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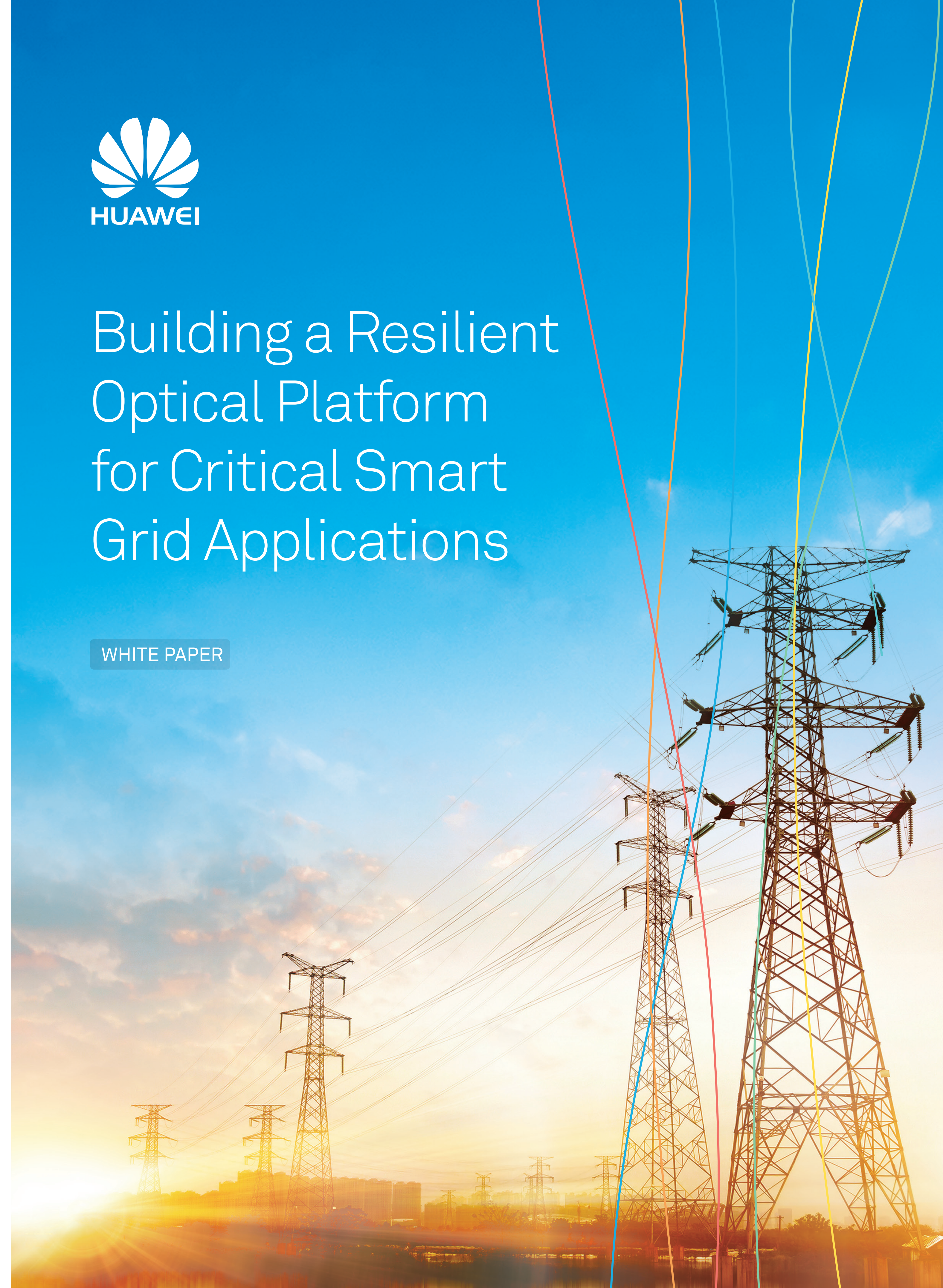

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# Building a Resilient Optical Platform for Critical Smart Grid Applications

WHITE PAPER

# ABSTRACT

In the smart grid era, the power industry is facing the rapid growth of electrical power networks and a corresponding dramatic increase in video surveillance and office automation (OA) data flow. It requires sufficient bandwidth resources to accommodate growing network scale and data volumes for several years to come.

Meanwhile, low-rate systems with traditional service are still the cornerstone of safe production and operation of power. Accordingly, the bearer networks of smart grids also need to be reliable enough to ensure real-time transmission of mission-critical electricity data, even in extreme environments.

This paper introduces the resilient optical platform for smart grid operating environments. It explains how this platform meets the capacity, security, reliability and long-distance communications requirements of power transmission networks, and supports a variety of electric power services on a unified network. This paper then explores the technologies and network architecture catering to the unique characteristics and various applications (such as teleprotection, SCADA, and networking) of substation automation (IEC61850) systems.

## Keywords

Universal Transport Solution, Smart Grid, Telecommunication, Bearer Network, Physical Separation, Built-in PCM/MUX, WDM, OTN, SDH.

# 1 Introduction

Rapid economic development has created new challenges for expansion. The power sector now requires a substantial increase in information exchange across the electrical power delivery system. A large volume of information flow is expected both within and between different stakeholders of the power sector (generation, transmission, distribution, energy market and consumption). The following are typical processes that include high amounts of bandwidth:

- Communication between control platforms (database synchronization between control centers and the communication of available power resources and load information, trends and predictive data, grid monitoring information, and stability margins).
- Communication between operational platforms and high voltage (HV) substations (SCADA, synchrophasor-based Wide Area Measurement System (WAMS), primary asset monitoring, site surveillance, and access control).
- Communication between HV substations (protection and control in digital substation contexts (IEC61850)).


- Communication between engineering or maintenance offices and substation assets (remote diagnostics and remote parameter configuration).
- Communication between central platforms and field workers located at substations (remote access to network-wide data, asset documentation, and technical support).

Additionally, the data exchange perimeter is being widened to incorporate distributed energy generation and storage, energy consumers, other utilities, trading platforms, and more. This was not an aspect of the previous power delivery scheme, and was not previously accessible for direct information exchange.

Furthermore, work practices in utility office environments now require intensified usage of integrated enterprise applications. Corporate enterprise traffic necessitates substantially more bandwidth on transport networks.

The spectrum of communication services associated with the operation and maintenance of electro-energetic systems has increased with the extended perimeter. Information volumes of previously existing applications have increased, and as a result altered requirements. This has created a need for a multi-annual plan for telecommunication infrastructure extension.

To overcome these challenges, many power companies are implementing a new transport platform over existing optical fiber infrastructure. This will both reinforce and complement the SDH network. The new transport platform discussed in this paper provides extensive capability for the bandwidth growth of enterprise networks without impacting the deterministic time behavior of mission-critical operations. Additionally, this platform will substantially increase packet-switch traffic capability on the operational network, allowing the deployment of new operational applications.

Secure, dependable, and fault-tolerant communication systems with controlled and deterministic behavior must be integrated in order to meet critical communication requirements. Integration should take place alongside a large capacity, scalable enterprise communication network on the same fiber infrastructure.

These requirements are achieved using the ITU-T Optical Transport Network (OTN) technology organized into regional rings. This technology supports transmissions across long distances at high speeds without requiring the modification of existing fibers. Packet-switched Gigabit Ethernet data traffic can be directly transported while still allowing the transport of Time Division Multiplex (TDM) channels.

The platform discussed in this paper transports IP-based corporate enterprise applications while providing operational communications for grid-related mission-critical services. This ensures fast communication between dispatch control centers, power grids, and critical applications, all of which typically require high levels of availability and controlled delay. The new data transmission system will optimize network management in real time while aligning operations and ensuring a continuous supply of power.

# 2 Communication Network Requirements

Considering the critical significance of information flow through the network, the main criteria for a communication network are:

### Large andwidth

As HD video surveillance emerges and OA in the electric power industry develops, network bandwidth acceleration will become an important industry development trend. Legacy bearer networks are difficult to upgrade, however, due to the outdated design.

Moreover, if optical fiber resources can be fully utilized, bandwidth operation can promote value-added services. As a result, bandwidth demand will show a geometric growth.

### High Reliability

As the fundamental structure of a grid network, communication networks must be reliable to ensure normal operation. The development of new services, such as dispersive renewable energy resources, smart meters and WAMS, has resulted in a more complicated network. During this period of change, however, communication networks have been just as reliable as they were in the past.

### High Security

With many different services running in the network, production services should be isolated from other services, and dedicated bandwidth should be assigned to production services. This will ensure such critical services are transmitted reliably. When more systems are added to a grid network, these systems need to connect to the internet, creating more potential risks to communication network security. For example, the cyber-attack on Ukraine's power grid network was due in part to the fact that the control systems and non-control systems were not physically isolated.

Legacy services such as SCADA, hotline, PA, and Ethernet services are still used in current network configurations, and networks still have to interconnect with these interfaces. In addition, new services, including video surveillance, advanced metering infrastructure (AMI), distributed automation (DA), and WAMS will be constructed on a large scale and must be supported by the network.

**Multi-Service Accessibility**

**High Availability**

Globally deployed power grids are essential to the livelihood of modern society, and as a result are very extensive. Transmission and distribution networks may span complex and varying environments such as deserts, rain forests, mountains, and wetlands. For smart grids, communication networks must always maintain high availability, adapt to a variety of environments, and continue to provide communications services.

With the development of the smart grid, more systems will be involved in the network. However, the OAM team may not be expanded. Therefore, the operation and maintenance of a communication network should be kept simple to maintain low CAPEX and OPEX.

**Low CAPEX & OPEX**

**Smooth Evolution Toward Future Networks**

The lifecycle of power equipment is longer than that of communication equipment, and communication interfaces are typically used for a long period of time after their End of Life (EOL). With this in mind, smooth network migration should be supported. This will ensure seamless interconnection with legacy services. Communication networks should support native packet service transmission to be ready for the evolution to IP networks.

# 3 Huawei Universal Transport Solution

The Huawei Universal Transport Solution uses high capacity optical systems. The TDM and packet planes will be included for the native transmission of TDM and packet services such as Teleprotection, SCADA, WAMS, and video surveillance. All these services can be directly accessed through hard and soft pipes provided by the universal transport equipment. The native transmission from TDM hard pipe to packet soft pipe can be achieved on optical fiber pairs in hybrid mode by using smart line cards, without the need of two optical fiber pairs for different services. The main advantages of the Universal Transport Solution are:

- The OTN technology supports large bandwidth.
- Hard and soft pipes ensure high reliability and efficiency.
- Physical hard pipes enhance network security.
- PCM/MUX all-in-one solution achieves multi-services access and simplifies networks.
- Ultra long haul transmission applies to UHV and EHV scenarios.
- The unified NMS improves operation and management efficiency.
- Smooth network evolution and migration are supported.

## 3.1 OTN Technology Supports Large Bandwidth

During the evolution of power company communication networks, traditional electric power services have shifted from unidirectional to bidirectional. Oncoming packet services such as CCTV, OA, and teleworking require higher network bandwidth. Smart 10G/40G boards can allow SDH and packet services to coexist and can be transmitted in one optical fiber pair simultaneously. TDM and packet capacity can be adjusted based on customer demands, saving optical fiber resources and subrack slots without a complex optical-layer design.

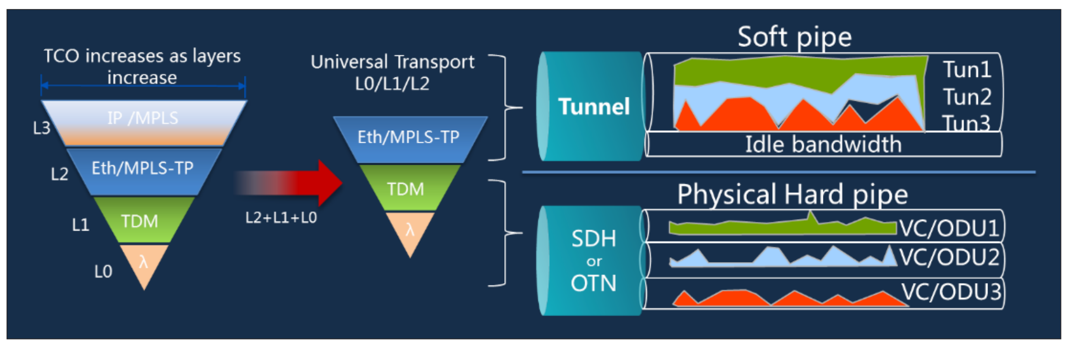
If a power company needs higher bandwidth, the Universal Transport Solution can provide up to 16 Tbit/s bandwidth per optical fiber. With such large bandwidth, electric power companies can efficiently expand their innovated services and even lease out some of their bandwidth to create new streams of revenue.

## 3.2 Hard and Soft Pipes Ensure High Reliability and Efficiency

Hard and soft pipes meet the demands of services for high security and large bandwidth.

Traditional SDH/OTN technology, also known as physical hard pipes, offers dedicated bandwidth for critical production services with high quality, low latency, and physical separation to ensure reliable transmission. Critical services such as SCADA, teleprotection, and other dispatching services are carried by physical hard pipes.

Packet soft pipes utilize highly efficient statistical multiplexing of MPLS-TP technology, increasing bandwidth utilization to meet demands of ever-increasing packet services such as video surveillance, OA, and other value-added services.




## 3.3 Physical Hard Pipes Enhance Network Security

Cyber criminals can target any digital device or system, including power and electrical systems. Some traditional services, such as SCADA and hotline services, have migrated from low-speed interfaces to IP interfaces. However, the main requirement of traditional services is still high security. Physical hard pipe is still the best choice for critical services.

The traffic at L0 and L1 is encapsulated and mapped through techniques such as Generic Framing Protocol (GFP) and Virtual Concatenation (VCAT). Soft pipes transmit data in plain text based on label forwarding and switching. In contrast, physical hard pipes support cipher-text transmission and are therefore more secure for production services.

Soft pipes use protocol-based logical isolation, which is difficult to prevent hackers from breaking through the entire system. In contrast, physical hard pipes use physical isolation technology (timeslot, VC, or wavelength isolation) in both time and space dimensions to achieve high security.

## 3.4 PCM/MUX All-in-One Solution: Multi-Service Access and Simplified Networks

Traditional transmission equipment cannot provide access to a large number of low-rate services, including analog and digital signals such as dispatching telephone signals, office telephone signals, monitoring, and dispatching. Two independent networks make complex network architecture and operation. The Huawei PCM/MUX (Pulse Code Modulation/Multiplexer) all-in-one solution can provide the following low-rate interfaces:

- FXS
- FXO
- 2- or 4-wire audio
- E&M
- V.35/V.24/X.21/V.11/V.28
- RS232/422

This solution provides direct access for low-speed services, minimizes conversion equipment and fault points, increases MTBF by 60%, saves space, reduces investment, and allows for easy network maintenance. Moreover, the Huawei Universal Transport System can provide an IEEE C37.94 optical interface and the "PCM in Packet" solution for different scenarios and requirements.

## 3.5 Ultra-Long Haul Transmission Applies to UHV and EHV Scenarios

In some regions, the distance between substations or between substations and the dispatching center is more than 80 km, exceeding the capabilities of optical modules. Traditionally, repeaters can be deployed for longer distances. However, this increases project investment. The Huawei Universal Transport can support 400 km/88 dB single spans, matching the transmission scenario of ultra-high voltage and extra-high voltage power supplies and reducing the number of relay stations.

## 3.6 Unified NMS for Effective Operation Management

The current network management systems (NMSs) in grid companies are very complicated. Different devices of the same manufacturer may require different NMSs. Moreover, devices of different levels are managed by different NMSs.

The Huawei U2000 NMS can be used to manage WDM, SDH, PCM (MUX) and Microwave devices to optimize network performance in different environments. The U2000 operates at both the Network Element Layer and Element Management Layer of the Telecommunications Management Network (TMN) model. Therefore, the U2000 can centrally manage all Huawei transport equipment, and covers all FCAPS functions of the EMS and NMS with a unified topology, security, alarm, and configuration management. Moreover, the open architecture and modular design of the Huawei U2000 support flexible deployment. Customers can save investment by selecting functions as required.

## 3.7 Smooth Network Evolution and Migration

Power grid networks have four reasons for network migration:

### Lifecycle

First generation transport products were launched before 2007. Many of them have been used for 10 years or more and are becoming unstable. Along with this, no spare parts are available to use as replacements.

### OPEX

Due to technological limitations, the power consumption of old SDH products was very high, their ecological footprint was very large, and the operation and maintenance was both complex and inefficient, sharply increasing the OPEX of bearer networks.

### Business Strategy

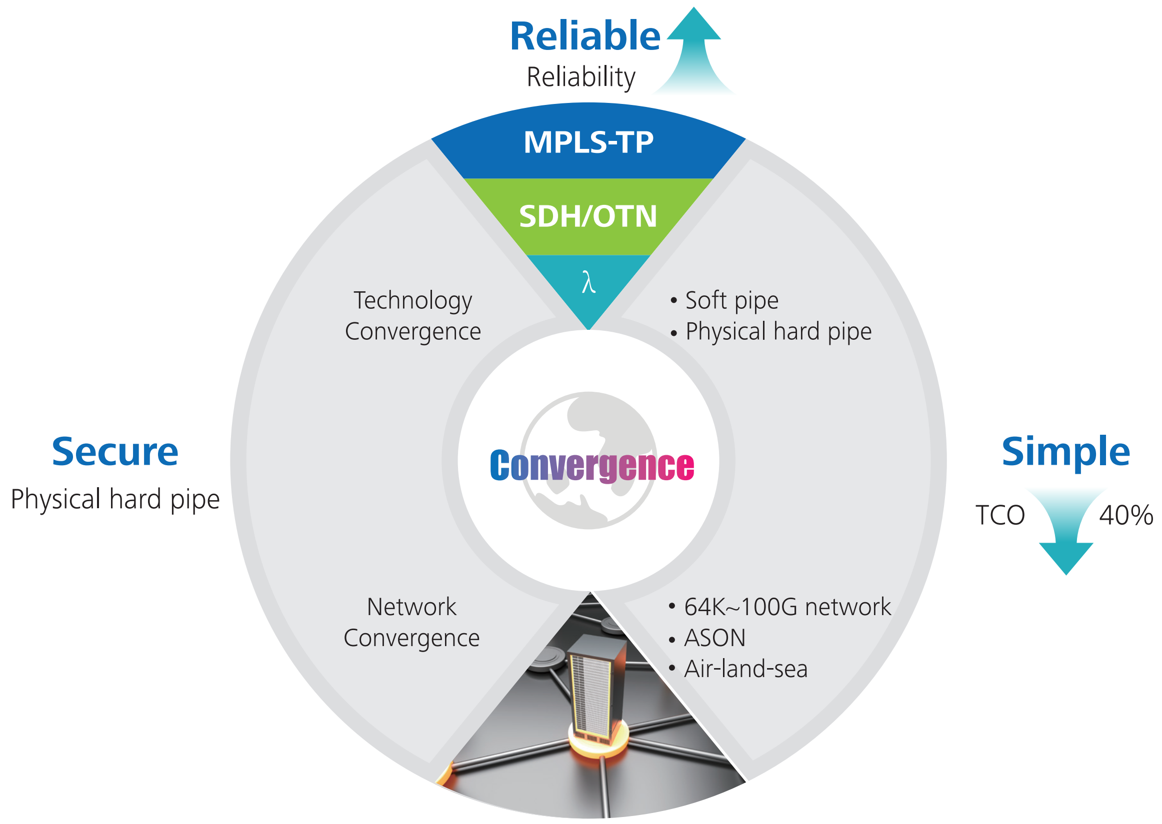
As value-added services launched, power companies begin to provide bandwidth wholesale, VIP private line, and broadband access services. Huawei's leading WDM technology meets future development requirements for electric power companies and implements infrastructure rental and sharing. The infrastructure can then turn from a support system into a production system. This customer-centric strategy also brings benefits to value-added services. With the development of these services, the need for bandwidth is growing fast.

### Migration

The Universal Transport Solution can provide both soft and hard pipes—GE/10GE interfaces and STM-N interfaces—which easily connect to devices from other vendors, achieving seamless interconnection with legacy networks and smooth evolution to the IP era with MPLS-TP technology.

# 4 Conclusion

The new architecture implemented in the Universal Transport Solution achieves converges technology, ensuring transmission quality and security of critical services while simultaneously improving the efficiency of bearer services. Additionally, the solution supports both hardware convergence and further convergence of multiple network layers, simplifying networks and reducing CAPEX, OPEX, and TCO by approximately 40%.




The Universal Transport Solution is an ideal solution for high capacity data transmission needed by corporate applications and critical services. At the same time, it also meets requirements for bandwidth, scalability, latency, protection, supervision, and maintenance.

# 5 Acronyms

| | |
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| **CAPEX** | Capital Expenditures |
| **CCTV** | Closed-Circuit Television |
| **DA** | Distribution Automation |
| **DWDM** | Dense Wavelength Division Multiplexing |
| **EHV** | Extra-High Voltage |
| **EMS** | Element Management System |
| **EOL** | End of Life |
| **EOS** | Ethernet over SDH |
| **FCAPS** | Fault, Configuration, Accounting, Performance, Security |
| **GFP** | Generic Framing Procedure |
| **IEC** | International Electrotechnical Commission |
| **IEEE** | Institute of Electrical and Electronics Engineers |
| **IP** | Internet Protocol |
| **MPLS-TP** | Multiprotocol Label Switching - Transport Profile |
| **MUX** | Multiplexer |
| **NMS** | Network Management System |
| **OA** | Office Automation |
| **OAM** | Operations, Administration and Maintenance |
| **OPEX** | Operating Expenditures |
| **OTN** | Optical Transport Network |
| **PCM** | Pulse Code Modulation |
| **PMU** | Phasor Measurement Unit |
| **SCADA** | Supervisory Control and Data Acquisition |
| **SDH** | Synchronous Digital Hierarchy |
| **TCO** | Total Cost of Operation |
| **TDM** | Time Division Multiplexing |
| **TMN** | Telecommunications Management Network |
| **UHV** | Ultra High Voltage |
| **VC** | Virtual Container |
| **VCAT** | Virtual Concatenate |
| **WAMS** | Wide Area Measurement System |
| **WDM** | Wavelength Division Multiplexing |