Grappa: PGAS for irregular applications

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Open source release coming soon!
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Irregular applications are important in a world full of big data

Irregular applications arise in:

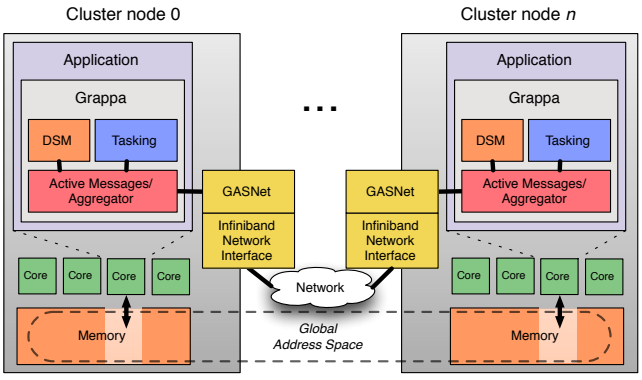
- Social network analysis
- Semantic databases
- Combinatorial optimization
- Circuit simulation
- Machine learning

Low locality and frequent random communication make these applications difficult to scale on commodity clusters.

Programming models like MapReduce and GraphLab can be restrictive; for example, parallel recursive algorithms are hard to express.

Grappa provides a familiar multithreaded programming model, making it easy to scale up irregular applications on commodity clusters.

Grappa uses *latency tolerance* to provide scalable performance on commodity clusters



Grappa's runtime system consists of three key components:

Tasking layer
Supports millions of threads across the cluster
Automatically balances load with *work stealing*

Distributed shared memory (DSM)
Provides a single system, shared memory abstraction

Communication
Supports high-throughput small message communication

See the other side of this page for details.

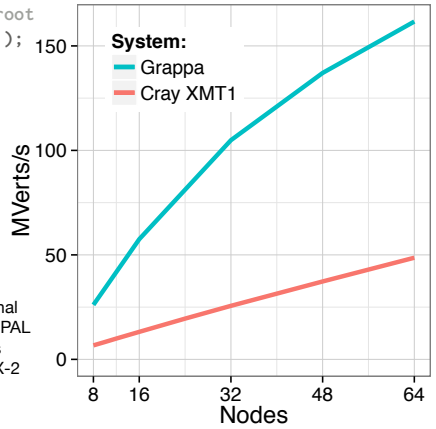
Programming Grappa

This is a simple example of doing random increments in a an array spread across the cluster. Grappa uses C++11 to make it easy to express parallelism. Grappa currently achieves 1.0 GUPS on 64 nodes. See the other side of this page for details.

```
using namespace Grappa;

void GUPS() {
  // A,B have type: GlobalAddress<long>
  auto A = global_alloc<int64_t>( N );
  auto B = global_alloc<int64_t>( N );
  random_init( B, N );

  forall( B, N, [=]( int64_t & b ){
    delegate::increment_async( A + b, 1 );
  });                          // A[B[i]]++

}
```

Below is a variant of the UTS tree search benchmark, traversing an imbalanced geometric tree in global memory. The implementation spawns tasks recursively; work stealing balances load across the cluster. Grappa performs especially well on such irregular recursive computations.

```
void search(GlobalAddress<Vertex> tree, index_t vertex_index) {
  // get current vertex
  Vertex v = delegate::read( tree + vertex_index );
  // explore children
  forall( v.first_child, v.num_children, [=]( index_t i ){
    search( tree, i );
  });
}

int main( int argc, char * argv[] ) {
  init( &argc, &argv );
  // T1XL: nodes: 1635119272, depth: 15, leaves: 1308100063
  GlobalAddress<Vertex> tree = uts_tree( "T1XL" );
  run( [=]{
    finish( [=]{
      // search from root
      search( tree, 0 );
    });
  });
  finalize();
  return 0;
```



Run at Pacific Northwest National Laboratory on Cray XMT-1 and PAL cluster (1.9GHz AMD Interlagos processors, Mellanox ConnectX-2 InfiniBand network)

Latency tolerance in Grappa's runtime system

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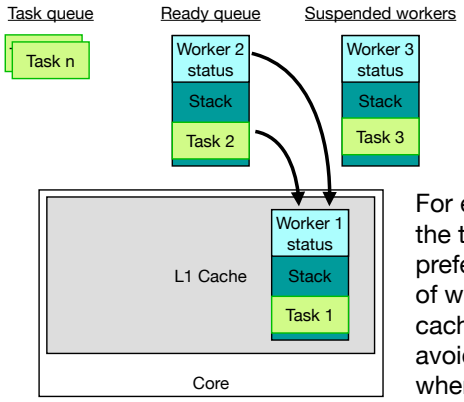
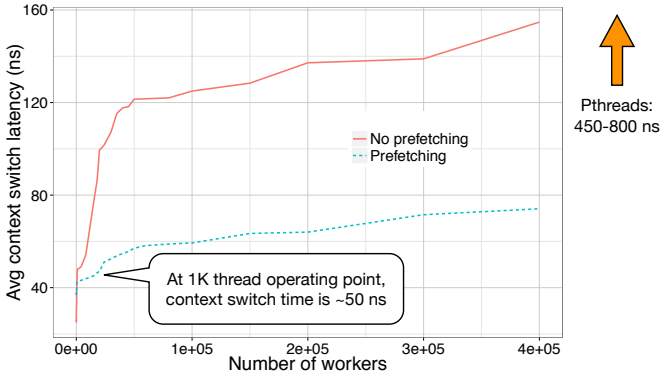
Grappa's tasking layer: Millions of threads, switching at the DRAM bandwidth limit

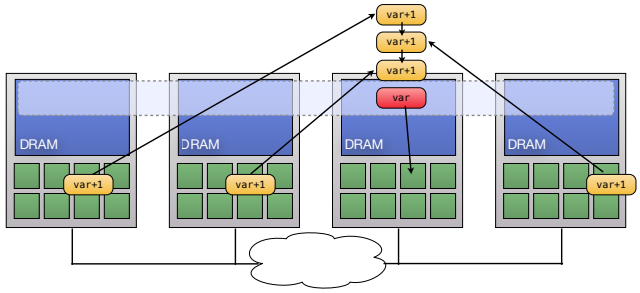


For each context switch, the task scheduler prefetches one cache-line of worker state and three cache-lines of stack, thus avoiding cache misses when loading contexts.



This micro-benchmark has many workers yielding in a loop. With 500K threads per core, context switch time is ~75 ns.
This is switching at the *bandwidth limit* to DRAM!

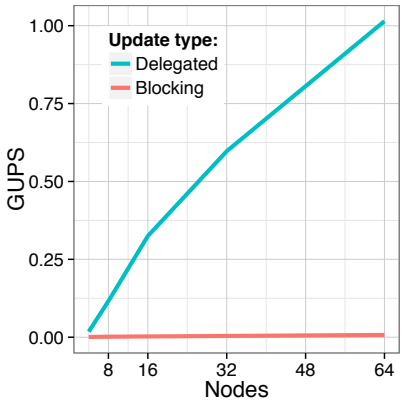
Distributed shared memory (DSM) in Grappa: Fast coherent updates through *delegation*



Every word in the system has a *home core*.

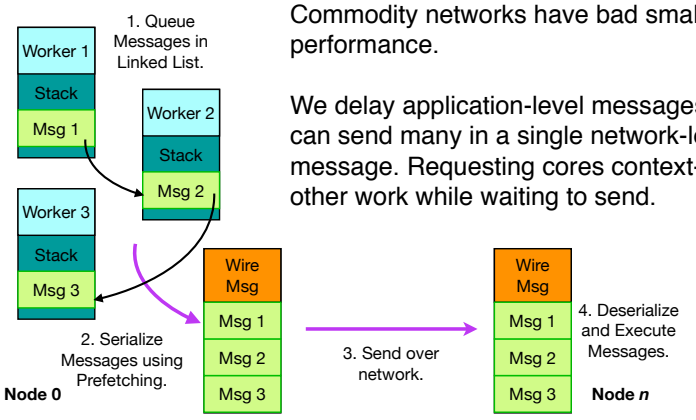
All memory accesses to a word are *delegated* to that core. Requesting cores context-switch to other work while waiting for a reply.

This gives us high-throughput atomic updates!



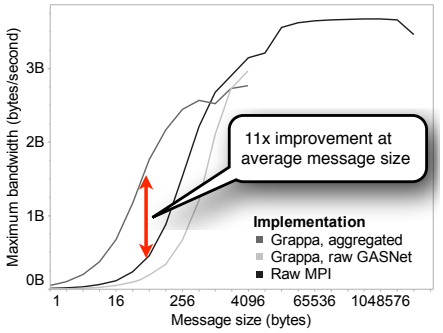
GUPS (RandomAccess) on PAL cluster at PNNL (1.9GHz AMD Interlagos processors, Mellanox ConnectX-2 Infiniband network)

Message aggregation



Commodity networks have bad small-message performance.

We delay application-level messages until we can send many in a single network-level message. Requesting cores context-switch to other work while waiting to send.



This micro-benchmark does ping-pong communication between two nodes.