An Evaluation of UPC++ Using Distributed Parallel Graph Algorithms

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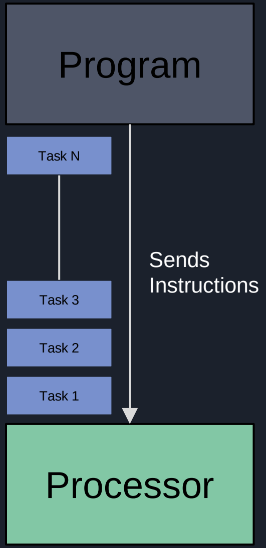
Parallel Computing



Program

Task N

Task 3

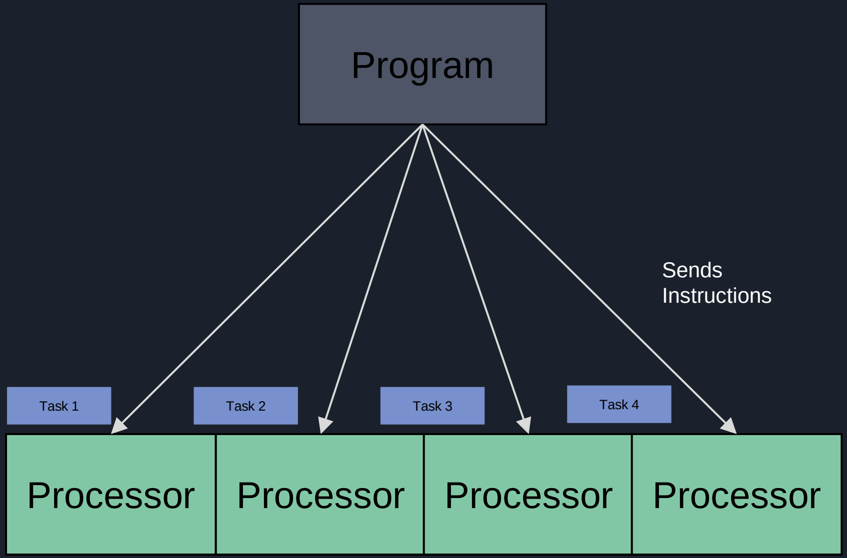
Task 2

Task 1

Sends Instructions

Processor

Serial



Program

Sends Instructions

Task 1

Task 2

Task 3

Task 4

Processor

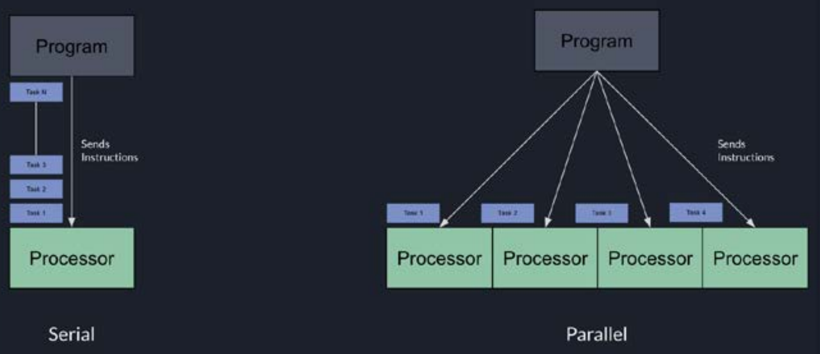
Processor

Processor

Processor

Parallel

Parallel Computing



Benefits

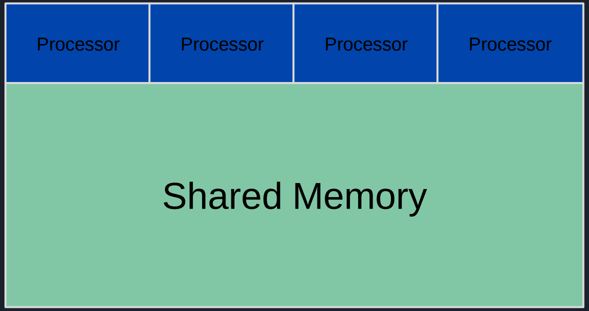
- Speed (*only* way)
- Scalability
- Real world is parallel

Challenges

- Synchronization
- Work distribution
- Communication overhead
- Hard to debug

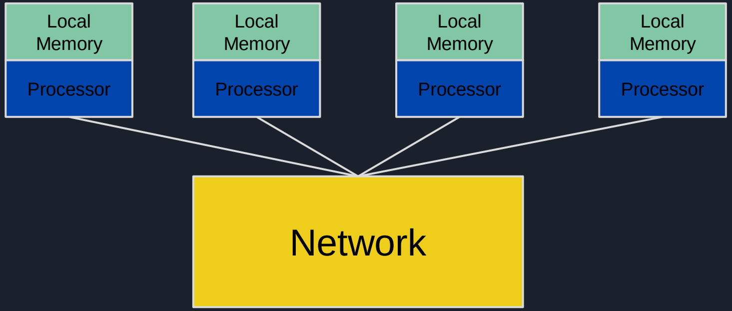
Shared Memory vs. Distributed Memory

- Memory shared by all processes
- Communicate through shared memory



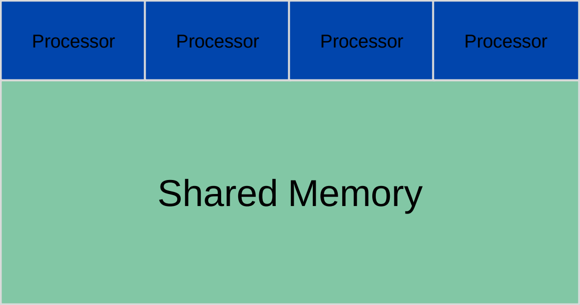
- Like our laptop: one shared memory block for multiple cores

- No shared memory
- Connected together by network

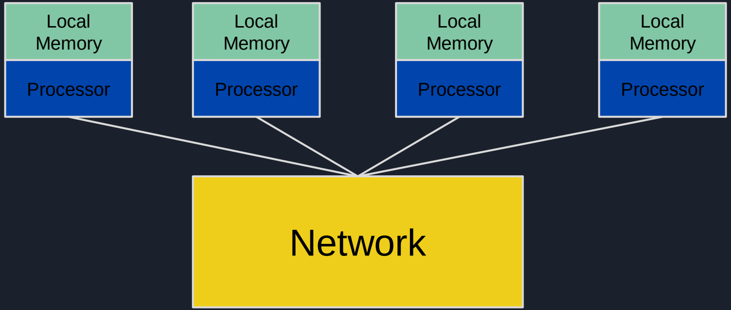


- Often on large network of computers, each with its own memory

Shared Memory vs. Distributed Memory



- Easy to program (data is shared)
- Fast communication
- Low scalability
  - Processors
  - Memory

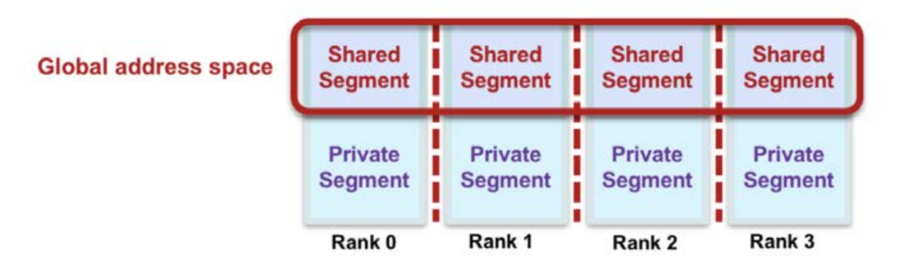


- Hard to program
- Latency in message passing
- High scalability
  - Processors
  - Memory

UPC++: Partitioned Global Address Space

[Zheng et al., IPDPS 14]

- An attempt to unify the two models



https://bitbucket.org/berkeleylab/upcxx/downloads/upcxx-guide-2019.9.0.pdf

- Memory is distributed, but UPC++ exposes global address interface
- Handles message passing

UPC++ (cont'd) and Motivations

UPC++'s Goals

- Easy programming
- Take advantage of scalability of distributed memory system
- Allows programmer to use the same API for local and non-local data
    - Handles details of reading/writing non-local data

Our Question: Promises Delivered?

1. How scalable? (Overhead?)
2. How fast?
3. How easy to use? (Does it feel distributed or shared when coding?)

Our Work

UPC++ vs. shared memory library (OpenMP): Scaling & Speed

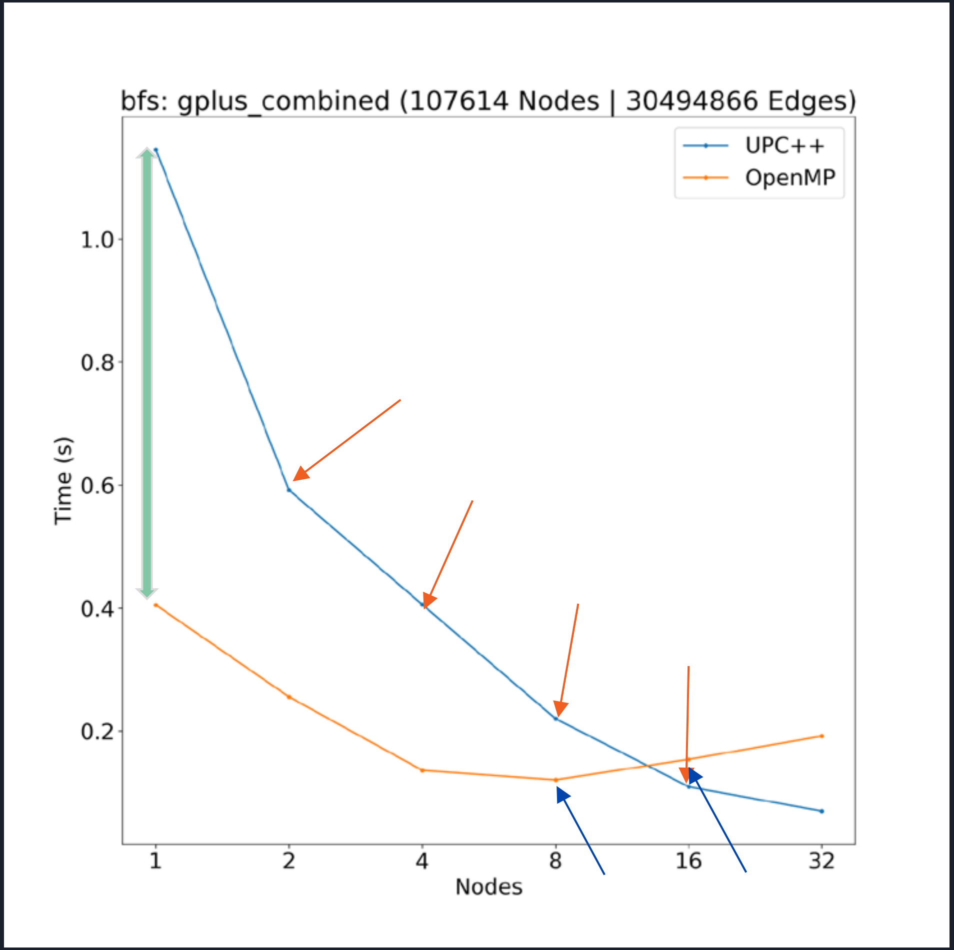
1. Implemented common graph algorithms on UPC++ and OpenMP
2. Ran tests on a single-node, multi-core system
    a. Varying core counts
    b. Real-world and randomly-generated graphs
3. Implemented optimizations (significant work)
    a. Dynamic top-down/grounds-up decision based on frontier density
    b. Different graph partition methods to maximize locality and minimize communication

Experiment Setup

- Single node, multi-core system on AWS
    - C5.18xlarge instance (36 Intel Xeon cores, 144 GBs memory)
- Breadth-first-search implemented on UPC++ and OpenMP
- Graph: ego-Gplus (social circles from Google Plus)
    - 107,614 nodes, 13,673,453 edges, diameter 6
    - Retrieved from Stanford Network Analysis Project
- Compare runtime of program on UPC++ and OpenMP with different numbers of cores used
- Goal is to explore
    - Scaling
    - UPC++'s overhead compared to OpenMP

Results

- Overhead on single node (2.82x)
- Great scaling on UPC++
  - 2x cores ~ ½ runtime
- Bad scaling on OpenMP
  - Overhead takes over



Other Results

- Other algorithms include: Bellman-Ford, Connected-Components, PageRank
- Real graphs

Graph	Nodes
ego-Facebook	4,039
ego-Twitter	81,306
ego-Gplus	107,614
com-Youtube	1,134,890
com-Orkut	3,072,441

Random graphs

  - 1,000 - 1,000,000 nodes
  - 1-100 edges per node

- Range of overhead: [0.66, 6.9]
- Consistently good scaling on UPC++

Conclusions

- Easy to work with
- Have to code with locality in mind to achieve good results
- Manageable local overhead
  - Communication has latency, but that depends on hardware
  - Given the advantages of distributed parallelism, overhead is acceptable
- Highly scalable

Future Work

- Run tests on multi-node machines (in progress)
  - Waiting on supercomputer hours
- Optimize codebase for fast code
  - Implement the Gemini system [Zhu et al., OSDI 16]
  - Compare with state-of-the-art distributed graph algorithms

Questions?