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Multi-layered service network: MPLS over SONET/SDH

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Abstract
Day to day advance research in next-generation SONET/SDH introduced novel features for generic protocol framing/encapsulation, virtual concatenation, inverse multiplexing, and along with dynamic *generalized multi-protocol label switching* control architectures have enabled many new service provisioning paradigms. This paper presents a novel multilayer network survivability scheme that emphasize on latest feature to support multiple levels of service survivability and focus on high capability of carrying load and service repercussion. Detailed simulation performance analysis results are also presented along with conclusions and directions for future work. Results from a sample performance evaluation study also are presented to quantify some of the achievable gains.

Keywords: Next-generation SONET/SDH; Virtual Concatenation; Inverse Multiplexing Network

Introduction
Subsequent-generation SONET/SDH is a large shade describing a range of proprietary and requisites-established traits which can be developed on the on hand SONET/SDH infrastructure. First deployed by means of lengthy-distance carriers in an effort to aid new offerings corresponding to Ethernet, Fibre Channel (FC), enterprise method Connection (ESCON), and digital video broadcast (DVB), next-iteration SONET/SDH makes it possible for the supply of high-speed, high-bandwidth data within very tight budget constraints. In traffic growth development has resulted in many advances in circuit-switched applied sciences. Major amongst these, optical dense wavelength division multiplexing (DWDM) has yielded unparalleled bandwidth-distance scalability within the core, with present systems assisting over 100 channels/fiber. DWDM is most often not suitable for the threshold as a result of the occurrence of “sub-wavelength” demands, for illustration, Ethernet-centered offerings, storage field network (SAN) extension, and legacy exclusive leased line (PLL) [1]. Thus, advances in next-generation synchronous optical community/synchronous digital hierarchy (SONET/SDH NGS) time-division multiplexing (TDM) have supplied much-needed multi-protocol grooming points here [2]. Emerging paradigms for subsequent-new release community architectures revolve across the proposal of the community as a heterogeneous “multilayer, multi-technology” assemble over which multiple “services” may also be offered. These offerings incorporate usual IP-routed services as good as native access offerings from cut back layers established on applied sciences reminiscent of multiprotocol label switching (MPLS), Ethernet, Ethernet supplier spine bridge (PBB), synchronous optical networking (SONET)/synchronous digital hierarchy (SDH), next-generation SONET/SDH, and wavelength-division multiplexing (WDM).
As network carriers has shifted towards new technologies constructing novel client offerings. In special, there's an emphasis on fielding a various range of customer tributaries and survivability desires fulfillment next-generation SONET/SDH [3] make it possible.

Multiservice
This term refers to the multiple service options, their associated service definitions can be varied based on the underlying network implementations and offer to client when connecting to the edge of a network. For example, typical service definitions are, the combination of the physical port type (e.g., Ethernet, SONET/SDH) and network transport instance (e.g. VLAN and SONET) with performance characteristics (e.g., bandwidth, delay, jitter).

Multitechnology
This term refers to use multiple technologies to implement to fulfil user required network services like IP, Ethernet, MPLS, T-MPLS, SONET, next generation SONET, and WDM.

Multilevel
This term refers to the fact that domains or network regions may operate in different routing areas in an abstract manner across linked boundaries.

Multilayer
This term encompasses both the concepts of multilevel and multi-technology along with control and management of a multilayer network (MLN) and its associated advanced network services. SDH/SONET-WDM multi-layer networks are a very attractive solution to cope with the increasing dynamics and capacities in today’s core networks. In SDH/SONET multi-layer networks, client layer SDH/SONET connections are groomed to wavelength channels and transported using end-to-end light paths. Also, intermediate grooming can yield to a more efficient utilization of network resources. In this paper we also summarize the current state of deployments and the use of network services based on multi-level network Architecture framework.

Next-Generation SONET/SDH
Initially, TDM was built for voice and PLL services and leveraged intermediate layer 2 asynchronous transfer mode (ATM) and Frame Relay (FR) systems for overlaying data

services. However, as data demands outpaced legacy services, the limitations of these multilayering set ups became apparent. Even though various solutions were developed to improve Internet Protocol (IP)-TDM interfacing, for example, packet over SONET (PoS) [4], these techniques suffered from high bandwidth inefficiencies via rigid mappings to "next-highest" TDM carrier. Moreover, all-or-nothing SONET/SDH protection proved very problematic for diversified multitiered services.

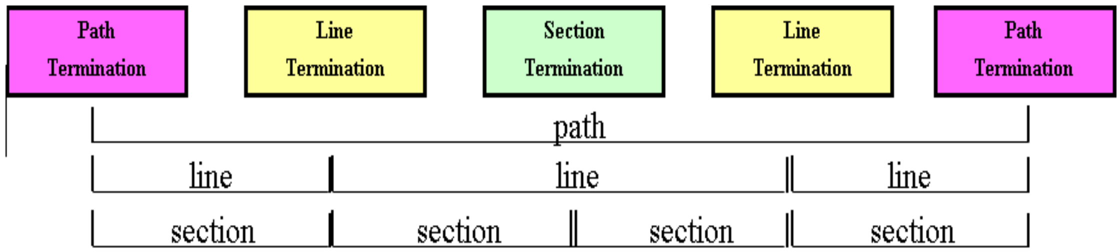


Fig 1: SONET/SDH Architecture

To address these problems, new NGS standards evolved, most notably, generic framing procedure (GFP G.7041), virtual concatenation (VCAT G.707), and link capacity adjustment scheme (LCAS G.7042). GFP provides efficient mappings of diverse protocols directly onto byte-synchronous TDM optical carrier-n (OC-n)/ synchronous transport mode (STM-n) channels, greatly improving data plane efficiencies [5]. This scheme uses robust error-controlled frame delineation (like asynchronous transport mode [ATM]) and supports two payload mappings, frame (GFP-F) and transparent (GFP-T). The former yields deterministic overheads for Ethernet medium access control (MAC) or IP packets, whereas the latter transparently maps 8b/10b encoded payloads (Fiber Channel, Enterprise Systems Connection [ESCON], fiber connectivity [FICON]) with minimal packetization/buffering delays. Meanwhile, VCAT addresses the inherent tributary mismatch of legacy SONET/SDH by combining multiple slower-speed time-slots to "right-size" end-user tributaries, namely, 1.54 Mb/s VT1.5, 48.38 Mb/s STS-1, or 155 Mb/s STS-3c increments [6]. SONET/SDH protection and operations administration and management (OAM) features are also extendible to these tributaries, yielding carrier-class management of data/SAN services.

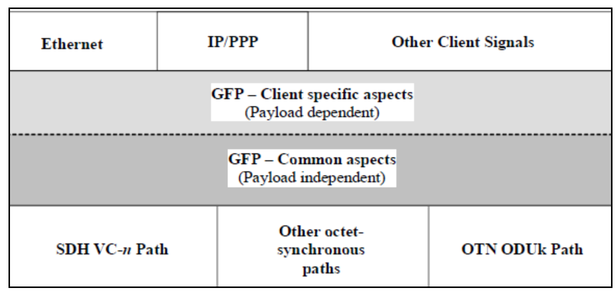


Fig 2: GFP relationship to client signals and transport Path

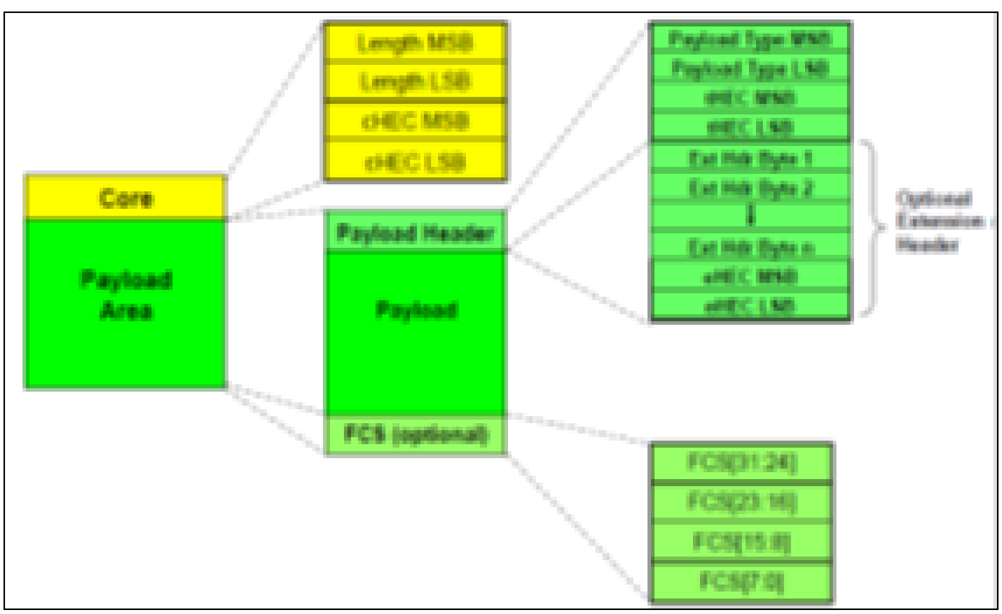


Fig 3: The Schematic of GFP frames

The two kinds of GFP frames are available. First is GFP client frames and other is GFP control frames [7]. Same frame structure is used by them. It is consists of two parts, one is core header and the other is payload area. The payload area involves of payload header, payload and payload FCS. The core header comprises of Payload Length Indicator, Indicate the length of the payload area. GFP sustenance many kind of protocols including local area network and storage area network. The Generic Framing Protocol, defined in ITU - T G.7041, is a mechanism for mapping constant and variable bit rate data into the synchronous SDH/SONET envelopes [8].

1. Frame - Mapped GFP is optimized for data packet protocols. Frame - Mapped GFP (GFP - F), a layer 2 encapsulation PDU - oriented adaptation mode.
2. Transparent GFP is optimized for protocols using 8B/10B physical layer which encapsulated onto constant size frames.

GFP can be used as a method to deploy metropolitan networks, and simultaneously to support mainframes and server storage protocols.

Another key VCAT provision is inverse multiplexing, which allows OC-n and/or concatenated tributaries to be split into multiple sub-connections. These entities constitute a virtual concatenation group (VCG), where each VCG member can be separately provisioned through multipath routing over legacy SONET/SDH or NGS networks using add-drop multiplexers (ADMs) or digital cross-connects (DCS). These streams are recombined at the receiver using buffering to resolve multipath delays. As per, current standards can handle up to 128 ms delay for up to 64 VCG members, which is adequate for global distances. In all, inverse multiplexing can achieve very good bandwidth efficiency in mesh networks. Finally, the LCAS protocol complements VCAT with “hitless” VCG trail readjustment — ideal for dynamic/time-varying or asymmetric demands. Namely, VCG end-points use two-way signaling to synchronize the addition/removal of channels from a VCG [9].

LCAS is well-suited for designing multitier services as it can provision pre/post-fault switchovers on a per-VCG member basis. For example, the VCG sink can monitor incoming members and notify the source of any trail failures within 64–128 ms, providing near SONET/SDH-like timescales [8]. Upon failure notification, the source can take various actions, for example, initiate protection for failed VCG members (high-end services), initiate slower signaling restoration for the failed VCG members (mid-tier services), or simply let the connection run at a lower rate (graceful degradation). Overall, the GFP-VCAT combination delivers higher-layer IP routing table and/or Ethernet spanning tree disruptions

Services Overview

Now a days as requirements increased, Network operators services growth across all sectors, including corporate, residential, and Research. Although the applications are different as per their markets, but the underlying requirements have same. As there is a continuous pressure for bandwidth scalability and reduced price-per-bit, equally important is the desire to deliver flexible multitier services to offset the continued price-per-bit declines of legacy services.

Specifically, carriers would like to support advanced service-level agreements (SLAs) for diversified applications with quantifiable quality of service (QoS) parameters such as bandwidth, delay/jitter, survivability, and so on. Today, PLL still represents a sizeable, although declining, portion of commercial traffic. Nevertheless, with the massive proliferation of IP/Ethernet based applications. The main challenges here are to resolve the low reliability, slow protection, and lack of latency/packet loss guarantees of enterprise Ethernet. Hence, new data interfaces were developed supporting long reach optics up to 100 km (10 Gigabit Ethernet).

With the advancement of Ethernet address scalability, management and wide area bridging the key requirement for the client is the definition of advanced Ethernet service models. MEF (Metro Ethernet Forum) categorized it into three broad categories:- EPL(Ethernet private line (EPL)),E-LAN(Ethernet Private LAN) and E-Tree(Ethernet Tree) along with UNI(User network interface) standards. Technology involved in EPL is point-to-point EVC (Ethernet Virtual Connectivity) which is generalized heritage PLL for point-to-point data interconnectivity. EVC validates SLA parameters such as CIR (Committed Information Rate), CBS (Committed Burst Size), frame jitter etc. Also EVPL (Ethernet Virtual Private Line) accomplishes edge multiplexing at the UNI. Carriers can re-establish EPL connection between corporate sites or underlying bearer service for high revenue like VOIP (Voice over IP), Video Conferencing, IP-VPN etc. E-LAN and E-Tree supports multipoint connectivity. Due to this the end-user cost decreases significantly because of non-requirement of ATM or PoS interfaces by enterprises. EVP-LAN and EVP-Tree also provides feature of multiple client LAN entities. In SONET/NGS the above explained services can be carried out using point-to-point EPL connections between switching and end points like mesh or tree [9].

Residential Services

As the number of users increased the residential market went through number of changes and further plan for ultra-broadband capabilities. To deliver services like combining high-speed internet, voice and video services at less and effective cost ISPs are moving towards all-IP access. Hence, Ethernet is again used to provide mountable bandwidth over various medium like, cable, copper, optical fiber and also air (WI-FI).cable operators have deployed data over cable service interface specification (DOCSIS) to back residential services. At present DOCSIS 2.0 has gained strong traction, supporting up to 20 Mb/s per user (operational speeds are limited to smaller values), and the newer DOCSIS 3.0 standard is encouraging even higher speeds through channel multiplexing. Many carriers use TDM-based backhaul (OC-3, OC-12 PLL) for residential xDSL aggregation, which can readily be supported via NGS.

Research Services

Large governmental and research organizations need more bandwidth. Hence, science of bandwidth services is another market which is experiencing fast growth. Many applications such as large-scale file transfer, grid computing, remote steering, cloud computing, data mining are emerging due to high requirements of E-Science services. Dedicated infrastructures with DWDM transport support are being built for outpacing commercial demands with datasets ranging from terabytes to petabytes. NGS affords a good means to rapidly overlap a wide range of full/fractional rate data services — from 1 Mb/s to 10 Gb/s over TDM or optical transport network. OC-3(155Mbps) is used for increasing scalability.

Tiered Services Support

Developments in next generation SONET (NGS) have unlocked doors for new services standards. DWDM have produced unparalleled scalability, it transports topologies interconnected with electronic SONET/SDH digital cross connect. The key module involved in the development of the NGS is the inverse-multiplexing capability which allows multi-path routing of circuits. NGS consists of three main features: GFP, ITU-T G.7041 and VCAT. GFP (Generic Framing Procedure) is an efficient method to map diverse protocols onto byte synchronous. Its uses vigorous error controlled frame delineation and supports two payload mappings, frame and transparent. VCAT (Virtual Concatenation) resolves timeslot matching problems by breaking rigid multiplexing hierarchies and combining multiple slower-speed time slots.

In tired service survivability carriers are being requested to carry an increasingly-diverse set of services in terms of bandwidth and service survivability requirements. The figure below depicts the inverse multiplexing scheme with partial protection. The topology below comprises of N nodes and M links modeled in graph G (V,L); V is the set of Next Generation SONET nodes and L is the set of Links.

$V=\{v1,v2,v3,\dots v_n\}$ and $L=(l_{12},l_{23},\dots l_{ij})$ i,j representslink between I and j nodes.

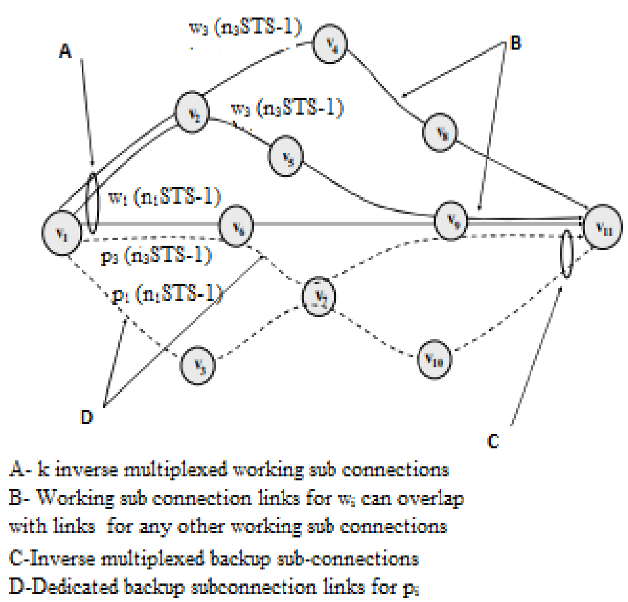
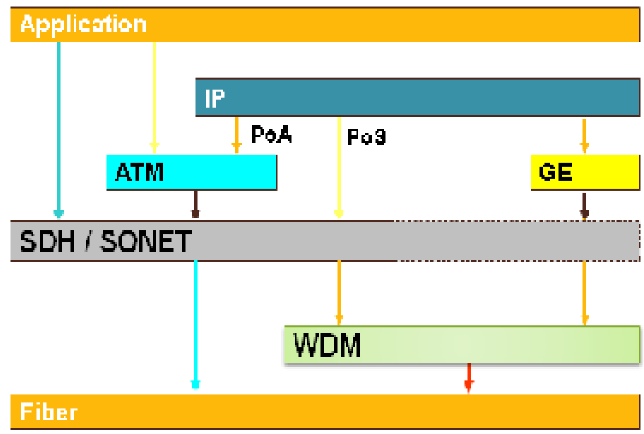


Fig 4: Inverse multiplexing scheme with partial protection

Multilayer Network Architectures

SDH/SONET-WDM multi-layer network that provide dynamics on both layers in order to cover the dynamics of IP traffic as well as to provide bandwidth adaptable connections. SDH/SONET multi-layer networks consist of multi-layer nodes with cross connects on the SDH/SONET layer as well as on the other layer. A main reason for this approach is the fact that a clear and efficient evolution path for the large base of installed SDH/SONET networks exists [10]. Although the network investigated in the following is based on an electronic SDH/SONET layer, an MPLS layer instead will yield the same principal results as an SDH/SONET connection and an MPLS path with a certain reserved bandwidth are modelled very similarly here.



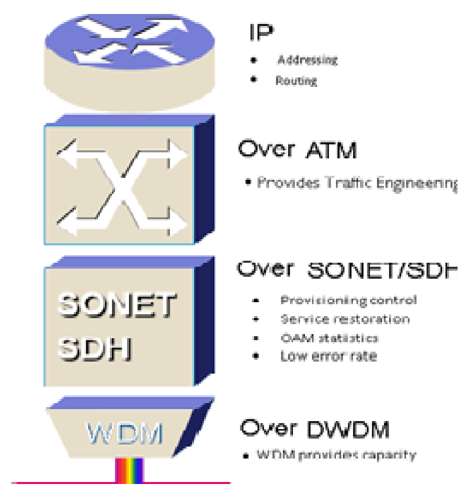


Fig 5: Protocol layering

Today majority of networks deployed consist of multiple technology layers, with routers over WDM being one common example. Different technology layers are selected based on a variety of technical and practical considerations. However, the layers are generally treated as separate and distinct, and not managed together in the multilayer context. We assume that existing networks are multilayer with new deployments and there will be increasing interest in integrated multilayer control and management capabilities.

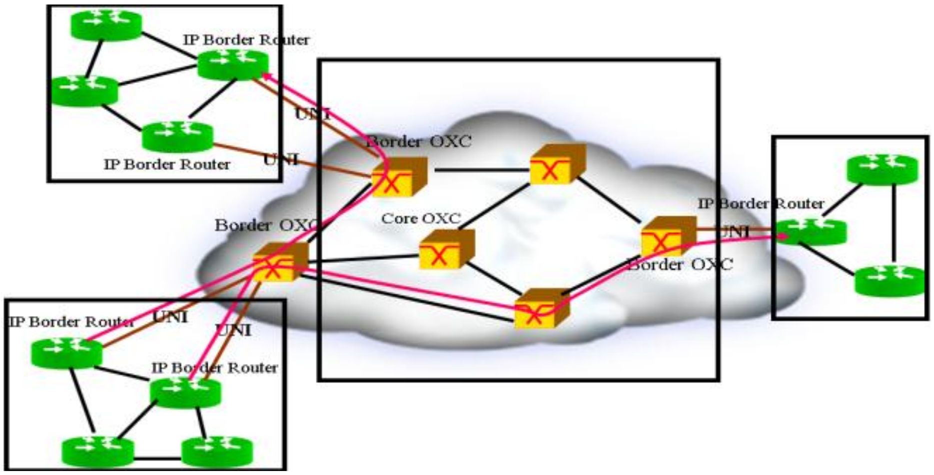


Fig 6: Client Server Model

This is our key point and interest area with describing GMPLS-based multilayer networks. In addition to the network layer concept, which is primarily from a Data Plane topology and connection perspective, the concept of layer associated Capability Planes provides us flexibility to explore multiple possible configurations for MLN. We classify them into four MLN models: MLN-Vertical, MLN-Horizontal, MLN-Combined, and MLN Inter Domain.

In vertical multilayer networking more than two data plane types are layered in vertical manner. It implies using lower layer service provisioning to provide competencies at higher layers. Vertical layer consists of PSC, L2SC and LSC technologies regions where LSC is the lowest layer and PSC is the higher layer.

In vertical multilayer networking more than two data plane types are layered in horizontal manner. This topology indicates the integration of services across different technical boundaries. Horizontal multilayer networking provides a path across various technologies in order to provide service. Ethernet is based on Horizontal networking.

Both the above networking viz. vertical and horizontal multilayer topologies can be integrated to create more supple and refined set of available network services. In this all peer links represents horizontal multilayer networking and the layers represents the vertical multilayers networking.

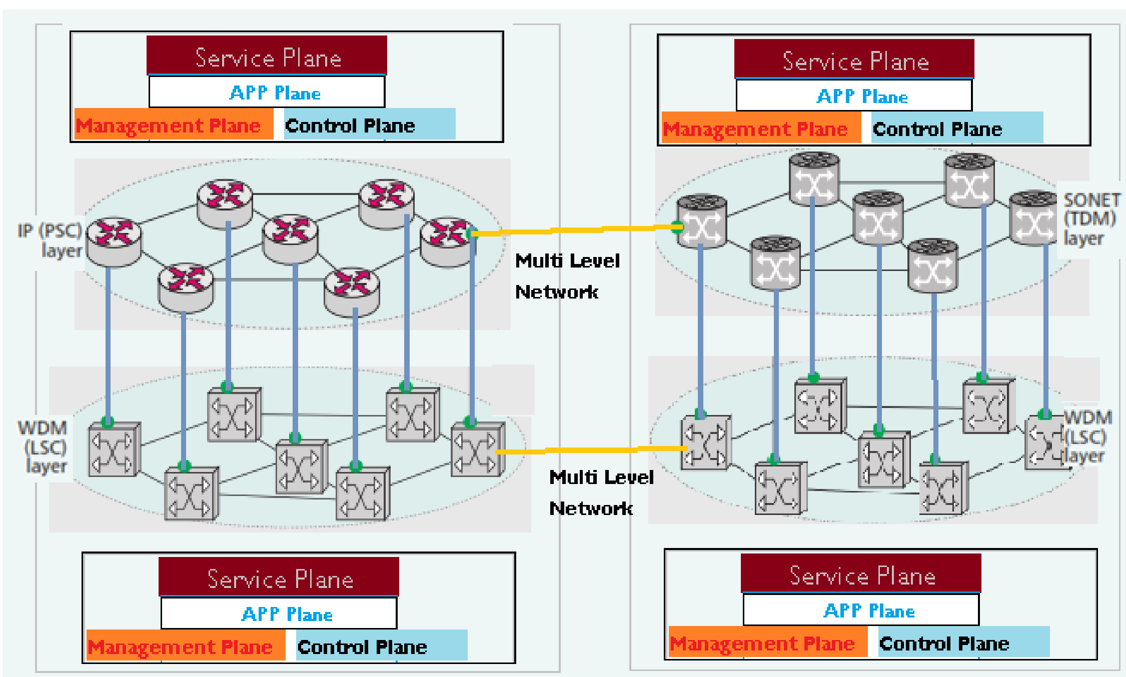


Fig 7: Hybrid Multilevel Network

The context of using multilayer networks used hybrid networking concept to conduct smooth management and transfer of dataflow in-between the various layers in a flexible and dynamic fashion. The intelligence and processes required to determine "why and when" to perform such functions is beyond the scope of this article. This area is of important key point which requires need for continued research, development and even implement of solutions. This article does cover the aspect of implementation as per market demand with respect to combined multi-layer networking. Specifically, the Service Plane interface will provide an entry point into one or all of the Data Plane layers where a hybrid networking could obtain network service and topology provisioning to support larger combined networking work chart.

In general, this design article utilizes the Vertical as well Horizontal multi-leveled capabilities as needed and available to accomplish its larger goals of hybrid networking traffic engineering and traffic grooming.

Summary

As traffic demands on edge, network operators also searching for better techniques and more efficient method to utilize their network infrastructures. Simply adding more bandwidth at a single technology layer will not help with future demands or provide a cost efficient method for network upgrades and performance improvements. The techniques described in this article are motivated by a belief that integrated technology provides control and management capabilities to better network resource utilization and improved user experiences. The concepts described in this article are intended to present a vision for moving forward to realize the seamless and dynamic movement of data flows, services, and virtualized network environments across all layers of network infrastructures.

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