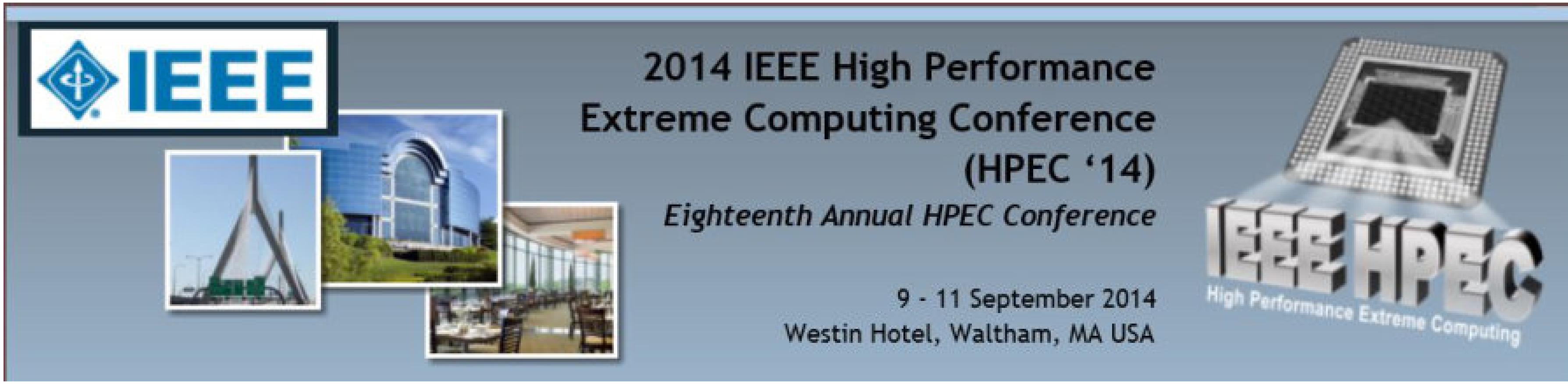

Fast Parallel Algorithm For Unfolding Of Communities In Large Graphs

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Outline

- Big data and graph processing
- Community detection
- Louvain method for community detection
- Our approach
- Results and discussion
- Conclusion

Big data and graph processing

- Complex Systems - > Complex data
  - Graph structured
  - Irregular memory access
  - Fast data rates
  - Large Volume

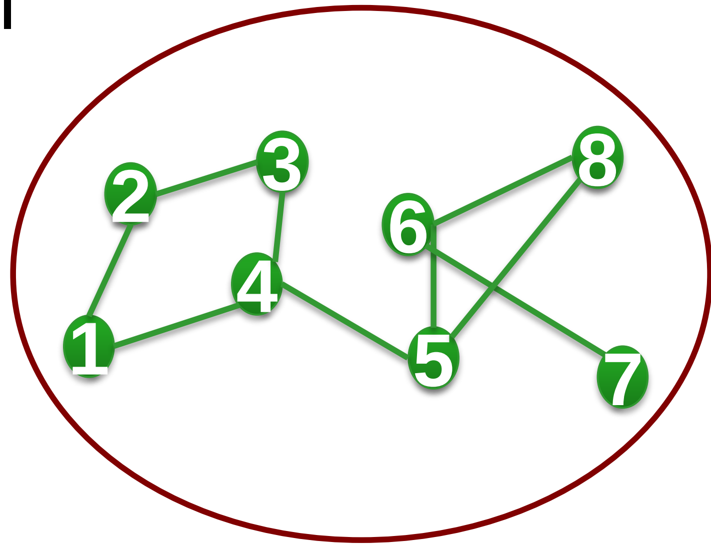
- Over 700M Daily Facebook users
- Over 1B websites
- Over 100 hours of Youtube videos uploaded per minute
- 143,199 Tweets per second

Community detection in graphs

- Approaches
  - Graph partitioning
  - Community structure detection
- Different goals
  - Graph partitioning
    - Division of tasks between processors
    - Known number of partitions/partition size
  - Community structure detection
    - Task is to find partitions of network

Community detection in graphs

- Problem : Given a graph check whether there exist any “natural division” of vertices in to “non overlapping groups.
- Minimize edge cuts ?
- More than expected number of edges within the group (compared to a random graph)
  – Statistically surprising arrangement of edges



Modularity

- A quantitative measure to determine quality of communities.

$$Q = \sum_{c \in C} \left[\frac{m_c}{M} - \frac{d_c^2}{4M^2} \right]$$

$$Q \in [-1, 1]$$

- m_c – number of edges inside community c
- d_c – sum of degrees of vertices inside community c
- M – total number of edges
- C – set of all communities in graph

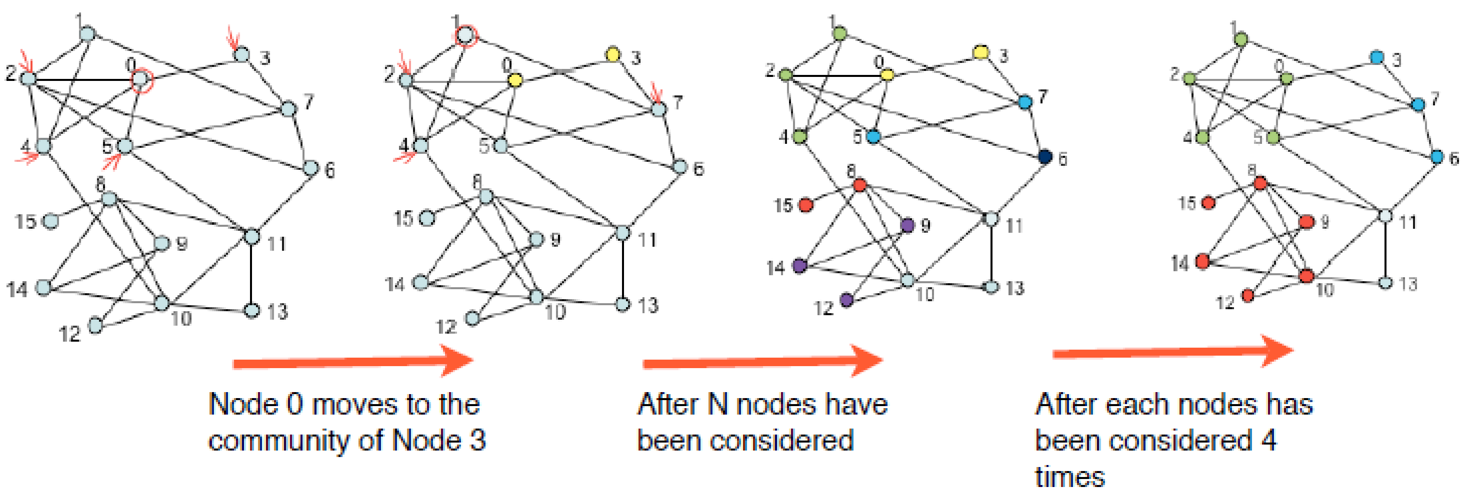
Louvain method for community detection(1)

- A greedy modularity maximization approach.
- Two main steps repeated iteratively

```
while(improvement) {
        detect-communities() //move one vertex at a time
        mod = modularity()
        if( (mod – prev_mod) > T)
                improvement = true
        else
                improvement = false
        prev_mod = mod
        collapse-graph()  //create a new graph
}
```

Louvain method for community detection (2)

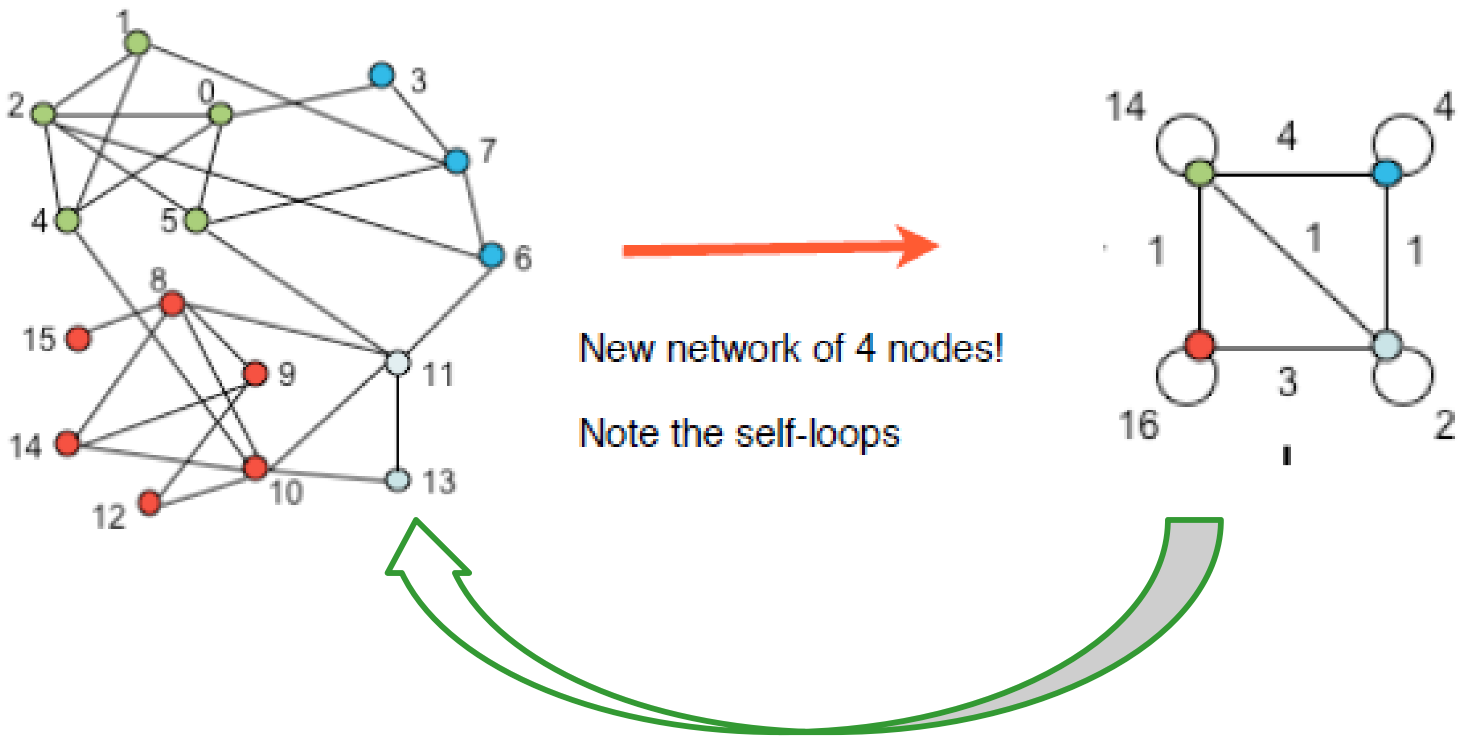
- Scan through all the nodes in a given order.
- Nodes adopts its neighbors community by joining to which gives a maximum increase in modularity.
- This processed repeated iteratively until local maximum modularity is reached.



Source: https://sites.google.com/site/findcommunities/

Louvain method for community detection(3)

- New network is built collapsing communities into single nodes



Source: https://sites.google.com/site/findcommunities/

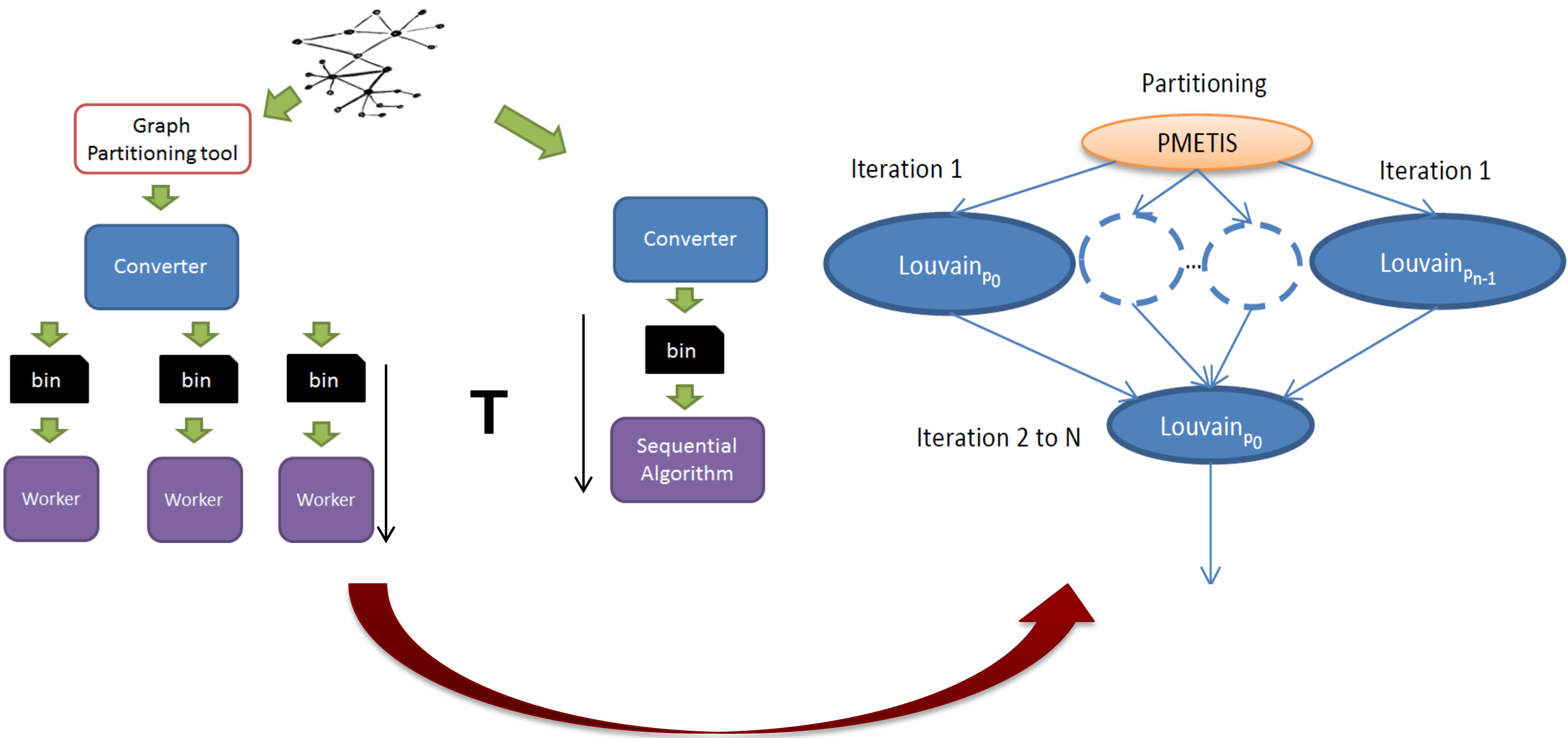
Observations

- First iteration is the costliest iteration - 79.53% of total time on average
- Graph reduced to a much smaller graph after the first iteration.
- First iteration community structures are smaller- less chance for cross partition communities

Our approach(1)

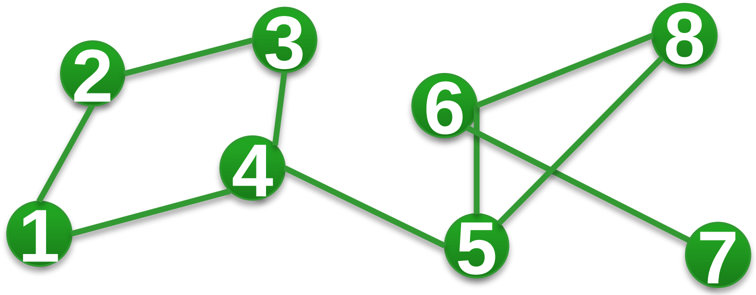
- Partition the graph into N partitions
- Execute first iteration of Louvain locally in each partition
- Merge the community graph in to a single worker
- Execute rest of the iterations of Louvain
- MPI implementation

Our approach(2)



Our approach(3)

- Vertex ordering strategies
  - High degree nodes first - HDF
  - Low degree nodes first -LDF
  - High degree node neighbors first - HNF

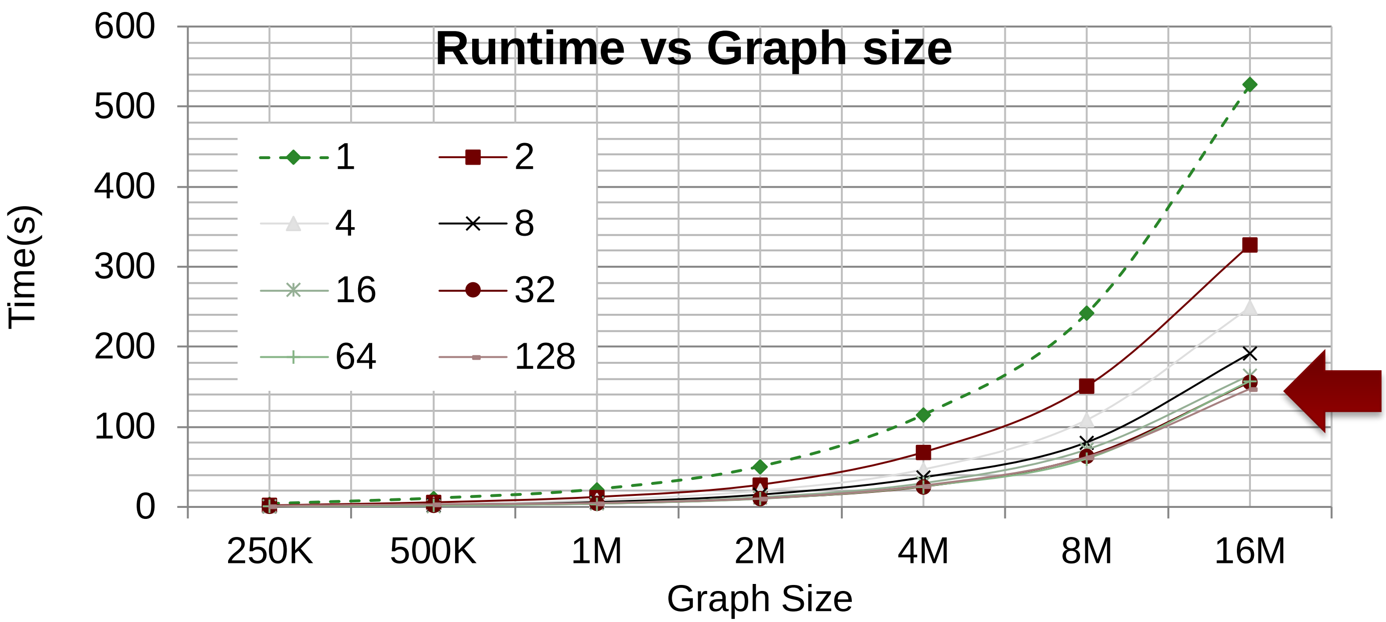


HNF = {3,1,5,6,8,7,2,4}

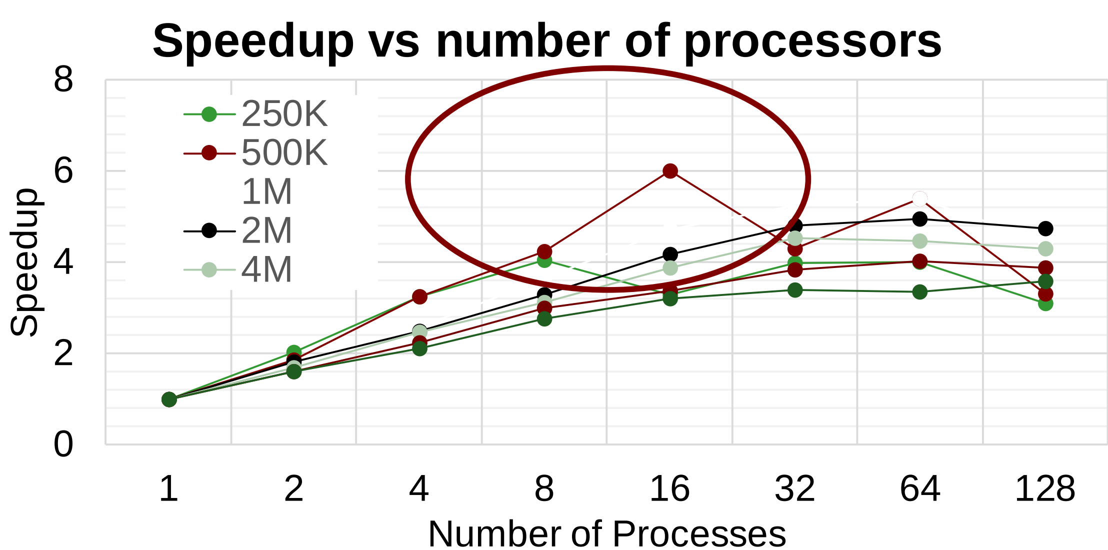
Experimental setup

- Benchmarking conducted at USC HPCC:
  - All benchmarking executed as single batch job of 16 compute nodes w/ 8 cores per node
- Automated testing:
  - Synthetic community graphs 250K -> 16M nodes
  - MPI Task sizes from 2 -> 128 processes
  - Performed strong scaling tests – 49 configurations

Results(1)

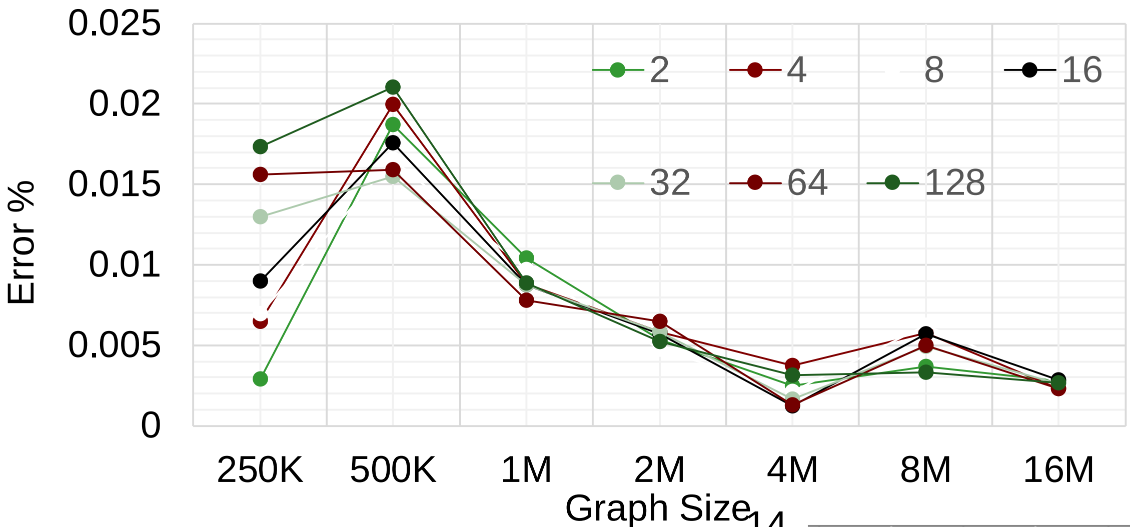


Runtime vs Graph size
600
500
400
300
200
100
0
Time(s)
1
2
4
8
16
32
64
128
250K
500K
1M
2M
4M
8M
16M
Graph Size



Speedup vs number of processors
8
6
4
2
0
Speedup
250K
500K
1M
2M
4M
1
2
4
8
16
32
64
128
Number of Processes

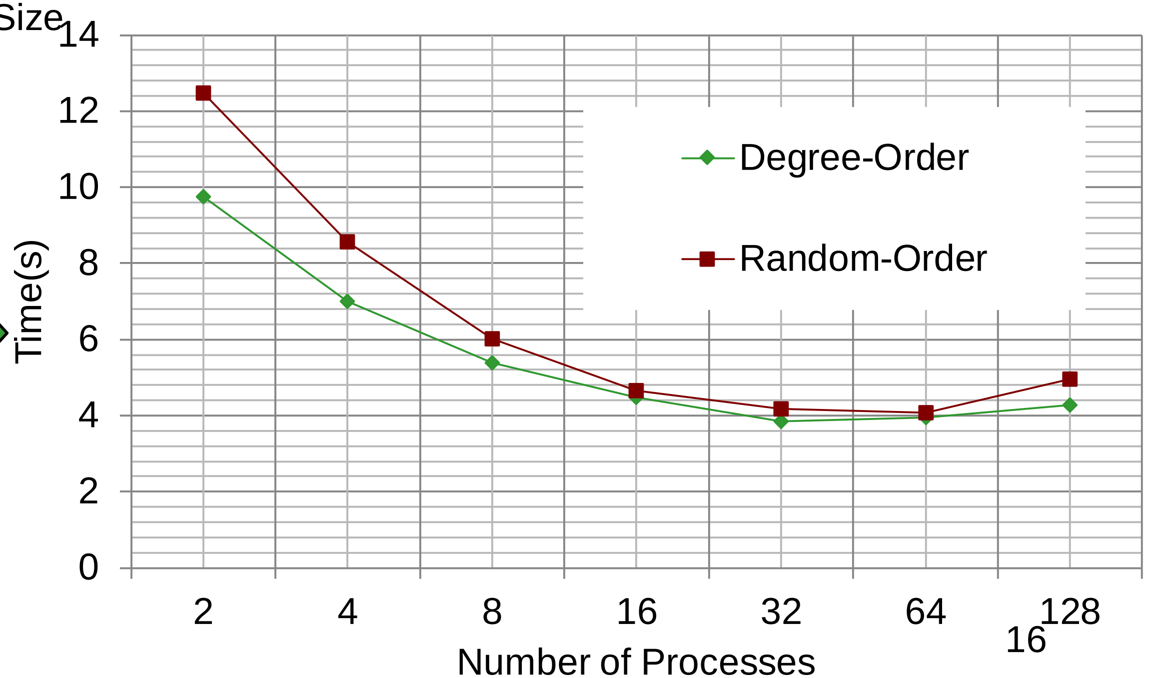
Results(2)



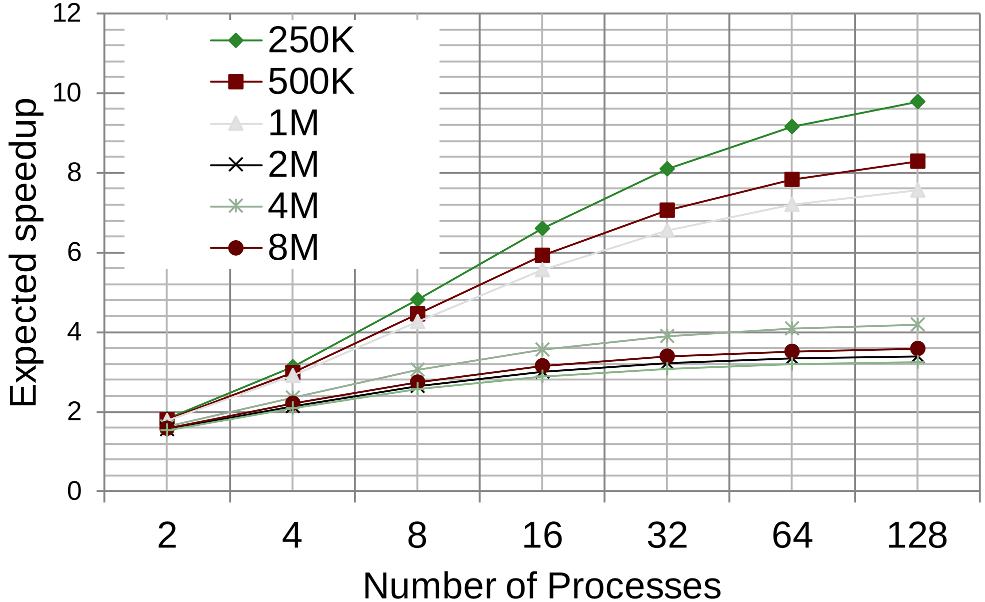
$$\text{Error} = \text{abs}\left(\frac{q_p - qs}{q_s}\right)$$

- q_p= parallel modularity
- q_s= sequential modularity

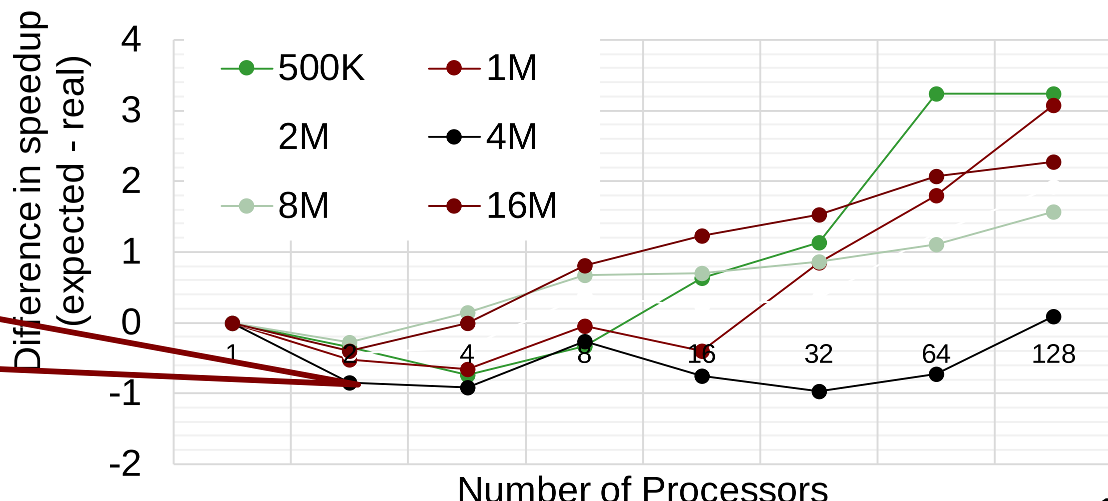
Runtime behavior for graph size : 1M



Results(3)



- Optimistic predicted speedup



super linear speedup

Conclusion

- Community detection in large graphs becoming increasingly popular
- Presented a simple way to speedup Louvain algorithm by using making its first iteration embarrassingly parallel using graph partitioning.
- Minimal impact on final quality
- Evaluate/Extend for much larger real world graphs with known ground truth.

Thank you!

Backup Slides

Cost of graph partitioning

- Question: It is fair to ignore graph partitioning cost
- Answer: Yes ☺
- Why? Think of big data analytic pipeline