Runtime Library Improvements

Chapel Team, Cray Inc.

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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;
  …
}
```

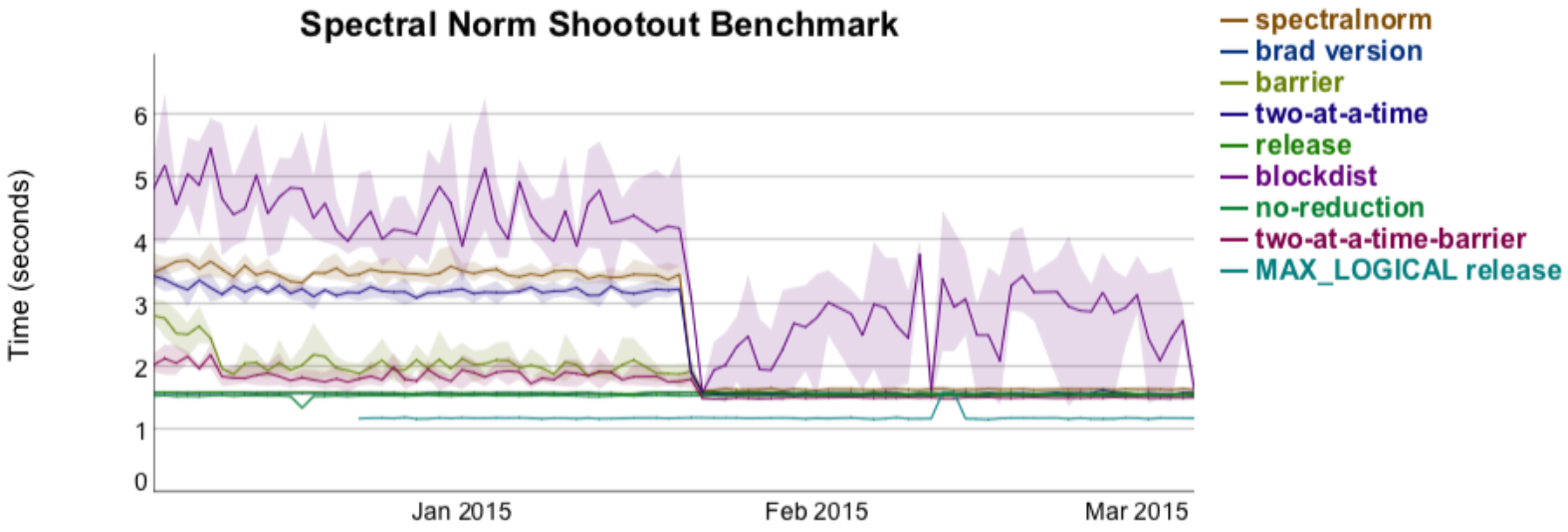
task T_1 is spinning on `syncVar`

task T_2 would release T_1 by writing to `syncVar`

  - 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



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+Cray 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

⇒ ugni 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

ugni 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

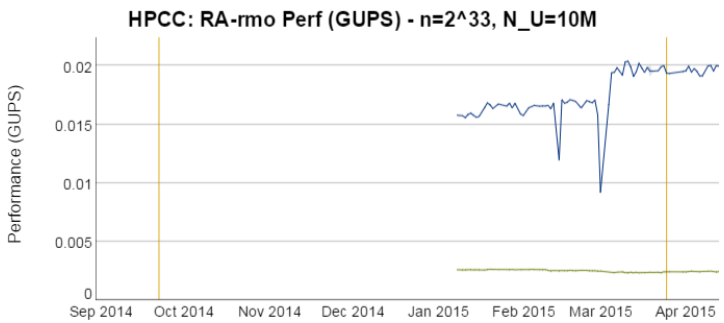
muxed tasking

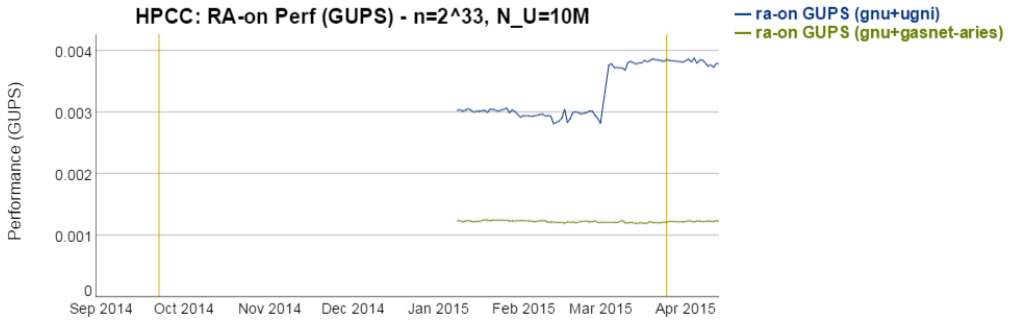
- Change default #threads per locale to #cores (matches other task layers)
  - Improved performance in most cases
  - More threads are still preferable for latency-limited code like SSCA2, RA, etc.
- Add support for oversubscription (more than 1 Chapel locale per node)
  - Supports testing with limited 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

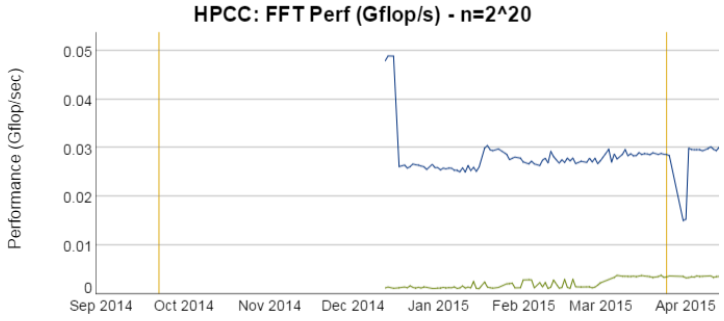
Cray RT Changes Impact #1: ugni Is Default

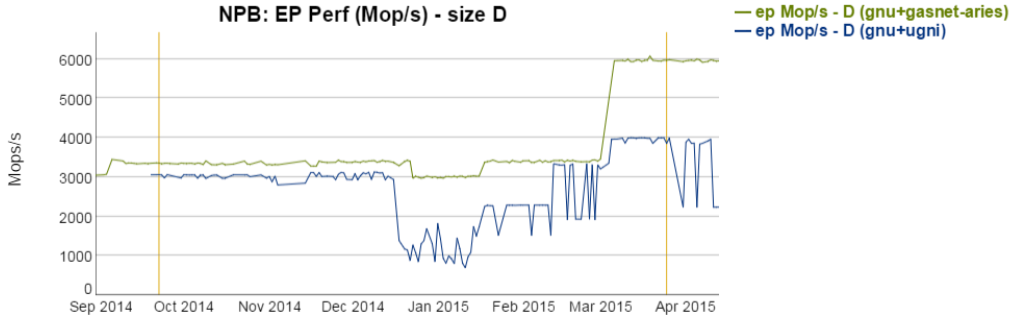
- **ugni+muxed is 1.11 default in pre-built Cray X* module!**
  - Have wanted this for a long time due to better performance
  - Didn't have the necessary testing confidence in previous releases
- **No big correctness testing disparities vs. gasnet+qthreads**
  - Comm diagnostics differences
  - Memory 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



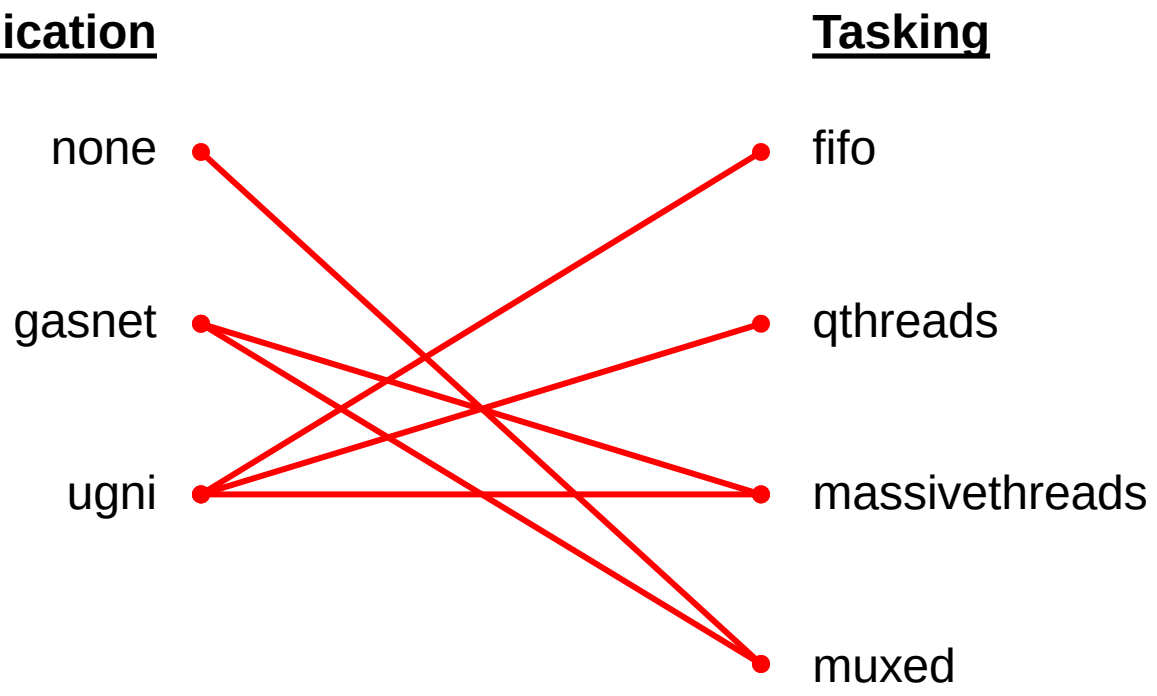






Cray RT Changes Impact #2: Interoperability

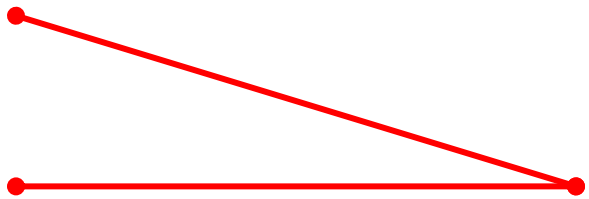
- **Combinations that did not work in Chapel 1.10:**



Cray RT Changes Impact #2: Interop

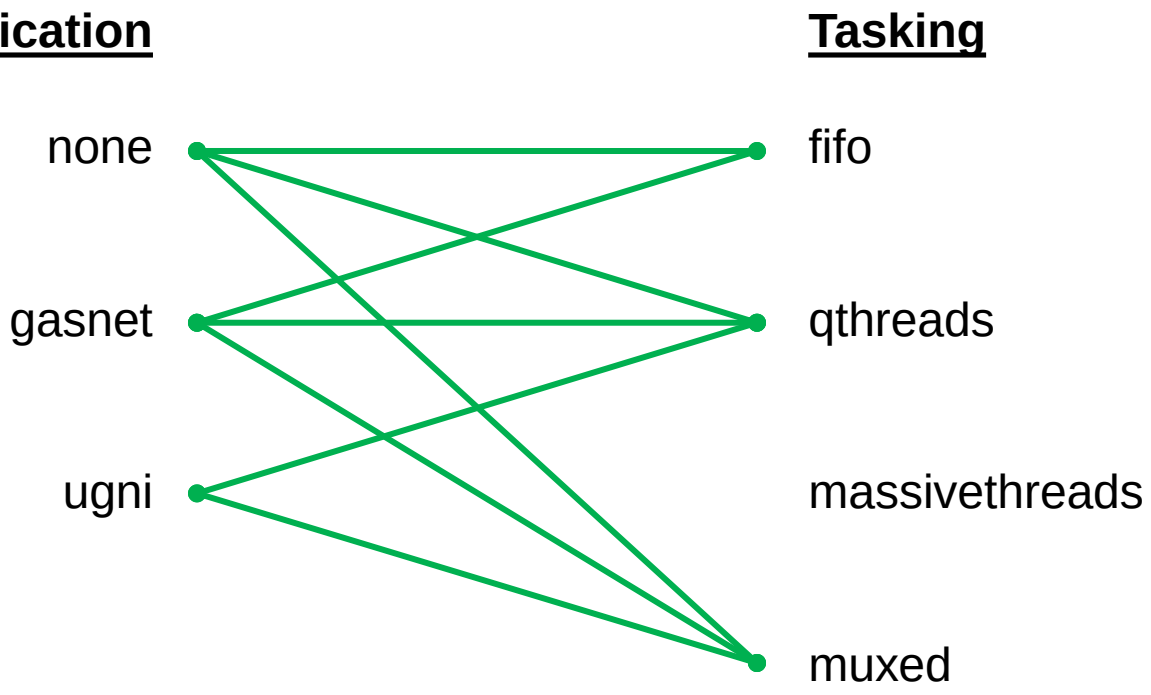
- **Combinations that do not work in Chapel 1.11:**

Communication	Tasking
none	fifo
gasnet	qthreads
ugni	massivethreads
	muxed



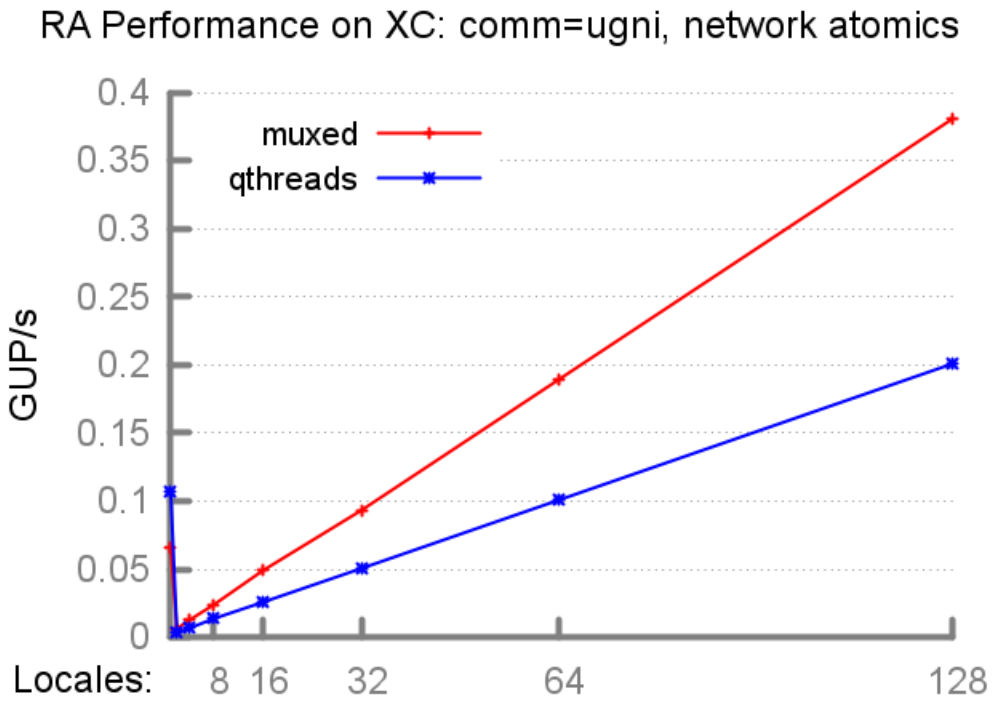
Cray RT Changes Impact #2: Interop

- **Combinations that are tested regularly:**



Cray RT Changes: Next Steps

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



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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