Memory Leaks

Chapel Team, Cray Inc.
Chapel version 1.14
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Outline

● **Sync/Single: A record-wrapped class**
● **Memory Leaks**
Sync/Single: A record-wrapped class
Sync/Single: Background

- Historically a type with special compiler support
- Defined as a class
  - with two fields
    - a generic field: constrained to primitive types and classes
    - an internal synchronization field
  - critical methods implemented using compiler primitives
  - compiler-based memory management
    - but only worked well for simpler cases
- A major source of leaks
  - The third largest category when counting tests with leaks
    - accounted for approximately 14% of leaking tests
  - Not intended to be a type that should be deleted by user
Sync/Single: This Effort

● **Convert to a record-wrapped class**
  ● The record:
    ● implements the user facing API
    ● wraps an instance of a class
    ● the defining record *owns* memory management of the instance
    ● a copy of the record merely references the instance
    ● Chapel semantics ensure copies will not outlive the owning record
  
  ● The class
    ● provides the unique *identity* required for the synchronization state
    ● is derived from the previous implementation
    ● uses extern procedure declarations in place of former compiler primitives
Sync/Single: This Effort

**Modified the handling of default intents**
- The default formal intent for sync/single is `ref`
- The default formal intent for user defined records is `const ref`
- Introduced a pragma to override the default intent

**Modified the Remote Value Forwarding optimization**
- Goal: send variables’ values with active messages for on-clauses
  - avoids communication to read such variables later
  - can only be done when safe according to MCM
- Disabled when body of on-statement includes sync/single (recursively)
  - old approach: identify functions with certain sync primitives
  - new approach: identify methods on sync/single types
Sync/Single: Status and Next Steps

● **Status**
  ● Removed leaks for approximately 200 tests
  ● Removed special compiler logic/primitives for sync and single
  ● No evidence of performance regression

● **Next steps**
  ● Revisit as a use case for delegation / smart pointers
Memory Leaks
Memory Leaks: Background

● Memory leak statistics are collected every night
  ● Performance team reviews every week
  ● Currently gathering single locale leaks only

● Two metrics are tracked
  1. Total bytes leaked
     ● Impacted by test parameters (e.g., choice of array sizes)
  2. Number of tests with leaks
     ● Some tests run in multiple variations, so one oversight leads to many leaks

<table>
<thead>
<tr>
<th></th>
<th>1.13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tests run</td>
<td>4,804</td>
</tr>
<tr>
<td>Total memory allocated (MiB)</td>
<td>36,749</td>
</tr>
<tr>
<td>Total memory leaked (MiB)</td>
<td>942</td>
</tr>
<tr>
<td>Tests with leaks</td>
<td>1,193</td>
</tr>
</tbody>
</table>

1 MiB = 1024 x 1024 bytes
Memory Leaks: This Effort

- Categorized primary causes of leaks (April 2016)

<table>
<thead>
<tr>
<th>Source</th>
<th>Count</th>
<th>%</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>User fails to reclaim memory</td>
<td>~400</td>
<td>37.3</td>
<td>Largely fixed</td>
</tr>
<tr>
<td>Sync/single</td>
<td>~155</td>
<td>14.4</td>
<td>Fixed</td>
</tr>
<tr>
<td>Tuples of records</td>
<td>~100</td>
<td>9.3</td>
<td>Fixed</td>
</tr>
<tr>
<td>main(args : [] string)</td>
<td>~20</td>
<td>1.9</td>
<td>Fixed</td>
</tr>
<tr>
<td>Distributed arrays</td>
<td>~190</td>
<td>17.7</td>
<td>Soon</td>
</tr>
<tr>
<td>Initialization of generic fields</td>
<td>~80</td>
<td>7.5</td>
<td>Unchanged</td>
</tr>
<tr>
<td>Field initializer</td>
<td>~40</td>
<td>3.7</td>
<td>Unchanged</td>
</tr>
<tr>
<td>First-class functions</td>
<td>~25</td>
<td>2.3</td>
<td>Unchanged</td>
</tr>
<tr>
<td>Runtime types</td>
<td>~15</td>
<td>1.4</td>
<td>Unchanged</td>
</tr>
<tr>
<td>Misc and further classification required</td>
<td>~50</td>
<td>4.7</td>
<td>Unchanged</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,073</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Memory Leaks: This Effort

- **Reduced total bytes (MiB) leaked**
  - Dominated by a few tests of distributed arrays
    - Continues to be true in release
    - Wrapping up work with a major impact on array/domain leaks*

<table>
<thead>
<tr>
<th></th>
<th>1.13</th>
<th>1.14</th>
<th>Soon*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total memory leaked (MiB)</td>
<td>942</td>
<td>951</td>
<td>47</td>
</tr>
<tr>
<td>Num tests that leak &gt; 5 MiB</td>
<td>7</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Fraction of all leaks</td>
<td>92.0%</td>
<td>91.1%</td>
<td>34.8%</td>
</tr>
<tr>
<td>Num tests that leak &gt; 1MiB</td>
<td>31</td>
<td>35</td>
<td>16</td>
</tr>
<tr>
<td>Fraction of all leaks</td>
<td>97.8%</td>
<td>97.8%</td>
<td>80.1%</td>
</tr>
</tbody>
</table>

1 MiB = 1024 x 1024 bytes

* This refers to the array reimplementation work described in the ongoing efforts slides, now on master, but still underway when these numbers were gathered.
Memory Leaks: This Effort

- Reduce number of tests with leaks

<table>
<thead>
<tr>
<th>Source</th>
<th>1.14</th>
<th>Soon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distributed arrays</td>
<td>~200</td>
<td>~40</td>
</tr>
<tr>
<td>Initialization of generic fields</td>
<td>~80</td>
<td>~80</td>
</tr>
<tr>
<td>App fails to reclaim memory</td>
<td>~45</td>
<td>~50</td>
</tr>
<tr>
<td>First class functions</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>Various/unclassified</td>
<td>~180</td>
<td>~125</td>
</tr>
<tr>
<td></td>
<td>539</td>
<td>330</td>
</tr>
</tbody>
</table>
Memory Leaks: Status and Next Steps

Status:
- Release 1.14
  - Leak by total bytes largely unchanged
  - Leak by number of tests less than 1/2 of 1.13 (45%)
- Soon
  - Leak by total bytes dramatically reduced
  - Leak by number of tests less than 1/3 of 1.13 (28%)

Next Steps:
- Continue to eliminate remaining leaks
  - prioritize based on impact and complexity
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