Connectivity Innovation for the Data Centric Era

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In a data centric world the dynamic range of architecture interconnect is large - requiring solutions that scale from microns to miles
Key Data Center Networking Challenges at Scale

<table>
<thead>
<tr>
<th>Performance</th>
<th>Agility</th>
<th>Visibility &amp; Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Demands from next gen workloads</td>
<td>• Flexibility to adapt network for fast changing requirements</td>
<td>• Growing security threats</td>
</tr>
<tr>
<td>• Growth of East-West traffic within datacenters and from edge to user</td>
<td>• &gt;41B IoT devices, generating &gt;79ZB of data by 2025¹</td>
<td>• Significant increase in complexity</td>
</tr>
<tr>
<td>• Pressure on efficiency/throughput</td>
<td>• Ability to innovate rapidly</td>
<td>• Monitor &amp; debug network difficult</td>
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<tr>
<td></td>
<td></td>
<td>• Need to meet QoS &amp; SLAs</td>
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Global Data Center Traffic per year growing 25% CAGR through '23

1. 2019 IDC's worldwide Global DataSphere IoT devices and data forecast
Data Center Networks of the Future
Unleashing the performance of compute at scale through innovations in end-to-end connectivity

Optical Modules
High-bandwidth connectivity at 100G, 400G and beyond

Ethernet Switch
P4-programmable scale-out fabric with uncompromising performance

Ethernet NIC
Programmable infrastructure acceleration for demanding data movement

CPUs & xPUs
Fabric-enabled endpoints aligned to accelerators & software pipelines

Intelligent, Programmable, Built on Open Standards
Continuous network innovation required to unbridle compute and storage at ever-increasing scale

Photonics is integrated and ubiquitous (Optical IO)
• 20x bandwidth density
• 2x cost & power improvement

SmartNIC becomes critical to offload
• Optimized for complex data flows
• Diverse workload acceleration

Network is a Programmable Platform
Empowers customers to create new E2E applications optimized for their workloads with hardware-level performance at software-like pace of innovation

E2E co-optimizations unleash performance @ scale
• Telemetry, QoS, flow control
• Traffic shaping, steering, coalescing

Optical Modules
Switch with Integrated Photonics

Ethernet NIC

TODAY

2025
Intel® Ethernet Architecture Evolution

## Intel Foundational NICs

### Intel® Ethernet 500 Series
- **Niantic**
  - Fixed Pipeline
  - SR-IOV and VMDq
  - Intel® Ethernet Adaptive Virtual Function

### Intel® Ethernet 700 Series
- **Fortville**
  - Partially Programmable Pipeline
    - Table definition modifications with a Dynamic Device Personalization (DDP) profile package

### Intel® Ethernet 800 Series
- **Columbiaville**
  - Queue and Steering Hardware Assists
    - Application Device Queues (ADQ)
  - Fully Programmable Pipeline
    - Table definition with DDP profile packages
  - Storage
    - RDMA (iWARP* & RoCE*v2)
    - NVMe over Fabric (RDMA, TCP)

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**1Features & schedule are subject to change. All products, computer systems, dates and figures specified are preliminary based on current expectations and are subject to change without notice.**
Intel® Ethernet 800 Series – Customers & Solutions

Application Device Queues (ADQ)

10X TAIL LATENCY REDUCTION

Maintain performance during peak times, response times limited by slowest outliers (tail latency). Reduction in tail latency enables Twitter to provide stricter latency targets to customers to access more data.

NVMe over Fabrics

UP TO 50% LOWER LATENCY
UP TO 70% HIGHER THROUGHPUT
UP TO 30% INCREASE PREDICTABILITY

Compelling mechanism to move from direct attached storage (DAS) to disaggregated storage over the network. Intel is teaming with Lightbits Labs to develop complete solutions for scalable, low-latency disaggregated storage.

Dynamic Device Personalization (DDP)

UP TO 78% LATENCY REDUCTION
UP TO 88% JITTER REDUCTION

Standalone User Plane Function capability based on 2nd gen Xeon® Scalable Processors and 800 Series Network Adapters by using Dynamic Device Personalization (DDP) along with a multi-Q software algorithm.

DDP & Ethernet Port Configuration Tool

UP TO 310GBPS vBNG PERFORMANCE
CONSUMING 50W LESS POWER

Multiple 100G Intel Ethernet 800 Series with DDP delivers customizable packet classification resulting in highly efficient packet-processing for NFV workloads.

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**Intel® Ethernet Series Delivering Real-World Value**

8/25/20 Verizon announces 1st E2E virtualized 5G data session

.. Intel's contribution to Verizon's recent milestone are the following: Intel® Xeon® Scalable processor for Layer 1 and 2 processing, Intel® field programmable gate array programmable acceleration card N3000 for workload acceleration and fronthaul processing, and Intel® ethernet network adapter XXV710 for network I/O connectivity.

9/10/20 SK Telecom signed an MoU evolved 5G NFV platform

... Intel's will provide its latest technologies, including Intel Xeon Processors, Ethernet 800 Series Network Adapters and Solid-State Drives.....

9/29/20 Intel Enters into Strategic Collaboration with Lightbits Labs

... announced an agreement to propel development of disaggregated storage solutions... system will utilize ..and Intel® Ethernet 800 Series Network Adapters with Application Device Queues (ADQ) technology... LightOS NVMe over Fabrics TCP (NVMe-oF/TCP) storage with remote direct memory access-class performance when accelerated with the Intel Ethernet 800 Series Network Adapter

“Our enterprise and cloud customers will benefit with up to 50% reduced latency with our new AOC-S100G-i2C dual 100G networking card based on the new Intel Ethernet 800 Series with ADQ.”

- Michael McNerney, Vice President Marketing, Supermicro

Inspur

“Intel’s new 800 series100G Ethernet solution brings significant features expected by the market, including fully programmable pipeline benefiting existing customers on 700 series to implement DDP profile, application device queue (ADQ) significantly reducing application latency as well as RDMA implementation in both iWARP and RoCE v2. Inspur expects to work with Intel to bring excellent networking solution for the end users”

- Mr. William Chen, Deputy GM of Inspur Server Product Group

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**Lightbits**

**Supermicro**

**SK Telecom**

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Intel Strategy for SmartNICS

SmartNIC value:
1. Increase performance & network agility
2. Enable new use cases
3. Free up more cores for scaling and/or adding applications

Intel Strategy

Infrastructure Workload Acceleration
- Networking (OVS, others)
- Storage
- Security

Focused Solutions
- Intel Ethernet
- Development Platforms
- Adapters
- Components

Cloud & Networking Segments
- Data center
- Edge Use Cases

Programmable
- Tailor hardware and software to address customer needs

Broad Ecosystem Partners
- Systems Vendors
- IP Providers
- Solutions Providers
New Intel® FPGA SmartNIC and PAC Portfolio
Transforming the Cloud and Network

**For the Cloud**

Intel® FPGA SmartNIC C5000X Platform Architecture
- Intel® Xeon® D processor SoC + FPGA platform
- Supercharge Your Cloud Data Center Like a Hyperscaler

**For the Network**

Silicom® FPGA SmartNIC N5010
- 1st Hardware-programmable 4x100G FPGA SmartNIC
- Multi-workload acceleration for Network Core

Intel® Ethernet Tofino™
Growing Customer Adoption of SmartNIC

6/23/20 Next-generation AirScale Cloud RAN
“The Intel® FPGA Programmable Acceleration Card (PAC) N3000 was used ...to boost the performance even further without impacting the fully cloud-based implementation.”

9/29/20 Project Monterey: Re-Imagining Hybrid Cloud Architecture to Support Next-Generation Applications
“...collaborating with ecosystem partners to deliver solutions based on Project Monterey including Intel... to help organizations address the increasingly complex application landscape. The initiative will span support for SmartNICs, platform re-architecture and security ...”

9/15/20 Baidu drive intelligent infrastructure acceleration
“...to improve virtualization and workload performance, while accelerating data processing speeds...deploying Smart NIC (network interface card) innovations based on Intel® SoC FPGAs and Intel® Ethernet 800 Series adapter with Application Device Queues (ADQ) technology...

Microsoft
FPGAs have been the core of Azure’s SmartNIC infrastructure for multiple generations, providing us a high performance, flexible, and differentiated solution,” says Derek Chiou, a Partner Architect at Microsoft. “We are pleased to see Intel continue to lead the industry by launching the ground-breaking Intel FPGA SmartNIC Platform C5000X that will enable cloud service providers to integrate FPGA technology in their data centers to increase their efficiency, while providing flexibility to suit their needs. - Microsoft

Silicom
“As a leading provider of connectivity solutions, it’s clear that SmartNICs can dramatically improve the performance and efficiency of 4G/5G edge deployments for Telco providers,” said Boris Beletsky, AVP, Emerging Technologies. “The Silicom FPGA SmartNIC N5010 is the first hardware programmable 200G FPGA accelerated SmartNIC that enables next generation IA-based servers to meet the performance and scaling needs of the 5G core network (UPF), access gateways (BNG, AGF), and security functions (Firewall, IPsec).” - Silicom

Inventec
“Inventec is proud to have partnered with Intel to create a unique SmartNIC hardware platform based on FPGA SmartNIC platform for cloud from Intel,” says George Lin, General Manager of Business Unit VI, Inventec Enterprise Business Group (Inventec EBG). “We immediately realized that this platform would stand out as the SmartNIC for the future, offering customers the ability to customize while still delivering the outstanding performance, programmability, and portfolio of technology that only Intel can provide”- Inventec
Open and Programmable Ethernet Switching

Intel is committed to carry out the Barefoot Networks Mission to unleash the power of network programmability by making Tofino the first open, programmable Ethernet switch ASIC.

End users and researchers can now openly publish the data plane and control plane code for Tofino.

Ethernet switch ASICs should be as open as CPUs:

- Accelerating innovation in the networking industry
- Enabling network owners and operators to customize and build new applications for their network infrastructures
- Encouraging collaboration among developers and researchers to foster the growth of the P4 ecosystem
**Common Software Framework**

- **Control Plane**
  - P4 Runtime, OpenConfig
  - Switching, Routing, Tunneling, NAT, INT

- **OS & API**
  - Linux
  - ESXi(o), Linux
  - Switch Abstraction Interface (SAI)

- **Profile & SDK**
  - custom.p4
  - sai.p4
  - vswitch.p4

- **Platform**
  - Tofino Switch
  - SmartNIC
  - PAC FPGA Card
  - Host (P4, DPDK, SPDK, XDP, vSwitch)

- **Features**
  - Open, modular, non-forked offering; supports hetero (& legacy) data planes
  - Supports a variety of orchestration platforms (e.g., SFD)
  - Common tool chain and programming model across all Intel data planes
Silicon Photonics 2020 and beyond

**Future - Optical IO**

- **Ultra-high bandwidth:** ~1Tbps per fiber
- **Reach:** Order of magnitudes better than copper
- **Shoreline Density:** >6x improvement over PCIe6
- **Energy efficiency:** Trending to 2pJ/b (50% of PCIe6)
- **Latency:** Comparable to electrical IO
Intel Aligned to Technology Trends

Emerging Trends in Connectivity
• SmartNIC becoming network control point for performance & workload acceleration
• Programable switch improves network performance and visibility
• Photonic links to go to higher bandwidth – more favorable for Silicon Photonics
• Co-packaging optics or optical IO for bandwidth density improvement and power reduction

Intel Delivers a Comprehensive Connectivity Product Portfolio
• Foundational NICs with advanced features and SmartNIC for workload acceleration
• Switch SoCs with full programmability
• Silicon Photonics optical TxRx to provide connectivity at 100, 200, 400, & 800Gb/s bandwidth

‘End-to-End’ Optimizations Delivers Performance at Scale

Networks Becoming Programmable Platforms