Programming Heterogeneous-ISA Platforms with Popcorn Linux OS and Compiler Framework

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Abstract

Computer systems are increasingly heterogeneous. Beside classic heterogeneity, CPUs of different instruction set architectures (ISAs) are being integrated on the same platform, including SoC, single machine, data-center, and at the edge. A programmer wanting to leverage such platforms is challenged by the fact that each ISA-different processor runs its own software stack. Although being part of the same system, each ISA-different processor ends up acting like an independent system. A fundamental limitation of current software is that applications started on one software stack cannot be migrated to another due to the ISA difference, limiting resource management, which negatively affects system-level properties such as performance and energy consumption.

The Popcorn family of projects [2, 3, 5] attack this problem by enabling users to exploit platforms with heterogeneous-ISA CPUs. Popcorn provides the familiar abstraction of a shared memory multiprocessor, enabling thread-level, process-level, and VM-level migration across ISA-different CPUs. This is achieved by a new compiler toolchain, runtime, OS, and VMM, which taken together, enable applications to execute on heterogeneous-ISA CPUs with minimal modifications. This tutorial introduces Popcorn Linux OS and Compiler Framework first, then shows how to compile, run, and map applications among heterogeneous CPUs.

1 What Popcorn OS and Compiler are?

The Popcorn Linux OS and Compiler Framework enable an application to be natively compiled into a new binary format that can be executed on CPUs of diverse ISAs. Since Popcorn requires minimal or no application code changes with respect to standard SMP, the ensuing programmability is high. Additionally, application execution can be migrated across ISA-different CPUs at run-time at the level of threads, processes, and virtual machines (VMs). Run-time execution migration enables flexible resource management, yielding improved performance, energy efficiency, etc. In contrast to Popcorn, managed languages such as Java and Python – ISA agnostic, don't natively allow run-time cross-ISA migration.

2 Why Popcorn OS and Compiler?

Popcorn Linux OS and Compiler Framework were introduced in 2014 [2] and firstly demoed at SOSP 2015, showing that natively compiled binaries can be migrated between ARM and x86 CPUs, with minimal overhead. In 2015, it was not clear that platforms with heterogeneous-ISA (general-purpose) processing units will become largely popular. However, today, many systems are being built with heterogeneous-ISA general-purpose processors. Examples include the cloud [3] and the edge, populated with ARM and x86 machines, and enterprise servers that integrate x86 host CPUs and smartNICs/smartSSDs powered by ARM CPUs [1]. Moreover, academia is developing heterogeneous-ISA CPUs [4].

3 Goals

The overarching goal of this tutorial is to demonstrate how platforms built with heterogeneous-ISA (general-purpose) processing units, such as ARM and x86, can be programmed like an SMP machine (i.e., a multicore) with Popcorn. The learning goals are: a) understanding the fundamentals of Popcorn Linux OS and Compiler Framework; b) how to write, compile, and run an application; c) how to orchestrate application migration among heterogeneous-ISA CPUs.

4 Organization

The tutorial briefly covers Popcorn project's motivations, goals, and history at first. Popcorn Linux OS and the Popcorn Compiler Framework (based on LLVM) are then overviewed. Afterwards, the tutorial switches from a lecture format to a lab format. A first hands-on session will introduce the Popcorn environment, a second session will demonstrate multiple versions of a "Hello World" application on Popcorn, and a final session will explain how to orchestrate thread, process, and VM migration with Popcorn – all of these, on a heterogeneous-ISA CPUs platform.

References

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