

Towards Efficient Many-Task Computing on Accelerators in High-End Computing Systems

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Abstract—Current software and hardware limitations prevent Many-Task Computing (MTC) workloads from leveraging hardware accelerators boasting ManyCore Computing architectures. This work aims to address the programmability gap between MTC and accelerators, through the innovative CUDA middleware GeMTC. By working at the warp level, GeMTC enables heterogeneous task scheduling and 10x number of workers compared to CUDA. In order to span multiple accelerators across nodes, we have adopted the Swift parallel programming system, which can both support fine grained millisecond tasks and extreme scale supercomputers at 100K-cores.

Keywords—Many-Task Computing, Swift, GPGPU, CUDA

I. INTRODUCTION

This work aims to provide an integration between data-flow driven parallel programming systems (e.g. Many-Task Computing - MTC) and hardware accelerators [1] (e.g. NVIDIA GPUs, AMD GPUs, and the Intel MIC). MTC aims to bridge the gap between two computing paradigms, high throughput computing (HTC) and high-performance computing (HPC). MTC emphasizes using many computing resources over short periods of time to accomplish many computational tasks (i.e. including both dependent and independent tasks), where the primary metrics are measured in seconds.[2] Swift is a particular implementation of the MTC paradigm, and is a parallel programming system that has been successfully used in many large-scale computing applications. [3] The scientific community has adopted Swift as a great way to increase productivity in running complex applications via a dataflow driven programming model, which intrinsically allows implicit parallelism to be harnessed based on data access patterns and dependencies. Swift is a parallel programming system that fits the MTC model, and has been shown to run well on tens of thousands of nodes with task graphs in the range of hundreds of thousands of tasks. This work aims to enable Swift to efficiently use accelerators (such as NVIDIA GPUs and Intel MIC) to further accelerate a wide range of applications, on a growing portion of high-end systems.

II. GEMTC

Currently CUDA developers may only have a maximum of 16 kernels running concurrently, one kernel per streaming multiprocessor (SM). The problem is that all kernels have to start and end at the same time, causing extreme inefficiencies

in heterogeneous workloads. By working at the warp level we trade local memory for concurrency and we are able to run up to 84 concurrent kernels. [4] This middleware allow independent kernels (MIMD style) to be launched and managed on many-core architectures that traditionally only support SIMD. [5] In Figure 1 Swift/T is calling the GeMTC API and passing tasks into memory on the device. Warp workers pick up those tasks, execute with the given parameters and place results on an outgoing result queue. This execution model is shown in further detail in Figure 2. Finally, Swift/T will poll the device return results from the result queue back to the appropriate task in the swift script. Figure 3 is a GK110 block diagram as presented by NVIDIA. [6] This diagram demonstrates how the current generation GPUs have O(10) Streaming Multiprocessors (SMX), O(100) Warps, and O(1000) cores.

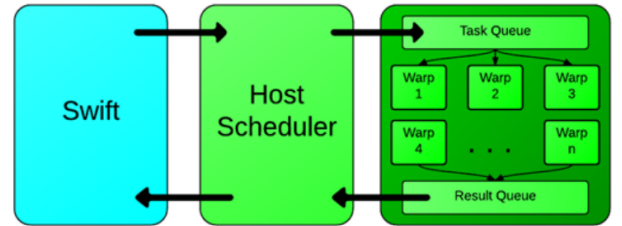


Fig. 1. Flow of a task through Swift/T and GeMTC.

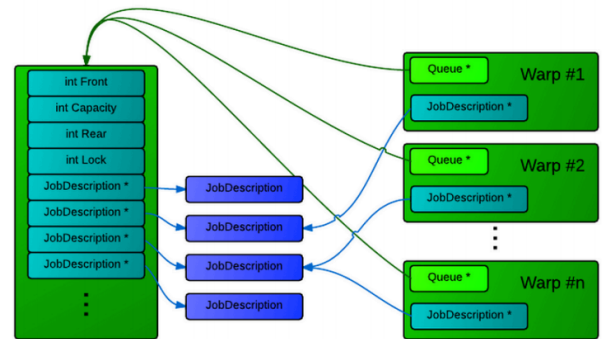


Fig. 2. Worker interaction with incoming work queue.



Fig. 3. Kepler GK110 full chip block diagram.

III. SWIFT/T

Swift is an implicitly parallel scripting language. By operating on data-flow driven scheduling of parallel tasks Swift is capable of extracting parallelism out of an application. The distributed executor eliminates centralized bottlenecks and an optimized compiler detects errors ahead of runtime for improved efficiency. Swift has been shown to scale over 100k cores and is portable to most MPI-based clusters. Finally, it's familiar C/Java like syntax makes it easy for developers to quickly understand language constructs. The diagram in Figure 4 demonstrates the 4 portions of the Swift stack which contains (1)A high level Swift Script, (2)A compiler, namely STC, to generate (3)An intermediate code and (4)Execution of the intermediate code. The most recent version of Swift, namely Swift/T, supports function calls.[7] This work also presents a novel API to allow interaction between GeMTC and Swift/T. By integrating the GeMTC middleware into the Swift/T stack Swift is capable of calling C wrapper functions to CUDA kernels/applications directly.

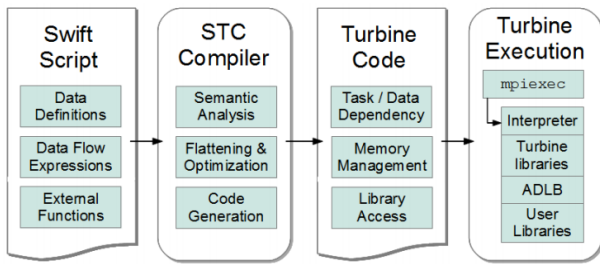


Fig. 4. Overview of Swift/T toolchain.

IV. PRELIMINARY RESULTS

V. CONCLUSIONS AND FUTURE WORK

Designed GeMTC Framework Improved Memory Management Integrated GeMTC + Swift/T Evaluated Synthetic Benchmarks

Abstract for other Accelerators Evaluate Real Applications Improve Current Performance

Efficiency of 1 Worker

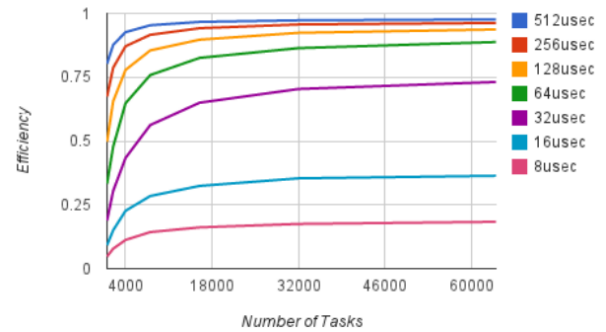


Fig. 5. GeMTC efficiency from launching a single worker on the GPU.

Efficiency of 84 Workers

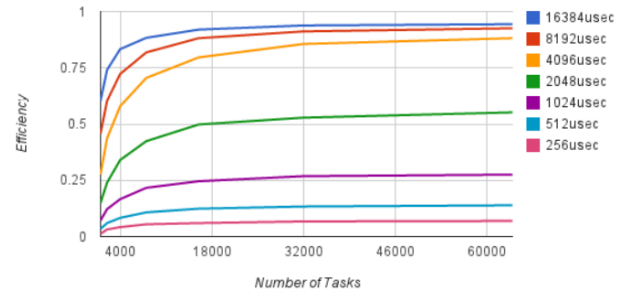


Fig. 6. GeMTC efficiency launching maximum workers on GTX680.

We plan to continue to push the performance envelope by enabling many MTC applications and systems to leverage the growing number of accelerated high-end computing systems. We also expect this work to enable other classes of applications to leverage accelerators, such as MapReduce and ensemble MPI. We also hope to influence future accelerator architectures by highlighting the need for hardware support for MIMD workloads.

VI. PROBLEM STATEMENT

VII. DESCRIPTION OF NOVEL APPROACH

We are also currently evaluating a real biochemistry application, namely the Open Protein Simulator (OOPS), which builds on the Protein Library (PL). OOPS is multipurpose and allows extensions to perform various simulation tasks relevant for life scientists, such as protein folding or protein structure prediction.[8] We have taken parts of this application and ported to NVIDIA GPUs via the CUDA programming language, in order to accelerate OOPS computations via Swift. We already have preliminary results in the costs associated with managing and launching concurrent kernels on NVIDIA FERMI GPUs, through the Swift system. We expect our results to be applicable to many HPC resources where GPUs are now common. For example the June 2012 Top 500 machines that are GPU enabled include Tianhe-1A, Jaguar, and Nebulae. Currently, Swift can only utilize the general processors on these machines to execute workloads and the GPUs are left idle. We will also explore many more applications from

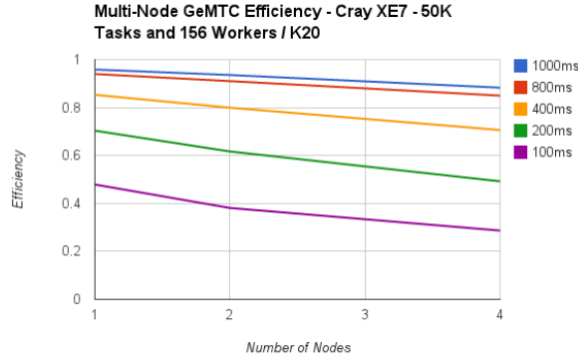


Fig. 7. GeMTC + Swift/T efficiency on 4 XK7 nodes.

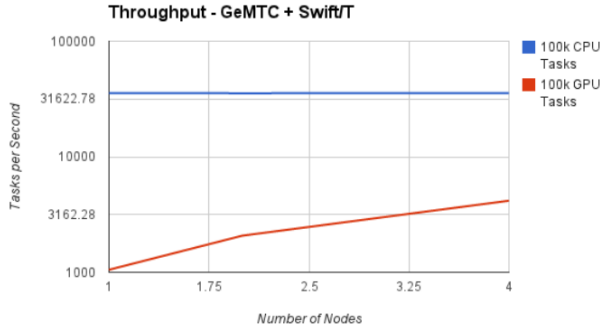


Fig. 8. GeMTC + Swift/T throughput on 4 XK7 nodes.

different domains, such as medicine, economics, astronomy, bioinformatics, physics, and many more.

VIII. CONTRIBUTIONS

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