WHITE PAPER

A Hardware-Accelerated MPI Implementation on SGI® UV™ 2000 Systems

June, 2012

Abstract

The SGI UV 2000 system has a rich set of hardware features that enable scalable programming models to be implemented with high efficiency and performance. In particular, the popular Message Passing Interface (MPI) programming model has been implemented to utilize the MPI hardware acceleration features included in the UV 2000 system. This paper describes the hardware-accelerated features of SGI UV 2000 MPI and shows the performance gains achieved by their use.

1.0 Introduction

One of the most interesting aspects of the SGI UV 2000 coherent shared memory processor (SMP) system is the size of the system—up to 2,048 cores (4,096 threads) —that can exist within a single Linux® OS instance. Such a "Big Brain" provides many potential parallel programming strategies. Techniques used on SMP systems like OpenMP and threaded access to shared memory segments are every bit as useful on scale-up UV 2000 systems as the popular MPI parallel programming model or other cluster-friendly programming models such as SHMEM™, UPC and other PGAS languages. Clearly, the UV 2000 system hardware supports much flexibility in parallel programming.

Nevertheless, MPI is the predominant scalable parallel programming model in the technical compute industry, and SGI UV 2000 hardware and administrative software have been engineered to meet the demanding performance needs of MPI users. This is true whether the user is running within a single SGI UV system (e.g. essentially one logical fat node), or a larger system built from multiple partitions. MPI is crucial to supporting the most scalable applications on the largest scale-out multi-partition UV 2000 systems, where many partitions are connected via NUMAlink® 6 interconnect and the system size can grow up to 256K processor cores. Such systems are clusters of large SMPs, and a natural way to program a parallel application to run across the system is through the use of MPI.

2.0 SGI UV 2000 MPI Software Stack

The SGI MPI software stack includes a number of software components. These software items are available from SGI via the SGI MPI product bundle. A list of the most significant components follows

- **MPI.** Libraries and commands to build and run MPI programs.
- **XPMEM.** This library and kernel module provides shared memory mapping for processor access and global memory mapping for references by the UV MPI Offload Engine (MOE) component known as the Global Reference Unit (GRU).
- **GRU Development Kit.** These libraries provide the API to directly control the global memory reference and MOE operations supported by the UV ASIC that implements MPI messages, DMA and synchronization.
- **NUMA tools.** The dplace and omplace commands pin processes and threads in MPI programs and MPI/OpenMP hybrid programs onto CPUs. The dlook command can display a process address space complete with NUMA placement information.
- **PerfBoost.** This tool allows you to run applications that have been compiled for many popular MPI implementations with UV 2000 acceleration features activated.
- **Perfcatcher.** A runtime profiling tool that reports on MPI and SHMEM function calls made.
- **MPInside.** An advanced MPI profiling and performance visualization tool optimized to use run-time state instead of excessively large trace files.

3.0 Dual Transport Methods

Because the scale-up SGI UV 2000 is a single SMP, MPI message queues and synchronization constructs can be implemented by memory reference via processor mapping of memory throughout the system. This approach is generally taken in the industry for best MPI performance within SMPs in general, and SGI MPI takes advantage of this technique as well. The SGI implementation has evolved and improved as it moved from one large SGI distributed memory SMP system to another over the years. Distributed memory support started with the SGI Origin® line of computer systems, continued in the SGI Altix® 3700 and 4700 lines, and most recently has been provided in the latest generation SGI UV 2000. Rich and robust handling of NUMA architectures has come out of this process of continued improvements.

One major hardware feature sets the UV class apart from earlier SGI NUMA computer systems, and opens the door to MPI acceleration and offload as well as efficient PGAS programming model support—MOE, or MPI Offload Engine. The MOE provides MPI message queues, innovative synchronization primitives and advanced RDMA capabilities such as strided and indexed global memory updates. The MOE provides a way to optimize MPI within a UV 2000 system, whether it is running as a an SMP machine or as a larger multi-partition (NUMAlink cluster) system. SGI MPI uses run-time heuristics in point-to-point and collective communication to choose the appropriate communication mode, either shared memory or MOE-based.

Within a single SGI UV 2000 SMP, all MPI process pairs can use either shared memory or MOE transport. Nearby nodes or in-cache messages are best suited for shared memory message passing because the latency is extremely low using this communication method. Distant nodes or messages larger than 400KB are good fits for MOE transport. The incremental latency per interconnect hop is much lower with MOE transport than with traditional shared memory.

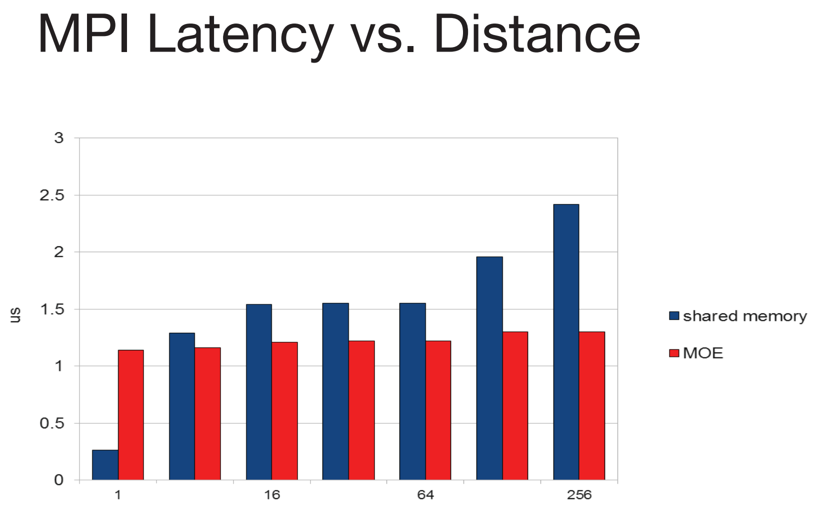
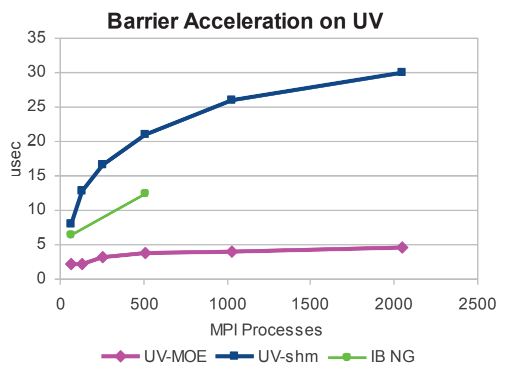


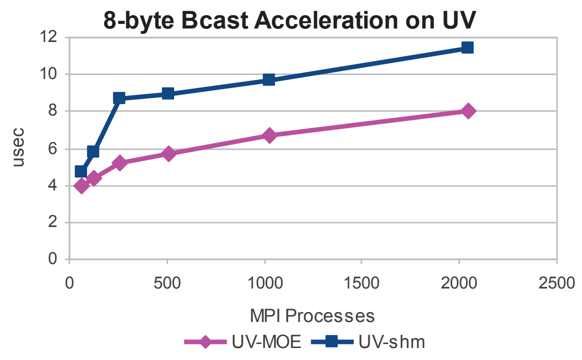
Figure 1: MPI Latency on an SGI UV 2000 System for Shared Memory and MOE Transport vs. Distance

4.0 SGI UV 2000 Hardware Accelerates MPI Collectives

The SGI UV 2000 MOE implements atomic memory operations in conjunction with a hardware multicast facility that helps to accelerate MPI_Barrier, MPI_Bcast and MPI_Allreduce. All of these collectives benefit from the multicast feature, and MPI_Barrier further benefits from the way the multicast feature is triggered by certain barrier counter variable updates.

The acceleration of these collectives is a compelling advantage for applications that run with large process counts. As the process count increases, the time spent in these collectives can grow while the overall time for the application decreases. The result is a greater dependency on performance of these collectives.





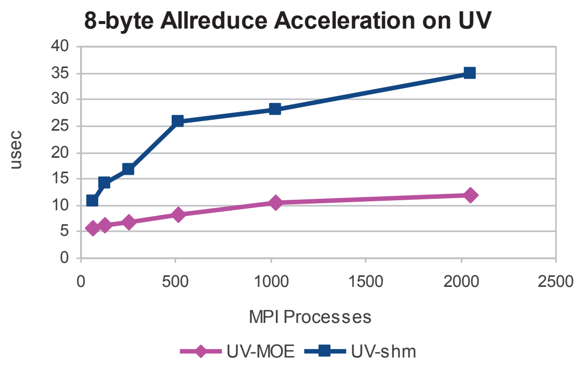


Figure 2: Accelerated MPI Collectives on SGI UV System

5.0 Conclusion

The SGI UV 2000 system has been designed to accelerate MPI point-to-point and collective communication. The MPI acceleration is performed by the UV MPI Offload Engine through hardware-implemented message queues, innovative hardware synchronization primitives and hardware multicast. The UV 2000 MPI implementation achieves a very flat MPI latency curve vs. distance, and offers industry-leading performance on some commonly used MPI collective communication operations.

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