Improving Large Graph Processing on Partitioned Graphs in the Cloud

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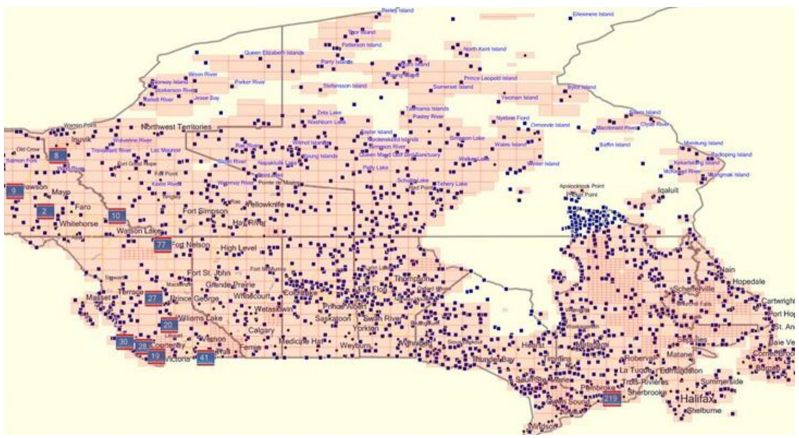
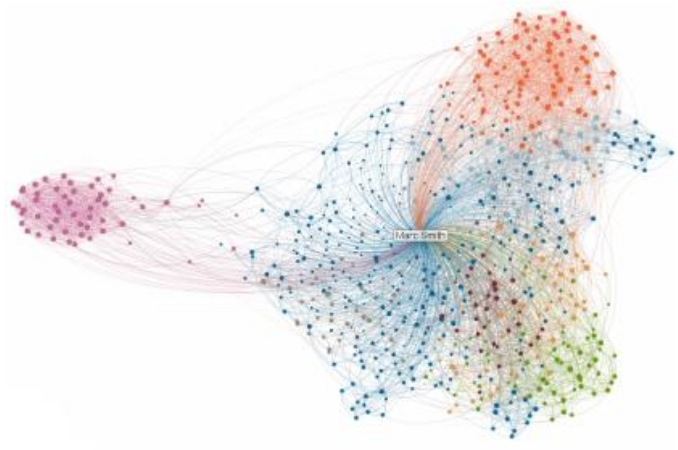
All images are sourced from the paper "Improving Large Graph Processing on Partitioned Graphs in the Cloud" unless specified otherwise.

Importance of Graphs

- Graphs abstract application-specific algorithms into generic problems represented as interactions using vertices and edges



Graph in road network



Graph in social networking

Image source: google.ca/images

Large Graph Processing Systems

- Study of large graphs of $\geq$ 100GB
- Hot and fruitful research area
- Existing Systems:
  - Vertex-oriented execution model
  - Significant amount of network traffic

Aim of the Paper

- Graph partitioning framework to improve network performance of graph partitioning itself.
- Partitioned graph storage.
- Vertex-oriented graph processing.

Result

- *Surfer*.

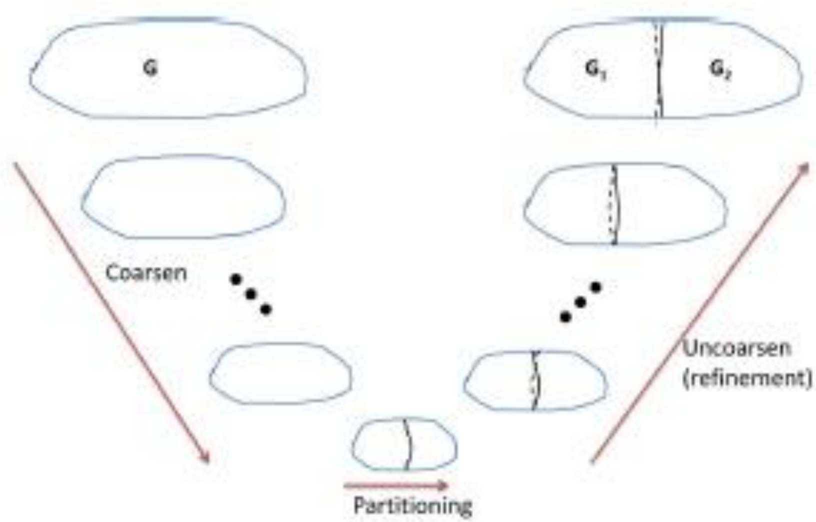
- A bandwidth aware graph partitioning framework to minimize network traffic in partitioning and processing.

- *Surfer - Pregel* (latest vertex-oriented graph engine by Google) extended with graph partitioning framework.

Processing and Partitioning

- Large graph processing:
  - Batched processing on large graphs
  - Network traffic – bottleneck for vertex-oriented computation

- Graph partitioning:
  - Graph bisection
    - Coarsening
    - Partitioning
    - Uncoarsening



Graph Partitioning Framework Models

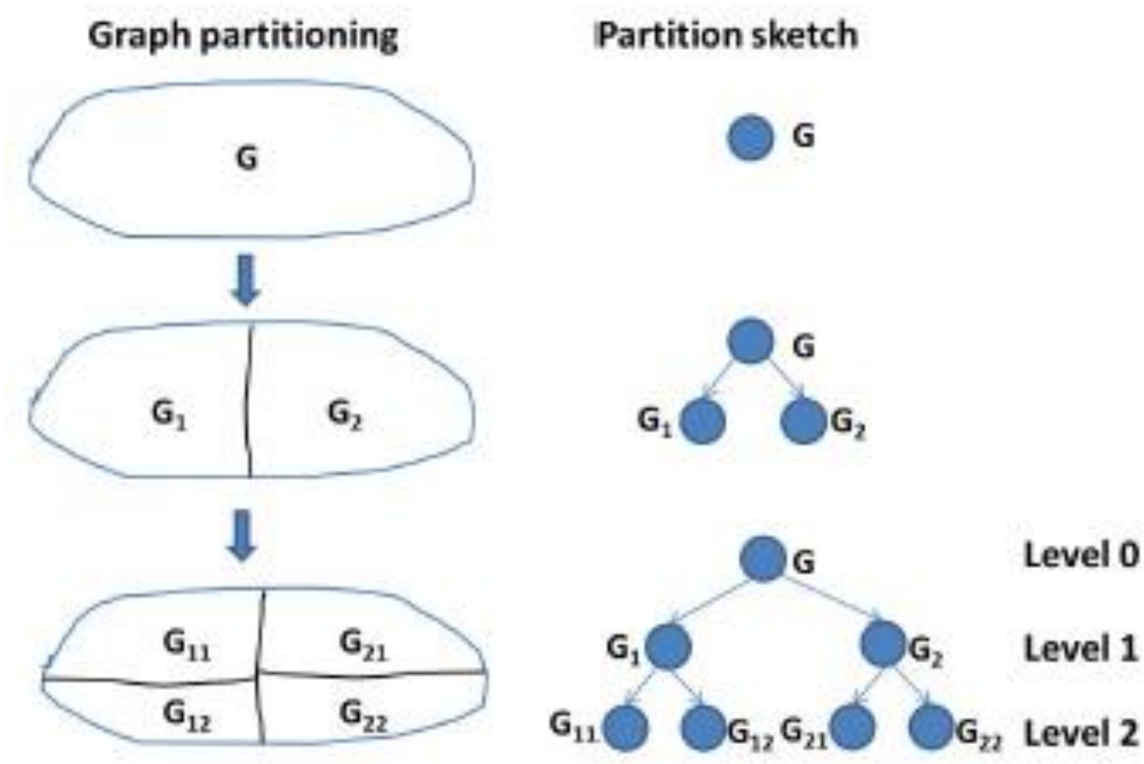
- Partition Sketch
  - Graph partitioning process
- Machine Graph Building
  - Network performance

Partition Sketch

- Basic idea is to partition and store graph partitions according to their # of cross-partition edges.

- Partitions with large # of cross-partition edges are stored in machines with high network bandwidth.

Partition Sketch



Partitioning the graph into four partitions

Partition Sketch

- Properties of ideal partition sketch:
  - Local optimality
    - $C(n_1, n_2)$ – # of cross-partition edges between two nodes n_1 and n_2, $C(n_1, n_2)$ is minimum on all possible bisections of common parent node *p*
  - Monotonicity
    - At the same level $T_i \leq T_j$, if $i \leq j$;

      T is total number of cross-partition edges at the same level.

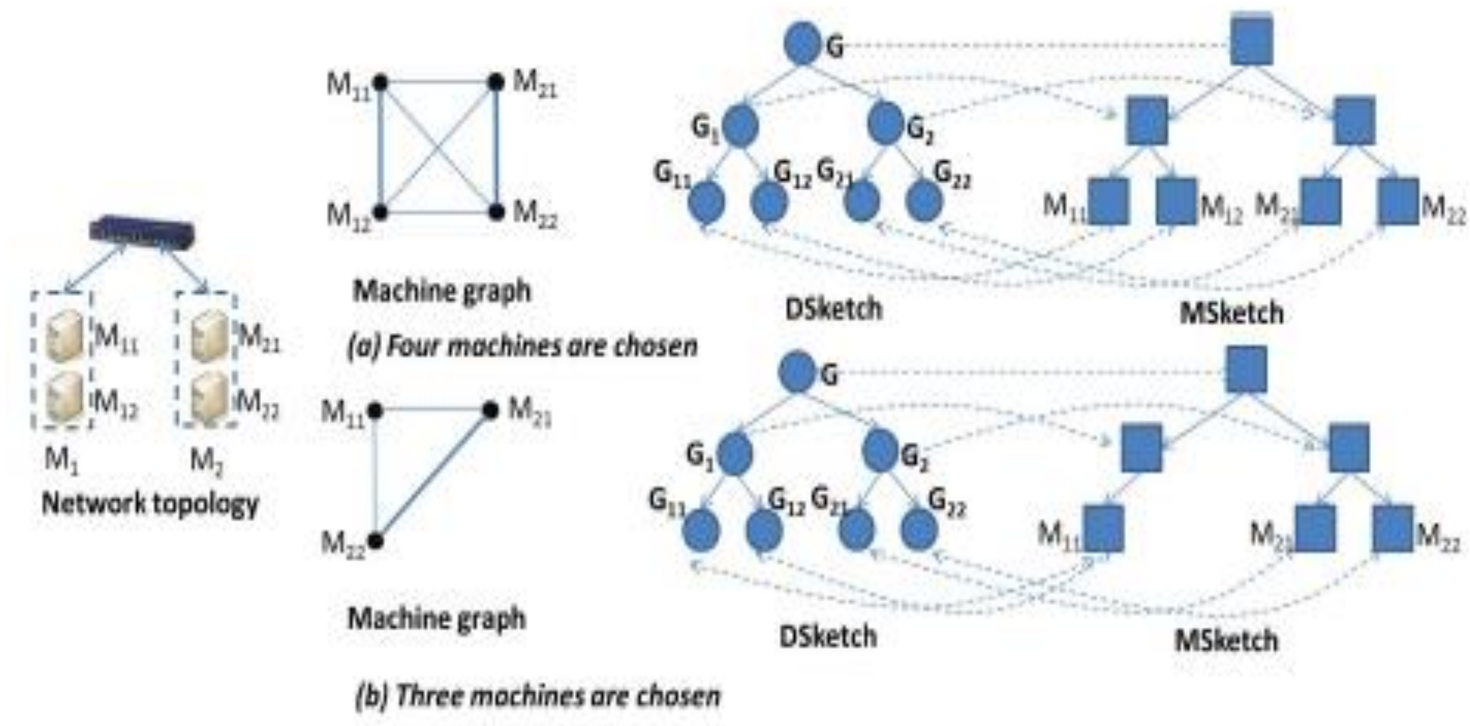
Partition Sketch

- Properties of ideal partition sketch:
  - Proximity
    - Nodes n_1 and n_2 with common parent p
    - Nodes n_3 and n_4 with common parent p'
    - p and p' with same parent
      - $C(n_1, n_2) + C(n_3, n_4) \geq C(n_{\pi(1)}, n_{\pi(2)}) + C(n_{\pi(3)}, n_{\pi(4)})$
      - Π is any permutation on (1, 2, 3, 4)

Machine Graph Building

- Modelled using machine graph
  - Each vertex – machine
  - Each edge – connectivity between machines
  - Weight of the edge is network bandwidth

Machine Graph Building



Mapping on partition sketches between machine graph and data graph

Bandwidth Aware Graph Partitioning

Algorithm 1 Bandwidth aware graph partitioning

Input: A set of machines S in the cloud, the data graph G, the number of partitions P ($L = \log_2 P$)

Description: Partition G into P partitions with S

1: Construct the machine graph M from S;
2: *BAPart*(M, G, 1);//the first level of recursive calls.

Procedures: BAPart(M, G, l)

1: Divide G into two partitions (G_1 and G_2) with the machines in M;
2: **if** M consists of a single machine **then**
3: Let the machine in M be m.
4: Divide G into 2^{L-l} partitions using m with the local partitioning algorithm;
5: Store the result partitions in m;
6: **else**
7: Divide M into two partitions M_1 and M_2;
8: Divide G into two partitions G_1 and G_2 with the machines in M with distributed algorithm [22];
9: *BAPart*(M_1, G_1, l+1);
10: *BAPart*(M_2, G_2, l+1);

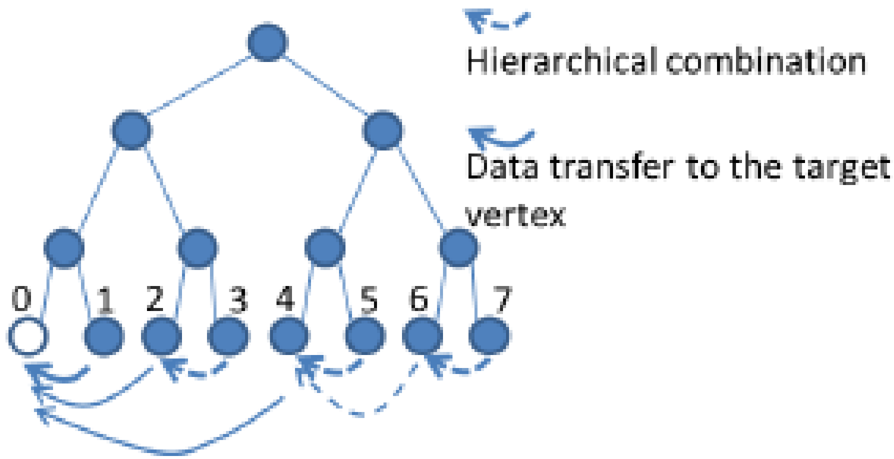
Bandwidth Aware Graph Partitioning

- Partitioning algorithm satisfies the three design principles of:
  - Local optimality
  - Monotonicity
  - Proximity

Hierarchical Combination

- *Local Combination* is a commonly used approach to reduce network traffic.
- *Local Combination* is not aware of the network unevenness in the cloud
- Solution is *Hierarchical Combination*.

Hierarchical Combination



Hierarchical combination of machine graph of eight machines

Experimental Setup

- Conducted experiments on a local cluster (with 32 machines) and Amazon EC2.
- System prototype called *Surfer* implemented in C++, compiled in Visual Studio 9.
- Tree-structured network topology
  - T_2(#pods, #level)

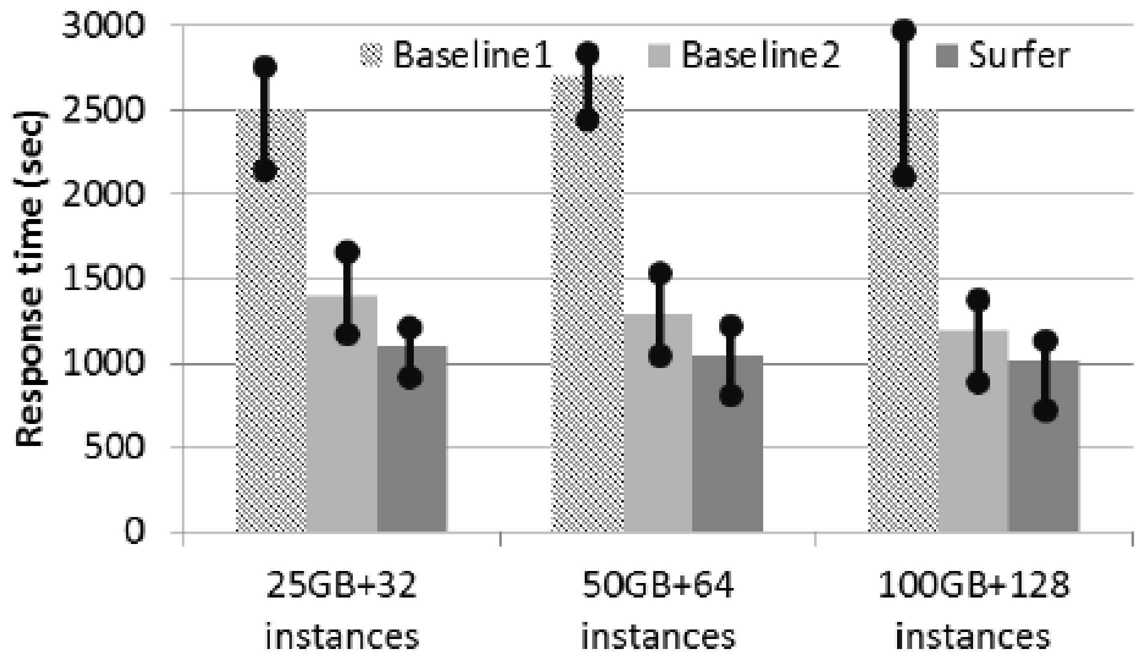
Results on Partitioning

Number of partitions	128	64	32	16
Partition granularity (GB)	1	2	4	8
ier of our partitioning(%)	50.3	57.7	65.5	72.7

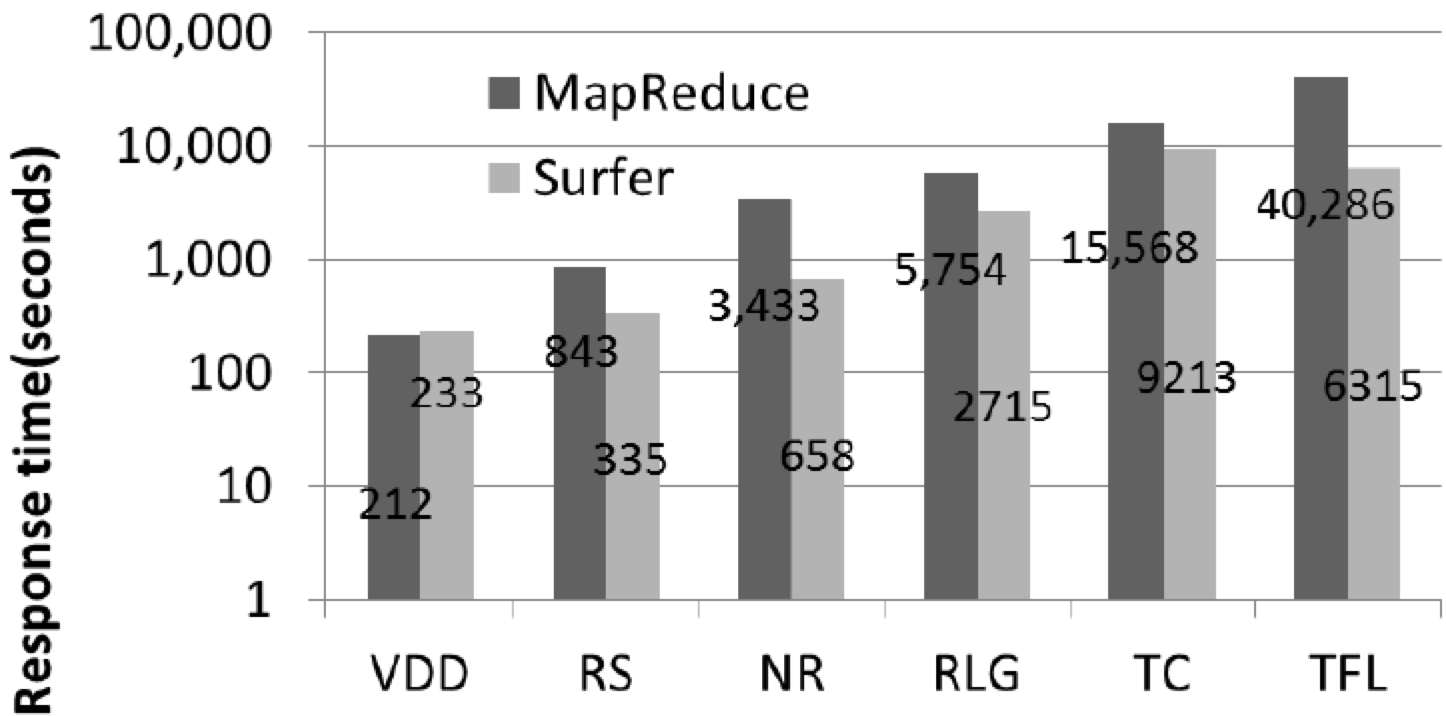
ier: Inner edge ratio

Validates Monotonicity: as depth of partition sketch increases, # of cross-partition edges increases.

Results on Amazon EC2



Comparisons with MapReduce



References

- [1] Improving Large Graph Processing on Partitioned Graphs in the Cloud, R Chen, X Weng, B He, M Yang, B Choi, X Li, 2012
- [2] On the Efficiency and Programmability of Large Graph Processing in the Cloud, R Chen, X Weng, B He, M Yang, B Choi, X Li, 2010

Thank you!