Single Consistent Scalable TERALYNX Architecture
# Overview

Innovium, born in the Cloud Era, delivers Industry leading Data Center

Rise of Edge Computing and Edge Data Centers

Single Consistent Scalable TERALYNX Architecture

Scalable TERALYNX Product Family

Summary
Growth of Data Centers

Massive secular growth of data centers continues, driven by economics, agility and flexibility. Cloud data centers such as AWS, Microsoft, Facebook, Alibaba, Tencent are experiencing massive year-over-year growth. Cisco Cloud Index highlights the huge growth being experienced in enterprise and service provider cloud data centers. Further, data centers are also expanding to support private/hybrid cloud and edge deployments.

Data centers have many common traits:
- Data centers typically have large scale with tens of thousands of servers or more
- They run highly distributed applications, often using dis-aggregated IP based storage
- They host applications & workloads are dynamic, unpredictable and agile
- All have AI workloads that are growing and becoming more pervasive

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Figure 1. Data Center Network Trends & Requirements
These trends in the data center translate to the following key requirements in the network.

- High bandwidth & radix: Network traffic is exploding in these large-scale data centers, with massive growth in east-west traffic driven by distributed micro-services based applications, Artificial Intelligence & Machine learning, NVMe-based IP storage and video. Customers need high bandwidth, high-radix and high-performance networking solutions.

- Deep Application Analytics: As the scale of data-center increases, network operators have a tremendous need for real-time telemetry, event driven analytics, and automation to trouble shoot problems and simplify operations.

- Software Programmable Infrastructure: Data center customers are looking for ways to future proof network hardware infrastructure using software programmability to support new network capabilities and protocols.

- Low Latency: With increasing use of distributed applications and networked storage, latency in each hop of the network is critical. Customers are looking for the lowest latencies in network infrastructure to boost performance.

TERALYNX 7 for Modern Data Centers

These customers were using legacy architectures & products originally developed to address enterprise and service provider networks. Further, with Moore’s Law slowing down, it was hard for existing solutions to scale performance higher. Innovium was born in the cloud era with an intense focus on the data center and not encumbered by legacy architectures. It assembled a strong, world-class data center network switch team that had delivered multiple generations of switching silicon pervasively deployed in data centers all over the world. Fueled by customer-focused innovation, the team continued its excellent engineering track record and delivered production ready TERALYNX 7 switch silicon in record time to address the growing data center networking challenges and requirements.
**TERALYNX 7**: Innovium’s market leading TERALYNX 7 programmable switch silicon delivers customers industry leading performance of up to 12.8Tbps with breakthrough telemetry, low-latency, comprehensive features and high port radix for 10G – 400G connectivity. It has made excellent progress in the marketplace.

**Hardware**: Innovium’s TERALYNX 7 switch silicon is highly robust and is in production. It has been selected by leading data-center switch OEM, ODM and cloud providers for a range of deployment scenarios enabling superior infrastructure and ROI. Multiple TERALYNX 7 based switches are available in configurations that include 1RU, 32x100/200/400G, 2RU, 64x100/200G and 4RU, fixed & modular 128x100G. Innovium and our ecosystem partners have jointly conducted extensive interoperability tests of TERALYNX 7 with an expansive set of NRZ and PAM-4 DAC and ACC cables, optics modules, retimer/gearbox, and network test equipment for 100G to 400G to enable rapid time to deployment for customers.

**Software**: Innovium has proven and comprehensive software and SDK, with feature-set that includes rich tunneling, robust RoCE and unmatched real-time telemetry. Multiple OEM, Cloud and open-source NOS including Cisco NXOS & SONiC have been seamlessly ported to TERALYNX leveraging Innovium’s software and SDK. The software supports standards-based CRUD APIs and is optimized for high performance, including warm and fast boot.
Lot of data is being created and collected at the edge of networks that needs processing. These include environments such as modern retail, industrial & factory automation, autonomous cars, 5G mobile devices and smart cities. Data processing and analysis is being brought close to the source of that data to reduce latency, minimize bandwidth cost for uploading that data to a data center, adhere to security/compliance regulations and meet real-time expectations. This has led to emergence of edge computing, which is growing very rapidly.

The industry recognizes the benefits of cloud and data center technologies – cost-effective standardized server-storage-network infrastructure, cloud-native applications, agile DevOps processes and automation. Edge computing has embraced cloud and data center technologies including networking, but at a smaller scale with focus on performance, power and cost.

Most enterprises today have standardized on hybrid cloud strategy, where they augment their internal data centers with public cloud data centers, with solutions like AWS Outpost, Microsoft Azure Stack and Google Anthos.

As we see above, IT investments are increasingly moving to data centers. Data centers exists in public cloud, private cloud/enterprises and at the edge, including in 5G deployments. Networking requirements for all these data centers are consistent, except for requirements for bandwidth/radix, power and cost. The size and scale of the network varies based on the type of data center and # of servers they host. All these customers want a consistent architecture with same features and functionality.
Innovium’s grounds-up TERALYNX architecture has been enhanced to scale from 1Tbps to 51.2Tbps+ to meet the customer’s modern data center feature consistent requirements ranging from edge to enterprise to the largest cloud data center operators. Ultra area-efficient and modular architecture with grounds-up data center optimizations enables TERALYNX v2 architecture to deliver scalable performance and consistent capabilities one process node earlier with time to market and cost advantage for customers.

**Architectural Advantages**

Innovium TERALYNX architecture has three key fundamental advantages.

1. It has been architected from ground-up with a clean sheet design to address the most demanding needs of data center customers. That helps TERALYNX deliver a comprehensive feature set, lowest latency and superior telemetry. Breakthrough patented innovations, with over 80 patents filed or in process, span a variety of areas including data structures, algorithms and R&D flow.

2. Patented TERALYNX architecture is ultra silicon-area optimized. It helps deliver lower power, smaller silicon area with larger on-chip buffers and lower cost. It also enables Innovium to design the switch in one process node earlier, delivering time to market advantage and lower cost to customers. While slowing down of Moore’s law has made multi-die solution more prevalent, that has not addressed the higher power and costs associated with multiple large-die tape-outs in leading edge process nodes such as 7nm and 5nm.

3. The TERALYNX architecture is modular and extremely scalable. It helps deliver products that scale from 1Tbps to 51.2Tbps+ with the same consistent features and functionality, with no trade-offs and same software.
TERALYNX Architecture

TERALYNX architecture consists of the following key components:

- **Programmable feature-rich INNOFLEX™ Forwarding Pipeline:** A programmable forwarding pipeline architecture that delivers comprehensive data center feature set with deterministic low latency, and ability to support new protocols through standards-based programming.

- **Highly Scalable TERASCALE™ Fabric:** A scalable and low-latency switch & buffer fabric architecture that delivers comprehensive QoS, superior traffic management, large smart packet buffers and scales from 1 to 51.2Tbps+ performance. TERASCALE has shown to deliver up to 2x performance and buffering in the same silicon area vs alternatives.

- **Advanced FLASHLIGHT™ Telemetry & Analytics:** A grounds-up telemetry architecture that delivers extensive real-time visibility and actionable granular network analytics to troubleshoot and resolve network congestion problems helping customers move towards higher-quality, autonomous networks.

Further, the architecture is flexible so that it works across single-chip and multi-chip system designs. All products in the TERALYNX family support 10/25G NRZ & 50G PAM4 SerDes to enable 10-400GbE connectivity. Some products support 100G PAM4 SerDes as well. Also, all products in the TERALYNX family runs on the same set of APIs in the software development kit (SDK), which optimizes R&D effort for our customers.

**Comparison with Alternate Switch Silicon Architectures**

Innovium’s TERALYNX architecture scales from 1Tbps to 51.2Tbps+ with consistent features and functionality with no feature trade-offs. However, alternate merchant silicon solutions have had to resort to different architectures to meet customer needs as shown in figure 6. There are performance optimized architectures that deliver performance, but cannot deliver features and functionality. Conversely, there are feature optimized architectures that deliver features and functionality, but not performance requirements. Hence, alternate solutions fall short on delivering consistent architecture, features and functionality for products with different performance requirements.
**Key Customer Benefits**

As described above, the TERALYNX architecture provides customers a single scalable architecture with these key benefits.

- Most scalable and modular architecture that scales from 1Tbps to 51.2Tbps+
- Consistent features for the entire TERALYNX product line.
- Best performance/$ and performance/W for all products one process node earlier
- Operational and development efficiency for customers from consistent features and functionality across products with different performance points, with no trade-offs and same software APIs.
- Superior FLASHLIGHT telemetry capabilities for autonomous networks
- Lowest latency to deliver best application performance
- 10-400G connectivity across entire TERALYNX family
- Ease of programming and software leverage across products
Scalable TERALYNX Product Family

TERALYNX 5 for ToR, Enterprise and Edge Data Centers

With the introduction of TERALYNX 5, Innovium extends market leading TERALYNX architecture and product line to deliver breakthrough capabilities for TOR, Enterprise, Edge and 5G data center applications.

It is an optimized data center switch silicon for 1.2 – 6.4Tbps performance, with up to 128x 10/25G NRZ & 50G PAM4 SerDes, 10GbE to 400GbE ports, largest on-chip buffers, powerful analytics, and industry’s best performance per $ and performance per Watt. It is the most advanced 10/25G NRZ switch silicon in the market, future-proofed with PAM4 support, enabling seamless transition from NRZ to PAM4 technology. TERALYNX 5 builds upon the patented, production-proven Innovium’s flagship 12.8Tbps TERALYNX 7 products and extends Innovium’s product lines from ToR to data center core with a single consistent architecture for data centers across public, private, hybrid cloud, enterprise and edge. TERALYNX 5 is fully feature & software compatible with TERALYNX 7.

Data analytics, AI, compute intensive applications and Flash-based storage are driving need for higher bandwidth from servers and storage. Ethernet NICs are delivering multi-100G interfaces with PCI Express Gen 4 and PAM4 support. Customers are looking for cost and power-efficient ToR switch silicon solutions to address their higher bandwidth needs with consistent features and functionality as higher tiers of the network.

With TERALYNX 5, Innovium supports 10G – 400G connectivity with NRZ & PAM4 technology, all the way to the server/storage, enabling seamless insertion into existing network infrastructure.

TERALYNX 5 provides breakthrough capabilities for ToR, Enterprise, Edge and 5G deployment scenarios. They include:

- Largest on-chip buffers in a switch of its class to deliver best-in-class network quality
- Robust RoCE for lowest latency and rich QoS necessary for distributed storage and AI applications
- Leading table sizes & ACLs needed at the access layer and edge
- Lower power needed in these space constrained deployments
- IEEE 1588 timing synchronization required in 5G and other data center applications
- FLASHLIGHT delivers actionable, real-time telemetry data correlated to applications, which is essential to monitor, troubleshoot and simplify network operations.

- Breakthrough cost that delivers 2X+ performance per $ vs alternatives.

- 10/25G NRZ & 50G PAM4 SerDes, needed to support 10-400GbE ports.

- SW programmability for support of new protocols, achieved without impact to throughput or latency suffered by alternatives.

In summary, TERALYNX 5 is a highly disruptive product that brings a combination of NRZ & PAM4 connectivity to the mass market with most advanced features at industry's best performance/$ and performance/W. As shown in figure 8, it is ideal for multiple use cases: ToRs, enterprise, edge and 5G data centers.

Figure 8. TERALYNX 5 Use Cases: ToR, Enterprise, Edge & 5G
Scalable TERALYNX Product Family

TERALYNX 8 for Most Demanding Customers

Adoption of cloud computing has continued to grow rapidly as customers benefit from efficiency, scalability, business continuity and cost savings. Cloud operators are looking to scale their data center networks using higher performance, higher radix and low-latency switches, while significantly reducing cost and power per bit.

100G PAM4 SerDes technology brings higher scale networking at better economics and power efficiency for the industry. The networking ecosystem has embraced this technology and has already started to deliver solutions. Hyperscalers and other customers plan to rapidly adopt this technology.

TERALYNX® 8 is the industry’s most advanced 25.6 Tbps programmable switch silicon with support for 100G PAM4 SerDes I/O. It enables customers to build highly compact, highest port-density single-chip switches for 100G to 800G configurations, including a 32 x 800G switch in 1RU. Built using proven TERALYNX architecture that is powering the largest cloud provider networks, TERALYNX 8 delivers the largest on-chip buffers, lowest-latency, unmatched FLASHLIGHT™ v3 telemetry and market-leading power efficiency. TERALYNX 8, along with TERALYNX 7 and TERALYNX 5, is the industry’s first and only complete data center product family that delivers a single scalable architecture with consistent feature-set and PAM4 connectivity for all switch and router requirements with bandwidth ranging from 1 Tbps to 25.6 Tbps.

Leveraging the same proven TERALYNX architecture, TERALYNX 8 provides the next level of scalability these data centers need to keep up with the massive growth being experienced by them. TERALYNX 8 is targeted at the most demanding customers for deployments in all tiers of the network, including DCI.

TERALYNX 8 provides breakthrough capabilities that include:

- Support for 100G PAM4 long-reach (LR) SerDes to deliver the best cost per bit and power efficiency
- 10/25G NRZ, 50/100G PAM4 SerDes, needed to support 10-400GbE ports
- Largest on-chip buffers in a switch of its class to deliver best-in-class network quality
- Highest radix with 256 ports to help flatten network tiers
- Robust RoCE for lowest latency and rich QoS necessary for distributed storage and AI applications
- Additional innovations in FLASHLIGHT v3 deliver actionable, real-time telemetry data correlated to applications, which is essential to solve toughest troubleshooting problems
- Enhanced forwarding and ACL table scales for next-gen networks
- SW programmability for support of new protocols, achieved without impact to throughput or latency suffered by alternatives
- Lower power needed for highly power efficient data center deployments

- Enables the industry’s most compact 32 x 800G (25.6Tbps) switch in 1RU form factor

In summary, TERALYNX 8 is the world’s only 25.6Tbps programmable switch silicon using proven and highly scalable architecture that delivers customers unmatched telemetry, best network quality, lowest latency and industry leading power efficiency.

As shown in figure 10, TERALYNX 8 is ideal for the most demanding data center customers for all tiers of the network, including DCI.

![TERALYNX 8 Use Cases: All tiers of DC Network, including DCI](image)
Innovium offers a single consistent scalable architecture for all data center switching solutions from top to bottom with unmatched capabilities and value. All TERALYNX products based on this architecture, deliver software programmability, advanced telemetry, low-latency and comprehensive rich data-center feature-set. TERALYNX 8 is ideal for the most demanding customers that need the highest bandwidth & highest radix switching solutions for all network tiers, including DCI. TERALYNX 7 is ideal for all network tiers of the data center. TERALYNX 5 is ideal for ToR, Enterprise, Edge and 5G switching solutions. TERALYNX switches have been selected and being deployed by market-leading OEM and cloud providers for hyperscale, enterprise and edge applications.

Figure 11. Proven and Scalable TERALYNX Product Family with Consistent Feature-set