Towards Architecture-aware Hierarchical Communication Trees on Modern HPC Systems

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Presentation Outline

- Introduction/Background
- Benchmark-level results for MPI_Allreduce and MPI_Bcast
- Application-level results
- Conclusion/Summary
Overview

• Modern multi-cores machines are complex
  • Hundreds of cores
  • Multiple levels of memory hierarchies

• Algorithms are based on abstract notion of the systems
  • E.g., An MPI rank participating in a broadcast

• Performance depends on software-level designs
  • How to map abstract notions used by algorithms on to real systems?

• Systems are changing and implementations are not able to cope-up
  • What happens to a socket-aware algorithm on a system with multi-NUMA and multi-CCX per NUMA e.g., ROME?
Motivation

• Problem-1
  • Implementations try to emulate the algorithms without notion of the hardware
  • Example: Processes (ranks) doing send/recv to replay a reduce-scatter allgather or recursive doubling Allreduce

• Problem-2
  • Implementations try to cater to hardware but not robust enough
  • Example: a socket-aware algorithm to minimize cross-socket traffic

• Observations
  • Modern systems have multiple levels of memories
    • Multiple coherence domains
  • Hardware should be the first-class citizen
    • Implementation should emulate the Hardware instead of abstract algorithms
    • High-level concepts should be translated for a given hardware first
OSMP (Optimized Shared Memory Processing)

- OSMP is an attempt to design shared memory communication on modern systems
- Design principle
  - "Hardware as a first-class citizen"
  - High-level algorithms should be machine-aware
- Key ideas
  - Software abstractions for hardware features e.g., topologies, distances, core-to-core communications
  - Software resources are placed on to coherence domains for locality.
  - Each hardware coherence domain has software resources e.g., synchronization flags, send/recv queues, etc.
  - Memories are local to coherence domains and tied up with hardware abstractions.
OSMP high level architecture

- The OSMP framework can be used by different communication runtimes
- Contains APIs for collective operations, abstractions for trees and other operations
- User implements high-level algorithms
  - Some are provided by default as well
- OSMP applies the high-level algorithms to internal abstractions
Implementing algorithms with OSMP using barrier as an example

- User implements “base-case” arrival and notify routines (assuming a group of processes)
  - Arrival used to tell the root process that every other process has reached the barrier
  - Notify used by the root process to tell every other process that it has received the “arrived” message
- OSMP takes the “base-case” implementation and runs it on every level of the abstracted tree
  - Essentially converts the “base-case” algorithm to a topology aware version by walking and executing it on a tree
  - Trees used by OSMP can be a regular hierarchy (NUMA, socket, system etc.) or “virtual”
Micro-benchmark results for MPI_Allreduce

CascadeLake 56ppn

- MPHOSMP
- MVAPICH2
- IntelMPI

Rome 128ppn

- MPHOSMP
- MVAPICH2
- IntelMPI

Up to 2X over base-case implementation

Power9 40ppn

ARM 48ppn

Message Size (bytes)

Latency (μs)
Micro-benchmark results for MPI_Bcast

CascadeLake 56ppn

Message Size (bytes)

Latency [us]

Rome 128ppn

Message Size (bytes)

Latency [us]

Power9 40ppn

Message Size (bytes)

Latency [us]

ARM 48ppn

Message Size (bytes)

Latency [us]

Up to 2.3X over base-case implementation
Application-level results

MiniAMR on Rome (Weak Scaling)

MiniAMR on CascadeLake (Weak Scaling)

AMG on CascadeLake (Weak Scaling)

Up to 18.8% improvements for 32 processes over base-case implementation for AMG on CascadeLake

Execution Time (s)

Number of Processes

MVAPICH2  IntelMPI  MPHOSMP

MVAPICH2  IntelMPI  MPHOSMP

MVAPICH2  IntelMPI  MPHOSMP
Conclusion and Future work

• Conclusion
  – Having simple algorithms are effective when the right abstractions are used
  – Designs extendable to future architectures by changing the topology trees – No change required with respect to algorithms

• Future work
  – Explore abstractions for other inter-process transfer mechanisms (such as XPMEM)
  – Add support for point to point and large message collectives
  – Extend topology and abstractions beyond the node (Example: Network Topologies)
Thank You!

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