Locality / Affinity Features

What is a Locale?

Definition:

- Abstract unit of target architecture
- Supports reasoning about locality
  - defines “here vs. there” / “local vs. remote” / ”cheap vs. $$$”
- Capable of running tasks and storing variables
  - i.e., has processors and memory

Typically: A compute node (multicore processor or SMP)

Getting started with locales

- Users specify # of locales when running Chapel programs

```
% a.out --numLocales=8
```

```
% a.out -nl 8
```

- Chapel provides built-in locale variables

```
config const numLocales: int = …;
const Locales: [0..#numLocales] locale = …;
```

- User's `main()` begins executing on locale #0

Locale Operations

- Locale methods support queries about the target system:

```
proc locale.physicalMemory(…) { … }
proc locale.numPUs() { … }
proc locale.id { … }
proc locale.name { … }
```

- *On-clauses* support placement of computations:

```
writeln("on locale 0");

on Locales[1] do
  writeln("now on locale 1");

writeln("on locale 0 again");
```

```
on A[i,j] do
  bigComputation(A);

on node.left do
  search(node.left);
```

Parallelism and Locality: Orthogonal in Chapel

- This is a **parallel**, but local program:

```
begin writeln("Hello world!");
writeln("Goodbye!");
```

- This is a **distributed**, but serial program:

```
writeln("Hello from locale 0!");
on Locales[1] do writeln("Hello from locale 1!");
writeln("Goodbye from locale 0!");
```

- This is a **distributed** and **parallel** program:

```
begin on Locales[1] do writeln("Hello from locale 1!");
on Locales[2] do begin writeln("Hello from locale 2!");
writeln("Goodbye from locale 0!");
```

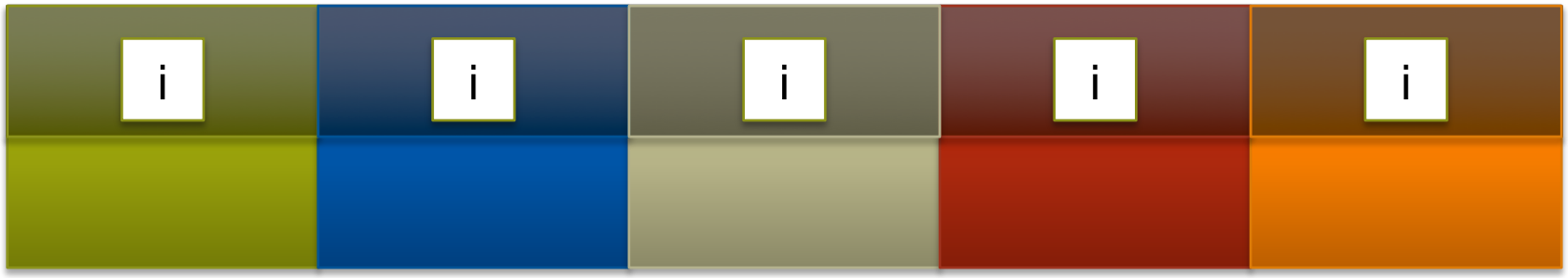
Partitioned Global Address Space (PGAS) Languages

(Or perhaps: partitioned global namespace languages)

- **abstract concept:**
  - support a shared namespace on distributed memory
    - permit parallel tasks to access remote variables by naming them
  - establish a strong sense of ownership
    - every variable has a well-defined location
    - local variables are cheaper to access than remote ones
- **traditional PGAS languages have been SPMD in nature**
  - best-known examples: Fortran Co-Arrays, UPC

SPMD PGAS Languages (using a pseudo-language, not Chapel)

```
shared int i(*);          // declare a shared variable i
```



SPMD PGAS Languages (using a pseudo-language, not Chapel)

```
shared int i(*);          // declare a shared variable i
function main() {
  i = 2*this_image();     // each image initializes its copy
```

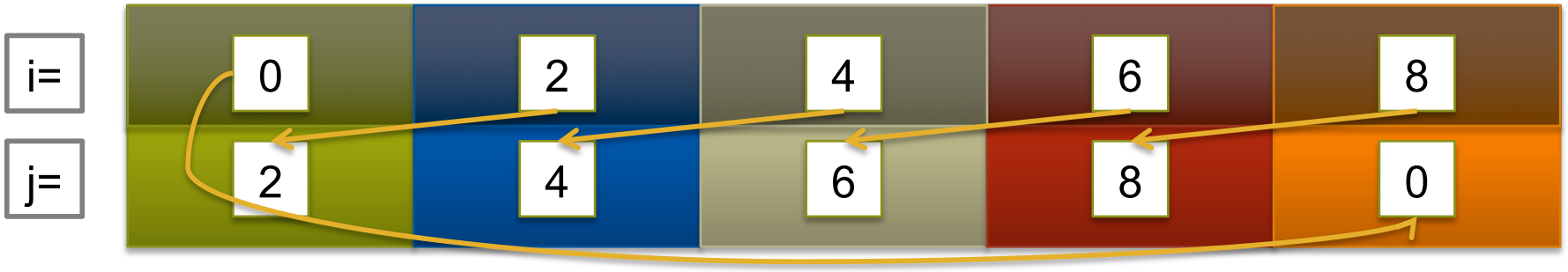
SPMD PGAS Languages (using a pseudo-language, not Chapel)

```
shared int i(*);          // declare a shared variable i
function main() {
  i = 2*this_image();     // each image initializes its copy

  private int j;          // declare a private variable j
```

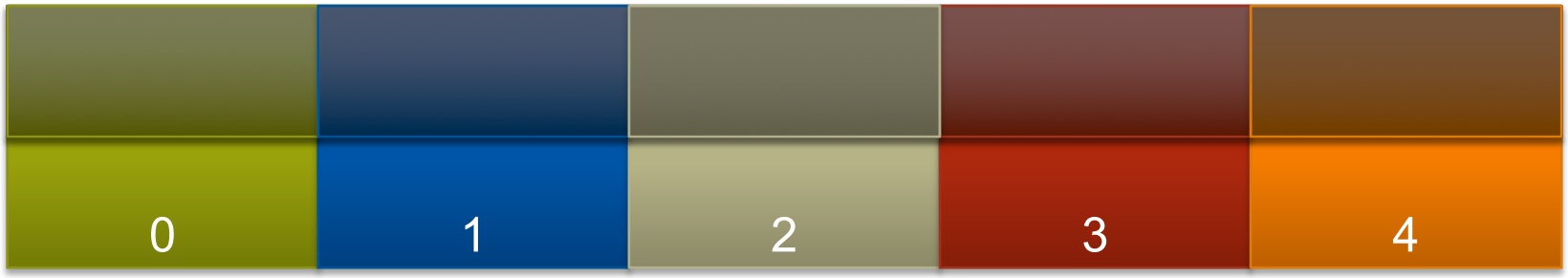
SPMD PGAS Languages (using a pseudo-language, not Chapel)

```
shared int i(*);          // declare a shared variable i
function main() {
  i = 2*this_image();     // each image initializes its copy
  barrier();
  private int j;          // declare a private variable j
  j = i( (this_image()+1) % num_images() );
    // ^^ access our neighbor's copy of i
    // communication is implemented by the compiler + runtime
    // Q: How did we know our neighbor had an i?  A: Because it's SPMD – we're
    // all running the same program.  (Simple, but restrictive)
```



Chapel and PGAS

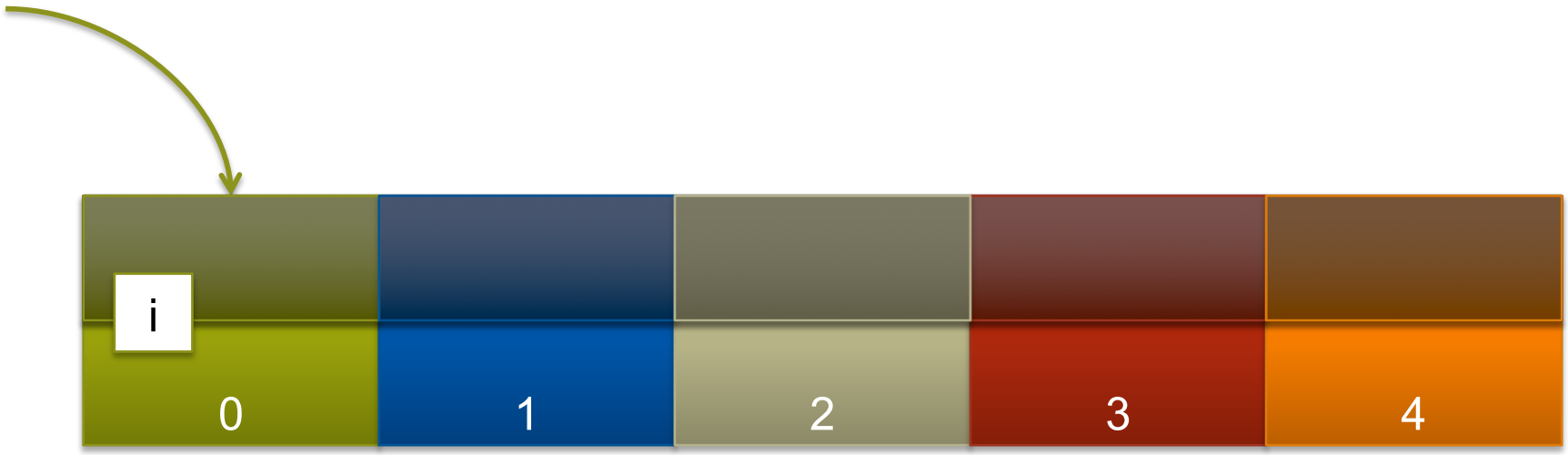
- **Chapel is PGAS, but unlike most, it's not inherently SPMD**
  - never think about "the other copies of the program"
  - "global name/address space" comes from lexical scoping
    - as in traditional languages, each declaration yields one variable
    - variables are stored on the locale where the task declaring it is executing



Locales (think: "compute nodes")

Chapel: Scoping and Locality

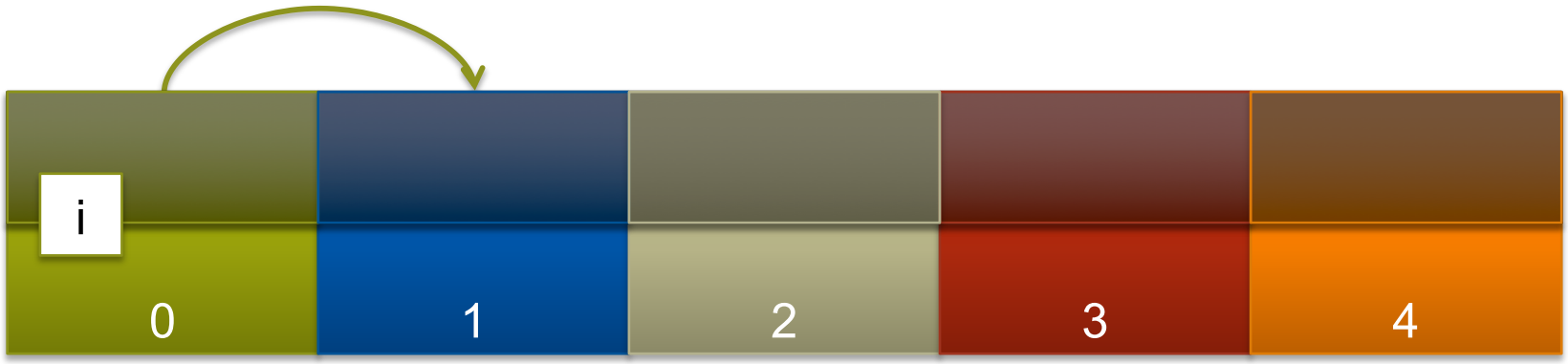
```
var i: int;
```



Locales (think: “compute nodes”)

Chapel: Scoping and Locality

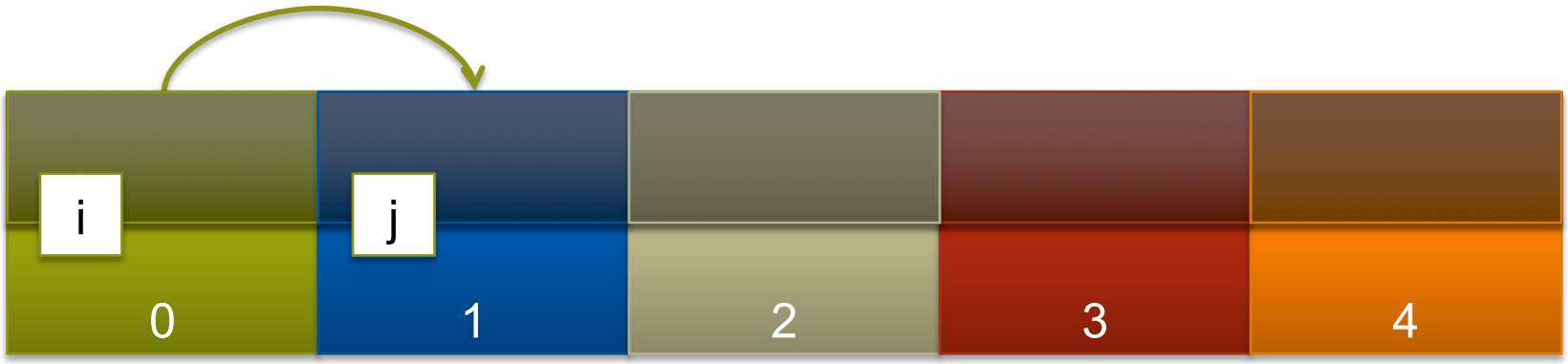
```
var i: int;
on Locales[1] {
```



Locales (think: “compute nodes”)

Chapel: Scoping and Locality

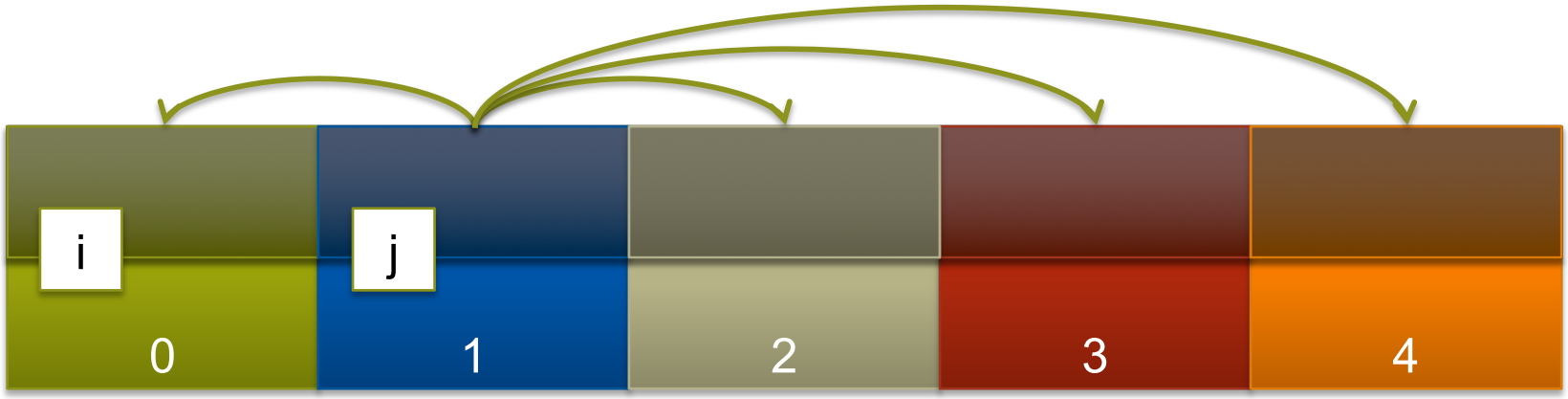
```
var i: int;
on Locales[1] {
  var j: int;
```



Locales (think: “compute nodes”)

Chapel: Scoping and Locality

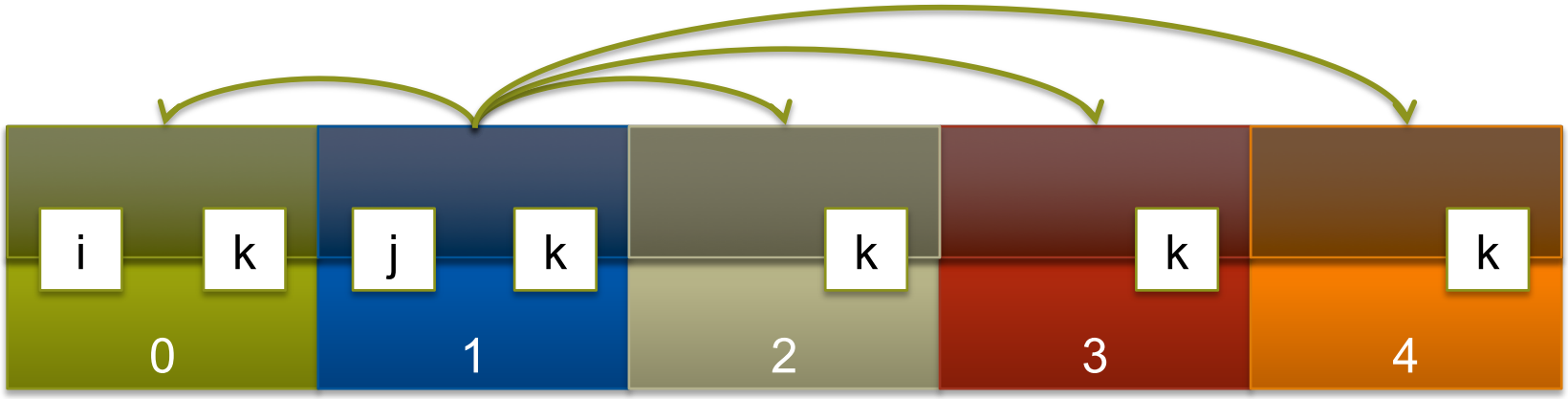
```
var i: int;
on Locales[1] {
  var j: int;
  coforall loc in Locales {
    on loc {
```



Locales (think: “compute nodes”)

Chapel: Scoping and Locality

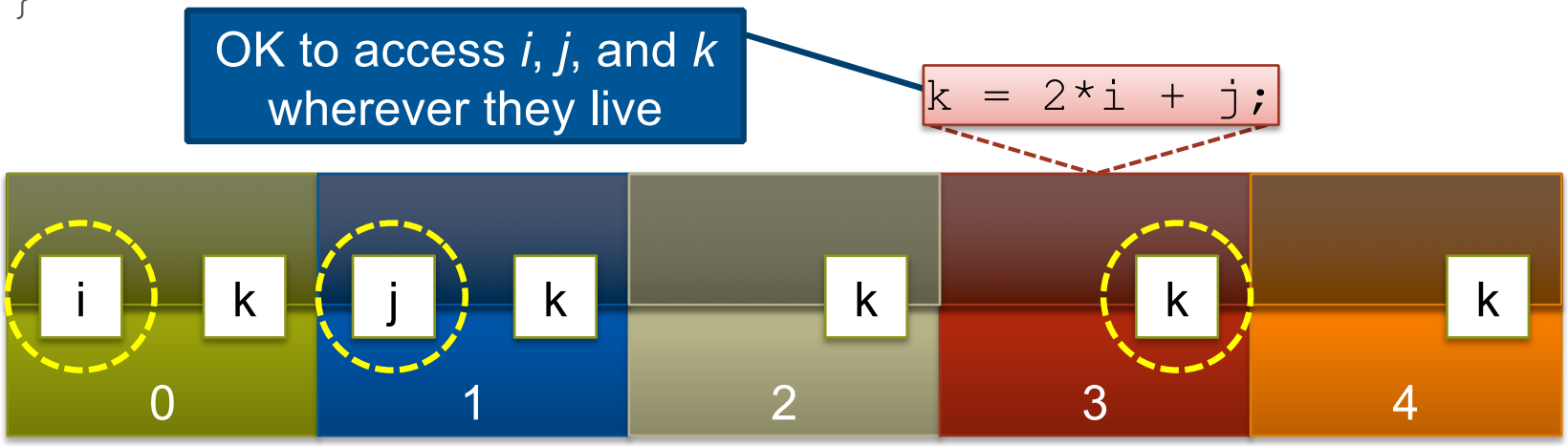
```
var i: int;
on Locales[1] {
  var j: int;
  coforall loc in Locales {
    on loc {
      var k: int;
      …
    }
  }
}
```



Locales (think: “compute nodes”)

Chapel: Scoping and Locality

```
var i: int;
on Locales[1] {
  var j: int;
  coforall loc in Locales {
    on loc {
      var k: int;
      k = 2*i + j;
    }
  }
}
```

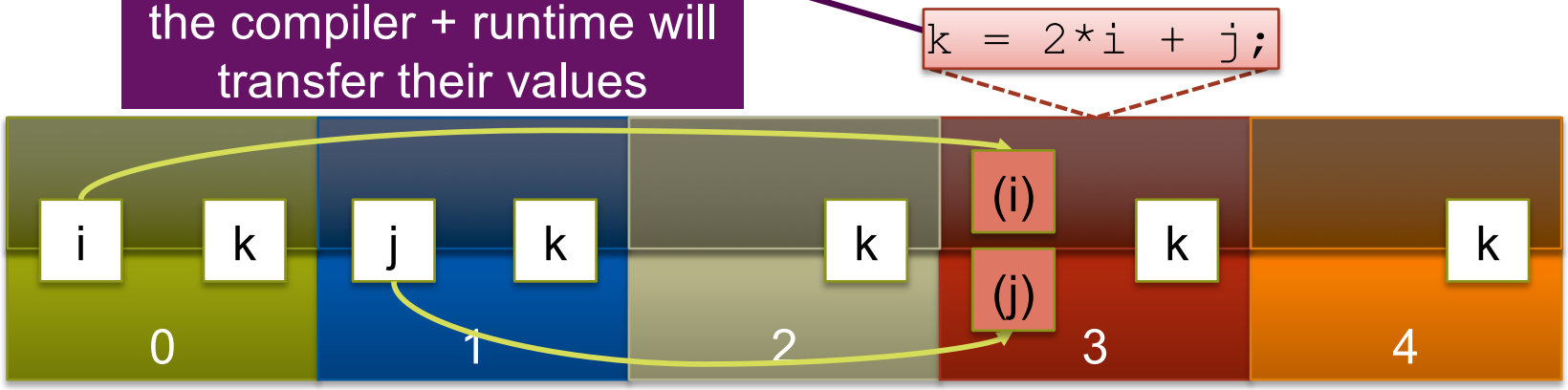


Locales (think: "compute nodes")

Chapel: Scoping and Locality

```
var i: int;
on Locales[1] {
  var j: int;
  coforall loc in Locales {
    on loc {
      var k: int;
      k = 2*i + j;
    }
  }
}
```

here, *i* and *j* are remote, so the compiler + runtime will transfer their values

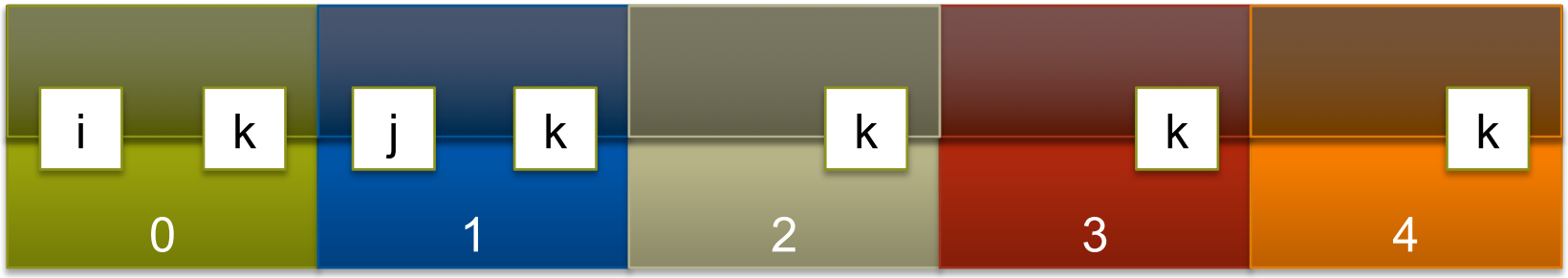


Locales (think: "compute nodes")

Chapel: Locality queries

```
var i: int;
on Locales[1] {
  var j: int;
  coforall loc in Locales {
    on loc {
      var k: int;

      …here…          // query the locale on which this task is running
      …j.locale…      // query the locale on which j is stored
    }
  }
}
```



Locales (think: “compute nodes”)

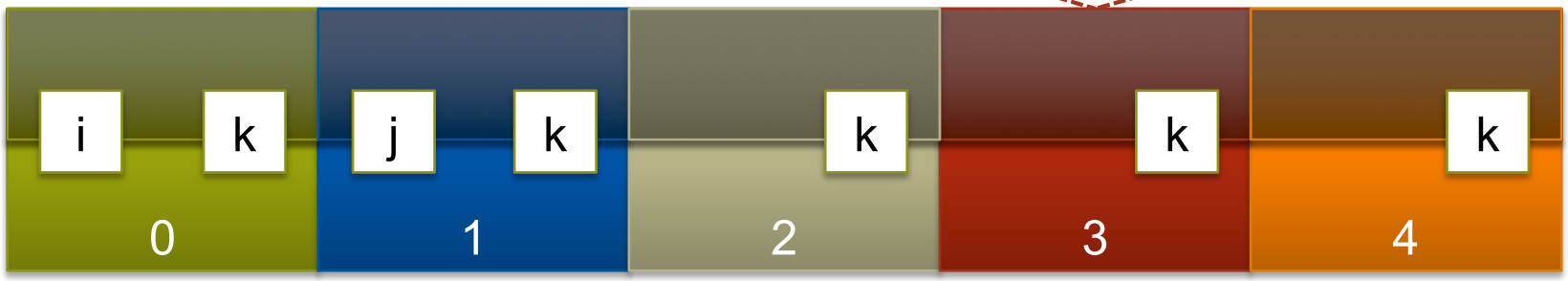
Chapel: Locality queries

```
var i: int;
on Locales[1] {
  var j: int;
  coforall loc in Locales {
    on loc {
      var k: int;

      …here…          // query the locale on which this task is running
      …j.locale…      // query the locale on which j is stored
    }
  }
}
```

Recall: scalars have ‘const in’ task intents by default

here.id = 3
j.locale.id = 3

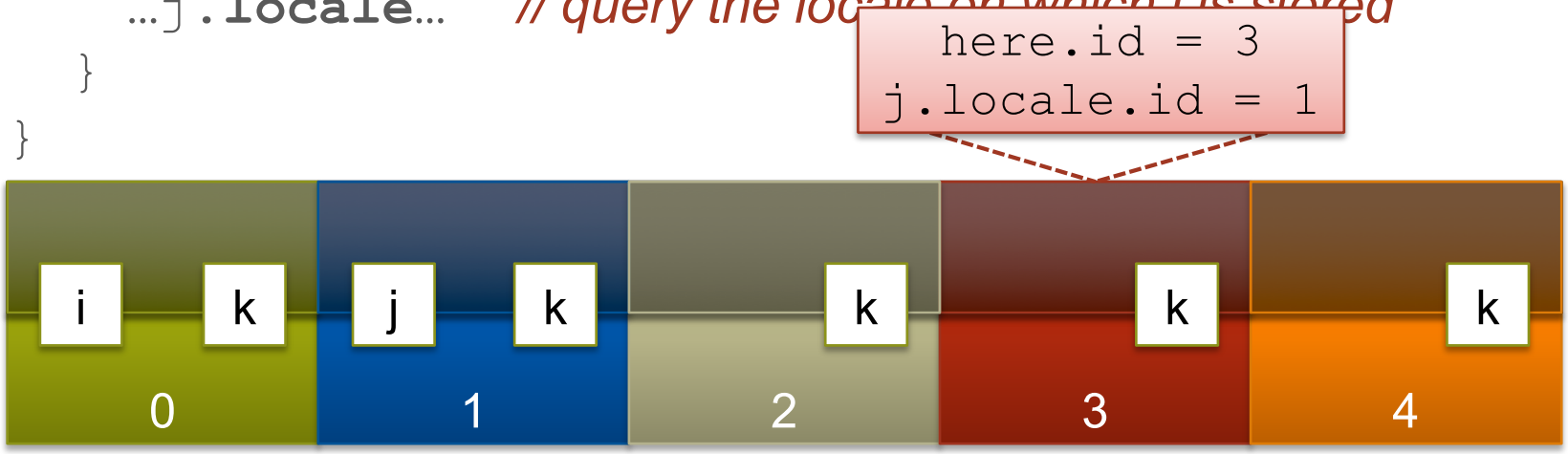


Locales (think: “compute nodes”)

Chapel: Locality queries

```
var i: int;
on Locales[1] {
  var j: int;
  coforall loc in Locales with (ref i, ref j) {
    on loc {
      var k: int;

      …here…          // query the locale on which this task is running
      …j.locale…      // query the locale on which j is stored
    }
  }
}
```



Locales (think: "compute nodes")

Querying a Variable's Locale

- **Syntax**

```
locale-query-expr:
  expr . locale
```

- **Semantics**
  - Returns the locale on which *expr* is stored
- **Example**

```
var i: int;
on Locales[1] {
  var j: int;
  writeln((i.locale.id, j.locale.id));   // outputs (0,1)
}
```

Here

- **Built-in locale variable**

```
const here: locale;
```

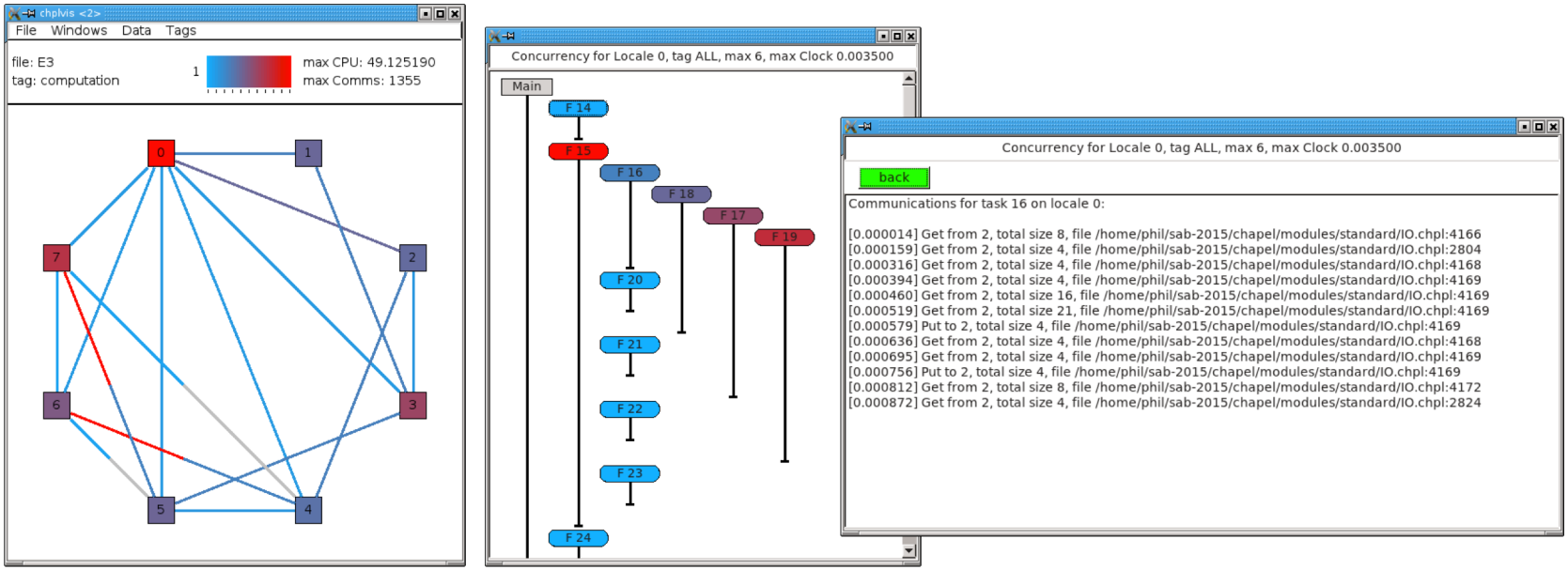
- **Semantics**
  - Refers to the locale on which the task is executing
- **Example**

```
writeln(here.id);      // outputs 0
on Locales[1] do
  writeln(here.id);    // outputs 1

on myC do
  if (here == Locales[0]) then …
```

Reasoning about Communication

- **Though implicit, users can reason about communication**
  - semantic model is explicit about where data is placed / tasks execute
  - execution-time queries support reasoning about locality
    - e.g., `here, x.locale`
  - tools should also play a role here
    - e.g., CommDiagnostics module which can count communications
    - e.g., *chplvis*, contained in the release (developed by Phil Nelson, WWU)

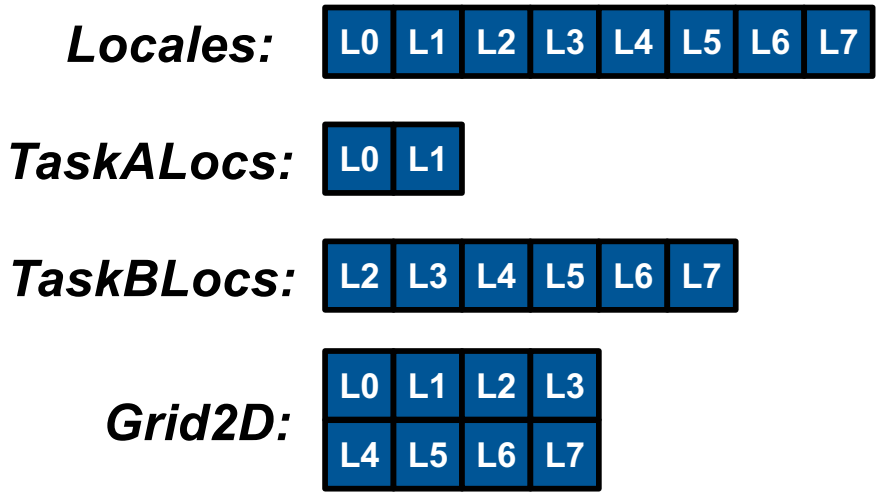


Rearranging Locales

Create locale views with standard array operations:

```
var TaskALocs = Locales[0..1];
var TaskBLocs = Locales[2..];

var Grid2D = reshape(Locales, {1..2, 1..4});
```



Questions about (low-level) locality in Chapel?

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