Structured Dagger: Supporting Asynchrony with Clarity

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  - Part of the Charm++ ecosystem (in C++)

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  - When an entry methods is called it causes the method parameters to be packed and sent over the network and then invoked on the other end

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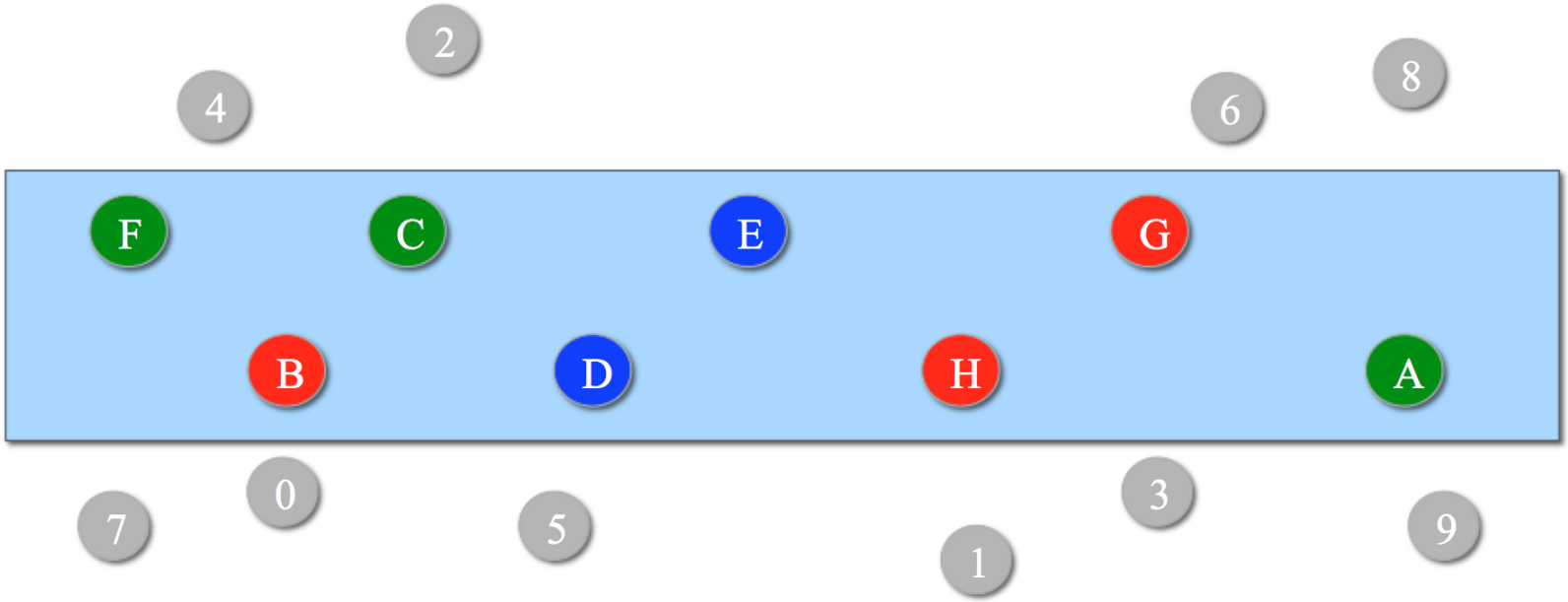

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  - The RTS deposits them in the message queue on the target processor

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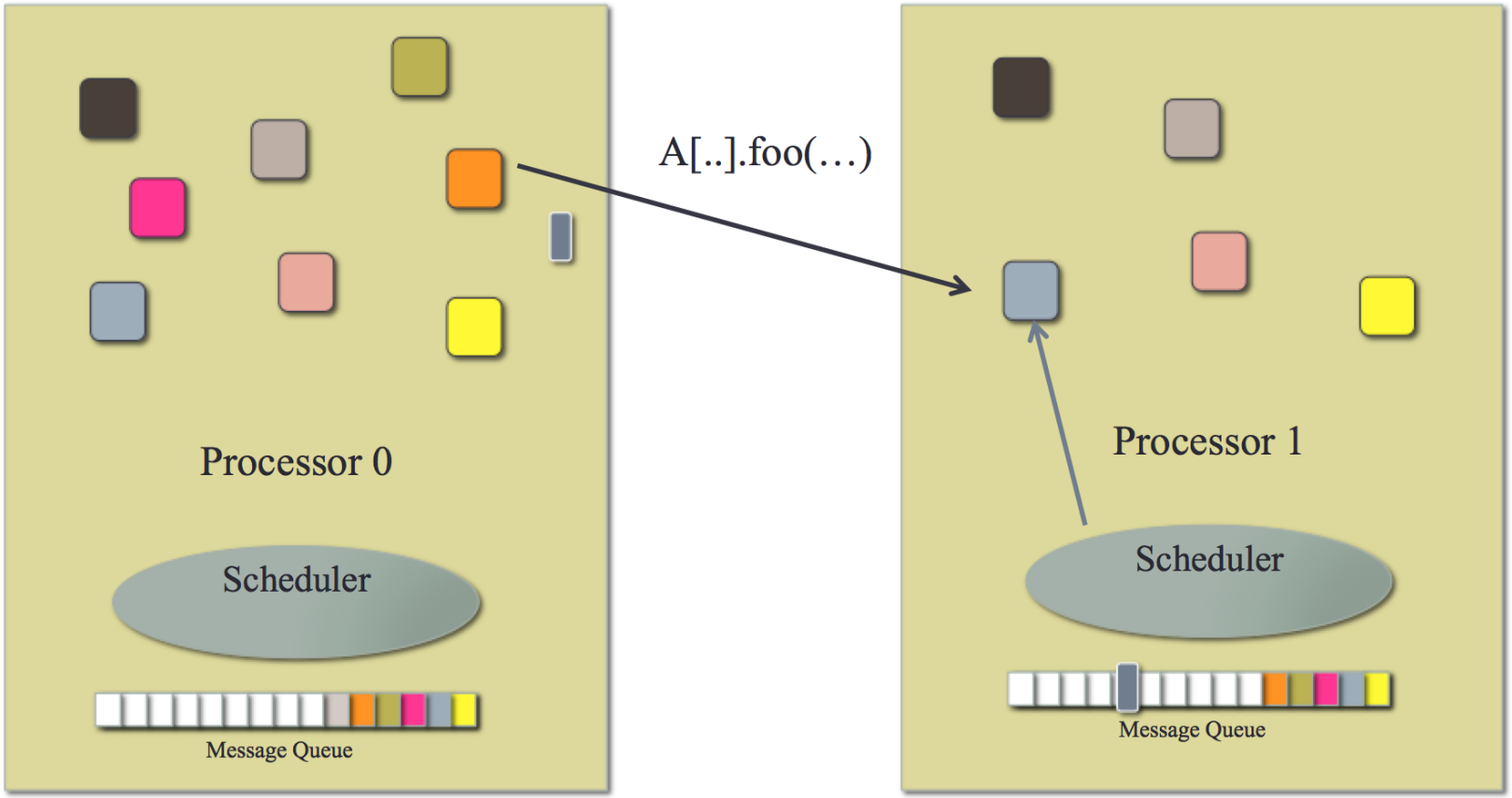

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- Simple Example: Fibonacci

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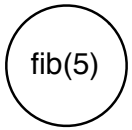

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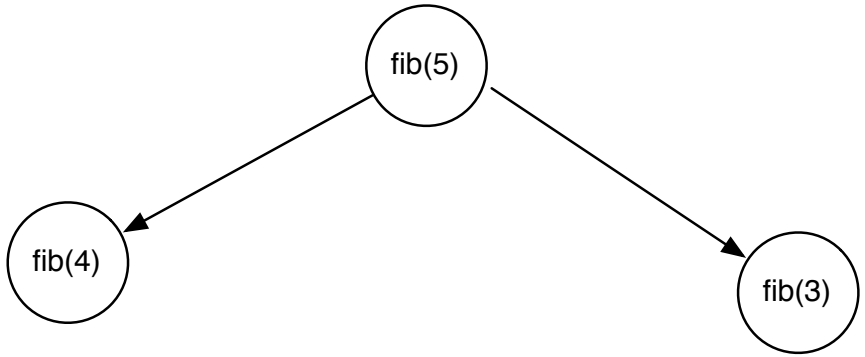

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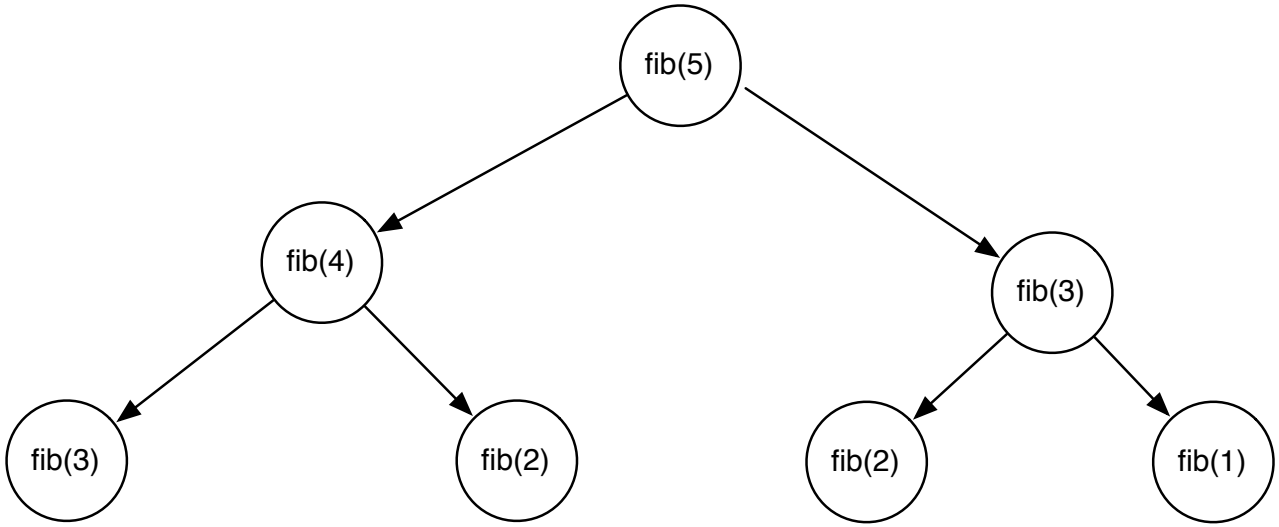

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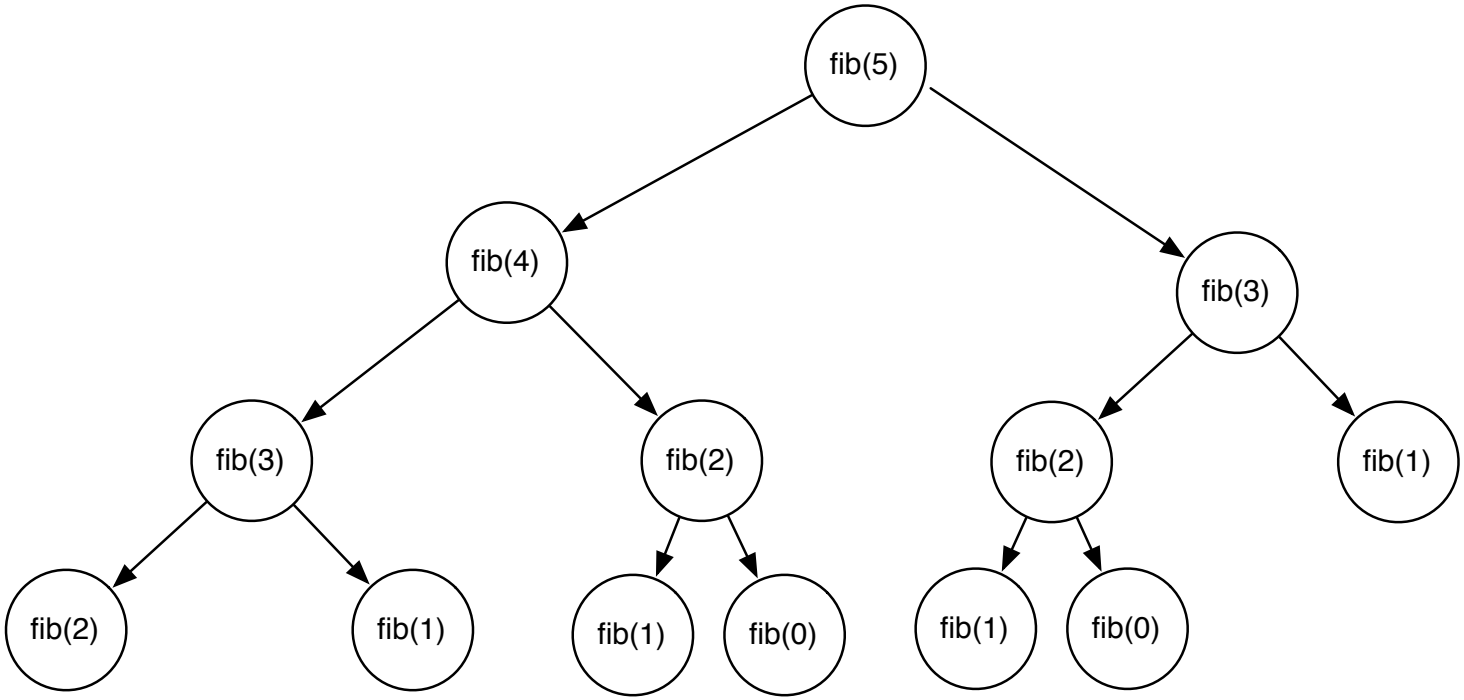

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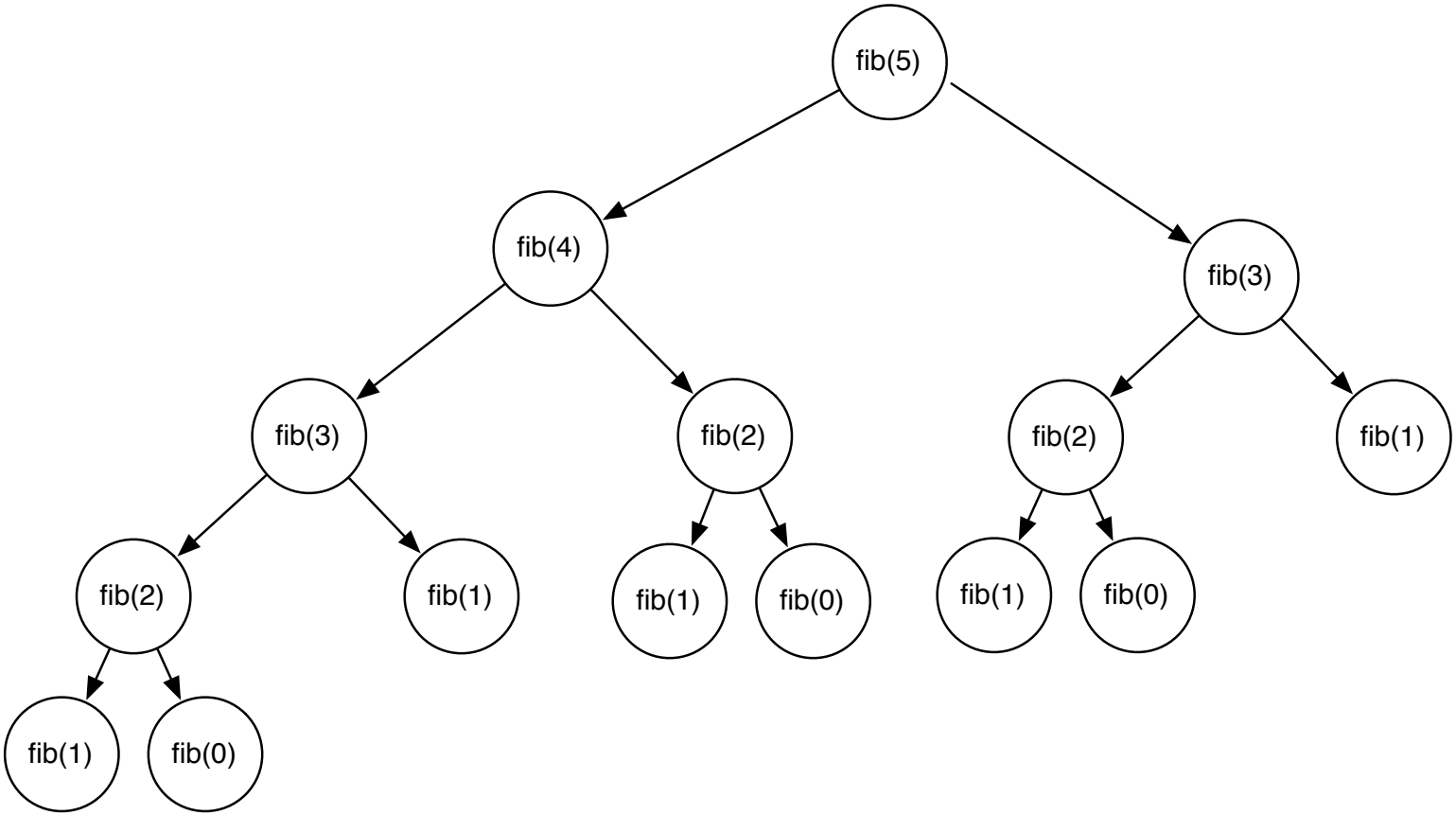

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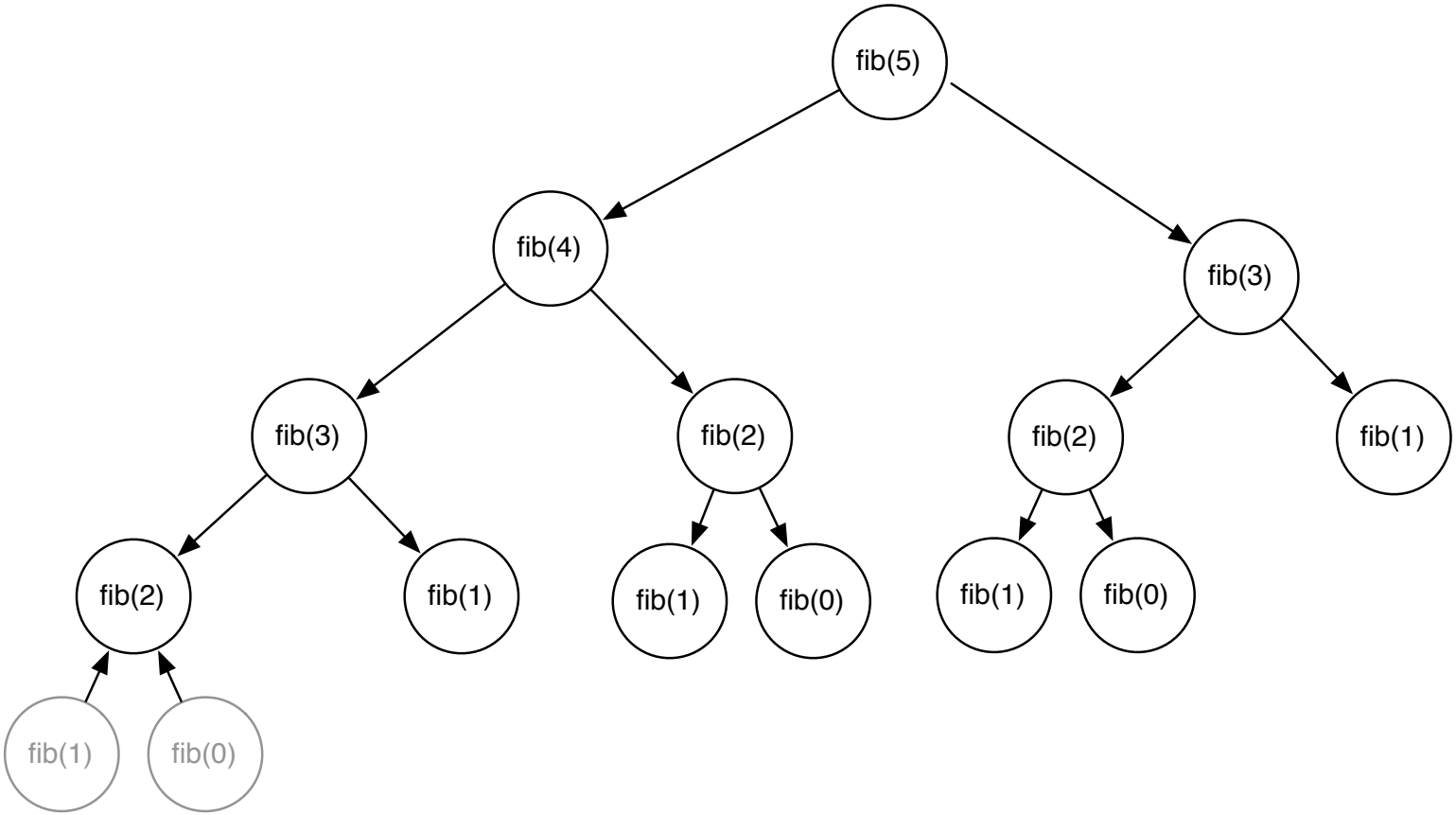

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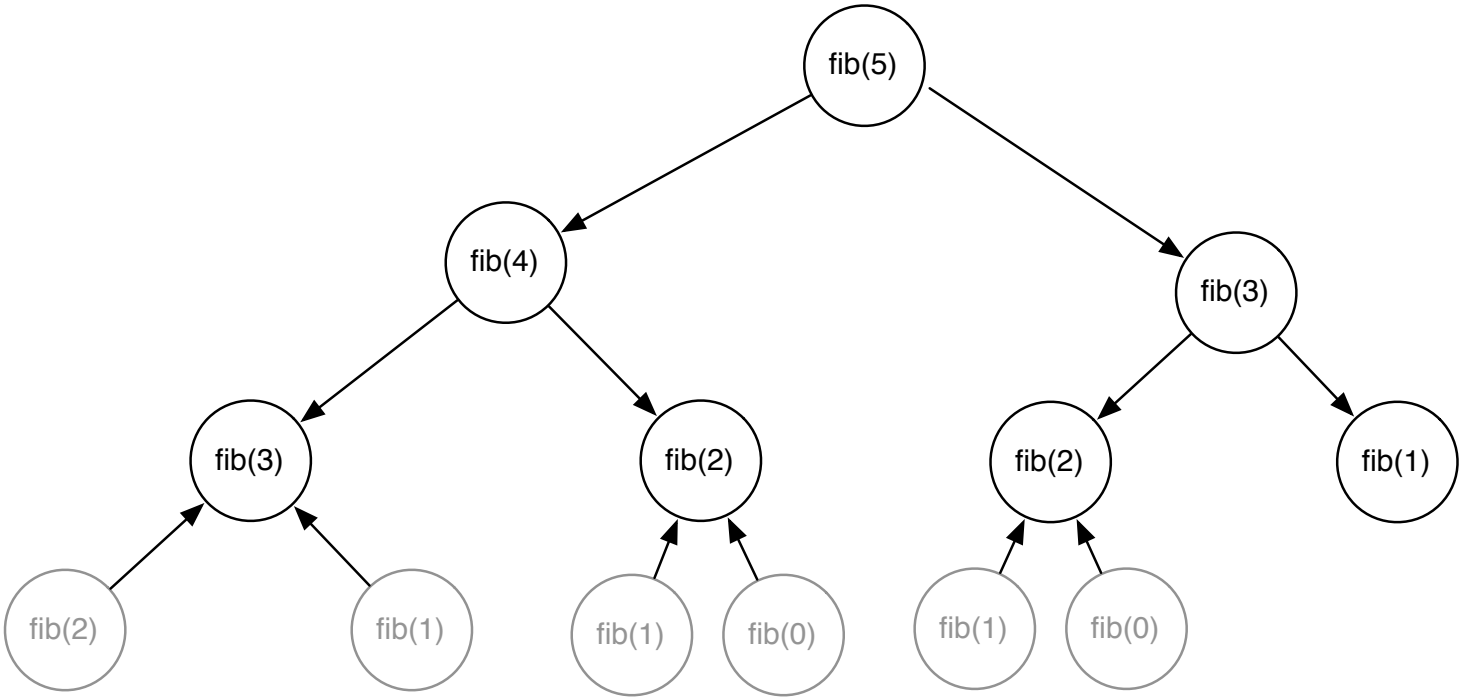

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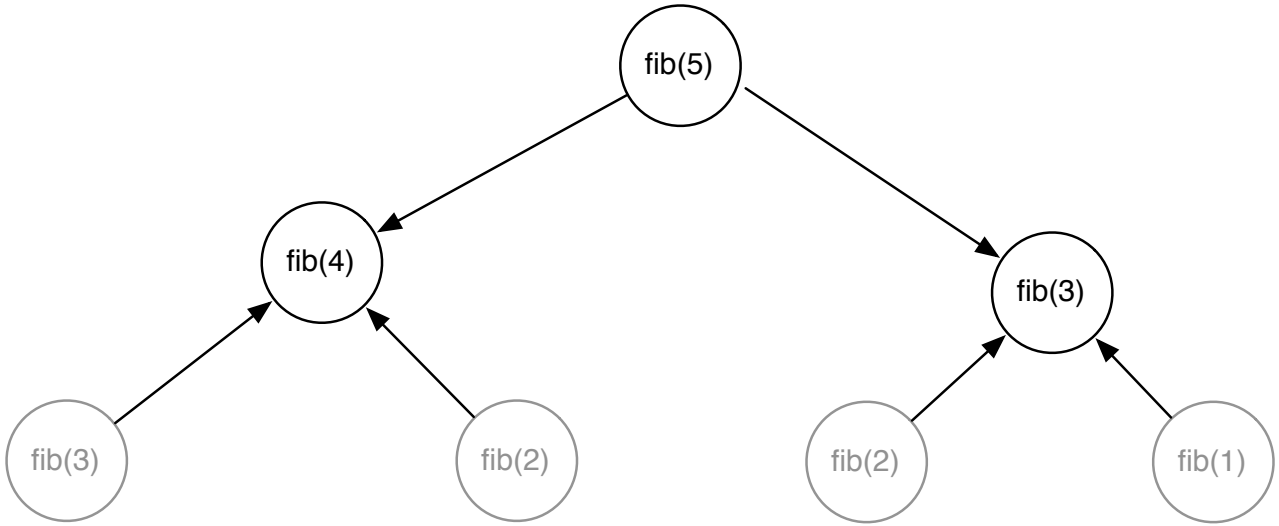

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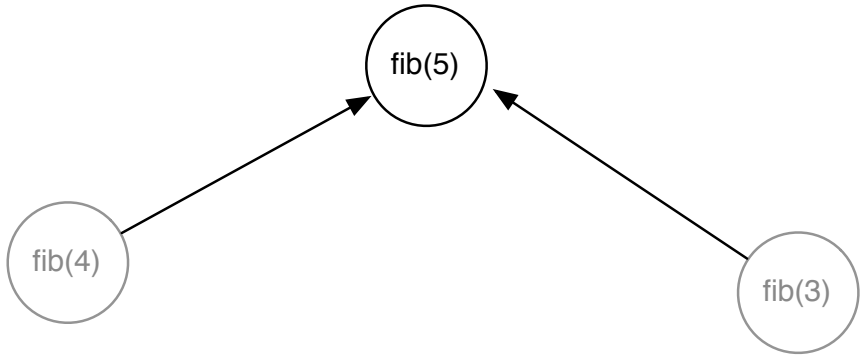

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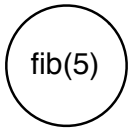

Consider the Fibonacci Chare

- The Fibonacci chare gets created
- If its not a leaf,
  - It fires two chares
  - When both children return results (by calling `response`):
    - ⋆ It can compute my result and send it up, or print it
  - But in our, this logic is hidden in the flags and counters . . .
    - ⋆ This is simple for this simple example, but . . .

Simple Fibonacci in Charm++

```
chare Fib {
  int saved_val, response_counter;
  entry void dowork() {
    if (n < THRESHOLD) { respond(seqFib(n)); }
    else { Fib::ckNew(n − 1); Fib::ckNew(n − 2); }
  }
  entry void response(int val) {
    response_counter++;
    if (response_counter == 1) saved_val = val;
    else respond(val + saved_val);
  }
  void respond(int val) {
    if (!isRoot) parent.response(val);
    else printf("Fibonacci number is: %d\n")
  }
}
```

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- Wait for `A` to complete and then proceed to `B`

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- If `A` and `B` can execute in any order, this must be explicitly defined using the `overlap` construct, implicit join

```
overlap {
  A
  B
}
```

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- The `when` construct allows you match a message using the name of the method and a reference number
- Syntax: `when` methods-to-wait-on block-to-execute

```
when recvData(int size, double data[size]) { /* do something */ }
```

- When a message is matched to a when, the associated block of code executes
- The data from that method is put into scope in the corresponding block

Structured Dagger: Waiting for Messages

- The `when` construct can be nested

```
when myMethod1(int param1, int param2) {
  when myMethod2(bool param3),
       myMethod3(int size, int arr[size]) /* block1 */
  when myMethod4(bool param4) /* block2 */
}
```

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  - Wait for `myMethod2` and `myMethod3`, upon arrival of both, execute `/* block1 */`
  - Wait for `myMethod4`, upon arrival execute `/* block2 */`
- If messages arrive out of order, the Structured Dagger buffers them

Fibonacci without Structured Dagger

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  entry void dowork() {
    if (n < THRESHOLD) { respond(seqFib(n)); }
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Fibonacci with Structured Dagger

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chare Fib {
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- If a reference number is specified for a `when`, the first parameter for the entry method must be the reference number
- The `when` will not be matched until a message arrives with that reference number

```
when method1[100](short ref, bool param1) /* block */
```

Two sends:

```
proxy.method1(200, false); /* will not be delivered to the when */
proxy.method1(100, true); /* will be delivered to the when */
```

Structured Dagger: More Advanced Constructs

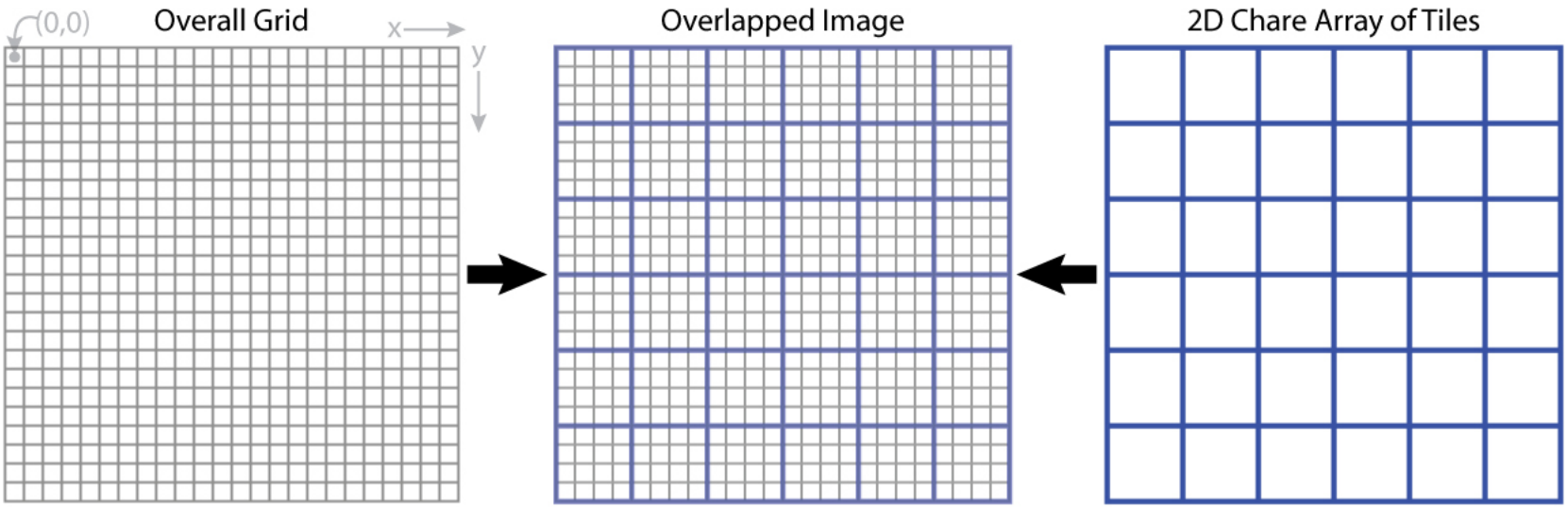
- The language includes `for`, `forall`, `while`
- `for` and `while` are ordered in their iteration space
- `forall` allows the iterations to execute in any order

```
for (iter = 0; iter < maxIter; ++iter) {
  overlap {
    when recvLeft[iter](short num, int len, double data[len]) { computeKernel(LEFT, data); }
    when recvRight[iter](short num, int len, double data[len]) { computeKernel(RIGHT, data); }
  }
}
```

```
while (i < numNeighbors) {
  when recvData(int len, double data[len]) { /* execute kernel */ }
  i++;
}
```

```
forall [block] (0 : numBlocks − 1, 1) {
  when method1[block](short ref, bool someVal) /* code block1 */
}
```

Example Program: Stencil 3D (Jacobi)



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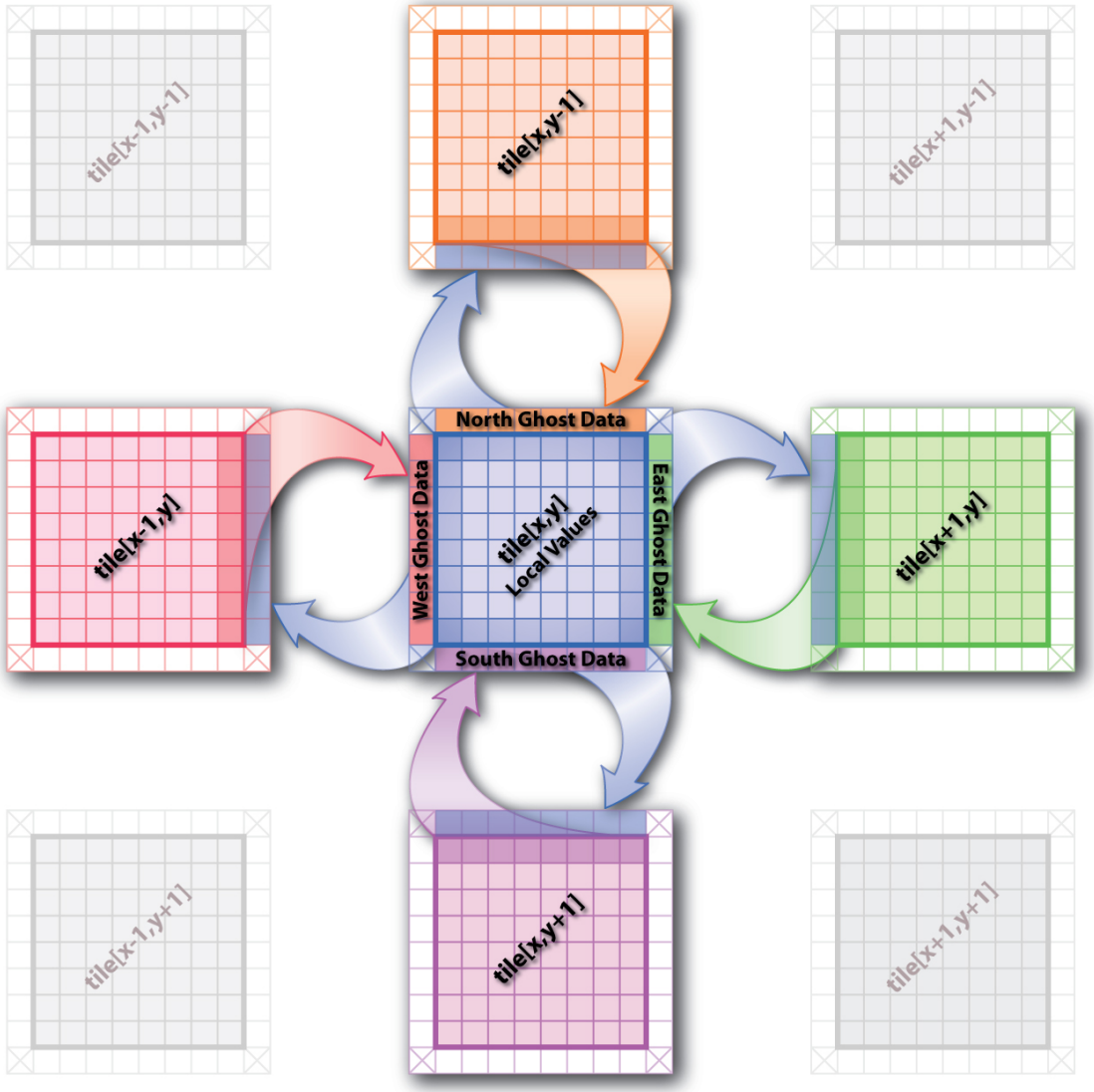

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```
while (!converged) {
  copyToBoundaries();
  sendToNeighbors();
  freeBoundaries();
  for (remoteCount = 0; remoteCount < 6; remoteCount++)
    when updateGhosts[iter](int ref, int dir, int w, int h, double buf[w*h]) {
      updateBoundary(dir, w, h, buf);
    }
  double error = computeKernel();
  int conv = error < DELTA;
  if (iter % 5 == 1)
    contribute_async_reduction(conv, logical_and, checkConverged);
  if (++iter % 5 == 0)
    when checkConverged(bool result)
      if (result) { mainChare.done(iter); converged = true; }
}
```

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  - Most DAGs can be expressed in Structured Dagger, but not all
  - For many scientific programs implemented in Charm++, we've found that Structured Dagger is sufficient

Questions?