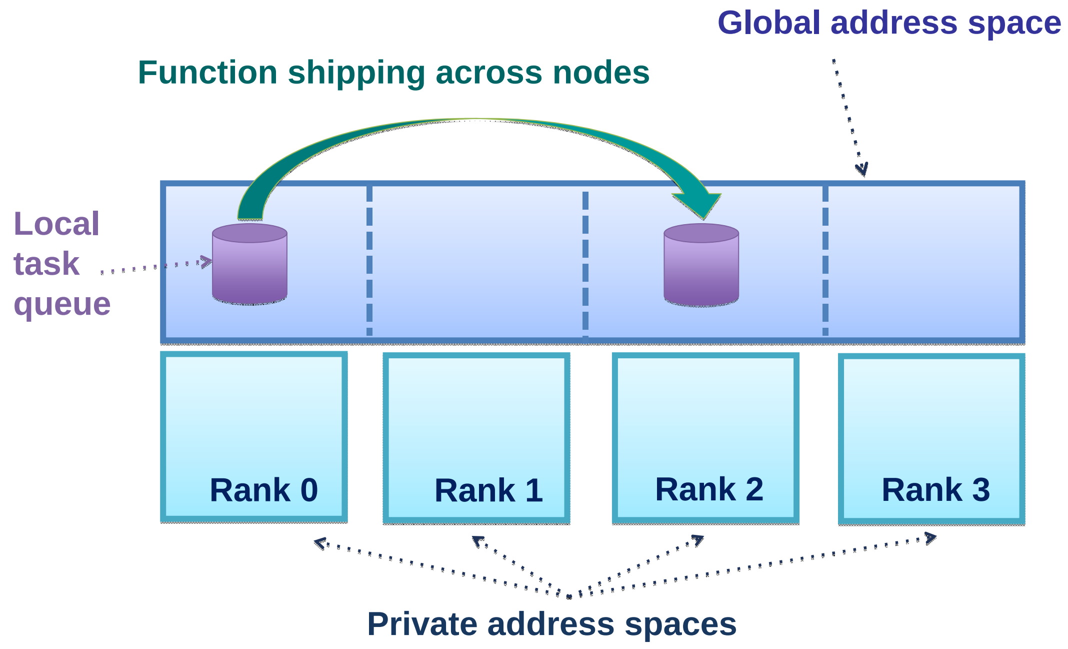
UPC++ and GASNet: PGAS Support for Exascale Apps and Runtimes

PIs: Scott B. Baden and Paul Hargrove

1.3.1.17

UPC++ at Lawrence Berkeley National Lab

UPC++ is a library providing lightweight PGAS one-sided communication
and asynchronous remote function execution with a C++ interface



- UPC++ is a C++11 library
  - No custom compiler
- Easy on-ramp and integration
  - Interoperable with MPI+OpenMP/CUDA/etc
  - Enables incremental development
  - Replace performance-critical sections with lightweight PGAS
- New extensions under development
  - Co-processor memory support, non-contiguous communication, teams, and active message interfaces

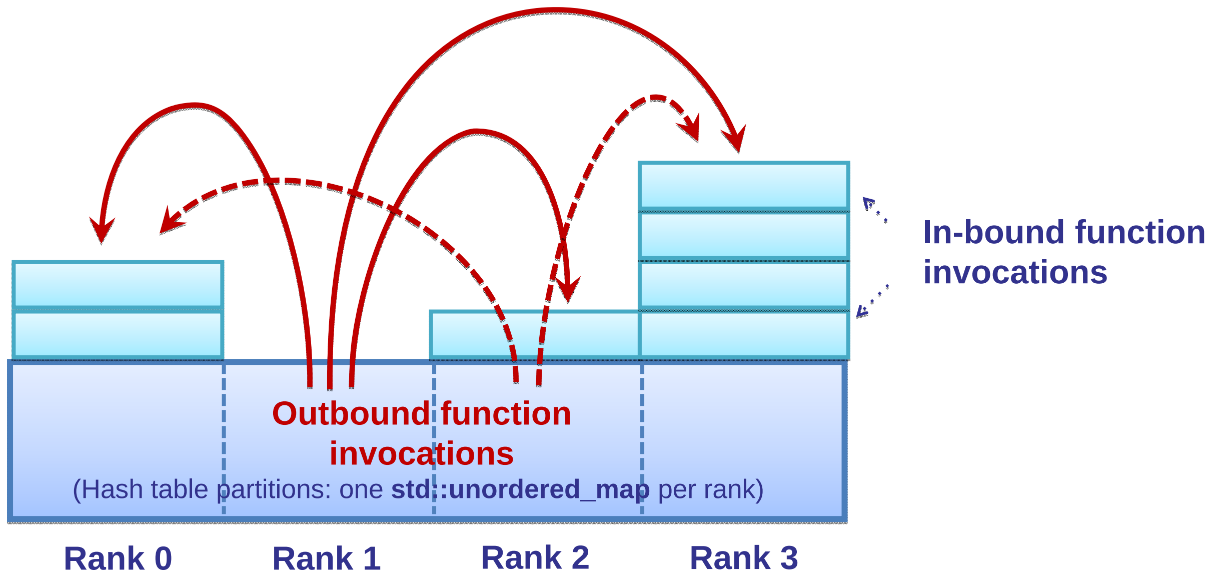
https://bitbucket.org/upcxx/upcxx

Case 1: Easy distributed hash-table via function shipping and futures

- **Function shipping** simplifies distributed data-structure design
  - Use a GASNet Active Message to ship updates to the key's owner, avoiding round trip communication
- **Futures** hide the latency of remote operations, naturally express overlap of independent operations

```
// c++ "global" variables become rank-local state.
std::unordered_map<int, int> _dht_local;

 // owner does the work, result is a future<int>
upcxx::future<int> dht_fetch_inc (int key) {
  return upcxx::ship_function(
    key % upcxx::rank_count(),                                    // owner in key-to-rank partition
    [=]() { return atomic_fNIncr(_dht_local[key]); }              // fetch and increment lambda
  );                                                              //  (the shipped function)
}
```



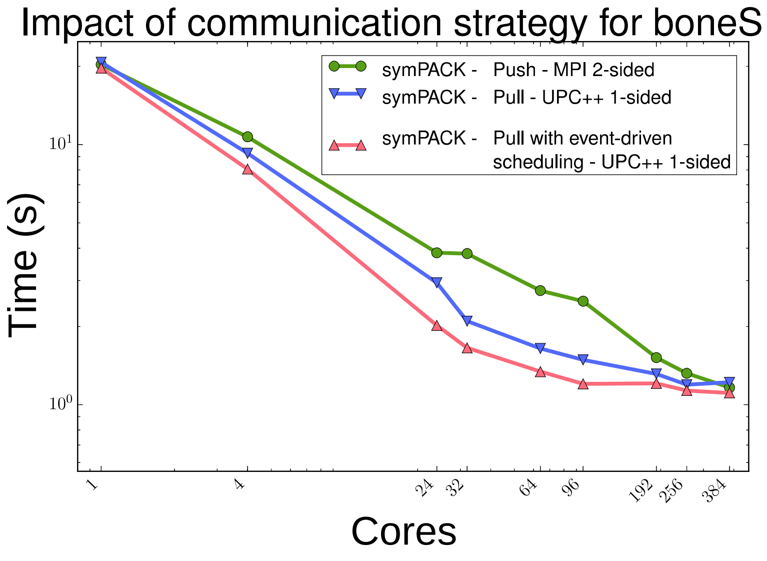
In-bound function invocations
Outbound function invocations
(Hash table partitions: one std::unordered_map per rank)
Rank 0
Rank 1
Rank 2
Rank 3

- UPC++ can directly express irregular comm. patterns
  - Effective semantic match for many applications
  - E.g. Graph algorithms, bioinformatics, adaptive meshes

Case 2: symPACK: UPC++ asynchronous task-based sparse Cholesky solver

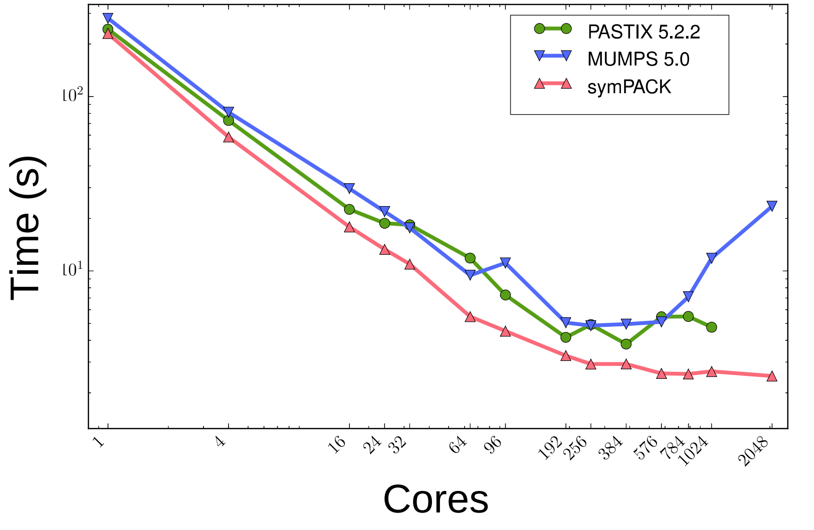
- **Application: *symPACK***, a sparse direct linear solver for symmetric matrices.
- **Challenges:** Sparse matrix factorizations have low computational intensity and irregular communication patterns.
- **Solution**: UPC++ **function shipping** enables an efficient pull communication strategy and event-driven scheduling.
- **Impact**: on average, ***symPACK*** delivers a ×2.65 speedup over the best state-of-the-art sparse symmetric solver.
  UPC++'s one-sided pull strategy avoids the need for (and cost of) unexpected messages in MPI.

Impact of communication strategy for boneS10



Push – MPI 2-sided communication
Pull – UPC++ 1-sided communication
with/without event driven scheduling

Run times for Flan_1565 on NERSC Edison



Strong scaling of symmetric solvers
(factorization time only)