HPCG @ Arm

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- 13th November 2018

Motivation

- HPCG is becoming increasingly important in the HPC world
- Few optimized versions are open-source
  - None are Arm-specific
- Establish a baseline codebase for the community to build upon
- Stop reinventing the wheel

Inspiration

- We have used different sources as inspiration
  - J. Park et al. 2014. Efficient shared-memory implementation of high-performance conjugate gradient benchmark and its application to unstructured matrices. In *Proceedings of the International Conference for High Performance Computing, Networking, Storage and Analysis* (SC '14). IEEE Press, Piscataway, NJ, USA, 945-955. DOI: https://doi.org/10.1109/SC.2014.82
  - E. Phillips and M. Fatica. 2014. A CUDA Implementation of the High Performance Conjugate Gradient Benchmark". In *High Performance Computing Systems. Performance Modeling, Benchmarking and Simulation,* ser. Lecture Notes in Computer Science. Springer, Cham, pp. 68-84. Available: https://link.springer.com/chapter/10.1007/978-3-319-17248-4_4
  - K. Kumahata et al. 2016. High-Performance conjugate gradient performance improvement on the K computer. In *The International Journal of High Performance Computing Applications,* vol. 30, no. 1, pp. 55—70. Available: https://doi.org/10.1177/1094342015607950
  - X. Zhang et al. 2014. Optimizing and Scaling HPCG on Tianhe-2: Early Experience. In *Algorithms and Architectures for Parallel Processing,* ser. Lecture Notes in Computer Science, Springer, Cham, pp 28-41. Available: https://link.springer.com/chapter/10.1007/978-3-319-11197-1_3

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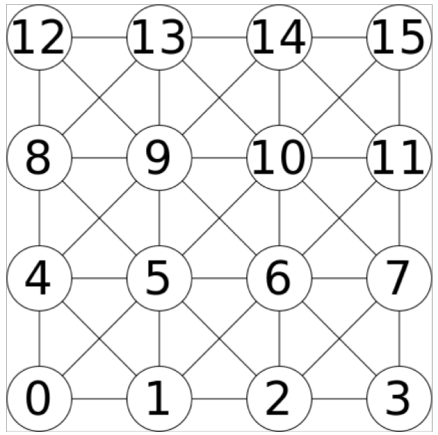
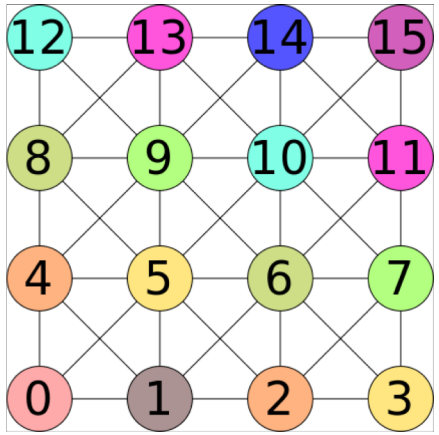
Multi-level task dependency graph





```
Level  0:      0
Level  1:      1
Level  2:   2, 4
Level  3:   3, 5
Level  4:   6, 8
Level  5:   7, 9
Level  7: 10, 12
Level  8: 11, 13
Level  9:     14
Level 10:     15
```

- Nodes in the same level of the graph can be processed in parallel
- How to:
  1. Add node 0 to the level 1
  2. Mark node 1 as visited
  3. Close level 1
  4. Check neighbors of nodes in previous level to see if dependencies are fulfilled
     1. If yes, add node to the level and mark node as visited
     2. If no, continue with the next node
  5. Close level, add new level and go to 4 if no more nodes to process

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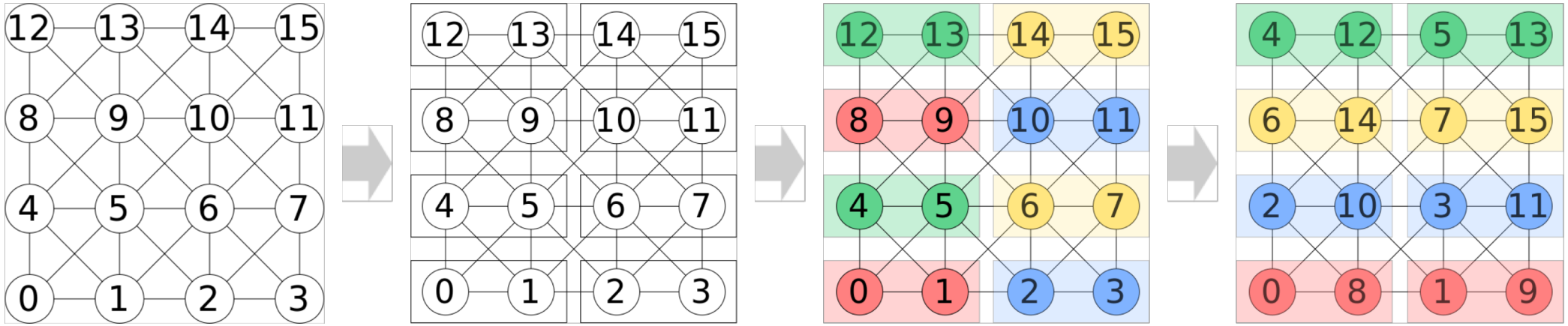
Block multi-coloring



- Blocks with the same color can be processed in parallel
- How to:
  1. Group N consecutive nodes in blocks
  2. Colorize blocks
  3. Reorder blocks and rows of blocks sharing the same color

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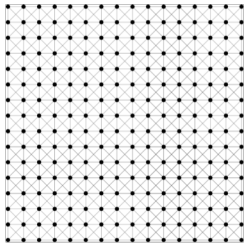
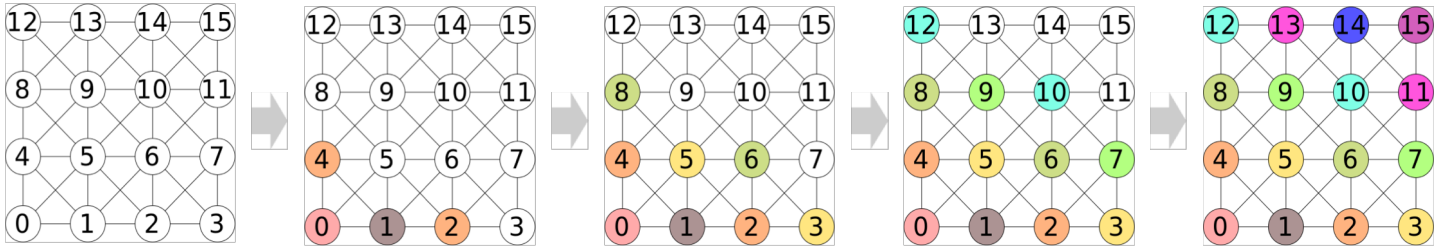
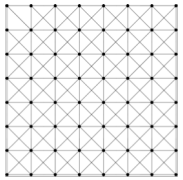
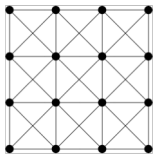
Merging all together



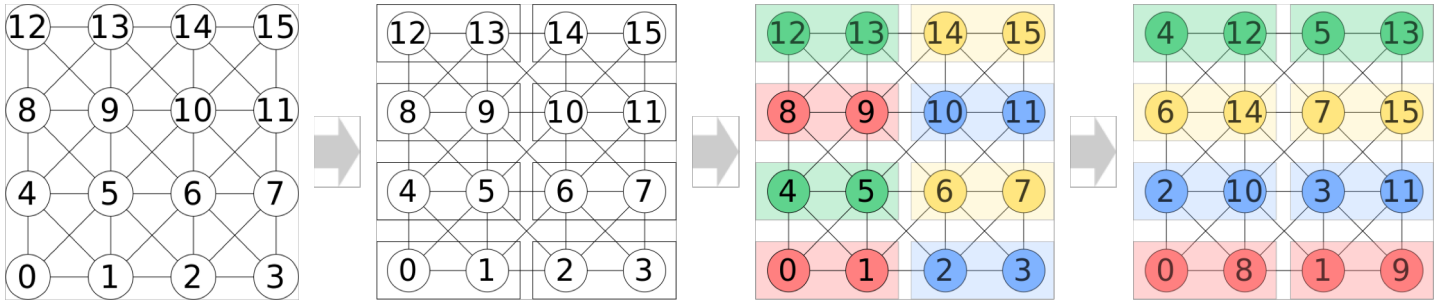
Finest level







Coarser levels



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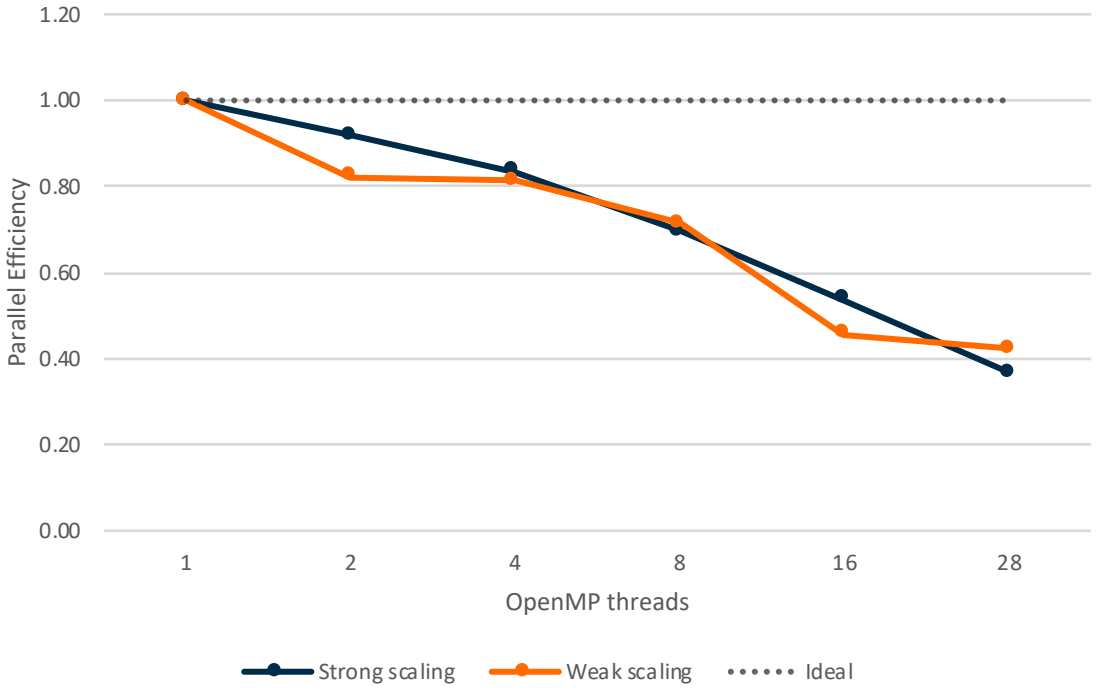
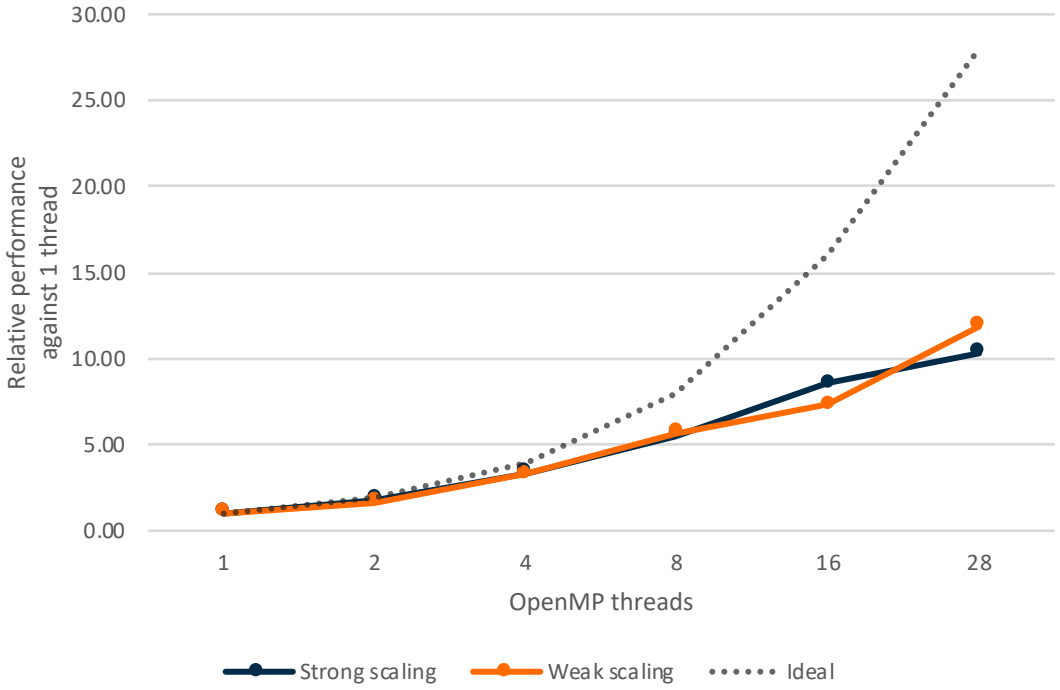
Intra-node performance





- Experiments executed on a dual-socket state-of-the-art Arm platform

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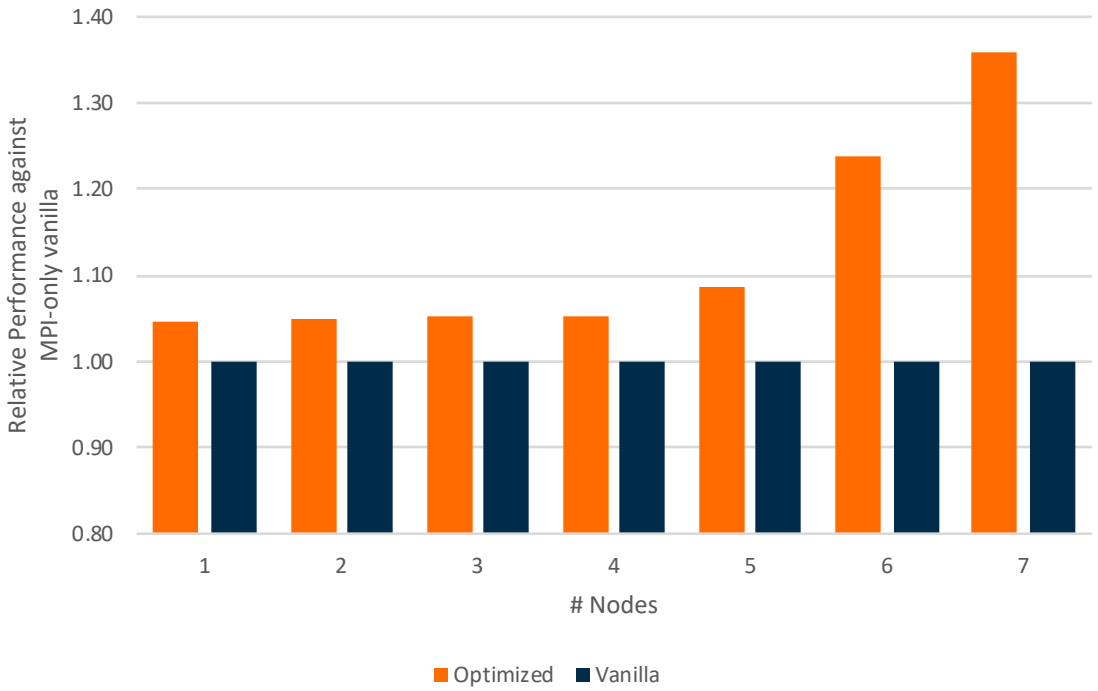
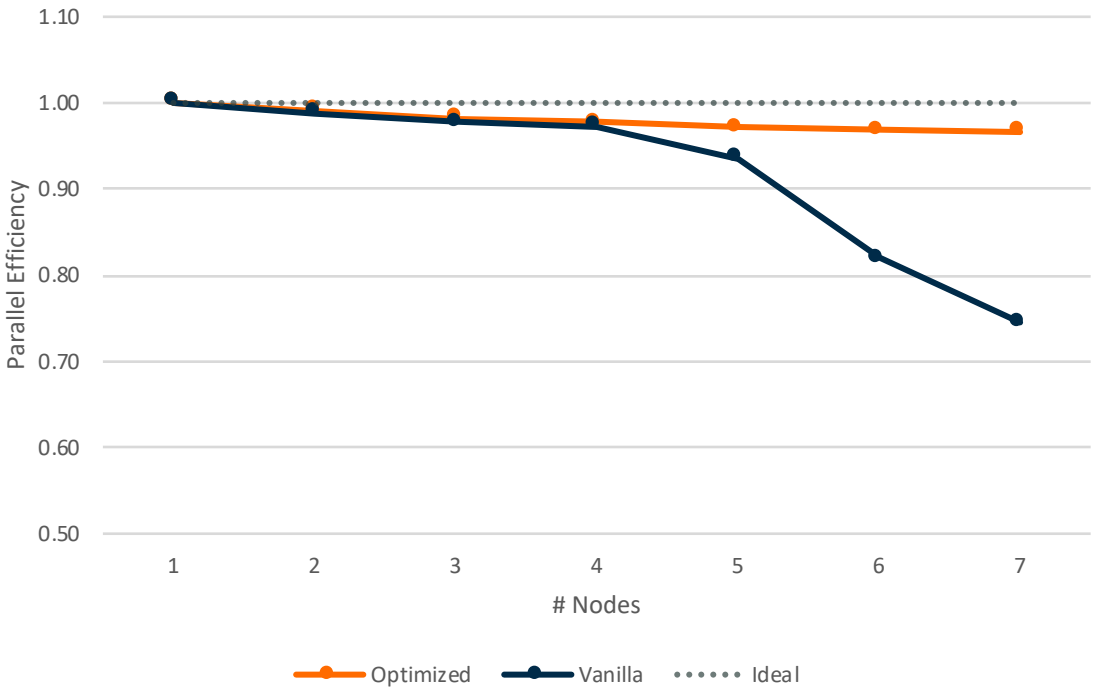
Multi-node performance





- Optimized:
  - 8 MPI ranks per node
  - 7 OpenMP threads per MPI rank
  - 256x224x256
- Vanilla:
  - 56 MPI ranks per node
  - OpenMP disabled
  - 128x128x128

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Summary

- The code is open-source
  - https://gitlab.com/arm-hpc/benchmarks/hpcg
  - We welcome contributions! 😃
- We can collaboratively improve things
  - Hand-made NEON code
  - Hand-made SVE code
  - Platform-specific optimizations
  - Network communication
- Further information about our code on the the Arm Community blog
  - https://community.arm.com/tools/hpc/b/hpc/posts/parallelizing-hpcg

Thank You
Danke
Merci
谢谢
ありがとう
Gracias
Kiitos
감사합니다
धन्यवाद
תודה

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