Runtime Library Improvements

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Outline

- Qthreads Improvements
- Cray Runtime Changes
- Launcher Improvements
- Runtime Priorities and Next Steps
Qthreads Improvements
Qthreads Tasking Changes

- As default tasking layer, Qthreads got more exposure
  - More testing, both over time and across configurations
- Mixing public+Cray runtime layers added configurations
- Result: needed to fix several small problems
QT Tasking: Tasks Can Monopolize Workers

● **Background:** Bug: tasks could monopolize worker threads
  
  ```
  while (syncVar.readXX() != N) {
      ...
      if ... then begin syncVar += 1;
      ...
  }
  ```

  - If the same thread hosted \( T_1 \) and \( T_2 \), \( T_1 \) could starve \( T_2 \)
  - `syncVar` F/E always as desired \( \Rightarrow \) \( T_1 \) never blocked \( \Rightarrow \) \( T_2 \) never ran
  - “Solved” in 1.10, but could execute slowly and cause testing timeouts

● **This Effort:** Occasionally yield worker even when not blocked
  
  - About 1% of the accesses for each sync var
  - But only when no other task seems to be trying to access it
QT Tasking: Impact of Worker Yielding

**Impact:** Qthreads more stable with default scheduler
- Nightly testing quieter (fewer sporadic timeouts)
- Performance improvements for Spectral Norm

![Spectral Norm Shootout Benchmark](chart.png)
QT Tasking: Host Tasks in Top-level Processes

Background: Top-level locale processes could not host tasks
- Symptom: intermittent qthreads internal check failure with gasnet
  - 1 test out of ~5000
  - Not a problem in 1.10; appeared following a post-1.10 runtime improvement
- Cause: processes lacked certain capabilities needed to host tasks
  - Example: task-private memory to hold serial state, etc.
  - Qthreads worker threads: host main program and tasks
  - Comm polling threads (Active Message handlers): host “fast” on-stmts
  - Top-level locale processes: host “fast” on-stmts when in comm barriers

This Effort: Added needed capabilities for top-level processes

Impact: Stability
- Qthreads more stable with multiple locales
- Nightly testing quieter
QT Tasking: Execute Serial Subtasks Directly

**Background:** Qthreads queued subtasks even when serial
- Followed Qthreads design point: many small tasks, well load-balanced
- Encouraged by Qthreads’ original default 4 kb stacks
- Costly for Chapel subtasks of serial tasks

**This Effort:** Execute serial subtasks directly, by calling them
- Matches behavior of other tasking layers
- Enabled by current default 8 mb stacks

**Impact:** Improved performance
- `quicksort --n=16777216 --thresh=3` 10X faster on 8 CPUs
QT Tasking: Worker Threads Sleep on Darwin

**Background:** Bug: Chapel sleep() suspends Qthreads worker
- Qthreads intercepts syscalls so workers don’t suspend
- So tasking shim sleep(3) should spin, yielding worker, until sleep done
- But intercept mechanism is broken for darwin (OS X)
- Thus tasking shim sleep(3) causes Qthreads worker to suspend

**This Effort:** work around broken syscall intercept
- Spin-yield until sleep time expires in the tasking layer shim

**Impact:** Fixes the broken syscall intercept with the most impact

**Next Steps:** Work around other instances?
- Better if Qthreads syscall intercept could be fixed for darwin, though
Cray Runtime Changes
Cray Runtime Changes: Outline

- Non-blocking comm interface mismatch, public vs. Cray
- Allow mixing public and Cray runtime layers
- Other Cray runtime layer changes
- Testing and performance status
Non-blocking Communication: Background

Two flavors of non-blocking communication support:

● In Cray ugni comm layer implementation:
  ● Styled after ugni interface
  ● Operations:
    Initiation: get
    Completion: try specific (NB), wait specific (B)
  ● NB token owned by caller, updated by comm layer

● In public gasnet comm layer implementation:
  ● Styled after GASNet interface, but incomplete
  ● Operations:
    Initiation: get, put
    Completion: check specific (NB without try), wait many (B)
  ● NB token owned and updated by comm layer
Non-blocking Comm Unification

This Effort:

● One flavor of non-blocking communication support:
  ● Styled after GASNet interface, and complete
  ● Operations:
    Initiation: get, put
    Completion: check specific (NB without try), try many (NB), **wait many (B)**
  ● NB token owned and updated by comm layer

● Refactored code to adapt to interface changes
  ● ugni comm: alloc/free descriptor, replace operations
  ● muxed tasking: rework fine-grained compute/communicate overlap
  ● gasnet comm: add **try many (NB)**
  ● all comm layers: changes to comm diags counters
Mixing Public+Crab Layers: Background

- **Public and Cray runtime layers did not interoperate**
  - Non-blocking communication mismatches (just discussed)
  - ugni comm and muxed tasking assumed each other, implicitly
  - Example:

  **muxed tasking:**
  - gets all memory from runtime
  - comm handler is a task

  **ugi comm layer sees only a few (special case) references to memory not registered with the NIC**

  **but:**

  **qthreads tasking:**
  - gets memory from libc
  - comm handler is a pthread

  **comm layer sees lots of references to memory not registered with the NIC**
Mixing Public+Cray Layers: This Effort

**ugini comm**

- Handle unregistered memory as source or target, local or remote

---

**muxed tasking**

- Make the comm handler a pthread
  - Improves latency, reduces starvation, follows Qthreads tasking lead

- Allow for running Chapel code in main process and comm thread
  - Adapt to comm handler change above, interoperate with gasnet comm
  - Mainly: emulate certain capabilities normally only present in soft-thread threads
Mixing Public+Cray Layers: This Effort (continued)

qthreads tasking

- Disable guard pages when impractical
  - Background: with comm=ugni we use libhugetlbfs, for NIC memory registration
    - But huge guard pages aren’t practical
  - This effort: auto-disable guard pages when heap page != system page
  - Impact: no stack overflow detection with ugni+qthreads

- Limit memory pool size
  - Background: specialized memory pools improve allocator performance
    - Chapel limits pool sizes, but a bug resulted in stack pools > 1 GiB with comm=ugni
  - This work: fix the bug
Other Cray Runtime Changes: ugni Comm

**ugni comm**

- Change default heap size to 2/3 available node memory
  - Done after diagnosing over-allocation with ugni+qthreads
  - Diagnosis false, but kept change because startup faster, esp. on 128g nodes
  - With slurm, default still just 16g due to resource limiting for node sharing
    (*note*: post-release, may have a solution for this)

- Fix bugs in `real(*)` network AMOs that happened to hit the local node
Other Cray Runtime Changes: muxed Tasking

muxed tasking

- Change default #threads per locale to #cores (matches other task layers)
  - Improved performance in most cases
  - More threads are still preferable for latency-limited code like SSCA2, RA, etc.
- Add support for oversubscription (more than 1 Chapel locale per node)
  - Supports testing with limited nodes (gasnet+muxed, for example)
- Add task-private data implementation
  - Was in tasking interface, but muxed had no implementation yet
  - Necessary but not sufficient for remote caching to work with muxed
Cray RT Changes Impact #1: ugni Is Default

- **ugi+muxed is 1.11 default in pre-built Cray X* module!**
  - Have wanted this for a long time due to better performance
  - Didn’t have the necessary testing confidence in previous releases

- **No big correctness testing disparities vs. gasnet+qthreads**
  - Comm diagnostics differences
  - Memory diagnostics differences
  - Message differences due to network atomics vs. processor atomics
  - Inter-locale races when writing output

- **Much improved performance**
Cray RT Changes Impact #1: ugni Is Default
Cray RT Changes Impact #2: Interoperability

- Combinations that did not work in Chapel 1.10:

![Diagram showing combinations of Communication and Tasking that did not work in Chapel 1.10.]

- Communication:
  - none
  - gasnet
  - ugni

- Tasking:
  - fifo
  - qthreads
  - massivethreads
  - muxed
Cray RT Changes Impact #2: Interop

- Combinations that do not work in Chapel 1.11:

**Communication**
- none
- gasnet
- ugni

**Tasking**
- fifo
- qthreads
- massivethreads
- muxed
Cray RT Changes Impact #2: Interop

- Combinations that are tested regularly:

```
Communication           Tasking
none                     fifo
gasnet                   qthreads
ugni                     massivethreads
                           muxed
```
Cray RT Changes: Next Steps

- **ugi+qthreads allows us to consider retiring muxed**
  - Qthreads has NUMA support, wider use, etc.
  - Would save maintenance
  - (Still need comm=ugi, due to performance)

- **But need up-front work**
  - ugni+muxed fine-grained compute/comm overlap very effective
  - Would need to replicate in qthreads without revealing Cray IP
  - Exploring possible solutions now

![Graph showing RA Performance on XC: comm=ugi, network atomics](chart.png)
Launcher Improvements
Launcher Improvements

slurm-srun:
- Added a CHPL_LAUNCHER_NODELIST / --nodelist option
  - maps down to slurm’s --nodelist option
- Removed use of expect scripts for interactive mode
  - no longer needed; added maintenance and testing complexity

pbs-aprun:
- updated to use place/select syntax for PBS Professional (PBSPro)
Runtime Priorities and Next Steps
Runtime Priorities and Next Steps

- Continue investigating retiring muxed tasking
- Address syscall intercept issue on Mac OS X
- Investigate Qthreads vs. OpenMP tasking differences
  - experiments in CSU ICS paper saw more noise in Chapel runs
  - may be due to task-to-core mapping or races in spinning up tasks
- Determine best practices for NUMA/KNL nodes
- Support optimization of reductions
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