GASNet-EX at Lawrence Berkeley National Lab (gasnet.lbl.gov)

- GASNet-EX: communications middleware to support exascale clients
  - One-sided communication – Remote Memory Access (RMA)
  - Active Messages - remote procedure call
  - Implemented over the native APIs for all networks of interest to DOE
- GASNet-EX is an evolution of GASNet-1 for exascale
  - Retains GASNet-1’s wide portability (laptops to supercomputers)
  - Provides backwards compatibility for the dozens of GASNet-1 clients, including multiple UPC and CAF/Fortran08 compilers
  - Focus remains on one-sided RMA and Active Messages
  - Reduces CPU and memory overheads
  - Improves many-core and multi-threading support
- Current enhancements:
  - “Immediate mode” injection to avoid stalls due to back-pressure
  - Explicit handling of local-completion (source buffer lifetime)
  - New AM interfaces, e.g., to reduce buffer copies between layers
  - Vector-Index-Strided for non-contiguous point-to-point RMA
  - Remote Atomics, implemented with NIC offload where available
  - Subset teams and non-blocking collectives
- Future enhancements include:
  - Communication directly to/from device memory (e.g., GPUTrack)

GASNet-EX RMA Performance versus MPI RMA and Isend/Irecv

- Three different MPI implementations
- Two distinct network hardware types
- On four systems the performance of GASNet-EX matches or exceeds that of MPI RMA and message-passing:
  - 8-byte Put latency 6% to 55% better
  - 8-byte Get latency 5% to 45% better
  - Better flood bandwidth efficiency, typically saturating at 1/2 or 1/3 the transfer size

GASNet-EX RMA:
- MPI RMA Put
- GASNet-EX Get
- MPI RMA Get
- MPI Band/Recvd

GASNet-EX Put:
- MPI RMA Put
- GASNet-EX Get
- MPI RMA Get
- MPI Band/Recvd

MPI RMA Get:
- MPI RMA Put
- GASNet-EX Get
- MPI RMA Get
- MPI Band/Recvd

MPI RMA Put:
- MPI RMA Put
- GASNet-EX Get
- MPI RMA Get
- MPI Band/Recvd

MPI ISend/IRecv:
- MPI RMA Put
- GASNet-EX Get
- MPI RMA Get
- MPI Band/Recvd

Remote Atomics with Cray Aries NIC Offload

- Implements the Atomic Domains concept (first introduced by UPC 1.3)
- Domains permit use of NIC offload even when not coherent with CPU
- Domains are created collectively outside the critical path
- A Domain has an associated data type and set of allowed operations
  - Domains select the best implementation for the data type and ops
  - e.g., use offload if and only if NIC implements all the requested ops
- Example: non-blocking atomic fetch-and-add (FADD) on unsigned 64-bit integer
  ```c
  gex::Event t_ev = // *result = ATOMICALLY(*target += addend)
  gex::AD::OpSB_064(domain, &result, target_rank, target_address,
   GEX_OF_FADD, addend, 0 /* unused op2 */, flags);
  flags includes optional behaviors and assertions, such as memory fences
  ```
- GASNet-EX provides a network-independent “reference implementation”
- Uses Active Messages to perform operations using the target CPU
- Uses GASNet-Tools for atomity (inline assembly for numerous CPUs)
- Specialization for Cray Aries improves performance vs. reference implementation
  - Reduces latency of inter-node FADD from 4.9us to 2.8us
  - Greatly increases throughput under contention

Remote Atomics on Theta (weak scaling, 256,000 core/proc):

- Arnes NIC Offload
- Reference Implementation

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