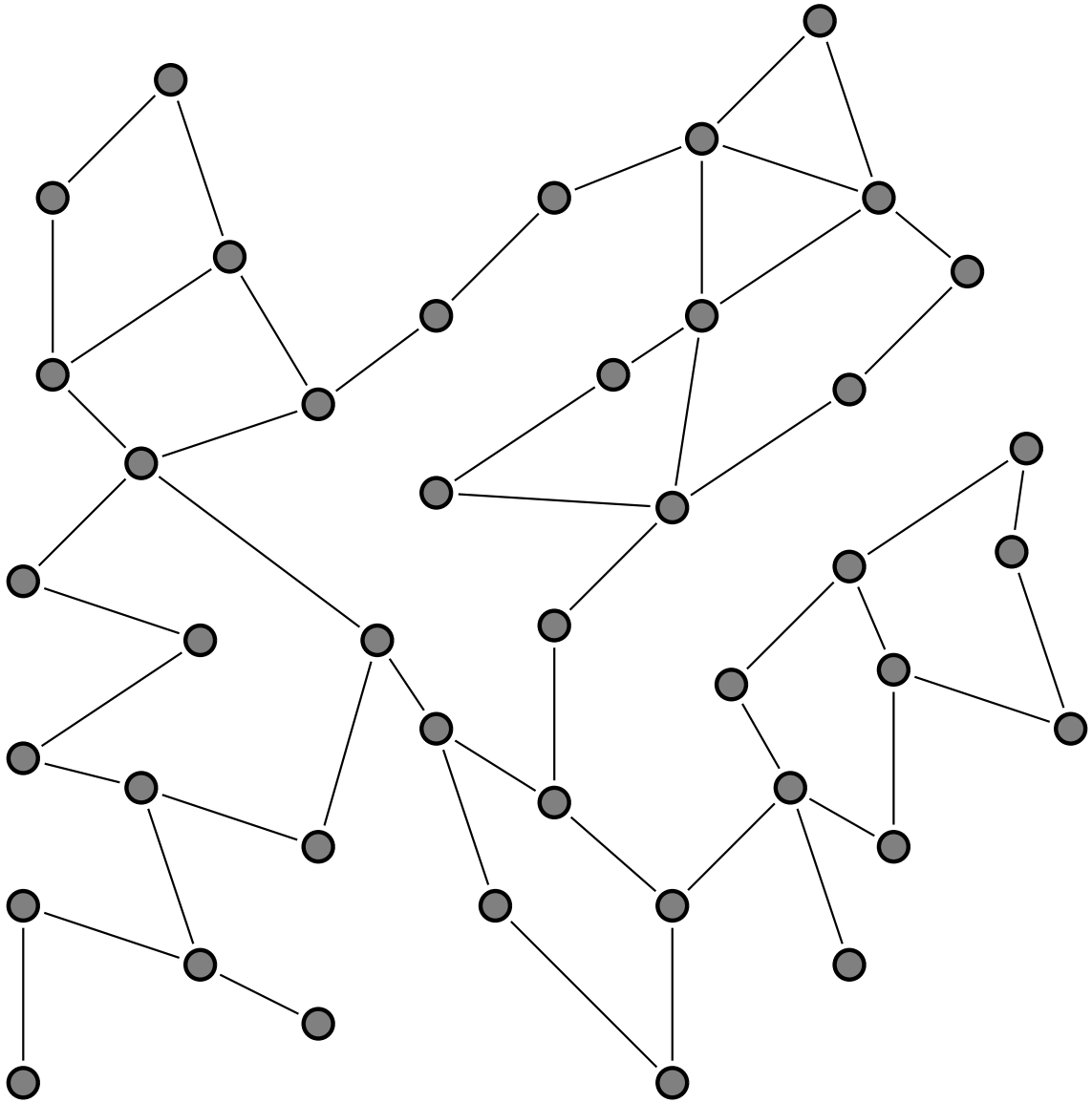
Fast and Stable Repartitioning of Road Networks

18th International Symposium on Experimental Algorithms

Valentin Buchhold Daniel Delling
Dennis Schieferdecker Michael Wegner

June 18, 2020

Partition-Based Route Planning



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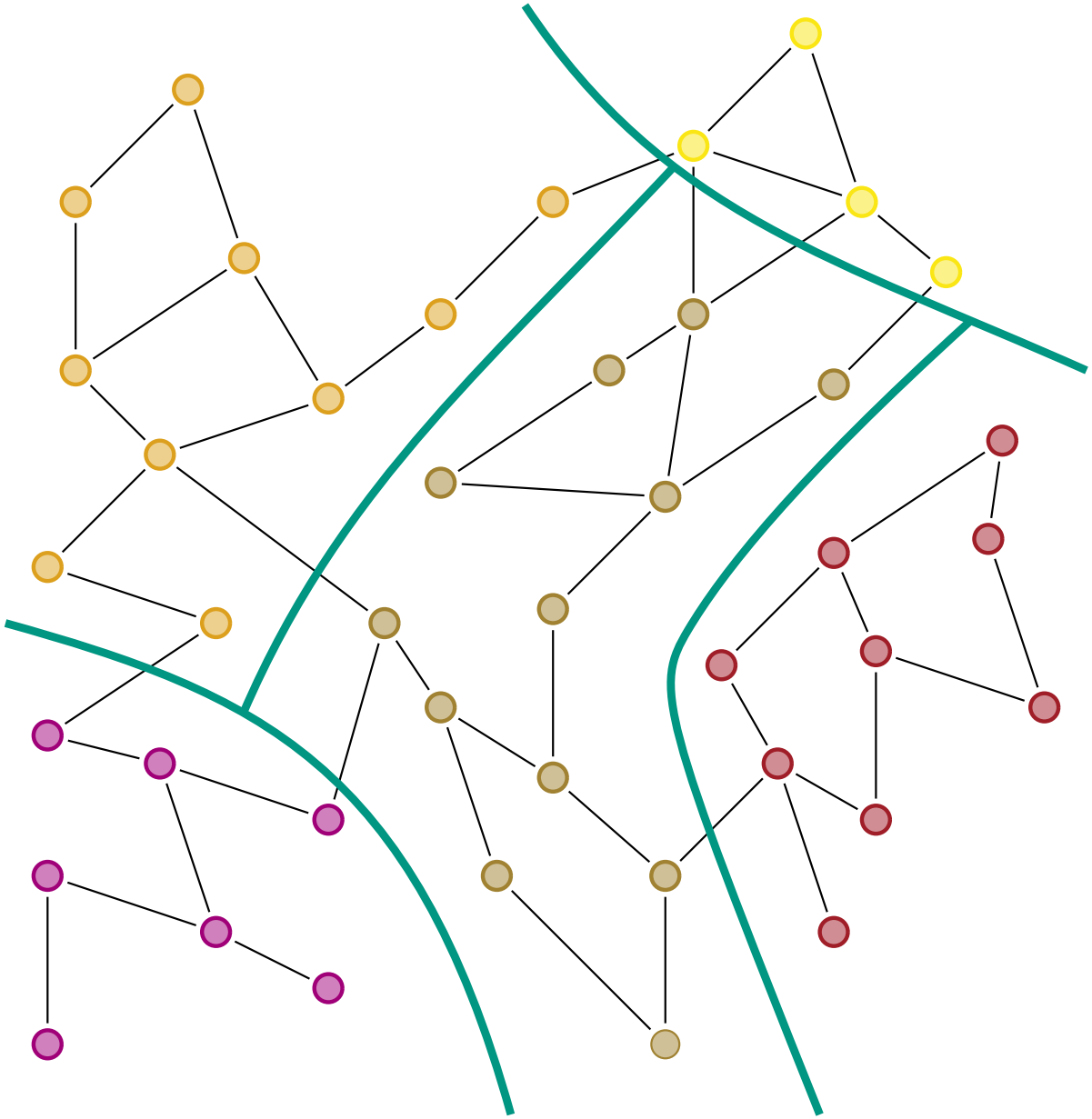

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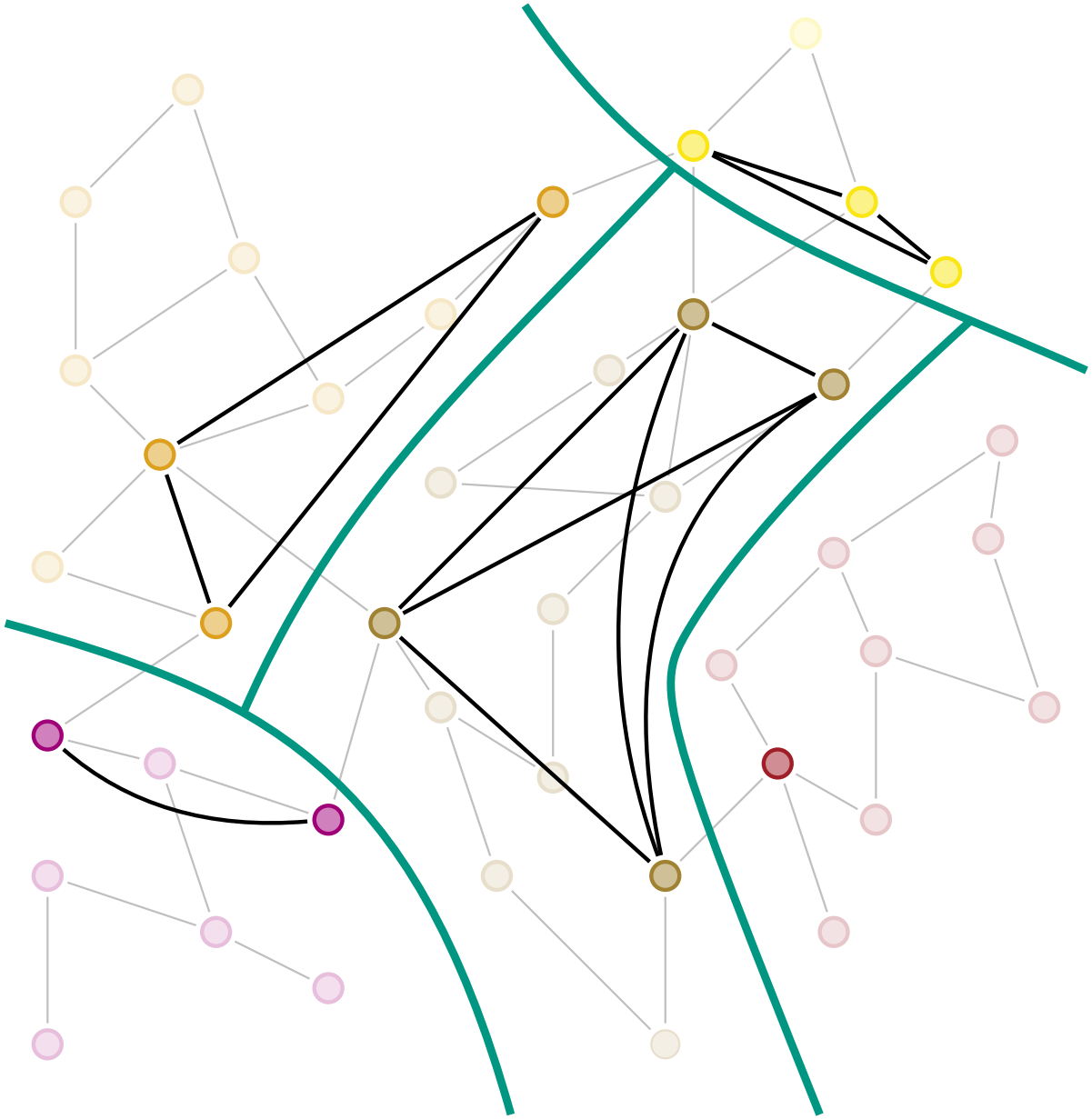

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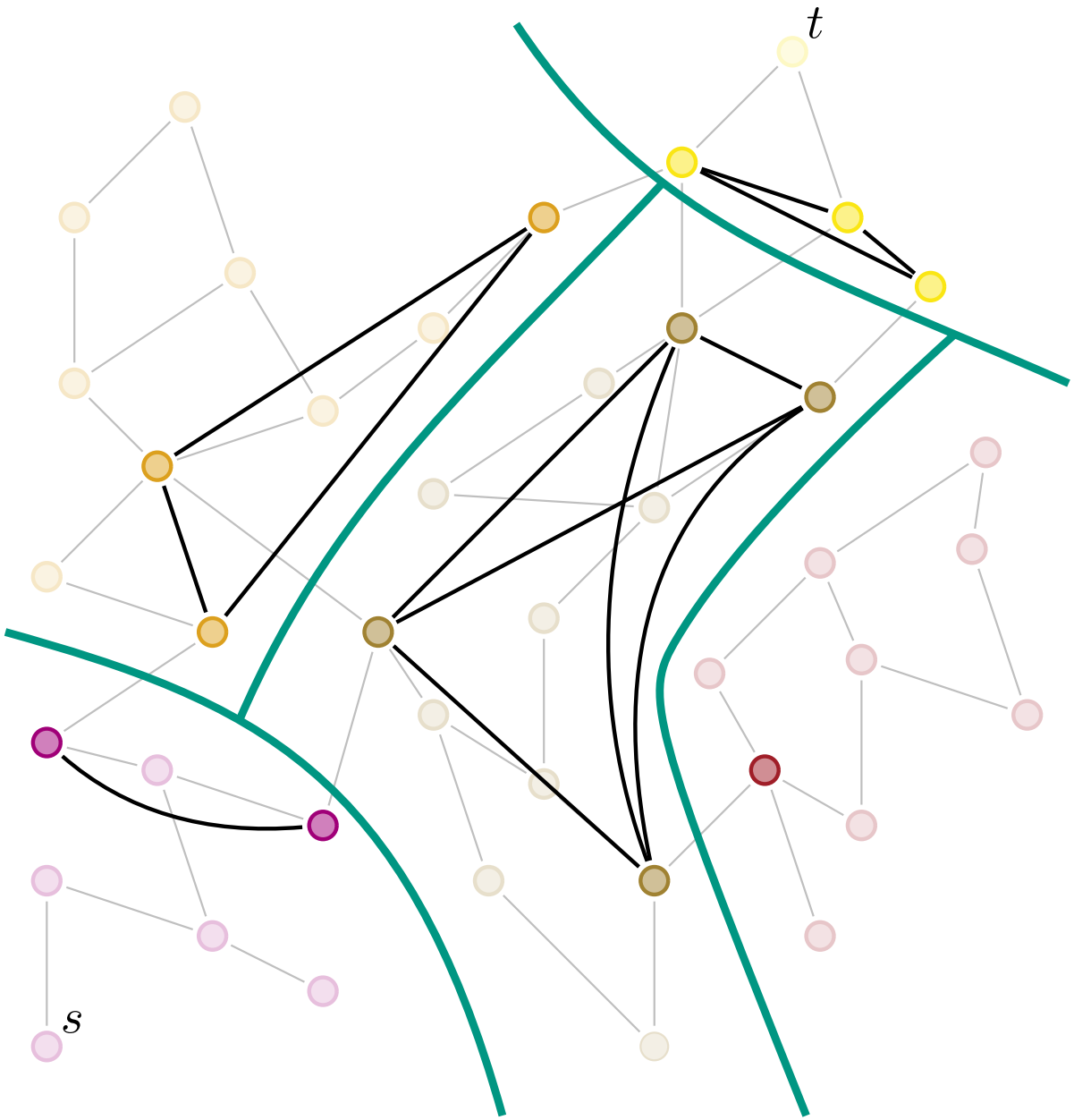

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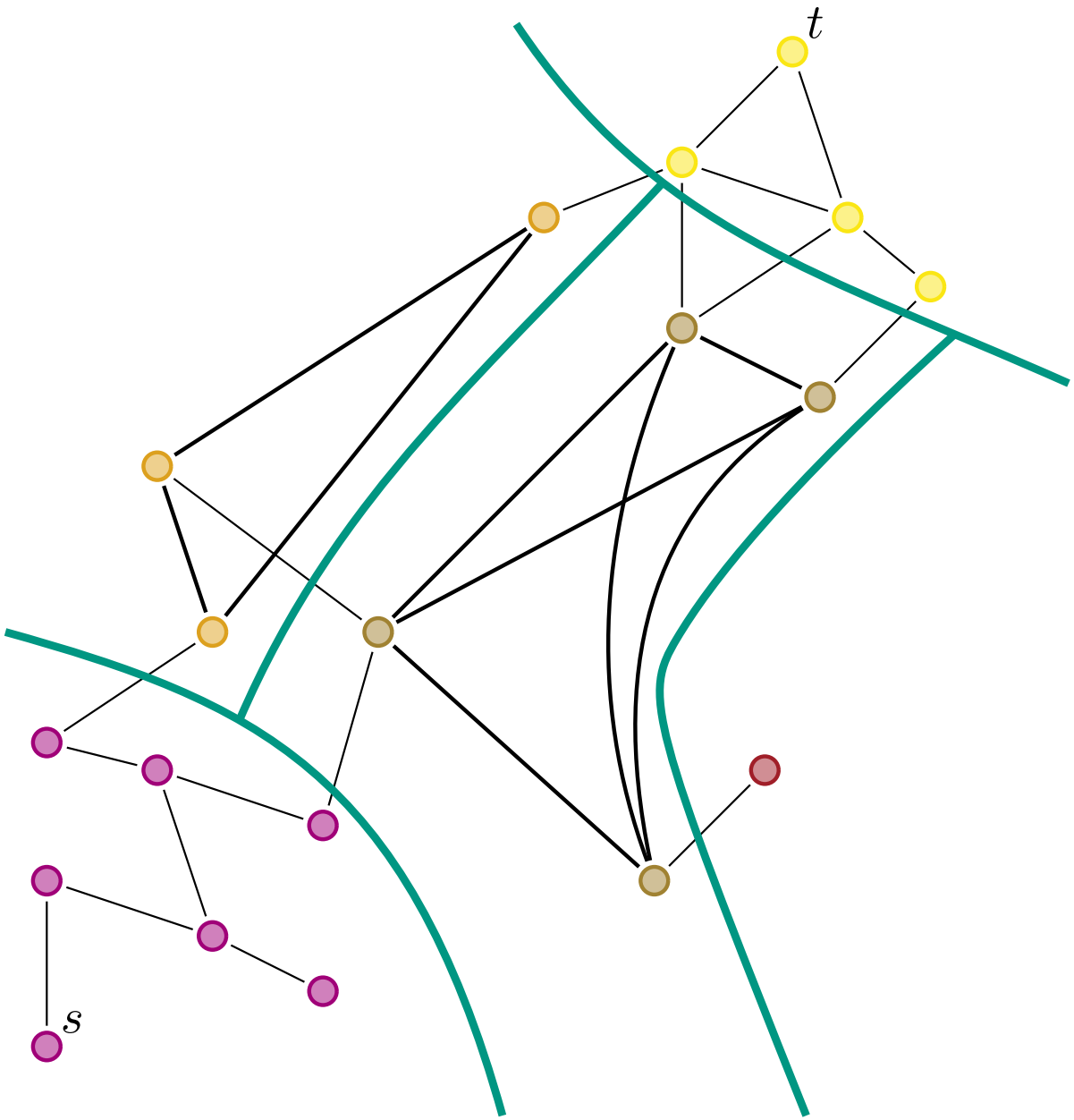
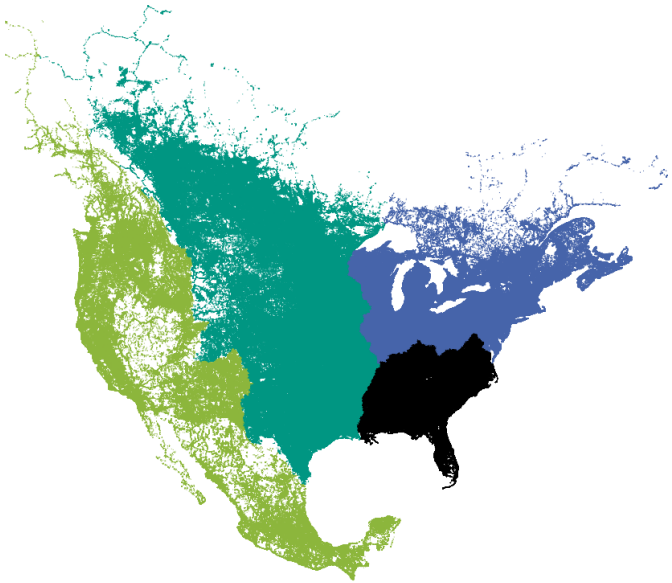


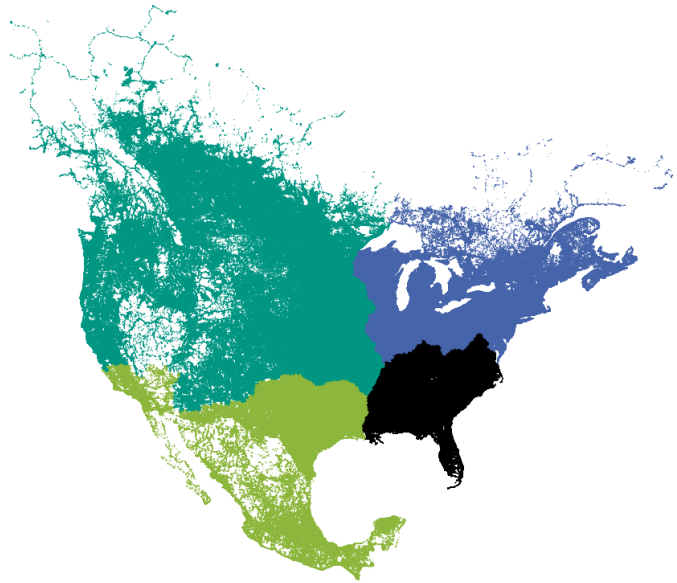
Real-World Production Systems

observations:

- data changes continuously
- OpenStreetMap: several million changes each day
- partitioning from scratch is highly sensitive to small changes



August 2018



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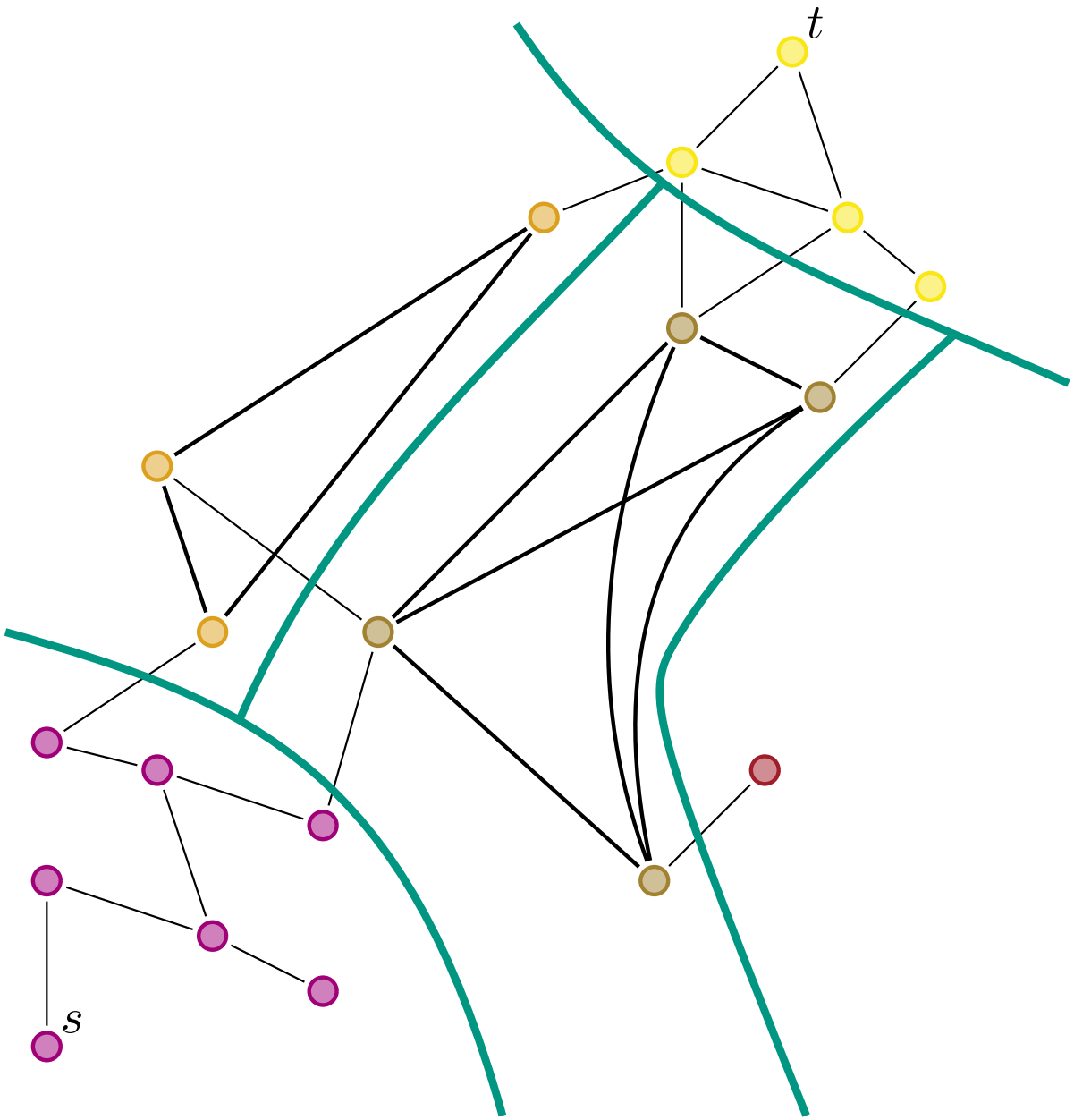
change in vertices: 0.36 % are added, 0.21 % are removed

Computing Alternative Routes



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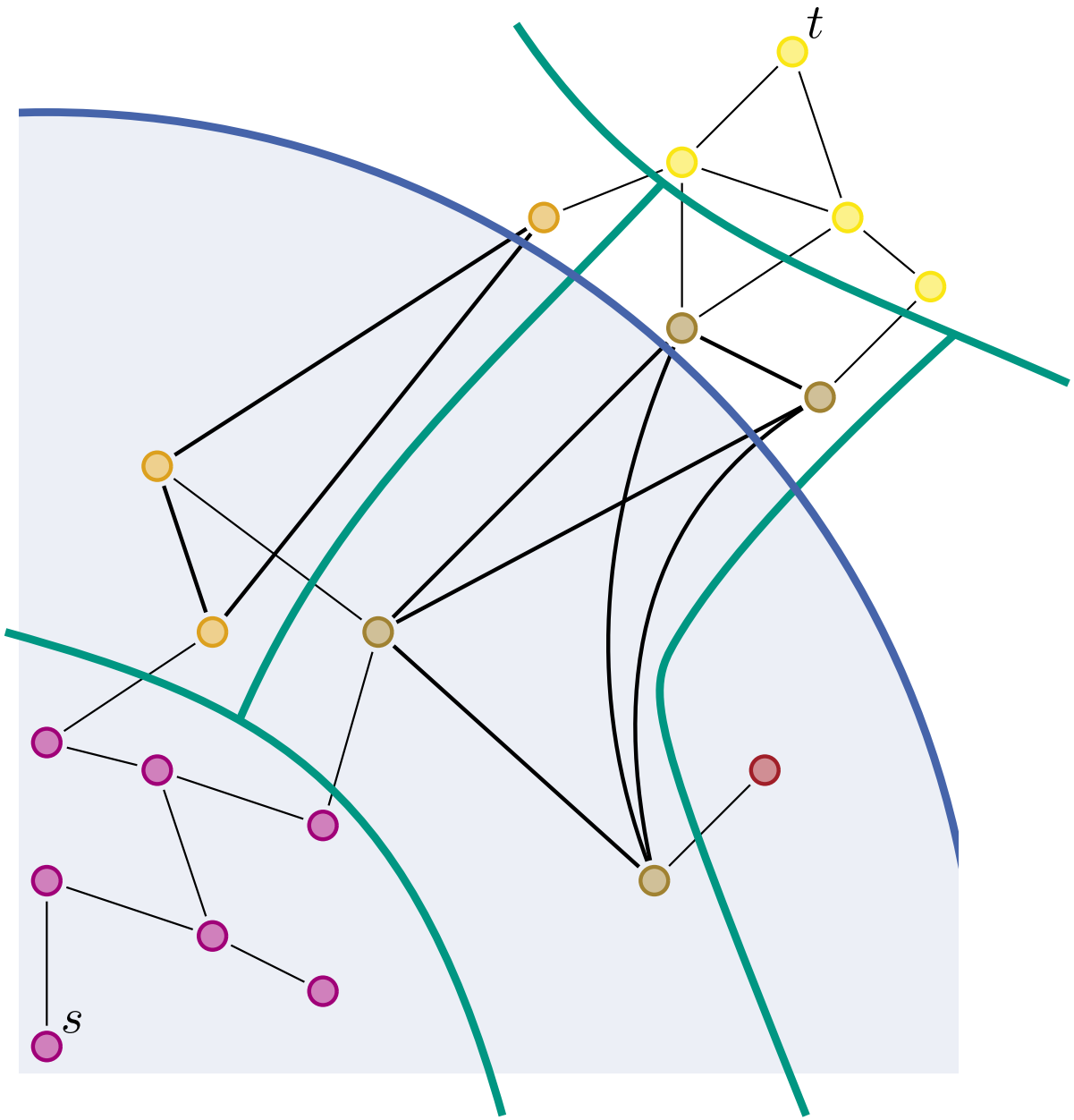

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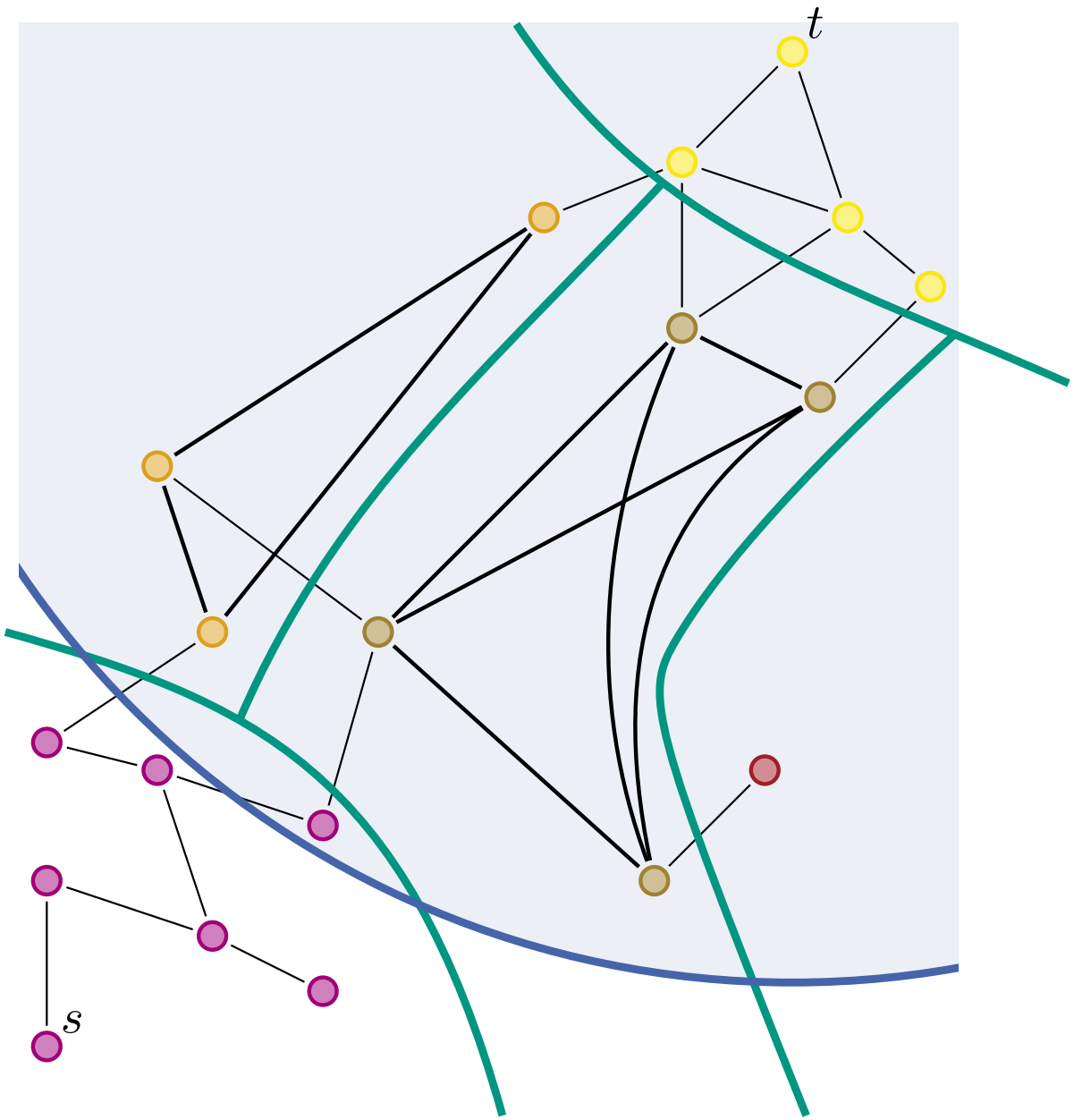

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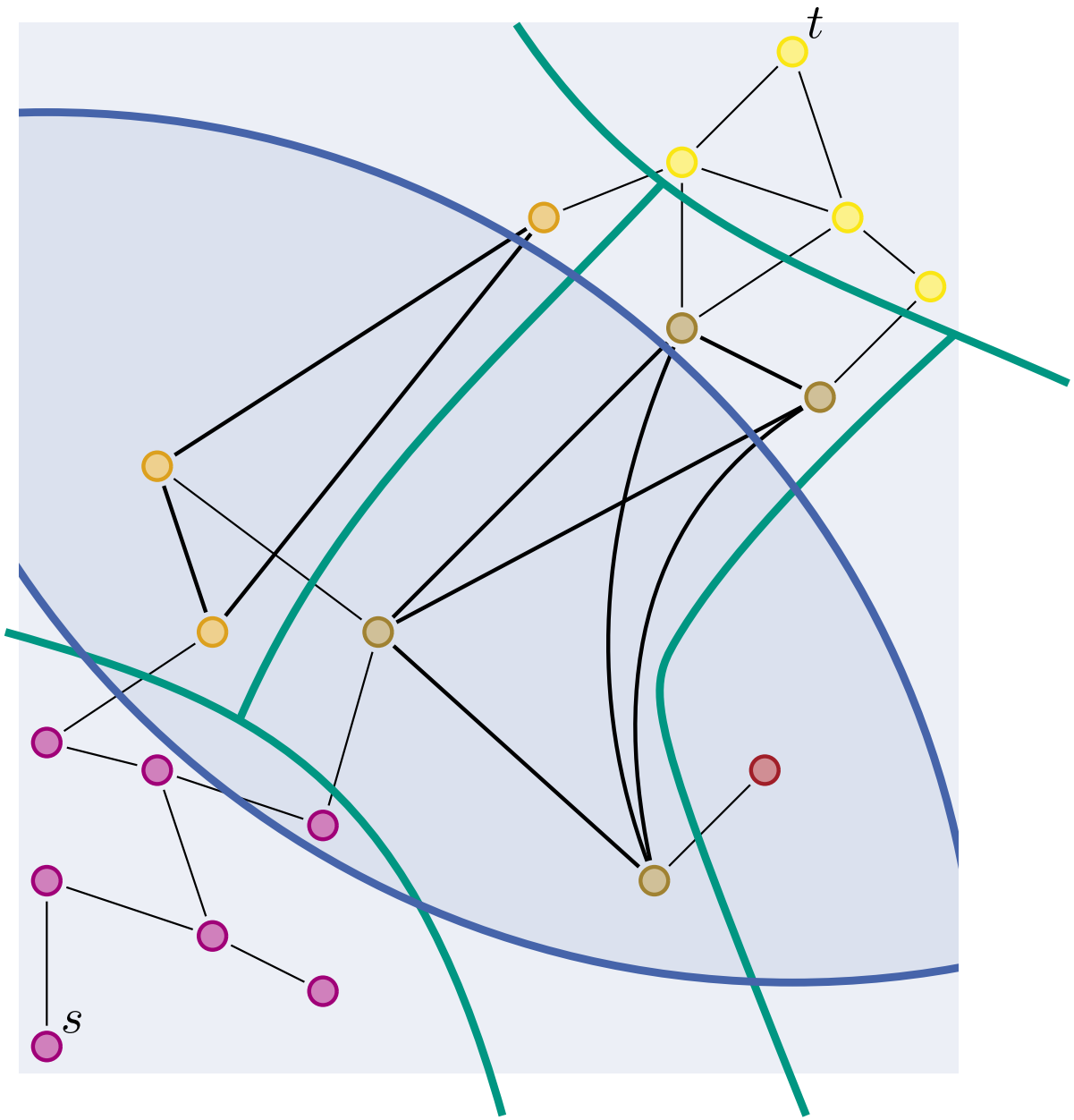
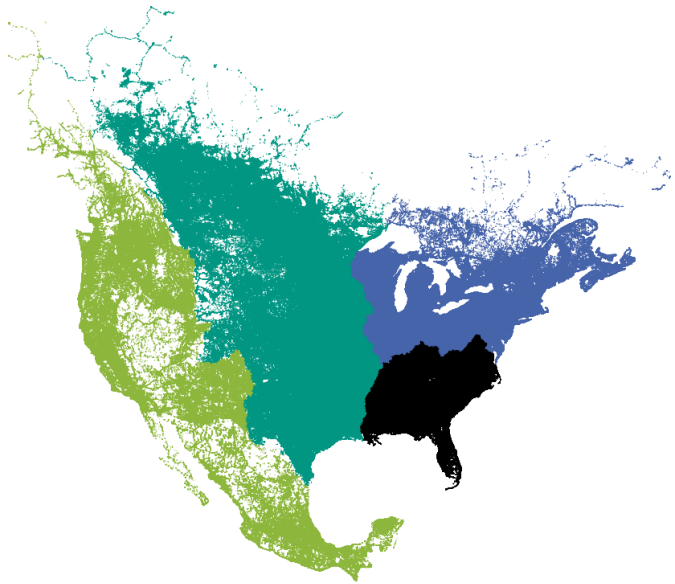


Stable Graph Repartitioning

input:

- old graph
- new graph obtained from old one
  by inserting and removing vertices and edges
- partition of old graph
  into disjoint cells of roughly equal size



problem:

- cut new graph into disjoint cells
- of roughly equal size bounded by U
- while minimizing number of cut edges
- and maximizing similarity to old partition

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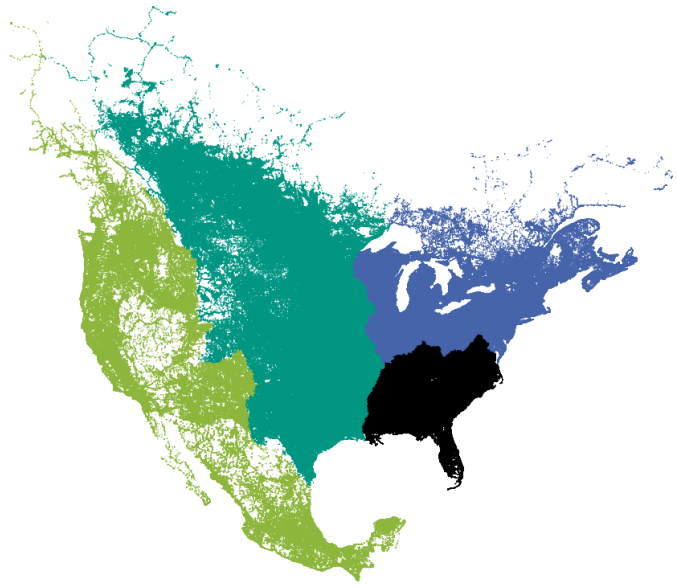

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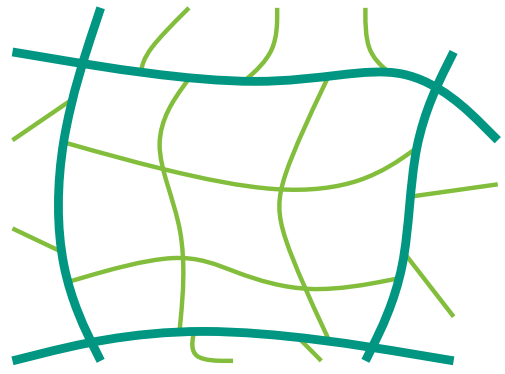

$\Rightarrow$ **we consider nested multilevel partitions**

Related Work

road network partitioning:

- PUNCH (2011)
- Buffoon (2012)
- Inertial Flow (2015)
- FlowCutter (2018)
- InertialFlowCutter (2019)

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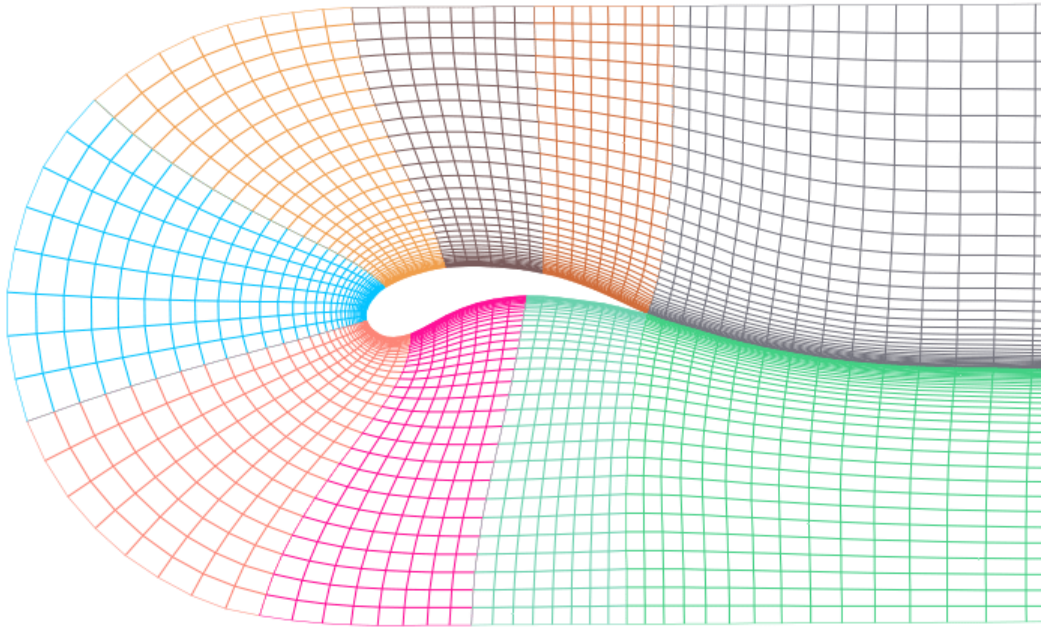

adaptive mesh repartitioning:

- scratch-remap repartitioners (1994, 1995, 1998, 2001)
- diffusion-based repartitioners (1997, 1997, 2001)
- unified repartitioning algorithm (2000)

$\Rightarrow$ new mesh obtained by splitting or merging vertices

$\Rightarrow$ most work considers a fixed topology

mesh refinements handled as vertex weight increases

Our Approach to Graph Repartitioning

idea:

- start with previous partition
- incorporate new vertices (cell assignment)
- repair and reoptimize partition

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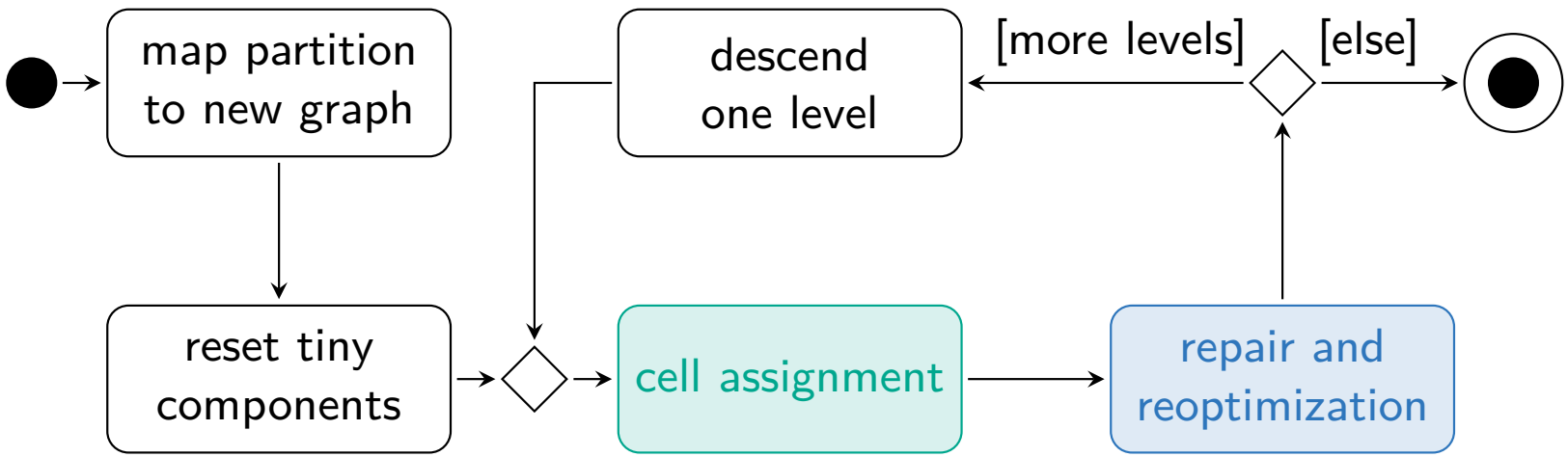
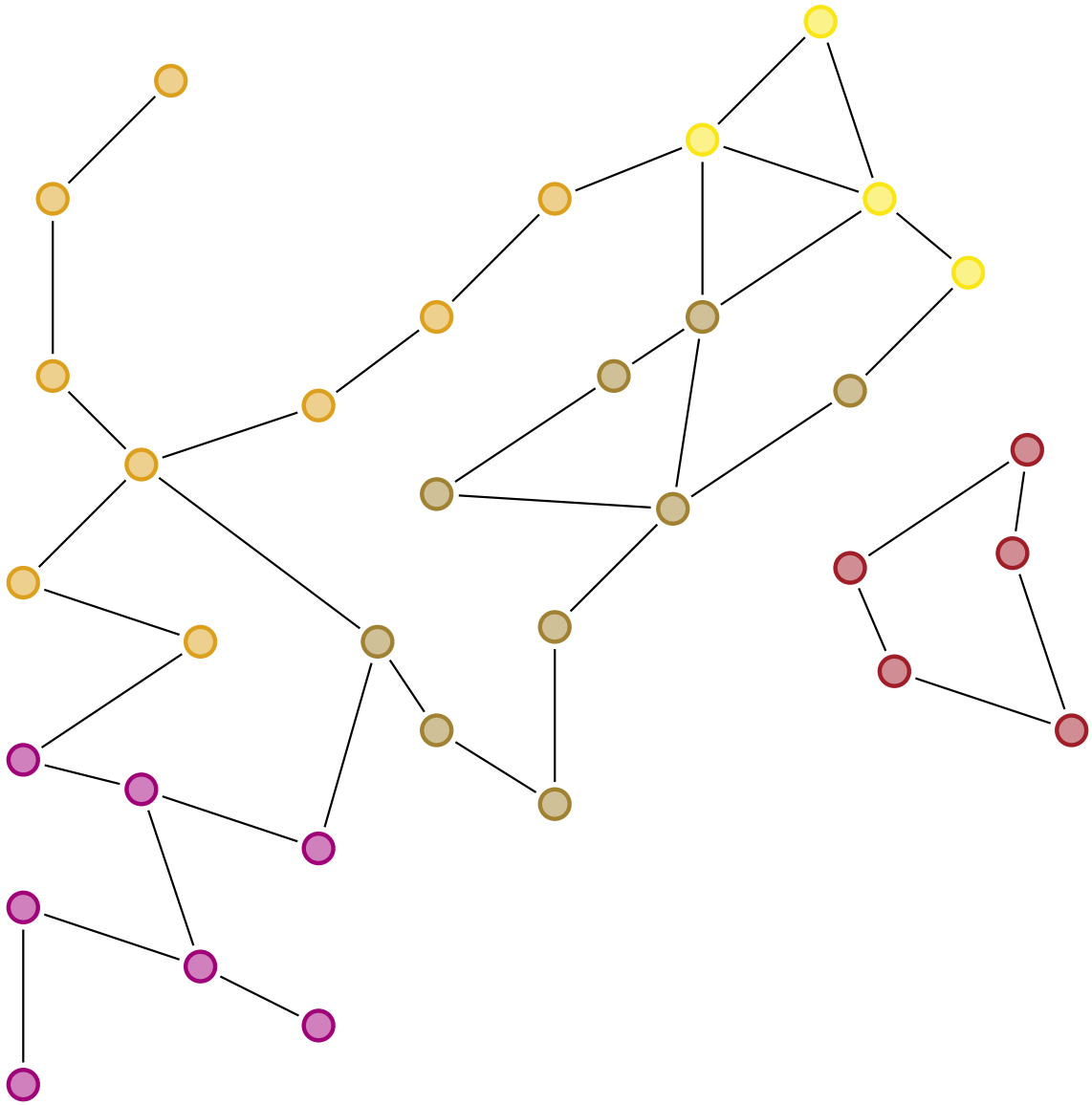
process levels in top-down fashion:



Cell Assignment

each new vertex chooses cell to which majority of its neighbors belong:



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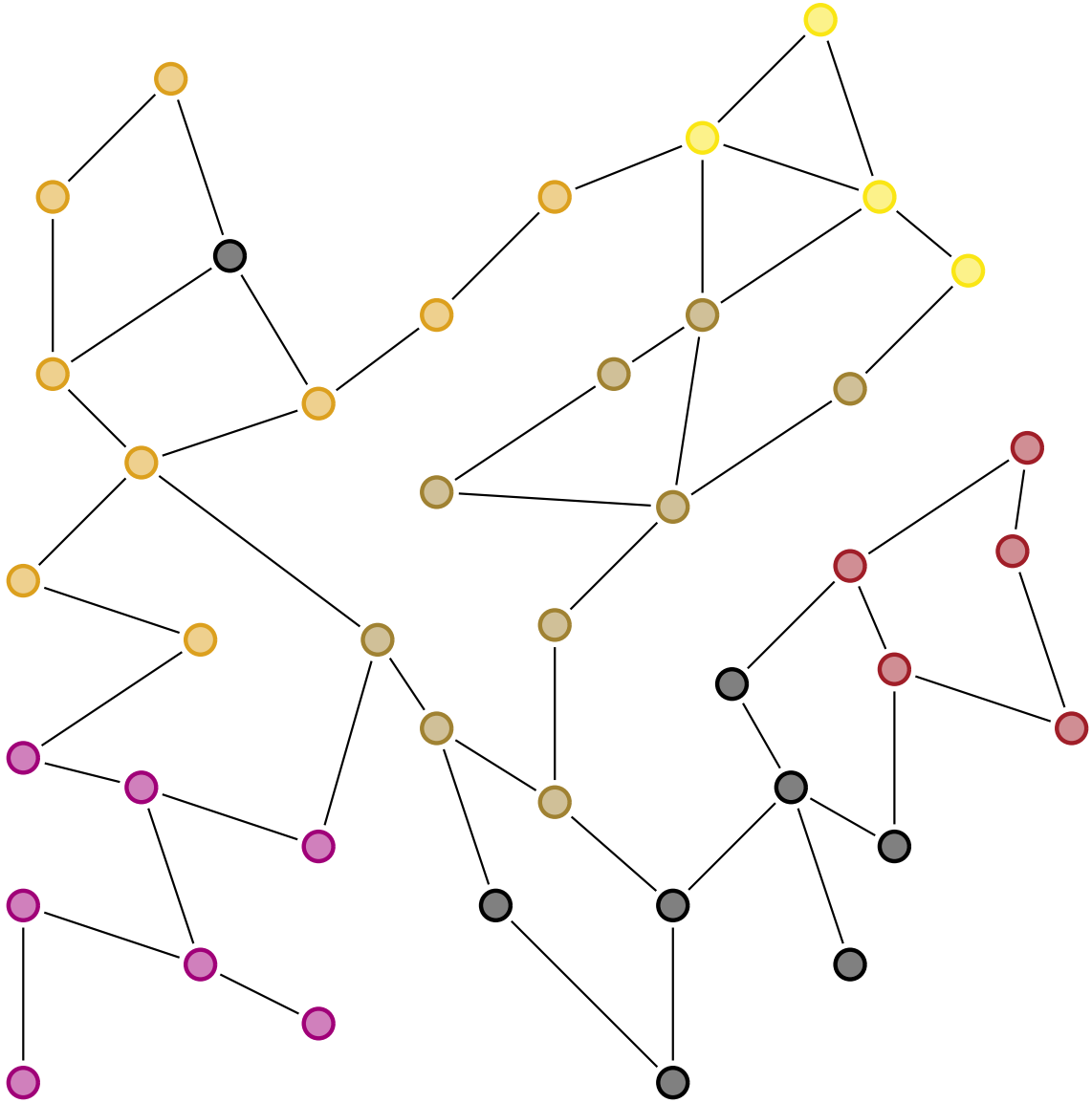

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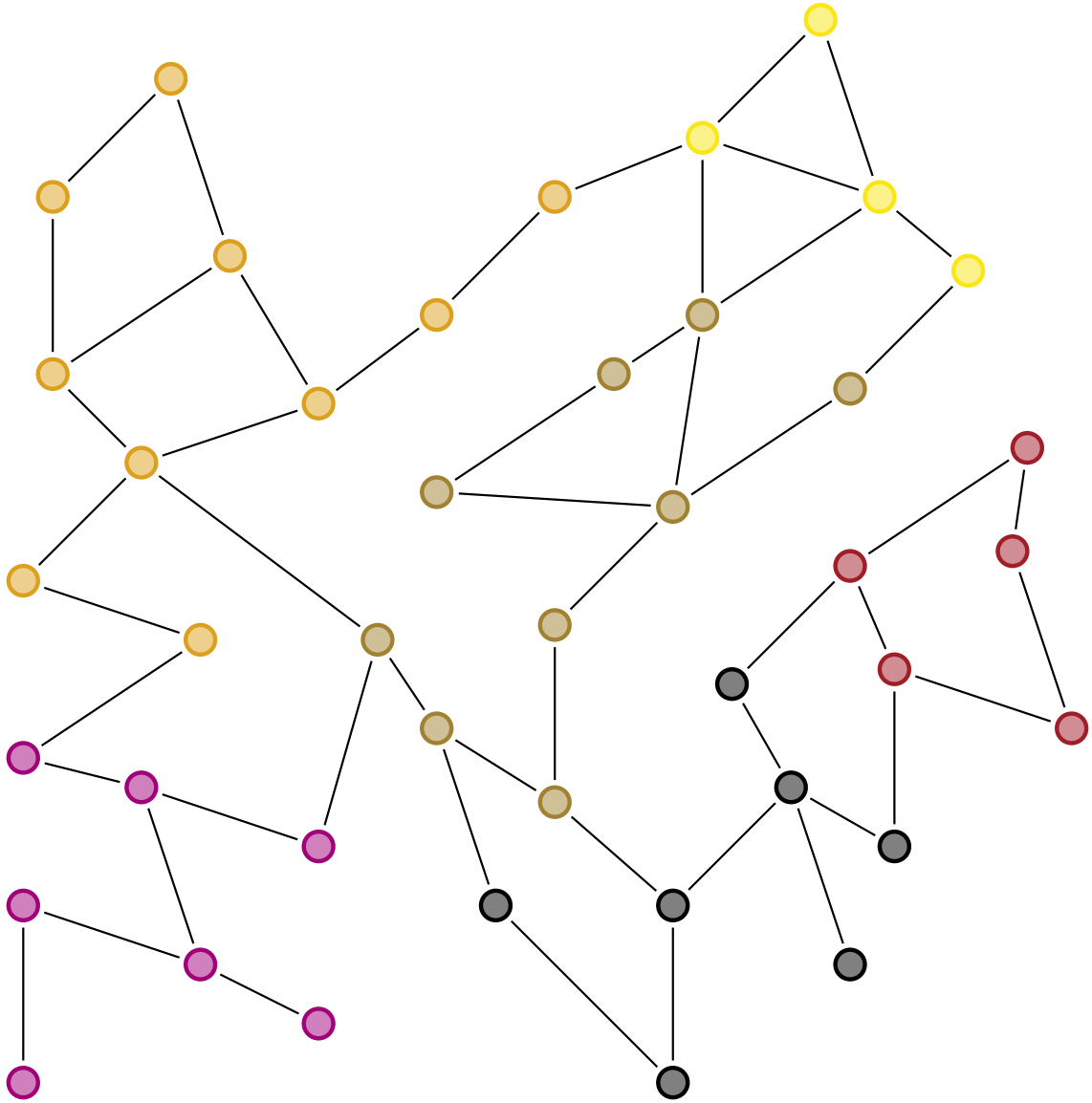

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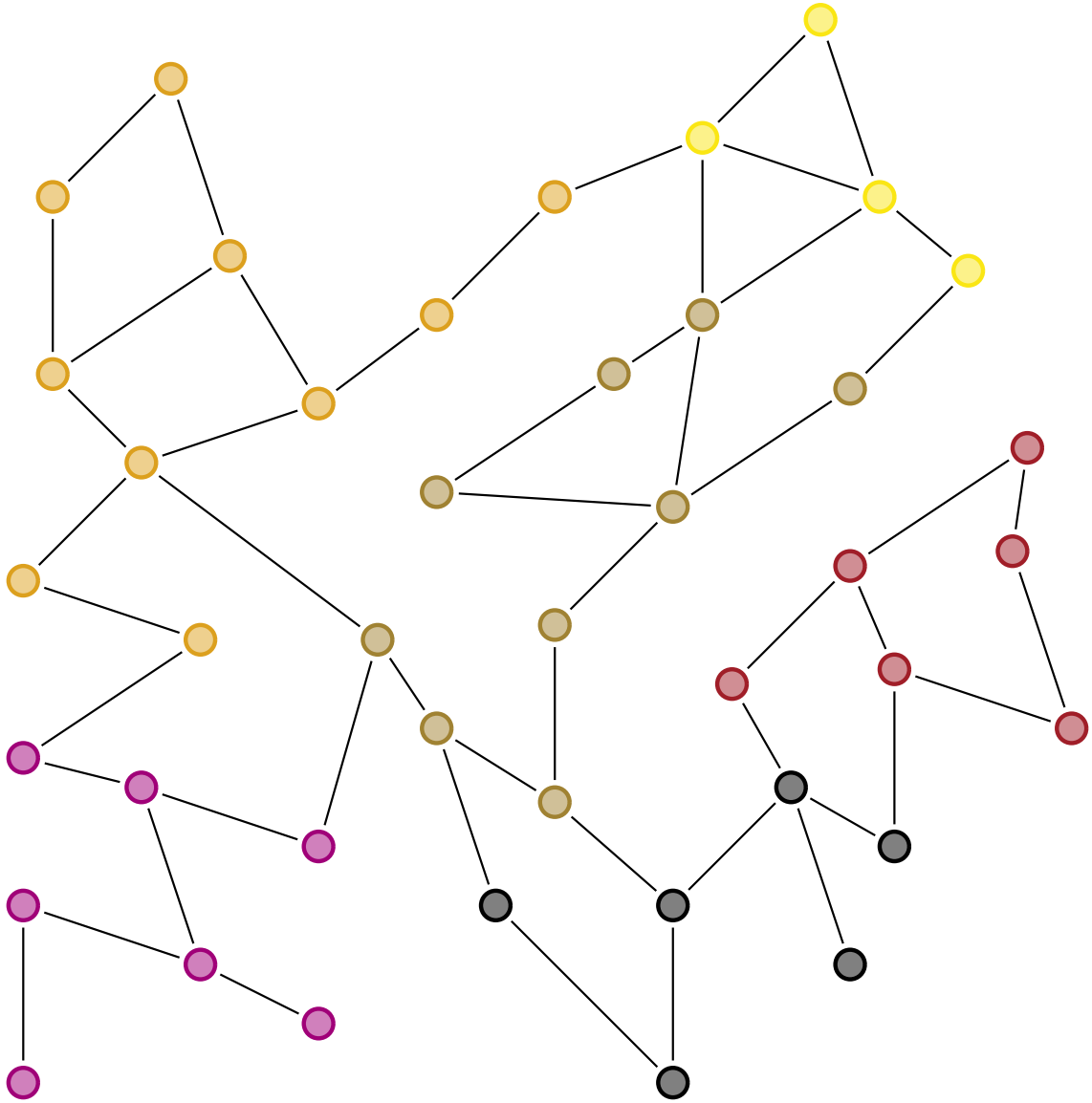

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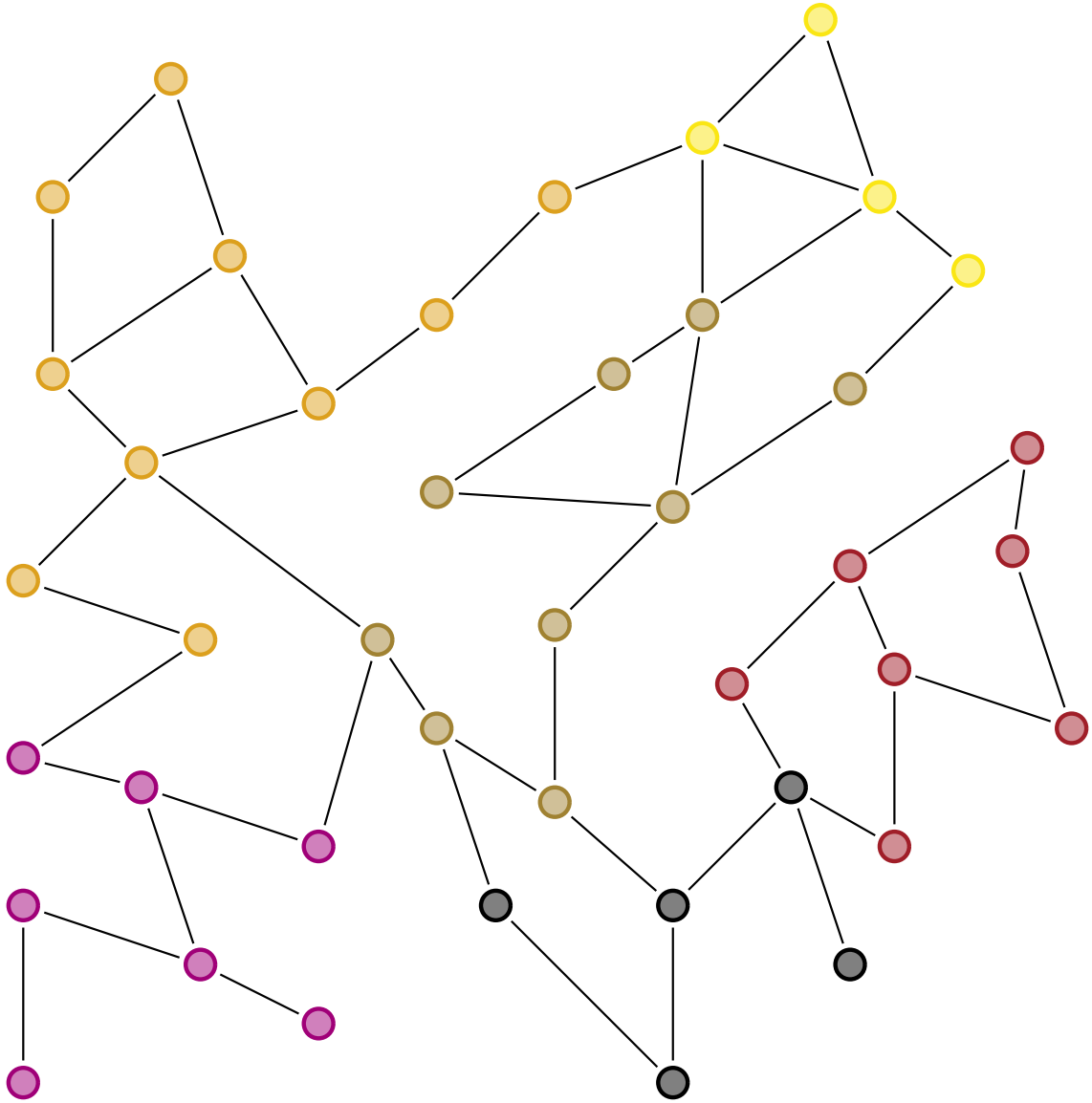

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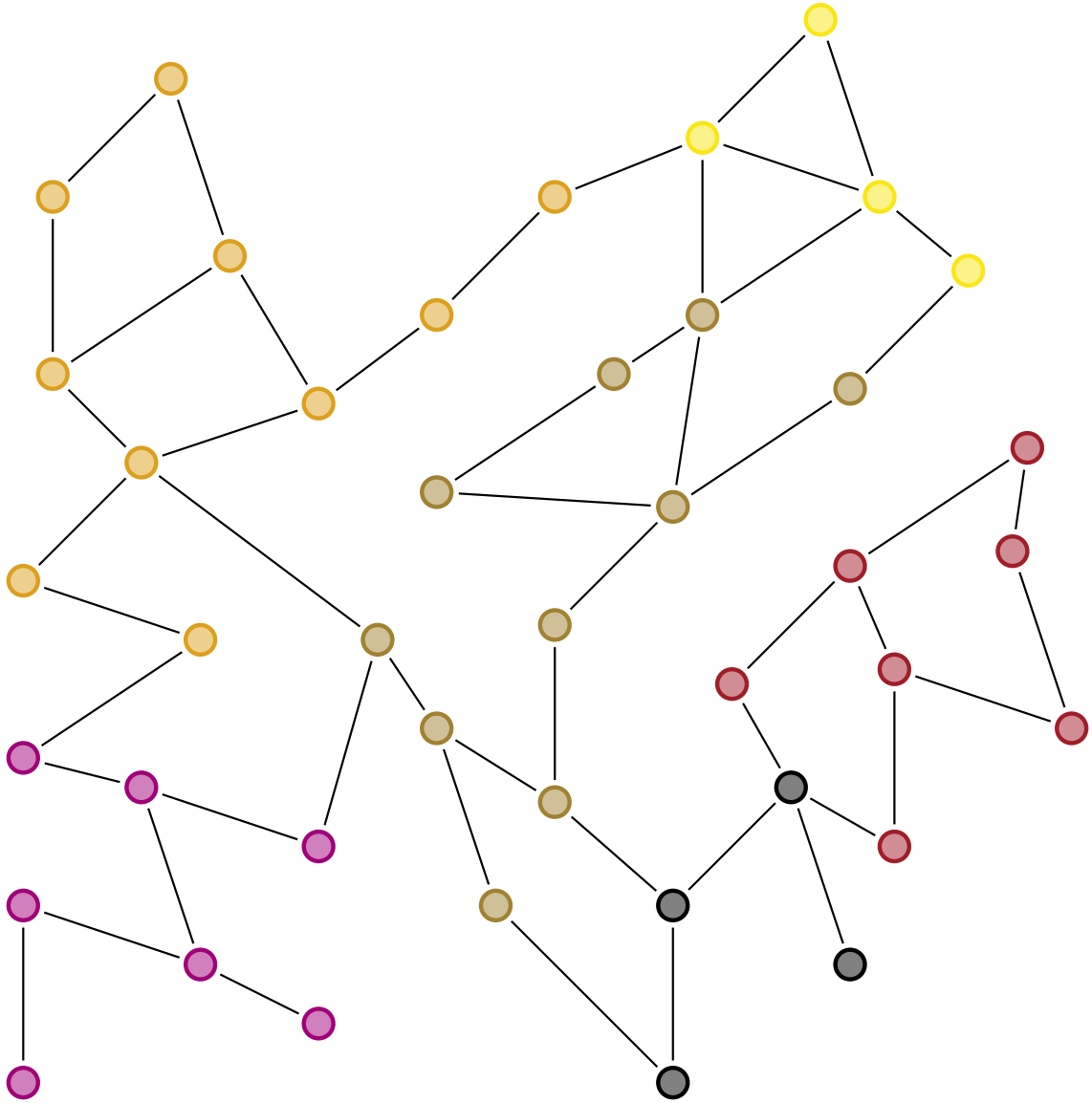

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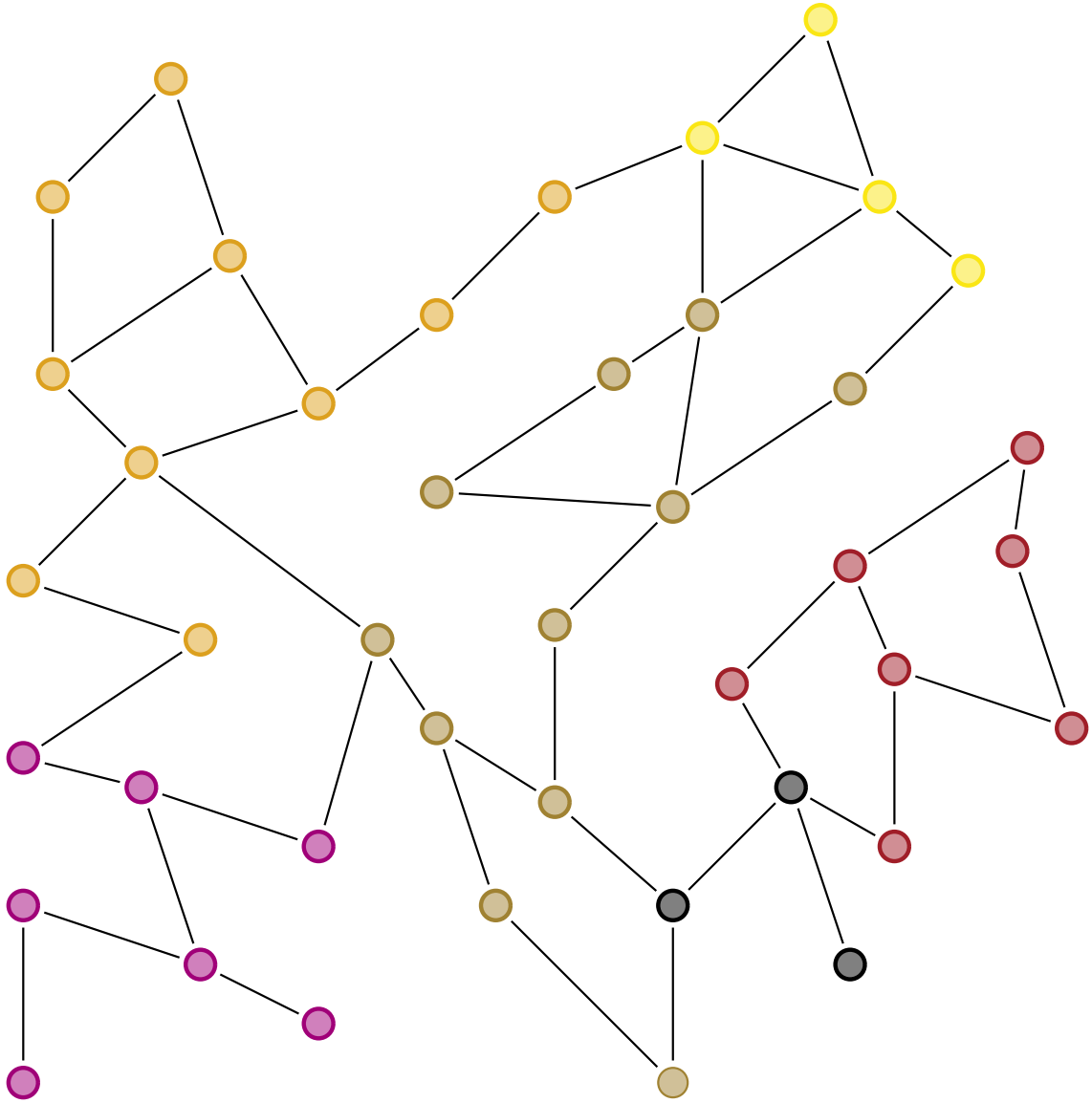

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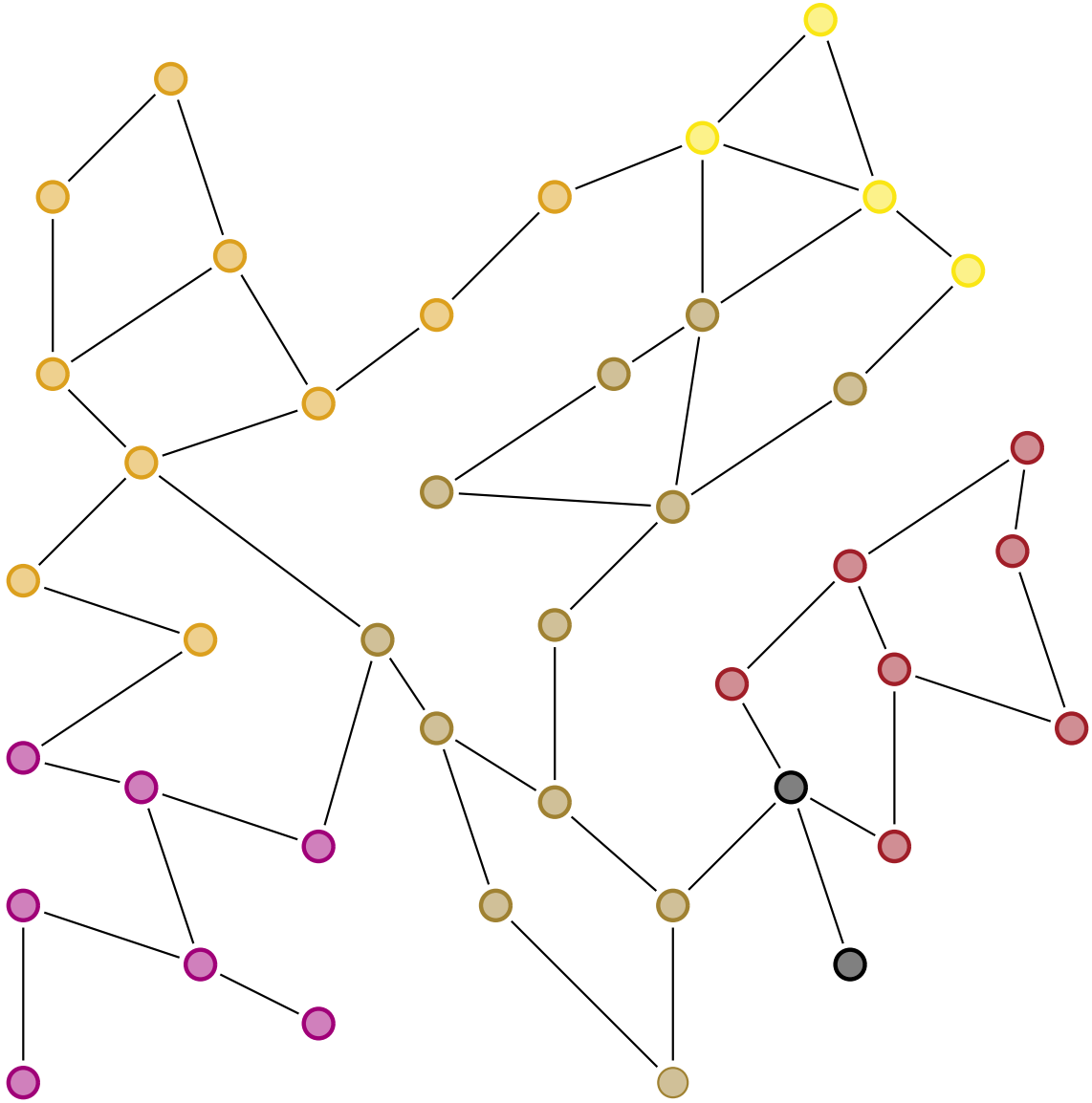

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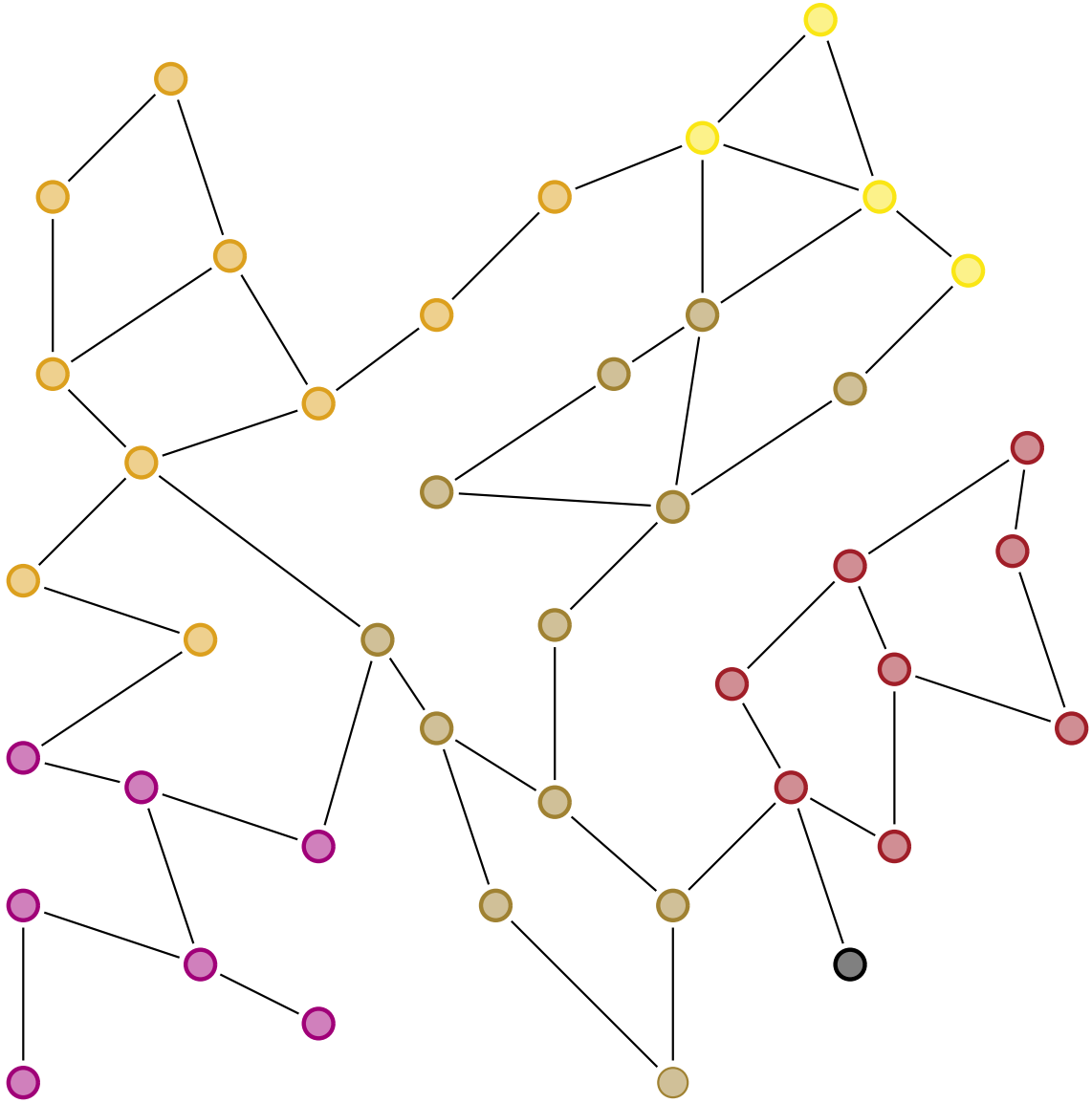

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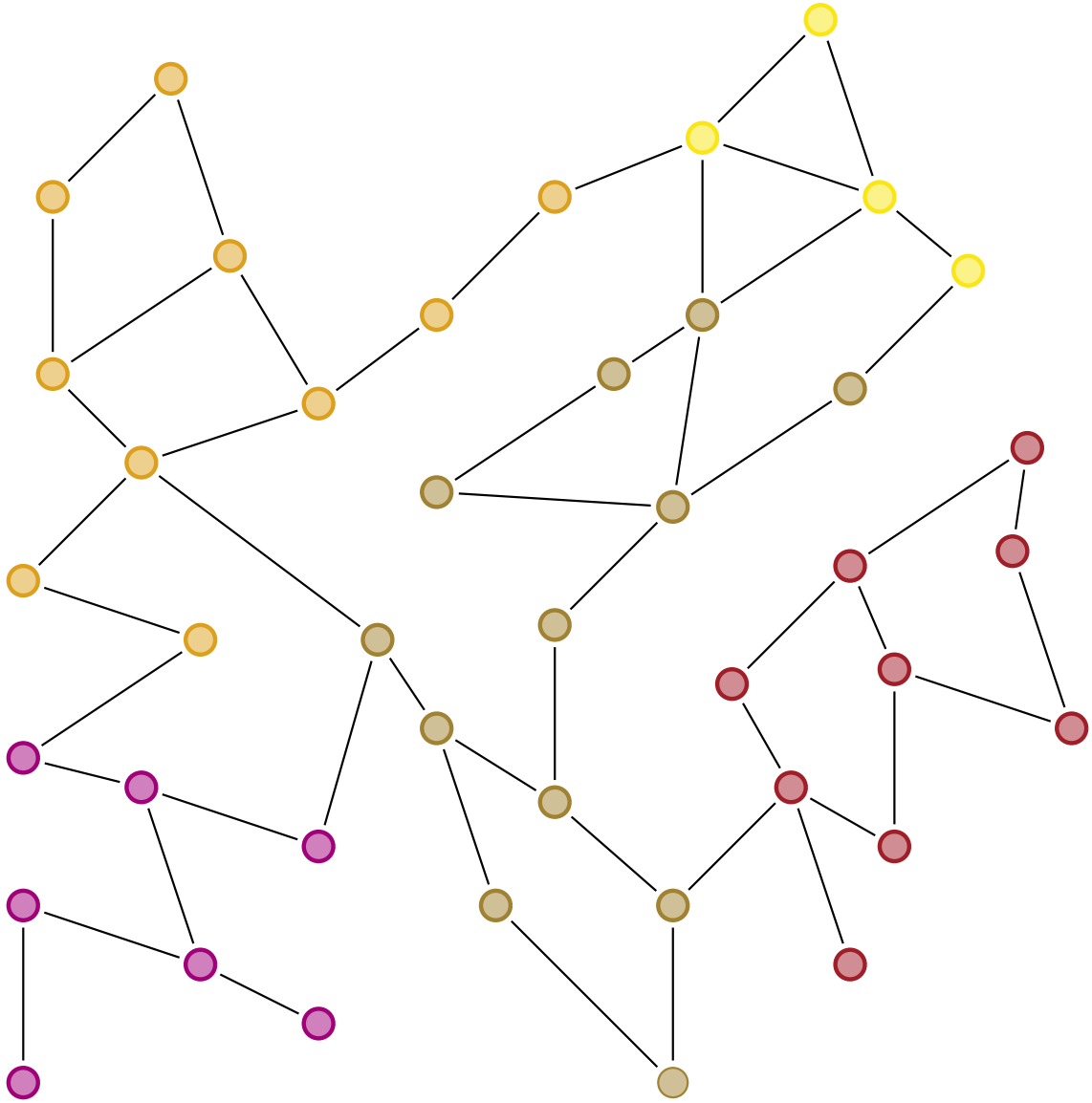
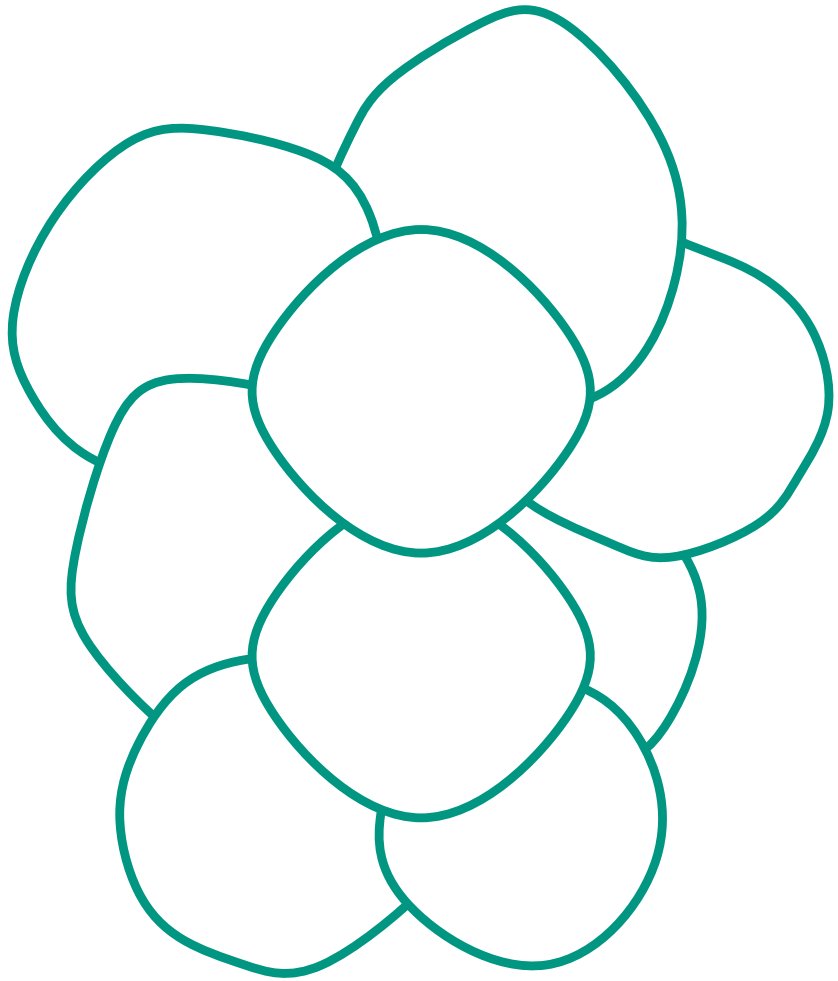


Repair and Reoptimization

observations:

- some cells are too large
- some cells are very small



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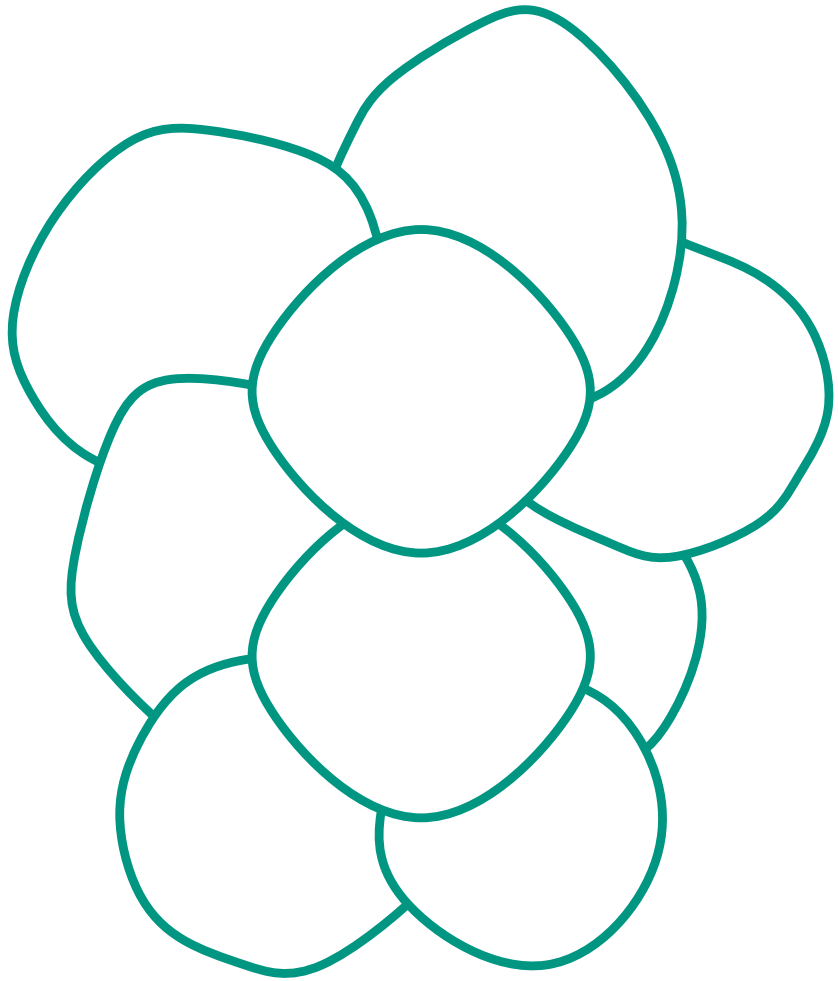

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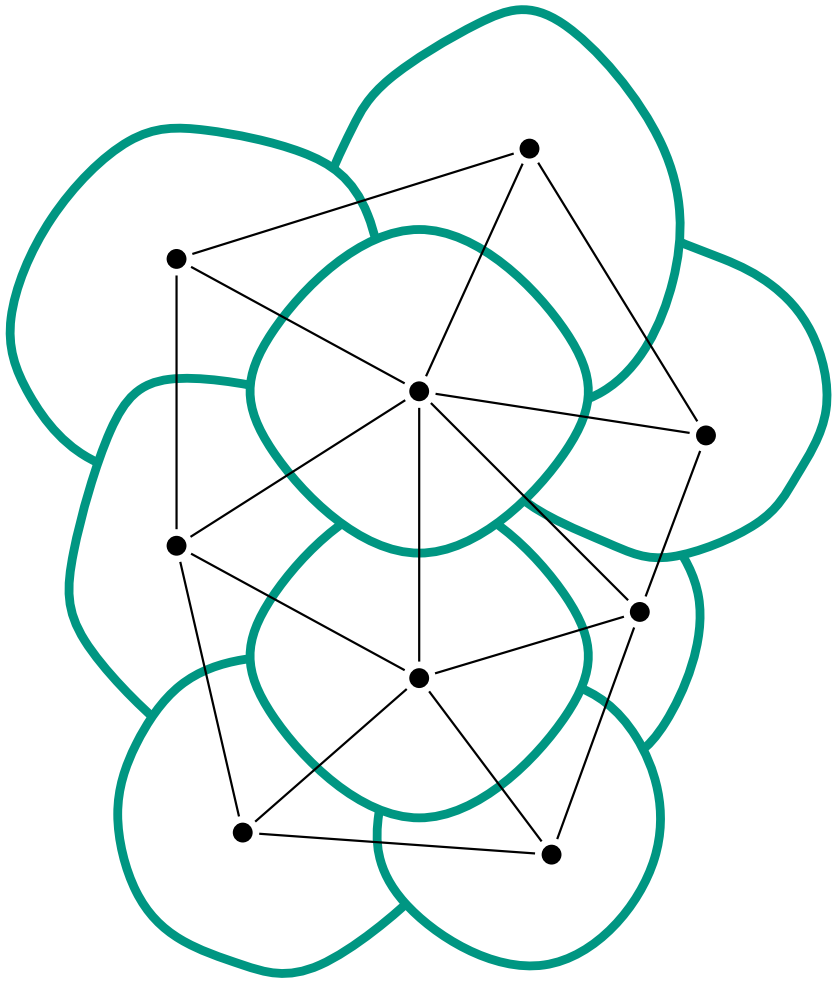

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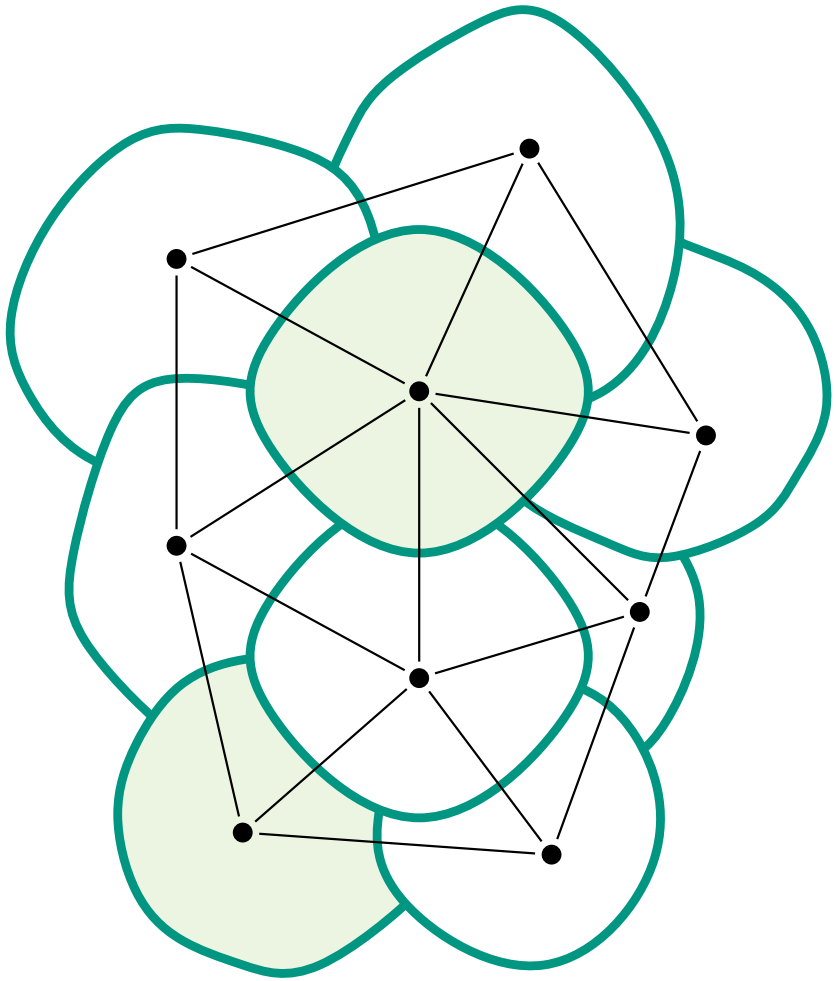

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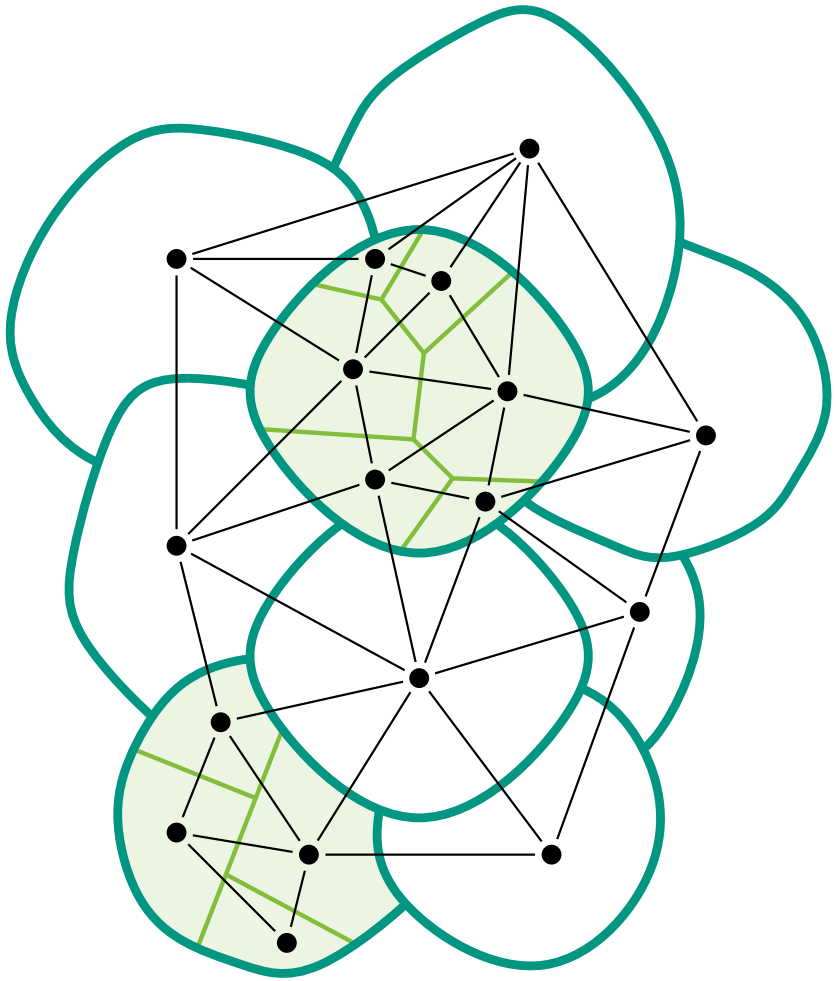

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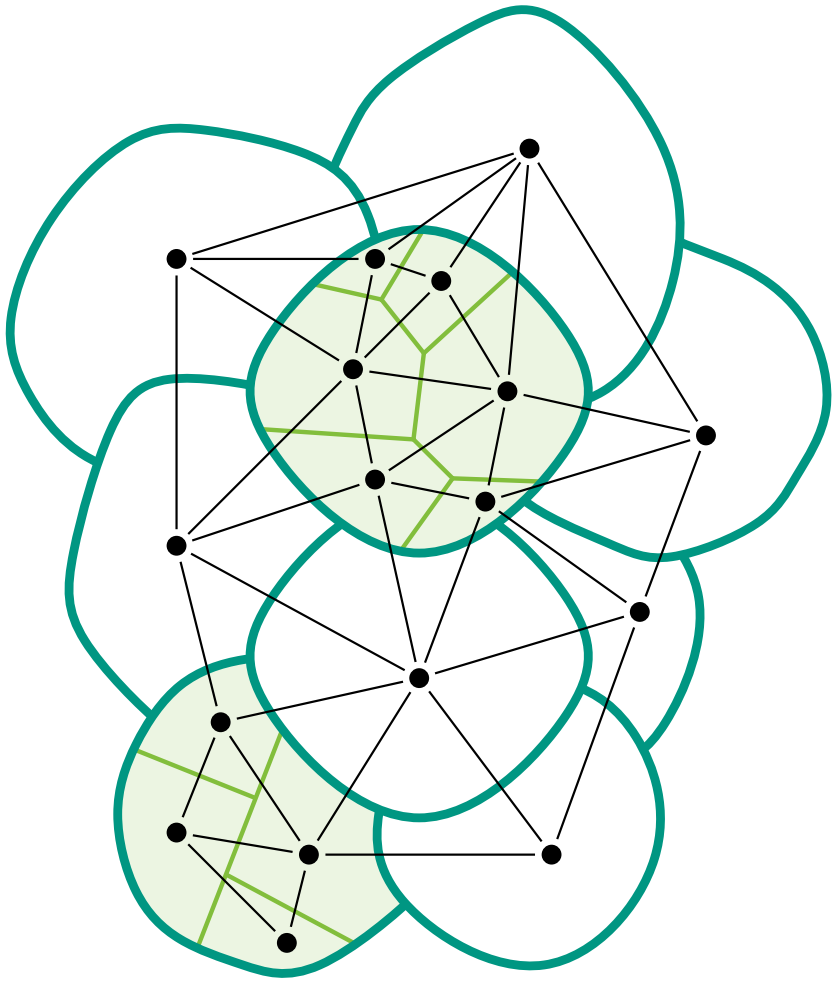
3. greedily merge pairs of adjacent vertices with combined size $\leq U$



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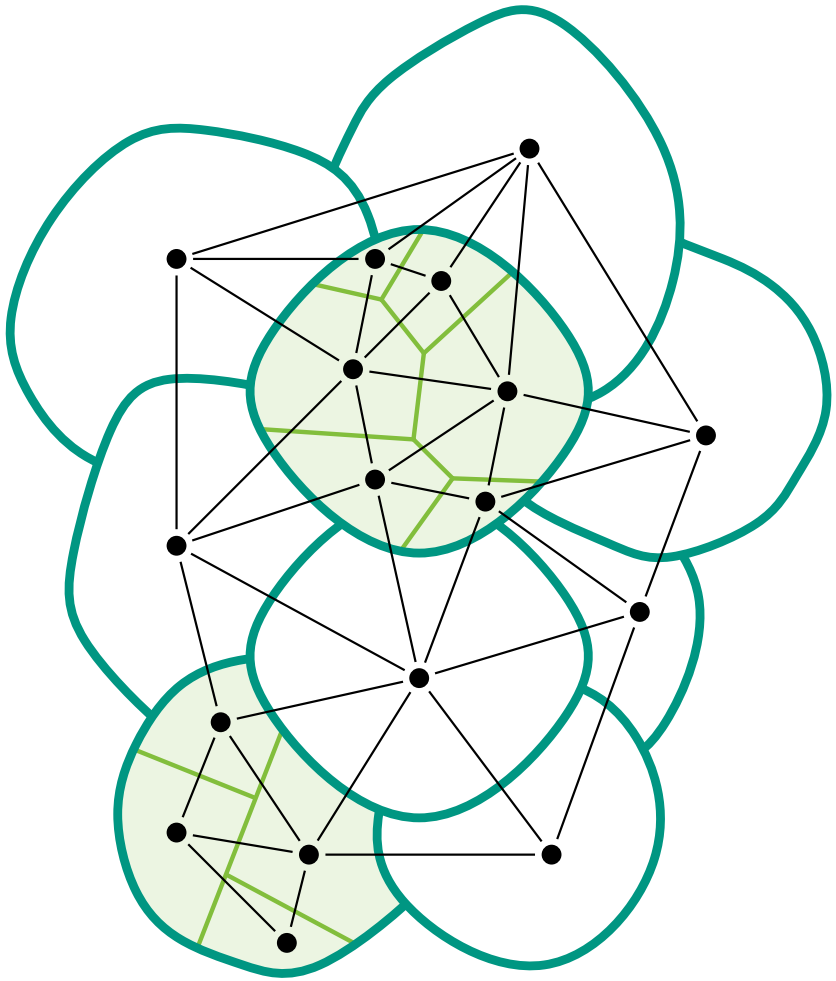

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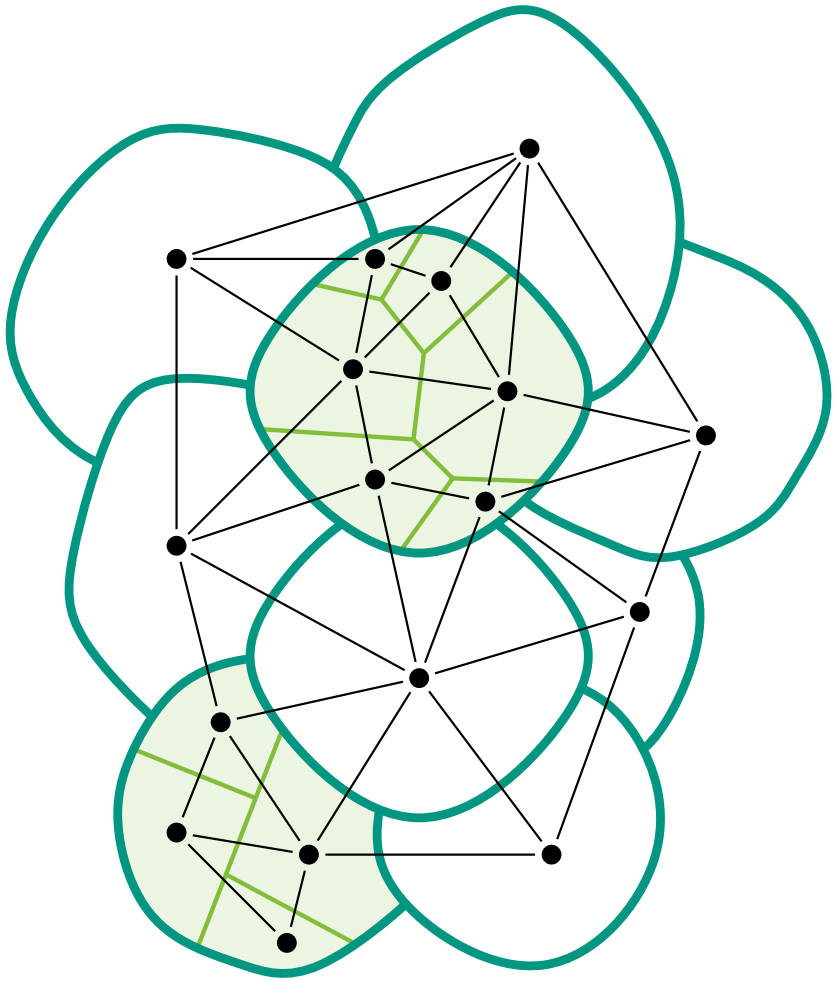
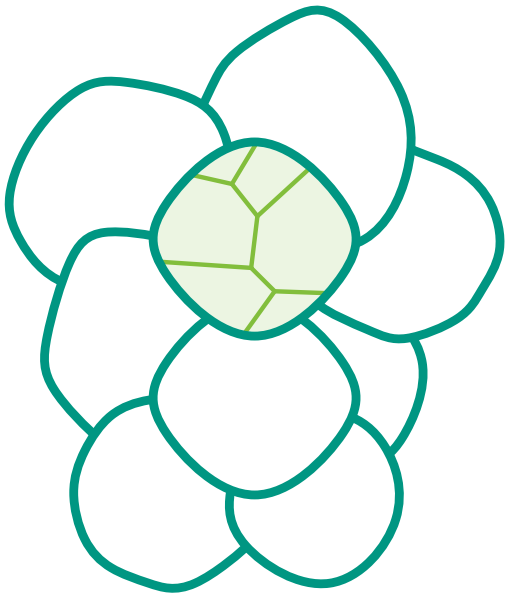
$\Rightarrow$ **greedy algorithm and local search are subroutines from PUNCH**



Cell Unpacking

simple unpacking:



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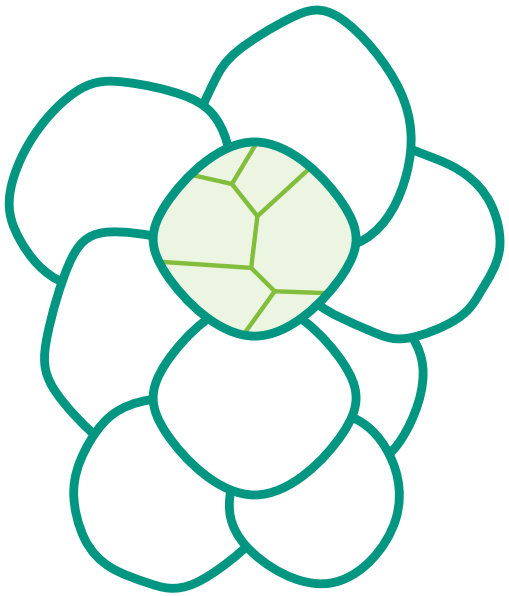

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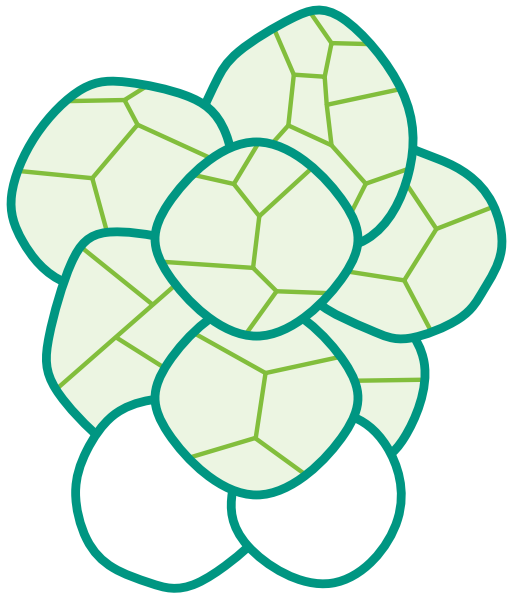

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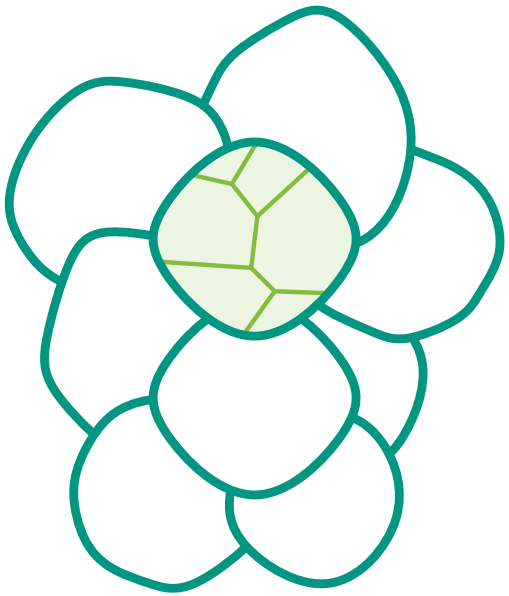

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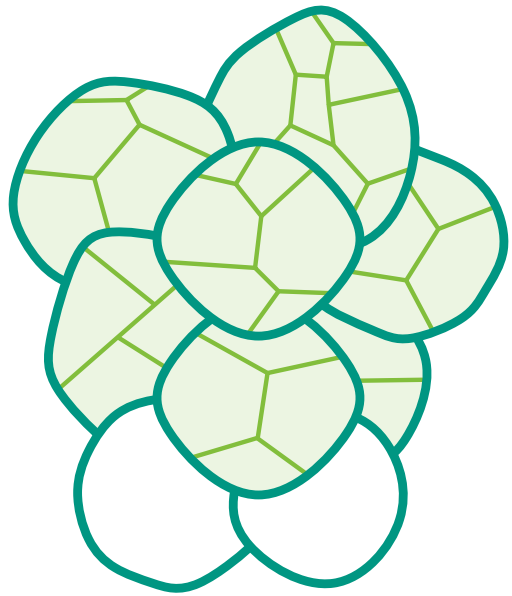

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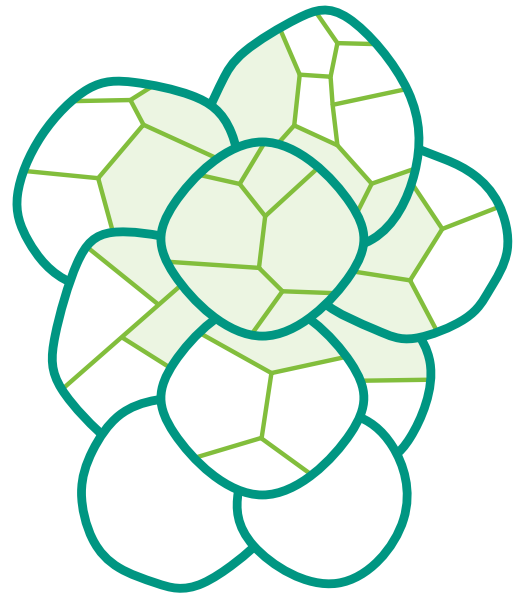

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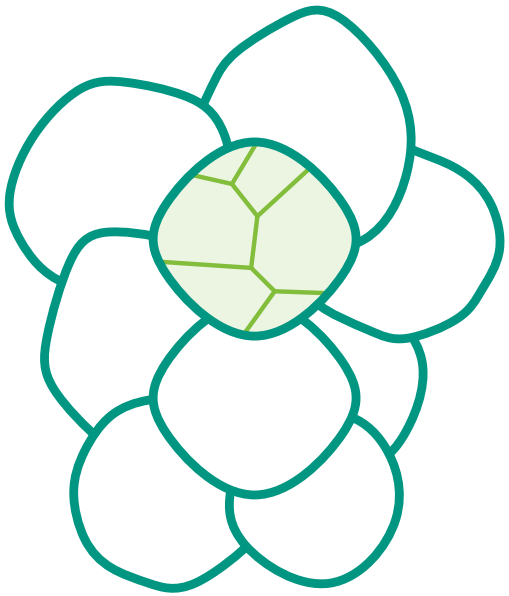

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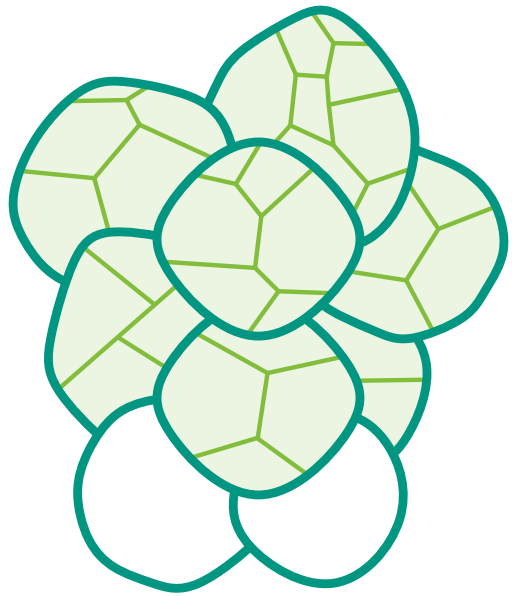

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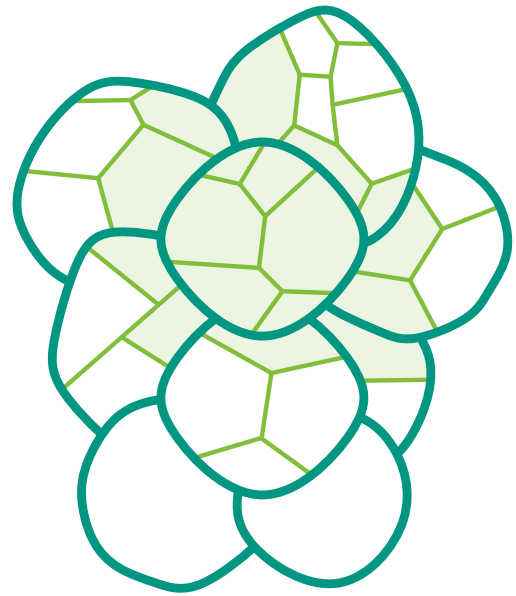
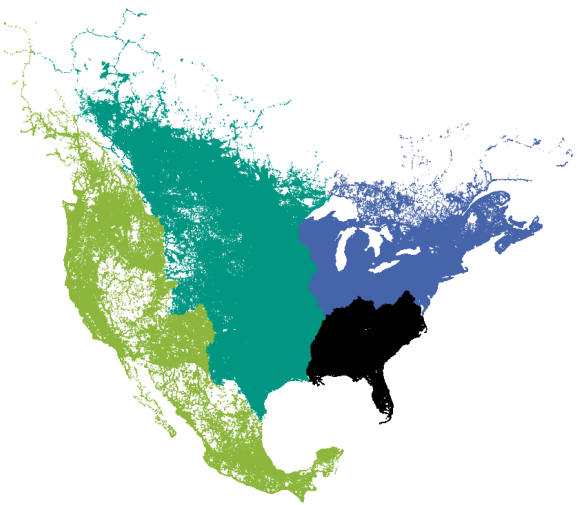


$\Rightarrow$ **simple unpacking yields good tradeoff between quality and similarity**

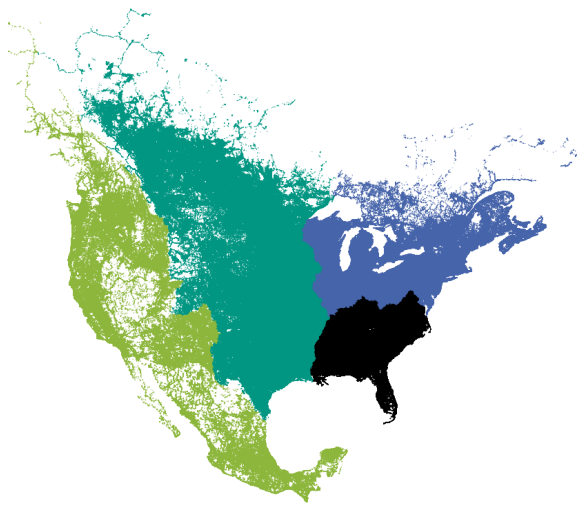
Experimental Evaluation

OSM North America:

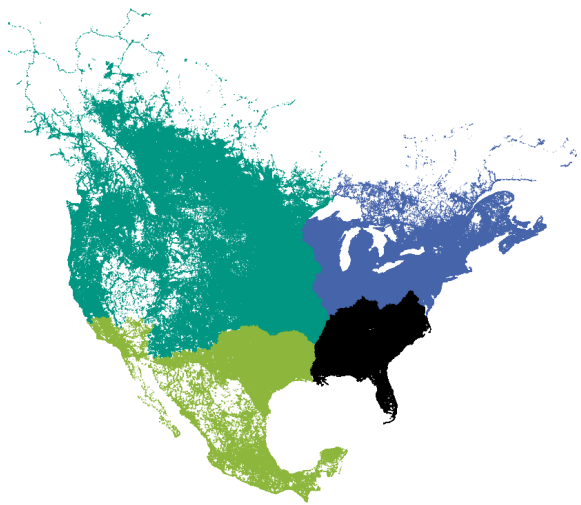
- 25 million vertices
- monthly snapshots
- change in vertices: 0.36 % are added, 0.21 % are removed



August 2018
from scratch



September 2018
repartitioned

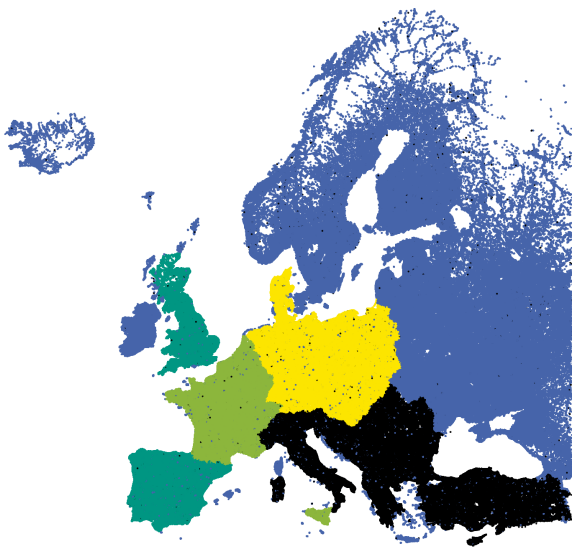


September 2018
from scratch

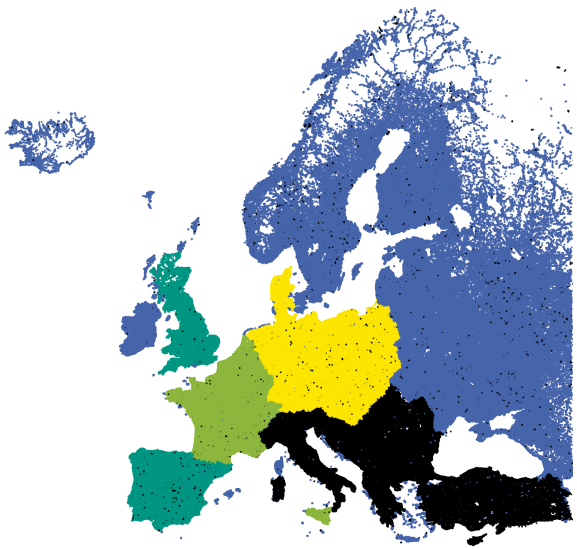
Experimental Evaluation

OSM Europe:

- 31 million vertices
- yearly snapshots
- change in vertices: 7.12 % are modified



January 2018
from scratch



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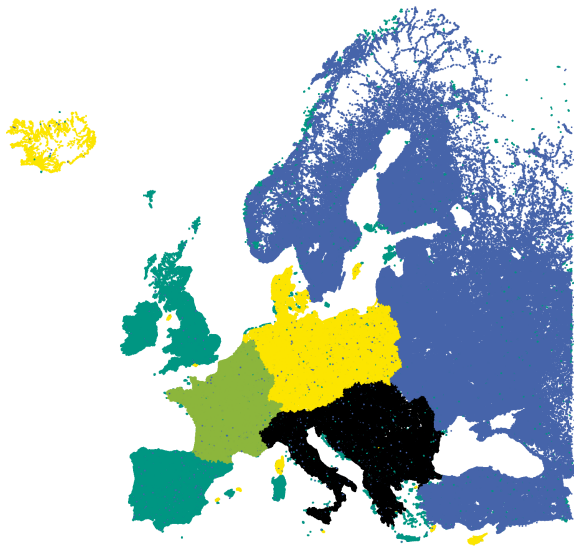


January 2019
from scratch

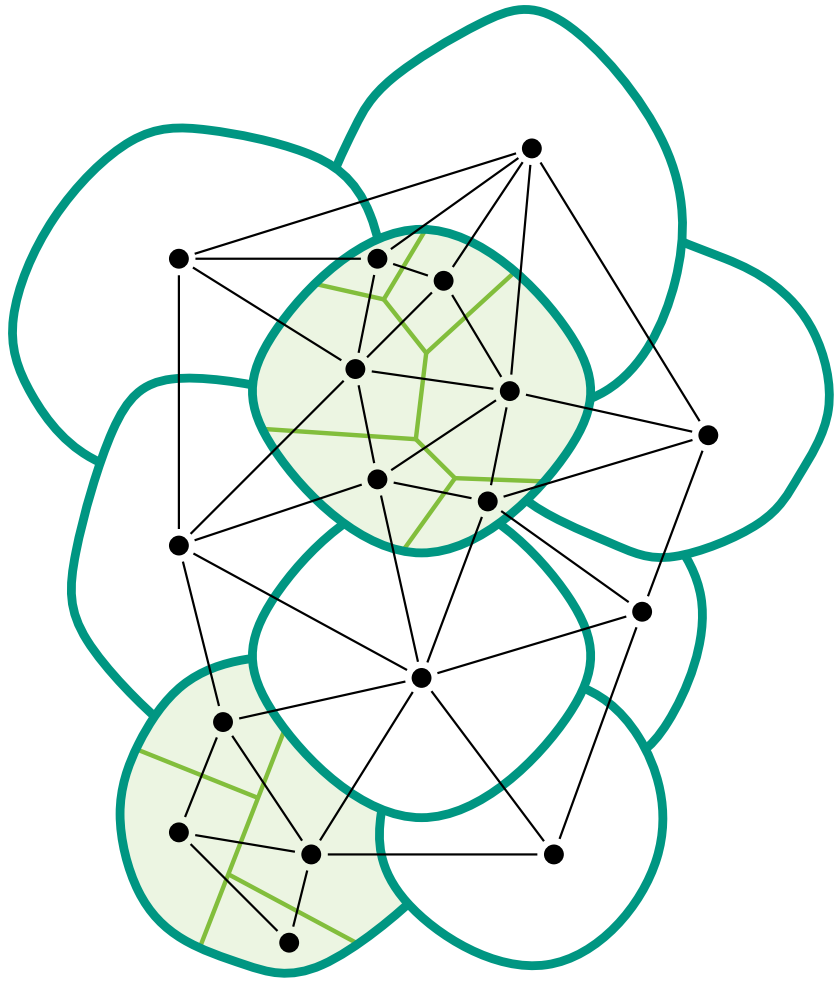
Experimental Evaluation

			similarity [%]				
		cut	lowest level		highest level		
period	instance	[%]	repair	full	repair	full	speedup
mo	Australia	3.09	98.87	64.57	97.60	39.27	12.07
	N America	3.11	98.64	64.01	87.16	31.07	9.64
	Europe	3.24	98.35	62.70	94.70	50.73	9.35
yr	Australia	10.91	85.16	49.60	75.49	23.33	6.31
	N America	13.14	91.04	54.55	62.46	32.53	4.09
	Europe	12.83	90.41	52.98	73.64	46.03	7.48

Conclusion

summary:

- new repartitioning algorithm
- improves fraction of unchanged overlay vertices to more than 90 %
- accelerates network repartitioning by an order of magnitude
- cut size is only about 3 % higher



Conclusion

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future work:

- handle larger changes
- other classes of evolving networks