Runtime and Third-Party Improvements

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Outline

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Ugni/Muxed Background
Ugni/Muxed: Introduction

- Chapel supports Cray-specific comm and tasking layers
  - CHPL_COMM=ugni
    - interacts with NIC via lightweight uGNI (user Generic Network Interface)
    - provides access to network atomics (CHPL_NETWORK_ATOMICS=ugni)
    - supports a high degree of communication concurrency
  - CHPL_TASKS=muxed
    - implements task-switching in user-space

- Tuned for fine-grain, latency-bound codes like SSCA/RA

- Historically, only available when using pre-built module
  - closed-source/proprietary for IP reasons
  - patent for IP was granted last year
Ugni: Background

- Ugni offers significant performance advantages
  - outperforms gasnet-aries in all studied applications
  - usually significantly, particularly for codes it was originally tuned for
Muxed: Background

- **Muxed used to offer significant performance advantages**
  - user-space task-switching allowed it to vastly outperform fifo

- **Nowadays qthreads typically outperforms muxed**
  - qthreads (our default) is highly optimized
    - also does user-space task switching
  - designed as a general tasking solution
    - whereas muxed was specifically designed/tuned for SSCA
  - qthreads is also numa-aware and has built-in full/empty support

- **Few notable cases where muxed still performed better**
  - as of 1.14: FFT, HPL, and MiniMD
Ugni/Muxed: Background

● Have wanted to open-source ugni
  ● users building from source will receive performance benefits

● Have also wanted to retire muxed
  ● qthreads generally performs much better
  ● need to improve qthreads for a few benchmarks before retiring muxed

● Combined, these efforts will simplify development
  ● eliminate development/maintenance cost for muxed
  ● ugni development will use public repo, public issue tracker, etc.
Communication Improvements
Open Source Ugni
Open Source Ugni: This Effort and Impact

This Effort: Open-sourced ugni communication layer
- now included in public repository
- ugni is now our default on Cray machines
  - historically, it was only the default with the pre-built module
- also compiles with PGI now
  - mostly for uniformity and ease of documentation

Impact: Easier development, perf benefit for open-source users
- have already seen benefits of ugni being open-sourced
  - open-source developer was able to test ugni-specific bug-fix
  - opened several GitHub issues to track ugni improvements
- additionally, publicizing ugni motivated us to revisit/review the code
  - led to removal of a performance-limiting memory registration limit
Ugni Registration Limit
Ugni Registration Limit: Background

- Ugni registers the heap with multiple comm domains
  - access to individual comm domains is serialized
  - having multiple comm domains improves comm concurrency
    - dramatically improves performance of latency-bound codes (SSCA, RA)
  - ideally, want at least one comm domain per core

- Early “native” slurm couldn’t get exclusive access to NIC
  - this limited the total amount of memory that could be registered
    - total memory is heapSize * numCommDomains

- Slurm limitation constrained number of comm domains
  - in practice, could only register up to 15 comm domains
    - ~1/2 the number cores on a modern Xeon-based XC
Revisited the need for registration limit
- learned that slurm can now get exclusive access to the NIC
  - i.e. registration limitation no longer exists

Removed comm-domain-limiting code from ugni
- limit now uniform between slurm and pbs/aprun systems

Comm domain limit is based on the number of cores
- currently capped at max of 30 comm domains
  - based on gemini limit; aries supports up to 127
  - doesn’t hurt us on current Xeon-based systems
    (but need to revisit for Xeon-Phi and future Xeon systems)
Ugni Registration Limit: Impact

- Resulted in significant performance improvements
  - for latency-bound applications run on slurm-managed machines

![Graphs showing performance improvements](image-url)
Ugni Registration Limit: Impact and Next Steps

**Impact:**
- led to some significant performance improvements

**Next Steps:**
- continue to improve ugni performance
  - evaluate performance of increasing comm domain limit for aries
- investigate poor gasnet-aries performance
  - evaluate GASNet’s --enable-gni-multi-domain support
Tasking Improvements
Register Qthreads Task Stacks
Registered Task Stacks: Background

● On Crays, only registered memory can be communicated
  ● unregistered memory has to be copied into a registered segment first
  ● for best performance, ugni registers the entire Chapel heap
    ● memory in the heap can be directly communicated (no copying needed)

● Muxed tasking uses Chapel’s allocator
  ● means task-stacks are part of the registered heap

● Historically, qthreads used the system allocator
  ● task-stacks were not part of the registered heap (had to be copied)

● Extra copying to/from qthreads stacks hurt performance
  ● identified as reason muxed was beating qthreads for FFT and HPL
Registered Task Stacks: This Effort

● Make qthreads use Chapel’s allocator
  ● task stacks are now in registered heap (as is all qthreads memory)

● Worked with qthreads team to add *external allocators*
  ● qthreads now has shim layers for qt_malloc, qt_free, etc.
    ● default forwards to system allocator (old behavior)
    ● new one forwards to Chapel’s allocator
  ● included in qthreads 1.12 release
Registered Task Stacks: Impact

- No real single-locale performance changes
  - minor changes (both positive and negative)
  - really just “noise” caused by memory layout differences between allocators

![Graph 1](SSCA#2 (SCALE=8))

![Graph 2](Submitted Chameneos Redux Shootout Benchmark (n=6,000,000))
Registered Task Stacks: Impact

- Improved multi-locale performance
  - qthreads now outperforms muxed for FFT and HPL

![Graph showing the performance comparison for FFT and HPL](image)

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Limit Qthreads Memory Pool
Limit Qthreads Memory Pool: Background

**Background:** Qthreads aggressively pools memory
- by default, qthreads allocates space for ~128 items per pool
  - qthreads assumes ~4KB stack size, but our default is 8MB
- Chapel sets limit on qthreads max pool size
  - previously something like: (2 * numCores * stackSize)
  - based on belief that there was a single pool for task stacks
- discovered that there is actually a pool per worker (core)
  - on 68-core KNL, resulted in trying to allocate >30 GB in task-stacks
  - only noticed once qthreads started using our allocator
    (limited heap size for some apps led to OOM)

**This Effort:** Further limit qthread pool size
- now just a multiple of the stack size
  - effectively just an upper bound of 65MB (8 default-sized stacks)
  - note that this only affects compute nodes with more than 4 cores
Applications now use less memory
- resolved KNL OOMs

Minor thread-ring regression for high core-count nodes
- thread-ring creates over 500 concurrent tasks
- new pool limit results in creating more pools
Deprecate Muxed
Deprecate Muxed

**Background:** No remaining cases where muxed beats qthreads
- array-views work resolved MiniMD difference
- registered task stacks resolved FFT and HPL differences
- task-spawning optimizations further improved qthreads performance

**This Effort:** Deprecated muxed tasking
- officially deprecated for 1.15 release

**Next Steps:** Remove muxed source code and documentation
- support will be removed for the 1.16 release
Other Runtime Improvements
Other Runtime Improvements

- Fixed dynamic linking for gasnet-aries on Cray systems
- Fixed support for gasnet+muxed without hugepages
- Switched qthreads initializer to run in detached state
  - contributed by Rob Upcraft
- Fixed massivethreads for stack-allocated arg-bundles
  - contributed by Kenjiro Taura
Other Third-Party Improvements
Other Third-Party Improvements

- Upgraded jemalloc to version 4.5.0
  - no major performance impact
  - now using a vanilla jemalloc (all our patches accepted upstream)

- Upgraded Qthreads to version 1.12
  - added support for external-allocators
  - fixed sleep-interception bug
  - added hybrid spin/condwait for nemesis

- Upgraded hwloc to version 1.11.6
  - fixed bug that KNL work encountered
  - improved startup time on high core-count machines by ~25%

- Upgraded GASNet to version 1.28.0

- Made GASNet build amudprun launcher for host machine
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