# Pagoda: Lightweight Communications and Global Address Space Support for Exascale Applications - UPC++

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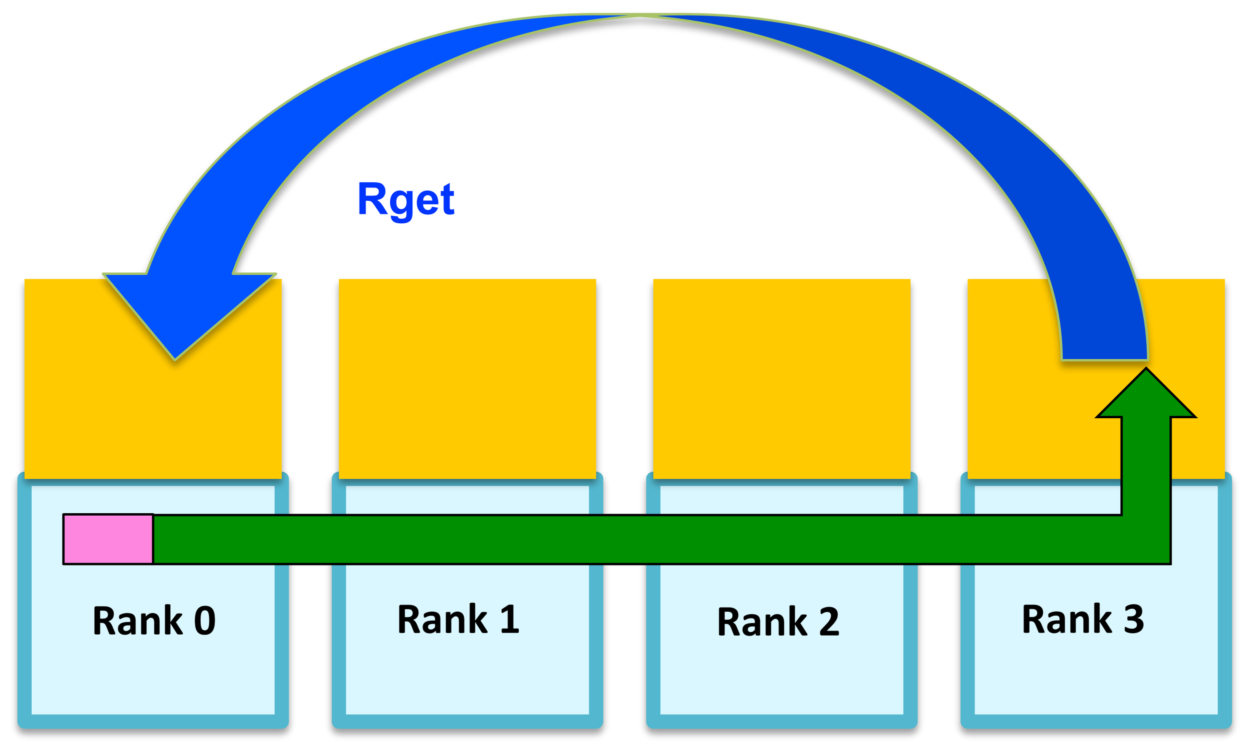
## UPC++ at Lawrence Berkeley National Lab (http://upcxx.lbl.gov)




Private address spaces

- UPC++ is a C++11 PGAS library
  - Lightweight, asynchronous, one-sided communication (RMA)
  - Asynchronous remote procedure call (RPC)
  - Data transfers may be non-contiguous
  - Futures manage asynchrony, enable communication overlap
  - Collectives, teams, remote atomic updates
  - Provides building blocks to construct irregular data structures
- Easy on-ramp and integration
  - Enables incremental development
  - Selectively replace performance-critical sections with UPC++
  - Interoperable with MPI, OpenMP, CUDA, etc.
- Latest software release: September 2018
  - Runs on systems from laptops to supercomputers

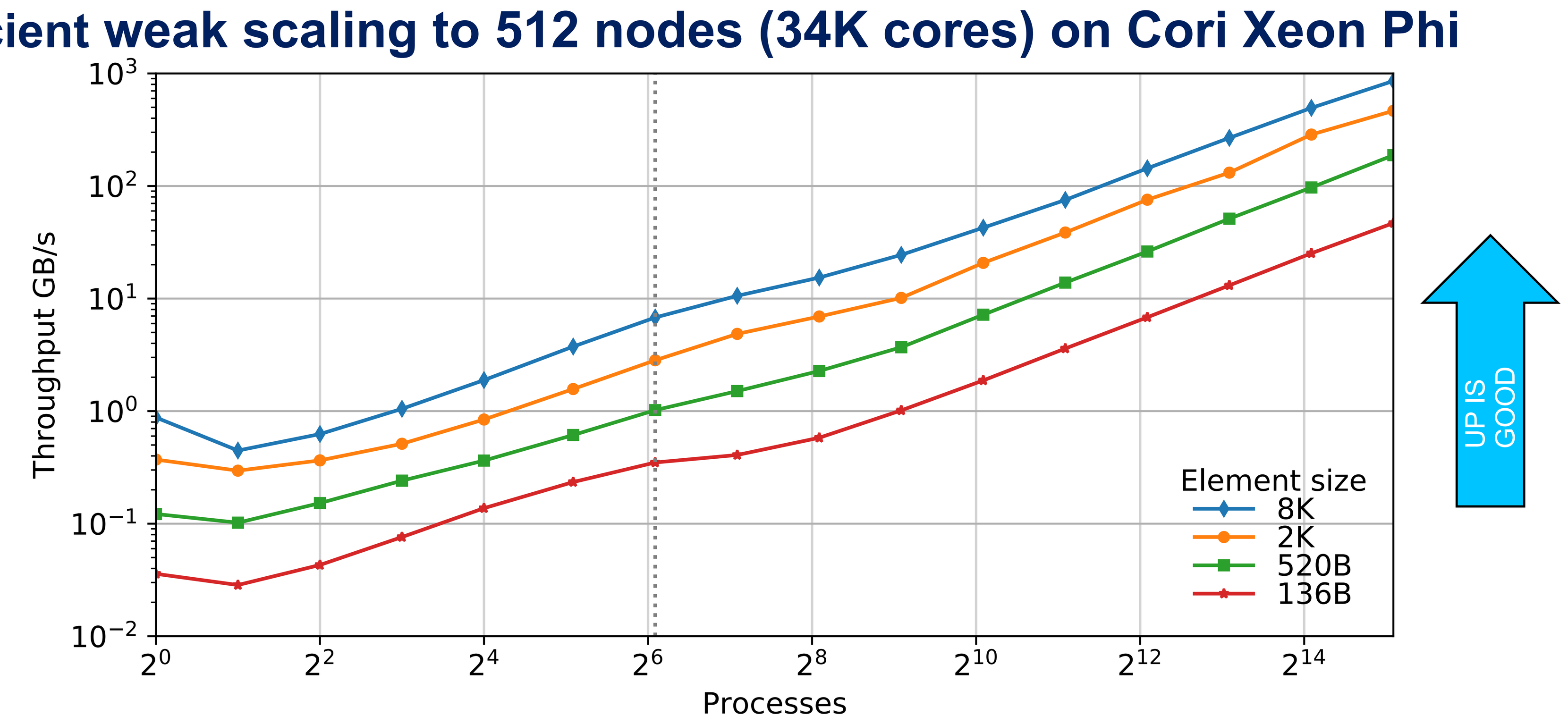
## Case 1: Easy Distributed Hash-Table via Function Shipping and Futures

- **Distributed hash-table design is based on function shipping**
  - RPC inserts the key metadata at the target
  - Once the RPC completes, an attached callback issues a one-sided RMA Put (rput) to store the value data

```
// C++ global variables correspond to rank-local state
std::unordered_map<uint64_t, global_ptr<char>> local_map;
// insert a key-value pair and return a future
future<> dht_insert(uint64_t key, char *val, size_t sz) {
 future<global_ptr<char>> fut =
     rpc(key % rank_n(),             // RPC obtains location for the data
            [key,sz]() -> global_ptr<char> {     // lambda invoked by RPC
              global_ptr<char> gptr = new_array<char>(sz);
              local_map[key] = gptr;               // insert in local map
              return gptr;
            });
 return fut.then(              // callback executes when RPC completes
       [val,sz](global_ptr<char> loc) -> future<> {
           return rput(val, loc, sz); });    // RMA Put the value payload
}
```

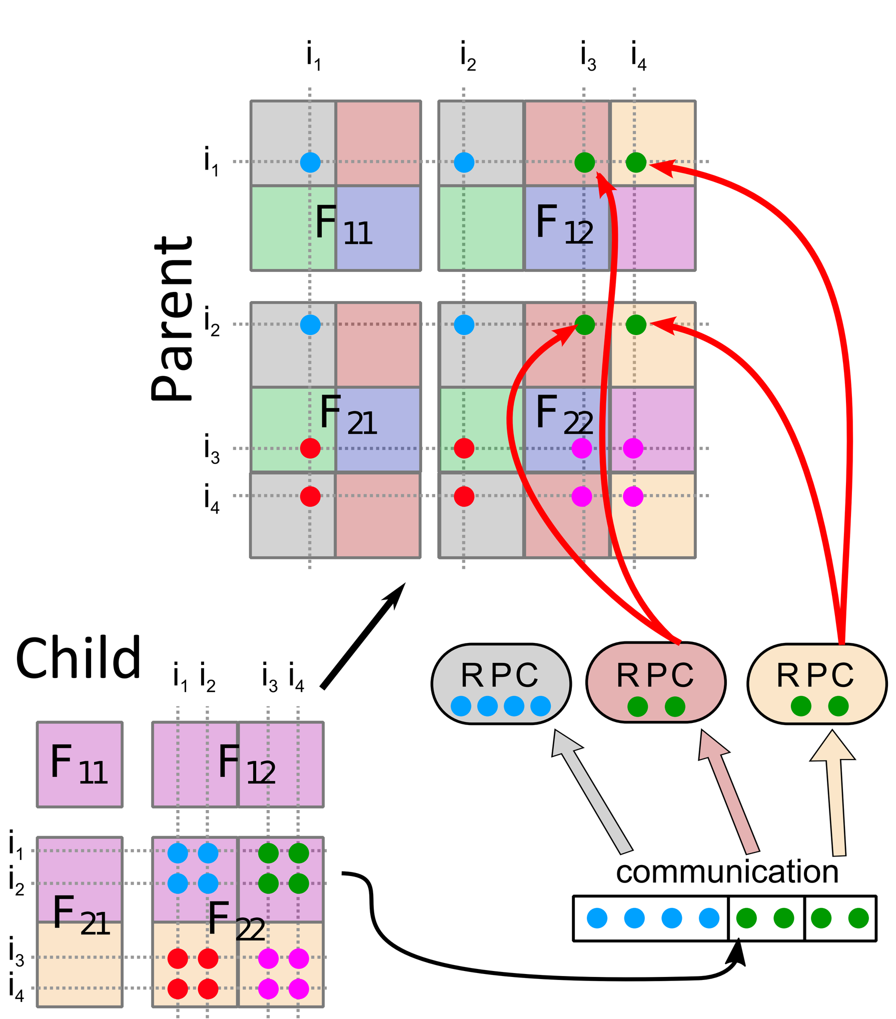
- **Benefits:**
  - Use of **RPC** simplifies distributed data-structure design
    - Argument passing, remote queue management and progress engine are factored out of the application code
  - Asynchronous execution enables overlap

**Efficient weak scaling to 512 nodes (34K cores) on Cori Xeon Phi**




## Case 2: Asynchronous Sparse Matrix Solvers

- **A time consuming operation in multifrontal sparse solvers:**
  - ***Extend-add:*** update a distributed sparse matrix, scattering the packed data source
- **Challenge:**
  - This operation has low computational intensity and exhibits irregular communication patterns
- **Solution**:
  - UPC++ **function shipping** via RPC enables efficient communication and asynchrony, increasing overlap and improving performance of ***Extend-add***

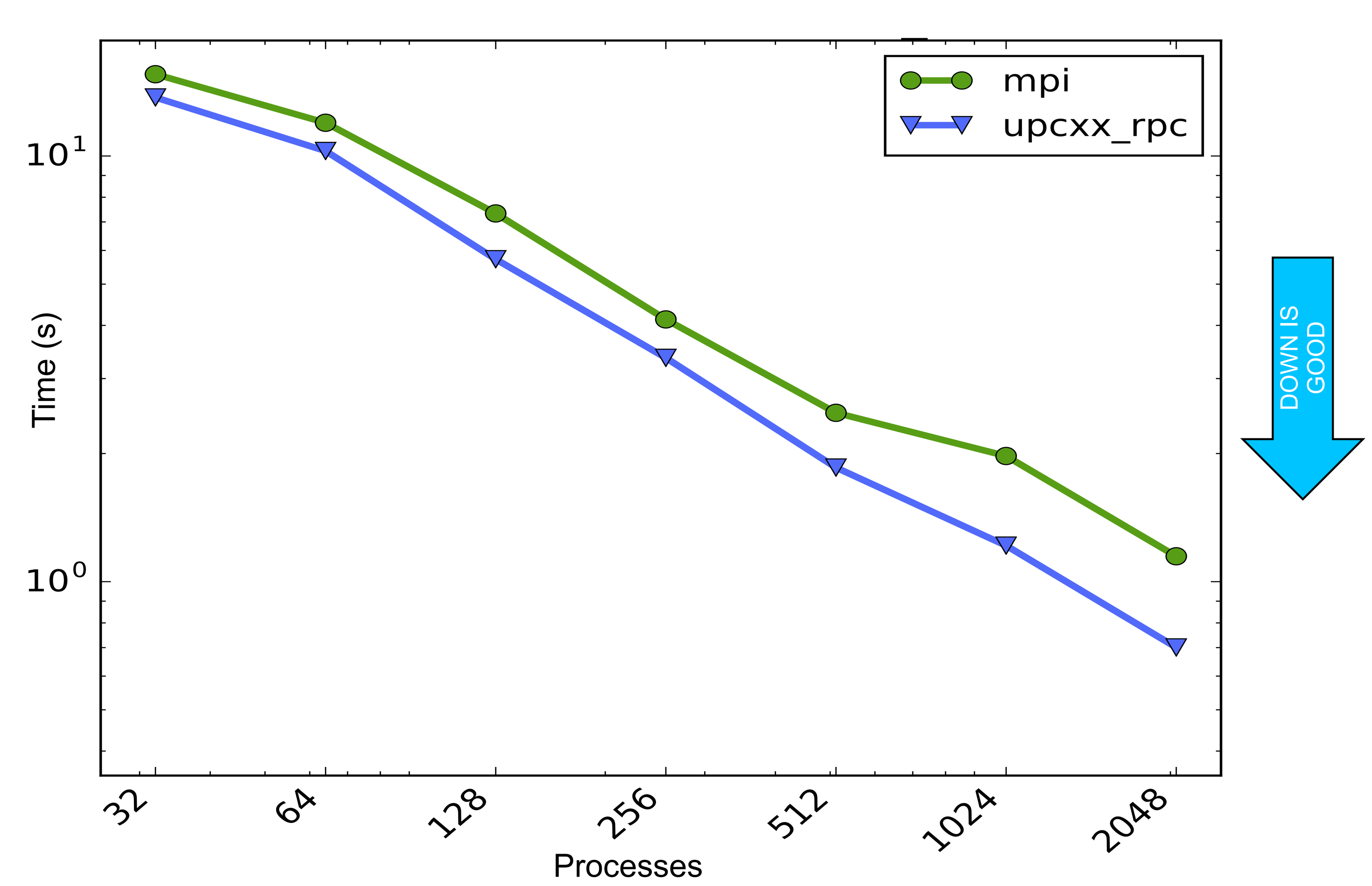



**Overview of Extend-add**

- Updates are shown for the left child only.
- Colored squares depict the distribution of parent and child matrices.
- Dots in the lower left child matrix depict the data to be sent and accumulated in the parent.
- The communication step initiated by one process in the left child is depicted in the lower right corner.
- RPCs communicate the data to the parent, which carries out the accumulation. Data linearization is handled by UPC++ views.

- **Impact:**
  - UPC++ enhances overlap in ***Extend-add***, yielding up to a 1.63x speedup over MPI collective and 3.11x over MPI message-passing implementations. The green line in the figure below corresponds to the fastest of these two variants.

**Strong scaling comparison of the UPC++ implementation of Extend-add using RPC and an MPI variant for the audikw_1 matrix on NERSC Cori Xeon Phi (using 64 cores/node)**

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