White Paper

# Wholesale Services, Dark Fiber, Data Centers and Carrier Ethernet

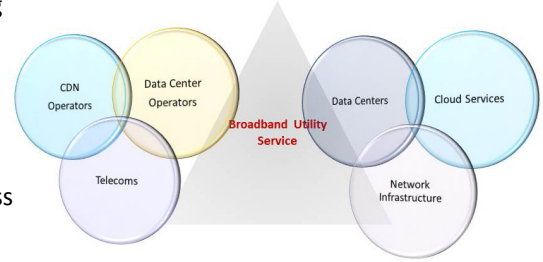
## The Future of Telecommunications Interconnection

The pace of technology, the organization of corporate IT resources and the dynamics of social media evolution are forming new business models for telecommunication service providers. In return, these new models are creating profit opportunities for new services. Data networking and IT managers are implementing applications that make corporations more efficient and give individuals the tools to manage their activities. These services and technologies are creating new terminology as well – global peering fabrics, tethering, Ethernet exchanges, cloud services, SaaS, disaggregation and many others. MRV Carrier Ethernet and Optical Transport products enable you to take advantage of the rapidly changing economics of this new telecommunications landscape.

Communications networks form the foundation of these applications, services and business models. The items listed below are, in part, responsible for the explosion in bandwidth demand that fuels the growth of telecom networks and the need for connectivity:

1. CPU processing power
2. Storage networking speed and capacity
3. Wave division multiplexing capabilities
4. Carrier Ethernet (CE) and CE management
5. Data center switching
6. Virtualization
7. Ubiquitous wireless connectivity
8. Software as a Service (SaaS), Infrastructure as a Service (IaaS), and Platform as a Service (PaaS) and data entries

These technologies combined with changes in work patterns, government regulation and social behavior make new telecommunications business models profitable and are rendering others obsolete. This new landscape is creating opportunities for service providers that are quick, aggressive and flexible with their offerings. MRV understands these developments and has created a suite of optical transport, Ethernet demarcation and network management products that enables service providers to optimize their networks to capitalize on these emerging business models and revenue opportunities.




## Dark Fiber

Fiber is the preferred media for connectivity due to its unlimited bandwidth and large telecom networks are built on fiber backbones. Bringing fiber from the backbone closer to the end-user is a long-term trend that continues to define the industry. However, building fiber networks is complex and time consuming, and understanding the regulatory process in each town and state where the fiber is built requires specialized skill and knowledge. Unique construction knowledge is required to build these dark fiber networks. Creating large fiber networks costs tens to hundreds of millions of dollars, making large capital outlays mandatory. Even with these challenges, the demand for data connectivity is so great that a new class of network provider has arisen that specializes in building and operating dark fiber networks. They may let others light the fiber and provide services under indefeasible right to use (IRU) agreements, and in some

cases, they may also provide lit services themselves. These new service providers are capitalizing on the opportunity to serve the growing demand for Carrier Ethernet and other data connectivity. The many benefits to owning dark fiber or leasing an IRU from dark fiber providers include:

1) Unlimited bandwidth when fiber is used in conjunction with WDM
2) Long-term fixed costs to ease financial planning issues
3) The ability to centralize IT assets in central offices, head ends and data centers
4) Significantly reducing active components in the network thereby lowering maintenance costs
5) The ability to easily connect to other service providers which lowers costs and increases coverage
6) The ability to reach new customers and generate new service revenue

Ring configurations are the most commonly deployed metro and long haul fiber architecture. Dark fiber configured in rings provides the ultimate in service resilience while minimizing the amount of fiber used. Fiber routed in separate paths protects services from "backhoe fade" and offers the simplest method of path diversity. Other fiber topologies include point-to-point and mesh architectures. Point-to-point fiber, sometimes called spurs are often used for last mile connections to customers when diversely routed fiber routes are unavailable or too expensive to construct. In these situations backup can be provided, at lower data rates, via coaxial, twisted pair or microwave connections.

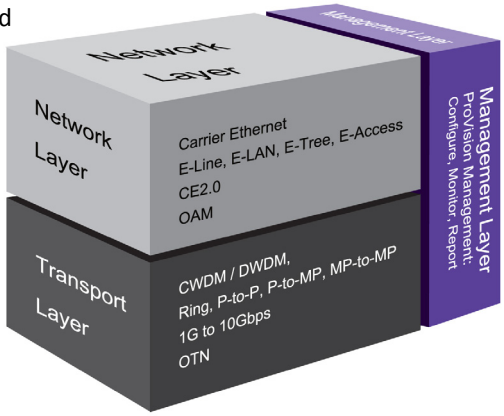
As mentioned above, dark fiber is capable of supporting almost unlimited data rates. Dispersion and attenuation of light over distance does affect the throughput, but for distances under 80kms current fiber networks can support hundreds of 10Gbps, 40Gbps and 100Gbps simultaneously. If architected correctly, fiber networks offer true future proof capacity.

When distances of more than 80km are required optical amplification is available to boost and regenerate the signal so that the bit error rate is maintained at acceptably low levels. For transcontinental and large regional networks amplification is a requirement, however, for most of the new business models for data centers, carrier hotels and dark fiber providers the metro network is where the customers and revenue generating opportunities exist.

## MRV Solutions for Dark Fiber Assets

Whether you build dark fiber networks or buy IRU access for dark fiber, MRV has solutions to insure you maximize the use of valuable fiber resources. Coarse and Dense Wave Division Multiplexing (C/DWDM) enable up to 160 wavelength channels on a single fiber strand. These physical layer channels can run at data rates up to 100 Gbps each, thus reaching enormous bandwidth capacity and future proof scalability. MRV pluggable optics supports any wavelength plan and therefore interoperates with other equipment and protocols that may share the fiber. With MRV's unique Layer 1 optical demarcation features you can manage individual wavelengths on the WDM network using tools that provide proactive, real-time management of telecom services. These mechanisms check link integrity and optical power parameters and can report Bit Error Rate and other issues before they become service-affecting in the field.

Dark fiber supports any protocol and data rate allowing unamplified distances of 80 km-120 km and, depending on the protocol, longer distances are achievable with optical amplification. The MRV lines of Lambda Driver™ and Fiber Driver™ optical transport products have options for any protocol, any distance and any data rate, and therefore, offer a comprehensive and flexible transport infrastructure for any dark fiber network.




The OptiSwitch® access and demarcation devices also comprise an important part of the MRV solution for dark fiber networks. Typically, WDM is used as a transport layer interconnecting OptiSwitch over individual wavelengths over fiber networks; however, many operators connect OptiSwitch directly over dark fiber. The entire product family supports the full suite of Metro Ethernet Forum

(MEF) 2.0 style service creation and management protocols, which are discussed below. In addition, the OptiSwitch adds additional layers of resilience to insure service continuity. OptiSwitch enables SONET-like scalable ring connectivity via support of G.8032, an ITU defined ring protocol that provides sub 50ms restoration. Other service resilience features of the OptiSwitch include: link aggregation, MST, and link reflection. Combining these OptiSwitch features on a diversely routed dark fiber is just one way that MRV provides the state-of-the-art tools needed to guarantee the service level agreements (SLA) required for mobile backhaul and enterprise Carrier Ethernet services.

## Global Ethernet Switched Services Peering Fabrics

New fiber networks are improving the ability of subscribers to purchase high bandwidth Carrier Ethernet services. This is stimulating the use of cloud computing and other high demand services like remote backup, video conferencing, IPTV and XaaS. These dynamics are driving the creation of new options for peering and interconnection between service providers. To increase their footprint and serve more customers, service providers are rapidly increasing their Carrier Ethernet peering capabilities. In addition, new high bandwidth applications that require 7/24 global availability are driving the move to MEF style External Network-to-Network Interface (ENNI) peering. According to a report released in late 2011 by Heavy Reading, Carrier Ethernet services are the fastest growing service at the majority of 70 service providers polled by the firm. The Carrier Ethernet 2.0 (CE 2.0) initiative launched in early 2012 devotes about one-third of its specifications for Carrier Ethernet interconnection via the ENNI.

When Ethernet service provider A connects to service provider B via ENNI they expand the reach of their network and are able to serve more customers. However, delivering Ethernet services over a 3rd party network requires careful planning between the two service providers. Peering on circuit based networks has been standardized for decades, but Ethernet peering is relatively new and there are hundreds of parameters that must be aligned to correctly interoperate Ethernet services between two providers. Over the past decade the ITU-T, IEEE, MEF and IETF have developed standards that enable the creation of Carrier Ethernet services and make ENNI connections simple and scalable. Today, due to these efforts, thousands of service providers interconnect in more locations than ever, often using ENNI ports. This interconnectivity can be thought of as creating a global Ethernet Switched peering fabric. No longer isolated in discreet, geographical islands of connectivity, contemporary service providers can reach almost anywhere in the world with their Ethernet service offerings though ENNI arrangements with other service providers. This new worldwide global switching fabric is massively parallel, virtual and hierarchical. It is enabling new business models for data centers, dark fiber providers, internet exchanges, carrier hotels and traditional service providers.

## MRV Solutions for Global Peering and Interconnect

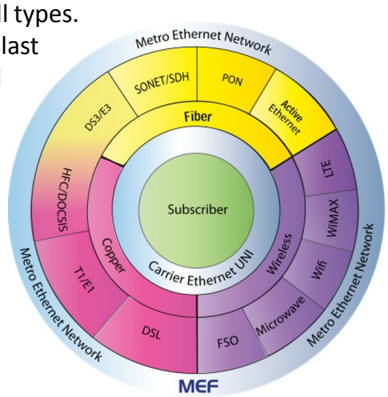
At MRV we understand these dynamics and the equipment requirements to support them. The MRV OptiSwitch Carrier Ethernet demarcation and aggregation devices support hundreds of parameters and dozens of protocols required at the ENNI. With the OptiSwitch you have the capability to precisely align services so that service quality, performance and manageability are maintained with each of these having the ability to be aligned at an ENNI. Services aligned at an ENNI are originally created at a User to Network Interface (UNI). To make network planning simple and flexible any port on the MRV OptiSwitch family can be configured as either an ENNI or a UNI. Other devices have fixed port configurations that can limit the network topology or performance and may require a fork-lift upgrade when a network change is required. With the ability to use any port on an OptiSwitch as an ENNI or UNI, the network operator maintains the flexibility needed in a growing environment when rack space limitations, port count issues and service interruption issues are important considerations. See the section below on CE 2.0 for more details on service creation and management protocols supported by the OptiSwitch at the UNI and ENNI.

To make most efficient use of the emerging global peering fabric the OptiSwitch line also offers hierarchical QoS that can assign QoS treatment to packets at L2, L3 and L4. Sophisticated queuing and ingress and egress shaping features of the OptiSwitch offer unparalleled flexibility to optimize traffic across the network including all access and at peering locations.

## Network Access

Reaching the customer usually requires extending new fiber from the backbone to the customer or finding other media that is physically co-resident at the customer's location. For this reason the owners of the last mile fiber or copper connections have a strategic advantage in the service delivery business. Geography, technology and regulatory issues are paramount in last-mile connectivity and the owner of this part of the network has a natural franchise on customer service delivery. Since there are tens of millions of customers in millions of locations getting high bandwidth, flexible services to subscribers presents ongoing opportunities for service providers of all types.

A number of existing and emerging technologies are designed for to support last mile connectivity including fiber, copper, microwave, LTE and the emerging Wi-Fi 2.0 protocols.




Over the past decade many existing last mile access technologies have evolved to support Carrier Ethernet. All of them, except fiber, have inherent physical limits on the bandwidth they support. Twisted pair, coaxial, microwave and even the newest LTE networks have bandwidth constraints that could limit their viability over time as bandwidth requirements increase. In a perfect world, fiber would be available everywhere, but since it is not, these technologies are very important for creating ubiquitous access for Carrier Ethernet.

## MRV Solutions for Access and Metro Regional Networks

MRV specializes in optical Metro access equipment and the entire product line including the OptiSwitch, Fiber Driver and Lambda Driver contains solutions for network access. The OptiSwitch line of Ethernet demarcation and aggregation devices is designed to deliver Carrier Ethernet services in a simple and cost effective manner. Supporting the entire range of CE 2.0 services, the OptiSwitch supports the full complement of optical and copper connectivity options. They come in a range of port counts from as few as six to as many as 44 for use at cell towers, SMB locations, multi-tenant buildings and large Enterprises.

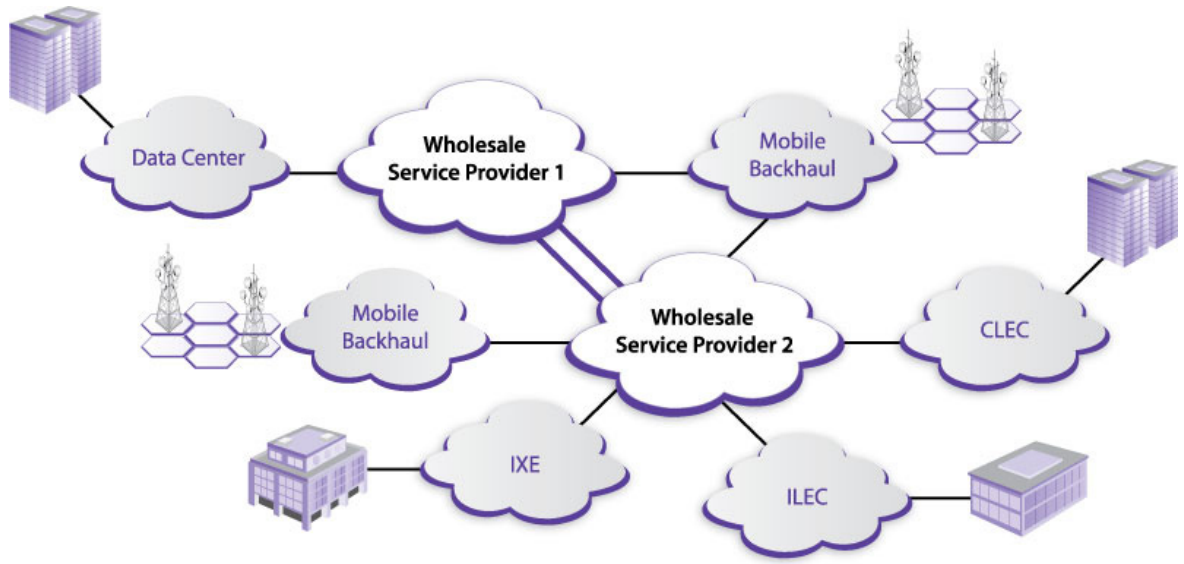
The Fiber Driver and Lambda Driver CWDM and DWDM families are optical transport equipment used for access and transport for one to 160 lambdas on a fiber pair. They support Ethernet services from a few Mbps to 10G, 40G, 100G, SONET, SDH, Fibre Channel, PDH conversion to copper, single fiber as well as other data rates and protocols all in compact, low power configurations. MRV's CWDM and DWDM solutions maximize wavelength utilization with highly flexible OTN Muxponders that allow you to place multiple channels of supported services on a single wavelength. The OTN Muxponders allow operators to mix SONET, Ethernet, Fiber Channel and video services on the same wavelength. Wavelength performance monitoring features track optical performance and BER and provide real-time notification of performance degradation. In addition, MRV's next generation ROADM capabilities allow you to remotely provision any channel to anywhere while future proofing your system for rates beyond 100G that may use channel spacing that is not common today. This agile optical network architecture increases flexibility while the remote capabilities reduce OPEX by reducing dispatches to intermediate points.

MRV has passive and active DWDM solutions that can aggregate 160 10 Gbps connections for very high bandwidth interconnect over campus and metro distances, and pluggable optics that integrate with any wavelength plan. Whether you need simple converters and transceivers or a fully managed, optically amplified, ROADM enabled, regional DWDM network MRV has the solution engineered for your requirements.

## Data Centers

High bandwidth, QoS enabled, fully managed access networks are required for subscribers to reach data centers and cloud applications. As IT resources within corporate data networks are disaggregated and the equipment and contents distributed, users are less often on campuses, where data resides, and increasingly access distributed information from remote data centers. There is no commonly accepted definition of a data center. If you ask five data center managers you'll get five different answers. For this discussion the categorizations suggested below are designed to explain the

latest data center communications developments but are not industry wide terms. Yet, these three data center models all share common characteristics. They all have significant computing power, massive amounts of digital storage and sophisticated local area data switching networks. In addition, they all have real estate, security, cooling and power constraints. They use so much power that the US Department of Energy suggests that up to 3% of the world's total power may be consumed by data centers. From these ingredients data center owners fashion a number of business models. The three types of data centers are described below along with MRV solutions that enable the services they offer.




### *Data Center Model 1 – Compute Focused*

The compute focused data center delivers IT resources to their customers. They concentrate on the virtual computing environment and deliver on-demand services that include servers, storage, operating systems and application processing. One of the benefits of this model is that IT resources can be rapidly expanded and contracted to meet corporate objectives. This model is driving the rapid expansion of public data centers open to one and all, and private data centers that are part of a single organization. They have sophisticated data center networks within their premises for rapid machine-to-machine communications but do not own or control an external wide area network. Network connectivity is typically brought to these locations and managed by others. The compute focused data center personnel rely on other service providers to manage connectivity to their customers. They strive to have as many connections as possible to other providers in order to solicit business from the widest variety of customers.

### *Data Center Model 2– Full Service*

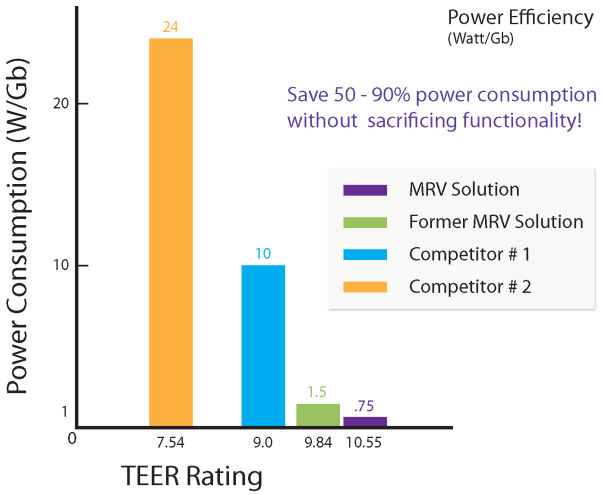
The full service data center model is represented by an operator of a wide area telecommunications network that includes a single data center or multiple data centers within it. The wide area network and access network are often the strategic benefit these organizations deliver to their customers. Access is their trump card. Organizations with this type of structure range from the dark fiber builders, to competitive local exchange carriers (CLEC) to the incumbent providers. Full service providers often have a large access network to leverage and may be less eager than the compute focused data center to encourage the widest variety of interconnections with other providers. In this model service providers attempt to satisfy their customers' requirements with their own network and data center resources. This works best when they have a large service footprint and significant data center resources.

### *Data Center Model 3 - Disaggregated*

Historically, data centers have had large facilities with the capacity to host thousands of machines and support millions of customers. The disaggregated data center functions are the newest innovation in data center architecture. In this model discrete functions of the data center are distributed geographically to optimize the cost and performance of the applications. Variables that may be disaggregated include: content, raw compute power, storage and the network interconnection locations. Content may be cached closest to the customers in large urban areas. As a result, response time is improved but has the drawback of higher space and power costs in metropolitan areas. Hence, heavy computing power and tier 3 storage is increasingly being built in locations that have access to inexpensive or clean power and cheap real estate. These are often places where a high percentage of their electric capacity is generated from hydroelectric sources. In addition, network access can be disaggregated as well. Connectivity costs for network access at carrier hotels, meet-me points and central offices can vary widely in large metropolitan areas. Consequently, network connectivity may be disaggregated from the other areas of the data center and distributed across a number of interconnection locations and companies. In this architecture the remote locations with processing and storage are "tethered" to the central connectivity points via dark fiber. These business models arbitrage the cost differences between, labor, power, network resources and real estate and represent the continuing evolution of the data center business.

## MRV Solutions for Data Centers and Cloud Computing

MRV provides the highest density, lowest power consumption data center connectivity of any Optical Transport vendor while meeting the markets need for low latency. Our High Density (HD) 10G Metro Optical Solution offers the lowest space and power consumption of any equipment on the market. While some suppliers may use one or more standard 42 RU racks for 80 channels of 10G, MRV's HD 10G Solution uses a mere 11RU or 25% of a single rack for the same capacity. In addition to saving 50-75% space compared to other solutions, the MRV solution uses less than 0.75 Watts per Gigabit of bandwidth, which represents an electrical OpEx savings of more than 50% compared to other equipment. Today's cloud computing frequently calls for low latency and MRV delivers less than 50 nanoseconds of latency per 10G channel, which is about the same as adding 10 meters of fiber to your span. MRV meets low latency standards while providing the highest density and lowest power consumption in the marketplace today.




*The TEER rating is a Verizon Green System Energy Efficiency Rating on a scale from one (least efficient) to ten (most efficient). Verizon established a TEEER of 7.54 as the minimum acceptable rating for Optical Transport. While many suppliers tout ratings around 9.0, MRV improved its industry-leading rating from* 9.84 to 10.55, cutting power consumption in half in the process.

In order to enable Carrier Etherent switched services over optical transport network for cloud connectivity, MRV OptiSwitch Ethernet access solutions include a broad range of models starting from low-data rate units for SMB and progressing up to high end enterprise units that require multi-port 10 Gbps connectivity to the cloud, culminating in units that support multiple 10Gbps for connectivity between data centers. This portfolio is useful for aggregation of lower speed customers onto higher speed aggregation rings while preserving QoS and EVC properties across the network. Optimizing traffic with L2, L3 and L4 awareness insures that data center providers can guarantee the SLAs they offer in their contracts. There are versions with standards based Circuit Emulation capabilities for interconnection with circuit based networks as well as temperature hardened units with dual AC and DC power supplies for use in remote environments. MRV has millions of OptiSwitch ports installed worldwide with Tier 1, competitive providers and all three types of data center operations. This experience has enabled MRV to progress through 4 generations of OptiSwitch so that the Operating System we deliver today is the most robust and mature in the industry.

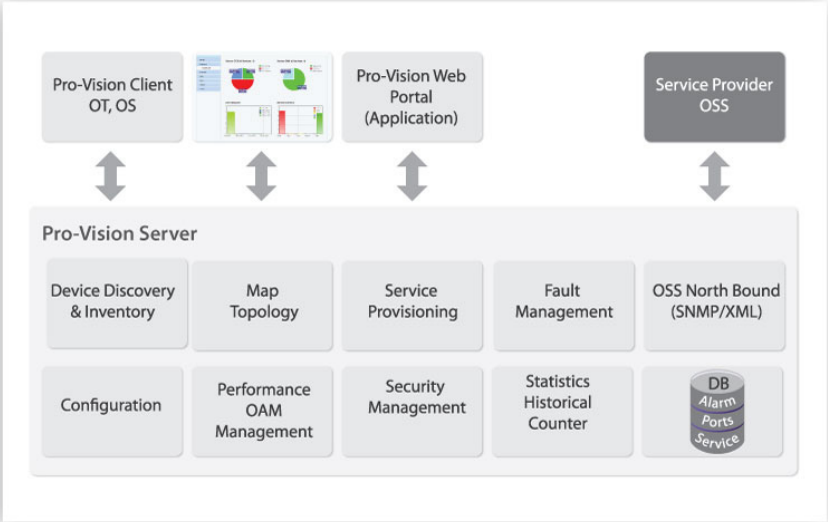
## MEF 2.0

In early 2012 the MEF released the specifications and implementation agreements for CE 2.0. A culmination of 10 years of work on Ethernet services, the agreement puts to work a coherent framework to support the need for QoS controlled services. CE 2.0 provides performance metrics for more than 20 services and defines the requirements for multiple CoS delivery across multiple EVCs at the UNI and at the ENNI. The initiative also clearly defines the management points from the link layer to the application layer. This coordinated program defines specifications for the creation, interconnection and delivery of Carrier Ethernet services worldwide. MRV has been in the forefront of this effort since the inception of the MEF in 2000.

## MRV Solutions for MEF 2.0

The key to lowering operational expenses for delivering service is the automated provisioning and management of thousands of customers in real time. MRVs answer to this requirement is Pro-Vision. MRV's Pro-Vision is a sophisticated, carrier class, scalable, service management platform for service providers and enterprises. It enables end-to-end service creation and deployment of cost-effective and reliable differentiated Carrier Ethernet 2.0 services. With user-friendly intuitive graphical interface, service providers can rapidly create, deploy, monitor and maintain end-to-end CE 2.0 services.

Pro-Vision gives the service provider the ability to configure and manage OptiSwitch devices anywhere on the network. Through it the operator can access the advanced classification, policing, metering and per-flow QoS features of the OptiSwitch. Pro-Vision enables automatic configuration of EVCs and Q-inQ mechanisms for both inner and outer VLAN tag translation. It has real-time graphing and charting capabilities for IEEE 802.1ag and ITU-T Y.1731 OAM features as well as link layer protocols. The auto discovery and Zero Touch provisioning enable any OptiSwitch to be placed in service and uniquely configured with no operator intervention. The OptiSwitch resilience features for ring, mesh and liner configurations through standards based protocols is configured, displayed and monitored through Pro-Vision as well. It has a robust service portal for service providers that want to offer their customers a real-time view into the performance of their services on line graphs and charts as well as other reporting features.




For E-Line, E-LAN, E-Tree and E-Access configurations and the virtual variations of these services the OptiSwitch is the ideal platform. Whether you support simple data applications or more demanding audio and video services the OptiSwitch has the advanced software features that make service deliver simple and reliable. Classification using a mix of port, MAC, Ethertype, double tagged VLAN, IP, TCI, UDP and marking with IEEE 802.1p between layers insure that you have the service flexibility to create and guarantee SLAs on any service or EVC.

Many OptiSwitch models support MPLS pseudowire with Traffic Engineering extensions. They include LSR and LER functionality with LDP, RSVP-TE, OSPF-TE, ISIS-TE and CSPF support. The unified OptiSwitch operating system uses the same image across all platforms so service provisioning and management are identical for all models. Support for MPLS-TP insures seamless interworking with the core IP network.

Service performance management is also a major component of CE 2.0 and OptiSwitch excels here too. Support for end-to-end service OAM via IEEE 802.1ag for CFM per service MEP/MIP and in-service EVC loopback, linktrace and continuity checks is standard on all models. End-to-end performance measurements managed and reported through Pro-Vision, guarantee that Carrier Ethernet services delivered with MRV's OptiSwitch demarcation and aggregation devices meet the delay, delay variation and frame loss specified in CE 2.0.

## Conclusion

For more than 20 years MRV has been a leading supplier of optical components and systems. In addition, our pioneering approach to Carrier Ethernet gives us a unique technical foundation on which to build next generation systems and networks. Starting at Layer 1, the physical layer, we offer the highest quality, low space, low power, WDM/OTN and ROADM systems; we help carriers build a rock solid transport foundation for any service. Moving up to Layer 2 we support the full suite of CE 2.0 and IP/MPLS protocols needed to deliver today's high bandwidth, high security, low latency, H-QoS controlled services for Enterprise and Cellular networks.

Wholesale and retail services need strict SLAs and sophisticated OAM that requires tight integration both Layer 1 and Layer 2 technology. MRV's expertise in optical transport is unique among Carrier Ethernet access equipment vendors. Our ability to provision the physical network at Layer 1 and virtual connections at Layer 2 in the same platform using Pro-Vision offers unprecedented control and visibility for the access network. This tight integration enables multi-protocol OTN wavelength optimization, physical layer performance monitoring, 100G capabilities, and reconfigurable optical transport in a single system that also provides the most robust Carrier Ethernet 2.0 features. The MRV roadmap calls for integration of a generalized MPLS control plane along with these solutions that will enable any service provider to build a state-of-the-art access network for any service that requires control, reliability, security, management and a low total cost of ownership.

The business case and service offered by dark fiber providers, wholesale service interconnect contracts, data center operators and telecommunications providers of all types is changing rapidly. Higher bandwidth, increasing mobility and virtualization demand new, more efficient networks and operating procedures. The MRV portfolio gives network operators the flexibility to efficiently create and manage new services while capturing a larger share of these expanding market opportunities.

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