Optimizing Collective Communication for Petascale Supercomputers

http://upc.lbl.gov

Introduction

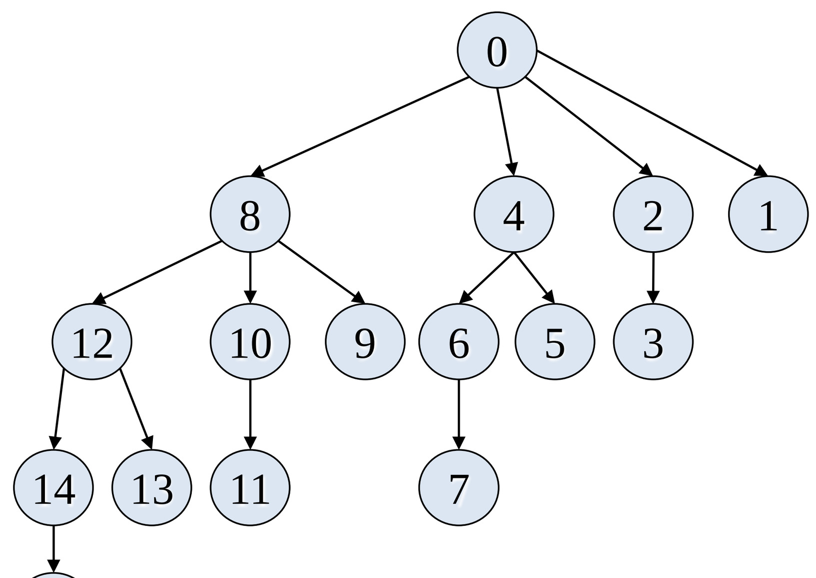
Collective communication

- Cooperative data-movement beyond one-to-one communication
- Common building blocks for many applications
- Key bottleneck of performance scalability

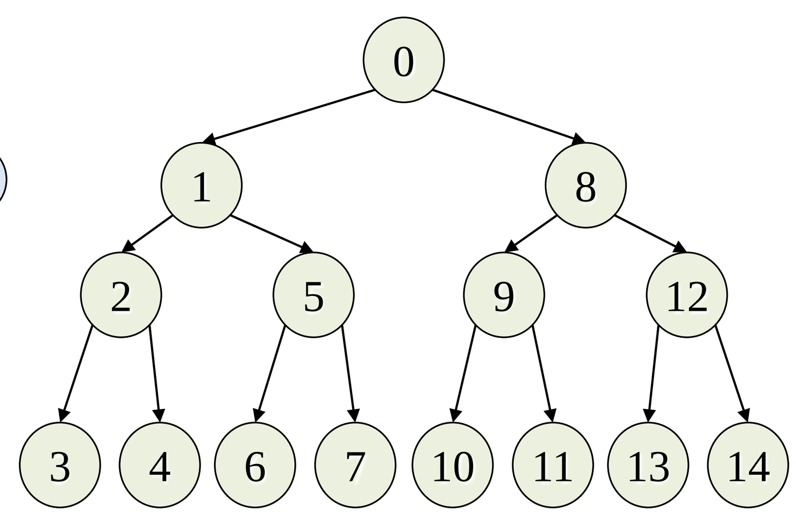
GASNet

- Portable high-performance communication primitives
- Used to implement partitioned global address space languages: e.g., UPC, Titanium, Co-array FORTRAN, and Chapel

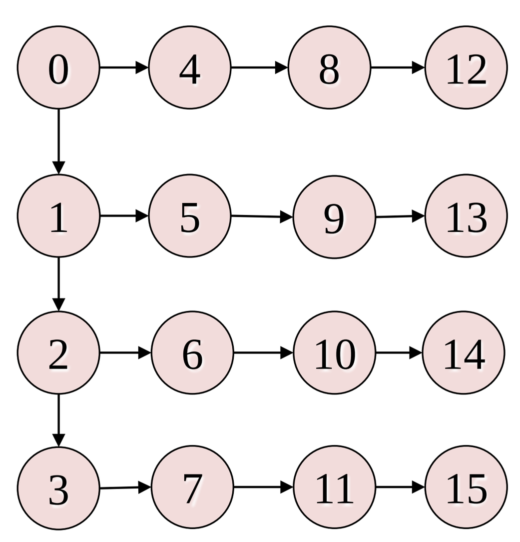
Example Communication Topologies



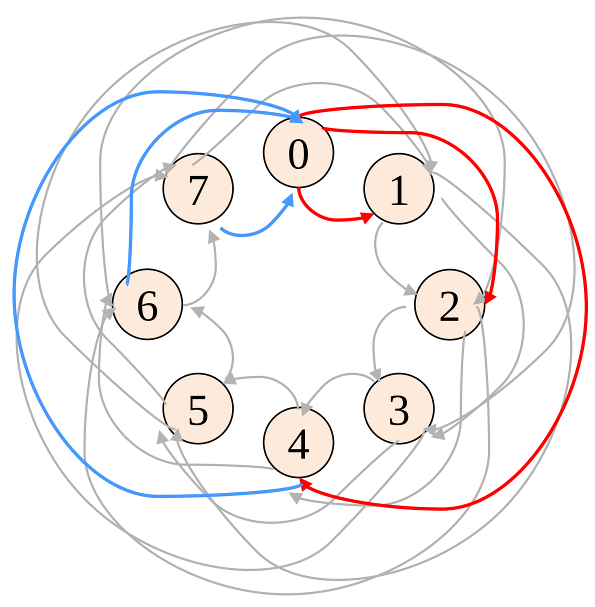
Radix 2 k-nomial tree (binomial)



Binary Tree



Fork Tree



Radix 2 Dissemination

Collectives for PGAS Languages

Teams

- Thread-centric: Programmer explicitly specifies the threads that take part in the collective through a language level team construction API.
- Data-centric: Programmer only specifies the data for the collective. Runtime system then figures out where the data resides and performs the collective.

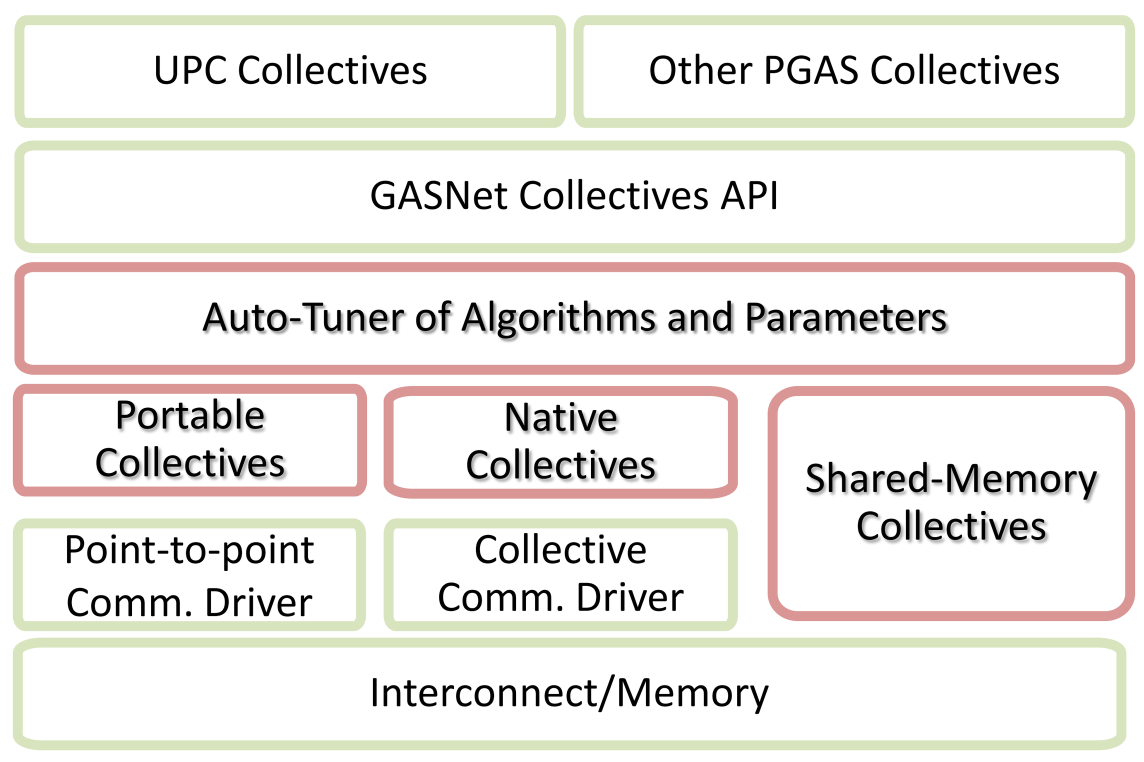
Synchronization modes

- Loose: Data movement can start and as soon as first thread enters collective and continue until last thread leaves the collective.
- Middle: Data movement into and out local memory can occur only when the data-owner thread is in the collective operation.
- Strict: Data movement can start only after all threads have entered the collective and must finish before any thread leaves the collective.

Optimizations

- Non-blocking collective operations that facilitate overlapping communication and computation
- Network-specific optimizations for leveraging hardware features
- Automated performance tuning for accommodating different application characteristics on multiple platforms

Organization of GASNet Collectives



Performance Auto-tuning

Offline tuning

- Optimize for platform common characteristics
- Minimize runtime tuning overhead

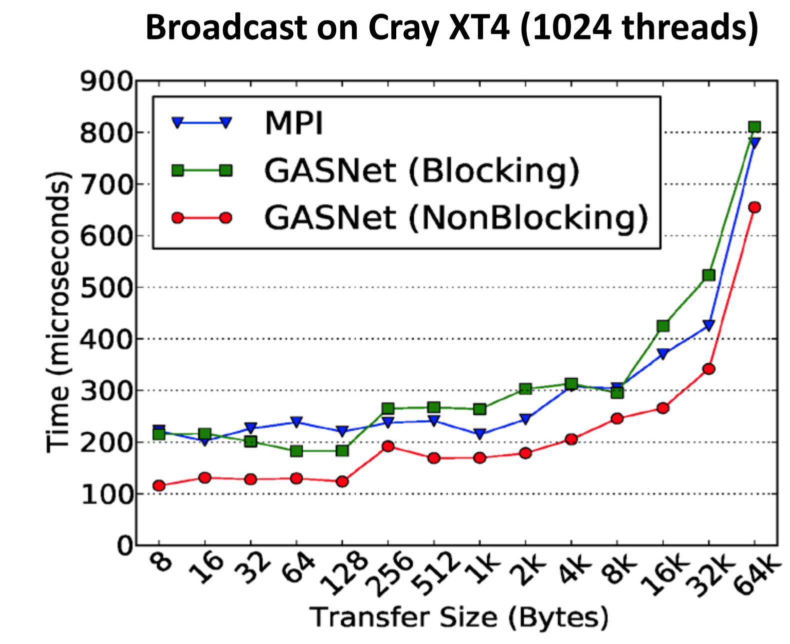
Online tuning

- Optimize for application runtime characteristics
- Refine offline tuning results

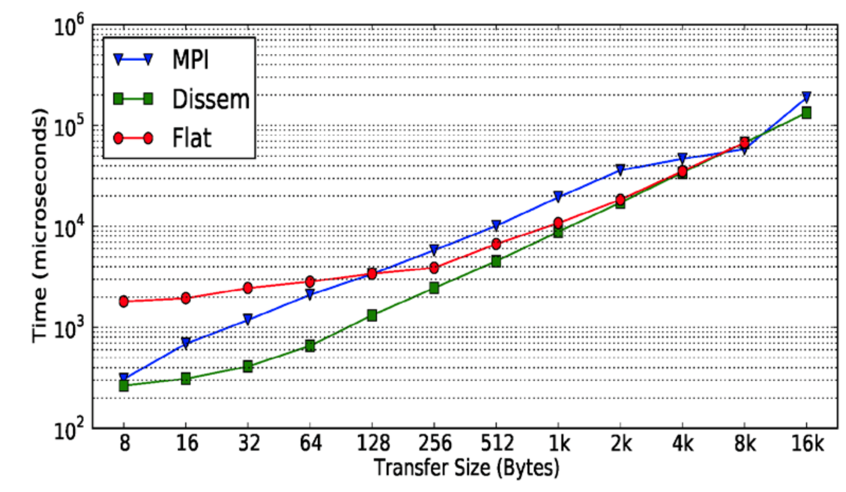
Performance Influencing Factors	Performance Tuning Space
Hardware • CPU • Memory system • Interconnect Software • Application • System software Execution • Process/thread layout • Input data set • System workload	Algorithm selection • Eager vs. rendezvous • Put vs. get • Collection of well-known algorithms Communication topology • Tree type • Tree fan-out Implementation-specific parameters • Pipelining depth • Dissemination radix

Micro-benchmarks

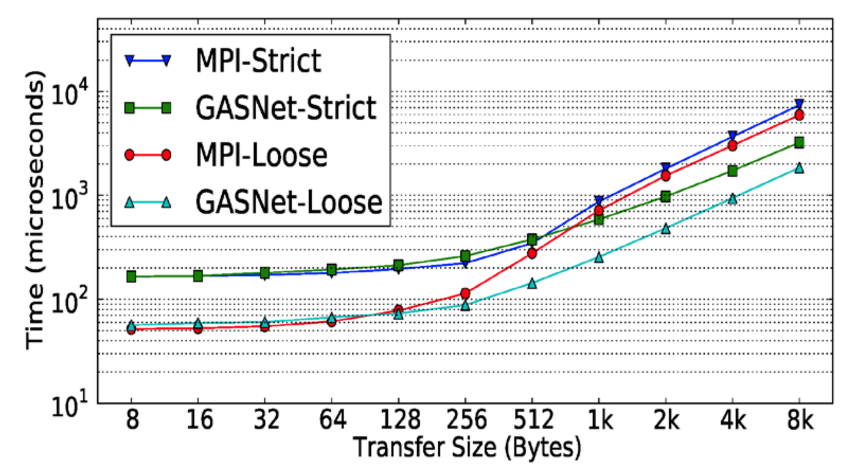
Broadcast on Cray XT4 (1024 threads)



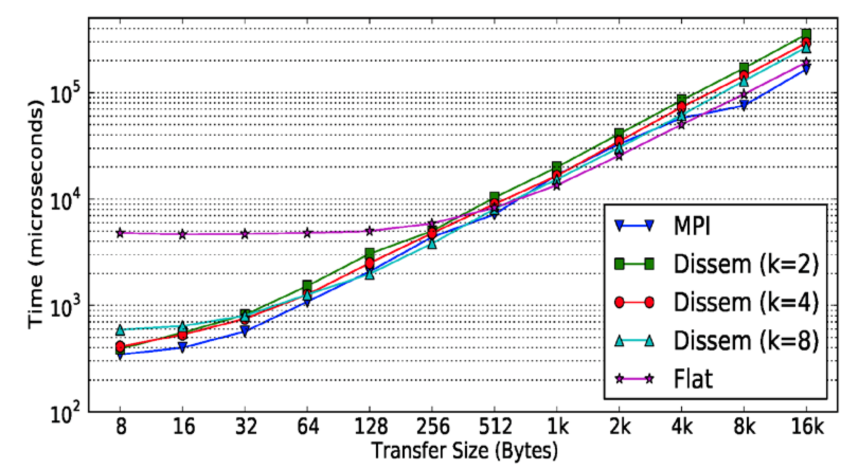
GatherAll on Cray XT5 (1536 threads)



Gather on Cray XT4 (1024 threads)

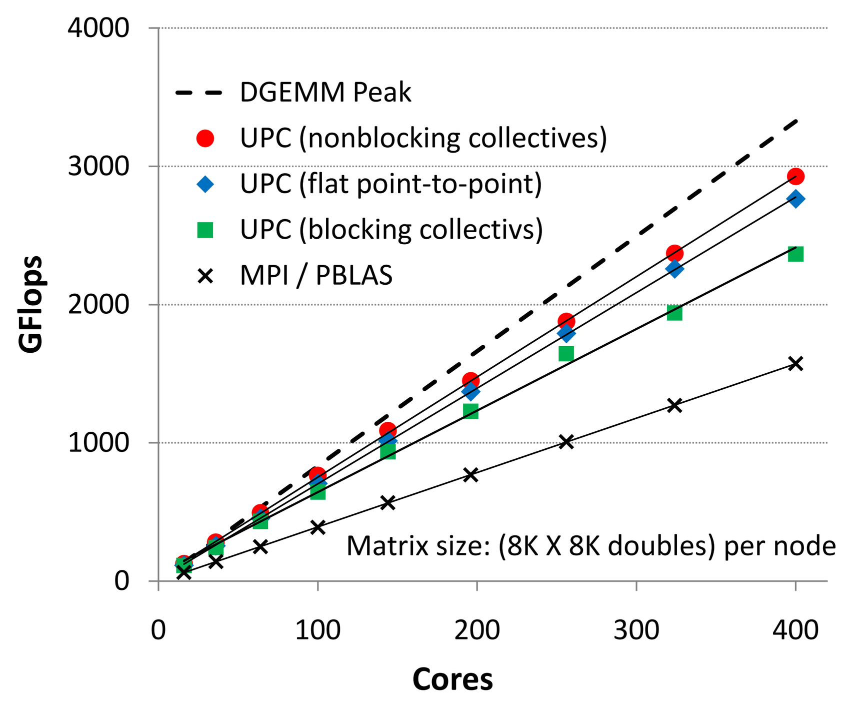


Exchange on SUN Constellation (256 threads)

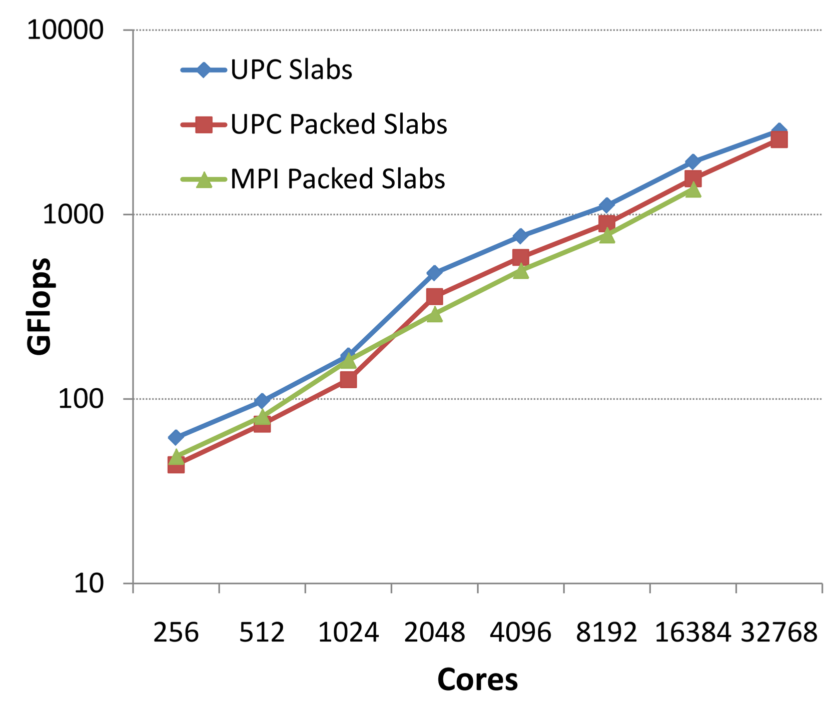


Applications

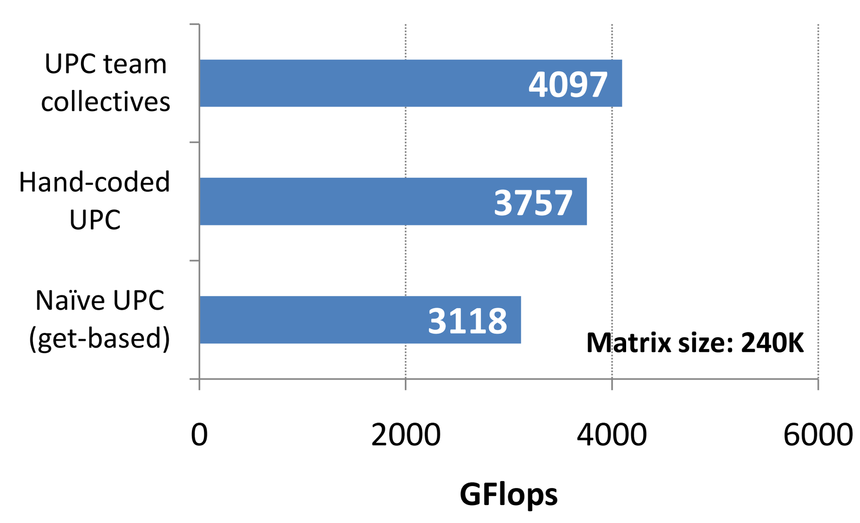
Matrix-Multiply Weak Scaling on Cray XT4



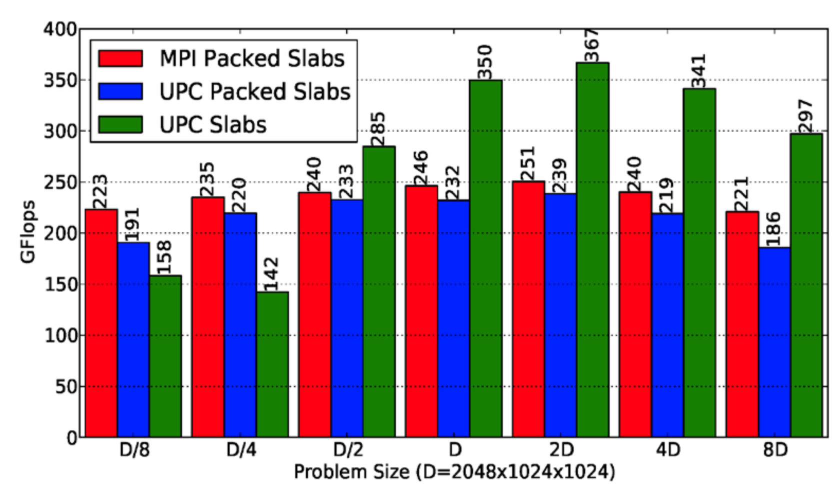
3-D FFT Weak Scaling on BlueGene/P



Cholesky Factorization Performance on Sun Constellation (2048 cores)



3-D FFT Performance on Cray XT4 (1024 cores)



Conclusion

High Productivity

- Portable performance from multi-core PCs to petascale supercomputers
- Compact and clean UPC code

Scalable Performance

- 3-D FFT (communication intensive)
  - Weak scaling: 38% over MPI (16K cores)
  - strong scaling: 20% over MPI (16K cores)
- Numerical linear algebra: highly scalable performance up to 2X MPI/PBLAS