DIGI-G4 and DIGI-G5

White Paper

Enabling Pay-as-You-Grow Layer-1 Private Line Services for the Enterprise Cloud

Released

June 2019

a MICROCHIP company

Contents

1 Revision History

The revision history describes the changes that were implemented in the document. The changes are listed by revision, starting with the most current publication.

1.1 Revision 1.0

Revision 1.0 was published in June 2019. It was the first publication of this document.

2 White Paper

This white paper provides an overview of G.HAO and discusses use cases for service providers to harness this technology.

2.1 Abstract

Cloud services are disrupting the way networks connect enterprises and consumers. Data center interconnect (DCI) networks are emerging, pushing content, compute, and services closer to the end users. Service providers are deploying multi-terabit 100G WDM connectivity and optical network switching (OTN) as the fabric of their metro and core optical networks to support the need for more and more bandwidth and faster connectivity. Mission-critical cloud enterprise workloads demand stringent service-level agreements (SLA), traffic separation, and the ability to rapidly scale available bandwidth in response to changing end-user needs. The ability for OTN switching networks to support the transport of dynamically scalable ODUflex end-to-end connections with G.HAO enables service providers to pay-as-you-grow layer-1 (L1) private line services that address the needs of the enterprise cloud and DCI markets.

2.2 The On-Demand Cloud Era

- Cloud enterprise services are changing the way optical networks are built.
- Service providers are deploying 100G WDM and OTN-switching equipment to address the traffic explosion.
- G.HAO can enable pay-as-you-grow L1 private line services targeted at the cloud enterprise market.

The way enterprises conduct business is changing rapidly, and this evolution presents opportunities for service providers to evolve existing services and infrastructure to tap into new revenue streams. Data migration to the cloud is pervasive across all verticals. New IT paradigms—such as SaaS, PaaS, and IaaS—are now a part of day-to-day enterprise workflows. A recent Verizon survey reported that more than 50% of enterprises plan to use the cloud for more than 75% of their workloads by 2018, with almost 70% of those surveyed saying that the cloud has enabled them to significantly re-engineer one or more business processes today. [1] (see page 11) These services—pioneered by the likes of SalesForce.com, Google Cloud Compute/Apps, Amazon Web Services (AWS), and furthered by the likes of SAP, Slack, and LinkedIn—are changing the ways enterprises connect and share data.

At a network level, these services are forcing an evolution of the underlying infrastructure that connects enterprises in two ways. First, data centers (DCs) and data center interconnect (DCI) networks are moving to distributed architectures to address cost and space operational challenges and in support of the need to push the connectivity and data closer to end users. Second, the raw bandwidth requirements of cloud services are driving the need for high-bandwidth, dense 100G WDM connectivity in both metro and core optical networks and a need for packet-optical OTN switching equipment that delivers the scalability and service/protocol flexibility to efficiently make use of expensive optical fiber infrastructure. [2] (see page 11)

From the service delivery standpoint, existing Ethernet private line or virtual private line services do not address all of the needs of cloud-based enterprise workloads, even if they do offer dynamic capabilities. Traffic is shared, not isolated, and SLAs are not as stringent as traditional L1 private line transport services. The bandwidths supported are generally 10 Gbps or less. For enterprises to move mission-critical workloads to the cloud en masse, these connections must scale flexibly and dynamically beyond 10 Gbps and inherit the qualities of private line transport services.

OTN equipment (in particular, Packet-Optical OTN switching platforms) addresses this challenge by supporting the transport of packet-based services through flexibly sized end-to-end connections in an optical network, otherwise known as ODUflex. They allow these connections to be resized on-the-fly without dropping packets as the end-user bandwidth needs change. The latter is known as G.HAO, or hitless adjustment of ODUflex (GFP).

2.3 Background: ODUflex, OTN Switching, and G.HAO

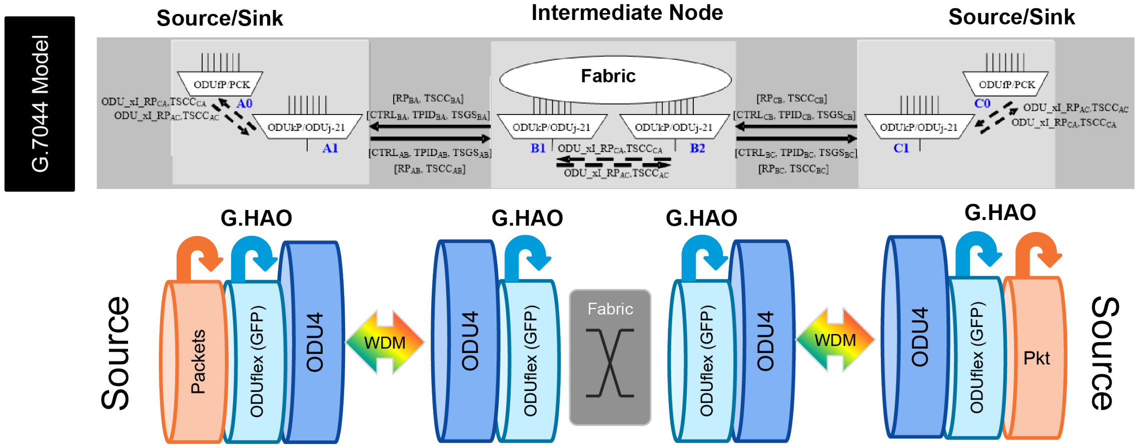
- Packet services with rates from 1.25 Gbps to 100 Gbps can be transported as ODUflex circuits in OTN networks.
- G.HAO is a standards-defined method allowing for hitless dynamic scaling of ODUflex circuits end-to-end.
- G.HAO reduces the need for service providers to over design networks while optimizing the costs of delivering flexible bandwidth connectivity.
- Combined with OTN switching, G.HAO allows for packet-based services to be turned up or down on-demand in response to changing end-user demands.

The concept of ODUflex (GFP) arose in response to the need to optimize the bandwidth used for transporting packet-based services with data rates less than that of a standard 10GbE/40GbE/100GbE Ethernet. In ODUflex, the ITU G.709 standard specifies an OTN transport container size that could be sized flexibly from 1.25 Gbps to 100 Gbps in increments of 1.25 Gbps. Individual packets or flows can be mapped through GFP-F into a "right-sized" ODUflex container and subsequently multiplexed into a high-order ODUk or ODUCn (100G or greater) wavelength. ODUflex, therefore, enables the concept of a sub-wavelength private line service or leased line with bandwidth aligned to the end-service need.

Taking the concept of ODUflex one step further, hitless adjustment of ODUflex (GFP) (G.HAO), specified by the ITU-T G.7044 standard, is a resizing mechanism that allows for on-demand scaling of an ODUflex (GFP) client data rate without affecting the integrity of existing traffic across an end-to-end connection path in a G.709-based OTN transport network. This enables service providers to adjust the end-to-end OTN connection capacity dynamically in response to variations in end-customer traffic patterns or demand.

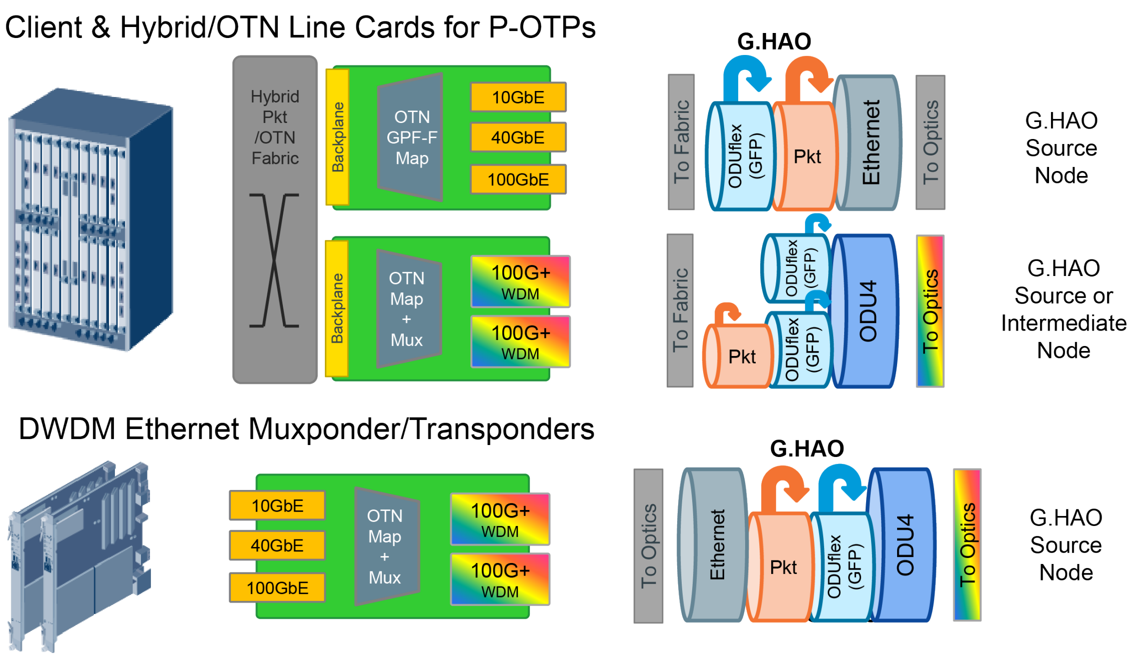
A G.HAO network, as shown in the following diagram, consists of source nodes and intermediate nodes.

Figure 1 • G.HAO OTN Network



Source nodes are the demarcation point for the ODUflex. At an equipment level, G.HAO source and intermediates can manifest in a number of forms, from Ethernet muxponder and transponder cards for DWDM networking equipment to line- and client-side cards for packet-optical or OTN-switching platforms (also known as P-OTPs/OTPs). The latter is the technology of choice today for service providers globally for their 100G optical networks. OTN-switching deployments are forecasted to grow at 10% annually through 2019, with metro P-OTPs forecasted to grow at 15% annually in the same time period. [3] (see page 11) These OTN switching networks are also uniquely positioned to harness the full potential of G.HAO to deliver new and differentiated services to address the cloud enterprise service market.

Figure 2 • G.HAO Source and Intermediate Node OTN Equipment Types



OTN switching equipment allows for the grooming of incoming sub-wavelength ODUk connections onto any outgoing wavelength. 4 (see page 11) As such, ODUflex-based packet services can be routed through diverse paths in a mesh network. This allows service providers to leverage the deployed fiber infrastructure as an effective pool of available bandwidth. In response to a ramp in the bandwidth of an ODUflex G.HAO service, a connection can be routed through a path with available bandwidth. In contrast to over-engineering available fiber bandwidth, OTN switching and G.HAO together allow service providers to maximize existing investments while at the same time optimizing operational costs to efficiently and quickly deliver bandwidth-on-demand enterprise service offerings.

2.4 Operator G.HAO Use Cases

- G.HAO allows pay-as-you-grow L1 private line services in support of cloud enterprise demands.
- G.HAO allows service providers to repurpose unused metro 100G bandwidth to deliver DCI services.

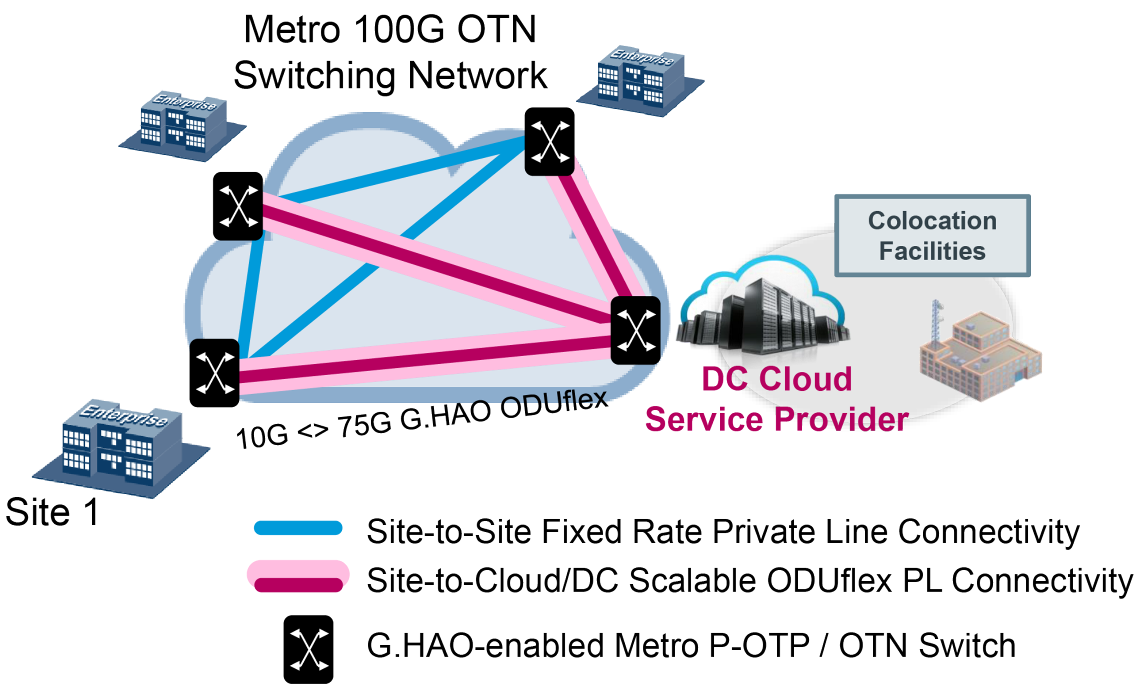
2.5 Cloud Connect/Enterprise Scalable Bandwidth-on-Demand Private Line Service

Private/leased line services still represent a significant source of revenue for operators. In the US alone, private line services represented a $30 billion market in 2014. 5 (see page 11) Historically, enterprises have looked to these services to address a need for constant bandwidth with guaranteed SLAs between points-of-presence. With site-connectivity needs diversifying (site-to-site, site-to-DC, etc.) and the migration of traditional in-house application workloads to cloud infrastructure, it is becoming increasingly important for customers to have the ability to scale a private line service rate on-demand. Cloud-based workloads are inherently bursty and therefore do not fit well in an environment where the bandwidth between end-users and applications is fixed. However, as mission-critical applications transition to the cloud, this rate scaling cannot come at the expense of the existing traffic's quality of service. By leveraging existing mesh-based metro optical OTN-switching networks and software upgrades to existing OTN-transport equipment to support ODUflex G.HAO features, service providers can augment existing Ethernet private line services with a high-value service option that supports adding or removing bandwidth on-demand without impacting the quality of the service. As new bandwidth is requested by the customer, it is pulled from the existing pool of bandwidth available in the network.

For example, the following diagram shows a customer that buys a private line service with 10 Gbps of bandwidth across multiple connections, spanning site-to-site as well as site-to-data center.

New application workloads supported by a cloud service partner need to be turned up and down on a periodic basis, driving the site-to-DC connectivity needs from 10 Gbps to 75 Gbps. In the absence of a flexible bandwidth private line service, the customer would need to permanently procure a new 100 Gbps Ethernet private line service that would remain significantly underutilized during off-peak workload hours in order to support these new cloud workloads.

Figure 3 • G.HAO Bandwidth-on-Demand Private Line Service



With G.HAO, service providers can offer a targeted, on-demand, pay-as-you-grow service that delivers the same quality of service, regardless of bandwidth required—and one that ultimately lowers the cost barrier for enterprises considering cloud service options.

2.6 "Follow the Moon" Flexible DCI Bandwidth-on-Demand Service

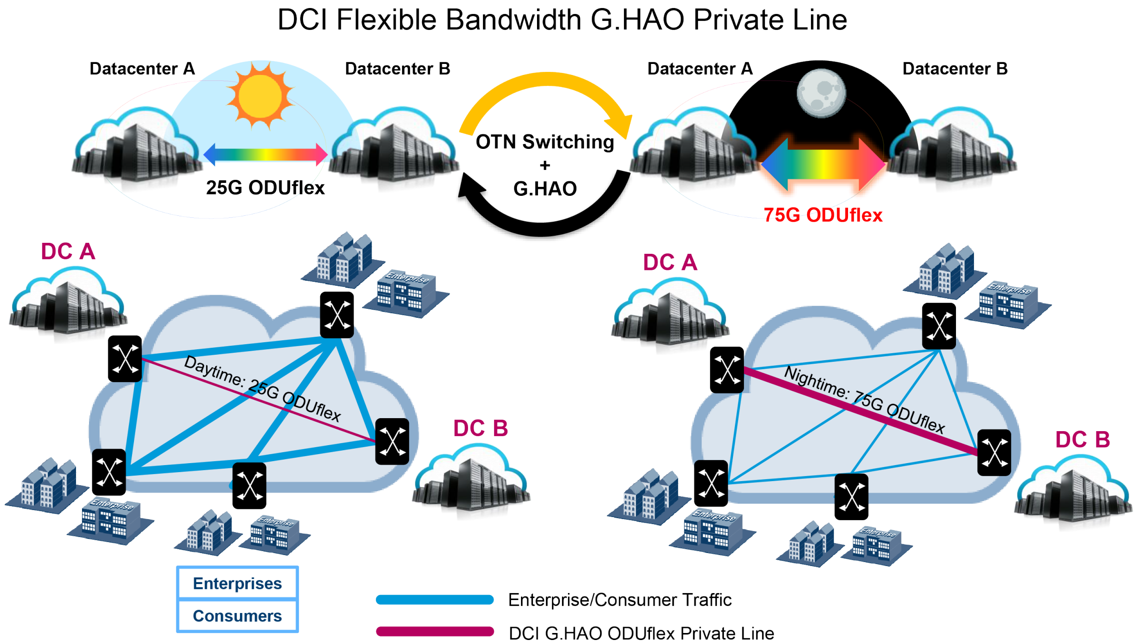
Adding G.HAO support to existing 100G OTN-switching equipment in globally deployed metro and core networks today presents service providers with an offering to address the rapidly growing DCI market.

Networks are designed to support peak traffic loads from traditional broadband and wireless services. Peak usage (also known as Internet rush hour) for these service types predominantly occurs during the daytime and primetime hours (4:00 p.m.–11:00 p.m.), driven primarily by video-on-demand services such as Netflix. [6] (see page 11) However, these networks are underutilized as peak usage declines in the overnight hours. [7] (see page 11)

The maintenance and operations behavior for data center and cloud service operators also tracks the same cycle. Daytime and primetime hours are focused on customer access to data and applications in the cloud, whereas bandwidth- and resource-intensive workloads—such as database replication and large-scale compute and backup exercises—are left to the overnight hours when the compute activity and network bandwidth utilization are at a minimum.

With G.HAO-enabled OTN-switching networks, service providers can dynamically repurpose unused network bandwidth during off-peak nighttime hours to offer high-value, high-bandwidth, flexible-rate private line services targeted to meet the needs of the data center interconnect market. During daytime hours, these G.HAO ODUflex DCI private line services can be scaled back to deliver basic services at minimum bandwidth.

Figure 4 • G.HAO + OTN Switching for DCI Flex-Bandwidth Private Line Service



Such a service offering could be cost-optimized—a key requirement for data center operators—in alignment with cheaper electricity costs during off-peak hours and with the new market serving as a second source of amortization for existing equipment. A "follow-the-moon" strategy, supported uniquely by an ODUflex G.HAO DCI private line service, would add top-line revenue growth from a rapidly growing market segment without the need to incur additional CAPEX expenses.

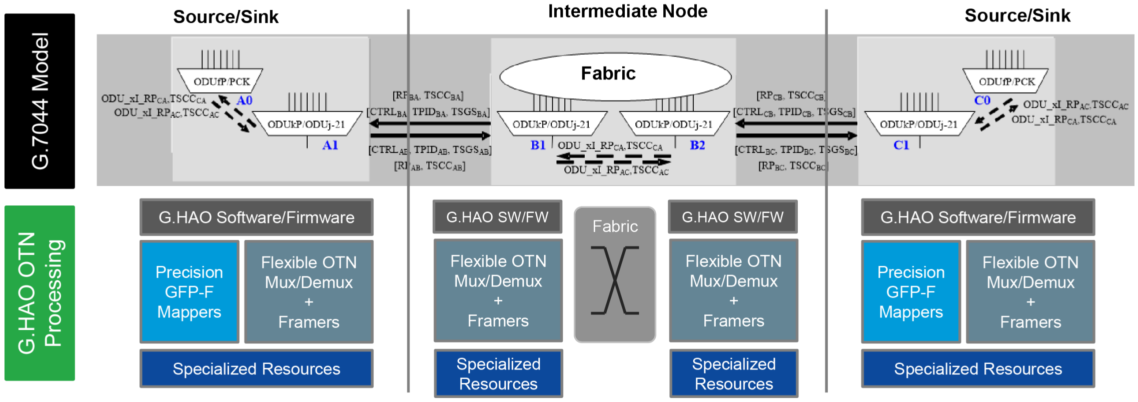
2.7 OTN-Processing Innovations Required for G.HAO-Enabled Systems

The hallmark of the G.HAO protocol is the precise ramp up/down and synchronization of changes to the ODUflex service rate at all nodes in the connection path, ensuring a smooth and hitless transition in bandwidth for the end-user service. This drives the need for innovations at an OTN-processing silicon level to ensure the following:

- Precision tracking of the ODUflex rate at source/sink and intermediate nodes
- Hitless changes to allocated bandwidth and OTN-multiplexing structures at the high-order 100G OTN-transport server layer
- Coordinated monitoring and handshaking between all nodes in the connection path

The following diagram shows the typical G.HAO network model, according to the ITU-T G.7044 standard, and provides a logical representation of the key innovations necessary in OTN-processing silicon to support G.HAO-capable connectivity in an OTN network.[8] (see page 11)

Figure 5 • OTN Processing Silicon Innovations Required for G.HAO Support in OTN Networks



At source node end-points in the connection, G.HAO ODUflex (GFP) mappers must initiate source/sink the ODUflex bandwidth ramp with a precision of ±512,000 kbps. At both source/sink and intermediate nodes, flexible OTN-multiplexing, -demultiplexing, and -framing resources must be capable of tracking and synchronizing the ODUflex rate changes from link-to-link in the connection path in order to hitlessly add or remove bandwidth. These OTN-processing resources must also be architected to keep path latency and delay variations to acceptable limits in order to support deployment in intermediate and source nodes with large centralized OTN or hybrid packet/OTN cross-connects where ODUflex (GFP) flows with large dynamic ranges are common. Specialized supporting hardware resources (production-grade device firmware and software APIs) complete the picture, maintaining stable operation during rate transitions and ensuring that appropriate monitoring and negotiation are completed throughout the entire G.HAO ODUflex resizing process, and that the performance and integrity of non-G.HAO traffic is not compromised.

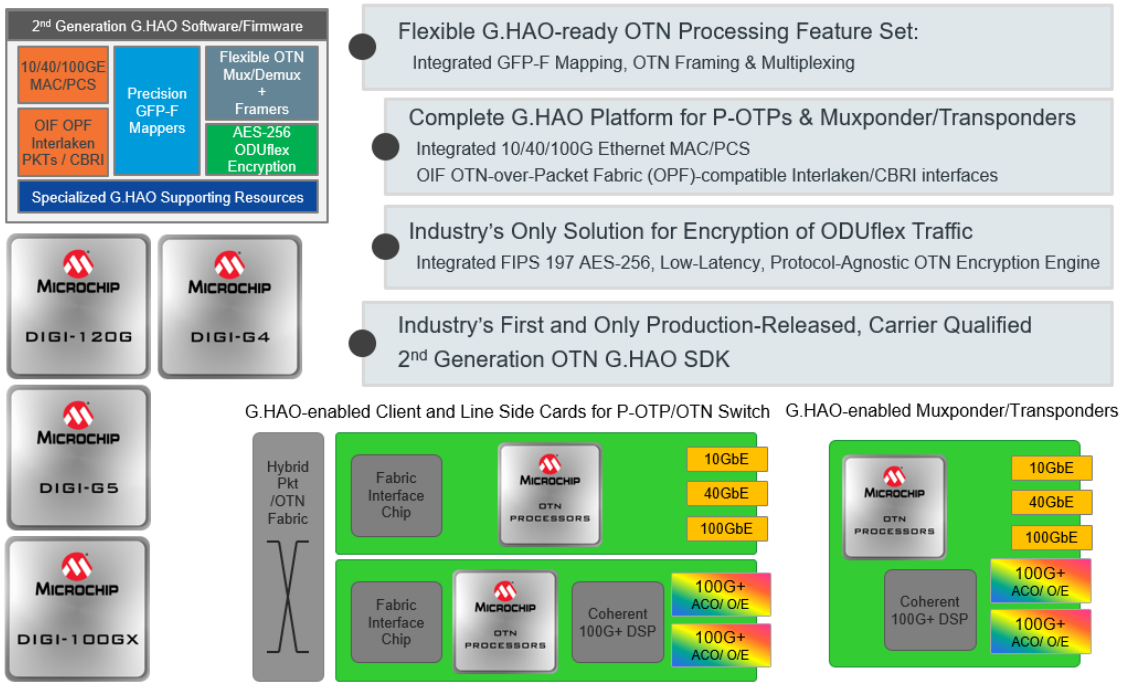
2.8 Microsemi DIGI OTN Processor Family: Pioneering G.HAO Solutions

- Microsemi DIGI family of 100G and B100G OTN processors is the industry's only G.HAO solution, with three generations of G.HAO 100G OTN IP and carrier-qualified, production-grade G.HAO software/firmware.
- Microsemi's DIGI-G4 and DIGI-G5 OTN processors are the industry's only solutions to support encryption of ODUflex traffic, allowing for secure transport of bandwidth-on-demand flexible bandwidth private line services.

Microsemi's market-leading DIGI family of OTN processors is the industry's first and only solution capable of supporting G.HAO ODUflex (GFP)–based services in OTN transport networks.

Based on three generations of carrier-qualified, G.HAO-enabled 100G OTN processing IP, the DIGI-120G, DIGI-100GX, DIGI-G4, and DIGI-G5 devices deliver a best-of-breed development platform with the integration and capabilities necessary for OEMs to develop and deploy a complete portfolio of G.HAO-capable OTN transport equipment, spanning client and line cards for P-OTP/OTN switching platforms and Ethernet muxponder/transponders for DWDM systems.

Figure 6 • Microsemi's DIGI Family: 100G and B100G OTN Processor Platforms for G.HAO-Enabled Metro Networks



The DIGI family of DIGI-120G, DIGI-100GX, DIGI-G4, and DIGI-G5 devices integrate the full GFP-F packet mapping that is necessary for mapping IP, Ethernet, or MPLS packet traffic into ODUflex from Interlaken in hybrid OTN/packet uplink P-OTP applications or from 10GE/25GE/40GE/50GE/100GE/200GE/400GE Ethernet client interfaces for client-side mapping card and muxponder/transponder applications. The DIGI family's integrated OTN-processing capabilities support fully channelized, two-stage ODUjk multiplexing/demultiplexing of G.HAO ODUflex connections over high-order 100G or beyond 100G wavelengths.

The DIGI-G4 and DIGI-G5, Microsemi's flagship OTN processors, are the industry's only solutions to support encryption of ODUflex traffic, enabling service providers to further differentiate with a secure transport option for G.HAO-enabled services. The DIGI-G4 and DIGI-G5's AES-256 OTN encryption engines are protocol agnostic, FIPS 197 AES-256–certified, and deliver the wire-speed, low-latency performance required for mission-critical cloud workloads. [9] (see page 11)

Completing the solution is the DIGI family OTN SDK, the industry's only production-grade, carrier-qualified software/firmware with G.HAO support. The device firmware and G.HAO APIs work in concert with the DIGI G.HAO hardware subsystems to ensure precise synchronization of ODUflex G.HAO bandwidth ramp, hitlessly end-to-end. The DIGI SDK supports hitless, in-field upgrades of fielded systems to G.HAO-capable nodes, allowing service providers to deliver new G.HAO services without impacting existing customer traffic.

3 G.HAO Adoption in China

China is the first region in the world to deploy G.HAO capabilities in their OTN switched network. Chinese telecommunications service providers like China Mobile (CMCC) and China Telecom (CTC) are building out their OTN networks from the Metro into the Access in order to deliver TDM-type end-to-end private leased line services for both government and enterprise customers. These customers demand the highest service quality and network availability that can only be met with OTN. G.HAO further enables Chinese carriers to deploy bandwidth-on-demand services powered by OTN.

Due to the end-to-end nature of G.HAO in a carrier's network, a crucial deployment requirement is multi-vendor interoperability. In January 2019, Microsemi was selected by CMCC and the China Academy of Information & Communications Technology (CAICT) to conduct the world's first G.HAO interoperability test[11] (see page 11). As the only commercial silicon and software supplier supporting G.HAO, Microsemi and its DIGI OTN processors were chosen as the benchmark solution. As a result, interoperability tests were successfully performed between DIGI OTN processors and the invited equipment vendors (Huawei, ZTE, and FiberHome) and between the equipment vendors.

With the success of this important milestone, Chinese telecommunications service providers have paved the way for large-scale worldwide deployment of G.HAO technology and bandwidth-on-demand services.

4 References

1. "State of the Market: Enterprise Cloud 2016. From Adoption to Transformation." Verizon, November 2015.
2. "Making 100G OTN Economical: OTN Switching & Packet-Optical Transport." Microsemi, May 2014.
3. "DCI, Packet-Optical, and OTN Equipment: Biannual Market Tracker: Regional, H2 2016." IHS Technology, March 2017.
4. "Making 100G OTN Economical: OTN Switching & Packet-Optical Transport." Microsemi, May 2014.
5. "Private Line and Wavelength Services, 2014-2019." Insight Research Corp, October 2014.
6. Joon Ian Wong. "The Internet Has Been Quietly Rewired, and Video Is the Reason Why". Quartz, October 2016. https://qz.com/742474/how-streaming-video-changed-the-shape-of-the-internet/
7. Sandvine, November 2016. http://www.internetphenomena.com/2016/11/us-election-2016-tv-trumps-the-internet/
8. "Recommendation ITU-T G.7044/Y.1347: Hitless Adjustment of ODUflex(GFP)." ITU-T, October 2011. https://www.itu.int/rec/T-REC-G.7044-201110-I/en
9. "'In-flight' Encryption in Service Provider Networks." Microsemi, 2015.
10. "China Mobile Completed World's First G.HAO Interoperability Test" http://www.cww.net.cn/article?id=445984
11. "Microchip Enables China to Deploy World's First Bandwidth-on-Demand Services Powered by Optical Transport Network (OTN)." Microchip Press Release, June 2019.

Microsemi Headquarters
One Enterprise, Aliso Viejo,
CA 92656 USA
Within the USA: +1 (800) 713-4113
Outside the USA: +1 (949) 380-6100
Sales: +1 (949) 380-6136
Fax: +1 (949) 215-4996
Email: sales.support@microsemi.com
www.microsemi.com

ESC-2190802