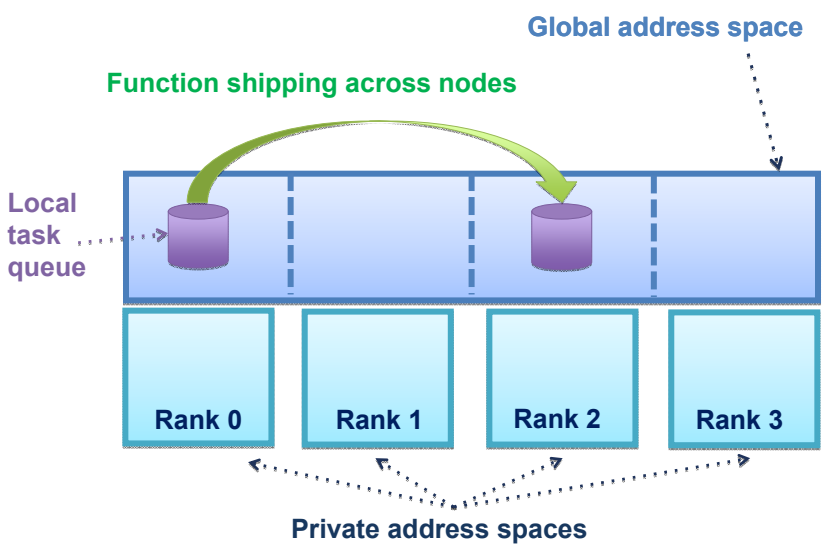
UPC++: a PGAS C++ Library

http://upcxx.lbl.gov

Execution model and PGAS interface

UPC++ provides PGAS-style lightweight one-sided communication and asynchronous task execution features to C++ applications



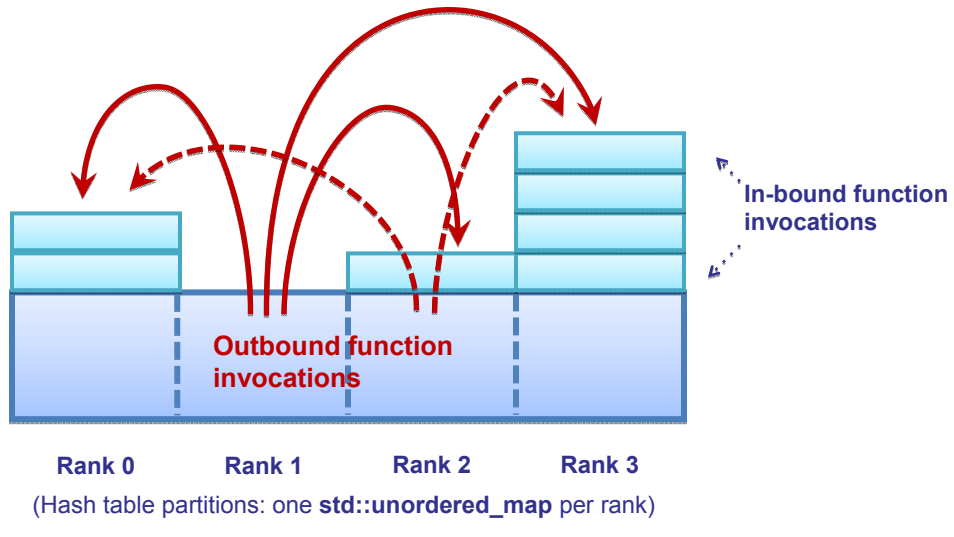
- Easy on-ramp for applications
  - A C++11 library
  - Compatible with existing MPI+OpenMP/CUDA code bases
- All data motion is asynchronous
  - Futures and continuations to manage overlap
  - RMA operations for direct access to remote shared data
  - Co-processor memory support
- Supports distributed irregular data structures used in adaptive mesh refinement, sparse solvers, graph algorithms
  - Remote Procedure Calls (RPC)
  - Distributed objects
  - Non-contiguous RMA communication
  - Remote atomics
- Teams and collectives

Easy distributed hash-table via remote procedure call and futures

- **Remote Procedure Calls** simplify distributed data-structure design.
  - Use ***rpc*** to ship updates to the key's owning rank.
  - One-sided nature avoids tedious work of declaring expected messages as is typical with two-sided messaging.
- **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> my_dht_local;

// owner does the work, result is a future<int>
upcxx::future<int> dht_fetch_inc (int key) {
  return upcxx::rpc(                          // `rpc` sends lambda to rank
    key % upcxx::rank_n(),                    // owner rank in key-to-rank partition
    [=]() { return my_dht_local[key]++; }     // [=] captures `key`, used remotely
  );
}
```



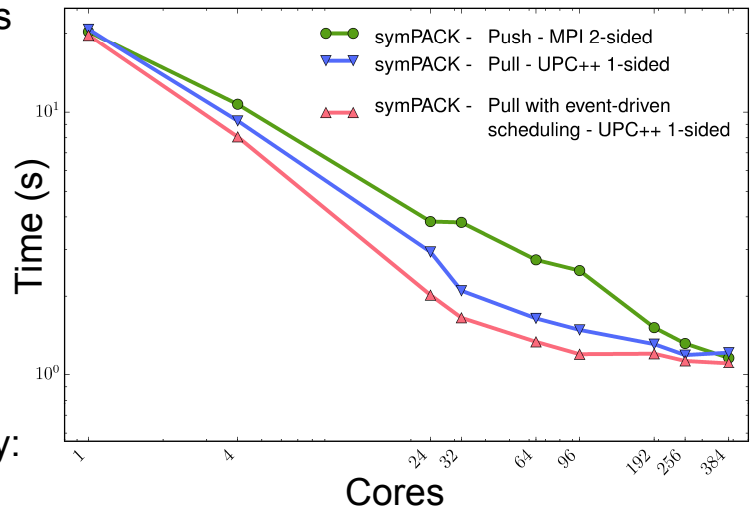
(Hash table partitions: one **std::unordered_map** per rank)

symPACK: UPC++ asynchronous task-based sparse symmetric 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++ **rpcs** and **rgets** enable 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++ enables a one-sided pull strategy: RPC avoids the need (and cost) of scheduling messages in MPI, to avoid deadlocking on many small messages.

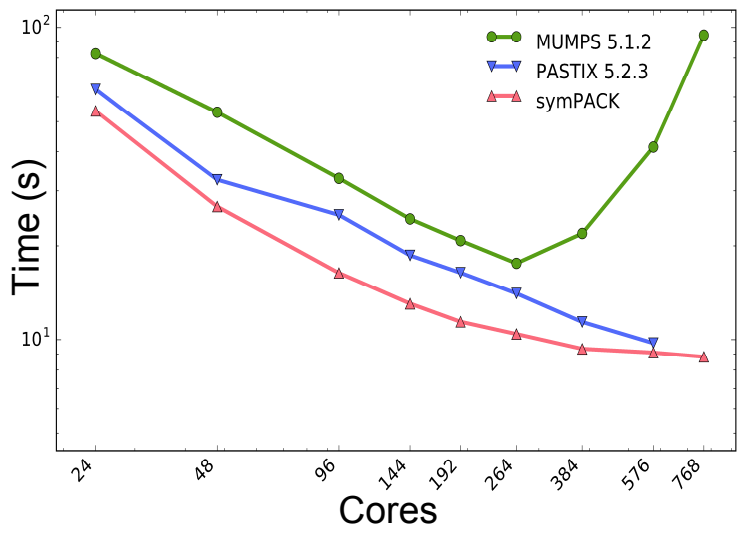
Strong Scaling on NERSC Edison - Cray XC30 (24 cores/node)

Impact of communication strategy (boneS10)



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

Comparison to competing solvers (Flan_1565)



Strong scaling of symmetric solvers (factorization time only)

Partners and acknowledgements

Pagoda Team

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Application Partners

- AMREx
- ExaBiome
- Sparse Solvers

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