Public Abstract

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Title:Critical Study of Parallel Programming Frameworks for Distributed Applications

Parallel programming frameworks such as the Message Passing Interface (MPI), Partitioned Global Address Space (PGAS) languages, Charm++, Legion and High Performance Parallel X (HPX) have been used in several scientific domains – such as bioinformatics, physics, chemistry, and others – to implement distributed applications. These frameworks allow distributing data and computation across the different nodes (or machines) of a high-performance computing cluster. However, these frameworks differ in their programmability, performance, and suitability to different cluster settings. For example, some of these frameworks have been designed to support applications running on homogeneous clusters that include only general purpose CPUs, while others offer support for heterogeneous clusters that include accelerators, such as graphics processing units (GPUs). Hence, it is important for programmers to select the programing framework that is best suited to the characteristics of their application (i.e. its computation and communication patterns) and the hardware setup of the target high-performance computing cluster.
This thesis presents a critical study of established and new parallel programming frameworks, including MPI, PGAS-based languages (OpenSHMEM, Chapel, X10, UPC), Cham++, Legion, HPX, and Inter-node Virtual Memory (IVM) – a programming system designed and developed at University of Missouri. I first investigate the main features of these programming systems: their memory model, their support for synchronization, their dependencies handling, their mechanisms for dynamic memory allocation, their scalability, their execution model, and their GPU support. I then analyze how these features affect programmability and performance on heterogeneous clusters and for benchmark applications exhibiting different computation and communication patterns. Finally, I develop a benchmark suite where each application is encoded using several programming systems (MPI, Charm++, IVM and OpemSHMEM). The goal of this study is two-fold: first, I want to provide programmers with guidance on the selection of the programming framework which is best suited for their application and cluster setup; second, I aim to provide guidelines for further development of existing and new parallel programming frameworks for distributed systems.