Control Plane Architecture and Design Considerations for Multi-Service, Multi-Layer, Multi-Domain Hybrid Networks

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I. INTRODUCTION

The hybrid network architecture promises the combined advantages of both the current best-effort Internet Protocol (IP) service and dedicated deterministic end-to-end network services. While the details of "deterministic services" are under active discussion and development at this time, they being are provisioned fundamentally as circuits. The vision for these hybrid networks is to enable flexible and dynamic provisioning of these services to empower e-Science and other large-scale networked applications to carry out tasks such as massive data transfers, remote interactive visualizations, and monitoring and steering of computations on supercomputers. Such tasks require hybrid network capabilities that can only be achieved by innovating and advancing the network services in a manner not possible on current network infrastructures.

A critical enabling technology to realize this vision is a control plane which allows for provisioning of services in this hybrid network multi-service, multi-layer, multi-domain environment. The multi-service aspect refers to the capability to provide a variety of connection modalities such as Ethernet, SONET, or InfiniBand. The multi-layer aspect refers to the fact end-to-end service may be instantiated via a data plane path which traverses multiple different network elements that belong to different technology layers. The multi-domain aspect refers to establishing services across multiple administrative domains to provide the largest value to end users and applications. While current packet-switched networks are uniform in that routers are key elements, the connection-oriented networks continue to be disparate. For, example, Energy Sciences Network (ESnet) [1] provides tunnels over a routed network using Multiple Protocol Label Switching (MPLS), and UltraScience Net (USN) [2] and CHEETAH [3] provide Synchronous Optical Network (SONET) switched networks using TL1/CLI and Generalized MPLS (GMPLS), respectively. The Internet2 Networks [4], HOPI and Dynamic Circuit Services, provides Ethernet-switched and SONET services, respectively, using the DRAGON [5] GMPLS control plane. The key observation is that the emerging hybrid network infrastructure will be built out of best practices from various current networks, and consequently will likely be extremely heterogeneous in nature at both the data plane and control plane levels. We propose to integrate various control planes into a "service plane", which allows heterogeneous administrative domains and technology regions to understand and accommodate one another's service requirements.

In this paper we discuss key architecture and design considerations associated with the development of a control plane capable of dynamic provisioning in this heterogeneous multi-domain, multi-layer, multi-service hybrid network environment. We present a framework for addressing the heterogeneous nature of the hybrid networks via the development of a flexible set of mechanisms which address the key control plane functions of routing, path computation and signaling. An interoperable set of constructs are proposed based on GMPLS and Web Service for seamless provisioning across heterogeneous data and control planes. This paper also includes a discussion of our recent design and implementation efforts to instantiate these concepts on ESnet [1], USN [2], and the Internet2 Networks [4].

II. HYBRID NETWORK CONTROL PLANES - ISSUES AND SOLUTION APPROACH

In a heterogeneous hybrid network, a given end-to-end service may be provisioned using one or more of the following data plane technology layers: i) IP router based MPLS tunnels, ii) Ethernet VLAN based circuits, iii) Synchronous Optical Network / Synchronous Digital Hierarchy (SONET/SDH) circuits, iv) Wavelength Division Multiplexing (WDM) connections. At the control plane level, administrative domain specific control planes may be based on a variety of technologies including GMPLS (as being defined in the IETF CCAMP [6] and OIF [7] communities), Centralized Management systems, and native Web Services based systems.

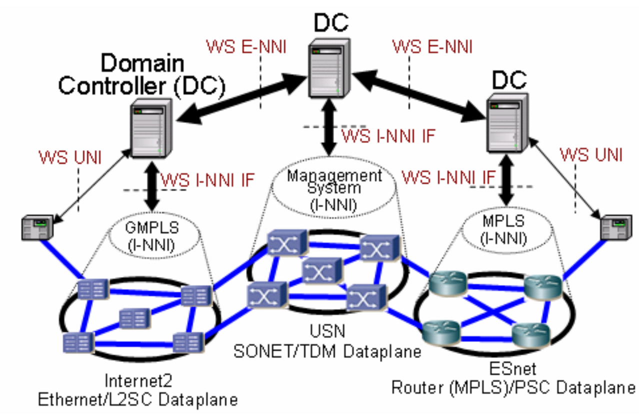

Figure 1 Multi-Domain Web Service Architecture

Our solution approach is rooted in the realization that different networks and administrative domains will implement different network data plane and control plane technologies that best suite their situation based on factors such as performance, cost, available physical resources (such a fiber plants), current equipment, vendor relationships and user requirements. To effectively peer and interoperate such diverse networks, the key capability of the control plane is the definition of Inter-Domain Communications (IDC). This is in line with the Automatically Switched Optical Network (ASON) [8] model that focus on communications between domains as opposed to intra-network operations.

Figure 1 show an architectural model which combines the ASON model of domain autonomy with Web Services to provide a uniform IDC mechanism for the currently available and evolving multi-domain control plane protocols. This approach allows us to take advantage of the current and future work in the standards bodies and also focus on critical issues of scalability, security, flexible application of policy, general AAA, and scheduling.

The key control plane architectural components are the Web Service UNI (WS-UNI) and E-NNI (WS E-NNI). The WS-UNI defines client service request structures. The WS E-NNI defines web service functions for inter-network routing/topology exchange, path computation/scheduling, and signaling/path setup. While these capabilities are inspired by the standards on control plane protocols, they do more than simply recreating that work at the web service level. They create a service plane by composing various individual control planes. Each domain will be served by one or more web services that present a uniform IDC mechanism described in Web Services Description Language (WDSL). Several of the key WSDL operations are described below.

The *createReservationRequest* operation is WS UNI operation initiated by a client to request a network service. The information provided includes: X.509 Certificate, Source IP, Destination IP, Bandwidth Requested, Start time, Duration, VLAN specific data.

The *getNetworkTopology* operation returns a full description of the topology. This topology will likely be an abstracted topology based on local domain policy and configuration.

The *getPathComputationResult* operation returns a explicit route object for both immediate and time constrained scheduled path requests. The associated *getPathComputationResultAndHold* operation allows for a two-phase request and commit procedure which will be necessary in multi-domain path computation and scheduling functions.

The *createReservation* operation creates the physical path segment based on the explicit route in the path computation results. Within each domain these messages will be converted into native signaling technologies.

III. DEPLOYMENT SUMMARY AND STATUS

We have begun initial implementation and testing of this control plane architecture on ESnet, USN, and Internet2 Network. This work is based on augmentation and adaptation of the OSCARS[9] system to include these new multi-domain web service features. As shown in Figure 1, this represents a heterogeneous dataplane and control plane environment on which to evaluate this service plane architecture. We have completed initial testing of web service based signaling/path setup between ESnet and Internet2 HOPI. This has verified an ability to provision interoperable end-to-end services spanning both a MPLS/PSC and GMPLS/L2SC region.

IV. CONCLUSION

The results of this work indicate that Web Service, GMPLS, and Management style based provisioning systems can be made to interoperate for the efficient provisioning of multi-layer, multi-domain hybrid network resources. Additional architecture, design, and implementation work will continue to further evaluate this approach.

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