CRAY
THE SUPERCOMPUTER COMPANY

Chapel: Locales

(Controlling Locality and Affinity)

The Locale

- **Definition**
  - Abstract unit of target architecture
  - Capable of running tasks and storing variables
    - i.e., has processors and memory
  - Supports reasoning about locality
- **Properties**
  - a locale's tasks have ~uniform access to local vars
  - Other locale's vars are accessible, but at a price
- **Locale Examples**
  - A multi-core processor
  - An SMP node

"Hello World" in Chapel: a Multi-Locale Version

- Multi-locale Hello World

```
coforall loc in Locales do
  on loc do
    writeln("Hello, world! ",
            "from node ", loc.id, " of ", numLocales);
```

Locales and Program Startup

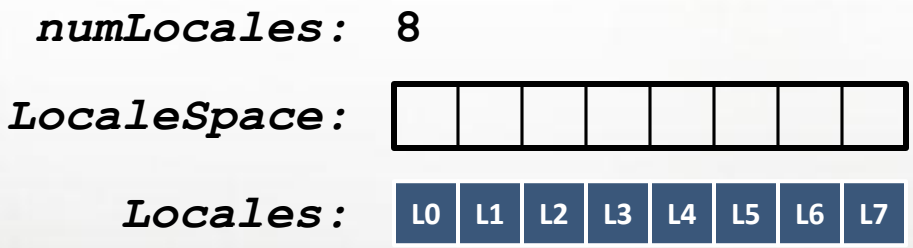
- Specify # of locales when running Chapel programs

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

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

- Chapel provides built-in locale variables

```
config const numLocales: int;
const LocaleSpace: domain(1) = [0..numLocales-1];
const Locales: [LocaleSpace] locale;
```



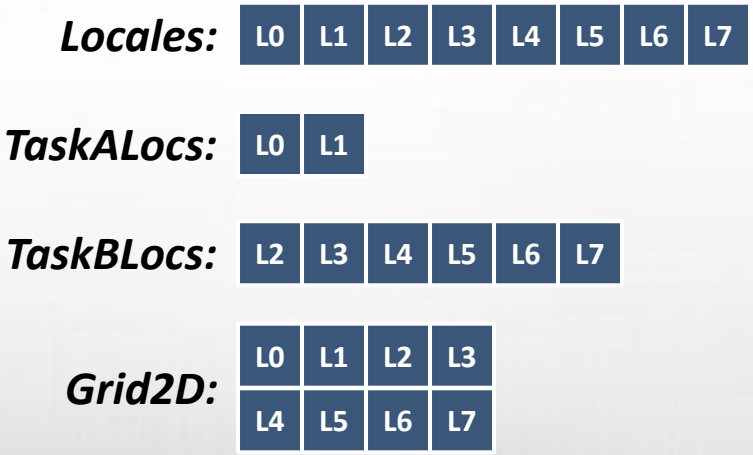
- main() begins as a single task on locale #0 (`Locales[0]`)

Rearranging Locales

Create locale views with standard array operations:

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

var Grid2D = Locales.reshape([1..2, 1..4]);
```



Locale Methods

- `def locale.id: int { ... }`

  Returns locale's index in LocaleSpace

- `def locale.name: string { ... }`

  Returns name of locale, if available (like uname -a)

- `def locale.numCores: int { ... }`

  Returns number of processor cores available to locale

- `def locale.physicalMemory(...) { ... }`

  Returns physical memory available to user programs on locale

Example

```
const totalPhysicalMemory =
  + reduce Locales.physicalMemory();
```

The On Statement

- Syntax

```
on-stmt:
  on expr { stmt }
```

- Semantics
  - Executes *stmt* on the locale that stores *expr*
- Example

```
writeln("start on locale 0");
on Locales(1) do
  writeln("now on locale 1");
writeln("on locale 0 again");
```

Locality and Parallelism are Orthogonal

- On-clauses do not introduce any parallelism

```
writeln("start on locale 0");
on Locales(1) do
  writeln("now on locale 1");
writeln("on locale 0 again");
```

- But can be combined with constructs that do:

```
writeln("start on locale 0");
begin on Locales(1) do
  writeln("now on locale 1");
on Locales(2) do begin
  writeln("now on locale 2");
writeln("on locale 0 again");
```

- (the final three statements could appear in any order)

SPMD Programming in Chapel Revisited

- A language may support both global- and local-view programming — in particular, Chapel does

```
def main() {
  coforall loc in Locales do
    on loc do
      MySPMDProgram(loc.id, Locales.numElements);
}

def MySPMDProgram(me, p) {
  ...
}
```

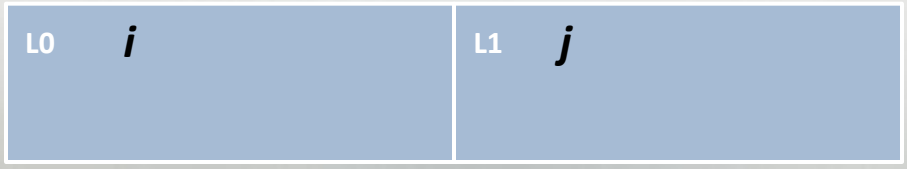
Querying a Variable's Locale

- 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 01
}
```



Here

- Built-in locale value

```
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
```

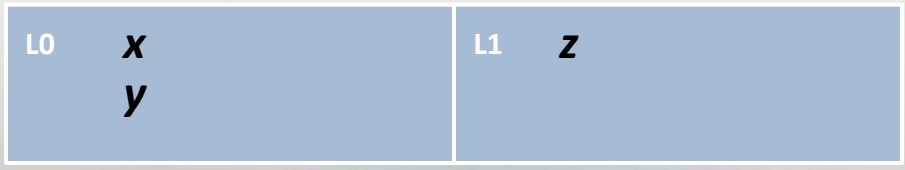
Serial Example with Implicit Communication

```
var x, y: real;       // x and y allocated on locale 0

on Locales(1) {       // migrate task to locale 1
  var z: real;        // z allocated on locale 1

  z = x + y;          // remote reads of x and y

  on Locales(0) do    // migrate back to locale 0
    z = x + y;        // remote write to z
                      // migrate back to locale 1
  on x do             // data-driven migration to locale 0
    z = x + y;        // remote write to z
                      // migrate back to locale 1
}                     // migrate back to locale 0
```



Local statement

- Syntax

```
local-stmt:
  local { stmt };
```

- Semantics
  - Asserts to the compiler that all operations are local
- Example

```
on Locales(1) {
  var x: int = …;
  var y: int = …;
  local {
    x += y;
  }
  writeln(x);  // outputs 1
}
```

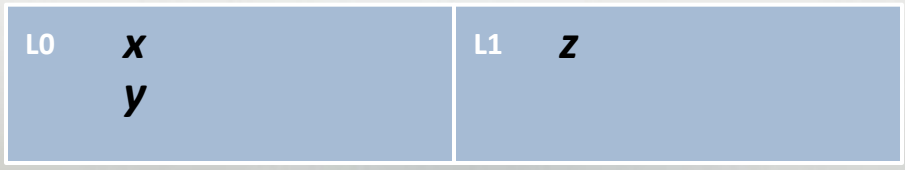
Serial Example revisited

```
var x, y: real;       // x and y allocated on locale 0

on Locales(1) {       // migrate task to locale 1
  var z: real;        // z allocated on locale 1

  z = x + y;          // remote reads of x and y

  on Locales(0) {     // migrate back to locale 0
    var tz: real;
    local tz = x+y;   // no "checks" performed
    z = tz;           // remote write to z
  }                   // migrate back to locale 1
  ...
}                     // migrate back to locale 0
```



Status: Locales

- Everything should be functioning perfectly
- The compiler is currently conservative about assuming variables may be non-local
  - Impact: scalar performance overhead
- The compiler is currently lacking several important communication optimizations
  - Impact: scalability tends to be limited for programs with structured communication

Future Directions

- Hierarchical Locales (joint work with UIUC)
  - Support ability to expose hierarchy, heterogeneity within locales
  - Particularly important in next-generation nodes
    - CPU+GPU hybrids
    - tiled processors
    - manycore processors

Questions?

- Multi-Locale Basics
  - Locales
  - on
  - here
  - local