xBGAS: An Address Space Extension for Scalable High Performance Computing

1Xi Wang, 2John D. Leidel, 1Brody Williams, 3Alan Ehret, 3Miguel Mark, 3Sahan Bandara, 3Michel Kinsky, 1Yong Chen
1Texas Tech University, 2Tactical Computing Laboratories, 3 Texas A&M University

Abstract
Given the recent reemergence of advanced memory and device interconnection technologies such as CCIX, GenZ and OpenCAPI, we have witnessed a resurgence in interest in extending local node addressing to remote devices and storage. This interest is especially prominent in high performance computing and high performance analytics communities as the need to exploit high bandwidth, low latency messaging techniques is critical to constructing scalable, efficient computing platforms.

xBGAS is designed as a bridge extension for the RISCV ISA, that extends the base 32/64 bits addressing in RV32I and RV64I to 64/128 bits, respectively with an extended set of registers and instructions. The goal of this extensible model is providing high-performance inter-node communications via highly efficient micro-architecture design and advanced scalable shared memory programming environments.

Introduction
Given the recent reemergence of extended memory interconnection technologies such as GenZ [1], CCIX [2] and OpenCAPI [3], architects in high performance computing (HPC) and high performance analytics (HPA) have sought to exploit these interconnection methodologies for extended or partitioned addressing across device and system architectural domains. However, we have yet to see a commercial architecture with native extended addressing capabilities in the ISA garner wide adoption.

Therefore, the Extended Base Global Address Space (xBGAS) extension is introduced to provide extended addressing capabilities beyond the core 64-bit addressing modes in the base RISC-V ISA for HPC. The introduced extended memory models can be potentially utilized in the HPC-PGAS, Security, Distributed file systems, HPC-FLAT, MMAP-I0, CloudBSP, etc. [4].

In this poster, we introduce the xBGAS extension in terms of:

- xBGAS architecture design
- ISA extension (xBGAS instructions, registers, etc.) [5]
- xBGAS software toolchains [7]

xBGAS Design
1. One-sided Communications
   - Memory semantics remote data accesses
   - Kernel bypassing and zero remote CPU involvement
2. Micro-architecture Support
   - Extended architecture
   - RISCV ISA extensions
3. Extended Addressing Capability
   - Global address space mapped to extended address bits
   - Machine-level runtime support for scalable shared memory programming model.

Architectures
Arbiter arbitrates requests to the local memory system if extended address is 0. Otherwise, it is a remote request

Object Lookaside Buffer (OLB) is a lookup table that maps shared data objects into extended addresses space

ISA Extension

Register Extensions

Symmetric Shared Memory Management

32 Extended Registers: e0 ~ e31 [4]