Open MPI for Cray XE/XK Systems

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A Collaborative Effort

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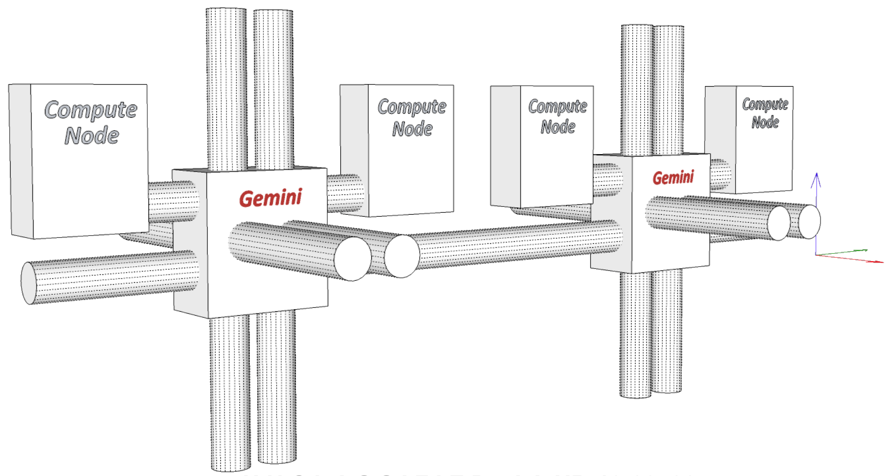
First Things First – Open MPI Overview

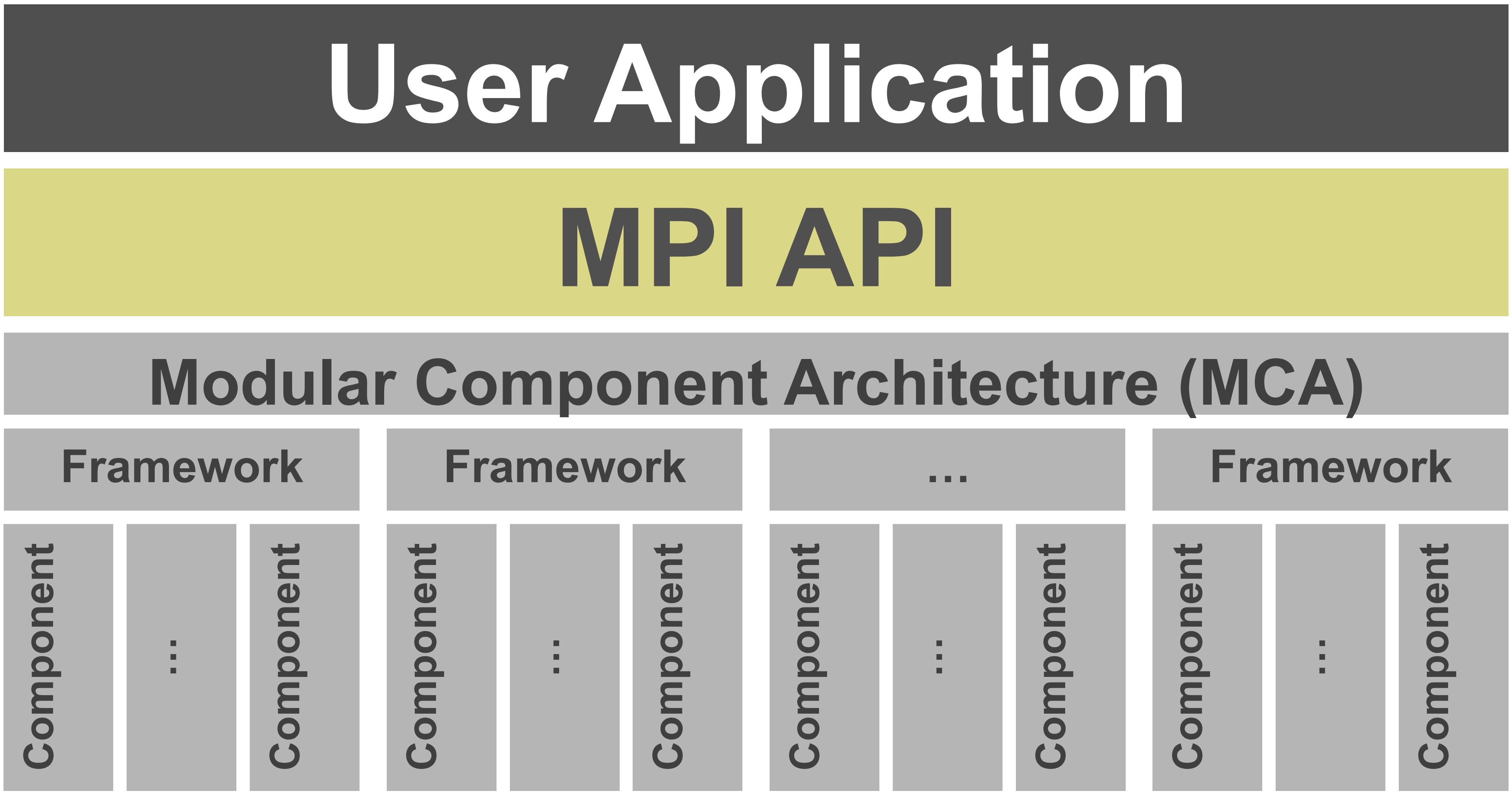
- **Open-Source Implementation of the MPI-2 Standard**
- **Developed and Maintained By**
  - Academia
  - Industry
  - National Laboratories
- **Supports a Range of High-Performance Network Interfaces**
  - Infiniband
  - Cray SeaStar
  - … and Now Cray Gemini

The Gemini System Interconnect[3] – An Overview

- **Network Used by the Cray XE and XK System Families**
- **Successor to the Cray SeaStar* Network Interconnect**
- **3D Torus Network Built of Gemini ASICs**
- **Gemini ASIC**
  - Provides 2 NICs and a 48-port Router
  - Connects 2 Opteron Nodes
  - Provides 10 Torus Connections – 2 x (+X, -X, +Z, -Z) – 1 x (+Y, -Y)

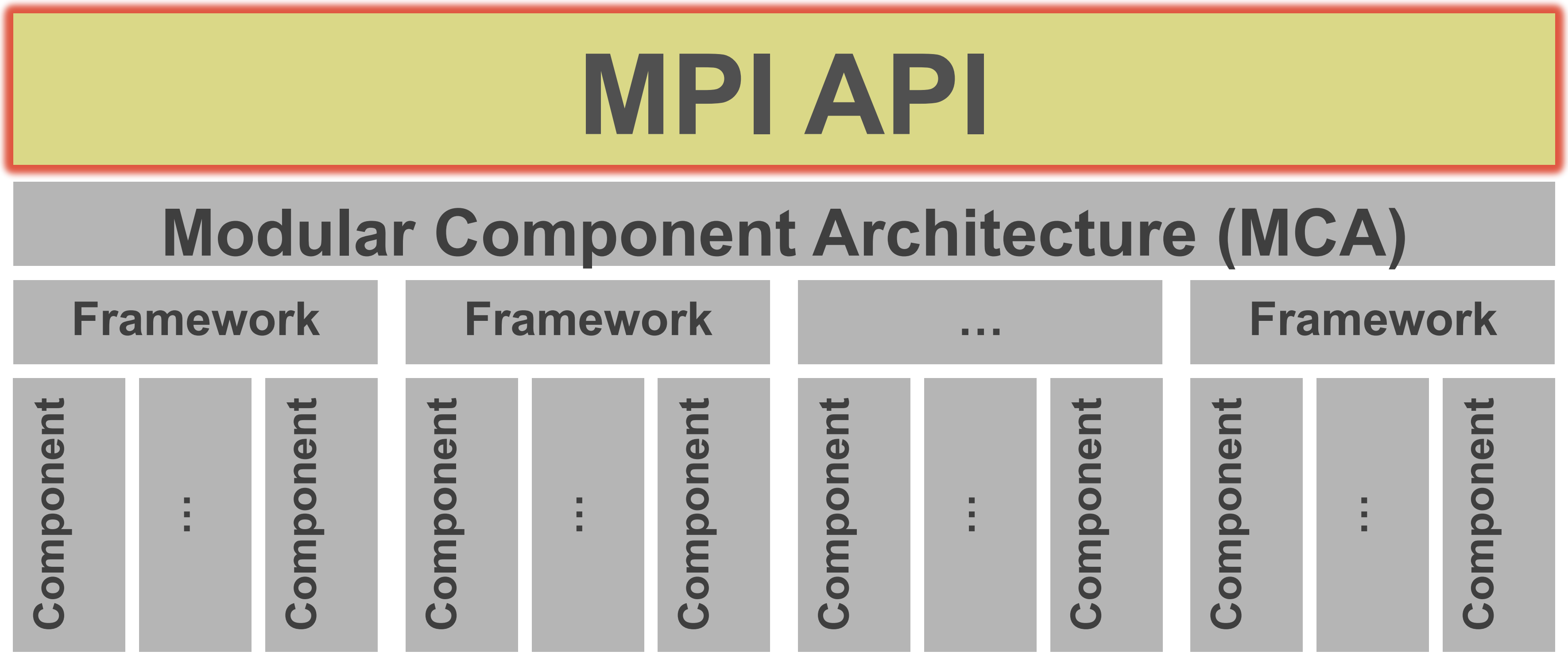


Open MPI's Plugin Architecture – A High-level Overview[1]



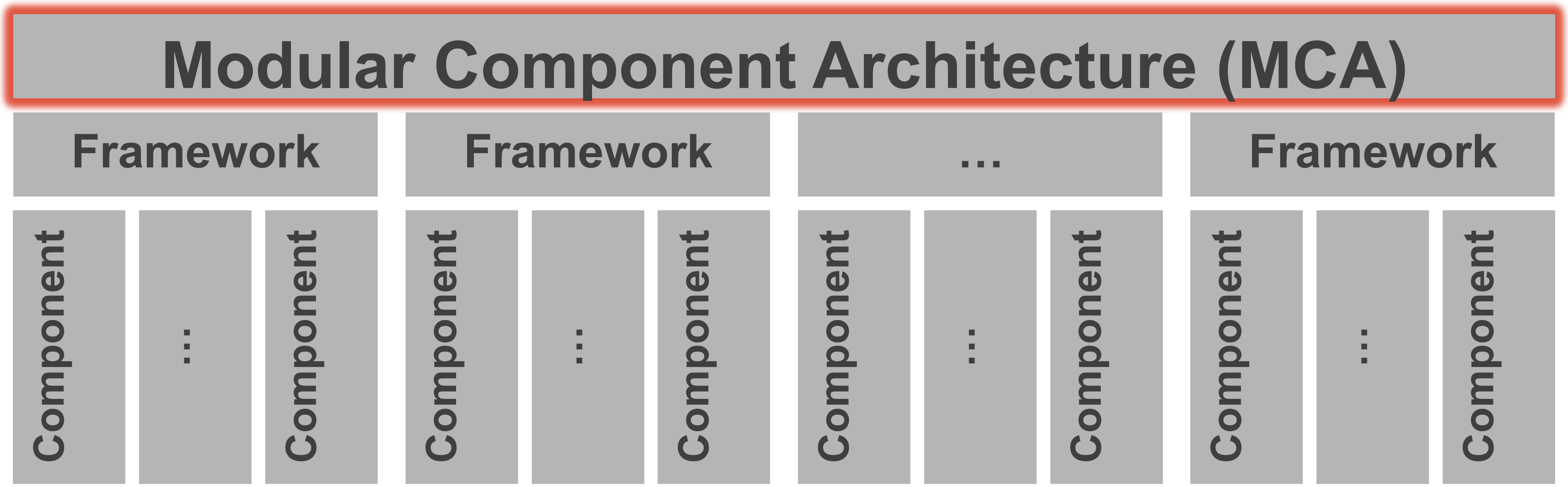
Open MPI's Plugin Architecture – A High-level Overview[1]

- **MPI API**
  - E.g. MPI_Send, MPI_Recv, MPI_Bcast



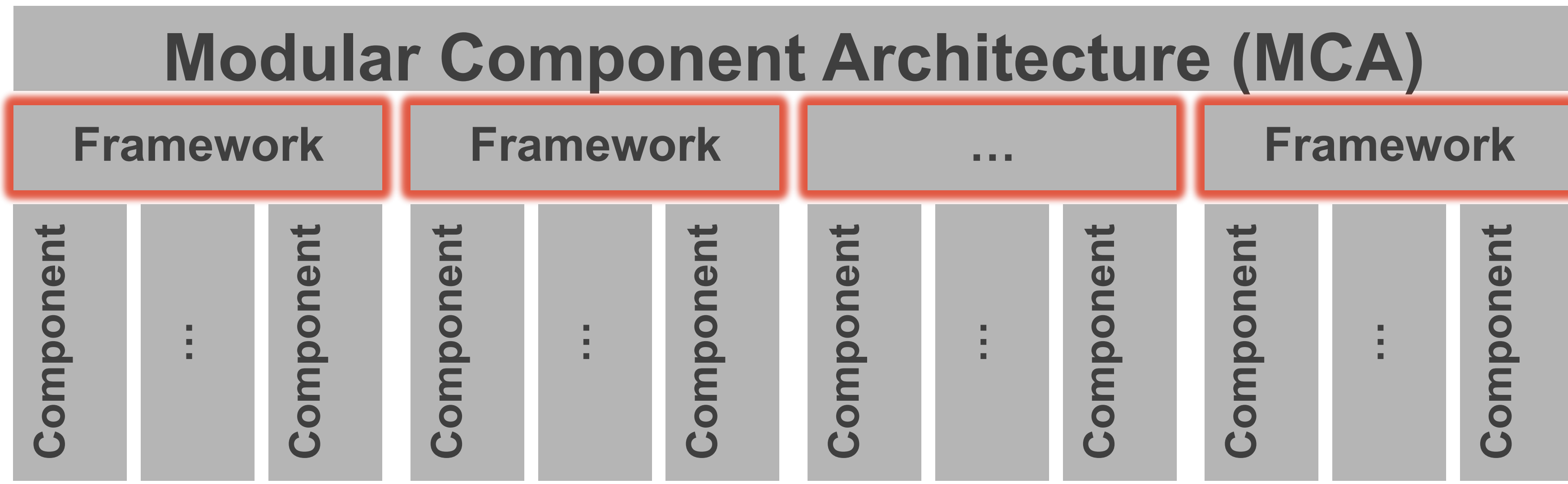
Open MPI's Plugin Architecture – A High-level Overview[1]

- **Modular Component Architecture (MCA)**
  - Backbone of Open MPI
  - Plugin System
  - Finds, Loads, and Parameterizes Components
- **Open MPI Hearts MCA Parameters**



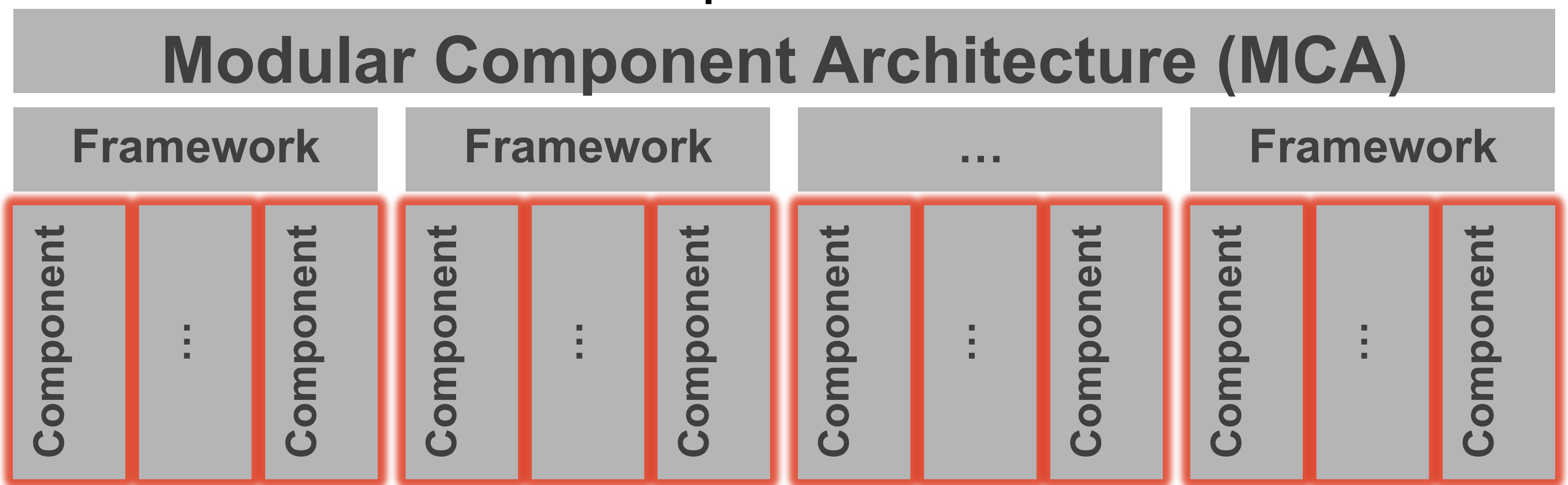
Open MPI's Plugin Architecture – A High-level Overview[1]

- **Frameworks**
  - Functionality Specification
  - E.g. Resource Manager, Point-to-Point, Collective Algorithm



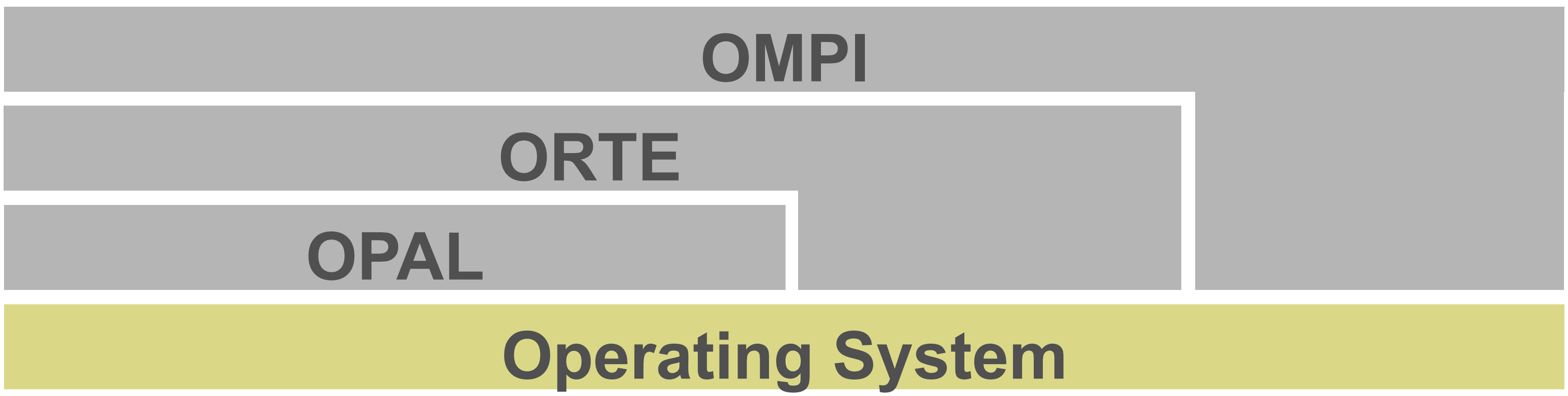
Open MPI's Plugin Architecture – A High-level Overview[1]

- **Components**
  - Implementation of a Framework Type – A Plugin
  - E.g. SLURM RAS Component, Open IB BTL Component
- **What a Developer Typically Creates to Support New Functionality**
- **Module: an Instance of a Component**



Open MPI's Plugin Architecture – Main Code Sections[1]

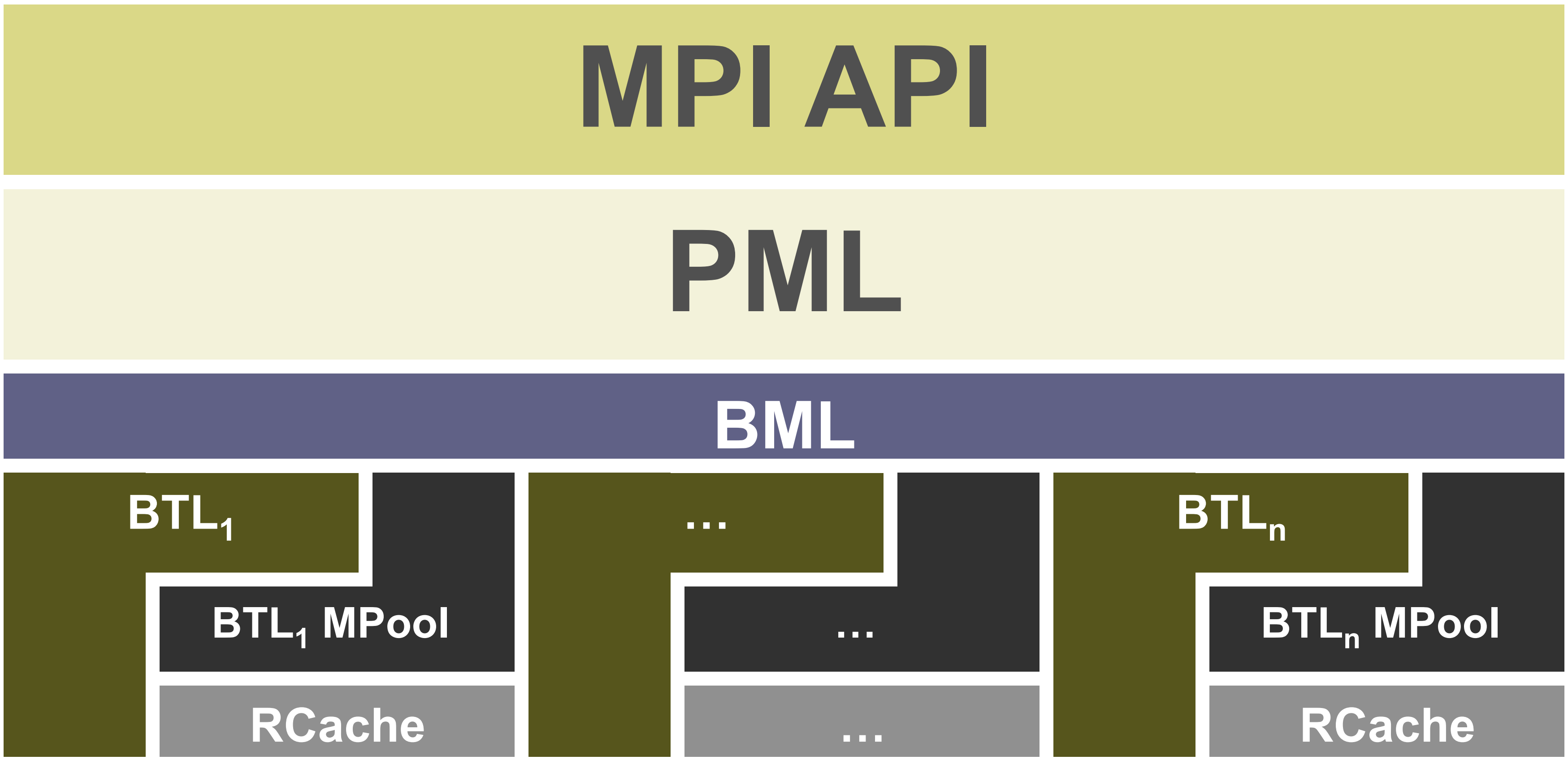
- **Open MPI Layer (OMPI)**
  - MPI API and Support Logic
- **Open Run-Time Environment (ORTE)**
  - Run-Time System
- **Open Portability Access Layer (OPAL)**
  - OS-Specific/Utility Code



The Port - ORTE

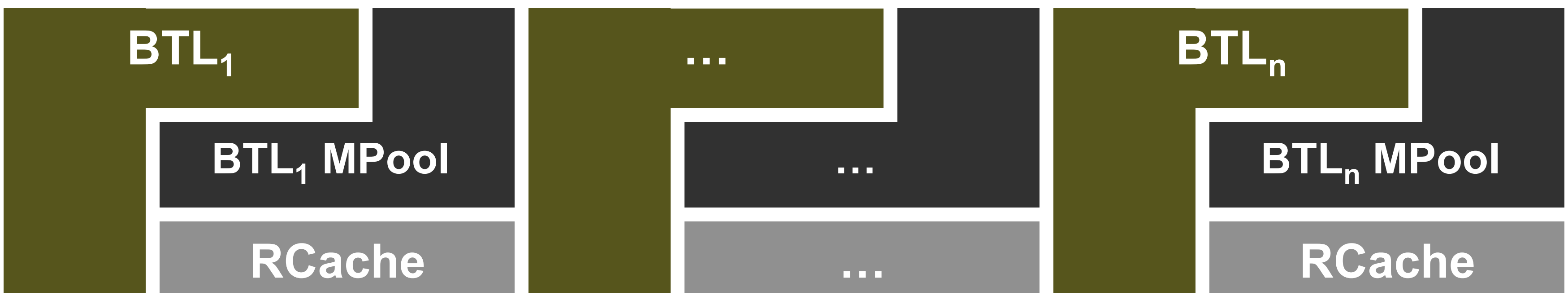
- **Environment-Specific Services (ESS)**
  - Run-Time Environment (RTE) Setup
  - Messaging, Routing, Module Exchange (ModEx)
  - Process Naming – Job Size and Locality Information
- **Process Lifecycle Management (PLM)**
  - Central Switchyard for All Process Management
  - Resource Allocation, Process Mapping, Process Launch, Process Monitoring
- **Resource Allocation Subsystem (RAS)**
  - Job Resource Availability and Allocation
- **RML Routing Table (ROUTED)**
  - “Next Hop” Routing Services – De Bruijn

OMPI Point-to-Point Overview[1]



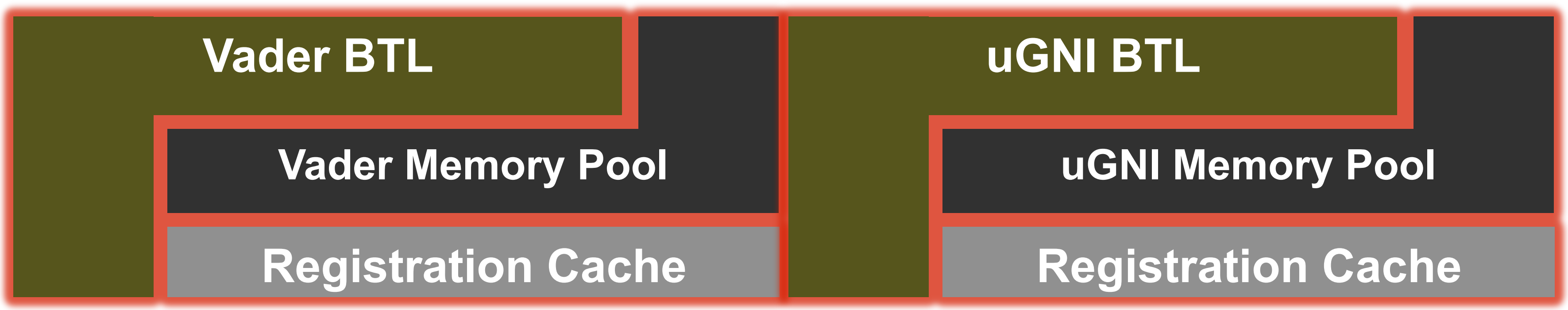
Byte Transfer Layers (BTLs)[1]

- **Transport Interface Support Plugins**
  - Think: Byte Transfer Driver
- **Thin Abstraction Layer Above Target Device**
  - Source/Destination Preparation
  - Protocol Definition – Short, Medium, Long
  - Send, SendI, Put, Get
- **No Notion of MPI Semantics**



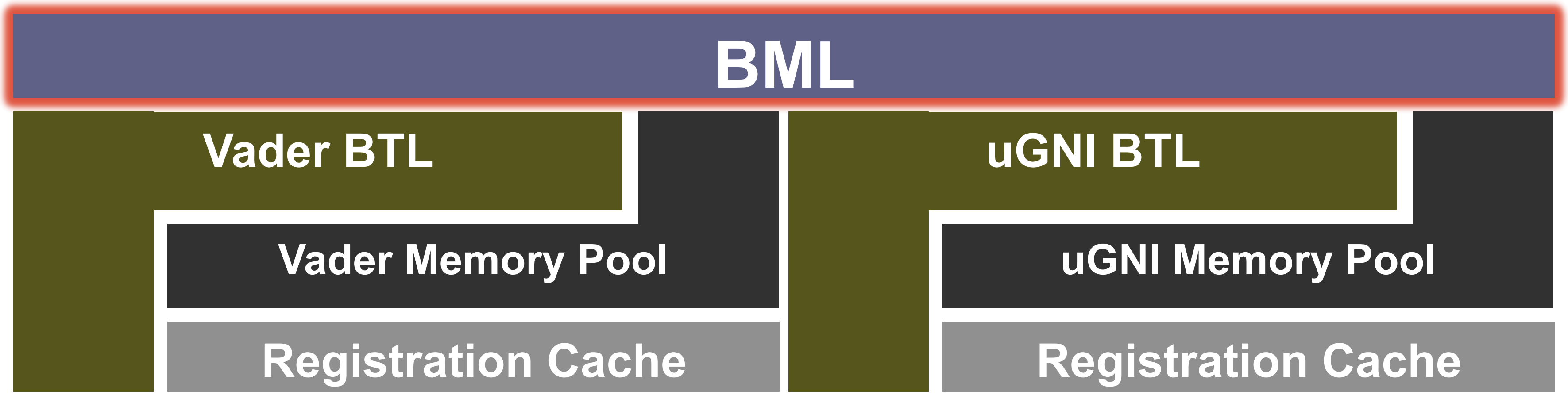
The Port: New BTLs

- **Kernel-Assisted (Single Copy) Shared Memory BTL**
  - Used Exclusively for Intra-Node Communication
  - Leverages XPMEM (http://code.google.com/p/xpmem/)
  - Currently Named *vader* in Development Trunk
- **Gemini BTL**
  - Used Exclusively for Inter-Node Communication
  - Leverages Cray's Generic Network Interface (uGNI)
  - Currently Named *ugni* in Development Trunk



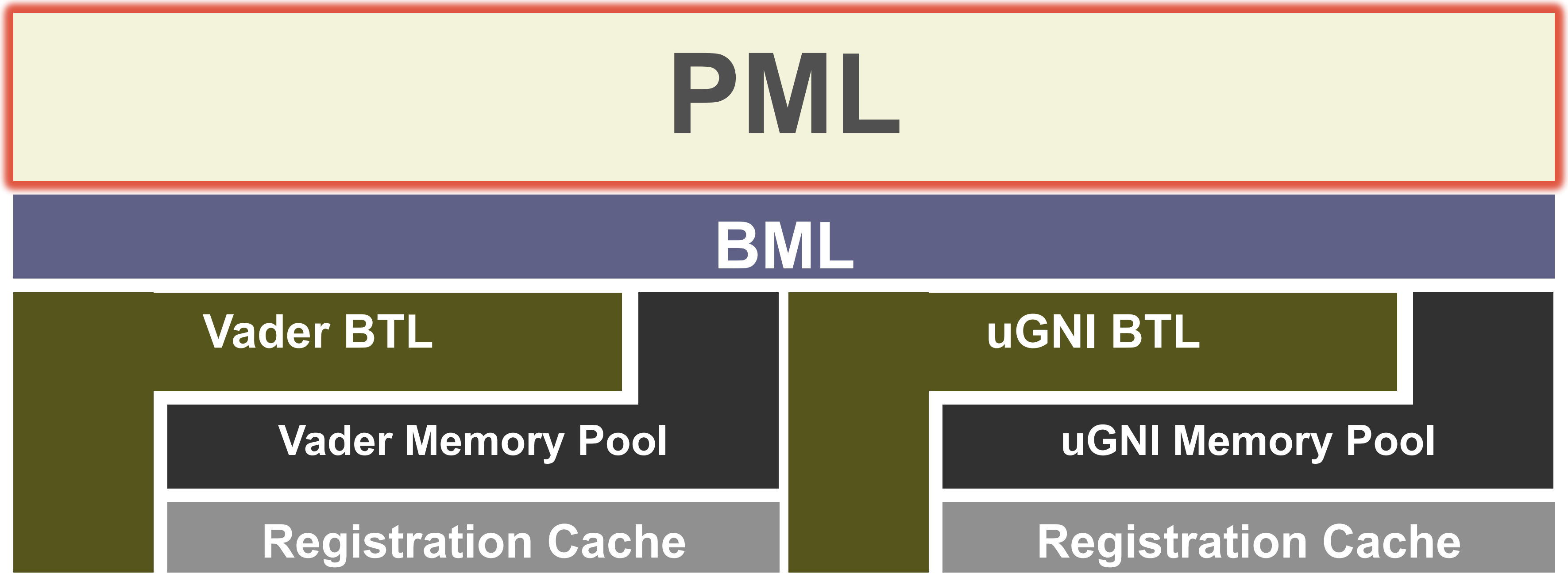
BTL Management Layer[1]

- Manages Multiple BTLs Within in Single Process
- No Modifications Needed for Port



Point-to-Point Management Layer[1]

- Provides Point-to-Point Functionality Required by the MPI Layer
- Minor Modification Required for Port



More About the XPMEM BTL - Vader

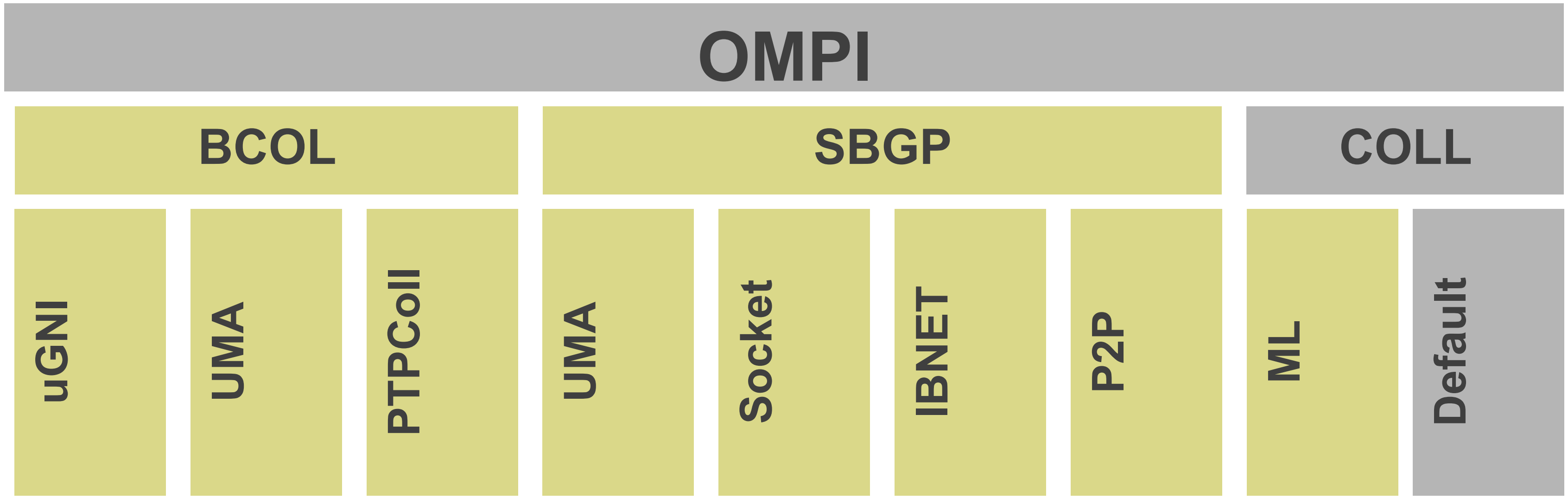
- **MPICH Nemesis-like Design**
  - Lock-Free Message Queues
  - “Fast Boxes” – I.e. Per-Peer Receive Queues for Short Messages
- **Copy Backend Changes Based on Message Size**
  - E.g. ***bcopy*** *[a,b)* - ***memcpy*** Otherwise
  - User Tunable with *Good* Defaults
- **Cross-Process Memory Mapping Allows for RDMA-Like Semantics**
  - Copy-In/Copy-Out (CICO) Avoided
  - No Backing Store Required
  - Heavy Use of Registration Cache
- **XPMEM Support Requires Kernel Patch and User-Level Library**
  - Already Available and Leveraged by Cray’s Native MPI Implementation

More About the uGNI BTL

- **Protocols**
  - Short Message – Fast Memory Access (FMA) Short Messaging (SMSG)
  - Medium Message – FMA RDMA
  - Long Message – Block Transfer Engine (BTE) RDMA
- **Lazy Connection Establishment**
  - Resource Utilization Directly Related to Application Communication Characteristics

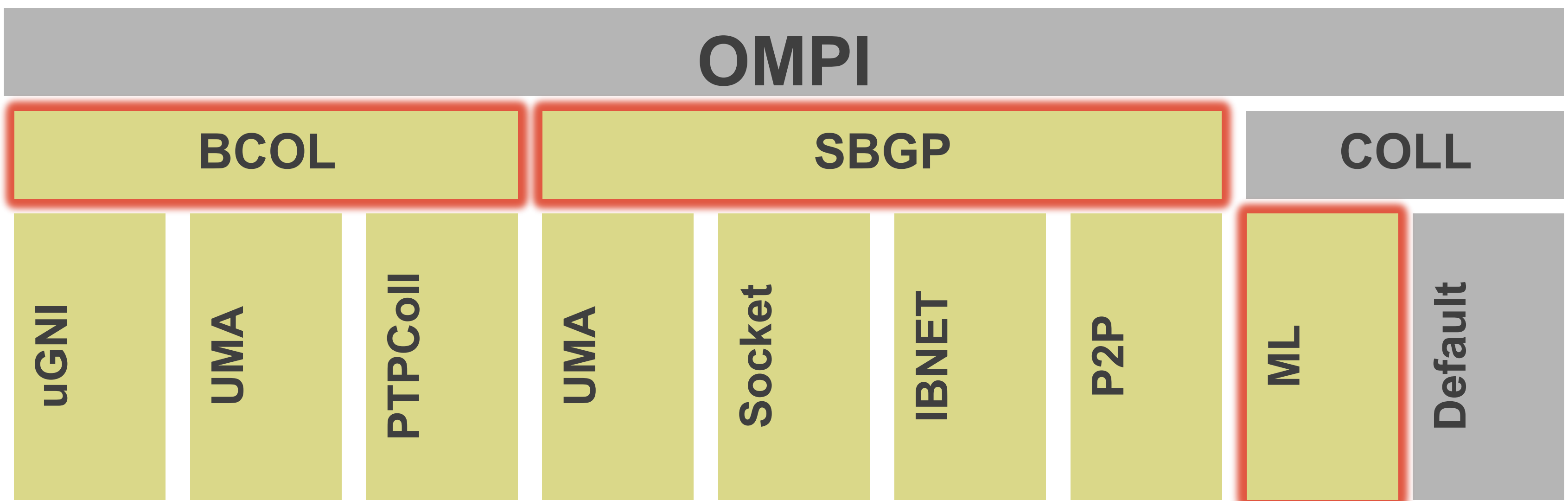
Improved Collectives: Cheetah[2]

- **ORNL's Cheetah – A Framework for Collective Operations**
  - Collectives Implemented with Collective Primitives
  - Each Primitive is Optimized for a Particular Communication Path
  - Progressed Asynchronously and Independently When Semantics Permit



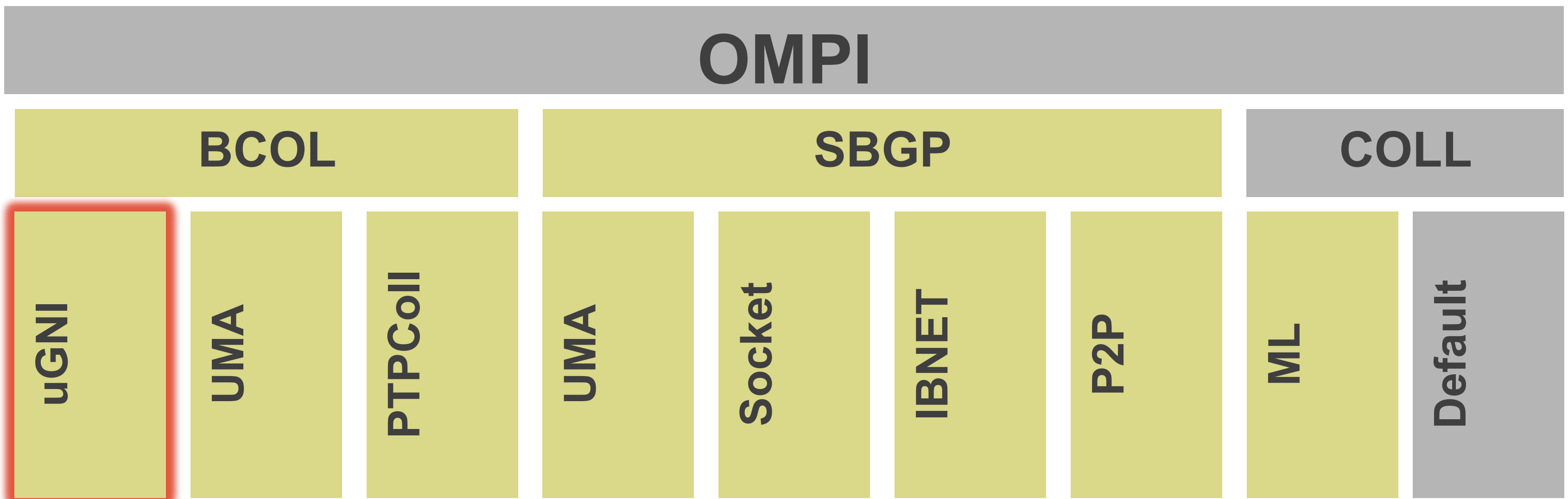
Improved Collectives: Cheetah^2

- Base Collectives (BCOL) – Implements Collective Primitives
- Subgrouping (SBGP) – Provides Process Grouping Rules
- Multilevel (ML) – Coordinates Collective Primitive Execution
- For Design and Implementation Details: See Cheetah Publications



Improved Collectives: uGNI BCOL Barrier

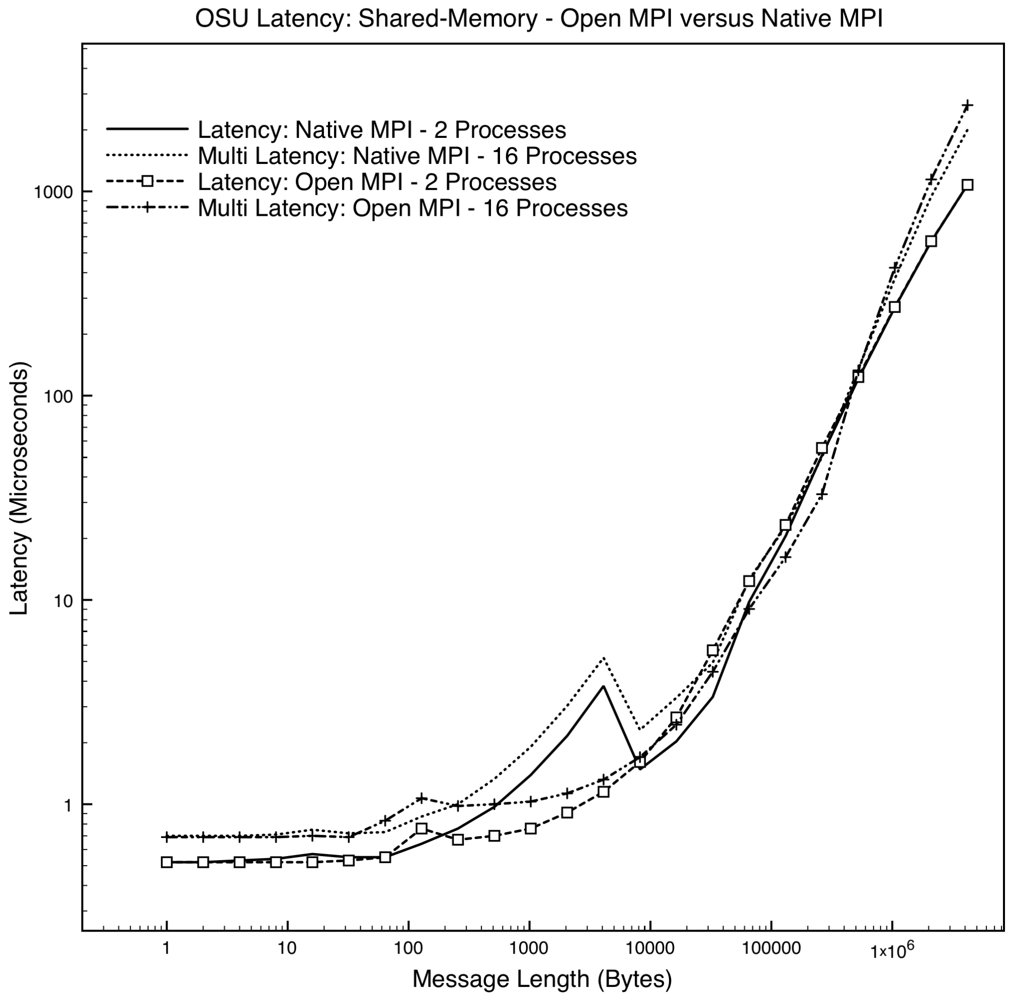
- **Implemented uGNI Cheetah Barrier**
  - Fan-In/Fan-Out Algorithm
  - Atomic Barrier Leverages Atomic Operations Provided by the uGNI Library
  - Currently Only Supports MPI_Barrier



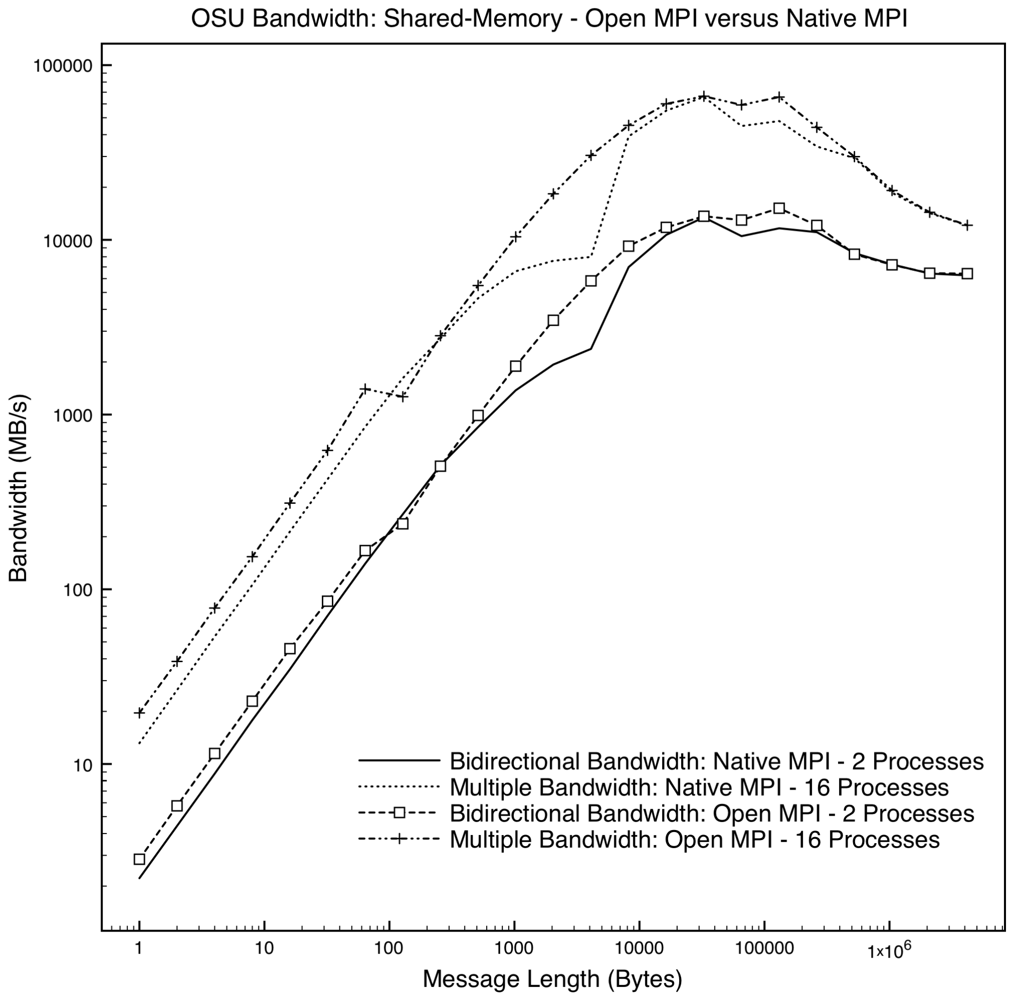
Performance Evaluation - Setup

- **Test Beds**
  - Cielo - 142,304 Core XE6
  - Enhanced Jaguar – 299,008 Core XK6
- **Point-to-Point Latency**
  - OSU's MPI Mico-Benchmark Suite – osu_latency & osu_multi_lat
- **Point-to-Point Bandwidth**
  - OSU's MPI Mico-Benchmark Suite – osu_bibw & osu_mbw_mr
- **Barrier Latency**
  - MPI_Barrier in a Tight Loop – Average Latency Reported

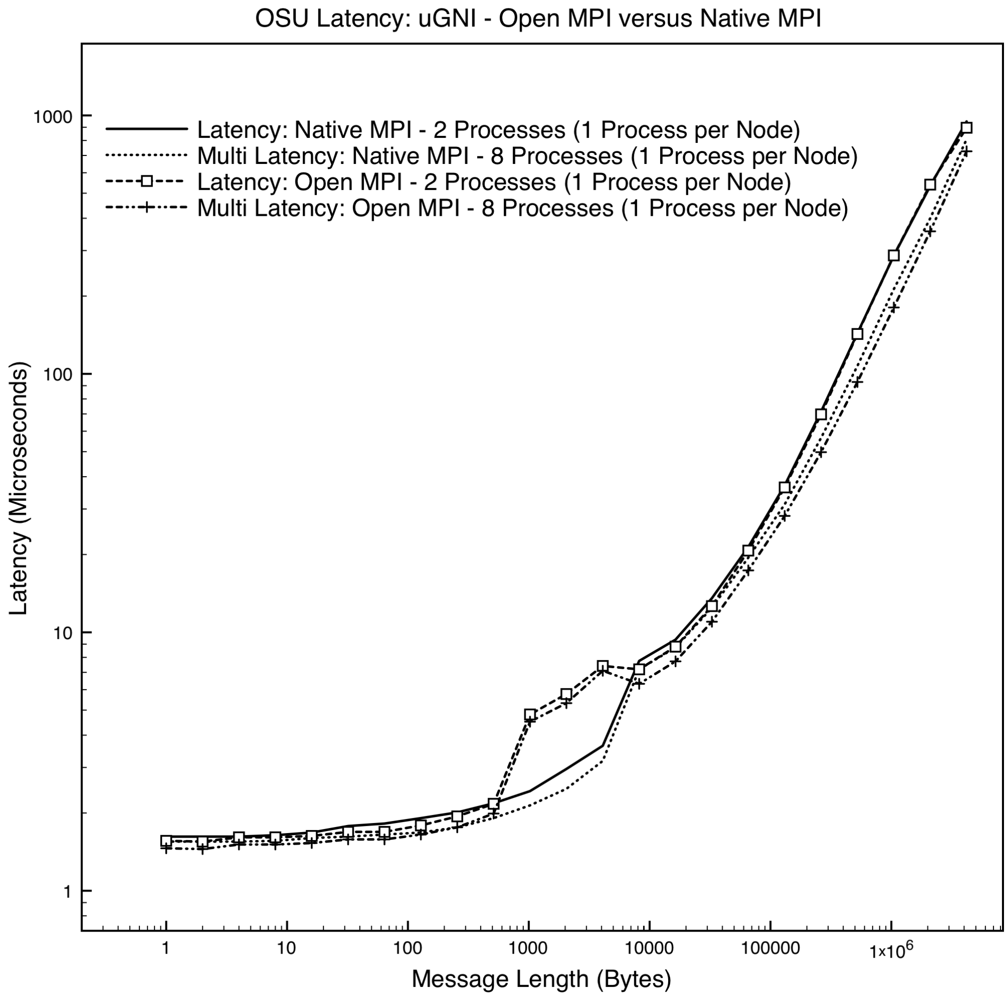
Vader Latency on AMD Magny-Cours



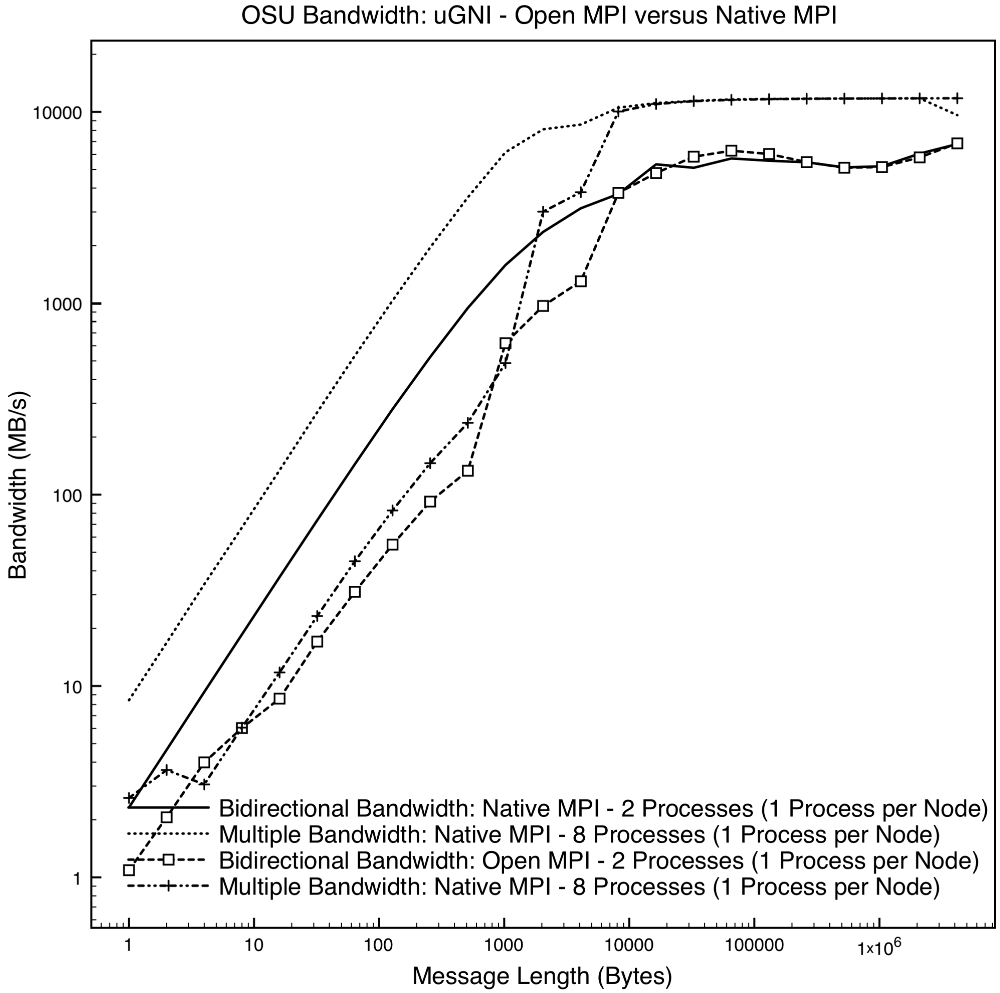
Vader Bandwidth on AMD Magny-Cours



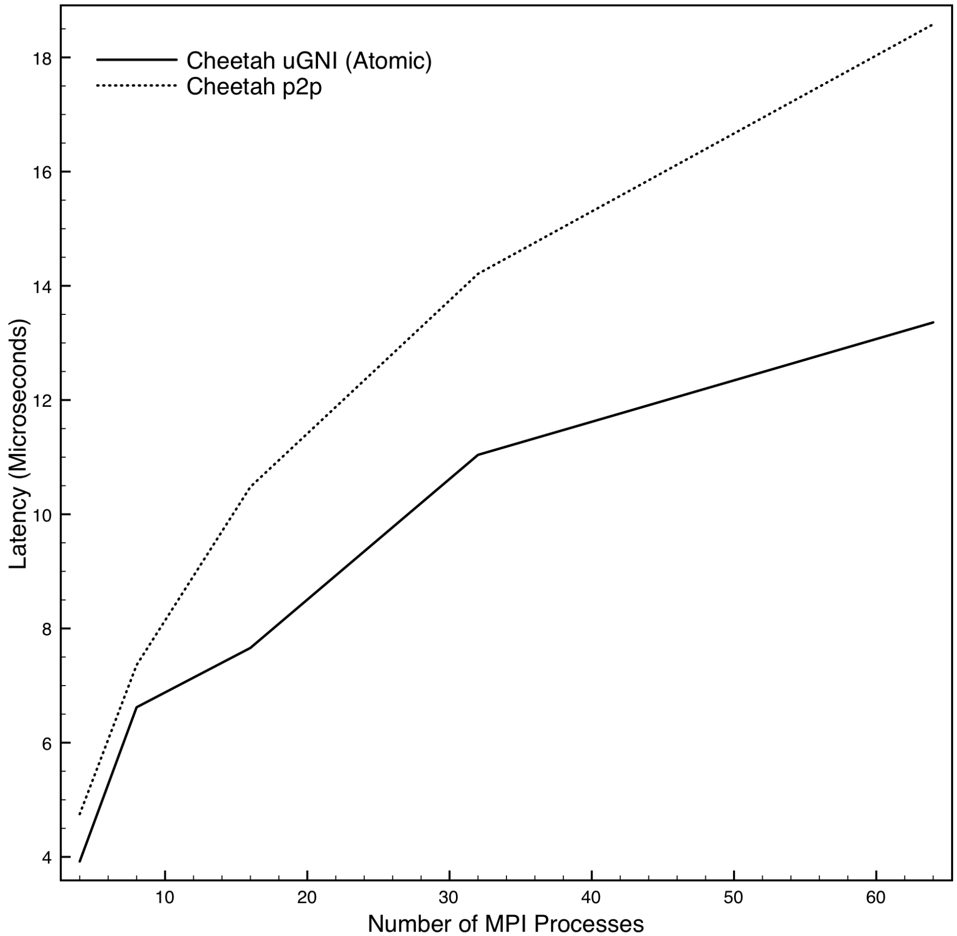
uGNI BTL Latency on XE6



uGNI BTL Bandwidth on XE6



Performance of Cheetah Barriers on XK6



Ongoing/Future Work

- **Point-to-Point Stabilization/Optimization**
  - Already Tested at 128k Processors (Cielo)
  - Investigating New Protocols
- **Continue Collectives Work**
  - Evaluate Performance and Scalability Characteristics of the Atomic Collective Operations at Larger Scales
  - Evaluate the Potential for Implementing Other Collective Operations Using the Atomic Collective Operations
- **Work with Friendly Testers**
- **Prepare for General Release**

Thanks!

Questions?

- Questions?
- Comments?

References

- [1] Open MPI. 13 Feb. 2012 <open-mpi.org>.
- [2] R. Graham, et al., "Cheetah: A Framework for Scalable Hierarchical Collective Operations," CCGRID 2011, 2011.
- [3] R. Alverson, et al., "The Gemini System Interconnect," in High Performance Interconnects (HOTI), 2010 IEEE 18th Annual Symposium on, Aug. 2010, pp. 83 –87.