INTRODUCTION TO THE FRONTIER SYSTEM

Frontier Application Readiness Kick-Off Workshop
Oct. 2019
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U.S. Department of Energy and Cray to Deliver Record-Setting Frontier Supercomputer at ORNL

Exascale system expected to be world’s most powerful computer for science and innovation

Topic: Supercomputing

May 7, 2019

OAK RIDGE, Tenn., May 7, 2019—The U.S. Department of Energy today announced a contract with Cray Inc. to build the Frontier supercomputer at Oak Ridge National Laboratory, which is anticipated to debut in 2021 as the world’s most powerful computer with a performance of greater than 1.5 exaflops.
Frontier is a Shasta system
Shasta is Cray’s platform for the Exascale Era

Flexible, Extensible, & Scalable Hardware Infrastructure
Wide Diversity of Processors
Slingshot Interconnect
Standards-based (interoperable and open)
High-Performance, Tiered, Integrated Storage
Dynamic, Cloud-like Environment for Hybrid Workflows

HPC
AI
Analytics
Cloud
IoT
Shasta Flexible Compute Infrastructure

**“Mountain”**
Dense, scale-optimized Cabinet

- Up to 300KW with warm water cooling
- 512+ high-performance processors
- Flexible, high-density interconnect

**“River”**
Standard 19” Rack

- Air cooled with liquid cooling options
- Wide range of available compute and storage

Same Interconnect - Same Software Environment
Slingshot Overview

Slingshot is Cray’s 8th generation scalable interconnect

Earlier, Cray pioneered:
- Adaptive routing
- High-radix switch design
- Dragonfly topology

64 ports x 200 Gbps
Over 250K endpoints with a diameter of just three hops

Ethernet Compliant
Easy connectivity to datacenters and third-party storage; “HPC inside”

World class Adaptive Routing and QoS
High utilization at scale; flawless support for hybrid workloads

Groundbreaking Congestion Control
Performance isolation between workloads

Low, Uniform Latency
Focus on tail latency, because real apps synchronize
HPC Ethernet Protocol
Enhancements for Efficiency and Resiliency

• Slingshot speaks standard Ethernet at the edge, and optimized HPC Ethernet on internal links
• Reduced minimum frame size
• Removed inter-packet gap
• Optimized header
• Credit-based flow control

• Protocol also provides resiliency benefits
  • Low-latency FEC (see 25Gbit Ethernet Consortium)
  • Link level retry to tolerate transient errors
  • Lane degrade to tolerate hard failures
Slingshot Congestion Management

- Hardware automatically tracks all outstanding packets
  - Knows what is flowing between every pair of endpoints
- Quickly identifies and controls causes of congestion
  - Pushes back on sources... just enough
  - Frees up buffer space for everyone else
  - Other traffic not affected and can pass stalled traffic
  - Avoids HOL blocking across entire fabric
  - Fundamentally different than traditional ECN-based congestion control
- Fast and stable across wide variety of traffic patterns
  - Suitable for dynamic HPC traffic
- Performance isolation between apps on same QoS class
  - Applications much less vulnerable to other traffic on the network
  - Predictable runtimes
  - Lower mean and tail latency – a big benefit in apps with global synchronization
Congestion Management Provides Performance Isolation

Job Interference in today's networks
Congesting (green) traffic hurts well-behaved (blue) traffic, and really hurts latency-sensitive, synchronized (red) traffic.

With Slingshot Advanced Congestion Management
Shasta Pulls Storage onto Slingshot HSN

Traditional Model

- High Speed Network
- Compute Node
- OSS (HDD)
- LNET
- OSS & MDS
- OSS (HDD)

Benefits:
- Lower complexity
- Lower latency
- Improved small I/O performance

Shasta

- Slingshot High Speed Network
- Compute Node
- OSS & MDS
- OSS (HDD & SSD)

Tiered Flash and HDD Servers
# Shasta Developer Environment

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<th>Programming Languages</th>
<th>Programming Models</th>
<th>Programming Environments</th>
<th>Optimized Libraries</th>
<th>Tools (continued)</th>
<th>Analytics / AI **</th>
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<td><strong>Distributed Memory</strong></td>
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<td><strong>Scientific Libraries</strong></td>
<td><strong>Tools</strong></td>
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<td>Cray MPI SHMEM</td>
<td>Cray Compiling Environment PrgEnv-cray</td>
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- **Cray Developed**
- **Cray added value to 3rd party**
- **3rd party packaging**
- **Licensed ISV SW**
Frontier Application Software Stack

- Cray, and AMD are working together with ORNL and other Labs to deliver a full software stack
- Provide Compiler and library choice
- Includes:
  - Multiple programming environments
  - Performance and correctness tools
  - Will Include Optimizations such as:
    - Cray MPI GPU-to-GPU data movement
    - libsci_acc
    - Cray PE DL Plugin
HIGH PERFORMANCE CPU
CUSTOMIZED FOR HPC

Custom AMD EPYC processor optimized for HPC and AI

Utilizes Future “Zen” Core High-Performance Architecture

AI-Optimized for Supercomputing Workloads
HIGH PERFORMANCE GPU OPTIMIZED FOR HPC AND AI

HPC-Customized Compute Engines
Extensive Mixed Precision Ops for Optimum Deep Learning Performance
High-Bandwidth Memory (HBM) for Maximum Throughput

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Infinity Fabric

High-Bandwidth, Low-Latency Connection Between CPU and GPU

Custom Coherent Fabric

Connects 4:1 GPU to CPU Per Node
Shasta Blades, Cabinets & Slingshot Network
## Frontier - System Summary

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<th>Hardware Element</th>
<th>Details</th>
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<td>Peak Performance</td>
<td>&gt; 1.5 ExaFlops</td>
</tr>
<tr>
<td>Footprint</td>
<td>&gt; 100 cabinets</td>
</tr>
<tr>
<td>Node</td>
<td>1 HPC and AI Optimized AMD Future EPYC CPU 4 Purpose Built AMD Radeon Instinct GPU</td>
</tr>
<tr>
<td>CPU-GPU Interconnect</td>
<td>AMD Infinity Fabric Coherent memory across the node</td>
</tr>
<tr>
<td>System Interconnect</td>
<td>Multiple Slingshot NICs per node providing 100 GB/s network bandwidth Slingshot dragonfly network which provides adaptive routing, congestion management, and quality of service.</td>
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<tr>
<td>Storage</td>
<td>2-4x performance and capacity of Summit’s I/O subsystem. Frontier will have near node storage.</td>
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BANDWIDTH

The network bandwidth of the Frontier system is 24,000,000 times greater than the top home internet connection. With it, you could download 100,000 HD movies in one second.

HORSEPOWER

Frontier will have the performance of the top 160 fastest supercomputers in the world combined.

SIZE

Frontier will cover over 7,300 square feet. That’s almost 2 basketball courts.

SPEED

If all 7.7 billion people on earth each completed one calculation per second, it would take over 6 years to do what the Frontier system can do in 1 second.

CABLING

The 90 miles of cables in the Frontier system would span the distance from Philadelphia to New York City.