ciena

White Paper

Network Automation

CoreDirector® Multiservice Switch Control Plane Strategy and Benefits

INDUSTRY INVESTMENT IN DEVELOPING A COMMON OPTICAL CONTROL PLANE FOR INTELLIGENT OPTICAL NETWORKS IS WELL UNDERWAY. The ultimate goal is to provide a suite of control plane protocols which react to service requests by automatically provisioning network resources end-to-end across a multi-technology, multi-vendor optical network. This results in the ability to increase the scope and capabilities of the network without a corresponding increase in manpower.

CIENA'S COREDIRECTOR® IS THE FIRST OPTICAL SWITCH TO HAVE IMPLEMENTED AND DEPLOYED CONTROL PLANE FUNCTIONS FOR DISCOVERY, ROUTING, AND SIGNALING and is by far the most widely deployed intelligent optical switch. CoreDirector standards-based signaling and routing protocols have been deployed by over 25 carriers (up to 120 nodes per network) around the world. Carrier analyses of operational expenses show significant savings after deploying an intelligent optical network, based on CoreDirector systems. The CoreDirector networks provide more efficient utilization of network resources and automate provisioning and equipment and resource inventory update processes. In addition to operational cost savings, service provisioning and/or change intervals were reduced from months to minutes, allowing carriers to optimize network revenue.

THE PROTOCOLS IMPLEMENTED BY CIENA SUPPORT EXTENSIONS THAT PROVIDE VALUE-ADD FUNCTIONALITY well beyond the capabilities currently proposed by optical control plane standards bodies. CoreDirector can be used today with O-UNI to support end-to-end service activation/deactivation across an intelligent network. With over four years of operating experience in live networks, CoreDirector intelligence is field-proven for feature-rich functionality, reliability, and scalability.

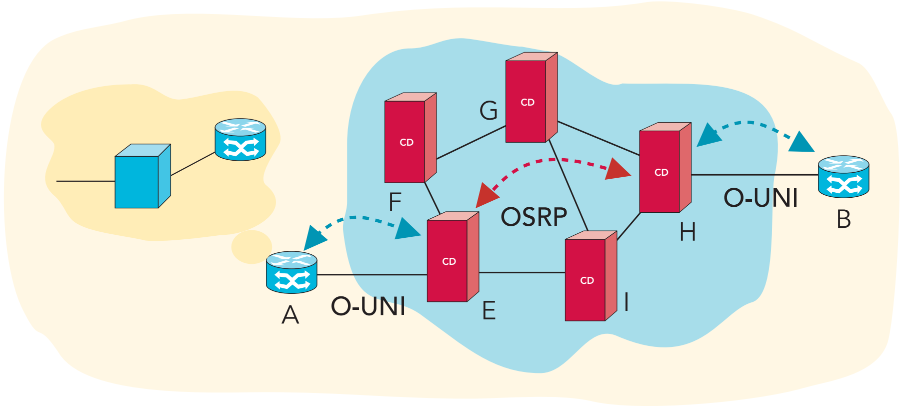
This paper will examine the state of the control plane standards, describe Ciena's implementation of these standards, and describe networking dividends delivered by CoreDirector intelligent networks.

Control Plane Standards: Two Approaches, Both Supported by Ciena

TWO DIFFERENT APPROACHES HAVE SOLIDIFIED IN THE STANDARDS BODIES. In the first carrier-oriented approach, policy boundaries are created between the user or client device and the optical network, and between different administrative domains within the carrier network. This allows the carrier to control the exchange of services and information across the boundaries for security, management, and billing purposes. These boundaries form the Optical User-Network Interface (O-UNI) and the Exterior Network-Network Interface (E-NNI), as defined in both the Optical Internetworking Forum (OIF) and the Union Telecommunication Standardization Sector (ITU-T).

IN THE SECOND APPROACH, all nodes belong to a common trusted environment and exchange complete topology and resource availability information throughout the network, including integration of information from Layer 1 up to Layer 3. This approach is the focus of the Internet Engineering Task Force (IETF) effort on Generalized Multi-Protocol Label Switching (GMPLS). The goal here is to achieve major improvements in Layer 3 network performance by equipping routers with knowledge about the underlying transport network, whereas the goal of the carrier-oriented approach is to improve the efficiency and flexibility of the existing transport network.

Ciena will support customer requirements in both approaches to optical networking and is working to reduce customer risk by converging the OIF/ITU-T and IETF efforts. CIENA is co-founder



of the OIF (together with Cisco), which provides a forum for closely coordinated work between vendors and carriers on optical networking. Through work in ITU-T Study Group 15, Ciena has been instrumental in aligning the work of the OIF and ITU-T ASON, and has implemented ASON control protocols internally and at the UNI and E-NNI interfaces on the CoreDirector multiservice optical switch. Ciena is also a major contributor to IETF efforts in IP and optical control plane integration standards, having co-authored many of the IETF GMPLS specifications. Ciena has been a core participant in GMPLS interoperability testing through the Isocore laboratory, which provides code testing sessions with both optical vendors and leading IP/MPLS vendors such as Cisco and Juniper. CIENA stands ready to support the convergence of carrier networks on IP/MPLS at the service level and agile optical networks at the physical level.

CIENA'S STRATEGY FOR OPTICAL CONTROL PLANE FUNCTIONALITY is to continue working with the OIF/ITU-T and IETF to complete and converge protocol, while continuing to enhance CoreDirector system software using standard specifications and validating the implementation through interoperability testing. As the specifications come to maturity, and as market drivers dictate, Ciena will make available support of the specifications as part of CoreDirector general product offerings. In addition, Ciena will continue investment in the enhancement of OSRP functionality to ensure interoperablility, where applicable, with the OIF and IETF standards.

CoreDirector Optical Control Plane Functionality Overview

CIENA OSRP The basic model of ITU-T ASON is the Overlay (or Domain) model. This supports separation of the network into different domains based on policy and technical reasons, for example, separating the client and network at the UNI and partitioning the network into multiple domains for administrative or policy reasons, such as to optimize restoration times. OSRP, as shown in the diagram above, subscribes to this model. The client device A has the ability to request a connection to other clients (e.g., B) but is given no detailed topology information about the network itself. The client device is only aware of its attachment to the ingress/egress NE (NE E) to the optical network.

In accordance with G.ASON, OSRP uses a signaling protocol based on ITU-T G.7713.1 for fast provisioning. ITU-T G.7713.1 is based on ATM Forum PNNI, modified for SONET/SDH. For routing, PNNI link-state routing protocol has been extended to incorporate routing parameters specific to the optical transport domain. The routing functionality distributes network topology and state information among nodes in the network, so the nodes may determine optimal routes based on an administrative policy defined by the user. Typical routing functionality such as automatic advertisements (including flooding) between all nodes and bandwidth advertisements capturing changes in available resources are supported. Using a combination of the signaling and routing protocols, OSRP can set up a light path (referred to as a Subnetwork Connection (SNC)) between any two nodes in a CoreDirector intelligent network.

CIENA HAS IMPLEMENTED EXTENSIONS TO G.ASON to provide value-add intelligent functionality far beyond that available with current industry standards. Value-add intelligent functionality available today includes:

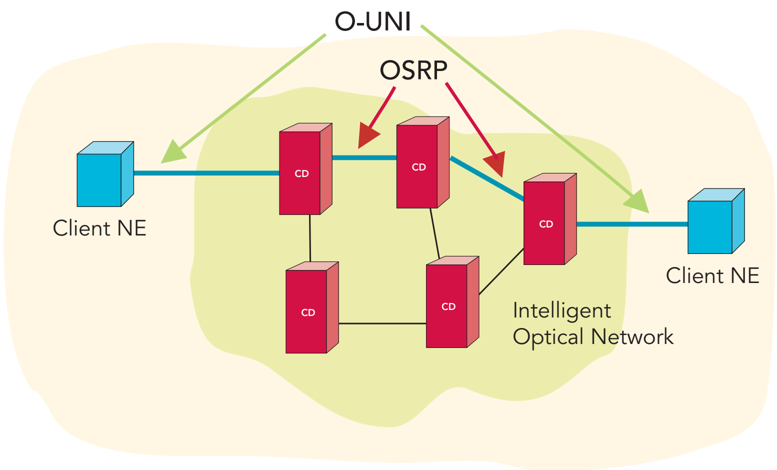
- **FastMesh**™ FastMesh is CoreDirector's mesh topology and restoration implementation, which can be deployed alone or concurrently with SONET/SDH lineprotection mechanisms. Thus, linear and ring protection can be implemented concurrently with FastMesh restoration to provide the highest levels of service availability. FastMesh restores connections on an end-to-end basis and operates independently of underlying linear and ring protection schemes. This provides the framework for a multitiered protection hierarchy, where for each end-to-end connection established by OSRP, the user has the option of configuring that connection as mesh protected or not.
- **Link Aggregation** Provides the ability for multiple links between two nodes to be managed as a single link. Link aggregation supports intelligent network scaling, faster restoration times and network simplification.
- **Local Span Mesh Restoration (LSMR)** LSMR supports faster restoration times in an intelligent network. In response to a failure event, such as breaking of fibers, the SNCs on that fiber are normally restored from their originating nodes using signaling functionality across the network. LSMR allows the SNCs to restore locally, between the nodes adjacent to the break.
- **Crankback** Crankback provides for continuous retry for restoration of an SNC if the initial attempt is blocked. The retry will attempt to find alternate paths in the network using any available capacity.

Implementing OIF O-UNI 1.0

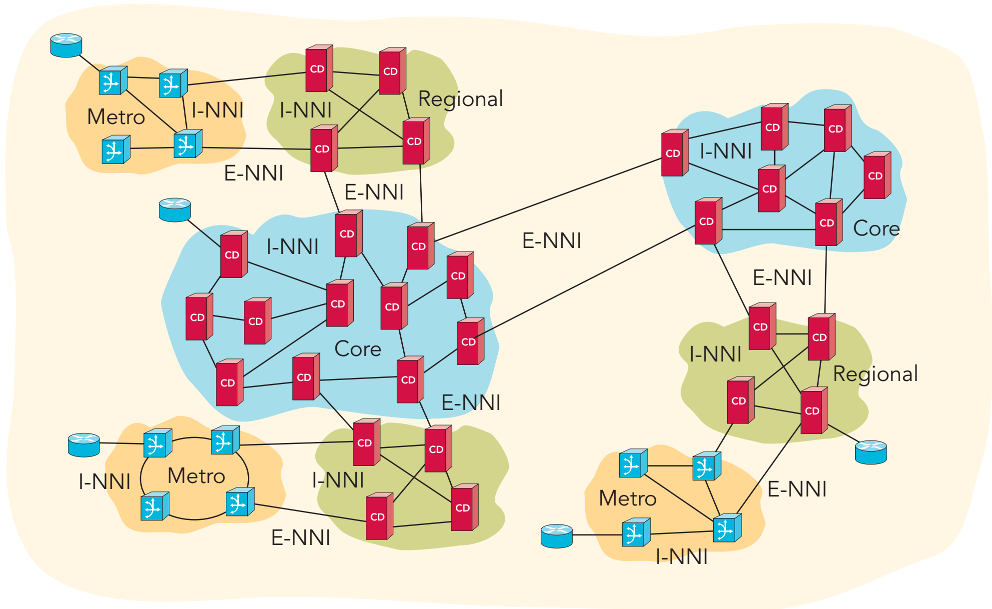
CIENA HAS IMPLEMENTED THE OIF'S O-UNI 1.0 AS PART OF THE COREDIRECTOR GENERAL PRODUCT OFFERINGS. CoreDirector support for O-UNI allows subtended network elements that also support O-UNI to request the set up or tear down of light paths across the CoreDirector network. Upon receiving the request from a subtended network element OSRP will automatically set up (or tear down) a light path. The automation of the request, set up and tear down process reduces operational costs and results in the ability to rapidly respond to service requests and generation of additional revenues. Major features of the initial CoreDirector O-UNI implementation include:

- RSVP-TE for signaling: In-band and out-of-band
- Neighbor discovery
- Support across all CoreDirector SONET/SDH optical interfaces
- Support for IPv4 addressing with potential extension to IPv6 and NSAP
- Handling for numbered and un-numbered links
- Support on mesh, ring or linear CoreDirector topologies

THE INITIAL VERSION OF O-UNI is available for customer lab testing in software release 3.0 and will be available for live network deployment in software release 4.1. CoreDirector O-UNI 1.0 software has been successfully tested for interoperability with 3rd party products on many occasions, both at industry interop demos and internally in CIENA development labs. The software is fully interoperable with OSRP as the I-NNI in the optical network. As shown in the diagram below, an intelligent network can be deployed with O-UNI signaling for activation/ deactivation of light paths across a CoreDirector network, with OSRP as the I-NNI managing the light paths in the optical network.



OIF E-NNI



OPTICAL CONTROL PLANE INTEROPERABILITY, based on OIF E-NNI/ ITU-T G.7713.2, is demonstrable today with CoreDirector. The implementation of E-NNI expands the end-to-end automated provisioning capabilities of the intelligent optical network across disparate optical control domains. This will allow services to be rapidly deployed worldwide across multiple carrier networks and multiple vendor equipment. E-NNI is an ASON standard in progress for control plane signaling and routing of Label Switched Paths (LSPs) between the optical control domains of a carrier's own network or between their network and another carrier's network, as shown in the diagram above.

COREDIRECTOR, WITH E-NNI FUNCTIONALITY, has participated in several OIF-sponsored interoperability events, proving successful interoperability with 3rd party products. Current CD implementation of E-NNI includes:

» Extensions to RSVP-TE for signaling

» Extensions to OSPF-TE for routing

» Interoperability with O-UNI 1.0

» Supported across all CoreDirector SONET/SDH optical interfaces

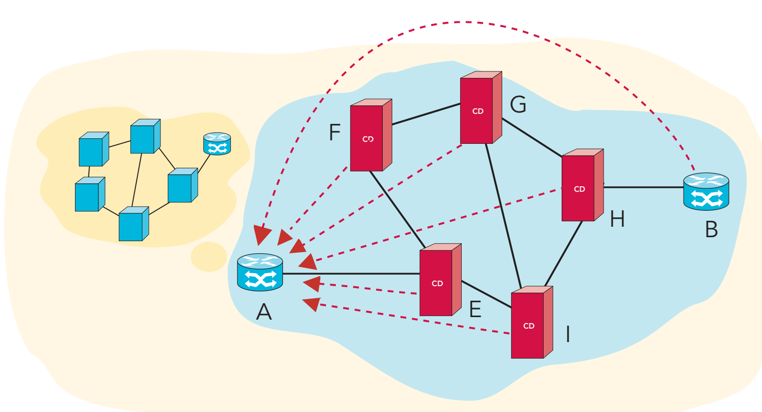
» IPv4 addressing, with potential extension to IPv6 and NSAP

» Handling of both numbered and un-numbered links

IETF GMPLS

CONTROL PLANE INTEROPERABILITY USING THE IETF'S GMPLS I-NNI SIGNALING AND ROUTING is demonstrable today with CoreDirector. Like the combination of O-UNI and CoreDirector OSRP, GMPLS also provides for automated end-to-end service provisioning within an optical control domain.

GMPLS is a standard in progress for a common control plane for signaling and routing of Label Switched Paths (LSPs) within the optical control domain of a carrier's own network. The initial CoreDirector implementation of GMPLS is based on the Peer-to-Peer model. In the Peer-to-Peer model, all elements (optical switches, routers, ADMs, etc.) on the optical network share the database for the entire optical network, as depicted below.



All network nodes act as peers, exchanging full topology information and essentially creating one core net-work. Shown here, NE A has built a database based on topology information from the other NEs (OXCs, routers, etc) and NE A knows exactly how to reach any other NE in the domain to set up light paths between itself and any of the other NEs.

CoreDirector, with GMPLS Peer-to-Peer functionality, has participated in Isocore interoperability code test events, proving successful interoperability with 3rd party products. Current CoreDirector implementation of GMPLS includes:

» Peer-to-Peer networking

» Extensions to RSVP-TE for signaling

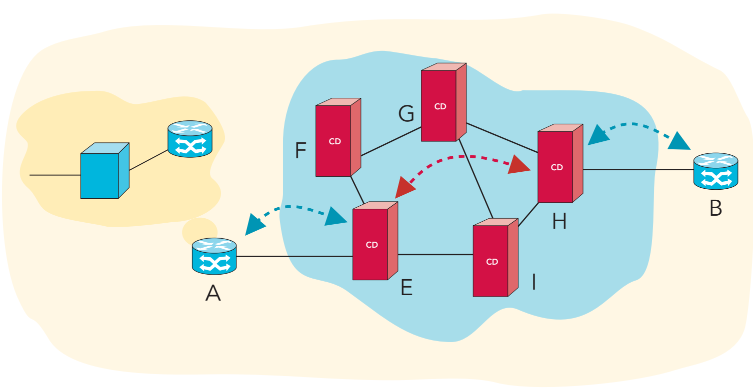
» Extensions to OSPF-TE for routing

» Support across all CoreDirector SONET/SDH optical interfaces

» IPv4 addressing, with potential extension to IPv6 and NSAP

» Handling of numbered and un-numbered links

SUPPORT FOR THE GMPLS OVERLAY MODEL is planned for the future. The GMPLS Overlay model, as shown below, allows the network to be subdivided into core-nodes (E through I) and edge-nodes (A and B), where the core-nodes participate in the routing protocol but the edge-nodes do not. A and B (routers, ADMs, etc.) are considered islands of a single overlaid network.



Financial Benefits of CoreDirector Intelligent Optical Networks

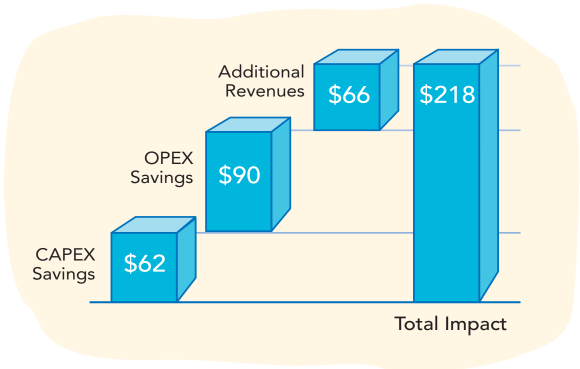
THE FINANCIAL BENEFITS of a CoreDirector intelligent network are most apparent in the following areas:

» Reduced cost for networking equipment, space, and power

» Improved resource utilization and service availability via mesh networking

» Reduced operations costs via automation

Ciena and customer studies show that significant CAPEX and OPEX savings can be achieved by deploying a CoreDirector network. The following graph represents the results of a Ciena study and shows that an intelligent optical network built with CoreDirector results in a six-year NPV of $218M, relative to legacy technology, resulting from CAPEX and OPEX savings and the generation of additional revenues.



The major assumptions of the Ciena study are:

» 15 node network

» 10 Gb/s links between nodes

» 30 to 40G aggregate traffic per node

» CoreDirector network scenario mixes mesh and ring restoration

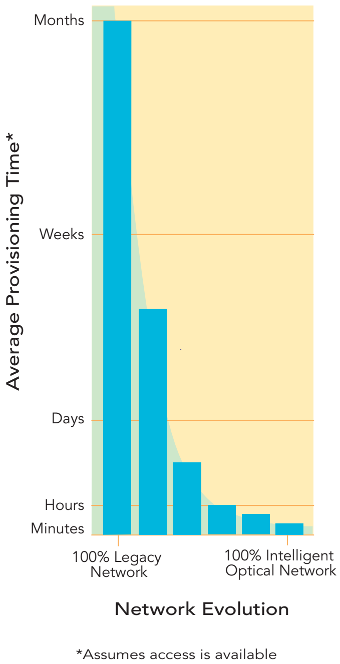
» 5 day service provisioning for legacy network

» Labor force sized for a typical carrier

The following quotes are from AT&T on the financial benefits they've achieved from deploying a CoreDirector intelligent network.[1]

» **Higher utilization / capital efficiency** Shifted from "a very large cushion to protect us from running out of capacity" to operating the network "at very high levels of utilization."

» **Workforce relief** Leveraging automation to operate its expanding network with 44% fewer people than it did in 1998.

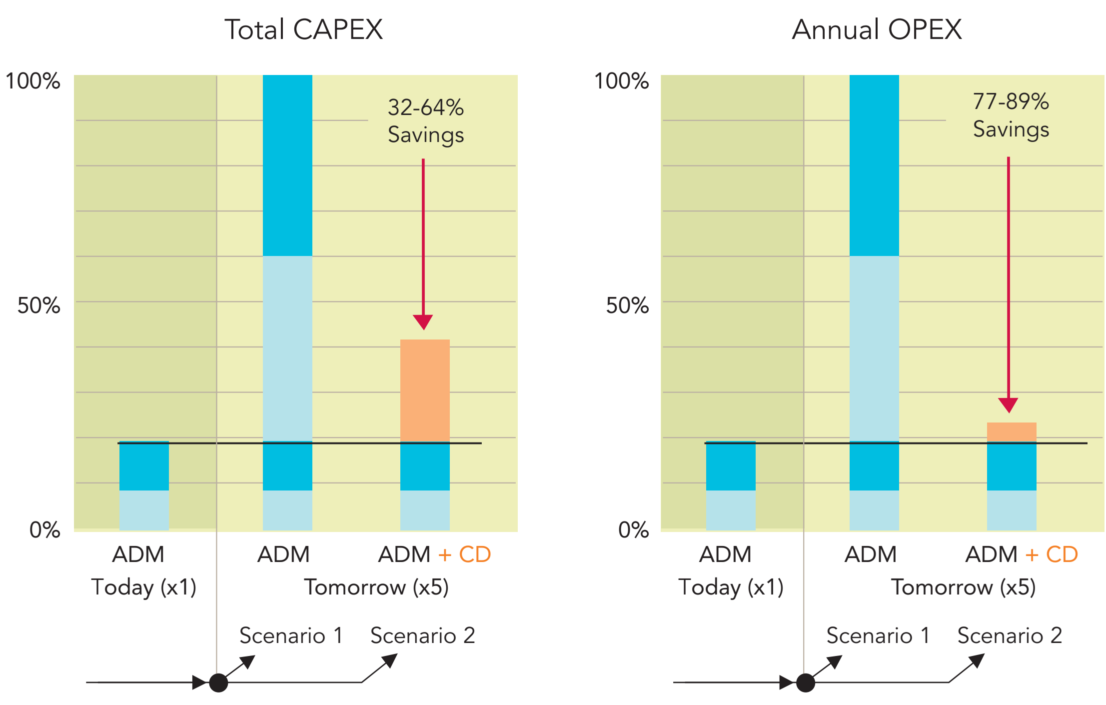


» **Higher productivity** Generating 18% more revenue per network employee than in 2000 while improving quality metrics

» **A critical measure of a companies operational effectiveness** Currently $500K to $600K/employee positioning AT&T well ahead of its competitors

The graph, to the left, shows the change in service provisioning time for an existing CoreDirector customer (not to be named because the information is not in the public domain), after deploying a CoreDirector intelligent network. It shows how their average service provisioning time has been significantly reduced as they've increased the footprint of their CoreDirector intelligent network. Reducing the time required to provision services results in incremental revenue generation. This will be expanded upon later.

The graphs below are the results of an analysis performed by Ciena for a major carrier (not to be named because the information is not in the public domain). The graphs show the estimated CAPEX and OPEX savings associated with capping the existing legacy ADM/DCS network and migrating to an intelligent CoreDirector network verses continuing to grow with the existing legacy network. The black line represents the



[1]Source: Network Fusion "AT&T: Not your mother's Ma Bell" March 8, 2004
Source: AT&T Q402 earnings call, Jan 03; CEO-elect Dave Dorman at UBS Warburg Conference, Nov 02; Frank Ianna at Yankee Group Forum, Oct 02.

baseline. In each graph, the CAPEX and OPEX costs associated with continuing the legacy network (Scenario 1) versus moving to a CoreDirector network (Scenario 2), respectively, are calculated from the baseline for five times the network capacity. The estimates clearly show significant savings. As a result of this, plus other analysis performed by the carrier, CoreDirector was deployed for network growth.

Reduced Cost for Networking Equipment, Space and Power

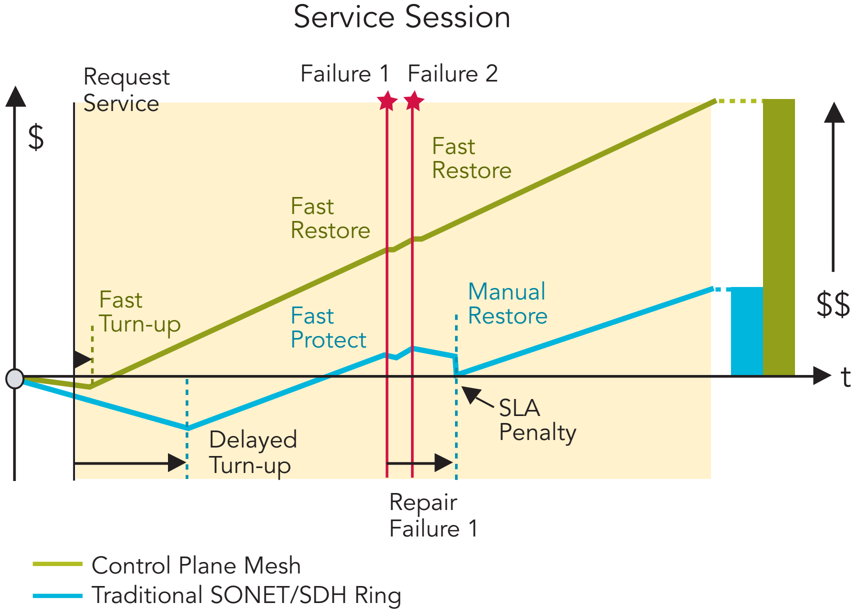
COREDIRECTOR SYSTEMS SUPPORT BOTH TDM AND DATA SERVICES and integrate the capabilities of ADMs/DCSs in a high-capacity switch. The systems provide savings of as much as a 65% of the cost of deploying multiple ADMs/MSPPs with DCSs for core and regional network switching applications. With support for a high number of ports (512 x 155/622M, 256 x 2.5G, 64 x 10G SONET/SDH ports or 640 x GbE or 64 x 10 GbE ports in a single bay) and a high-capacity, any-to-any switching matrix, a single CoreDirector can be deployed in lieu of multiple ADMs/MSPPs and DCS equipment for core and regional network switching applications These applications include: multiple (stacked) ring support, interconnection of multiple rings and/or hubbing of metro rings. In addition to the network equipment cost savings, deploying a single CoreDirector in lieu of multiple NEs for these applications also results in space and power capital savings. In-Service expansion of 4x CoreDirector switching capacity and port density, within the existing chassis, is planned for the future. This expansion will further increase the equipment, space, and power savings provided by CoreDirector.

Improved Resource Utilization and Service Availability by Mesh Networking

UNLIKE LEGACY SONET/SDH NETWORKS, PROTECTION BANDWIDTH IS SHARED across multiple working services in a CoreDirector intelligent, meshed network. Therefore, equal capacity does not have to be built for both working and protection bandwidth. This results in significant savings on switching and transport equipment for the network.

Because of CoreDirector's ability to restore services in a meshed network with available spare bandwidth anywhere in the network, CoreDirector meshed networks provide higher service availability than legacy SONET/SDH networks. CoreDirector meshed networks are field proven, with greater than 99.999% reliability. As depicted in the diagram above, high availability of services can result in increased revenue for service providers.

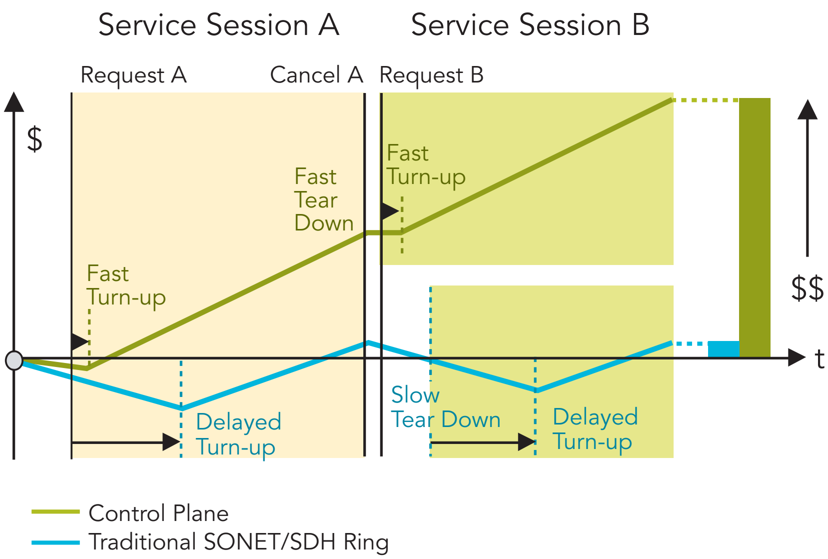
The diagram below shows the conceptual advantages of intelligent mesh restored networks compared to traditional networks for supporting service reliability and availability. Mesh-restored networks are able to handle multiple failures easily. Traditional ring networks are designed to restore service quickly



in the event of a single failure, but usually cannot manage a second failure, which will then require manual intervention to fix. Mesh restoration will handle any number of failures up to the point where the network is partitioned, maximizing the time that the circuit is active and generating revenue.

Reduced Operations Costs via Automation

THE AUTOMATION OF OPERATIONS FUNCTIONS such as service provisioning, equipment inventory, and topology updates result in the ability for a carrier to reduce the number of personnel to operate the network, while still responding faster to requests for new services, moves, adds, and changes. For example, the diagram on the next page conceptually shows how automated service activation can increase service provider revenues.



This diagram considers the full life cycle of the circuit and shows the advantages of automated provisioning compared to traditional SONET/SDH. Initially, turn-up of the circuit on the intelligent network is achieved on an order of magnitude faster, thereby allowing revenue to be generated more quickly and reducing the idle time of the circuit, during which it generates costs to maintain rather than generate revenue. Subsequently at tear down of a service, automated provisioning accelerates the tear down process and reduces the idle time until the circuit is available for subsequent re-use.

IN ADDITION TO THE POTENTIAL ADDITIONAL REVENUES associated with faster service turn-up, there are also operational savings associated with automated database updates. With CoreDirector control plane intelligence, updates to equipment inventory and topology changes are done automatically, without human intervention. The automated updates ensure accuracy of the database, eliminating the additional work that would be associated with human errors in the database entries.

Summary

WITH OVER FOUR YEARS OF EXPERIENCE IN LIVE NETWORKS, CIENA IS THE LEADER IN OPTICAL CONTROL PLANE TECHNOLOGY AND FUNCTIONALITY and is an active, contributing member in standards bodies for ASON, O-UNI, E-NNI, and GMPLS optical control plane technologies. These technologies are demonstrable today on the CoreDirector multiservice optical switch. As a result of Ciena's leadership in intelligent switching, Ciena is the market leader in optical switch deployment. Ciena's CoreDirector systems have been deployed in over 25 carrier networks, with over 600 systems in operation. Over 20 of these carriers are reaping the financial benefits of CoreDirector's intelligent networking functionality and proven reliability for carrier class networks.