Parallel Programming Models on Ookami

Tony <anthony.curtis@stonybrook.edu>
Ookami User Group Meeting 2023

Parallel Programming Models on Ookami

- Ookami is a high performance computing (HPC) cluster of Fujitsu A64FX processors
  - It only has CPUs, not GPUs!
  - Nodes connected with Infiniband

- So how do we program the system?
- Let’s take a look at the nodes
Ookami User Group Meeting 2023

Parallel Programming Models on Ookami
Ookami User Group Meeting 2023

Parallel Programming Models on Ookami

![Diagram of Ookami machine architecture]

Host: fj099
Date: Fri 10 Feb 2023 01:58:32 PM EST
Ookami User Group Meeting 2023
Parallel Programming Models on Ookami

• Ookami’s compute nodes have an interesting architecture:
  – 4 NUMA groups (Core Management Groups) of 12 processors
    • Each CMG has 8GB of high bandwidth memory (HBM)
  – On-chip communication ring that connects all the groups & memories
  – Groups 0 and 1 are paired, 2 and 3 are paired
    • Communication metrics are
      – 10 to self
      – 20 to pair/twin
      – 30 to other

fj-debug1$ numactl -H
node   0   1   2   3
0:  10  20  30  30
1:  20  10  30  30
2:  30  30  10  20
3:  30  30  20  10
Ookami User Group Meeting 2023

Parallel Programming Models on Ookami

• Which parallel programming models are available?
• Let’s break it down into 1 node and many nodes…
Ookami User Group Meeting 2023
Parallel Programming Models on Ookami

• On 1 node
  – Threads (low-level)
    • Pthreads
      – Linux/POSIX standard
      – Basis of most OpenMP implementations
    • Qthreads
      – Alternative from Sandia
      – E.g. implementation choice in Chapel
Parallel Programming Models on Ookami

• On 1 node
  – OpenMP & compilers for C, C++, Fortran
    • GCC
      – -fopenmp
    • ARM
      – -fopenmp
    • Fujitsu
      – -Kopenmp (traditional mode) and/or -fopenmp (Clang mode)
    • Cray
      – -homp and/or -fopenmp (newest version)
    • NVIDIA
      – -fopenmp
Ookami User Group Meeting 2023
Parallel Programming Models on Ookami

- On many nodes
  - MPI
    - Open-MPI
      - Has multiple modules that understand both intra- and inter-node communication, uses UCX
        » e.g. XPMEM, KNEM, Infiniband, TCP, Collectives
      - We have builds with different compilers, esp. for different Fortran capabilities (e.g. for LLVM/ARM flang)
  - De-facto wrapper names: mpicc, mpicxx, mpif90
Parallel Programming Models on Ookami

- On many nodes
  - MPI
    - MVAPICH2
      - The well-known MPI implementation from Ohio State
      - Integrated with SLURM, launch via `srun` not `mpirun/mpiexec`
    - We have versions installed by Cray for use with their compilers, and local “vanilla” versions
Ookami User Group Meeting 2023
Parallel Programming Models on Ookami

• On many nodes
  – MPI
    • MPICH
    – One of the “original” MPI implementations from Argonne (ANL)
    – Also supports various intra- and inter-connects, via UCX or libfabric
  – N.B. Cray’s MPI on their “big” machines is based on MPICH, but this isn’t it!
On many nodes
  - MPI
    - Fujitsu
      - Vendor-customization of Open-MPI
        » Meant mostly for the TOFU interconnect
        • E.g. as on Fugaku
          » But also works on Infiniband
      - Custom wrappers: can confuse build systems
        » mpifcc, mpiFCC, mpifrt
Ookami User Group Meeting 2023

Parallel Programming Models on Ookami

• On many nodes
  – OpenSHMEM
    • Available as part of Open-MPI
      – Accent on sparse/irregular 1-sided communication
        » Put/get data with no corresponding receive call
        » Relaxed synchronization
Both? YES!

- Hybrid: usually known as MPI + X
  - MPI to distribute work across nodes
  - OpenMP (often the “X”) to parallelize computation on a node
- Ookami is a great target for this model
  - Understand thread and process placement
  - Ask on Slack any time, and visit office hours for hands-on
Parallel Programming Models on Ookami

• On many nodes
  – Chapel
    • Programming language from HPE/Cray
    • High-level local- and global-views of parallelism
      • https://www.stonybrook.edu/commcms/ookami/support/index_links_and_docs.php
Ookami User Group Meeting 2023
Parallel Programming Models on Ookami

• Newer languages/environments to consider/test
  – Chapel (HPE/Cray language) *ookami modules*
  – Kokkos (a64fx-aware!) *ookami modules*
  – Legion/Regent
  – Go
  – Rust
  – Julia (a64fx-aware!) *ookami modules*
  – Native C++ parallelism
Ookami User Group Meeting 2023

Parallel Programming Models on Ookami

• Stony Brook’s community involvement?
  – Barbara Chapman’s group is involved in:
    • OpenMP ARB
    • LLVM (clang and GPU-offload friends)
    • SPEC HPG benchmarks
    • PMIx, PRRTE, XPMEM, UCX, Open-MPI

• OpenACC (not overly relevant for Ookami)
Ookami User Group Meeting 2023
Parallel Programming Models on Ookami

• Selected links
  – https://www.open-mpi.org/
  – https://mvapich.cse.ohio-state.edu/downloads/
  – https://www.mpich.org/downloads/
  – https://www.openmp.org/
  – https://chapel-lang.org/
  – https://kokkos.github.io/
  – https://legion.stanford.edu/
  – https://www.stonybrook.edu/commcms/ookami/support/faq/ookami-fujitsu-compilers
  – http://www.openshmem.org/