Hewlett Packard Enterprise

# RECENT INFINIBAND OPTIMIZATIONS IN CHAPEL

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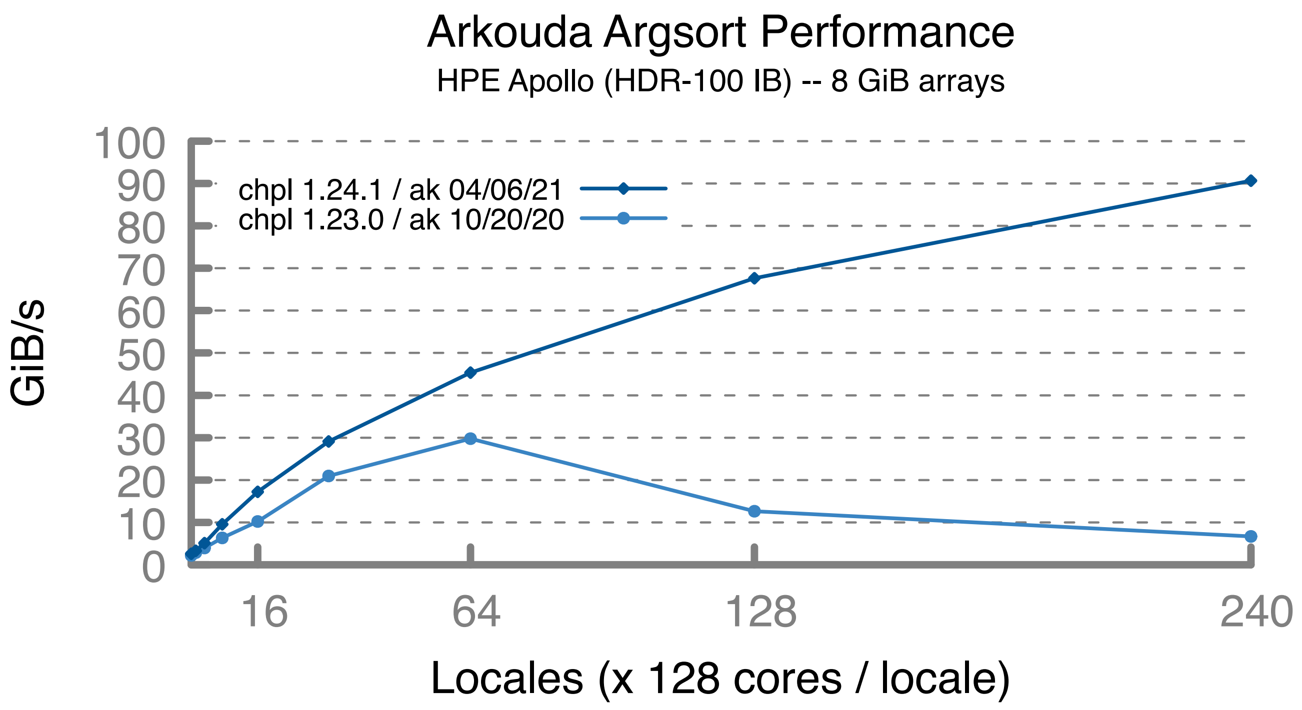
# TEASER FOR THIS TALK

- Recent optimizations have significantly improved Chapel's performance and scalability on InfiniBand
  - ~15x performance improvement for Arkouda Argsort at 240 nodes (~30K cores)



# INFINIBAND BACKGROUND

- Historically, the Chapel team primarily focused on performance for Cray networks
  - Intent was to ensure Chapel had the right language features/semantics first, then optimize for other networks

- More recently, focus has shifted to improving performance for InfiniBand networks
  - Chapel uses the GASNet communication library with the ibv conduit to target InfiniBand (gasnet-ibv)

# GASNET-IBV BACKGROUND

- Memory must be registered with the network in order to do one-sided GETs/PUTs (RDMA)
  - gasnet-ibv supports two registration modes:
    - Static: All memory is registered at startup—fast communication, but hurts NUMA affinity and leads to long startup times
    - Dynamic: Memory is registered at communication time—can add overhead, but good NUMA affinity and fast startup

- Chapel defaults to dynamic registration to get good NUMA affinity and fast startup times
  - We believe this is the right choice for most users getting started
    - Have recommended static registration to some users with certain communication-heavy idioms in the past
  - Ideally, we just want to have one mode with no, or few, downsides

- Late in the 1.24 release cycle, we identified root cause of some InfiniBand performance issues
  - Somewhat improved NUMA affinity and startup times for static registration (not covered in this talk)
  - Significantly improved communication performance for dynamic registration (main topic for this talk)
    - These improvements motivated April's 1.24.1 release

# DYNAMIC REGISTRATION IMPROVEMENTS

# DYNAMIC REGISTRATION BACKGROUND

- gasnet-ibv dynamic registration only registers memory at communication time
  - Fast startup time since little registration occurs at startup
  - NUMA affinity is based on user first-touch
  - Memory registration is expensive, want to amortize costs
    - Ideally only register a memory region once and then reuse
    - This requires tracking which memory regions are currently registered

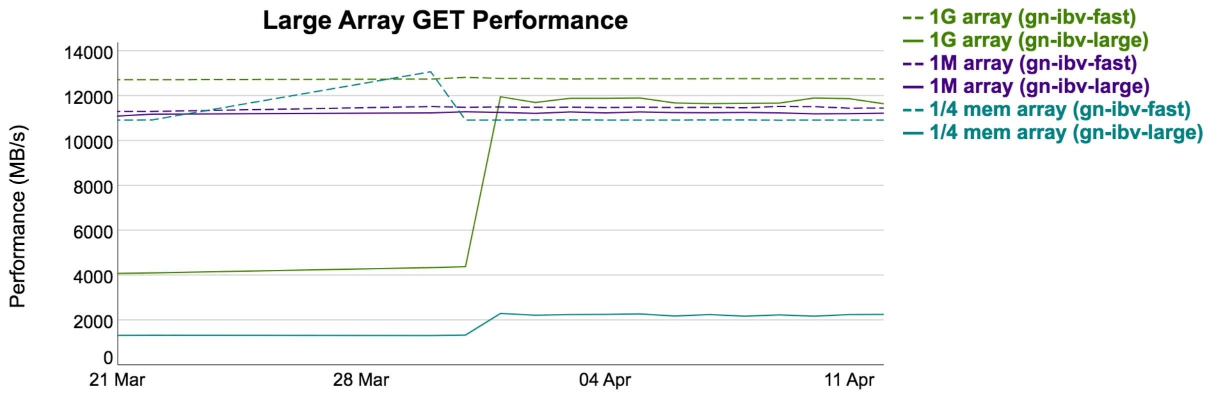
# DYNAMIC REGISTRATION IMPROVEMENTS

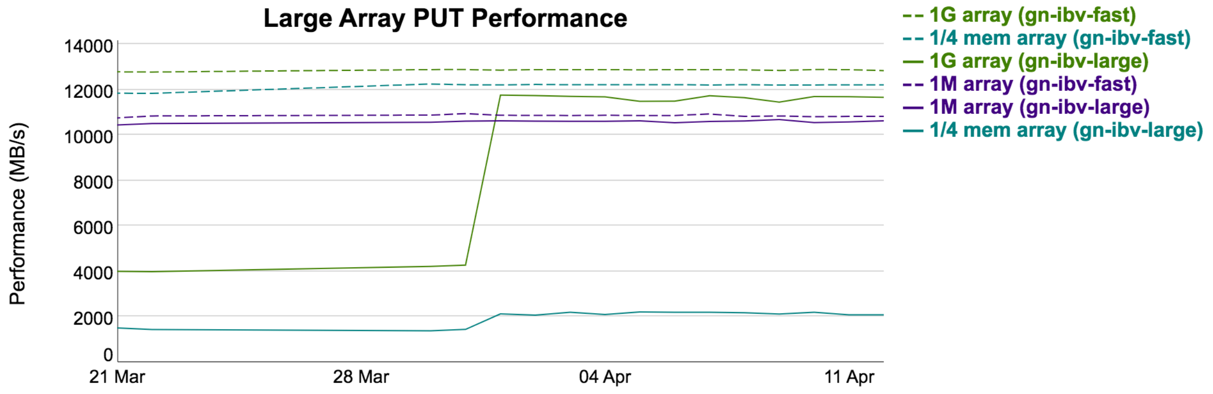
- Identified bottleneck in registration tracking code that limited performance and scalability
  - Core issue was that we were running out of dynamic registration entries
    - Led to deregistration and reregistration cycles, preventing amortization

- Collaborated with the GASNet team to resolve this issue
  - Increased number of dynamic registration entries based on execution-time query of hardware capabilities
  - Improved data structures used to track which regions are registered

# SERIAL TRANSFER PERFORMANCE

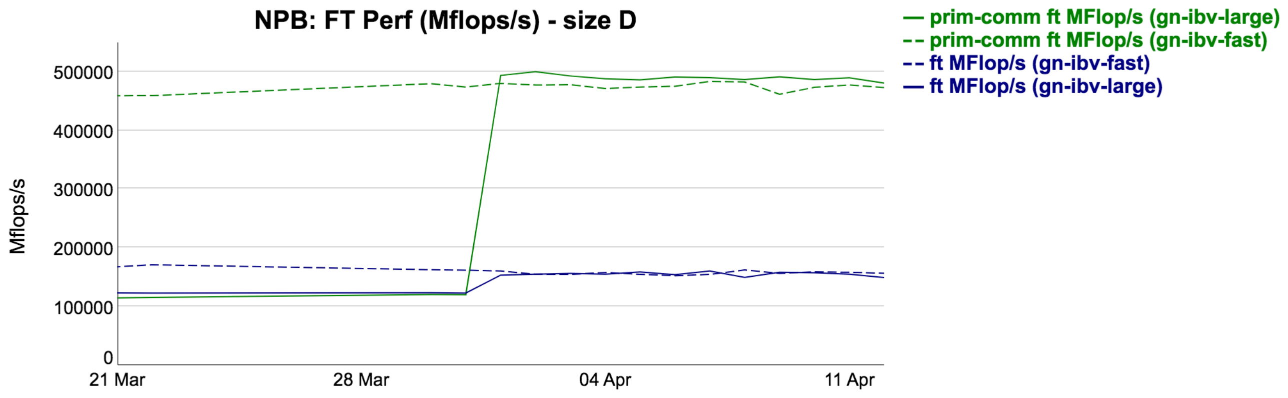
- Significant performance improvements for codes with large point-to-point communication patterns

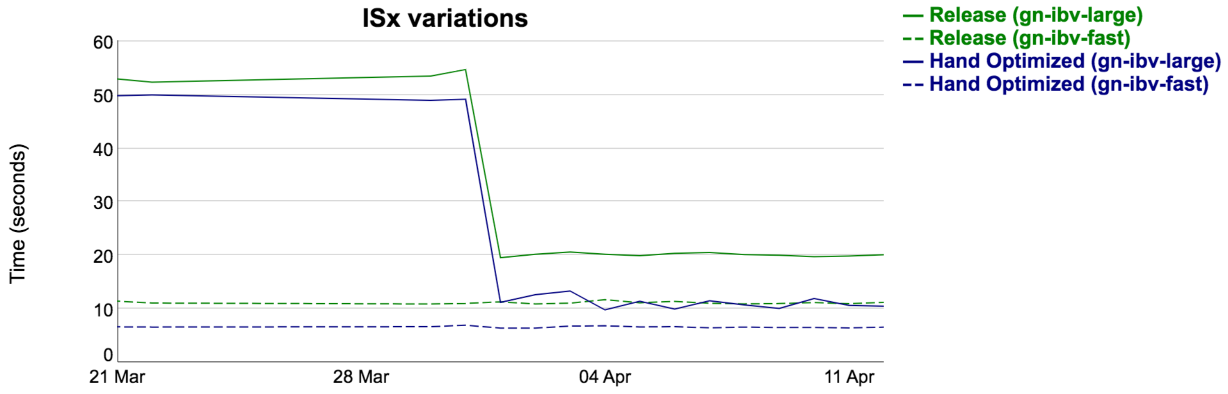


# PARALLEL TRANSFER PERFORMANCE

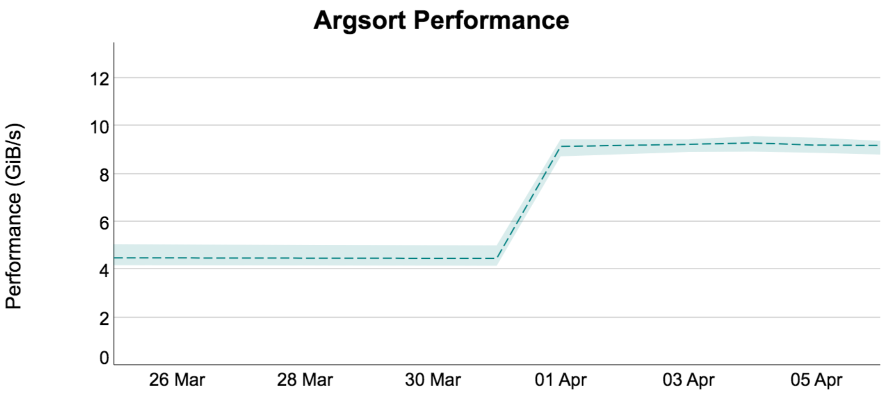
- Significant performance improvements for codes with all-to-all communication patterns

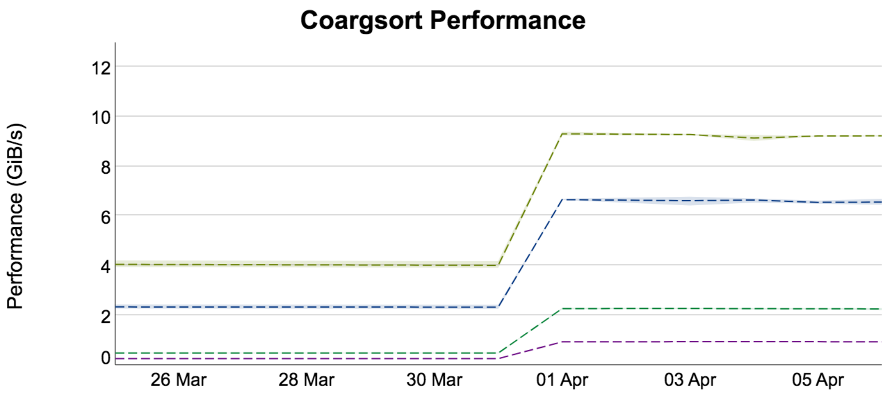


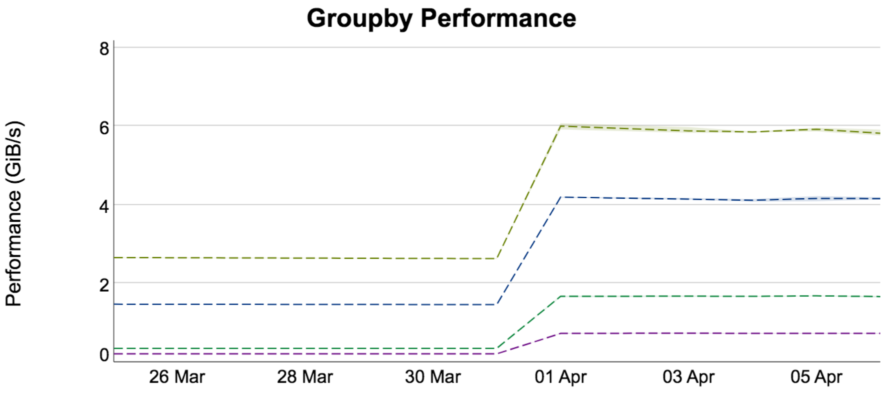



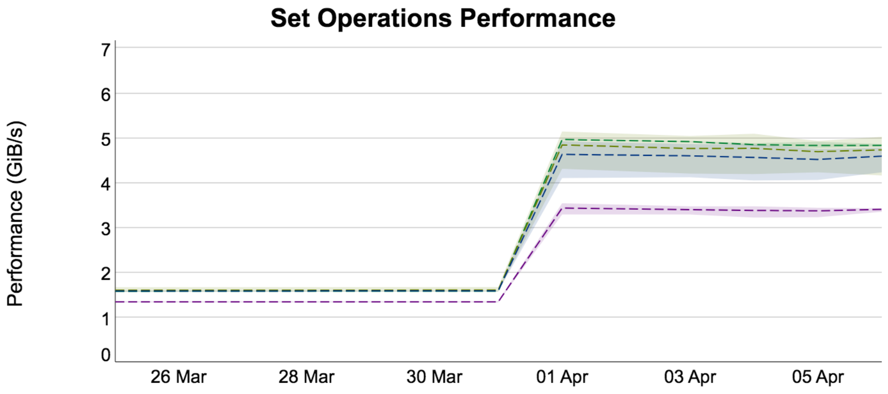
# ARKOUDA PERFORMANCE

- Significant performance improvements for Arkouda



# ARKOUDA SCALABILITY IMPROVEMENTS

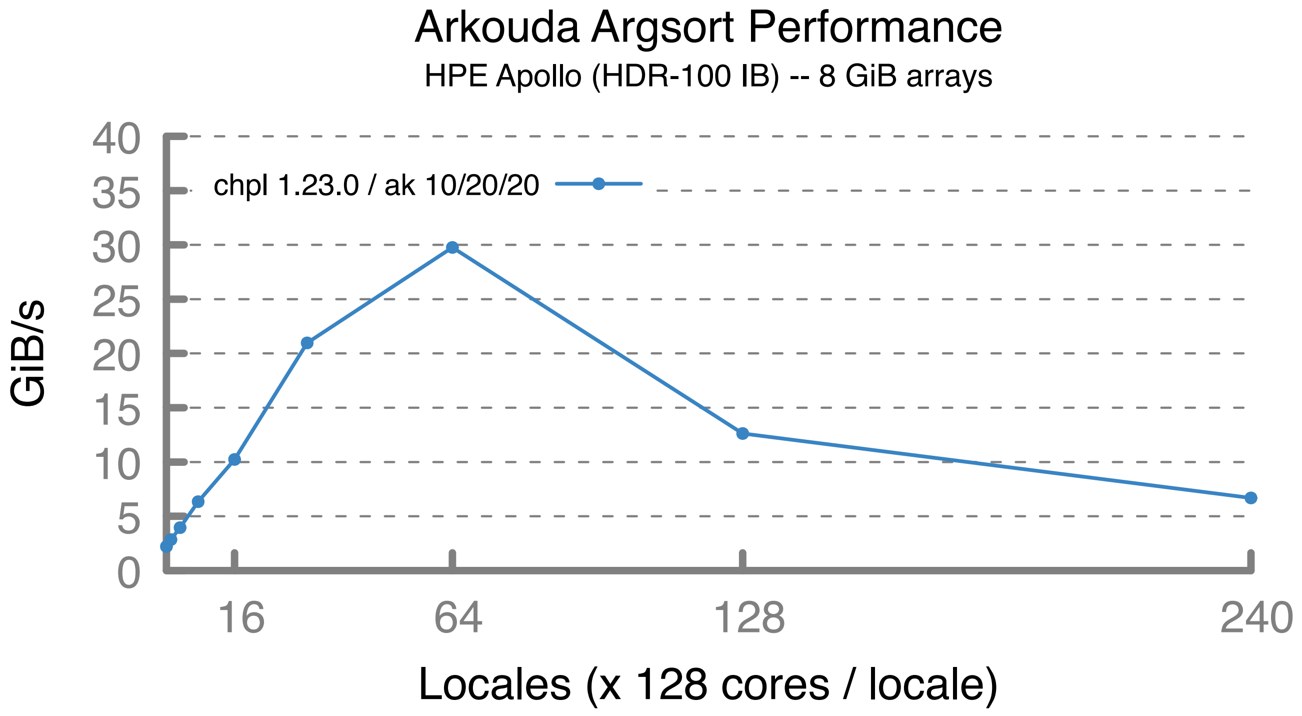
# ARKOUDA BACKGROUND

- Arkouda provides NumPy-like arrays at HPC scale
  - A NumPy/Pandas Python interface, backed by Chapel
    - https://github.com/mhmerrill/arkouda

- We track Arkouda performance nightly at small-scale
  - Had an opportunity to run on a large HPE Apollo system
    - 128-cores – (2) 64-core AMD Rome Processors
    - 2 TB of memory
    - HDR-100 InfiniBand network

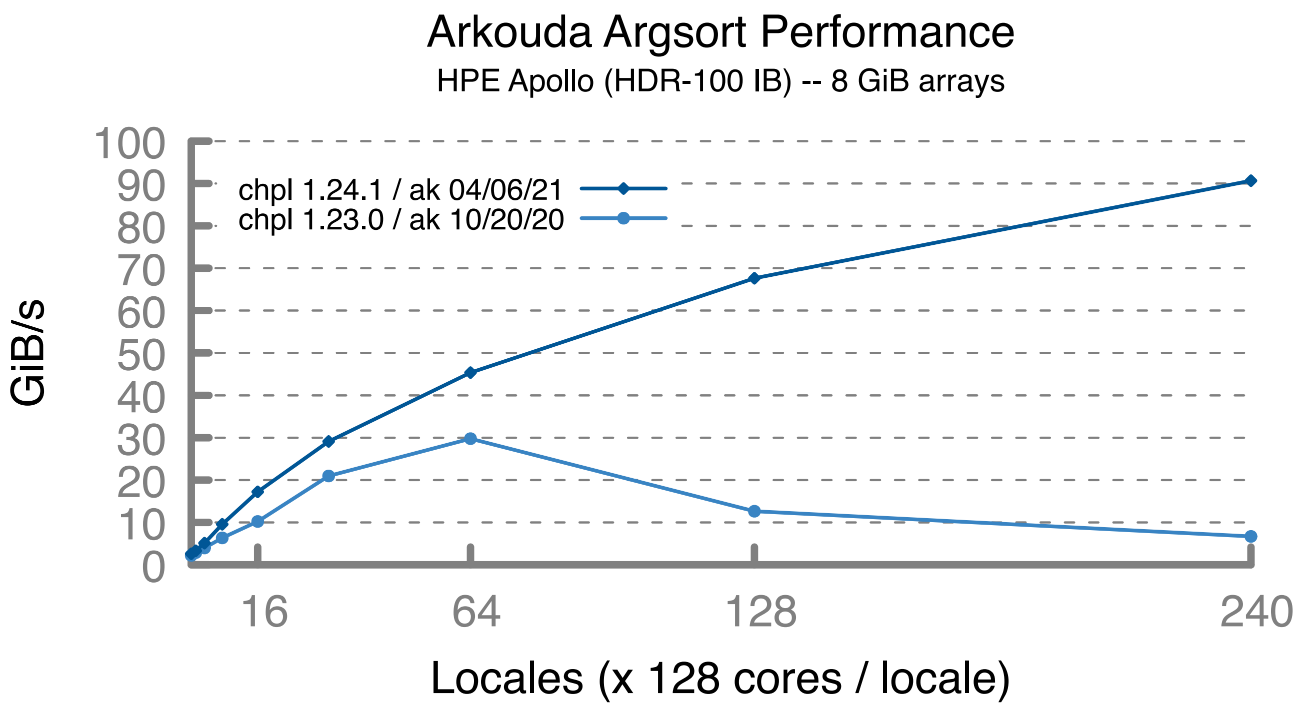
# INITIAL ARKOUDA SCALABILITY

- Previously, performance fell off above 64 nodes for Argsort
  - Gather, Scatter, and other core idioms also suffered



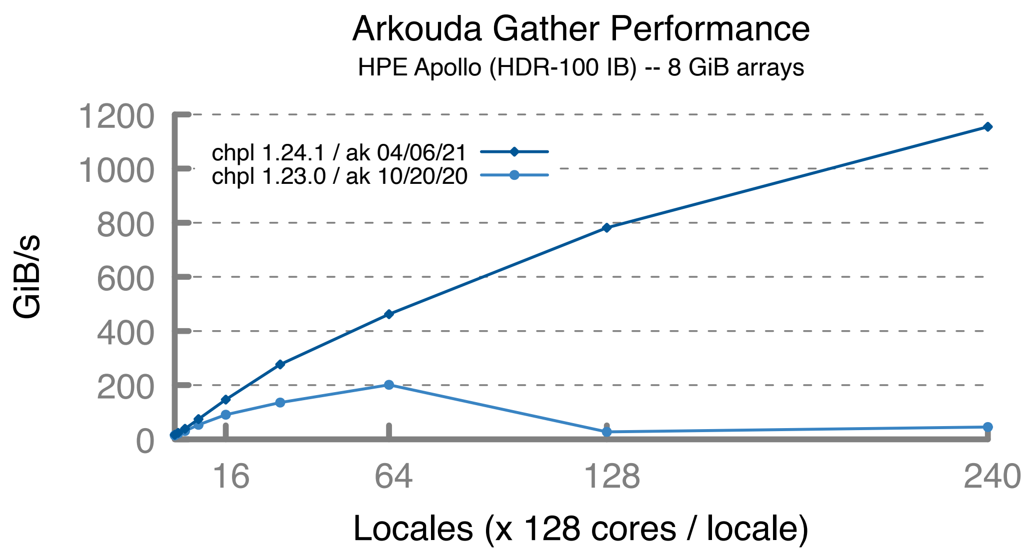
# CURRENT ARKOUDA SCALABILITY

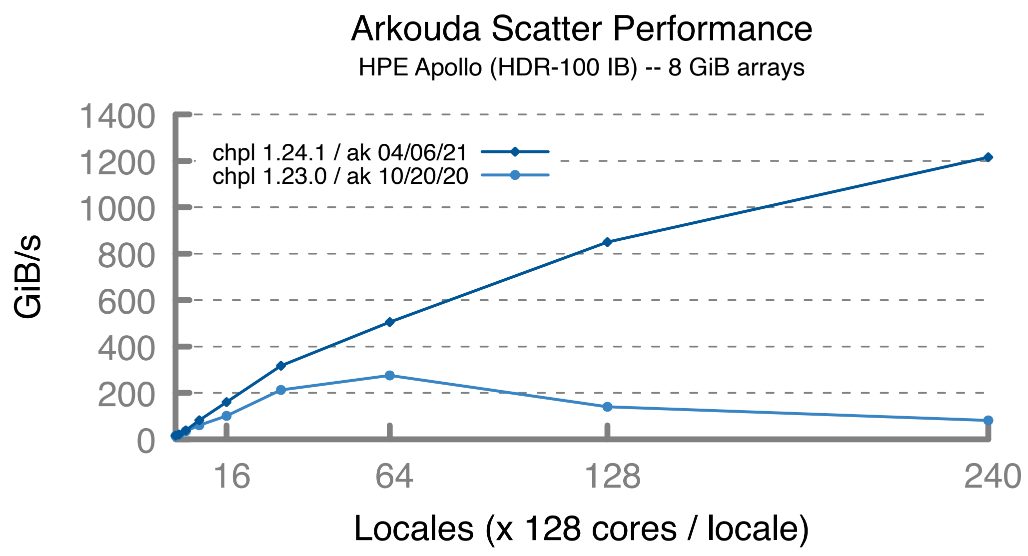
- Fixing dynamic registration improved performance and enabled tuning aggregation
  - Argsort is ~50% faster at 16 nodes, ~15x faster at 240 nodes



# CURRENT ARKOUDA SCALABILITY

- Fixing dynamic registration improved performance and enabled tuning aggregation
  - Gather and Scatter see similar improvements



# ARGSORT BACKGROUND

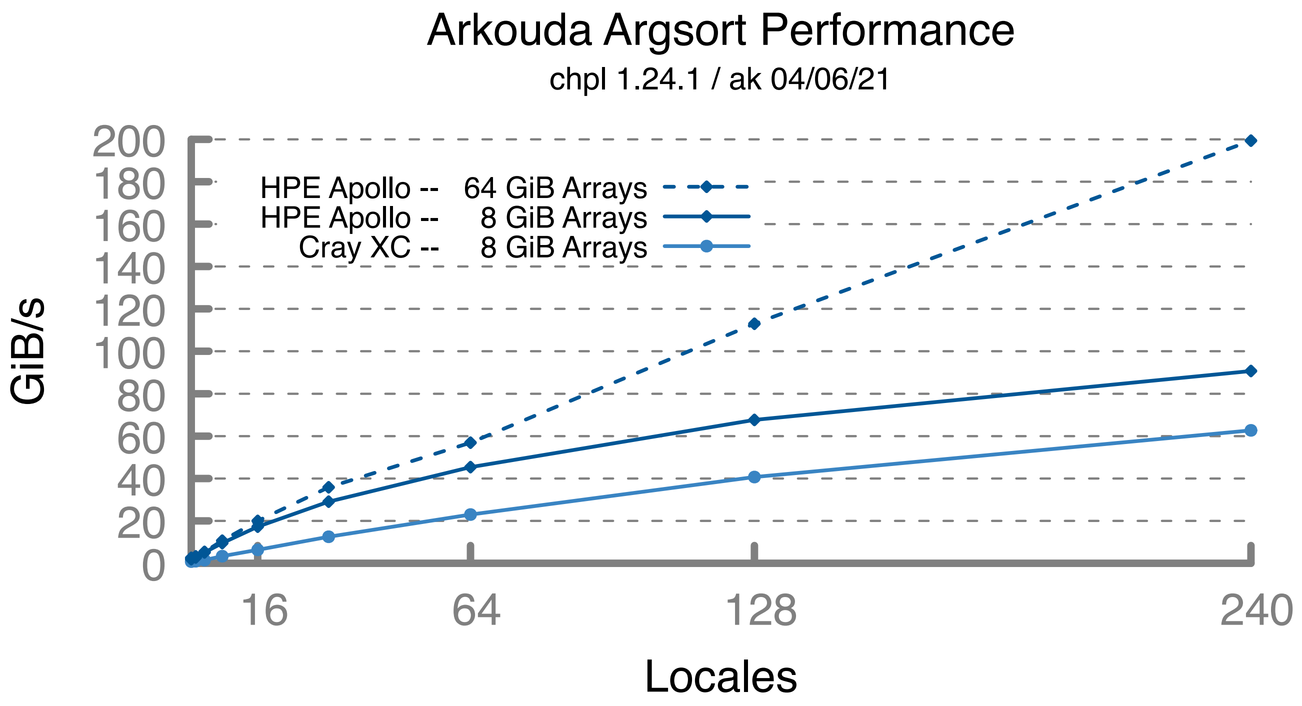
- Argsort requires ~6x the input data for scratch space

- Previous Arkouda scalability graphs used 8 GiB-per-node input arrays
  - This was the largest power of 2 we could reliably sort on our XC
  - Apollo system has significantly more memory, allowing much larger problem sizes to be used

- Argsort has a fixed startup overhead that depends on 'numCores*numLocales’
  - More cores on Apollo system means higher startup overhead, which can be amortized with larger problem sizes

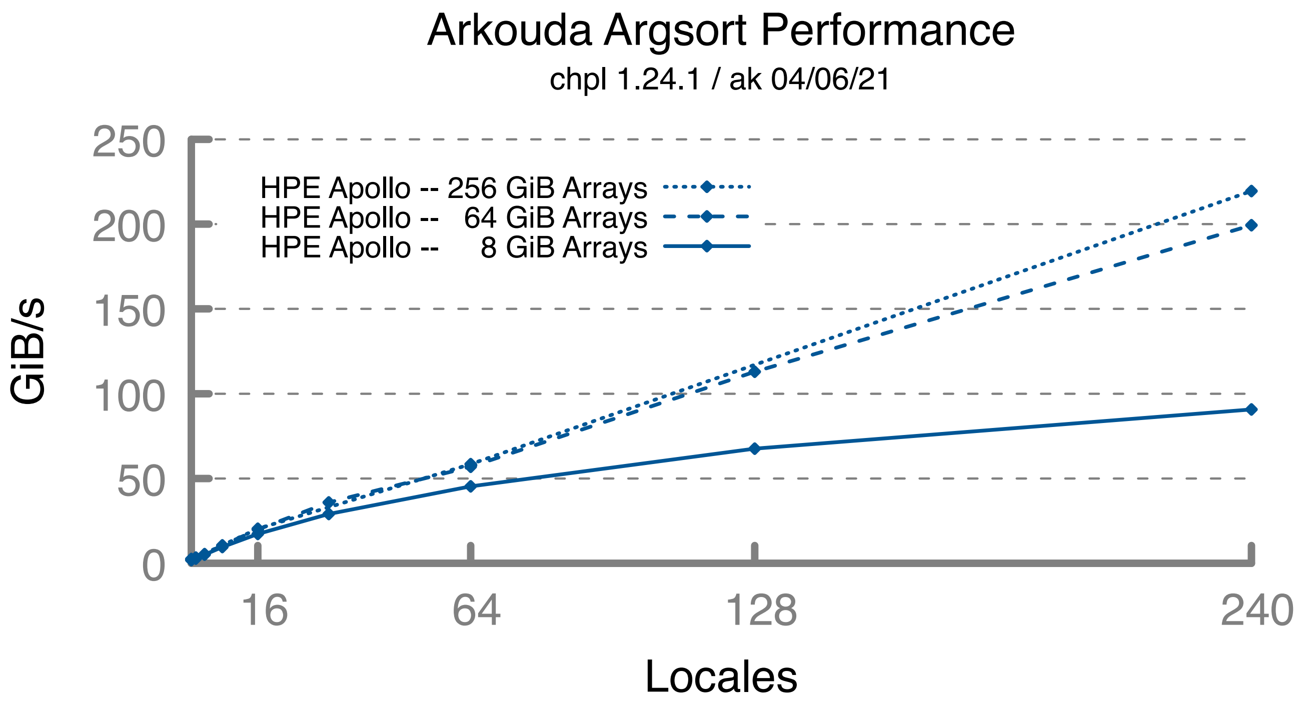
# ARGSORT XC COMPARISON

- Apollo system offers performance improvements over Cray XC, especially at larger problem sizes
  - For equivalent problem sizes: ~2.5x improvement at 16 nodes and ~50% at 240 nodes
  - For larger problem sizes: ~3x improvement at 16 and 240 nodes



# ARGSORT LARGER PROBLEM SIZE

- Can run significantly larger problem sizes on Apollo system
  - Sorting up to 256 GiB per node input arrays (60 TiB at 240 nodes in under 5 minutes)



# SUMMARY

- Performance and scalability of large transfers on InfiniBand systems has been improved
  - Dynamic registration communication performance is nearly on par with static registration
    - While retaining fast startup and good NUMA affinity

# FUTURE WORK

- Continue to improve dynamic registration performance
  - ISx and some other communication-intensive applications lag slightly still

- Look at using On-Demand-Paging (ODP) as an alternative registration mechanism
  - Hardware/firmware takes care of registration on-demand rather than tracking in software

- Improve other aspects of InfiniBand performance
  - Network injection is currently serialized, limiting performance of fine-grained communication
    - Mapping to the upcoming GASNet-EX multi-endpoint API should resolve this
  - Target the GASNet-EX network atomic API

# THANK YOU

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