SNIA NSF | NETWORKING STORAGE

You've Been Framed! xPU, GPU and Computational Storage Programming Frameworks

Live Webcast

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Today's Presenters

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SNIA - By the Numbers

Industry Leading Organizations

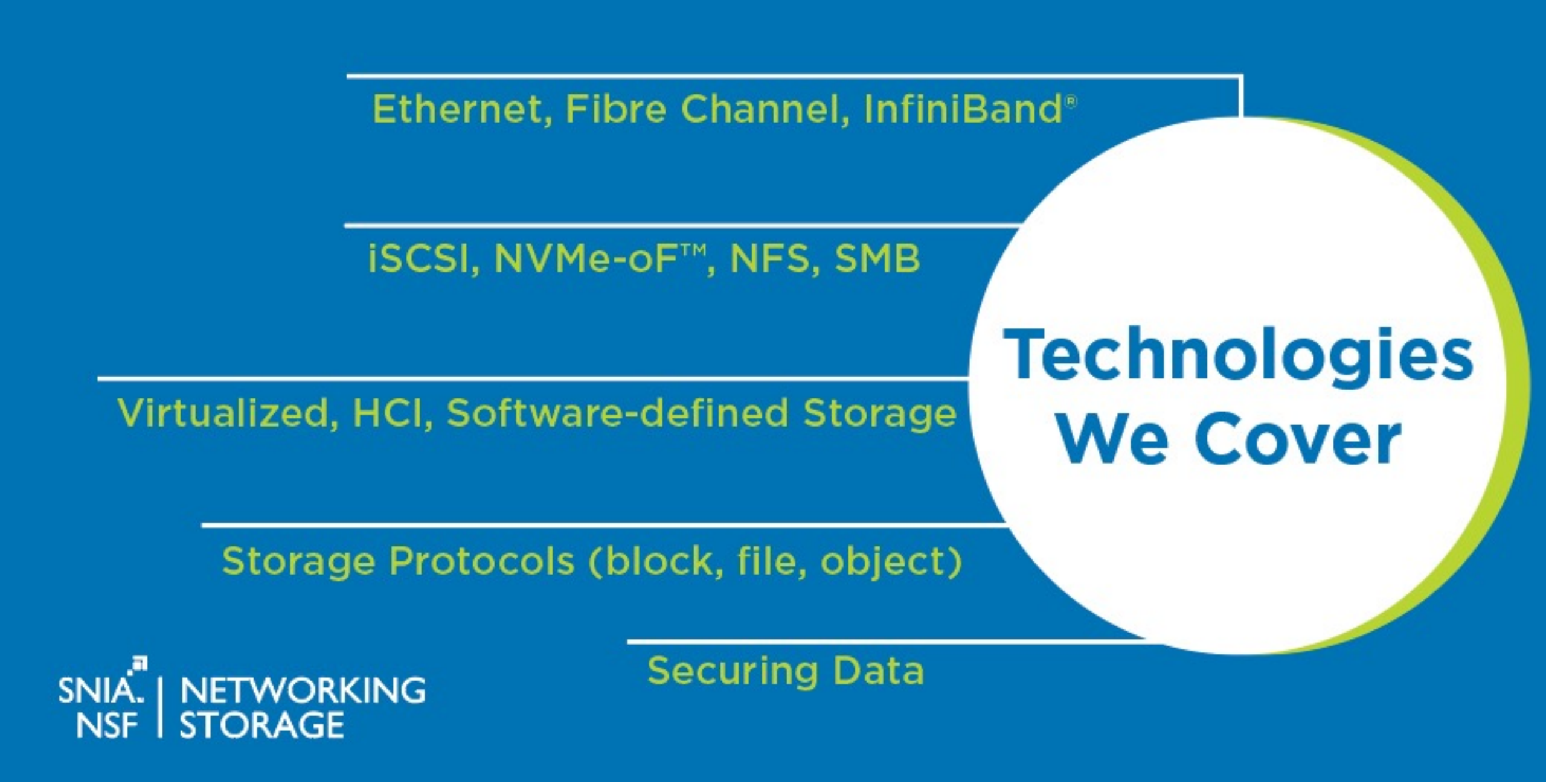
180

Active Contributing Members

2,500

IT End Users & Storage Pros Worldwide

50,000



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Today's Agenda

- High-level overview:
  - AI/ML: OpenCL, CUDA, SYCL, oneAPI
  - xPU: DOCA, OPI, DASH, IPDK
  - Core data path frameworks: SPDK, DPDK
  - Computational Storage: SNIA Standard 0.8 (in public review), TP4091
- Stay tuned for future deeper dives

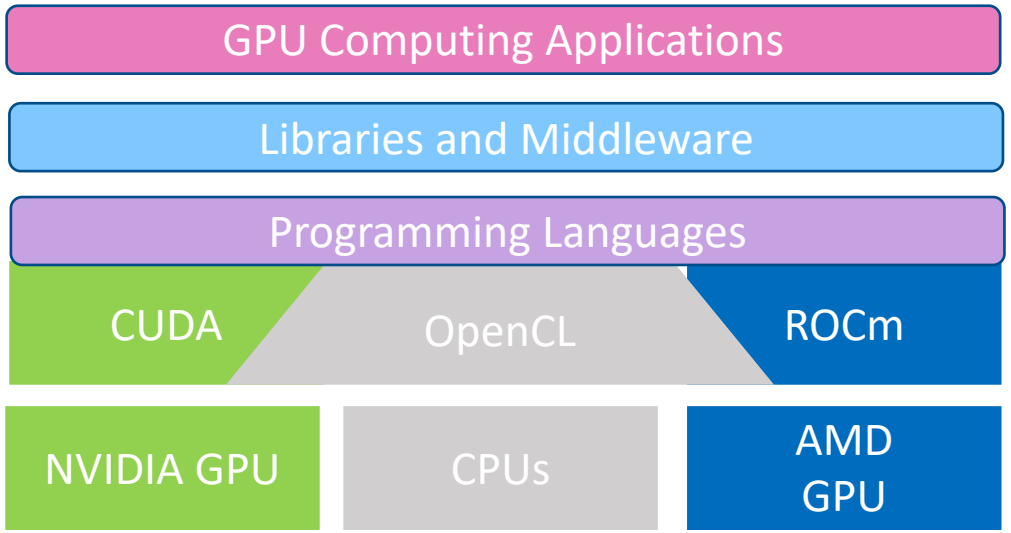
OpenCL and CUDA

John Kim, NVIDIA

What Are OpenCL and CUDA?

- Let general purpose computing use GPUs
- Libraries, APIs, compilers and drivers
- Extensions to programming languages

- OpenCL works with any GPU or CPU
- CUDA works only with NVIDIA GPUs
- ROCm works only with AMD GPUs



Choosing How to Accelerate Compute

Which Software Platform?

- Vendor-specific or cross-platform (and which cross-platform?)
- Which hardware do you need to support—GPU, CPU, FPGA, etc.
- Availability of suitable applications and libraries: AI, ML, HPC, etc.

Which Level?

- Applications—high level and easy, but limited to what's been built
- Libraries and Middleware—more flexible but require more effort
- Drivers and APIs—highest flexibility, potentially fastest performance, but highest amount of work

SYCL and oneAPI

James Reinders, Intel

Q: What is **SYCL**?

A: C++ solution for heterogeneous programming

An open, multivendor, multiarchitecture approach.

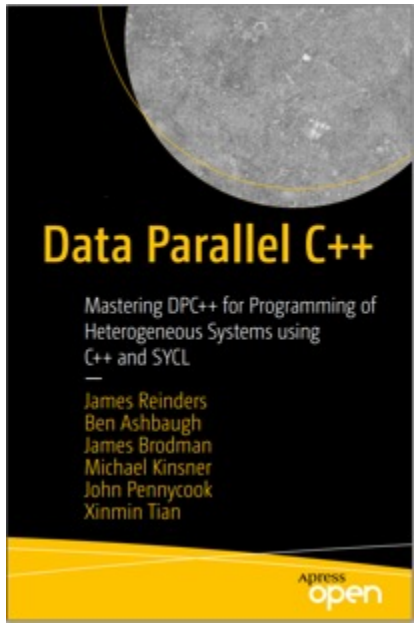
Provides:

1. **find a device,**
2. **manage memory, and**
3. **manage offloads.**

Q: What is DPC++?

A: LLVM compiler (includes clang) implementation of SYCL.

The SYCL book



PDF >670K accesses direct from publisher
and
Consistently a top C++ Book on Amazon

Q: What is oneAPI?

A: Complementary open standards initiative to provide multivendor multiarchitecture support through libraries, profilers, debuggers, etc.

https:// sycl . tech


```
1. ! Fortran loop
2. do i = 1, n
3.   z(i) = alpha * x(i) + y(i)
4. end do
```

```
1. // C++ loop
2. for (int i=0;i<n;i++) {
3.   z[i] = alpha * x[i] + y[i];
4. }
```

```
1. // SYCL kernel
2. myq.parallel_for(range{n},[=](id<1> i) {
3.   z[i] = alpha * x[i] + y[i];
4. }).wait();
```

“**myq**”
is how SYCL
supports gives us the ability to direct
work to our device of choice at runtime
(single source: any vendor, any architecture)

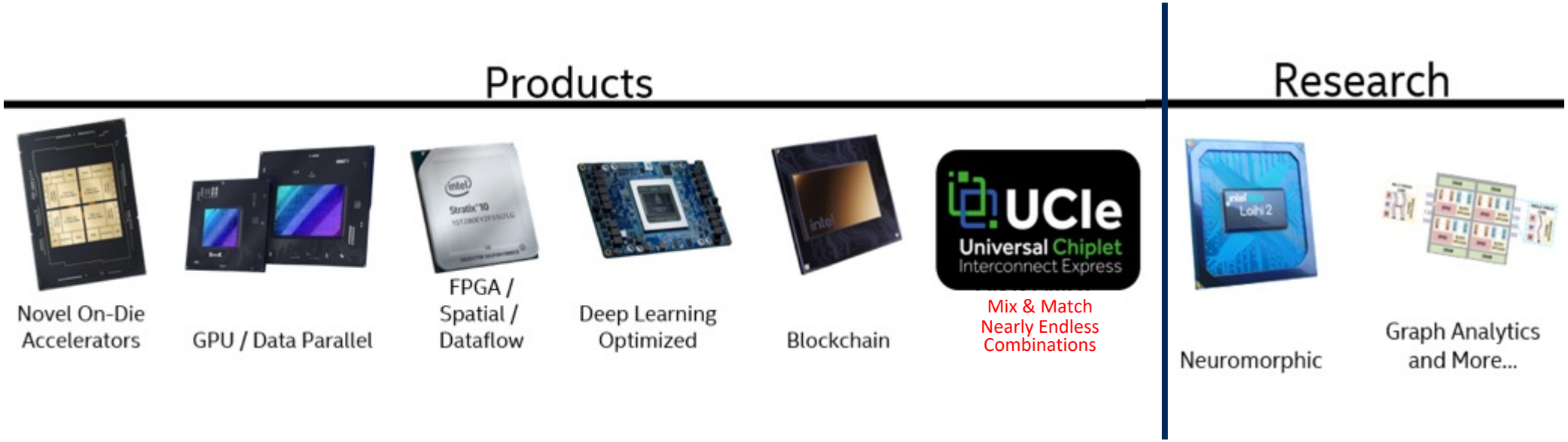
https:// sycl . tech

Why?
A New Golden Age for Computer Architecture

"The next decade will see a **Cambrian explosion of novel computer architectures**, meaning exciting times for computer architects in academia and industry."

ACM Turing Award laureates
John Hennessy and David Patterson (CACM, Feb 2019, Vol 62, No 2, pp 48-60)

PDF for H&P paper



A Complete SYCL Program

Host code

Accelerator device code

Host code

```
#include <CL/sycl.hpp>
constexpr int N=16;
using namespace sycl;
int main() {
  queue q;
  int *data = malloc_shared<int>(N, q);
  q.parallel_for(N, [=](auto i) {
      data[i] = i;
  }).wait();
  for (int i=0; i<N; i++) std::cout << data[i] << "\n";
  free(data, q);
  return 0;
}
```

https:// sycl . tech

C++ with SYCL and oneAPI…

…allows our application, in a single version, to identify and use any number of accelerators regardless of vendor or architecture – and do so with access to their best performance.

…are foundational efforts to ensure accelerated computing is open, multivendor, and multiarchitecture.

Higher layers of the software stack benefit without being forced to change.

Offering an essential alternative to proprietary foundations.

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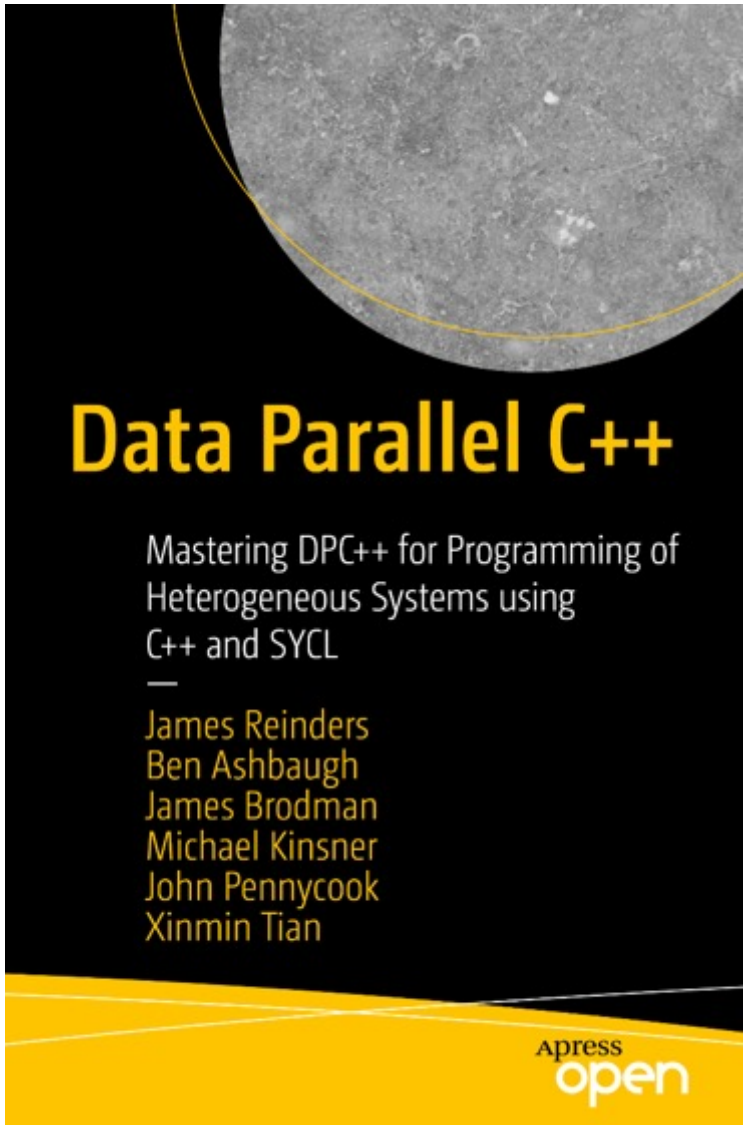
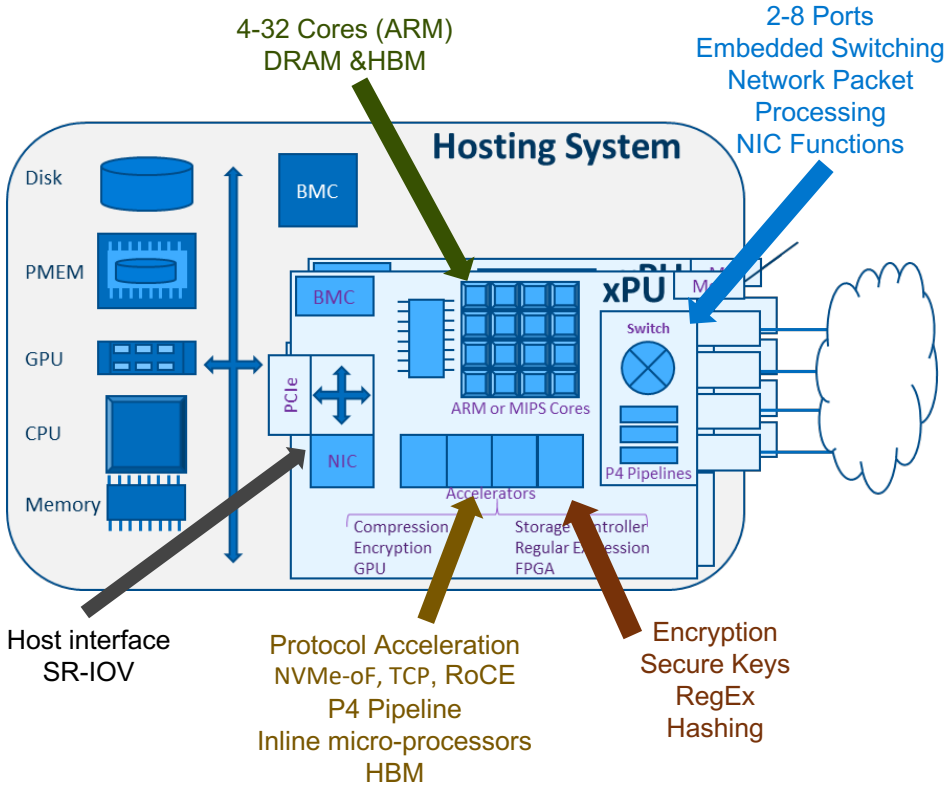


xPU: DOCA, OPI, DASH, IPDK

Joe White, Dell

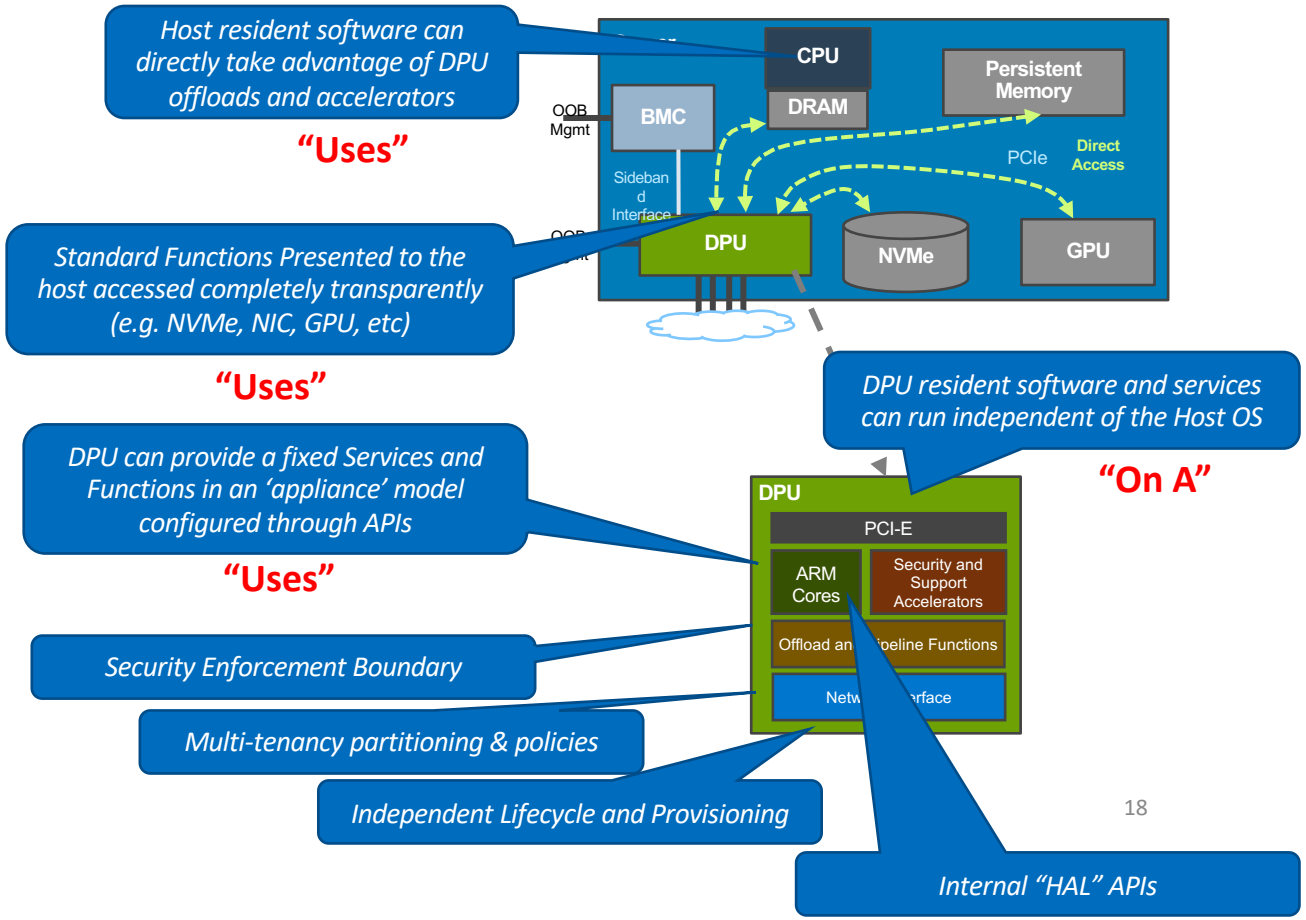
A Perspective on DPU Programming and Frameworks



DPU - Data Processing Unit (aka xPU)

Effectively a micro-server optimized for dataflow and packet processing providing accelerators, offload engines, & local services

Presents virtual functions to a host (looks like a NIC, GPU, etc)



*The objective of the Open Programmable Infrastructure Project is to foster a community-driven standards-based **open ecosystem** for next generation architectures and frameworks based on **DPU/IPU-like technologies**.*

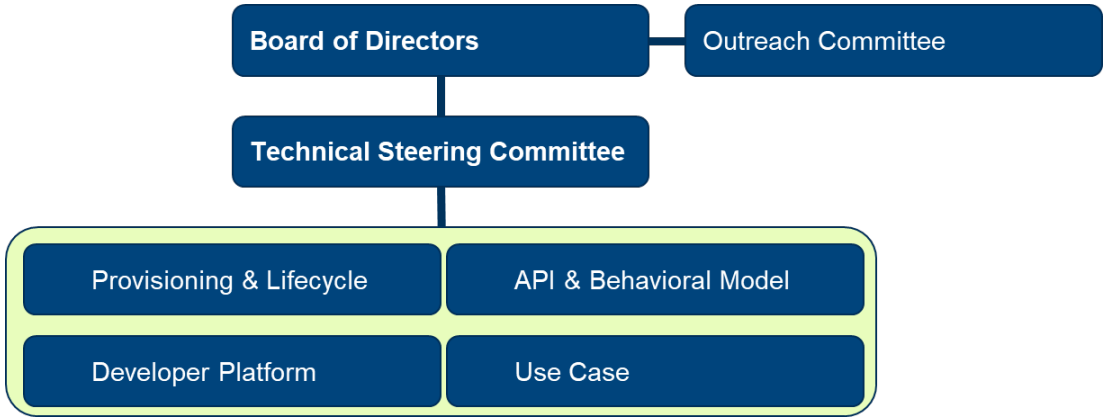
https://opiproject.org

https://github.com/opiproject

https://lists.opiproject.org/g/opi

OPI Project Goals

- Create community-driven standards-based open ecosystem for DPU/IPU-like technologies
- Create vendor agnostic framework and architecture for DPU/IPU-based software stacks
- Reuse existing or define a set of new common APIs for DPU/IPU-like technologies when required
- Provide implementation examples to validate the architectures/APIs



OPI Technical Deliverables

- Open-Source Projects
- Specifications/Standards
- Reference Platforms
- Test Suites & Cases
- POC/Prototypes

OPEN PROGRAMMABLE INFRASTRUCTURE PROJECT

Open DPU/IPU Ecosystem

OPI APIs Common Components & Tools

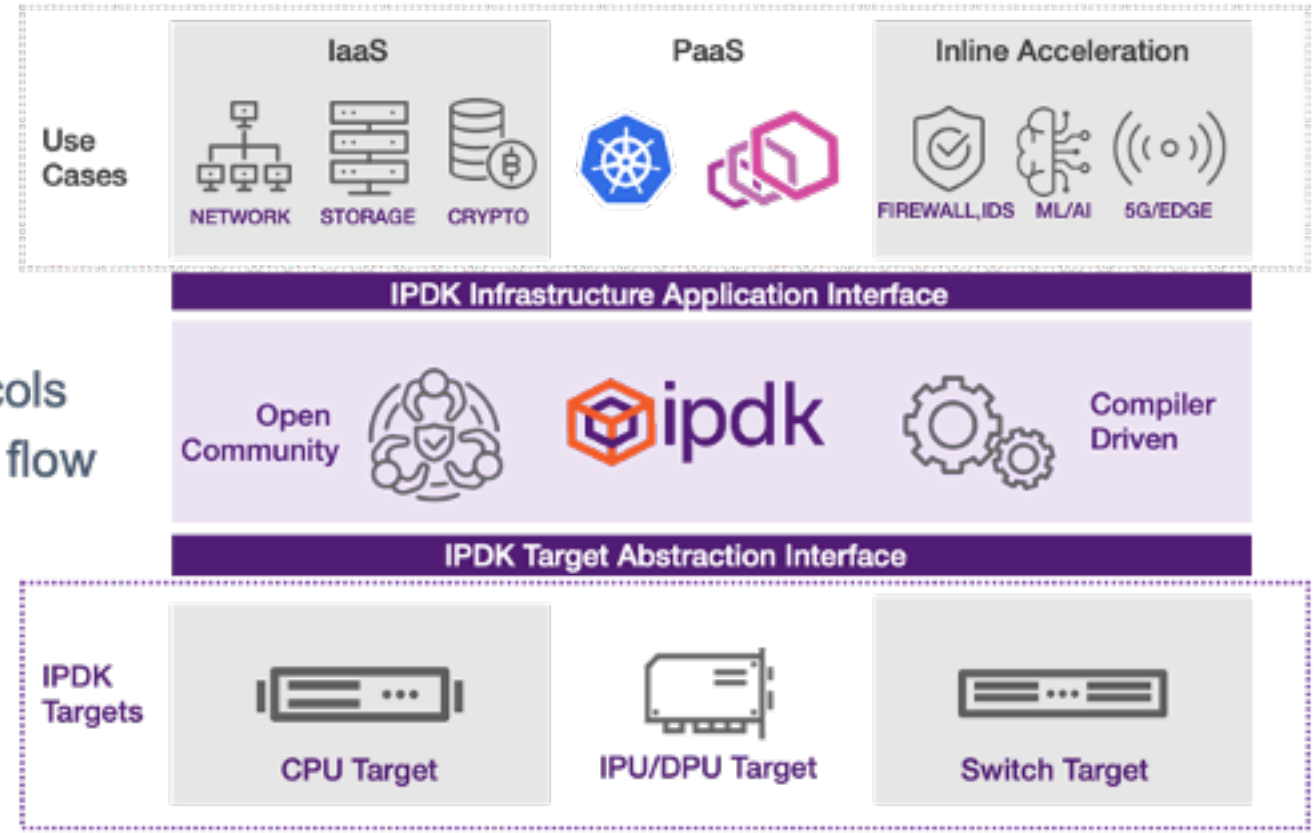
Common Governance

ipdk Infrastructure Programmer Development Kit

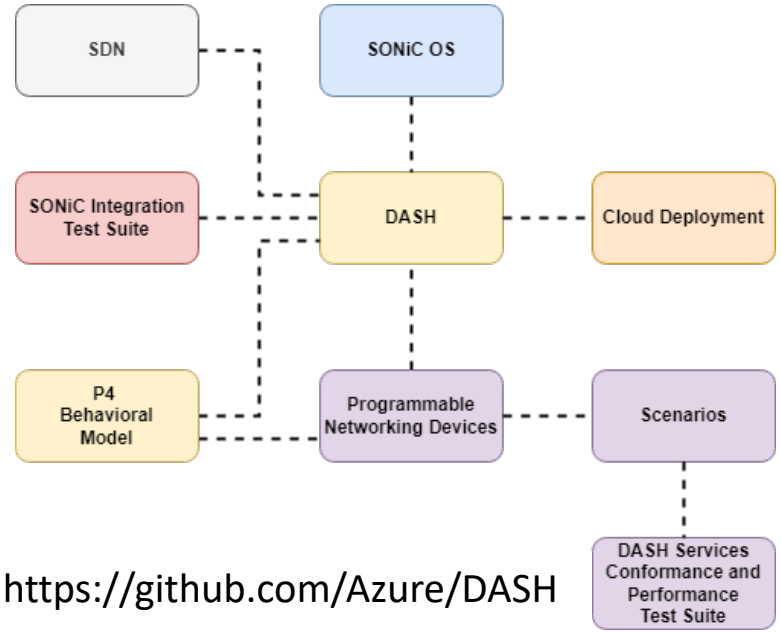
A sub-project of OPI

An Implementation of OPI Across CPU, DPU, IPU & Switch

- Open source abstraction layer
- Runs across multiple platforms
- Standards Based Accelerations
  - P4 to program the network
  - SPDK for customized storage protocols
  - DPDK or eBPF to accelerate packet flow
  - OVS, SONIC, INT with Deep Insight



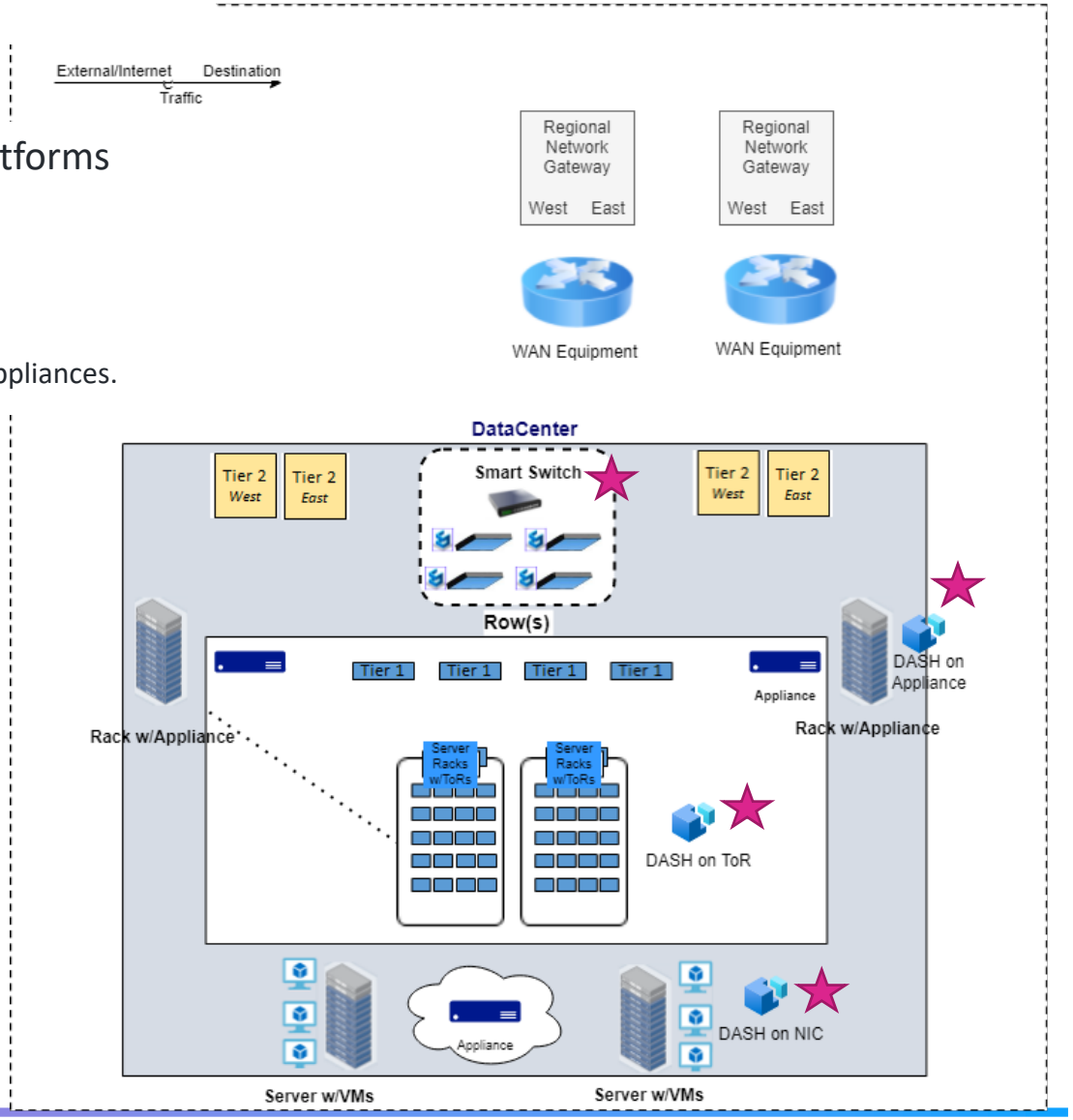
DASH - Disaggregated API for SONiC Hosts



https://github.com/Azure/DASH

★ multiple application and platforms

- NIC on a host
- a Smart Switch
- Network Disaggregation
- high performance Network Appliances.



- **SONiC-DASH is an open-source project that will "deliver enterprise network performance to critical cloud applications".**
  - Develop APIs + object models describing network services for the cloud
  - The goal of DASH is to be specific enough for SMART Programmable Technologies to optimize network performance and leverage commodity **hardware** technology to achieve 10x or even 100x stateful connection performance.

NVIDIA DOCA

DPU Software Development Kit

DOCA is for DPUs what CUDA is for GPUs

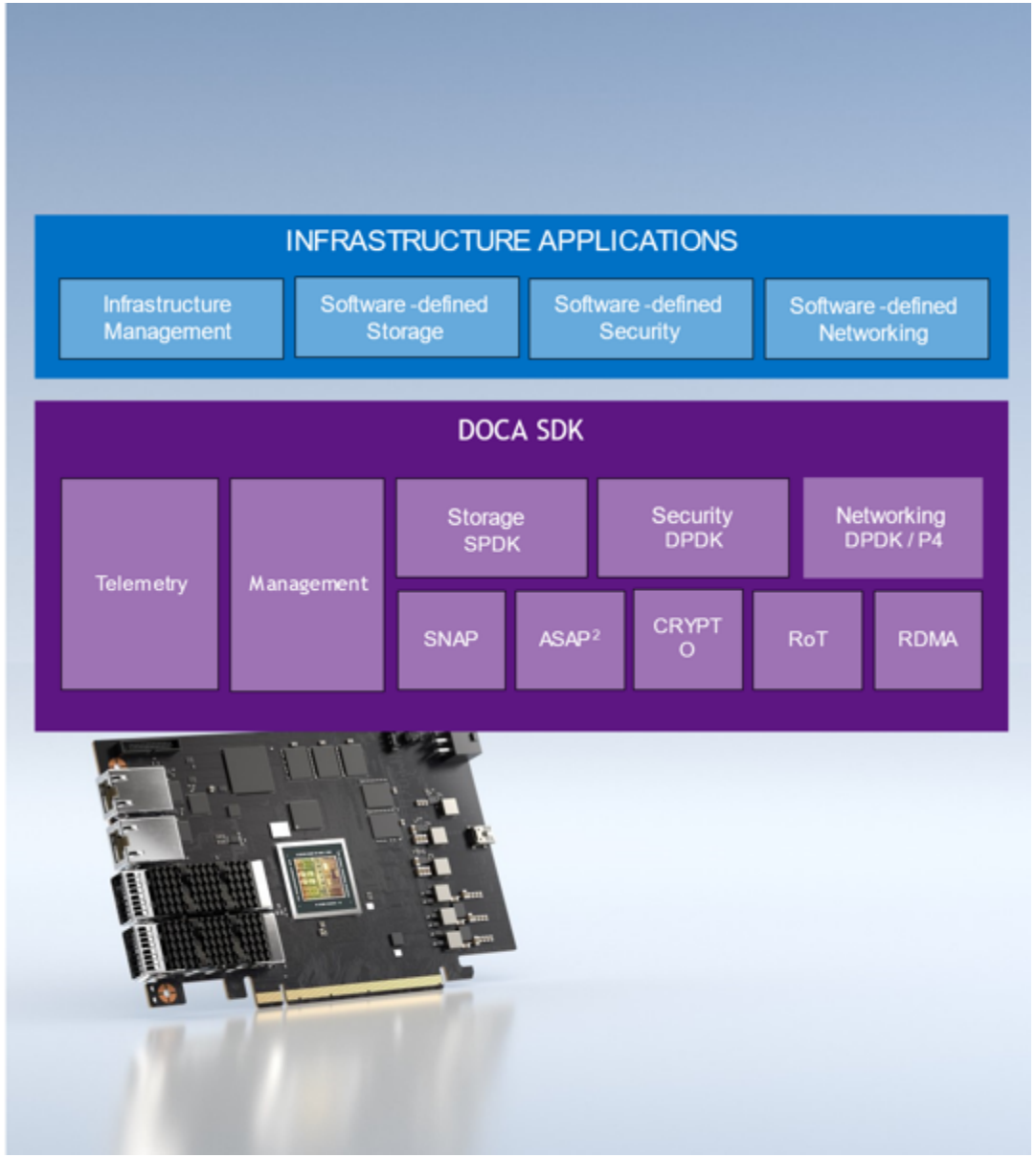
Built on open, industry-standard APIs: DPDK, SPDK, TLS and P4

DOCA libraries provide higher abstraction for enhanced developer experience

Preserves developer investment as DPUs evolve

Support for multiple OS

https://developer.nvidia.com/networking/doca



Core Data Path Frameworks: SPDK, DPDK

Ben Walker, Intel

Overview

The previous section covered xPU-centric frameworks

These xPU frameworks are built on top of existing software projects

These projects handle the data path and contain the device drivers

Use Case: Virtual Switch Offload

- When running many VMs on a single system, they often talk to each other over a virtual network with a virtual, software-based switch.
- This virtual switch is often implemented using DPDK and OVS
- This virtual switch can be offloaded to an xPU.

Data Plane Development Kit (DPDK)

Long-standing packet processing framework widely deployed in switches and on servers

Open source, BSD Licensed

Runs on x86, POWER, and ARM on top of Linux

Serves as the core data-path framework for software-defined networking across the industry

Virtual Switch Offload Implementation

- The xPU may present multiple PCIe (virtual) functions to be direct assigned to VMs/containers. Switching is done inside the xPU instead of in host system software.
- May be implemented as xPU hardware or as xPU software (firmware?) or as a hybrid
  - When implemented as xPU software, typically based on DPDK and OVS – the same code that ran on the host!
  - But most commonly, xPUs have extra accelerators or a full hardware path for switching and use software only has a fall back for corner cases

Use Case: Block Device Virtualization

- VMs can directly use NVMe or virtio-(blk/scsi) disks. The guest only has drivers for those.
- The real disk may be network attached using some other protocol.
- A storage virtualization target presents VMs with emulated NVMe/virtio disks and forwards I/O using the necessary protocols.
- This storage virtualization can be offloaded to an xPU.

Storage Performance Development Kit (SPDK)

Long-standing storage framework widely deployed in the cloud, NAS, and SAN systems

Open source, BSD Licensed

Runs on x86, POWER, and ARM on top of Linux

Serves as the core data-path framework for software-defined storage across the industry

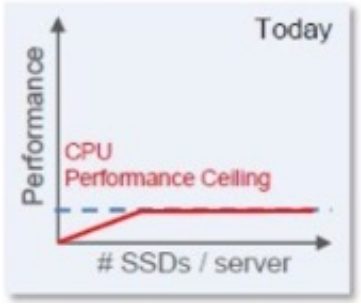
Storage Virtualization Implementation

- The xPU may present multiple PCIe (virtual) functions to be direct assigned to VMs/containers. Ideally, these appear as NVMe devices.
- May be implemented as xPU hardware or as xPU software (firmware?) or as a hybrid (most common)
  - When implemented as xPU software, typically based on SPDK– the same code that ran on the host!
  - But most commonly, xPUs have extra accelerators (crypto, compression, RDMA) to accelerate data movement

Computational Storage

David McIntyre, Samsung

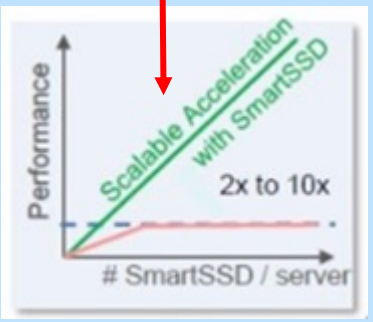
Problem Statement: Data Processing Resources Can Be Misbalanced



Performance Limit

Computational Storage Resolution

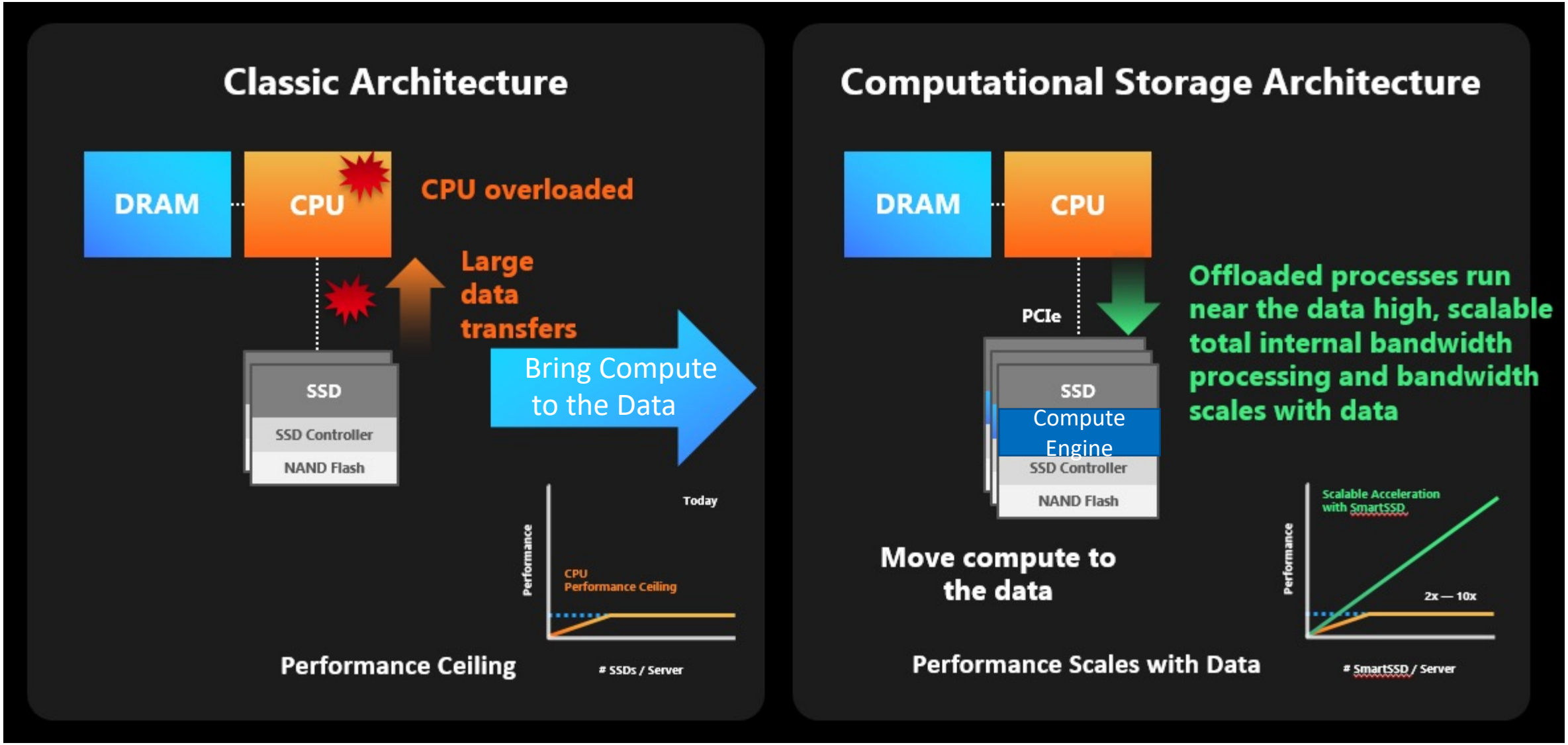
Scalable Performance



Computational Storage Benefits

- **Host Offload (Data Analytics and Mgt)**
- **Reduce Data Movement**
- **Application Performance Focus**
- **Security**

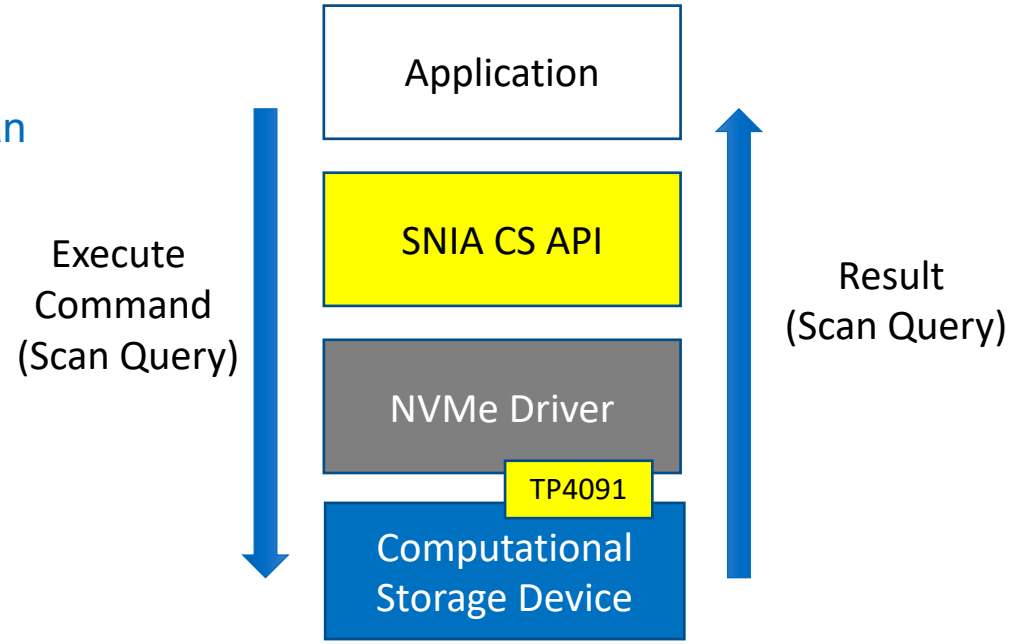
Computational Storage Explained



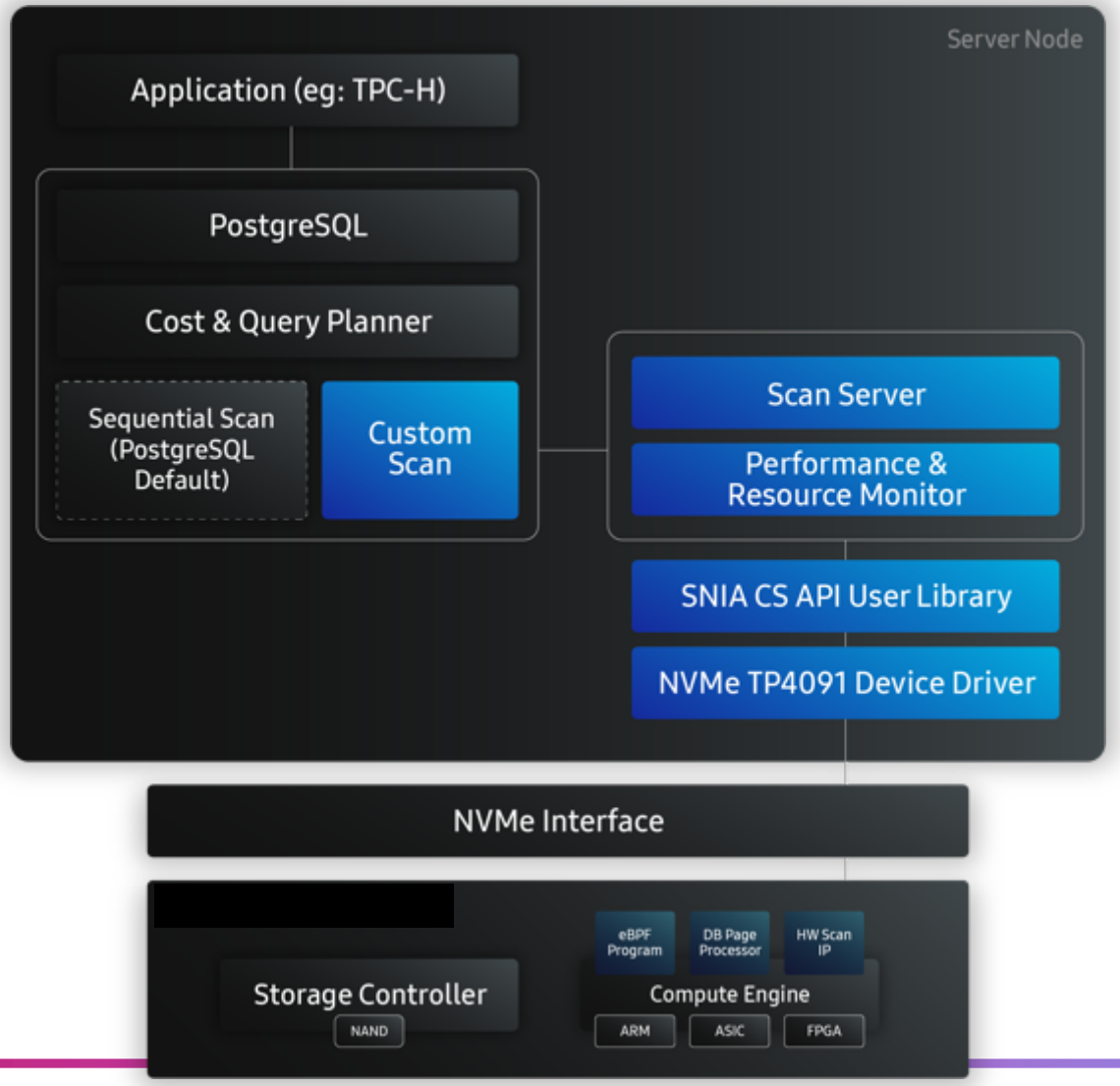
Computational Storage Programming Methodology

Standards based Computational Storage

- **SNIA CS API Specification (Host)**
  - Defines methodology for Host Applications to initiate commands to computational storage resource (e.g. scan query)
- **NVMe TP4091 Specification (Device)**
  - Defines command environment from host to target (e.g. Compute Engine)
  - Target supports NVMe 2.0 specification



Computational Storage Scan Acceleration Programming Build Steps



1. **Build Open Sourced Software Modules**
   - Custom scan extension, scan server, CS API lib, etc.
2. **Enable PostgreSQL to use custom scan extension**
   - Modify just one line of postgresql.conf
   - No PostgreSQL recompilation required
3. **Load Samsung NVMe device driver**
   - TP4091 enabled
4. **Run application**

Today We Covered…

- High-level overview of significant & important developments:
  - AI/ML: OpenCL, CUDA, SYCL, oneAPI
  - xPU: DOCA, OPI, DASH, IPDK
  - Core data path frameworks: SPDK, DPDK
  - Computational Storage: SNIA Standard 0.8 (in public review), TP4091
- What specific topics would you like us to cover in future deeper dives?
  - Use the feedback text area as you leave the presentation

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Thank You

