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Graph-based proxy applications and derivative benchmarking on Ookami

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Sayan Ghosh
Computer Scientist, PNNL

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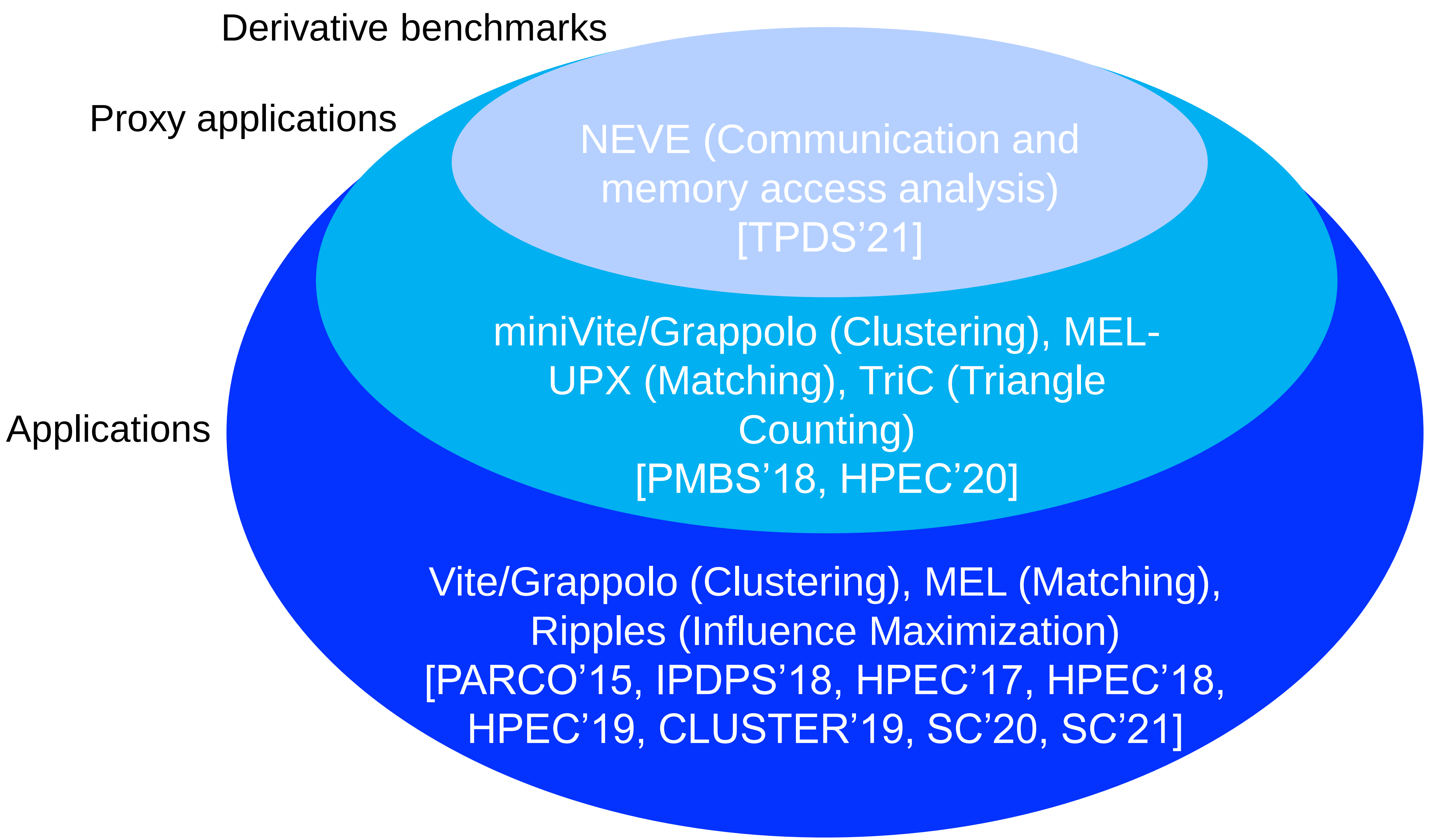
Graph analytics codes

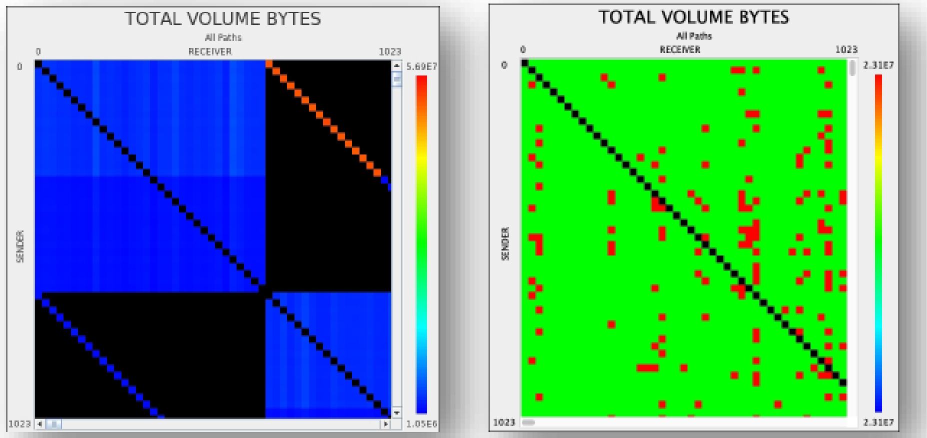


Graph algorithms

- Combinatorial (graph) algorithms are key enablers in data analytics
  - Graph coloring, matching, community detection, pattern, centralities, traversals, etc.
- Relatively *less* computation and *more* memory accesses
  - Graph codes on accelerators mainly exploits the b/w, ALUs are relatively underutilized (many algorithms have 0 FLOPS)
  - Limited vectorization advantage
- Graphs are multifarious, distributed-memory poses challenges
  - Asynchronous, irregular and adversarial communication patterns
  - Network contention

```
Input: G(V,E), s ∈ V
Q.enqueue((visit(s))
while (!Q.empty()):
  u = Q.dequeue()
  for v in neighbor(u):
    if (!visited(v)):
      Q.enqueue((visit(v))
```

```
Input: G(V,E)
for u in V:
  for v in neighbor(u):
    visit(v)
```



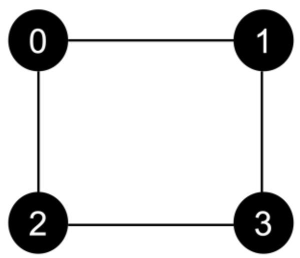
Pair-wise communication volume for BFS (left) and Graph neighborhood (right) for same graph

Communication is shown as a heat map of bytes/process pair, black is 0 bytes

Graph500 or traversal-based algorithms are not necessarily representative use cases!

Derivative Benchmark: Analyzing Graph Memory Accesses via simple kernels

Graph

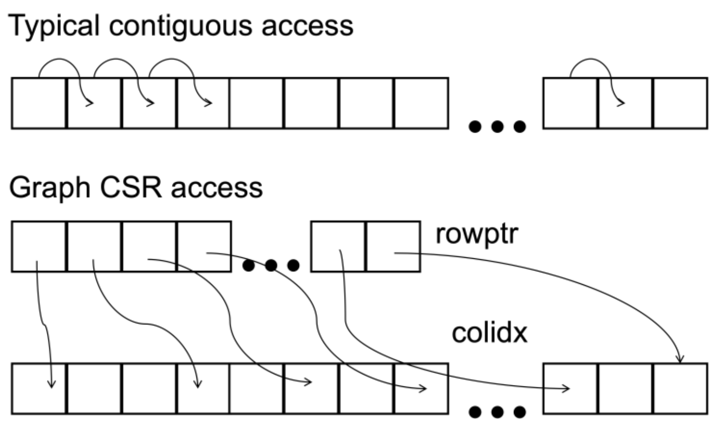


Adjacency matrix

	0	1	2	3
0	0	1	1	0
1	1	0	0	1
2	1	0	0	1
3	0	1	1	0

CSR

rowptr: 0 2 4 6 9
colidx : 1 2 0 3 0 3 1 2



Input: $G = (V, E)$, (undirected) graph G.

1: **for** $v \in V$ **do**
2: **for** $u \in \text{adj}(v)$ **do** {Neighbors of v}
3: {Perform some work with $\{v, u\}$}

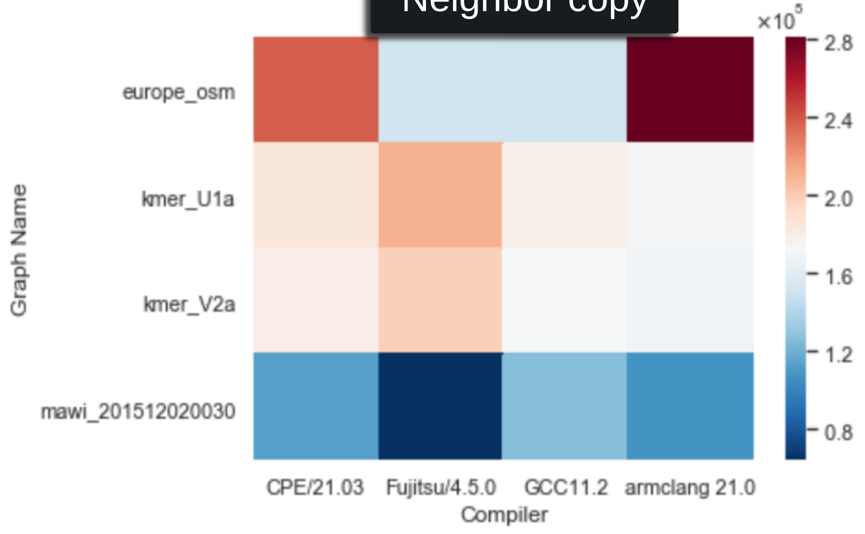
Scanning the neighborhood of a vertex in a graph is common

Disparity in maximum and average #edges impacts performance (unstructured parallelism)

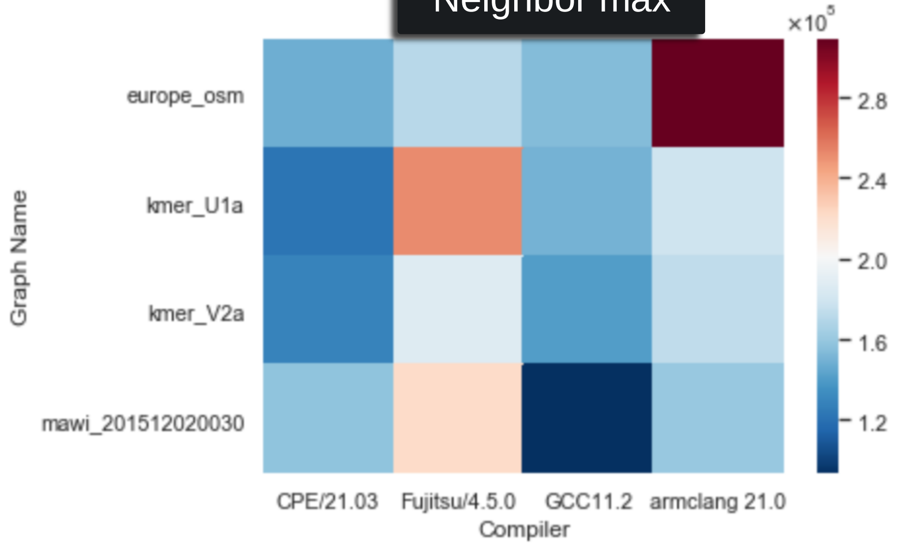
Different graphs (100M+ edges) on different compilers

Red spectrum is good, blue/white not so much

Neighbor copy

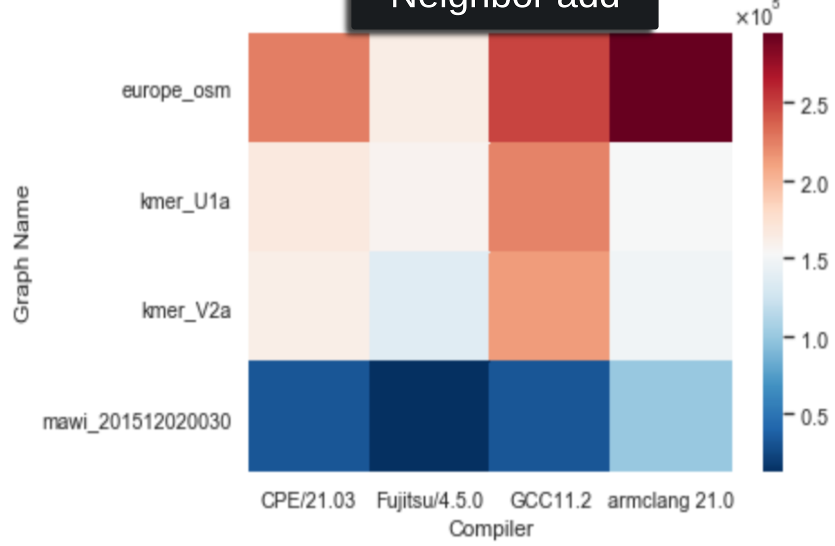


Neighbor max



- Reporting TEPS (higher the better)
- Detect issues with systems and runtimes
- Sandbox for building graph applications

Neighbor add

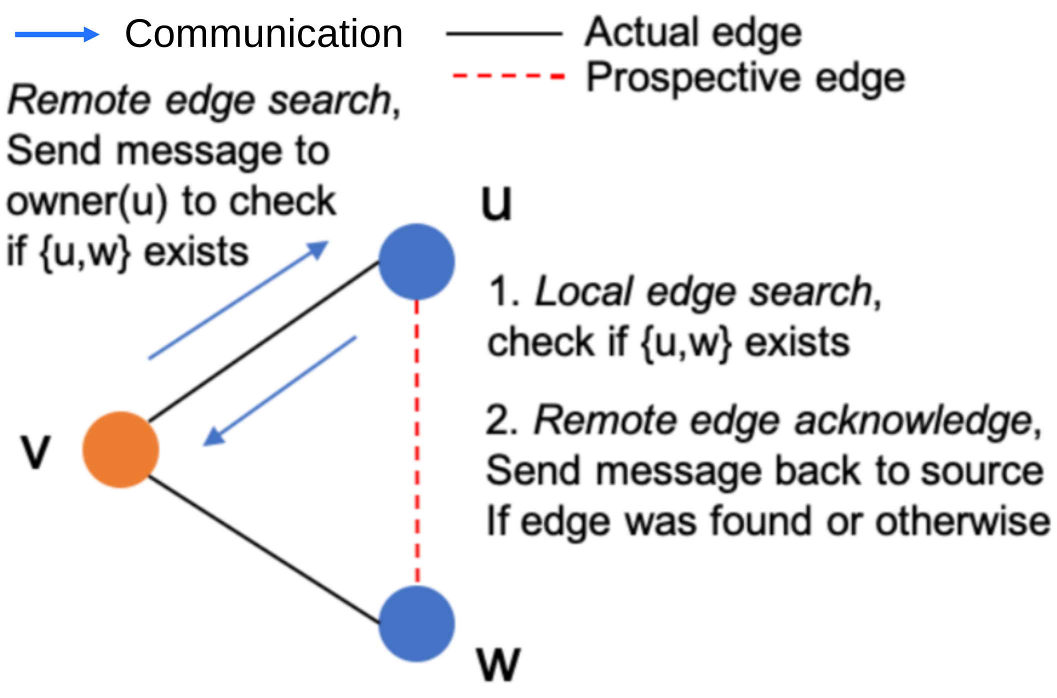


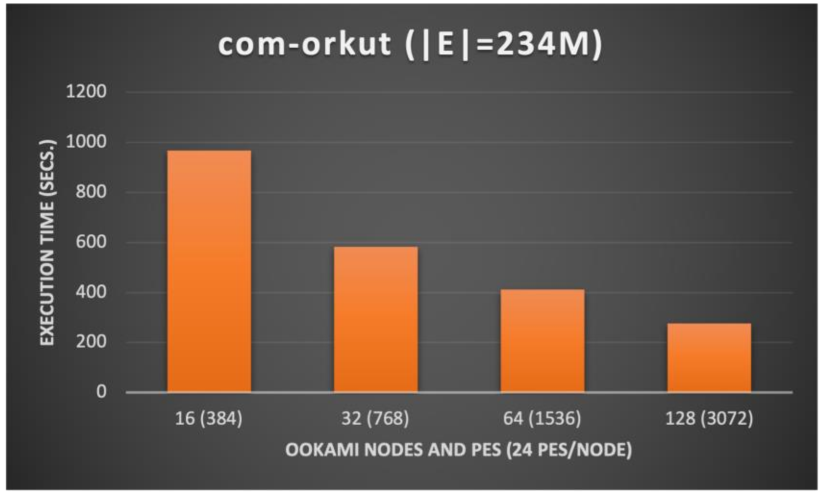
- Column-wise variation depict differences in compilers
- Row-wise variation depict differences across graphs (structure is impeding parallelism, investigate)
- Will try ZFILL

* Results from Yan Kang, PSU

Proxy: Triangle counting by exploiting graph structure

- Developed several variants of distributed exact graph triangle counting
  - Simple formulation – exploits vertex-centric distributed graph structure – process-based
  - Options to suspend and resume work on a vertex based on a customizable buffer
    - ✓ Throttle messages and limit neighborhood size
  - Different communication models: MPI send/recv, RMA, neighborhood collectives
- This code is a pilot before moving on optimizing other apps – clustering/matching, etc
- Preliminary results on Ookami shows about 3.5x speedup relative to 8x nodes





Ghosh S, Halappanavar M. TriC: Distributed-memory Triangle Counting by Exploiting the Graph Structure. In 2020 IEEE High Performance Extreme Computing Conference (HPEC) 2020 Sep 22 (pp. 1-6). IEEE. [code: https://github.com/sg0/tric]

Summary

- Most of our codes are distributed and have a startup problem (more nodes to run – major communication overhead!)
  - Mitigating it with fixed-buffer and suspend-restart mechanism
  - Buffer size is a trade-off (too large OOM, too small more iters)
  - More processes and less threads lead to better results (not much on-node parallelism – could be more) – using 12-24 PEs per node
  - Investigate communication avoiding heuristics and extract more bandwidth from node
  - Impact of SVE?
- armclang (21.0) performance seems to be generally better
- Software setup/building was straightforward – thanks for the support and active Slack channel!