Dynamic Graph Network Optimization

(Implementing SOSP And MOSP)

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Problem Statement

Challenges

- **Dynamic Graph Challenge**: In large-scale networks, frequent updates (like edge insertions) make full re-computation of multi-objective shortest paths (MOSP) inefficient.
- **Scalability Limitation**: Traditional sequential approaches fail to meet the performance demands of real-time, high-volume data in large graphs.

Our Parallel Solution

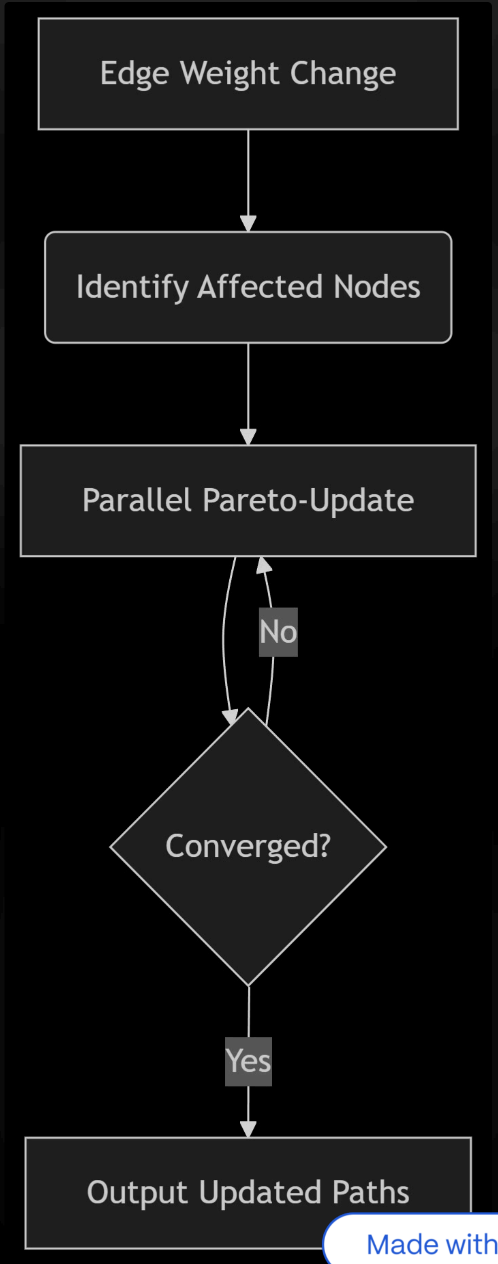
- To handle real-time updates in massive dynamic graphs efficiently, we propose a parallel solution that combines MPI, OpenMP/OpenCL, and METIS for scalable and incremental MOSP updates.

Paper Summary

SOSP (Single-Objective Shortest Path): A shortest path problem that optimizes a single objective in a graph.

MOSP (Multi-Objective Shortest Path): An extension of SOSP that finds optimal paths considering multiple objectives in a graph.

Paper Summary: The paper presents a parallel SOSP update algorithm, a heuristic MOSP update strategy for dynamic networks, and shared-memory parallel implementations optimized for scalable computation of SOSPs and MOSPs.



Key Contributions Of The Paper

Parallel SOSP Update Algorithm

Parallel SOSP Update Algorithm

The paper introduces an efficient parallel SOSP update algorithm using grouping techniques to reduce the total iteration count, improving scalability for large dynamic networks.

Heuristic Approach for MOSP

A heuristic algorithm is proposed to quickly update a single MOSP in large networks under time-varying dynamics, providing a practical solution for real-time applications.

Shared-Memory Parallel Implementation

The paper develops shared-memory parallel implementations that optimize SOSP and MOSP computations, leveraging multi-core architectures for scalable performance.

Tools Used

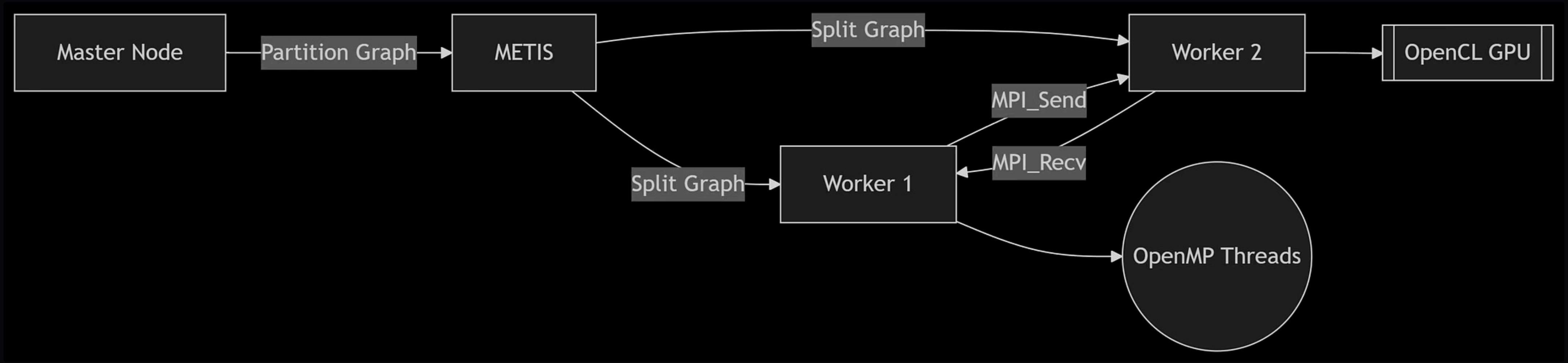
Tools

1. METIS
2. **MPI**
3. OpenMP
4. OpenCL

Role

1. Partitions graph to minimize edge cuts to reduce communication.
2. Distributes partitions and handles inter-process communication.
3. Parallelizes path computations within each node using multithreading.
4. Offers GPU acceleration for intensive Pareto-frontier updates.

System Architecture



Implementation Plan And Workflow

1 Graph Partitioning

METIS partitions the large graph into smaller subgraphs minimizing edge cuts.

2 Task distribution (MPI)

Each partition is assigned to an MPI process for parallel execution with minimal communication.

3 Intra-Node Computation (OpenMP/OpenCL)

Each node updates SOSP/MOSP locally using OpenMP threads or GPU via OpenCL.

4 Pareto-Optimal Update & Synchronization

Update MOSP solutions and synchronize affected nodes across partitions.

Proposed Parallel Strategy

The proposed strategy combines graph partitioning, distributed computing, and multithreading. Below is the pseudo code:

```
G = load_graph()
Parts = METIS_Partition(G, P)

MPI_Init()
rank = MPI_Comm_rank()
LocalG = Parts[rank]

#pragma omp parallel for
for node in LocalG:
    update_SOSP(node)

MPI_Allgather(updates)

if GPU_enabled:
    launch_OpenCL(update_Pareto)

MPI_Finalize()
```

Expected Results

Strong Thread Scaling

OpenMP scales well from 1 to 64 threads. Speed increases for different Δ⊠ sizes.

Decreased Execution Time

Sparse graphs improve with increased threads. Shows consistent improvements.

Road-USA Speedup

Up to 15× speedup due to size and sparsity. This network is the most performant.

SOSP Update Dominance

SOSP_update accounts for 90% of runtime. Key contributor to parallel performance.

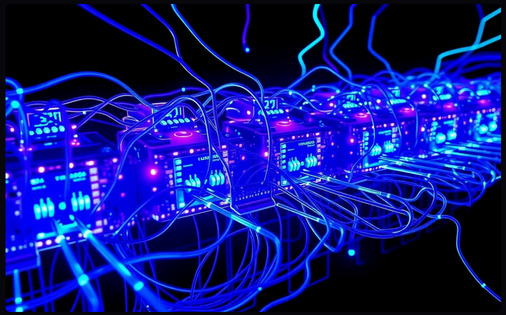
Speedup

We target a 5–8x speedup on an 8-node cluster using parallel computing.

Scalability

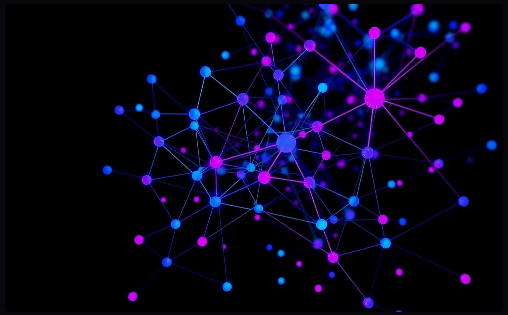
Aim for weak scaling efficiency >70%. Double nodes, double problem size.

Conclusion



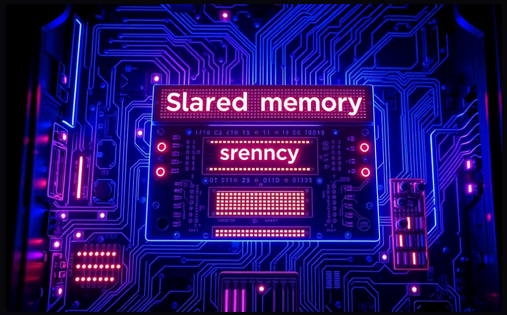
Parallel SOSP Algorithm

Enhanced the algorithm by grouping nodes to reduce iterations.



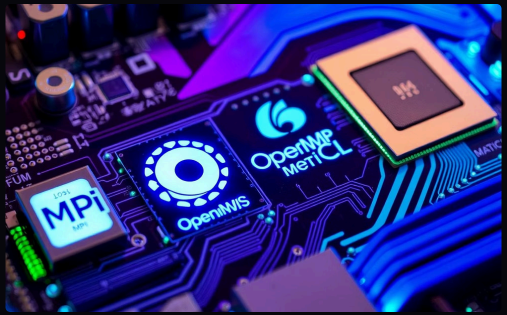
MOSP Update Approach

Developed a heuristic-based approach for large dynamic graphs.



Scalability Achieved

Significant scalability using shared-memory parallelism.



Future-Ready Implementation

Proposed MPI + OpenMP/OpenCL + METIS for hybrid parallelism.

Ending Note

Thank you for your attention. This work demonstrates efficient parallelization for multi-objective shortest path updates in dynamic networks. Future improvements with MPI, OpenMP/OpenCL, and METIS will further enhance scalability and performance.

Appendix

Dataset Sources: DIMACS, SNAP, OSMnx (listed in report).

METIS Parameters:

```
gpmetis -ptype=rb -objtype=cut input_graph.graph 8
```

MPI Commands:

```
mpirun -np 8 ./mosp_algorithm --input network.txt
```

Reference paper:

A Parallel Algorithm for Updating a Multi-objective Shortest Path in Large Dynamic Networks

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