Performance Evaluation of Open MPI on Cray XE/XK Systems

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Hot Interconnects 2012

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A Collaborative Effort
Outline

1. Open MPI Overview
2. Gemini Overview
3. Protocols Overview
4. Test Environment
5. Results
6. Conclusions/Future Work
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 APIs**
  - Verbs (Infiniband, RoCE, iWarp)
  - PSM (QLogic/Intel HCAs)
  - MXM (Mellanox HCAs)
  - Portals (Cray SeaStar, Infiniband)
  - uGNI (Cray Gemini, Cray Ares)
Open MPI’s Plugin Architecture – A High-level Overview

User Application

MPI API

Modular Component Architecture (MCA)

Framework
Component
Component
Component
Component
Component
Component
Component
Component
Component

...
Open MPI’s Plugin Architecture – Main Code Sections

- **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 Gemini System Interconnect\(^3\) – An Overview

- Network Used by the Cray XE and XK System Families
  - Titan, Cielo, Hopper

- Successor to the Cray SeaStar* Network Interconnect

- 3D Torus Network Built of Gemini ASICs

- Gemini ASIC
  - Provides 10 Torus Connections – 2 x (+X, -X, +Z, -Z) – 1 x (+Y, -Y)
  - Provides 2 NICs and a 48-port Router
OB1 PML High-Level Protocol Overview

- **Eager Message Protocol**
  - Uses BTL buffered, inline, and in-place send protocols

- **Remote Get Protocol**
  - 2 Protocol Messages: RGET (ready to send + segment), FIN
  - Available When Registration Cache is Enabled and BTL Implements Get

- **RDMA Pipeline Protocol (Put)**
  - 3 Protocol Messages: RNDV + segment, RDMA, FIN
  - Used When Remote Get protocol is not Available

- **Remote Get Fallback (New)**
  - Essentially a Rendezvous
  - Fallback Initiated by the Receiver During Remote Get Protocol if BTL Get Protocol is not Available

- **Rendezvous (no RDMA)**
uGNI BTL Overview

- **Protocols**
  - **Send**
    - In-place Send for Small Messages Directly Using Small Message Protocol (SMSG)
    - Buffered Send Using Get for Larger Eager Messages (Eager Get)
  - **Get**
    - Uses FMA Or BTE
    - Available Only if Source And Destination Segments Are 4-Byte aligned and a Multiple of 4-Bytes in Size
  - **Put**
    - Uses Fast Memory Access (FMA) or Byte Transport Engine (BTE)
    - No Alignment Restrictions

- **Lazy Connection Establishment**
  - Resource Utilization Directly Related to Application Communication Characteristics
uGNI BTL Eager Get Protocol Details (Send)

1. BTL Send Called
2. Size Larger Than SMSG Limit?
   - Yes: Send GET_INIT With SMSGSendwTag
   - No: Send Data Using SMSGSendwTag
3. Progress Remote MSG
4. RDMA COMPLETE
5. Send Complete
uGNI BTL Eager Get Protocol Details (Receive)

- OPAL Progress
- Progress Remote SMSG
  - GET_INIT
  - Size Smaller Than FMA Limit
    - No: Start RDMA GET
    - Yes: Start FMA GET
      - Progress Local FMA/RDMA CQ
      - Get Complete
      - Send RDMA_COMPLETE with SmsgSendwTag
      - Receive Complete
Vader BTL Overview

- 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 to Amortize Attach Latency
  - Exposes Both Put and Get Interfaces to PML Layer

- XPMEM Support Requires Kernel Patch and User-Level Library
  - Already Available and Leveraged by Cray’s Native MPI Implementation
Test Environment

- **Testing Platforms**
  - Cielito - 1088 Core XE6
  - Cielo - 142,304 Core XE6

- **Microbenchmarks**
  - NetPIPE – Measure Lat/BW Benchmark
  - AMG2006 – Algebraic Multi-grid Solver
  - LAMMPS – Classical Molecular Dynamics Code
  - All Microbenchmarks Were Run on Live Production System

- **Launcher**
  - orterun
NetPIPE Latency on XE6 (on ASIC)
NetPIPE Bandwidth on XE6 (on ASIC)
Microbenchmark – LAMMPS

LAMMPS ASC Benchmark for Scaled-size Lennard-Jones Liquid

Loop Time (100 Steps, Seconds)

Cores

Vendor MPI
Open MPI

Los Alamos National Laboratory
Operated by Los Alamos National Security, LLC for the U.S. Department of Energy’s NNSA
Microbenchmark – AMG2006

AMG2006 ASC Benchmark (3D 7-Point Laplace Problem on a Cube)
Conclusion and Ongoing/Future Work

- **Conclusion**
  - Bandwidth, Latency, and Scalability Similar to Vendor MPI Implementation

- **Stabilization/Optimization**
  - Improve Launch Scalability (Over a Minute to Launch 131072 MPI Tasks)
  - Investigating New Protocols (Shared Message Queue-- MSGQ)
  - Reduce Memory Requirements

- **Improved Collective Performance Using uGNI Atomics**

- **Work with Friendly Testers**

- **Prepare for General Release in Open MPI 1.7.0**
Thanks!
Questions?

- Questions?
- Comments?
References