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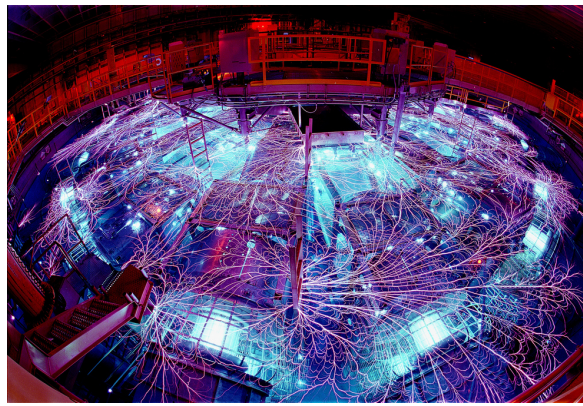

Lessons Learned from

Porting the MiniAero Application to Charm++

David S. Hollman, Janine Bennett (PI), Jeremiah Wilke (Chief Architect),
Ken Franko, Hemanth Kolla, Paul Lin, Greg Sjaardema, Nicole Slattengren,
Keita Teranishi, Nikhil Jain, Eric Mikida

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U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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Outline

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The Process: Porting an Explicit Aerodynamics Miniapp to the Chare Model

- What was easy?
- What was harder?

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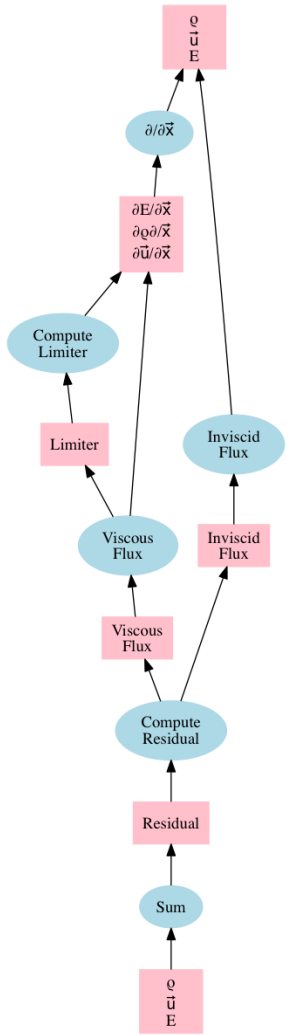

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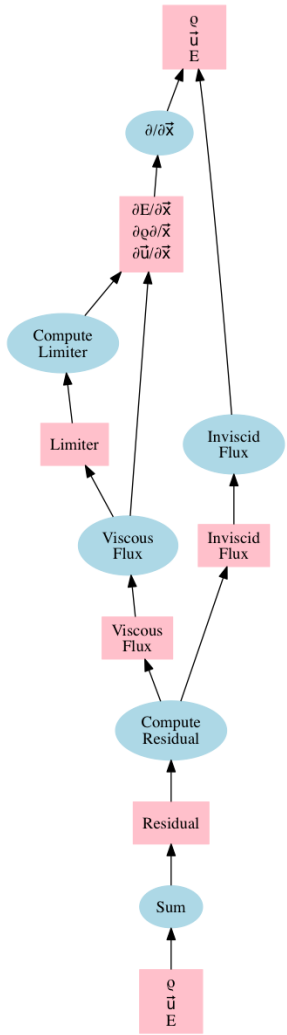

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Both of these require only serialization on the user side

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class OldStuffDoer {
  /* ... */
  void do_stuff() {
    generate data();
    /* ... */
    MPI_Irecv(data, n_send,
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  entry void receive_data(int src,
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  entry void do_stuff_1() {
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    /* ... */
    thisProxy[partner].receive_data(
      n_send, data
    );
  };
  entry void do_stuff_2() {
    when receive_data(int partner,
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    serial {
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- a lot of size and metadata communication setup can be skipped

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- For production code, a complete "top down" overhaul is completely impractical
- Is there a good middle ground?
  - "Bottom up"-ness vs. "top down"-ness of approach should be assessed before writing too much code (in any porting project)

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1  template <typename Device>
2  struct ddot {
3    const Kokkos::View<Device>& A, B;
4    double result;
5
6    ddot(
7      const Kokkos::View<Device>& A_in,
8      const Kokkos::View<Device>& B_in
9    ) : A(A_in), B(B_in), result(0)
10   { }
11
12   inline void operator()(int i) {
13     result += A(i) * B(i);
14   }
15 };
16
17 void do_stuff() {
18   /* ... */
19   Kokkos::parallel_for(
20     num_items,
21     ddot<Kokkos::Cuda>(v1, v2)
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- MiniAero was originally written in "MPI+Kokkos"

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- Kokkos is a performance portability layer aimed primarily at on-node parallelism
  - handles memory layout and loop structure to produce optimized kernels on multiple devices
- Application developer implements generic code, Kokkos library implements device-specific specializations
- MiniAero was originally written in “MPI+Kokkos”
- What happens when you need to write templated code that uses Kokkos?

```
1  template <typename Device>
2  struct ddot {
3    const Kokkos::View<Device>& A, B;
4    double result;
5
6    ddot(
7      const Kokkos::View<Device>& A_in,
8      const Kokkos::View<Device>& B_in
9    ) : A(A_in), B(B_in), result(0)
10   { }
11
12   inline void operator()(int i) {
13     result += A(i) * B(i);
14   }
15 };
16
17 void do_stuff() {
18   /* ... */
19   Kokkos::parallel_for(
20     num_items,
21     ddot<Kokkos::Cuda>(v1, v2)
22   );
23 }
```

What was harder: Kokkos integration and templated code

Sandia National Laboratories

- Kokkos is a performance portability layer aimed primarily at on-node parallelism
  - handles memory layout and loop structure to produce optimized kernels on multiple devices
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- MiniAero was originally written in "MPI+Kokkos"
- What happens when you need to write templated code that uses Kokkos?
  - Explicitly listing all specializations can get out of hand quickly. For instance…

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Template specialization explosion

- The MiniAero solver has five different ghost exchanges.

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  Kokkos::View<Device,double*,5> m_data1;
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  Kokkos::View<Device,int*> m_data3;
  /* etc... */
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- The devices we'd like to test include `Kokkos::Serial`, `Kokkos::Threads`, `Kokkos::Cuda`, and `Kokkos::OpenMP`
- That already leads to *20 different explicit signatures* for `receive_ghost_data()`.

Template specialization: our workaround

- Pattern: templated setup, non-templated entry method, templated cleanup

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/* comm_stuff.ci */
template <typename Device>
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  entry void do_stuff() {
    /* ... */
    serial {
      int src = /*...*/, dest = /*...*/;
      send_it(dest, my_data_1_);


    }



  };
};
```

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  entry [local] void do_recv(int src) {
    when recv_it[src](int s, int size,
        double data[size]) serial {
      memcpy(recv_buffers[src], data,
        size*sizeof(double));
      do_recv_done();
    }
  };
  entry void do_stuff() {
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```

Is this ideal?
Obviously not

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Is this typical of the effort required to make templated code work with an asynchronous many-task runtime system (AMT RTS)?

Maybe

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  }
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  void setup_recv(int src, ViewT& data) {
    recv_buffers_[src] =
      get_buffer(data, src);
  }
  template <typename ViewT>
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Does Charm++ even support templated entry methods inside templated chares?
(We couldn't figure out how to do it)

Distinguishing Entry Methods from Regular Method Calls

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```
1 entry void do_stuff() {
2   serial {
3     do_stuff_1();
4     do_stuff_2();
5   }
6 };
```

Distinguishing Entry Methods from Regular Method Calls

- Suppose all of the `do_stuff_*()` methods are ordinary, non-entry methods.

```
1 entry void do_stuff() {
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- Suppose all of the `do_stuff_*()` methods are ordinary, non-entry methods.
  - What happens first?

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- Suppose all of the `do_stuff_*()` methods are ordinary, non-entry methods.
  - What happens first?
- Now suppose `do_stuff_1()` is an entry method and `do_stuff_2()` is a normal method.

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- Suppose all of the `do_stuff_*()` methods are ordinary, non-entry methods.
  - What happens first?
- Now suppose `do_stuff_1()` is an entry method and `do_stuff_2()` is a normal method.
  - Now what happens first?

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1 entry void do_stuff() {
2   serial {
3     do_stuff_1();
4     do_stuff_2();
5   }
6 };
```

Distinguishing Entry Methods from Regular Method Calls

- Suppose all of the `do_stuff_*()` methods are ordinary, non-entry methods.
  - What happens first?
- Now suppose `do_stuff_1()` is an entry method and `do_stuff_2()` is a normal method.
  - Now what happens first?
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In short, mixing entry method calls and regular method calls without using naming conventions makes it *difficult to write self-documenting code*

Distinguishing Entry Methods from Regular Method Calls

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```

```
1  /* stuff_doer.h */
2  class StuffDoer
3    : public CBase_StuffDoer {
4    /*...*/
5    void do_stuff_2() {
6      // uh-oh
7      thisProxy.EM_do_stuff_4();
8    }
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```

Distinguishing Entry Methods from Regular Method Calls

- Further complication: non-blocking calls from a blocking context
- In fact, `do_stuff_2()` may only be blocking *most* or the time, but occasionally contain non-blocking calls

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2  class StuffDoer
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  - Just use comments?

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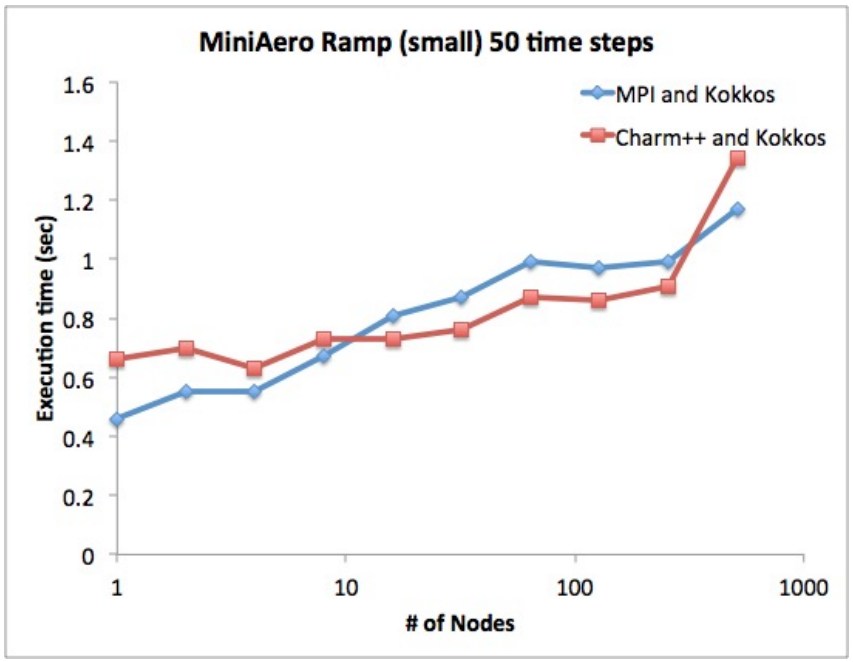
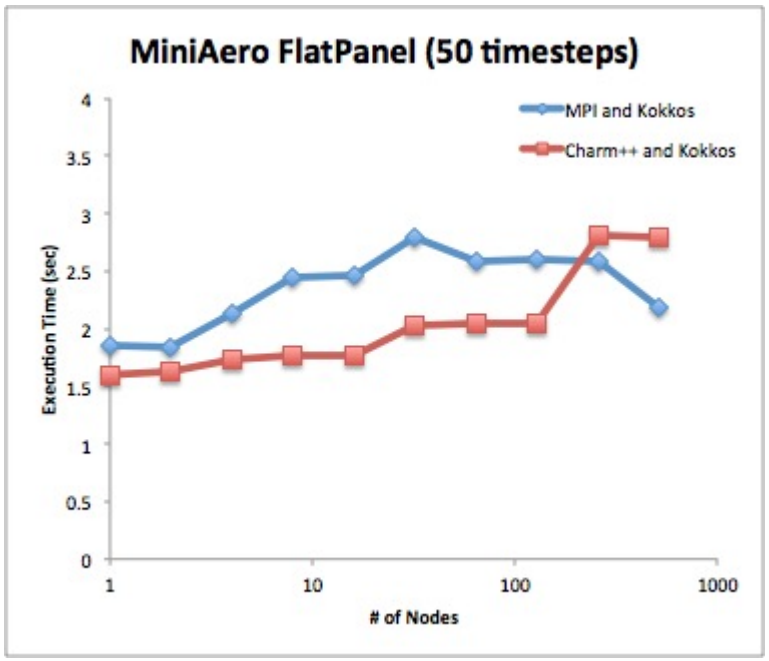
- What was harder?

Preliminary Results and Performance

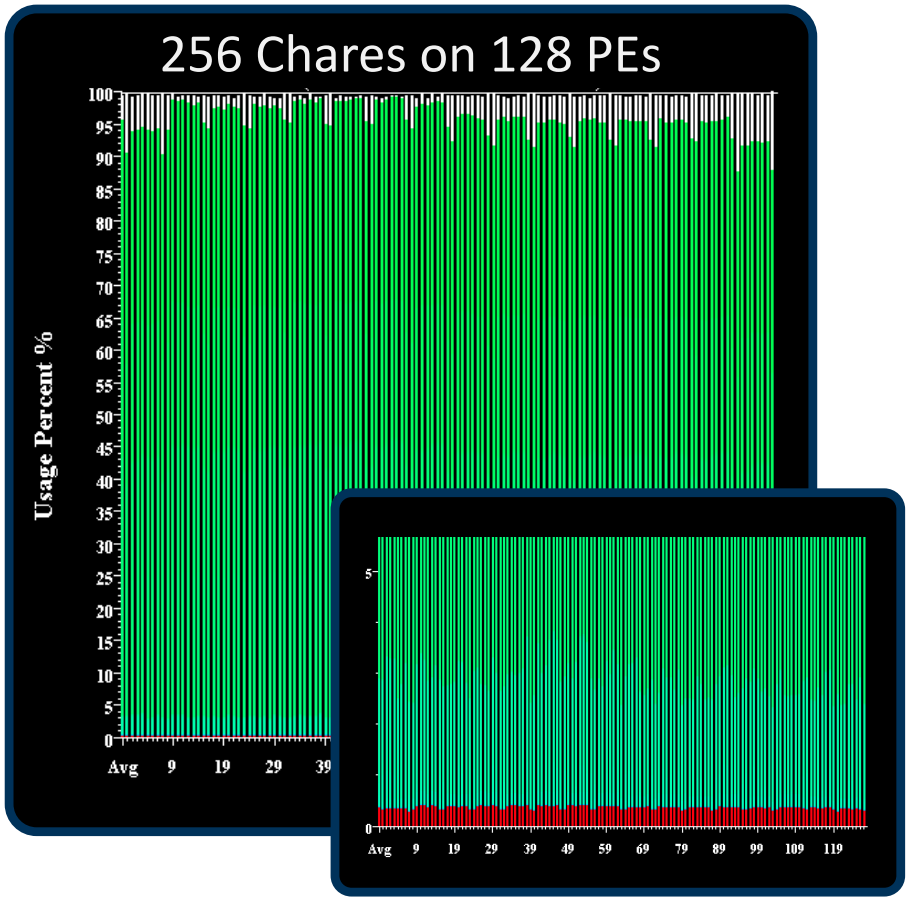
Next Steps

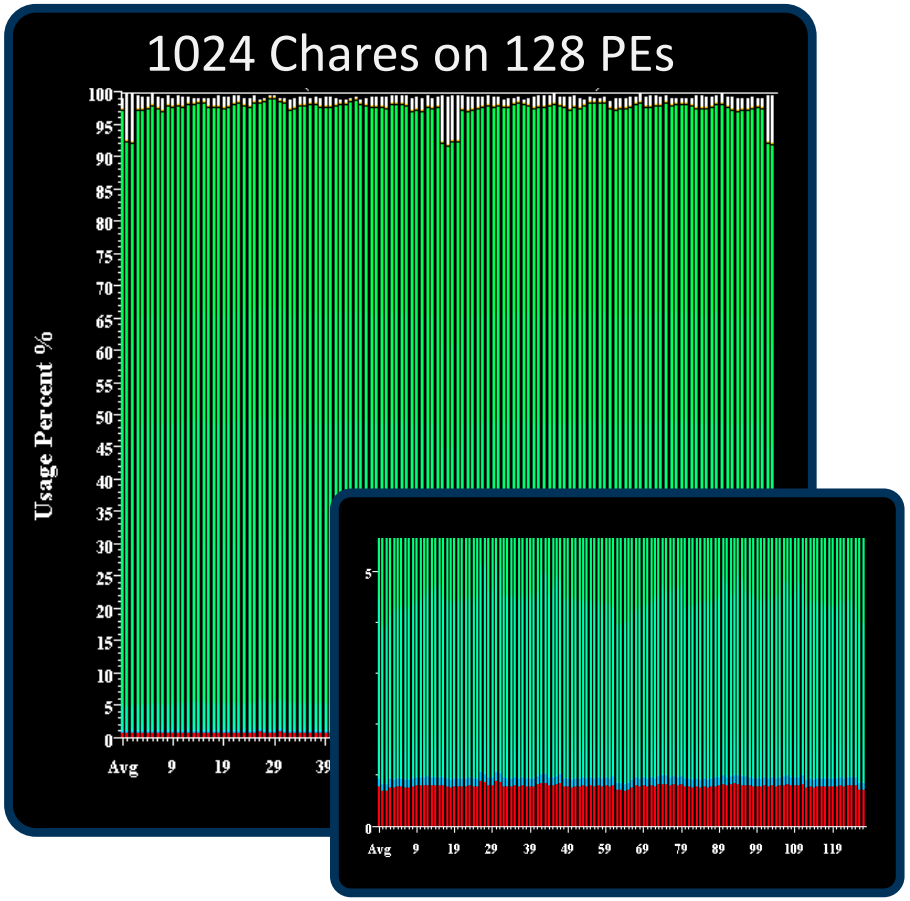
Performance vs. MPI Version: Weak Scaling





Performance: Overdecomposition and Runtime Overhead





Application code in green, runtime overhead in red, idle time in white

(Insets are enlargements of y-axes)

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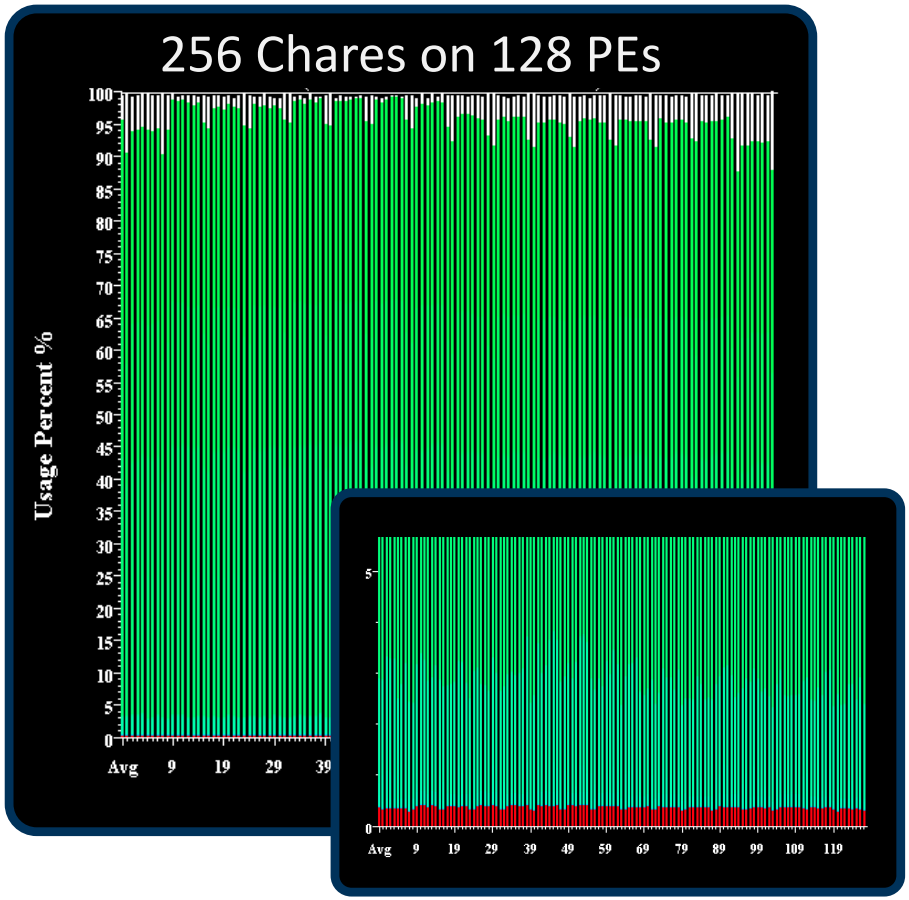

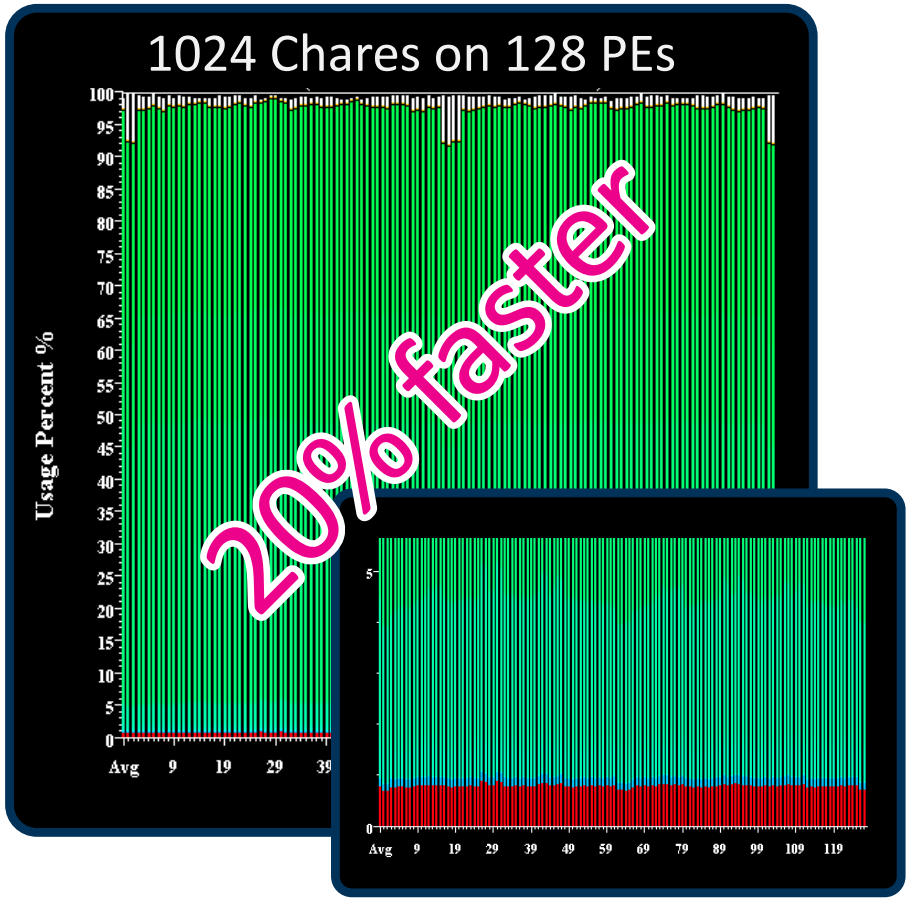

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Questions?

Extra Slides

Overdecomposition and Zero-Copy Semantics

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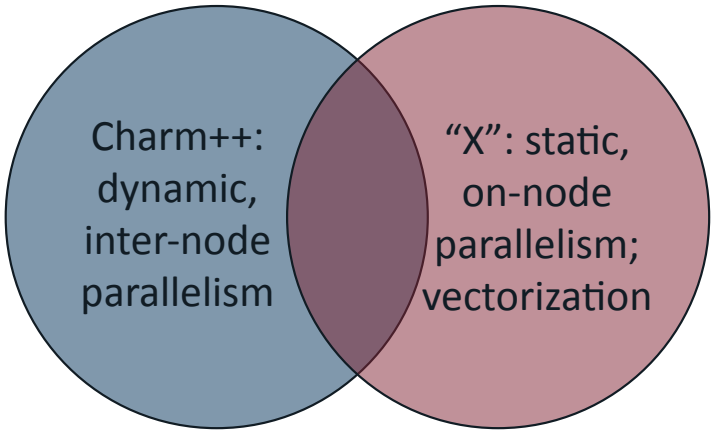
- The “Charm + X” model:



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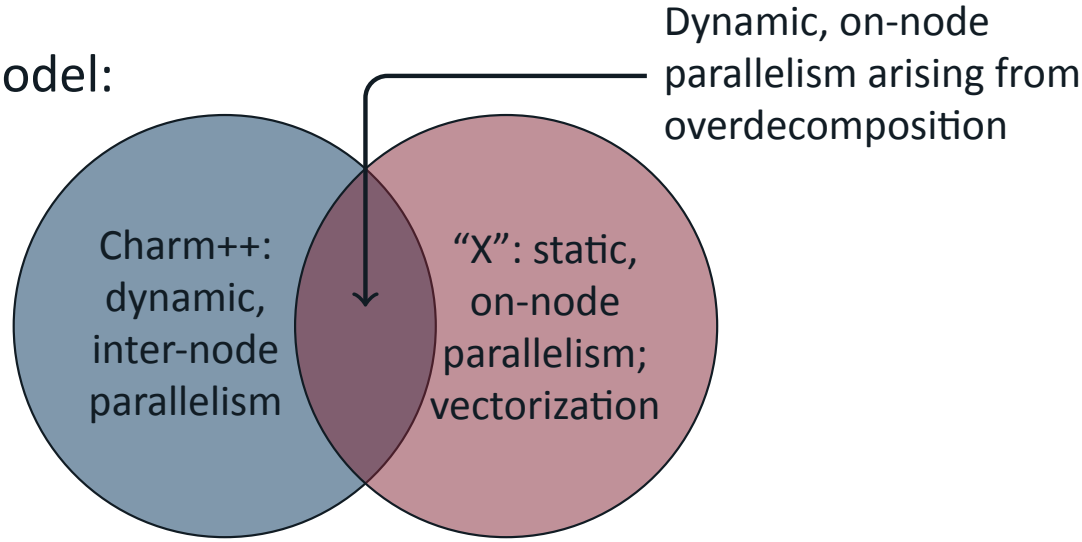

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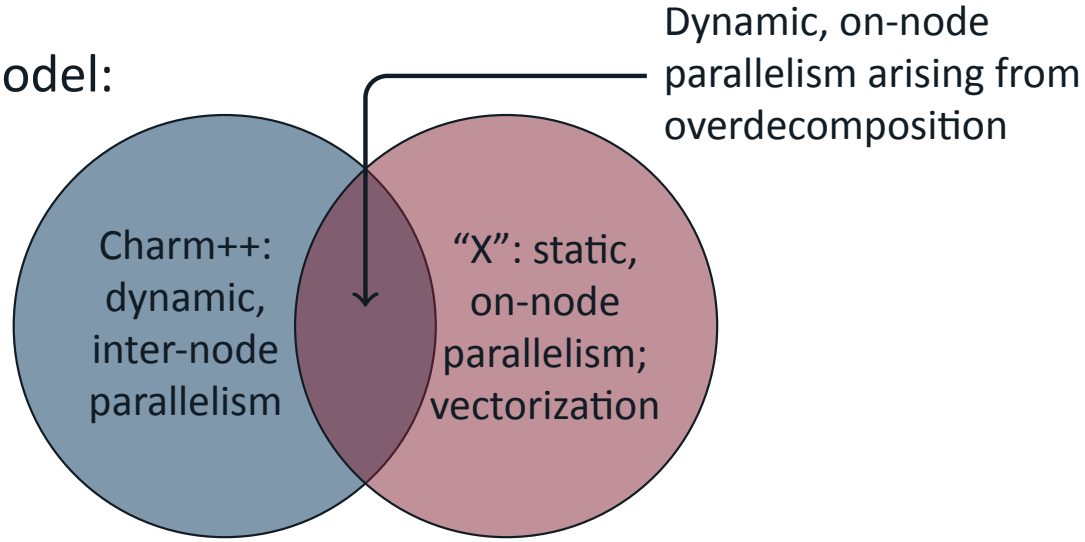

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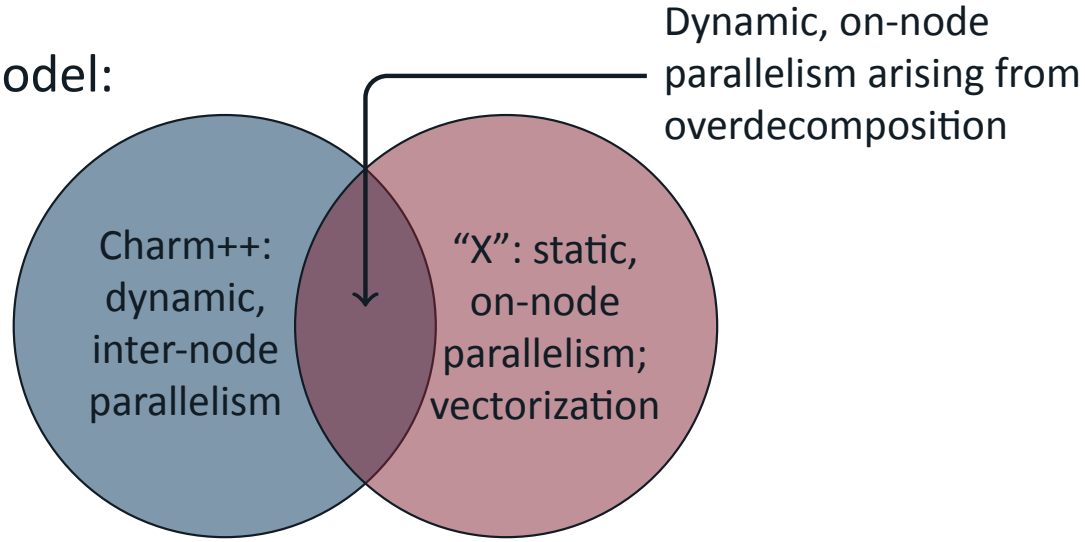

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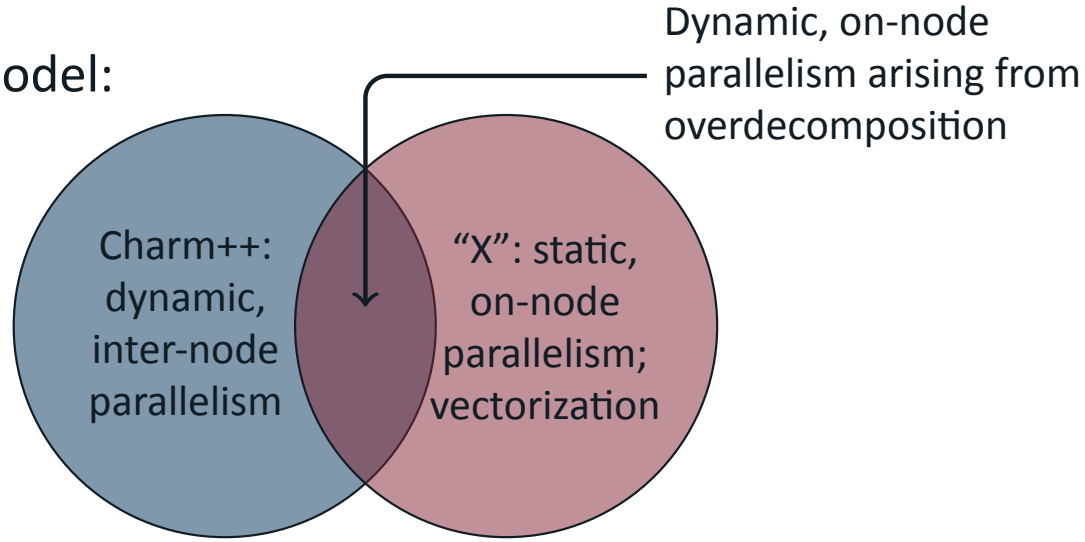

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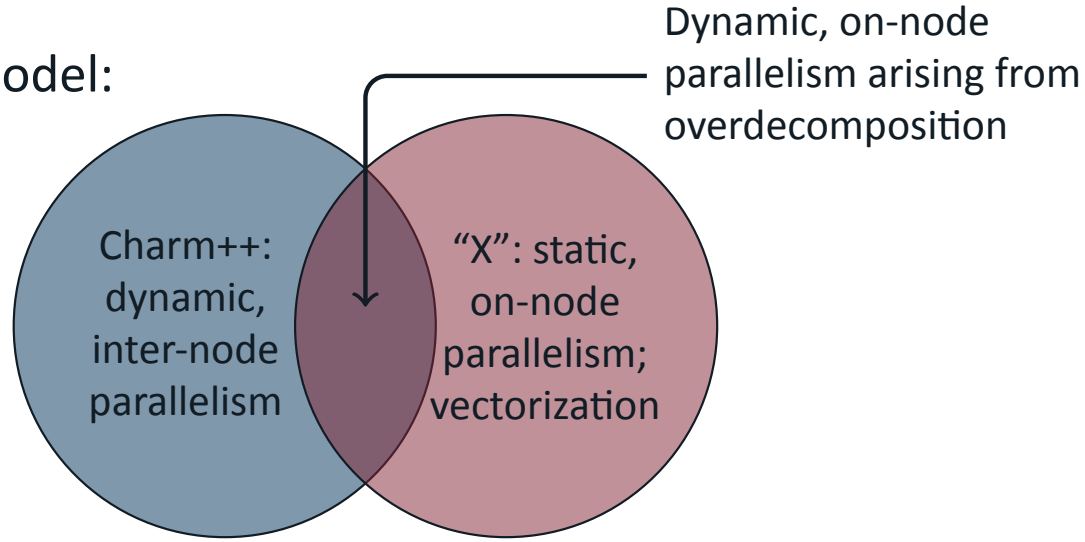

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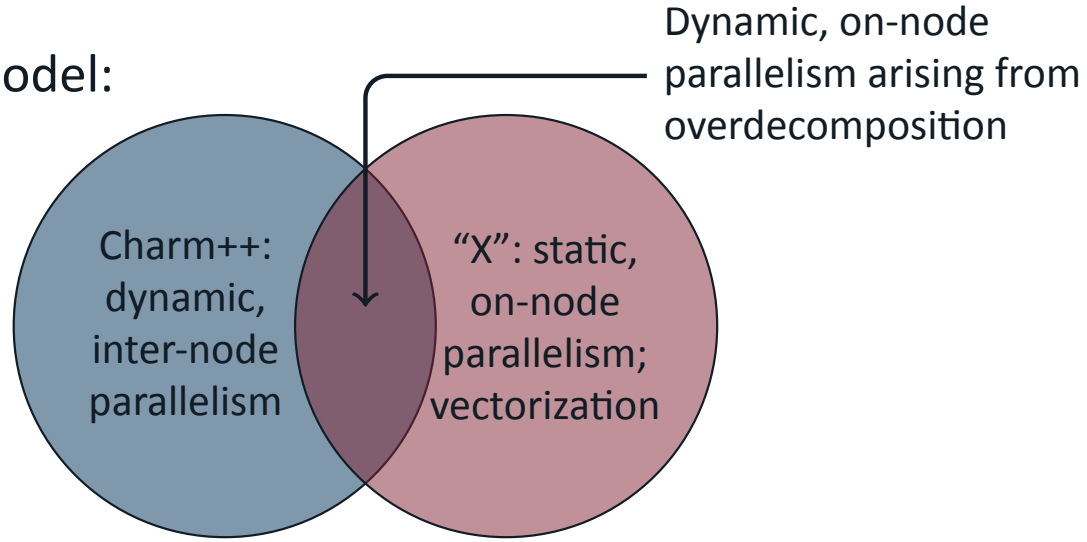

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- The concept of a *shared data block* is missing
  - For instance, `PackedMessage` s have no access privileges (e.g., read only, shared read/write, exclusive read/write)

Other minor issues

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- SMP version: no way to initialize libraries on main thread?

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  - *But…* our current implementation is already comparable to MPI