocation*, and *Resource Monitoring*, refers to the network resource that should be utilized by the Connection Service before the establishment of new connection like the available bandwidth, the available ports and channels, the physical constrains of the network nodes.

Every basic service function is in turn mapped to a set of UNI primitives for network resource setting.

A. The Grid User to Network Interface (GUNI)

The Grid Network Services interact with the Service Provider via the Grid User to Network Interface (GUNI) that permits Grid applications to dynamic control and manage the optical network resources according to the SLA stipulated between the Grid user and the Service Provider. GUNI functionalities, identified by GHPN-RG [20], are listed and associated to the NIMS, CS and NCES Grid Network Services as shown in table I.

Signaling	
Bandwidth allocation	NIMS, CS
Automatic light-path setup	CS
Automatic neighbor discovery	NIMS, NCES
Automatic service discovery	NIMS (NIS)
Fault detection	NIMS
Protection and restoration	CS, NIMS
Security at signalling level	NIMS, CS, NCES
Transport	
Traffic classification	NIMS, CS
Traffic grooming	CS
Traffic shaping	CS
Transmission entity construction	CS
Data plan security	NIMS, CS, NCES

TABLE I

GUNI SUPPORTING SERVICES

About the specific GUNI implementation, the XML appears to be the best candidate thanks to its representation format which can be useful to describe and transmit management information. The ability of the Service Plane to hide the complexity of the service provisioning permits to define simple XML-based messages capable of supporting high level services.

In particular we want to describe the messages exchanged through GUNI related to the Grid Topology service, implemented in the testbed described in section V, that permits to a Grid Application to be aware of its Grid Virtual Network Topology. The XML-based Topology Request message is reported.

```
<?xml version="1.0" encoding="UTF-8"?>
 <Topology
   xmlns:xsi=
    "http://www.w3.org/2001/XMLSchema-instance"
   xsi:noNamespaceSchemaLocation=
    "TopologyRequest.xsd">
  <TopologyRequest/>
 </Topology>
```

This message represents the simplest form of request because consists of only one XML tag. An extract of the XML Topology Response file, related to the testbed depicted in Fig. 6, is reported.

```
<?xml version="1.0" encoding="UTF-8"?>
 <Topology xmlns:xsi=
   "http://www.w3.org/2001/XMLSchema-instance"
   xsi:noNamespaceSchemaLocation=
    "TopologyResponse.xsd">

  <Node ID="100" Name="A">
    <Interface ID="1"
      Address="217.9.70.11" Type="2">
      <Port ID="1">
        <Performance Delay="300"
            Jitter="50" BER="7"/>
        <Bandwidth Available="1"
          Utilized="0"/>
        <Destination NodeId="300"
            InterfaceId="1" PortId="1"/>
      </Port>
    </Interface>
    <Interface ID="2"
        Address="217.9.70.12" Type="2">
      <Port ID="1">
        <Performance Delay="400"
            Jitter="50" BER="8"/>
        <Bandwidth Available="1"
          Utilized="0"/>
        <Destination NodeId="200"
            InterfaceId="2" PortId="1"/>
      </Port>
    </Interface>
  </Node>
  ...
</Topology>
```

Each network node is described by a set of XML `interface` elements. Network topology is drawn by mutually referencing node interfaces through the attributes of the `Destination` elements. Note that every Interface is characterized by the link (individualized by the `Port` engaged in conjunction with the `Destination` tag) that in turn is characterized by a set of attributes (Delay, Jitter, BER, Bandwidth available, and Bandwidth utilized).

B. SO-ASTN Architecture novelties and relative advantages for Grid Computing

After the introduction of the SO-ASTN functional architecture and relative application to Grid computing, we are able to summarize the novelties of this architecture and the relative Grid benefits according to the requirements described in section I:

- **Service functionality and Transport functionality separation**: it permits Service Provider and Network Provider to focus over their core business. NP is independent of the creation of new service and can concentrate its efforts improving data transport capability. SP, that exploits basic network services provided by UNI, in case of an evolution of the network technology should just change the mapping to the new UNI messages. The functional separation makes SP-NP interworking easier so that NP can serve several SPs and an SP can interact with different NPs simultaneously. In this way different services can be provided using the same network infrastructure.
- **Novel Service Provider Architecture**: it can be considered the merging of the centralized approach adopted in the network management plane (that permits secure access thanks to user identification/authentication and retrieves the list of accessible services depending on users' subscription) with the distributed approach typical of the network control plane used for service control information exchanging for implementing service provisioning logic and supported by the signaling established between the DSEs.
- **Service Mapping**: permits to easily obtain complex service arrangement by recombining the basic general

purpose network services in a static or even dynamic way.

- **Enhancement of existing ASTN architecture**: the interaction between SO-ASTN Service Plane and the standard ASTN Network Plane is dealt via UNI through which basic network primitives can be invoked for service provisioning. This choice permits to separate the service provisioning logic from the actual service implementation and therefore an advanced service oriented optical network can be smoothly arranged just referring to the existing ASTN architecture without any modification to the current standard.
- **Grid-oriented network specific interfaces**: ASTN provides a multi-purpose UNI interface that provides only basic network services, on the contrary the SO-ASTN architecture permits to design Service Providers, focused on Grid computing needs. A suitable interface between Grid application and Service Provider, called GUNI, can be tailored to the Grid Network Services defined by the Grid High Performance Networking Research Group [16].
  GUNI protocol suite achieve high scalability and flexibility because easy to implement using XML technology and to update, without affecting network infrastructure, thanks to the Service Plane Intelligent Network mapping.

V. THE TESTBED

The testbed that we have developed, named *Service Oriented Optical Network (SOON)*, is shown in Fig. 6. It aims at validating the functional modelling of the SO-ASTN architecture and the mapping between Grid Network service requests toward Service Provider and the corresponding SP requests toward the Network Provider in a real scenario. The targeted use case is the Grid virtual network topology request. The Grid virtual network topology represents the virtual network established among several Grid nodes and is not related to the physical network topology.

The testbed consists of four PCs interconnected by TCP sockets over Ethernet LAN. One PC implements the Centralized Service Plane functionality and three PCs embed both the Grid Network Service Plane and the Distributed Service Plane functionalities. In particular they run two different software modules: the Grid Application (GA) requesting optical services and able to generate data packets and the Distributed Service Application (DSA) implementing DSE functions. Since these software applications run on the same PC, the communication between Grid application and Service Provider through CSI-D interface is realized using interprocess communication mechanisms instead of remote communication mechanisms. This choice is depicted in Fig. 6 by a dashed box that includes the two software modules running on the same PC.

The Network Plane infrastructure consists of three routers connected to a DWDM ring through Giga-Ethernet (GE) links. Every PC is connected to a correspondent router by two communication channels: a Fast Ethernet (FE) data channel for data traffic (solid line) and signalling channel (dashed line) for network service requests.

Commercial routers are not yet provided with standard UNI but, in general, are equipped with an application programming interface (API) based on the Extensible Markup Language (XML) that routers use to exchange information with client applications. Using this interface it is possible to manage and monitor the connections and relative traffic and performance parameters. We implemented the signaling interface between the DSAs and the routers by using XML-script language via TCP socket.

A. The use case: Grid virtual network topology request

The testbed SOON was utilized for implementing the case of a Grid node that makes a request to the Service Provider for obtaining information on the Grid network topology (number of nodes involved, the links bandwidth occupation, the network performance etc.). This permits to provide Grid applications with network-awareness capability. The request is satisfied through messages exchange between the grid node, the Distributed Service Elements, the Centralized Service Element, and the Control Plane Elements (CPE) (represented by the UNI interface in the routers). The message set utilized is described:

*1) **Interface GUNI**:*

- *Topology Request*: (GA → DSE) permits to query a DSE for obtaining the grid virtual network topology and related information.
- *Topology Response*: (DSE → GA) contains the available information about all the grid Nodes (address, name, ID) and the related virtual links attributes like delay, jitter, BER, bandwidth available, and bandwidth utilized.

*2) **Interface DSE-CSE**:*

- *Access Request*: (DSE → CSE) permits to obtain grid service authentication and authorization.
- *Access Response*: (CSE → DSE) contains the response that permits to accept or reject a grid service request.

*3) **Interface DSE-DSE**:*

- *Request*: encapsulates a *Local Adjacency Request* message in order to redirect it to another DSE.
- *Response*: encapsulates a *Local Adjacency Response* message in order to redirect it to another DSE.

*4) **Interface DSE-CPE**:*

- *Local Adjacency Request*: (DSE → CPE) permits to query the CPE for obtaining the information about all the grid connection established. It contains the grid node ID.

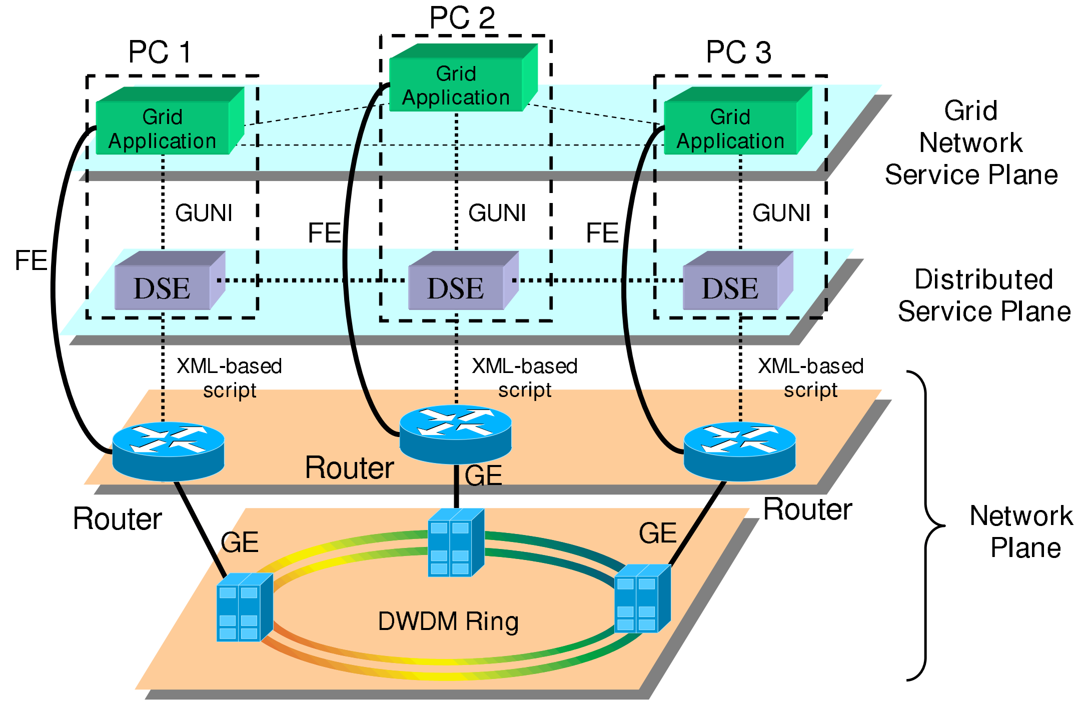

Fig. 6. The SOON testbed

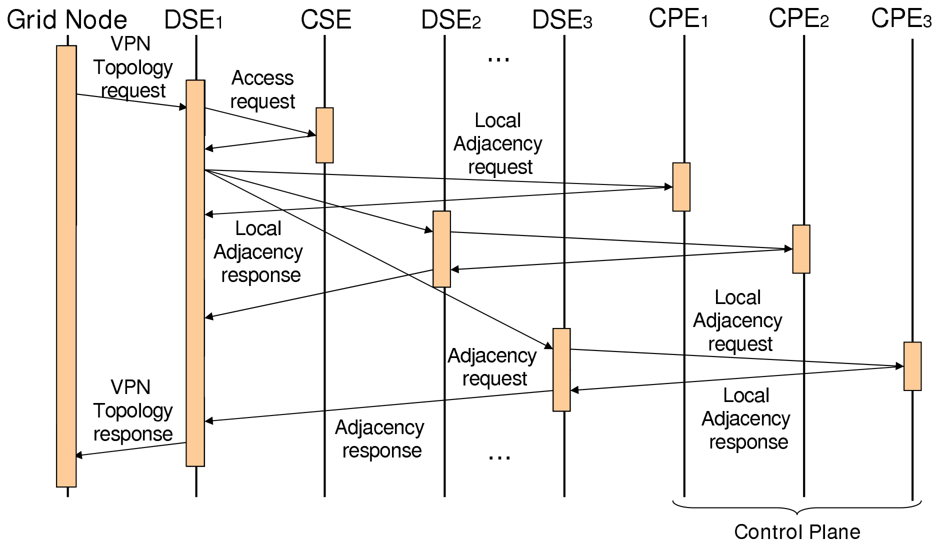

Fig. 7. VPN case study workflow

- *Local Adjacency Response*: (CPE → DSE) contains the list of all the connections established by the grid network and relative attributes.

As shown in Fig. 7 grid request is fulfilled by invoking, through GUNI, the DSE_1 of the Service Plane that in turn sends an Access Request Message to the Central Service Element (CSE) for access authentication and service authorization. CSE, after a query to the database containing grid SLA, sends an Access Request Message to the DSE_1.

If the CSE authorization response is positive the DSE_1 performs a request to the CPE connected with it (CPE_1) and at the same time triggers other DSE to perform the same request to their corresponding CPE. As soon as DSE_1 receives all replies from CPE_1 and from every peer DSE, it correlates adjacency information and obtain. In the end the grid virtual topology that is sent via GUNI to the grid node terminating the session request.

VI. CONCLUSION

In this paper a novel service oriented optical network architecture, called SO-ASTN, suitable for implementing network awareness in global grid computing, has been proposed. The main novelty of this architecture is the introduction of an additional functional layer, called Service Plane, between the customer and the network plane. This permits to logically separate the technology-dependent transport capability from the service provisioning issues.

Service Plane functional architecture can be considered as the union of centralized functionalities and distributed functionalities. The first is related to both user and service authentication and the second regards the actual service implementation that is based on a combination between high-level services and basic services in order to achieve the dynamic mapping between customer service request and the network services. This permit to address flexibility requirements in service provisioning thanks to the implemented Intelligent Network paradigm.

Service Providers can specialize on serving specific class of customers and offer custom services by means of a dedicated interface (e.g., the GUNI for the proposed Grid Service Provider) that maps specific service requests without requiring modifications in the underlying network infrastructure. In particular we designed and developed a Service Provider architecture that is focused on providing high level services to grid computing applications.

The GUNI interface between Grid application and Service Provider, tailored to the Grid Network Services, was defined and implemented using XML technology.

The implementation of the testbed SOON for evaluating the feasibility of the proposed solution in an Access Network scenario has also been outlined.

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REFERENCES

[1] David Benjamin, Richard Thudel, Stephen Shew, Ed Kus, “Optical services over the intelligent optical network,” *IEEE Communications Magazine*, September 2001.

[2] B. Tierney and et. al., “A Grid Monitoring Architecture,” GFD-I.7, January 16th 2002.

[3] W. Allcock and et. al., “GridFTP: Protocol Extensioins to FTP for the Grid,” GWD-R GFD-R.020, April 2003.

[4] V. Sander and (Ed.), “Networking Issues of Grid Infrastructures,” GHPN-RG GFD-I.037, November 22 2004.

[5] B. St Arnaud, A. Bjerring, O. Cherkaoui, R. Boutaba, M. Pott, and W. Hong, “Web services architectures for user control and management of optical internet networks,” *Proceedings of the IEEE*, vol. 92, pp. 1490 – 1500, September 2004.

[6] “Recommendation G.8080/Y.1304, Architecture for the Automatically Switched Optical Network (ASON),” ITU-T, Tech. Rep., November 2001.

[7] “Recommendation G.807/Y.1302, Requirements for Automatic Switched Transport Networks (ASTN),” ITU-T, Tech. Rep., July 2001.

[8] “UNI 1.0 Controlling Optical Networks,” OIF, Tech. Rep., 2003.

[9] B. Martini, F. Baroncelli, and P. Castoldi, “A novel service oriented framework for automatic switched transport network,” *to appear in Proceedings of IM 2005*, September 2004.

[10] CCITT, “Principles of Intelligent Network Architecture,” CCITT Rec. I.312Q.1201, Oct. 1992.

[11] I. Foster and et. al., “Open Grid Services Architecture,” GWD-R (draft-ggf-ogsa-spec-014), March 10 2004.

[12] K. Czajkowski and et. al., “From Open Grid Services Infrastructure to WS-Resource Framework: Refactoring and Evolution.” www.globus.org, May 3 2004.

[13] “Globus Toolkit,” http://www-unix.globus.org/toolkit/.

[14] “UDR 1 - Grid.it Project,” http://www.pisa.cnit.it/projects/firb_project.html.

[15] M. Aldinucci, S. Campa, P. Ciullo, M. Coppola, S. Magini, P. Pesciullesi, L. Potiti, R. Ravazzolo, M. Torquati, M. Vanneschi, and C. Zoccolo, “The Implementation of ASSIST, an Environment for Parallel and Distributed Programming,” in *Intl. Conference EuroPar2003: Parallel and Distributed Computing*, ser. LNCS, no. 2790, Klagenfurt, Austria, Aug. 2003.

[16] G. Clapp and et. al., “Grid Network Services,” draft-ggf-ghpn-netservices-1.0, August 2004.

[17] “Recommendation M.3010, Principles for a Telecommunications Management Network,” ITU-T, Tech. Rep., February 2002.

[18] “Recommendation M.3320, Management requirements for the TMN X-interface,” ITU-T, Tech. Rep., March 1997.

[19] M.Finkelstein, J.Garrahan, D.Shrader, G.Weber, “The future of the intelligent network,” *IEEE Communications Magazine*, June 2000.

[20] D. Simeonidou, “Optical Network Infrastructure fot Grid,” GHPN-RG (draft-ggf-ghpn-opticalnets-1), March 2004.